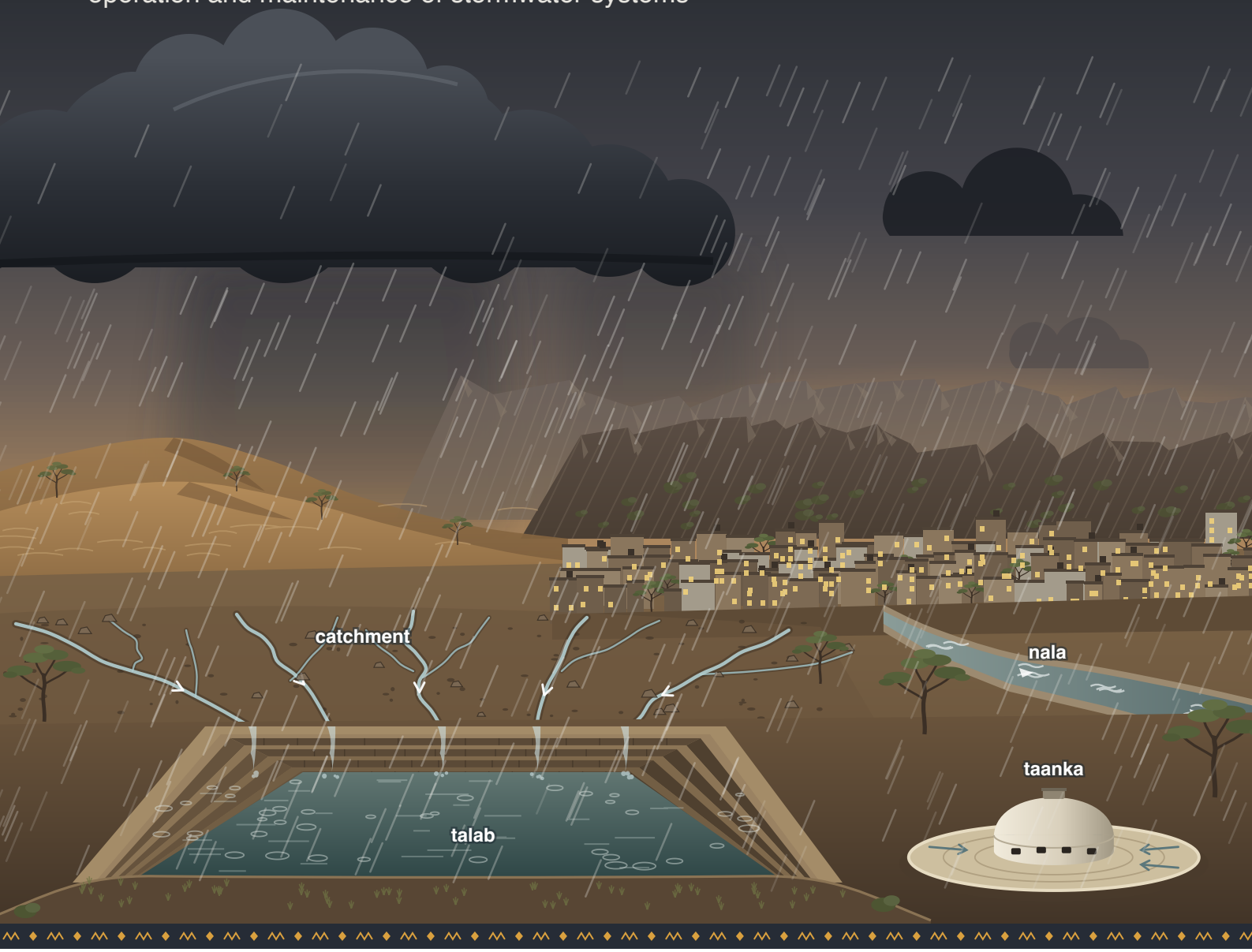
RAJASTHAN

Stormwater Design Manual

Standards for the planning, design, construction, operation and maintenance of stormwater systems



Preserve | Retain | Detain | Convey | Maintain

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Prepared by

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About this draft

Status. This is Draft v1.0 of the *Rajasthan Stormwater Design Manual*. It was prepared by Neer as a proposed stormwater design standard for Rajasthan.

Not adopted. This Manual has not been adopted, notified or endorsed by the Government of Rajasthan or by any of its departments, local bodies or agencies. In particular, it has not been adopted, notified or endorsed by the Urban Development and Housing Department (UDH), the Local Self Government Department (LSG) or its Directorate of Local Bodies (DLB), the Water Resources Department (WRD), the Rajasthan Lakes Development Authority, any development authority, any Urban Improvement Trust (UIT), any Municipal Corporation, Municipal Council, Municipal Board or other local body, the Rajasthan Urban Infrastructure Development Project (RUIDP), or any other agency. Where it names a body, such as the Revenue Department, the Ground Water Department, the Public Health Engineering Department (PHED), the State Wetland Authority, the Rajasthan State Pollution Control Board (RSPCB), the Rajasthan State Disaster Management Authority (RSDMA), the Rajasthan State Industrial Development and Investment Corporation (RIICO), the Jaipur Municipal Corporation (JMC), the Jaipur Development Authority (JDA), the river commission or authority that the Supreme Court has directed the State to set up, or a district administration, it describes the role that body would have if the Manual were adopted. It does not say the body has agreed to that role.

No legal force. Until a competent authority adopts it, with or without changes, this Manual has no legal force. The Model Rajasthan Building Regulations 2025 as brought into force by each local body or authority, master development plans, drainage schemes, orders of courts and tribunals and approval conditions in force continue to apply.

Names. Some places, rivers and lakes have more than one name or spelling in statutes, sources and on IMD and CWC stations:

- older sources write Chittor for Chittorgarh, Sachor for Sanchore, Karoli for Karauli, Ganganagar for Sri Ganganagar, Abu for Mount Abu, Pokharan for Pokaran and Jhalara Patan for Jhalrapatan. The district map of Rajasthan was reorganised in 2023–24, with new districts such as Balotra, Phalodi and Didwana-Kuchaman; IMD and CWC sources, and the rainfall data in this Manual, use the earlier districts, and a clause that names a district must be checked against the current list;
- IMD's observatory for Jaipur is at **Sanganer**, the airport, and is called Jaipur (Sanganer) in this Manual. Sanganer is also the old town on the Dravyavati south of the city, and the Sanganer–Sitapura industrial belt lies beside it. Udaipur has two IMD stations, Udaipur City and Udaipur (Dabok) at the airport, and Kota has Kota (A) at the aerodrome and an older Kota observatory;
- the **Dravyavati** is the river of Jaipur that, over time, turned into a nala, also called the **Amanishah** (or Amanisha) **nala**. Its channel has been rebuilt by JDA from the Nahargarh hills to its outfall into the Dhund river. The word nala is also written *nallah* or *nalla* in project documents;
- **Kota City** is the CWC river gauge on the Chambal at Kota, against which this Manual checks the city's outfalls. It is not the Kota Barrage, whose full reservoir level and releases are reservoir figures. The Jojari, the river of Jodhpur and a tributary of the Luni, is also written Jojri;
- the levels of the Udaipur lakes (Pichola, Fateh Sagar, Udai Sagar) and of Ana Sagar at Ajmer are reported in **gauge feet**, read on a gauge whose zero is not tied to mean sea level in any source found. This Manual quotes them as reported and does not convert them to metres until the gauge zero is surveyed [TBC]; and
- **Marwar** is the region of Jodhpur and the Luni basin, **Shekhawati** the region of Sikar, Jhunjhunu and Churu, **Dhundhar** the region of Jaipur, **Mewat** and **Braj** the north-east around Alwar and Bharatpur, **Hadoti** the south-east around Kota, Bundi, Baran and Jhalawar, **Mewar** the region of Udaipur and Chittorgarh, and **Vagad** the south around Banswara and Dungarpur. The names describe regions, not administrative units.

The **Aravalli** hills run from south-west to north-east across the State and divide the dry west, which drains to the Luni or inland, from the east and south, which drain mostly to the Chambal, through the Banas and its other tributaries, and to the Mahi.

This Manual uses the first form and keeps the others where a title, a source or a station uses them. Some names of bodies need a word of explanation:

- a **Municipal Corporation**, a **Municipal Council** or a **Municipal Board** is constituted under the Rajasthan Municipalities Act, 2009. All three are urban local bodies (ULBs). Under that Act public tanks, streams and reservoirs, with any adjacent land that is not private property, and public drains and watercourses in, alongside or under any street, vest in the Municipality, to be held by it as trustee (s.68). Jaipur's two corporations, Greater and Heritage, created in 2019, were reported in 2025 to have been merged again into one Jaipur Municipal Corporation, and the twin corporations of Jodhpur and Kota likewise; the notifications were not seen;
- **JDA** in this Manual is the Jaipur Development Authority, constituted under the Jaipur Development Authority Act, 1982. It is not the Jabalpur Development Authority, which the Madhya Pradesh edition calls JDA. **JoDA** is the Jodhpur Development Authority (Act of 2009), **AjDA** the Ajmer Development Authority (Act of 2013), **KDA** the Kota Development Authority and **UDA** the Udaipur Development Authority (Acts of 2023); the Bikaner and Bharatpur Development Authorities (Acts of 2025) are named in full. In other cities a **UIT** (Urban Improvement Trust), constituted under the Rajasthan Urban Improvement Act, 1959, plans and develops land;
- **UDH** is the Urban Development and Housing Department, which issues the building regulations and oversees the development authorities, the UITs and the master plans. **LSG** is the Local Self Government Department, and **DLB** its Directorate of Local Bodies, which oversee the ULBs;
- **RUIDP** is the Rajasthan Urban Infrastructure Development Project, a programme of urban water supply, sewerage and drainage works funded by the Asian Development Bank, whose works have been executed through the LSG Department;
- **WRD** is the State's Water Resources Department, which operates its dams and reservoirs. The **Ground Water Department** is named in this Manual as the State groundwater agency; the Rajasthan Ground Water (Conservation and Management) Authority Act, 2024 (Act No. 20 of 2025) comes into force only on a date the State notifies, and no such notification was found. **PHED** is the Public Health Engineering Department, which gives drinking-water connections;
- the **Rajasthan Lakes Development Authority** is the authority for which the Rajasthan Lakes (Protection and Development) Authority Act, 2015 provides;
- **gair mumkin** (गैर मुमकिन, "not possible", that is, uncultivable) is a class of land in the revenue record. Land recorded as **gair mumkin nala**, **gair mumkin nadi** (नदी, a river) or **gair mumkin talab** is land under a nala, a river or a tank, and the High Court has held that land recorded as gair mumkin nala is a natural drainage channel that cannot be diverted or built on;
- **agor** (आगोर) is the catchment of a tank in Rajasthani usage. The standard dictionaries consulted do not give that sense (Platts gives only "watchman"), so the clauses of this Manual say *catchment*, or *flow area*, the term of the Lakes Act; and
- a **tehsil** is the revenue subdivision of a district, under a Tehsildar.

Some abbreviations have more than one meaning:

- AMC is the antecedent moisture condition in Chapters 2 and 3; this Manual does not use it for any municipal body;
- HFL is the highest flood level recorded at a gauge, as CWC uses it. It is not a design level, and sources sometimes give different values for the same gauge. The "High Flood Line" that the Supreme Court has directed the State to demarcate along its rivers is a line on the ground; this Manual calls it the court's High Flood Line, and proposes how a design flood line is drawn (Chapter 7);
- FTL is the full tank level of a lake or tank and FRL the full reservoir level of a dam; the values published for the same lake sometimes differ, and some are given in gauge feet;

- the Building Regulations 2025 are the Model Rajasthan Building Regulations 2025 as published by the local body or authority concerned; the regulations of 2020 that they repeal are cited as their predecessor;
- NGT CZ is the Central Zone bench of the National Green Tribunal, at Bhopal, which hears cases from Rajasthan; and
- SWD is a storm water drain.

The sense is clear from the context. Hindi and Rajasthani terms used in the text, such as *talab* (तालाब, a pond or tank that holds rainwater), *johad* (जोहड़, an earthen village pond, "kachcha talab"), *nadi* (नाडी, the village pond of Marwar; not नदी, a river), *sagar* and *sarovar* (सागर, सरोवर, a large tank or lake, used in names such as Ana Sagar and Fateh Sagar), *baori* or *bawdi* (बावड़ी, a step-well), *kund* (कुंड, a small walled tank), *taanka* (टाँका, a walled cistern, usually covered, that stores runoff from a roof or a plastered apron), *khadin* (a field bund that holds runoff for farming in the west), *nala* (natural drain or large storm drain), *nali* (small street drain), *agor* and *gair mumkin*, are explained where they first appear.

Use with care. Clauses and values may change after review. Designers remain responsible for their designs and for checking the data they use. Neer accepts no liability for decisions made on the basis of this draft.

Disclosure. Neer publishes the India Flood Atlas, a national map of modelled 1% AEP flood depth. Clause 6.11.3 names it as one example of a regional map that an Approving Authority may adopt for floor levels. The Manual does not require the Atlas; any map adopted under Clause 7.3.4 may be used.

Comments. Comments and corrections are welcome at info@neer.ai.

Preface

Rajasthan's cities flood for three reasons. Jaipur showed the first on 19 July 1981, when 326.0 mm of rain fell in a day, more than half the city's normal rain for the whole monsoon; Ramgarh, the lake that once supplied Jaipur, shows the second, its catchment built over and mined until the courts stepped in, and the lake was found still dry in 2017; and Barmer showed the third in August 2006, when about 577 mm fell in three days around the town and the water, with nowhere to go, stood for months, as reported.

1. **Short, intense storms on a dry land, with drains built for 1- to 2-year storms.** The only State drainage guideline found, RUIDP Circular No. 8 of 2008, lets the towns of its programme design drains for a return period of 1 to 2 years, culverts for 25 years and bridges for 50, and says that the design intensity in India is "usually in the range of 12mm/hr to 20mm/hr". The one station analysis of short-duration rainfall in the State, for Jaipur (Sanganer) from IMD's hourly record of 1970–2013, gives 53.1 mm in an hour for a 5-year storm and 93 mm for a 50-year storm. On 19 July 1981 Jaipur (Sanganer) recorded 326.0 mm, its highest day; the city recorded 82 cm in three days, from 18 to 20 July, and the same day Kanota recorded 589.2 mm and Dausa 550.0 mm. Records far exceed the CWC maps: Ajmer recorded 412.3 mm on 10 June 2002, nearly twice the 100-year day on the map for the city (about 220 mm), and Mount Abu 653.0 mm on 8 September 1992. On 31 July and 1 August 2024 about 173 mm was reported in Jaipur, and three members of one family died in a flooded basement in the Vishwakarma Industrial Area, as reported. In July 2022 Jodhpur received about 119 mm, reported as its highest July rain since 1943, and more than 30 colonies were flooded, as reported. Ajmer's colonies flood when the escape gates of Ana Sagar are opened to hold the lake at its full gauge, as reported in September 2024 and July 2025. In the west a single storm can exceed a year's rain: Sam, in Jaisalmer district, recorded 540.0 mm on 17 August 1973, against a district normal of 172.9 mm a year, and from 19 to 22 August 2006 about 577 mm fell around Barmer, as reported, against a district normal of 251.7 mm a year; Kawas was reported still under water months later, and the reported deaths range from about 140 to more than 300.
2. **Natural flow paths and lake catchments built over, which the courts have had to protect.** Ramgarh dam, built in 1903 with a catchment of about 769.20 km² over four tehsils, supplied Jaipur's drinking water. From 2004 the High Court ordered the free flow of water in its catchment restored (*Abdul Rahman*, 2 August 2004), then encroachment and construction stopped in its drainages, channels and nalas (*Suo Motu*, 23 August 2011), and on 29 May 2012 barred the allotment of land in the catchments of any "Johar, Nala, Tank, River, Pond"; in 2017 the Supreme Court found the lake "still bone dry" and that "nothing substantive appears to have been achieved on the ground over the years". In 2017 the High Court recorded the State's concession that master plans cannot disturb rivers, lakes and other natural resources, and directed encroachments on nadis, ponds, river beds and catchments removed (*Gulab Kothari*), and on 7 May 2026 that land recorded as gair mumkin nala is a natural channel that cannot be diverted "merely on the ground that the utilisation is for a public purpose" (*Ramji Lal Saini*). At Ajmer the NGT ordered a park and other works removed from the edge of Ana Sagar in 2023 for breaching the Wetlands Rules, the Supreme Court refused to stay the order and in March 2025 rejected a plan to remodel them, and demolition began on 12 September 2025, as reported. On 7 August 2026, in the case of the Jojari at Jodhpur, the Supreme Court directed the State to demarcate "the High Flood Line and the requisite ecological buffer zone qua all the river systems in the State", barred fresh permissions for development within the identified river corridors until then, and directed a river commission or authority to be set up, finding the State's river basin authority "largely defunct". Jaipur's own river, the Dravyavati, became a nala carrying storm water and sewage before JDA rebuilt it as a 47.5 km channel designed to pass the 100-year flood, with 170 MLD of sewage treatment.
3. **Much of the State has no outfall at all.** About 60% of Rajasthan drains inland, as reported. In the CWC subzone that covers the Thar and the Luni basin, rivers "either disappear in the sandy [wastes] or the marshy land in 'Runn of Kutch'"; Bikaner and much of Jaisalmer and Barmer have no defined drainage; and the Sambhar salt lake has no outlet. Where water cannot be sent away it must be stored, and infiltrated or evaporated, and the State needs it in the ground: in 2024 Rajasthan drew 149.86% of its extractable groundwater, and 214 of its 302 assessment

units were over-exploited. Two places are the exception: in the old city of Jodhpur the water table has risen since canal water arrived in 1997, to about 1 m below ground in parts, and in the Ganganagar–Hanumangarh canal belt the water lies within 2 m of the surface in places and land is waterlogged.

Behind all three lies lost storage. The *talabs*, *johads*, *nadis*, *taankas*, *kunds* and *baoris* that once held and stored rain are protected mainly by the revenue record and by the courts. No khatedari (tenancy) rights accrue in tank-bed land (Rajasthan Tenancy Act, 1955, s.16); the Rajasthan Lakes (Protection and Development) Authority Act, 2015 provides for lake boundaries, protected areas and the "flow area" of a lake's feeders to be notified, but no such notification was found; about 75 wetlands were reported notified under the Wetlands Rules, 2017 by January 2026, and in June 2026 the High Court barred filling, construction and untreated sewage in wetlands and their catchments. Four Ramsar sites lie in the State: Keoladeo (1981), Sambhar (1990), and Khichan and Menar (2025).

Design for Rajasthan therefore has to cover a monsoon that comes last to the north-west, on rock, sand and black soil, in cities that drain to lakes held by gates, to rivers raised by dam releases, and in much of the State to nowhere at all. The monsoon normally reaches Jhalawar by 24 June, Udaipur by 25 June, Kota by 26 June, Jaipur by 29 June, Ajmer by 1 July, Jodhpur by 2 July and Bikaner and Pokaran by 6 July, and withdraws between 17 September at Pokaran and 28 September at Jhalawar; 91% of the year's rain falls in the south-west monsoon. Annual normals run from 172.9 mm in Jaisalmer district and about 250 mm in Barmer and Bikaner to 921.2 mm in Jhalawar district, and 1,677.0 mm at Mount Abu. Large days fall outside the season too: 156.8 mm at Jodhpur on 26 April 1982, Ajmer's 412.3 mm on 10 June 2002, 500.0 mm at Nasirabad on 5 October 1989 and 350.0 mm at Jhalawar on 5 October 1997.

National guidance sizes public drains but does not control the runoff that new building adds. This Manual makes stormwater a **condition of development approval**. Every development above a modest size must:

- hold frequent rainfall on site;
- release the large storms no faster than the undeveloped land did, or slower where catchments already flood, and, where there is no outfall, store the design volume and let it soak in or evaporate; and
- show that its outfall still works when the receiving nala, lake or river is high, when the escape gates of a lake or the gates of a barrage are open, or when the flap gate on its outfall is shut.

The Manual also sets how public drains, roads, nalas, talabs, lakes and other water bodies, gated and pumped outfalls and basin-wide master plans are designed, so that private sites and public works aim at the same standard.

The Manual draws on leading stormwater standards from India and abroad. Each is adapted to Rajasthan's south-west monsoon from late June to September and the short, intense storms and rare multi-day deluges that come with it; the Chambal, the Banas, the Luni, the Mahi and the Ghaggar, the dams and barrages that regulate them, the lakes into which so many city drains empty and the inland basins that have no outlet; the dune sands and calcrete pans of the Thar, the rock and thin soils of the Aravallis, the alluvium of the east and the black soils of Hadoti, over aquifers drawn down across most of the State and rising in a few places; the talabs, johads, nadis, taankas, kunds and baoris; and cities whose old cores, new colonies on catchments and nalas, and basements turn ordinary storms into floods.

1. **National base.** The CPHEEO *Manual on Storm Water Drainage Systems* (2019). This Manual builds on it and sets higher standards where it allows a State to do so. IRC road-drainage codes and the NDMA urban flood guidelines are also used.
2. **Overall structure.** Kansas City Metro APWA Section 5600 (Version 2025.01), the most recent comprehensive regional standard. It supplies the preserve, retain, detain, convey and maintain sequence and the required retention volume.
3. **Design rainfall.** The CWC *Flood Estimation Reports* for the four subzones that cover Rajasthan, 1(a) Luni, 1(b) Chambal, 1(e) Upper Indo-Ganga Plains and 3(a) Mahi and Sabarmati, as the interim source. The analysis of IMD's hourly record for Jaipur (Sanganer) by Ghate and Timbadiya (2022) is used for storms of up to an hour in and around Jaipur and as a floor elsewhere in the centre of the State. IMD's rainfall intensity curves for Jaipur and Jaisalmer (Das et al., 2022) repeat a curve printed for many other cities and are not used; a volume of IMD's atlas of return-period rainfall maps covering Rajasthan was not found; and frequency analysis of gridded rainfall by the National Institute of Hydrology (NIH), Roorkee, is used for comparison only.

4. **Monsoon practice.** The PUB Singapore *Code of Practice on Surface Water Drainage* (7th ed., 2025), for the fixed-coefficient route for small sites and drainage reserves. Malaysia's MSMA 2 (2012), for monsoon design storms and simplified on-site detention.
5. **Runoff reduction and treatment.** The Georgia Stormwater Management Manual (2016), for runoff reduction and downstream analysis. CIRIA C753 *The SuDS Manual* (2015), for the treatment train. The Mile High Flood District criteria manual, for outlet and storage design.
6. **Local rules.** The Model Rajasthan Building Regulations 2025; the Rajasthan Municipalities Act, 2009; the Rajasthan Urban Improvement Act, 1959 and the Acts of the development authorities; the Rajasthan Lakes (Protection and Development) Authority Act, 2015; the Rajasthan Tenancy Act, 1955 and the revenue record; the Wetlands (Conservation and Management) Rules, 2017; and the orders of the Supreme Court, the High Court of Rajasthan and the NGT on catchments, nalas, lakes, wetlands, rivers and sewage. This Manual follows them or, where disclosed, makes them stricter. The Building Regulations are cited from the Hindi text issued with the UDH order of 12 May 2025, read from a third-party copy; they take effect in each area from their publication in the Gazette by the local body or authority concerned (reg. 1.2), so the date varies from city to city [TBC], and an amendment of 2026 on building heights has been reported but was not read. The Municipalities Act is cited from a third-party copy whose amendments were not checked, the Lakes Act from the text of the Bill of 2015, and section 73(c) of the Urban Improvement Act as the regulations cite it; every rule cited must be checked against the current text.

Why this Manual is needed

India has no uniform stormwater design standard. The CPHEEO *Manual on Storm Water Drainage Systems* (2019) is the country's first manual dedicated to storm water drainage, but it is advisory. The Ministry of Housing and Urban Affairs lists it among advisory guidelines and treats urban flooding as a matter for State Governments and urban local bodies. None of the national rules or State building rules reviewed for this Manual makes runoff control a condition of building approval, and neither does the Model Building Bye-Laws 2016.

The national documents leave key values open, or give different answers.

- **Return periods.** CPHEEO recommends 5 years for drains in Class I cities and 2 years elsewhere, and lets a State committee adopt higher values. A 2023 CPHEEO presentation shows a different table. IRC:SP:50-2013 suggests 1–2 years for urban road drains; IRC:SP:42-2014 suggests 25 years. An engineer designing a drain in Rajasthan can cite 1, 2, 5 or 25 years, depending on the code chosen.
- **Detention.** CPHEEO describes limiting peak outflow to pre-development rates as general practice. It uses no "shall" and names no storm frequencies.
- **Climate.** The NDMA Urban Flooding Guidelines (2010) call for detention and retention facilities and for rainfall curves adjusted for climate change, but give no sizing rule or return period.
- **Design rainfall.** No national document gives design rainfall that a designer can apply directly to a given town. Each project chooses its own source. IMD's 2022 national set of rainfall intensity curves has two panels for the State, Jaipur and Jaisalmer, and both repeat the curve printed for many other cities: for Jaisalmer it implies a 2-year day of about 170 mm, against a district normal of 172.9 mm a year. The CWC reports for the State's four subzones date from 1984 to 1993; their ratios of the 1-hour to the 24-hour rain run from 0.34 to 0.36, and the losses they assume from 1.7 to 5 mm/h. The unit hydrograph of the Luni subzone, which covers about 59% of the State, rests on seven gauged bridge catchments on the Aravalli fringe, none of them in dune country. Jaipur's station analysis gives a 50-year hour of 93 mm, about a third more than the 70 mm that the CWC map and ratio give for the city. The reanalysis grids of NIH-DHAARA read 151 mm for a 50-year day at Jaipur, against about 200 mm on the map and 194.6–249.9 mm from the station record, and 89 mm at Bikaner, against about 180 mm on the map.

Rajasthan has no drainage design standard of its own. Research for this Manual found one State drainage guideline, RUIDP Circular No. 8 of 2008, which lets town drains be designed for a 1- to 2-year storm at intensities far below those measured at Jaipur, and one stated design flood, the 100-year flood for which JDA rebuilt the Dravyavati, whose design discharge was not found. No standard, IDF relationship or circular of UDH, LSG, WRD, any development authority or any Municipal Corporation that fixes return periods or design rainfall for city storm drains was found, and no detailed project report (DPR) for a storm drain under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) or the Smart Cities Mission that states one. This Manual is offered as a technical companion to the Building Regulations 2025, the Municipalities Act, the Lakes Act and the master plans: it supplies the design storm, detention, water-level and buffer values that they leave open. It has not been adopted by UDH, LSG or any other body. In particular:

- **The building rules require rainwater harvesting, but not detention.** The Building Regulations 2025 require a rainwater harvesting structure, or a rooftop rainwater storage tank with a filter, on every plot of 225 m² or more (reg. 8.3; the threshold was 300 m² in the regulations of 2020), secured by a refundable deposit of ₹50,000 to ₹5 lakh that is returned only after the Ground Water Department, WRD or an experienced retired engineer reports that the structure works; areas that a local body marks as waterlogged are exempt. They require a green area of 10 to 20% of non-commercial plots of more than 750 m², at least half of it on natural ground (reg. 8.1), and, for 5,000 to 20,000 m² of built-up area, that the inlet and outlet points of the natural drainage be kept as they are, with one recharge bore per 5,000 m² and at least 20% of the open space unpaved (schedule of environmental conditions). The Municipalities Act makes rainwater harvesting a duty, with a fine, and bars a water connection to a new building without a municipal certificate that the structure has been provided (s.238). No rule requires on-site detention, limits peak runoff or sets "zero runoff";
- **There is no setback from water.** Neither the regulations of 2025 nor those of 2020 set any distance from a nala, river or lake. The Municipalities Act bars building over a drain vested in the Municipality without its written consent (s.213(2)) and the construction or occupation of a building until a drain is made for its "effectual drainage" (s.202). The Lakes Act provides for protected areas around lakes, but sets no distance and none was found notified. Plinths must be at least 0.45 m above the road in front (reg. 6.6), but no rule was found that keeps surface water out of a basement;
- **No design return period is set, except one.** Apart from the Dravyavati's 100-year flood, no design return period was found for any city drain, nala or river corridor in the State; none was found for JDA's drainage upgrade of 2025, reported to use a storm water model;
- **The courts have set the lines, and asked for a method.** The working limits come from the courts: catchments of tanks and nalas closed to allotment since 2012; land recorded as gair mumkin nala kept to its recorded character (2026); a no-construction zone around the Udaipur lakes notified in 1997, and a hotel held void for lying within 200 m of the high flood level of Udai Sagar, as reported; no filling or construction in wetlands or their catchments (High Court, 1 June 2026); 100 m along the Jojari, as reported from an order of 24 August 2026; and, on 7 August 2026, the Supreme Court's direction to demarcate the High Flood Line and an ecological buffer for every river system in the State, with no fresh permissions in the identified river corridors meanwhile. The order read does not say for what flood the line is drawn. This Manual offers a technical method for that work (Chapter 7); it does not replace any line that a court or the State draws, and where such a line binds and is wider, it governs; and
- **No document sets the lake or river level for which an outfall is designed.** The Udaipur lakes and Ana Sagar are run to gauge readings in feet whose zero has not been tied to mean sea level; the Chambal at Kota City reached 248.68 m in September 2019, against a danger level of 242 m, when the barrage upstream released water from the dams above it; and no level was found for the Dravyavati or the Jojari at the city outfalls. Danger levels and highest flood levels are flood-warning levels and records, not design levels.

So each agency and each local body interprets the central manual its own way. JMC and the other Municipal Corporations, the Municipal Councils and Boards, JDA and the other development authorities, the UITs, RUIDP, WRD, PHED, RIICO, Smart City companies, road agencies, their consultants and funding agencies fill the gaps differently. Two drains on the same street, built by different agencies, can be sized for different storms from different rainfall sources. A nala in Jaipur can rise in the Nahargarh hills, pass through colonies laid out by JDA and wards cleaned by JMC, and join the Dravyavati, a channel built for the 100-year flood, while the drains that feed it were planned for a storm of 1 or 2 years. And a reviewer has no common basis against which to check a design.

What this Manual does about it. It turns those open choices into one State standard:

- one source and method for design rainfall across the four CWC subzones, in three rainfall zones, with a checked station analysis to govern where one exists, and floors where the CWC ratios understate short storms (Chapter 2);
- named return periods for every drainage element (Chapters 2 and 6);
- a required pre- versus post-development rule for private sites, and a design volume to be stored and soaked away where there is no outfall (Chapter 4);
- a required tailwater check for outfalls to nalas, lakes, reservoirs and rivers, gated, flap-gated or pumped, against a design lake or river level (Chapter 5);
- a design flood line, and corridors and setbacks along nalas and around talabs and lakes, which no rule now sizes, proposed by this Manual for use with the lines the courts have drawn (Chapter 7);
- recharge first across a State whose aquifers are over-drawn, with a groundwater check in old Jodhpur and the canal belt, no infiltration credit on black soil once its cracks close, and treatment where nalas carry sewage (Chapter 8); and
- basin-wide master plans, so that the agencies that share a basin plan together (Chapter 11).

It uses the route the CPHEEO manual itself provides: a State may adopt standards higher than the national values (CPHEEO 2019, Table 4.1, Note 2). A Municipal Corporation, a development authority or UDH can still adopt a stricter standard (Chapter 1).

Sources: CPHEEO (2019) Part A §4.4–4.5 and Table 4.1; CPHEEO presentation to CSE (August 2023); IRC:SP:50-2013 §6; IRC:SP:42-2014 §6; NDMA (2010) Urban Flooding Guidelines, para 6.6.2; MoHUA Model Building Bye-Laws (2016); Government of Rajasthan, UDH, Model Rajasthan Building Regulations, 2025 (मॉडल राजस्थान भवन विनियम, 2025), issued with UDH order No. P.11(5) नविवि/Building Regulations-2025/2025 of 12 May 2025 (Hindi text and order read from third-party copies), regs. 1.2, 4.13, 6.5, 6.6, 8.1–8.6 and 18, and Schedule 2, item 4; date of publication by each local body or authority not confirmed [TBC]; amendment of 2026 on building heights (as reported; not read); JDA (Jaipur Region) Building Regulations, 2020, Rajasthan Gazette (Extraordinary), 7 January 2021, regs. 10.4, 10.11 and 11.6 and Annexure 4, and Model Rajasthan Building Regulations, 2020, reg. 10.11.1; Rajasthan Municipalities Act, 2009 (Act 18 of 2009), ss.45, 68, 200, 202, 204, 213 and 238 (third-party copy; amendments not checked); Rajasthan Urban Improvement Act, 1959, s.73(c) (as cited in the regulations; not read); Rajasthan Lakes (Protection and Development) Authority Bill, 2015 (Bill No. 11 of 2015, authorised English translation), ss.1–6 and 27; Rajasthan Tenancy Act, 1955, s.16 (as quoted by the Supreme Court); Rajasthan Ground Water (Conservation and Management) Authority Act, 2024 (Act No. 20 of 2025); Wetlands (Conservation and Management) Rules, 2017; High Court of Rajasthan, Abdul Rahman v. State of Rajasthan, D.B. C.W.P. 1536/2003, judgment of 2 August 2004, Suo Motu v. State, S.B. C.W.P. 11153/2011, orders of 23 August 2011 and 29 May 2012, and Gulab Kothari v. State, D.B. C.W.P. 1554/2004, order of 12 January 2017 (all as quoted in later judgments); High Court of Rajasthan, Ramji Lal Saini v. State, D.B. C.W.P. (PIL) 6614/2021, order of 7 May 2026; High Court of Rajasthan (Jodhpur), suo motu case on the wetlands of Rajasthan, order of 1 June 2026; Supreme Court of India, National Institute of Medical Science University v. State of Rajasthan, SLP (C) 38040-38041 of 2012, judgment of 9 November 2017; Supreme Court of India, In Re: 2 Million Lives at Risk, Contamination in Jojari River, Rajasthan, Suo Motu W.P. (C) 8 of 2025, judgments of 21 November 2025 and 18 March 2026 and order of 7 August 2026, and order of 24 August 2026 (as reported); NGT (Central Zone) on Ana Sagar (2023) and the Supreme Court's orders of December 2023 and March 2025 (as reported); High Court orders on the Udaipur lakes and the notification of 17 January 1997 (as reported); RUIDP, Circular No. 8, General guide lines for Drainage Sector work to be taken under RUSDIP, 4 March 2008; JDA, Dravyavati River Rejuvenation Project, environmental impact assessment, Chapter 2; Ghate and Timbadiya (2022), MAUSAM 73(2): 341–354; Gupta and Jindal (1987), MAUSAM 38(3): 362–364; CWC, Flood Estimation Reports for Subzones 1(a) (L/20/1992), 1(b) (C/16/1988), 1(e) (1984) and 3(a) (MS/13/1986), including their isopluvial plates; IMD, Extremes of Temperature and Rainfall for Indian Stations (up to 2012); IMD, Climate of Rajasthan (2010); IMD, Pai et al. (2020), new normal dates of onset and withdrawal of the south-west monsoon, Table 2; Das et al. (2022), MAUSAM 73(4), Fig. 4(xiv) and 4(xv); NIH-DHAARA (accessed 6–7 November 2026); CGWB and the State, Dynamic Ground Water Resources of Rajasthan, 2024; CGWB, Ground Water Year Book 2020-21, Rajasthan; NIH, study of the rise of the water table in Jodhpur (2025); CWC flood bulletins of 16–17 September 2019 and the CWC list of flood forecasting sites (as copied by SANDRP); share of the State draining inland (secondary sources); MoEF&CC list of Ramsar sites and the

number of notified wetlands (as reported); reports of the floods at Jaipur (1981, 2024), Barmer (2006), Kota (2019), Jodhpur (2022) and Ajmer (2024, 2025), of the merger of the municipal corporations (2025) and of JDA's drainage upgrade (2025) (press and secondary sources).

How to use this Manual

Clauses and commentary. Numbered clauses (for example 4.5.2) are the requirements of this Manual and use "shall". Paragraphs headed **Commentary** explain the reason for a clause and cite its precedent. They are guidance, not requirements. Where a value has no direct precedent elsewhere, the commentary says so and explains why this Manual sets it.

Return periods. Storms are described both by annual exceedance probability (AEP) and by return period. For example, "1% AEP (100-yr)" means a storm with a 1-in-100 chance of being equalled or exceeded in any year.

Illustrative values. Worked examples and figures marked "Illustrative — not design values" show method and scale only. Design values come from the sources set in Chapter 2.

Annexes and forms. Each chapter lists the annexes and forms it relies on. They follow the chapters, grouped by chapter, and hold the forms to submit, worked examples, templates, model text and standard drawings. Annexes that need data not yet collected are marked *To be prepared*. They say what they will contain, and the clause that depends on them states the rule that applies in the meantime.

Figures. All figures are original drawings prepared for this Manual. Where a figure follows a published concept, its caption credits the source.

Where to start.

If you are…	Read first
A developer or architect	Chapter 1 (does it apply?), Chapter 4 (what to provide), Chapter 10 (what to submit)
A design engineer	Chapters 2–6, then 8 and 9
A local body or approving authority	Chapters 1, 10 and 11
A planner or waterbody manager	Chapters 7 and 11

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Abbreviations

Abbreviation	Meaning
AEP	Annual exceedance probability
AjDA	Ajmer Development Authority
AMC	Antecedent moisture condition
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
APWA	American Public Works Association
ARF	Areal reduction factor
AWS	Automatic weather station
BSMP	Basin Stormwater Master Plan
CAG	Comptroller and Auditor General of India
CAZRI	Central Arid Zone Research Institute, Jodhpur
CGWA	Central Ground Water Authority
CGWB	Central Ground Water Board
CN	Curve number (SCS/NRCS method)
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organisation
CSE	Centre for Science and Environment
CWC	Central Water Commission
DLB	Directorate of Local Bodies, Government of Rajasthan
DPR	Detailed project report
DWF	Dry-weather flow
EIA	Environmental impact assessment
ESC	Erosion and sediment control
FAR	Floor area ratio
FER	Flood Estimation Report (CWC)
FRL	Full reservoir level
FTL / MWL	Full tank level / maximum water level

Abbreviation	Meaning
HAT / MHWS	Highest astronomical tide / mean high water springs (coastal terms; not applicable in Rajasthan)
HFL	High flood level (the highest level recorded at a gauge); see About this draft for the court's High Flood Line
HGL	Hydraulic grade line
HSG	Hydrologic soil group
IDF	Intensity–duration–frequency
IMD	India Meteorological Department
IRC	Indian Roads Congress
JDA	Jaipur Development Authority (not the Jabalpur Development Authority of the Madhya Pradesh edition)
JMC	Jaipur Municipal Corporation
JoDA	Jodhpur Development Authority
KDA	Kota Development Authority
LSG	Local Self Government Department, Government of Rajasthan
MLD	Million litres a day
MoEF&CC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
NDMA	National Disaster Management Authority
NGT	National Green Tribunal (CZ: its Central Zone bench, at Bhopal)
NIH	National Institute of Hydrology, Roorkee
NOC	No-objection certificate
PHED	Public Health Engineering Department, Rajasthan
PSD	Permissible site discharge
RIICO	Rajasthan State Industrial Development and Investment Corporation
RRV	Required retention volume
RSDMA	Rajasthan State Disaster Management Authority
RSPCB	Rajasthan State Pollution Control Board
RUIDP	Rajasthan Urban Infrastructure Development Project
RWH	Rainwater harvesting
SANDRP	South Asia Network on Dams, Rivers and People
SLA	Sea-level allowance (coastal term; not applicable in Rajasthan)
SoI	Survey of India
SRRG	Self-recording rain gauge
STP	Sewage treatment plant
SUH	Synthetic unit hydrograph (CWC)
SW monsoon / JJAS	South-west monsoon, June–September

Abbreviation	Meaning
SWD	Storm water drain
UDA	Udaipur Development Authority
UDH	Urban Development and Housing Department, Government of Rajasthan
UIT	Urban Improvement Trust (under the Rajasthan Urban Improvement Act, 1959)
ULB	Urban local body (a Municipal Corporation, Municipal Council or Municipal Board)
UTM	Universal Transverse Mercator
WQv	Water quality volume
WRD	Water Resources Department, Government of Rajasthan
WSUD	Water-sensitive urban design

CHAPTER 1

Policy, Applicability and Adoption

1.1 Purpose and objectives

1.1.1 This Manual sets the minimum standards for the planning, design, construction, operation and maintenance of stormwater systems in Rajasthan. It applies to private development and to public works, as set out in Clause 1.5.

1.1.2 The Manual has the following objectives:

- (a) to make stormwater management a **condition of development approval**, so that new development and redevelopment do not increase flood peaks or runoff volumes downstream;
- (b) to retain frequent rainfall on site, so that groundwater recharge is sustained and pollutant loads are reduced;
- (c) to size storage for the long-duration south-west monsoon storms of July–September, brought by monsoon depressions that reach the State late in their track, which can drop several days' rain on a desert town with no outfall, fill the lakes of Udaipur and Ajmer to their spill levels and raise the Chambal at Kota with the releases of the dams upstream, as well as for short-duration intensities;
- (d) to design outfalls for the levels of the lakes into which city drains discharge, such as the Udaipur lake chain of Pichola, Fateh Sagar and Udai Sagar, Ana Sagar at Ajmer and Kailana and Takhat Sagar at Jodhpur, which spill through gates and escape channels; the stage of the rivers, the Chambal at Kota and Dholpur, raised by the releases of the dams upstream, the Luni at Balotra and the Banas at Tonk; the levels of the nalas and talabs into which local drains discharge; and, where a town has no outfall at all, the level of the depression in which its runoff collects, including the case where the outfall is closed;
- (e) to protect tanks (talabs), marshes, rivers, supply channels and surplus courses as part of the drainage system;
- (f) to give every element of the drainage network a safe overland path for the 1% AEP (100-yr) storm;
- (g) to make design inputs, approvals and facility records public, so that designs can be checked and repeated; and
- (h) to make sure that facilities, once built, are maintained and remain effective.

1.1.3 This Manual does not replace the rainwater harvesting (RWH) mandate, the building regulations that each urban local body and development authority brings into force, by publication in the Rajasthan Gazette, on the model issued by the Urban Development and Housing Department with its order of 12 May 2025 (the Model Rajasthan Building Regulations 2025), or the statutes on waterbodies. It adds runoff control requirements to them (Clause 1.8).

> **Commentary.** Rajasthan's floods come from three sources, often together. The first is the long, heavy storm. On 18–20 July 1981 a low that formed over the State and stagnated gave Jaipur city 82 cm of rain in three days, 35 cm of it in the 24 hours of 19 July; the city was cut off, and downstream in Tonk the Dhund and the Morel flooded and the village of Hingonia was washed away (Gupta & Jindal, *Mausam*, 1987). IMD records 326.0 mm at Jaipur (Sanganer) that day, and 589.2 mm at Kanota and 550.0 mm at Dausa nearby (IMD). In the desert, where a town may have no outfall at all, the storm is measured against the year: on 19–22 August 2006 about 577 mm fell in three days in Barmer district, whose annual normal is 251.7 mm (IMD), and Kawas and the villages around it stood under water for months; reported deaths range from about 140 to more than 300 (as reported). In the same week every water body around Udaipur was reported to be overflowing and the Army was alerted (as reported). The second source is the rivers and lakes, and the gates that release them. In September 2019 the releases of the

> dams on the Chambal brought the river at Kota City to 248.68 m, its highest recorded level, against a danger level of 242 m (CWC), with the Kota Barrage reported to be releasing about 6.5–6.9 lakh cusecs and about 2,500 houses submerged (as reported); at Ajmer the escape channel of Ana Sagar, opened when the lake passes its full gauge, waterlogged Hathi Bhata, Brahmapuri and Shivpuri on 11 September 2024 and flooded the city again on 18–20 July 2025 (as reported). The third is the city drainage that fails in a fall that is not extreme. Jodhpur received about 118–119 mm in some five hours on 18–19 July 2022, its heaviest July rain since 1943, and more than 30 colonies were flooded (as reported); at Jaipur, after 173 mm on 31 July–1 August 2024, three members of one family died in a flooded basement in the Vishwakarma Industrial Area (as reported). The 2025 season was the State's second wettest since 1901, at 64% above normal (IMD).
>
> Missing design makes all three worse. The only State rule found for the design of town drains is RUIDP Circular No. 8 of 2008, which asked for a 1–2-year storm and called 12–20 mm/h the usual design intensity, about a quarter to two-fifths of the 1-hour depth that the Jaipur gauge gives for a 5-year storm (Chapter 2); the only city design standard found is the 100-year flood for which JDA rebuilt the Dravyavati, whose design discharge was not found. Catchments, nalas and river corridors have been protected mainly by the courts, from the Ramgarh catchment in 2004 to the Supreme Court's order of 7 August 2026 on the Jojari, and the Model Rajasthan Building Regulations 2025 control rainwater harvesting, not runoff. Objectives (b) to (e) address the storage, outfall and building-level failures, which a drain-sizing manual alone cannot fix.
>
> No national instrument requires on-site detention. CPHEEO (2019) is advisory and describes peak control only as typical practice. NDMA (2010) says detention and retention "will" be included but gives no sizing rule. MBBL 2016 and the Model Rajasthan Building Regulations 2025 mandate RWH only. Objective (a) is therefore the main new step this Manual takes.

1.2 Stormwater management hierarchy

1.2.1 Every development to which Chapter 4 applies shall consider stormwater measures in the following order. A designer shall not use a lower measure in place of a higher one that is practicable on the site.

1. **Preserve** — keep or restore natural drainage features, tanks, wetlands, permeable soils, trees and overland flow paths (Chapter 7).
2. **Retain** — hold the runoff from the retention depth of Annex 2E on site, by infiltration, reuse or evapotranspiration (Chapters 4 and 8).
3. **Detain** — store larger storms temporarily and release them at or below the rates in Chapter 4, checked against downstream and tailwater conditions (Chapters 4 and 5).
4. **Convey** — carry the remaining flow safely in the minor system, and the 1% AEP flow in the major system (Chapters 6 and 9).

1.2.2 **Maintenance** underlies all four measures. A measure that cannot be maintained by its owner under Chapter 10 shall not be credited.

1.2.3 Credits from higher measures reduce the requirements of lower ones. Preserved areas and retained volume reduce detention storage as set out in Chapter 4.

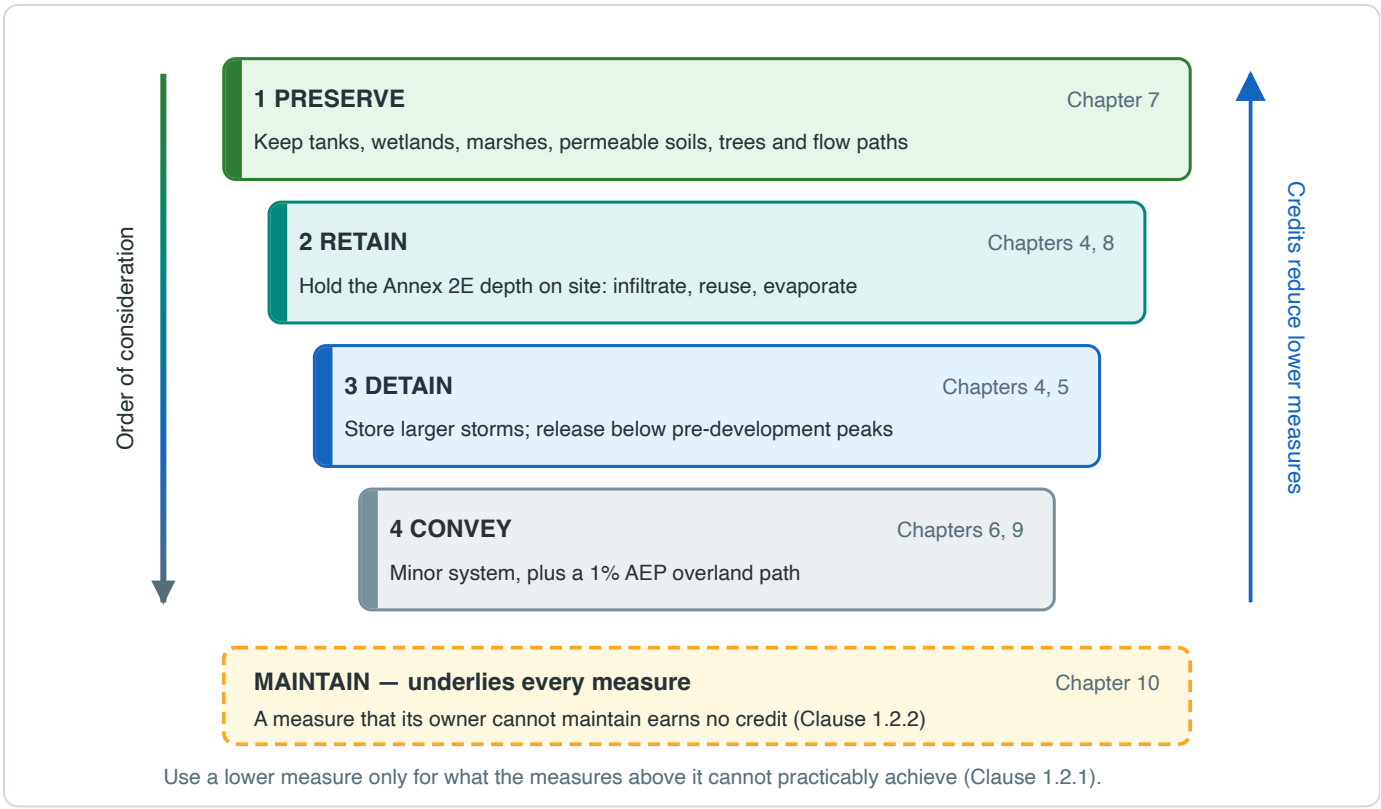

Figure 1.1 — Stormwater management hierarchy: preserve, retain, detain, convey, with maintenance underlying each measure. Original drawing for this Manual, adapted from Mid-America Regional Council / Kansas City Metro Chapter APWA, "Layers of Stormwater Management", APWA 5600 Manual Factsheet, 2025 (concept).

Commentary. The order follows the "layers" of Kansas City Metro APWA Section 5600, Version 2025.01: preserve or restore, retain, detain, convey, maintain (MARC factsheet, 2025). The same logic is behind Georgia's runoff-reduction standard and CSE's "attenuate and infiltrate first" principle (CSE, 2023). For Rajasthan, the top layer has a particular meaning. In a State where about 60% of the land drains inland and much of the west has no defined outfall (as reported), the storage that matters is in the talabs and the earthen johads and nadis of the villages, in the walled taankas and kunds that hold roof and courtyard water, in the baoris of the old towns, in the khadins of the Jaisalmer plains, and in the large sagars and lakes that the cities were built around: the Pichola–Fateh Sagar–Udai Sagar chain at Udaipur, Ana Sagar at Ajmer, Kailana and Takhat Sagar at Jodhpur and Man Sagar at Jaipur. The State has four Ramsar sites, Keoladeo (1981), Sambhar (1990) and Khichan and Menar (both 4 June 2025) (as reported). Losing that storage has a record: the High Court found the catchment of the Ramgarh dam, about 769.20 km² that once supplied Jaipur, so built over and mined that the dam ran dry, and the Supreme Court found it "still bone dry" in 2017 (*National Institute of Medical Science University v. State of Rajasthan*, 9 Nov 2017). The law protects some of this storage. Public tanks, streams and drains in a municipality vest in it as trustee (Rajasthan Municipalities Act, 2009, s.68); no khatedari rights accrue in pasture and tank-bed land (Rajasthan Tenancy Act, 1955, s.16); the High Court has barred allotment in the catchments of "Johar, Nala, Tank, River, Pond" (29 May 2012) and held that land recorded as gair mumkin nala is a natural channel that cannot be diverted even for a public purpose (*Ramji Lal Saini*, 7 May 2026); and the Lakes Act of 2015 protects the "flow area" of a lake, the area through which its feeders flow (s.2(viii), as read from the Bill text). The Rajasthani word agor, used for the catchment of a tank, has no dictionary or statutory source found for this Manual, so the statutory "flow area" is used instead. Losing that storage cannot be offset economically by pipes and pumps.

1.3 Legal basis and status

1.3.1 **Notification.** This Manual shall be given statutory effect by the Government of Rajasthan through:

- (a) an amendment to the Model Rajasthan Building Regulations 2025 that makes compliance with this Manual a condition of planning permission, building permit, layout approval and completion certificate, for development to which Clause 1.5 applies; and
- (b) bye-laws or standing orders of each urban local body (ULB), adopting the Manual for works executed or approved by that ULB, including the ULB's own drains and roads.

1.3.2 **Higher State standards.** The design return periods and performance criteria of this Manual exceed the national advisory minimums of the CPHEEO Manual on Storm Water Drainage Systems (2019). The State shall constitute, by notification, a high-powered committee (the **State Stormwater Technical Committee**, Clause 1.9) to adopt these higher standards. This is the route that CPHEEO (2019) provides for higher return periods.

1.3.3 **Precedence.** Within its scope, this Manual governs where it is stricter than CPHEEO (2019), IRC:SP:42-2014, IRC:SP:50-2013 or any departmental standard. Where a statute or statutory rule sets a stricter requirement (for example a waterbody setback), the statute governs.

1.3.4 **Design-practice standard for public works.** Departments and ULBs that procure drainage, road or waterbody works shall require compliance with this Manual in detailed project reports (DPRs) and contracts, from the dates in Clause 1.11.

> Commentary. In Rajasthan the building rules are the Model Rajasthan Building Regulations, 2025 (मॉडल राजस्थान भवन विनियम, 2025), issued by the Urban Development and Housing Department (UDH) with its order No. P.11(5) नविवि/Building Regulations-2025/2025 dated 12 May 2025, which invokes the byelaw and regulation powers of the Rajasthan Municipalities Act, 2009 (s.337), the Rajasthan Urban Improvement Act, 1959 (s.104-A), and the Acts of the development authorities of Jaipur, Jodhpur, Ajmer, Kota, Udaipur, Bikaner and Bharatpur. Each urban local body or authority brings the regulations into force by its own publication in the Rajasthan Gazette (reg. 1.2), so the date from which they apply varies by city and is to be confirmed for each [TBC]; one secondary source gives 5 December 2025. On taking effect they repeal the earlier building regulations and their amendments (reg. 18.1). Their predecessors were the Model Building Regulations of 2020 and the versions each authority notified, such as JDA's (Jaipur Region) Building Regulations, 2020, published in the Gazette on 7 January 2021. An amendment of 2026 is reported to lift the caps on building height (as reported; text not read). This Manual cites the 2025 text as read from a third-party copy. The regulations require rainwater harvesting on plots of 225 m² and more (reg. 8.3; 300 m² under the 2020 regulations), a green area of 10–20% of larger plots with at least half of it on natural ground (reg. 8.1), and, for buildings of 5,000–20,000 m² built-up, that the inlet and outlet points of the natural drainage be kept as they are, with one recharge bore for each 5,000 m² and at least 20% of the open space unpaved (the environmental schedule, as read in JDA's 2020 text); they set the plinth at least 0.45 m above the road in front (reg. 6.6). They set no design storm, return period, release rate or detention volume, no "zero runoff" rule, and no setback from a nala, river or lake. The route of Clause 1.3.1(a) therefore runs through UDH, which would amend the model, and through each urban body and authority, which would publish the amendment for its area. This Manual is a draft; neither the Government nor any authority has adopted it. MoHUA told Parliament in July 2026 that urban flooding "falls under the purview of the State Governments and the ULBs" and listed the CPHEEO manual among "advisory guidelines" (Lok Sabha AU1847). The State therefore needs no central approval to adopt higher standards. CPHEEO's Note 2 to Table 4.1 (§4.4.1.4) allows "a high powered committee constituted by State/UT Government through a notification" to adopt higher return periods. Clause 1.3.2 uses that route so that higher standards are on record for centrally funded schemes.

1.4 Definitions

1.4.1 The following terms apply throughout this Manual. Chapter-specific terms are defined in each chapter (for example Clause 2.2).

Term	Meaning in this Manual
Approving Authority (the Authority)	The body that grants planning permission, building permit or layout approval for a development, or that sanctions a public work: the Municipal Corporation, Municipal Council or Municipal Board, the development authority or the Urban Improvement Trust that approves building plans and layouts in its area under the building regulations in force there, including approval through an empanelled architect where those regulations allow it (Model Rajasthan Building Regulations 2025, chapter 11); or RIICO in its industrial areas, under its own building regulations [TBC], or a department for its own works.
Applicant	The owner, developer or department that seeks approval, and its successors in title.
Development	Any building, layout, sub-division, road, paving or land-use change that requires approval under the Model Rajasthan Building Regulations 2025 or that is executed as a public work.
Redevelopment	Development on a site where impervious cover already exists.
Land disturbance	Clearing, grading, excavation, filling or paving of land, measured in plan area over the whole of a common plan of development (Clause 1.5.5).
Impervious area	Roofs, paving, compacted gravel, decks and other surfaces that prevent infiltration. Permeable paving designed to Chapter 8 is counted as pervious only for the area it treats.
New or replaced impervious area	Impervious area created, or removed and rebuilt down to the subgrade, by the development. Resurfacing that leaves the base in place is not "replaced".
Retention	Permanent removal of runoff from the drainage system on site, by infiltration, reuse or evapotranspiration (Chapter 4).
Detention	Temporary storage of runoff with a controlled outlet, emptied after the storm (Chapter 4).
Rainwater harvesting (RWH)	Collection of rainfall for supply or recharge under the RWH mandate. RWH storage is not detention unless Chapter 4 allows it.
Minor system	Drains, pipes and inlets designed for the minor-system AEP of Chapter 6.
Major system	The overland and floodway path that carries the 1% AEP (100-yr) flow (Chapter 6).
Pre-development condition	Greenfield: open land in good condition for the mapped hydrologic soil group. Existing impervious cover is not counted (Chapter 3).
Flood-sensitive catchment	The catchments of the Dravyavati and the nalas that join it through Jaipur, with the low-lying colonies of the city that drain to them; the catchments of the Jojari and of the Bhairav, RTO and other city nalas at Jodhpur, and the old city of Jodhpur, where the water table has risen close to the ground; the land that drains to the Udaipur lake chain of Pichola, Swaroop Sagar, Fateh Sagar, the Ayad (Ahar) and Udai Sagar; the catchment of Ana Sagar at Ajmer and the land along its escape channel; the land of Kota that drains to the Chambal, where the river is raised by the releases of the dams upstream; and Balotra and the land that drains to the Luni there, with Barmer town and the low ground of its district, and any catchment the Authority notifies (Chapter 4; Annex 1B).
Waterbody	A river, stream, canal, tank (talab), lake, pond, marsh, supply channel or surplus course, whether perennial or seasonal (Chapter 7).
Regional facility	A detention, retention or tank storage facility serving more than one development, built or restored under a basin plan (Chapter 4).
Tier A / Tier B authority	An Approving Authority classed under Clause 1.6.
Policy supplement	The set of adoptable alternative clauses in Clause 1.7 and Annex 1C.
Drainage report	The preliminary or final report required by Chapter 10.

Term	Meaning in this Manual
Registered professional	A person registered under the Model Rajasthan Building Regulations 2025 to prepare and sign the relevant plans, with any further qualification required by Clause 10.6.
Compliance calculator	The State-issued tool for computing and reporting compliance (Clause 10.5).
Maintenance declaration	The registered undertaking by an owner to maintain a stormwater facility (Clause 10.10).
Variance	Approval to depart from a numeric requirement, with equivalent performance shown (Clause 1.10).
Waiver	Approval that a requirement does not apply to a site, on the grounds in Clause 1.10.
Notified	Published by the Government or the State Stormwater Technical Committee in the Rajasthan Gazette.

> **Commentary.** "Replaced" impervious area is defined to the subgrade so that redevelopment of a fully paved site is captured, while routine resurfacing is not. This follows the approach of the APWA 5600 (2025.01) redevelopment triggers (MARC Supplement, 2025).

1.5 Applicability

1.5.1 **Who is covered.** This Manual applies to:

- (a) all development requiring planning permission, building permit or layout approval under the Model Rajasthan Building Regulations 2025;
- (b) all drainage, road, bridge, culvert, waterbody and flood-mitigation works executed by a ULB, a State department, a board, or a State undertaking; and
- (c) works executed by Central agencies or their contractors within Rajasthan, to the extent that the Authority's approval or no-objection is required.

1.5.2 **Retention and detention threshold.** Chapters 4 and 5 (retention, detention, downstream and tailwater analysis) apply to any development that, over the common plan of development, involves:

- (a) land disturbance of **0.1 ha or more**; **or**
- (b) new or replaced impervious area of **500 m² or more**.

1.5.3 **RWH.** The existing RWH mandate continues to apply under regulation 8.3 of the Building Regulations 2025 to every plot of **225 m²** and more, by a rainwater harvesting unit or structure or a rooftop rainwater storage tank with a filter, secured by a refundable deposit of ₹50,000–₹5 lakh that is returned only after the Ground Water Department, WRD or an experienced engineer reports that the structure works, except in waterlogged areas once the local body has marked them; and under section 238 of the Rajasthan Municipalities Act, 2009, which bars a public water connection to a new building without the Municipality's certificate that the structure has been built (as read from a third-party copy), as now. This Manual does not change it.

1.5.4 **Provisions that apply at every size.** The following apply to all development under Clause 1.5.1, whatever its size, unless exempted by Clause 1.5.8:

- (a) no sewage connection to a storm drain (Chapter 8);
- (b) lowest habitable floor and openings at or above the 1% AEP level plus 0.5 m, where a 1% AEP level is mapped or determinable (Chapter 6);
- (c) waterbody setbacks and the no-fill zone (Chapter 7); and
- (d) no obstruction of a natural drainage path or major-system flow path (Chapter 6).

1.5.5 **Common plan of development.** The thresholds of Clause 1.5.2 apply to the total area of a development, including all phases, plots and sub-divisions under one layout approval or one ownership at the date of application. A development shall not be divided to avoid the thresholds.

1.5.6 **Redevelopment.** For redevelopment, the thresholds apply to new plus replaced impervious area. Retention and detention apply to the whole of the new and replaced impervious area, and the pre-development condition is greenfield (Clause 1.4). Where greenfield control cannot be achieved on a constrained redevelopment site, the relief route of Clause 4.5.6 applies: a minimum on-site cut of 50% from existing peaks, with the shortfall paid as fee-in-lieu into basin storage.

1.5.7 **Linear public works.** For roads, widening and other linear works, the impervious area threshold applies to the added impervious area within each drainage catchment crossed. Retention and detention shall be provided within the right of way, or in a regional facility under Chapter 4, where the right of way cannot hold them.

1.5.8 **Exemptions.** The following are exempt from Chapters 4 and 5:

- (a) a single dwelling on its own plot, where the thresholds of Clause 1.5.2 are not met; and
- (b) linear road resurfacing that adds no impervious area.

Exempt development remains subject to the RWH mandate and to Clause 1.5.4.

1.5.9 **Applicability determination.** The Applicant shall record the applicability decision on **Form 1-1** (Applicability Determination) with the first submittal under Chapter 10. The Authority may confirm or correct it at the pre-application stage.

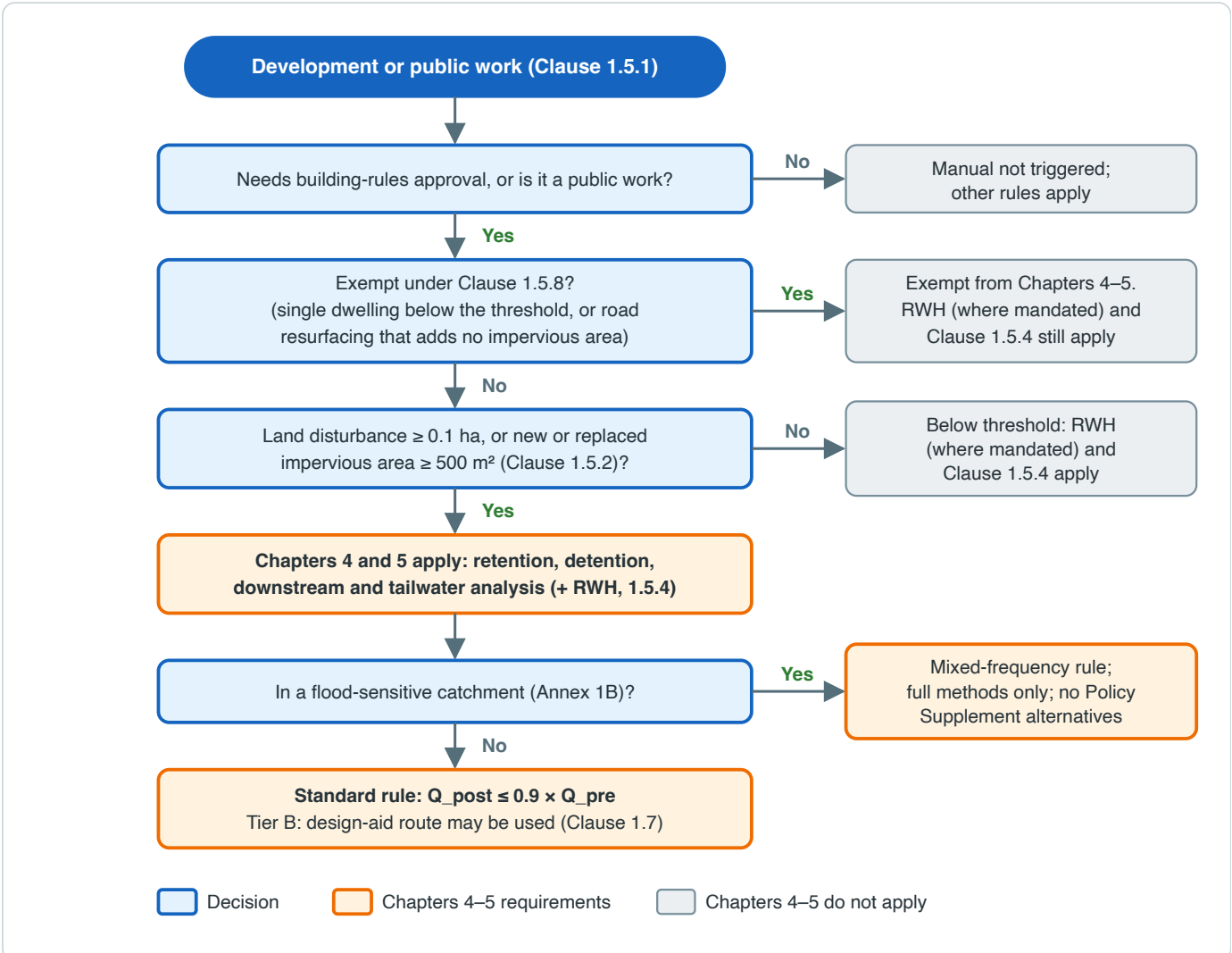

Figure 1.2 — Applicability decision flowchart for Clause 1.5. Original drawing for this Manual.

> **Commentary.** The thresholds have no single direct precedent; they are set by this Manual. Precedents span a wide range:
>
> - Singapore controls peak runoff from developments of 0.2 ha or more (PUB Code of Practice on Surface Water Drainage, 7th ed., cl. 7.1.5).
> - Malaysia's 2008 DID checklist used on-site detention for sites up to 0.1 ha and community ponds above that.
> - The APWA 5600 (2025.01) Policy Supplement offers alternative triggers of ¼ acre (about 0.1 ha) disturbed, or 1 acre (about 0.4 ha) with 10,000 sq ft (about 930 m²) impervious, and warns agencies not to exceed a 1-acre trigger.
> - MBBL 2016 makes recharge mandatory for buildings over 500 m².
>
> The 0.1 ha / 500 m² trigger sits at the strict end of these, because typical Rajasthan plots are small and the cumulative effect of many small plots is what fills Jaipur's drains. For small buildings in Rajasthan, regulation 8.3 of the Building Regulations 2025 requires a rainwater harvesting unit or structure, or a rooftop rainwater storage tank with a filter, on plots of 225 m² and more, secured by a refundable deposit of ₹50,000 on the smallest plots and returned after the Ground Water Department, WRD or an experienced engineer reports that the structure works (Schedule 2). None of this is sized to a runoff volume, none of it limits what leaves the plot, plots below 225 m² have no rule at all, and a plot in a waterlogged area that the local body has marked is exempt (reg. 8.3(iii)). The regulations set the plinth at least 0.45 m and at most 1.2 m above the road in front (reg. 6.6), and JDA's 2020 regulations kept the roof of a basement outside the building to 1.20 m above the road (reg. 11.6(v)); but neither height is related to any flood level, and no clause on keeping surface water out of a basement was found in the pages read. At the start of August 2024 three people died in a flooded basement in Jaipur (as reported). Clause 1.5.4(b) applies to every building whatever its size for this reason.
>
> Clause 1.5.4(b) has no direct precedent; this Manual sets it because floor levels are the cheapest protection a building can have, and it would be perverse to protect only large developments. Where no 1% AEP level is mapped, Chapter 6 gives the method for small sites.

1.6 Tiered adoption

1.6.1 **Tier A authorities.** The following are Tier A:

- (a) the Jaipur Municipal Corporation (JMC), and JDA and every other Approving Authority within the Jaipur Region of JDA;
- (b) every other Municipal Corporation constituted under the Rajasthan Municipalities Act, 2009, as constituted from time to time; and
- (c) every other development authority constituted by an Act of the State (JoDA, AjDA, KDA, UDA and the Bikaner and Bharatpur Development Authorities, and any constituted later), with every Approving Authority within its region.

1.6.2 **Tier B authorities.** All other Municipal Councils and Municipal Boards are Tier B.

1.6.3 **What differs between tiers.** All criteria of this Manual apply in both tiers. The tiers differ only in method and review:

Table 1.1 — Differences between Tier A and Tier B authorities

Item	Tier A	Tier B
Performance criteria (Chapters 2–9)	Apply in full	Apply in full
Hydrologic method for storage	Hydrograph method (Chapter 3)	Hydrograph method, or the design-aid route of Clause 1.7 where eligible
Compliance calculator (Clause 10.5)	Required as a summary	Required; may be the sole calculation on the design-aid route
Policy supplement alternatives (Clause 1.7)	Only with State Stormwater Technical Committee concurrence	May be adopted by council resolution
Technical review	By the Authority	By the Authority, with UDH regional support or an empanelled reviewer (Clause 10.7)
Flood-sensitive catchment rule	Applies	Applies

1.6.4 **Moving between tiers.** A Tier B authority may opt into Tier A by council resolution. The Government may notify a Tier B authority as Tier A when it becomes a Corporation, joins the region of a development authority (JDA, JoDA, AjDA, KDA, UDA or the Bikaner or Bharatpur Development Authority) as notified under its Act, or is found by a post-event review (Clause 10.16) to need the full methods.

1.6.5 **Flood-sensitive catchments override tier.** In a flood-sensitive catchment, whatever the tier, the alternatives of Clause 1.7 are available only as Table 1.2 allows: S-1 (the design-aid route) for sites of 0.5 ha or less (Clause 4.14.1), and S-5 fee-in-lieu where a basin plan has been notified (Clause 1.10.3(d)). S-2, S-3 and S-4 are not available.

> **Commentary.** Jaipur Municipal Corporation, with its engineering wing and a city of nalas that drain to the Dravyavati, the 47.5 km channel that JDA rebuilt to pass the 100-year flood, and a small Municipal Board with one assistant engineer cannot be asked to review the same hydrograph models. The Kansas City solution was to keep one regional standard and publish adoptable alternatives for the most contested criteria, so that smaller agencies can "opt down" without leaving the standard (MARC Supplement, Nov 2025). The tiers here keep the performance criteria the same in both tiers and vary only the method, so that a building in a Tier B town is protected to the same level as one in Jaipur.

1.7 Policy supplement: adoptable alternatives

1.7.1 The Government shall publish, with this Manual, a **Policy Supplement** (Annex 1C) of alternative clauses. An Approving Authority may adopt one or more alternatives under the conditions in Clause 1.7.3.

1.7.2 The alternatives are:

Table 1.2 — Policy supplement: adoptable alternatives S-1 to S-5

No.	Main-text requirement	Adoptable alternative	Eligibility
S-1	Storage sized by hydrograph method (Chapter 3)	**Design-aid route:** retention and detention volumes taken from the unit-storage tables (m³ per ha, by rainfall zone, soil group and impervious fraction) in Annex 4 and the compliance calculator	Sites ≤ 2 ha outside flood-sensitive catchments; ≤ 0.5 ha within them (as Clause 4.14.1)
S-2	Release rate Q_post(T) ≤ 0.9 × Q_pre(T), computed for the site	**Permissible site discharge (PSD):** a tabulated unit-area release rate (m³/s/ha) by zone and AEP, derived from the 0.9 × Q_pre rule	Any site outside flood-sensitive catchments

No.	Main-text requirement	Adoptable alternative	Eligibility
S-3	Waterbody setback extended to the mapped 1% AEP flood extent plus margin (Chapter 7)	**Fixed-width setback table** by waterbody class, where no 1% AEP extent is mapped. Never less than the Zone 1 minimum of Clause 7.4.7	Waterbodies with no mapped 1% AEP extent
S-4	Downstream analysis by hydraulic model (Chapter 5)	**Screening checklist** of downstream capacity and known flooding, with a model only where the screen fails	Sites < 1 ha, outside flood-sensitive catchments, not discharging to a tidal outfall
S-5	On-site detention	**Fee-in-lieu** toward a regional facility or restored tank storage in a master-planned basin (Chapter 4)	Where a basin plan has been notified

1.7.3 **Conditions on adoption.**

- (a) An alternative shall not lower any criterion below the values of this Manual. S-1 and S-2 are simplified methods for meeting the same criterion. They are not lower criteria.
- (b) A Tier B authority adopts an alternative by council resolution, sent to the State Stormwater Technical Committee within 30 days. A Tier A authority needs the Committee's concurrence before adoption.
- (c) The adopted alternatives shall be published on the Authority's website and in the register of Clause 10.17.
- (d) Retention (Annex 2E depth) cannot be replaced by any alternative, except where fee-in-lieu under S-5 funds equivalent retention in the same basin.
- (e) The tables for S-1, S-2 and S-3 shall be issued by the State Stormwater Technical Committee, and reviewed with Chapter 2 (Clause 2.14).

> **Commentary.** The supplement follows the model of the APWA 5600 (2025.01) Policy Supplement, which gives alternatives for the four most contested criteria (applicability, Rational Method limits, stream setback trigger, and Zone 2 setback width). Two of those map onto S-3 and onto the applicability threshold of Clause 1.5.2. Alternative S-3 copies the APWA answer to the same problem: the 1% AEP extent is not mapped for small drainage areas, so a fixed-width table is offered. S-2 follows the Kansas City 2011 shift from "match existing" to fixed unit-area release rates. Local agencies preferred a set rate because existing conditions were hard to determine consistently (MARC Evolution deck). It also reflects the Sydney Water permissible site discharge (PSD) method. The 2 ha / 0.5 ha limits for S-1 (matching Clause 4.14.1) and the 1 ha limit for S-4 have no direct precedent; they are set by this Manual.

1.8 Relationship with other instruments

1.8.1 This Manual shall be applied together with the instruments below. Where they overlap, Clause 1.3.3 governs.

Table 1.3 — Relationship with other instruments

Instrument	Relationship
Model Rajasthan Building Regulations, 2025 (UDH order No. P.11(5) नविवि/Building Regulations-2025/2025 of 12 May 2025; in force in each urban area from its publication in the Rajasthan Gazette by the local body or authority, a date to be confirmed for each [TBC]); their predecessors, the Model Building Regulations, 2020 and the authorities' versions, such as JDA's of 7 January 2021, repealed by reg. 18.1	Continue. They require rainwater harvesting on plots of 225 m² and more (reg. 8.3); a green area of 10–20% of non-commercial plots of more than 750 m², at least half of it on natural ground with no slab below (reg. 8.1); for buildings of 5,000–20,000 m² built-up, the natural drainage inlets and outlets kept as they are, with channels sized for unobstructed flow, one recharge bore for each 5,000 m² and at least 20% of the open space unpaved (environmental schedule; read in JDA's 2020 text); and a plinth at least 0.45 m above the road in front (reg. 6.6). Underground tanks, drains and catch chambers in the setbacks are not counted in ground coverage (reg. 4.13). Norms set for lake protected areas override the regulations (JDA 2020, reg. 10.4). They set no design storm, release rate or detention volume, and no setback from a nala, river or lake; the design criteria of Chapters 2–6 and the hydraulic corridor and setbacks of Chapter 7, whose Zone 1 is at least 15 m, are this Manual's proposals; they are not statutory values, and no authority has adopted them. Where the regulations, a master plan, a statute or a court order are stricter, they govern (Clause 1.3.3).
Rainwater harvesting: Building Regulations 2025, reg. 8.3 and Schedule 2; Rajasthan Municipalities Act, 2009, s.238; Rajasthan Urban Improvement Act, 1959, s.73(c)	Continue unchanged. Regulation 8.3 makes a rainwater harvesting unit or structure, or a rooftop rainwater storage tank with a filter, compulsory on plots of 225 m² and more, secured by a refundable deposit of ₹50,000–₹5 lakh that is returned only after the Ground Water Department, WRD or an experienced retired engineer reports that it works, and exempts waterlogged areas once the local body has marked them. Section 238 makes harvesting compulsory in government buildings and, as the byelaws prescribe, in every other building, with a fine of ₹10,000–20,000, and bars a public water connection to a new building without the Municipality's certificate that the structure has been built (as read from a third-party copy). The 2020 regulations cite s.73(c) of the 1959 Act, which was not read [TBC]. The Rajasthan Ground Water (Conservation and Management) Authority Act, 2024 (Act No. 20 of 2025) is in force only from a date to be notified, and no commencement notification was found [TBC]. The State drew 149.86% of its annual extractable groundwater in 2024, and 214 of its 302 assessment units were over-exploited (CGWB). None of these gives an outlet rule or a storage that is empty when a storm arrives. RWH storage is not detention unless it is a dedicated empty-on-arrival volume with an outlet, and tanks are assumed full at the start of SW monsoon storms (Chapter 4). Recharge structures may count toward retention where they meet Chapters 4 and 8, which make recharge the first choice across the State, with pre-treatment, except in the old city of Jodhpur and the Ganganagar–Hanumangarh canal belt, where the water table is shallow and a groundwater check comes first.
Rajasthan Municipalities Act, 2009 (Act 18 of 2009), ss.45, 68, 200–215 and 238 (as read from a third-party copy; amendments not checked [TBC])	Continue. Drainage, sewerage and the drains, culverts, tanks and dams of the area are among the Municipality's duties (s.45); public tanks, streams, reservoirs and their adjacent public land, and the public drains, channels, culverts and watercourses in, alongside or under any street, vest in it as trustee (s.68); all drains within the Municipality are under its survey and control (s.200); no building may be built, rebuilt or occupied without a drain at the level and fall the Municipality requires, discharging to a municipal drain within 50 ft or else to a cess-pool (s.202); sewage and rain-water drains are to be distinct (s.204, by its title; text not obtained [TBC]); and no drain may be connected to a municipal drain, and no building built over one, without the Municipality's written consent (s.213). This Manual does not change those powers; Chapter 7 treats tanks as drainage assets and Chapter 8 keeps sewage out of storm drains.
Rajasthan Urban Improvement Act, 1959; the Jaipur Development Authority Act, 1982, the Jodhpur Development Authority Act, 2009, the Ajmer Development Authority Act, 2013, the Kota and Udaipur Development Authority Acts, 2023, and the Bikaner and Bharatpur Development Authority Acts, 2025	Continue. They constitute the Urban Improvement Trusts and the development authorities, which prepare master and zonal plans and approve schemes and layouts in their areas, and they are among the parent Acts of the Building Regulations 2025 (s.104-A of the 1959 Act, s.90 of the JDA Act, s.85 of the Jodhpur and Ajmer Acts and s.88 of the others, as cited in the order of 12 May 2025). Their texts were not read for this Manual [TBC]. The High Court has held that a master development plan cannot disturb hills, forests, rivers, lakes or catchments (*Gulab Kothari*, 12 Jan 2017). This Manual does not decide zoning; the drain reserves and regional facility sites of Chapters 4 and 7 are meant to be shown in those plans.

Instrument	Relationship
Rajasthan Lakes (Protection and Development) Authority Act, 2015 (Act No. 5 of 2015; read from the authorised translation of the Bill, not the enacted text [TBC])	Continues. A "lake" is any inland water body, recorded or not and holding water or not, that had a submerged area of at least 3 ha (of socio-cultural, heritage or religious importance) or 10 ha (otherwise) at any time in the fifty years before the Act; its "flow area" is the area through which streams or feeders flow to it (s.2). The State may notify a lake's boundaries and a protected area around it; town planning authorities must consult the Rajasthan Lakes Development Authority, and a plan covering a lake needs its prior approval; no construction in a protected area is allowed without permission; and the Authority may remove an obstruction in the protected area or the flow area (ss.4–6). No notification of lake boundaries or protected areas under the Act was found [TBC]. Chapter 7 treats the flow area as the catchment it protects.
Rajasthan Tenancy Act, 1955, s.16, and the revenue records (land recorded as gair mumkin nala, nadi or talab)	Continue. Khatedari rights do not accrue in pasture land, tank-bed land and the other classes listed (s.16, as quoted by the Supreme Court; the full list not read [TBC]). The High Court has barred allotment of land in the catchments of "Johar, Nala, Tank, River, Pond" and ordered cancellation of allotments made against s.16 (29 May 2012), and has held that land recorded as gair mumkin nala is a natural drainage channel that cannot be diverted, obstructed or altered even for a public purpose (*Ramji Lal Saini*, 7 May 2026). Chapter 7 uses the recorded extent of a nala, nadi or talab as the least extent of its corridor.
Wetlands (Conservation and Management) Rules, 2017; the Rajasthan State Wetland Authority; the four Ramsar sites of the State	Continue. The Rules regulate activities within notified wetlands and their zone of influence. The State Wetland Authority was set up in 2019 and reconstituted in 2020, and 75 wetlands were reported notified by January 2026 (as reported). The Ramsar sites are Keoladeo (1981), Sambhar (1990), and Khichan and Menar (4 June 2025) (as reported). On 1 June 2026 the High Court ordered a district-wise survey of wetlands and barred encroachment, filling, construction and the discharge of untreated sewage into wetlands or their catchments, pending further orders (suo motu, Jodhpur). Where a notification or an order is wider than the setback of Chapter 7, it governs (Clause 1.3.3).
Orders of the Supreme Court, the High Court and the National Green Tribunal on catchments, channels, lakes and rivers	Apply where they bind. Ramgarh dam: the High Court ordered the catchment of the dam, about 769.20 km², cleared of construction and mining (*Abdul Rahman*, DBCWP 1536/2003, 2 Aug 2004; suo motu SBCWP 11153/2011, orders of 23 Aug 2011 and 29 May 2012), and the Supreme Court confirmed the line and ordered demolition on encroached land in 2017 (*NIMS University*, 9 Nov 2017). Natural channels: *Gulab Kothari* (DBCWP 1554/2004, 12 Jan 2017) and *Ramji Lal Saini* (7 May 2026), above. Rivers: on 7 August 2026 the Supreme Court ordered the State to determine and demarcate the high flood line and an ecological buffer for all the river systems of the State, barred fresh permissions for industrial, commercial or residential development within the identified river corridors until then, and directed a River Commission or River Rejuvenation Authority under the Chief Secretary (*In Re: 2 Million Lives at Risk, Contamination in Jojari River, Rajasthan*, Suo Motu WP (C) 8 of 2025); an interim order of 24 August 2026 is reported to bar construction within 100 m of the edge of the Jojari (as reported). Wetlands: the High Court's order of 1 June 2026, above. Udaipur: a no-construction zone around Pichola and Fateh Sagar dates from a notification of 17 January 1997, and the High Court is reported to have held a project within 200 m of the high flood level of Udai Sagar void (as reported). Ajmer: the NGT ordered the removal of structures built on the Ana Sagar wetland, among them the Seven Wonders park, in 2023, the Supreme Court refused to interfere in 2023–2025, and demolition of the park began on 12 September 2025 (as reported). The hydraulic corridor and setbacks of Chapter 7, with a Zone 1 of at least 15 m, are this Manual's proposals; where a court's line binds and is wider, it governs.
Disaster Management Act, 2005; RSDMA; the State and district control rooms	Continue. The State and district control rooms are reported to run round the clock from 15 June each monsoon (as reported). No urban flood plan or SOP of RSDMA was found, and the State Disaster Management Plan found is dated 2014 (as reported) [TBC]. Chapter 10 links its pre-monsoon checks to these dates.
RUIDP Circular No. 8, "General guide lines for Drainage Sector work to be taken under RUSDIP" (4 March 2008)	Superseded for works designed under this Manual. The circular asked for a design return period of 1–2 years for the drains of the RUSDIP towns, 25 years for culverts and 50 years for bridges, and described design intensities as "usually in the range of 12mm/hr to 20mm/hr". It is cited as the history of practice; the return periods of Table 2.1 and the rainfall of Chapter 2 apply instead.
CPHEEO Manual on Storm Water Drainage Systems (2019)	Engineering reference. This Manual sets higher return periods under Clause 1.3.2.
NDMA Guidelines on Management of Urban Flooding (2010) and MoHUA SOP (2017)	This Manual puts into effect the NDMA directives on catchment-based design, detention and retention, waterbody protection and climate-adjusted IDF.

Instrument	Relationship
NDMA Urban Flood Risk Management Programme (UFRMP) and AMRUT 2.0	Works funded under these programmes shall comply with this Manual. The development controls of Chapters 4–5 protect the capacity those works create.
IRC:SP:42-2014 and IRC:SP:50-2013	Apply to road drainage only where they do not conflict with Chapter 6.
MBBL 2016, Chapter 9	Model for RWH and for the inspection regime in Chapter 10.

Commentary. RWH in Rajasthan is framed as a water supply and recharge measure. It works well for that purpose. It cannot, however, be relied on for flood control in the SW monsoon, because RWH sumps are usually full or the ground saturated by the time a July or August monsoon depression arrives after weeks of rain. The Manual therefore keeps harvest volume and attenuation volume apart, while letting recharge count as retention where it truly removes water from the system.

Rajasthan is spending on its nalas and city rivers. JDA rebuilt about 47.5 km of the Dravyavati (the Amanishah nala) through Jaipur as a channel to pass the 100-year flood, with sewage treatment plants of 170 MLD, at a reported cost of ₹1,490.85–1,676 crore (JDA EIA; the higher figure includes ten years of maintenance, as reported); it began a ₹80 crore drainage upgrade of the city with a storm water model in 2025 (as reported); and the ADB-funded RUIDP programme is building new drains at Jodhpur, the 13.1 km Bhairav nala and the 7.0 km RTO nala to the Jojari (ADB resettlement plan, 2023). Of these works only the Dravyavati has a stated design standard, and its design discharge and rainfall were not found. No development-control condition stops new plots in the same catchments from using up the capacity such works create. Linking Chapters 4–5 to approvals closes that gap.

The State's law already holds many of the tools. Public tanks, streams, drains and watercourses vest in the Municipality as trustee (Rajasthan Municipalities Act, 2009, s.68); no building may be built or occupied without a drain "for the effectual drainage" of it, at the level and fall the Municipality requires (s.202), or built over a municipal drain without consent (s.213(2)); and sewage and rain-water drains are to be kept distinct (s.204, by its title). The Lakes Act of 2015 gives lakes and their flow areas to an Authority whose approval a plan covering a lake needs; revenue law and the High Court keep land recorded as gair mumkin nala, nadi or talab to its recorded use; and the Supreme Court has ordered the State to demarcate the high flood line and an ecological buffer for all its river systems (7 Aug 2026). What the law lacks is a design standard. None of these instruments says how large a drain must be, which storm it must carry, how wide a nala's corridor must be, or how much storage a filled talab or a paved plot removes. This Manual's checks are framed as part of the building plan and layout approval of the local bodies, the development authorities and the Urban Improvement Trusts, and of the test behind the refund of the rainwater harvesting deposit, not as a separate NOC. This Manual is offered as a technical companion to these instruments, to the orders of the courts on catchments, channels, lakes and rivers, and to the drainage works of the cities: it supplies the design storm, detention and buffer numbers they do not set, as a proposal for the Government and the authorities to consider. Neither the Urban Development and Housing Department nor any other body has adopted it.

1.9 Roles and responsibilities

1.9.1 The responsibilities below apply under this Manual. They do not change any agency's statutory powers.

Table 1.4 — Roles and responsibilities under this Manual

Agency	Role under this Manual
Urban Development and Housing Department (UDH)	Issues the Building Regulations 2025 (order of 12 May 2025) and oversees the development authorities, the Urban Improvement Trusts and the master plans, through the Chief Town Planner. Would prepare the amendment of Clause 1.3.1(a) as a model for the urban bodies to publish, give regional support to Tier B authorities (Table 1.1) and maintain the empanelled reviewer list (Clause 10.7).
State Stormwater Technical Committee (Clause 1.3.2)	Would adopt higher standards, issue Annexes, tables and the compliance calculator, concur with Tier A alternatives, decide variances referred to it and review the Manual (Clause 1.12).
Local Self Government Department and the Directorate of Local Bodies (LSG/DLB)	Oversee the Municipal Corporations, Councils and Boards under the Rajasthan Municipalities Act, 2009; the Department is the executing agency of RUIDP (as reported). Would issue the model ULB bye-law of Clause 1.3.1(b) and require this Manual in the drainage works of the local bodies.
Jaipur Municipal Corporation (JMC) and the other Municipal Corporations; Municipal Councils and Municipal Boards	Hold the public drains, watercourses and tanks of their areas in trust (Rajasthan Municipalities Act, 2009, s.68), keep all drains under their survey and control (s.200), require a drain for every building (s.202), and approve building plans. The twin corporations of Jaipur, Jodhpur and Kota are reported to have been merged again in 2025 (as reported; notifications not seen [TBC]). Would apply this Manual to their works, receive handed-over assets (Clause 10.14), and inspect and enforce (Clauses 10.12–10.15).
Development authorities (JDA, JoDA, AjDA, KDA, UDA and the Bikaner and Bharatpur Development Authorities) and the Urban Improvement Trusts	Prepare master and zonal plans and approve schemes, layouts and building plans in their regions; JDA rebuilt the Dravyavati and acts against encroachment of catchment land (as recorded by the Supreme Court, 2017). Their drainage functions under their Acts were not researched for this Manual [TBC]. Would apply this Manual to their schemes, show drain reserves and regional facility sites in their plans, and hand over drains and storage to the local body under Clause 10.14.
Rajasthan Urban Infrastructure Development Project (RUIDP)	Executes ADB-funded urban works, including storm-water drains at Jodhpur (as reported); its Circular No. 8 of 2008 set the drainage design rules for the RUSDIP towns. Would apply this Manual in its DPRs and designs.
WRD	Holds the dams, reservoirs and irrigation tanks of the State and their gates, and, with the District Environment Committees, is surveying the high flood lines and buffers on the Jojari under the Supreme Court's orders (2026). Would provide design river and reservoir levels, maximum water levels, gate-operation rules and release schedules for Chapter 5, consent to outfalls into its works, and certify rainwater harvesting for the refund of the deposit where asked (reg. 8.3(ii)).
Public Health Engineering Department (PHED)	Supplies drinking water, and is reported to give water connections to buildings on plots of 225 m² and more only after the recharge structure is built (as reported). Would apply Chapter 8 to the protection of supply sources from storm runoff.
Ground Water Department	Certifies rainwater harvesting structures for the refund of the deposit (reg. 8.3(ii)). Would supply groundwater levels and quality with CGWB for Chapters 4 and 8, and advise on the groundwater check in the old city of Jodhpur and the canal belt.
Rajasthan Lakes Development Authority	Constituted under the Lakes Act of 2015; consulted on plans covering a lake, and gives permission for construction in a notified protected area (ss.5–6). Would certify the boundary, full level and flow area of a notified lake for Chapter 7.
Rajasthan State Wetland Authority	Set up under the Wetlands Rules 2017; keeps the list of notified wetlands, 75 by January 2026 (as reported), and is a respondent in the High Court's wetlands case (2026). Would permit regulated activities in notified wetlands (Chapter 7).
RSDMA and the District Disaster Management Authorities	Approve the State and district disaster management plans; the control rooms are reported to run round the clock from 15 June (as reported); its urban flood work was not researched [TBC]. Would recommend flood-sensitive catchments, hold the record of flood-prone locations with the Collectors, and lead the post-event review (Clause 10.16).
Rajasthan State Pollution Control Board (RSPCB)	Grants consents to industries and monitors rivers, lakes and drains, including the Jojari under the Supreme Court's supervision. Supports the removal of sewage and effluent from storm drains (Chapter 8).

Agency	Role under this Manual
Rajasthan State Industrial Development and Investment Corporation (RIICO)	Develops and regulates industrial areas under its own building regulations (as reported); its drains at Jodhpur are reported by the Supreme Court to discharge into municipal drains. Would apply this Manual in its industrial areas.
Revenue Department: the Collectors and the tehsil offices	Keep the revenue records in which tanks, nalas, nadis and their catchments are recorded as gair mumkin land, act against encroachment of public land, and lead flood relief. Would certify the recorded extent of a nala, nadi or talab for Chapter 7.
River Commission or River Rejuvenation Authority (directed by the Supreme Court, 7 Aug 2026)	To be constituted under the Chief Secretary, with a mandate that includes the high flood lines and catchments of the State's rivers; its constitution was not found [TBC]. Would supply the high flood lines and buffers that Chapter 7 applies where they bind.
Central Water Commission (CWC), a body of the Union	Publishes the Flood Estimation Reports for subzones 1(a), 1(b), 1(e) and 3(a) used in Chapters 2 and 3, and the river levels at its flood forecasting sites, such as Kota City and Dholpur on the Chambal. Would supply river stage records and forecasts for Chapter 5.
Central Ground Water Board (CGWB), a body of the Union	Assesses the groundwater units of the State and their categories. Would supply groundwater levels and quality with the Ground Water Department.
National Institute of Hydrology (NIH), Roorkee	Runs NIH-DHAARA (Chapter 2).
IMD (Meteorological Centre Jaipur), and road and rail owners (the Public Works Department, NHAI, Indian Railways)	IMD's stations supply the rainfall records of Chapter 2. Road and rail owners would apply this Manual to road drainage (Chapter 6), culverts and linear works (Clause 1.5.7).

Commentary. Stormwater in Rajasthan is split between UDH, through the building regulations, the master plans and the development authorities and Urban Improvement Trusts; the Local Self Government Department, through the Municipal Corporations, Councils and Boards and the drains vested in them; WRD, through the dams, reservoirs and irrigation tanks and their gates; the Lakes Development Authority, through the notified lakes and their flow areas; the Revenue Department, through the revenue records of nalas, nadis and talabs; and the State Wetland Authority, with the courts setting the catchment, channel, lake and river lines. Ajmer shows why the split matters. The city floods when the escape channel of Ana Sagar is opened in heavy rain (as reported), but the lake, its gates, the escape channel and the colonies along it fall to different bodies, and no order found says who sets the level at which the gates open [TBC]. The Municipalities Act vests public drains, streams and tanks in the Municipality (s.68), but no rule or order found divides the natural nalas from the municipal drains, or the lakes from the dams and channels below them, between the local bodies, the development authorities and the State's departments [TBC]. Until such a rule is made, this Manual assigns the drainage elements as in Table 1.5. The assignment is this Manual's working split for applying its clauses; it does not change any agency's powers.

Table 1.5 — Working assignment of drainage elements under this Manual

Element	Assigned to
Rivers and their floodplains, dams and reservoirs with their gates (such as the Kota Barrage, Ramgarh and Bisalpur), and irrigation tanks	WRD, with the River Commission or River Rejuvenation Authority for high flood lines once constituted
Lakes within a city (such as Pichola and Fateh Sagar at Udaipur, Ana Sagar at Ajmer and Kailana and Takhat Sagar at Jodhpur), with their gates and escape channels	The Lakes Development Authority for a notified lake, and otherwise the local body for the lake and WRD for the gates, until an order assigns them otherwise [TBC]
Natural nalas and city rivers within a Municipal Corporation or a development-authority region (such as the Dravyavati at Jaipur and the Bhairav and RTO nalas at Jodhpur), with their reserves	The Municipal Corporation (s.68), or the development authority for a channel it has built until it hands it over

Element	Assigned to
Land recorded as gair mumkin nala, nadi or talab outside municipal limits, and village tanks	The Revenue Department (Collector), with the Panchayat that manages the tank
Road-side and lane drains and public tanks within the limits of a local body	The Municipal Corporation, Municipal Council or Municipal Board
Drains and storage within a scheme of a development authority or Urban Improvement Trust, until handed over	The development authority or Trust
Drains within an industrial area	RIICO
Sewers, interceptors and the interception and diversion of nalas, and sewage treatment plants	The local body or the body executing the work for it
Drains of State and national highways	The Public Works Department or NHAI
Notified wetlands and Ramsar sites	The Rajasthan State Wetland Authority, with the owner of the land

This Manual names departments and authorities as the statutes, orders and records name them. A manual that names one owner for each task does not fix institutions by itself, but it removes ambiguity about who signs what.

1.10 Variances and waivers

1.10.1 **Variance.** The Authority may grant a variance from a numeric requirement where the Applicant shows, through a report certified under Clause 10.6, that:

- (a) compliance is impracticable because of site conditions such as a high groundwater table, contaminated soil, rock, or a site area too small for the required facility; and
- (b) the proposed alternative gives equal or better performance at the downstream point of Chapter 5, or the shortfall is made up by fee-in-lieu or off-site works in the same catchment.

1.10.2 **Waiver.** The Authority may waive Chapter 4 detention requirements (not retention) where a hydraulic analysis certified under Clause 10.6 shows that the site discharges directly to the sea, or to a tidal reach with no flood-prone property downstream, and that undetained flow does not worsen the outfall-closed condition of Chapter 5. Rajasthan has no coast and no tidal reach, so no site in the State qualifies for this waiver. A site that drains to a lake held by gates or an escape channel, as at Udaipur and Ajmer, to a river raised by dam releases, as the Chambal at Kota, or to a depression with no outfall, as in much of the west, is in the outfall-closed condition of Chapter 5 whenever the receiving water is high, and detention is not waived for it.

1.10.3 **No variance or waiver.** No variance or waiver shall be granted for:

- (a) a sewage connection to a storm drain;
- (b) the lowest habitable floor level of Chapter 6;
- (c) any reduction of a waterbody setback below the Zone 1 minimum of Clause 7.4.7, or any fill or construction in the no-fill zone of Chapter 7; or
- (d) the retention requirement in a flood-sensitive catchment, except by fee-in-lieu under Clause 1.7.

1.10.4 **Procedure.**

- (a) The request shall be made on **Form 1-2** (Variance / Waiver Request) with the preliminary drainage report.
- (b) A Tier B authority shall refer any variance on a site of 1 ha or more to the State Stormwater Technical Committee.
- (c) A decision shall state its reasons and any conditions, and shall be entered in the public register of Clause 10.17.

- (d) A variance runs with the approval. It lapses if the approval lapses.

> Commentary. The 2006 APWA 5600 included a waivers section (5601.6), and Georgia allows waivers where downstream analysis shows a peak control is unnecessary. The waiver of Clause 1.10.2 is narrow: on a tidal coast, undetained flow can help by passing through before the tide closes the outfall, but only an analysis can show that. This Manual requires every decision to be published because publication deters case-by-case erosion of the standard; in Rajasthan the High Court found the catchment of the Ramgarh dam, which once supplied Jaipur, so built over and mined that the dam ran dry, and the Supreme Court recorded in 2017 that "nothing substantive appears to have been achieved on the ground over the years" (*National Institute of Medical Science University v. State of Rajasthan*, 9 Nov 2017).

1.11 Transition provisions

1.11.1 **Effective date.** This Manual takes effect for new applications **6 months** after notification (the effective date).

1.11.2 **Applications in process.** An application filed complete before the effective date may be decided under the rules in force when it was filed, if a decision is issued within 12 months of the effective date. Otherwise, this Manual applies.

1.11.3 **Phased start for Tier B.** In Tier B authorities, Chapters 4 and 5 apply from **24 months** after notification, except in flood-sensitive catchments, where they apply from the effective date.

1.11.4 **Public works.** DPRs sanctioned before the effective date may proceed as sanctioned. Any DPR revised or re-tendered after the effective date shall comply. Departments shall report non-compliant works in progress to the State Stormwater Technical Committee within 12 months.

1.11.5 **Before the annexes are issued.** Until an annex referred to in this Manual is issued, the Applicant shall use the method stated in the clause, with values agreed with the Authority and recorded in the drainage report.

> Commentary. The 6-month lead time matches the lead time for NIH-DHAARA updates in Clause 2.14.2. Singapore gave a similar interval for its 2025 detention addendum (issued 16 Apr 2025, applied from 1 Oct 2025). The 12- and 24-month periods are set by this Manual to let Tier B authorities train staff and to let the State issue the design-aid tables (Clause 1.7).

1.12 Review and amendment

1.12.1 The State Stormwater Technical Committee shall review this Manual every **10 years**, and after any event that exceeds the 1% AEP design depth as set out in Clause 2.14.1.

1.12.2 Amendments shall be notified in the Gazette, published with a change log, and take effect 6 months after notification unless the notification states otherwise.

1.12.3 Any person may propose an amendment to the Committee. Proposals and the Committee's decisions shall be published.

References (chapter)

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Annexes and forms

Annex / Form	Content
1A	List of Tier A authorities, with the boundaries of the Municipal Corporations and of the regions of the development authorities
1B	Maps of flood-sensitive catchments
1C	Policy Supplement: text of alternatives S-1 to S-5 and model council resolution
1D	Model Building Regulations 2025 amendment and model ULB bye-law
Form 1-1	Applicability Determination
Form 1-2	Variance / Waiver Request

CHAPTER 2

Design Rainfall and Design Storms

2.1 Purpose and scope

2.1.1 This chapter sets the rainfall inputs for every hydrologic calculation in this Manual: drain and inlet sizing (Chapter 6), retention and detention sizing (Chapter 4), downstream and tailwater analysis (Chapter 5), and waterbody and tank works (Chapter 7).

2.1.2 It specifies:

- (a) the approved sources of design rainfall depth and intensity;
- (b) how depths are converted between durations, between point and area, and from present to future climate;
- (c) how design storms (hyetographs) are constructed; and
- (d) the storms that must be applied to pre- and post-development conditions.

2.1.3 This chapter applies throughout Rajasthan. Where a Municipal Corporation, Municipal Council, Municipal Board, development authority or Urban Improvement Trust has adopted a stricter rainfall standard under Chapter 1, the stricter standard governs.

Commentary. Most past drainage failures in Rajasthan trace to the rainfall input, not the hydraulics. Rajasthan shows how. The only State rule found for the design of town drains, RUIDP Circular No. 8 of 2008, asked for a 1–2-year storm in the drains of the RUSDIP towns and described design intensities as "usually in the range of 12mm/hr to 20mm/hr", while the IMD recording gauge at Jaipur gives 53.1 mm in 1 hour for the 5-year storm (Ghate & Timbadiya, 2022). The only city standard found, the 100-year flood for which JDA rebuilt the Dravyavati, was published without its design discharge or rainfall, and no storm-drain DPR of any city with a stated return period and rainfall analysis was found for this Manual. The figures that circulate after a flood are often unsourced or conflicting: the Barmer storm of August 2006 is reported as about 577 mm in three days, 600 mm in 72 hours and 723–750 mm in a week, and *Climate of Rajasthan* gives district records of 780.3 mm at Parbatsar and 802.9 mm at Chittor that other IMD and CWC sources do not support. The two published sources that seem to fill the gap do not. The IMD Das et al. (2022) panels for Jaipur and Jaisalmer repeat a curve that the paper prints for a dozen other cities, and for Jaisalmer that curve gives a 2-year day equal to the district's annual rainfall; and NIH-DHAARA's reanalysis-based depths are below the CWC plates and the station records almost everywhere, by about half at Bikaner, and low at 1 hour everywhere (Clause 2.3.6). The CWC Flood Estimation Reports are the only regional sub-daily source, and their ratios give a 50-year 1-hour depth at Jaipur about a third below the station's value. Fixing one transparent source and method for the whole state is the main purpose of this chapter.

2.2 Definitions

Term	Meaning in this Manual
Annual exceedance probability (AEP)	Probability that a given rainfall depth is equalled or exceeded in any one year. A 1% AEP storm is the "100-year" storm. Both forms are used here: T-year = 1/AEP.
IDF / DDF	Intensity–duration–frequency and depth–duration–frequency relationships for a location.
Point rainfall	Rainfall at a single location, as measured by a rain gauge.
Design storm	A hyetograph (rainfall depth versus time) of stated AEP, duration and temporal pattern.
Critical duration	The storm duration that produces the largest peak flow, water level or storage requirement for the element being designed.
Areal reduction factor (ARF)	Ratio of catchment-average rainfall to point rainfall for the same AEP and duration.
SW monsoon season (JJAS)	June–September, with about 91% of the annual rainfall of the State falling in the south-west monsoon (IMD, *Climate of Rajasthan*). Annual normals run from 172.9 mm in Jaisalmer district and about 240–260 mm in Ganganagar, Barmer and Bikaner to 596.8 mm in Jaipur, 758.7 mm in Kota, 882.2 mm in Banswara and 921.2 mm in Jhalawar, and 1,677.0 mm at Mount Abu (IMD, district normals of 1951–2000). The normal date of onset is 24 June at Jhalawar, 25 June at Udaipur, 26 June at Kota, 29 June at Jaipur, 1 July at Ajmer, 2 July at Jodhpur, 4 July at Churu, 5 July at Barmer and 6 July at Bikaner and Pokaran; and of withdrawal 17 September at Pokaran, 18 September at Bikaner, 19 September at Jodhpur and Churu, 20 September at Barmer, 21 September at Ajmer, 23 September at Jaipur, 25 September at Kota and Udaipur and 28 September at Jhalawar (IMD, new normals of 2020). The antecedent moisture rule of Clause 2.11.4 refers to this season; the pre-monsoon deadline of 15 June is set ahead of the earliest onset (Chapter 10).
Storms outside the season	Large falls come before, early in and after it. Several stations hold their highest day in June: Ajmer 412.3 mm on 10 June 2002, Udaipur City 292.0 mm on 30 June 1983 and Nagaur 310.6 mm on 23 June 1996 (IMD), and Cyclone Biparjoy brought heavy rain to Ajmer in June 2023 (as reported). Before the monsoon, Jodhpur recorded 156.8 mm on 26 April 1982 and Jaisalmer 116.3 mm on 22 May 1999; after it, Nasirabad recorded 500.0 mm on 5 October 1989 and Jhalawar 350.0 mm on 5 October 1997, and on 9 November 1982 Dungarpur recorded 144.6 mm and Udaipur (Dabok) 118.7 mm (IMD). Design statistics use annual maxima from all months, and no works deadline or operating rule shall assume that heavy rain is confined to June–September.
Climate factor (CF)	Multiplier applied to present-day design depths to represent the design-life climate.
Approved source	A rainfall source listed in Clause 2.3.

2.3 Approved sources of design rainfall

2.3.1 **Primary source.** Design rainfall depths and intensities shall be taken from the National Institute of Hydrology, Roorkee **NIH-DHAARA** platform (Design Hydrology and Advanced Rainfall Analysis, nihdhaara.in). Use its IDF / frequency tools for the site's coordinates, for each duration and AEP required by Clause 2.4. In Rajasthan this clause is suspended until Annex 2A is published: Clause 2.3.6 sets the interim source.

2.3.2 **Station IDF.** A station-specific IDF relationship may be used in place of 2.3.1 only if all of the following hold:

- (a) it is derived from at least 30 years of recording-gauge (hourly or finer) data;
- (b) it has been published or approved by IMD, the State Hydrology Authority or the approving authority; and
- (c) the gauge is within 10 km of the site, with no major change of terrain or coastal exposure in between.

Where a station IDF is used, the design value shall be the **greater** of the station value and the NIH-DHAARA value.

2.3.3 **Cross-checks (mandatory, not alternatives).** The designer shall report, but need not adopt, the following values for comparison:

- (a) the IMD isopluvial / IDF values of Das et al. (2022), *MAUSAM* 73(4), for durations of 1–24 h;
- (b) for catchments of 25–5,000 km², the 24-hour point rainfall from the CWC Flood Estimation Report for subzone 1(a) (Luni), 1(b) (Chambal), 1(e) (Upper Indo-Ganga Plains) or 3(a) (Mahi and Sabarmati), as applicable.

Where the design value is lower than the CWC 1(a)/1(b)/1(e)/3(a) value for the same AEP, the CWC value shall be adopted as a floor.

2.3.4 **Not permitted.** None of the following shall be used as a design rainfall source:

- (a) generalised all-India IDF formulae (for example Kothyari & Garde, 1992);
- (b) rainfall values that cite no source, including vendor or web-calculator tables;
- (c) single-event maxima; or
- (d) design intensities carried forward from a previous project without a stated AEP.

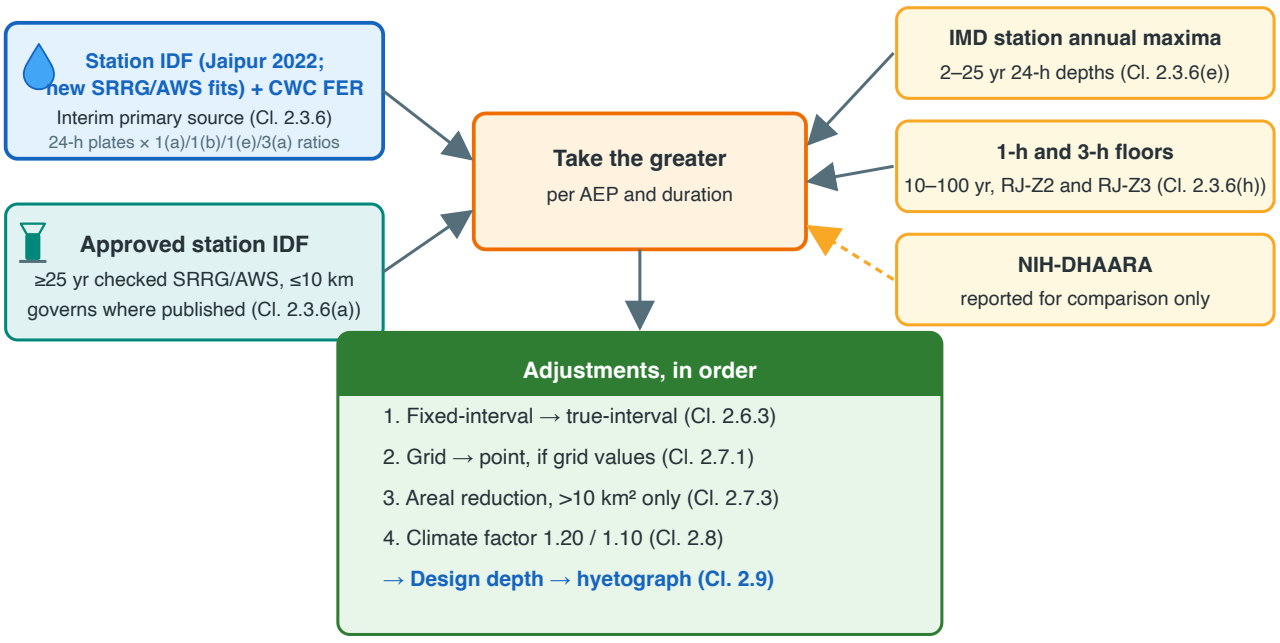

Figure 2.1 — Design rainfall source hierarchy and adjustment sequence. Original drawing for this Manual.

2.3.5 **Version control.** Every submittal shall record the source, its version or access date, the coordinates queried, and the values extracted (Clause 2.13).

2.3.6 **Interim source in Rajasthan.** Until Annex 2A is published and confirms NIH-DHAARA, or an approved station IDF, for a zone, Clause 2.3.1 does not apply in Rajasthan, and design rainfall shall be taken as follows:

- (a) **Station IDF.** Where a station IDF fitted to a checked IMD recording-gauge (SRRG) or automatic weather station record of at least 25 years has been published in Annex 2B, it governs, within 10 km of the station, for the durations and AEPs it covers, in place of (g) and (h); the comparison of Clause 2.3.2 is then made with the 24-hour and longer depths of (d) to (f), and the CWC floor of Clause 2.3.3 still applies. A record is checked when its annual totals and annual maxima have been compared with the IMD normals and station extremes for the station, and every year that disagrees has been explained or removed. An IDF derived from daily data by the one-third rule (Clause 2.6.4) or by any other fixed ratio is not a station IDF. In Rajasthan Clause 2.3.2(a) is read with 25

years in place of 30 (set by this Manual, so that the recording gauges of the State's main cities can qualify once analysed). No IDF has yet been published in Annex 2B; the only published frequency analysis of short storms in the State is that of (b).

- (b) **Jaipur.** Ghate & Timbadiya (2022) analysed 44 years (1970–2013) of hourly data from the IMD recording gauge at Jaipur (26°48'N, 75°48'E), and give the 1-hour depth as 53.1 mm at 5 years and 93 mm at 50 years. Within the Jaipur Region of JDA, the 1-hour design depth shall be the value below for each AEP, and shall not be reduced towards the product of (g); elsewhere in RJ-E it is a floor on the 1-hour depth. A fit under (a) to a longer Jaipur record governs where it is higher, but not where it is lower. The values at 2, 10, 25 and 100 years are set by this Manual on the Gumbel reduced variate through the paper's 5- and 50-year values; the authors' suggested design value of 70 mm at 25 years is lower than this and is not used. The paper gives no depth for durations of 2 to 12 hours; at those durations (g) and (h) apply.

Duration	50% (2)	20% (5)	10% (10)	4% (25)	2% (50)	1% (100)
1 hour (mm)	34	53.1	66	81	93	105

- (c) **Subzone.** The site's CWC subzone is that of the Flood Estimation Report whose area contains it, by the boundaries drawn on the reports' plates. Four subzones cover the State: 1(a) (Luni, L/20/1992), which holds 202,422 km² of the State, about 59% of it, including Jaisalmer, Barmer and Balotra, **Jodhpur** and Phalodi, **Bikaner**, Sri Ganganagar, Hanumangarh, Churu, Nagaur, Sikar, Pali, Jalore, Sirohi with Mount Abu, the west of Ajmer district (Pushkar) and the west of Jaipur district (Sambhar, Phulera and Dudu); 1(b) (Chambal, C/16/1988), including **Jaipur** city and the rest of Jaipur district, Dausa, Tonk, the east of Ajmer district with **Ajmer** city, Nasirabad and Kekri, Bhilwara, Chittorgarh, Rajsamand, the north and east of Udaipur district with **Udaipur** city and its lakes, north Pratapgarh, **Kota**, Bundi, Baran, Jhalawar, Sawai Madhopur, Karauli and Dholpur; 1(e) (Upper Indo-Ganga Plains, 1984), including Alwar with Bhiwadi and Behror, Bharatpur and Deeg; and 3(a) (Mahi and Sabarmati, MS/13/1986), including Banswara, Dungarpur, the south of Udaipur district, south Pratapgarh and the Sabarmati headwaters in south-east Sirohi. Jhunjhunu, and the Ghaggar strip of Hanumangarh and Sri Ganganagar, lie on the 1(a)/1(e) line. Within 5 km of a subzone boundary, the higher of the two plate values is used, and at each duration the higher of the two products under (g). This applies in particular to **Jaipur** and **Ajmer**, which lie on the boundary of 1(a) and 1(b) (Jaipur's city drains south to the Dhund and the Banas, in 1(b), while the Sambhar side drains inland, in 1(a); Ana Sagar and the east of Ajmer drain to the Banas, while Pushkar and the west drain to the Luni), and to **Udaipur**, which lies on the boundary of 1(b) and 3(a) (its lake chain drains through the Ayad to the Banas, in 1(b), and its southern suburbs to the Mahi or the Sabarmati, in 3(a)); in these three cities the higher value is used throughout the Municipal Corporation area (set by this Manual). The district names are those of the sources, from before the reorganisation of districts of 2023–24; a district formed since takes the subzone of the land it was formed from. The district lists are a guide: the plate boundaries govern, and are to be confirmed on the reports' index maps [TBC]. The rainfall zone and sub-area of the site are those of Annex 2A.

- (d) **24-hour depth, 2% and 1% AEP (50- and 100-yr).** The 24-hour point value at the site read from the 50- and 100-year isopluvial plates of the report for its subzone (Plates 9 and 10 of 1(a), 1(b) and 1(e), and Plates 10 and 11 of 3(a)), whatever the catchment area. Where the site lies between two contours, the higher contour value is used; where it lies inside a closed contour with no higher contour within it, the value is that contour plus one contour interval (set by this Manual). Plates are read by the coordinates of the site, not by the town labels. For orientation only, read by eye to about one contour, the 50-year plates give about 120–160 mm at Jaisalmer and about 120 mm at Pokaran, about 160 mm at Sri Ganganagar and Nagaur, about 180 mm at Bikaner, 180–200 mm at Barmer and Ajmer, about 200 mm at Jodhpur, Jaipur, Alwar and Dholpur, 200–220 mm at Udaipur, 220–240 mm at Bharatpur, 240–280 mm at Kota, Tonk and Bhilwara, about 280 mm at Chittorgarh and on the Pali–Sirohi plains, 280–320 mm at Jhalawar, Sawai Madhopur, Banswara and Dungarpur, and a closed cell of 440–480 mm and more over Mount Abu; the 100-year values are about 20–40 mm higher, and more than 560 mm at Mount Abu. The worked example of the 1(a) report, on the Mithri at the Kherwa–Bhumadra road, reads 25.0 cm at 50 years.

The station records of the State far exceed the plates, as at Jaipur (Sanganer) (326.0 mm), Ajmer (412.3 mm), Jaisalmer (204.0 mm, and 540.0 mm at Sam in the same storm), Bharatpur (630.0 mm) and Mount Abu (653.0 mm) (IMD); where the Gumbel estimate of (e) for the station of the site is higher for the same AEP, it governs.

- (e) **24-hour depth, 50%, 20%, 10% and 4% AEP (2-, 5-, 10- and 25-yr).** The reports have no plates for these. The depth is the Gumbel (EV1) estimate from the annual maximum daily rainfall series, of all months, of the IMD station agreed with the Authority, checked as in (a), multiplied by the fixed-interval factor of Clause 2.6.3. The station is, for example, Jaipur (Sanganer) (A), 42348 (daily record 1901–2012), for Jaipur; Jodhpur, 10202 (1901–2012); Bikaner, 42165 (1901–2008); the higher of Udaipur City, 42543 (1898–2012), and Udaipur (Dabok) (A), 42542 (1965–2010), for Udaipur; the higher of Kota, 42451 (1901–2008), and Kota (A), 42452 (1961–2012), for Kota; Ajmer, 42343 (1879–2012); Mount Abu, 42540 (1901–2012); Barmer, 42435 (1931–2012); Jaisalmer, 42328 (1949–2012); Sriganganagar, 42123 (1951–2012); Phalodi, 42237 (1901–2012); Sikar, 42249 (1946–2012); Jhalawar, 42555 (1930–2012); Alwar, 42255 (1956–2000); or Bharatpur, 42258 (1974–2012). Elsewhere it is the nearest IMD station with 30 or more years of record, from the candidates in Annex 2A. The full record is used, and no year is left out because it is an outlier. A day of record that IMD has not confirmed is left out of the series, and the fit with it is reported beside the fit without it on Form 2-1: this applies to the 780.3 mm given for Parbatsar on 16 September 1900 and the 802.9 mm given for Chittor on 14 July 1982 by *Climate of Rajasthan*, which the CWC report (306.8 mm at Parbatsar) and IMD's station extremes (227.0 mm at Chittorgarh) do not support, until IMD confirms them [TBC]; and Mount Abu's day of 8 September 1992 is used at the 653.0 mm of IMD's station extremes, with the 700.0 mm of *Climate of Rajasthan* reported beside it [TBC] (set by this Manual).

- (f) **48- and 72-hour depths.** The Gumbel estimate from the annual maximum 2-day and 3-day rainfall series of the same station, with the fixed-interval factors of Clause 2.6.3, and not less than the 24-hour depth for the same AEP.

- (g) **Durations of 1 to 24 hours.** The 24-hour depth of (d) or (e) multiplied by the ratios of the report for the site's subzone in Table 2B.1, at every AEP: in 1(a), on the report's 10-year basis, 0.36 at 1 hour, 0.58 at 3 hours, 0.72 at 6 hours, 0.79 at 9 hours, 0.85 at 12 hours, 0.89 at 15 hours and 0.94 at 18 hours; in 1(b), on the 50-year basis, 0.35, 0.53, 0.67, 0.74, 0.80, 0.85 and 0.90 at the same durations; in 1(e), 0.34 at 1 hour, 0.475 at 2 hours, 0.56 at 3 hours, 0.607 at 4 hours, 0.647 at 5 hours, 0.68 at 6 hours, 0.77 at 9 hours, 0.84 at 12 hours, 0.89 at 15 hours and 0.93 at 18 hours; and in 3(a), 0.36, 0.57, 0.70, 0.78, 0.85, 0.89 and 0.93 at 1, 3, 6, 9, 12, 15 and 18 hours. The 1(a) report found its ratios comparable for every return period above 5 years and recommends its 10-year ratios for all; the ratios of 1(b), 1(e) and 3(a) are applied at every AEP in the same way (set by this Manual). Between the tabulated durations the ratio is interpolated on logarithmic axes. The 1-, 2- and 3-hour depths are then subject to (h) in RJ-Z2 and RJ-Z3, and the 1-hour depth in RJ-E to (b).

- (h) **Floor for short storms, 10-yr and rarer, in RJ-Z2 and RJ-Z3.** The 1-hour and 3-hour depths shall be not less than the greater of (i) 0.37 times (1 hour) and 0.56 times (3 hours) the 24-hour depth of (d) or (e) for the same AEP, and (ii) the following values for a site in RJ-Z2 or RJ-Z3 of Annex 2A, all set by this Manual; the 2-hour depth shall be not less than the value interpolated on logarithmic axes between the 1- and 3-hour values for the same AEP:

Zone	Duration	10% (10)	4% (25)	2% (50)	1% (100)
RJ-Z2 East and central; RJ-Z3 South and the Abu hills	1-hour depth not less than (mm)	66	81	93	105
RJ-Z2 East and central; RJ-Z3 South and the Abu hills	3-hour depth not less than (mm)	100	125	140	160

The reason is that the subzone ratios, derived in 1984–1993 from short recording-gauge records averaged over each subzone, understate the short storms of the one station in the State with a published analysis. At Jaipur the 1(b) plates and ratios give about 70 mm in 1 hour for the 50-year storm (about 200 mm × 0.35); the station analysis of (b) gives 93 mm, about 33% more. The authors' suggested design values for 25 years, 70 mm in 1

hour and 190 mm in 24 hours, give a ratio of 0.37, above every subzone ratio in the State (0.34–0.36); the ratio floor of (i) takes that value at 1 hour, and at 3 hours the same value scaled by the 1(b) ratio of the 3-hour to the 1-hour depth (0.53/0.35), 0.56. The 1-hour depths of (ii) are the Jaipur values of (b) at 10, 25, 50 and 100 years, and the 3-hour depths the same values scaled by 0.53/0.35 and rounded to 5 mm. They are applied across both zones because the 24-hour plate values there, about 180–320 mm in the east and centre and from about 200 mm to more than 480 mm in the south and the Abu hills, are mostly equal to or higher than Jaipur's 200 mm; where the 24-hour depth is large, as in Hadoti, Vagad and the Abu hills, the ratio floor of (i) governs. The floors are present-day, true-interval values: the fixed-interval factor of Clause 2.6.3 is not applied to them, and the climate factor of Clause 2.8 is. The paper reports clock-hour correction factors of 1.176–1.212 for its series, and its 1-hour values were read in research for this Manual as given with a factor of 0.39 on the 24-hour depth; whether the 53.1 mm and 93 mm are fits to the hourly maxima or 24-hour depths so scaled, and whether they are for fixed clock hours, is to be confirmed against the paper [TBC]. The floors are interim: no IMD hourly maximum for a recent storm in the State was found in research for this Manual [TBC], and Annex 2B is to replace the floors with frequency analyses of the IMD recording-gauge and automatic weather station records of the State, beginning with Jaipur (Sanganer), Jodhpur, Udaipur, Kota (A), Ajmer and Bikaner.

- (i) **Arid west and north (RJ-Z1), and catchments with no defined outfall.** In RJ-Z1 no absolute floor is set on the 1-hour or 3-hour depth, and (h) does not apply: the depths at those durations are the products of (g) with the 1(a) ratios, or, within 5 km of the 1(e) line, the higher products. The reason is that no analysis of short storms at any recording gauge in the zone was found, the 1(a) ratios resting on 12 recording gauges with 8 or more years of record, and that in the desert it is the storm of several days, not the peak hour, that floods a town: single days there exceed the annual normal (540.0 mm at Sam, in a district whose normal is 172.9 mm, IMD), the Barmer storm of August 2006 brought about 577 mm in three days (as reported), and much of the zone has no outfall, so the water of such a storm stays where it falls. In RJ-Z1, therefore, the storage of every element is checked for the **72-hour design volume**: the runoff volume of the 1% AEP (100-yr) 72-hour design storm of (f), with the climate factor of Clause 2.8, from the whole area draining to the storage, including run-on, computed by Clause 3.8 at AMC III for the post-development condition (set by this Manual), as well as for the durations of Clause 2.5.2. Anywhere in the State, where a catchment has no defined outfall, the 72-hour design volume shall be stored on site or in a public basin and removed by infiltration and evaporation, with a safe overflow path, and shall not be discharged onto a neighbour's land; Clause 4.12.7 sets how. The 72-hour depth is that of (f); in RJ-Z1 its 2-day and 3-day series are taken over the station's full record, which includes the storms of 1973, 1990, 1992 and 2006 where they fall within it.

- (j) **Durations below 1 hour.** No sub-hourly frequency analysis for any station in the State was found in research for this Manual. Until Annex 2B gives one, the ratio of the depth for a duration below 1 hour to the 1-hour design depth is agreed with the Authority, from a published recording-gauge analysis whose source is stated, and recorded on Form 2-1 [TBC]; the average intensity for a duration below 1 hour shall be not less than the 1-hour design intensity for the same AEP (set by this Manual).

- (k) **Order of depths.** For the same AEP, no depth shall be less than the depth for a shorter duration.

- (l) **NIH-DHAARA.** Its present-day values at the site are reported on Form 2-1 beside the interim values, for comparison only: in the State they are too low at 24 hours almost everywhere, by about half at Bikaner, too high in Hadoti, and low at 1 hour everywhere (commentary). Its projected depths are not used under Clause 2.8.4; the ratio of its projected to its present-day depths may be reported as a check on the climate factors of Table 2.2, which apply.

- (m) **IMD Das et al. (2022).** The paper's panels for Jaipur and Jaisalmer repeat the curve that it prints for a dozen other cities, about 60–109 mm/h at 1 hour for 2–100 years; for Jaisalmer that curve implies a 2-year day of about 170 mm, equal to the district's annual normal of 172.9 mm. Neither panel is used as a value, a check or a floor, and the cross-check of Clause 2.3.3(a) is recorded on Form 2-1 as not available. The paper's range for its West region, 3–8 cm at 1 hour and 8–24 cm at 24 hours, is not used: the paper does not name the stations of the region, and its 24-hour upper bound is below the records of a dozen stations in the State, such as Jaipur (Sanganer) (326.0 mm, 19 July 1981) and Ajmer (412.3 mm, 10 June 2002).

- (n) **Earlier design values.** The values of RUIDP Circular No. 8 of 2008, a design return period of 1–2 years for the drains of the RUSDIP towns and design intensities "usually in the range of 12mm/hr to 20mm/hr", are not a design source: the return periods of Table 2.1 apply, and the intensities are design values carried forward without a stated AEP (Clause 2.3.4(d)). An IDF built from 15 years of IMD data, as the circular allowed, is a station IDF only if it meets (a).
- (o) **Other clauses.** Where Clauses 2.3.2, 2.6.1, 2.7.1 and 2.13, Annexes 2A to 2C and Form 2-1 refer to the NIH-DHAARA value, the value under this clause is meant.

Commentary. NIH-DHAARA is a national, publicly accessible product from a Government of India institution, and it can be queried at any point in the State. That makes it a reproducible default that an approving authority can check. NIH-DHAARA's sub-daily values are derived from hourly records, not disaggregated from daily totals. That makes it the only public source suitable for sizing drains, which depend on short-duration intensity. Its values should still be checked against the long IMD daily record at 24 hours and longer (Annex 2A). In Rajasthan the platform does not yet meet that purpose. Its present-day values there come from IMDAA reanalysis (about 12 km), not from gauges, and they err mostly low. Its 50-year 24-hour depths are below the CWC plates and the station records over most of the State: 151 mm at Jaipur, against a plate value of about 200 mm and a station analysis of 194.6–249.9 mm; 127 mm at Ajmer, against about 180–200 mm and a record of 412.3 mm; 153 mm at Jodhpur, against about 200 mm; 175 mm at Udaipur, against about 200–220 mm; 89 mm at Bikaner, against about 180 mm; 94 mm at Jaisalmer and 123 mm at Barmer, against about 120–160 mm and 180–200 mm; and 407 mm at Mount Abu, against 440–480 mm and more. They are close to the plates at Jhalawar (283 mm) and Banswara (249 mm), and above them only in Hadoti: 318 mm at Kota, against about 240–280 mm, and 270 mm at Tonk. Its 50-year 1-hour depths, 33–68 mm, are 0.16–0.45 of its 24-hour depths, the highest ratios where its 24-hour depths are lowest; at Jaipur it gives 46.3 mm, half the 93 mm of the station analysis (NIH-DHAARA, queried 6–7 Nov 2026; IMD; CWC; Ghate & Timbadiya, 2022). A source that errs by these margins cannot be adopted, so Clause 2.3.6 uses the Jaipur station analysis, the CWC reports and the long IMD station records until Annex 2A has been done, and uses NIH-DHAARA for comparison and as a check on the climate factors only. Rajasthan is like the Gangetic plain in one respect and unlike it in another. As on that plain, the CWC sub-daily ratios give less than the one station analysis in the State, at Jaipur, which is why Clause 2.3.6(h) sets floors at 1 and 3 hours in the east and the south. In the arid west, where no hourly analysis was found, many towns have no outfall and a single day can exceed the year's normal, the governing check is the volume of the 72-hour storm, not the peak hour (Clause 2.3.6(i)). The State's only drainage design rule found, RUIDP Circular No. 8 of 2008, asked for a 1–2-year storm and intensities of 12–20 mm/h for the drains of the RUSDIP towns, about a quarter to two-fifths of Jaipur's 5-year 1-hour depth of 53.1 mm; it is the history of practice, not a design basis (Clause 2.3.6(n)). The interim rules for the more frequent AEPs, the 48- and 72-hour depths, the reading of the plates, the subzone of each district, the Jaipur values at 2, 10, 25 and 100 years, the floors of (h), the 72-hour design volume and durations below 1 hour are set by this Manual. Several points are unresolved. The plate values were read by eye on scans, to about one contour, and the 1(a) plates near Jaisalmer and Sri Ganganagar need better copies [TBC]. The time-distribution and areal-reduction annexes of the 1(a) report are too garbled in the scan to read [TBC], and its unit hydrograph rests on 7 bridge catchments of 18–682 km² on the Aravalli fringe, none in dune terrain (Chapter 3). The basis of the Jaipur 1-hour values is to be confirmed (Clause 2.3.6(h)) [TBC]. *Climate of Rajasthan* gives district records of 780.3 mm at Parbatsar (1900) and 802.9 mm at Chittor (1982) that the CWC reports and IMD's station extremes do not support, and 700.0 mm at Mount Abu on 8 September 1992 against IMD's 653.0 mm; these values are not relied on until IMD confirms them [TBC]. The 100-year design of the Dravyavati was published without its design discharge or rainfall, and no storm-drain DPR for any other city was found [TBC], so the design basis of the drainage works now being built could not be compared with this clause.

2.4 Design return periods (summary)

2.4.1 Design AEPs are set in the chapters for each element. They are summarised here so that the correct rainfall is extracted at the start of design.

Table 2.1 — Design return periods (summary)

Element	Design AEP (return period)	Check event	Chapter
Minor drains: Jaipur, Jodhpur, Kota, Udaipur and Ajmer core and high-density areas	10% (10-yr)	1% (100-yr) overland path	6
Minor drains: other Class I urban areas	20% (5-yr)	1% overland path	6
Minor drains: other areas	50% (2-yr)	1% overland path	6
Arterial roads and crossings	2–4% (25–50-yr)	next higher AEP	6
Collector / local roads	4% / 10% (25 / 10-yr)	2% / 4% (50 / 25-yr), plus the 1% overland path	6
Major (overland) system	1% (100-yr)	—	6
Retention volume	Percentile daily rainfall (Clause 2.10)	—	4
Detention: standard catchments	50%, 10%, 1% (2, 10, 100-yr)	1% emergency spillway	4
Detention: flood-sensitive catchments	Mixed-frequency rule, Clause 2.11	1%	4
Building floor levels	1% + 0.5 m freeboard	—	6
Detention emergency spillway	1% with outlet blocked	0.2% (500-yr) where high hazard	4

> **Commentary.** These values exceed the CPHEEO (2019) national advisory minimums of 5-yr (Class I cities) and 2-yr (other areas). CPHEEO allows a State to set higher values. The values are set in Chapters 4 and 6, and the table is reproduced here for convenience.

2.5 Design durations

2.5.1 **Conveyance elements** (pipes, open drains, inlets, culverts) shall be designed with the intensity for a duration equal to the time of concentration (Tc) of the contributing area (Chapter 3). The minimum duration is **10 minutes**.

2.5.2 **Storage elements** (detention, retention, tanks, pumped sumps) shall be checked for every duration in the set {1, 2, 3, 6, 12, 24, 48, 72 h}. The largest required storage or water level governs. The 24-, 48- and 72-hour storms are **mandatory** checks at every site, whatever the critical-duration result.

2.5.3 **Tidally influenced outfalls.** For storage draining to a tidally influenced outfall (Chapter 5), the 48- and 72-hour storms shall also be run with the tailwater boundary of Clause 2.12.

> **Commentary.** Rajasthan's worst floods have come from storms of two to seven days. At Jaipur on 18–20 July 1981 the city received 82 cm in three days, of which 35 cm fell on 19 July (Gupta & Jindal, 1987), and July 1981 brought 956.9 mm to the Sanganer gauge, more than one and a half times its annual normal (IMD). In Barmer district on 19–22 August 2006 about 577 mm fell in three days, against an annual normal of 251.7 mm, and the

water stood in the depressions of Kawas for months (as reported); in July 1990 about 714 mm fell at Bali (Pali) in six days (Singh et al., 1992). Single days in the desert exceed a whole year's rain: Sam recorded 540.0 mm on 17 August 1973 in a district whose normal is 172.9 mm (IMD). Where a town has no outfall, as across much of the west, the water of such a storm has nowhere to go but into the ground and the air, and it is the volume of the whole storm, not its peak hour, that sets the depth of flooding. At Udaipur and Ajmer the lakes reach their spill levels only after weeks of rain, and the escape channel of Ana Sagar is then opened, so the drains that outfall to the lakes and channels meet a raised water level that the whole wet spell has set. A rule based only on critical duration, applied to a small site, picks a 1–2 hour storm and misses this failure mode. That is why the long-duration checks are mandatory.

2.6 Sub-daily rainfall

2.6.1 Where NIH-DHAARA or an approved station IDF provides values directly for the required duration, those values shall be used.

2.6.2 Where only daily (24-hour) depths are available for a duration below 24 hours, the sub-daily depth shall be derived using the **ratio set of Annex 2B**. These are duration-to-24-hour ratios calibrated to Rajasthan recording gauges. They shall not be lower than the ratios of the CWC Flood Estimation Report for the subzone (1(a), 1(b), 1(e) or 3(a)). The IMD Das et al. (2022) Jaipur and Jaisalmer panels repeat a generic curve and are not used.

2.6.3 **Fixed-interval adjustment.** Depths from fixed observation windows (for example 08:30–08:30 IST daily data, or clock-hour data) shall be converted to sliding-window ("true interval") depths:

- 1.13 for a single fixed observation interval;
- 1.04 for 2 intervals;
- 1.02 for 3–4 intervals.

This adjustment does not apply where the approved source already gives true-interval values.

2.6.4 The empirical relationship P(t) = P(24)·(t/24)^(1/3) shall not be used for design unless Annex 2B confirms it for the zone concerned.

> Commentary. The one-third power rule is common in Indian project reports, but no primary IMD source for it was found during research for this Manual. It applies one fixed curve shape everywhere: P(1h)/P(24h) = 0.35, P(3h) = 0.50, P(6h) = 0.63 and P(12h) = 0.79. It cannot represent the difference between a short convective burst and a long SW monsoon soak, and it tends to understate short-duration depths in convective coastal storms. Annex 2B shall tabulate the NIH-DHAARA ratios P(t)/P(24h) against these values by zone. That comparison shows whether the rule is acceptable anywhere in the State and corrects older daily-based analyses. The fixed-interval factors are the standard WMO (Hershfield) values. The IMD 2022 study applies similar clock-hour to any-hour corrections.

2.7 Point, grid and areal rainfall

2.7.1 Design depths are point values. Where an approved source provides grid-average values (for example 0.25° cells), they shall be converted to point values with the grid-to-point factors in Annex 2C before use.

2.7.2 For catchments **≤ 10 km²**, ARF = 1.0.

2.7.3 For catchments **> 10 km²**, apply ARF as follows:

- for 25–5,000 km² in subzone 1(a), 1(b), 1(e) or 3(a): use the ARF curves of the applicable CWC Flood Estimation Report;
- for 10–25 km²: interpolate linearly between ARF = 1.0 at 10 km² and the CWC value at 25 km².

2.7.4 An ARF shall never be applied to storage design for a single development site.

> **Commentary.** Gridded and district-average return levels are much lower than point values. For example, NIH-DHAARA's IMDAA cell at Jaipur gives a 50-year 24-hour depth of about 151 mm, while the CWC plate gives about 200 mm and the Jaipur (Sanganer) gauge has recorded 326.0 mm (19 July 1981); its cell at Ajmer gives about 127 mm, while the Ajmer gauge has recorded 412.3 mm (10 June 2002); and its cell at Bikaner about 89 mm, half the plate value of about 180 mm (NIH-DHAARA, queried 6–7 Nov 2026; IMD; CWC FER 1(a) and 1(b)). In Hadoti the same product errs the other way: about 318 mm at Kota, against a plate value of about 240–280 mm. Single storms are patchy at a scale that no cell of about 12 km can show: on 19 July 1981 Kanota recorded 589.2 mm and Dausa 550.0 mm, against 326.0 mm at Sanganer a few kilometres away (IMD). Neither error can be corrected without the factors of Annex 2C. Using grid values as point values without correction would make site-level design unsafe.

2.8 Climate factor

2.8.1 Until a statewide future-climate rainfall product is adopted, present-day design depths shall be multiplied by the following interim climate factors:

Table 2.2 — Interim climate factors

Duration	Climate factor (CF)
≤ 6 h	**1.20**
> 6 h to 72 h	**1.10**

2.8.2 The CF applies to all elements with a design life of more than 25 years. For temporary works (design life ≤ 5 years), CF = 1.0.

2.8.3 The climate factor does not apply to the retention depth (Clause 2.10) or to the water quality volume depth (Chapter 8). Those depths are percentile or frequent-event statistics of everyday rainfall, not AEP design values.

2.8.4 Where NIH-DHAARA, or a product adopted on review under Clause 2.14, provides projected future-climate depths, those depths shall replace the interim factors.

> **Commentary.** CPHEEO (2019) considers a fixed climate factor "not feasible" nationally and recommends trend testing instead. That leaves designers without a usable number. The 1.20 short-duration factor matches the UK value cited by CPHEEO itself. It is at or below published projections for India: Ali and Mishra (2018) project 3-hourly 100-year maxima rising by about 20% at 1.5 °C and 25% at 2.0 °C of warming. No design uplift factor has been adopted in Rajasthan. The evidence on trends points different ways. IMD's analysis of 1989–2018 is reported to find no significant trend in the monsoon or annual rainfall of any district, with a significant increase in heavy-rainfall days in the south-east (as summarised [TBC]); a press report of an IMD analysis of the same period gives a rise in heavy-rain days especially in the west, and normal rainfall in west Rajasthan up 32% since 2010 (as reported); a study of 1871–2016 finds rising monsoon and annual rainfall in west Rajasthan (Mehta & Yadav, 2022, abstract only); and the extremes at Jaipur show a non-significant fall over 1970–2013 (Ghate & Timbadiya,

2022). Recent extremes have not fallen: Mount Abu (1992), Pachpadra (1992), Nagaur (1996), Bharatpur (1996 and 2003), Kota (A) (2001), Ajmer (2002) and Chittorgarh (2008) set their highest days after the CWC plates of 1984–1993 were drawn, Jaisalmer had its wettest month in August 2006 (IMD), Nainwa (Bundi) recorded 502 mm on 23 August 2025, and the 2025 season was the State's second wettest since 1901 (IMD). Unlike the Gangetic plain, the arid west may be getting wetter, which makes the 72-hour volume check of Clause 2.3.6(i) matter more there than the uplift. NIH-DHAARA offers a projection but no historical run of the same model, so no ratio of future to present depths can be formed; under Clause 2.3.6(I) it would serve only as a check. The factors of Table 2.2 are therefore interim values, not Rajasthan estimates.

2.9 Temporal patterns (design hyetographs)

2.9.1 **Storms up to 24 hours.** Use the nested **alternating-block** method:

- construct the storm from the same IDF relationship (after the climate factor), at time steps no longer than Tc/3 and no longer than 15 minutes;
- place the peak block at **50%** of the storm duration.

2.9.2 **48- and 72-hour storms (SW monsoon pattern).** Construct as follows:

- (a) The total storm depth equals the design depth for the full duration (48 or 72 h).
- (b) The **final 24 hours** contain the 24-hour design depth for the same AEP, distributed by the alternating-block method of 2.9.1.
- (c) The remaining depth (total minus the 24-hour depth) is spread uniformly over the preceding 24 or 48 hours.

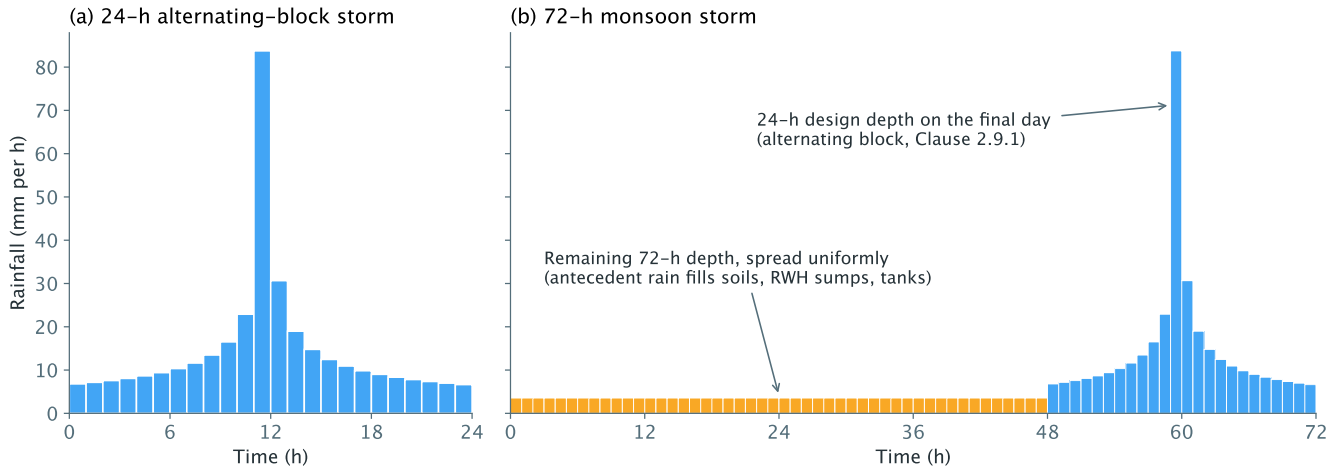

Figure 2.2 — (a) 24-hour alternating-block design storm; (b) 72-hour SW monsoon design storm with the 24-hour design depth on the final day. Illustrative depths only. Original drawing for this Manual. The alternating-block method follows Chow, Maidment & Mays, Applied Hydrology (1988), §14.4.

2.9.3 **Other temporal patterns.** Huff-type or mass-curve patterns derived from Rajasthan storms may be used instead of 2.9.1 and 2.9.2 only after they are published in Annex 2D. SCS Type I, IA, II and III distributions shall not be used.

2.9.4 **Large catchments.** For catchments of 25–5,000 km², the CWC Flood Estimation Report time-distribution curves may be used, and a sensitivity run with 2.9.1 shall be reported.

> **Commentary.** The alternating-block storm embeds every shorter-duration design intensity in one hyetograph. That makes it conservative and consistent across durations. The 72-hour pattern puts the most intense day last. This reproduces the monsoon sequence of Rajasthan: the heaviest falls come in July–September from monsoon depressions that reach the State late in their track, after days of rain that have wetted the sands, filled the talabs and the depressions of the desert towns, closed the cracks of the black soils of Hadoti, brought the lakes of Udaipur and Ajmer to their spill levels, and raised the Chambal at Kota with the releases of the dams upstream. SCS distributions are excluded because they come from US convective and Gulf storm data and have no basis in Rajasthan records.

2.10 Retention rainfall depth

2.10.1 The **retention design depth** is the 24-hour rainfall depth not exceeded on **90%** of days with rain (≥ 2.5 mm) in the long-term record, read from the zone value in Annex 2E.

2.10.2 The site must retain on site the runoff from this depth (Chapter 4). Retention earns a detention credit equal to the reduction in required detention storage found by routing with the retention in place (Clause 4.4.6). The credit is not the retained volume subtracted one-for-one.

> **Commentary.** This follows the Kansas City Metro APWA 5600 (2025.01) Required Retention Volume concept and Georgia's 1.0-inch runoff reduction standard. Both are based on percentile storms. A percentile depth is a statistic of everyday rainfall, not an AEP value, so it is computed from the daily record rather than from the frequency curves.

2.11 Design storms for pre- and post-development comparison

2.11.1 **Same storm for both scenarios.** Pre- and post-development runs shall use the same design storms:

- same AEP, duration, temporal pattern and climate factor;
- same antecedent moisture condition (Clause 2.11.4).

The two runs differ only in land surface parameters and Tc.

2.11.2 **Standard catchments.** For each of the 50%, 10% and 1% AEP storms and each duration in Clause 2.5.2:

> $Q_{post}(T) \leq 0.9 \times Q_{pre}(T)$

2.11.3 **Flood-sensitive catchments** (as listed in Chapter 4: the catchments of the Dravyavati and the low colonies of Jaipur, of the Jojari and the old city at Jodhpur, of the Udaipur lake chain, of Ana Sagar and its escape channel at Ajmer, of the Chambal at Kota, and of the Luni at Balotra and Barmer, and any catchment notified by the authority). The **mixed-frequency rule** applies:

> Q_{post}(1% AEP, 100-yr) ≤ Q_{pre}(10% AEP, 10-yr), and Q_{post}(50% AEP, 2-yr) ≤ Q_{pre}(50% AEP, 2-yr),

The post-development peak is checked for each duration in Clause 2.5.2. The caps are taken at the **pre-development critical duration**. The 10-yr cap is the largest pre-development 10-yr peak over all durations, and the 2-yr cap is the largest pre-development 2-yr peak over all durations. Each cap applies to every post-development duration.

2.11.4 **Antecedent moisture.** Use **AMC III** (wet conditions) for every design storm, whatever its duration, from 15 August to 15 September at a site in sub-area RJ-G Hadoti and the Chambal or RJ-H Mewar and Vagad of Annex 2A, and on black soil (vertisols) anywhere in the State (Clause 3.7.2). At any other time, and at every other site, use AMC III for a design storm that follows, or contains, a 5-day rainfall total of more than 53 mm. Use AMC II (average conditions) for every other storm. AMC I is not used for design.

2.11.5 **Pre-development condition.** Pre-development is defined in Chapter 3: greenfield, open land in good condition for the mapped hydrologic soil group. Existing impervious cover is not counted as pre-development.

> **Commentary.** Matching each site's post-development peak to its own pre-development peak does not protect the catchment. Denver's analysis found that 100% matching at every site still produced 106% of historic peak downstream, which led to the 90% rule. The mixed-frequency rule is stricter. It caps the 100-yr post-development release at what the undeveloped site produced in a 10-yr storm. Malaysia (DID 2008: all ARIs ≤ pre-development 2-yr) is a tropical precedent for this kind of cap. AMC III for long storms reflects that SW monsoon extremes arrive after weeks of rain. In Rajasthan that holds only in part. Over most of the State the ground is dry for most of the year, the water table is deep, more than 40 m below ground at about a fifth of the wells before the monsoon (CGWB), and the dune and hummocky sands of the west take in the first rains fast; a seasonal AMC III would overstate runoff there, so AMC II is the default (Clause 2.11.4). The exception is the black soil (vertisol) of Hadoti and the mixed red-and-black soils of Mewar, which crack open in the dry season but, once wetted and closed, take in water at about 1–3 mm/h in the Chambal series (Nathani et al., as summarised), and the CWC loss rate for the Chambal subzone, 1.7 mm/h, is the lowest in the State. The monsoon reaches Hadoti and Mewar first (Jhalawar 24 June, Udaipur 25 June, Kota 26 June) and leaves them last (25–28 September) (IMD), so by mid-August their soils have closed. This Manual therefore uses AMC III from 15 August to 15 September in RJ-G and RJ-H and on black soil anywhere (a month later than the date used for the black soils of central India, because the monsoon arrives here later), and at any other time only after a 5-day total of more than 53 mm, the NRCS growing-season threshold for AMC III. AMC I is not used even in the Thar, because the storms that govern there are multi-day storms that wet the profile, as in Barmer in 2006. These are interim choices set by this Manual; no study in the State has yet validated AMC classes against observed runoff.
>
> **Illustrative scale of the mixed-frequency rule.** The values below are not design values. They assume a 2 ha site in a colony on a Dravyavati tributary nala in south Jaipur with 24-h depths of 200 mm (10-yr) and 350 mm (100-yr), SCS-CN runoff with Ia = 0.2S, and CN 70 pre-development and CN 92 post-development:

Table 2.3 — Illustrative scale of the mixed-frequency rule (not design values)

Case	Runoff depth	Runoff volume (2 ha)
Pre-development, 10-yr 24 h	111 mm	2,210 m³
Post-development, 100-yr 24 h	325 mm	6,500 m³

The post-development 100-yr storm generates about three times the runoff volume of the pre-development 10-yr storm. A peak-rate cap at the pre-development 10-yr level means most of the difference must be stored and released slowly, so storage of the order of 0.2 m³ per m² of site may be needed. For this reason the rule applies only in flood-sensitive catchments (Clause 2.11.3); elsewhere the 0.9 × Q_pre rule of Clause 2.11.2 applies.

2.12 Joint occurrence with tailwater

2.12.1 For outfalls under tidal or river backwater influence, the design rainfall of this chapter shall be combined with the tailwater conditions of Chapter 5 as follows. The more severe case governs.

- (a) Design rainfall (AEP as required) with a mean high water springs (MHWS) tailwater plus the sea-level allowance.
- (b) A 10% AEP (10-yr) 48-hour storm with the 1% AEP still-water level (tide plus surge) plus the sea-level allowance.

Rajasthan has no coast, so no outfall in the State is tidal and cases (a) and (b) do not arise. The tailwater is the river or lake into which a city drains, the nalas and talabs that local drains discharge into, or, where a town has no outfall, the depression in which its runoff collects. For an outfall under river or lake backwater, the site storm is combined with the receiving-water level under Clause 5.8.4, which pairs a design event on one side with a 10-yr event on the other in the same way as case (b). On the Chambal the CWC site at Kota City has a danger level of 242 m and a highest flood level (HFL) of 248.68 m, set on 16 September 2019, when the Kota Barrage (full reservoir level 260.3 m) was reported to be releasing about 6.5–6.9 lakh cusecs after releases from Gandhi Sagar and Rana Pratap Sagar (CWC; releases as reported); the HFL stands 6.7 m above the danger level, so an outfall below it can be shut for days. At Dholpur the danger level is 130.79 m and the HFL 145.54 m (23 August 1996) (CWC). The HFLs are 108.755 m (18 July 1979) for the Luni at Balotra, 262.05 m (9 September 1973) for the Banas at Tonk and 265.4 m (31 August 1973) for the West Banas at Abu Road (as copied from CWC's list; the CWC site sheets were not read [TBC]). At Jodhpur the full reservoir levels of Kailana and Takhat Sagar are 273.7 m and 269.75 m (NIH, 2025). The lakes of Udaipur and Ajmer are managed on gauges in feet above a zero that has not been found: Pichola is full at 11 ft, Fateh Sagar at 13 ft (one report gives 14 ft), Udai Sagar at 24 ft and Ana Sagar at 13 ft, at which it is held by opening its escape channel (as reported); their levels in metres are to be confirmed [TBC]. The Dravyavati at Jaipur was rebuilt to pass the 100-year flood, but its design levels and discharge were not found [TBC]. About 60% of the State drains inland (as reported); a town on an inland drainage has no external tailwater, and its runoff collects in a depression whose level rises through the storm, so Clause 2.3.6(i) and Clause 4.12.7 apply. When a lake is at its spill level or the Chambal is high, outfalls into them are held up, so storage and pumps are checked for the outfall-closed condition, with the local storm falling before, during or after the high water. No document found in research for this Manual sets a design receiving-water level for the outfalls of any city in the State [TBC], and Chapter 5 sets the interim rule: for a lake, its maximum water level, or its full tank level plus the surcharge of the design flood, from WRD or the custodian, and, where neither is published, the full tank level plus 0.5 m (set by this Manual); for a river, a level related to the highest recorded at the nearest gauge. Every level is stated on a named datum, as Chapter 5 requires; the datum of the levels quoted here is to be confirmed [TBC].

> Commentary. Rajasthan has no coast, so no outfall is tidal and there is no storm surge; the coincident load is the level of the rivers and lakes that receive the city drains, or, where a town has no outfall, the water already standing in the depression it drains to. The coincidence is on record. In September 2019 the Chambal at Kota City set its highest recorded level, 248.68 m (CWC), while the Kota Barrage released about 6.5–6.9 lakh cusecs after releases from the dams upstream and low-lying Kota was evacuated (as reported); at Ajmer the escape channel of Ana Sagar was opened in the same storms that waterlogged the city on 11 September 2024 and 18–20 July 2025 (as reported); and at Udaipur the lakes spill into the Ayad and on to Udai Sagar in the storms that flood the city's colonies (as reported). These levels are set by rain over catchments upstream and by the operation of gates, so they give no warning of a local storm that falls while they are high. The levels of the sources are on different datums, and those of the lakes of Udaipur and Ajmer are kept in feet on gauges whose zero has not been found, which is why Chapter 5 requires every level to name its datum. Because rainfall and surge share a weather cause (in Rajasthan, which has no coast, the counterpart of surge is the level of the rivers and lakes that receive the city drains, raised by the same monsoon systems that bring the heaviest rain to the cities and by the releases of the dams and gates above them: in September 2019 the Chambal at Kota City set its highest recorded level, 248.68 m (CWC), while the Kota Barrage released about 6.5–6.9 lakh cusecs after releases from Gandhi Sagar and Rana

> Pratap Sagar upstream, and in July 2025 the escape channel of Ana Sagar was opened in the storm that flooded Ajmer, both as reported), they cannot be treated as independent. Case (b) is a simple joint-probability surrogate until a statistical joint analysis is adopted.

2.13 Submittal requirements

Every hydrologic submittal shall include a **Design Rainfall Sheet** (Form 2-1) stating:

1. the site coordinates and zone;
2. the source (Clause 2.3), version or access date, and a screenshot or export of the values extracted;
3. a depth table for each AEP and duration used, before and after the fixed-interval factor, grid-to-point factor, ARF and climate factor;
4. the cross-check values of Clause 2.3.3 and the floor check;
5. the hyetographs used, as a table and a plot, for each design storm; and
6. the AMC and pre-development definition adopted.

Figure 2.3 shows the steps of this chapter in the order in which the sheet records them.

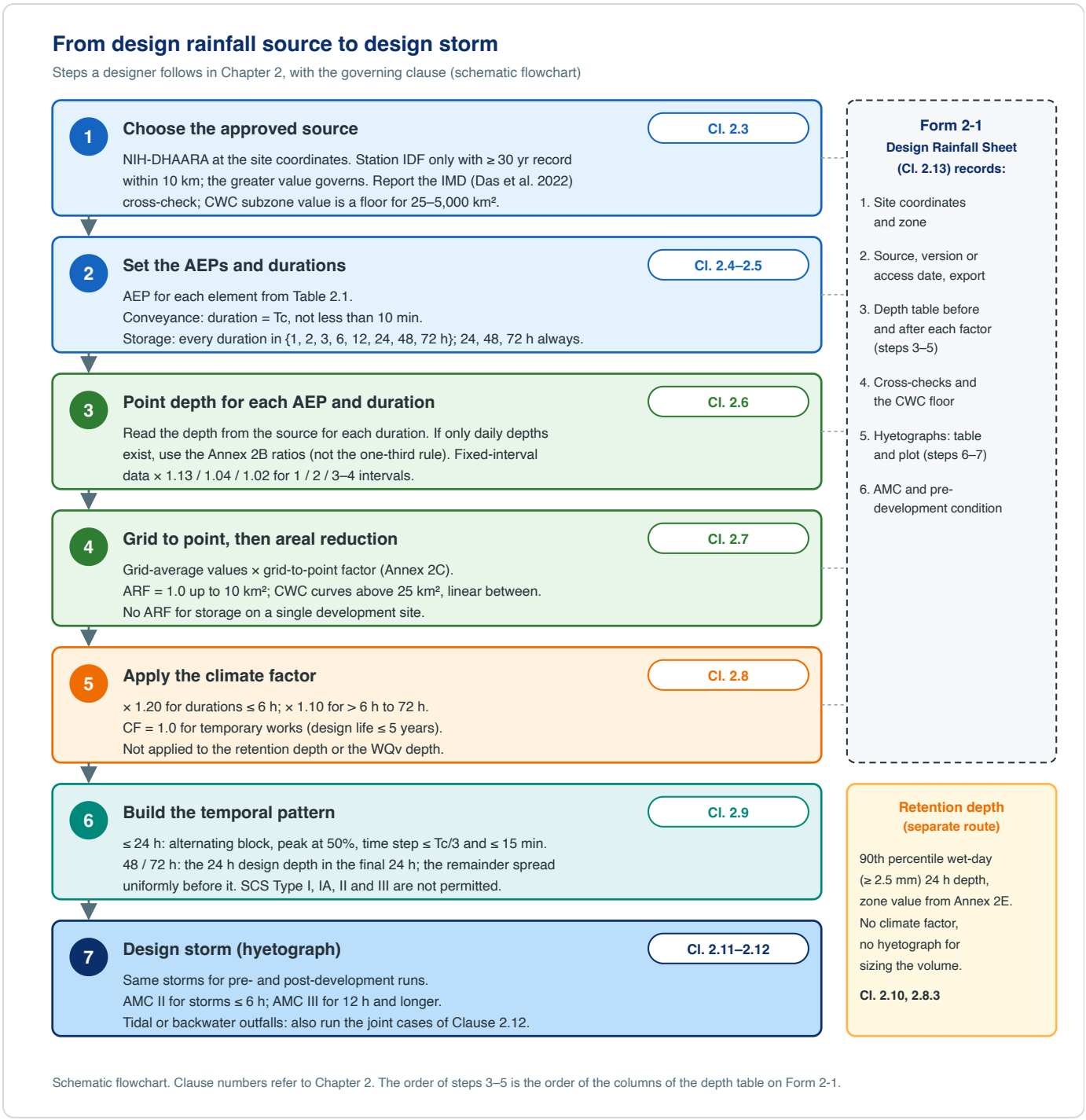

Figure 2.3 — From design rainfall source to design storm: the steps a designer follows (source, AEPs and durations, point depth, grid-to-point and areal reduction, climate factor, temporal pattern, design storm), the clause that governs each step, what Form 2-1 records, and the separate route for the retention depth. Schematic. Original drawing for this Manual.

2.14 Review and update

2.14.1 The approving authority shall review this chapter **every 10 years**. It shall also review it within 2 years of any event in which recorded rainfall exceeds the 1% AEP 24-hour or 72-hour design depth at two or more approved gauges in the State.

2.14.2 Updates to NIH-DHAARA take effect for new submittals 6 months after release, unless the authority notifies otherwise.

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Annexes

Annex	Content
2A	NIH-DHAARA vs IMD station and IMD gridded checks at benchmark points; zone map
2B	Sub-daily ratios P(t)/P(24h) by zone: NIH-DHAARA (hourly-based) vs the one-third rule
2C	Grid-to-point factors
2D	Rajasthan temporal patterns (Huff curves)
2E	Retention percentile depths by zone
Form 2-1	Design Rainfall Sheet

CHAPTER 3

Hydrologic Methods

3.1 Purpose and scope

3.1.1 This chapter sets out how design rainfall from Chapter 2 is turned into runoff peaks, volumes and hydrographs for:

- (a) drain, inlet and culvert sizing (Chapter 6);
- (b) retention and detention sizing, and the pre- vs post-development comparison (Chapter 4);
- (c) downstream and tailwater analysis (Chapter 5); and
- (d) waterbody, tank (talab) and regional facility studies (Chapter 7).

3.1.2 It specifies:

- (a) which method may be used for which purpose and catchment size (Clause 3.4);
- (b) how the pre- and post-development land surfaces are defined (Clause 3.3);
- (c) the parameters of each method: runoff coefficients, time of concentration, soils, curve numbers, unit hydrographs and routing (Clauses 3.5–3.12);
- (d) when continuous simulation and model calibration are required (Clauses 3.13 and 3.15);
- (e) the step-by-step pre- vs post-development comparison (Clause 3.14); and
- (f) software acceptance and documentation (Clauses 3.16 and 3.17).

3.1.3 Rainfall inputs (depth, duration, areal reduction, climate factor, temporal pattern and antecedent moisture) are governed by Chapter 2 and shall not be varied in this chapter.

> **Commentary.** The CPHEEO (2019) Manual on Storm Water Drainage Systems gives a full Rational Method procedure and names SWMM for hydrograph work, but it is a drain-sizing guide. It does not say how a regulator should define "pre-development" or which method must be used to test a development against it (CPHEEO Part A §4.4, §8.5.1). APWA Section 5600 does both: it limits the Rational Method, names baseline hydrograph methods, and fixes the land-use assumptions for existing and proposed conditions (KC Metro APWA 5600, 2011, §5602.2–5602.3; Version 2025.01, §5603.4). This chapter follows that model.

3.2 Definitions

Term	Meaning in this Manual
Pre-development condition	The reference land surface defined in Clause 3.3.2, against which post-development runoff is tested. It is not the existing condition.
Post-development condition	The land surface after the proposed works are complete, as defined in Clause 3.3.3.
Point of comparison (POC)	A location where site runoff leaves the site, at which pre- and post-development flows are compared (Clause 3.14).

Term	Meaning in this Manual
Time of concentration (Tc)	The time for runoff to travel from the hydraulically most distant point of the catchment to the point of interest.
Lag (tL)	The time from the centroid of rainfall excess to the peak of the runoff hydrograph.
Hydrologic soil group (HSG)	The NRCS classification (A, B, C, D) of a soil by its minimum infiltration rate when wet (USDA NRCS, NEH Part 630, Ch. 7).
Curve number (CN)	The NRCS parameter that combines soil group, land cover and antecedent moisture into a single runoff-potential index (USDA NRCS, NEH Part 630, Ch. 9–10).
Antecedent moisture condition (AMC)	The soil wetness at the start of a storm: AMC I (dry), II (average), III (wet).
Directly connected impervious area (DCIA)	Impervious surface that drains to a drain, pipe or channel without first flowing over a pervious surface.
Disconnected impervious area	Impervious surface whose runoff flows as sheet flow over a pervious surface before reaching the drainage system, and meets Clause 3.9.3.
Peak rate factor (PRF)	The constant in the unit hydrograph peak equation (484 in US customary units; 0.208 in the SI form of Clause 3.11.2).
Continuous simulation	A model run over a long rainfall record (years), with soil moisture, storage and tank levels carried forward between storms.
Tank cascade	A chain of tanks (talabs) in which the surplus of one tank feeds the next.

3.3 Pre-development and post-development land surface

3.3.1 **Same site, same storm.** Pre- and post-development runs shall cover the same area draining to each POC, and use the same design storms (Clause 2.11.1). They shall differ only in the land-surface parameters of this clause, the resulting Tc, and the stormwater controls.

3.3.2 **Pre-development condition.** The pre-development land surface shall be **greenfield: open land in good condition for the mapped hydrologic soil group**, as follows:

- (a) All land within the site, including land that is now built on, paved, compacted or cultivated, is treated as open land (grass cover > 75%) in good condition. **Existing impervious cover shall not be counted.**
- (b) The curve number is the TR-55 value for "open space, good condition" for the HSG of Clause 3.7: **CN 39 (A), 61 (B), 74 (C), 80 (D)** at AMC II (Table 3.5).
- (c) The HSG is the natural HSG of Clause 3.7, including the dual-group rule for high water table (Clause 3.10.1). No HSG improvement for drainage works is allowed.
- (d) Tc is computed on the pre-development ground surface using unchannelled overland and shallow concentrated flow and natural channels only (Clause 3.6). Existing pipes, lined drains and kerbs are ignored.
- (e) Existing waterbodies, tank waterspreads up to the full tank level (FTL), natural channels and supply or surplus channels are kept as they are, and modelled as water surfaces or channels, not as open land.

3.3.3 **Post-development condition.** The post-development land surface shall represent the proposed works at full build-out:

- (a) Impervious areas shall be measured from the site plan, separately for roofs, paved surfaces, roads and other sealed surfaces, and classified as directly connected or disconnected (Clause 3.9). Lot-size residential rows of TR-55 shall not be used for the site itself.

- (b) Pervious areas disturbed by construction (graded, filled or trafficked) shall be assigned one HSG lower in infiltration capacity than the natural HSG (A to B, B to C, C to D), unless post-construction infiltration tests (Clause 3.7.3) show otherwise. Soil disturbed by construction shall never be classed as HSG A.
- (c) Rainwater harvesting (RWH) sumps shall be treated as full at the start of storms of 12 hours or more, and the roof area draining to them as directly connected for those storms (Chapter 4).
- (d) Retention and detention facilities shall be represented explicitly as storage (Clause 3.12), not by lowering CN.

3.3.4 **Redevelopment.** The pre-development condition of Clause 3.3.2 applies to redevelopment as well. A site that is already fully paved is tested against greenfield, not against its existing state. For the constrained-redevelopment route of Clause 4.5.6, the existing condition shall also be modelled, with existing impervious areas as surveyed, so that the 50% minimum can be checked.

3.3.5 **Off-site areas.**

- (a) For conveyance design (Chapter 6), areas upstream of the site shall be taken at their ultimate land use under the approved master plan or development plan. Where no plan exists, upstream undeveloped land shall be assumed to be at least 35% impervious.
- (b) For the pre- vs post-development comparison, off-site run-on shall be modelled identically in both runs, at its existing condition (Clause 3.14.2).

> **Commentary.** A greenfield reference stops each redevelopment from being judged against an already degraded baseline. The UK non-statutory standards and KC APWA take the same approach in different forms: APWA caps existing agricultural land at no more than "good condition pasture, grassland or range (C = 0.30, CN = 74)" for HSG C, and forbids disturbed soils from being classed as HSG A or B (KC Metro APWA 5600, 2011, §5602.3A and E). The TR-55 "open space, good condition" values used in (b) are identical to TR-55's "pasture, grassland or range, good" values (USDA SCS TR-55, 1986, Tables 2-2a and 2-2c), so this Manual's pre-development CN equals the APWA cap on HSG C soils. The one-class downgrade for disturbed soils in 3.3.3(b) is set by this Manual as a simpler, less strict version of the APWA rule, suited to the dune sands, calcrete-capped desert soils, Aravalli rock, alluvium and Hadoti black soils of Rajasthan, where an HSG A to C jump would be excessive. The 35% minimum imperviousness for unplanned upstream land in 3.3.5(a) is the APWA value (2011, §5602.3E.2). Using the master-plan land use for conveyance follows CPHEEO, which requires C to reflect "ultimate development of the catchment as per the master plan" (CPHEEO 2019, Part A §4.4.1.5).

3.4 Selection of method

3.4.1 The method shall be selected from Table 3.1 by purpose and catchment size. Figure 3.1 shows the same rules as a flowchart.

Table 3.1 — Permitted hydrologic methods

Purpose	Catchment / condition	Permitted method	Clause
Peak flow for one conveyance element (inlet, pipe reach, drain reach, culvert)	≤ 16 ha contributing, no upstream storage, no backwater	Rational Method	3.5
Peak flow for conveyance	> 16 ha, or any upstream storage, tank or pond	Hydrograph method (SCS-CN with SCS unit hydrograph, SWMM or HEC-HMS)	3.8–3.12
Retention, detention, any storage; pre- vs post-development comparison	Any size	Hydrograph method; **Rational Method not permitted**	3.8–3.12, 3.14

Purpose	Catchment / condition	Permitted method	Clause
Pipe or drain network with backwater, tidal or tank tailwater	Any size	Hydrograph method with dynamic-wave hydraulic routing	3.12.4; Chapter 5
Catchment-scale flows	25–5,000 km² in CWC subzone 1(a), 1(b), 1(e) or 3(a)	HEC-HMS or SWMM, benchmarked against the CWC synthetic unit hydrograph (SUH)	3.11.4
Regional facilities	Draining > 25 km²	Design-storm hydrograph method **plus** continuous simulation	3.13
Tank (talab) cascades	Any size	Design-storm hydrograph method **plus** continuous simulation	3.13
Tier B: small sites under Chapter 1	Within the limits of the design aid	Design aids issued under Chapter 4, which are themselves derived by the methods of this chapter	3.4.4
Small sites, any authority	≤ 1 ha, within the limits of Clause 4.14.3	Fixed-coefficient route of Chapter 4 (fixed release coefficients, rainfall-mass storage)	3.4.4; 4.14.3

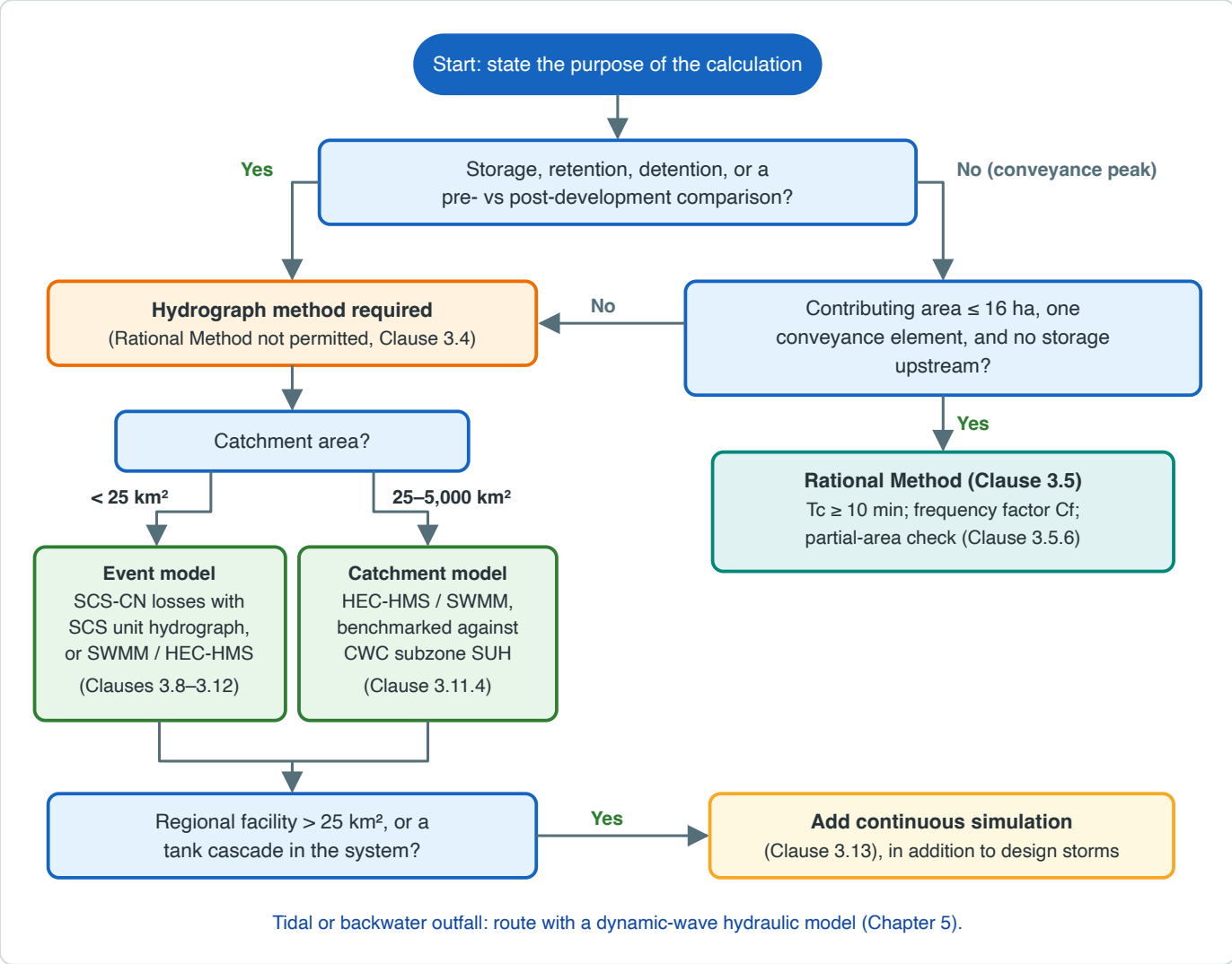

Figure 3.1 — Selection of hydrologic method. Original drawing for this Manual, adapted from KC Metro APWA, Section 5600 Storm Drainage Systems and Facilities, 2011 (§5602.2) and Version 2025.01 (§5603.4, Policy Supplement, 2025).

3.4.2 **Rational Method limits.** The Rational Method shall be used only for catchments of **16 ha or less** and only to compute the peak flow to a **single conveyance element**. It shall **never** be used to size retention, detention or any other storage, nor to derive a hydrograph or runoff volume.

3.4.3 **Hydrograph methods.** Above 16 ha, and for every storage calculation, a hydrograph method shall be used: SCS-CN losses with the SCS (NRCS) unit hydrograph, EPA SWMM, or HEC-HMS. For 25–5,000 km² the CWC synthetic unit hydrograph shall also be computed as a benchmark (Clause 3.11.4).

3.4.4 **Simplified routes.** In Tier B areas (Chapter 1), sites within the limits stated on a design aid issued under Chapter 4 may use that design aid in place of a site-specific hydrograph model. In any area, sites of 1 ha or less may use the fixed-coefficient route of Clause 4.14.3; it is the only exception to the rule in 3.4.2 that rainfall-based peak methods shall not be used for storage. The Rational Method remains available for conveyance under 3.4.2.

3.4.5 **Catchments above 5,000 km².** These are outside the scope of this Manual and require a basin study approved by the Water Resources Department (WRD).

> **Commentary.** The 16 ha limit and the single-element rule follow APWA 5600 Version 2025.01, which cut the Rational Method from 200 ac to 40 ac and restricted it to "a single pipe segment". The MARC Policy Supplement adds that it "cannot be used to size runoff reduction practices or determine retention volumes and detention volumes" (MARC, APWA Stormwater Standards Supplement, 2025). CPHEEO (2019, Part A §4.4.1.3) allows the Rational Method up to 8–10 km², which is too large for a method that assumes uniform rainfall intensity over the whole catchment for the whole of Tc and gives no volume. The Rational Method is excluded from storage design because it gives a peak, not a hydrograph, and storage depends on volume and timing.

3.5 Rational Method

3.5.1 **Equation.** The peak flow shall be computed as:

> $$Q = C \cdot Cf \cdot i \cdot A / 360$$

where Q is the peak flow (m³/s); C is the runoff coefficient (Table 3.2); Cf is the frequency factor (Table 3.3), with $C \cdot Cf \le 1.0$; i is the rainfall intensity (mm/h) for a duration equal to Tc, from Chapter 2 (with the climate factor of Clause 2.8); and A is the contributing area (ha).

> **Commentary.** This is the CPHEEO equation Qp = 10 C I A, with Qp in m³/h (CPHEEO 2019, Part A §4.4.1.1–4.4.1.3), converted to m³/s.

3.5.2 **Runoff coefficients.** C shall be taken from Table 3.2. Within a range, the designer shall use the upper half of the range unless site data justify a lower value.

Table 3.2 — Runoff coefficient C (for AEP of 10% or more frequent)

Surface or land use	C	Source
Commercial	0.70–0.95	CPHEEO 2019, Table 4.2
Industrial	0.60–0.90	CPHEEO 2019, Table 4.2
Institutional	0.70–0.95	CPHEEO 2019, Table 4.2
Residential, high density	0.60–0.75	CPHEEO 2019, Table 4.2
Residential, low density	0.40–0.60	CPHEEO 2019, Table 4.2

Surface or land use	C	Source
Recreational	0.10–0.25	CPHEEO 2019, Table 4.2
Asphalt	0.70–0.95	CPHEEO 2019, Table 4.2
Concrete	0.80–0.95	CPHEEO 2019, Table 4.2
Brick paving	0.70–0.85	CPHEEO 2019, Table 4.2
Roofs: tiles	0.80–0.90	CPHEEO 2019, Table 4.2
Roofs: metal	0.70–0.90	CPHEEO 2019, Table 4.2
Roofs: concrete	0.70–0.90	CPHEEO 2019, Table 4.2
Lawns, sandy soil, flat (≤ 2%)	0.05–0.10	ASCE/WPCF 1969
Lawns, sandy soil, average (2–7%)	0.10–0.15	ASCE/WPCF 1969
Lawns, sandy soil, steep (> 7%)	0.15–0.20	ASCE/WPCF 1969
Lawns, heavy (clay) soil, flat (≤ 2%)	0.13–0.17	ASCE/WPCF 1969
Lawns, heavy soil, average (2–7%)	0.18–0.22	ASCE/WPCF 1969
Lawns, heavy soil, steep (> 7%)	0.25–0.35	ASCE/WPCF 1969
Undeveloped land (maximum for any condition)	0.30	KC APWA 5600 (2011), §5602.3E

3.5.3 **Frequency factor.** For design AEPs rarer than 10%, C shall be multiplied by Cf from Table 3.3. The product C · Cf shall not exceed 1.0.

Table 3.3 — Frequency factor Cf

Design AEP (return period)	Cf
10% (10-yr) and more frequent	1.00
4% (25-yr)	1.10
2% (50-yr)	1.20
1% (100-yr)	1.25

3.5.4 **Composite C.** Where a catchment contains more than one surface, C shall be the area-weighted value $C = \Sigma(C_j \cdot A_j) / \Sigma A_j$, computed from the measured areas of each surface. Cf is applied to the composite C.

3.5.5 **Time of concentration and networks.**

- (a) Tc shall be computed by Clause 3.6 and shall not be less than **10 minutes**.
- (b) For each reach of a network within the 16 ha limit, the peak shall be computed with the cumulative $\Sigma(C \cdot A)$ upstream of that reach and the longest Tc to that reach. Peaks from upstream reaches shall not be added.

3.5.6 **Partial-area check.** Where a compact, highly impervious part of the catchment has a much shorter Tc than the whole, the peak shall also be computed for that part alone, using its own area, C and Tc. The larger peak governs.

> **Commentary.** The developed-surface coefficients in Table 3.2 are CPHEEO Table 4.2, which CPHEEO adapted from ASCE/WPCF (1969). CPHEEO keeps C constant for all return periods. Table 3.3 instead adopts the APWA antecedent-precipitation factors (KC Metro APWA 5600, 2011, §5602.2A: K = 1.1, 1.2 and 1.25 for 4%, 2% and 1% storms, with C·K ≤ 1.0). These factors matter here because Rajasthan's rare storms arrive on wet ground (Clause 2.11.4). The 10-minute minimum Tc matches the minimum design duration of Clause 2.5.1. APWA 2011 bounds

inlet time between 5 and 15 minutes (§5602.7A). The partial-area check follows CPHEEO's treatment of "partial area effect" (CPHEEO 2019, Part A §4.4.1.7). This Manual requires the upper half of each range in 3.5.2 because Indian urban plots are typically more densely covered than the US land uses behind the ASCE ranges.

3.6 Time of concentration

3.6.1 **General.** Tc shall be computed separately for the pre- and post-development conditions, along the flow path that gives the longest travel time to the point of interest, as the sum of travel times in each flow segment. Tc shall not be less than **10 minutes** for either condition.

3.6.2 **NRCS velocity (segment) method.** The NRCS segment method is the default for all catchments. Tc = Tt(sheet) + Tt(shallow) + Tt(channel), where:

- (a) **Sheet flow:**

  > Tt = 0.091 (n · L)^0.8 / (P2^0.5 · S^0.4)

  where Tt is in hours; n is the sheet-flow roughness from Table 3.4; L is the sheet-flow length (m); P2 is the present-day 50% AEP (2-yr) 24-hour rainfall (mm) from Clause 2.3, without the climate factor; and S is the land slope (m/m).

- (b) **Sheet-flow length.** In urban areas, and for all post-development conditions, the sheet-flow length shall not exceed **30 m**. For pre-development greenfield surfaces, up to 90 m may be used only where survey shows unchannelled planar ground; otherwise 30 m applies.

- (c) **Shallow concentrated flow:** Tt = L / (3,600 V), with V = 4.918 S^0.5 (unpaved) or V = 6.196 S^0.5 (paved), V in m/s, L in m and S in m/m.

- (d) **Channel and pipe flow:** Tt = L / (3,600 V), with V from Manning's equation at bank-full or pipe-full flow.

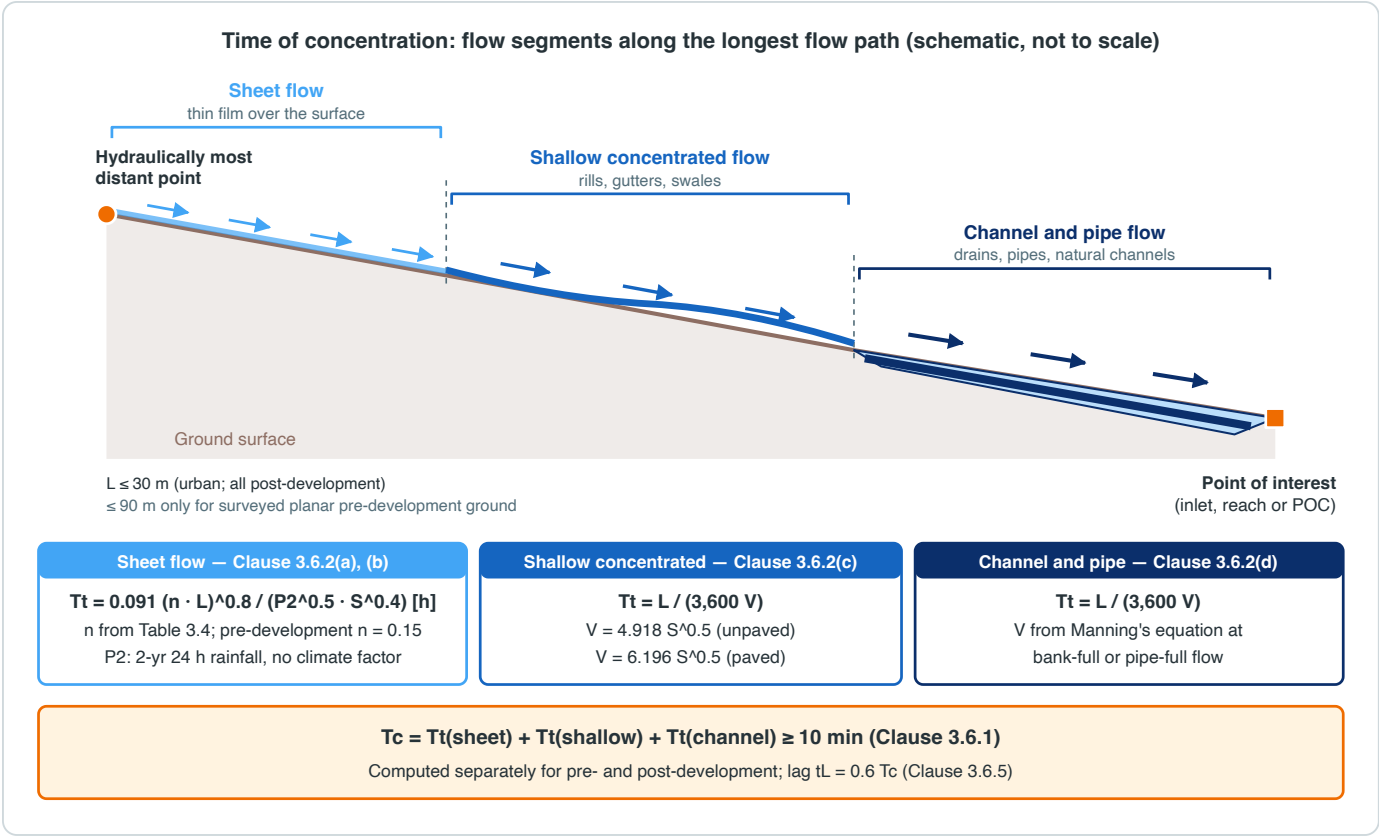

Figure 3.2 — Time of concentration by the NRCS segment method: sheet flow, shallow concentrated flow and channel or pipe flow along the longest flow path, with the travel-time equations and limits of Clause 3.6. Schematic, not to scale. Original drawing for this Manual, adapted from USDA SCS TR-55 (1986), Ch. 3, and USDA NRCS, NEH Part 630, Ch. 15 (2010).

Table 3.4 — Manning's n for sheet flow (USDA SCS TR-55, 1986, Table 3-1)

Surface	n
Smooth surfaces (concrete, asphalt, gravel, bare soil)	0.011
Fallow (no residue)	0.05
Cultivated, residue cover ≤ 20%	0.06
Cultivated, residue cover > 20%	0.17
Grass: short-grass prairie	0.15
Grass: dense grasses	0.24
Range (natural)	0.13
Woods: light underbrush	0.40
Woods: dense underbrush	0.80

3.6.3 **Pre-development roughness.** For the pre-development greenfield surface of Clause 3.3.2, sheet-flow n shall be **0.15** unless the designer justifies another Table 3.4 value from the natural vegetation of the area.

3.6.4 **Kirpich formula.** The Kirpich formula may be used only as a cross-check, or for pre-development rural catchments with a defined main channel:

> tc = 0.0195 L^0.77 S^−0.385

where tc is in minutes, L is the length of the main flow path (m) and S is its average slope (m/m). It shall not be used for urban or post-development catchments.

3.6.5 **Lag.** Where a unit hydrograph method requires lag, tL = 0.6 Tc.

3.6.6 **Check.** Post-development Tc shall normally be shorter than pre-development Tc. Where it is longer, the designer shall explain why in the submittal.

> Commentary. The segment method and its equations are from TR-55 (USDA SCS, 1986, Ch. 3) and NEH Part 630, Ch. 15 (USDA NRCS, 2010). The SI constants are direct conversions of the US equations: 0.007 becomes 0.091 with L in m and P2 in mm, and 16.1345 and 20.3282 ft/s become 4.918 and 6.196 m/s. TR-55 (1986) allowed sheet flow up to 300 ft (≈ 90 m). NEH 630 Ch. 15 states that sheet flow typically lasts no more than about 100 ft (≈ 30 m) before becoming shallow concentrated flow (citing Merkel, 2001), and many US agencies now cap it there. This Manual sets the 30 m urban limit in 3.6.2(b) on that basis: in Indian urban plots, flow reaches a drain, kerb or compound-wall weep hole within a few metres. The undisturbed P2 is used in the sheet-flow equation because P2 is a parameter of the travel-time relationship, not a design load. The default n = 0.15 for greenfield is the TR-55 short-grass value; this Manual adopts it to avoid long pre-development Tc values that would make Q_pre artificially low. The Kirpich formula is the SI form given by Chow, Maidment and Mays (1988, Table 15.1.2), from small agricultural catchments in Tennessee (Kirpich, 1940), so it does not suit urban surfaces. The lag ratio 0.6 is the NRCS value, also used by APWA (2011, §5602.7C).

3.7 Soils and hydrologic soil groups

3.7.1 **Mapping.** HSG shall be assigned from the soil series mapped by the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) or the Central Arid Zone Research Institute (CAZRI, for the arid zone) or the Rajasthan Department of Agriculture (soil survey) [TBC], using the soil-series-to-HSG lookup of Annex 3A. The source map and its scale shall be stated.

3.7.2 **Assignment rule.** Where Annex 3A is not yet available for a series, the HSG shall be assigned from the measured saturated hydraulic conductivity and depth to an impermeable layer or water table using the criteria of NEH Part 630, Ch. 7. Until Annex 3A is published, this Manual sets the following interim groups for Rajasthan: the dune and hummocky-plain sands of the Thar (Typic Torripsamments), HSG A, except that a sand with a calcrete (kankar) or petrocalcic pan, a gypsum layer or rock within 1 m of the surface is HSG C, and HSG D where the pan or rock lies within 50 cm (NEH Part 630, Ch. 7), and that the saline depressions and their margins are HSG D; the sandy loams, loamy sands and grey-brown desert soils of Marwar, Shekhawati and the Luni basin (Psammentic and coarse-loamy Haplocambids), HSG B, and HSG A only where a field test shows it; the alluvium of the Jaipur, Alwar and Bharatpur plains, of the Banas and the Chambal and of the Ghaggar, HSG B or C by texture, and HSG C where a kankar layer lies within 1 m; the medium and deep black soils (vertisols) of Hadoti, in Kota, Bundi, Baran and Jhalawar, and black clay soils wherever else they occur, as within the mixed red-and-black soils of Chittorgarh, Bhilwara and Pratapgarh, HSG D for every design storm, whatever a test on dry ground shows; the only credit for the cracks of the dry soil is the AMC II that Clause 3.8.4 allows before 15 August, unless the 5-day rule applies, and no infiltration practice founded in this soil earns retention credit for a storm from 15 August or on the strength of a test made on dry, cracked ground; the rock and thin soils of the Aravalli hills, in Udaipur, Rajsamand, Ajmer, the Jaipur hills, Alwar, Sirohi and Mount Abu, HSG D; the red loams of Mewar and Vagad, in Banswara, Dungarpur, Pratapgarh and the south of Udaipur, and the red parts of the mixed red-and-black soils, HSG C, and HSG D where rock lies within 50 cm; and made ground and fill, HSG C unless a field test shows otherwise. A field infiltration test is required on every site larger than the limits of the simplified method

of Clause 4.14.1, made as a pit or borehole test at the depth of the proposed facility after pre-wetting and taken through any calcrete or kankar layer that lies within the depth of the facility; on smaller sites, a soil that has not been tested shall be given the less permeable of the groups listed for it. Clause 3.10.1 applies to all of these groups, and in the Ghaggar–canal plains of Sri Ganganagar and Hanumangarh and the old city of Jodhpur the seasonal high water table shall be established (Clause 3.10.2) before any group other than D is used.

3.7.3 **Site verification.** For every site that relies on retention by infiltration (Chapter 4), the mapped HSG shall be verified by site infiltration tests at the location and depth of each infiltration facility. Where the tests show a lower infiltration capacity than the mapped HSG, the test result governs for both the retention design and the post-development CN. Where they show a higher capacity, the pre-development HSG shall not be changed without the approval of the authority.

3.7.4 **Disturbed and filled ground.** Clause 3.3.3(b) applies.

> Commentary. NBSS&LUP soil maps are typically at 1:250,000 to 1:50,000 scale and classify soils by series and taxonomy, not by HSG. A lookup table is therefore needed (Annex 3A). Site tests matter most on the dune sands of the west, where a calcrete or gypsum pan a metre down can turn a sand that takes in more than 100 mm/h at the surface into a perched soil that ponds; on the black soils of Hadoti, where a test on dry, cracked ground in May or June can show a high rate while the same soil takes in 1–3 mm/h or less once it is wet; and on the Aravalli fringe around Udaipur, Ajmer and Jaipur, where the depth to rock can change from a few centimetres to several metres within one site. No statewide HSG map of Rajasthan was found during research for this Manual [TBC], and no official statewide area shares of the soil groups were found either; the qualitative pattern is desert soils west of the Aravallis, medium black soils in Hadoti, red loams in Banswara, Dungarpur, Pratapgarh and Udaipur, mixed red-and-black soils in Chittorgarh and Bhilwara, and alluvium in the east and the Ghaggar plain (secondary compilations [TBC]). The arid zone has been mapped in detail. Of about 196,000 km² mapped, Entisols cover 51.84%, almost all of them sands: Typic Torripsamments of the dune phase 34.28% and of the hummocky-plain phase 16.34%; Aridisols cover 41.05%, of which Cambids are 30.83% and Calcids 9.34%, the petrocalcic soils with a calcrete hardpan among them about 3.6% (by NEER's sum); and saline depressions cover 660 km² (Dhir et al., 1997, *Annals of Arid Zone* 36(4)). The CWC report for subzone 1(a) records that "the Thar desert contains mainly Rhegosolic soils with small pockets of Lithosolic soils" near Bikaner and Jaisalmer, and that the Luni catchment has submontane soils and a strip of old alluvium from Ahor to the Rann; the report for 1(e) describes "desert and grey brown soils" near its south-western boundary and calcareous alluvium along the middle Ghaggar. Measured rates show the range, all from search summaries [TBC]: an initial infiltration of 15–30 cm/h in the aeolian sands of the west (CAZRI); a final rate of about 156 mm/h in the Jassi Pauwali series near Jodhpur, about 91% sand, and 30–54 mm/h in the loamy sands and sandy loams of the Jodhpur area (*Annals of Arid Zone*); and 5.1–13.6 mm/h in the Kota series vertisols of the Chambal command, 1.5–3.0 mm/h in the Chambal series clay loam and 0.9 mm/h in its clay, which needs "more than 8 h to absorb 7 cm" (Nathani, Sharma and Nagar, *J. Soil Water Conserv.*). No measured rate for a calcrete or petrocalcic pan was found [TBC]. This Manual therefore places deep sand in group A only where no pan lies within 1 m, because a pan perches water over a few decimetres of sand and the soil then behaves as C or D, and places the Hadoti black soil in group D for every design storm, giving its cracks only an early-season credit, through AMC II before 15 August. The date is set by this Manual: the monsoon reaches Jhalawar by about 24 June, Udaipur by 25 June and Kota by 26 June (IMD, Pai et al., 2020), so 15 August leaves about seven weeks of the monsoon to wet and close the soil in a normal year; it is later than it would be in a State with an earlier onset, and no field record of crack closure in Rajasthan was found [TBC]. AMC III then applies to 15 September, about ten days before the monsoon withdraws from Kota (25 September) and Jhalawar (28 September). Elsewhere the sandy soils and deep water tables of most of the State make a seasonal AMC III rule unjustified, and AMC III follows the 5-day rule of Clause 3.8.4 alone. The only regional measures of losses are the design loss rates of the CWC subzones: 5 mm/h in 1(a), 4.5 mm/h in 3(a), 3.0 mm/h in 1(e) and 1.7 mm/h in 1(b) (Annex 3E). They are φ-indices fitted to the floods of whole rural catchments, which include the area under standing water and the land beside saturated channels, not the infiltration capacity of any soil; the 1(a) rate comes from gravel and sand catchments on the Aravalli fringe, not from dunes, and the 1(b) rate reflects black soils near saturation. They shall not be used to assign an HSG or to size an infiltration practice. The interim

groups of Clause 3.7.2, the 1 m and 50 cm pan and rock rules, the 15 August limit for black soil, the pre-wetted test taken through any pan and the rule for untested soil on small sites are set by this Manual pending a soil-series lookup for Rajasthan.

3.8 SCS curve number (SCS-CN) loss method

3.8.1 **Runoff equation.** Runoff depth shall be computed by:

> $Q = (P - Ia)^2 / (P - Ia + S)$ for $P > Ia$; $Q = 0$ otherwise $S = 25{,}400 / CN - 254$

where Q is runoff depth (mm), P is the cumulative rainfall depth (mm), S is potential maximum retention (mm) and Ia is initial abstraction (mm). In hydrograph models the equation is applied to the cumulative rainfall at each time step to obtain incremental rainfall excess.

3.8.2 **Curve numbers.** CN at AMC II shall be taken from Table 3.5, for the HSG of Clause 3.7.

Table 3.5 — Runoff curve numbers, AMC II, Ia = 0.2S (USDA SCS TR-55, 1986, Tables 2-2a and 2-2c)

Cover type	HSG A	HSG B	HSG C	HSG D
Pre-development reference (Clause 3.3.2): open space, good condition (grass > 75%)	39	61	74	80
Open space, fair condition (grass 50–75%)	49	69	79	84
Open space, poor condition (grass < 50%)	68	79	86	89
Impervious: roofs, paved parking, driveways, paved roads with kerbs and drains	98	98	98	98
Paved roads with open ditches (including right-of-way)	83	89	92	93
Gravel roads (including right-of-way)	76	85	89	91
Dirt roads (including right-of-way)	72	82	87	89
Newly graded areas (pervious, no vegetation)	77	86	91	94
Fallow, bare soil	77	86	91	94
Meadow (continuous grass, protected from grazing)	30	58	71	78
Brush, good condition	30	48	65	73
Woods, good condition	30	55	70	77
Woods, fair condition	36	60	73	79
Woods, poor condition	45	66	77	83
Water surfaces, tank waterspreads, wet detention basins	Runoff = rainfall (no losses)			

3.8.3 **Use of Table 3.5.**

- (a) Post-development CN shall be built up from measured surfaces (Clause 3.9). The TR-55 urban district and residential lot-size rows shall not be used for the site.

- (b) Pervious areas in the post-development condition shall use "open space" in the condition the landscape plan will achieve. Where no landscape plan is submitted, fair condition applies.
- (c) Cultivated rows of TR-55 may be used for off-site existing conditions, but never for the pre-development reference of Clause 3.3.2.

3.8.4 **Antecedent moisture.** AMC shall follow Clause 2.11.4: AMC III for every design storm, whatever its duration, from 15 August to 15 September at a site in sub-area RJ-G Hadoti and the Chambal or RJ-H Mewar and Vagad of Annex 2A, and on black soil (vertisols, Clause 3.7.2) anywhere in the State; at any other time, and at every other site, AMC III for a design storm that follows, or contains, a 5-day rainfall total of more than 53 mm; and AMC II for every other storm. CN for AMC I and III shall be obtained from AMC II by:

> CN(I) = 4.2 CN(II) / (10 − 0.058 CN(II)) CN(III) = 23 CN(II) / (10 + 0.13 CN(II))

The conversion shall be applied **to the pervious component only**. Impervious surfaces stay at CN 98 for all AMC. Composite CNs shall not be converted directly.

Illustrative — not design values. Pre-development reference CNs at AMC III are: HSG A 59.5; HSG B 78.2; HSG C 86.7; HSG D 90.2.

3.8.5 **Initial abstraction.**

- (a) **Default:** Ia = 0.2S, with the CNs of Table 3.5.
- (b) **Sensitivity run (mandatory):** every storage design shall also be run with Ia = 0.05S. For this run, S shall be converted as S0.05 = 1.33 · S0.20^1.15 (S in inches), which in SI is:

  > S0.05 = 25.4 × 1.33 × (S0.20 / 25.4)^1.15 (mm)

- (c) The design shall be based on the default run. The sensitivity results shall be reported on Form 3-2. Where the sensitivity run increases the required retention volume or water quality volume, the larger value governs for that volume.

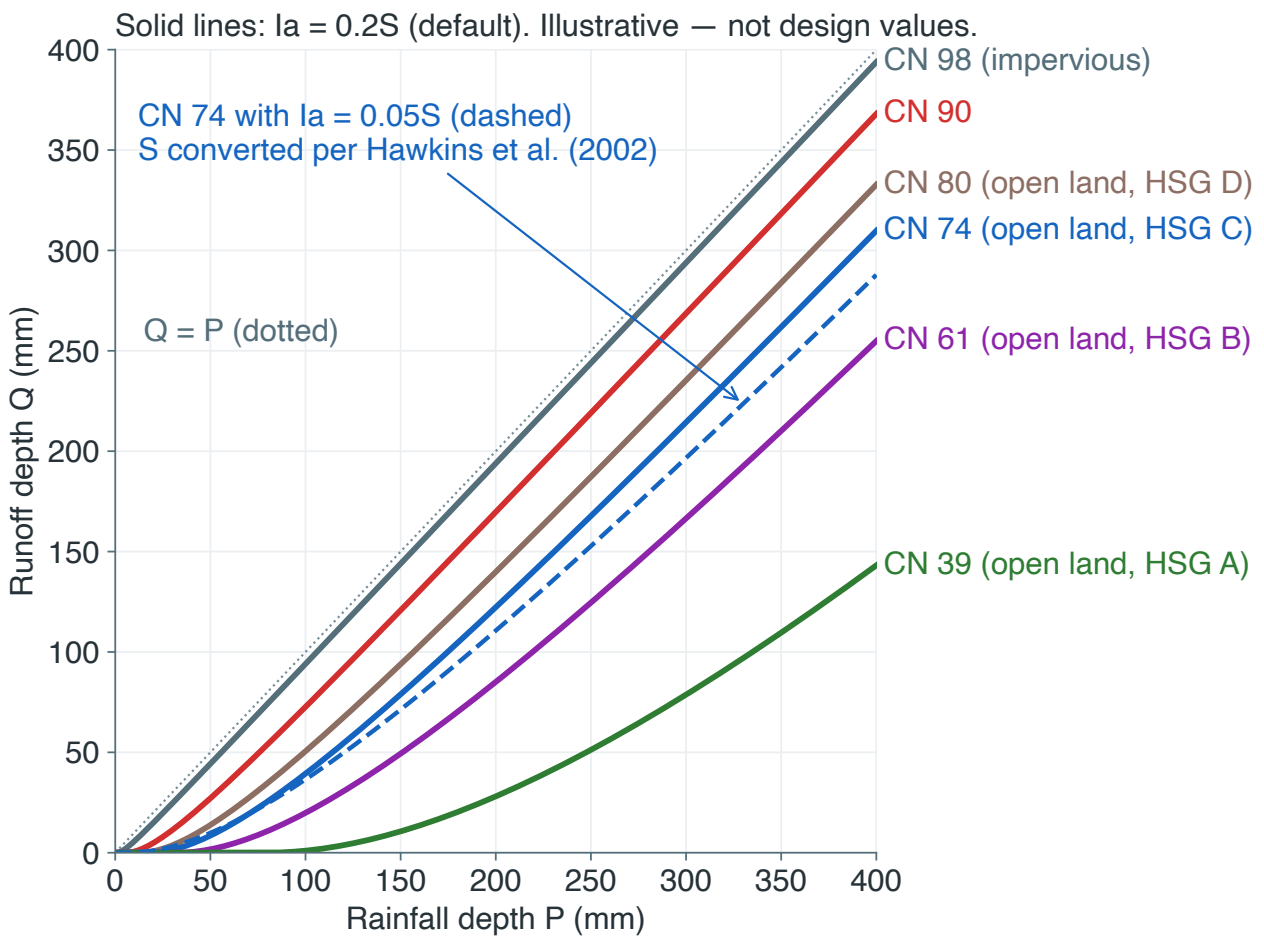

Figure 3.3 — SCS-CN runoff depth versus rainfall depth for selected curve numbers at Ia = 0.2S, with the Ia = 0.05S sensitivity case for CN 74. Original drawing for this Manual, computed from the runoff equation of USDA NRCS, NEH Part 630, Ch. 10 (2004) and USDA SCS TR-55 (1986), and the S-conversion of Hawkins et al. (2002). Illustrative — not design values.

Commentary. Table 3.5 reproduces standard NRCS TR-55 (1986) values. They were derived from US catchments and have not been calibrated in Rajasthan. The AMC conversion equations are the standard NEH-4 relationships as given by Chow, Maidment and Mays (1988, §5.5). Converting only the pervious component follows APWA, which states that "direct conversion of composite antecedent moisture conditions is not appropriate" (KC Metro APWA 5600, 2011, §5602.2C). Converting a composite CN would wrongly lower the CN of the impervious part.

Ia = 0.2S is the original NRCS ratio. Analysis of US rainfall–runoff data found that 0.05S fits better on average (Hawkins et al., 2002; Woodward et al., 2003), and gave the conversion of 3.8.5(b). NRCS has not formally replaced 0.2S, so this Manual keeps it as the default. Figure 3.3 shows why the sensitivity run is needed: for CN 74, the 0.05S case gives **more** runoff for small storms (about 2.0 mm vs 0.5 mm from 25 mm of rain) but **less** for large storms (about 242 mm vs 262 mm from 350 mm). *Illustrative — not design values.* The ratio therefore matters most for retention and water quality volumes, and the default 0.2S is the conservative choice for peak and detention design. The rule in 3.8.5(c) that the larger retention or water-quality volume governs has no direct precedent; this Manual sets it because the 0.05S case gives more runoff from the small storms that set those volumes.

3.9 Impervious connectivity

3.9.1 **Classification.** Every impervious surface in the post-development condition shall be classified as directly connected (DCIA) or disconnected, and shown on the drainage plan.

3.9.2 **Preferred representation.** In hydrograph models, DCIA and pervious areas shall be modelled as separate sub-areas (or as the separate impervious and pervious fractions of a SWMM subcatchment), each with its own loss parameters. The runoff from disconnected impervious areas shall be routed onto the receiving pervious area.

3.9.3 **Disconnection criteria.** An impervious area may be classed as disconnected only if all of the following hold:

- (a) its runoff discharges as sheet flow onto a pervious area, without a pipe, channel or kerb;
- (b) the pervious flow path is at least as long as the impervious flow path draining to it;
- (c) the pervious area is not compacted, not HSG D, and is protected from paving by the approved plan; and
- (d) for storms of 12 hours or more, it does not drain to an RWH sump or tank (Clause 3.3.3(c)).

3.9.4 **Composite CN.** Where a single composite CN is used instead of 3.9.2, it shall be computed as:

- for directly connected impervious area: $CNc = CNp + (Pimp / 100)(98 - CNp)$;
- where total impervious area is below 30% and part of it is disconnected: $CNc = CNp + (Pimp / 100)(98 - CNp)(1 - 0.5\,R)$,

where CNp is the pervious CN, Pimp is the percentage of impervious area and R is the ratio of disconnected to total impervious area. The composite CN shall not be used for retention or water quality volumes.

> **Commentary.** The composite equations are from TR-55 (USDA SCS, 1986, Ch. 2, Figures 2-3 and 2-4). This Manual prefers separate representation in 3.9.2 because a composite CN spreads the impervious response over the whole area, which suppresses runoff from small storms. For a site that is 50% directly connected impervious on HSG B open space (CNp 61), 25 mm of rain gives about 9.9 mm of runoff when the two parts are modelled separately, but only about 1.8 mm with the composite CN 79.5. At 200 mm the two methods agree (139.5 mm vs 138.4 mm). *Illustrative — not design values.* The error is largest for the frequent storms that set retention and water-quality volumes. The disconnection criteria of 3.9.3 are set by this Manual, drawing on common practice in US runoff-reduction manuals. Criterion (d) follows the rule of Clause 3.3.3(c) that RWH sumps are full at the start of SW monsoon storms.

3.10 Groundwater, high water table and tank backwater

3.10.1 **High water table (dual HSG).** Where the seasonal high groundwater table is within 0.6 m of the ground surface, the soil shall be assigned HSG D for both the pre- and post-development runs, whatever its texture, unless it is permanently drained by works that are maintained under Chapter 10. This rule applies in every case to storms of 12 hours or more, which are run at AMC III (Clause 2.11.4).

3.10.2 **Water-table data.** The seasonal high water table shall be taken as the highest level recorded in the SW monsoon season (June–September), from site piezometers or trial pits, or from the nearest Central Ground Water Board (CGWB) or Ground Water Department observation well, adjusted for ground level.

3.10.3 **Infiltration-based losses.** Where Green–Ampt, Horton or soil-moisture-accounting losses are used instead of SCS-CN, the cumulative infiltration in any storm shall not exceed the storage available in the soil above the seasonal high water table.

3.10.4 **Tank and waterbody backwater.** Where a site or sub-catchment drains to a tank, talab, marsh or other waterbody:

- (a) the water level in the receiving waterbody shall be applied as the downstream boundary of the model, per Chapter 5 and Chapter 7;
- (b) land below the level of the receiving waterbody in the design event (including the tank foreshore below FTL) shall be modelled as water surface or storage, with no losses; and
- (c) where the outfall is submerged by the waterbody level, the routing shall use the dynamic-wave method of Clause 3.12.4.

> Commentary. The dual-group rule follows NEH Part 630, Ch. 7 (USDA NRCS, 2009), which places wet soils with a water table within 60 cm (24 in) of the surface in group D in their undrained state, with a dual group (A/D, B/D, C/D) where drainage is feasible. Over most of Rajasthan the dual-group rule seldom binds, because the water table lies deep. Before the monsoon of 2020 the depth to water at the State's 1,266 observation wells ranged from 0.1 m to 142.90 m below ground, at Ranisar in Jodhpur district; 20.2% of the wells were deeper than 40 m and only 2.7% shallower than 2 m, and after the monsoon the range was 0.17–119.02 m, with 5.2% of wells shallower than 2 m (CGWB, *Ground Water Year Book 2020-21, Rajasthan*). Water stands deeper than 40 m under much of Jhunjhunu, Sikar, Jaipur, Jodhpur, Nagaur, Bikaner, Barmer, Jalore and Alwar, and shallower than 20 m in the south-east half of the State. Groundwater is drawn harder than anywhere else in India: in the 2024 assessment the stage of extraction for the State was 149.86%, and of its 302 assessment units 214 were over-exploited, 27 critical, 21 semi-critical, 37 safe and 3 saline (CGWB, *Dynamic Ground Water Resources* 2024). The exceptions are local, and they are the reason they are named in Clauses 3.7.2 and 4.12.1. In the canal command of Sri Ganganagar and Hanumangarh the water table lies within 2 m of the ground in pockets and the land waterlogs (CGWB). In Jodhpur, since canal water reached the city in 1997, the water table under the old city has risen by about 1–1.5 m a year, to about 1 m below ground in places where at least 5 m would be normal, over at least 40% of the city, and shop basements are pumped daily (as reported); a study by the National Institute of Hydrology found that the city drains south and south-east to the Jojari and that "The drainage is not well developed on the surface" (NIH, 2025). No monsoon water-table depths for Jaipur, Udaipur, Kota, Ajmer or Bikaner, and no map of the water table of the canal belt or of the lake foreshores, were obtained [TBC]; Annex 3A is to supply them. Clause 3.10.4 reflects the State's receiving waters, many of which are lakes held at a gauge level rather than rivers: the Pichola at Udaipur overflows by the Swaroop Sagar side into the Ayad, Fateh Sagar is held by its gates, and Udai Sagar lies downstream on the Ayad; Ana Sagar at Ajmer is held at its full gauge by four escape gates; and Kailana and Takhat Sagar above Jodhpur have full reservoir levels of 273.7 m and 269.75 m (NIH, 2025). The levels of the Udaipur lakes and Ana Sagar are known only in feet on gauges whose zero has not been tied to mean sea level [TBC]. In the inland basins of the west and north a site drains to a depression with no outlet, such as the Sambhar Salt Lake, so its downstream boundary is the level that the depression reaches in the design event, and Clause 4.12.7 applies.

3.11 Unit hydrographs and runoff transformation

3.11.1 **Permitted transforms.**

- (a) SCS (NRCS) dimensionless unit hydrograph, curvilinear or triangular, for catchments below 25 km² and for any sub-area of a larger model;
- (b) the SWMM non-linear reservoir with kinematic overland flow;
- (c) Clark or ModClark unit hydrograph in HEC-HMS, where parameters are calibrated under Clause 3.15; and
- (d) the CWC synthetic unit hydrograph, for 25–5,000 km² (Clause 3.11.4).

3.11.2 **SCS unit hydrograph.** The peak and time to peak of the unit hydrograph shall be:

qp = PRF' · A · Q / tp, with PRF' = 0.208 (SI form of the standard peak rate factor 484) tp = Δt / 2 + tL, tL = 0.6 Tc

where qp is the peak flow (m³/s); A is the area (km²); Q is the runoff depth (mm), equal to 1 mm for the unit hydrograph; tp is the time to peak (h); and Δt is the computation interval (h).

3.11.3 **Computation interval and sub-areas.**

- (a) Δt shall not exceed 0.133 Tc of the smallest sub-area, nor the hyetograph time step of Clause 2.9.1.
- (b) Sub-areas shall be reasonably uniform in HSG, land cover and slope. Pervious and directly connected impervious areas shall be separate sub-areas, per Clause 3.9.2.

3.11.4 **CWC synthetic unit hydrograph.** For catchments of 25–5,000 km² in CWC subzone 1(a) (Luni), 1(b) (Chambal), 1(e) (Upper Indo-Ganga Plains) or 3(a) (Mahi and Sabarmati):

- (a) the SUH parameters, design storm duration, loss rate, base flow, areal reduction and time distribution shall be taken from the applicable CWC Flood Estimation Report, using the catchment's physiographic parameters measured from survey or a DEM;
- (b) the 24-hour design rainfall shall follow Clause 2.3.3(b) and Clause 2.7.3, and the climate factor of Clause 2.8 shall be applied;
- (c) the SUH result shall be reported alongside the HEC-HMS or SWMM result for the existing natural condition; and
- (d) where the hydrograph model gives a lower 1% AEP peak than the CWC SUH, the designer shall either justify the model by calibration under Clause 3.15 or adopt the CWC SUH peak.

3.11.5 **Peak rate factor for flat coastal land.** The standard factor (484; PRF' = 0.208) is the default. A lower factor may be used only:

- (a) for unchannelled, flat coastal-plain land without piped or lined drainage;
- (b) in the same way in both the pre- and post-development runs for any land that stays unchannelled; and
- (c) after the authority adopts calibrated values in Annex 3D.

Land drained by pipes, lined drains or kerbs in the post-development condition shall use the standard factor.

Commentary. The SCS unit hydrograph, the 0.6 lag ratio and the 0.133 Tc interval are from NEH Part 630, Ch. 16 (USDA NRCS, 2007). The interval follows from the unit hydrograph geometry: with tp = Δt/2 + 0.6 Tc and Tc + Δt = 1.7 tp, Δt = 0.133 Tc. The SI constant 0.208 is the direct conversion of 484 (cfs, mi², in, h). APWA uses the SCS dimensionless unit hydrograph as its basis (2011, §5602.5). The CWC Flood Estimation Reports give regression equations for SUH parameters, a design storm duration, a constant loss rate and ARF and time-distribution curves for each subzone (CWC 1984, 1987, 1988 and 1993; see Chapter 2). They were derived from natural, mostly rural catchments with data that predate the reports of 1984 to 1993, so they represent pre-development conditions, not urbanised ones. That is why the SUH is used as a benchmark rather than as the post-development model. Clause 3.11.4(d) mirrors the floor principle of Clause 2.3.3. HEC-HMS has been calibrated against CWC subzone SUH responses in Indian studies, which shows the two can be linked.

The lower-factor option of 3.11.5 is based on the NRCS Delmarva unit hydrograph, which uses a peak rate factor of 284 (PRF' ≈ 0.122) for flat, poorly channelled coastal-plain catchments on the Delmarva Peninsula (Welle et al., 1980, as adopted by NRCS; New Jersey Department of Agriculture, Delmarva bulletin, which uses 285). A lower factor gives a lower, later peak. Used only in the pre-development run, it would lower Q_pre and make the release cap stricter; used in a piped post-development run, it would understate Q_post. Clause 3.11.5(b) prevents both biases.

3.12 Routing

3.12.1 **Storage routing.** Routing through detention and retention facilities, tanks, ponds and any storage behind embankments shall use level-pool (modified Puls, storage-indication) routing with:

- (a) a stage–storage relationship from the design grading or survey;
- (b) a stage–discharge relationship for every outlet (orifices, weirs, surplus weirs, pumps), including the minimum orifice and trash screen of Chapter 4; and
- (c) the tailwater boundary of Chapter 5, where the tailwater affects the outlet rating.

3.12.2 **Channel routing.** Routing through channels and drains shall use the Muskingum–Cunge method, or the Muskingum method with parameters K and X that are derived from channel geometry or calibration. For the Muskingum method, the routing interval Δt shall satisfy $2KX \le \Delta t \le 2K(1 - X)$.

3.12.3 **Incidental storage.** Storage behind road embankments, culverts or boundary walls that is not part of an approved facility shall not be counted in the design unless the authority is satisfied that it will be maintained for the design life.

3.12.4 **Dynamic-wave routing.** Dynamic-wave (full Saint-Venant) routing, in SWMM or HEC-RAS unsteady flow, shall be used where:

- (a) the outfall is under tidal, river or tank backwater (Chapter 5, Clause 3.10.4);
- (b) flow can reverse, or the network has loops or overflow links; or
- (c) the network surcharges in the design event and the hydraulic grade line sets the design.

3.12.5 **Tank cascades.** Tanks in a cascade shall each be routed by Clause 3.12.1, with the surplus weir and sluice ratings and the documented operating rule of Chapter 7. The starting water level in each tank shall be FTL unless continuous simulation (Clause 3.13) supports a lower level.

> Commentary. Modified Puls routing for storage and Muskingum–Cunge for channels are the APWA requirements (KC Metro APWA 5600, 2011, §5602.8). APWA also excludes "incidental detention" behind embankments unless it will be maintained, which 3.12.3 adopts. CPHEEO's detention procedure uses the same three inputs as 3.12.1: an inflow hydrograph, a stage–storage curve and a stage–discharge curve (CPHEEO 2019, Part A §8.5.3). The Muskingum stability limits are standard (Chow, Maidment and Mays, 1988, §8.4). This Manual starts talabs, lakes and reservoirs at FTL in 3.12.5 because Rajasthan's heaviest rain falls in the middle and late monsoon, on waterbodies that have taken the earlier rains, and because the lakes that matter most for city drainage are held at their full levels by gates and escape channels. The south-west monsoon brings about 91% of the State's annual rain, and of the 197 storms and depressions that affected the State in 1891–2000 most reached it in August and September (IMD, *Climate of Rajasthan*, 2010). The stations' heaviest 24-hour falls came in every monsoon month, among them 412.3 mm at Ajmer on 10 June 2002, 292.0 mm at Udaipur City on 30 June 1983, 251.7 mm at Kota (A) on 2 July 2001, 326.0 mm at Jaipur (Sanganer) on 19 July 1981, 204.0 mm at Jaisalmer on 16 August 1973, 350.2 mm at Jhalawar on 17 August 1969 and 653.0 mm at Mount Abu on 8 September 1992 (IMD, *Extremes of Temperature and Rainfall for Indian Stations*). Ana Sagar at Ajmer is kept at 13 ft on its gauge by opening its escape gates, and stood at 15 ft 11 in before they were opened in July 2025; the Pichola is full at 11 ft, Fateh Sagar at 13 ft (one report gives 14 ft) and Udai Sagar at 24 ft on their gauges, and the link gate from the Pichola to Fateh Sagar is closed once Fateh Sagar reaches 11 ft (as reported). These are gauge readings above a local zero, not levels above mean sea level, and the zeros have not been found [TBC]. No talab, lake or reservoir in the State's cities was found with a published operating rule for flood drawdown [TBC]. Talabs, lakes and reservoirs should therefore be assumed full from mid-July, a gate-controlled lake should be modelled with its gate or escape rule from WRD or its custodian, and a waterbody should be modelled below FTL only where a continuous simulation under Clause 3.13 or a notified operating rule supports it. The window of 10 July to 30 September in Clause 3.13.5(a) is set by this Manual. It starts after the monsoon normally covers the whole State, by about 6 July (new normal onset 24 June at Jhalawar, 29 June at Jaipur, 2 July at Jodhpur and 6 July at Bikaner and Pokaran; IMD, Pai et al., 2020), because the dry days of early July in the west would lower the starting level. It

ends on 30 September, the date to which this Manual keeps gates, pumps and escape channels on standby, because withdrawal normally completes between 17 September at Pokaran and 28 September at Jhalawar (IMD, Pai et al., 2020). Heavy storms have also fallen in October, such as 500.0 mm at Nasirabad on 5 October 1989 (IMD, *Climate of Rajasthan*) and 350.0 mm at Jhalawar on 5 October 1997 (IMD, *Extremes*), so a continuous simulation shall carry the record through October and November even though the starting level is taken from the window.

3.13 Continuous simulation

3.13.1 **When required.** Continuous simulation shall be carried out, in addition to the design-storm analysis, for:

- (a) regional facilities draining more than 25 km²; and
- (b) any system that includes a tank cascade whose storage is counted in the design (Chapter 7).

The authority may also require it for any facility where the starting storage level governs the design.

3.13.2 **Rainfall input.**

- (a) The longest available hourly record from IMD or another approved recording gauge representative of the catchment shall be used.
- (b) Where hourly data are shorter than 30 years, the record shall be extended with the IMD 0.25° gridded daily data. The full gridded record (1901 to present) should be used; at least the most recent 30 years shall be. The daily data shall be disaggregated to hourly by a method stated in the submittal and checked against the hourly gauge for the overlapping years. Grid values shall be converted to point values under Clause 2.7.1 where applicable.
- (c) A future-climate run shall scale the record by the climate factors of Clause 2.8.

3.13.3 **Model content.** The model shall include soil-moisture accounting with evaporation (IMD pan evaporation or equivalent), groundwater or base flow, tank storage with operating rules and irrigation withdrawals, and the tailwater series of Chapter 5 (predicted tides plus a surge allowance for coastal outfalls).

3.13.4 **Use of results.** Annual maxima of water level, storage and volume, and the duration of outfall closure, shall be extracted and fitted by frequency analysis. Results shall be compared with the design-storm results. The more severe result at each AEP governs. Peak flows in drains and channels with a response time of less than one day shall be taken from the design-storm analysis where the continuous record was disaggregated from daily data, because the disaggregated hourly peaks are synthetic.

3.13.5 **Two-step approach.** The continuous simulation need not use the full hydraulic model. It may use a simplified hydrologic and storage model, at a daily or hourly step, that represents the soil moisture, groundwater, tank storage, operating rules and tailwater of 3.13.3. Its results shall then be passed to the design-storm runs of the full hydraulic model as:

- (a) the **starting level of each tank**, taken as the level exceeded on 10% of the days from 10 July to 30 September over the record; and
- (b) the **antecedent soil-moisture condition**, taken from the same days and compared with the AMC rule of Clause 3.8.

The designer shall show that the simplified model reproduces the water balance of the full model for at least one recorded event.

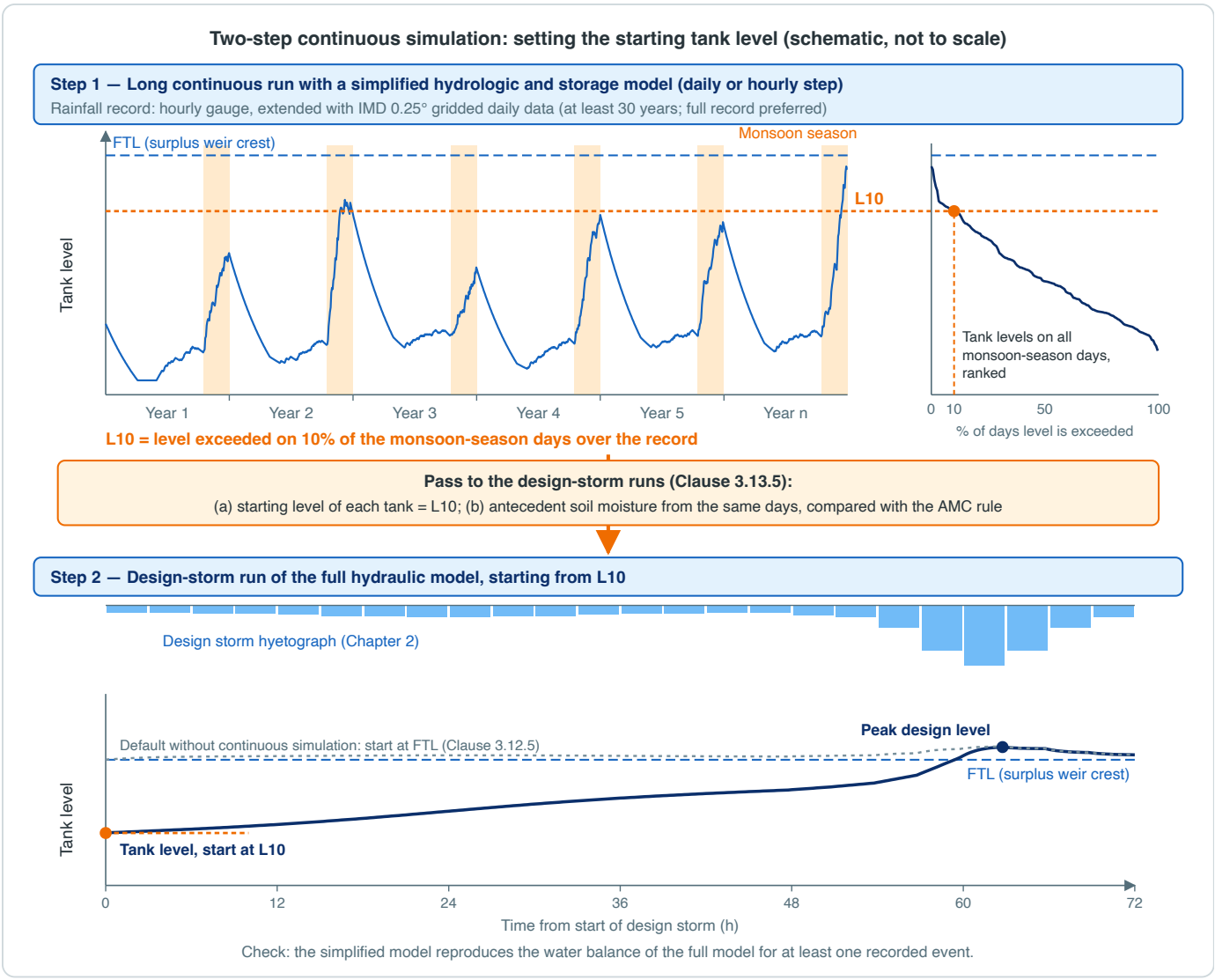

Figure 3.4 — Two-step approach of Clause 3.13.5. Step 1: a long continuous run with a simplified hydrologic and storage model gives the tank level exceeded on 10% of the days from 10 July to 30 September (L10). Step 2: the design storms are run in the full hydraulic model from that starting level, in place of the default start at FTL of Clause 3.12.5. Schematic, not real data. Original drawing for this Manual, illustrating the two-step approach set by this Manual in Clause 3.13.5.

Commentary. Design storms assume one starting condition, but in a tank cascade the governing variable is how full the tanks are when the storm arrives, which depends on the weeks of rain before it. An Australian study of 20 real on-site detention systems found that designs based on one temporal pattern, or even an ensemble of ten, "cannot reliably produce an OSD system design that will always be effective" under real rainfall, and continuous simulation showed frequent-event peaks exceeding pre-development levels (Water Science and Engineering, 2019). The 30-year minimum in 3.13.2(b) matches the station IDF rule of Clause 2.3.2; a longer record is better, and the IMD gridded daily record, which starts in 1901, is the practical long series for Rajasthan. The record length matters less than what the simulation is for. Its main purpose here is to find how full the tanks and soils usually are when a south-west monsoon storm arrives, and how often heavy rain coincides with a closed outfall. A design storm cannot answer either question, because it starts from one assumed condition. It is not intended to replace design storms for the peak flow in urban drains. Clause 3.13.5 therefore allows the long run to be made with a simple storage model, which takes minutes, and passes the starting tank levels to the detailed hydraulic model, which is then run only for the design storms. Running a detailed 1D–2D city model continuously for decades is rarely practical and is not required. The 10% exceedance level in 3.13.5(a) is set by this Manual: it represents a wet but not exceptional monsoon, so that the design storm arrives on tanks that are already well filled, as they

were in August 2006 at Udaipur, when all the water bodies of the region were reported to be overflowing, or July 2025 at Ajmer, when Ana Sagar stood at 15 ft 11 in on its gauge against a full gauge of 13 ft before its escape gates were opened (as reported).

3.14 Pre- vs post-development comparison procedure

3.14.1 The comparison required by Clause 2.11 and Chapter 4 shall be carried out by the following steps. The results shall be recorded on Form 3-2.

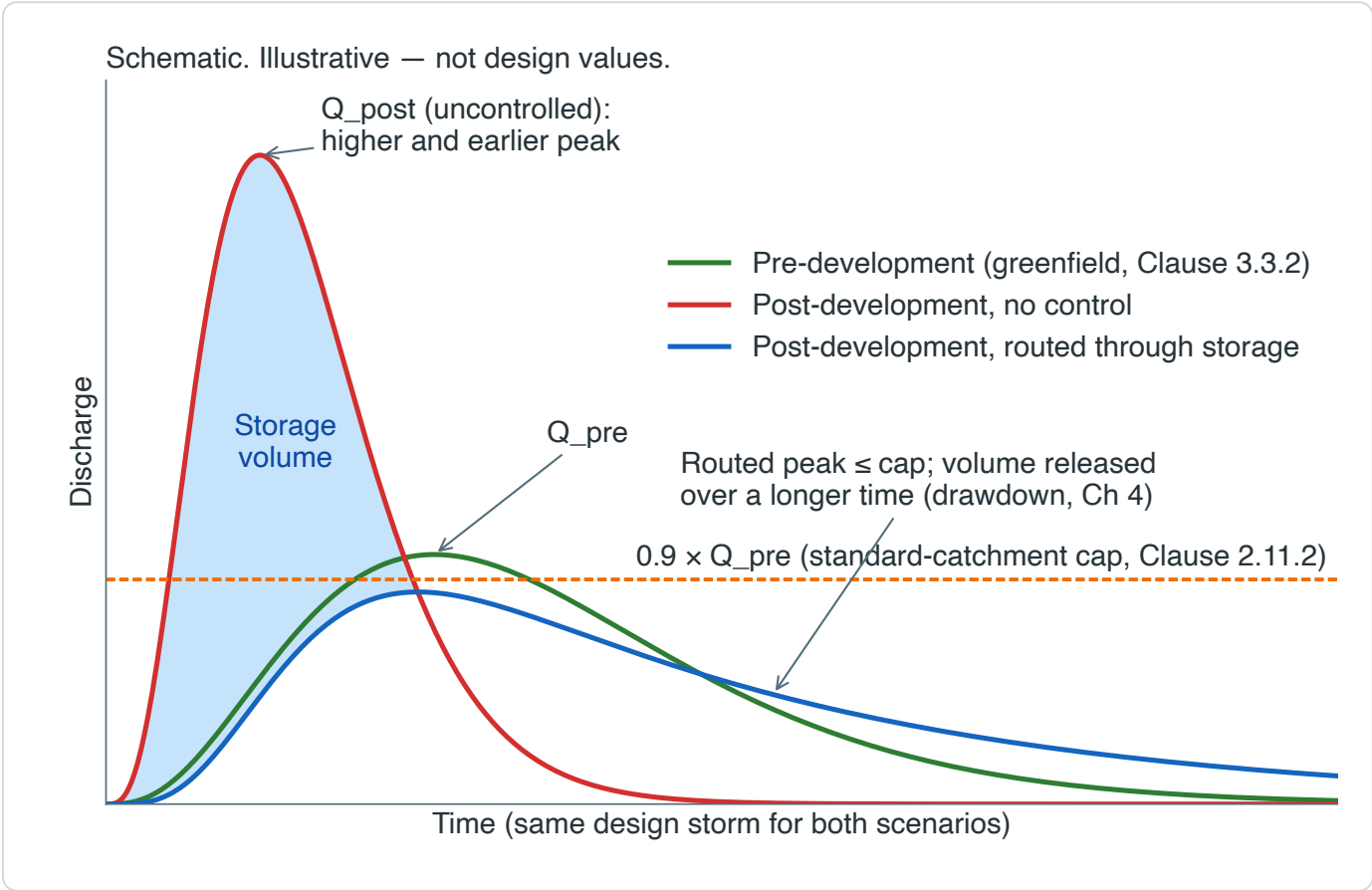

Figure 3.5 — Pre-development, uncontrolled post-development and routed post-development hydrographs for the same design storm. Original drawing for this Manual, adapted from the pre- vs post-development detention concept in CPHEEO, Manual on Storm Water Drainage Systems, Part A §8.5, 2019, and KC Metro APWA Section 5600, 2025.01. Schematic. Illustrative — not design values.

3.14.2 **Step 1 — Define the site, catchments and points of comparison.**

- (a) Delineate the site and every area that drains to it, from survey.
- (b) Identify each POC where runoff leaves the site. Each POC shall be tested separately. Runoff shall not be diverted from one natural catchment to another to meet the criterion.
- (c) Model off-site run-on identically in both runs, at its existing condition (Clause 3.3.5(b)). Where it passes through the site's storage, the criterion applies to the total outflow at the POC.

3.14.3 **Step 2 — Soils.** Map HSG (Clause 3.7), apply the high-water-table rule (Clause 3.10.1) and record the infiltration tests.

3.14.4 **Step 3 — Pre-development model.** Build the pre-development model per Clause 3.3.2: greenfield CN (Table 3.5), Tc (Clause 3.6, with n = 0.15), and existing waterbodies and channels. Compute CN at AMC II and AMC III.

3.14.5 **Step 4 — Post-development model.** Build the post-development model per Clause 3.3.3: measured impervious areas, connectivity (Clause 3.9), disturbed-soil HSG, CN, Tc, and the proposed retention, detention and outlets as storage (Clause 3.12.1).

3.14.6 **Step 5 — Design storms.** From Chapter 2, prepare for each required AEP (50%, 10% and 1%; 2-, 10- and 100-yr) and each duration in {1, 2, 3, 6, 12, 24, 48, 72 h}:

- the depth with the climate factor (Clause 2.8), ARF = 1.0 for the site (Clause 2.7.4);
- the hyetograph (Clause 2.9); and
- the AMC (Clause 2.11.4).

The same storms shall be used in both runs (Clause 2.11.1).

3.14.7 **Step 6 — Run the pre-development model** for every storm and tabulate $Q_{pre}(T, d)$. For flood-sensitive catchments, identify the largest 10% AEP pre-development peak over all durations; that value is the cap of Clause 2.11.3.

3.14.8 **Step 7 — Run the post-development model without controls** and tabulate $Q_{post}(T, d)$ and runoff volumes. This shows the size of the problem and is reported, not tested.

3.14.9 **Step 8 — Add retention and detention.**

- (a) Represent the retention volume of Chapter 4 as storage that is lost to infiltration or reuse (not released to the POC) within the period verified under Chapter 4.
- (b) Route the remaining hydrograph through the detention storage and outlets (Clause 3.12.1).
- (c) Apply the tailwater of Chapter 5, including the joint cases of Clause 2.12, where the outfall is tidal or under backwater.
- (d) Adjust storage and outlets until Step 9 is met.

3.14.10 **Step 9 — Test the criterion** at each POC, for every AEP and every duration:

- (a) standard catchments: $Q_{post}(T) \le 0.9 \times Q_{pre}(T)$ for the 50%, 10% and 1% AEP (Clause 2.11.2);
- (b) flood-sensitive catchments: $Q_{post}(1\%\ AEP) \le Q_{pre}(10\%\ AEP)$, and $Q_{post}(50\%\ AEP) \le Q_{pre}(50\%\ AEP)$ (Clause 2.11.3).

The governing duration for storage is the one that needs the largest storage or gives the highest water level; the 24, 48 and 72 h runs are always reported (Clause 2.5.2).

3.14.11 **Step 10 — Sensitivity runs.** Repeat Steps 6–9 for the governing storms with $I_a = 0.05S$ (Clause 3.8.5) and, where a lower peak rate factor is used, with the standard factor (Clause 3.11.5). Report the change in peaks and required storage.

3.14.12 **Step 11 — Associated checks.** Using the final routed model, check the drawdown times, minimum orifice and emergency spillway of Chapter 4, the outfall-closed storage check of Chapter 5, and the downstream analysis of Chapter 5.

3.14.13 **Step 12 — Document** the results on Forms 3-1 and 3-2 (Clause 3.17).

> Commentary. The step sequence follows the standard event-based workflow: delineate; set pre-development CN and Tc; set post-development CN and shorter Tc; run identical storms through a unit hydrograph or kinematic model; compare peaks and volumes; and size storage by modified Puls routing. It adds the Rajasthan elements: the 48–72 h storms, AMC III, and tailwater. Figure 3.5 shows why the long-duration runs matter: the routed peak

can meet the cap while the storage holds the volume difference between the post- and pre-development hydrographs, which must then drain within the Chapter 4 limits. The ban on diverting runoff between catchments in 3.14.2(b) stops a site meeting the rule at one POC by moving flow to a neighbour's drain.

3.15 Model calibration and validation

3.15.1 **When required.** Calibration and validation are required for:

- (a) catchment models of 25 km² or more;
- (b) regional facilities and continuous simulation under Clause 3.13;
- (c) city or basin drainage master plans; and
- (d) any model whose parameters differ from the defaults of this chapter (for example a Clark transform or a lower peak rate factor).

3.15.2 **Data.** Calibration shall use observed rainfall (gauges, and radar where available) and observed flows or water levels (WRD gauging sites, JMC or RSDMA level sensors, tank gauges, or surveyed flood marks).

3.15.3 **Events.** At least three independent events shall be used for calibration and at least one further event for validation. At least one event shall be a long-duration SW monsoon or cyclone event (for example the Jaipur storm of 18–20 July 1981 (326.0 mm in 24 hours at Jaipur (Sanganer) on 19 July, IMD), the Barmer rains of 19–22 August 2006 (about 577 mm in 3 days, as reported), the Jodhpur storm of July 2022 (about 118 mm in 5 hours, as reported) or the Chambal flood of September 2019 at Kota, where data exist).

3.15.4 **Performance.** The submittal shall report, for each event, the observed and modelled peak, volume and time to peak, and for continuous models the Nash–Sutcliffe efficiency (NSE) and percent bias. As a guide, a calibrated model should reproduce event peaks and volumes within ±25%, and a continuous model should achieve NSE ≥ 0.5 and percent bias within ±25%.

3.15.5 **Limits on calibration.** Calibration shall not be used to justify design flows lower than those given by the default methods of this chapter, unless site-specific factors are thoroughly examined and documented and the authority agrees.

3.15.6 **Reasonableness check.** Design peak flows shall be plotted as discharge per unit area against catchment area and compared with the CWC SUH results, regional gauged estimates and known historical floods.

Commentary. Clauses 3.15.5 and 3.15.6 follow APWA, which states that "model calibration shall not be used to justify discharge estimates that are lower than those provided by the baseline unit hydrograph method" and requires unit discharges to be plotted against tributary area and compared with regression, gauge and historical values (KC Metro APWA 5600, 2011, §5602.9). The event-count and performance values in 3.15.3 and 3.15.4 are set by this Manual. The NSE ≥ 0.5 and ±25% bias thresholds are the "satisfactory" streamflow ratings of Moriasi et al. (2007), which were developed for monthly continuous simulation; their use for event peaks and volumes here is an extension.

3.16 Software acceptance

3.16.1 **Accepted software.** The following are accepted without further demonstration, in a version current at the time of submittal:

- (a) EPA Storm Water Management Model (SWMM 5.x);

- (b) USACE HEC-HMS and HEC-RAS;
- (c) USDA NRCS WinTR-55 and WinTR-20; and
- (d) spreadsheets for the Rational Method and single-area SCS-CN calculations, where every formula and input is shown.

3.16.2 **Other software.** Commercial packages built on the SWMM or HEC engines are accepted if the engine and version are stated. Any other method or software is accepted only if the designer reports, for every sub-area, the peak flow, lag, runoff volume and equivalent CN from both that method and a baseline method of 3.16.1, identifies every difference greater than 5%, and justifies every difference that gives a less conservative result.

3.16.3 **Benchmark problems.** The authority shall publish benchmark test problems (Annex 3C). Software not listed in 3.16.1 shall reproduce them within the stated tolerance.

3.16.4 **Model files.** Native model input and output files shall be submitted with every hydrograph-based design.

> Commentary. The 5% equivalence test is the APWA rule for alternative methods (KC Metro APWA 5600, 2011, §5602.2D). APWA names TR-55, TR-20, HEC-1 and HEC-HMS as baseline methods (§5602.2B). CPHEEO names SWMM for hydrograph and continuous modelling (CPHEEO 2019, Part A §4.4.2). Submitting native model files lets the authority rerun the model and is the main safeguard against unreviewable black-box results.

3.17 Documentation

Every hydrologic submittal shall include:

1. **Form 3-1, Hydrologic Calculation Summary**, stating the method used and why (Table 3.1), the software and version, and the computation interval.
2. **Catchment maps** for the pre- and post-development conditions, showing sub-areas, flow paths used for Tc, POCs, and off-site run-on.
3. **Soils:** the HSG map and its source and scale (Clause 3.7), water-table data (Clause 3.10), and infiltration test results.
4. **Parameter tables** for each sub-area and condition: area, impervious area by type and connectivity, HSG, CN at AMC II and III (or C and Cf), Tc worksheets, and n values.
5. **Rainfall:** the Design Rainfall Sheet (Form 2-1) and the hyetographs used.
6. **Results:** hydrograph tables and plots for each storm; stage–storage and stage–discharge tables; routed outflows; and peak water levels.
7. **Form 3-2, Pre- vs Post-Development Comparison**, with Q_pre, Q_post (uncontrolled and routed) and the criterion for each POC, AEP and duration, and the sensitivity runs of Clause 3.14.11.
8. **Calibration report**, where Clause 3.15 applies.
9. **Model files** (Clause 3.16.4).
10. **A statement by the responsible engineer** that the methods and parameters of this chapter have been used, with any departures listed and justified.

References (chapter)

- MoHUA / CPHEEO (2019). Manual on Storm Water Drainage Systems, Volume I, Part A: Engineering Design. Ministry of Housing and Urban Affairs, New Delhi. §4.4 (Rational Method, Table 4.2 runoff coefficients, time of concentration, partial area effect), §8.5 (detention).
- Kansas City Metro Chapter APWA (2011). Section 5600 Storm Drainage Systems and Facilities (Feb 16, 2011), §5602.2–5602.9.
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- Mid-America Regional Council (2025). APWA Stormwater Standards Supplement (Policy Supplement). https://www.marc.org/document/apwa-stormwater-standards-supplement
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Annexes and forms

Annex / Form	Content
3A	Rajasthan soil series to HSG lookup; seasonal high water table map
3B	Rajasthan CN calibration and supplementary land covers (dune and hummocky sand, calcrete pans and saline depressions, cracked black-soil fallow, talab, johad, nadi and khadin beds, Aravalli rock and thin soils, desert scrub and grassland)
3C	Benchmark test problems for software acceptance
3D	Peak rate factor study for flat coastal land
3E	CWC SUH parameters for subzones 1(a), 1(b), 1(e) and 3(a), with worked example
Form 3-1	Hydrologic Calculation Summary
Form 3-2	Pre- vs Post-Development Comparison

CHAPTER 4

Site Runoff Control: Retention and Detention

4.1 Purpose and scope

4.1.1 This chapter sets the performance standard that every regulated development shall meet for runoff leaving the site. It covers:

- (a) the order in which runoff-control measures are to be applied (Clause 4.3);
- (b) retention of frequent rainfall, and how retained volume is credited against detention (Clause 4.4);
- (c) release-rate criteria for standard and flood-sensitive catchments (Clause 4.5);
- (d) the procedure for sizing detention storage and outlets (Clauses 4.6 to 4.9);
- (e) facility types, rainwater harvesting (RWH) accounting, and high-groundwater sites (Clauses 4.10 to 4.12);
- (f) regional detention and fee-in-lieu (Clause 4.13);
- (g) simplified methods for small sites: the Tier B tables and the fixed-coefficient route (Clause 4.14); and
- (h) public safety (Clause 4.15).

4.1.2 This chapter applies to land disturbance of **0.1 ha or more**, or new or replaced impervious area of **500 m² or more**, as set in Chapter 1. Single dwellings below that threshold, and road resurfacing that adds no impervious area, are exempt. The existing RWH mandate of the building rules (a rainwater harvesting unit or structure, or a rooftop rainwater storage tank with a filter, on every plot of 225 m² or more, under regulation 8.3 of the Model Rajasthan Building Regulations 2025 as published by the urban body concerned, with a refundable deposit, and the duty of every owner under section 238 of the Rajasthan Municipalities Act 2009; the rules are discussed in the Commentary to Clause 4.11) continues to apply to every building it covers, whether or not this chapter applies.

4.1.3 Rainfall inputs come from Chapter 2. Hydrologic methods come from Chapter 3. Tailwater, downstream analysis and the outfall-closed check come from Chapter 5. Water quality volume (WQv) treatment comes from Chapter 8. Where this chapter and those chapters overlap, the more stringent requirement governs.

> **Commentary.** No Indian national rule or Rajasthan rule found during research for this Manual limits the rate of discharge from a site, and none requires on-site detention or "zero run-off". The building rules are the Model Rajasthan Building Regulations 2025 (मॉडल राजस्थान भवन विनियम, 2025), issued by UDH with its order No. P.11(5) नविवि/Building Regulations-2025/2025 dated 12 May 2025 under section 337 of the Rajasthan Municipalities Act 2009, section 104-A of the Rajasthan Urban Improvement Act 1959 and the corresponding sections of the development authority Acts (the JDA Act 1982, the Jodhpur Act 2009, the Ajmer Act 2013, the Kota and Udaipur Acts 2023 and the Bikaner and Bharatpur Acts 2025). Each urban local body or authority brings them into force by its own publication in the Gazette (regulation 1.2), so the date from which they apply varies by city and is to be confirmed for each [TBC]; one secondary source gives 5 December 2025. They repeal the earlier building regulations (regulation 18.1), among them the Model Building Regulations 2020 and the versions that each authority notified, such as the JDA (Jaipur Region) Building Regulations 2020 (Gazette, 7 January 2021); an amendment of 2026 lifting the limits on building height is reported but was not read [TBC]. This Manual cites the 2025 text as read from a third-party copy of the Hindi regulations. The stormwater provisions of the regulations protect the building and the groundwater, not the catchment. Plots of 225 m² or more shall provide rainwater harvesting (regulation 8.3; Commentary to Clause 4.11); non-commercial plots of more than 750 m² shall keep 10–20% of their area as green area, at least half of it on natural ground with no slab below (regulation 8.1); for

buildings of 5,000–20,000 m² built-up area the environmental conditions require that the inlet and outlet points of the natural drainage be kept as they are, with channels large enough for unobstructed flow, at least one recharge bore for every 5,000 m² of built-up area, and an unpaved area of at least 20% of the open space (Schedule 4 of the 2025 regulations, whose pages were not rendered, and Annexure 4 of the JDA 2020 regulations, which were read [TBC]); and underground tanks, drains and catch chambers in the setbacks are not counted in ground coverage (regulation 4.13, Table 6), so a detention tank can be placed there. The regulations set no detention volume, release rate, design storm or overflow path, and no setback from a nala, river, lake or talab. The Rajasthan Municipalities Act 2009 makes drainage a duty of the Municipality (section 45) and vests public tanks, streams, drains and watercourses in it as trustee (section 68); it allows no building to be built or occupied until a drain is made "at such level and with such fall" as the Municipality thinks necessary for its "effectual drainage", emptying into a municipal drain within fifty feet or else into a cess-pool (section 202), and forbids building over a municipal drain without written consent (section 213) (read from a third-party copy of the Act [TBC]). None of these sets a design standard. The only Rajasthan drainage design rule found is RUIDP Circular No. 8 of 4 March 2008, which let the towns of its ADB-funded programme design their drains for a return period of "1-2 years", with 25 years for culverts and 50 for bridges, and notes that design intensities in India are "usually in the range of 12mm/hr to 20mm/hr", far below the 5-year 1-hour fall of 53.1 mm at Jaipur (Ghate and Timbadiya, 2022); this Manual does not use it. JDA designed the Dravyavati channel to pass the 100-year flood, but its design discharge was not found [TBC]. The courts, not the regulations, have set the lines that exist: no allotment of land in the catchments of johads, nalas, tanks, rivers and ponds (Rajasthan High Court, *Abdul Rahman*, D.B.C.W.P. 1536/2003, 2 August 2004, and the suo motu orders in S.B.C.W.P. 11153/2011 of 23 August 2011 and 29 May 2012 on the catchment of the Ramgarh dam, 769.20 km², upheld in the Supreme Court's NIMS judgment of 2017); master plans that may not disturb rivers, lakes, nalas or their catchments (*Gulab Kothari*, D.B.C.W.P. 1554/2004, 12 January 2017); land recorded as gair mumkin nala, nadi or talab treated as a natural channel that cannot be diverted or built on (*Ramji Lal Saini*, 7 May 2026); and a high flood line and ecological buffer to be demarcated for all the river systems of the State, with no fresh permissions in identified river corridors meanwhile (Supreme Court, order of 7 August 2026; Chapter 7). The requirements of this chapter are therefore best checked within the building and layout permission of the urban body or authority, together with the rainwater harvesting affidavit and drawings that the regulations already require, rather than as a separate clearance. Basements are regulated, but not for flooding. The plinth shall be at least 0.45 m and not more than 1.2 m above the road in front of the plot (regulation 6.6); basements are allowed by plot size, up to three on plots of 1,500 m² or more (regulation 6.5); and under the JDA 2020 regulations the roof of a basement outside the building could stand no more than 1.20 m above the level of the road (regulation 11.6(v)). No clause on keeping surface water out of a basement was found in the pages read [TBC]. A plinth 0.45 m above the road gives a basement no protection when the road itself becomes a flow path, as many city roads do in a heavy storm: around 1 August 2024, after about 173 mm fell at Jaipur, three members of one family died in a flooded basement in the Vishwakarma Industrial Area (as reported). This Manual therefore adds its own requirements for every basement: no detention storage in a habitable basement (Clause 4.10.1); the crest of every basement ramp and the sill of every basement opening at least 0.5 m above the 1% AEP flood level, with basement drainage pumped to the surface drain through a non-return valve (Clauses 6.11.1 and 6.11.4); and no basement in Zone 2 (Clause 7.5.2). In the flood-sensitive catchments of Clause 4.5.3.2 and in any catchment notified under Clause 4.5.4, it recommends that no basement be permitted where the 1% AEP flood level stands 0.45 m or more above the road in front, because the plinth rule of regulation 6.6 then leaves the ground floor and every opening at plinth level below the flood; and in the old city of Jodhpur and the canal belt of Sri Ganganagar and Hanumangarh, where the water table is shallow or rising, that a basement be permitted only as a watertight structure checked against flotation at the design groundwater level (Clauses 4.12.1 and 4.12.3). These are the Manual's proposals, not rules of the regulations. This chapter is written so that it can supply, as a technical companion to the regulations and the Municipalities Act, the design storm, release rates and storage volumes that they leave open; it has not been adopted for either purpose. In practice many city nalas carry sewage: the nalas of Jaipur reach the Dravyavati, whose project includes 170 MLD of sewage treatment, the Jojari at Jodhpur carries textile effluent and sewage, and the Ayad at Udaipur receives sewage (as reported; Clause 8.9). Retention and detention apply in full on every site whatever the drain carries: every litre a site releases at the peak of a storm

takes up capacity in a drain that is already part-filled with sewage. The CPHEEO (2019) manual describes limiting outflow to the pre-development peak as typical practice, but it uses no "shall" and names no storm frequencies (CPHEEO Part A §8.5.1). This chapter turns that description into a development-control requirement.

4.2 Definitions

Term	Meaning in this Manual
Retention	Permanent removal of runoff from the surface drainage system by infiltration, evapotranspiration or reuse, so that the water never reaches the outfall.
Retention depth	The 90th percentile wet-day 24-hour rainfall depth for the site's zone (Clause 2.10, Annex 2E).
Required retention volume (RRV)	The runoff volume from the retention depth over the post-development site (Clause 4.4.2).
Detention	Temporary storage of runoff, released through a controlled outlet at a rate set by Clause 4.5.
Retention credit	The reduction in required detention storage that results from retention practices, determined by routing under Clause 4.4.6. It is **not** the same as the retained volume.
Permissible site discharge (PSD)	The maximum rate at which a site may discharge for a stated AEP, in L/s or L/s/ha.
Site storage requirement (SSR)	The detention storage required per hectare of site under the simplified method of Clause 4.14.
Multi-stage outlet	An outlet structure with separate openings at different levels, each controlling a different AEP (Figure 4.2).
Drawdown time	Time from the peak stored volume until the stated fraction of that volume has been released.
Emergency spillway	A secondary overflow that passes flows above the primary outlet capacity, or all flow when the primary outlet is blocked, without overtopping the embankment.
Freeboard	Vertical distance between the maximum design water level and the embankment crest or other critical level.
Flood-sensitive catchment	A catchment listed in Clause 4.5.3 or notified under Clause 4.5.4.
Authority	The approving authority under Chapter 1 (the Municipal Corporation, Municipal Council or Municipal Board under the Rajasthan Municipalities Act 2009, the development authority in its region (JDA, or the Jodhpur, Ajmer, Kota, Udaipur, Bikaner or Bharatpur Development Authority) or the Urban Improvement Trust under the Rajasthan Urban Improvement Act 1959, that grants building or layout permission under the Model Rajasthan Building Regulations 2025 as it has published them, and RIICO in its industrial areas [TBC], as applicable).
Tier A / Tier B	Adoption tiers defined in Chapter 1. Tier A: the Jaipur Municipal Corporation (JMC), and JDA and every other approving authority within the Jaipur Region of JDA; every other Municipal Corporation constituted under the Rajasthan Municipalities Act 2009; and every other development authority constituted by an Act of the State (the Jodhpur, Ajmer, Kota, Udaipur, Bikaner and Bharatpur Development Authorities, and any constituted later), with every approving authority within its region. Tier B: Municipal Councils and Municipal Boards.

4.3 Order of measures

4.3.1 Every site runoff-control design shall apply measures in the following order, and shall document in the submittal why each earlier step could not do more:

1. **Preserve.** Keep existing waterbodies, talabs, natural drainage lines, wetlands, and permeable soils and vegetation. Avoid fill in flood storage (Chapter 7).
2. **Retain.** Retain the RRV on site by infiltration, reuse or evapotranspiration (Clause 4.4).
3. **Detain.** Detain the remaining runoff so that the release-rate criteria of Clause 4.5 are met for every design storm and duration (Clauses 4.6 to 4.9).
4. **Convey.** Convey the 1% AEP (100-yr) flow safely through the site to the receiving system on a defined overland path (Chapter 6), and check the receiving system downstream (Chapter 5).

4.3.2 Preservation and retention reduce the detention required (Clauses 4.4.6 and 4.4.7). They do not relieve the site of the release-rate criteria of Clause 4.5 or of the downstream analysis of Chapter 5.

> Commentary. This order follows the "layers of stormwater management" adopted in the Kansas City Metro APWA Section 5600 Version 2025.01: preserve or restore, retain, detain, convey, maintain (MARC factsheet; MARC Supplement, Nov 2025). Maintenance is the fifth layer and is set in Chapter 10. The 2025.01 manual credits retention and natural-area preservation against detention size (MARC Supplement, Nov 2025). Clause 4.4.6 adopts that credit, and defines it so that it cannot be claimed twice.

4.4 Retention

4.4.1 Requirement

The site shall retain the RRV. Retention shall be achieved by one or more of the following:

- infiltration practices (soakaways, infiltration trenches, permeable pavement with an infiltration base, bioretention);
- rainwater reuse that is drawn down by a demonstrated non-potable demand;
- green roofs and landscape areas that do not drain to the outfall in the retention-depth storm.

The limits of Clause 4.4.4 apply.

4.4.2 Computation of the RRV

> $RRV\ (m^3) = 10 \times Q_R \times A$

where:

- Q_R (mm) is the runoff depth from the retention depth P_R (Annex 2E). It is computed with the SCS-CN method for the post-development cover of each sub-area, at AMC II, with $Ia = 0.2S$ (Chapter 3); and
- A (ha) is the area of the site that drains to the outfall.

Q_R shall be computed for each sub-area separately and summed. An area-weighted CN shall not be used where impervious and pervious areas differ by more than 20 CN points.

The volumetric method RRV = 10 × P_R × Rv × A, with Rv = 0.05 + 0.009 × I (I = percent impervious), may be used for sites under 0.5 ha and under the Tier B method.

> **Commentary.** The Rv formula is the one used in the KC water quality volume (MARC BMP Manual 2012). It is simple to review for small sites. The SCS-CN form is required for larger sites so that the retention computation uses the same runoff model as the detention routing. That keeps the credit computation of Clause 4.4.6 consistent.

4.4.3 Verification

Retention by infiltration shall be supported by:

- (a) site infiltration tests at the location and depth of each practice, at the frequency set in Chapter 8;
- (b) a design infiltration rate of no more than **half** of the measured rate; and
- (c) groundwater evidence showing the seasonal high groundwater table at least **1.0 m** below the base of the practice (Chapter 8).

Retention by reuse shall be supported by a demand calculation showing that the RRV is drawn down within 72 hours by a continuous non-potable use, such as toilet flushing, cooling or irrigation.

> **Commentary.** The factor of 2 on measured infiltration rate has no direct precedent; this Manual sets it to allow for clogging and for the difference between a test pit and a full-scale practice. Chapter 8 may set a different factor; if it does, Chapter 8 governs.

4.4.4 Limits on retention

4.4.4.1 Infiltration practices shall not be used:

- where the seasonal high groundwater table is less than 1.0 m below the base (Chapter 8);
- on contaminated land;
- within the setbacks from foundations, wells and septic systems set in Chapter 8; or
- on fill, unless tested after placement.

4.4.4.2 Where the RRV cannot be fully retained, the shortfall shall be stated in the submittal. The shortfall shall be treated as WQv under Chapter 8 and shall get no retention credit.

4.4.5 Drawdown of retention

Retention storage shall be emptied by infiltration or reuse within **72 hours** of the end of the retention-depth storm, verified by the tests of Clause 4.4.3.

4.4.6 Retention credit: definition and computation

4.4.6.1 **What the credit is.** The retention credit is the reduction in required detention storage that results when the retention practices are included in the post-development routing. It is computed. It is not assumed equal to the RRV.

4.4.6.2 **Tier A method (routing).** For each design storm and duration of Clause 4.6.3:

- (a) model each retention practice explicitly as a storage that is **empty at the start of the storm**, unless Clause 4.11 says otherwise;

- (b) let the practice fill from the front of the storm, and let it lose water during the storm only at the design infiltration or reuse rate of Clause 4.4.3;
- (c) once it is full, route its overflow to the detention facility; and
- (d) size the detention for the residual hydrograph.

The required detention storage is the largest storage over all storms and durations. The credit is the difference between that storage and the storage required with no retention. No further deduction shall be made.

4.4.6.3 **Tier B method (simplified).** The detention storage required by Clause 4.14 may be reduced by:

> $V_{credit} = C_R \times RRV_{provided}$

where C_R is the retention credit factor from Annex 4B for the zone, soil group and drawdown rate. Until Annex 4B is published, $C_R = 0$.

4.4.6.4 Retention that is not verified under Clause 4.4.3 gets no credit.

> **Commentary.** "Credited against detention" (APWA 5600 2025.01) can be read in two ways. One reading subtracts the retained volume from the detention volume, cubic metre for cubic metre. The other routes the storms with retention in place and sees what detention is still needed. The two readings give very different answers in Rajasthan, because the mandatory 48- and 72-hour storms (Clause 2.5.2) fill any retention practice on the first day, long before the peak arrives on the last day (Clause 2.9.2). Unless the practice keeps infiltrating during the storm, it is full at the peak and does nothing to reduce the peak storage.
>
> The illustrative example in Clause 4.6.7 shows the size of the effect. A 2 ha site with 552 m³ of retention (no infiltration during the storm) needs 138 m³ less detention for the 24-hour storm. That is a credit of about a quarter of the retained volume. For the 48- and 72-hour storms, which govern, the credit is close to zero. Subtracting the retained volume directly would have under-sized the detention by about 545 m³ (about 19%).
>
> This Manual therefore defines the credit as the result of routing. Retention on fast-draining sandy soils, which keeps infiltrating through a multi-day storm, will earn a real credit. Retention that only fills will earn little. Both outcomes are physically correct. Setting $C_R = 0$ until Annex 4B exists is a safe default for Tier B, not a judgement that retention has no value: retention is still required for water quality and recharge (Chapter 8).

4.4.7 Preservation credit

Areas of the site that are permanently preserved in natural cover may be modelled at their pre-development CN in the post-development condition, provided that:

- they are protected by a registered covenant or dedication; and
- their runoff is not concentrated onto impervious surfaces.

This lowers both the RRV and the detention required. No other preservation credit applies.

4.5 Release-rate criteria

4.5.1 General

4.5.1.1 Peak discharge from the site shall be computed by a hydrograph method (Chapter 3) for the pre-development and post-development conditions with identical design storms (Clause 2.11.1). The Rational Method shall not be used for any part of storage sizing.

4.5.1.2 Pre-development is greenfield: open land in good condition for the mapped HSG. Existing impervious cover is not counted (Clause 2.11.5, Chapter 3). This applies to redevelopment as well, subject only to the constrained-redevelopment route of Clause 4.5.6.

4.5.1.3 The criteria apply at each point where runoff leaves the site. Where a site drains to more than one outfall, the criteria apply to each outfall for the area draining to it. Runoff shall not be diverted between catchments.

4.5.2 Standard catchments

For each of the 50%, 10% and 1% AEP (2-, 10- and 100-yr) storms, and for every duration in {1, 2, 3, 6, 12, 24, 48, 72 h}:

> $Q_{post}(T, d) \le 0.9 \times Q_{pre}(T, d)$

4.5.3 Flood-sensitive catchments

4.5.3.1 In the catchments listed below, the **mixed-frequency rule** of Clause 2.11.3 applies, for every duration in Clause 2.5.2:

> Q_{post}(1% AEP, 100-yr) ≤ Q_{pre}(10% AEP, 10-yr), and Q_{post}(50% AEP, 2-yr) ≤ Q_{pre}(50% AEP, 2-yr).

Each cap is the pre-development peak at the duration that maximises it: the 10-yr peak for the 100-yr check, and the 2-yr peak for the 2-yr check. The cap applies to every post-development duration (Clause 2.11.3).

4.5.3.2 The flood-sensitive catchments are:

- (a) **Jaipur on the Dravyavati**: the catchment of the Dravyavati river (the former Amanishah nala) and of the nalas that join it, among them the Naharika and Ambabari nalas, the walled-city Ganda nala, the Jawahar nala and the nalas of Sanganer town, with the low-lying colonies of the city that drain to them;
- (b) **Jodhpur on the Jojari and the old city**: the catchments of the Jojari through the city and of the Bhairav and RTO nalas and the other city nalas that drain to it, and the old city, where the water table has risen to about 1–1.5 m below ground in places;
- (c) **Udaipur's lake chain**: the land that drains to the Pichola, Swaroop Sagar, Fateh Sagar, the Ayad (Ahar) and Udai Sagar, whose outfalls are held up when the lakes are full and their gates are open;
- (d) **Ajmer on Ana Sagar and its escape channel**: the catchment of Ana Sagar and the land along its escape channel, which floods when the escape gates are opened to hold the lake at its full gauge;
- (e) **Kota on the Chambal**: the land that drains to the Chambal through the city, where the river is raised by releases from the Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar dams and the Kota Barrage;
- (f) **Barmer and Balotra on the Luni**: Balotra town and the land that drains to the Luni there, and Barmer town and the low ground of its district, such as Kawas, where water stood for months after August 2006; and
- (g) any catchment notified under Clause 4.5.4.

The boundaries shall be those mapped in Annex 4A.

4.5.4 Notification of further flood-sensitive catchments

4.5.4.1 The Authority may propose that a catchment be notified as flood-sensitive where one or more of the following is documented:

- (a) buildings or arterial roads flooded in an event of 1% AEP or more frequent, on at least two occasions in the previous 20 years;
- (b) receiving drains or channels with capacity below the 10% AEP flow under existing conditions;
- (c) an outfall to a lake whose level is held at its full gauge by opening its gates or escape channel, as at Ana Sagar at Ajmer and the Pichola and Fateh Sagar at Udaipur, or an outfall that is held up by a river in flood or by releases from upstream dams, such as the Chambal at Kota, raised by releases from the Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar dams and the Kota Barrage, for part of the SW monsoon (Chapter 5);
- (d) loss of more than a quarter of the mapped tank and talab storage in the catchment since the earliest available survey; or
- (e) a basin master plan that relies on limiting site discharge.

4.5.4.2 The procedure shall be:

1. The Authority prepares a technical note with the catchment boundary in GIS form and the evidence for 4.5.4.1.
2. The State-level technical committee constituted under Chapter 1 reviews the note.
3. The draft notification and map are published for public comment for at least 60 days.
4. The Government notifies the catchment and the map is added to Annex 4A.
5. The rule applies to applications received **6 months** or more after notification. Applications received earlier are assessed under Clause 4.5.2.

4.5.4.3 A notified catchment may be de-notified only by the same procedure, and only after a basin study shows that the downstream system meets Chapter 5 with all development under Clause 4.5.2.

> **Commentary.** The 0.9 factor is derived from the Denver (MHFD) analysis. In that analysis, ten basins each releasing 100% of the historic 100-yr peak still produced 106% of the historic peak at the outlet; releasing 90% at each gave 97% (UDFCD Full Spectrum Detention Release Rate Memorandum, 2012). The mixed-frequency rule has no direct precedent; the nearest is the Malaysian DID (2008) checklist, which required post-development 2-, 10-, 50- and 100-yr peaks below the pre-development 2-yr peak. The specific "100-yr post ≤ 10-yr pre" form appears in a New Berlin, Wisconsin planning discussion (not an adopted rule). The Jaipur entry follows the Dravyavati, which JDA has rebuilt along about 47.5 km as a channel designed "to make the river section capable of safely passing the hundred year flood"; it collects the Naharika and Ambabari nalas, the walled-city Ganda nala, Sanganer town and the Jawahar nala and discharges to the Dhund (JDA, Dravyavati EIA), but its design discharge was not found [TBC]. The city's reference storm is that of 18–20 July 1981, when Jaipur recorded 82 cm in three days and 35 cm in 24 hours on 19 July and was "cut-off" (Gupta and Jindal, *Mausam*, 1987); Jaipur (Sanganer) recorded 326.0 mm that day and Kanota 589.2 mm (IMD). The 50-yr 1-hour depth fitted to the Jaipur hourly record is 93 mm (Ghate and Timbadiya, 2022). Around 1 August 2024, after about 173 mm fell at Jaipur, three members of one family died in a flooded basement in the Vishwakarma Industrial Area (as reported), JDA began a citywide drainage upgrade with a storm-water model in 2025, naming Sodala a critical zone (as reported), and in July 2026 the High Court asked JDA to explain why drain channels had not been built near Ambawadi on the Dravyavati (*Alok Gupta v. State*, as reported). The Jodhpur entry follows the Jojari, to which the city drains south and south-east: the new Bhairav nala (13.1 km) and RTO nala (7.0 km) built under an ADB-funded programme both end in it, and the existing primary nalas are 4–15 m wide and 1.2–4 m deep (ADB, Resettlement Plan, 2023). In July 2022 about 118 mm fell in about five hours, the heaviest July fall since 1943, and more than 30 colonies were flooded (as reported). The Jojari carries textile effluent and sewage and is before the Supreme Court, which in August 2026 barred construction within 100 m of its edge pending the demarcation of its flood line (as reported; Chapter 7), and the rising water table of the old city floods basements from below (Commentary to Clause 3.10). The

Udaipur entry follows the lake chain: in August 2006 all the water bodies of the region were reported to be overflowing and the Army was alerted, and some colonies have flooded every season since (as reported); in July 2025 two hours of heavy rain submerged parts of the city (as reported). The lakes are held at gauge levels in feet above an unknown zero, the Pichola at 11 ft, Fateh Sagar at 13 ft and Udai Sagar at 24 ft (as reported [TBC]), and the main bund of Fateh Sagar was reported in 2010 to have only about 0.75 m of freeboard. The Ajmer entry follows Ana Sagar, which is held at 13 ft on its gauge by opening its four escape gates: on 11 September 2024 the escape channel was opened and Hathi Bhata, Brahmapuri and Shivpuri were waterlogged, and on 18–20 July 2025 the lake stood at 15 ft 11 in before the gates were opened, the JLN Hospital was flooded and people were swept away in Nala Bazaar (as reported); the capacity of the escape channel was not found [TBC]. Ajmer recorded 412.3 mm on 10 June 2002 (IMD). The Kota entry follows the Chambal, whose level at Kota City has a danger level of 242 m and a highest flood level of 248.68 m, set on 16 September 2019 (CWC), when the Kota Barrage (full reservoir level 260.3 m) was reported releasing about 6.5–6.9 lakh cusec and Nayapura, Balita and Gavndi were evacuated (as reported; the CWC bulletin of 14 September gives 4.42 lakh cusec). The Barmer and Balotra entry follows the Luni, whose highest flood level at Balotra is 108.755 m, set on 18 July 1979 (CWC list, as reported), and the storm of 19–22 August 2006, when about 577 mm was reported in three days against a district annual normal of 251.7 mm (IMD, *Climate of Rajasthan*), 120 mm and 160 mm fell at Barmer on 21 and 22 August, and Kawas stayed under water for months; the death toll is reported from about 140 to more than 300 (as reported). Bharatpur, where the Gambhir and Banganga floods of 1981 endangered the Ajan bund and 630.0 mm fell on 25 August 1996 (IMD, *Climate of Rajasthan*), Tonk on the Banas (highest flood level 262.05 m, 1973, as reported), Sri Ganganagar and Hanumangarh on the Ghaggar (floods of 1976, 1981, 1993, 2004, 2010 and 2023, as reported), Bikaner, Alwar, and Mount Abu and Abu Road on the West Banas (highest flood level 265.4 m, 1973, as reported; 653.0 mm at Mount Abu on 8 September 1992, IMD) are candidates for notification under Clause 4.5.4. The notification triggers in 4.5.4.1 have no direct precedent and are set by this Manual. The 6-month lead time follows the update rule of Clause 2.14.2. Clause 4.16 explains why releases below pre-development are needed at all.

4.5.5 Minimum outlet and short-duration 2-yr checks

4.5.5.1 Where the PSD for any AEP and duration is less than the discharge of a **50 mm** orifice (Clause 4.8.2) at the corresponding stage, the 50 mm orifice is deemed to comply for that AEP and duration.

4.5.5.2 Where meeting the 2-yr criterion at a duration of 3 hours or less would require a low-flow orifice so small that the drawdown requirement of Clause 4.7 cannot be met, the designer shall:

- size the low-flow orifice as the smallest opening that meets Clause 4.7; and
- report the resulting 2-yr exceedance for those durations.

The Authority may accept the design if the exceedance is below the discharge of the 50 mm orifice at the 2-yr stage, or if the downstream analysis of Chapter 5 shows no adverse effect.

Commentary. Under AMC II, a greenfield site produces almost no runoff in a 1- or 2-hour, 2-yr storm, because most of the rain is lost to initial abstraction. A pre-development peak of a few litres per second, compared duration by duration, then forces a very small low-flow orifice. That orifice cannot release the 10-yr volume within 48 hours. Checked as if it were outside a flood-sensitive catchment, the illustrative example of Clause 4.6.7 would need a low-flow orifice of about 75 mm to match the 1-hour, 2-yr pre-development peak. 90% drawdown of the 10-yr volume would then take about 84 hours even with a clean orifice, against the 48-hour limit. The 170 mm orifice that meets drawdown with 50% blockage exceeds the 1-hour, 2-yr pre-development peak by about 11 L/s. Clause 4.5.5.2 resolves that conflict in favour of drawdown, because a basin that is still partly full when the next SW monsoon storm arrives fails in the event that matters more. KC APWA 5600 (2006) used a 75 mm (3 in) minimum orifice with trash racks. This Manual sets a 50 mm minimum (Clause 4.8.2).

4.5.6 Constrained redevelopment sites

4.5.6.1 **Eligibility.** The relief route of this clause is available only for **redevelopment** where all of the following hold:

- (a) the existing site is at least **60% impervious**, as surveyed before demolition;
- (b) the site is **1 ha or less**; and
- (c) the designer shows, in a Constraint Statement submitted with Form 4-1, that the greenfield criteria of Clauses 4.5.2 or 4.5.3 cannot be met on the site. The statement must show that every storage option of Clause 4.10 has been assessed: rooftop and podium storage, tanks under parking or landscape, permeable paving with sub-base storage, and landscape depressions. It must also give the storage each option can provide.

New development on undeveloped land is never eligible.

4.5.6.2 **Minimum on-site performance.** An eligible site shall provide all of the following on site:

- (a) the full retention volume (Clause 4.4) and the WQv treatment (Chapter 8), with no relief;
- (b) post-development peak discharge no more than **50% of the existing-condition peak** for the 50%, 10% and 1% AEP storms, at each duration of Clause 2.5.2. The existing condition is modelled under Clause 3.3.4; and
- (c) no increase in the 1% AEP water level at any building or road downstream (Chapter 5).

4.5.6.3 **Shortfall.** The shortfall is the detention storage required to meet the greenfield criteria (Clause 4.6) minus the storage provided on site under 4.5.6.2. The applicant shall pay for the shortfall as a fee-in-lieu at the unit rate of Clause 4.13.3. The fee shall be:

- (a) paid into the ring-fenced account of the basin in which the site lies;
- (b) spent only on regional detention or on restoring talab or tank flood storage identified in the basin stormwater master plan (Chapter 11); and
- (c) recorded in the public ledger of Clause 4.13.4, which shall show the volume owed and the volume delivered in each basin.

Where no basin master plan has yet been approved, the fee shall be held for up to **5 years**. If no plan is approved in that time, it shall be spent on restoring tank flood storage in the same basin, with WRD agreement.

4.5.6.4 **Flood-sensitive catchments.** In the catchments of Clause 4.5.3, the route is available under the same conditions. The Authority may, however, refuse it where the downstream analysis of Chapter 5 shows existing flooding of buildings in the 10% AEP event within the analysis extent.

> **Commentary.** Greenfield is the target for all redevelopment, because a dense city only reduces its runoff as it rebuilds. On small, fully built plots in areas such as the walled city of Jaipur, the old city of Jodhpur, or the old cores of Udaipur, Ajmer, Bikaner and Kota, there is often no space for the full greenfield storage. A rule that cannot be met invites variances and non-compliance, which help no one downstream. This clause follows the approach of the UK Non-statutory Technical Standards for Sustainable Drainage (Defra, 2015, S2–S3). For previously developed sites, those standards require peak runoff "as close as reasonably practicable to the greenfield runoff rate" and never above the pre-redevelopment rate. The fixed 50% minimum reduction has no direct precedent; this Manual sets it to give reviewers a clear number in place of a "reasonably practicable" judgement. The fee-in-lieu turns the shortfall into regional storage in the same basin, so the basin still receives greenfield-equivalent control in total. Retention and water quality get no relief, because they are small volumes that almost every site can hold.

4.6 Detention sizing procedure

4.6.1 Method

Detention shall be sized by hydrograph routing through the stage–storage–discharge relationship of the facility, by level-pool (Modified Puls) or an equivalent numerical method (SWMM, HEC-HMS). Fixed-ratio and Rational-based storage formulae shall not be used. The simplified methods of Clause 4.14 (the Tier B tables and the fixed-coefficient route) are the only exceptions.

4.6.2 Steps

1. Delineate the site and sub-areas. Map HSG and confirm by testing (Chapter 3).
2. Extract design rainfall for 50%, 10% and 1% AEP and every duration in Clause 2.5.2, with the climate factor (Chapter 2, Form 2-1).
3. Build design hyetographs: alternating block for ≤ 24 h; the "peak day last" pattern for 48 and 72 h (Clause 2.9).
4. Compute pre-development hydrographs (greenfield CN; AMC III for storms of every duration from 15 August to 15 September in sub-areas RJ-G and RJ-H and on black soil, and at other times and places after a 5-day total of more than 53 mm, AMC II otherwise).
5. Compute the release caps for each AEP and duration under Clause 4.5.2 or 4.5.3.
6. Compute post-development hydrographs with the same storms and AMC, including retention practices (Clause 4.4.6).
7. Choose a trial facility geometry (stage–storage) and a multi-stage outlet (Clause 4.6.5).
8. Route every storm and duration. Use a time step of no more than **5 minutes**, and no more than Tc/3 of the post-development catchment.
9. Check every release against its cap, and check drawdown (Clause 4.7). Adjust the outlet and storage and repeat.
10. Check the tailwater condition of Clause 4.6.6 and the downstream analysis of Chapter 5.
11. Size the emergency spillway and set freeboard (Clause 4.9).
12. Report the governing storm for storage, for each outlet stage, and for the spillway (Clause 4.17).

4.6.3 Storms to be routed

Every facility shall be routed for the full matrix:

Table 4.1 — Design storms to be routed for detention sizing

AEP	Durations (h)	AMC
50% (2-yr)	1, 2, 3, 6, 12, 24, 48, 72	II for ≤ 6 h; III for ≥ 12 h
10% (10-yr)	1, 2, 3, 6, 12, 24, 48, 72	II for ≤ 6 h; III for ≥ 12 h
1% (100-yr)	1, 2, 3, 6, 12, 24, 48, 72	II for ≤ 6 h; III for ≥ 12 h

The 24-, 48- and 72-hour runs are mandatory whatever the critical-duration result (Clause 2.5.2). Where Ia = 0.05S sensitivity is required by Chapter 3, it shall be run for the governing storage case.

4.6.4 Initial conditions

Each run shall start with:

- detention storage empty, down to the invert of the lowest outlet;
- any permanent pool full;
- retention practices empty, except as limited by Clause 4.11; and

- RWH storage full (Clause 4.11).

The 48- and 72-hour storms already contain their antecedent rain, so no further pre-filling is applied.

4.6.5 Multi-stage outlet design

4.6.5.1 The outlet shall have a separate control for each criterion, normally stacked as in Figure 4.2:

- **Stage 1**, at the invert: the low-flow orifice. It releases the WQv over 24–48 h (Chapter 8) and controls the 2-yr release.
- **Stage 2**: an orifice or slot set at or near the maximum 2-yr level. It controls the 10-yr release.
- **Stage 3**: a weir, riser crest or larger orifice set at or near the maximum 10-yr level. It controls the 100-yr release.
- **Emergency spillway**: separate from the primary outlet (Clause 4.9).

Stages may be combined where routing shows that every cap is met.

4.6.5.2 Orifices shall be computed with a discharge coefficient of 0.60 unless a rated device is used. Weirs shall use a coefficient appropriate to their shape. Submerged-outlet and tailwater effects shall be included (Clause 4.6.6).

4.6.5.3 Vortex flow controls and other proprietary devices may be used where the supplier provides a certified head–discharge curve and the minimum clear opening is at least 50 mm.

4.6.6 Tailwater on the outlet

The outlet shall be routed against the tailwater of the receiving system, not free outfall, wherever the receiving water level can rise above the outlet invert. The tailwater shall be:

- for a receiving drain: its water level in the same storm, from the Chapter 5 analysis or, for Tier B, the drain obvert;
- for tidal or backwater-affected outfalls: the levels and joint cases of Clause 2.12 and Chapter 5, including the outfall-closed check (Clause 5.10).

Where tailwater governs, a flap gate shall be fitted to the outlet (Clause 5.11). The storage below the tailwater level shall not be counted as available unless the routing includes the gate closure.

4.6.7 Illustrative example

Illustrative — not design values. This example shows the procedure and the sizes it produces. The inputs are invented to be plausible for a colony on a Dravyavati tributary nala in south Jaipur. They are not NIH-DHAARA values and must not be used for design.

Inputs:

- Site: 2.0 ha, flood-sensitive catchment (Clause 4.5.3).
- Land cover: pre-development all pervious, CN 70. Post-development as two sub-areas (Clause 3.9.2): 1.57 ha of directly connected impervious surface at CN 98, never converted for AMC, and 0.43 ha of pervious open space at CN 70, on the same soil as pre-development; the area-weighted CN at AMC II is 92. For storms of 12 h and longer the pervious CN only is converted to AMC III: CN_III = 23·CN / (10 + 0.13·CN) = 84.3 (Clause 3.8.4).
- Time of concentration (Tc): 45 min pre-development, 15 min post-development (used for both sub-areas). SCS triangular unit hydrograph; 5-minute time step.
- 24-h depths: 110, 200 and 350 mm for 2-, 10- and 100-yr (the same 10- and 100-yr values as Clause 2.11).
- Shorter durations: P(t) = P24·(t/24)^0.40, an assumed ratio set and not Annex 2B.
- Longer durations: 48-h and 72-h depths taken as 1.25 and 1.40 × P24, laid out per Clause 2.9.2.
- Storage: vertical-walled, 2,500 m² plan area.

- Outlet, sized so that drawdown is met with the low-flow orifice 50% blocked (Clause 4.8.3). Annex 4C shows the trial outlet that failed this check.
    - Stage 1: 170 mm orifice at the invert.
    - Stage 2: 460 mm orifice with its invert 0.53 m above the floor.
    - Stage 3: none needed, because the 100-yr cap is met by Stages 1 and 2.

Results (discharges in L/s; storage in m³):

Table 4.2 — Illustrative example: peak discharges and storage used, by duration (Illustrative — not design values)

Duration (h)	2-yr pre	2-yr post, detained	10-yr pre	10-yr post, detained	100-yr post, uncontrolled	100-yr post, detained	100-yr storage used	10-yr drawdown, 50% blocked (h)
1	4	15	51	28	922	42	1,426	31.3
2	14	20	84	34	961	79	1,911	32.1
3	19	22	104	37	981	139	1,999	32.8
6	32	25	150	41	1,010	194	2,154	34.2
12	127	30	302	46	1,074	276	2,512	39.0
24	149	32	327	49	1,081	320	2,766	**45.3**
48	173	34	349	82	1,087	343	**2,913**	44.8
72	180	34	356	84	1,089	343	2,911	44.7

How to read it:

- **100-yr cap.** The cap is the largest pre-development 10-yr peak, 356 L/s (72 h). Every 100-yr detained peak is at or below it; the largest is 343 L/s.
- **2-yr cap.** The site is flood-sensitive, so the 2-yr cap is the largest pre-development 2-yr peak, 180 L/s (72 h; Clause 4.5.3.1). The largest 2-yr detained peak is 34 L/s. At 1, 2 and 3 hours the detained 2-yr peak is above the pre-development peak of the same duration (15 against 4 L/s, 20 against 14 L/s, and 22 against 19 L/s). That comparison is not required here. It would be for a site under Clause 4.5.2, and Clause 4.5.5.2 would then apply.
- **Governing storage.** Storage is governed by the **48- and 72-hour** storms: 2,913 m³, which is 0.146 m³ per m² of site, at a maximum depth of 1.17 m. A design that checked only the critical-duration peak storm (1–3 h here) would have provided about 2,000 m³, roughly two-thirds of what is needed.
- **Drawdown.** With the low-flow orifice 50% blocked (Clause 4.8.3), 90% of the 10-yr storage drains in at most 45.3 h (the 24-hour storm), within the 48 hours of Clause 4.7. A 120 mm orifice would drain it in about 42 h when clean but 54 to 75 h when half blocked, so it fails. Annex 4C shows that trial and the routing step by step.
- **Retention credit.** With an illustrative retention depth of 40 mm, RRV = 552 m³, computed for each sub-area (Clause 3.9.4). Modelled as filling from the start of the storm with no infiltration during it, the retention reduces the 24-hour storage by 138 m³ and the 48- and 72-hour storage by 7 m³ or less. The credit under Clause 4.4.6 is therefore effectively zero for this site.

The order of magnitude, about 0.15 m³ per m² of site, is consistent with the indication in Clause 2.11.

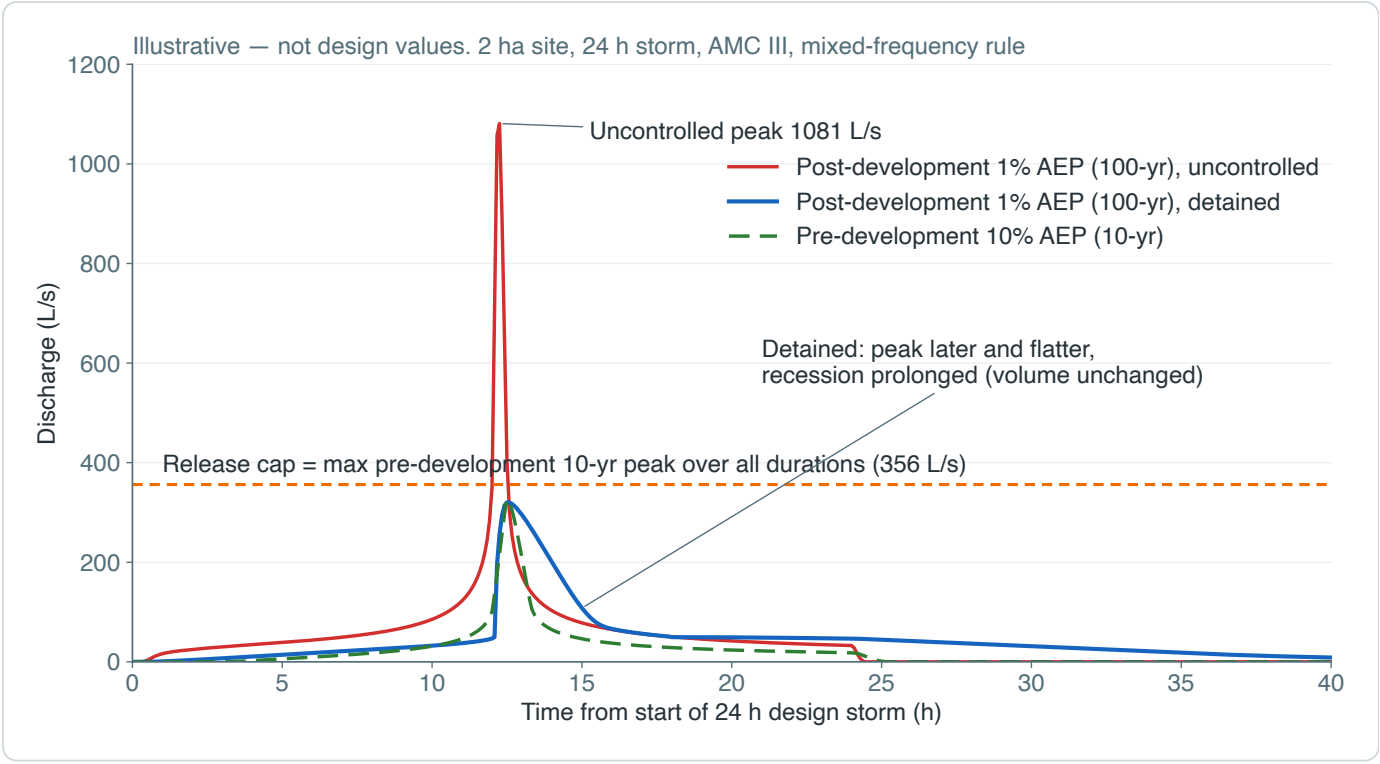


Figure 4.1 — Pre-development 10-yr, post-development 100-yr uncontrolled and detained hydrographs for the 24-hour storm of the illustrative example (Clause 4.6.7). Illustrative — not design values. Original drawing for this Manual, adapted from the pre/post-development hydrograph concept in MARC/KC APWA Section 5600 and the Georgia Stormwater Management Manual (2016).

> **Commentary.** Figure 4.1 shows what detention does and does not do. It cuts and delays the peak. It does not reduce the volume: the area under the detained curve equals the area under the uncontrolled curve, more than twice the pre-development 10-yr volume. The extra volume leaves the site over many hours after the storm. That prolonged release can coincide with the peak of the larger catchment downstream (Clause 4.16), and it must still drain when the outfall is tide-locked (Chapter 5).

4.7 Drawdown

4.7.1 **Detention.** At least **90%** of the maximum volume stored in the 10% AEP (10-yr) storm of each duration shall be released within **48 hours** of the time of maximum storage, by gravity, with the tailwater of Clause 4.6.6.

4.7.2 **Water quality volume.** The WQv shall be released over not less than 24 hours and not more than 48 hours (Chapter 8).

4.7.3 **Retention.** Retention storage shall be emptied within 72 hours by infiltration or reuse (Clause 4.4.5).

4.7.4 **Tidal outfalls.** Where gravity drawdown is prevented by tide for part of each cycle, the 48-hour limit applies with the tidal tailwater modelled. Where it cannot be met by gravity, pumped drawdown shall be provided under Clause 5.12.

> **Commentary.** KC APWA 5600 (2006) required dry basins to release at least 80% of storage within 24 hours of the inflow peak and to empty within 72 hours. Singapore PUB requires detention to be restored within 4 hours. The 48-hour, 90% rule is longer than PUB's because Rajasthan storage must hold multi-day volumes. It is still short

enough that a basin filled by one SW monsoon depression will have most of its volume back before the next, which in August 2006 at Barmer (heavy rain on successive days from 19 August, about 577 mm in 3 days in the district, with 120 mm on the 21st and 160 mm on the 22nd at Barmer, as reported) followed within days.

4.8 Outlet structures

4.8.1 **General.** Primary outlets shall be:

- unattended, with no moving parts, valves or pumps, except where Clause 5.12 permits pumped drawdown;
- accessible for inspection and cleaning from the surface without confined-space entry, where practicable; and
- built of durable materials. In coastal areas these shall be corrosion-resistant (Clause 4.12.5).

4.8.2 **Minimum orifice.** No control orifice shall be smaller than **50 mm** in diameter, or 50 mm in least dimension for a slot.

4.8.3 **Trash racks and screens.** Every orifice and weir shall be protected by a trash rack or screen. The rack shall:

- have a clear bar spacing no greater than half the smallest opening it protects, and not less than 25 mm;
- have a clear open area at least **10 times** the area of the opening it protects;
- be inclined, or set as a cage around the riser, so that debris rises with the water and does not pin against the bars;
- be removable or hinged for cleaning; and
- for routing, be assumed **50% blocked** at the low-flow orifice when checking drawdown.

4.8.4 **Anti-vortex devices.** Riser crests and orifices that may run under more than 1.5 times their diameter of head shall have an anti-vortex plate or hood (Figure 4.2).

4.8.5 **Outlet barrels.** Outlet barrels through embankments shall:

- be at least 300 mm in diameter (Chapter 6);
- have watertight joints;
- have a filter diaphragm or seepage collars over the length within the embankment; and
- have an energy-dissipating outfall (Chapter 9).

4.8.6 **Isolation.** Facilities serving more than 1 ha shall have a means of isolating the outlet for maintenance, such as a stop-log slot or penstock. In normal service it shall be left fully open.

> Commentary. The 50 mm minimum is smaller than the 75 mm (3 in) of KC APWA 5600 (2006), so the trash-rack requirements are correspondingly stricter. The ratios in 4.8.3 (bar spacing at half the opening, open area 10 times the opening, 50% blockage for the drawdown check) have no direct precedent and are set by this Manual. The blockage factor matches the 50% grate clogging factor for sag inlets in Chapter 6. Indian urban drains carry heavy loads of solid waste, so a low-flow orifice without an effective rack will block within one season.

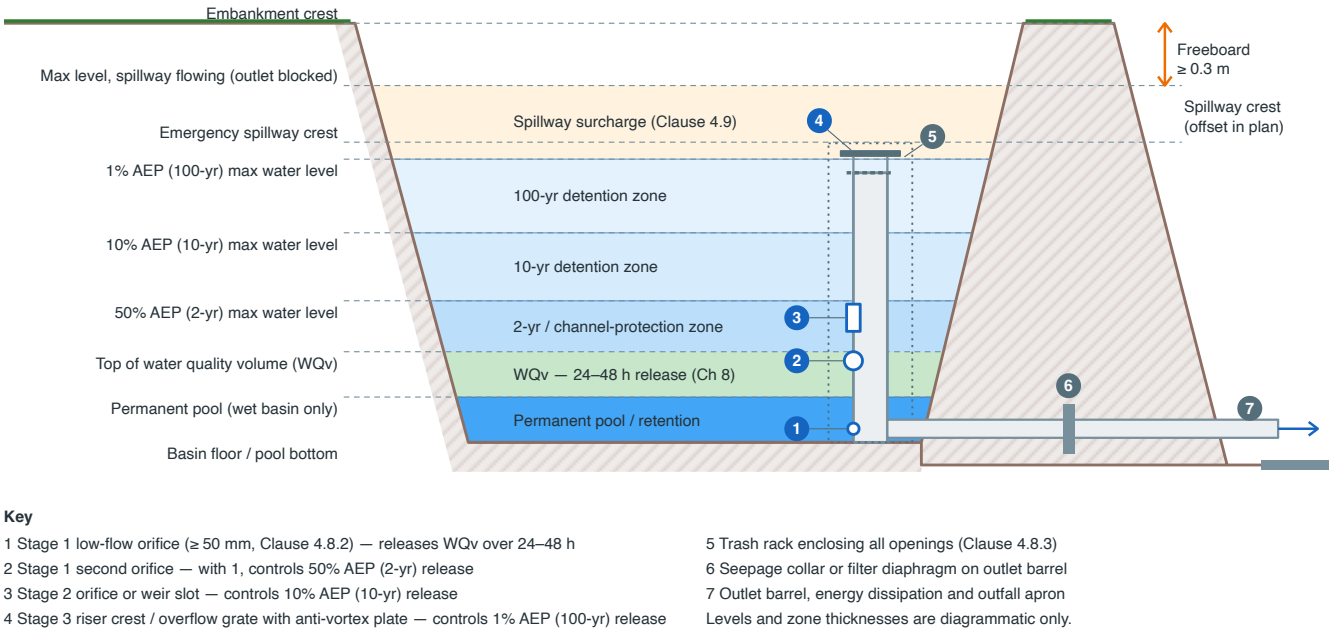


Figure 4.2 — Detention storage stack (permanent pool, WQv, 2-yr, 10-yr and 100-yr zones, spillway surcharge and freeboard) and multi-stage riser outlet. Schematic, not to scale. Original drawing for this Manual, adapted from the multi-stage outlet and storage-zone concepts in MARC/KC APWA Section 5600 (2006, 2025.01) and the Mile High Flood District Urban Storm Drainage Criteria Manual, Volume 2 (full-spectrum detention).

4.9 Emergency spillway, freeboard and embankment safety

4.9.1 **Spillway capacity.** Every detention facility formed wholly or partly by an embankment, or whose overflow would reach buildings, shall have an emergency spillway that passes the **1% AEP (100-yr) peak inflow**:

- with the primary outlet assumed fully blocked;
- with the facility full to the spillway crest at the start of the storm; and
- with at least **0.3 m freeboard** from the maximum water level to the embankment crest.

4.9.2 **High-hazard facilities.** A facility is high-hazard if its failure or overflow could:

- endanger life;
- flood a habitable building or critical facility; or
- close an arterial road.

High-hazard facilities shall also be checked for the **0.2% AEP (500-yr)** peak inflow under the conditions of 4.9.1, with the embankment not overtopped.

4.9.3 **Spillway crest.** The spillway crest shall be at or above the 1% AEP maximum water level from routing with the primary outlet working. The recommended clearance is 0.15 m.

4.9.4 **Spillway location.** The spillway shall be:

- on natural ground or a reinforced section, not on fill, unless protected against erosion for the full design flow;
- discharging to the 1% AEP overland flow path of Chapter 6; and

- placed so that its flow does not reach a building.

4.9.5 **Underground and enclosed facilities.** Tanks, vaults and podium storage shall have an overflow route that operates when the outlet is blocked. The route shall carry the 1% AEP inflow to the overland path without surcharging any building, basement or lift pit.

4.9.6 **Embankments.**

- (a) Embankments more than **2 m** high (measured from the downstream toe to the crest) shall be designed by a qualified geotechnical engineer. The design shall include stability, seepage and settlement analysis.
- (b) Side slopes shall be no steeper than 3H:1V on any face that is mown or accessible to the public. Slopes shall be flatter where Clause 4.15 requires.
- (c) Embankments shall have:
  - a crest width of at least 3 m;
  - compacted, engineered fill with a core or cut-off where required by the seepage analysis; and
  - no trees or large shrubs.
- (d) An embankment structure that falls within the Dam Safety Act, 2021 is subject to that Act in addition to this Manual.

4.9.7 **Excavated facilities.** Facilities wholly below the surrounding ground, with no embankment, need not meet 4.9.6. They shall still meet 4.9.1, with the overflow route treated as the spillway.

> Commentary. The spillway criterion (1% inflow, outlet blocked, basin full, 0.3 m freeboard; 0.2% for high hazard) follows the KC APWA 5600 (2006) rule: the spillway passes the 1% storm with 1 ft (0.3 m) freeboard to the top of the dam, assuming zero storage and a clogged primary outlet, with the crest at least 0.5 ft (0.15 m) above the 1% maximum water surface. KC designed dams above 10 ft (3 m) to SCS TR-60 Class C. The 2 m embankment trigger, the 3H:1V slope (KC wet ponds), and the 3 m crest width have no direct precedent and are set by this Manual.

4.10 Facility types

4.10.1 **General.** Any storage that meets Clauses 4.5 to 4.9 may be used. Surface storage that is visible and can be inspected without confined-space entry is preferred. Storage shall not be placed in a habitable basement or in any space whose flooding would endanger life.

4.10.2 **Underground tanks and vaults.**

- (a) Gravity outlet is required where the receiving drain allows it. Pumped outlets are permitted only under Clause 5.12, with a registered maintenance declaration (Chapter 10).
- (b) Access openings shall be provided over the outlet chamber and over every inlet. In tanks over 500 m², they shall be no more than 30 m apart.
- (c) The floor shall fall at least 1% to a sump at the outlet, with a sediment pocket below the low-flow orifice invert.
- (d) The tank shall be ventilated.
- (e) Inlets shall pass through a silt trap or gross pollutant trap (Chapter 8).
- (f) Flotation and groundwater ingress shall be checked under Clause 4.12.

4.10.3 **Rooftop detention.**

- (a) It is permitted on flat roofs designed for the full ponded load with the outlet blocked. The ponding depth shall not exceed **150 mm** unless a structural engineer certifies a greater depth.
- (b) Each roof outlet shall have a flow-control ring or weir with a certified rating, and every roof area shall have at least one overflow scupper, independent of the controlled outlets, that passes the 1% AEP inflow.

- (c) Roofs used for RWH collection may also provide rooftop detention. The detained volume is released through the control, not into the RWH sump.

4.10.4 **Podium and landscape-deck detention.**

- (a) It is permitted above ground level or above a basement car park, provided the structure is designed for full saturation and ponding, and waterproofed.
- (b) The release, overflow and safety rules for rooftop detention (4.10.3) apply.

4.10.5 **Parking-lot detention.**

- (a) It is permitted only on surface parking. Ponding depth shall not exceed:
  - **200 mm** in the 10% AEP storm and **300 mm** in the 1% AEP storm at any parking bay;
  - zero on accessible routes, ramps and pedestrian crossings; and
  - zero in the 10% AEP storm on fire-tender access routes.
- (b) Signs shall warn that the area floods.
- (c) Ponding shall not reach a building wall unless the wall is waterproofed above the 1% level plus freeboard (Chapter 6).

4.10.6 **Multi-use detention (parks, playfields, open space reservation).**

- (a) Open space land may be used for detention, provided its primary use remains available in at least the 50% AEP storm.
- (b) The storage areas shall be graded to drain fully within the times of Clause 4.7.
- (c) A low-flow channel or underdrain shall carry dry-weather and frequent flows, so that the park is not waterlogged.
- (d) The depth and slope limits of Clause 4.15 apply.
- (e) Play equipment and seating shall be placed above the 10% AEP level.

4.10.7 **Ponds and wet basins.**

- (a) A permanent pool shall be at least 1.2 m deep over most of its area to discourage weed growth and mosquito breeding, with a vegetated safety bench at the edge (Clause 4.15).
- (b) Only storage above the permanent pool counts as detention.

> Commentary.
>
> - The rooftop depth (150 mm) and parking depths (200 and 300 mm) have no direct precedent. This Manual sets them so that a blocked outlet is noticed before it becomes dangerous.
> - The 1.2 m pool depth equals the 4 ft minimum permanent pool of KC APWA 5600 (2006). This Manual adopts it mainly for weed and mosquito control.
> - Pumped detention tanks need maintenance declarations in Singapore (PUB Addendum No. 3, April 2025). This Manual adopts the same approach through Chapter 10.
> - Using open space for multi-use detention fits the Model Rajasthan Building Regulations 2025, which require a non-commercial plot of more than 750 m² to keep 10–20% of its area as green area, at least half of it on natural ground with no slab below and none of it on a terrace (regulation 8.1), and a project of 5,000–20,000 m² built-up area to keep at least 20% of its open space unpaved (Schedule 4). Public parks, gardens and open spaces vest in the Municipality (Rajasthan Municipalities Act 2009, section 68(1)(f)); no Rajasthan rule limiting the paving of parks or open spaces was found [TBC]. A detention area graded into the open space below the level of the road keeps it pervious and usable, which is what 4.10.6 requires. Three kinds of land are not open space for this purpose. A talab, johad, nadi or lake on the land is preserved under step 1 of Clause 4.3.1 and modelled as a water surface (Clause 3.3.2(e)) that starts at its full level (Clause 3.12.5), so only its flood storage above that level can count, and only as Chapter 7 allows: public tanks and the adjacent land that is not private property vest in the Municipality as trustee (section 68(1)(c)

of the 2009 Act); no khatedari rights accrue in pasture or in tank-bed and river-bed land (Rajasthan Tenancy Act 1955, section 16); land recorded as gair mumkin nala, nadi or talab is a natural channel or waterbody that is to be kept to its recorded character (*Ramji Lal Saini*, Rajasthan High Court, 7 May 2026); and a lake of 3 ha or more of heritage or religious importance, or of 10 ha or more otherwise, with the "flow area" of its feeders, falls under the Rajasthan Lakes (Protection and Development) Authority Act 2015. Land in a buffer fixed by a court or a notification is not spare land either: the no-construction zone of the Udaipur lakes (notification of 1997; the High Court has applied a line 200 m from the highest flood level around Udai Sagar, as reported); the 100 m from the edge of the Jojari within which the Supreme Court has barred construction until its flood line is demarcated (as reported); the river corridors in which no fresh permission may be granted until the high flood lines of the State's rivers are demarcated (Supreme Court, 7 August 2026); the wetlands and their catchments that the High Court has ordered be kept free of filling and construction (suo motu order of 1 June 2026); and the foreshore of Ana Sagar, where the NGT ordered the removal of structures built in breach of the Wetlands Rules and the demolition of the Seven Wonders park began on 12 September 2025 (as reported). And land in the hydraulic corridor of a nala, talab or river under Chapter 7, whose minimum width of 15 m is this Manual's proposal, is corridor or flood land already: water reaches it first, so it is not counted as detention for the development beside it (Chapter 7).

4.11 Rainwater harvesting versus detention accounting

4.11.1 **No double counting.** RWH storage (sumps, tanks, recharge pits and wells provided under the RWH mandate) shall **not** be counted as detention.

4.11.2 **RWH sumps assumed full.** For all routing under this chapter, RWH sumps and tanks shall be assumed **full at the start of every storm**, in every season. Their overflow shall be routed to the detention facility, or directly to the outfall if it bypasses detention. In the latter case the bypass flow counts against the PSD.

4.11.3 **Combined tanks.** A single tank may provide both RWH and detention only if:

- (a) the detention zone lies wholly **above** the RWH overflow level;
- (b) the detention zone is drained by its own gravity control orifice set at the RWH overflow level, meeting Clauses 4.7 and 4.8;
- (c) no pump, valve or user action can hold water in the detention zone; and
- (d) the two zones and the orifice level are shown on the drawings and in the maintenance declaration.

Only the volume between the RWH overflow level and the detention overflow level counts as detention.

4.11.4 **Recharge structures.** Recharge pits, trenches, shafts and wells may count as **retention** (not detention) if they meet Clauses 4.4.3 to 4.4.5. In particular, the seasonal high groundwater table shall be at least 1.0 m below their base. In the routing they are treated under Clause 4.4.6 with the groundwater level for the SW monsoon season.

4.11.5 **RWH remains mandatory.** Nothing in this chapter reduces the RWH requirement of regulation 8.3 and Schedule 2 of the Model Rajasthan Building Regulations 2025 as published by the urban body concerned, section 238 of the Rajasthan Municipalities Act 2009, any condition of a building or layout permission, or any rainwater harvesting rule or direction of an approving authority.

Commentary. RWH in Rajasthan is required by regulation 8.3 of the Model Rajasthan Building Regulations 2025: on every plot of 225 m² or more, a rainwater harvesting unit or structure, or a rooftop rainwater storage tank with a filter, is compulsory (8.3(i)). The 2020 regulations set the threshold at 300 m² and, for plots of more than 1,000 m², asked for recharge structures designed with the help of the geology department or an expert (Model 2020 and JDA 2020 regulations, regulation 10.11.1). The applicant pays a refundable deposit, from ₹50,000 for a plot of 225–500 m² to ₹5 lakh for one of more than 10,000 m² (Schedule 2, item 4), which is returned only after the

Ground Water Department, WRD or an experienced retired engineer reports that the structure works (8.3(ii)), and gives an affidavit at approval that is checked at the completion certificate (Schedule 3). In waterlogged areas, once the authority, trust or urban body has marked them, the structure is not compulsory (8.3(iii)). The Rajasthan Municipalities Act 2009 adds a statutory duty on every owner, a fine of ₹10,000–20,000 and a bar on any public water connection to a new building without the Municipality's RWH certificate (section 238, read from a third-party copy [TBC]); the Rajasthan Urban Improvement Act 1959 is cited by the regulations for RWH (section 73(c)), but its text was not read [TBC]; industrial plots of RIICO of 500 m² or more have their own requirement (as reported); and the Rajasthan Ground Water (Conservation and Management) Authority Act 2024 (Act No. 20 of 2025) includes recharge and rainwater harvesting among its purposes, but no notification bringing it into force was found [TBC]. The regulations set no storage volume, runoff calculation, infiltration test or depth to the water table, so the functionality check behind the deposit has no stated standard; the tests of Clauses 4.4.3 and 4.11.4 can supply one. This Manual credits these structures against its own retention requirement (Clause 4.4) as follows:

- An RWH storage tank, including the rooftop rainwater storage tank of regulation 8.3(i), or a sump, a taanka or a kund, is RWH storage. It is not detention (Clause 4.11.1), and it is assumed full at the start of every storm (Clause 4.11.2). A tank may also provide detention only if it is built as a combined tank under Clause 4.11.3, with a detention zone above its RWH overflow level that drains through its own orifice; only that zone counts.
- An RWH tank counts toward the **retention** requirement of Clause 4.4 only to the extent that it is emptied within 72 hours by a continuous non-potable use, such as toilet flushing, demonstrated under Clause 4.4.3; it is then modelled under Clause 4.4.6 like any other retention practice.
- Recharge pits, trenches, shafts, bores and wells, including the recharge bores of Schedule 4, count as retention only where they meet Clause 4.11.4: they are credited only to the extent that they drain within 72 hours at half the rate measured in a site test (Clauses 4.4.3 and 4.4.5), with their base at least 1.0 m above the seasonal high water table, and the credit is found by routing under Clause 4.4.6, not by deducting their volume.
- **Recharge first, statewide.** Rajasthan draws far more groundwater than is recharged: the stage of extraction was 149.86% in the 2024 assessment, and 214 of the State's 302 assessment units were over-exploited, 27 critical and 21 semi-critical (CGWB, *Dynamic Ground Water Resources* 2024). Retention shall therefore be provided by recharge before reuse or detention wherever site tests allow, except where the bullets below say otherwise. Every pit, shaft, bore or well shall have pre-treatment ahead of it (a silt trap and filter and a first-flush diverter), because fluoride, nitrate and salinity are already common in the aquifers (in 2024, 43.2% of samples exceeded 1.5 mg/L of fluoride and 49.5% exceeded 45 mg/L of nitrate; CGWB) and runoff that enters a bore reaches them with little filtering (Chapter 8). Road and parking runoff shall be recharged only through a surface infiltration practice with a filter, such as a vegetated basin or trench, never directly into a bore or well, and runoff from a drain that carries sewage or effluent, such as the Jojari, the Bandi or the city nalas of the Dravyavati, shall not be recharged at all.
- **Groundwater clearance first in the old city of Jodhpur and the canal belt.** In the old city of Jodhpur the water table has risen by about 1–1.5 m a year since canal water arrived in 1997, to about 1 m below ground in places (as reported; NIH, 2025), and in the canal command of Sri Ganganagar and Hanumangarh pockets lie within 2 m of the ground and waterlog (CGWB). There, recharge earns no credit until a groundwater check shows the seasonal high water table at least 1.0 m below the base of the practice (Clause 4.11.4) and not rising over the last three years of record; reuse is then the practical way to earn retention. These are the areas to which the waterlogged-area exemption of regulation 8.3(iii) most clearly applies, once the authority marks them.
- **No infiltration credit in wetted black soil.** In the deep black soils of Hadoti (Clause 3.7.2), a pit, trench or basin whose floor is in the clay earns no retention credit for any design storm from 15 August, because once the soil is wet and the cracks have closed its infiltration falls to about 1–3 mm/h or less (0.9 mm/h in the Chambal series clay, as reported). A pit in such soil is the RWH that the regulations require, but it is not retention under this Manual unless it reaches a permeable layer below the clay and is tested there.
- **Calcrete pans.** Where a calcrete (kankar) or petrocalcic pan lies within the depth of a practice, the practice earns credit only if it is taken through the pan and tested below it; a pit that stops on the pan perches the water and is not retention.

- The green area of regulation 8.1 and the unpaved area of Schedule 4 are pervious area. They enter the post-development run as pervious land under Clause 3.9.2 and get no further credit as retention or detention unless they are built and tested as an infiltration practice.

In black soil, in the canal belt and in the old city of Jodhpur, a recharge pit drains slowly or not at all in the SW monsoon, and a sump or taanka is full after the first heavy rain. Treating RWH as detention would therefore credit storage that does not exist when it is needed. That is why this Manual assumes RWH sumps are full at the start of every storm. Applying the assumption to every season keeps one simple rule. The combined-tank provision (4.11.3) lets an owner build one structure, as long as the detention part is empty when the storm arrives. The recharge-first rule and its exceptions, the 15 August limit for black soil, the rule for calcrete pans, the three-year check of a rising water table and the pre-treatment and road-runoff rules are set by this Manual; no Rajasthan rule on where recharge may or may not be credited was found.

4.12 High-groundwater and sandy coastal sites

4.12.1 **Design groundwater level.** Each site in the Ghaggar–canal plains of Sri Ganganagar and Hanumangarh, the old city of Jodhpur, the floodplains of the Chambal, the Banas, the Luni and the Ghaggar, and the foreshores of the lakes and talabs of Udaipur, Ajmer, Jaipur and the other cities, or any area where the groundwater table lies within 3 m of the surface at any time of year shall establish a design groundwater level (DGWL) for the facility. The DGWL is the seasonal high level during or after the SW monsoon, from:

- (a) site piezometer readings over at least one full June–November season; or
- (b) where (a) is not available, the higher of the CGWB or Ground Water Department record for the nearest observation well, plus **0.5 m**, and the design flood level of any adjacent river, nala or talab, or the full tank level of an adjacent lake.

For the flotation check of 4.12.3 at sites in the Ghaggar–canal plains of Sri Ganganagar and Hanumangarh and the old city of Jodhpur, where (a) is not available, the DGWL shall be taken as existing ground level.

4.12.2 **Lined storage.** Where the DGWL is less than 1.0 m below the base of a storage facility:

- (a) the facility shall be watertight (lined or of watertight concrete), and no infiltration credit applies (Clause 4.4.4); or
- (b) if unlined, the volume below the DGWL shall not be counted as detention, and groundwater inflow shall be added to the routed inflow.

4.12.3 **Uplift and flotation.** Every below-ground tank, vault, lined pond or chamber shall be checked for flotation:

- with the facility empty;
- with groundwater at the DGWL; and
- for coastal sites, with groundwater also at the major-system tailwater level of Chapter 5, where that is higher.

The factor of safety against uplift, counting only permanent dead loads and ignoring wall friction unless supported by geotechnical design, shall be at least **1.2**. Anchoring by ballast, toe extensions or tension piles may be used.

4.12.4 **Shallow and above-ground storage preferred.** On sites where the DGWL is within 1.5 m of ground, storage should be provided above ground where possible: rooftop, podium, landscape or surface storage. Deep tanks should be avoided.

4.12.5 **Durability.** Concrete and metal parts in contact with saline or brackish groundwater or tidal water shall be designed for the exposure class appropriate to coastal conditions under IS 456:2000. Outlet fittings, trash racks and gates shall be of stainless steel, HDPE, FRP or another corrosion-resistant material.

4.12.6 **Sandy soils with deep groundwater.** Where the DGWL is 1.0 m or more below the base, infiltration retention in sandy soils is encouraged. The design infiltration rate of Clause 4.4.3 applies, and the Chapter 8 requirements on pollution of shallow aquifers shall be met.

4.12.7 **Sites and catchments with no defined outfall.** Where a site, or the catchment it drains to, has no defined outfall to a river, nala, municipal drain or waterbody that carries water away from it, as over much of the inland drainage of western and northern Rajasthan (the interdunal depressions and the town sites of the Thar, Shekhawati and the canal command, and the basin of the Sambhar Salt Lake), the release-rate criteria of Clause 4.5 cannot be met by detention and do not apply. In their place, the 72-hour design volume shall be stored on site or in a public basin and removed by infiltration and evaporation, with a safe overflow path, and shall not be discharged onto a neighbour's land (Clause 2.3.6(i)). In applying this rule:

- (a) the **72-hour design volume** is the runoff volume of the 1% AEP (100-yr) 72-hour design storm of Clause 2.3.6, with the climate factor of Clause 2.8, from the whole area draining to the storage, including run-on, computed by Clause 3.8 at AMC III for the post-development condition;
- (b) the volume shall be held on the site, or in a public basin that is identified in a basin or city plan and has the capacity for it (Clause 4.13), below the level of its overflow, and shall be removed only by infiltration and evaporation, or by reuse demonstrated under Clause 4.4.3; infiltration during the storm is counted only at the design rate of Clause 4.4.3;
- (c) the stored volume of the 10% AEP (10-yr) 72-hour storm shall be emptied within **7 days** of the end of the storm; storage that cannot meet this is a wet basin under Clauses 4.10.7 and 4.15.2;
- (d) every storage shall have a safe overflow path that carries the 1% AEP peak inflow, with the storage full, to a public road, open space or public basin without flooding a building (Clause 4.9.4); and
- (e) no site shall discharge, by pipe, channel or overflow, onto a neighbour's land, and runoff shall not be diverted to another catchment (Clause 4.5.1.3).

Retention (Clause 4.4), water quality (Chapter 8), the groundwater rules of this clause and the safety provisions of Clause 4.15 apply in addition. The 72-hour design volume (Clause 2.3.6(i)), the 7-day emptying time and the overflow rule are set by this Manual.

> **Commentary.** Rajasthan is landlocked, so the coastal provisions of this clause, the tidal water levels of 4.12.1 and 4.12.3, do not apply in the State. The exposure provisions of 4.12.5 apply where groundwater at a site is saline or brackish, which in the arid west is common: the conductivity of groundwater reaches 47,670 µS/cm at Kuri in Barmer district, and in 2024 48.6% of the State's samples exceeded 3,000 µS/cm (CGWB). Over most of the State the water table lies deep, from 0.1 m to 142.90 m below ground before the monsoon of 2020, with a fifth of the wells deeper than 40 m (CGWB, *Ground Water Year Book 2020-21*), so a lined tank seldom floats and an unlined one seldom fills from below. The exceptions are the canal command of Sri Ganganagar and Hanumangarh, where pockets lie within 2 m of the ground and waterlog, and the old city of Jodhpur, where the water table has risen to about 1–1.5 m below ground and shop basements are pumped daily (as reported; NIH, 2025); there an empty lined tank can float, and the design groundwater level of 4.12.1 is taken as existing ground level for the flotation check unless piezometers show otherwise. Along the Chambal at Kota, the Banas, the Luni and the Ghaggar, and on the foreshores of the lakes of Udaipur and Ajmer, the river or the lake sets the water table in the monsoon, so the design groundwater level of 4.12.1(b) takes the design flood level of the adjacent river, nala or talab, or the full level of the adjacent lake, where that is higher than the well record. Elsewhere the case for recharge is the strongest of any State: the stage of groundwater extraction was 149.86% in 2024, with 214 of 302 assessment units over-exploited (CGWB, *Dynamic Ground Water Resources* 2024), and this Manual puts recharge first everywhere except in the canal belt, the old city of Jodhpur and wetted black soil (Commentary to Clause 4.11; Chapter 8). No current monsoon depths to water for Jaipur, Udaipur, Kota, Ajmer or Bikaner were obtained [TBC]. The June–November monitoring season of 4.12.1(a) is set by this Manual to cover the SW monsoon and the post-monsoon high that the CGWB measures in November. The factor of 1.2, the 0.5 m allowance and the "ground level" default for the canal belt and the old city of Jodhpur have no direct precedent; this Manual sets them because no published site-scale seasonal groundwater depths for Rajasthan were found during research.

> Clause 4.12.7 is needed because much of the State has no outfall at all. About 60% of Rajasthan drains inland (as reported); the rivers of the Luni subzone "either disappear in the sandy [wastes] or the marshy land in 'Runn of Kutch'" (CWC, report for subzone 1(a)); much of Jaisalmer, Bikaner and Barmer has no defined drainage, and the canal command of Bikaner is described as having no natural drainage system (as reported). There, peak control has nothing to protect downstream: the governing failure is water that collects in the lowest ground and stays, as at Kawas in Barmer district, which was still under water months after about 577 mm fell in three days in August 2006 (as reported). Single days in the west exceed the annual normal: 540.0 mm fell at Sam on 17 August 1973 against a Jaisalmer district normal of 172.9 mm (IMD, *Climate of Rajasthan*), so the design volume is set by the multi-day storm, which is why the 72-hour storm of Chapter 2 is used rather than the critical duration. The 1% AEP is used for the volume because a no-outfall site has no downstream release to rely on once its storage is full; the 10% AEP is used for the emptying check because evaporation and infiltration, not an orifice, must restore the storage before the next monsoon spell. The 7-day limit is set by this Manual: it is short enough that a basin filled by one spell has most of its volume back before the next, and long enough for a dune-sand or bored infiltration bed to empty at half its tested rate; a storage that cannot empty in 7 days stands as a pond, and is then designed and fenced as one. The overflow path of (d) and the bar of (e) on discharging onto a neighbour's land give a design form to the duty that already applies at law to provide for the "effectual drainage" of a building before it is built or occupied (Rajasthan Municipalities Act 2009, section 202). In a closed basin the public basin of (b) is the terminal depression itself, and the downstream boundary of Clause 3.10.4 is the level that it reaches in the design event; no surveyed capacity or design level of any terminal depression in the State was found [TBC]. FER 1(a) has no method calibrated on dune terrain (Annex 3E), so for these catchments the volume, not a unit-hydrograph peak, is the design quantity.

4.13 Regional detention and fee-in-lieu

4.13.1 **Where permitted.** In a basin covered by a Basin Stormwater Master Plan approved under Chapter 11, a development may meet all or part of its detention requirement through:

- (a) a regional detention facility identified in the plan; or
- (b) a fee-in-lieu paid toward restoration of talab or tank storage identified in the plan.

4.13.2 **Conditions.** Regional detention or fee-in-lieu shall be accepted only where:

- (a) the regional facility or restored tank is operational, or is funded and scheduled to be operational within **3 years**. Until then, interim on-site detention is required.
- (b) the conveyance from the site to the facility carries the 1% AEP post-development flow without increasing water levels at buildings or roads between them (Chapter 5);
- (c) the storage credited at a tank is the **flood storage** only. This is the volume between full tank level (FTL) and the maximum water level the bund and surplus weir can safely hold, plus any volume below FTL that a notified operating rule commits to empty before the SW monsoon. Storage below FTL that is held for irrigation or supply through June to September shall not be credited.
- (d) the tank meets Chapter 7: surveyed FTL, a documented operating rule, and a maintained surplus weir;
- (e) the site still provides **retention** (Clause 4.4) and **WQv** treatment (Chapter 8) on site; and
- (f) in flood-sensitive catchments, the regional facility meets the mixed-frequency rule for its whole contributing area.

4.13.3 **Fee.** The fee-in-lieu shall be computed as:

> Fee = (detention volume required on site under Clause 4.6, m³) × (unit rate, ₹/m³, notified by the Authority)

The unit rate shall include land, construction and 10 years of maintenance. Fees shall be held in a ring-fenced basin account and spent only on the facilities named in the plan.

4.13.4 **Ledger.** The Authority shall keep a public ledger of:

- detention volume credited to each regional facility;
- volume delivered; and
- fees received and spent.

Commentary. The Malaysian DID (2008) checklist favoured community ponds over on-site detention for sites above 0.1 ha. Studies of on-site detention show that its benefit depends on location and fades with distance downstream (Colorado State University thesis; McEnroe for Kansas City), and that a pond low in the catchment can synchronise with the main-stem peak (*Water* 2016). Regional storage therefore has to be sited by basin modelling, not simply aggregated.

Rajasthan has a lake statute, and its other waterbodies are protected through the revenue records and the courts. The Rajasthan Lakes (Protection and Development) Authority Act 2015 vests the protection and development of all lakes in the State Government; a "lake" is any inland water body, "whether it contains water or not and whether it has been recorded as such … or not", that has had a submerged area of at least 3 ha, if it is of socio-cultural, heritage or religious importance, or 10 ha otherwise, at any time in the fifty years before the Act; its "flow area" is "the area through which streams or feeders flow to the lake for its recharge"; the State may notify lake boundaries and a protected area around each lake; plans covering a lake need the prior approval of the Lakes Development Authority, which may remove obstructions within the protected or flow area (read from the Bill of 2015 [TBC]). No notification of a lake boundary, protected area or flow area under the Act was found [TBC]. In a Municipality, public tanks and the adjacent land that is not private property vest in the Municipality as trustee (Rajasthan Municipalities Act 2009, section 68(1)(c)); outside the towns, no khatedari rights accrue in tank-bed or river-bed land (Rajasthan Tenancy Act 1955, section 16), the High Court has barred the allotment of land in the catchments of "Johar, Nala, Tank, River, Pond" (suo motu order of 29 May 2012, as quoted in *Gulab Kothari*, 2017), and land recorded as gair mumkin nala, nadi or talab is to be kept to its recorded character (*Ramji Lal Saini*, 7 May 2026). The catchment of the Ramgarh dam, 769.20 km², is the leading case (Supreme Court, NIMS judgment, 2017). The State Wetland Authority is reported to have notified 75 wetlands by January 2026, and four wetlands are Ramsar sites: Keoladeo (1981), Sambhar (1990), and Khichan and Menar (both 4 June 2025); the High Court has ordered a statewide survey and barred filling, construction and untreated sewage in wetlands and their catchments (suo motu order of 1 June 2026). The State's regional storage is of five kinds: the lakes of the cities, such as the Pichola, Fateh Sagar and Udai Sagar at Udaipur, Ana Sagar at Ajmer, Man Sagar at Jaipur and Kailana and Takhat Sagar at Jodhpur; the dams of WRD, from Ramgarh and Bisalpur to the Kota Barrage; the talabs, johads and nadis of the villages and towns, recorded in the revenue records; the traditional structures, such as baoris, kunds, taankas and khadins; and the terminal depressions of the inland basins. Three points follow:

- A talab on the record may not be a working talab. No inventory of the talabs within any Municipal Corporation was found [TBC]. A talab, johad or nadi is credited only after a survey shows its bed, bund and outlet, and only for the storage above its full level.
- The gate-controlled lakes and the reservoirs are not spare capacity for a site. Their storage below full level is held for supply or amenity through the monsoon and is not credited (Clause 4.13.2(c)), and the storage above full level is used by the lake's own catchment; Ana Sagar and the Udaipur lakes are held at their full gauges by opening their gates, and Kailana and Takhat Sagar store the city's water. The full levels of the Udaipur lakes and of Ana Sagar are known only in gauge feet [TBC], so their flood storage cannot be computed until the gauge zeros are surveyed.
- A dam, gate or canal of WRD is not regional storage. Storm water spilled to a reservoir, a canal or a river uses capacity that is operated for the whole basin, and the outfall is held up when the gates are open or the river is high; it can be relied on only with the written agreement of WRD, for a stated flow and level. A terminal depression counts as the public basin of Clause 4.12.7 only where it is surveyed, its capacity is shown in a basin or city plan, and the land is kept free of building. No rule dividing natural nalas from

> municipal drains was found [TBC]. Until one is made, this Manual treats rivers, reservoirs, dams, canals and their gates as WRD's; the nalas, drains and public tanks within the limits of a Municipality as the Municipality's (section 68 of the 2009 Act), and those built by a development authority or Urban Improvement Trust in its schemes as that body's until they are handed over; lakes that meet the thresholds of the 2015 Act as within the remit of the Lakes Development Authority; village talabs, johads, nadis and nalas recorded as gair mumkin land as the State's, under the Collector; and the Ramsar sites and any notified wetland as within the remit of the State Wetland Authority. This is the Manual's working assignment, not a statutory one.
>
> The first point is the basis of condition 4.13.2(c) in Rajasthan. A talab gives flood storage only above its full level, unless a notified operating rule commits it to be lowered before the SW monsoon. The 3-year operational limit and the 10-year maintenance allowance have no direct precedent and are set by this Manual.

4.14 Simplified methods for small sites

4.14.1 **Applicability.** Tier B local bodies may permit the simplified method for sites of **2 ha or less** outside flood-sensitive catchments. In flood-sensitive catchments, it may be used for sites of **0.5 ha or less**. All other sites shall use Clause 4.6. Until Table 4.3 (Annex 4B) is published, all Tier B sites shall also use Clause 4.6.

4.14.2 **Method.**

1. Read the PSD (L/s/ha) and SSR (m³/ha) for the site's zone, HSG and post-development imperviousness from **Table 4.3** (Annex 4B).
2. Required storage: V = SSR × A − V_credit (Clause 4.4.6.3).
3. Permissible discharges: Q_PSD,T = PSD_T × A for the 2-yr and 100-yr stages.
4. Select the low-flow orifice and upper control from the standard outlet table in Annex 4B (orifice sizes for the PSD at the stated depths), subject to the 50 mm minimum.
5. Provide a spillway or overflow under Clause 4.9, the RWH accounting of Clause 4.11, and the safety provisions of Clause 4.15.
6. Complete Form 4-2 (Tier B site sheet).

Table 4.3 — Tier B permissible site discharge and site storage requirement (template)

Zone (Annex 2A)	HSG	Imperviousness	PSD 2-yr (L/s/ha)	PSD 100-yr (L/s/ha), standard	PSD 100-yr (L/s/ha), flood-sensitive	SSR (m³/ha), standard	SSR (m³/ha), flood-sensitive
RJ-Z1 Arid west and north: RJ-A Thar core	A / C / D	50% / 70% / 90%	[TBC]	[TBC]	[TBC]	[TBC]	[TBC]
RJ-Z1 Arid west and north: RJ-B Marwar and Luni basin	A / B / D	50% / 70% / 90%	[TBC]	[TBC]	[TBC]	[TBC]	[TBC]
RJ-Z1 Arid west and north: RJ-C Shekhawati and Bikaner	A / B / C	50% / 70% / 90%	[TBC]	[TBC]	[TBC]	[TBC]	[TBC]
RJ-Z1 Arid west and north: RJ-D Ghaggar–IGNP canal plains	B / C / D	50% / 70% / 90%	[TBC]	[TBC]	[TBC]	[TBC]	[TBC]
RJ-Z2 East and central: RJ-E Dhundhar–Ajmer central	B / C / D	50% / 70% / 90%	[TBC]	[TBC]	[TBC]	[TBC]	[TBC]

Zone (Annex 2A)	HSG	Imperviousness	PSD 2-yr (L/s/ha)	PSD 100-yr (L/s/ha), standard	PSD 100-yr (L/s/ha), flood-sensitive	SSR (m³/ha), standard	SSR (m³/ha), flood-sensitive
RJ-Z2 East and central: RJ-F Mewat–Braj north-east	B / C	50% / 70% / 90%	[TBC]	[TBC]	[TBC]	[TBC]	[TBC]
RJ-Z2 East and central: RJ-G Hadoti and the Chambal	C / D	50% / 70% / 90%	[TBC]	[TBC]	[TBC]	[TBC]	[TBC]
RJ-Z3 South and the Abu hills: RJ-H Mewar and Vagad	C / D	50% / 70% / 90%	[TBC]	[TBC]	[TBC]	[TBC]	[TBC]
RJ-Z3 South and the Abu hills: RJ-I Mount Abu and the Sirohi hills	C / D	50% / 70% / 90%	[TBC]	[TBC]	[TBC]	[TBC]	[TBC]

Worked example (illustrative — not design values).

A 0.4 ha residential layout in a Tier B Municipality, in a flood-sensitive catchment, with about 80% directly connected impervious area (area-weighted post-development CN about 92). Suppose Table 4.3 had been computed and gave the per-hectare equivalent of the Clause 4.6.7 example:

- PSD 100-yr = 356 / 2.0 = 178 L/s/ha
- SSR = 2,913 / 2.0 ≈ 1,460 m³/ha
- PSD 2-yr ≈ 17 L/s/ha

Then:

- Storage: V = 1,460 × 0.4 = **584 m³**. C_R = 0, so there is no retention credit.
- 100-yr release: 178 × 0.4 = **71 L/s**.
- 2-yr release: 17 × 0.4 = **7 L/s**. At about 1 m head this needs a low-flow orifice of about 60 mm, above the 50 mm minimum (Clause 4.8.2).
- Layout options:
  - a 400 m² underground tank 1.5 m deep; or
  - 250 m² of podium storage at 0.3 m (75 m³) plus a 350 m² tank 1.5 m deep (525 m³).
  - Rooftop storage at 150 mm over 1,200 m² of roof (180 m³) could replace part of the tank.
- RWH sumps are additional, and are assumed full (Clause 4.11).

> Commentary. Australian councils use permissible site discharge and site storage requirement tables in the same way (Sydney Water OSD guide; the Upper Parramatta River Catchment Trust handbook listed SSR of about 455 m³/ha). The illustrative SSR here, about 1,460 m³/ha, is much larger. That is the expected effect of combining a mixed-frequency cap with mandatory 48–72-hour storms at AMC III. MSMA 2 in Malaysia offers a similar simplified OSD method for sites under 5 ha. The MARC policy supplement offers smaller Kansas City municipalities adoptable alternatives within the regional standard; Clause 4.14 follows that model for Tier B.

4.14.3 **Fixed-coefficient route.** As an alternative to Clauses 4.6 and 4.14.2, the designer of any site of **1 ha or less**, under any Approving Authority and in any catchment, may size detention by Clauses 4.14.4 to 4.14.7. The route shall not be used where:

- (a) the site counts tank or waterbody storage in its design (Chapter 7);
- (b) any part of the site lies within a waterbody setback (Chapter 7); or
- (c) the site drains to a tank cascade whose storage is counted in a downstream design.

The route sets the release caps by fixed coefficients and does not need Table 4.3. It may therefore be used before Annex 4B is published. Retention (Clause 4.4), drawdown (Clause 4.7), outlets (Clause 4.8), the spillway (Clause 4.9), the downstream and tailwater checks (Chapter 5) and water quality (Chapter 8) still apply.

4.14.4 **Release caps.** Two caps apply at each point where runoff leaves the site:

$Q_{cap,10} = 2.78 \times C_{10} \times i_{10} \times A$ and $Q_{cap,2} = 2.78 \times C_2 \times i_2 \times A$

where Q_{cap} is in L/s; A is the site area (ha); i_{10} and i_2 are the 10% AEP (10-yr) and 50% AEP (2-yr) rainfall intensities (mm/h) for a **15-minute** duration at the site, from the sources of Chapter 2, with the climate factor of Clause 2.8; and C_{10} and C_2 are the fixed coefficients of Table 4.3A for the site's hydrologic soil group (Clause 3.7). For a site with more than one soil group, the coefficients are area-weighted.

Table 4.3A — Fixed release coefficients (provisional)

Hydrologic soil group	C_{10}	C_2
A (sandy, well drained)	0.05	0.02
B	0.08	0.03
C	0.15	0.08
D (clay, poorly drained)	0.25	0.15

$Q_{cap,10}$ is the maximum release for **every storm up to and including the 1% AEP (100-yr) storm**, in every catchment. $Q_{cap,2}$ is the maximum release for the 50% AEP (2-yr) storm. Where a cap is smaller than the discharge of a 50 mm orifice at the corresponding stage, the 50 mm orifice is deemed to comply (Clause 4.5.5.1).

4.14.5 **Storage.** The detention storage V (m³) is the larger of V_{100} and V_2, each the largest over the durations d of Clause 2.5.2 (1 to 72 hours):

$V_{100} = \max_d [\, 10 \times C_v \times P_{100}(d) \times A - 1.8 \times Q_{cap,10} \times d \,]$

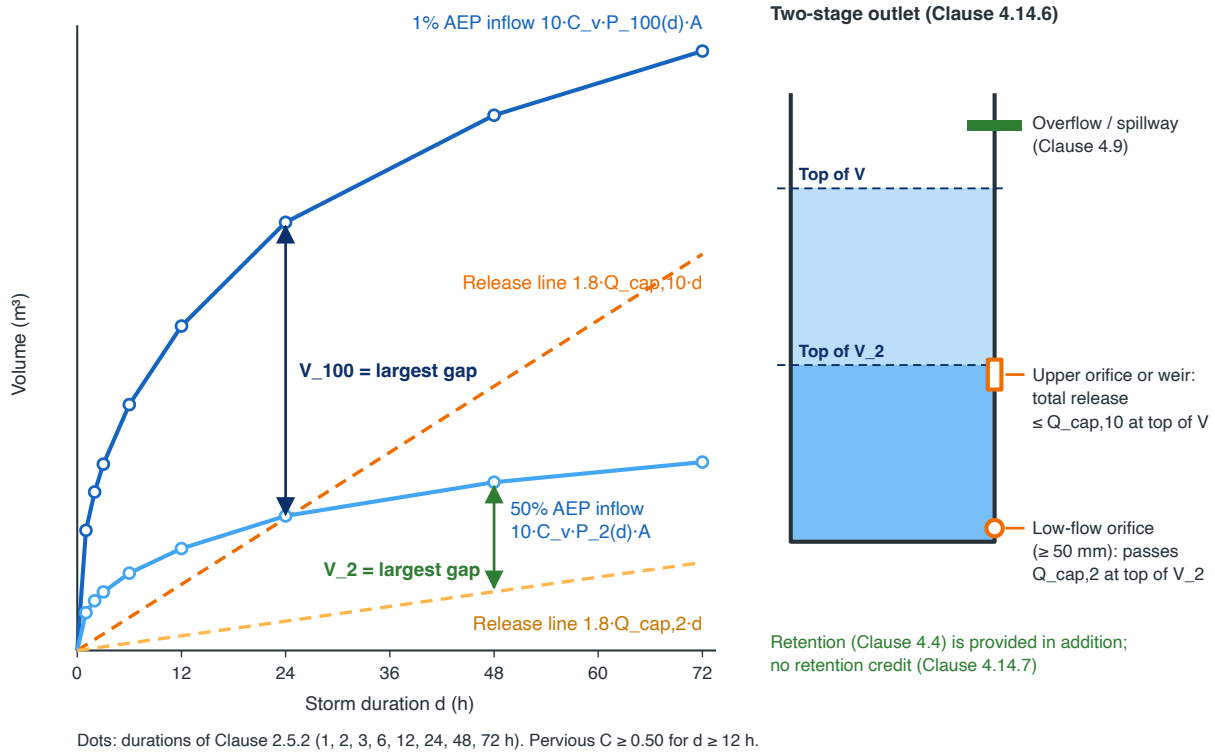
$V_2 = \max_d [\, 10 \times C_v \times P_2(d) \times A - 1.8 \times Q_{cap,2} \times d \,]$

where $P_{100}(d)$ and $P_2(d)$ are the 1% and 50% AEP rainfall depths (mm) for duration d (hours), with the climate factor; and C_v is the post-development volumetric coefficient: the composite C of Table 3.2 (upper half of each range), multiplied by Cf of Table 3.3 for the 1% AEP. For durations of 12 hours or more, C for every pervious surface shall be taken as not less than **0.50**. The factor 1.8 assumes an average release of half the cap over the storm (3.6 × 0.5).

4.14.6 **Outlet.** The outlet shall be a two-stage control: a low-flow orifice that passes $Q_{cap,2}$ when the storage holding V_2 is full, and an upper orifice or weir that limits the total release to $Q_{cap,10}$ at the top of V. The outlet table of Annex 4B may be used once it is published.

4.14.7 **Retention.** The retention volume of Clause 4.4 is provided in addition to V. No retention credit (Clause 4.4.6) is taken under this route.

Fixed-coefficient route for sites of 1 ha or less (Clauses 4.14.3–4.14.7) — schematic, not to scale



Dots: durations of Clause 2.5.2 (1, 2, 3, 6, 12, 24, 48, 72 h). Pervious C ≥ 0.50 for d ≥ 12 h.

$Q_{cap,10} = 2.78 \times C_{10} \times i_{10} \times A$; $Q_{cap,2} = 2.78 \times C_2 \times i_2 \times A$; (L/s; A in ha; i in mm/h)

C_{10}, C_2 from Table 4.3A by soil group; i_{10}, i_2 for a 15-minute duration with the climate factor (Clause 2.8)

$V = \max(V_{100}, V_2)$; $V_T = \max$ over d of $[\, 10 \times C_v \times P_T(d) \times A - 1.8 \times Q_{cap} \times d \,]$ (m^3) ; 1.8 = 3.6 × 0.5 (average release of half the cap)

Figure 4.3 — Fixed-coefficient route for sites of 1 ha or less (Clauses 4.14.3 to 4.14.7): the release caps Q_cap,10 and Q_cap,2 from Table 4.3A; the storage V as the largest gap, over the durations of Clause 2.5.2, between the cumulative inflow 10·C_v·P(d)·A and the release line 1.8·Q_cap·d, for the 1% and 50% AEP storms; and the two-stage outlet that passes Q_cap,2 at the top of V_2 and Q_cap,10 at the top of V. Schematic, not to scale. Original drawing for this Manual, adapted from the rainfall mass-curve (inflow minus outflow) storage concept and the single-coefficient peak cap of the PUB Code of Practice on Surface Water Drainage, 7th ed. (cl. 7.1.5).

Commentary. The fixed-coefficient route follows Singapore, which caps the peak runoff from every development of 0.2 ha or more with one runoff coefficient, C = 0.55, applied to the 10-yr storm (PUB Code of Practice on Surface Water Drainage, 7th ed., cl. 7.1.5, Addendum No. 3, 2025). It is quick to apply and quick to check: the cap needs only the site area, the soil group and two intensities. PUB's 0.55 is not used here, because Singapore's baseline is the existing urban drainage system, while this Manual's baseline is greenfield land (Clause 4.5.1.2). The coefficients of Table 4.3A are set by this Manual from the greenfield curve numbers of Clause 3.3 (CN 39, 61, 74 and 80 for soil groups A to D). They are the ratios of runoff to rainfall that those curve numbers give for 1-hour depths typical of the Jaipur plain, rounded down. They are therefore **provisional**. The State Stormwater Technical Committee shall confirm or revise them against NIH-DHAARA values for each zone when it issues Annex 4B.

The route is deliberately **stricter** than the full method, so that simplicity costs the developer storage rather than costing the people downstream. The 100-yr release is held to about the greenfield 10-yr peak everywhere, which is the flood-sensitive rule of Clause 4.5.3; the storage assumes the outlet releases only half the cap on average; pervious ground is assumed wet in long storms; and no retention credit is taken. A designer who wants a smaller tank can use the full method of Clause 4.6. The storage formula is the rainfall-mass (inflow minus outflow)

method. Clause 3.4.2 otherwise forbids rainfall-based peak methods for storage, because they ignore the shape of the hydrograph; this route is a stated exception because its conservative assumptions cover that error for small sites, and the 24- to 72-hour durations are always checked.

4.15 Safety, fencing and multi-use

4.15.1 **Depth limits for publicly accessible storage.** Where the public has access to a storage area (parks, playfields, open space, school grounds):

- (a) maximum depth in the 10% AEP storm: **0.45 m**;
- (b) maximum depth in the 1% AEP storm: **1.2 m**, except in a fenced zone under 4.15.3;
- (c) side slopes: no steeper than **4H:1V**, with at least a quarter of the perimeter at **6H:1V** or flatter for escape; and
- (d) no vertical drop greater than **0.3 m** within the storage area or at its edge.

4.15.2 **Wet basins.** Permanent pools shall have:

- a safety bench at least 3 m wide, no more than 0.3 m below the normal water level; and
- an emergent planting fringe that deters entry.

4.15.3 **Fencing.** A fence at least **1.2 m** high, of a non-climbable design with a lockable gate, is required around any part of a storage that:

- has a vertical wall or headwall drop greater than **0.6 m**;
- exceeds 1.2 m depth in the 1% AEP storm with slopes steeper than 4H:1V; or
- contains an outlet structure with an opening larger than 300 mm that is not grated.

4.15.4 **Outlets.** Every inlet and outlet opening larger than 300 mm accessible to the public shall be fitted with a grate or rack. The grate shall be designed so that a person pinned against it can escape: low approach velocity, inclined, with a large open area.

4.15.5 **Signs and depth markers.** Every publicly accessible storage shall have signs in Hindi and English stating that the area floods during rain, and a depth marker at the deepest point.

4.15.6 **Confined spaces.** Underground tanks shall have lockable covers. They shall be marked as confined spaces, and the maintenance declaration (Chapter 10) shall state the entry procedure.

4.15.7 **Vector control.** Dry storage shall drain completely (Clause 4.7) and have no low points that pond for more than 72 hours. Wet basins shall meet Clause 4.10.7.

> **Commentary.** The numeric limits in Clause 4.15 have no single direct precedent. They are drawn from common international practice, for example KC APWA 5600 (2006), which required at least a quarter of a dry-pond perimeter at 5:1 or flatter, a 20 ft (6 m) clearance from property lines and a 15 ft (4.6 m) maintenance strip. They are made somewhat stricter here because multi-use storage on open space land and in schools will be used by children during the monsoon. Standing water in dry basins is a mosquito-breeding risk, so complete drainage (Clause 4.15.7) is a public-health requirement, not an amenity.

4.16 Basis: why peak matching alone fails

Commentary. This section has no requirements. It records why this chapter requires release **below** pre-development rates, retention, long-duration checks and a downstream analysis, rather than simple peak matching.

1. **Timing.** Detention lowers a site's peak but stretches its hydrograph (Figure 4.1). Downstream, the stretched releases from many sites overlap with each other and with the main-stem peak. In Denver's study, ten basins each releasing 100% of the historic 100-yr peak produced 106% of the historic peak at the outlet. Only releasing 90% at each site brought it to 97% (UDFCD memo, 2012). A Colorado State University thesis found that location-blind on-site detention "can actually increase peak flows above post-development peaks". An optimisation study found that a downstream pond performed worse than upstream ponds because its outflow synchronised with the main stem (Water 2016, 8(7):290).
2. **Volume.** Detention does not remove volume. In the illustrative example, the post-development 100-yr storm produces about three times the runoff volume of the pre-development 10-yr storm (Clause 2.11). Only retention, or storage that empties to somewhere other than the receiving drain, reduces volume.
3. **Scale.** Kansas City modelling (McEnroe, 2005) found that uniform 3 cfs/ac control reduced Q100 by 36% in a 200-ac watershed. With the same control everywhere, Q100 still rose by 40% at 14 sq mi, and the benefit faded beyond about 1–2 sq mi. The KC committee concluded that "'match existing' can harm streams" (MARC Evolution deck). Georgia makes a ten-percent downstream analysis mandatory for the same reason: "Due to peak flow timing and runoff volume effects, some structural practices fail to reduce discharge peaks to pre-development levels downstream" (GSMM 2016).
4. **Design-storm dependence.** An Australian study of 20 real on-site detention systems found that designs using even ten temporal patterns "cannot reliably produce an OSD system design that will always be effective" under real rainfall (Water Science and Engineering, 2019). This is why Clause 4.6.3 routes the full duration matrix rather than one critical storm.
5. **Closed outfalls.** In Rajasthan, outfalls fail in two ways. At the lake cities and at Kota the outfall is held up by water that is already high: a lake held at its full gauge by its gates, or a river raised by releases from the dams above it. Ana Sagar at Ajmer is kept at 13 ft on its gauge by opening its four escape gates, and the colonies along the escape channel flood when they are opened, as in September 2024 and July 2025 (as reported); at Udaipur the Pichola and Fateh Sagar are joined by a gated channel and both spill to the Ayad (Ahar), which runs to Udai Sagar, and in August 2006 all the lakes were overflowing (as reported). For an outfall to a lake or reservoir this Manual takes the tailwater as the maximum water level, or the full tank level plus the surcharge in the design flood, from WRD or the custodian, and, where neither is published, the full tank level plus 0.5 m, set by this Manual [TBC], and never below the highest recorded level (Chapter 5); the full levels of the Udaipur lakes and of Ana Sagar are known only in feet on gauges whose zero has not been tied to mean sea level, so they are still to be converted to metres [TBC]. On the Chambal, Kota depends on dam operation: on 16 September 2019 the river at Kota City reached 248.68 m, its highest recorded level, against a danger level of 242 m (CWC), with the Kota Barrage reported releasing about 6.5–6.9 lakh cusec; Dholpur downstream has a danger level of 130.79 m and a highest flood level of 145.54 m, set on 23 August 1996 (CWC). No hourly record of how long the Chambal or a city lake stays above a city's outfalls was obtained [TBC]. For a river outfall this Manual uses the highest recorded level at the nearest gauge, with the 10% AEP level not below the danger level, and a closure taken from the record and of at least 72 hours for a flood driven by dam releases unless a study shows otherwise (Chapter 5). In the west and north the outfall does not close; it does not exist. About 60% of the State drains inland (as reported), and at Kawas in Barmer district water stood for months after August 2006 (as reported): there the storage must hold the volume, under Clauses 2.3.6(i) and 4.12.7. A perfectly orificed basin behind a closed outfall simply fills. No release-rate rule can fix that; it is handled by the outfall-closed check of Chapter 5.

The response in this Manual is layered:

- release below pre-development (Clause 4.5);
- retain the frequent storms (Clause 4.4);

- route long SW monsoon storms (Clause 4.6.3);
- prefer regional storage in the talab system (Clause 4.13); and
- check downstream and at the outfall (Chapter 5).

Kansas City's own history shows the price. On a test site, peak matching needed 3.0 ac-ft of storage and the 2011 comprehensive criteria needed 4.9 ac-ft (MARC Evolution deck). Over-detention costs more storage. That is the cost of protecting the catchment rather than only the site boundary.

4.17 Submittal requirements

Every site runoff-control submittal shall include a **Site Runoff Control Report** (Form 4-1) containing:

1. the Design Rainfall Sheet (Form 2-1) and the hydrology inputs (Chapter 3);
2. the evidence for the order of measures under Clause 4.3.1;
3. the RRV computation, infiltration tests, groundwater evidence and drawdown calculation (Clause 4.4);
4. the retention credit computation (Clause 4.4.6);
5. the release-rate criterion applied, standard or flood-sensitive, with the Annex 4A map extract (Clause 4.5);
6. a results table in the format of Clause 4.6.7 for every AEP and duration, with the governing case highlighted;
7. stage–storage and stage–discharge tables and plots, and inflow/outflow hydrographs for the governing cases;
8. the drawdown calculation (Clause 4.7);
9. outlet details, including orifice sizes and levels, trash racks and anti-vortex devices (Clause 4.8);
10. the spillway or overflow calculation, freeboard and hazard classification, and the geotechnical report where required (Clause 4.9);
11. the RWH and detention accounting, with tank sections showing zone levels (Clause 4.11);
12. the design groundwater level and flotation check (Clause 4.12);
13. the downstream and tailwater report (Chapter 5, Form 5-1); and
14. the safety provisions (Clause 4.15) and the draft maintenance declaration (Chapter 10).

Tier B sites using Clause 4.14.2 shall submit Form 4-2 in place of items 6 and 7. Sites using the fixed-coefficient route (Clause 4.14.3) shall submit Form 4-3 in place of items 6 and 7.

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Annexes and forms

Annex / Form	Content
4A	Flood-sensitive catchment boundaries (GIS); shallow-groundwater zone map
4B	Tier B tables: PSD and SSR (Table 4.3), retention credit factor C_R, standard outlet sizes; confirmed fixed release coefficients (Table 4.3A)
4C	Worked example (Tier A) with full routing tables
Form 4-1	Site Runoff Control Report
Form 4-2	Tier B Site Sheet
Form 4-3	Fixed-coefficient Route Sheet (Clauses 4.14.3 to 4.14.7)

CHAPTER 5

Downstream and Tailwater Analysis

5.1 Purpose and scope

5.1.1 This chapter sets two checks that every regulated development and every public drainage project must pass.

- **The downstream analysis** (Clauses 5.3 to 5.5) confirms that the project does not make flooding worse below its outfall.
- **The tailwater analysis** (Clauses 5.6 to 5.13) sets the water level the system discharges into, including tide, storm surge, sea-level rise, river backwater and sand-bar closure. It also requires the system to cope when its outfall is closed.

5.1.2 This chapter applies to:

- (a) every site to which Chapter 4 applies;
- (b) every minor- and major-system drainage project under Chapter 6; and
- (c) every regional detention or tank restoration project under Clause 4.13 and Chapter 7.

5.1.3 Rainfall and joint-occurrence inputs come from Chapter 2, in particular Clauses 2.5.3 and 2.12. Hydrologic methods come from Chapter 3. Site release criteria come from Chapter 4. Hydraulic design of gates, culverts and pumps follows Chapter 9.

5.1.4 **No tidal outfalls in Rajasthan.** Rajasthan is landlocked: it has no coast, no tide and no Coastal Regulation Zone. No outfall in the State discharges to the sea, a tidal creek or an estuary, so the provisions of this chapter that depend on tide, storm surge, sea-level rise or a river mouth do not apply in Rajasthan: Clause 5.7 and Annex 5A, cases J1 to J3 of Table 5.2, the tidal lock windows of Clause 5.10.3, the seawater requirement of Clause 5.11.3(a) (gates and seats shall still be of corrosion-resistant materials), and Clause 5.13. They are kept so that the clause numbers of this Manual match its other State editions. In Rajasthan the receiving water is one of three kinds: none at all, where a site or the catchment it drains to has no defined outfall and ends in a closed depression, as in much of the inland drainage of the west and north (Clause 4.12.7); a lake, sagar or talab, often held at its full level by gates or an escape channel; or a river, reached directly, through a gate in a bank or ghat wall or through a pumping station, whose level is often set by the releases of the dams upstream, together with the drains and canals of WRD and the nalas of a Municipal Corporation, Council or Board, a development authority, an Urban Improvement Trust or RIICO that lead to it, and:

- (a) its tailwater is set by Clauses 5.6 and 5.8, including Clause 5.8.5;
- (b) where Clauses 5.10 to 5.12, Form 5-1 or Chapter 6 refer to the J1 tailwater or the J1 tidal curve, the minor-system tailwater of Clause 5.6.2 or 5.8.5 applies, as a time series where the receiving level varies; where they refer to the J2 tailwater or to HAT + surge + SLA, the major-system tailwater applies: the design-AEP river level of Clause 5.8.4(b), or the major-system tailwater of Clause 5.8.5, whichever is higher at the outfall;
- (c) the outfall-closed check of Clause 5.10 applies where an outfall is closed by a lake, a river or a receiving drain, with the river lock of Clause 5.8.5(b) and the lake closure of Clause 5.8.5(c) in place of the tidal lock windows; and
- (d) where there is no defined outfall, Clause 4.12.7 and Clause 5.8.5(a) apply: the outfall is treated as closed for the whole storm and after it (Clause 5.9.4), and the downstream analysis ends at the storage or at the closed depression that receives it.

Commentary. The drains of Rajasthan's cities fail in places that site design does not see, and in three different ways. About 60% of the State drains inland, to no river and no sea (as reported); there, in the interdunal depressions and the town sites of the Thar, Shekhawati and the canal command, and in the basin of the Sambhar salt lake, water that runs off stays where it collects, and after the Barmer storm of August 2006 (about 577 mm in 3 days against an annual normal of about 277 mm, as reported) Kawas was reported still under water seven months later. In the east and south the drains end in lakes held at their full level by gates or escape channels, or in rivers whose level is set by the dams above them. The lakes of Udaipur form a chain: Pichola and Fateh Sagar are joined by a gated channel and both spill to the Ayad (Ahar), which runs to Udai Sagar (as reported). Ana Sagar at Ajmer is held at its full gauge by opening escape gates, and the escape channel floods the colonies along it (as reported, 2024 and 2025). Jaipur's nalas end in the Dravyavati, which discharges to the Dhund (JDA, Dravyavati EIA), and Jodhpur's in the Jojari. At Kota the Chambal is raised by the releases of Gandhi Sagar, Rana Pratap Sagar, Jawahar Sagar and the Kota Barrage, and in September 2019 the river at Kota City set its highest recorded level, 248.68 m, against a danger level of 242 m (CWC). The outfalls also belong to one body while the drains above them belong to others: the dams, reservoirs and canals are held by WRD, the public tanks and street drains by the Municipality, the land recorded as gair mumkin nala by the Revenue Department, and the drains of new schemes by the development authority, the Urban Improvement Trust or the colony developer, and no rule divides them (Chapter 6, Clause 6.9). No document found during research sets a design level for any lake or river outfall, and the only design return period published for a city channel is the 100-year flood of the Dravyavati (JDA, Dravyavati EIA). A detention basin that meets every release rate in Chapter 4 still fails if the drain below it is already full, if the lake or river it drains to stands above its outfall for days, or if there is nowhere for the water to go. This chapter makes all three failure modes part of the design. Rajasthan has no tidal outfall, so Clause 5.1.4 says which of the chapter's coastal provisions fall away and what takes their place.

5.2 Definitions

Term	Meaning in this Manual
Analysis point	A location on the downstream system where pre- and post-project conditions are compared (Clause 5.3.3).
Contributing catchment	The whole area draining to an analysis point, on and off site.
Major drain	A channel listed as a major drain in the basin plan or Annex 5B, or any river, WRD canal, the Dravyavati (the former Amanishah nala) of Jaipur and the Dhund to which it discharges, the Naharika, Ambabari, Ganda, Jawahar, Brahmapuri and Nagtalai nalas and the other nalas of Jaipur, the Jojari and the Bandi and the Bhairav, RTO and other nalas of Jodhpur that drain to the Jojari, the Ayad (Ahar) at Udaipur, the escape channel of Ana Sagar at Ajmer, the nalas of Kota that drain to the Chambal, any drain or canal of WRD, including the Indira Gandhi Canal (IGNP) and its distributaries and escapes, any drain maintained by a Municipal Corporation, a Municipal Council, a Municipal Board, a development authority, an Urban Improvement Trust or RIICO with an internal width of 1.0 m or more, any irrigation canal that receives storm water, or a tidal creek.
Chart datum (CD)	The datum of the published tide tables and nautical charts, to which tidal heights are referred.
Mean sea level (MSL)	Average sea level over a long period at a tide gauge.
MHWS	Mean high water springs: the average of high waters at spring tides.
HAT	Highest astronomical tide: the highest level predicted under average meteorological conditions over a full tidal cycle (18.6 years).
Storm surge	The rise in sea level above the astronomical tide caused by wind and low pressure, mainly during cyclones.

Term	Meaning in this Manual
Still-water level	Astronomical tide plus surge, excluding individual waves.
Sea-level allowance (SLA)	The allowance added to present-day tidal levels for sea-level rise over the design life (Clause 5.7.4).
Tailwater	The water level at the downstream end of a drain, outlet or storage.
Tide-lock	The condition in which the tailwater is at or above the upstream water level, so a gravity outfall cannot discharge.
Lock window	A period during which the outfall-closed check of Clause 5.10 sets gravity discharge to zero.
Sand bar	A bar of beach sand that partly or fully closes a river mouth or creek inlet.
Project datum	The levelling datum used on the project drawings. It must be tied to a Survey of India benchmark (Clause 5.7.2).

5.3 Extent of the downstream analysis

5.3.1 The downstream analysis shall start at each site or project outfall. It shall continue downstream to the **first** of:

- (a) the point at which the project area is **10% or less** of the contributing catchment;
- (b) the next **tank, talab** or other waterbody with a surplus weir or controlled outlet; or
- (c) the next **major drain**, or the sea.

The end point itself shall be analysed (Figure 5.1).

5.3.2 Where the analysis ends at a tank or talab under 5.3.1(b), it shall report:

- the change in the tank's maximum water level; and
- the change in surplus-weir discharge, for the AEPs and durations of Clause 5.4.3.

If the maximum water level rises, the analysis shall continue below the surplus weir to the next end point.

5.3.3 Analysis points shall be set at least at:

- (a) each site outfall;
- (b) each confluence with a drain or channel whose contributing catchment is at least half that of the receiving drain at that point;
- (c) each culvert, bridge or road crossing;
- (d) each location recorded as flood-prone by the local body, JMC, RSDMA or WRD; and
- (e) each building or road segment lying within the 1% AEP flood extent along the route. Representative points may be used where buildings are closely spaced.

5.3.4 **Small sites.** For sites of less than **0.5 ha**, the Authority may accept a simplified downstream statement (Form 5-2) in place of the full analysis, where all of the following hold:

- the receiving public drain has documented capacity for its minor-system design flow (Chapter 6);
- no flood-prone location is recorded within 500 m downstream; and
- the site does not drain to a tidal or backwater-affected outfall.

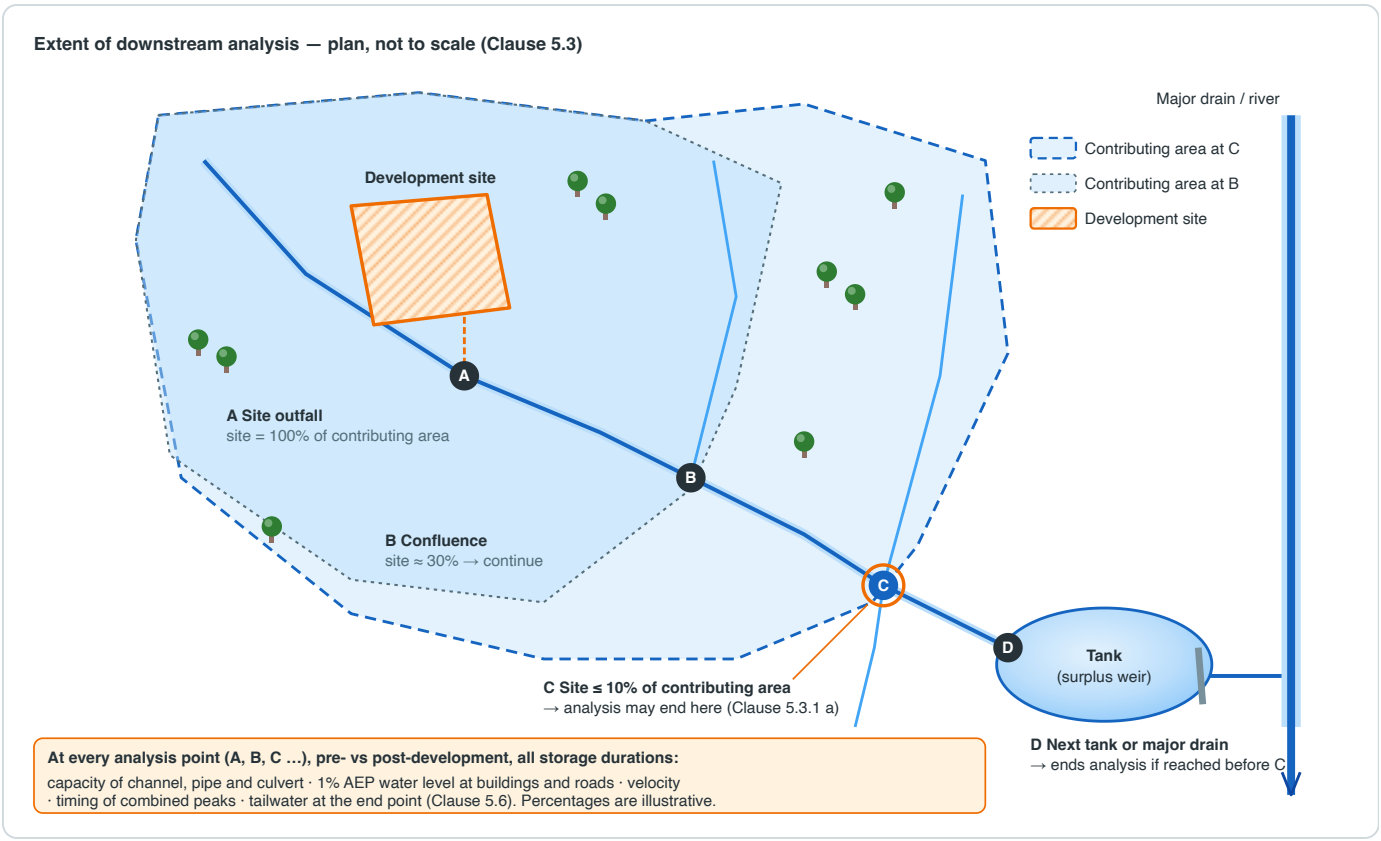

Figure 5.1 — Extent of downstream analysis: analysis points A–D, the contributing area at each point, the 10% point, and the next talab or major drain as an alternative end point. Schematic; percentages are illustrative. Original drawing for this Manual, adapted from the ten-percent rule in the Georgia Stormwater Management Manual (2016, Vol. 2 §3.1.9) and KC APWA Section 5600 (2006, 5601.5).

> Commentary. The 10% rule has established precedent. KC APWA 5600 (2006) required the downstream system to be analysed "to the point the development's land mass is less than 10% of the total watershed". The Georgia manual makes the ten-percent analysis a mandatory standard (GSMM 2016, Standard #8). The tank or major-drain end point has no direct precedent; this Manual adds it for Rajasthan. In Jaipur, where the Dravyavati (the former Amanishah nala) collects the nalas of the walled city, Sanganer and the newer colonies along about 47.5 km before it discharges to the Dhund (JDA, Dravyavati EIA), in Udaipur, where the lakes form a chain from Pichola and Fateh Sagar through the Ayad (Ahar) to Udai Sagar (as reported), and in Jodhpur, where the city's nalas run south and south-east to the Jojari, a tributary of the Luni (NIH, 2025), the 10% point can lie many kilometres downstream, across several tanks. A tank with a working surplus weir changes the hydrograph completely, so the analysis is better ended there and the tank level reported. Clause 5.3.2 prevents that end point from hiding a rise in the tank level. The small-site statement (5.3.4) and its 500 m distance have no direct precedent and are set by this Manual.

5.4 What the analysis must check

5.4.1 **Scenarios.** Each analysis shall compare:

- (a) **Existing**: the present downstream system and present land use of the whole contributing catchment, with the project site at its pre-project state; and
- (b) **With project**: the same, with the project and all its controls (Chapter 4) in place.

Where the Authority's basin plan defines future land use, the Authority may also require:

- (c) **Future**: the catchment fully developed under the plan, all to Chapter 4 standards, with and without the project.

5.4.2 **Quantities to be checked at every analysis point:**

- (a) **Capacity**: peak flow against the capacity of every channel, pipe, culvert and crossing, for the minor-system AEP of that element (Chapter 6) and for 1% AEP;
- (b) **Flood levels**: 1% AEP maximum water level at buildings (at the lowest opening) and on roads (at the crown and at the deepest point);
- (c) **Velocities**: peak velocity for 50%, 10% and 1% AEP;
- (d) **Timing of combined peaks**: the hydrograph at each confluence, showing the time to peak of the project outflow and of the receiving drain; and
- (e) **Duration of inundation**: on roads and at buildings, the time above the Chapter 6 depth limits.

5.4.3 **Storms.** The analysis shall use:

- 50%, 10% and 1% AEP;
- the duration set of Clause 2.5.2, at least the durations that give the highest level at each analysis point (these will usually be longer than at the site); and
- the 24-, 48- and 72-hour storms in every case.

The AMC rule of Clause 2.11.4 applies. Areal reduction follows Clause 2.7, applied to the contributing catchment at each analysis point and never to the site storage.

5.4.4 **Method.** The analysis shall:

- use a hydrograph method that combines hydrographs at confluences (SWMM, HEC-HMS, or an equivalent);
- include a hydraulic model with backwater (SWMM dynamic wave, HEC-RAS, or equivalent) wherever tailwater or backwater affects any analysis point; and
- not use the Rational Method at any analysis point, because it cannot represent timing.

Off-site areas shall be modelled at their present land use. Upstream detention shall be included only where it is built, maintained and documented.

5.4.5 **Tailwater.** The downstream end of the model shall use the tailwater of Clauses 5.6 to 5.9 and the sand-bar condition of Clause 5.13 where applicable.

> **Commentary.** Clause 5.4.2(d) exists because detention changes when the site's water arrives, not only how much arrives (Clause 4.16). A Colorado State University thesis and a *Water* (2016) optimisation study both found that delayed site releases can coincide with the main-stem peak and raise it. Georgia's manual states the result directly: some structural practices "fail to reduce discharge peaks to pre-development levels downstream" because of "peak flow timing and runoff volume effects" (GSMM 2016). The duration-of-inundation check (5.4.2(e)) matters in the lake- and river-controlled cities of Rajasthan and in its closed depressions: in September 2019 the Kota Barrage was reported releasing about 6.5 to 6.9 lakh cusec through 18 or all 19 of its gates, and low-lying Nayapura, Balita and Gavndi in Kota were evacuated (as reported); in July 2025 Ana Sagar was reported at 15 ft 11 in on its gauge against a full level of 13 ft, its escape gates were opened and JLN Hospital and the Chaupati in Ajmer were flooded (as reported); and after the Barmer storm of August 2006 Kawas was reported still under 3 to 4 ft of water seven months later, because the low ground it stands in has no outfall (as reported). Detention that prolongs releases can lengthen that time even when it lowers the peak.

5.5 Acceptance criteria

5.5.1 The project is acceptable if, at every analysis point and for every AEP and duration of Clause 5.4.3, comparing "with project" to "existing":

- (a) the 1% AEP maximum water level does not rise by more than **10 mm** at any habitable building, at any building's lowest opening, or on any road carriageway;
- (b) no building that is not flooded in the existing case is flooded with the project, and no building or road that meets the Chapter 6 freeboard or depth limits in the existing case fails them;
- (c) peak flow does not exceed the existing peak at the minor-system AEP of each element, or at 1% AEP;
- (d) peak velocity in lined channels stays within the permissible velocity for the lining (Chapter 6: 3.0 m/s maximum); and
- (e) in unlined or natural channels, peak velocity for 50% and 10% AEP does not increase by more than **10%**, unless protection is provided under Chapter 9.

5.5.2 The duration of inundation under 5.4.2(e) shall be reported. The Authority may refuse a project that increases the duration of road closure on an arterial or emergency route.

5.5.3 **Where the criteria are not met**, the project shall do one or more of the following:

- (a) reduce release rates or increase storage (Chapter 4);
- (b) build downstream improvements, with the consent of the owner of the downstream system. These shall not transfer the problem further downstream, and shall be re-analysed under this chapter;
- (c) contribute to a regional facility under Clause 4.13; or
- (d) under Clause 5.5.4, change the release strategy.

5.5.4 **Timing exception.** Where the analysis shows that detention raises downstream levels because of timing, the Authority may vary the site release-rate criteria of Clause 4.5. This applies only where the site discharges within the lower tenth of the contributing catchment, directly to a major drain, tidal creek or the sea, and only on the following conditions:

- (a) the varied strategy meets 5.5.1;
- (b) the retention requirement (Clause 4.4) and WQv treatment (Chapter 8) are met in full; and
- (c) the outfall-closed check (Clause 5.10) is met.

> **Commentary.** The 10 mm tolerance (5.5.1(a)) has no direct precedent. It is meant to be at or below the numerical precision of a typical one-dimensional model, so that "no increase" can be tested without arguing over rounding. The 10% velocity tolerance is likewise set by this Manual. The timing exception in 5.5.4 follows the Georgia manual, where the downstream analysis can show "that peak controls are not needed" and allow them to be waived (GSMM 2016, Standard #8). It is limited here to sites low in the catchment, which is where synchronisation with the main-stem peak is most likely (*Water* 2016, 8(7):290). It is not available above that, because the evidence on scale (Clause 4.16) shows that early release from many upstream sites raises peaks.

5.6 Tailwater: general and non-tidal outfalls

5.6.1 Every drain, outlet and storage shall be designed against a stated tailwater. A free outfall shall be assumed only where the outlet invert is above the maximum receiving water level for the case being checked.

5.6.2 **Minor-system tailwater, non-tidal.** The tailwater is the receiving system's water level at the time of the minor-system peak, from the downstream model. Where no model exists, use:

- for a receiving pipe, its obvert; or
- for a receiving open drain, its full-bank level less freeboard (Chapter 6).

5.6.3 **Major-system tailwater, non-tidal.** The tailwater is the receiving system's 1% AEP water level, unless Clause 5.8 allows a coincident lower level.

5.6.4 **Tidal and backwater outfalls.** Clauses 5.7 to 5.13 apply in addition.

5.6.5 **Storage elements.** Detention, tanks and pumped sumps shall be routed with a time-varying tailwater (Clause 4.6.6), not a constant level, wherever the tailwater varies with tide or with the receiving system's hydrograph.

5.7 Tidal tailwater: datums, surge and sea-level allowance

5.7.1 **Design tailwater levels.** For outfalls to the sea, tidal creeks, estuaries, backwaters and tidal reaches of rivers and canals:

Table 5.1 — Design tailwater levels for tidal outfalls

Design case	Tailwater
Minor-system design (Chapter 6)	**MHWS + SLA**
Major-system design and storage design	**HAT + surge + SLA**, with the surge term defined in Clause 5.7.3
Joint case (Clause 2.12(b))	1% AEP still-water level + SLA

The SLA is **+0.3 m minimum** (Clause 5.7.4). The cases to be run are listed in Clause 5.9.

5.7.2 **Sources and datums.**

- (a) **Tidal levels.** MHWS, HAT and MSL shall be taken from the current edition of the Indian tide tables published by the National Hydrographic Office (NHO) or by the Survey of India, for the nearest standard or secondary port, or from the port authority's published tidal levels. The edition and port shall be stated.
- (b) **Datum conversion.** Tide-table heights are referred to chart datum. They shall be converted to the project datum through a documented connection between chart datum, the tide gauge zero and a Survey of India benchmark. The offset and its source shall be stated on Form 5-1.
- (c) **Estuaries, creeks and canals.** For outfalls inside estuaries, creeks, backwaters or tidal canals (for example the estuaries of the coastal States; there is none in Rajasthan, Clause 5.1.4), tidal levels may differ from the open coast. Open-coast levels shall be used unless measured levels over at least one spring–neap cycle, or a calibrated hydrodynamic model, justify a different value. No reduction below open-coast levels shall be taken without such evidence.
- (d) **Interim.** Until Annex 5A is published, the designer shall obtain the values directly from the sources in (a) and record them.

5.7.3 **Storm surge.**

- (a) **Major-system and storage design.** The surge term in "HAT + surge" is the **10% AEP (10-yr) storm surge** for the coastal segment, given in Annex 5A. The 1% AEP surge is used only in the joint case of Clause 2.12(b), with the 10-yr 48-hour storm. That keeps the two cases symmetric, so that a rare rainfall is never paired with a rare surge.
- (b) **Joint case.** The 1% AEP still-water level for Clause 2.12(b) is taken from Annex 5A.
- (c) Until Annex 5A is published, both values shall be taken from a site-specific study using INCOIS, IMD or NCCR surge hindcasts or return-level analyses. The study shall state its source, method and record length.

- (d) Wave set-up shall be added where the outfall faces the open sea without a protected entrance.

5.7.4 **Sea-level allowance.** The SLA shall be:

- (a) **+0.3 m** minimum for every element;
- (b) greater than 0.3 m where the State, JDA or the Authority adopts a higher projection for the planning area; and
- (c) assessed for the design life of the element. For elements with a design life of more than 50 years, the designer shall report the effect of a sea-level rise of twice the SLA as a sensitivity run.

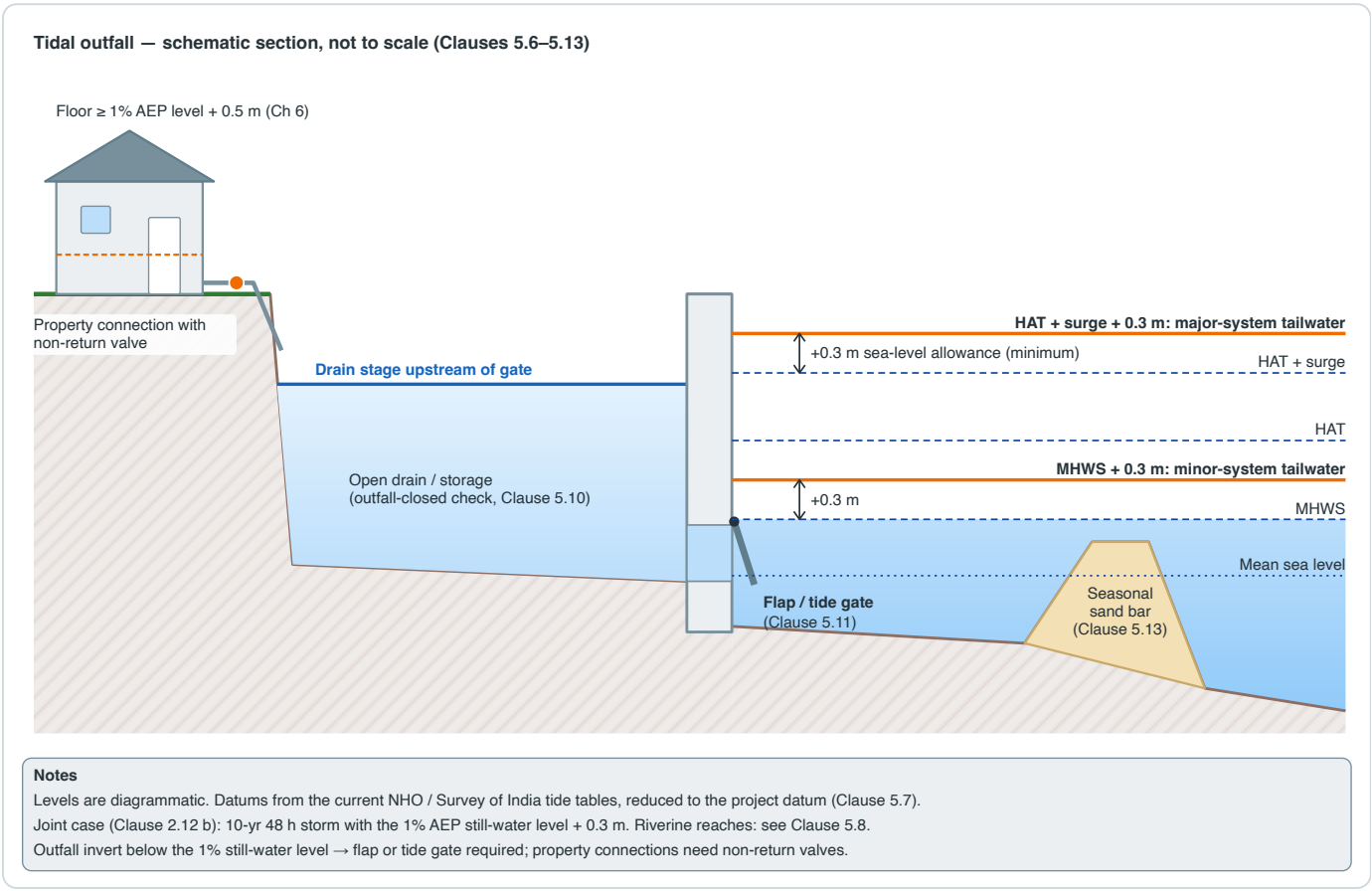

Figure 5.2 — Tidal outfall: flap gate, property non-return valve, and the design tailwater levels (MHWS + 0.3 m for the minor system; HAT + surge + 0.3 m for the major system), with a seasonal sand bar at the mouth. Schematic, not to scale. Original drawing for this Manual, adapted from the tidal tailwater table in MoHUA/CPHEEO Manual on Storm Water Drainage Systems (2019), Part A, Table 6.2.

Commentary. CPHEEO (2019) Table 6.2 sets the design tailwater for coastal outfalls as:

- MHWN to MHWS for a minor storm (more frequent than 1 in 5 years);
- MHWS to HAT for a major storm; and
- "Effect of climate change: additional 0.3 m".

CPHEEO also says the joint probability of storm, tide and surge "should" be considered, with the state maritime board consulted. This Manual takes the upper end of each CPHEEO range, adds surge for the major system, and makes the joint case explicit (Clause 2.12). CPHEEO does not require surge to be added; this Manual adds it because the surge records of the coastal States showed why it is needed there; Rajasthan has no coast, and the surge term does not arise in the State.

Indian tide tables have been published by the Survey of India since the nineteenth century (Survey of India, Tidal Predictions). Current Indian tidal predictions also appear in the NHO's tide tables. One port document describes the current edition as covering 95 Indian ports, based on NHO observations and on data from civil ports, NIO and

> INCOIS (Adani Ports, Dahej tide table 2025, citing NHO INP-12). INCOIS runs coastal tide gauges and issues storm-surge and swell-surge warnings. None of these is used for design in Rajasthan, which has no coast, and Annex 5A is not prepared for the State (Clause 5.1.4).

5.8 Riverine backwater

5.8.1 **Where it applies.** Outfalls to rivers and canals whose water level in a storm can exceed the outfall invert shall be designed with riverine backwater. This includes:

- the **Chambal** at **Kota** below the **Gandhi Sagar**, **Rana Pratap Sagar** and **Jawahar Sagar** dams and the **Kota Barrage**, and the nalas of the city that end in it (Clauses 5.8.3 and 5.8.5(b) and (d));
- the **Chambal** at **Dholpur** (Clause 5.8.5(b) and (d));
- the **Banas** at **Tonk** below the **Bisalpur** dam, the **Luni** at **Balotra**, the **West Banas** at **Abu Road** and the **Gambhiri** at **Chittorgarh** (Clause 5.8.5(b));
- the **Dravyavati** (the former Amanishah nala) of **Jaipur** and the **Dhund** below it, the **Jojari** and the **Bandi** at **Jodhpur**, the **Ayad** (Ahar) at **Udaipur**, and the **Ghaggar** at **Hanumangarh** and **Sri Ganganagar**, for which no gauge level was found (Clause 5.8.5(b));
- **Pichola**, **Swaroop Sagar**, **Fateh Sagar** and **Udai Sagar** at **Udaipur**, **Ana Sagar** and its escape channel at **Ajmer**, **Kailana** and **Takhat Sagar** at **Jodhpur**, **Man Sagar** (Jal Mahal) at **Jaipur**, and the pond of the **Kota Barrage**, with every nala that ends in them (Clause 5.8.5(c));
- any drain or canal of **WRD**, the **Indira Gandhi Canal** (IGNP) and its distributaries and escapes, and any irrigation or lift canal that receives storm water (Clause 5.8.5(f)); and
- elsewhere: any river or WRD channel listed in Annex 5B.

5.8.2 **River levels.** River water levels shall be taken from:

- (a) WRD design flood levels or recorded highest flood levels for the reach, where published; or
- (b) a hydraulic model (HEC-RAS or equivalent) of the river reach. The model shall use:
  - the river design flood from a hydrograph method (Chapter 3), with continuous simulation where Chapter 3 requires it;
  - the tidal boundary of Clause 5.7 at the mouth; and
  - the sand-bar condition of Clause 5.13.

5.8.3 **Reservoir and tank releases.** Where a reservoir or tank upstream can release to the river (for example the Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar dams and the Kota Barrage on the Chambal above Kota and Dholpur, the Bisalpur dam on the Banas above Tonk, the Panchana dam in Karauli, the escape gates of Ana Sagar at Ajmer, and the gated links between the lakes of Udaipur), the river level shall include the release given by the reservoir's operating rule for the storm being checked. Where there is no published rule, it shall include the largest recorded release.

5.8.4 **Coincidence of site storm and river flood.** Unless a joint-probability study is accepted by the Authority, the more severe of the following governs:

- (a) the site design storm (AEP as required), with the river at its **10% AEP (10-yr)** level; and
- (b) the site **10% AEP** storm, with the river at its design-AEP level (1% AEP for the major system).

The two storms in each pair shall have the same duration and timing where they are generated by the same rainfall event.

5.8.5 **Catchments with no outfall, river-locked outfalls, lake outfalls and escape gates, rivers driven by dam releases, the Chambal at Kota and Dholpur, and discharges to WRD channels and canals.**

- (a) **Catchments with no outfall.** Where a site, or the catchment it drains to, has no defined outfall (Clause 4.12.7), as in the interdunal depressions and the town sites of the Thar, Shekhawati and the canal command, and in the Sambhar basin:
    - there is no receiving water and no tailwater. The outfall is treated as closed for the whole storm and after it (Clause 5.9.4): the storage shall hold the 72-hour design volume of Clause 4.12.7(a) below the level of its overflow, and shall be emptied only by infiltration, evaporation or reuse within the time of Clause 4.12.7(c), with no gravity or pumped discharge credited to a drain, nala or road;
    - where the site drains to a public basin or to a closed depression that also receives other land, the downstream analysis of Clauses 5.3 to 5.5 shall end at that basin or depression, and shall report its maximum water level in the 1% AEP 72-hour storm, with the whole area that drains to it at its present land use, with and without the project; Clause 5.5.1 applies at every building, road and plot around it. The basin or depression shall start the storm at the level that the 10% AEP 72-hour storm leaves in it 7 days after that storm ends, or higher where its flood marks or the records of the local body or the Collector show it (set by this Manual);
    - the overflow path of Clause 4.12.7(d) shall be traced to where it ends, with its depth and velocity on every road and plot it crosses, within the limits of Table 6.3; it shall not end on a neighbour's land or in another catchment (Clause 4.12.7(e)), and a pump or a pipe that moves the water onto a road, a neighbour's land or another catchment is not an outfall; and
    - where the depression is a lake or a wetland, such as Sambhar Lake (a Ramsar site), item (c) also applies, and no storm water shall be discharged to it without the consents of that item.
- (b) **River-locked outfalls.** For an outfall to a river directly, through a gate in a bank, ghat wall or embankment or through a pumping station, or into a drain that itself discharges in one of those ways, the designer shall identify the body that operates each gate and pumping station, and obtain the sill of each gate, the crest of the bank or wall, the installed pumping capacity and the operating levels, including the river level at which each gate is closed. Every level shall state its datum and its connection to the gauge datum of the nearest CWC or WRD gauge.
    - **Design river level.** The river level of Clause 5.8.2 at the outfall shall be, for the major-system cases (Clause 5.8.4(b)), the **1% AEP river level at the outfall**: the 100-year level of a flood-frequency study or floodplain delineation that gives a level at the outfall, or a level from a hydraulic model under Clause 5.8.2(b), with the dam releases of item (d). The level shall in no case be less than the **highest recorded level** at the nearest CWC or WRD gauge on the same river, transferred to the outfall. The highest levels found during research (Table 5B.1), from the CWC bulletins of September 2019 and a 2022 copy of the CWC site list, none read in a CWC site sheet [TBC], are: the Chambal at Kota City **248.68 m** (16 September 2019) and at Dholpur **145.54 m** (23 August 1996; another value, 142.55 m, is not supported by the CWC bulletins read), the Banas at Tonk **262.05 m** (9 September 1973), the Luni at Balotra **108.755 m** (18 July 1979), the West Banas at Abu Road **265.4 m** (31 August 1973) and the Gambhiri at Chittorgarh **409.24 m** (24 July 1992). Where a later flood has exceeded the listed level, the later level governs. The recorded level shall be transferred along the river with the water-surface slope of the flood that set it, from the CWC and WRD gauge records, or from the model. Until either is available, the recorded level of the nearest gauge upstream applies unchanged at the outfall, except that where the outfall lies between two gauges on the same river, with no tributary joining between them, the level may be interpolated linearly by river distance between the highest recorded levels of the two gauges (set by this Manual). The Kota City gauge applies to the Chambal below the Kota Barrage; an outfall to the pond above the barrage takes the pond level of item (c), and the position of the gauge relative to each outfall is to be confirmed with CWC [TBC]. **No danger level or highest flood level was found for the Dravyavati, the Jojari or the Bandi, the Ayad at Udaipur, the Ghaggar at Hanumangarh and Sri Ganganagar, or any river in the State's closed basins** [TBC]. The Dravyavati was designed to pass the 100-year flood, but neither its design discharge nor its design water levels were found (JDA, Dravyavati EIA) [TBC]. On such a reach, and for an outfall upstream of every gauge on its reach, the river level shall be the higher of the level from a model under Clause 5.8.2(b), or JDA's design water-surface profile of the 100-year flood where JDA provides it for the Dravyavati, and the highest

flood level surveyed at the outfall from flood marks and from the records of the local body, WRD or the Collector, with its source stated; an outfall shall not be designed on such a reach without one of them (set by this Manual). For the cases with the river at its 10% AEP level (Clause 5.8.4(a)), the level shall be taken from the same model or a frequency analysis of the gauge record, and not less than the **danger level** at the nearest gauge, transferred in the same way: **242 m** at Kota City (240 m in the CWC bulletin of 2019; 242 m from 2022), **130.79 m** at Dholpur (129.79 m in 2019), **262.8 m** at Tonk, **259 m** at Abu Road and **407.9 m** at Chittorgarh (all set by this Manual, from CWC [TBC]). Where the danger level is higher than the highest recorded level, as at Tonk, the design river level of this item shall be not less than the danger level (set by this Manual). Where no danger level has been found, as at Balotra, the 10% AEP case shall use the design river level of this item until a frequency analysis is accepted (set by this Manual). The datum of every level is to be confirmed for each gauge [TBC].
    - **Tailwater.** The tailwater at the outfall shall be the higher of that river level beyond the gate, bank or wall, and the maximum level in the drain behind it, computed by routing the drain as a closed storage for as long as the river stands above the level behind it, with the inflow of the whole catchment that drains to it, its storage as surveyed in its present condition, net of silt, sand, encroachment and vegetation, and an outflow of no more than the pumping capacity that the operator confirms in writing is available in a storm, and in no case more than the installed capacity of the permanent pumps less the largest pump (set by this Manual), with gravity discharge through the gate only while the river is lower than the level behind it. Pumps shall deliver against the design river level of this item, and every pump, panel and control shall remain operable with the river at that level (Clause 5.12.5).
    - **River lock.** Portable dewatering pumps brought in for an event, and capacity that has been sanctioned or proposed but not commissioned, shall not be counted. The outfall-closed check of Clause 5.10 applies with a single lock that lasts for as long as the river stays above the outfall invert, or above the level at which its gate is closed if that is lower, taken from the river model or from the stage record of the nearest CWC or WRD gauge in the flood that set the highest recorded level (2019 at Kota City; 1996 at Dholpur; 1973 at Tonk and Abu Road; 1979 at Balotra; 1992 at Chittorgarh) or in a comparable flood, with the dam releases of item (d), and **not less than 72 hours**, covering the whole of the 48- and 72-hour storms of Clause 5.10.2, so that storage and pumping handle the full storm volume (Clause 5.9.4) and the drawdown of Clause 5.10.5 is met by pumping until the lock ends (set by this Manual). A shorter lock may be used only where the outfall invert is above the 1% AEP river level of this item, or where a gauge analysis under Clause 5.10.6, including the releases of the dams above, shows it and the Authority approves it. Floor levels and pumped outfalls behind a gate, bank, ghat wall or embankment shall also be checked for the failure of the gate and for a breach of the bank or wall, with the land and drains behind it filled to the river level beyond it.
- (c) **Lake outfalls and escape gates.** For an outfall to a lake, sagar or talab, directly or through a nala that ends in it, such as Pichola, Swaroop Sagar, Fateh Sagar and Udai Sagar at Udaipur, Ana Sagar at Ajmer, Kailana and Takhat Sagar at Jodhpur, Man Sagar (Jal Mahal) at Jaipur, and the pond of the Kota Barrage:
    - **Consent.** Storm water shall not be discharged to a lake without the written consent of its custodian, the body that holds and operates it: WRD for its reservoirs and the Kota Barrage, the Municipality for a tank vested in it under s.68 of the Rajasthan Municipalities Act 2009, or another custodian the State names (the custodian of each Udaipur lake, of Ana Sagar and its escape gates, and of Kailana and Takhat Sagar was not confirmed during research [TBC]). Where the lake is a lake under the Rajasthan Lakes (Protection and Development) Authority Act 2015, any permission that the Lakes Development Authority requires within the lake's boundaries or protected area shall also be obtained; where it is a Ramsar site (Sambhar, Keoladeo, Menar or Khichan) or a notified wetland, any permission that the State Wetland Authority requires shall be obtained, and the interim directions of the High Court on wetlands and their catchments (order of 1 June 2026) apply (Chapter 7). Kailana and Takhat Sagar are fed by the Rajiv Gandhi Lift Canal (NIH, 2025), and an outfall to either needs the custodian's written consent to the quality of the water as well as its volume. An outfall that carries dry-weather flow is dealt with under Clause 8.9.
    - **Design lake level.** The tailwater for the major-system and storage cases shall be the lake's **maximum water level (MWL)** as WRD or the custodian publishes it, or, where only the full tank level (FTL) is published, **FTL plus the surcharge in the lake's design flood**, computed from the rating of its spillway, weir, escape channel

and gates with the gates operated only as the custodian's written rule provides. Where neither the MWL nor the surcharge has been published, the tailwater is **FTL + 0.5 m** (set by this Manual) [TBC]. In every case it shall be not less than the highest level recorded at the lake (set by this Manual). The minor-system tailwater is the FTL, or the level at which the custodian's rule opens the gates if that is higher. The project's discharge shall be included in the lake level (Clauses 5.3.2 and 5.12.3).

  - **Levels known only as gauge readings.** The full levels of the Udaipur lakes and of Ana Sagar are known only as readings on each lake's own gauge, in feet above a gauge zero whose level was not found: Pichola 11 ft, Fateh Sagar 13 ft (14 ft in another report), Udai Sagar 24 ft and Ana Sagar 13 ft, with readings of up to 15 ft 11 in reported at Ana Sagar before its escape gates were opened in July 2025 (as reported). Their FTL in metres is therefore [TBC]. For an outfall to such a lake, the designer shall tie the gauge zero to the project datum and a Survey of India benchmark by levelling, with the custodian's confirmation of the full gauge reading and of the highest reading on record, and state the tie on Form 5-1; no outfall to such a lake shall be designed without that tie (set by this Manual). Where two full readings are reported, the higher applies until the custodian confirms the level (Fateh Sagar 14 ft). At Ana Sagar the highest reading on record (15 ft 11 in, as reported) is above FTL + 0.5 m, so it governs until a surcharge is published.
  - **Levels published in metres.** Kailana has an FRL of **273.7 m** and Takhat Sagar of **269.75 m** above MSL (NIH, 2025), so their lake tailwater is **274.2 m** and **270.25 m** where no MWL is published. The Kota Barrage pond has an FRL of **260.3 m** and an MWL of 260.9 m or 261.2 m in two CWC listings; **261.2 m** applies until WRD confirms it [TBC]. No FTL was found for Man Sagar, Swaroop Sagar or Ramgarh [TBC].
  - **The Udaipur chain.** Each lake of the chain shall be routed with the outflow of the lakes above it in the same storm: Bada Madar to Fateh Sagar, Pichola and Fateh Sagar to the Ayad, and the Ayad to Udai Sagar, with the gate between Pichola and Fateh Sagar closed once Fateh Sagar reaches 11 ft on its gauge, as reported, unless the custodian's written rule says otherwise (set by this Manual).
  - **Closed outfall.** Where the outfall invert is below the design lake level of this item, the outfall shall be treated as closed for the whole storm (Clause 5.9.4), with storage and pumping handling the full storm volume, unless the custodian's stage record shows the lake below the invert at the start of comparable storms and the Authority accepts it. The lake starts every design storm at FTL, or at its full gauge reading (Clause 7.7.3). No lowering of the lake before a storm and no early or additional gate opening shall be assumed unless the custodian's written operating rule and records show it.
  - **Below the gates.** An outfall to the channel below a lake's gates, weir or escape, such as the escape channel of Ana Sagar, the Ayad below Pichola and Fateh Sagar, and the Chambal below the Kota Barrage, shall take the river or channel level of item (b) with the release of Clause 5.8.3 from the gates above it, at the largest gate opening on record as the custodian states it (as reported: the Ana Sagar escape gates opened 30 inches in July 2025; 18 or all 19 gates of the Kota Barrage in September 2019), coincident with the design storm on the city under item (d). Floor levels and pumped outfalls below a dam, gated lake or escape shall also be checked for the release that results from a gate failing open.

- (d) **Rivers driven by dam releases.** For an outfall to a river below a dam or a gated lake, such as the Chambal at Kota and Dholpur below the Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar dams and the Kota Barrage, the Banas at Tonk below the Bisalpur dam, and the escape channel of Ana Sagar:
  - in addition to the cases of Clause 5.8.4, the site design storm (each AEP required) shall be run with the river at the level that results from the largest recorded release of the dams above, with the flow of the catchment below them as it occurred in the same event (set by this Manual), until WRD publishes an operating rule [TBC]. As reported, the Kota Barrage released between 4.42 lakh cusec (CWC, 14 September 2019) and 7.9 lakh cusec (about 22,400 m³/s) in September 2019; the higher value applies until WRD gives the record (set by this Manual). The largest recorded release of each dam shall be obtained from WRD and stated [TBC];
  - the river level shall not be reduced on the ground that the flood comes from rain that falls outside the city or outside the State, or that the site storm is small, and the release shall be placed before, during and after the site storm;
  - an outfall in Kota to the Chambal below the barrage shall take the level of item (b), not less than 248.68 m at the Kota City gauge transferred to the outfall, with the releases of all four dams included; and

    - an outfall in Dholpur shall take the level of item (b), not less than 145.54 m at the Dholpur gauge transferred to the outfall.
- (e) **WRD consent; the High Flood Line; court lines.** No outfall structure, gate, pumping station or drain shall be built in the bed, bank or floodplain of a river, or of a reservoir or canal of WRD, without the consent of WRD; the procedure for that consent was not found during research [TBC].
    - **The State's High Flood Line.** The Supreme Court has directed the State to determine and demarcate the High Flood Line and an ecological buffer zone for all the river systems in the State and, until that is done, to grant no fresh permissions facilitating industrial, commercial or residential development within the identified river corridors (*In Re: 2 Million Lives at Risk, Contamination in Jojari River, Rajasthan*, order of 7 August 2026). The designer shall state whether the outfall lies in an identified river corridor and whether the High Flood Line has been demarcated for the reach. Where it has, the design river level of item (b) shall be not less than the High Flood Line at the outfall, and the High Flood Line may be used as the 1% AEP level of item (b) only where the study that produced it gives its return period as 100 years or rarer; the return period is not stated in the order [TBC] (set by this Manual).
    - **Court lines.** The designer shall also check the outfall against the lines that courts have set or are setting, as they stand at the time of design (Chapter 7): the 100 m from the edge of the Jojari, and 500 m for hazardous industries from its flood line or flow path (Supreme Court, interim order of 24 August 2026, as reported); the no-construction zone around the Udaipur lakes (notification of 17 January 1997; 200 m from the high flood level around Udai Sagar, as reported) and the High Court's directions of 2025 and 2026 on the Fateh Sagar catchment and the Udaipur lakes (as reported); the removal of structures from the Ana Sagar wetland (NGT, 2023; Supreme Court, 2023–2025, as reported); the catchment of the Ramgarh dam (*Abdul Rahman*, 2004; suo motu, 2011 and 2012; Supreme Court, 2017); and land recorded as gair mumkin nala, nadi or talab (*Ramji Lal Saini*, 2026). Whether a drain outfall is permitted within each line is to be confirmed with the authority concerned before design [TBC].
- (f) **WRD channels, canals and canal escapes, and the nalas of other bodies.** Storm water shall not be discharged to a drain or canal of WRD, to the Indira Gandhi Canal (IGNP), its distributaries, its escapes or another irrigation or lift canal, or to a drain of RIICO or another owner, without the written consent of WRD or the channel's owner. A supply canal or a lift canal is not a drainage outfall, and an IGNP escape is an outlet for canal water, not for storm water, unless WRD consents in writing (set by this Manual). Where consent is given:
    - the discharge shall not exceed the rate the consent allows;
    - the tailwater is the higher of the channel's design water level as WRD or the owner states it and its level in the coincident case of Clause 5.8.4, computed from all the storm water it receives, including the nalas of other bodies, and with its downstream boundary at the river or lake level of items (b) and (c); until a design water level is published for a channel, the computed level governs [TBC];
    - the channel shall be taken in its present condition, net of silt, sand, encroachment and obstruction by crossing services, and a widening, lining, remodelling or diversion that has been proposed but not completed shall not be counted; and
    - the outfall shall have a flap gate (Clause 5.11) where the design water level or the computed level is above the outfall invert.

No pump, gate, sluice or dam operation that helps drainage, such as pumping a drain down before a storm, lowering a lake before a storm, closing a gate late or opening dam gates early, shall be assumed unless the operator's written records show it. Where the outfall invert is below the tailwater of this clause, the outfall shall have its own flap gate (Clause 5.11) and, where the outfall-closed check requires it, pumping (Clause 5.12), with the pumped volume included in the routing of the drain, the lake or the river (Clause 5.12.3). Pumping shall not be used to move water out of a catchment with no outfall (item (a)).

> **Commentary.** In large continental river basins, a site storm and a river flood are usually treated as roughly independent. That is the basis of tables of coincident frequencies such as FHWA HEC-22 Table 7.3. Rajasthan's rivers break that assumption, because a dam stores the first rain of a monsoon spell and spills when it is already full, at the time the same spell is falling on the city below, and because the State's largest storms are slow-moving monsoon systems that fall on the city and its river together. The Kota flood of September 2019 came from the

releases of the Chambal dams after the same monsoon spell had filled them (SANDRP, 2019). The Jaipur storm of 19 July 1981, when 326.0 mm fell at Jaipur and 589.2 mm at Kanota in a day (IMD), raised the Banas at Baranwada to its highest recorded level, 202.865 m, on 20 July (CWC list, as copied by SANDRP). The highest level of the West Banas at Abu Road, 265.4 m, was set on 31 August 1973, in the storm that brought 635.0 mm to Pindwara on 1 September (IMD). The two cannot be treated as independent, and a local storm can fall before, during or after the release. Clause 5.8.4 therefore pairs a design event on one side with a 10-yr event on the other, in the same way as Clause 2.12(b). This pairing has no direct precedent. It is more severe than an independence assumption would give.

Clause 5.8.3 reflects the dams above the State's cities. The Chambal reaches Kota below a cascade of four dams: Gandhi Sagar in Madhya Pradesh (full reservoir level about 399.9 m, maximum water level 401 m), Rana Pratap Sagar (full reservoir level 352.8 m, maximum water level 354.18 m), Jawahar Sagar, and the Kota Barrage (full reservoir level 260.3 m; maximum water level 260.9 m in the CWC bulletin of 2019 and 261.2 m in a 2022 copy of the CWC list) (CWC; SANDRP, 2022); the barrage has 19 radial gates (as reported). In September 2019, with the Gandhi Sagar gates reported opened late (SANDRP, 2019) and 12 to 19 gates opened at the Kota Barrage on 13–14 September, the barrage was reported releasing about 4.42 lakh cusec on 14 September (CWC daily report, seen only as a search summary), and 6.5 lakh cusec through 18 gates, 6.93 lakh cusec through 19 gates or 7.9 lakh cusec in the days that followed (as reported); a government document seen only as an extract gives 7.2 lakh cusec and a revised design spillway discharge of 24,953 m³/s, and is not used [TBC]. The Chambal then runs on to Dholpur, where its highest recorded level, 145.54 m, was set on 23 August 1996 (CWC). On the Banas, the Bisalpur dam (full reservoir level 315.5 m, CWC) stands above Tonk. The Panchana dam (full reservoir level 258.62 m, as listed) releases towards Bharatpur, where its water is reported to reach Keoladeo through the Ajan bund. In the cities, Ana Sagar is held at its full gauge by four escape gates, and the lakes of Udaipur are joined by gated channels (as reported). No operating rule or release record for any of these dams or gates was obtained during research, and no CWC hourly stage record for any gauge in the State was obtained [TBC]. Until they are, the largest recorded release applies, with the flow of the catchment below the dam as it occurred in the same event (Clause 5.8.5(d)). The levels used in this Manual come from the CWC bulletins of 16 and 17 September 2019, read through archived copies, from search summaries of later bulletins and from a 2022 copy of the CWC site list (SANDRP); their datum and gauge zero are to be confirmed from CWC [TBC].

Clause 5.8.5 is set by this Manual. In Rajasthan the tailwater at a city outfall is set not by the tide but by a lake held at its full gauge by gates or an escape channel, by a river held high by the releases of the dams above it, or, over much of the west and north, by nothing at all, because the land has no outfall. No document found during research gives a design level for any of them. The Rajasthan Municipalities Act 2009 requires the drain of a building to empty into a municipal drain or a place set apart within fifty feet, or else into a cess-pool (s.202(2), as read from a third-party copy), but it does not say against which level. No State floodplain-zoning law or WRD order was found, and the only design return period published for a city channel is the Dravyavati's 100-year flood.

The first is the catchment with no outfall. About 60% of the State drains inland (as reported); much of Jaisalmer, Bikaner and Barmer has no defined drainage, the IGNP command near Bikaner is reported to have no natural drainage system at all, and the Sambhar salt lake is the end of a closed basin of about 5,500–5,700 km² (as reported). In such a catchment the governing failure is the volume of a multi-day storm, not a 1-hour peak: in August 2006 about 577 mm fell on Barmer in 3 days against an annual normal of about 277 mm, and the water stood at Kawas for months (as reported). Item (a) therefore applies the 72-hour design volume of Clause 4.12.7, treats the outfall as closed for the whole storm and after it, and makes the overflow path end on public land, because a site that drains to a closed depression either stores its water or puts it on someone else's land. The starting level of a shared basin or depression, the level left by a 10-year 72-hour storm a week earlier, is set by this Manual so that a depression already holding water from an earlier spell is not treated as empty; it is to be replaced by the depression's own flood marks and records.

The second is the lake. Several of the State's cities stand around lakes: Udaipur around Pichola, Fateh Sagar and Udai Sagar, Ajmer around Ana Sagar, Jodhpur with Kailana and Takhat Sagar, and Jaipur with Man Sagar (Jal Mahal). A lake at its full level does not fall for the rest of the monsoon; it passes its inflow over a weir or through

its gates or escape, and its level rises above FTL by whatever head the flood needs. Ana Sagar is held at 13 ft on its gauge by opening its escape gates, but readings of 14 ft to 15 ft 11 in have been reported before they were opened (as reported), and Fateh Sagar has been reported held 20–25 cm above its design full level with sandbags (India Water Portal, 2010). Item (c) therefore takes the MWL, or FTL plus the design-flood surcharge, as the tailwater, and not less than the highest level recorded, and treats an outfall below it as closed for the whole storm, which is what Clause 5.9.4 already requires when the tailwater stays above the outfall. No MWL and no surcharge was found for any of the lakes, so FTL + 0.5 m is set as the interim value: it is the freeboard that this Manual uses for floor levels (Clause 6.11.1), and it is a floor, not an estimate of the surcharge, which depends on the gates and the flood [TBC]. The levels of the Udaipur lakes and of Ana Sagar raise a further problem: they are published, by custodians and the press alike, as gauge readings in feet above a gauge zero whose level was not found, so 13 ft on the Ana Sagar gauge cannot be compared with a drain invert in metres until the gauge zero is levelled to a benchmark. That is why item (c) requires a survey tie before any outfall to such a lake is designed. Only Kailana and Takhat Sagar have published full reservoir levels in metres above MSL (NIH, 2025). The custodian's consent is required because a storm drain added to a lake raises its level for every other outfall, and because the lakes also receive the cities' sewage: the High Court has directed that no untreated sewage reach the wetlands of the State or their catchments (order of 1 June 2026), which is the subject of Clause 8.9.

The third is the river below a dam. Outside the Chambal, most of the State's rivers are short-lived in flood: the Luni and its tributaries rise in flash floods in dry beds, such as the flood of July 1979 that set the highest level at Balotra (Dhir et al., 1982, as cited by Singh et al., 1992). On their own they would lock an outfall for hours, not days. But a dam spills only when it is full, and it goes on spilling while the inflow lasts and while its level is brought back to its full reservoir level. At Kota the barrage gates were opened from 13–14 September 2019, releases of 4.42 to 7.9 lakh cusec were reported over the following days, and the river at Kota City set its highest level on 16 September (CWC; as reported), so the river stood high for about three days at least. No hourly stage record for any gauge in the State was obtained during research [TBC]. The single lock of at least 72 hours therefore covers the whole of the longest design storm of Clause 2.5.2, so that the site does not rely on the river falling during the storm, which a dam release does not allow; it matches the 72-hour design volume of Clause 4.12.7, and it is to be lengthened from the gauge record of the flood that set the highest recorded level on each river. The CWC levels listed in item (b) come from the CWC bulletins of September 2019, read through archived copies, and from a 2022 copy of the CWC site list; their datum and gauge zero are to be confirmed [TBC]. The danger level is used as the floor of the 10% AEP level because the rivers have crossed it by wide margins in recent floods, by 6.68 m at Kota City in 2019 and 14.75 m at Dholpur in 1996 (CWC), so a level reached about once in ten years is unlikely to lie below it; it is to be replaced by a frequency analysis of the CWC record [TBC]. At Tonk the danger level (262.8 m) is above the highest recorded level (262.05 m, 1973), so item (b) takes the danger level as the floor of both cases rather than let the 1% AEP level fall below the 10% AEP level. Item (b) counts only the permanent pumps less the largest one, for the same reason that Clause 5.12.2(b) requires a standby pump.

The fourth is the coincidence of the release and the storm. Item (d) runs the design storm on the city with the river at the largest recorded release because the rain that fills a reservoir and the rain on the city come from the same monsoon spell (see the Commentary to Clause 5.8.4). The Chambal floods at Kota are driven by dams outside the city and partly outside the State, and SANDRP attributes the 2019 flood to the late opening of the Gandhi Sagar gates (SANDRP, 2019). The reported releases conflict, from 4.42 lakh cusec in the CWC report of 14 September to 7.9 lakh cusec in the press, so item (d) takes the highest until WRD gives the record. For the Dravyavati, the Jojari, the Ayad and the Ghaggar no level was found at all, which is why item (b) requires a modelled or surveyed level on those reaches and does not let an outfall be designed without one.

The fifth is the body that owns the receiving water, and the line that the courts are drawing. The dams, reservoirs and canals are WRD's, the public tanks and street drains vest in the Municipality (Rajasthan Municipalities Act 2009, s.68), the lakes fall under the Lakes Act 2015 once notified, and no rule dividing the natural nalas from the municipal drains was found (Chapter 6, Clause 6.9). Items (c), (e) and (f) ask for the owner's consent and design level because a design that discharges to a channel or a lake cannot be checked without them. The Indira Gandhi Canal and the lift canals that feed the city reservoirs carry supply water; a canal escape that takes storm water in a storm would put it where the canal operator does not expect it. The Supreme Court's order of 7 August 2026 will

produce a High Flood Line for every river in the State, and item (e) makes the Manual's design river level no lower than that line when it is demarcated, so that a drain is not designed to a level that the State has already found too low. The court lines of item (e) are listed because they decide where an outfall can be built, not its level; their status is set out in Chapter 7.

5.9 Joint-probability cases

5.9.1 Every element draining to a tidal or backwater-affected outfall shall be checked for the cases below. The most severe governs each design quantity: storage, water level, pipe size and pump capacity.

Table 5.2 — Joint-probability cases for tidal and riverine outfalls

Case	Rainfall	Tailwater	Applies to	Basis
J1	Minor-system design AEP, Tc to 24 h	MHWS + SLA (tidal curve)	Minor system	Clause 2.12(a); Clause 5.7.1
J2	1% AEP, all durations of Clause 2.5.2	HAT + surge + SLA	Major system, detention, tanks, pumped systems	Clause 5.7.1
J3	10% AEP, **48 h**	1% AEP still-water level + SLA	Major system, detention, tanks, pumped systems	Clause 2.12(b)
J4	Design AEP, **48 h** (72 h reported)	Tidal curve per J1 with two **6 h lock windows** (Clause 5.10)	All storage and every gated or tide-affected outfall	Clause 5.10
R1	Site design AEP	River at 10% AEP level	Riverine outfalls	Clause 5.8.4(a)
R2	Site 10% AEP	River at design-AEP level	Riverine outfalls	Clause 5.8.4(b)

5.9.2 For storage elements, the 48- and 72-hour storms shall be run with the J2 and J3 tailwaters (Clause 2.5.3).

5.9.3 For tidally influenced riverine outfalls, R1 and R2 shall be run with the river model's downstream boundary at the J1 tidal curve. The Authority may also require them at J2.

5.9.4 Where tailwater is constant at a level above the outfall invert for the whole storm, the case is treated as a fully closed outfall. Storage and pumps shall then handle the full storm volume.

> **Commentary.** Clause 2.12 sets two joint cases. Case (a) is design rainfall with MHWS plus the sea-level allowance. Case (b) is the 10-yr, 48-hour storm with the 1% still-water level. This Manual adds HAT plus surge for major-system design (Clause 5.7.1). Case J2 combines these. J4 is the outfall-closed check, which tests the timing of tide against the storm rather than a single level. Rainfall and surge share a cyclone cause, so they cannot be treated as independent (Clause 2.12 commentary). These cases are simple surrogates, to be replaced when a statistical joint analysis of IMD rainfall and tide-gauge records is adopted.

5.10 Outfall-closed (tide-locked) storage check

5.10.1 **Where it applies.** The check applies to:

- every storage facility;
- every minor- and major-system element; and

- every pumped system

whose outfall invert is below HAT + surge + SLA, or which drains to a reach subject to tide-lock or sand-bar closure (Clause 5.13).

5.10.2 **Storm.** Use the 48-hour design storm built per Clause 2.9.2 (peak day last), at:

- the AEP of the element: 1% AEP for detention, tanks and the major system; the minor-system AEP for minor drains; and
- AMC III.

The 72-hour storm shall also be run and reported.

5.10.3 **Lock windows.** Unless a site study under 5.10.6 gives otherwise:

- (a) the outfall is closed for **two consecutive lock windows of 6 hours each**, centred on two consecutive high tides of the local tidal curve. For a semi-diurnal tide, the window starts are therefore about 12.4 hours apart.
- (b) During each lock window, gravity discharge is **zero**.
- (c) Between lock windows, gravity discharge is computed against the J1 tidal curve, including the head loss of the flap gate and any non-return valve.
- (d) The first lock window shall be placed so that it is centred on the peak 1-hour block of the final 24 hours of the storm. A second run with the first window **starting** at that peak block shall also be made. The more severe governs.

5.10.4 **Requirement.** Storage plus pumping (where provided) shall hold the inflow so that, throughout the check:

- (a) the maximum stage in any detention facility stays below its emergency spillway crest, so the spillway does not operate. Where the outfall-closed stage is higher than the 1% AEP maximum water level of the free-outfall design, it becomes the facility's 1% AEP maximum water level for Clause 4.9.3, and the spillway crest, freeboard and wall height are set from it;
- (b) the maximum stage in the minor and major systems meets the Chapter 6 limits: building floor levels, and street depths of no more than 150 mm at the crown and no more than 350 mm at the deepest point; and
- (c) no property connection surcharges above the lowest opening it serves, or a non-return valve is fitted under Clause 5.11.

In volume terms, over each lock window and the full storm:

> $V_{inflow} \le V_{storage\ available} + V_{pumped} + V_{gravity\ (between\ locks)}$

This shall be demonstrated by routing, not by a single volume balance. The release from each facility after a lock window ends may exceed the release caps of Chapter 4, because the facility is emptying into a drain that has just reopened. That release shall be included in the downstream analysis (Clauses 5.4 and 5.9).

5.10.5 **Drawdown after the storm.** After the second lock window, the storage shall drain under the J1 tidal curve. The drawdown requirement of Clause 4.7 shall be met, with pumping where gravity cannot meet it (Clause 5.12).

5.10.6 **Site study.** A longer or shorter lock may be used where a site study gives a time series of still-water level for the design case. The study may use a calibrated hydrodynamic model, gauge records of past events, or a surge hindcast. Locks shorter than the default require the Authority's approval. A longer lock shall be used where:

- sand-bar closure (Clause 5.13) or river backwater (Clause 5.8) keeps the outfall closed for longer; or
- the gauge record shows tailwater above the outfall invert for more than 6 hours per tide in comparable past events.

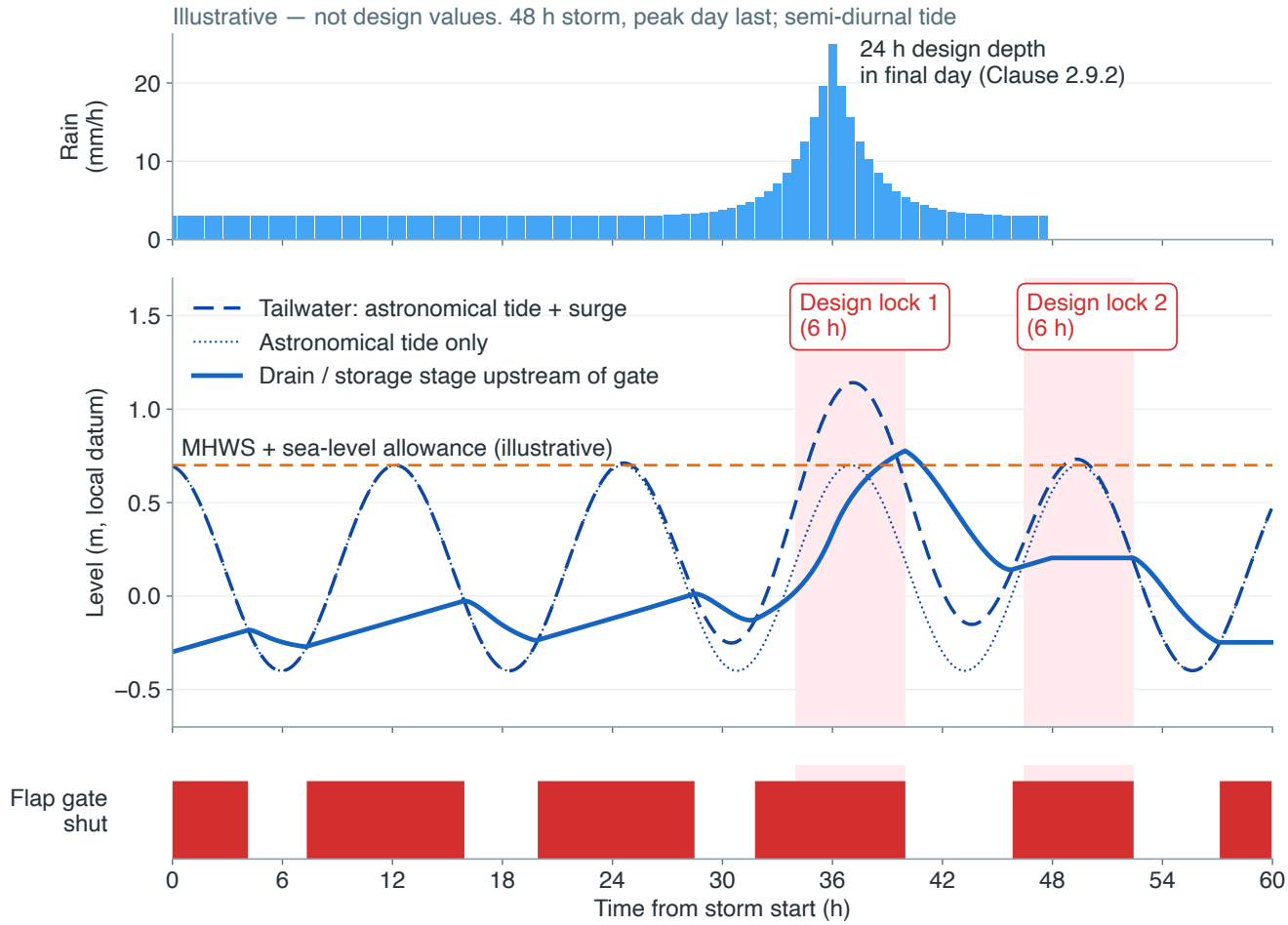

Figure 5.3 — Outfall-closed check: 48-hour storm with the peak day last (Clause 2.9.2), tailwater of astronomical tide plus surge, two 6-hour design lock windows, and the resulting stage upstream of the flap gate. Illustrative — not design values. Original drawing for this Manual, adapted from the tidal tailwater and joint-probability concepts of MoHUA/CPHEEO Manual on Storm Water Drainage Systems (2019), Part A, §6.3.6.

Commentary. The outfall-closed check is the distinctive Rajasthan requirement in this Manual. In Rajasthan it applies where an outfall is shut not by the tide but by a lake held at its full gauge, by a river raised by the releases of the dams above it, or by the absence of any outfall at all. In September 2019 the Kota Barrage was reported releasing about 6.5 to 7.9 lakh cusec, the Chambal at Kota City set its highest recorded level, 248.68 m, 6.68 m above its danger level (CWC), and low-lying Nayapura, Balita and Gavndi were evacuated (as reported). In July 2025 Ana Sagar was reported at 15 ft 11 in on its gauge against a full level of 13 ft, and the opening of its escape gates flooded the land along the channel (as reported). In the closed depressions of the west the water has nowhere to go: after the Barmer storm of August 2006, Kawas was reported still under 3 to 4 ft of water seven months later. A lake at its full gauge stays there for the rest of the monsoon, a river below a spilling dam stays high for as long as the dam spills, and a closed depression empties only by infiltration and evaporation, which is why Clause 5.8.5 replaces the two 6-hour windows described below with a closure for the whole storm at a lake outfall and where there is no outfall, and with a single river lock of at least 72 hours. A rate rule cannot help when there is no outlet: an orificed basin behind a closed gate simply fills.

The default of two consecutive 6-hour locks has no direct precedent. It represents gravity outfalls failing to discharge for about half of each tidal cycle around the two high tides nearest the storm peak. Figure 5.3 shows why both windows matter. The first lock catches the storm peak. The second arrives before the storage has drained, so the stage rises again.

> Placing the first window on the rainfall peak is deliberately unfavourable. Cyclone rainfall and surge share a cause, and Clause 2.12 already treats them as dependent. The check replaces neither the J2 and J3 level checks nor the downstream analysis; it adds a test of timing and volume.

5.11 Flap gates, tide gates and non-return valves

5.11.1 **Where required.** A flap gate, tide gate or equivalent non-return device is required on every outfall whose invert is below the **1% AEP still-water level** (Clause 5.7.3). It is also required on outfalls into irrigation channels under Clause 5.8.5.

5.11.2 **Hydraulics.** The design shall include:

- the gate's head loss and opening head, from the manufacturer's certified head–discharge curve; and
- the reduction in effective outfall capacity when the gate is partly open.

Gates shall not be assumed to seal perfectly in the outfall-closed check unless they are tested.

5.11.3 **Construction.**

- (a) Gates, hinges and seats shall be of corrosion-resistant materials suitable for seawater (Clause 4.12.5).
- (b) The gate shall be set so that sand, silt or debris on the downstream side cannot hold it shut or open. Where the bed is mobile, the gate invert shall be raised above the bed, or the approach shall be protected.
- (c) A trash screen shall be provided upstream where the gate could be jammed by debris.
- (d) A stop-log slot or penstock shall be provided upstream for maintenance isolation on outfalls larger than 600 mm.
- (e) The gate chamber shall be accessible at all tides, with its access above HAT + surge + SLA.

5.11.4 **Non-return valves on property connections.** A non-return valve, or a backwater valve with an accessible cleaning eye, is required on every property drainage connection where the lowest opening served is below:

- the major-system tailwater (J2) at the point of connection; or
- the maximum stage in the outfall-closed check (Clause 5.10).

Basement drainage shall in addition be pumped to a level above both, with its own non-return valve.

5.11.5 **Inspection.** Gates and valves shall be inspected and operated:

- before **20 June** each year;
- after every event in which they closed against a storm flow; and
- as set in the maintenance plan (Chapter 10).

> **Commentary.** The requirement for gates below the 1% still-water level is set by this Manual. The construction details follow common coastal-drainage practice. A gate that is jammed open by debris lets the tide into the drain. A gate held shut by a sand bank turns a gravity outfall into a dead end. In Rajasthan the outfalls do not cross a beach, but many of them end in a lake whose level is held by gates, or in a river whose level is set by the gates of the dams upstream. Ana Sagar at Ajmer is held at 13 ft on its gauge by opening its four escape gates, but readings of 14 ft to 15 ft 11 in have been reported before the gates were opened, and when they were opened in September 2024 and July 2025 the colonies along the escape channel were waterlogged (as reported). At Udaipur the gate between Pichola and Fateh Sagar is reported to be closed once Fateh Sagar reaches 11 ft, and the main bund of Fateh Sagar has been reported to have about 0.75 m of freeboard, with sandbags holding the lake 20–25 cm above its design full tank level (India Water Portal, 2010). On the Chambal, SANDRP attributes the Kota flood of September 2019 to the late opening of the Gandhi Sagar gates upstream (SANDRP, 2019). A gate

> that is opened late, or not at all, raises the lake and every outfall that drains to it; a gate opened in a hurry raises the channel or river below. The lakes, dams and gates are held by WRD, the Municipal Corporation or another custodian, while the drains that reach them belong to the Municipal Corporation, a development authority, an Urban Improvement Trust or a colony developer, and no rule linking the operation of any of these gates to the levels of the drains was found during research [TBC], so a gate and the drains behind it can belong to different bodies. The 20 June inspection date is set ahead of the SW monsoon.

5.12 Pumped outfalls

5.12.1 **When required.** Pumping shall be provided where gravity discharge cannot meet:

- the outfall-closed check of Clause 5.10;
- the drawdown requirement of Clause 4.7; or
- the J2 and J3 cases.

Pumping shall not be used where a gravity solution meets these requirements.

5.12.2 **Capacity.**

- (a) The duty pumps together, with the storage provided, shall pass every case of Clause 5.9 (including J4), demonstrated by routing.
- (b) **Standby** capacity at least equal to the largest duty pump shall be installed (duty + 1 standby as a minimum).
- (c) Pump capacity shall be stated at the static head for the **J2** tailwater, not at mean tide.

5.12.3 **Effect on the receiving water.** Pumped discharge to a river, canal or creek shall be included in the river or creek level analysis of Clause 5.8. Pumping that raises the receiving water level above the acceptance criteria of Clause 5.5 elsewhere is not permitted.

5.12.4 **Power supply.** Pumping stations shall have either:

- two independent power supplies; or
- standby generation for 100% of the duty capacity, with on-site fuel for at least **72 hours** of duty operation.

Changeover shall be automatic.

5.12.5 **Flood immunity.** Electrical panels, control equipment, generators and fuel storage shall be set above the higher of:

- the 1% AEP flood level + 0.5 m; and
- HAT + surge + SLA + 0.5 m.

Access to the station shall remain usable in the 1% AEP event.

5.12.6 **Discharge arrangement.** Rising mains shall discharge:

- over a level above the J2 tailwater; or
- through a non-return valve and a flap gate.

The arrangement shall prevent back-siphoning.

5.12.7 **Controls and monitoring.** Each station shall have:

- automatic level control;
- remote alarms for high level, pump failure and power failure, sent to the operator; and
- a level and run-time log kept for at least 5 years.

Wet wells shall be sized to keep pump starts within the manufacturer's limits.

5.12.8 **Screens.** Inlet screens shall be provided with a cleaning method that works during a storm (a mechanical rake, or duplicate screens).

5.12.9 **Testing.** Every pumped outfall shall be test-run at full duty, including on standby power, before **20 June** each year. Private pumped systems shall be covered by a registered maintenance declaration (Chapter 10).

> Commentary. Duty + standby, 72 hours of fuel and flood-immune electrics have no single direct precedent and are set by this Manual. The 72-hour fuel figure matches the longest mandatory design storm (Clause 2.5.2). A pump station that depends only on grid power can stop exactly when it is needed, because supply to flooded areas is often switched off for safety. Singapore's April 2025 amendments added annual maintenance declarations for pumped detention tanks (PUB Addendum No. 3). Clause 5.12.9 and Chapter 10 adopt the same approach. Clause 5.12.3 prevents pumping that simply moves water from one tide-locked drain into a tide-locked river.

5.13 Sand-bar closure of river mouths

5.13.1 **Where it applies.** This clause applies to outfalls into any river or creek whose mouth is subject to seasonal sand-bar closure. That includes the mouths of the coastal States (there is none in Rajasthan: Clause 5.1.4), and any other mouth listed in Annex 5B.

5.13.2 **Assumption at the start of the SW monsoon.** The mouth shall be assumed **closed** by a bar at the start of the June–September season, at the crest level of the most recent pre-monsoon survey. This applies unless WRD certifies that:

- a mouth-maintenance programme (dredging, bar cutting or training walls) has kept the mouth open at the start of each of the previous three SW monsoon seasons; and
- the programme is funded for the current season.

5.13.3 **Tailwater with a closed mouth.** With the mouth closed, the tailwater at the outfall shall be the higher of:

- (a) the tidal tailwater of Clause 5.7; and
- (b) the level in the river reach behind the bar, computed with the bar as a weir at its surveyed crest level. That level shall include the river flow of Clause 5.8 and the head needed to pass the flow over or through the bar.

5.13.4 **No credit for emergency cutting.** Bar cutting or breaching during the storm shall not be assumed in design, unless WRD has a documented operating procedure, with equipment stationed for it. Where it does, the bar may be assumed lowered to the procedure's target level only after the time the procedure states.

5.13.5 **Outfall-closed check.** Where the closed-mouth level of 5.13.3(b) exceeds the outfall invert for longer than the default lock windows, the lock duration of Clause 5.10 shall be extended to that period.

> Commentary. Rajasthan has no coast and no river mouth, so Clause 5.13 does not apply in the State (Clause 5.1.4). Its nearest inland counterparts are the gated outlets and escape channels of its lakes and the silt and sand that its rivers leave at an outfall. A lake whose gates are not opened when it reaches its full gauge rises above it and holds every drain that ends in it, as Ana Sagar has been reported to do at 14 ft to 15 ft 11 in against a full gauge of 13 ft, and silt and sand left by a flash flood in a dry river bed can hold a flap gate shut or open. No written gate-operation rule for the escape gates of Ana Sagar, the gates of the Udaipur lakes or any other lake outlet was

found during research [TBC]. Clause 5.8.5 deals with both by giving no credit for a gate operation or a storage that the custodian's records do not show. Clause 5.13.2 has no direct precedent. It puts the burden of proof on showing that the mouth is open rather than assuming it.

5.14 Documentation

Every project subject to this chapter shall submit a **Downstream and Tailwater Report** (Form 5-1). It shall contain:

1. a plan of the analysis extent showing:
    - the site;
    - each analysis point with its contributing catchment area and the site's percentage of it; and
    - the end point and the reason it was chosen (Clause 5.3);
2. the model description:
    - software and version;
    - the network schematic, with survey sources for the drains and crossings;
    - land use and CN for off-site areas;
    - any upstream detention included; and
    - calibration or validation evidence where available;
3. for each analysis point, AEP and duration, the existing and with-project:
    - peak flow;
    - time to peak;
    - maximum water level and velocity; and
    - duration of inundation (Clause 5.4);
4. the comparison against Clause 5.5, with each failure identified and the remedy adopted;
5. the tailwater derivation:
    - tide-table edition and port;
    - MHWS, HAT and MSL relative to chart datum;
    - the datum connection to the Survey of India benchmark and the project datum;
    - surge source and value;
    - SLA; and
    - river levels and their sources (Clauses 5.6 to 5.8);
6. the joint-case table of Clause 5.9 with results;
7. the outfall-closed check (Clause 5.10):
    - storm and lock alignment;
    - stage hydrographs; and
    - the volume balance for each lock window;
8. a schedule of flap gates, tide gates and non-return valves, with certified head–discharge data (Clause 5.11);
9. pumped outfall design, power supply, flood immunity and controls, where provided (Clause 5.12);
10. the sand-bar assumption and supporting WRD certification, where relevant (Clause 5.13); and
11. inspection and maintenance requirements for Chapter 10.

Small sites under Clause 5.3.4 shall submit Form 5-2 (Simplified Downstream Statement) instead.

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Annexes and forms

Annex / Form	Content
5A	Tidal datums (MSL, MHWS, HAT vs CD and Survey of India datum), surge allowances and 1% still-water levels by coastal segment
5B	Major drains, riverine outfall reaches, and river mouths subject to sand-bar closure; map
5C	Worked example: outfall-closed check for a site on a Dravyavati tributary nala in south Jaipur
Form 5-1	Downstream and Tailwater Report
Form 5-2	Simplified Downstream Statement (small sites)

CHAPTER 6

Minor and Major Drainage Systems

6.1 Purpose and scope

6.1.1 This chapter sets the level of service and the hydraulic criteria for the conveyance system that carries runoff from a development, a road or a public drainage scheme to a receiving waterway, tank or outfall. It covers:

- (a) the dual drainage concept: a minor system and a major system (Clause 6.3);
- (b) design return periods by land use and road class (Clause 6.4);
- (c) street hydraulics: spread, depth and flow hazard (Clause 6.5);
- (d) inlets, including clogging (Clause 6.6);
- (e) pipes and open and covered drains (Clause 6.7);
- (f) hydraulic grade line analysis (Clause 6.8);
- (g) overland flow paths, ponding at sags and building floor levels (Clauses 6.9 to 6.11);
- (h) culverts and road crossings (Clause 6.12); and
- (i) Rajasthan construction-practice requirements for covered drains, silt, solid waste, utilities and desilting access (Clause 6.13).

6.1.2 The detailed hydraulic design of individual structures (culverts, channels, energy dissipators, screens, pumps, gates, manholes) is in Chapter 9. Rainfall is in Chapter 2, runoff methods in Chapter 3, on-site storage in Chapter 4, tailwater in Chapter 5, waterbodies in Chapter 7 and water quality in Chapter 8.

6.1.3 This chapter applies to all public drains, all roads with kerbs or roadside drains, and all private drainage systems in developments that meet the applicability thresholds of Chapter 1. In Tier B local bodies, the simplified procedures and design aids referred to in Chapter 1 may be used for elements serving ≤ 16 ha, but the criteria of this chapter still apply.

> Commentary. Rajasthan's drains have been designed with a low stated level of service and no plan for floods larger than the drain. The only drainage design rule of the State found during research is RUIDP's guideline of 2008 for its town drainage works, which says that "Most RUSDIP city areas may adopt a design return period of 1-2 yeas [sic]", with 25 years for culverts and 50 for bridges, and that "In Indian conditions, intensity of rainfall adopted in design is usually in the range of 12mm/hr to 20mm/hr" (RUIDP Circular No. 8, 4 March 2008). Jaipur's own gauge gives a 5-year 1-hour rainfall of 53.1 mm and a 50-year 1-hour rainfall of 93 mm (Ghate and Timbadiya, 2022, from IMD hourly records of 1970–2013), so a drain built to the circular's intensities is sized for a fraction of a storm that the city can expect about once in five years. The Dravyavati was designed for the 100-year flood (JDA, Dravyavati EIA), but no approved drainage master plan with a design return period was found for any city. Jaipur's highest 24-hour rainfall on record, 326.0 mm, fell on 19 July 1981 (IMD); on 31 July–1 August 2024 three members of one family died in a flooded basement in the city (as reported); and in July 2022, 119 mm in 24 hours, Jodhpur's highest July fall since 1943, flooded more than 30 colonies of the city (as reported). Where the drains overflow, the water runs along the roads and collects in the low colonies: in July 2026 Tonk Road, Rambagh and the walled city of Jaipur were waterlogged (as reported), and the walled city drains through the Ganda nala to the Dravyavati (JDA, Dravyavati EIA). The nalas that should carry the overflow are protected mainly by the courts: the High Court has held that land recorded as gair mumkin nala is a natural channel that cannot be diverted or built on, even for a public purpose (*Ramji Lal Saini v. State of Rajasthan*, 7 May 2026). The drains are also divided among owners: the Municipal Corporations, Councils and Boards, the development authorities and Urban

Improvement Trusts, colony developers, RIICO, WRD and the Revenue Department all build or hold drains and receiving waters in the same city, and no rule divides them (see the Commentary to Clause 6.9). Fixing the rainfall (Chapter 2) is only half the answer. The other half is a second, surface-level system that carries the flows the pipes cannot, without flooding buildings. That is the dual drainage concept of this chapter, taken from Kansas City Metro APWA Section 5600 (5601.8, Levels of Service), which requires every element to have a 1% AEP overflow path.

6.2 Definitions

Term	Meaning in this Manual
Minor system	Inlets, pipes, covered drains and open drains that carry runoff up to the minor design AEP of Table 6.1 without surcharge above the limits of Clause 6.8.
Major system	The surface flow paths (streets, overland flow paths, open channels, floodways and storage) that carry flow above the capacity of the minor system, up to the 1% AEP (100-yr) event.
Overland flow path	A defined surface route, in public land or a recorded easement, that carries major-system flow to a receiving waterway.
Spread (T)	Width of flow in the gutter and carriageway, measured from the face of the kerb.
Sag	A low point on a road or flow path from which water can leave only through an inlet or by ponding to an overflow level. A trapped sag has no surface overflow route.
Clogging factor	The fraction of an inlet's clean hydraulic capacity assumed lost to debris (Clause 6.6.3).
Hydraulic grade line (HGL)	The line joining the free-surface levels in a conduit system, or the piezometric levels where the system is under pressure.
Covered drain	A rectangular drain, usually beside a road, closed by cast-in-situ or precast cover slabs that form a footpath.
Sediment allowance	The depth or area of a drain or pipe assumed filled with silt when its design capacity is computed (Clause 6.7.8).
Check event	An AEP rarer than the design AEP at which the combined minor and major system must still meet the limits of Table 6.2.
High-density area	An area notified as such by the approving authority under Clause 6.4.4.
Class I area	An urban local body with a population of 1 lakh or more (the CPHEEO definition).

6.3 The dual drainage concept

6.3.1 Every drainage system shall be designed as two systems that work together:

- (a) a **minor system** that carries the minor design flow of Table 6.1 below ground or in drains, keeping streets usable and spread within Table 6.2; and
- (b) a **major system** that carries all flow above the minor-system capacity, up to the 1% AEP (100-yr) flow, on the surface without entering buildings and within the depth and hazard limits of Clause 6.5.

6.3.2 **Every element has a 1% path.** Every inlet, sag, pipe, drain, culvert and storage element shall have an identified 1% AEP overland flow path to a receiving waterway, tank or outfall. The path shall be shown on the drainage plan (Clause 6.15).

6.3.3 **Major-system design flow.** The major system at any point shall carry the 1% AEP peak flow less the minor-system capacity at that point. The minor-system capacity used in this subtraction is the capacity of the inlets after the clogging factors of Clause 6.6.3, or the pipe capacity, whichever is less. At sags and at any location used to set building floor levels, the major system shall also be checked with the minor system **fully blocked** (Clause 6.10.3).

6.3.4 **Rainfall and method.** Design flows shall use the rainfall of Chapter 2 (including the climate factor of Clause 2.8) and the methods of Chapter 3:

- (a) the Rational Method only for catchments ≤ 16 ha and a single conveyance element. It shall not be used to accumulate flows down a network whose total catchment exceeds 16 ha;
- (b) a hydrograph method with hydraulic routing (for example SWMM, HEC-HMS with a hydraulic model, or an equivalent 1D/2D model) for networks above 16 ha and for any network with storage, pumping or a tidal outfall;
- (c) a minimum time of concentration of 10 minutes.

6.3.5 **No transfer between catchments.** Neither the minor nor the major system shall divert flow from one natural catchment to another unless the approving authority accepts a catchment-wide study showing no adverse effect.

> Commentary. The CPHEEO (2019) manual defines major and minor systems in its glossary but gives no return period for the major system. APWA 5600 (2006, 5601.8) requires the system to convey the 1% peak and, where in-system capacity is less, an overflow system to carry the remainder. Clause 6.3.3 subtracts only the *clogged* inlet capacity, not the full pipe capacity, because in practice the pipes cannot take more water than the inlets admit. The fully-blocked check at sags has no direct precedent; this Manual sets it because of the Jaipur experience that drains under footpaths are often silted or blocked by solid waste when the heaviest rain arrives (CPHEEO 2019 Part A, Ch 1 and 2, Figures 1.2 and 2.1 on solid waste dumping in drains). The prohibition on inter-catchment transfer follows the DID Malaysia 2008 submission checklist, which prohibits inter-catchment diversion.

6.4 Design return periods

6.4.1 The minor system, roads and crossings shall be designed for the AEPs of Table 6.1. Where both a land-use row and a road-class row apply to an element, the **rarer** AEP (longer return period) governs.

Table 6.1 — Design AEPs for conveyance (matches Clause 2.4)

Element	Design AEP (return period)	Check event	Basis
Minor system: Jaipur, Jodhpur, Kota, Udaipur and Ajmer core and other high-density areas	10% (10-yr)	1% (100-yr) overland path	This Manual (see Commentary)
Minor system: other Class I areas	20% (5-yr)	1% overland path	This Manual; CPHEEO Table 4.1
Minor system: other areas	50% (2-yr)	1% overland path	This Manual; CPHEEO Table 4.1
Arterial road drainage and crossings	2% (50-yr) for arterials that are notified evacuation or emergency routes; 4% (25-yr) for other arterials	Next higher AEP: 1% for a 2% design; 2% for a 4% design	This Manual (25–50-yr); split set by this Manual
Collector road drainage and crossings	4% (25-yr)	2% (50-yr)	This Manual
Local road drainage and crossings	10% (10-yr)	4% (25-yr)	This Manual
Road underpasses and other trapped sags on public roads	2% (50-yr)	1% (100-yr)	This Manual (Clause 6.10.5)

Element	Design AEP (return period)	Check event	Basis
Airports, railway stations, power stations and other critical infrastructure	1% (100-yr) in Class I areas; 2% (50-yr) elsewhere	—	CPHEEO 2019 Table 4.1
Major (overland) system, every element	1% (100-yr)	—	This Manual
Building floor levels	1% level + 0.5 m freeboard	—	This Manual (Clause 6.11)

6.4.2 **Check events.** At the check event of Table 6.1, the combined minor and major system shall carry the check-event flow within the 1% AEP limits of Table 6.2 and without water entering any building. The 1% overland path requirement of Clause 6.3.2 applies in addition to the check event.

6.4.3 **Higher standards.** An approving authority may adopt a rarer AEP for any element, including through the high-powered committee route in Note 2 of CPHEEO Table 4.1. It shall not adopt a more frequent AEP than Table 6.1.

6.4.4 **High-density areas.** The approving authority shall notify, by map, the high-density areas to which the 10% AEP minor-system standard applies. Until it does, the 10% AEP standard applies to:

- (a) the walled cities of Jaipur, Jodhpur, Udaipur and Ajmer and the old city of Kota: the older, densely built city within the Municipal Corporation's area that the applicable master plan identifies as the walled city, old city, core or heritage area, including the walled city of Jaipur, which the JDA Building Regulations 2020 leave outside their extent, with the boundary of each to be confirmed by the Municipal Corporation and the development authority [TBC];
- (b) in every other Municipal Corporation, the area that the applicable master plan identifies as the walled city, the old city or the central business district, and the old abadi of the villages that have been taken into the built-up area; and
- (c) any area in a Tier A body where the master plan permits a floor space index above the base value for the zone.

6.4.5 **Retrofit.** Where an existing drain cannot practicably be enlarged to the Table 6.1 AEP, the shortfall shall be made good by upstream storage (Chapter 4), regional storage (Chapter 7) or an improved major-system path. The approving authority shall record the residual level of service.

> **Commentary.** The values in Table 6.1 match the Clause 2.4 summary and add rows for underpasses and critical infrastructure. They exceed the CPHEEO (2019) national advisory minimums of 5-yr for Class I cities and 2-yr elsewhere (CPHEEO Part A, Table 4.1). Note 2 of that table allows a State committee to adopt higher values. The 10-yr tier for high-density areas follows Gupta (IIT Bombay), who recommends "1 in 10 year for residential-high density", and Malaysia's MSMA 2, which uses 10-yr minor and 100-yr major systems for link houses, apartments, commercial and industrial land. The road values resolve a conflict in Indian codes. IRC:SP:50-2013 recommends 1–2 years for urban road drains. IRC:SP:42-2014 suggests 25 years for urban roadside drains and a check flood at the next higher return period. APWA 5600 (2006) uses 50-yr for arterial, 25-yr for collector and 10-yr for residential street crossings. Table 6.1 adopts the APWA tiers and the IRC:SP:42 check-flood concept. Splitting arterials into 50-yr evacuation routes and 25-yr others has no direct precedent and is set by this Manual. The 50-yr standard for underpasses is likewise set by this Manual, because an underpass is a trapped sag where the failure mode is deep water on a live carriageway. The default high-density areas in Clause 6.4.4 are set by this Manual and apply until the approving authority notifies a map.

6.5 Street hydraulics: spread, depth and flow hazard

6.5.1 **Gutter flow.** Flow in a triangular kerb-and-gutter section shall be computed with the modified Manning (Izzard) equation:

> Q = (Ku / n) · Sx^(5/3) · SL^(1/2) · T^(8/3)

where Q is the gutter flow (m³/s), Ku = 0.376 (SI), n is the Manning roughness of the gutter (Table 6.6), Sx is the cross slope (m/m), SL is the longitudinal slope (m/m) and T is the spread (m). Composite and depressed gutter sections shall be analysed by the methods of FHWA HEC-22 (4th edition, 2024).

6.5.2 **Spread and depth limits.** Street flow shall not exceed the limits of Table 6.2.

Table 6.2 — Street flow limits

Road class	Minor design event (Table 6.1)	Check event and 1% AEP event
Arterial	Spread shall leave at least one through lane in each direction clear of water. No flow across the crown.	Depth ≤ 150 mm at the crown and ≤ 350 mm at the deepest point; hazard limits of Clause 6.5.3
Collector	Spread T ≤ 3 m. No flow across the crown except at a sag intersection.	As above
Local	Spread T ≤ 3 m. Flow shall not overtop the kerb.	As above
All classes, at intersections	Cross-flow over the crown ≤ 0.03 m³/s at sag intersections and superelevation transitions; none at mid-block sags.	As above

6.5.3 **Flow hazard limits.** In the check event and the 1% AEP event, the product of depth (D, m) and velocity (V, m/s) of street and overland flow shall not exceed the limits of Table 6.3.

Table 6.3 — Flow hazard limits for streets and overland flow paths

Location	Required hazard class (Table 6.4)	Limits
Carriageways of all roads	H2 or better	D·V ≤ 0.6 m²/s; D ≤ 0.35 m (Table 6.2); V ≤ 2.0 m/s
Footpaths, pedestrian crossings, school, hospital and transit-stop frontages	H1	D·V ≤ 0.3 m²/s; D ≤ 0.3 m; V ≤ 2.0 m/s
Notified evacuation and emergency routes	H1	D·V ≤ 0.3 m²/s; D ≤ 0.3 m; V ≤ 2.0 m/s
Overland flow paths in public open space or easements, away from roads	H3 or better, with warning signs	D·V ≤ 0.6 m²/s; D ≤ 1.2 m; V ≤ 2.0 m/s

Table 6.4 — Combined flood hazard vulnerability classes (reproduced for reference)

Class	Description	D·V limit (m²/s)	Depth limit D (m)	Velocity limit V (m/s)
H1	Generally safe for vehicles, people and buildings	≤ 0.3	0.3	2.0
H2	Unsafe for small vehicles	≤ 0.6	0.5	2.0
H3	Unsafe for vehicles, children and the elderly	≤ 0.6	1.2	2.0

Class	Description	D·V limit (m²/s)	Depth limit D (m)	Velocity limit V (m/s)
H4	Unsafe for vehicles and people	≤ 1.0	2.0	2.0
H5	Unsafe for vehicles and people; buildings vulnerable to structural damage	≤ 4.0	4.0	4.0
H6	Unsafe for vehicles and people; all buildings vulnerable to failure	> 4.0	—	—

Source: AIDR Guideline 7-3, *Technical flood risk management guideline: Flood hazard* (2014), Tables 1 and 2, modelled after Smith and Wasko (2012).

6.5.4 Depth and velocity for Clause 6.5.3 shall be taken from the gutter-flow calculation for simple sections, or from a 1D or 2D hydraulic model where flow leaves the kerb-and-gutter section.

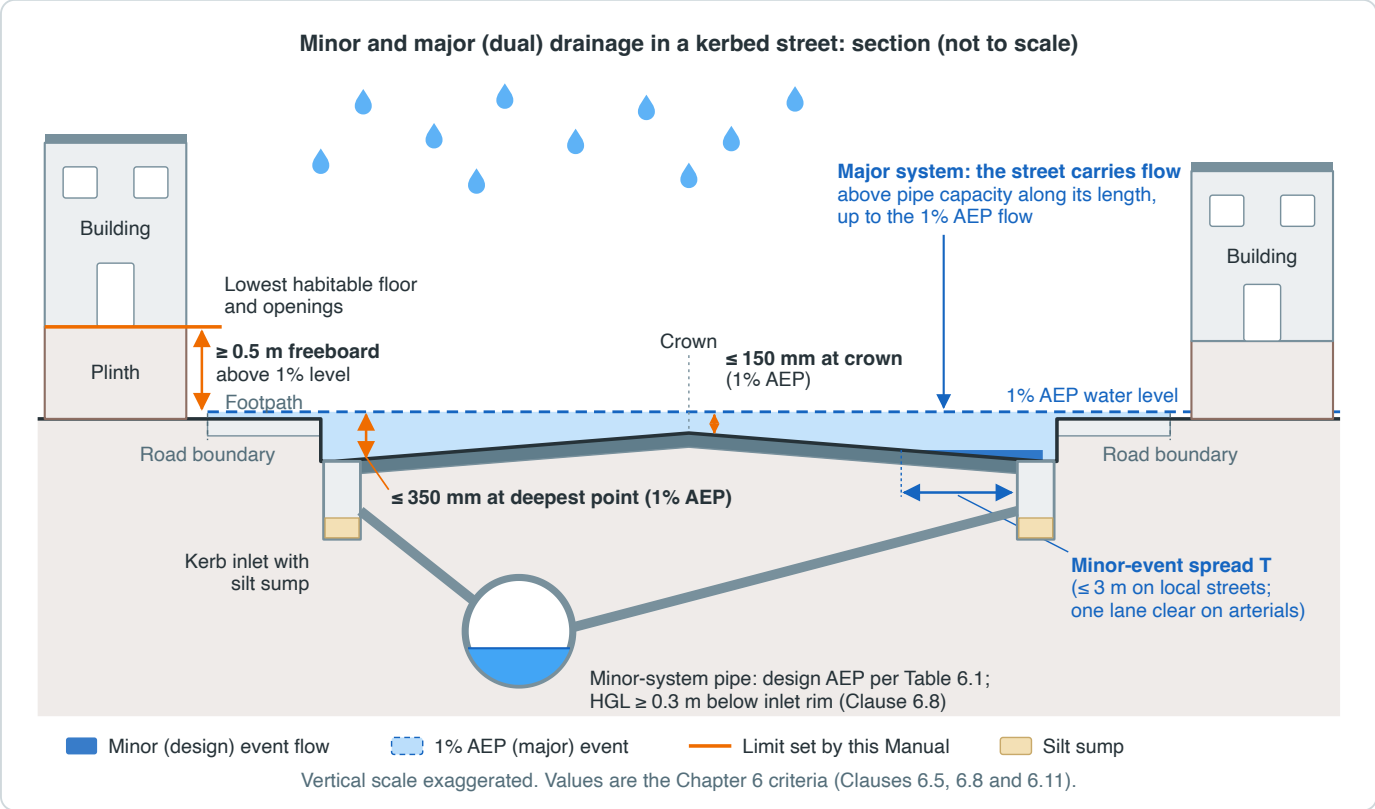


Figure 6.1 — Minor and major drainage in a kerbed street. Original drawing for this Manual, adapted from Kansas City Metro APWA, Section 5600 (2006, 5601.8) and FHWA, HEC-22 Urban Drainage Design Manual (4th ed., 2024).

Commentary. The Izzard form of Manning's equation with Ku = 0.376 is used both in FHWA HEC-22 and in the CPHEEO (2019) manual (Part A, Example 5.5, where the constant is written Kc = 0.376). The arterial spread rule (one lane clear) and the 3 m spread for local and collector streets are close to the APWA 5600 (2006, 5604.2) limit of 12 ft (3.66 m) from the back of kerb in each outside lane. The cross-flow limit of 0.03 m³/s is the SI equivalent of the APWA limit of 1.0 cfs at intersection sumps and superelevation transitions, with no cross-flow at mid-block sumps. The 150 mm and 350 mm depth limits are close to the APWA 5600 limits for 1% overflow at road crossings (7 in, about 180 mm, at the crown; 14 in, about 360 mm, at the deepest point). Mumbai's criterion of no flooding above 15 cm (IRC:SP:50-2013, §6.4.1) is a local precedent for the 150 mm crown value.

The hazard classes of Table 6.4 are the combined hazard curves published by the Australian Institute for Disaster Resilience (AIDR Guideline 7-3, 2014), which are modelled after Smith and Wasko (2012). Requiring H2 or better on carriageways means the 1% depth limit of 350 mm (Table 6.2) governs the depth, and the D·V product controls

fast, shallow flow on steep streets. H2 is described as "unsafe for small vehicles". Two-wheelers are the dominant vehicles on Rajasthan streets, so the 1% event must be treated as a road-closure event on all roads except notified evacuation routes, which must meet H1. The assignment of hazard classes to locations in Table 6.3 has no direct precedent and is set by this Manual.

6.6 Inlets

6.6.1 **Inlet types.** Inlets may be kerb-opening inlets, grate inlets, combination inlets (a grate with a kerb opening) or slotted and trench drains. On public streets:

- (a) kerb-opening or combination inlets shall be used, unless the approving authority accepts grate-only inlets for a specific location;
- (b) inlet openings shall be set at road level, with a gutter depression where practicable, so that water is not held on the carriageway by a raised kerb or footpath;
- (c) grates in carriageways, cycle lanes and footpaths shall be of a bicycle- and pedestrian-safe pattern (Chapter 9, Clause 9.11).

6.6.2 **Inlet capacity.** The clean capacity of inlets on grade and in sags shall be computed by the methods of FHWA HEC-22 (4th edition, 2024), or from tested ratings published by the manufacturer for the exact grate and kerb-opening geometry. The empirical kerb-inlet equations of CPHEEO (2019) Part A §5.6.2 may be used as a cross-check only.

6.6.3 **Clogging factors.** The design capacity of every inlet shall be its clean capacity reduced by the clogging factors of Table 6.5:

Table 6.5 — Inlet clogging factors (share of clean capacity assumed lost)

Inlet type	On grade	In a sag
Grate	50%	50%
Kerb opening	10%	20%
Combination	Apply the grate and kerb factors to each part separately	Apply the grate and kerb factors to each part separately

Design capacity = (1 − clogging factor) × clean capacity.

6.6.4 **Inlet spacing.** Inlets shall be located by a sequential calculation that starts at the top of each gutter run. At each inlet, the intercepted flow is computed, and the bypass flow is added to the gutter flow arriving at the next inlet. Spacing shall be such that the spread limits of Table 6.2 are met everywhere in the minor design event. In addition:

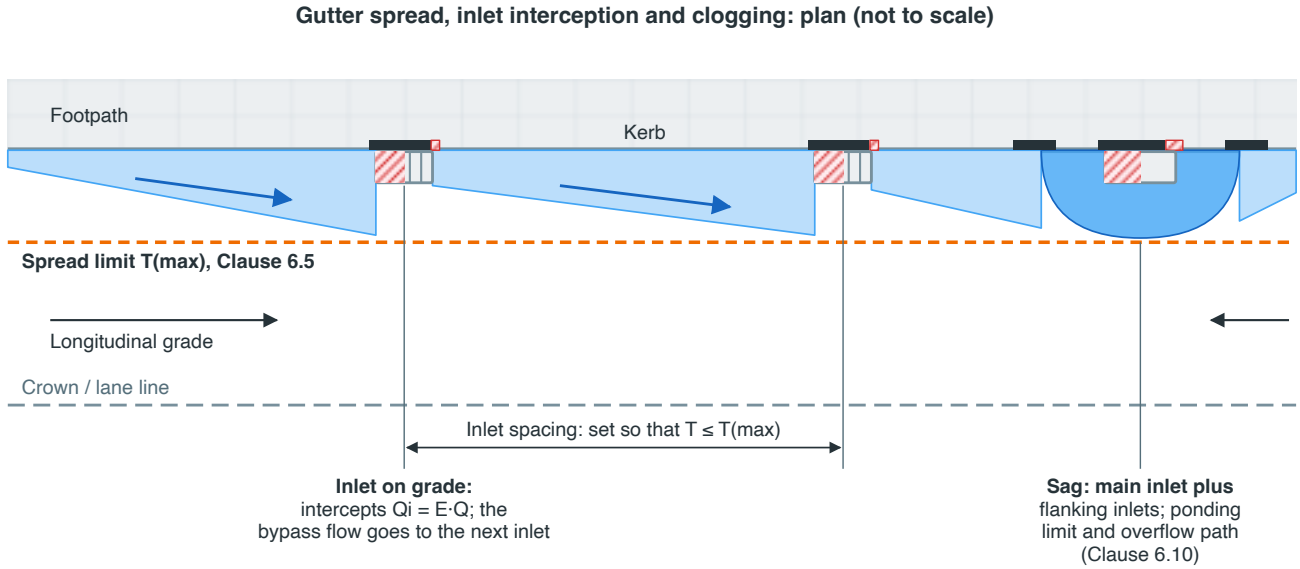
- (a) inlet spacing shall not exceed 30 m on kerbed roads, whatever the calculation gives;
- (b) inlets shall be provided at every sag, immediately upstream of pedestrian crossings and intersections, upstream of bridge decks and superelevation transitions, and at the end of every gutter run;
- (c) bypass flow from the last inlet of a run shall not be passed onto a road of a higher class or into private land.

6.6.5 **Sag inlets.** At a sag on a kerbed road:

- (a) the sag inlet's design capacity (after clogging) shall be not less than the total minor design flow arriving at the sag;
- (b) flanking inlets shall be placed on each side of a sag on any road where ponding could spread beyond the Table 6.2 limits, and at every underpass;
- (c) the ponding at the sag shall comply with Clause 6.10.

6.6.6 **Inlet connections.** The pipe connecting an inlet to the main drain shall have a diameter of at least 300 mm and shall be laid at a gradient that gives at least 0.9 m/s at the inlet's design flow.

6.6.7 **Silt sumps.** Every inlet chamber on a public road shall have a silt sump at least 300 mm deep below the invert of its outlet pipe, accessible for cleaning from the surface.



Clogging factors (share of clean capacity lost), Clause 6.6

Inlet type	On grade	Sag
Grate	**50%**	**50%**
Kerb opening	10%	20%
Combination	Each part as above	Each part as above

Gutter flow spread (minor event)
Ponding at sag
Assumed clogged portion
Kerb opening

Figure 6.2 — Gutter spread, inlet interception and clogging. Original drawing for this Manual, adapted from FHWA, HEC-22 Urban Drainage Design Manual (3rd ed., 2009; 4th ed., 2024) and CPHEEO, Manual on Storm Water Drainage Systems (2019).

> **Commentary.** The clogging factors are more severe than the APWA 5600 (2006, 5604.2) rating of sump inlets at 80% of theoretical capacity (a 20% reduction), because grates in Rajasthan streets are routinely blinded by plastic and leaves. CPHEEO (2019) Part A shows solid waste dumped in drains as a primary cause of drain failure (Figures 1.2 and 2.1). APWA 5600 (2006) allows only kerb-opening inlets on public streets; Clause 6.6.1(a) is less strict because combination inlets are useful on flat roads. The 30 m maximum spacing and the treatment of combination inlets in Table 6.5 have no direct precedent and are set by this Manual. A fixed cap stops a single blocked inlet from leaving a long dry gutter run. The 300 mm silt sump is set by this Manual. It matches the 0.3 m sump shown on the CPHEEO catch-basin detail (CPHEEO 2019, Figure 5.9).

6.7 Pipes and open and covered drains

6.7.1 **Uniform flow.** Pipe and drain capacity shall be computed with Manning's equation:

> V = (1/n) · R^(2/3) · S^(1/2); Q = A · V

where V is the mean velocity (m/s), n is the Manning roughness (Table 6.6), R is the hydraulic radius (m), S is the friction slope (m/m), A is the flow area (m²) and Q is the discharge (m³/s). Where backwater from a tailwater, a junction or a structure affects the water level, a gradually varied flow (standard step) or hydraulic network model shall be used, and the HGL requirements of Clause 6.8 apply.

6.7.2 **Manning roughness.** Design values of n shall be taken from Table 6.6. For concrete pipes and masonry or concrete drains, the design value shall be not less than the "fair" or "rough" condition value listed, to allow for sediment, biofilm and ageing.

Table 6.6 — Manning's n for design (from CPHEEO 2019)

Material	Condition	n (CPHEEO)	Minimum design n in this Manual
Cement concrete pipe (collar joints)	Good / fair	0.013 / 0.015	0.015
Spun concrete pipe (RCC, PSC) with S/S joints	Manufacturer's design value	0.011	0.013
HDPE / uPVC pipe	—	0.010	0.011
Plastic (smooth), asbestos cement	—	0.011	0.011
Concrete drain, steel trowelled / wood trowelled	—	0.014 / 0.015	0.015
Sand and cement plaster	—	0.015	0.015
Brick masonry	Good / rough	0.015 / 0.017	0.017
Masonry	Bad condition	0.020	0.020
Rubble set in cement	—	0.017	0.017
Earth channel	Regular, good / ordinary	0.020 / 0.025	0.025
Earth channel	With stones and weeds / poor	0.030 / 0.035	0.035
Earth channel	Partly obstructed by debris or weeds	0.050	0.050
Gutter: concrete	—	0.013	0.013
Gutter: hot-mix asphalt	—	0.015	0.015
Gutter: sprayed seal	—	0.018	0.018

Source of the CPHEEO column: CPHEEO (2019) Part A, Table 5.1 (itself from the CPHEEO Manual on Sewerage and Sewage Treatment Systems, 2013) and Table 5.8 (gutters).

6.7.3 **Velocity limits.** At the minor design flow:

- (a) minimum (self-cleansing) velocity: **0.6 m/s** in open and covered drains and **0.9 m/s** in pipes;

- (b) maximum velocity: **3.0 m/s** in lined drains and in pipes, unless the drain or pipe is designed as a chute under Chapter 9. CPHEEO permits up to 6.0 m/s in plastic or plastic-lined pipes in hilly regions; this may be used in Mount Abu and the towns of the Aravalli hills and other hill towns with the approving authority's agreement;
- (c) maximum velocity in unlined and vegetated channels: Chapter 9, Table 9.2;
- (d) the Froude number of flow in open and covered drains shall not exceed 0.8 at the design flow, unless the drain is designed for supercritical flow under Chapter 9.

6.7.4 **Gradient.** Each pipe and drain shall be laid at a gradient that achieves Clause 6.7.3(a). Where flat terrain or a fixed outfall level makes this impossible, the designer shall:

- (a) report the velocity achieved;
- (b) double the sediment allowance of Clause 6.7.8; and
- (c) provide access for mechanical desilting at the spacing of Clause 6.13.2.

6.7.5 **Pipe flow condition.** Pipes shall be sized so that the minor design flow does not exceed the pipe-full capacity. The greater discharge that a circular pipe carries at about 0.95 of its depth shall not be relied on.

6.7.6 **Minimum sizes.**

- (a) Pipes: 300 mm internal diameter; **450 mm** for public mains.
- (b) Open drains: bed width 0.3 m.
- (c) Covered public drains (drains closed by cover slabs): clear internal width **0.6 m** and clear internal depth **0.6 m**.

6.7.7 **Cover to pipes.** Pipes shall have at least 0.6 m of cover to finished level, and at least 0.9 m under carriageways unless a structural design for the traffic load is submitted. Where the seasonal high groundwater table is within 1 m of the pipe crown, the pipe shall be checked for flotation with the pipe empty (CPHEEO 2019, Table 11.2) and anchored where necessary.

6.7.8 **Sediment allowance.** The design capacity of open drains, covered drains and pipes of 600 mm diameter or more shall be computed with the following depth of sediment at the invert:

- (a) open and covered drains: the greater of **75 mm** and **10%** of the clear internal depth;
- (b) pipes of 600 mm diameter or more: **5%** of the internal diameter;
- (c) pipes below 600 mm: no allowance, but Clause 6.7.3(a) shall be met.

The Manning n for the reduced section shall be that of the drain material in Table 6.6.

6.7.9 **Freeboard in open and covered drains.** At the minor design flow, the water surface (computed with the sediment allowance) shall be below the top of the drain wall, or below the soffit of the cover slab in a covered drain, by at least the freeboard of Table 6.7.

Table 6.7 — Minimum freeboard in open and covered drains

Drain	Minimum freeboard	Source
Bed width up to 300 mm	100 mm	CPHEEO 2019 Table 5.3 (from IRC:SP:50-2013)
Bed width 300–900 mm	150 mm	CPHEEO 2019 Table 5.3
Bed width 900–1,500 mm	300 mm	CPHEEO 2019 Table 5.3
Wider drains and engineered channels, Q < 3 m³/s	450 mm	CPHEEO 2019 Table 5.12 (from IS 7784 (Part 1): 1993)
Q 3 to < 30 m³/s	600 mm	As above
Q 30 to < 300 m³/s	900 mm	As above
Q 300 to < 3,000 m³/s	1,200 mm	As above
Q ≥ 3,000 m³/s	1,500 mm	As above

Drain	Minimum freeboard	Source
Any roadside drain	Not less than 150 mm	IRC:SP:42-2014
Steep (supercritical) channels	Equal to the flow depth	CPHEEO 2019 §5.3.2

At bends, the freeboard shall be measured from the water level on the outside of the bend, including the superelevation $\Delta y = V^2 T / (2\,g\,r_c)$, where T is the top width and r_c the centreline radius (CPHEEO 2019, Eq. 5.29).

6.7.10 **Bends and junctions.**

- (a) The centreline radius of a bend in a drain shall be at least 3 times the drain width (CPHEEO 2019 §5.3.3). In engineered channels it shall be at least 2 times the top width and not less than 30 m (CPHEEO 2019 Table 5.11).
- (b) Where drains meet, a junction sump shall be provided with an internal width of at least twice the width of the outgoing drain. Incoming drains shall enter at less than a right angle to the outgoing flow, and the outgoing invert shall be below the sump floor so that water does not stand in the sump (CPHEEO 2019 §5.3.4).

6.7.11 **Manholes and access chambers on pipes.** Manholes shall be provided at every junction, change of size, alignment or gradient, and at the head of every pipe. Spacing on straight runs shall not exceed Table 6.8.

Table 6.8 — Maximum spacing of manholes on straight pipe runs

Pipe diameter	Maximum spacing
300–600 mm	40 m
700–1,000 mm	100 m
1,050–1,400 mm	150 m
1,500 mm and above	300 m

Source: CPHEEO 2019 Table 11.5. Manhole sizes, drops and covers: Chapter 9, Clause 9.12.

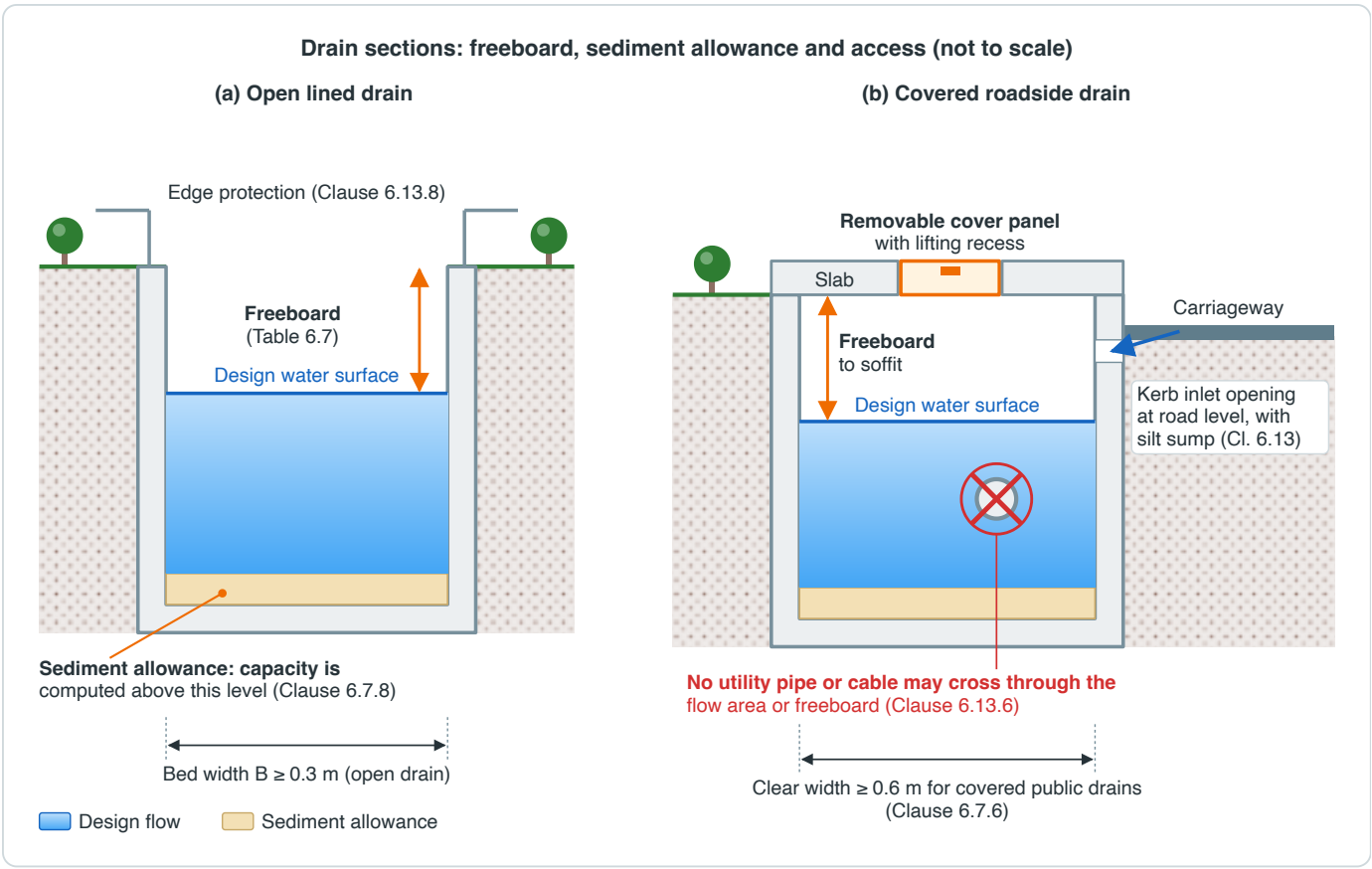


Figure 6.3 — Drain sections: freeboard, sediment allowance and access. Original drawing for this Manual, adapted from CPHEEO, Manual on Storm Water Drainage Systems (2019), Tables 5.3 and 5.12, and IRC:SP:50-2013.

Commentary. The n values are those of CPHEEO (2019) Table 5.1. The higher minimum design values have no direct precedent; this Manual sets them because CPHEEO notes that the 0.011 value for spun pipes "may be taken as given by the manufacturer". That is a clean-pipe value, and Rajasthan drains carry heavy silt and solid waste. The 0.6 m/s minimum velocity is CPHEEO's (Table 5.2), based on carrying 0.09 mm sand (§5.3.1). The 0.9 m/s value for pipes is stricter, because a silted pipe cannot be cleaned as easily as an open drain. The 3.0 m/s maximum is from CPHEEO Table 5.2 (WPCF/ASCE 1982). The Froude limit of 0.8 is from CPHEEO §5.3, which advises avoiding critical flow because the water surface becomes unstable.

The 0.6 m × 0.6 m minimum for covered drains has no direct precedent and is set by this Manual. A covered drain narrower than this cannot be desilted by hand or by small machines through a cover opening, and silted, inaccessible drains were a recurring finding after floods in other States; no survey of the condition of the drains of any Rajasthan city was found during research [TBC], but in July 2026 the Chief Minister was reported to have directed that the drains be cleaned in full (as reported), and in the same month the High Court asked JDA to explain why it had not built the drain channels near Ambawadi recommended for the Dravyavati catchment in a NEERI report (*Alok Gupta v. State*, order of 25 July 2026, as reported). The 0.6 m minimum cover is the value used in the CPHEEO (2019) worked pipe-design computation sheet (Part A, Chapter 5). The 0.9 m cover under carriageways is set by this Manual.

The sediment allowance values (75 mm or 10% for drains, 5% for large pipes) are set by this Manual. No Indian standard sets a sediment allowance for design. Jaipur's experience is that drains run partly full of silt for much of the year, so a capacity computed for a clean section overstates the real capacity.

The CPHEEO freeboard table (Table 5.3) prints the first row as "Beyond 300 mm bed width". Read with the second row ("Beyond 300 mm & up to 900 mm"), the first row must mean "up to 300 mm"; Table 6.7 is written that way. The CPHEEO manhole spacing table (Table 11.5) gives overlapping ranges (700–1,050 mm and 1,000–1,400 mm); Table 6.8 removes the overlap by assigning 1,050 mm to the 150 m class.

6.8 Hydraulic grade line

6.8.1 **HGL analysis.** For every pipe and covered-drain network, the designer shall compute the HGL for the minor design event and for the check event, starting at the outfall and working upstream. The analysis shall include friction losses and losses at junctions, manholes, bends, inlets, outlets and gates.

6.8.2 **Starting water level.** The starting (tailwater) level at the outfall shall be the higher of:

- (a) the tailwater level of Chapter 5: mean high water springs (MHWS) plus the sea-level allowance of +0.3 m for minor-system design at tidal outfalls, and the level in the receiving drain, river or tank for the coincident event at other outfalls; and
- (b) the level computed at the outlet pipe from the critical depth and the pipe diameter, (dc + D)/2, where the receiving water is lower.

6.8.3 **Minor-event limit.** In the minor design event, the HGL shall be at least **0.3 m below** the rim of every inlet and the cover level of every manhole and access chamber.

6.8.4 **Check-event and 1% limit.** In the check event and the 1% AEP event, the HGL may rise above the inlet rims. Water that leaves the minor system shall then be carried by the major system within the limits of Table 6.2 and shall not enter any building. Manholes that can surcharge above ground in these events shall have bolted or locked covers (Chapter 9, Clause 9.12).

6.8.5 **Structure losses.** Losses at manholes and junctions shall be computed by the energy-based access-hole method of FHWA HEC-22 (2009 or 2024 edition), or by an equivalent method in an approved hydraulic model. A simplified loss-coefficient method ($h = K V^2/2g$) with coefficients from HEC-22 may be used for Tier B networks below 16 ha.

6.8.6 **Invert and soffit levels.** Where pipe size increases at a manhole, the soffits (crowns) of the incoming and outgoing pipes shall be matched, or the outgoing soffit set lower. The outgoing invert shall not be higher than the lowest incoming invert. Vertical drops in manholes shall follow Chapter 9, Clause 9.12.

6.8.7 **Gates and valves.** The head loss through flap gates and non-return valves in the open position shall be included in the HGL (Chapter 9, Clause 9.10).

6.8.8 **Private connections.** Building drainage that connects to a public drain whose 1% HGL is above the building's lowest drainage fitting shall have a non-return valve.

Commentary. The 0.3 m clearance between the minor-event HGL and the inlet rim is set by this Manual. It keeps a margin for losses that a model underestimates, and it stops water from bubbling out of inlets in the event the system is designed for. In Rajasthan many city drains end in a lake held at its full gauge by gates or an escape channel, in a river held high by the releases of the dams above it, or in a closed depression with no outfall at all (Clause 5.8.5). In Jaipur the nalas end in the Dravyavati, a channel designed for the 100-year flood (JDA, Dravyavati EIA), so the level at each nala outfall is set by the Dravyavati in the storm and not by the nala's own capacity. In Udaipur the drains end in lakes that are joined by gated channels and spill to the Ayad, in Ajmer in Ana Sagar or its escape channel, and in Kota in a Chambal raised by the releases of four dams. A drain whose HGL is started from a free outfall, or computed one length at a time without the lake, river or depression level and the

gates, fails in exactly that way. An HGL computed from the outfall, with the tidal tailwater of Chapter 5, exposes those errors at design stage. The MHWS plus 0.3 m starting level is from CPHEEO (2019) Table 6.2. The access-hole method is described in HEC-22 from the 2009 edition onward.

6.9 Major system: overland flow paths, easements and drainage reserves

6.9.1 **Streets as the primary major system.** Streets shall be graded so that the 1% AEP major-system flow is carried along the road reserve to a receiving waterway without being trapped, except at sags designed under Clause 6.10.

6.9.2 **Overland flow paths outside streets.** Where a major-system path leaves the road reserve, it shall be:

- (a) in public land, in the open space of a layout, or in an easement recorded on the layout approval and the title;
- (b) at least as wide as the 1% AEP flow top width plus 0.5 m on each side, and not less than 3.0 m;
- (c) kept free of buildings, compound walls, fences, fill, stored materials and planting that would obstruct flow;
- (d) graded to a continuous fall with no sag that lacks an outlet; and
- (e) within the hazard limits of Table 6.3.

6.9.3 **Compound walls.** A compound wall or fence shall not be built across a mapped overland flow path. Where a wall must cross one, it shall have openings with a total area that passes the 1% AEP flow with a 50% blockage, without raising the upstream water level above the limits of this chapter.

6.9.4 **Access along open drains.** Open drains with a top width of 2 m or more shall have a maintenance access strip at least 3.5 m wide along one bank, connected to a public road at intervals of not more than 500 m.

6.9.5 **Supply channels, surplus courses and tanks.** Tank supply channels and surplus courses are part of the major system and shall be protected under Chapter 7.

6.9.6 **Drainage reserves.** A drainage reserve is a strip of land, including the drain, kept free of buildings so that the drain can be maintained, widened and used as a flood path. A drainage reserve shall be provided:

- (a) along every public drain or channel with an internal width of 1.0 m or more that runs through or along a layout or site being developed or redeveloped;
- (b) along every drain or channel shown in an adopted Basin Stormwater Master Plan (Chapter 11), at the width of the future drain in that plan; and
- (c) along every new public drain with an internal width of 1.0 m or more built by a public body.

6.9.7 **Width.** The reserve shall be not less than the width in Table 6.9, measured from the drain's internal width W. The width is based on the **required** drain size (for a planned drain, the size in the master plan), not the existing size. Where the access strip of Clause 6.9.4 is wider than the margin in Table 6.9, the wider governs.

Table 6.9 — Minimum drainage reserve width (adopted from PUB Singapore)

Internal width of drain, W	Open drain	Closed (covered) drain
1.0 m to 1.2 m	3.0 m	W + 0.6 m
more than 1.2 m to 3.0 m	W + 2.6 m	W + 1.6 m
more than 3.0 m to 4.5 m	W + 3.5 m	W + 1.6 m
more than 4.5 m to 6.0 m	W + 4.5 m	W + 3.0 m
more than 6.0 m to 9.0 m	W + 6.0 m	W + 3.0 m
more than 9.0 m to 25.0 m	W + 7.5 m	W + 3.0 m

Internal width of drain, W	Open drain	Closed (covered) drain
more than 25.0 m	W + 12.0 m	W + 3.0 m

For an open drain, the larger part of the margin shall be on the side used for maintenance access.

6.9.8 **Use and protection.**

- (a) The reserve shall be shown as a separate plot on the layout or site plan and transferred to the Approving Authority free of cost, as roads and open space reservations are. Where the drain is a WRD channel, the reserve is transferred to WRD.
- (b) No building, compound wall, fence, ramp, step, fill or other structure shall be built in the reserve. Compound walls and boundary fences shall stand outside it.
- (c) The access strip in the reserve shall be level and continuous, and connected to a public road. Bollards or posts and chains may be used at entrances to keep out vehicles other than maintenance vehicles.
- (d) Where the reserve is not fenced off, its edge shall be marked with concrete markers at not more than 50 m spacing.
- (e) Services shall cross under the drain, with at least 1.0 m clearance below the invert, or over it on an approved structure. Services shall not run along the reserve inside the drain section.
- (f) A structure within 2 m of the edge of the reserve shall be designed to remain stable when the drain is excavated to 1.0 m below its invert. The design shall be signed by a qualified structural engineer.
- (g) The reserve counts toward the site's open space requirements only where the Approving Authority's rules allow it; it does not reduce any setback required by Chapter 7.

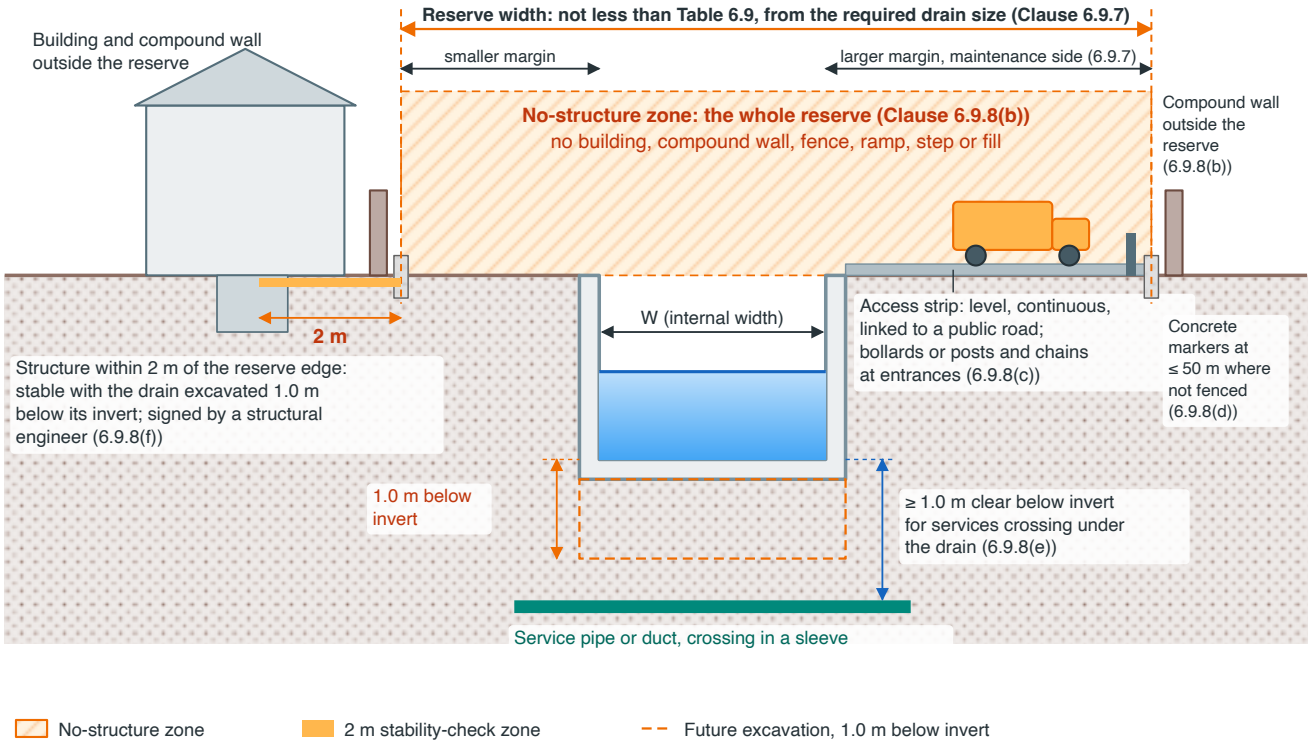


Figure 6.4 — Drainage reserve along an open drain: reserve width from Table 6.9, no-structure zone, access strip on the maintenance side, the 1.0 m service clearance below the invert and the 2 m stability-check zone (Clauses 6.9.6 to 6.9.8). Original drawing for this Manual, adapted from PUB Singapore, Code of Practice on Surface Water Drainage (7th ed., with Addendum No. 3, 2025), clauses 5.1, 5.3, 9.6 and 9.7 and Appendix 1.

Commentary. Drainage reserves follow Singapore, where "the width of a drainage reserve is based on the required drain size" and the reserve is set aside as a separate plot, "kept free of all encumbrances" (PUB Code of Practice on Surface Water Drainage, 7th ed. with Addendum No. 3, 2025, cl. 1.1). Table 6.9 reproduces PUB's Appendix 1 widths. Clauses 6.9.8(b) to (f) follow PUB clauses 5.1 (no structure within a drain or drainage reserve), 5.3 and 5.3.1 (stability for excavation 1.0 m below the invert; engineer's calculations within 2 m of the reserve), 9.6 (level, continuous access, with bollards or posts and chains) and 9.7 (markers at a maximum of 50 m). The 1.0 m clearance for services crossing under a drain is from PUB's development-plan guidance. In Rajasthan, buildings and compound walls are often built up to the edge of a drain, so it cannot be widened or desilted by machine. Reserving the land when a plot is developed or redeveloped is the cheapest time to secure it, because widening later needs land acquisition. Basing the width on the master-plan drain size (6.9.6(b)) protects the land a future drain will need. Rajasthan has no statutory reserve width along a nala. No setback from a nala, river or lake was found in the Model Rajasthan Building Regulations 2025 or in their predecessors, the Model Building Regulations 2020 and the JDA Building Regulations 2020; for a project of 5,000–20,000 m² of built-up area, the JDA regulations require only that "the inlet and outlet points of the natural drainage system be kept as they are" and that the channel be "adequate to ensure the unobstructed flow of water" (Annexure 4, translated; the 2025 schedule carries the same text, not read in full), and they let the norms of a lake protected area override them (reg. 10.4). The Rajasthan Municipalities Act 2009 vests in the Municipality, as trustee, "all public tanks, streams, reservoirs" with "any adjacent land, not being private property, appertaining to any public tank", and "all public sewers and drains, channels, tunnels, culverts and watercourses in, alongside, or under, any street" (s.68(1)(c) and (d)); it provides that "No building shall be newly constructed or reconstructed over any sewer, drain, culvert or gutter vested in the Municipality without the written consent of the Municipality", which may require the building to be pulled down (s.213(2)); and it bars the construction or occupation of a building until a drain has been built "at such level and with such fall" as the Municipality finds "necessary for the effectual drainage" of it (s.202) (all as read from a third-party copy of the Act). Section 213(2) protects only the drains vested in the Municipality, not the natural nalas outside the streets. For those the line has been drawn by the courts. The High Court recorded the State's concession that natural resources such as a "river, lake etc. cannot be disturbed while preparing the Master Development Plan or modifying the same", in answering a question on the land of nadis, ponds, lakes, river beds and catchment areas (*Gulab Kothari v. State of Rajasthan*, DBCWP 1554/2004, 12 January 2017), and had already restrained the allotment of land "falling in catchment areas of water reservoirs like Johar, Nala, Tank, River, Pond" (suo motu SBCWP 11153/2011, order of 29 May 2012, as quoted). In 2026 it held that land recorded as "Gair Mumkin Nala" "constitutes a natural drainage and water flow channel" that cannot be "diverted, obstructed or altered for any non-conforming purpose merely on the ground that the utilisation is for a public purpose", ordered a road and a crematorium built on such land removed, and directed that adjoining land so recorded be kept to its recorded character (*Ramji Lal Saini v. State of Rajasthan*, D.B. CWP 6614/2021, 7 May 2026). The Supreme Court has directed the State to determine and demarcate "the High Flood Line and the requisite ecological buffer zone qua all the river systems in the State" and, until that is done, to grant no fresh permissions "facilitating industrial, commercial or residential development within the identified river corridors" (*In Re: 2 Million Lives at Risk, Contamination in Jojari River, Rajasthan*, Suo Motu WP (C) 8 of 2025, order of 7 August 2026). None of these gives a reserve width along a nala. This Manual therefore gives the reserve a width, as its own proposal and not as a statutory width: a **hydraulic corridor** made up of the reserve of Table 6.9, based on the drain size needed to carry the design flow (Clause 6.9.7), the access strip of Clause 6.9.4 on the access bank, and, along a natural drain or a drain of WRD that drains 8 ha or more, the setbacks of Clause 7.4 measured from its top of bank, or from the edge of the land recorded as gair mumkin nala where that is wider, with a Zone 1 of at least 15 m; where a 1% AEP flood extent has been mapped, it governs Zone 2, and where a court or the State has set a wider line, such as the 100 m from the edge of the Jojari in the Supreme Court's interim order of 24 August 2026 (as reported), the no-construction zone around the Udaipur lakes (notification of 17 January 1997; 200 m from the high flood level around Udai Sagar, as reported), or the High Flood Line and ecological buffer that the State demarcates under the order of 7 August 2026, that line applies for as long as it binds (Chapter 7). For this Manual, every nala that drains 8 ha or more is a natural channel under Clause 7.4.1(b), whoever maintains it and whether or not it is lined, piped or covered, and land recorded in the revenue records as gair mumkin nala, nadi or talab is part of the channel or waterbody whatever its present use (set by this Manual). The corridor is set by this Manual.

It should be shown in the master plans and in the layout and scheme plans that the development authorities, Urban Improvement Trusts and local bodies approve, with the revenue (khasra) map overlaid so that every gair mumkin nala, nadi and talab is shown, rather than made a new NOC.

The reserve matters because the drains of Rajasthan's cities are divided among owners, and no rule divides them. The Rajasthan Municipalities Act 2009 vests the public drains and the drains in, alongside or under a street, and the public tanks, in the Municipality (s.68(1)); land recorded as gair mumkin nala, nadi or talab outside the vested drains is State land under the Revenue Department, on which the Rajasthan Tenancy Act 1955 lets no khatedari rights accrue in tank and river beds (s.16, as reported); WRD holds the dams, reservoirs and canals; the development authorities, the Urban Improvement Trusts and colony developers build the drains of the schemes and layouts they develop; RIICO builds the drains of its industrial areas; and a lake of 3 ha or more (heritage or religious) or 10 ha or more falls under the Rajasthan Lakes (Protection and Development) Authority Act 2015 once its boundaries are notified, of which none was found. No rule dividing the natural nalas from the municipal drains was found during research. For the purposes of this Manual, and until the State issues such a rule [TBC], the drains are assigned as follows: rivers, dams and their gates, reservoirs, canals, including the Indira Gandhi Canal and its escapes, and the drains of canal commands to WRD; the nalas, road drains and lane drains within the limits of an urban local body, and the tanks vested in it under s.68, to its Municipal Corporation, Municipal Council or Municipal Board; the internal drains of a scheme or colony that has not been handed over to the local body to the development authority, Urban Improvement Trust or developer that built it; the drains of an industrial area to RIICO; highway drains to PWD or NHAI; and land recorded as gair mumkin nala, nadi or talab outside those drains to the Collector, to be kept to its recorded character (set by this Manual). Under Clause 6.9.8(a), the reserve along a WRD drain is transferred to WRD. Where a channel's status is disputed, the corridor follows the channel and not its name: the Dravyavati is both a river and the trunk drain of Jaipur. The only design standard found for a city channel in the State is the Dravyavati's, designed "to make the river section capable of safely passing the hundred year flood" (JDA, Dravyavati EIA), whose design discharge was not found [TBC]; RUIDP's drainage guidelines of 2008 allowed a return period of "1-2 years" for town drains (RUIDP Circular No. 8), below every value of Table 6.1, and no approved city drainage master plan with a design return period was found. Until a Basin Stormwater Master Plan is adopted (Clause 6.9.6(b)), the required drain size of Clause 6.9.7 is the size computed by the designer under this chapter. This Manual does not prescribe a lined or an unlined section. It requires the section to meet the velocity limits of Clause 6.7.3 and Chapter 9, and a reserve wide enough for an unlined or vegetated section is a reserve that keeps both options open.

Commentary. Requirements 6.9.2(b)–(e), 6.9.3 and 6.9.4 have no direct precedent and are set by this Manual. Compound walls around individual plots are almost universal in Rajasthan and are one of the most common ways that overland flow paths get blocked. The 50% blockage assumption for wall openings is set to match the grate clogging factor of Clause 6.6.3. The 3.5 m access width is set by this Manual, sized for a small excavator or desilting vehicle. For comparison, APWA 5600 (2006, 5608.4) requires a 15 ft (about 4.6 m) maintenance access strip for detention facilities.

6.10 Ponding at sags and low points

6.10.1 **Minor event.** At every sag, the minor design flow shall be removed by inlets (after clogging) with ponded spread within Table 6.2.

6.10.2 **1% AEP event.** At every sag:

- (a) the ponded depth shall not exceed 350 mm at the deepest point of the carriageway;
- (b) a surface overflow route shall be provided (for example over a lowered kerb and footpath into a designated overland flow path), so that the ponding level cannot rise above the overflow level; and

- (c) building floor levels around the sag shall comply with Clause 6.11.

6.10.3 **Fully-blocked check.** At sags, the 1% AEP ponding level shall also be computed with the minor system fully blocked and all flow leaving by the surface overflow route. Floor levels around the sag shall be set from the higher of the two ponding levels.

6.10.4 **Trapped sags.** Where a sag has no surface overflow route, the inlets and conduits (after clogging) shall carry the 1% AEP flow, and the approving authority shall agree the arrangement.

6.10.5 **Road underpasses.** Underpasses and other trapped sags on public roads shall:

- (a) be drained by a minor system (with pumping under Chapter 9, Clause 9.9, where gravity drainage is not possible) designed for the 2% AEP (50-yr) flow, checked at the 1% AEP flow;
- (b) have flanking inlets at both approaches to intercept flow before it reaches the low point;
- (c) be protected from inflow from surrounding streets by raised approach crests where practicable; and
- (d) have depth markers and automatic warning or closure signals that operate at 150 mm depth on the carriageway.

> Commentary. The fully-blocked check, the trapped-sag rule and the underpass requirements have no direct precedent and are set by this Manual. No record of an underpass flooding in Rajasthan was found during research [TBC]. The same failure has been reported in a building: on 31 July–1 August 2024 three members of one family died in a flooded basement in the Vishwakarma Industrial Area of Jaipur, a trapped sag with no overflow route (as reported). The roads already act as the major system: in July 2026 Tonk Road, Rambagh and the walled city of Jaipur were waterlogged after about 35 minutes of heavy rain (as reported). Clause 6.10.5(d) links the 150 mm crown depth limit of Table 6.2 to the point at which traffic should stop.

6.11 Building floor levels

6.11.1 The lowest habitable floor, and every opening through which water could enter a building (doors, ventilators, basement ramps, lift pits and service entries), shall be at least **0.5 m above the 1% AEP flood level**.

6.11.2 The 1% AEP flood level is the highest of:

- (a) the 1% AEP major-system water level in the street or overland flow path next to the building (Clauses 6.9 and 6.10, including the fully-blocked check at sags);
- (b) the 1% AEP flood level of any river, channel, tank or waterbody (Chapter 7); and
- (c) the 1% AEP level with the tailwater of Chapter 5; and
- (d) where the Approving Authority has adopted a 1% AEP flood depth map under Clause 7.3.4, the ground level at the plot plus the mapped 1% AEP depth.

6.11.3 **Default where no level has been computed.** For a plot below the Chapter 1 thresholds, or where no 1% AEP level has been computed for the plot, the lowest habitable floor and openings shall be at least the higher of:

- (a) **0.65 m above the highest crown level of the road on which the plot fronts**; and
- (b) where an adopted 1% AEP flood depth map covers the plot, **the ground level plus the mapped 1% AEP depth plus 0.5 m**.

The Approving Authority may adopt a regional map, such as a State-approved map or a published national map of modelled 1% AEP flood depth (for example the India Flood Atlas), until a local study replaces it. A map that does not model storm surge shall not be used in place of Clause 6.11.6.

6.11.4 **Basements.** The crest of every basement ramp and the sill of every basement opening shall meet Clause 6.11.1. Basement drainage shall be pumped to the surface drain through a non-return valve.

6.11.5 **Services.** Electrical panels, transformers, standby generators, lift machinery and pumps that serve a building shall meet Clause 6.11.1.

6.11.6 **Coastal band.** The coastal band is the land within **500 m** landward of the High Tide Line along the sea front, as defined by the CRZ Notification, 2019, with the High Tide Line as demarcated in the approved Coastal Zone Management Plan. Where the Survey of India Hazard Line lies further inland than 500 m, the band extends to the Hazard Line. Within the coastal band, in addition to Clauses 6.11.1 to 6.11.5:

- (a) the lowest habitable floor and every opening shall also be at least **0.5 m above the coastal flood level**, which is the 1% AEP still-water level (Clause 5.7.3(b), Annex 5A) plus **twice** the sea-level allowance of Clause 5.7.4 (so at least 0.6 m), because buildings have a design life of more than 50 years (Clause 5.7.4(c));
- (b) where the plot fronts the open beach, the coastal flood level shall include wave set-up from a site study;
- (c) no habitable room, electrical service room or plant listed in Clause 6.11.5 shall be placed in a basement; and
- (d) every basement opening, ramp crest and ventilation opening shall meet Clause 6.11.6(a).

Clause 6.11.6 does not authorise any construction that the CRZ Notification prohibits. Where both apply, the stricter governs.

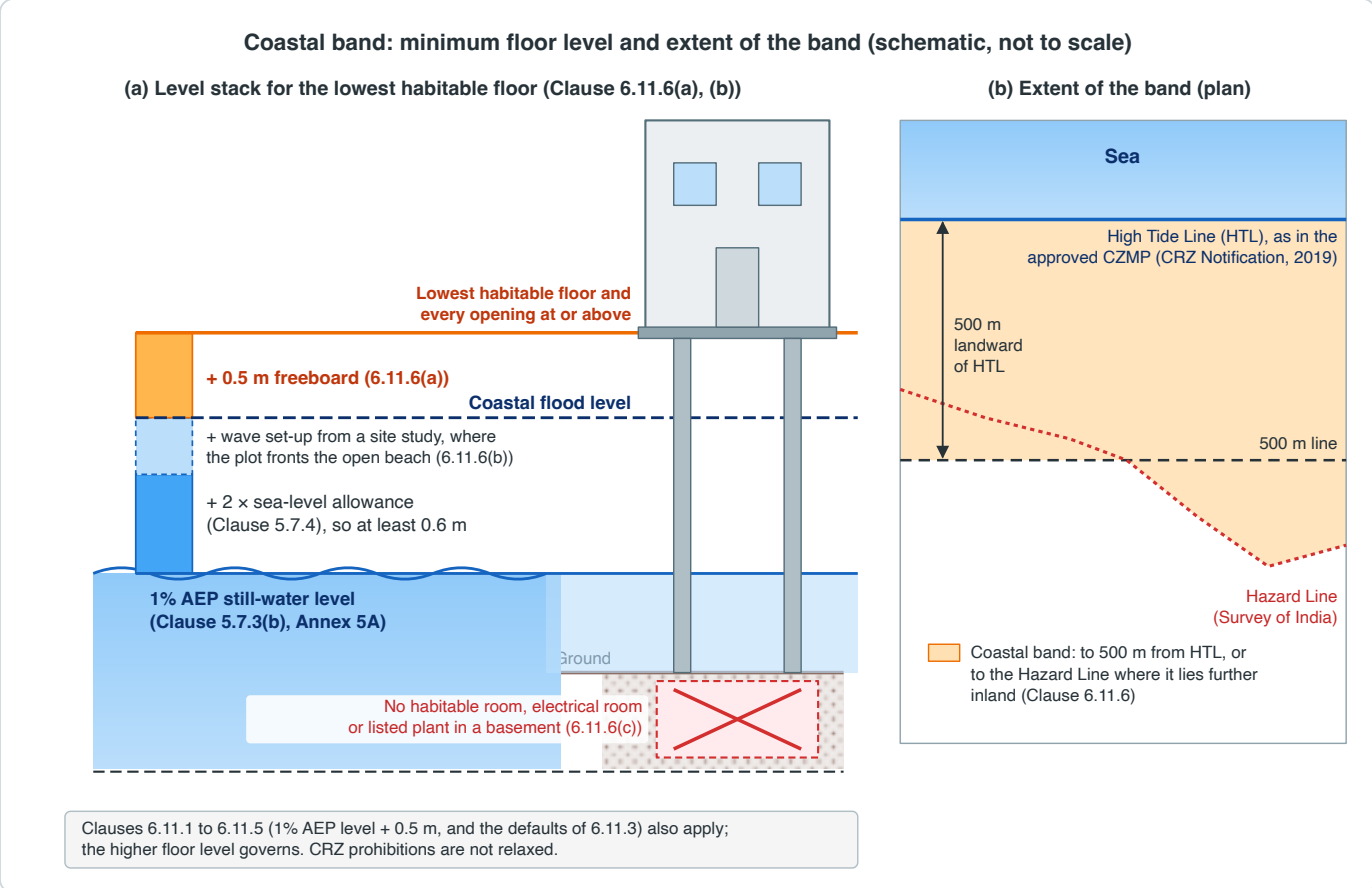


Figure 6.5 — Coastal band: the minimum floor level built up from the 1% AEP still-water level, twice the sea-level allowance, wave set-up where the plot fronts the open beach and 0.5 m freeboard; and the extent of the band, to 500 m from the High Tide Line or to the Hazard Line where it lies further inland (Clause 6.11.6). Original drawing for this Manual, adapted from the CRZ Notification, 2019 (para 1(i) and Annexure IV) and PUB Singapore, Code of Practice on Surface Water Drainage (7th ed.), cl. 2.1.1.

Commentary. The 0.5 m freeboard above the 1% AEP level follows the DID Malaysia 2008 checklist (platform and lowest floor at 100-yr ARI + 0.5 m). It is more than the APWA 5600 (2006, 5601.8 A2) requirement of 1 ft (about 0.3 m) above the 1% stage. The 0.65 m default in Clause 6.11.3 is derived from the other limits of this chapter, not separately sourced: the 1% water level at the crown may be up to 150 mm (Table 6.2), plus the 0.5 m freeboard. It has no direct precedent and applies to plots where no flood level exists. URDPFI (2015) also links minimum plinth levels to flood frequency in its flood-plain zoning, which is covered in Chapter 7.

Clause 6.11.3(b) lets a small plot use a mapped 1% AEP depth where no local study exists, instead of guessing from the road level alone. Modelled national maps are coarse (about 30 m), and most model rainfall and river flooding but not storm surge, which is why 6.11.3 keeps the road-crown check and Clause 6.11.6 sets a separate coastal rule.

The coastal band of Clause 6.11.6 uses the 500 m line of the CRZ Notification, 2019 (G.S.R. 37(E), para 1(i): "the land area from High Tide Line ... to 500 meters on the landward side"), because every coastal authority already maps it and it needs no new survey. The Hazard Line, demarcated by the Survey of India to show the extent of flooding and shoreline change, extends the band where it lies further inland (CRZ Notification, 2019, Annexure IV). The band takes the coastal level from the joint-case still-water level of Chapter 5 rather than from the rainfall map. The higher standard reflects the setting: a coastal flood rises with the sea, cannot be drained while the tide is up, and will rise further with the sea. Singapore takes the same approach with a fixed minimum platform level of 4.0 m above datum on its southern coast and 4.5 m on its northern coast, whatever the rainfall flood level (PUB Code of Practice on Surface Water Drainage, 7th ed., cl. 2.1.1). Each coastal State's tide and surge levels vary too much along its coast for one fixed level, so this Manual uses the computed still-water level instead. Using twice the sea-level allowance applies the sensitivity case of Clause 5.7.4(c) as the design case, because a building, unlike a drain, cannot easily be raised later. The basement restriction in 6.11.6(c) is set by this Manual: a basement in the coastal band fills from the sea as well as from rain, and cannot be pumped out to a tide-locked outfall. Rajasthan has no coast, no High Tide Line and no Coastal Regulation Zone, so the coastal band is empty in the State and Clause 6.11.6 does not apply there. Clauses 6.11.3 and 6.11.4 matter instead. The Model Rajasthan Building Regulations 2025 require the plinth to be at least 0.45 m above the road in front of the plot, and at least 0.15 m above an internal driveway, with a maximum plinth height of 1.2 m (reg. 6.6); they limit the number of basements by plot size and keep basements inside the setbacks (reg. 6.5), and the JDA Building Regulations 2020 cap the roof of a basement that extends beyond the building at 1.20 m above road level (reg. 11.6(v)). No clause on keeping surface water out of a basement was found in the pages read, and the regulations recognise waterlogged areas only to exempt them from rainwater harvesting once the local body has marked them (reg. 8.3(iii)); they do not restrict basements there. Clause 6.11.3, which sets the lowest habitable floor and every opening 0.65 m above the road crown where no flood level has been computed, and Clause 6.11.4, which applies the same level, or 0.5 m above the 1% AEP flood level, to the crest of every basement ramp and the sill of every basement opening, are set by this Manual and are stricter than the regulations; 0.65 m lies within the 1.2 m plinth that the regulations allow, so the two can be met together. The deaths in a flooded basement in Jaipur in August 2024 (as reported) are the failure these clauses address. Near the Udaipur lakes, Ana Sagar and the Jojari, and on land recorded as gair mumkin nala, nadi or talab, the lines of Chapter 7 also apply.

6.12 Culverts and road crossings

6.12.1 **Design AEP.** A culvert or bridge that carries a road over a drain or waterway shall pass the design AEP flow of Table 6.1 for that road class without overtopping the road, and with the headwater limits of Chapter 9, Clause 9.4. Where the waterway is a State highway or national highway crossing, the design AEP shall also be not less than that of IRC:SP:42-2014 §7.1.4 for the span. The rarer AEP governs.

6.12.2 **Check event and 1% AEP.** At the check event and at the 1% AEP event, the crossing and the road together shall pass the flow:

- (a) with overtopping depth ≤ 150 mm at the road crown and ≤ 350 mm at the deepest point of the road;
- (b) within the hazard limits of Table 6.3;
- (c) with no overtopping at all of arterial roads that are notified evacuation routes; and
- (d) without raising the 1% AEP flood level at any upstream building or property boundary above the level for the existing condition, unless the affected owners and the approving authority agree.

6.12.3 **Where overtopping is not permitted.** Overtopping in the 1% AEP event is permitted only where the structure span is less than 6 m **and** the 1% AEP peak flow is not more than 7 m³/s, unless a guard rail is installed downstream of the overtopping section. Otherwise, the crossing shall pass the 1% AEP flow without overtopping.

6.12.4 **Blockage check.** The 1% AEP check shall be repeated with a blocked inlet:

- (a) 50% of the inlet area blocked for culverts with a span or diameter below 1.5 m; and
- (b) 20% blocked for larger culverts.

The results of this check shall meet Clause 6.12.2(a) and (d).

6.12.5 **Minimum size.** Culverts under public roads shall be at least 900 mm in diameter, or 900 mm × 900 mm for box culverts.

6.12.6 **Hydraulic design.** Culvert hydraulics, including inlet and outlet control, tailwater, road overtopping and outlet protection, shall follow Chapter 9, Clauses 9.4 and 9.6.

> Commentary. The design AEPs are those of Table 6.1. The overtopping limits are the street-depth limits of Table 6.2. The span and flow threshold in Clause 6.12.3 is the SI conversion of APWA 5600 (2006): overtopping allowed only where the structure span is under 20 ft and the 1% peak is 250 cfs or less, unless a downstream guard fence is installed. IRC:SP:42-2014 (§7.1.4) sets 25-yr for NH/SH culverts up to 2 m span and 50-yr for 2–6 m spans. The blockage percentages in Clause 6.12.4 and the 900 mm minimum size have no direct precedent and are set by this Manual. The 50% value matches the grate clogging factor.

6.13 Rajasthan construction-practice requirements

6.13.1 **Covered roadside drains.** Where a roadside drain is covered by slabs that form a footpath:

- (a) it shall be designed as an open channel with the freeboard of Table 6.7 measured to the soffit of the cover slab, and its HGL shall meet Clause 6.8 measured to the footpath and inlet levels;
- (b) road runoff shall enter through openings in the drain wall at road level (Clause 6.6.1(b)), each with a silt sump (Clause 6.6.7), at the spacing of Clause 6.6.4;
- (c) footpath runoff shall enter through slots or grated openings in the cover, not by ponding on the footpath; and
- (d) the clear section shall meet Clause 6.7.6(c).

6.13.2 **Removable covers and access openings.** Covered drains shall have:

- (a) removable cover panels at not more than **10 m** centres, each at least 0.6 m long and spanning the full clear width, with recessed lifting points, liftable by two workers or by a hand-operated lifting device, and flush with the footpath;
- (b) access chambers with a clear opening of at least 0.6 m × 0.6 m at every junction, bend and change of section, and at not more than **30 m** centres on straight runs; and
- (c) covers rated for the traffic or pedestrian load at their location (Chapter 9, Clause 9.11).

6.13.3 **Silt traps.** In addition to the inlet sumps of Clause 6.6.7, silt trap chambers shall be provided:

- (a) upstream of every culvert under an arterial road;
- (b) upstream of every pump station and detention facility; and
- (c) at every outfall to a tank, river or other waterbody (with the gross pollutant trap required by Chapter 8).

Each silt trap shall be sized to hold the sediment expected between scheduled cleanings, using the sediment yield in Annex 6B, and shall be reachable by a desilting vehicle.

6.13.4 **Garbage and gross pollutant screens.** Screens shall be provided where an open drain enters a covered drain, a pipe or a culvert, and at outfalls under Chapter 8. Each screen shall:

- (a) be designed under Chapter 9, Clause 9.8;
- (b) have a bypass or overflow, so that a fully blinded screen does not flood properties or the road beyond the limits of this chapter; and
- (c) be checked hydraulically with 50% of its area blocked.

6.13.5 **No building over drains.** No structure other than an approved crossing or a removable cover shall be built over a public drain. Shop frontages, ramps and steps that cross a drain shall be removable or shall leave access openings that meet Clause 6.13.2.

6.13.6 **Utilities.** No water main, sewer, power or telecom cable, gas pipe or duct shall be laid along, or pass through, the flow area or freeboard of any drain. A utility that must cross a drain shall:

- (a) cross above the cover soffit or below the drain invert, inside a sleeve; and
- (b) be shown on the drainage plan with its level.

Where an existing utility crossing obstructs a drain, its area shall be deducted from the drain section, with a 50% blockage allowance for the debris it traps, until the utility is relocated. The utility owner shall relocate it when the drain is rebuilt.

6.13.7 **Sewage.** No sewage connection is permitted to a storm drain (Chapter 8). Covered drains shall be built with sealed joints where they run next to sewers.

6.13.8 **Edge protection.** Open drains deeper than 1.0 m beside a footpath, a carriageway or a public open space shall have railings or barriers. Open drains of any depth shall not be left uncovered across a footpath.

6.13.9 **As-built levels.** The as-built invert levels of every public drain, pipe and manhole shall be surveyed and submitted (Chapter 10). Inverts shall be within ±15 mm of design. An HGL re-check shall be submitted where they are not.

6.13.10 **Desilting.** Public drains shall be desilted before the south-west monsoon each year, as set out in Chapter 10.

> Commentary. Clause 6.13 has no direct precedent; this Manual sets it on the basis of Rajasthan practice. Most urban drains in the State are covered roadside drains under footpaths. They are often built with continuous cast-in-situ slabs and few openings, so they cannot be cleaned and fill with silt and solid waste within a season. CPHEEO (2019) notes that uncovered channels "are prone to the dumping of garbage" (Part A, Ch 2), which is why the drains are covered. Covering without access openings simply moves the problem out of sight. NDMA (2010) recommends that pre-monsoon desilting be complete by 31 March. In Rajasthan the south-west monsoon normally sets in at Jhalawar on 24 June, at Udaipur on 25 June, at Kota on 26 June, at Jaipur on 29 June, at Ajmer on 1 July, at Jodhpur on 2 July and at Bikaner and Pokaran on 6 July, and normally withdraws from Pokaran on 17 September, from Jaipur on 23 September, from Kota and Udaipur on 25 September and from Jhalawar on 28 September (IMD, new normals). So Clause 6.13.10 refers to the south-west monsoon, and Chapter 10 requires desilting and drain works to be complete by 15 June, when the State's disaster control rooms begin to run round the clock (as reported); the gates, sluices, escape channels, flap gates, pumps and standby generators are certified ready and test-run by 20 June (Clauses 5.11.5 and 5.12.9), before the normal onset everywhere except

Jhalawar; and pumps and gates stay on standby until 30 September, after the last normal withdrawal. Large storms also fall before the onset, such as Ajmer's 412.3 mm on 10 June 2002 (IMD) and 131.8 mm at Ajmer in Cyclone Biparjoy on 18–19 June 2023 (as reported), which is why the drain works are not left later than 15 June. No desilting order of the State was found during research [TBC]: the drives of the Jaipur corporations are reported without dates, and the Chief Minister's direction of July 2026 that the drains be cleaned in full was reported without one. These dates are therefore set by this Manual.

The JDA Building Regulations 2020 require the inlet and outlet points of the natural drainage of a large project to be kept as they are (Annexure 4; the schedule of the Model Rajasthan Building Regulations 2025 carries similar text), and the Rajasthan Municipalities Act 2009 bars the construction or reconstruction of a building over any sewer, drain, culvert or gutter vested in the Municipality without its written consent (s.213(2)) and requires a drain for "the effectual drainage" of a building before it is built or occupied (s.202). Natural drains and the drains of WRD are open channels with a drainage reserve (Clause 6.9), and should not be covered, decked or built over: the High Court has ordered a road and a crematorium built on land recorded as gair mumkin nala to be removed and the land restored (*Ramji Lal Saini v. State of Rajasthan*, 7 May 2026). Where a drain is covered, Clause 6.13.2 applies to it in full.

Clause 6.13.7 is not yet the practice. The nalas of Jaipur carry storm and waste water to the Dravyavati (JDA, Dravyavati EIA), along which treatment plants of 170 MLD have been built, and an inspection in July 2026 still indicated sewage or industrial effluent downstream at the Morel dam (Supreme Court, 7 August 2026); Jodhpur generates about 230 MLD of sewage against treatment capacity of 120 MLD in November 2025 and about 175 MLD in March 2026, and treated and untreated sewage reaches the Jojari (Supreme Court, 21 November 2025 and 18 March 2026); and at Udaipur, where the Ayad takes the spill of the lakes, the High Court directed in 2026 that no untreated sewage reach the lakes (as reported). The Rajasthan Municipalities Act 2009 already requires sewage and rain-water drains to be kept distinct (s.204, by its title). Clause 8.9 sets how dry-weather flow in storm drains is surveyed and intercepted until the connections are removed, including the rule that interception shall not reduce the capacity of the drain (Clause 8.9.5(b)).

The 10 m and 30 m spacings and the ±15 mm tolerance have no direct precedent and are set by this Manual. Clause 6.13.6 responds to the common sight of water mains and cables running through drains. Each one traps debris and reduces the section. Mechanical cleaning through cover openings, rather than manual entry, is assumed throughout, consistent with the Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013.

6.14 Outfalls

6.14.1 Outfalls shall be designed for the tailwater conditions of Chapter 5. Outfalls below the 1% AEP still-water level shall have flap or tide gates or non-return valves (Chapter 5 and Chapter 9, Clause 9.10).

6.14.2 Outfall protection and energy dissipation shall be designed under Chapter 9, Clause 9.6. Outfalls to tanks and waterbodies shall also meet Chapters 7 and 8.

6.15 Submittal requirements

Every conveyance submittal shall include a **Conveyance Design Report** (Form 6-1) containing:

1. a catchment plan showing sub-catchments, the minor system, inlet locations and the major-system overland flow paths for the 1% AEP event (Clause 6.3.2);
2. the land-use and road-class AEP adopted for each element (Table 6.1), and the high-density area status;
3. design flows, with the rainfall sheet of Chapter 2 and the method of Chapter 3;

4. gutter spread, depth and D·V checks for the minor, check and 1% events (Tables 6.2 and 6.3);
5. an inlet schedule with clean capacity, clogging factor, design capacity and bypass flow (Clause 6.6);
6. pipe and drain design tables with n, velocity, sediment allowance and freeboard (Clause 6.7);
7. HGL profiles for the minor and check events, with the tailwater used (Clause 6.8);
8. sag ponding levels, including the fully-blocked check (Clause 6.10);
9. a floor-level schedule for every building (Clause 6.11);
10. culvert and crossing calculations (Clause 6.12 and Chapter 9); and
11. a utilities-crossing schedule and access-opening layout for covered drains (Clause 6.13).

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Annexes and forms

Annex / Form	Content
6A	Standard inlet types for Rajasthan with capacity curves (on grade and sag)

Annex / Form	Content
6B	Sediment yield for silt-trap sizing and calibration of the sediment allowance
6C	Standard drawings: covered roadside drain with removable covers, access chamber, inlet with silt sump
Form 6-1	Conveyance Design Report checklist

CHAPTER 7

Waterbodies, Talabs (Ponds) and Setbacks

7.1 Purpose and scope

7.1.1 This chapter treats waterbodies as part of the drainage system. It sets the rules for:

- (a) identifying and mapping every waterbody that a development or public work affects;
- (b) the setback zones around waterbodies, and the uses allowed in each zone;
- (c) fill in flood-prone land, and the compensatory storage needed where fill is allowed;
- (d) counting tank (talab) storage, including tank cascades, as design storage;
- (e) restoring and desilting tanks and ponds;
- (f) protecting supply channels, surplus courses, inlets and outlets;
- (g) wetlands, marshes and estuaries, which in Rajasthan, with no coast and no tidal water, means the four Ramsar sites (Keoladeo National Park, Sambhar Lake, Khichan and Menar), the wetlands that the Rajasthan State Wetland Authority notifies or lists under the 2017 Rules, the wetlands identified in the statewide survey ordered by the High Court in June 2026, the city lakes and sagars, the salt lakes and inland depressions, the floodplain wetlands of the rivers, and the talabs, johads and nadis recorded in the Revenue records;
- (h) the interface with encroachment and its removal;
- (i) fee-in-lieu contributions to regional tank storage (with Chapter 4); and
- (j) the safety of tank bunds and other embankments.

7.1.2 This chapter applies to every development and public work to which this Manual applies under Chapter 1 and that:

- (a) adjoins a waterbody or lies wholly or partly within its setback (Clause 7.4);
- (b) discharges to a waterbody, directly or through a drain, within the downstream analysis extent of Chapter 5; or
- (c) alters a waterbody, its bund, sluice, surplus weir, supply channel or surplus course.

7.1.3 Where a statute or statutory rule sets a wider setback or a stricter restriction, the statute governs (Clause 1.3.3). Nothing in this chapter authorises any work that the Rajasthan Lakes (Protection and Development) Authority Act, 2015, the Rajasthan Municipalities Act, 2009 (sections 68, 202 and 213), the Rajasthan Tenancy Act, 1955 (section 16), the Rajasthan Land Revenue Act, 1956, the Wetlands (Conservation and Management) Rules, 2017, or any other law, prohibits.

> Commentary. Rajasthan has a lake Act but no tank Act, and most of its talabs, johads and nadis are protected not by a statute of their own but by revenue law, municipal law and the courts. The **Rajasthan Lakes (Protection and Development) Authority Act, 2015** (as read from the Bill of 2015, the enacted text not having been read) vests the protection and development of all lakes in the State Government. It defines a "lake" as an inland water body, natural or man-made, "whether it contains water or not and whether it has been recorded as such in any revenue or other official record or not", that has had at any time in the fifty years before the Act a submerged area of at least 3 ha (where it has socio-cultural, heritage or religious importance) or 10 ha (in other cases) (s. 2(x)); it defines the "flow area" as "the area through which streams or feeders flow to the lake for its recharge" (s. 2(viii)); it lets the State notify lake boundaries and a protected area around a lake (s. 4); it requires every town planning authority to consult the Lakes Development Authority, and to have its prior approval for any spatial or development plan of an area with a lake, and bars construction in a protected area without permission (s. 5); and

it empowers the Authority to remove any obstruction within the protected area or the flow area (s. 6(2)). No notification of a lake boundary or protected area under the Act was found for this Manual. In the towns, all public tanks, streams, reservoirs and cisterns, with the adjacent land that is not private property, and all public drains, channels, culverts and watercourses in, alongside or under any street, vest in the Municipality, "held and applied by it as trustee" (Rajasthan Municipalities Act, 2009, s. 68(1)(c) and (d)); no express bar on putting a vested tank to another use was seen in that section. In the villages and on the urban fringe, khatedari rights do not accrue in pasture land and, as reported, in river and tank beds (Rajasthan Tenancy Act, 1955, s. 16), and talabs, nadis and nalas are recorded in the Revenue records as gair mumkin talab, nadi or nala (land that cannot be cultivated).

The High Court has carried this protection from the waterbody to its catchment. In *Abdul Rahman v. State of Rajasthan* (D.B. C.W.P. 1536/2003, 2 August 2004) it gave directions "to ensure free flow of water in the catchment areas of Ramgarh Dam", the reservoir of 1903 that supplied Jaipur, with a catchment of about 769.20 km² over four tehsils (as summarised by the Supreme Court in 2017); in a case it took up of its own motion (S.B.C.W.P. 11153/2011) it directed the departments in 2011 "to stop encroachment and illegal construction in the drainages, channels, nalas, river etc." of those tehsils and to plan the removal of encroachments "so as to restore the position as was existing on 15.08.1947", and on 29 May 2012 it restrained "allotment of the land falling in catchment areas of water reservoirs like Johar, Nala, Tank, River, Pond etc." (as quoted by the High Court in 2026). The Supreme Court found in 2017 that the Ramgarh lake was "still bone dry" (*National Institute of Medical Science University v. State of Rajasthan*, 9 November 2017). In *Gulab Kothari v. State of Rajasthan* (D.B. C.W.P. 1554/2004, 12 January 2017) the State conceded that natural resources such as rivers and lakes "cannot be disturbed while preparing the Master Development Plan or modifying the same", and in *Ramji Lal Saini v. State of Rajasthan* (D.B. C.W.P. 6614/2021, 7 May 2026) the High Court held that "a 'Gair Mumkin Nala' constitutes a natural drainage and water flow channel forming an integral part of the ecological framework and hydrological system", which cannot be diverted "for any non-conforming purpose merely on the ground that the utilisation is for a public purpose", and that "preservation of water bodies, natural drains, catchment areas and traditional water channels assumes even greater significance in a State like Rajasthan". On 7 August 2026 the Supreme Court directed the State to demarcate "the High Flood Line and the requisite ecological buffer zone qua all the river systems in the State", and until then to grant no fresh permissions for development within the identified river corridors (*In Re: 2 Million Lives at Risk, Contamination in Jojari River*, Suo Motu W.P. (C) 8 of 2025). Wetlands notified under the Wetlands (Conservation and Management) Rules, 2017, and the State's four Ramsar sites, are the concern of the **Rajasthan State Wetland Authority**, under the High Court's suo motu order of 1 June 2026 (Clause 7.12, Commentary).

This Manual treats every recorded talab, johad and nadi, with its recorded catchment (agor) and the flow paths that feed it, as drainage infrastructure. Rajasthan's traditional systems were built to catch the runoff of a catchment and hold it: the talab, johad and nadi of the villages and towns, the baori and jhalra (step-wells), the kund and the taanka (walled cisterns), and the khadin (a bund across a slope behind which runoff stands and is then farmed). A talab is only as good as its agor: the Ramgarh dam had "Less/no inflow … Despite Average and Above Average Rainfall" (Technical Committee report of 9 January 2013), after the High Court had ordered a survey of the parts of its catchment "misused for construction and mining purposes" (order of 18 July 2003; both as summarised by the Supreme Court in 2017). No design under this Manual shall assume or rely on the filling of a recorded talab, or on the blocking or diversion of a flow path that feeds it, unless a drainage assessment under Chapters 3 to 5 shows where the storage and the flow go, and the lost storage is replaced under Clause 7.6.4 (see "Recorded talab" and "Agor" in the definitions after Clause 7.2). The protection of the agor and its flow paths is this Manual's proposal, built on the court orders above; it is not a statutory rule, and where a court order or the Lakes Act gives wider protection, that governs. Neither the Model Rajasthan Building Regulations 2025 nor the 2020 regulations they replace set a setback from water; the nearest provision is the environmental condition for buildings of 5,000 to 20,000 m² built-up area that "the inlet and outlet points of the natural drainage system shall be kept as they are" and channels sized for unobstructed flow (Annexure 4 of the JDA regulations of 2020, in translation; Schedule 4 of the 2025 regulations is reported to carry the same text). This chapter gives the design

rules that protect waterbody storage and conveyance. It does not replace the revenue, municipal, planning, lake and wetland procedures that record and protect waterbodies in law, or the directions of the Supreme Court, the High Court and the National Green Tribunal.

7.2 Definitions

Term	Meaning in this Manual
Waterbody	A river or dry river bed (such as the Chambal, the Banas, the Luni, the Jojari, the Mahi, the Ghaggar and the Dravyavati), natural drain or nala, canal, lake, sagar or reservoir (such as Pichola, Fateh Sagar, Udai Sagar, Ana Sagar, Man Sagar, Kailana and the Ramgarh dam), talab or pond (talab, johad, nadi), baori or kund (step-well or small walled tank), taanka (walled cistern) that receives runoff, khadin (runoff-farming bund and its bed), salt lake, playa or inland depression with no outfall (such as Sambhar), marsh or low wet land, floodplain wetland or depression, abandoned quarry or borrow pit, supply channel or surplus course, perennial or seasonal (as in Chapter 1).
Tank (talab)	A waterbody impounded by an earthen bund, fed by its own catchment and/or a supply channel, with a surplus weir and one or more sluices.
Tank cascade	A chain of tanks in which the surplus or sluice outflow of one tank feeds the next (as in Chapter 3).
Full tank level (FTL)	The crest level of the surplus weir (spillway, overflow, escape or outlet) of a tank, or the permanent crest of its regulating structure. The tank holds water up to FTL without spilling.
Maximum water level (MWL)	The highest water level in a tank when the surplus weir passes the tank's design flood. For this Manual, it is the greater of the level recorded by the WRD and the level computed for the 1% AEP (100-yr) inflow with the climate factor of Clause 2.8 (Clause 7.7.4).
Top bund level (TBL)	The crest level of the tank bund.
Waterspread	The area of a tank submerged at FTL.
Foreshore	The land around a tank between the FTL contour and the MWL contour. Foreshore land is flooded whenever the tank surpluses, and is part of the tank's flood storage.
Supply channel (feeder channel, nala or canal)	A channel that brings water from a river, anicut or upstream tank into a tank.
Surplus course	The channel that carries the overflow of a surplus weir to the next tank, a river, a drain or the sea.
Sluice (sluice, sluice gate or regulator)	A controlled outlet through a tank bund, usually to an irrigation channel.
Top of bank	For a channel, the break in slope at the edge of the channel. Where it cannot be identified, the edge of the water surface at the 50% AEP (2-yr) flow.
1% AEP flood extent	The land flooded by the 1% AEP (100-yr) flood with the climate factor of Clause 2.8, from a hydraulic model that meets Chapter 3 and Chapter 5, or from a map adopted by the Authority under Clause 7.3.4.
Floodway	The waterbody and the adjoining land that must be kept free of obstruction to pass the 1% AEP flood without raising the 1% AEP water level by more than **0.1 m** at any point (Clause 7.6.1). For a tank, all land below MWL.
Flood fringe	The part of the 1% AEP flood extent outside the floodway.
Zone 1 (waterbody protection zone)	The inner setback zone defined in Clause 7.4.3.
Zone 2 (flood fringe setback)	The outer setback zone defined in Clause 7.4.4.

Term	Meaning in this Manual
Setback	Zone 1 and Zone 2 together.
Compensatory storage	Excavated storage that replaces flood storage lost to fill, under Clause 7.6.4.
Flood cushion	Storage below FTL kept empty, under a documented operating rule, to absorb a flood (Clause 7.8).

Rajasthan terms. The following terms are used in this chapter in addition to those above (see also Annex 7E):

Term	Meaning in this Manual
Talab (तालाब; johad, nadi)	A natural or excavated depression, usually with an earthen bund, that stores rainfall runoff from its own catchment: "Pond, pool, tank, reservoir of water" in Platts (Annex 7E). A johad is an earthen (unlined) talab, and a nadi is the village pond of Marwar and the west; both are talabs for this chapter. A talab is a tank or pond under Clause 7.2. Most talabs have no surplus weir or sluice, only a low point in the bund or the rim over which they spill; where a talab has none, its FTL is the level at which it spills to the next talab, a khadin, a nala or low ground, found by survey. A talab need not hold water to be a talab: one that is dry for years at a time keeps its bed, its bund, its agor and its flow paths.
Recorded talab	A talab, johad, nadi, sagar or lake shown in the Revenue records (including land recorded as gair mumkin talab), a Municipality's records, a master development plan, a record or notification under the Rajasthan Lakes (Protection and Development) Authority Act, 2015, a list of the Rajasthan State Wetland Authority, or a survey made under a court's directions. A recorded talab is part of the drainage system for this Manual. Where it is proposed to be filled or built on, in whole or part, a drainage assessment under Chapters 3 to 5 shall show the storage and flow paths lost and their effect upstream and downstream, and the lost storage shall be replaced under Clause 7.6.4 before any design relying on the filling is approved. This definition and rule are set by this Manual, and do not override a court order or statute that forbids the filling.
Agor (catchment) and flow paths	The agor of a talab, johad or nadi is the land that drains to it, and its flow paths are the nalas, channels and depressions by which that runoff reaches it, recorded or not. ("Agor" is used in Rajasthan for the catchment of a tank; that sense was not confirmed in a dictionary or a revenue text, and Platts gives only the unrelated sense "watchman" (Annex 7E), so the word is always used here with its gloss.) Where the catchment of a recorded talab is recorded (in the Revenue records, a court-ordered survey, or as the flow area of a lake under the Lakes Act, 2015, s. 2(viii)), or can be delineated from the terrain under Chapter 3, it shall be shown on the Waterbody Sheet (Form 7-1), and in it: (a) every flow path draining 8 ha or more is a natural channel under Clause 7.4.1(b), with its setback, whether or not it is recorded as gair mumkin nala; (b) no flow path shall be blocked, filled, diverted or built across except by a crossing that meets Clause 7.10.3; (c) the runoff of a development that is not retained on site under Chapter 4 shall leave it, after treatment under Chapter 8, by the flow path it used before development, so that the talab keeps its inflow; and (d) the catchment boundary shall be marked on the approved layout plan. Where a court has barred allotment or construction in a recorded catchment, as for the Ramgarh dam, that order governs (Clause 7.4.5). This definition and items (a) to (d) are this Manual's proposal, built on the orders of the High Court on catchments (Commentary to Clause 7.1); they are not a statutory rule.
Gair mumkin nala, nadi or talab	The Revenue record class (गैर मुमकिन, uncultivable) for land that is a nala, a nadi or a talab. The High Court has held that land recorded as gair mumkin nala is a natural drainage channel that cannot be diverted, obstructed or altered for a non-conforming purpose, even a public one, and that adjoining land so recorded is to be kept to its recorded character (*Ramji Lal Saini*, 2026). Every such parcel within or next to a site is a waterbody under Clause 7.3, whatever its present state, and its recorded width is its least width under Clause 7.10.3(b).
Monsoon water line	The outer edge of a talab's, lake's or wetland's water in the monsoon: the largest of the edge shown by dated imagery of the monsoon and the month after it (July to October) in the years of record, which shall cover at least 20 years so as to include wet years, the edge recorded in the Revenue records, and the spill level (FTL) contour; where none is available, the MWL contour. The boundary of a talab or lake under Clauses 7.3.3 and 7.13.1 is the largest of its Revenue record boundary, its surveyed FTL and its monsoon water line, and setbacks are measured from that boundary. A dry year's edge never sets the boundary. This definition, and the 20 years, are set by this Manual, because many of Rajasthan's talabs fill only in wet years.
Lake (Lakes Act, 2015)	A water body that meets the definition of the Rajasthan Lakes (Protection and Development) Authority Act, 2015 (s. 2(x); 3 ha or 10 ha of submerged area at any time in the fifty years before the Act, whether or not it holds water or is recorded); its flow area is "the area through which streams or feeders flow to the lake for its recharge" (s. 2(viii)). Such a lake is a tank under Clause 7.2, and its flow area is its agor. Where a lake boundary or protected area is notified (s. 4), the notified line governs where it is wider (Clause 7.4.5).

Term	Meaning in this Manual
Sagar; city lake	A sagar or sarovar is a large tank or lake (Annex 7E), and in Rajasthan the name of many city lakes, such as Fateh Sagar and Udai Sagar at Udaipur, Ana Sagar at Ajmer and Man Sagar at Jaipur. A city lake is a lake or sagar within or next to a town whose level is held by a dam or bund with an overflow, escape channel or gates, such as Ana Sagar, which releases through the gates of its escape channel into the town. Each is a tank under Clause 7.2; where it is a Ramsar site or a notified or listed wetland, Clause 7.12 also applies.
Lake-locked outfall	A drain or nala outfall into a city lake or talab, which cannot discharge freely while the lake is at or above its FTL. Its tailwater is the lake level: the lake's MWL, or its FTL plus the surcharge of the design flood, as the custodian records them, and where neither is published, the level that Chapter 5 sets. The lake's gates are a controllable outlet under Clause 7.8 only where they are operated to a written rule.
Taanka; kund; baori, jhalra	A taanka is a small walled cistern, usually underground, that stores runoff from a roof, a courtyard or a prepared catchment; a kund is a small walled or embanked tank, and in the west the word (and kundi) is also used for a cistern fed by a saucer-shaped catchment; a baori (bawdi) or jhalra is a step-well (Annex 7E). Each is a waterbody for Clause 7.3. A taanka or kund is storage for use under Clause 8.11.2(a), and its storage is not counted as detention; a baori or jhalra is kept for recharge and heritage, and no runoff from roads or paved areas shall be led into it (Clause 8.11.3(b)).
Khadin	A long earthen bund built across the lower edge of a sloping catchment, behind which runoff stands in the monsoon and soaks in, and the bed is then farmed. A khadin is a talab for Clauses 7.3 and 7.10: its bund, its bed and its agor shall not be cut, built on or cut off from its flow paths, and its overflow is a surplus course. Its storage is counted only under Clause 7.7. No dictionary source was found for the word (Annex 7E).
Nala; nali	A nala is a watercourse or drain, natural or cut (Annex 7E), such as the nalas that drain to the Dravyavati at Jaipur; a nali is a small street or house drain. Every nala that drains 8 ha or more is a natural channel under Clause 7.4.1(b), whoever maintains it and whether or not it is lined, piped or covered. No rule dividing natural nalas from municipal drains was found; the definition, not the owner or the name, decides which clauses apply.

7.3 Inventory and mapping of waterbodies

7.3.1 **Statewide inventory.** The Authority, with the WRD and the Revenue Department, shall maintain a GIS layer of every waterbody in its area (Annex 7A). For each waterbody it shall record:

- (a) its type (Clause 7.2), name and survey numbers;
- (b) its custodian (a Municipal Corporation, Council or Board (in which public tanks, streams, reservoirs, cisterns and adjacent land, and the public drains and watercourses in, alongside or under any street, vest as trustee under section 68 of the Rajasthan Municipalities Act, 2009), a development authority (such as the JDA, JoDA, AjDA, KDA or UDA) or an Urban Improvement Trust, the WRD (for its dams, reservoirs, irrigation tanks and canals), the Lakes Development Authority (for a lake under the Rajasthan Lakes (Protection and Development) Authority Act, 2015), the State Government through the Collector and the Tehsildar (for land recorded as gair mumkin talab, nadi or nala, tank-bed land and other State land), the Gram Panchayat, the Rajasthan State Wetland Authority (for a notified wetland), RIICO (for drains and ponds in its industrial areas), a private owner, or another body);
- (c) its boundary as recorded in Revenue records;
- (d) for tanks: FTL, MWL, TBL, the surplus weir crest length and type, sluices, the supply channel and the surplus course, each with its datum;
- (e) its position in any tank cascade, with the upstream and downstream tanks;
- (f) the 1% AEP flood extent, where mapped; and
- (g) known encroachments, with the date recorded.

7.3.2 **Project mapping.** Every drainage report shall include a Waterbody Sheet (Form 7-1) showing all waterbodies:

- (a) within the site;
- (b) within 100 m of the site boundary; and
- (c) downstream, to the extent of the downstream analysis of Chapter 5.

The sheet shall show, on a plan at a scale of 1:1,000 or larger for (a) and (b):

- the Revenue record boundary;
- the surveyed FTL or top of bank;
- the MWL contour (tanks) and the 1% AEP flood extent;
- Zone 1 and Zone 2 (Clause 7.4); and
- every supply channel, surplus course, sluice and surplus weir.

7.3.3 **Sources.** Waterbodies shall be identified from all of the following. Where they conflict, the larger waterbody extent governs:

- (a) Revenue records and khasra maps of the Revenue Department, in which talabs, johads, nadis, nalas and rivers, and the catchments of tanks and ponds where they are recorded, are entered as gair mumkin talab, nadi or nala or in other classes of land in which no khatedari rights accrue under section 16 of the Rajasthan Tenancy Act, 1955; the public tanks, streams, reservoirs, drains and watercourses vested in a Municipality under section 68 of the Rajasthan Municipalities Act, 2009; the record of lakes, with their boundaries and flow areas, and the lake boundaries and protected areas notified under the Rajasthan Lakes (Protection and Development) Authority Act, 2015 (none was found for this Manual); the waterbodies, nalas and catchments shown in master development plans; the catchment surveys made under the directions of the High Court, such as that of the Ramgarh dam; the High Flood Line and ecological buffer of each river, once demarcated under the Supreme Court's order of 7 August 2026; the boundary of every wetland notified under the Wetlands (Conservation and Management) Rules, 2017 and of the four Ramsar sites; and the wetland survey ordered by the High Court on 1 June 2026;
- (b) WRD and Gram Panchayat tank registers and records of FTL and MWL;
- (c) the Authority's inventory (Clause 7.3.1) and any list published under court directions;
- (d) historical topographic maps and satellite imagery, including the ISRO National Wetland Inventory and Assessment; and
- (e) a site survey by a licensed surveyor, levelled to the datum stated in Clause 7.3.5.

7.3.4 **Flood extent maps.** The Authority may adopt 1% AEP flood extent or flood depth maps for its area. A depth map adopted under this clause also sets floor levels under Clause 6.11. Where a map has been adopted, it shall be used unless a site hydraulic study under Chapters 3 and 5 shows a larger extent. Where no map has been adopted, the Applicant shall determine the 1% AEP extent by a hydraulic study for:

- (a) any site in a flood-sensitive catchment (Chapter 1);
- (b) any site of 1 ha or more adjoining a waterbody; and
- (c) any site where the Authority so requires.

For other sites, the fixed-width setback of Clause 7.4.6 may be used.

7.3.5 **Datum.** All levels in this chapter shall be stated to one datum, stated on every drawing. Where WRD records use a local or older datum, the conversion to the project datum shall be surveyed and stated.

> **Commentary.** No 1% AEP flood map of any Rajasthan city was found, and the only design standard found for a Rajasthan urban channel is the 100-year flood of the Dravyavati at Jaipur, which the JDA's project aims "to make … capable of safely passing" (EIA, Chapter 2; no design discharge was found). No State law, rule or WRD order zoning the floodplains of the rivers was found either. The flood lines that are coming are court-made: on 7 August 2026 the Supreme Court directed a "comprehensive scientific exercise for determination and demarcation of the High Flood Line and the requisite ecological buffer zone qua all the river systems in the State", and the State told the Court that "comprehensive river restoration blueprints based on the revenue records" had been prepared for the Luni and the Jojari, and that surveys to fix the High Flood Line and buffer zones near the Jojari were "presently under progress in consultation with the concerned District Environment Committees" (Suo Motu W.P. (C) 8 of 2025); the return period of the High Flood Line is not stated in the order read for this Manual. The Lakes Act, 2015 requires a survey and published record of lakes "including their boundaries, flow area" (s. 6(1)(a)), but no such

> record was found. The Revenue records are therefore the main map of Rajasthan's waterbodies: the High Court has made the record class gair mumkin nala decisive (*Ramji Lal Saini*, 2026), and every site plan under this Manual shall overlay the khasra map and show each gair mumkin nala, nadi and talab, and the catchments of the talabs, on the Waterbody Sheet (Form 7-1). Levels shall be stated to one datum (Clause 7.3.5), because the levels of the lakes of Udaipur and Ajmer are published only as gauge readings in feet above an unknown zero (for example, Pichola 11 ft, Fateh Sagar 13 ft, Udai Sagar 24 ft and Ana Sagar 13 ft, as reported), which cannot be used until they are tied to a surveyed datum [TBC]. Clause 7.3.4 lets the Authority adopt flood maps once they are issued; until then the Applicant must produce the 1% AEP extent for larger and flood-sensitive sites, and the High Flood Lines and buffers demarcated under the Supreme Court's order, once drawn, are minimums that the 1% AEP extent of this Manual, with the climate factor, may exceed but never reduce. Clause 7.3.3 makes the larger of the recorded and surveyed extents govern, because the Revenue boundary and the surveyed water edge often differ, and either may have been reduced by encroachment. The 100 m search band in Clause 7.3.2 is set by this Manual.

7.4 Setbacks

7.4.1 **Waterbodies to which setbacks apply.** Setbacks apply to:

- (a) every waterbody recorded under Clause 7.3.1 or found under Clause 7.3.3, whatever its size; and
- (b) every natural channel, whether recorded or not, that drains **8 ha** or more at the site.

7.4.2 **Two zones.** The setback has two zones, shown in Figure 7.1:

- **Zone 1 (waterbody protection zone)**, next to the waterbody; and
- **Zone 2 (flood fringe setback)**, outside Zone 1.

7.4.3 **Zone 1 width.** Zone 1 is measured outward from the FTL contour (tanks, lakes and ponds) or from the top of bank (channels). Where both apply, use whichever gives the wider zone. Zone 1 extends to the **greatest** of:

- (a) **15 m**, the minimum set by this Manual (no statute, rule or building regulation read for this Manual sets a distance in metres from a nala, talab, lake or river in Rajasthan; see the Disclosure below);
- (b) the outer edge of the floodway (Clause 7.6.1); and
- (c) for a tank, the MWL contour.

7.4.4 **Zone 2 width.** Zone 2 extends from the outer edge of Zone 1 to the **1% AEP flood extent plus 10 m**. Where the 1% AEP flood extent lies inside Zone 1, Zone 2 is 10 m wide.

7.4.5 **Statutory and approval setbacks.** Where a statute, a statutory rule, a condition of planning permission or the approval of the WRD for a work on or next to one of its dams, reservoirs, canals or rivers, the prior approval or permission of the Lakes Development Authority for a plan covering a lake or a construction in a lake's protected area (Rajasthan Lakes (Protection and Development) Authority Act, 2015, s. 5), the permission of the Rajasthan State Wetland Authority for a regulated activity in a notified wetland, or a direction of the Supreme Court, the Rajasthan High Court or the National Green Tribunal (such as the river, lake, catchment and wetland lines listed in the Disclosure to Clause 7.4) sets a setback wider than Zone 1 or Zone 2, the wider setback governs for the uses it restricts.

7.4.6 **Fixed-width setback where no 1% AEP extent is available.** Where Clause 7.3.4 does not require a hydraulic study and no map has been adopted, the setback (Zone 1 plus Zone 2) shall be not less than the following, measured as in Clause 7.4.3:

Table 7.1 — Fixed-width setback where no 1% AEP extent is available

Waterbody	Total setback (Zone 1 + Zone 2)	Of which Zone 1
Channel draining 8 ha to 65 ha	25 m	15 m
Channel draining 65 ha to 20 km²	40 m	15 m
Channel draining more than 20 km², and rivers	50 m	20 m
Tank, lake or pond	MWL contour + 25 m	to MWL contour, and not less than 15 m from FTL
Marsh, estuary or backwater	as notified by the Authority, and not less than 50 m	15 m

This table is the alternative S-3 of the Policy Supplement (Annex 1C) and may be adopted under Clause 1.7.

7.4.7 **Minimum in all cases.** No setback under this chapter, and no variance under Clause 1.10, shall reduce Zone 1 below 15 m (Clause 1.10.3(c)).

> Commentary. The 15 m minimum is set by this Manual. Rajasthan has no general statutory distance from water: neither the Model Rajasthan Building Regulations 2025 nor the 2020 regulations they replace set a setback from a nala, river, lake or talab, and the Rajasthan Municipalities Act, 2009 bars building only over a drain vested in the Municipality (s. 213(2)). The lines that exist are court-made or tied to one waterbody: land recorded as gair mumkin nala is a natural channel that cannot be diverted or built on (*Ramji Lal Saini*, High Court, 2026); land in the catchments of johads, nalas, tanks, rivers and ponds is not to be allotted (High Court, 2012); the High Flood Line and an ecological buffer are to be demarcated for every river system in the State, with no fresh permissions in identified river corridors until then (Supreme Court, 7 August 2026); and around a notified wetland no permanent construction is permitted within 50 m of the mean high flood level (Wetlands Rules, 2017, r. 4(2)(vi)). This Manual's 15 m gives every talab, nala and watercourse a hydraulic corridor where nothing wider binds, and is this Manual's proposal, not a statutory width (see the Disclosure below). Extending the setback to the mapped 1% AEP extent plus a margin follows the Kansas City Metro APWA Section 5600 (2025.01) two-zone structure:
>
> - APWA Zone 1 (streamside) is measured from top of bank, and only utility and road crossings are allowed in it.
> - APWA Zone 2 is the 1% AEP flood extent plus 10 ft (about 3 m), for streams draining 20–40 acres.
> - APWA lowered the trigger for stream setbacks from 40 acres to 20 acres (about 8 ha) in 2025.01.
>
> (MARC, APWA 5600 Policy Supplement, Nov 2025.) Clause 7.4.1(b) adopts the 8 ha trigger. This Manual's 10 m margin is wider than APWA's 10 ft and has no direct precedent. This Manual sets it because Rajasthan flood maps are mostly coarser than US maps, the alluvial plains around Jaipur and Alwar, the black-soil plains of Hadoti and the inland basins of the arid west, where runoff spreads and stands, are flat (so a small error in level moves the flood edge a long way), and the margin gives room for maintenance access along the waterbody.
>
> The fixed-width table in Clause 7.4.6 is set by this Manual. Its channel widths are scaled from the 2006 APWA default stream buffers, which were 40 ft, 60 ft, 100 ft and 120 ft (12, 18, 30 and 37 m) for drainage areas of less than 40 acres, 40–160 acres, 160–5,000 acres and more than 5,000 acres (KC APWA 5600, 2006, §5605.3). They are rounded up and floored at the 15 m minimum. APWA offered a fixed-width table for the same reason: communities objected that the 1% extent is often unmapped for small drainage areas (MARC Supplement, 2025). The table should be replaced by mapped extents as soon as the Authority adopts them.
>
> URDPFI (2015) reserves the area flooded at a 10-year frequency for parks and playgrounds, and allows residential use in the 25-year flood zone only on stilts, with minimum plinth levels and no basements. This chapter is stricter. It keeps habitable buildings out of the whole 1% AEP extent plus margin, because the 1% AEP (100-yr) event is the major-system standard of this Manual (Chapter 6).

Rajasthan's building regulations give no distance in metres from water. The Model Rajasthan Building Regulations 2025 and the 2020 regulations they replace were searched for nala, river, lake, talab, flow and flood terms, and set no setback from any of them; the 2020 regulations of the JDA let the norms of a "lake protected area" (झील संरक्षित क्षेत्र) set by the Centre or the State override them (reg. 10.4). The Rajasthan Municipalities Act, 2009 adds no width: it bars a new building over a sewer, drain, culvert or gutter vested in the Municipality without its written consent (s. 213(2)), and vests public tanks and the adjacent land that is not private property in the Municipality (s. 68(1)(c)), but sets no strip around them. Around a notified wetland, no permanent construction is permitted within 50 m of the mean high flood level (Wetlands Rules, 2017, r. 4(2)(vi)). The other lines are court-made or tied to one waterbody: for every river system in the State, the High Flood Line and an ecological buffer, to be demarcated, with no fresh permissions for industrial, commercial or residential development in the identified river corridors meanwhile (Supreme Court, 7 August 2026); along the Jojari, no construction or development within 100 m of the river's edge, and no hazardous industry within 500 m of the flood line or flow path, pending demarcation (Supreme Court, interim order of 24 August 2026, as reported; the order was not read); on land recorded as gair mumkin nala, no diversion, obstruction or other non-conforming use, and the same for adjoining land so recorded (*Ramji Lal Saini*, 2026); in the catchments of johads, nalas, tanks, rivers and ponds, no allotment (High Court, 29 May 2012, as quoted), and in the catchment of the Ramgarh dam, no encroachment or construction (High Court, 2011); around the lakes of Udaipur, a no-construction zone under a notification of 17 January 1997, within which the High Court is reported to have held a hotel within 200 m of the high flood level of Udai Sagar void, and an order of November 2025 against construction and the dumping of soil in the catchment of Fateh Sagar (all as reported; the notification and its datum were not read); around a lake under the Lakes Act, 2015, the protected area, once notified (s. 4; no distance is set in the Act, and no notification was found); and around Ana Sagar at Ajmer, the removal of structures built in the lake's area, ordered by the National Green Tribunal in 2023 and upheld by the Supreme Court in 2025 (as reported; Clause 7.12, Commentary). Clause 7.4.7 makes 15 m the floor of Zone 1 everywhere.

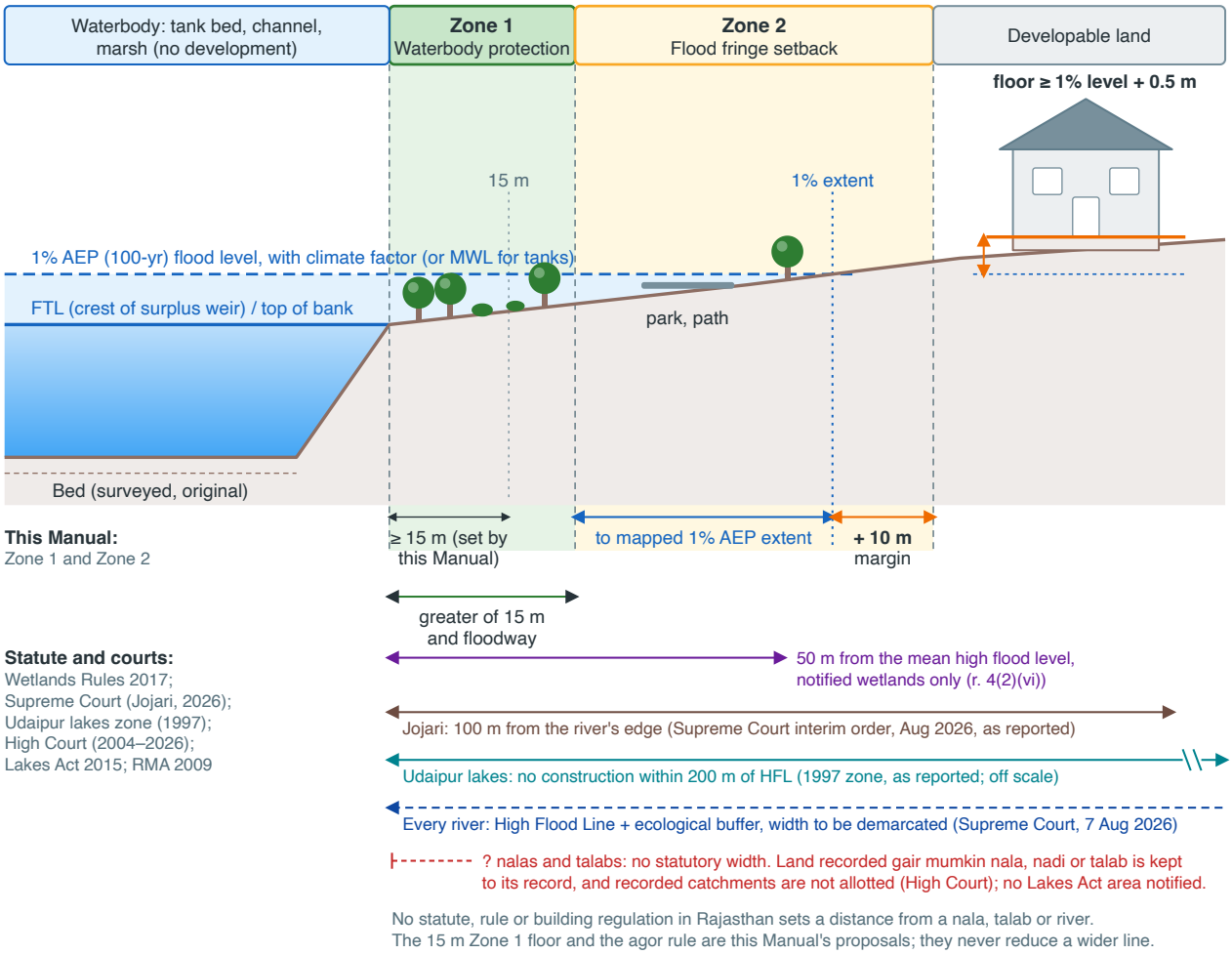
Disclosure. Rajasthan has **no statutory setback in metres from a nala, talab, lake or river**: no statute, rule or building regulation read for this Manual sets one, and **no State floodplain zoning law or order was found**. The **15 m minimum** Zone 1 of Clauses 7.4.3 and 7.4.7, and every value derived from it in Table 7.1, is **set by this Manual** as a hydraulic corridor, and so are the protection of each talab's agor and flow paths and the reading of the monsoon water line (definitions after Clause 7.2). They are **this Manual's proposal, not a statutory width or rule**, and no government has adopted them. The lines set by the Supreme Court, the High Court and the National Green Tribunal are **not the design extent**: the 1% AEP extent of this Manual, with the climate factor, governs Zone 2 wherever it is wider. The setback is applied as **the larger of the corridor and any statutory or court line**, so the Manual is **stricter than statute** along talabs, nalas and watercourses, and no less strict anywhere. What does exist, and governs wherever it is wider or stricter (Clause 7.4.5), is:

- **Rivers.** The High Flood Line and ecological buffer of every river system in the State, to be demarcated, with no fresh permissions for development in the identified river corridors until then (Supreme Court, 7 August 2026); and on the Jojari, no construction within 100 m of the river's edge and no hazardous industry within 500 m of the flood line or flow path (Supreme Court, interim order of 24 August 2026, as reported).
- **Natural channels and catchments.** Land recorded as gair mumkin nala, nadi or talab kept to its recorded character, and not diverted or built on (*Ramji Lal Saini*, High Court, 2026); no allotment of land in the catchments of johads, nalas, tanks, rivers and ponds (High Court, 2012); and no encroachment or construction in the catchment of the Ramgarh dam (*Abdul Rahman*, 2004, and the orders of 2011 and 2012, confirmed in the Supreme Court's judgment of 2017).
- **Lakes.** The protected area and flow area of a lake under the Rajasthan Lakes (Protection and Development) Authority Act, 2015, once notified (none was found); the no-construction zone around the lakes of Udaipur (notification of 1997; 200 m from the high flood level, as reported); and the orders of the National Green Tribunal and the Supreme Court on Ana Sagar at Ajmer (2023 to 2025, as reported).
- **Wetlands.** No permanent construction within 50 m of the mean high flood level of a notified wetland (Wetlands Rules, 2017, r. 4(2)(vi)); and no encroachment, filling, construction or untreated sewage in identified wetlands or their catchments (High Court, suo motu order of 1 June 2026).

- **Public tanks, drains and watercourses.** Public tanks, streams, drains and watercourses vest in the Municipality as trustee (Rajasthan Municipalities Act, 2009, s. 68), and no building may be put over a municipal drain without consent (s. 213(2)). These protect the waterbody, not a flood corridor; the whole recorded and monsoon extent is a waterbody for this chapter.
- **WRD dams, reservoirs and canals.** Works on or next to them need the custodian's approval.

This Manual sets 15 m as the floor because no width exists in Rajasthan for nalas or talabs; because 15 m is above the smallest APWA default stream buffer (12 m) from which Table 7.1 is scaled; and because it leaves room for the maintenance track and desilting machinery that the nalas need. The reasons for the corridor and the agor rule are the record: the Ramgarh dam, Jaipur's old water supply, has had little or no inflow while its catchment was built over and mined (as the High Court and its Technical Committee recorded), and the Supreme Court found nothing substantive achieved on the ground over the years (2017); the Dravyavati, "the active river of Jaipur", turned into a nala (JDA, EIA); and on the Jojari, units of the Kakani industrial area stand "merely 30 to 60 metres" from the riverine area, with about 12.805 ha of the area within the "apparent High Flood Area" (Supreme Court, 7 August 2026). Until a statute, rule, notification or master plan adopts it, the 15 m minimum is this Manual's recommended standard, and the statutory and court controls above remain the only legal minimum. Approving authorities should state in each approval which was applied.

Waterbody setback: Zone 1 and Zone 2, with Rajasthan's court and statutory limits (section, not to scale)



Zone 1: no buildings, fill, paving or dumping. Crossings, utilities, flood works and native vegetation only.

Zone 2: no habitable buildings. Parks, unpaved paths, open-sided structures; fill only with 1:1 compensatory storage.
Setback measured from the largest of the Revenue boundary, FTL (or top of bank) and the monsoon water line.

Wider lines govern: river HFL and buffer once demarcated; Jojari 100 m; Udaipur lakes 200 m; notified wetlands 50 m; Lakes Act protected and flow areas; gair mumkin land and recorded catchments; WRD lines.

Figure 7.1 — Waterbody setback zones: section through a tank or channel showing FTL, the 1% AEP flood level, the 15 m minimum line, Zone 1 and Zone 2. Original drawing for this Manual, adapted from Kansas City Metro APWA, Section 5600 Version 2025.01 and Policy Supplement (MARC, 2025).

7.5 Uses permitted in each zone

7.5.1 **Zone 1.** No building, fill, paving, retaining wall, boundary wall, compound wall, dumping of earth, debris or solid waste, storage of materials, or construction-stage stockpile shall be placed in Zone 1. Only the following are permitted, each subject to the custodian's NOC:

- (a) road, rail and utility crossings that meet Clause 7.10.3;
- (b) flood and drainage works: outfalls, inlet structures, gross pollutant traps, sluices, surplus weirs, bund strengthening and bank protection;
- (c) native vegetation, planting and habitat works;
- (d) unpaved or permeable footpaths and maintenance tracks at existing ground level; and
- (e) waterbody restoration under Clause 7.9.

7.5.2 **Zone 2.** No habitable building, basement, school, hospital, fuel store or hazardous-material store shall be placed in Zone 2. The following are permitted:

- (a) all uses permitted in Zone 1;
- (b) parks, playgrounds, open-air sports fields and urban agriculture;
- (c) open-sided structures (shelters, pavilions) with no walls that obstruct flow;
- (d) surface parking with permeable surfacing at existing ground level, where the 1% AEP flood depth is not more than 0.3 m;
- (e) retention, detention and water quality facilities under Chapters 4 and 8, provided they are outside the floodway and their storage is not counted twice (Clause 7.6.5); and
- (f) fill, only for (a) to (e) or for essential public infrastructure, and only with compensatory storage under Clause 7.6.4.

7.5.3 **Fences.** Fences in Zone 1 and Zone 2 shall be open (chain-link or railing) with no plinth wall above existing ground level, so that they do not obstruct flow or trap debris.

7.5.4 **Open space reservation.** Zone 2 land may be counted toward the green area or open space required by the Model Rajasthan Building Regulations 2025, where the Authority agrees. Zone 1 land shall be handed over to the custodian or kept free of private use, as the Authority decides.

> **Commentary.** The permitted uses follow APWA 2025.01: in Zone 1, only utility and road crossings; in Zone 2, linear utilities, trails and open-sided structures; no clearing, grading, fill or paving in either zone without approval (MARC Supplement, 2025). Clause 7.5.2 adds parks and playgrounds, the uses URDPFI (2015) allows in the 10-year flood zone. The ban on walls in Clauses 7.5.1 and 7.5.3 responds to urban Rajasthan practice: compound walls along channels and tanks act as dams in floods, and are often the first step toward encroachment. The 0.3 m depth limit for parking in Clause 7.5.2(d) has no direct precedent and is set by this Manual.

7.6 Floodway, flood fringe and compensatory storage

7.6.1 **Floodway delineation.** The floodway shall be delineated by a hydraulic model of the 1% AEP flood (with the climate factor), using the encroachment method: the conveyance of the flood fringe is removed equally from both banks until the 1% AEP water level rises by 0.1 m. Where the floodway has not been delineated, the whole 1% AEP flood extent shall

be treated as floodway. For a tank, all land below MWL is floodway.

7.6.2 **No fill in the floodway.** No fill, building, embankment, raised road or other obstruction shall be placed below the 1% AEP flood level within the floodway, except the works permitted in Zone 1 under Clause 7.5.1(a) and (b). Those works shall be shown by hydraulic analysis to raise the 1% AEP water level by no more than 0.01 m, upstream or downstream, outside the Applicant's land.

7.6.3 **Fill in the flood fringe.** Fill below the 1% AEP flood level in the flood fringe is permitted only:

- (a) for uses permitted under Clause 7.5.2, or outside the setback where the Authority has notified a developed-fringe area under Clause 7.6.6; and
- (b) with compensatory storage under Clause 7.6.4.

7.6.4 **Compensatory storage.** Where fill is placed in the flood fringe, compensatory storage shall be provided that (Figure 7.2):

- (a) replaces at least **1.0 m³ of storage for each 1.0 m³ of fill** placed below the 1% AEP flood level;
- (b) is provided at **equivalent levels**: the volume lost and the volume replaced shall be balanced in each elevation band of not more than **0.3 m**, from the normal water level (or the 50% AEP level, where higher) up to the 1% AEP flood level;
- (c) is in the same reach of the same waterbody, hydraulically connected to it, and not further downstream than the fill;
- (d) drains freely by gravity back to the waterbody as the flood recedes, with no pumping and no permanent pool below the normal water level;
- (e) is built before, or at the same time as, the fill is placed; and
- (f) is secured by a covenant or handover so that it is never filled later.

7.6.5 **No double counting.** Compensatory storage shall not be counted as detention or retention storage under Chapter 4. Detention and retention storage placed within the 1% AEP flood extent shall be counted only for the volume above the 1% AEP flood level, unless a model of the joint event (Clause 2.12) shows that it is available.

7.6.6 **Developed-fringe areas.** The Authority may notify, by map, areas of existing built-up land within the 1% AEP flood extent but outside the floodway, where it is impractical to apply Zone 2 to redevelopment. In a notified developed-fringe area:

- (a) redevelopment may be approved without the Zone 2 restriction;
- (b) the lowest habitable floor and all openings shall be at least 0.5 m above the 1% AEP flood level (Chapter 6);
- (c) basements are not permitted;
- (d) the redevelopment shall cause no net loss of flood storage below the 1% AEP flood level (Clause 7.6.4), and stilt construction may be used for this; and
- (e) Zone 1 continues to apply in full.

> **Commentary.** The 1:1 compensatory storage at equivalent levels is set by this Manual. A simple volume balance is not enough: storage excavated below the normal water level is full before the flood arrives and gives no flood benefit. Storage gained high up does not replace storage lost low down, because the low storage is used in every flood and the high storage only in the largest. Balancing volume within each elevation band avoids both problems. The 0.3 m band, the 0.01 m allowance for crossings, and the use of the encroachment method in Clause 7.6.1 are set by this Manual; the encroachment method is the standard way to delineate a floodway in a one-dimensional hydraulic model. The 0.1 m limit on the rise in the 1% AEP water level is tighter than the 1 ft (about 0.3 m) used by the US National Flood Insurance Program. The alluvial plains around Jaipur and Alwar, the black-soil plains of Hadoti and the inland basins and pans of the arid west, where runoff has no outfall and spreads, are flat, so a small rise in level spreads flooding over a wide area, and many small encroachments along the same channel add up.

In Rajasthan the lines around lakes are measured from a high level, not from the dry-season water line: the Udaipur no-construction zone is reported to run from the high flood level, and the Wetlands Rules, 2017 measure their 50 m from the mean high flood level. The Lakes Act, 2015 goes further, defining a lake by the largest area it has submerged at any time in fifty years, "whether it contains water or not" (s. 2(x)). The difference matters more in Rajasthan than elsewhere, because many talabs, nadis and lakes fill only in wet years and stand dry, or nearly dry, in between: Jaisalmer's normal annual rainfall is 172.9 mm, and Barmer and Jaisalmer each had fourteen years of 125% or more of normal between 1951 and 2000 (IMD, *Climate of Rajasthan*, 2010). A line drawn from the edge of a dry year would leave the foreshore that a wet year floods, and that the talab needs to store it, open to building. This Manual gives the same rule a level for every talab, johad, nadi and lake: its monsoon water line, read over at least 20 years, and its FTL are part of its boundary (definitions after Clause 7.2), and the foreshore up to MWL is its flood storage. Treating all land below MWL as floodway (Clause 7.6.1) means that no new building or fill is approved in a tank foreshore.

The developed-fringe mechanism of Clause 7.6.6 is set by this Manual. Large parts of the riverside and lakeside wards of Rajasthan's cities, such as Nayapura and Balita on the Chambal at Kota, below the Kota Barrage (evacuated in September 2019), Hathi Bhata, Brahmapuri and Shivpuri along the Ana Sagar escape channel at Ajmer (waterlogged in September 2024), and the Udaipur colonies flooded by lake and river water in 2006 and since (all as reported), already lie within the 1% AEP extent. A blanket Zone 2 ban on redevelopment there would stop the replacement of older, lower buildings with buildings raised above flood level. The mechanism follows the URDPFI (2015) approach for the 25-year flood zone (stilts, minimum plinth, no basements), applied here to the 1% AEP extent.

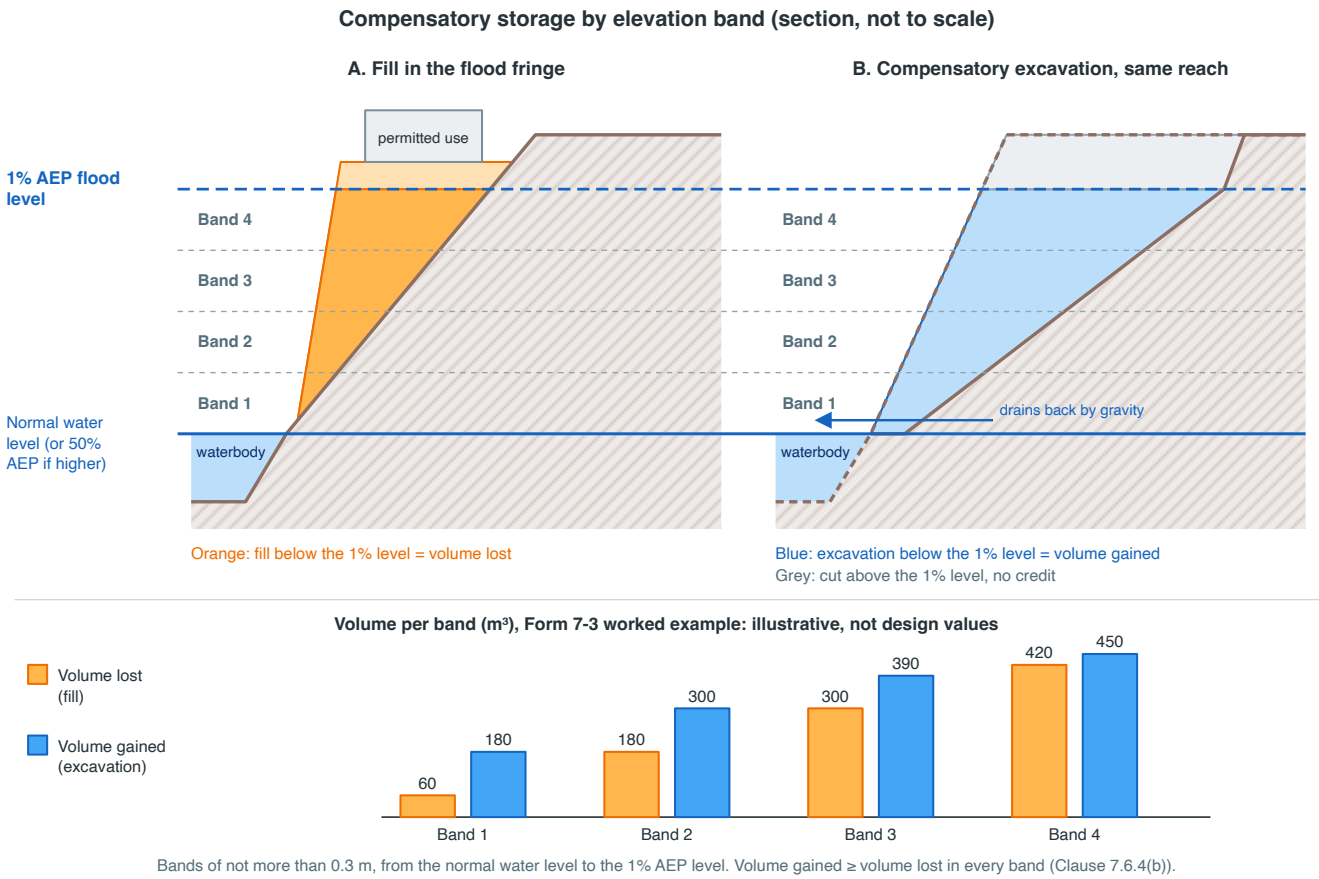


Figure 7.2 — Compensatory storage by elevation band: section through the flood fringe showing fill placed below the 1% AEP flood level and an equal or greater volume excavated within each band of not more than 0.3 m, from the normal water level (or 50% AEP level) up to the 1% AEP level, with the excavation draining back to the waterbody by gravity.

Band-by-band calculation on Form 7-3. Original drawing for this Manual, illustrating the method of Clause 7.6.4, which is set by this Manual.

7.7 Tank cascades as design storage

Rajasthan has no tank Act, and its storages range from the taanka of a single house to city lakes held by gated escape channels. The storages that matter for urban drainage are of six kinds. The first is the village and urban talab, johad or nadi, usually with no outlet structure, recorded in the Revenue records as gair mumkin talab or, inside a town, vested in the Municipality (Rajasthan Municipalities Act, 2009, s. 68), and fed by its agor through flow paths that are often unrecorded. The second is the city lake or sagar with a dam or bund and an overflow, escape channel or gates, which takes the town's nalas and releases to a downstream channel: Ana Sagar at Ajmer, whose escape-channel gates are opened into the town when it is full (as reported); the lakes of Udaipur, Pichola, Fateh Sagar and Udai Sagar, linked by the Ayad, which carries the spill of the upper lakes to Udai Sagar (as reported); Kailana and Takhat Sagar at Jodhpur, with reported full reservoir levels of 273.7 m and 269.75 m; and Man Sagar at Jaipur. These are the tanks for which Clauses 7.7 and 7.8 matter most, and no operating rule for any of them was published. The third is the WRD's reservoirs and barrages, such as the Kota Barrage on the Chambal, Bisalpur on the Banas and Mahi Bajaj Sagar, and the Ramgarh dam; they are not tanks for these clauses, and their releases enter a design as inflow and tailwater (Chapter 5). The fourth is the khadin, whose bed is farmed after the water has soaked in; its storage is counted only under Clause 7.7, and never while the bed is under a crop that the custodian will not flood. The fifth is the taankas, kunds, kundis, baoris and jhalras of the old towns and villages, small storages that are better kept for use, recharge and heritage than counted as detention. The sixth is the salt lakes and inland depressions of the arid west with no outfall, such as the Sambhar Lake, a Ramsar site, which are the terminal storage of their catchments and are wetlands under Clause 7.12. Clauses 7.7 and 7.8 apply to any of these whose storage is counted; any city lake or sagar whose storage is to be counted is subject to Clause 7.7.1 in full, with the WRD, the Municipality, the Lakes Development Authority or other custodian, and the custodian of each city lake shall be confirmed for the inventory (Annex 7A), because it was not established for this Manual.

7.7.1 **When tank storage may be counted.** The storage of a tank or tank cascade may be counted as design storage (in a basin plan, a regional facility or a fee-in-lieu scheme under Clause 7.11) **only** where all of the following are met:

- (a) **Surveyed levels.** FTL, MWL, TBL, the surplus weir crest and length, and the sluice sill levels have been surveyed to the datum of Clause 7.3.5 within the previous 5 years.
- (b) **Stage–storage curve.** A stage–storage curve has been derived from a bathymetric and topographic survey of the waterspread and foreshore within the previous 5 years, or after the last desilting, whichever is later.
- (c) **Operating rule.** A documented operating rule has been agreed with the custodian (Clause 7.8).
- (d) **Maintained structures.** The surplus weir, sluices and bund are maintained under an O&M plan (Chapter 10), and the latest pre-monsoon inspection found them serviceable.
- (e) **Custodian concurrence.** WRD, or the other custodian, concurs in writing.

Storage in a tank that fails any of (a) to (e) shall not be counted, though the tank shall still be modelled as an existing feature (Chapter 3).

7.7.2 **Modelling.** Tank cascades shall be modelled under Clause 3.12.5 (level-pool routing of each tank, with surplus weir and sluice ratings) and Clause 3.13 (continuous simulation). The whole cascade, from the uppermost tank whose surplus can reach the site or facility to the next river, major drain or sea outfall, shall be modelled together, including the agor (catchment) of each talab, johad or nadi and the flow paths that feed it, and the talab with its FTL and its overflow or escape to the next talab, khadin or nala, as shown in Figure 7.3, and, for a city lake with escape gates, such as Ana Sagar at Ajmer, the gates and the downstream channel, with the lake level as the tailwater of the inflowing drains (Chapter 5).

7.7.3 **Starting level.** The starting level in every tank shall be **FTL** for the design-storm analysis. A lower starting level may be used only under a flood-cushion operating rule that meets Clause 7.8.

7.7.4 **Design maximum level.** For the 1% AEP inflow with the climate factor, routed through the cascade:

- (a) the computed maximum level shall be not higher than MWL (as defined in Clause 7.2); and
- (b) the freeboard from the computed maximum level to the lowest point of the bund (TBL) shall be not less than WRD's freeboard standard for the tank.

Where (a) or (b) fails, the tank storage above FTL shall not be counted until the surplus weir capacity is increased or the bund raised under Clause 7.7.6.

7.7.5 **Creditable volume.** The creditable design storage of a tank is the volume between the starting level (Clause 7.7.3) and the computed maximum level of Clause 7.7.4, less any volume already committed to another facility or scheme.

7.7.6 **Changes to FTL, weirs and bunds.** No surplus weir crest shall be raised or lowered, no shutters or falling boards shall be added, and no bund shall be raised, cut or breached except under a design approved by the custodian that:

- (a) routes the cascade under Clause 7.7.2;
- (b) shows the effect on flood levels in the foreshore and upstream, and on flows in the surplus course and downstream; and
- (c) checks the bund under Clause 7.14.

> Commentary. This Manual allows tank cascades to be used as design storage subject to three basic conditions (surveyed FTL, a documented operating rule and maintained surplus weirs). Clause 7.7.1 adds the stage–storage survey and the custodian's concurrence, because the storage a tank actually offers depends on its silt level and on who controls the sluices. The 5-year survey interval is set by this Manual.
>
> The FTL starting level follows Clause 3.12.5. Rajasthan's talabs are often dry, but its worst urban floods have come when the lakes and reservoirs were full and releasing. At Ajmer, the gates of the Ana Sagar escape channel were opened in September 2024, and Hathi Bhata, Brahmapuri and Shivpuri were waterlogged; in July 2025, after a reported 8 to 9 inches of rain in a day, the lake overflowed, the gates were opened 30 inches, and the area around the JLN Hospital was flooded (all as reported). At Udaipur in August 2006 "all water bodies in the region" were reported to be overflowing, and colonies were submerged by lake and river water (as reported). At Kota in September 2019, 18 of the 19 gates of the Kota Barrage released about 6.5 to 6.9 lakh cusecs (reported figures conflict), and low-lying wards were evacuated (as reported); the CWC's highest recorded level of the Chambal at Kota City is 248.68 m (2019), against a danger level of 242 m. At Jaipur in July 1981, 82 cm of rain fell on the city in three days, with 35 cm in 24 hours on 19 July (Gupta and Jindal, *Mausam*, 1987), and downstream in Tonk district the Dhund and Morel rivers flooded. No record of how long Rajasthan's lakes stay at or above FTL in a wet spell was obtained for this Manual. A dry talab at the start of the season is not a design assumption: in a wet spell the talab fills, and while it is full it stores nothing more below FTL, its inflowing nalas discharge against a high level, and every release adds to the flow below it. A tank cascade passes floods from one tank to the next, so a design that counts storage in one tank and ignores the surplus arriving from the tank above it will overstate the benefit. That is why Clause 7.7.2 requires the whole cascade to be modelled.

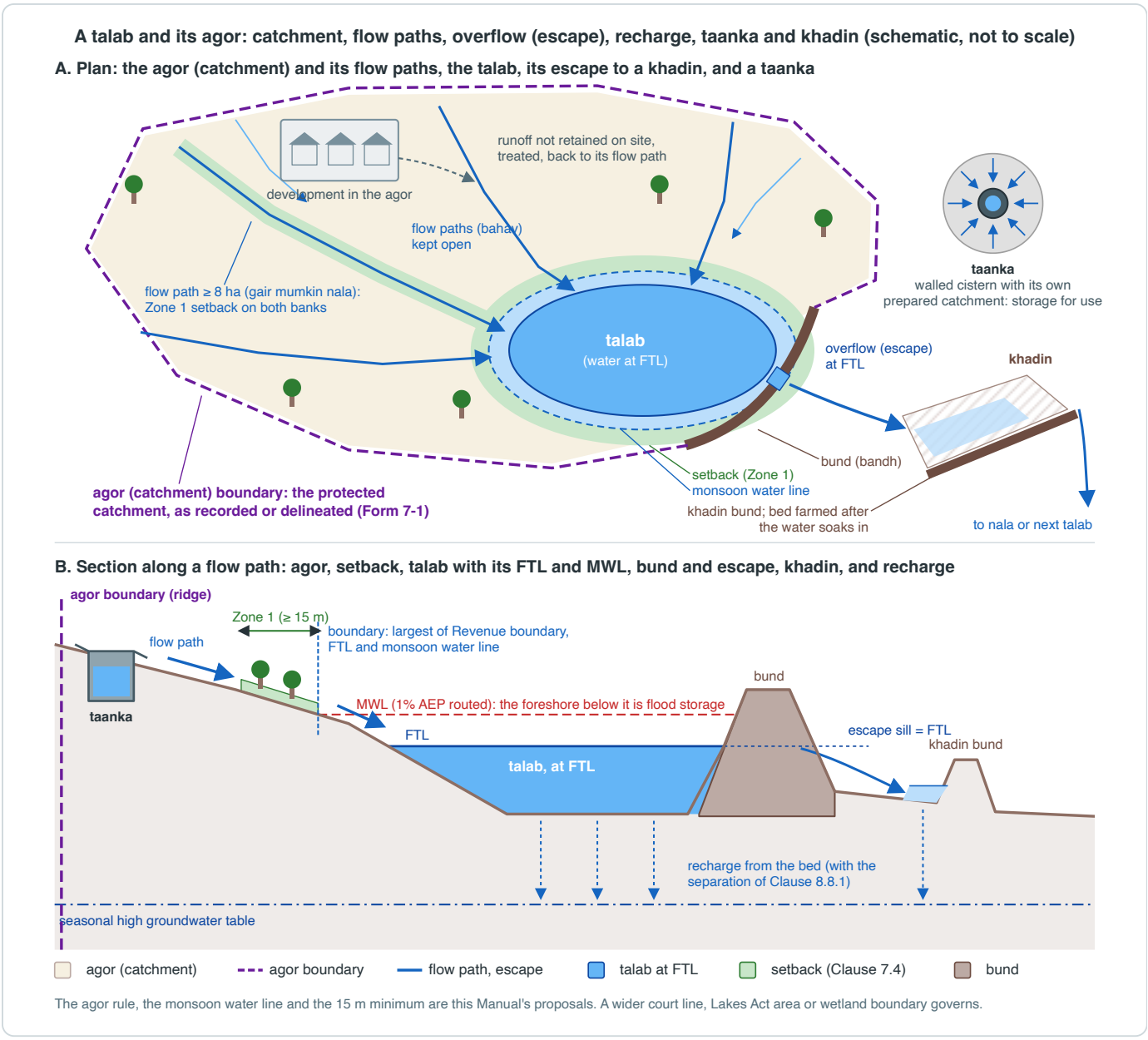


Figure 7.3 — A talab with its agor (catchment) and the traditional systems around it (schematic, not to scale; no particular talab is shown). A: in plan, the agor drains along its flow paths (bahav) to the talab; the talab spills at its FTL over its overflow (escape) to a khadin or the next talab and on to a nala; a taanka stores the runoff of its own small prepared catchment for use. The catchment boundary, the flow paths and the talab are one waterbody system for this Manual (definitions after Clause 7.2): a development in the agor keeps its flow paths open, with the setback of Clause 7.4 on every path draining 8 ha or more, and sends the runoff it does not retain on site, after treatment (Chapter 8), down the path it used before. B: in section, the talab holds water up to its FTL and the foreshore up to MWL is its flood storage; water soaks from its bed and from the khadin into the ground (recharge, subject to Clause 8.8.1); the setback is measured from the largest of the Revenue boundary, the FTL and the monsoon water line. The agor rule, the monsoon water line and the 15 m minimum are this Manual's proposals, built on the High Court's orders on catchments and natural channels (Clause 7.1, Commentary); a court line, the flow area or protected area of a lake under the Lakes Act, 2015, or a notified wetland boundary governs where it is wider. Original drawing for this Manual.

7.8 Operating rules and pre-monsoon flood cushion

7.8.1 **Operating rule content.** Every tank whose storage is counted under Clause 7.7 shall have a written operating rule, agreed by the custodian and kept with the O&M plan (Chapter 10). It shall state:

- (a) the levels and dates for filling, holding and drawdown through the year;
- (b) the sluice and regulator settings at each level;
- (c) who operates the sluices and regulators, and who may order a release;
- (d) the maximum release rate, set so that the release, added to the flow from the downstream catchment, does not cause flooding of buildings downstream;
- (e) the forecast and warning triggers (IMD district warnings, RSDMA alerts, and city forecast systems where available) and the actions taken at each trigger;
- (f) communication with downstream ULBs and residents before any release; and
- (g) the records to be kept: daily levels in the SW monsoon, releases, and gate settings.

7.8.2 **Flood cushion.** A tank may be operated with a flood cushion (a level below FTL during part of the SW monsoon), and the cushion counted under Clause 7.7.3, only where:

- (a) the tank has a gated sluice, regulator or other controllable outlet able to draw the tank down to the cushion level in the time stated in the rule;
- (b) the operating rule fixes the cushion level and the dates it applies;
- (c) continuous simulation (Clause 3.13) shows that the cushion is available at the start of a design storm in at least **90%** of SW monsoon seasons in the record, allowing for the rain that usually comes before the peak storm;
- (d) the custodian accepts any loss of irrigation or water-supply yield, and any agreed compensation is recorded; and
- (e) the release needed to create or restore the cushion meets Clause 7.8.1(d).

7.8.3 **No storage credit without control.** Where a tank has no controllable outlet, no flood cushion shall be assumed, whatever the past practice.

7.8.4 **Coordination.** For tanks under WRD control, the operating rule shall be WRD's rule. This Manual does not authorise any other body to operate a WRD tank.

> **Commentary.** No operating rule for a Rajasthan talab or city lake that keeps a flood cushion was found, and most talabs, johads and nadis have no controllable outlet, so Clause 7.8.3 applies to them. The controlled flows that matter in the towns are the releases of the gated lakes and the reservoirs: the gates of the Ana Sagar escape channel at Ajmer are reported to be opened when the lake is full and to flood the colonies along the channel (2024 and 2025, as reported), and the releases of the Kota Barrage, driven by the releases of the Chambal dams upstream in Madhya Pradesh, flooded the low-lying wards of Kota in September 2019 (as reported). The State's disaster control rooms have opened from 15 June in recent monsoons (as reported for 2025), but no warning protocol tied to a lake release was found. Without an agreed rule with dates, levels, release rates and a named operator, storage in a lake cannot be relied on, and a release made without warning to the colonies downstream is itself a flood. Clause 7.8.2 turns that principle into a rule that can be checked, with a reliability test, because a cushion that is usually refilled by the early monsoon rain gives no protection in a July or August monsoon depression. The 90% reliability in Clause 7.8.2(c) has no direct precedent and is set by this Manual.
>
> Many talabs and lakes have other users. Kailana and Takhat Sagar store water for Jodhpur, the Ramgarh dam supplied Jaipur until it went dry, the lakes of Udaipur and Pushkar Sarovar are places of worship, and the beds of khadins are farmed after the water soaks in. Drawing a talab or a lake down before a storm has a cost to those who use it, which is why Clause 7.8.2(d) requires the custodian to accept it.

7.9 Restoration, desilting and deepening

7.9.1 **Pre-works survey.** Before any desilting or restoration, the proponent shall:

- (a) survey the waterspread, foreshore, bund, weirs and sluices (Clause 7.7.1(a) and (b));
- (b) find the original bed level by test pits or augering on a grid, and from historical records where available; and
- (c) where the tank receives urban runoff or sewage, test the silt for heavy metals and other contaminants before disposal is planned.

7.9.2 **Desilting limit.** Desilting shall remove accumulated sediment down to the original bed level. It shall not deepen the tank below the original bed, except under Clause 7.9.3.

7.9.3 **Deepening.** Deepening below the original bed is permitted only where a hydrogeological report shows that:

- (a) it will not cut through a clay or silt layer that holds water in the tank or protects an aquifer from polluted water;
- (b) in coastal areas, it will not draw saline water into the tank or the aquifer; and
- (c) the extra storage will be refilled and used, and will not stand stagnant below the sluice sill.

Storage created below the lowest sluice sill shall not be counted as flood storage.

7.9.4 **Safe edges.** Where the public has access to the waterbody edge:

- (a) side slopes shall be no steeper than **1V:4H** from 0.5 m above FTL down to 1.2 m below FTL, or a level safety bench at least 3 m wide shall be provided between 0.3 m and 0.5 m below FTL; and
- (b) no isolated deep pit or vertical cut shall be left in the bed.

7.9.5 **Storage not to be reduced.** Restoration shall not reduce the storage below MWL. Islands, walkways, bund widening into the waterspread, ring roads, parking, buildings and "lake-front" platforms within the waterspread or foreshore shall be counted as lost storage and shall be offset under Clause 7.6.4.

7.9.6 **Silt disposal.** Desilted material shall not be placed within the setback, on the bund (except for approved bund strengthening), or on any flood path. Silt found to be contaminated shall be disposed of as the Rajasthan State Pollution Control Board (RSPCB) directs.

7.9.7 **Inlet treatment.** Every restoration of a tank that receives urban runoff shall include sediment and gross pollutant control at each inlet: a sediment forebay, a constructed wetland inlet zone, or a gross pollutant trap (Chapter 8), so that the restored storage does not silt up again.

7.9.8 **Timing.** Desilting shall be completed, and the waterbody made safe, by **15 June** each year (Chapter 10).

> Commentary. No statewide order of the Urban Development and Housing Department or of the Local Self Government Department for the pre-monsoon desilting of nalas or talabs was found; in July 2026 the Chief Minister was reported to have directed that all drains be cleaned (as reported). The date of 15 June in this Manual is set by this Manual: it is the date from which the State's disaster control rooms have opened in recent monsoons (as reported), and it comes before the monsoon's normal onset in the State, from about 24 June at Jhalawar to about 6 July at Bikaner and Pokaran (IMD, new normal dates, 2020). Village johads, nadis and talabs are also desilted and deepened under State and national programmes, such as the Mukhya Mantri Jal Swavlamban Abhiyan, which is reported to have built more than 3.8 lakh structures in three phases, and the Amrit Sarovar mission (as reported); no published measure of their effect on recharge was found. Excavation to "increase capacity" is governed by Clause 7.9.3. The 15 June deadline matches the pre-monsoon inspection date of Chapter 10. The limits on deepening are set by this Manual. Deepening tanks to "increase capacity" is common, but it can breach the silt and clay layer that holds water in the tank, it can let polluted urban water reach the

aquifer, it can draw salt water toward the coast, and it creates storage below the sluice sill that never empties and gives no flood benefit. Deep pits with steep sides are also a drowning hazard. The slope and bench values in Clause 7.9.4 are adapted from common pond-safety practice; they have no Rajasthan precedent.

7.10 Supply channels, surplus courses, inlets and outlets

7.10.1 **Part of the major system.** Supply channels and surplus courses are part of the major drainage system (Chapter 6). They shall be protected as waterbodies, with Zone 1 and Zone 2 setbacks under Clause 7.4.

7.10.2 **No closure or covering.** No supply channel or surplus course shall be closed, filled, diverted, covered, culverted along its length, or converted into a road or a closed drain, except under a design approved by the custodian that keeps or increases its 1% AEP capacity and its access for maintenance.

7.10.3 **Crossings.** Every road, rail, utility or access crossing of a waterbody, supply channel or surplus course shall:

- (a) pass the 1% AEP flow (with the climate factor), or the surplus of the upstream tank at its MWL, whichever is greater, with the freeboard required by Chapter 9;
- (b) not reduce the waterway width at the crossing below the full channel width as recorded in Revenue records or as surveyed, whichever is greater;
- (c) keep the channel bed level and grade; and
- (d) not raise the 1% AEP water level by more than the limit in Clause 7.6.2.

7.10.4 **Capacity.** The design capacity of a surplus course shall be the greater of the surplus weir discharge at MWL and the 1% AEP flow from its own catchment, combined as the cascade model (Clause 7.7.2) shows.

7.10.5 **Protection at structures.** Outlets of surplus weirs and sluices, and drain outfalls into waterbodies, shall have energy dissipation and scour protection designed under Chapter 9, so that the flow leaving them does not erode the bund, the bank or the channel bed.

7.10.6 **Drain outfalls into waterbodies.** A storm drain outfall into a tank, channel or wetland shall:

- (a) have its invert at or above the normal water level of the receiving waterbody, unless the drain is designed for submerged outfall under Chapter 5;
- (b) be located and aligned so that it does not cut through or weaken a tank bund;
- (c) have a gross pollutant trap and first-flush treatment (Chapter 8); and
- (d) not carry sewage or dry-weather flow (Chapter 8).

Commentary. This Manual protects supply channels and surplus courses as part of the major system. In urban areas they are often the first to be lost. Surplus courses are narrowed by culverts and compound walls, and supply channels are covered and turned into roads, which cuts the tank off from its source or leaves its surplus with nowhere to go. In Rajasthan the drains and watercourses of the streets vest in the Municipality, but the natural nalas outside the streets are State land in the Revenue records, and the split between them has not been written down. The Rajasthan Municipalities Act, 2009 vests in the Municipality "all public sewers and drains, channels, tunnels, culverts and watercourses in, alongside, or under, any street" (s. 68(1)(d)), puts all drains within the Municipality "under the survey and control of the Municipality" (s. 200), and bars a new building over any sewer, drain, culvert or gutter vested in it without its written consent, with power to have one pulled down (s. 213(2)). A nala outside a street is usually recorded as gair mumkin nala, and the High Court has held that such land cannot be diverted or used for any non-conforming purpose, and ordered a road and a crematorium built on it removed (*Ramji Lal Saini*, 2026). No rule or order dividing natural nalas from municipal drains, or the Municipalities' drains from the WRD's rivers and canals, was found for this Manual. In practice the rivers, dams, reservoirs and canals lie with the WRD (and the High Flood Lines of the rivers, under the Supreme Court's order of

2026, with the State and a River Commission or River Rejuvenation Authority it is to constitute); the drains of the streets with the Municipality; the drains of a development authority's or an Urban Improvement Trust's scheme with that body until they are handed over; the drains of an industrial area with RIICO; the nalas recorded as gair mumkin nala, and the village tanks, with the Revenue Department and the Gram Panchayat; and the lakes of 3 or 10 ha and more with the Lakes Development Authority once notified. This Manual uses that division as its working assignment, not as a statement of law. Jaipur's main channel shows what is lost when a nala is treated as a drain: the JDA describes the Dravyavati as "the active river of Jaipur which, over the time turned into a Nallah (Amanisha Nallah)", and rebuilt it as a 47.5 km channel for the 100-year flood (EIA, Chapter 2); the High Court has asked the JDA why it has not built the concrete channels near Ambawadi that a NEERI report recommended (*Alok Gupta v. State*, order of 25 July 2026, as reported). On the Jojari at Jodhpur, the Supreme Court found units of the Kakani industrial area "merely 30 to 60 metres" from the riverine area, with about 12.805 ha within the "apparent High Flood Area" (7 August 2026). The Model Rajasthan Building Regulations 2025 keep no width along a nala, which is the failure Clauses 7.10.2 and 7.10.3 are written to prevent. Clause 7.10.3(b) prevents a crossing from narrowing a channel to its current, encroached width.

7.11 Fee-in-lieu and regional tank storage

7.11.1 Where a basin plan has been notified, and the Authority has adopted alternative S-5 of the Policy Supplement (Clause 1.7), a development may pay a fee in lieu of on-site detention under Chapter 4. The fee shall be applied to restoring or creating storage in a tank, pond or regional facility in the same basin.

7.11.2 Tank storage funded by fee-in-lieu shall:

- (a) meet Clause 7.7.1 in full before it is counted;
- (b) be downstream of the contributing development and upstream of the flood-prone area it is meant to protect;
- (c) be created, or under construction, before the development it serves is occupied, or within a period the basin plan fixes; and
- (d) be recorded in the register of Clause 10.17 with the developments that funded it, so that the same volume is not sold twice.

7.11.3 Fee-in-lieu does not replace:

- (a) the retention requirement of Chapter 4, which is always met on site; or
- (b) the water quality requirement of Chapter 8, which is met on site or in a regional facility treating the same runoff before it reaches the tank.

Commentary. Chapter 4 provides for fee-in-lieu toward restored talab or tank storage in master-planned basins. Malaysia's 2008 DID checklist allowed on-site detention only for small sites and required community ponds for larger areas (DID, 2008). In Rajasthan no shared form of storage is required by the building regulations: the rainwater harvesting of the Model Rajasthan Building Regulations 2025 is plot-level (reg. 8.3, plots of 225 m² or more), the large-project conditions ask for recharge bores and unpaved open space, and the regulations have no detention, peak-flow or "zero runoff" rule. The talabs, johads and nadis renewed under the Mukhya Mantri Jal Swavlamban Abhiyan and the Amrit Sarovar mission, and the Dravyavati channel at Jaipur, are the nearest existing forms of shared storage or conveyance. None of these sets a technical standard for counting storage. Clause 7.11.2(b) matters because a tank downstream of the flood-prone area protects nothing. Clause 7.11.3 keeps retention on site: it is the volume-control layer of this Manual, and a regional tank cannot recharge the aquifer under the developed site.

7.12 Wetlands, marshes and estuaries

7.12.1 **Scope.** This clause applies to marshes, swamps, backwaters, estuaries, and tidal creeks and lagoons, including:

- (a) wetlands notified under the Wetlands (Conservation and Management) Rules, 2017 or listed by the Rajasthan State Wetland Authority;
- (b) the four Ramsar sites of Rajasthan (Keoladeo National Park, designated in 1981; Sambhar Lake, designated in 1990; and Khichan and Menar, designated in 2025), each to its boundary as designated, and any wetland notified under the 2017 Rules or identified in the statewide survey ordered by the High Court on 1 June 2026;
- (c) the city lakes and sagars, the salt lakes, playas and inland depressions of the arid west, and the marshy low land and depressions of the river floodplains, such as those of the Chambal, the Banas and the Luni, within the 1% AEP extent of Clause 7.3.4 or the High Flood Line and buffer once demarcated under the Supreme Court's order of 7 August 2026, whichever is larger (the river channel itself is a waterbody under the rest of this chapter); and
- (d) any other marsh, wetland, talab or lake that the Authority notifies, that the wetland authority lists, or that a court or the National Green Tribunal directs to be protected.

7.12.2 **No drainage of wetlands.** No drain, channel, cut or pump shall be designed to drain a wetland, to lower its normal water level, or to reduce the period for which it is wet, except under a plan approved by the wetland authority.

7.12.3 **Inflows.** Every drain discharging into a wetland in Clause 7.12.1 shall:

- (a) meet Clause 7.10.6;
- (b) pass through water quality treatment for the WQv of its catchment (Chapter 8) before entering the wetland; and
- (c) where practicable, spread its flow across a vegetated margin rather than discharge at one point.

7.12.4 **Hydraulic connectivity.** Roads, embankments and utility corridors across or along a wetland shall have openings that:

- (a) pass the 1% AEP flow without raising the 1% AEP water level by more than the limit in Clause 7.6.2; and
- (b) keep the wetland's normal water exchange, including tidal exchange in estuaries, with openings spread along the crossing so that no part of the wetland is cut off.

7.12.5 **Storage counted at basin scale only.** Wetland storage shall be included in basin and regional models. It shall not be counted as detention for any individual development.

7.12.6 **Tidal wetlands and estuaries.** For estuaries and tidal wetlands:

- (a) tailwater shall be taken from Chapter 5 (Clause 2.12 joint cases);
- (b) works shall also comply with the Coastal Regulation Zone Notification in force; and
- (c) mouth-opening works, training walls and dredging are outside the scope of this Manual and need their own studies.

7.12.7 **No dumping.** No solid waste, construction debris or dredged material shall be placed in a wetland or its setback.

> **Commentary.** Rajasthan's wetlands are the concern of the Rajasthan State Wetland Authority, reported to have been constituted in 2019 and reconstituted in 2020 (as reported). A draft notification of 44 wetlands in 19 districts was reported in July 2023, 67 wetlands by August 2023, and 75 notified wetlands by January 2026 (as reported; the notifications were not read). The State has four Ramsar sites (dates and areas as reported from the national list; the Ramsar Information Sheets were not read): Keoladeo National Park at Bharatpur, designated in 1981 over about 2,873 ha; Sambhar Lake, the salt lake, designated in 1990 over about 24,000 ha; and Khichan (Phalodi) and Menar (Udaipur), designated on 4 June 2025, whose reported areas conflict. The High Court is the working regulator: acting of its own motion, it ordered on 1 June 2026 a district-wise survey of the State's

wetlands, of which about 46,748 units are reported (as cited by the Court), and directed that there be "no further encroachment, reclamation, dumping, filling, construction activity or alteration of the physical boundaries of identified wetlands", and that no untreated sewage, municipal waste, industrial effluent or construction debris be discharged "into wetlands or their catchment areas"; and in a case on the lakes of Udaipur in 2026 (C.W. 12630/2026) it is reported to have barred filling, dumping and construction in identified lake, canal and catchment areas (as reported). At Ajmer, the National Green Tribunal found in 2023 that a park and other works built on the bed and edge of Ana Sagar violated the Wetlands Rules, 2017, and ordered them removed; the Supreme Court refused a stay, rejected a plan to remodel them in March 2025, and demolition began on 12 September 2025, with the State committing to seek the lake's notification as a wetland (all as reported). A drain outfall, desilting, diversion or gate operation in or near a Ramsar site or a notified wetland therefore needs the Wetland Authority's permission where the notification or the Rules regulate it, and compliance with the High Court's and the Tribunal's directions, as well as compliance with this chapter; for the talabs and lakes that are not notified, this chapter, the Lakes Act, 2015 and the revenue and municipal law are the only controls. Clause 7.12.2 targets a specific risk: drains built to relieve flooding next to a marsh can drain the marsh itself, and once it is dry it is encroached. Sewage reaches Rajasthan's lakes, rivers and wetlands through the nalas (Clause 8.9, Commentary). At Jodhpur, the Supreme Court recorded in November 2025 that the city produced about 230 MLD of sewage against an existing treatment capacity of about 120 MLD, and that "Treated and untreated sewage is discharged" to the Jojari, and in March 2026 that treatment was limited to about 175 MLD, a gap of about 55 MLD, with effluent reaching the river through concealed pipelines and storm water drains; downstream of Jaipur, samples at the Morel dam in 2026 "indicated the possible presence of sewage and/or industrial effluents" (Supreme Court, 7 August 2026). The High Court has directed that no untreated sewage reach the State's wetlands or their catchments (1 June 2026) or the lakes of Udaipur (2026, as reported). Clauses 7.10.6(d) and 7.12.3 therefore cannot yet be met by many existing outfalls. In Rajasthan they apply in full to every new outfall, and every existing outfall to a lake, talab, wetland or river that carries dry-weather flow comes under the annual survey and the interception of Clauses 8.9.4 and 8.9.5 until its sources are removed.

7.13 Encroachment interfaces

7.13.1 **Boundary.** For design under this Manual, the boundary of a waterbody is the larger of its Revenue record boundary and its surveyed FTL (or top of bank), as in Clause 7.3.3. Setbacks are measured from that boundary.

7.13.2 **No reliance on encroached land.** No design shall:

- (a) count, as storage or conveyance, land within a waterbody boundary that is occupied by encroachment, unless its removal is ordered and funded; or
- (b) treat the encroached width of a channel as its design width.

7.13.3 **Public works in encroached reaches.** Where a public drainage work passes through an encroached reach:

- (a) it shall be designed for the full waterbody width (Clause 7.13.1);
- (b) where the full width cannot be cleared before the work is built, the design report shall state the interim capacity and the flood risk until it is cleared; and
- (c) the work shall be built so that the full width can be restored later without rebuilding it.

7.13.4 **Boundary marking.** Every development adjoining a waterbody shall, before the completion certificate:

- (a) mark the outer edge of Zone 1 on the ground with permanent survey markers at intervals of not more than 30 m and at every change of direction; and
- (b) show the setback zones on the approved layout plan and in the sale documents of every plot that includes setback land.

7.13.5 **Retaining walls.** No retaining wall, bund or embankment shall be built along the edge of a waterbody, within Zone 1, to protect or reclaim land, except to protect existing public infrastructure under the custodian's approval.

> **Commentary.** Rajasthan's main controls on filling and building in talabs, nalas and their catchments are revenue law and the courts. Khatedari rights do not accrue in pasture land and, as reported, in tank and river beds (Rajasthan Tenancy Act, 1955, s. 16), and the High Court directed in 2012 that allotments of land in the catchments of "Johar, Nala, Tank, River, Pond" made in defiance of section 16 be cancelled (as quoted). In the Ramgarh catchment the High Court ordered in 2011 that encroachments be removed "so as to restore the position as was existing on 15.08.1947"; the Supreme Court, finding that "nothing substantive appears to have been achieved on the ground over the years", imposed costs of ₹10 lakh on each of two petitions by a university that had encroached on 8,125 m² of catchment land and directed the JDA to demolish the encroachment (*National Institute of Medical Science University*, 9 November 2017). In 2026 the High Court ordered a road and a crematorium built on land recorded as gair mumkin nala to be removed and the land restored (*Ramji Lal Saini*). The Supreme Court is reported to have read the High Court's catchment orders in 2022 as aimed at protecting genuine catchments, not at perpetuating wrong entries in the Revenue records (*State of Rajasthan v. Ultratech Cement*, as summarised; the judgment was not read). The Lakes Act, 2015 empowers the Lakes Development Authority to remove any building or obstruction in a lake's protected area or flow area (s. 6(2)), and at Ajmer the works built on Ana Sagar have been demolished under the orders of the National Green Tribunal and the Supreme Court (2023 to 2025, as reported). In the towns, public tanks vest in the Municipality as trustee (Rajasthan Municipalities Act, 2009, s. 68), but no express bar on their change of use was seen; this Manual treats a recorded talab, and its agor and flow paths, as drainage infrastructure (definitions after Clause 7.2). The Rajasthan Land Revenue Act, 1956, its rules on tank-bed lands and on conversion, and the encroachment sections of the development authority Acts were not read for this Manual. This Manual cannot evict anyone. It can stop designs from treating encroachment as permanent (Clause 7.13.2), make public works restorable to full width (Clause 7.13.3), and make the setback visible on the ground and in property documents so that new buyers know it is there (Clause 7.13.4). The 30 m marker interval is set by this Manual.

7.14 Safety of tank bunds and embankments

7.14.1 **Dam Safety Act screening.** For every tank, and every embankment built or altered under this Manual, the designer shall determine whether it is a "specified dam" under the Dam Safety Act, 2021. Under the Act, a specified dam is a dam:

- (a) more than 15 m high, measured from the lowest point of the general foundation area to the top of the dam; or
- (b) between 10 m and 15 m high, where the crest length is not less than 500 m, or the reservoir capacity is not less than one million m³, or the maximum flood discharge dealt with by the dam is not less than 2,000 m³/s, or the dam has specially difficult foundation problems, or the dam is of unusual design.

Where it is a specified dam, the Act and the requirements of the State Dam Safety Organisation govern, in addition to this Manual.

7.14.2 **Hazard class.** Every tank bund and detention embankment that is not a specified dam shall be given a hazard class:

- **High hazard:** a breach could flood a habitable building, a school, a hospital, an arterial road or critical infrastructure.
- **Low hazard:** any other case.

7.14.3 **High-hazard embankments.** For high-hazard tank bunds and embankments:

- (a) the surplus weir or spillway shall pass the 1% AEP inflow at MWL with the freeboard of Clause 7.7.4(b), and shall be checked for the 0.2% AEP (500-yr) inflow without overtopping the bund (as for detention basins in Chapter 4);
- (b) a breach analysis shall map the area flooded by a breach at MWL;
- (c) an emergency action plan shall be prepared, with the warning and evacuation arrangements for the breach area; and
- (d) the design shall be certified and independently checked under Clause 10.6.

7.14.4 **Inspection.** Every tank whose storage is counted under Clause 7.7, and every high-hazard embankment, shall be inspected before the SW monsoon (by 15 June) and after every heavy-rainfall event (Chapter 10) for seepage, slips, cracks, animal burrows, trees on the bund, and blockage of the weir and sluices.

7.14.5 **No unauthorised cutting.** No person shall cut, lower or breach a tank bund or surplus weir during a flood except under the custodian's emergency procedure.

> Commentary. The definition of a specified dam is quoted from the Dam Safety Act, 2021 (Act 41 of 2021). The Act defines a "dam" as an artificial barrier constructed across rivers or tributaries to impound or divert water. It excludes flood embankments, dikes and guide bunds. The bunds of most talabs, johads, nadis and khadins are low and are not expected to make them specified dams, but each shall be screened under Clause 7.14.1. The dams and bunds of the city lakes and town reservoirs, such as those of Pichola, Fateh Sagar and Udai Sagar at Udaipur, Ana Sagar at Ajmer, Kailana and Takhat Sagar at Jodhpur and the Ramgarh dam, are of heights that were not found for this Manual; each shall be screened, and the larger of them may be specified dams. Where the storage of a talab, sagar or city lake is counted under Clause 7.7, its bund or dam is a tank bund for Clause 7.14.2 unless the Act applies. Whether a tank bund that is not across a river or tributary is a "dam" under the Act is not clear from its text. In Rajasthan the dams and bunds that matter to the towns are those of the city lakes, such as Ana Sagar and the lakes of Udaipur, the reservoirs that supply the towns, such as Kailana and Takhat Sagar at Jodhpur, and the barrages and reservoirs upstream of them, such as the Kota Barrage. In September 2019 the Kota Barrage released about 6.5 to 6.9 lakh cusecs through 18 of its 19 gates and more than 5,000 people were rescued at Kota (as reported); at Ajmer the opening of the Ana Sagar escape-channel gates has flooded the colonies along the channel (2024 and 2025, as reported). No breach map or emergency action plan for a city lake bund or a talab bund was found. A failed or overtopped lake bund floods the colonies below it, and an unannounced release floods them too, which is why Clause 7.14.3 asks for breach mapping and an emergency action plan for high-hazard embankments. The hazard classes, the breach analysis and the emergency action plan for high-hazard tanks are set by this Manual. They extend the Chapter 4 requirement for detention basins (1% AEP spillway with outlet blocked, 0.2% AEP for high-hazard basins) to tanks that are counted as design storage.

7.15 Submittal requirements

Every drainage report for a development or work under Clause 7.1.2 shall include:

1. the **Waterbody Sheet (Form 7-1)** under Clause 7.3.2, with the setback zones and their basis (mapped extent, hydraulic study or fixed width);
2. the hydraulic study of the 1% AEP extent and floodway, where Clause 7.3.4 requires it;
3. the **Compensatory Storage Calculation (Form 7-3)**, by elevation band, where fill is proposed in the flood fringe;
4. for any tank storage counted: the **Tank Storage Credit Sheet (Form 7-2)**, with the survey, stage–storage curve, operating rule, cascade model results and custodian concurrence of Clause 7.7.1;
5. for any crossing, outfall or work in Zone 1: the custodian's NOC and the hydraulic analysis of Clause 7.6.2 or 7.10.3;

6. for restoration or desilting: the pre-works survey, silt tests and hydrogeological report of Clause 7.9; and
7. for any embankment: the Dam Safety Act screening and hazard class of Clause 7.14.

7.16 Review and update

7.16.1 This chapter shall be reviewed with the rest of the Manual (Chapter 1). The fixed-width table of Clause 7.4.6 shall also be reviewed within 2 years of the Authority adopting 1% AEP flood maps for its area.

7.16.2 Where the Authority adopts new 1% AEP flood maps, they apply to new submittals **6 months** after adoption, unless the Authority notifies otherwise.

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Annexes and forms

Annex / Form	Content
7A	Statewide waterbody GIS layer and inventory fields
7B	Fixed-width setback table (alternative S-3, with Annex 1C)
7C	Template tank operating rule, with flood cushion
7D	Desilting and restoration specification
7E	Glossary of Hindi and Rajasthani waterbody terms and regional variants
Form 7-1	Waterbody Sheet
Form 7-2	Tank Storage Credit Sheet
Form 7-3	Compensatory Storage Calculation (by elevation band)

CHAPTER 8

Water Quality and Recharge

8.1 Purpose and scope

8.1.1 This chapter sets the requirements for the quality of stormwater leaving a site or a public drainage system, and for groundwater recharge. It covers:

- (a) the water quality volume (WQv) and the water quality design flow;
- (b) the treatment train, and the selection and design of best management practices (BMPs);
- (c) the criteria for infiltration and recharge;
- (d) the exclusion of sewage and dry-weather flow from storm drains;
- (e) gross pollutant traps, first-flush treatment and screens at outfalls to waterbodies;
- (f) how rainwater harvesting (RWH) fits with retention and detention;
- (g) erosion and sediment control during construction; and
- (h) monitoring.

8.1.2 This chapter applies to every development and public work to which Chapter 4 applies (Chapter 1). Clauses 8.9 (sewage) and 8.12 (construction erosion and sediment control) apply to every development that needs a building permit or layout approval, and to every public drainage work, whatever its size.

8.1.3 Retention under Chapter 4 is the first and preferred form of water quality control. Runoff retained on site is treated in full. The rest of this chapter applies to the part of the WQv that is not retained.

> Commentary. CPHEEO (2019) is the only Indian manual that covers stormwater quality in any detail. Its Chapter 9 reproduces US event mean concentrations, but cautions that "in an Indian context the values would be much higher" because drains receive night soil, urine and food waste, and it sets no Indian numeric criteria (CPHEEO 2019, Part A §9.5). Its Chapter 10 describes water-sensitive urban design, LID and SuDS treatment trains (CPHEEO 2019, Part A Ch. 10). This chapter turns that guidance into requirements. It follows the treatment approach of the MARC/APWA BMP Manual (2012), now merged into APWA 5600 (2025.01), with the Malaysian 3-month ARI water quality storm (MSMA 2, 2012) and the Georgia water quality volume (GSMM, 2016) as tropical and US benchmarks.

8.2 Definitions

Term	Meaning in this Manual
Water quality volume (WQv)	The runoff volume that must be retained or treated, from the water quality rainfall depth (Clause 8.4).
Water quality rainfall depth (P_wq)	The greater of the retention depth (Annex 2E, Clause 2.10) and the 24-hour 3-month ARI depth (Annex 8A).

Term	Meaning in this Manual
3-month ARI depth	The 24-hour rainfall depth equalled or exceeded on average four times a year, from a partial-duration series of the long-term daily record.
Water quality design flow (Q_wq)	The peak flow from the 3-month ARI storm, used to size flow-through devices and diversion structures (Clause 8.4.5).
Runoff coefficient for WQv (Rv)	The volumetric runoff coefficient for small storms, Rv = 0.05 + 0.009·I.
BMP	A best management practice: a structural or non-structural measure that reduces pollutant loads or runoff volume.
Treatment train	Two or more BMPs in series, from source to site to regional scale (Clause 8.5).
Pretreatment	A BMP that removes coarse sediment, litter and oil before runoff reaches a filter or infiltration BMP.
First flush	The early part of a runoff event, which usually carries the highest concentrations of sediment, litter and oil.
Gross pollutant trap (GPT)	A device that captures litter, plastics, vegetation and coarse sediment, typically above about 5 mm.
Dry-weather flow (DWF)	Flow in a storm drain when it has not rained for at least 72 hours. In a separate storm system, DWF is evidence of sewage, sullage, groundwater infiltration or illicit discharge.
Cross-connection	Any pipe, channel or opening that lets sewage or sullage (grey water from kitchens, bathrooms and laundries) enter a storm drain.
Infiltration facility	A facility designed to store runoff below the ground surface, or in a depression, and let it soak into the soil: infiltration trenches and basins, unlined bioretention, permeable pavement with an open base, soakaways, recharge pits and recharge wells.
Seasonal high groundwater table	As defined in Clause 3.10.2: the highest level in the SW monsoon season.
Hotspot	A land use with a high risk of spills or contaminated runoff (Clause 8.8.8).
Level of Service (LoS) / Value Rating (VR)	The scoring system of Clause 8.6, from the MARC/APWA BMP Manual (2012).

8.3 Objectives and pollutants of concern

8.3.1 Stormwater treatment under this Manual shall aim to:

- (a) remove litter, plastics and other gross pollutants before they reach a waterbody;
- (b) remove suspended sediment, and the metals, nutrients and oil carried on it;
- (c) keep sewage and sullage out of storm drains and waterbodies;
- (d) recharge groundwater where soils and groundwater depth allow, without polluting it; and
- (e) prevent erosion and sediment discharge during construction.

8.3.2 The design shall address the following pollutants for every site, and the hotspot pollutants of Clause 8.8.8 where they apply:

Table 8.1 — Pollutants of concern, sources and primary controls

Pollutant	Main sources in Rajasthan towns	Primary control
Gross pollutants (plastics, litter, vegetation)	Streets, markets, open dumping in drains	Source collection; GPTs and screens (Clause 8.10)

Pollutant	Main sources in Rajasthan towns	Primary control
Suspended sediment	Construction sites, unpaved roads and verges, road wear, drain silt	Erosion and sediment control (Clause 8.12); pretreatment; filtration
Oil, grease and fuel	Roads, parking, fuel stations, workshops, bus depots	Oil-grit separators at hotspots; bioretention
Pathogens and organic load (BOD)	Sewage and sullage cross-connections, animal waste	Exclusion and DWF interception (Clause 8.9)
Nutrients (N, P)	Sewage, fertiliser, food waste, detergents	Exclusion; bioretention; wetlands
Heavy metals	Roads, roofs, industrial yards	Filtration; sedimentation

> **Commentary.** Gross pollutants and sewage come first in Clause 8.3 because they dominate the pollution of urban waterbodies in Rajasthan, and because no treatment BMP works for long if they are not removed. CPHEEO (2019) notes that Indian drains carry night soil, urine and food waste (Part A §9.5). In its WSUD procedure it lists TSS, total nitrogen, total phosphorus and gross pollutants as the key pollutants (Part A Ch. 10). AMRUT 2.0 funds the harvesting of rainwater "through storm water drains into water body (which is not receiving sewage/effluent)" (Lok Sabha unstarred question AU1419), which only works if sewage is first kept out of the drains.

8.4 Water quality volume and design flow

8.4.1 **Water quality rainfall depth.** The water quality rainfall depth is:

$$P_{wq} = \max(P_{ret}, P_{3m})$$

where:

- P_{ret} = the retention depth for the site's zone (Annex 2E, Clause 2.10), mm; and
- P_{3m} = the 24-hour 3-month ARI depth for the site's zone (Annex 8A), mm.

8.4.2 **Water quality volume.** The WQv shall be computed as:

$$WQv = (P_{wq} / 1000) \times Rv \times A$$

where:

- WQv is in m³;
- A = the contributing area, m²;
- $Rv = 0.05 + 0.009 \cdot I$; and
- I = the impervious percentage of the contributing area (0–100), after the connectivity rules of Clause 3.9.

The Rv form above may be used only for sites under 0.5 ha and under the Tier B simplified method (Clause 4.14). This is the same limit as for the retention volume (Clause 4.4.2). For all other sites the WQv shall be computed with the SCS-CN method, as the retention volume is: WQv (m³) = 10 × Q_{wq} × A, where Q_{wq} (mm) is the SCS-CN runoff from P_{wq} for each sub-area and A is in ha.

8.4.3 **Climate factor.** The climate factor of Clause 2.8 shall not be applied to P_wq. P_ret and P_3m are frequency statistics of ordinary rainfall, not AEP design depths.

8.4.4 **WQv met by retention.** The volume retained on site under Chapter 4 counts toward the WQv in full. Where the retained volume is equal to or greater than the WQv, no further treatment is required for that area, except:

- (a) pretreatment of inflows to each retention facility (Clause 8.5.3);
- (b) hotspot controls (Clause 8.8.8); and
- (c) the outfall requirements of Clause 8.10, where the site discharges to a waterbody.

8.4.5 **Water quality design flow.** Flow-through devices (swales, filter strips, oil-grit separators, GPTs) and diversion weirs for off-line BMPs shall be sized for Q_wq. Q_wq shall be computed from the 3-month ARI intensity at the time of concentration of the contributing area:

- (a) by the Rational Method, where Chapter 3 allows it (a single element draining no more than 16 ha); or
- (b) as the peak of a hydrograph method using the 3-month ARI 24-hour depth with the alternating-block pattern of Clause 2.9.1.

8.4.6 **Bypass.** Flows above Q_wq shall bypass flow-through and off-line treatment devices without washing out the material already captured. The bypass shall be part of the minor or major system (Chapter 6).

8.4.7 **Drawdown.** Where the WQv is held in an extended-detention BMP (wet pond, constructed wetland or dry extended-detention basin), it shall be released over **24–48 hours** (Chapter 4).

> Commentary. The WQv depth is the runoff from the 3-month ARI storm or the retention depth, whichever is greater. The 3-month ARI is the Malaysian water quality design storm (MSMA 2, 2012). The Malaysian 2008 checklist gave its depth as about 40 mm and said it captures 90% or more of 24-hour storm runoff volume (DID, 2008). The Rajasthan value must be computed (Annex 8A). Georgia sets its WQv as the runoff from 1.2 inches (about 30 mm), the depth that covers 85% of storms in an average year, and requires 80% removal of the average annual post-development TSS load (GSMM 2016, Vol 1, Standard #4). Kansas City's water quality storm is the 1.37-inch (about 35 mm) event that produces up to 90% of the runoff from all 24-hour storms in a year (MARC BMP Manual, 2012).
>
> The Rv formula is from the MARC/APWA BMP Manual (2012), which computes WQv = P × Rv with Rv = 0.05 + 0.009·I. Rv is used instead of the SCS curve number because the CN method greatly understates runoff from small storms on pervious ground. Not applying the climate factor (Clause 8.4.3) has no direct precedent; this Manual does so because it treats P_wq like the retention depth, as a statistic of ordinary rainfall. Bypass of larger flows and the 24–48 hour drawdown follow Chapter 4; MARC (2012) required at least 40 hours of extended detention of the WQv.
>
> **Illustrative — not design values.** For a 1.0 ha site with 80% impervious cover and an assumed P_wq of 50 mm:
>
> - Rv = 0.05 + 0.009 × 80 = 0.77
> - WQv = (50 / 1000) × 0.77 × 10,000 = 385 m³

8.5 Treatment train and pretreatment

8.5.1 **Treatment train.** Water quality control shall be designed as a treatment train, in the order shown in Figure 8.1:

- (a) **source controls** on the plot: roof runoff to RWH, rain gardens, permeable paving, disconnection of impervious areas, and silt traps at inlets;

- (b) **site controls**: bioretention, swales, filter strips, infiltration, oil-grit separators at hotspots, wet ponds and extended detention; and
- (c) **regional controls**, for public drainage: GPTs and DWF interceptors at outfalls, constructed wetlands at tank inlets, and regional ponds.

8.5.2 A development shall meet the WQv on site, through (a) and (b). Regional controls under (c) may count toward a development's WQv only where a regional facility treating the same runoff has been built under a notified basin plan (Clause 7.11).

8.5.3 **Pretreatment.** Every bioretention cell, infiltration facility, permeable pavement receiving run-on, wet pond and constructed wetland shall have pretreatment at each concentrated inflow. Pretreatment shall be a sediment forebay, grass filter strip, silt trap or proprietary device that holds at least **10% of the WQv** of its contributing area, or that is sized for Q_wq for flow-through devices.

8.5.4 Pretreatment shall be accessible for cleaning without entering or disturbing the main BMP.

> **Commentary.** The treatment train follows CPHEEO (2019, Part A §10.2.3, SuDS treatment train) and CIRIA C753 *The SuDS Manual* (2015). It is also the order of priorities of this Manual: preserve, retain, detain, convey (Chapter 1). The 10% forebay volume has no Indian precedent; it is a common sizing rule for forebays in US manuals. In Rajasthan, unpaved verges, construction sites and drain silt deliver a heavy sediment load. Bioretention and infiltration facilities without pretreatment clog, often within a year or two.

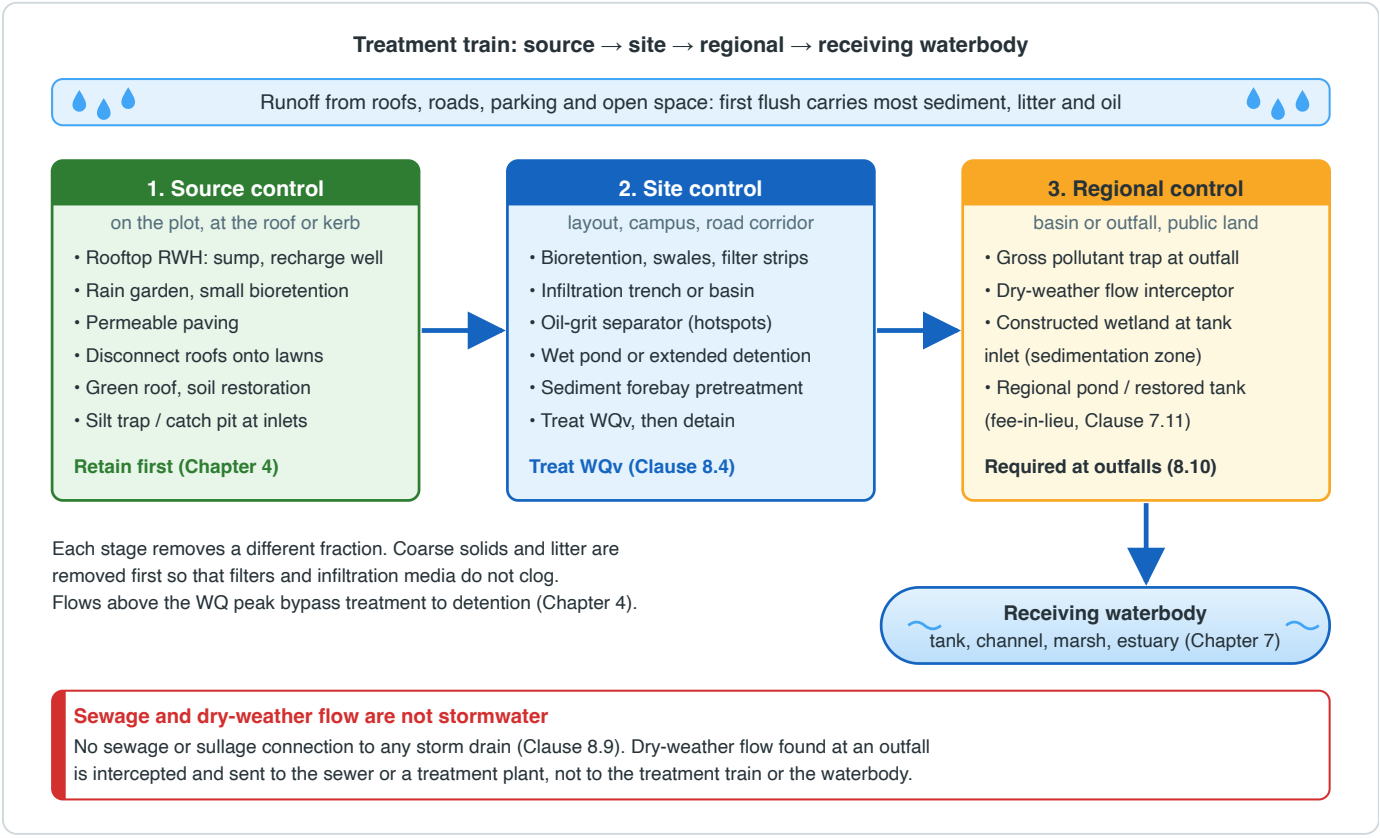


Figure 8.1 — Treatment train: source, site and regional controls before the receiving waterbody, with sewage and dry-weather flow kept out of the system. Original drawing for this Manual, adapted from CIRIA, The SuDS Manual (C753), 2015, and MARC/APWA, Manual of Best Management Practices for Stormwater Quality, 2012.

8.6 BMP selection: Level of Service and Value Rating

8.6.1 **Method.** In Tier A areas, the BMPs for each site shall be selected by the Level of Service (LoS) method of this Clause. In Tier B areas, the simplified route of Clause 8.6.5 may be used.

8.6.2 **Required Level of Service.** For a site that is not redevelopment, the required LoS depends on the change in curve number (ΔCN) from pre- to post-development (Chapter 3):

Table 8.2 — Required Level of Service for sites that are not redevelopment

ΔCN	Impact	Required LoS
17 or more	High	8
7 to 16	Moderate	7
4 to 6	Low	6
1 to 3	Minimal	5

For redevelopment (existing impervious cover of 20% or more of the site), the required LoS shall be taken from Annex 8B.

8.6.3 **Value Rating.** Each BMP treating the WQv has a Value Rating (VR) from Table 8.3. The site's composite VR is the area-weighted average of the VRs of the BMPs serving each part of the site. Treatment trains get a composite VR under Annex 8B. The composite VR shall be equal to or greater than the required LoS.

8.6.4 **Conditions for a Value Rating.** A BMP earns its VR only if:

- (a) it is sized for the WQv (or Q_wq for flow-through devices) of the area credited to it;
- (b) it meets the design requirements of Clause 8.7 and, for infiltration, Clause 8.8; and
- (c) it has pretreatment under Clause 8.5.3.

8.6.5 **Tier B simplified route.** In Tier B areas, the requirement of Clause 8.6.3 is deemed met where the whole WQv of the site is either:

- (a) retained on site under Chapter 4; or
- (b) treated by a bioretention cell, rain garden or infiltration facility designed under Clauses 8.7 and 8.8, with pretreatment.

Table 8.3 — BMP Value Ratings and suitability in Rajasthan

BMP	VR (MARC 2012)	Main pollutants removed	Volume reduction / recharge	Dune sands, sandy loams and alluvium	Laterite / hard rock	Black cotton soil / calcrete pan / high water table	Rajasthan notes
Native vegetation (preserved)	9.25	All	High	Suited	Suited	Suited	Counts only for preserved, undisturbed area
Rain garden / infiltration	9.0	Sediment, metals, oil, nutrients	High	Suited if 1.0 m separation met	Conditional (test)	Not suited	Mosquito control: drain within 48 h
Bioretention	8.5	Sediment, metals, oil, nutrients	Medium–high (unlined); low (lined)	Suited	Suited, with underdrain	Lined, with underdrain	Media source and phosphorus content to be specified

BMP	VR (MARC 2012)	Main pollutants removed	Volume reduction / recharge	Dune sands, sandy loams and alluvium	Laterite / hard rock	Black cotton soil / calcrete pan / high water table	Rajasthan notes
Permeable pavement	7.5	Sediment, metals, oil	Medium–high	Suited	Conditional	Lined only	Not where run-on carries heavy silt
Extended detention wetland	7.0	Sediment, nutrients, metals	Low	Conditional (water balance)	Suited	Suited	Good at tank inlets (Clause 7.9.7)
Media / sand filter	6.0	Sediment, metals	Low	Suited	Suited	Suited (lined)	Needs frequent cleaning
Extended wet detention (wet pond)	5.0	Sediment, metals, some nutrients	Low	Conditional (water balance)	Suited	Suited	Dry-season water balance (Clause 8.7.8)
Vegetated filter strip	5.0	Sediment	Low–medium	Suited	Suited	Suited	Mostly as pretreatment
Native vegetation swale	4.0	Sediment, oil	Low–medium	Suited	Suited	Suited	Not where Q_wq velocity is high
Extended dry detention	4.0	Coarse sediment	Low	Suited	Suited	Suited	Combine with detention (Chapter 4)
Proprietary / hydrodynamic devices	3.0–5.0	Coarse sediment, oil, litter	None	Suited	Suited	Suited	VR from verified test data only
Signage (public education)	+0.25	—	—	—	—	—	Added to composite VR

The VR column is from the MARC/APWA BMP Manual (2012), Table 4.4. The suitability columns and notes have no direct precedent and are set by this Manual.

> **Commentary.** The LoS and VR method is from the MARC/APWA Manual of Best Management Practices for Stormwater Quality (2012), Tables 4.2 and 4.4. The VRs combine a water quality score, based on effluent TSS concentrations in the International Stormwater BMP Database, with scores for volume reduction, temperature, and oils and floatables. The method suits Rajasthan for two reasons. It rewards volume reduction and preservation, which also serve recharge. It can also be checked by a reviewer without water quality modelling. Its weakness is that the scores come from US data. Rajasthan stormwater carries more litter and more sewage than the US runoff behind the scores (CPHEEO 2019, §9.5), so this Manual requires GPTs and DWF exclusion separately (Clauses 8.9 and 8.10) and does not let a VR stand in for them.

8.7 BMP design summaries

8.7.1 **General.** Each BMP shall be designed to the requirements below and to Annex 8D (BMP design sheets). The dimensions given are **recommended starting values** where marked; the designer shall justify any departure. Every BMP shall be designed for safe passage of flows above Q_wq (Clause 8.4.6) and shall have access for maintenance (Chapter 10).

8.7.2 **Bioretention and rain gardens** (Figure 8.2).

- (a) Surface ponding depth not more than **300 mm** above the mulch, with an overflow at the maximum ponding level.
- (b) Surface ponding drained within **48 hours**.
- (c) Filter media 600–900 mm deep: an engineered sandy loam with low fines and low phosphorus content (Annex 8D), with a 50–75 mm mulch layer.
- (d) A transition (choker) layer and a gravel drainage layer below the media.
- (e) A perforated underdrain where the design infiltration rate of the native soil (Clause 8.8.4) is below the rate needed to meet (b), or where the cell is lined.
- (f) Unlined cells shall meet the infiltration criteria of Clause 8.8. Cells that cannot meet them, and cells at hotspots, shall be lined.
- (g) Plants: native or naturalised species tolerant of both waterlogging and long dry spells.

8.7.3 **Vegetated swales.**

- (a) Trapezoidal or parabolic section, with side slopes no steeper than 1V:3H.
- (b) Longitudinal slope 0.5% to 4%, with check dams where steeper.
- (c) Flow depth at Q_wq not more than the height of the grass, and velocity at Q_wq not more than 0.3 m/s.
- (d) The 1% AEP flow (or the bypass) shall not erode the swale (Chapter 9 permissible velocities).
- (e) Where longitudinal slopes are below 1% or the subsoil is poorly drained, an underdrained ("dry") swale with filter media.

8.7.4 **Vegetated filter strips.**

- (a) Receive sheet flow only, with a level spreader where flow arrives concentrated.
- (b) Length in the direction of flow at least 5 m, and slope 1% to 8%.
- (c) Used mainly as pretreatment for bioretention, infiltration and swales.

8.7.5 **Permeable pavement.**

- (a) Run-on from impervious areas not more than twice the permeable area, and no run-on from unpaved or eroding areas.
- (b) Base reservoir of clean, open-graded aggregate, sized to hold its share of the WQv in its voids.
- (c) An open base (infiltrating) only where Clause 8.8 is met; otherwise lined with an underdrain, and then counted as filtration only.
- (d) Structural design for the traffic loading by the road authority's standards.
- (e) Not at hotspots, and not where the surface will be resurfaced with impermeable material.

8.7.6 **Infiltration trenches and basins** (Figure 8.3).

- (a) Pretreatment under Clause 8.5.3 in every case.
- (b) Trenches filled with clean washed aggregate, with a void ratio confirmed by test, wrapped in geotextile on the sides and top, on a sand base.
- (c) An observation well to the base of each trench.
- (d) Storage volume = WQv (or the retention volume of Chapter 4, where greater) held in the voids; emptied within 72 hours at the design infiltration rate.
- (e) An overflow to the minor or major system at grade.
- (f) Not brought into service until the contributing area is stabilised (Chapter 10).

8.7.7 **Wet ponds (extended wet detention).**

- (a) A permanent pool of at least the WQv, plus extended detention of the WQv above the pool, released over 24–48 hours.
- (b) A sediment forebay at each inlet (Clause 8.5.3).
- (c) Length-to-width ratio of the flow path at least 3:1, with no short-circuiting.

- (d) Permanent pool depth 1.0–2.5 m, with a safety bench (Clause 7.9.4).
- (e) A dry-season water balance (Clause 8.7.8).
- (f) The detention storage of Chapter 4 may sit above the extended detention level.

8.7.8 **Water balance for permanent pools.** Wet ponds and wetlands shall be shown, by a monthly water balance using IMD rainfall and pan evaporation, to keep at least 50% of the permanent pool volume (or the minimum wetland depth) through the driest year in 10. They shall not be topped up with groundwater, potable water or sewage. Where the balance fails, a dry extended-detention basin or a constructed wetland with a smaller permanent pool shall be used instead.

8.7.9 **Constructed wetlands.**

- (a) An inlet sedimentation pond (forebay) followed by a shallow vegetated macrophyte zone.
- (b) Extended detention of the WQv above the normal water level, released over 24–48 hours, with an extended detention depth not more than 0.5 m.
- (c) A flow path length-to-width ratio of at least 3:1, with deep zones across the flow path to spread the flow.
- (d) A high-flow bypass so that floods do not scour the macrophyte zone.
- (e) Where built at a tank inlet, the wetland shall sit within the tank's setback but outside its waterspread, and its storage shall not be counted as tank storage.

8.7.10 **Gross pollutant traps.**

- (a) Sized to treat Q_wq, with all flows up to the 1% AEP passing without washing out captured material.
- (b) Capture of gross pollutants down to about 5 mm.
- (c) Head loss included in the hydraulic grade line of the drain (Chapter 9), with the screen assumed **50% blocked**.
- (d) Storage for captured material sized for the cleaning interval of the O&M plan, and not less than the 3-monthly cleaning of Chapter 10.
- (e) Vehicle access for cleaning by suction or grab.

8.7.11 **Oil-grit separators.**

- (a) Required at the hotspots of Clause 8.8.8 that involve fuel or oil: fuel stations, vehicle workshops and washing bays, bus and truck depots, and parking areas of more than 50 spaces.
- (b) Sized for Q_wq, with a high-flow bypass.
- (c) Not to be used as the only treatment: they shall be followed by a filtering BMP where the site needs a VR above 5.

8.7.12 **Silt traps and catch pits.**

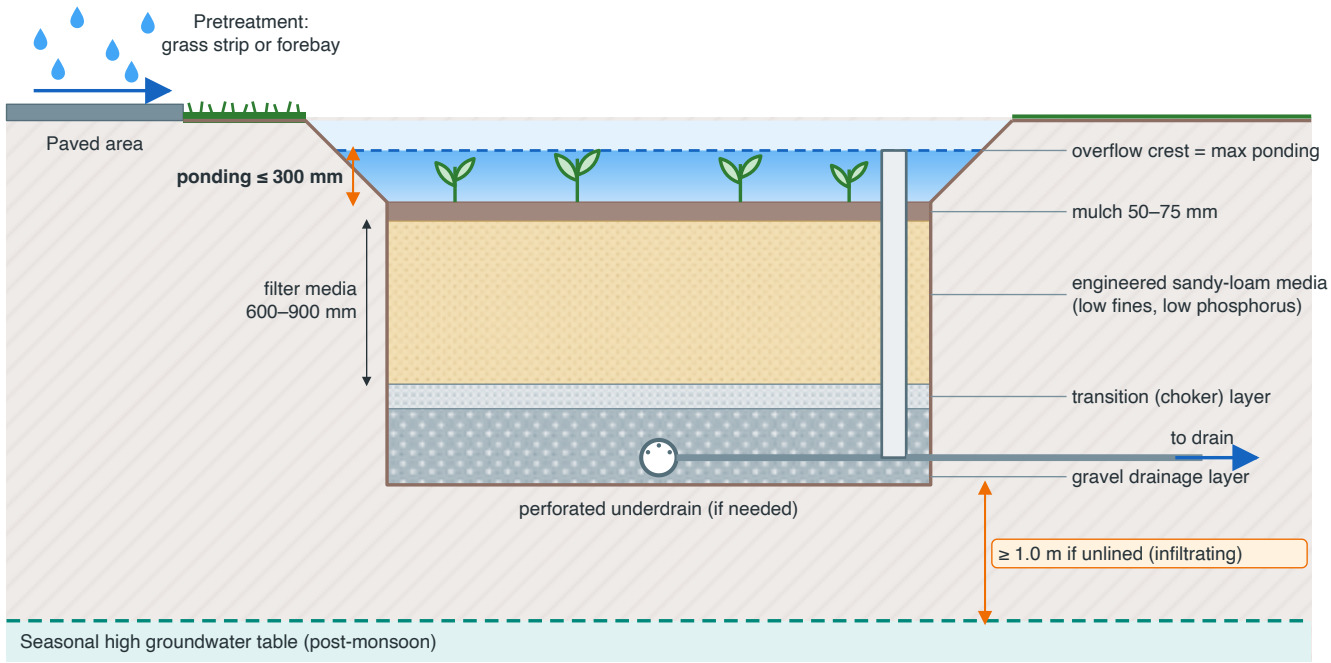
- (a) At every inlet that receives runoff from unpaved ground, and at the inlet of every drain discharging to a BMP or waterbody.
- (b) A sump at least 300 mm below the outlet invert.
- (c) Silt traps are pretreatment only and earn no VR.

> **Commentary.** The design summaries draw on the MARC/APWA BMP Manual (2012), the Georgia Stormwater Management Manual (2016, Vol 2), CIRIA C753 *The SuDS Manual* (2015) and PUB Singapore's ABC Waters Design Guidelines. The dimensions are typical of those manuals but have not been calibrated in Rajasthan. Three local issues drive changes from the source manuals:
>
> - **Mosquitoes.** Dengue is endemic in Rajasthan. Surface ponding in bioretention and rain gardens must drain within 48 hours (Clause 8.7.2(b)), well inside the time mosquito larvae need to develop. This is consistent with the 24–48 hour WQv drawdown of Clause 8.4.7.
> - **Dry seasons.** Rajasthan is the driest State in this series, and almost all its rain falls in the south-west monsoon: about 91% of the year's rain (IMD, *Climate of Rajasthan*, 2010), with district normals from 172.9 mm at Jaisalmer and about 250 mm at Barmer and Bikaner to 596.8 mm at Jaipur, 758.7 mm at Kota and

921.2 mm at Jhalawar, and 1,677 mm on Mount Abu (normals of 1951–2000). The monsoon now sets in at Jhalawar on about 24 June, at Jaipur on about 29 June and at Bikaner and Pokaran on about 6 July, and withdraws from Pokaran by about 17 September and from Jhalawar by about 28 September (IMD, new normal dates, 2020). For eight or nine months of the year talabs, johads and nadis fall or dry out, and in the towns the nalas that feed them often carry only sewage (Clause 8.9, Commentary). A wet pond or constructed wetland whose water balance (Clause 8.7.8) cannot keep its permanent pool through the dry months on its own catchment's runoff is not to be used; in most of the State the dry forms of Clause 8.7 (bioretention, swales, infiltration and extended dry detention) are the practical choice. Clause 8.7.8 applies to BMPs, which shall not be topped up with sewage; talabs, johads, nadis, sagars and city lakes are waterbodies under Chapter 7 and are not to be used as treatment for a development. Wet ponds that dry out turn into stagnant pools or are used for dumping. Clause 8.7.8 requires a water balance and bans topping up with sewage, which is a common practice for keeping urban ponds "full".

- **Litter and silt.** GPTs and silt traps are treated as essential, not optional, because Rajasthan drains carry heavy litter and silt loads. The 50% blockage factor for screens matches the grate clogging factor of Chapter 6.

The 50-space threshold for oil-grit separators, the 5 mm GPT capture size, the 0.3 m/s swale velocity and the other dimensions in this Clause have no direct precedent and are set by this Manual.



Lined version (no infiltration): impermeable liner below the gravel layer. Required at pollution hotspots and wherever the 1.0 m separation to seasonal high groundwater cannot be met.

Dimensions as set in Clause 8.7.2.

Figure 8.2 — Bioretention cell (rain garden) in section: pretreatment, surface ponding, filter media, transition and gravel layers, underdrain, overflow, and the 1.0 m separation to seasonal high groundwater for an unlined cell. Original drawing for this Manual, adapted from MARC/APWA, Manual of Best Management Practices for Stormwater Quality, 2012, and CIRIA, The SuDS Manual (C753), 2015.

8.8 Infiltration and recharge criteria

8.8.1 **Groundwater separation.** An infiltration facility is permitted only where the **seasonal high groundwater table is at least 1.0 m below the base** of the facility. There is no exception in Rajasthan, which has no coastal sand areas (Clause 8.8.9). In the following, no infiltration facility, recharge pit, recharge well or recharge shaft shall receive runoff of any kind, and the exception for roof water in Clause 8.11.3(c) does not apply; roof water there goes to storage for use, such as a taanka: (i) river beds and floodplains, the beds and foreshores of talabs, johads, nadis and lakes, and saline depressions; and (ii) any other site where the seasonal high groundwater table is within this separation of the base. **Recharge first.** Rajasthan's groundwater is the most over-drawn of any State in this series: the stage of extraction was 149.86% in 2024, and 214 of the 302 assessment units were over-exploited (CGWB). Recharge, with pretreatment, is therefore the first means of meeting retention wherever this Clause is met, throughout the State, except as follows. In the old city of Jodhpur, where the water table has been rising since canal water arrived in 1997, and in the canal belt of Sri Ganganagar and Hanumangarh (sub-area RJ-D), where the water is within 2 m of the ground in pockets and land is waterlogged, no recharge or infiltration shall be credited until a groundwater-clearance check, a hydrogeologist's report of the seasonal high water table and its trend over at least the past five years, shows that this Clause is met and that the water table is not rising; where it is rising, retention there is met by storage for use, by evaporation from shallow lined storage, and by detention, and an area that the Authority has marked as waterlogged under regulation 8.3(iii) of the Model Rajasthan Building Regulations 2025 is treated in the same way. On the black soils of Hadoti (sub-area RJ-G) and other black soils, a surface infiltration facility earns no retention or WQv credit for storms after 15 August, when the soil is wet and its cracks have closed; recharge there is only through a recharge well or shaft that passes through the clay, and only for filtered roof water or runoff that has passed through a filtering BMP (Clause 8.8.10(b)). Where a calcrete (kankar) or petrocalcic pan lies within the infiltration depth, the tests of Clause 8.8.3 shall be made below the pan, and only a structure that passes through it earns credit. Recharge does not make groundwater with high fluoride, nitrate or salinity fit to drink: in the districts where these are common, water drawn back from a recharged aquifer shall be tested before drinking use, and no industrial or sewage-laden runoff shall be led to any recharge structure. These limits are set by this Manual. The seasonal high groundwater table shall be determined under Clause 3.10.2.

8.8.2 **Other separation.** The base of an infiltration facility shall also be at least 1.0 m above bedrock or any impermeable layer, unless the facility is designed to recharge a fractured or weathered rock aquifer under Clause 8.8.10.

8.8.3 **Infiltration tests.** The infiltration rate shall be measured at the proposed base level of the facility:

- (a) by a double-ring infiltrometer test (ASTM D3385) for basins, bioretention and permeable pavement;
- (b) by a falling-head borehole or trial-pit soakage test (for example BRE Digest 365) for trenches, soakaways, recharge pits and recharge wells;
- (c) with at least **2 tests per facility**, and at least 1 test per 100 m² of infiltration base area or per 50 m of trench length; and
- (d) by a person competent in geotechnical testing, with the results reported on the Infiltration Test Record (Form 8-2).

Tests made in the dry season shall be reported with the groundwater level at the time of test and the seasonal high level of Clause 8.8.1.

8.8.4 **Design infiltration rate.** The design infiltration rate is the measured rate divided by a safety factor:

- (a) **2.0** where the tests meet Clause 8.8.3(c) and the results vary by no more than a factor of 2; and
- (b) **3.0** otherwise.

8.8.5 **Minimum rates.**

- (a) Full infiltration (no underdrain) only where the design rate is at least **13 mm/h**.
- (b) Partial infiltration, with an underdrain, where the design rate is 3 mm/h to 13 mm/h. Only the volume that infiltrates within 72 hours is credited as retention.
- (c) No infiltration credit where the design rate is below 3 mm/h.

8.8.6 **Setbacks for infiltration facilities.** Infiltration facilities receiving runoff from roads, parking or other paved surfaces shall be at least:

- (a) **3 m** from building foundations, and **5 m** from a basement;
- (b) **1.5 m** from a property boundary, unless the neighbour agrees in writing;
- (c) **30 m** from a drinking-water well or borewell;
- (d) **15 m** from a septic tank or soak pit; and
- (e) **6 m** from the crest of a slope steeper than 1V:3H, unless a geotechnical report shows the slope remains stable.

Roof-only runoff to recharge structures is subject to (a) and (b) only, and to Clause 8.11.3.

8.8.7 **Drawdown and verification.** Every infiltration facility shall empty within **72 hours** at the design rate (Chapter 4), and shall be tested after construction (Clause 10.9.3).

8.8.8 **Hotspots.** Runoff from the following shall not be infiltrated without treatment, and shall not be infiltrated at all where (d) or (e) applies:

- (a) fuel stations;
- (b) vehicle workshops, washing bays, and bus and truck depots;
- (c) industrial yards and loading areas where hazardous materials are handled or stored;
- (d) solid waste transfer stations and landfill areas; and
- (e) land known or suspected to be contaminated.

Treatment for (a) to (c) shall include an oil-grit separator and a lined filtering BMP before any infiltration.

8.8.9 **Sandy coastal aquifers.** This Clause applies only to coastal sand aquifers. Rajasthan has none, so the Clause has no effect in the State; it is kept only so that the clause numbers stay unchanged. The dune and hummocky sands of the Thar and the sands of the river beds are not coastal sand areas: Clause 8.8.1 applies there in full, and the reduced separation of item (d) does not. In coastal sand areas:

- (a) infiltration is the preferred means of meeting retention and the WQv wherever Clause 8.8.1 is met;
- (b) storm drains shall not be designed to lower the groundwater table: inverts below the seasonal high groundwater table shall be watertight, with no weep holes or subsoil drains that discharge groundwater to the outfall, unless a hydrogeological report shows no harm to the freshwater aquifer;
- (c) no long-term pumping of groundwater into storm drains shall be approved (for example basement dewatering); and
- (d) in notified coastal sand areas, **roof-only runoff** may be infiltrated with a separation of not less than **0.5 m** to the seasonal high groundwater table, provided a groundwater mounding check shows that the mound stays at least 0.3 m below the facility base and does not reach adjacent foundations or basements. No other runoff may use this reduced separation;
- (e) where neither the 1.0 m separation nor clause (d) can be met, the site shall use surface retention that does not infiltrate below ground (for example shallow vegetated depressions, disconnection of roofs onto lawns, and reuse), and detention under Chapter 4.

8.8.10 **Laterite and hard-rock areas.** In laterite and hard-rock terrain (for example the Aravalli schist, quartzite and granite of Udaipur, Rajsamand, Ajmer and the Jaipur hills, the granite and rhyolite of Mount Abu and the Sirohi hills, and the thin soils over rock of Mewar and Vagad, where groundwater is held mainly in the weathered and fractured zone):

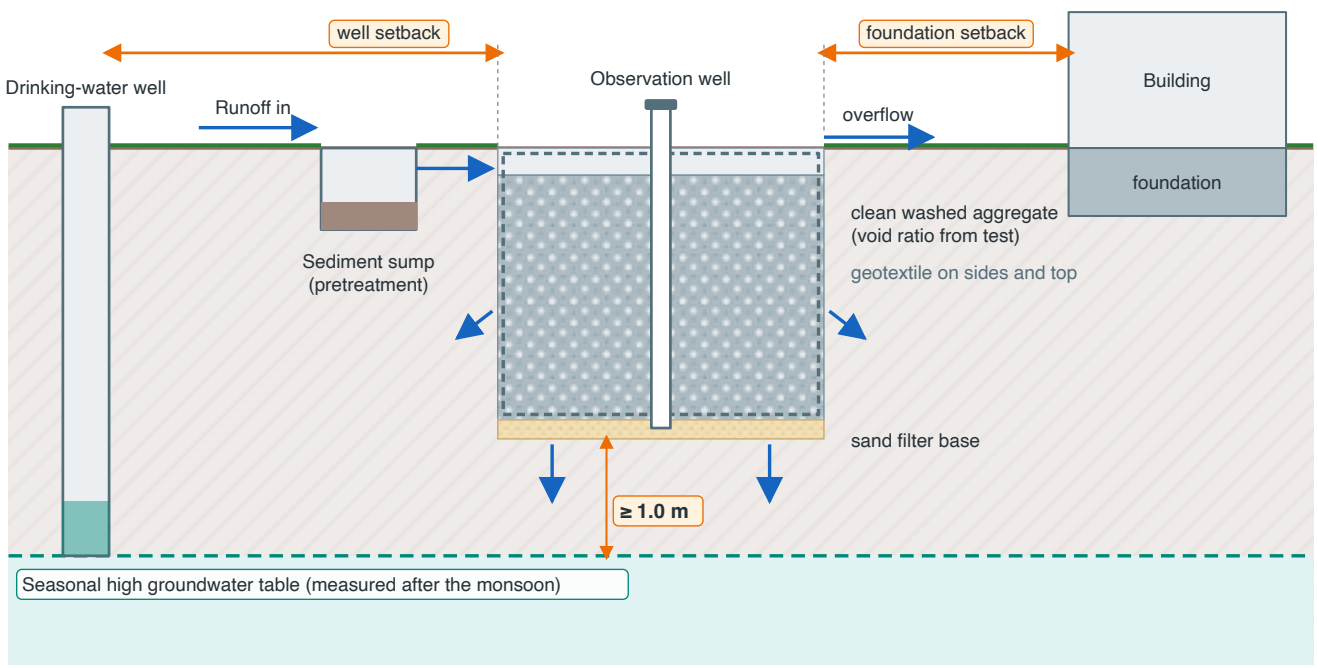
- (a) tests shall be made at the facility base, below any surface crust or hardpan;
- (b) recharge into weathered or fractured rock is permitted only for roof runoff, or for runoff that has passed through a filtering BMP, because fractures give little treatment; and
- (c) infiltration on or above slopes shall be checked for slope stability.

8.8.11 **Delta clays and black cotton soils.** In the silted beds of talabs, johads, nadis and lakes, on the saline depressions of the arid west, on ground where a calcrete (kankar) or petrocalcic pan lies within about 1 m of the surface, and in expansive black cotton soils:

- (a) infiltration facilities will usually fail Clause 8.8.5 and need not be tested where the soil survey (Chapter 3) shows HSG D; and
- (b) where infiltration is used near buildings on expansive soils, the setback of Clause 8.8.6(a) shall be doubled.

Commentary. The 1.0 m groundwater separation is a core requirement of this Manual. The other values in this Clause (the 1.0 m bedrock separation, test numbers, safety factors, minimum rates and setbacks) are typical of US and UK practice and have no Rajasthan precedent. The well setback in Clause 8.8.6(c) applies to runoff from paved surfaces, not to roof water. Rajasthan RWH practice routes roof water into open wells and recharge wells, and Clause 8.11 keeps that practice.

No statewide map of hydrologic soil groups for Rajasthan was found, and every infiltration design needs the tests of Clause 8.8.3. The State's ground falls into five broad kinds. West of the Aravallis, in the arid zone, about half the land is sand: dune and hummocky sands (Torripsamments) cover about 51.8% of the mapped arid zone, and desert soils (Aridisols) about 41%, among them calcrete (kankar) hardpans within about a metre of the surface over some 3.6% and small saline depressions (Dhir and others, *Annals of Arid Zone*, 1997). The sands take water fast, with initial rates of 15 to 30 cm/h reported for the aeolian sands and about 30 to 54 mm/h for the loamy sands near Jodhpur (as reported), but the pans and the saline depressions hold it at the surface. In Hadoti the medium black soils (vertisols) of the Kota and Chambal series take only about 1 to 14 mm/h (as reported). Around Jaipur, Alwar and Bharatpur and in the Ghaggar plain the ground is alluvium and sandy loam; in Mewar, Vagad and the Aravalli hills, as around Udaipur, Ajmer and Mount Abu, it is thin soil over rock. This Manual's interim soil groups follow from these: dune and hummocky sands A, but C or D where a calcrete or petrocalcic pan lies within 1 m, and D on saline depressions; sandy loams and desert soils B; alluvium B or C; the black soils of Hadoti D, with no infiltration credit after 15 August; Aravalli rock and thin soils D; and made ground C unless tested. **Groundwater is the State's binding constraint.** In the assessment of 2024 the stage of groundwater extraction for the State was 149.86%, and of 302 assessment units 214 were over-exploited, 27 critical, 21 semi-critical, 37 safe and 3 saline (CGWB). Pre-monsoon depths to water across the monitoring wells ranged from 0.1 m to 142.9 m below ground in May 2020, with a fifth of the wells deeper than 40 m, mostly in Jhunjhunu, Sikar, Jaipur, Jodhpur, Nagaur, Bikaner, Barmer, Jalore and Alwar, and pockets shallower than 2 m in the south-east and in the canal areas of Sri Ganganagar and Hanumangarh (CGWB, Ground Water Year Book 2020–21). The old city of Jodhpur runs the other way: its water table has risen by about 1 to 1.5 m a year in places since canal water reached the city in 1997, to about 1 m below ground in parts, and basements are pumped daily (as reported; a study by the National Institute of Hydrology of 2023–2025 describes the city's surface drainage as "not well developed"). The quality of the groundwater is poor: of 630 samples tested in 2024, 48.6% had an electrical conductivity above 3,000 µS/cm, 43.2% fluoride above 1.5 mg/L and 49.5% nitrate above 45 mg/L (CGWB), with fluoride worst in Bharatpur, Jalore, Tonk and Barmer. The Rajasthan Ground Water (Conservation and Management) Authority Act, 2024 (Act No. 20 of 2025), which provides for groundwater recharge, comes into force on a date the State notifies, and no such notification was found. **The State therefore needs recharge almost everywhere, and a check before it in a few places.** In the over-exploited units, which are most of the State, recharge comes first, with pretreatment; in the old city of Jodhpur and the canal belt, a groundwater-clearance check comes before any recharge is credited; on black soil after mid-August, on calcrete pans and saline depressions, and on river beds and talab beds, infiltration is not used, or only through a structure that passes the clay or the pan (Clause 8.8.1). Everywhere, runoff from roads and open land goes to surface systems and never directly to a recharge well, borewell or shaft (Clause 8.11.3(b)), and water drawn back from a recharged aquifer for drinking should be tested for fluoride, nitrate and salinity. Clause 8.8.9 has no effect in Rajasthan, which has no coast.



Test infiltration at the proposed base level. Design rate = measured rate ÷ safety factor. Empty within 72 h.
Setback distances and test methods: Clauses 8.8.3 to 8.8.6. Road and parking runoff is never piped into a well.
Sandy coastal soils: high rates, shallow groundwater. Laterite, hard rock: low rates. Delta clay: usually unsuitable.

Figure 8.3 — Infiltration trench in section: pretreatment sump, aggregate-filled trench in geotextile, observation well, overflow, the 1.0 m minimum separation to the seasonal high groundwater table, and setbacks to wells and foundations. Original drawing for this Manual, adapted from the Georgia Stormwater Management Manual, 2016 (Vol 2), and CIRIA, The SuDS Manual (C753), 2015.

8.9 Sewage cross-connections and dry-weather flow

8.9.1 **No sewage in storm drains.** No sewage or sullage (grey water from kitchens, bathrooms and laundries), septic tank effluent, or trade effluent shall be connected to, or discharged into, any storm drain, by any pipe, channel or opening.

8.9.2 **Condition of approval.** Before the completion certificate, the Applicant shall show, by a dye or smoke test witnessed by the Authority or the sewerage agency, that every sewage and sullage outlet on the site discharges to a sewer or to an approved on-site system, and that none discharges to a storm drain. Any existing cross-connection on the site shall be removed as a condition of approval, including on redevelopment and on additions to existing buildings.

8.9.3 **Where no sewer exists.** Where no sewer is available, sewage and sullage shall go to an approved on-site or decentralised treatment system. The treated effluent of such a system may be discharged to a storm drain only with the written consent of the Rajasthan State Pollution Control Board (RSPCB) and the drain owner.

8.9.4 **Public drains: DWF survey.** Every ULB in a Tier A area shall survey its storm drain outfalls to waterbodies for dry-weather flow at least once a year, before the SW monsoon, and record:

- (a) the outfalls with DWF;
- (b) the estimated DWF rate; and
- (c) the upstream sources found by tracing, CCTV, dye or smoke testing.

The results shall be published in the register of Clause 10.17.

8.9.5 **DWF interception.** Until the sources are removed, every outfall to a waterbody that carries DWF shall have a DWF interceptor that:

- (a) diverts the DWF to a sewer or a treatment plant;
- (b) does not reduce the capacity of the storm drain for the minor or major event (Chapter 6), with its weir or diversion head losses included in the hydraulic design (Chapter 9);
- (c) has a screen ahead of the diversion; and
- (d) is not a substitute for removing the source connections.

8.9.6 **Sewage overflows.** No new sewage overflow, emergency bypass or pumping station overflow shall be designed to discharge into a storm drain or waterbody, except where the sewerage agency shows that no alternative exists, and then only with screening and with the overflow frequency stated.

> **Commentary.** The prohibition of sewage connections and the removal of existing cross-connections as a condition of approval are core requirements of this Manual, and Clause 1.10.3 allows no variance from them. Sewage in storm drains is the single largest water quality problem of urban drainage in Rajasthan. It defeats every other measure in this chapter: BMPs designed for stormwater are overloaded, GPTs fill with sludge, and the receiving tanks and channels become sewage lagoons. CPHEEO (2019) notes that Indian drains carry night soil and urine (Part A §9.5). DWF interception (Clause 8.9.5) is an interim measure. It protects the waterbody while the sources are traced and removed, but it can become permanent if the source work is not done, which is why the annual survey and publication of Clause 8.9.4 are required. The annual survey frequency is set by this Manual.
>
> In Rajasthan the law already separates the two: the Rajasthan Municipalities Act, 2009 has a section headed "Sewage and rain water drains to be distinct" (s. 204; its text was not obtained for this Manual), requires every new or rebuilt building to be drained, before it is occupied, into a municipal drain within fifty feet or else into a cess-pool (s. 202), and penalises any drain made into a municipal drain without the Municipality's written consent (s. 213(1)). In practice the cities' nalas carry sewage. In Jaipur, the Dravyavati, "the active river of Jaipur which, over the time turned into a Nallah", collects storm and waste water from the city's nalas, and its rejuvenation intercepts the sewage to treatment plants with a combined capacity reported to the Supreme Court as 170 MLD (JDA, EIA; Supreme Court, 7 August 2026). In Jodhpur, the Jojari receives the city's sewage, treated and untreated, and textile effluent, and the Supreme Court, which has taken up the river of its own motion, recorded a treatment gap of about 55 MLD in 2026 and directed that no contaminated storm water enter the river (2025 and 2026). In Udaipur, the Ayad carries the overflow of the upper lakes to Udai Sagar, and the High Court has directed in 2026 that no untreated sewage reach the lakes (as reported). These interceptions are DWF interceptors under Clause 8.9.5, and Clause 8.9.5(b) applies to them in full: an interceptor on a nala or at a lake inflow shall not reduce the nala's capacity for the minor and major events, and flows above its capacity shall pass on down the nala or to the lake without backing up into the colonies.

8.10 Outfalls to waterbodies: first flush, gross pollutant traps and screens

8.10.1 **Requirement.** Every new storm drain outfall to a waterbody, and every existing outfall on a drain that is rebuilt, widened or extended, shall have:

- (a) a GPT designed under Clause 8.7.10; and
- (b) first-flush treatment: treatment of the WQv (or Q_wq) of the contributing catchment by the BMPs of Clause 8.7, either on the contributing sites or at the outfall.

8.10.2 **Where treatment at the outfall is impracticable.** Where land is not available at a public outfall, first-flush treatment may be provided by:

- (a) a proprietary first-flush or hydrodynamic device sized for Q_wq; or
- (b) a treatment wetland or forebay within the waterbody setback (Clause 7.5.1(b)), outside the waterspread.

8.10.3 **Screens and trash racks.** Screens at outfalls, culvert inlets and pump sumps shall:

- (a) be designed with **50% blockage** for hydraulic capacity;
- (b) have an overflow or bypass path so that a fully blocked screen does not flood property;
- (c) have bar spacing chosen for the hazard: closer spacing for litter capture, wider spacing where blockage would cause flooding; and
- (d) be cleanable from a safe platform, with vehicle access.

8.10.4 **Existing outfalls.** Each ULB shall prepare a programme to fit GPTs and DWF interceptors to its existing outfalls to waterbodies, starting with outfalls to tanks used for drinking water supply and to notified wetlands (Clause 7.12), and shall report progress in the register of Clause 10.17.

> Commentary. This Manual requires first-flush treatment and gross pollutant traps at outfalls to waterbodies. Gross pollutants are the most visible form of pollution in Rajasthan waterbodies, and plastics also block drains and culverts, which links water quality to flooding. The 50% screen blockage matches the grate clogging factor of Chapter 6. Clause 8.10.3(c) warns against fine screens on large drains, which block in the first hour of a storm and cause the flooding they were meant to prevent.

8.11 Rainwater harvesting integration

8.11.1 **RWH mandate continues.** The rainwater harvesting required by the Model Rajasthan Building Regulations 2025 (regulation 8.3, under which a rainwater harvesting unit or structure, or a rooftop rainwater storage tank with a filter, is mandatory on plots of 225 m² or more, with a refundable deposit returned only after a report of satisfactory working from the Ground Water Department, the WRD or an experienced retired engineer; and the environmental conditions of Schedule 4 for large projects, of recharge bores and unpaved open space), and by section 238 of the Rajasthan Municipalities Act, 2009, under which no public water connection is given to a new building without the Municipality's certificate that rainwater harvesting has been provided, continues to apply, subject to the limits of Clause 8.8.1 (Chapter 1). This Clause sets how RWH structures are counted under this Manual.

8.11.2 **Three different functions.** The designer shall keep apart, on the drawings and in the calculations:

- (a) **harvesting**: storage for use (sumps and tanks);
- (b) **recharge**: recharge pits, trenches, shafts and wells that put water into the ground; and
- (c) **detention**: storage with an orifice outlet that is empty at the start of a storm (Chapter 4).

8.11.3 **Recharge structures.**

- (a) Roof runoff may be led to recharge wells, open wells, recharge pits and shafts after a filter or settling chamber.
- (b) Runoff from roads, parking and other paved areas shall not be led directly into any well, borewell or recharge shaft. It may be recharged only through an infiltration facility that meets Clause 8.8, with pretreatment.
- (c) Recharge structures shall meet the groundwater separation of Clause 8.8.1, measured from the base of the pit or the bottom of the filter media, except recharge wells that receive filtered roof water only.

8.11.4 **Credit toward retention and WQv.** A recharge structure counts toward the retention volume of Chapter 4 and the WQv only where:

- (a) its infiltration rate has been tested under Clause 8.8.3;
- (b) it empties within 72 hours at the design rate; and
- (c) it has pretreatment.

A harvesting sump counts toward retention only where its contents are used, by a demand stated in the drainage report, within 72 hours (Chapter 4).

8.11.5 **No credit as detention.** RWH storage does not count as detention unless it is a dedicated volume that is empty when a storm arrives, with an outlet. RWH sumps are assumed **full** at the start of every SW monsoon (JJAS) design storm (Chapter 4).

8.11.6 **Overflow.** Every RWH structure shall have an overflow that discharges at grade to the site drainage, never onto a neighbouring plot or into a sewer.

8.11.7 **Surface-runoff recharge in public spaces.** Recharge trenches, shafts and percolation pits in roads, medians, parks and other public spaces shall meet Clause 8.8 in full, including the hotspot rules for roads with heavy traffic, and shall have a GPT or silt trap at each inlet.

> Commentary. The rule that RWH storage does not count as detention is set in Chapter 4. Rajasthan's building regulations make rainwater harvesting mandatory, but none of them sets a detention rule. Under the Model Rajasthan Building Regulations 2025, a rainwater harvesting unit or structure, or a "Rooftop Rain Water Storage Tank" with a filter, is mandatory on every plot of 225 m² or more (reg. 8.3(i)); a refundable deposit, from ₹50,000 for plots of 225 to 500 m² to ₹5 lakh for plots over 10,000 m², is returned only after a report of satisfactory working from the Ground Water Department, the WRD or an experienced retired engineer (reg. 8.3(ii) and Schedule 2); and in areas that the authority, trust or urban local body marks as waterlogged, the structures are not mandatory (reg. 8.3(iii)). The 2020 regulations they replace set the threshold at 300 m², with recharge structures on plots over 1,000 m² designed with the technical help of the geology department or an expert (reg. 10.11.1 of the Model and JDA regulations of 2020), and the change to 225 m² is reported to date from 2024 (as reported; the notification was not found). For buildings of 5,000 to 20,000 m² built-up area, the environmental conditions ask for at least one recharge pit or bore per 5,000 m² and an unpaved area of at least 20% of the open space (Annexure 4 of the JDA regulations of 2020). The Rajasthan Municipalities Act, 2009 makes rainwater harvesting compulsory in government buildings and, as the bye-laws prescribe, in all others, with a fine of ₹10,000 to ₹20,000, and bars a public water connection to a new building without the Municipality's certificate that it has been provided (s. 238); the PHED is reported to give connections to buildings on plots of 225 m² or more only after the recharge structure is built (2024, as reported), and RIICO to require harvesting on industrial plots of 500 m² or more (as reported). The regulations set no sizing method, first-flush standard, storage to be empty before a storm or peak-flow limit. The taanka, the walled cistern that stores roof and courtyard runoff for use, is Rajasthan's own form of harvesting, and the 2025 regulations' rooftop storage tank is its modern form. Because the State's groundwater is the most over-drawn in this series (Clause 8.8.1), recharge is the main function of harvesting in most of it (Clause 8.11.2(b)); in the old city of Jodhpur, the canal belt and the areas marked as waterlogged, storage for use comes first and recharge waits for the groundwater-clearance check of Clause 8.8.1. RWH serves water supply and recharge. It is usually full, or its soil saturated, by the time a July or August monsoon depression arrives after weeks of rain, which is why it cannot be counted as detention.
>
> Clause 8.11.3(b) has no direct precedent; this Manual sets it because road runoff carries oil, metals and pathogens. A recharge shaft or borewell bypasses the soil that would otherwise filter it and delivers it straight to the aquifer that supplies wells nearby. The CGWB *Manual on Artificial Recharge of Ground Water* (2007) gives recharge structure types and filter designs; this Manual adds the source-water restrictions.

8.12 Construction-stage erosion and sediment control

8.12.1 **ESC plan.** Every development with land disturbance of **0.1 ha** or more, and every public drainage or road work, shall have an Erosion and Sediment Control (ESC) plan, approved with the drainage report. It shall show:

- (a) the sequence of clearing, earthworks and stabilisation;
- (b) the area exposed at each stage;
- (c) the measures of Clause 8.12.3, with their locations and sizes;
- (d) the protection of infiltration and retention areas (Chapter 10);
- (e) stockpile, concrete washout and fuel storage locations; and
- (f) the inspection and maintenance schedule.

8.12.2 **Monsoon timing.** Earthworks shall be planned so that:

- (a) the area exposed during the SW monsoon (June to September) is as small as practicable;
- (b) all completed earthworks are stabilised by vegetation, mulch, matting or paving by **15 June**; and
- (c) any area exposed between 15 June and 30 September has sediment controls in place before it is cleared.

8.12.3 **Measures.**

- (a) **Silt fences** along the downslope edge of disturbed areas receiving sheet flow, with the area draining to each fence limited as set in Annex 8E.
- (b) **Sediment traps** for concentrated flow from disturbed areas of up to 2 ha.
- (c) **Sediment basins** for disturbed areas of more than 2 ha. The storage volume below the outlet shall be at least the greater of the runoff from the 50% AEP (2-yr) 24-hour storm and **250 m³ per hectare** of drainage area, with a dewatering outlet that draws water from the surface.
- (d) **Inlet protection** at every existing drain inlet that receives runoff from the site.
- (e) **Stabilised construction exits**, with wheel washing where vehicles enter public roads.
- (f) **Stockpiles** outside Zone 1 of any waterbody setback (Chapter 7), at least 10 m from any drain, and covered during the SW monsoon.
- (g) **Dewatering** discharges passed through a sediment basin, settling tank or filter bag, never pumped directly into a drain or waterbody.
- (h) **Concrete washout** in a lined pit, never into a drain.

8.12.4 **Design storm for temporary works.** Temporary ESC measures use the rainfall of Chapter 2 with a climate factor of 1.0 (Clause 2.8.2).

8.12.5 **Inspection.** ESC measures shall be inspected weekly and within 24 hours after every heavy-rainfall event (as defined in Chapter 10), repaired within 48 hours, and cleaned when half full of sediment.

8.12.6 **Removal.** Temporary measures shall be removed only after the area draining to them is stabilised. Sediment shall be removed from any permanent facility used for sediment control before its as-built survey (Chapter 10).

> **Commentary.** The 0.1 ha threshold is the applicability threshold of Chapter 1. The sediment basin volume of 250 m³/ha is the US EPA Construction General Permit minimum of 3,600 ft³ per acre drained, converted to SI (US EPA, 2022 CGP); the CGP allows the alternative of the 2-year, 24-hour runoff. This Manual requires the greater of the two, because Rajasthan's 2-year 24-hour depths are high and construction sites are commonly left exposed through the SW monsoon. The 2 ha division between traps and basins, the 15 June stabilisation date, the 10 m stockpile distance and the inspection frequency have no direct precedent and are set by this Manual. The 15 June date matches the pre-monsoon deadline of Chapter 10. Construction sediment is a direct flood hazard as well as a pollutant: it fills drains, culverts and tanks, and in Rajasthan it settles in the talabs, johads and nadis that the nalas and flow paths feed, and in the city lakes (Clause 7.9, Commentary).

8.13 Monitoring

8.13.1 **Outfall monitoring.** Each Tier A authority shall monitor water quality at a representative set of its outfalls to waterbodies, including every outfall to a drinking-water tank or notified wetland. Monitoring shall include:

- (a) dry-weather sampling (Clause 8.9.4), at least once a year before the SW monsoon; and
- (b) wet-weather sampling of at least three events each SW monsoon at a set of index outfalls.

8.13.2 **Parameters.** At minimum: TSS, BOD, COD, faecal coliform, total nitrogen, total phosphorus, oil and grease, and, for industrial catchments, heavy metals. Results shall be compared with the CPCB water quality criteria for the designated best use of the receiving waterbody.

8.13.3 **Gross pollutant records.** The mass or volume of material removed from each GPT and screen at each cleaning shall be recorded in the O&M records (Chapter 10).

8.13.4 **BMP performance monitoring.** The State Stormwater Technical Committee shall run a BMP performance calibration programme and shall revise Table 8.3 and Annex 8C from its results.

8.13.5 **Publication.** Monitoring results shall be published in the register of Clause 10.17.

> Commentary. No Rajasthan programme of stormwater quality monitoring was found during research for this Manual, and CPHEEO (2019) sets no Indian targets. The monitoring in Clause 8.13 is the minimum needed to calibrate Table 8.3 and to show whether DWF interception and source removal are working. The parameter list follows the key pollutants named in CPHEEO's WSUD procedure (TSS, nitrogen, phosphorus and gross pollutants), with BOD and faecal coliform added because of sewage contamination. The monitoring frequencies are set by this Manual.

8.14 Submittal requirements

Every drainage report under this chapter shall include:

1. the **Water Quality Sheet (Form 8-1)**: P_ret, P_3m and P_wq; the WQv and Q_wq for each drainage area; the volume retained under Chapter 4; and the BMP serving each area;
2. for Tier A: the LoS calculation (ΔCN, required LoS) and the composite VR (Clause 8.6);
3. the design of each BMP to Clause 8.7 and Annex 8D, with pretreatment;
4. for infiltration and recharge: the **Infiltration Test Record (Form 8-2)**, the seasonal high groundwater level and its source, the design rate, the drawdown time, and the setbacks of Clause 8.8.6;
5. the sewage and sullage connection plan and the dye or smoke test record of Clause 8.9.2;
6. the GPT and first-flush design for any outfall to a waterbody (Clause 8.10);
7. the RWH layout, separating harvesting, recharge and detention (Clause 8.11); and
8. the ESC plan (Clause 8.12).

8.15 Review and update

8.15.1 This chapter shall be reviewed with the rest of the Manual (Chapter 1). Table 8.3 shall also be reviewed when the calibration programme of Clause 8.13.4 reports, and in any case within 5 years of notification.

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Annexes and forms

Annex / Form	Content
8A	3-month ARI 24-hour depth and IDF by zone
8B	Redevelopment LoS table and treatment-train composite VR
8C	Rajasthan BMP performance calibration
8D	BMP design sheets, media specification, plant lists
8E	Erosion and sediment control standard details
Form 8-1	Water Quality Sheet
Form 8-2	Infiltration Test Record

CHAPTER 9

Hydraulic Design of Structures

9.1 Purpose and scope

9.1.1 This chapter sets the hydraulic design methods for the structures used in the minor and major systems (Chapter 6), in retention and detention facilities (Chapter 4), at outfalls (Chapter 5) and at waterbodies (Chapter 7). It covers:

- (a) pipes and box drains (Clause 9.3);
- (b) culverts (Clause 9.4);
- (c) open channels (Clause 9.5);
- (d) energy dissipators, outlet protection and drop structures (Clause 9.6);
- (e) detention outlet structures (Clause 9.7);
- (f) trash racks and screens (Clause 9.8);
- (g) pumps and sumps (Clause 9.9);
- (h) tide gates, flap gates and non-return valves (Clause 9.10);
- (i) inlets and gratings (Clause 9.11);
- (j) manholes, junction chambers and access (Clause 9.12); and
- (k) materials and durability, including coastal and saline exposure (Clause 9.13).

9.1.2 **Structural design is outside the scope of this Manual.** Structures shall be designed structurally to the applicable Indian Standards and IRC codes, for example IS 456 (plain and reinforced concrete), IS 458 (concrete pipes), IRC:SP:13 (small bridges and culverts) and the IRC bridge codes. Where this chapter refers to a structural standard, it does so only for durability (Clause 9.13) or hydraulic performance.

9.1.3 Design flows, design AEPs and level-of-service limits come from Chapters 2 to 7. This chapter does not change them.

> **Commentary.** APWA Section 5600 places most structure hydraulics in its sections on inlets and manholes (5604), enclosed pipe systems (5606), engineered channels (5607) and detention (5608). CPHEEO (2019) spreads them across Chapters 5, 6, 8 and 11. This chapter gathers them in one place and points to the US Federal Highway Administration (FHWA) hydraulic circulars for methods that Indian codes do not cover in enough detail: HDS-5 for culverts, HEC-14 for energy dissipators, HEC-22 for inlets and access holes, and HEC-24 for pump stations. The FHWA editions cited are those listed in the FHWA hydraulics library as of October 2026.

9.2 General requirements

9.2.1 **Tailwater.** Every structure that discharges to a river, nala, talab, lake or reservoir whose level can rise above the outfall invert shall be analysed with the tailwater conditions of Chapter 5: the non-tidal tailwater of Clause 5.6 for minor- and major-system design; the riverine backwater of Clause 5.8, including the flood from releases at any dam or barrage upstream, such as Gandhi Sagar, Rana Pratap Sagar, Jawahar Sagar and the Kota Barrage on the Chambal, or Bisalpur on the Banas; the outfall-closed check of Clause 5.10 wherever the receiving water can rise above the outfall invert,

which is the case for the city drains of Kota that outfall to the Chambal, and for the drains and nalas that outfall to the lakes of Udaipur (Pichola, Fateh Sagar and the lakes below them on the Ayad), to Ana Sagar in Ajmer and to the other city lakes and talabs whose levels are held by gates or escape channels; for an outfall to a lake or reservoir, the lake's maximum water level, or its full tank level plus the surcharge in the design flood, as Chapter 5 sets it, or, where neither is published, the full tank level plus 0.5 m (set by this Manual); the level held in a drain by any sluice, interception structure, anicut, check dam or pumping station downstream of the outfall, taken as a fixed control at its gate-closed level, its weir crest or the start level of its pumps; and the joint case of Clause 2.12. Where a catchment has no defined outfall and ends in a depression, a dune hollow or an infiltration basin, the tailwater is the level reached in that terminal storage when it holds the 72-hour design volume with no outflow other than infiltration and evaporation, as this Manual requires for catchments with no outfall (Clause 4.12.7). No document found sets a design river or lake level at any outfall in Rajasthan; until one is published, the levels of Chapter 5 apply.

9.2.2 **Climate factor.** Design flows shall include the climate factor of Clause 2.8.

9.2.3 **Maintenance access.** Every structure shall be accessible for inspection and cleaning by the methods in Clause 9.12 and Chapter 10, without manual entry into confined spaces wherever practicable.

9.2.4 **Design life.** Structures shall be designed for a service life of at least 50 years for concrete and masonry works, and at least 25 years for mechanical and electrical equipment, unless the approving authority agrees otherwise.

9.2.5 **Blockage.** Where a structure can be blocked by debris, it shall be checked in the blocked condition set out in this chapter, and a safe overflow route shall exist for that condition (Chapter 6, Clause 6.3.2).

> Commentary. The design-life values in Clause 9.2.4 have no direct precedent; this Manual sets them because they are needed to decide when the climate factor applies (Clause 2.8.2 applies it to elements with a design life over 25 years).

9.3 Pipes and box drains

9.3.1 **Capacity and roughness.** Pipe and box-drain capacity shall be computed by Manning's equation with the design n of Chapter 6, Table 6.6. For precast or cast-in-situ RCC box drains, the design n shall be at least 0.015.

9.3.2 **Partly full flow.** Depth, velocity and discharge in partly full circular pipes shall be computed from the hydraulic-element relationships for circular sections (for example CPHEEO 2019, Table 5.5). The minimum velocity of Clause 6.7.3 applies at the design flow.

9.3.3 **Pressure flow.** Where a pipe runs full or surcharged, the HGL shall be computed under Chapter 6, Clause 6.8, with friction and structure losses.

9.3.4 **Steep pipes.** Where the design flow in a pipe is supercritical (Froude number above 1), the designer shall:

- (a) locate any hydraulic jump and show that it occurs in a structure designed to contain it, not in a pipe run;
- (b) provide air venting where the jump can seal the pipe; and
- (c) meet the maximum velocity of Clause 6.7.3(b).

9.3.5 **Changes of size and direction.**

- (a) Pipe size shall not decrease downstream.
- (b) Pipes shall join only at manholes or junction chambers, except that inlet connections may join pipes of 1,200 mm or more through a factory-made junction.
- (c) Changes of direction greater than 90° in a single structure are not permitted.

9.3.6 **Flotation.** Pipes and box drains in high groundwater shall be checked for flotation (Chapter 6, Clause 6.7.7).

> Commentary. The design n of 0.015 for box drains is set by this Manual to match the "fair" concrete value in Table 6.6. Clauses 9.3.4 and 9.3.5 follow common practice in FHWA HEC-22 and other manuals. A jump inside a pipe run causes pressure surges and can blow off manhole covers.

9.4 Culverts

9.4.1 **Method.** Culverts shall be designed by the methods of FHWA *Hydraulic Design of Highway Culverts*, HDS-5, 3rd edition (2012), or by software that implements them (for example FHWA HY-8). The design headwater is the **greater** of the headwater under inlet control (HWi) and the headwater under outlet control (HWo).

9.4.2 **Inlet control.** HWi shall be computed from the HDS-5 inlet-control equations or nomographs for the barrel shape, material and inlet edge condition actually built.

9.4.3 **Outlet control.** HWo shall be computed as:

> HWo = ho + H − L·S

> H = [1 + ke + (19.63 n² L) / R^1.33] · V² / 2g (SI units, full barrel)

> ho = the greater of TW and (dc + D)/2

where ho is the outlet water depth used for control (m), H is the total head loss through the barrel (m), L is the barrel length (m), S is the barrel slope (m/m), ke is the entrance loss coefficient (Table 9.1), n is the barrel roughness, R is the hydraulic radius (m), V is the barrel velocity (m/s), TW is the tailwater depth above the outlet invert (m), dc is the critical depth (m) and D is the barrel rise (m). Part-full barrels under outlet control shall be analysed by backwater calculation as set out in HDS-5.

Table 9.1 — Entrance loss coefficients ke (outlet control, full or partly full)

Barrel and inlet	ke
Concrete pipe, projecting from fill, socket (groove) end	0.2
Concrete pipe, projecting from fill, square-cut end	0.5
Concrete pipe, headwall or headwall with wingwalls, socket end	0.2
Concrete pipe, headwall or headwall with wingwalls, square edge	0.5
Concrete pipe, headwall, rounded entrance (radius = D/12)	0.2
Concrete pipe, mitred to conform to fill slope	0.7
Concrete pipe, bevelled edges	0.2
Corrugated metal pipe, projecting from fill	0.9

Barrel and inlet	ke
RCC box, headwall parallel to embankment, square edge on three sides	0.5
RCC box, headwall parallel to embankment, three edges rounded or bevelled	0.2
RCC box, wingwalls at 30°–75° to barrel, square-edged crown	0.4
RCC box, wingwalls at 10°–25° to barrel, square-edged crown	0.5
RCC box, wingwalls parallel (extension of sides), square-edged crown	0.7

Source: FHWA HDS-5 (2012), entrance loss coefficient table (Appendix C).

9.4.4 **Tailwater.** TW shall be the higher of:

- (a) the normal or backwater depth in the downstream channel at the design flow; and
- (b) the tailwater level of Clause 9.2.1, for culverts within tidal or river backwater reach.

9.4.5 **Headwater limits.** At the design AEP of Chapter 6, Table 6.1:

- (a) HW/D shall not exceed 1.2;
- (b) the headwater shall be at least 0.3 m below the edge of the road shoulder at the upstream face; and
- (c) the headwater shall not raise water levels at any upstream building or property boundary above the limits of Chapter 6, Clause 6.12.2(d).

9.4.6 **Road overtopping.** Flow over the road in the check and 1% AEP events shall be computed with the broad-crested weir equation:

> Qr = Cd · L · h^1.5

where Qr is the overtopping flow (m³/s), L is the length of the overtopping section (m) and h is the depth of the headwater above the road crest (m). Cd shall be taken from HDS-5 for the road surface and the ratio of h to road width, and shall not exceed 1.66 (SI). The culvert and overtopping flows shall be balanced at a common headwater. The overtopping depths and hazard shall meet Chapter 6, Clause 6.12.

9.4.7 **Outlet velocity.** The outlet velocity at the design AEP and at the 1% AEP shall be computed and the outlet protected under Clause 9.6.

9.4.8 **Barrels and debris.**

- (a) Multi-barrel culverts shall be avoided in debris-prone urban drains. Where they are used, one barrel shall carry the dry-weather flow, and the inlet shall have a debris fin or deflector.
- (b) Culverts shall meet the minimum size and blockage checks of Chapter 6, Clauses 6.12.4 and 6.12.5.
- (c) Culvert inverts shall match the bed of the drain. They shall not be set above the bed, which traps silt and water upstream.

9.4.9 **Headwalls and cut-offs.** Inlets and outlets shall have headwalls, wingwalls and cut-off walls designed to prevent piping and undermining.

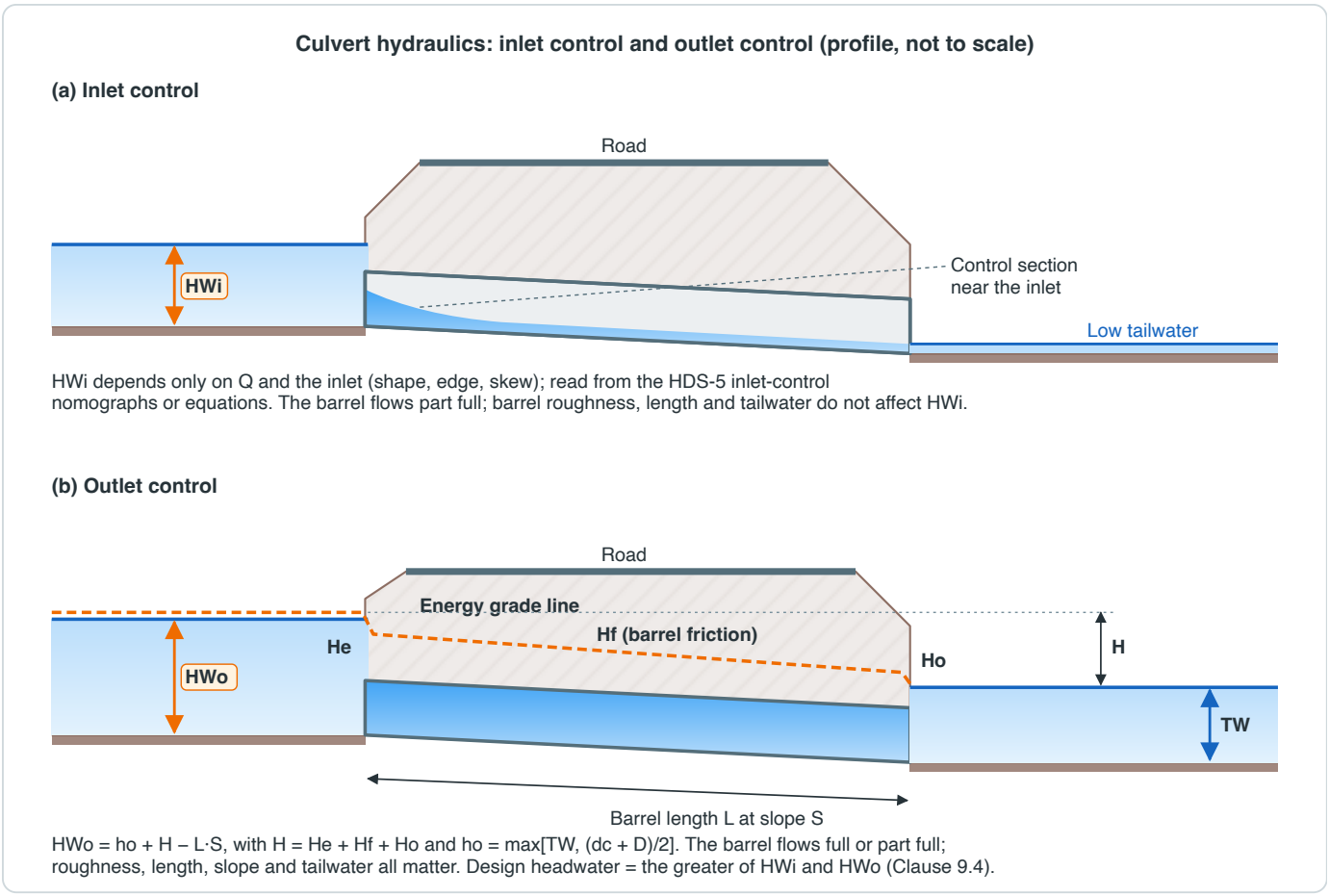

Figure 9.1 — Culvert hydraulics: inlet control and outlet control. Original drawing for this Manual, adapted from FHWA, Hydraulic Design of Highway Culverts, HDS-5 (3rd ed., 2012).

> **Commentary.** HDS-5 (3rd ed., FHWA-HIF-12-026, April 2012) merged the culvert design material of HEC-5, HEC-10 and HEC-13 and is the current FHWA culvert manual. The outlet-control equation in Clause 9.4.3 is the HDS-5 energy equation in SI units: the friction coefficient 19.63 equals 2g. The ke values in Table 9.1 are reproduced from HDS-5. The weir coefficient cap of 1.66 (SI) is the conversion of the APWA 5600 (2006) limit of C ≤ 3.0 (US units) for overtopping calculations. The headwater limits of Clause 9.4.5 are set by this Manual: HW/D ≤ 1.2 keeps the inlet from operating far into submerged-orifice flow at the design event, where small increases in flow give large increases in headwater. Clause 9.4.8(c) has no direct precedent; it is included because raised culvert inverts are common in Rajasthan where a road is rebuilt on top of an old culvert, and they hold standing water and silt upstream.

9.5 Open channels

9.5.1 **Flow computation.** Open channels shall be designed by Manning's equation for uniform flow, with the n of Table 6.6. Water levels shall be computed by gradually varied flow (standard step) analysis where tailwater, bridges, culverts, bends or changes of section affect them, which on the city drains of Kota that outfall to the Chambal, whose level the releases from the Kota Barrage and the dams above it set, on the drains and nalas that outfall to the lakes of Udaipur and to Ana Sagar in Ajmer, whose levels are held by gates and escape channels, and on nalas stepped by drop structures, anicuts and check dams, as the Dravyavati channel in Jaipur is by its fall structures, is the normal case.

9.5.2 **Flow regime.** At the design flow, the Froude number shall not exceed 0.8 (CPHEEO 2019, §5.3), unless the channel is designed as a supercritical chute. Flows with a Froude number between 0.8 and 1.2 are not permitted at the design flow in any channel.

9.5.3 **Permissible velocities.** Mean velocity at the design flow shall not exceed the limits of Table 9.2.

Table 9.2 — Maximum permissible mean velocities in channels

Lining or soil	Maximum velocity (m/s)	Source
Concrete lining	3.0	CPHEEO 2019 Table 5.11
Riprap lining	1.8	CPHEEO 2019 Table 5.11
Grassed lining	1.2	CPHEEO 2019 Table 5.11
Stabilised earthen channel (modified natural channel)	2.0, or the critical velocity if less	CPHEEO 2019 §5.10.3
Unlined, fine sand	0.46	Fortier and Scobey (1926), clear water
Unlined, sandy loam	0.53	As above
Unlined, silt loam	0.61	As above
Unlined, firm loam	0.76	As above
Unlined, stiff clay	1.14	As above
Unlined, fine gravel	0.76	As above
Unlined, coarse gravel	1.22	As above

Flexible linings (vegetation, riprap, geosynthetics) may instead be designed by the permissible shear stress method of FHWA HEC-15, *Design of Roadside Channels with Flexible Linings*, 3rd edition (2005).

9.5.4 **Longitudinal slope.** In engineered channels, the longitudinal slope shall not exceed 0.4% for natural linings and 0.2% for concrete linings, unless drop structures (Clause 9.6.6) or a chute are provided (CPHEEO 2019, Table 5.11).

9.5.5 **Freeboard and bends.** Freeboard shall meet Chapter 6, Table 6.7, measured above the water level that includes superelevation at bends. Bend radii shall meet Chapter 6, Clause 6.7.10.

9.5.6 **Side slopes.** Unless a structural or geotechnical design supports a steeper slope:

- (a) unlined earth channels shall have side slopes no steeper than 1V:2H; and
- (b) grassed channels that are mown shall have side slopes no steeper than 1V:3H.

9.5.7 **Low-flow channel.** Channels with a bed width of 3 m or more shall have a defined low-flow channel that carries the dry-weather flow at the self-cleansing velocity of Clause 6.7.3.

9.5.8 **Transitions.** Changes of section shall use gradual transitions. Abrupt expansions and contractions are not permitted in supercritical flow.

9.5.9 **Linings in high groundwater.** Lined channels in areas of high groundwater or tidal influence shall have weep holes with filters, or shall be designed to resist uplift with the channel empty.

9.5.10 **Natural channels.** Natural channels shall be preserved where possible (CPHEEO 2019, §5.10.3 note; Chapter 7). Where a natural channel must be modified, its capacity shall meet the design AEP of Chapter 6 and its velocities shall meet Table 9.2.

Commentary. The lined-channel velocities and slopes are CPHEEO (2019) Table 5.11 values. The unlined-soil values are the classic Fortier and Scobey (1926) permissible velocities for clear water, as reproduced in Chow (1959). They are given for soils common in Rajasthan (the dune and hummocky sands and sandy desert soils of the Thar, the calcrete-capped and saline soils of the arid plains, the sandy loams and alluvium of the east and of the Ghaggar plains, the deep black soils of Hadoti, and the thin soils and weathered rock of the Aravallis). The ban on Froude numbers between 0.8 and 1.2 extends CPHEEO's advice to avoid critical flow, where the water surface "becomes unstable and wavy" (§5.3). This extension is made by this Manual. The side slopes and the low-flow channel are also set by this Manual, because many Rajasthan urban channels carry sewage-mixed dry-weather flow until the cross-connections of Chapter 8 are removed. A wide flat bed then deposits sludge across its whole width, and a low-flow channel keeps the dry-weather flow concentrated.

9.6 Energy dissipators, outlet protection and drop structures

9.6.1 **When required.** Outlet protection or an energy dissipator shall be provided at every pipe, culvert and channel outlet where the outlet velocity at the design AEP or the 1% AEP exceeds the permissible velocity of the receiving channel in Table 9.2, and at every outlet to an unlined channel, tank or waterbody.

9.6.2 **Method.** Energy dissipators and outlet protection shall be designed by the methods of FHWA HEC-14, *Hydraulic Design of Energy Dissipators for Culverts and Channels*, 3rd edition (2006), selecting the dissipator type by its range of application.

9.6.3 **Riprap aprons.** For a circular outlet discharging to a flat apron, the median riprap size shall be computed with the HEC-14 apron equation:

$$D50 = 0.2 \cdot D \cdot [Q / (g^{0.5} \cdot D^{2.5})]^{(4/3)} \cdot (D / TW)$$

where D50 is the median stone size (m), D is the culvert diameter or rise (m), Q is the design discharge (m³/s), g = 9.81 m/s² and TW is the tailwater depth (m). Where TW is not known, it shall be taken as 0.4D.

Apron length and thickness shall follow the HEC-14 riprap-class table (Table 9.3). The apron width at the outlet shall be at least 3D and shall flare to the downstream channel.

Table 9.3 — Riprap classes and apron dimensions (HEC-14)

Class	D50 (mm)	Apron length	Apron thickness
1	125	4D	3.5 D50
2	150	4D	3.3 D50
3	250	5D	2.4 D50
4	350	6D	2.2 D50
5	500	7D	2.0 D50
6	550	8D	2.0 D50

Source: FHWA HEC-14 (2006), §10.2 and Table 10.1, as reproduced in state-agency design worksheets. Where the computed D50 exceeds Class 6, a riprap basin or a structural stilling basin shall be used.

9.6.4 **Riprap filter and grading.** Riprap shall be placed on a granular filter or a geotextile. Stone shall be angular, durable and graded so that the D50 of Clause 9.6.3 is met.

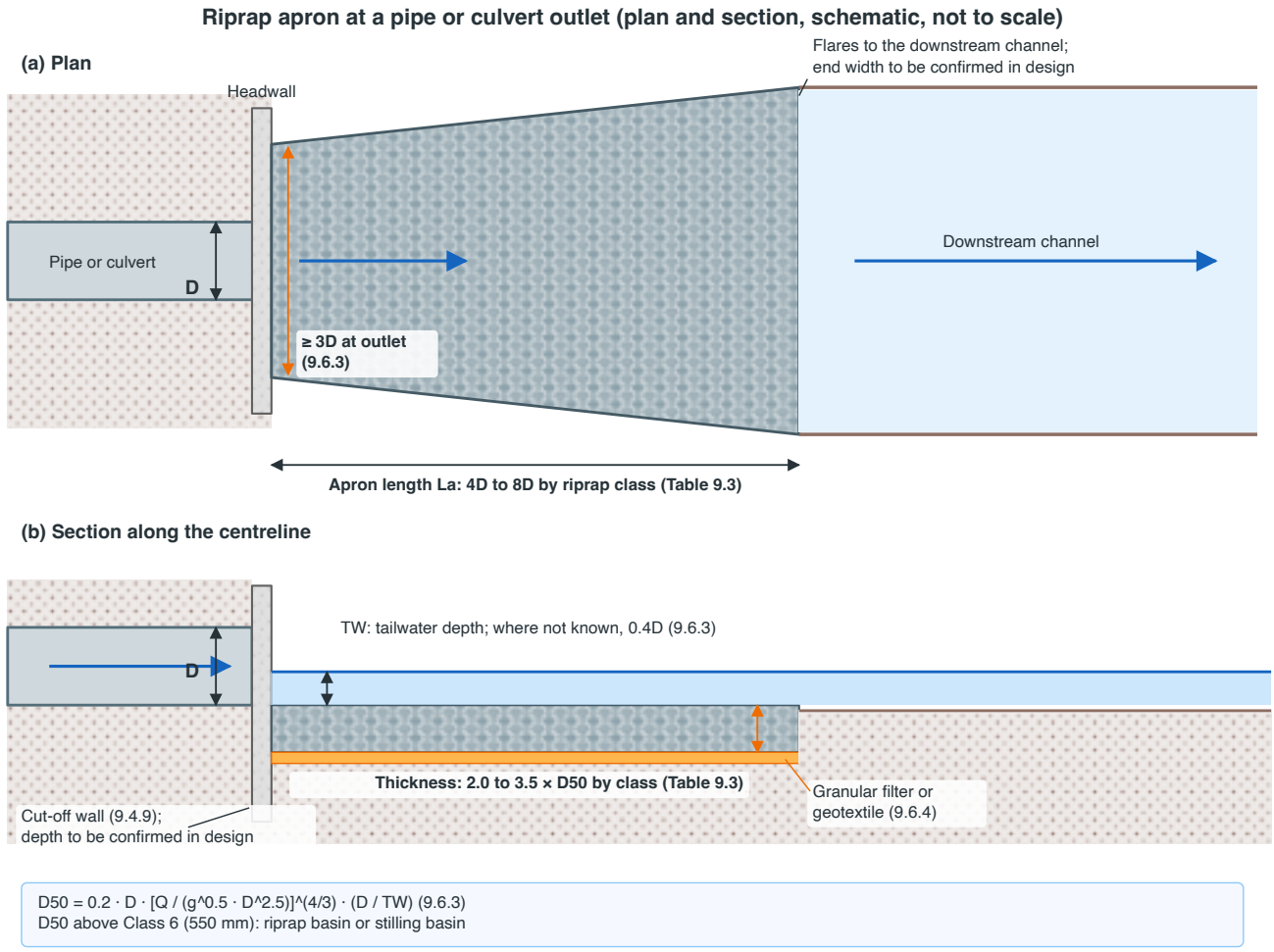

Figure 9.2 — Riprap apron at a pipe or culvert outlet: apron width at least 3D at the outlet, flaring to the downstream channel; length and thickness from Table 9.3; stone on a granular filter or geotextile (Clauses 9.6.3 and 9.6.4). Original drawing for this Manual, adapted from FHWA, Hydraulic Design of Energy Dissipators for Culverts and Channels, HEC-14 (3rd ed., 2006), §10.2.

9.6.5 **Stilling basins.** Where velocities or Froude numbers are above the range of riprap aprons and basins, a structural stilling basin or impact basin shall be designed from HEC-14 or from the US Bureau of Reclamation basin types it describes.

9.6.6 **Drop structures.** Drop structures shall be used where the channel slope would otherwise exceed Clause 9.5.4 or the velocity limit of Table 9.2.

- (a) For a straight vertical drop, the drop number $D = q^2 / (g\,h^3)$ shall be computed, where q is the unit discharge (m^2/s) and h is the drop height (m). The pool geometry shall be set from the Rand (1955) relationships: drop length Ld/h = 4.30 D^0.27; pool depth Yp/h = 1.00 D^0.22; sequent depths y1/h = 0.54 D^0.425 and y2/h = 1.66 D^0.27.
- (b) Baffled chutes and stepped drops shall be designed by HEC-14 or US Bureau of Reclamation methods.
- (c) The height of a single vertical drop in a public drain shall not exceed 1.5 m. Drops shall have edge protection under Chapter 6, Clause 6.13.8.

9.6.7 **Coastal and beach outfalls.** Outfalls onto beaches or into estuaries shall be protected against wave action and scour. Where littoral sand can close the outfall, the outfall shall be designed so that it can be reopened by machine, and the drainage system shall be checked with the outfall closed under Chapter 5.

> Commentary. HEC-14 (3rd ed., FHWA-NHI-06-086, July 2006) is the current FHWA energy-dissipator manual. The apron equation and the class table are from HEC-14 §10.2 (Equation 10.4 and Table 10.1). The equation and table are given here as reproduced in secondary design documents (a Tennessee handbook and a state-agency riprap worksheet). The 3D apron width is from the same sources. A Purdue study (JTRP) found the HEC-14 apron method somewhat conservative within its range of application. The Rand (1955) drop relationships are standard and are reproduced in Chow (1959). The 1.5 m limit on a single vertical drop has no direct precedent; this Manual sets it for public safety in urban drains.

9.7 Detention outlet structures

9.7.1 **Primary outlet.** The primary outlet of a detention facility shall:

- (a) produce the release rates and drawdown times of Chapter 4;
- (b) work without mechanical parts or operator action, except in pumped facilities (Clause 9.9);
- (c) have no orifice smaller than **50 mm**, and every orifice shall be protected by a trash screen (Clause 9.8.5); and
- (d) be accessible for cleaning from the surface.

9.7.2 **Orifices.** Orifice flow shall be computed as:

> Q = Cd · A · (2 g h)^0.5

where A is the orifice area (m²) and h is the head (m) on the centroid of the orifice, or the difference between the upstream and downstream water levels where the orifice is submerged. Cd shall be 0.60 for a sharp-edged orifice in a thin plate. Other edge conditions shall use published tested values.

9.7.3 **Weirs.** Weir flow shall be computed as Q = Cw · L · H^1.5, with:

- (a) sharp-crested rectangular weirs: Cw = 1.84 (SI), with the effective length reduced by 0.1 H for each end contraction;
- (b) V-notch weirs: Q = 1.38 · tan(θ/2) · H^2.5 (SI), where θ is the notch angle; and
- (c) broad-crested weirs and spillway crests: Cw = 1.44 to 1.70 (SI), selected from published tables for the crest shape and head.

Submerged weirs shall be corrected for submergence from published relationships.

9.7.4 **Stage–discharge rating.** For multi-stage outlets (orifices and weirs in a riser, with an outlet pipe), the designer shall compute, at each stage, the discharge under every possible control (each orifice, each weir, riser crest, and the outlet pipe under inlet and outlet control) and use the **smallest** combined value. The rating shall be tabulated from the outlet invert to the emergency spillway crest plus the design head.

9.7.5 **Tailwater.** Ratings shall be computed with the tailwater of Clause 9.2.1. Where the receiving water can rise above the outlet, the outlet shall have a flap gate or non-return valve under Clause 9.10, and the storage shall meet the outfall-closed check of Chapter 5.

9.7.6 **Emergency spillway.** The emergency spillway shall pass the 1% AEP inflow with the primary outlet assumed blocked and the basin full at the start, with **0.3 m** freeboard to the embankment crest. High-hazard basins shall also be checked for the 0.2% AEP inflow (Chapter 4).

9.7.7 **Outlet pipes through embankments.** Outlet pipes through embankments shall have a filter diaphragm or seepage collars to prevent piping along the pipe, and a flared or headwalled inlet.

9.7.8 **Anti-vortex.** Riser outlets with a design head above the riser crest greater than the riser diameter shall have an anti-vortex plate.

> Commentary. The 50 mm minimum orifice with a trash screen, the emergency-spillway criterion and the drawdown times are core criteria of this Manual (Chapter 4). The minimum orifice is smaller than the APWA 5600 (2006, 5608.4) minimum of 3 in (about 75 mm). It allows the low release rates of the Chapter 4 mixed-frequency rule on small sites, and it relies on a good screen (Clause 9.8.5). The "no mechanical parts" rule follows APWA 5600 (2006, 5608.4), which requires the primary outlet to function unattended. The orifice and weir coefficients are standard textbook values (for example Brater and King, *Handbook of Hydraulics*; Chow 1959). The 1.84 sharp-crested coefficient and the 0.1H end-contraction correction are the Francis formula in SI units. The broad-crested range 1.44–1.70 is the SI equivalent of the US range 2.6–3.1 commonly tabulated. Clauses 9.7.7 and 9.7.8 follow common dam and detention practice.

9.8 Trash racks and screens

9.8.1 **Where required.** Trash racks or screens shall be provided:

- (a) where an open drain enters a pipe, covered drain or culvert longer than 30 m (Chapter 6, Clause 6.13.4);
- (b) at every detention outlet orifice (Clause 9.7.1);
- (c) at the inlet of every pump sump (Clause 9.9); and
- (d) at outfalls to waterbodies, as part of the gross pollutant trap of Chapter 8.

9.8.2 **Conduit-entrance racks.** Racks at the entrance to conduits and culverts shall have:

- (a) clear bar spacing not less than 75 mm and not more than half the smallest internal dimension of the conduit;
- (b) a gross area at least 4 times the conduit's cross-sectional area;
- (c) a mean velocity through the rack at the design flow, with 50% of the rack blocked, of not more than 1.0 m/s; and
- (d) an inclination no steeper than 1V:2H where the rack is to be raked by hand, with a working platform and handrail.

9.8.3 **Head loss.** Head loss through a clean rack shall be computed with the Kirschmer equation:

$$h_r = \beta \cdot (t / b)^{4/3} \cdot (V^2 / 2g) \cdot \sin\theta$$

where t is the bar thickness, b is the clear bar spacing, V is the approach velocity, θ is the angle of the rack from the horizontal, and β is the bar shape factor (2.42 for sharp-edged rectangular bars; 1.79 for circular bars). The HGL and headwater shall be checked with the rack **50% blocked** (head loss computed with half the open area).

9.8.4 **Overflow when blocked.** Every rack shall have an overflow route so that a fully blocked rack does not flood buildings or exceed the limits of Chapter 6.

9.8.5 **Detention outlet screens.** Screens over detention orifices shall have openings smaller than the orifice they protect, and an open area at least 10 times the orifice area.

9.8.6 **Pump sump screens.** Bar screens at pump-station inlets shall have a clear spacing smaller than the largest solid the pumps can pass, as stated by the pump manufacturer. Screens shall be built in removable modules, and a mechanically raked screen shall be used where the design inflow exceeds 1 m³/s.

9.8.7 **Safety.** Racks at the entrance to long conduits shall prevent people from being drawn in. They shall be designed for the hydrostatic load of a fully blocked rack.

> Commentary. CPHEEO (2019, §8.3.1.3) describes pump-station bar screens with a spacing of "approximately 58 mm", built in modules, with an emergency overflow in case of clogging. Clause 9.8.6 follows that approach but links the spacing to the pump's solids-passing size, which varies by pump. The 50% blockage check matches the grate clogging factor of Chapter 6. The Kirschmer equation and its shape factors are standard (Kirschmer 1926, as reproduced in hydraulic handbooks). The rack spacing, area ratio, through-velocity, the 30 m conduit length trigger, the 10× screen area for orifices and the 1 m³/s trigger for mechanical raking have no direct precedent and are set by this Manual.

9.9 Pumps and sumps

9.9.1 **When pumping is used.** Pumping shall be used only where gravity drainage cannot meet the requirements of Chapters 5 and 6, for example at road underpasses (Chapter 6, Clause 6.10.5), basements, low-lying areas and outfalls that are tide-locked under the outfall-closed check of Chapter 5.

9.9.2 **Design inflow and storage.** The station shall be designed with the inflow hydrograph routed through the catchment and any upstream storage. Pump capacity and storage shall be chosen together:

- (a) the station shall meet the design AEP of the element it serves (for underpasses, the 2% AEP with a 1% AEP check);
- (b) where the station serves a tidal outfall, storage plus pumps shall hold the 48 h design volume with the outfall throttled for the tidal-lock duration (default: two consecutive high tides of 6 h each), as required by Chapter 5; and
- (c) the pumps shall be selected for the full range of static head between the lowest sump level against the lowest tailwater, and the highest tailwater (HAT plus surge plus 0.3 m).

9.9.3 **Wet-well volume.** The effective wet-well volume (between the pump-stop and the lowest pump-start level) shall be the greatest of:

- (a) where variable-speed drives and automatic controls are installed, 5 minutes of the minimum inflow (CPHEEO 2019, §8.3.3);
- (b) otherwise, 10 to 15 minutes of the peak inflow, or the volume needed for the pump manufacturer's minimum cycle time, from $V = Q \cdot t$ (CPHEEO 2019, Eq. 8.1); and
- (c) for constant-speed pumps, the volume $V = \Theta \cdot q / 4$ for each pump, where Θ is the minimum cycle time recommended by the motor manufacturer and q is the pump capacity (FHWA HEC-24, 2001).

9.9.4 **Duty and standby.**

- (a) Duty pumps shall be of the same size where practicable (CPHEEO 2019, §8.3.3).
- (b) Standby capacity shall be at least equal to the largest duty pump, and not less than 50% of the number of duty pumps.
- (c) Duty and standby roles shall alternate automatically.

9.9.5 **Pump type.** Pumps shall be solids-handling (non-clog) types suited to stormwater with sand and debris. Axial-flow pumps shall be used only behind a screen that meets Clause 9.8.6, because they cannot handle debris (CPHEEO 2019, §8.3.2).

9.9.6 **Sump and intake design.** Sump geometry, pump spacing, minimum submergence and approach flow conditions shall follow the pump manufacturer's requirements and ANSI/HI 9.8 (Rotodynamic Pumps for Pump Intake Design). A physical hydraulic model study shall be carried out where any pump exceeds 1 m^3/s, or where the sump does not follow standard ANSI/HI 9.8 geometry. The minimum clear space between adjacent pumps or motors is 0.6 m for small and medium units and 1.0 m for large units (CPHEEO 2019, §8.2.5).

9.9.7 **Silt and screens.** A silt trap and a bar screen shall be provided upstream of the wet well (Clause 9.8.6; Chapter 6, Clause 6.13.3).

9.9.8 **Controls and monitoring.**

- (a) Pumps shall be controlled by a primary level sensor (ultrasonic, radar or pressure) with an independent float-switch back-up.
- (b) High-level and pump-fault alarms shall be sent by telemetry to the local body's control room.
- (c) Sump levels, pump run hours and power status shall be logged and kept for at least 5 years.

9.9.9 **Power supply.**

- (a) The station shall have two independent power sources: the grid supply and a standby generator (or a second independent grid feeder) able to run all duty pumps at once (CPHEEO 2019, §2.4.2.3(j)).
- (b) Fuel for at least **72 hours** of continuous operation of all duty pumps shall be stored on site, above the flood level of Clause 9.9.10.
- (c) Changeover to standby power shall be automatic.

9.9.10 **Flood protection of the station.** The floor of the electrical and control room, the generator and the transformer shall be at least 0.5 m above the 1% AEP flood level at the station (Chapter 6, Clause 6.11). Access to the station for maintenance vehicles shall remain usable in the 1% AEP event.

9.9.11 **Discharge.** Each pump shall have its own rising main, or a non-return valve and an isolating valve where mains combine. Rising mains shall discharge into a delivery chamber or outfall fitted with a flap gate or non-return valve under Clause 9.10. Discharge piping shall be sized by a recognised friction formula (CPHEEO 2019, §8.3.9).

9.9.12 **Emergency connections.** Every station shall have a hard-standing area and a quick-coupling connection for mobile pumps to discharge into the delivery chamber.

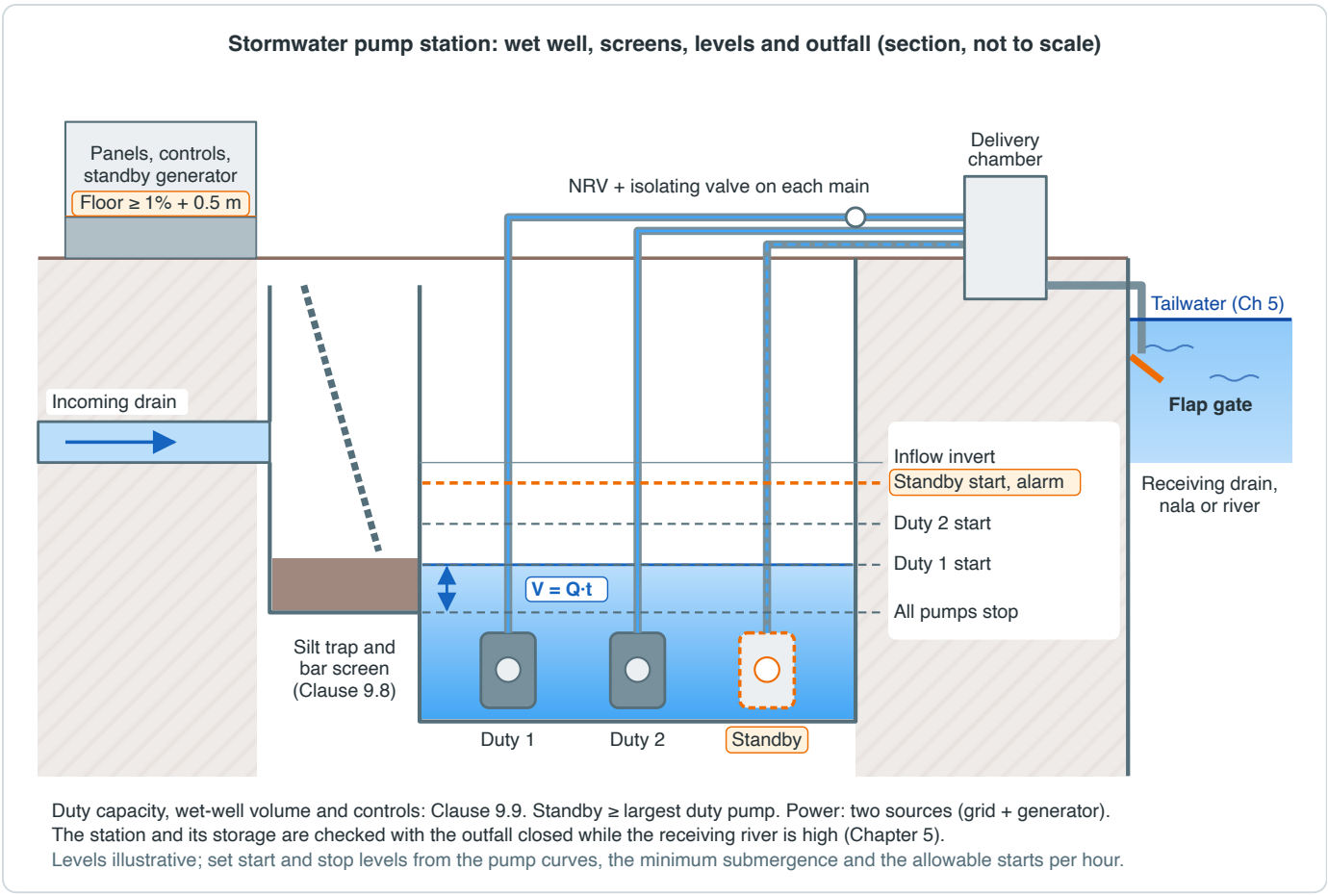

Figure 9.3 — Stormwater pump station: wet well, screens, levels and outfall. Original drawing for this Manual, adapted from CPHEEO, Manual on Storm Water Drainage Systems (2019), Chapter 8, and FHWA, Highway Stormwater Pump Station Design, HEC-24 (2001).

> **Commentary.** CPHEEO (2019) Chapter 8 covers stormwater pumping: wet-well sizing (§8.3.3), pump types (§8.3.2), trash screens (§8.3.1.3), space requirements (§8.2.5) and the need for generator sets "as standby for emergency operation during failure of electricity" (§2.4.2.3). It recommends standby units of "minimum 50% of the duty pump units". Clause 9.9.4(b) is stricter: the standby must at least equal the largest duty pump, so the station still meets its design duty with its largest pump out of service. This stricter rule is set by this Manual. FHWA HEC-24 (*Highway Stormwater Pump Station Design*, FHWA-NHI-01-007, 2001) is the FHWA pump-station manual. The 72 h fuel storage is set by this Manual to match the 72 h design storm of Chapter 2. The model-study trigger, the telemetry and data-retention requirements, and the emergency connection have no direct precedent and are set by this Manual.

9.10 Tide gates, flap gates and non-return valves

9.10.1 **Where required.** Flap gates, tide gates or non-return valves shall be provided on every outfall whose invert is below the 1% AEP still-water level of the receiving water (Chapter 5).

9.10.2 **Types.** Acceptable devices are:

- (a) hinged flap gates (cast iron, ductile iron, stainless steel, HDPE or composite);
- (b) elastomeric in-line or end-of-pipe check valves (duckbill type); and
- (c) penstocks or sluice gates, manual or motorised, as a secondary closure.

9.10.3 **Secondary closure.** Outfalls of 900 mm or more, and every outfall serving a pumped or storage system, shall have a penstock or stop-log slot upstream of the flap gate so that the gate can be maintained, and as a back-up if the gate jams open.

9.10.4 **Hydraulics.** The head loss through the device in the open position shall be taken from the manufacturer's tested data and included in the HGL (Chapter 6, Clause 6.8.7). Flap gates shall open at a small head difference (CPHEEO 2019, §6.3.10.1).

9.10.5 **Sand and debris.** At beach, estuary and creek outfalls where sand or debris can hold a gate open or shut:

- (a) the gate shall be housed in a chamber with surface access, or elastomeric check valves shall be used; and
- (b) the gate shall be inspected after every high-tide or surge event during the monsoon season (Chapter 10).

9.10.6 **Materials.** Hinges, pins, links and fixings shall be of corrosion-resistant material (CPHEEO 2019, §6.3.10.1). In coastal and tidal locations this means stainless steel grade 316, bronze or a non-metallic material (Clause 9.13).

9.10.7 **Storage behind gates.** Where gates close during a storm, the storage or pumping behind them shall meet the outfall-closed check of Chapter 5.

> Commentary. CPHEEO (2019, §6.3.10.1) describes flap gates and flood gates at outfalls to tidal waters. It notes that "adequate storage may be necessary if pumping is to be avoided during the closure of the gate" and that hinge pins and links "should be of corrosion-resistant materials". Rajasthan has no coast, so no outfall in the State is closed by the tide, and the beach, estuary and tidal provisions of Clauses 9.6.7, 9.9.2(b) and 9.10.5, and the coastal and tidal rows of Table 9.5, do not arise; in Clause 9.9.2(c) the highest tailwater is the highest river or lake level of Chapter 5. The saline-groundwater row of Table 9.5 applies wherever groundwater or soil is saline, and the tests of Clause 9.13.3 and the metalwork of Clause 9.13.6 should be used there too, as it is in much of the west, around Sambhar and on the saline depressions, where CGWB has measured electrical conductivity of up to 47,670 µS/cm (Kuri, Barmer). Gates are still required below the 1% still-water level, because many city outfalls end in lakes whose levels are held by gates and escape channels, or in the Chambal, which barrage releases hold high. In Ajmer, Ana Sagar is held at a full gauge of 13 ft by opening the four gates of its escape channel; readings of 14 ft to 15 ft 11 in were reported before the gates were opened, and the opening of the escape channel waterlogged Hathi Bhata, Brahmapuri and Shivpuri in September 2024; in July 2025 the lake overflowed, the gates were opened 30 inches, and the JLN Hospital and Chaupati were flooded (as reported). The Udaipur lakes spill in a chain: Pichola and Fateh Sagar, which Bada Madar feeds, are linked by a gated channel that is closed once Fateh Sagar reaches 11 ft on its gauge, and both overflow to the Ayad, which flows on to Udai Sagar, full at 24 ft on its gauge; Pichola is full at 11 ft and Fateh Sagar at 13 ft, or 14 ft in another report, and the freeboard at the main bund of Fateh Sagar has been put at about 0.75 m against the 1.5 m minimum of the Indian Standard, with water held 20–25 cm above the design full tank level by sandbags (as reported). These gauges read in feet above a local zero whose level above mean sea level was not found, so no lake level in Udaipur or Ajmer can yet be stated in metres [TBC]. A drain that outfalls to one of these lakes is therefore closed or throttled while the lake is at or above its full level, and its storage or pumping is checked under Clause 9.10.7 and Chapter 5; and a drain downstream of an escape channel or a lake spill receives the released flow as an inflow. At Kota the Chambal stood at 248.68 m at the CWC Kota City site on 16 September 2019, its high flood level, against a danger level of 242 m (CWC), while the Kota Barrage (full reservoir level 260.3 m) released about 6.5–6.9 lakh cusecs through 18 or 19 of its 19 gates, figures that conflict with CWC's 4.42 lakh cusecs on 14 September (as reported); low-lying Nayapura and Balita were evacuated (as reported). An outfall to the Chambal at Kota is closed for the whole of such a release, so it needs a flap gate, a penstock and either storage or a pumping station sized under Clause 9.9 and the outfall-closed check of Chapter 5. Screens matter as much as gates, because the nalas carry silt, wind-blown sand, solid waste and sewage: the Dravyavati in Jaipur was a storm channel that had become a sewer before it was rebuilt as a lined channel with about 100 fall structures and treatment plants of 170 MLD (JDA; as reported), and Jodhpur's drains reach the Jojari with sewage and industrial effluent that the Supreme Court has found entering through storm drains (2025–26). Anicuts and check dams are built across nalas and streams throughout the State, and water-harvesting programmes such as the Mukhyamantri Jal Swavlamban Abhiyan

report more than 3.80 lakh structures in 12,056 villages (as reported); an anicut, check dam or interception weir across a nala takes up part of its section and fixes a level upstream, so its effect on the storm capacity is checked under Clause 8.9.5 and the HGL of Chapter 6, its crest is taken as a fixed control in Clause 9.2.1, and one built in a channel recorded as gair mumkin nala must also respect the High Court's bar on obstructing such channels (*Ramji Lal Saini*, 2026). About 60% of the State drains inland, to no river or sea (as reported), and in the canal command around Bikaner no surface drainage outlet exists (as reported); there the terminal structure of a drain is an infiltration basin, soakaway, recharge shaft or storage basin designed under Chapter 4 and Clause 4.12.7, with its outlet and overflow under Clause 9.7, its screen under Clause 9.8 and a safe overflow path that does not discharge onto a neighbour's land, and a pumped outlet from such a basin is used only where storage and infiltration cannot hold the 72-hour design volume. No inventory of the sluices, flap gates, escape channels, interception structures, anicuts and pumping stations on the drains of any Rajasthan city, with their capacities and operating rules, no published operating rule for the Ana Sagar escape channel or the gates of the Udaipur lakes, no escape-channel capacity, and no design river or lake level at any outfall was found in the public domain. Clauses 9.10.3 and 9.10.5 are set by this Manual because a flap gate or sluice that fails, or is jammed open by silt, sand, solid waste or debris, lets a river or lake in flood back into the drain network, and one jammed shut blocks it. The city nalas of Rajasthan carry silt, wind-blown sand, solid waste and sewage to their outfalls, and many end in lakes whose levels are held by gates and escape channels, as at Ana Sagar and in the Udaipur chain, or in the Chambal, so a gate, its screen and the interception weir or anicut beside it are exposed to the same debris and must be kept clear together; and because the recorded high flood level of the Chambal at Kota City (248.68 m, 16 September 2019) stands about 6.7 m above its danger level (CWC), and releases from the Chambal dams and the Kota Barrage can hold the river high for days, a gate that leaks or jams can be exposed for the whole of a flood.

9.11 Inlets and gratings

9.11.1 **Hydraulics.** Inlet capacity, spacing and clogging shall follow Chapter 6, Clause 6.6.

9.11.2 **Load class.** Gratings, covers and frames shall be rated for the traffic at their location. Load classes shall be those of IS 1726 (cast iron manhole covers and frames) or EN 124 (gully tops and manhole tops), at least:

- (a) carriageways and medians: EN 124 class D400 or the equivalent heavy-duty IS class;
- (b) kerb-side channel inlets within 0.5 m of the kerb: class C250 or equivalent; and
- (c) footpaths and cycle tracks: class B125 or equivalent.

9.11.3 **Grate pattern.**

- (a) Grates in carriageways, cycle tracks and footpaths shall not have openings parallel to the direction of travel wider than 25 mm.
- (b) Grate types without tested capacity data shall be rated by the weir and orifice methods of FHWA HEC-22 (2024), with the clogging factors of Chapter 6.

9.11.4 **Kerb openings.** Kerb-opening inlets shall have a clear opening height of at least 100 mm and a length of at least 1.0 m. Where a kerb inlet discharges through the wall of a covered drain (Chapter 6, Clause 6.13.1), the opening shall be at road level.

9.11.5 **Security.** Gratings and covers on public land shall be hinged or locked to their frames, so that they cannot be removed without a tool.

9.11.6 **Inlet chambers.** Inlet chambers shall have the silt sump of Chapter 6, Clause 6.6.7, and shall be sized so that the sump can be emptied by a suction or grab machine.

> **Commentary.** NDMA (2010, §4.13) cites IS 5961 for cast-iron gratings for drainage inlets. The load classes are based on the EN 124 classes used internationally. The 25 mm limit on parallel openings is set for cyclist and pedestrian safety. APWA 5600 (2006, 5604.2) requires kerb openings of at least 4 ft (about 1.2 m) long and 6 in (about 150 mm) clear height. Clause 9.11.4 sets smaller minimums suited to the narrower roads and lower kerbs common in Rajasthan towns.

9.12 Manholes, junction chambers and access

9.12.1 **Location and spacing.** Manholes shall be provided at the locations and spacings of Chapter 6, Clause 6.7.11 and Table 6.8. Where pipes are too large for a standard manhole, a junction chamber with a riser to the surface shall be used (CPHEEO 2019, §11.3.7.3).

9.12.2 **Minimum internal size.** Manholes shall have at least the internal dimensions of Table 9.4 (CPHEEO 2019, §11.3.7.6):

Table 9.4 — Minimum internal size of manholes

Shape and depth	Minimum internal size
Rectangular, depth below 0.9 m	900 mm × 800 mm
Rectangular, depth 0.9–2.5 m	1,200 mm × 900 mm
Circular, depth above 0.9 m and up to 1.65 m	900 mm diameter
Circular, depth above 1.65 m and up to 2.30 m	1,200 mm diameter
Circular, depth above 2.30 m and up to 6.0 m	1,500 mm diameter
Circular, depth above 6.0 m and up to 9.0 m	1,800 mm diameter

The manhole shall also be large enough to fit the largest pipe connected plus the benching on each side.

9.12.3 **Access openings.** The clear access opening of manholes and access chambers on public drains shall be at least 600 mm, so that cleaning equipment can be lowered.

9.12.4 **Drops.** Where the difference between incoming and outgoing inverts exceeds 0.6 m, a drop connection shall be provided. Below 0.6 m, the difference shall be taken up by adjusting the slope of the incoming pipe or the benching (CPHEEO 2019, §11.3.7.5). The invert drop across a manhole where pipe size changes shall be at least the following fraction of the difference in diameters (CPHEEO 2019, Table 11.6):

- conduits below 400 mm: one-half;
- 400 mm to 900 mm: two-thirds;
- above 900 mm: four-fifths.

9.12.5 **Benching.** Manhole floors shall be benched to at least the crown of the outgoing pipe, with channels shaped to guide flow from each incoming pipe.

9.12.6 **Surcharge.** Manholes on mains where the 1% AEP HGL can rise above the cover (Chapter 6, Clause 6.8.4) shall have bolted, locked or hinged covers designed for that pressure.

9.12.7 **Mechanical cleaning.** Manholes, chambers and covered drains shall be designed for cleaning by machine (suction, jetting, grab or robotic equipment) from the surface. Fixed ladders shall be of corrosion-resistant, encapsulated material where provided.

> **Commentary.** The size and drop requirements are from CPHEEO (2019) Chapter 11. The 600 mm access opening, the benching rule and the bolted covers are set by this Manual. Designing for mechanical cleaning supports the prohibition on hazardous manual cleaning under *The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013*.

9.13 Materials and durability

9.13.1 **Exposure classes.** Concrete structures shall be designed for the exposure class of IS 456: 2000, Table 3. In Rajasthan the minimum classes of Table 9.5 apply unless a site investigation shows a more severe condition:

Table 9.5 — Minimum IS 456 exposure classes for Rajasthan locations

Location	Minimum IS 456 exposure class
Inland drains and structures	Moderate
Drains and structures in the coastal environment, and any drain that carries or may carry sewage-mixed flow	Severe
Structures exposed to sea-water spray, or in contact with saline or aggressive groundwater	Very severe
Structures in the tidal zone	Extreme

9.13.2 **Concrete.** Minimum concrete grade, maximum water–cement ratio, minimum cement content and nominal cover to reinforcement shall be those of IS 456 for the exposure class. For the reader's convenience, IS 456 sets the minimum reinforced-concrete grades as M25 (moderate), M30 (severe), M35 (very severe) and M40 (extreme), and the nominal covers as 30, 45, 50 and 75 mm respectively.

9.13.3 **Aggressive ground.** Groundwater and soil at every structure in coastal and delta areas shall be tested for chlorides and sulphates. Cement type and concrete mix shall be chosen to suit the results under IS 456.

9.13.4 **Sewage-mixed flow.** Pipes and covered drains that carry, or may carry, sewage-mixed flow shall be protected against sulphide (crown) corrosion, by a sacrificial concrete thickness, a corrosion-resistant lining or a non-concrete pipe material.

9.13.5 **Pipes.** Concrete pipes shall comply with IS 458, with the class selected by structural design. Other pipe materials (for example ductile iron, HDPE or structured-wall plastic pipes) shall comply with the applicable Indian Standard and be approved by the approving authority.

9.13.6 **Metalwork.** Within 5 km of the coast, and in all tidal and saline locations:

- (a) fixings, hinges, ladders, handrails and screen frames shall be stainless steel grade 316, or hot-dip galvanised steel with a protective coating, or a non-metallic material; and
- (b) dissimilar metals shall be isolated from each other.

9.13.7 **Masonry.** New public drains in Tier A bodies shall be in reinforced or plain concrete. Brick or stone masonry may be used for drains in Tier B bodies only if it is plastered on the wetted face and meets the n value of Table 6.6.

> **Commentary.** The IS 456 exposure classes and the grade and cover values are quoted from IS 456: 2000 (Tables 3, 5 and 16) for convenience. The standard governs, and designers shall use its current amendment. Assigning Rajasthan locations to exposure classes, the sulphide-corrosion requirement and the ban on new masonry drains

in Tier A bodies have no direct precedent and are set by this Manual. Drains that receive sewage cross-connections (a common condition, Chapter 8) generate hydrogen sulphide, which attacks unprotected concrete above the water line.

9.14 Submittal requirements

Every structure design shall be submitted with a **Hydraulic Structures Report** (Form 9-1) containing, as applicable:

1. culvert calculations (HDS-5 or HY-8 output) with HWi, HWo, outlet velocity, tailwater, overtopping and the blockage check;
2. channel water-surface profiles, velocities, Froude numbers and freeboard;
3. outlet protection and dissipator design, with riprap sizing;
4. detention outlet stage–discharge tables and the emergency spillway check;
5. screen and rack design with the 50% blocked check;
6. a pump station design report: inflow hydrograph, storage, pump curves and system curves, wet-well volume, controls, power supply and the Chapter 5 outfall-closed check;
7. gate and valve selection with head-loss data;
8. inlet, grate and cover load classes; and
9. an exposure class and materials statement (Clause 9.13).

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Annexes and forms

Annex / Form	Content
9A	HDS-5 inlet-control coefficients and worked culvert example in SI units
9B	Standard drawings: headwalls, riprap aprons, drop structures, trash racks, detention risers
9C	Pump station design checklist and standard control philosophy

Annex / Form	Content
Form 9-1	Hydraulic Structures Report checklist

CHAPTER 10

Submittals, Review, Operation & Maintenance and Enforcement

10.1 Purpose and scope

10.1.1 This chapter sets out how compliance with this Manual is shown, checked, built, kept working and enforced. It covers:

- (a) the submittal stages and their contents (Clauses 10.3–10.4);
- (b) the compliance calculator (Clause 10.5);
- (c) professional certification and review (Clauses 10.6–10.7);
- (d) construction inspection and as-built certification (Clauses 10.8–10.9);
- (e) maintenance declarations, O&M plans, inspection and access (Clauses 10.10–10.13);
- (f) handover of public assets (Clause 10.14);
- (g) enforcement (Clause 10.15); and
- (h) monitoring, post-event review and data publication (Clauses 10.16–10.17).

10.1.2 This chapter applies to every development and public work to which Chapters 4 and 5 apply under Clause 1.5.2. Clauses 10.3.1 (Stage 0), 10.15 and 10.17 also apply to development that is subject only to Clause 1.5.4.

Commentary. A criterion that is not checked at approval, built as approved, and maintained afterwards has no effect. In Rajasthan the failure is one of missing criteria and of conditions checked only for rainwater harvesting. No document of UDH, the LSG Department, a Municipal Corporation, a development authority or an Urban Improvement Trust stating a design return period, intensity or runoff coefficient for urban storm drains was found, other than RUIDP's guidance of 2008 for its own projects (1–2 years for town drains). The Rajasthan Municipalities Act 2009 makes drainage a duty of the Municipality (s.45), vests in it the public tanks and streams and the drains and watercourses in, alongside or under any street (s.68), and puts all drains within the Municipality under its survey and control (s.200); the rivers, dams and reservoirs that receive the drains are with WRD. The approval route shapes this chapter. The Building Regulations 2025 were issued by UDH with its order No. P.11(5) नविवि/Building Regulations-2025/2025 of 12 May 2025, under s.337 of the Municipalities Act, s.104-A of the Rajasthan Urban Improvement Act 1959 and the Acts of the development authorities; each urban local body or authority brings them into force by its own publication in the Gazette (reg. 1.2), so the date of commencement varies by city [TBC for each city; one secondary source gives 5 December 2025], and on commencement they repeal the earlier regulations, among them the Model Building Regulations 2020 and the JDA (Jaipur Region) Building Regulations 2020 (reg. 18.1). Under them a building plan is approved by the urban local body, the development authority or the Urban Improvement Trust, or by an empanelled architect; rainwater harvesting on plots of 225 m² or more is declared by affidavit at approval and checked for the completion certificate (Schedule 3), and the refundable deposit of ₹50,000 to ₹5 lakh is returned only after the Ground Water Department, WRD or an experienced retired engineer reports that the structure works (reg. 8.3(ii) and Schedule 2); the plinth must stand at least 0.45 m above the road in front (reg. 6.6). The Municipalities Act bars the construction or occupation of a building until a drain is built "at such level and with such fall" as effectual drainage needs, emptying to a municipal drain within 50 ft or else to a cess-pool (s.202), requires written consent to connect to, or build over, a drain vested in the Municipality (s.213), and bars a public water connection to a new

building without the Municipality's certificate that rainwater harvesting has been provided (s.238(4)), a condition PHED is reported to apply (as reported). In a lake's protected area, construction needs the prior permission of the Lakes Development Authority, and a plan that covers a lake its prior approval (Lakes Act 2015, s.5, as read from the Bill), though no protected area was found notified. Since 7 August 2026 the Supreme Court has barred any department, statutory authority or local body from granting fresh permissions for industrial, commercial or residential development within the identified river corridors of the State until the High Flood Line and ecological buffer of every river system have been demarcated (*In Re: 2 Million Lives at Risk, Contamination in Jojari River, Rajasthan*). No rule asks for a drainage report, limits peak runoff, requires on-site detention or sets a setback from a nala, river or lake. Every stormwater item in this chapter is therefore written so that the architect or engineer on record can certify it on Forms 1-1, 2-1, 10-2 and 10-3, and the Authority can check it with the building plan at approval, at the completion certificate and at the functionality check that releases the rainwater harvesting deposit. This chapter is the process.

10.2 Definitions

Term	Meaning in this chapter
Submittal	A set of documents lodged with the Authority at one of the stages of Clause 10.3.
Drainage report	The preliminary (Stage 1) or final (Stage 2) report required by Clause 10.4.
Stormwater facility	Any retention, detention, water quality, conveyance, pumping, gate or outfall element required by this Manual, public or private.
Hold point	A construction stage at which work shall not proceed until the Authority or the certifying professional has inspected it (Clause 10.8).
As-built certificate	The certificate of Clause 10.9 that the facility was built as approved and performs as designed.
Owner	The person or body responsible for a facility under its maintenance declaration, or the ULB for a handed-over asset.
O&M plan	The operation and maintenance plan of Clause 10.11.
Facility register	The public register of facilities of Clause 10.17.

Other terms are defined in Clause 1.4.

10.3 Submittal stages

10.3.1 Submittals shall be made in the following stages, linked to the approval steps of the Model Rajasthan Building Regulations 2025 (Table 10.1):

Table 10.1 — Submittal stages and linked approvals

Stage	Submittal	When	Linked approval
0	**Pre-application** meeting and **Form 1-1** (Applicability Determination)	Before the planning permission or layout application	None (advisory record)
1	**Preliminary drainage report**	With the planning permission or layout application	Planning permission / layout approval
2	**Final drainage design**	Before building permit, or before commencement where the permit is issued with the planning permission	Building permit / commencement

Stage	Submittal	When	Linked approval
3	**Construction inspections** at hold points	During construction	None (records filed)
4	**As-built certificate** and verification tests	Before the completion certificate	Completion / occupancy certificate
5	**Maintenance declaration** registered, or **handover** of public assets	Before or with the completion certificate	Completion certificate; asset acceptance
6	**Annual declarations** and inspection reports	Every year after completion	Continuing compliance

10.3.2 **Stage 0 is mandatory** for:

- (a) sites of 2 ha or more;
- (b) sites in a flood-sensitive catchment;
- (c) sites proposing a variance, waiver, regional facility or fee-in-lieu; and
- (d) sites draining to a tidal outfall or adjoining a waterbody.

For other sites, Stage 0 is optional, and Form 1-1 is lodged with Stage 1.

10.3.3 **Combined stages.** For sites of less than 1 ha outside flood-sensitive catchments, the Authority may accept Stages 1 and 2 as one submittal.

10.3.4 **Public works.** For a public work, Stage 1 is the drainage section of the DPR and Stage 2 is the drainage section of the tender drawings. The sanctioning authority shall not sanction or tender the work until the relevant stage has been reviewed under Clause 10.7.

10.3.5 **Changes after approval.** Any change that alters impervious area, levels, storage, outlet or outfall after Stage 2 shall be resubmitted, with the compliance calculator re-run, before the change is built.

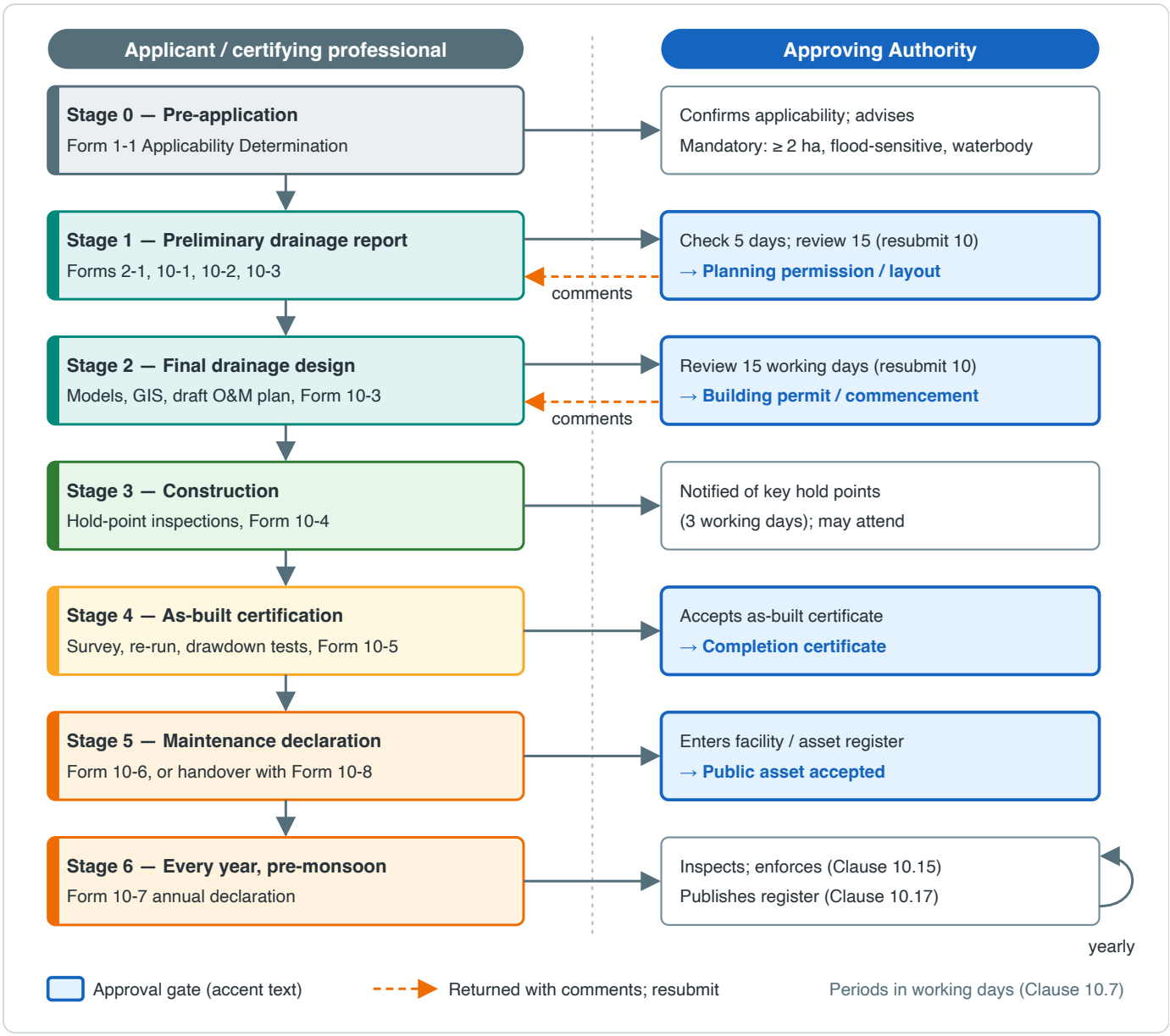

Figure 10.1 — Submittal, review and approval workflow (Clauses 10.3–10.10). Original drawing for this Manual.

> **Commentary.** The stages follow the APWA 5600 sequence of preliminary and final stormwater studies, construction inspection and maintenance agreements (APWA 5600, 2006, §5608 and §5609), mapped onto the Building Regulations 2025 steps a Rajasthan applicant already follows. Linking Stage 4 to the completion certificate copies the MBBL 2016 RWH model, which requires inspection before the completion certificate (MBBL 2016, §9.6). The 2 ha and 1 ha limits in Clauses 10.3.2 and 10.3.3 have no direct precedent and are set by this Manual.

10.4 Required contents and checklists

10.4.1 **Preliminary drainage report (Stage 1).** The report shall contain at least:

- (a) Form 1-1 and, where applicable, Form 1-2 (Variance / Waiver Request);
- (b) a site plan with existing and proposed levels, impervious areas, and the catchment boundaries draining to and through the site;

- (c) soils (HSG), the seasonal high groundwater table, and infiltration test results or a test plan (Chapter 3);
- (d) the **Design Rainfall Sheet (Form 2-1)**, completed as Clause 2.13 requires;
- (e) the pre-development condition and hydrologic method (Chapter 3);
- (f) how the hierarchy of Clause 1.2 has been applied: areas preserved, retention method, detention concept and conveyance;
- (g) preliminary retention, water quality and detention volumes, and release rates, from the compliance calculator (Clause 10.5);
- (h) the downstream extent and tailwater case (Chapter 5);
- (i) waterbodies, setbacks and the 1% AEP level (Chapters 6 and 7); and
- (j) the land reserved for facilities and maintenance access (Clause 10.13).

10.4.2 **Final drainage design (Stage 2).** The final design shall contain, in addition to updated Stage 1 contents:

- (a) the final calculations for every storage duration of Clause 2.5.2 and every AEP required by Chapter 4, including the outfall-closed check of Chapter 5;
- (b) stage–storage–discharge tables for each facility, and the emergency spillway design (Chapter 4);
- (c) hydraulic design of conveyance elements, inlets and structures (Chapters 6 and 9);
- (d) the water quality design and the first-flush or gross pollutant trap where required (Chapter 8);
- (e) construction drawings, details and specifications of every facility;
- (f) the construction sequence, including protection of retention and infiltration areas from sediment and compaction (Clause 10.8.3);
- (g) the hold-point schedule (Clause 10.8);
- (h) the draft O&M plan (Clause 10.11) and draft maintenance declaration (Clause 10.10);
- (i) the model input files and the GIS data of Clause 10.4.4; and
- (j) the certificates of Clause 10.6.

10.4.3 **Checklist.** Each submittal shall include the **Drainage Report Checklist (Form 10-1)**, showing for each item of Clauses 10.4.1–10.4.2 the page or sheet where it is addressed, or the reason it does not apply. The Authority shall not start technical review of a submittal without a completed Form 10-1.

10.4.4 **Digital submittal.**

- (a) Reports and drawings shall be submitted as searchable PDF.
- (b) Hydrologic and hydraulic models shall be submitted in their native, runnable format (for example SWMM .inp, HEC-HMS or HEC-RAS project files), with the version of the software used.
- (c) Facilities, outfalls, flow paths and catchment boundaries shall be submitted as GIS data (GeoPackage or shapefile) in WGS 84 (EPSG:4326) or the applicable UTM zone (43N statewide, except the districts of Jaisalmer and Barmer, which use 42N; the part of Dholpur district east of 78° E also uses 43N; one zone is used for the whole of a project), with attributes as listed in Annex 10B.
- (d) Levels shall be stated relative to a named vertical datum. The relationship to the river datums of the CWC and WRD gauges on the receiving rivers and the level datums of WRD and the lake custodians for the lakes and reservoirs that receive city drainage, with lake gauge readings in feet above a local zero converted to metres on a named datum used in Chapter 5 shall be stated.

10.4.5 **Summary of forms used in submittals** (Table 10.2):

Table 10.2 — Forms used in submittals

Form	Title	Stage
1-1	Applicability Determination	0 or 1
1-2	Variance / Waiver Request	1
2-1	Design Rainfall Sheet	1, 2

Form	Title	Stage
10-1	Drainage Report Checklist	1, 2
10-2	Compliance Calculator Summary	1, 2, 4
10-3	Professional Design Certificate	1, 2
10-4	Hold-Point Inspection Record	3
10-5	As-built Certificate	4
10-6	Maintenance Declaration	5
10-7	Annual Maintenance Declaration and Inspection Report	6
10-8	Asset Handover Certificate	5

> **Commentary.** Runnable models and GIS data cost the applicant little and let the Authority check the work, and later build a city-wide picture of private storage. Rajasthan has no notified design return period, runoff coefficient or design storm for its drains. The only statewide guidance found is RUIDP's Circular No. 8 of 4 March 2008 for the drainage works of its ADB-funded towns, which allows a return period of 1–2 years for town drains, 25 years for culverts and 50 years for bridges, the Rational method up to 50 km² and runoff coefficients of 0.7–0.9 in dense areas, and says that design intensities in India are "usually in the range of 12mm/hr to 20mm/hr"; that is far below Jaipur's measured 5-year 1-hour depth of 53.1 mm, so the circular is history, not a design basis. JDA designed the Dravyavati channel in Jaipur to pass the 100-year flood (EIA), but its design discharge was not found; the ADB documents for the Jodhpur storm water drains and for other RUIDP towns state no return period, intensity or runoff coefficient; and the return period of JDA's integrated storm water model of 2025 was not found. In IMD's national IDF study (Das et al. 2022) the Jaipur and Jaisalmer panels repeat a generic curve drawn for several other cities and are not used; the only station fit is the study of 44 years of IMD hourly data at Jaipur (Ghate and Timbadiya 2022), whose 50-year 1-hour depth of 93 mm is about a third above the value from the CWC ratios. The State's sub-daily design values are otherwise the short-duration ratios of the CWC Flood Estimation Reports for subzones 1(a), 1(b), 1(e) and 3(a), with the interim floors of Chapter 2. Form 2-1 and Form 10-2 therefore carry the whole design basis of each submission. Form 2-1 and Form 10-2 ensure that every design states its inputs.

10.5 Compliance calculator

10.5.1 The State Stormwater Technical Committee shall issue and maintain a **compliance calculator**: a version-controlled spreadsheet or web tool that, for a given site:

- (a) applies the applicability tests of Clause 1.5;
- (b) computes the retention volume from the Annex 2E depth, and the water quality volume (Chapter 8);
- (c) applies the credits for preserved areas and retained volume against detention (Chapter 4);
- (d) on the design-aid route (Clause 1.7, S-1), gives retention and detention volumes from the unit-storage tables;
- (e) on alternative S-2, gives the permissible site discharge for each AEP; and
- (f) produces the **Compliance Calculator Summary (Form 10-2)**.

10.5.2 **Use.**

- (a) Every Stage 1, 2 and 4 submittal shall include Form 10-2 from the current version of the calculator.
- (b) On the design-aid route, the calculator may be the only storage calculation.

- (c) Outside the design-aid route, the calculator is a summary and a screening check. It does not replace the hydrograph analysis of Chapter 3. Where a model result differs from the calculator screen by more than the tolerance stated in the calculator guide, the report shall explain why.

10.5.3 **Version control.** The calculator shall record its version in every output. A new version applies to new submittals 6 months after release, in line with Clause 2.14.2. A submittal shall use one version throughout Stages 1 to 4, unless the Applicant elects a later one.

10.5.4 **Openness.** The calculator, its user guide, and the source of every table in it shall be published free of charge.

> Commentary. The Mid-America Regional Council issued a Compliance Calculator (.xlsm) and a Calculator Start-Up Guide with APWA 5600 Version 2025.01, together with a site activity plan template and the Policy Supplement (MARC stormwater management page, 2025). The calculator turns a layered standard with credits into one consistent set of numbers that a reviewer can check quickly. Singapore achieves a similar effect with a much simpler rule: a single allowable C value of 0.55 for 10-yr storms up to 4 h, applied by formula (PUB Code of Practice, cl. 7.1.5). A Rajasthan calculator serves Tier B authorities in particular, where it may be the whole calculation.

10.6 Professional certification

10.6.1 **Who may sign.** Drainage reports and designs shall be prepared and signed by a registered professional (Clause 1.4) competent in hydrology and hydraulics. For any of the following, the signatory shall be a civil engineer **empanelled as a Stormwater Design Professional** by the Authority or UDH:

- (a) Tier A sites of 1 ha or more;
- (b) any site in a flood-sensitive catchment;
- (c) any facility with an embankment, or a high-hazard basin checked for the 0.2% AEP (Chapter 4); and
- (d) any pumped facility, tide gate or regional facility.

10.6.2 **Empanelment criteria** shall be issued by UDH and shall include a civil engineering degree, relevant experience in drainage design, and completion of a training course on this Manual.

10.6.3 **Certificate.** The signatory shall complete the **Professional Design Certificate (Form 10-3)**, certifying that:

- (a) the design complies with this Manual, except for variances listed and approved;
- (b) the rainfall, soils and tailwater inputs are as recorded in Forms 2-1 and 10-2; and
- (c) the models submitted reproduce the results reported.

10.6.4 **Independent check.** Facilities under Clause 10.6.1(c) and (d) shall be checked by a second empanelled professional who is independent of the designer. That professional shall sign Form 10-3 as checker.

10.6.5 **False certification.** A false or negligent certificate is an offence under Clause 10.15.

> Commentary. Singapore requires that its ABC Waters design features used for peak control be endorsed by an ABC Waters Professional who is also a Professional Engineer (Civil) (PUB Detention Tank Guide, 2024). India has no statutory register of professional engineers comparable to Singapore's, so this clause uses the Building Regulations 2025 registration and adds empanelment for the higher-risk cases. The 1 ha limit is set by this Manual.

10.7 Review procedure and timelines

10.7.1 **Completeness check.** The Authority shall check each submittal against Form 10-1 within **5 working days** and either accept it for review or return it with a list of missing items.

10.7.2 **Technical review.** The Authority shall complete technical review and issue approval, conditional approval or a single consolidated list of comments within:

- (a) **15 working days** of acceptance for a first submittal; and
- (b) **10 working days** of acceptance for a resubmittal.

10.7.3 **No new comments.** On resubmittal, the Authority shall not raise new comments on matters that were unchanged and not commented on in the earlier review, unless the matter affects safety.

10.7.4 **Review capacity.** A Tier B authority, or a Tier A authority for overflow work, may use an empanelled reviewer from the UDH list. The empanelled reviewer shall not have worked on the same site. The Authority remains the decision-maker.

10.7.5 **Concurrent clearances.** Where the permission of WRD for a work on, or a discharge to, one of its rivers, dams, reservoirs or canals, the written consent of the Municipality to connect to a municipal drain or to build over a drain vested in it under the Rajasthan Municipalities Act 2009 (s.213), the prior permission of the Rajasthan Lakes Development Authority for construction in the protected area of a lake, or its prior approval of a plan that covers a lake (Rajasthan Lakes (Protection and Development) Authority Act 2015, s.5), the approval of the Rajasthan State Wetland Authority for a regulated activity in a notified wetland, the consent of the custodian of a lake or reservoir for a discharge to it, the consent of RIICO for a discharge to a drain in one of its industrial areas, the consent of the body that owns or runs the receiving drain where that body is not the Authority (for example a development authority or an Urban Improvement Trust), or another agency's concurrence is required (Chapter 7), the Authority shall forward the submittal on the day it is accepted for review, and the review periods shall run concurrently.

10.7.6 **Fit with permit timelines.** The periods in Clauses 10.7.1–10.7.2 run within, and do not extend, the overall time limits for planning permission and building permits set by the Government.

10.7.7 **Reasons.** Every refusal or condition shall state the clause of this Manual on which it is based.

> Commentary. The review periods have no direct precedent and are set by this Manual. A single consolidated comment list and the "no new comments" rule follow common good practice for engineering review.

10.8 Construction inspection

10.8.1 **Hold points.** The approved hold-point schedule (Form 10-4) shall include at least:

- (a) the excavated base of each retention, infiltration and detention facility, before any media, liner or structure is placed;
- (b) the outlet structure, orifice and trash screen, before backfill or before the facility is first allowed to fill;
- (c) the infiltration tests of Clause 10.9.3;
- (d) the outfall, flap or tide gate and non-return valve, before the downstream connection is made; and
- (e) pumps and controls, at commissioning.

10.8.2 Each hold point shall be inspected by the certifying professional and recorded on Form 10-4 with dated, geotagged photographs. For sites under Clause 10.6.1, the Authority shall be given at least 3 working days' notice of hold points (a) and (b), and may attend.

10.8.3 **Protection during construction.**

- (a) Retention and infiltration areas shall be fenced off from construction traffic and stockpiles.
- (b) Infiltration facilities shall not be brought into service until the area draining to them is stabilised.
- (c) Sediment shall be removed from any facility used for temporary sediment control before the as-built survey.

Figure 10.2 — Construction hold points from approval to as-built certification and handover, with the form used at each step (Clauses 10.8–10.10 and 10.14). Hold points are lettered as in Clause 10.8.1. Original drawing for this Manual, adapted from the construction-inspection and maintenance-agreement sequence of APWA Section 5600 (2006), §5608.

> **Commentary.** Infiltration facilities fail most often in construction, when they are compacted or filled with silt before they ever operate. Hold points (a) and (c) target that failure. The 3-day notice is set by this Manual.

10.9 As-built certification

10.9.1 Before the completion certificate is issued, the certifying professional shall submit the **As-built Certificate (Form 10-5)** with:

- (a) an as-built survey by a licensed surveyor of each facility's levels, storage volume, outlet dimensions and inverts, and the outfall;
- (b) a re-run of the compliance calculator, and of the model where one was used, with as-built values;
- (c) the completed hold-point records (Form 10-4); and
- (d) the final O&M plan and the executed maintenance declaration or handover documents (Clauses 10.10 and 10.14).

10.9.2 **Acceptance.** The as-built facility is accepted where:

- (a) the as-built storage volume at each design level is not less than the volume required by Chapter 4;
- (b) the outlet dimensions and inverts match the approved design; and
- (c) the re-run shows compliance with every criterion of Chapters 4 and 5.

Any deviation shall be corrected, or re-certified as compliant under Clause 10.3.5.

10.9.3 **Verification tests.** Every retention facility that relies on infiltration shall be tested after construction to show that it empties within **72 hours**, as Chapter 4 requires. Pumped facilities shall be tested at their design duty point. Tide gates and non-return valves shall be shown to open and seal.

10.9.4 The Authority shall not issue the completion certificate until Form 10-5 is accepted.

> Commentary. The 72-hour retention drawdown is the criterion of Chapter 4. This Manual requires it to be tested after construction, rather than relying on pre-construction tests alone, because compaction during construction can cut infiltration rates far below the design values.

10.10 Maintenance declarations and covenants

10.10.1 **Declaration.** The owner of every private stormwater facility shall execute a **Maintenance Declaration (Form 10-6)** before the completion certificate is issued. The declaration shall:

- (a) identify each facility, its location and the approved O&M plan;
- (b) bind the owner and successors in title to operate, inspect and maintain the facility under the O&M plan;
- (c) grant the Authority a right of entry to inspect, and to carry out works in default under Clause 10.15;
- (d) prohibit removal, filling, covering, reduction or change of use of the facility without the Authority's approval; and
- (e) be registered so that it runs with the land and is disclosed to purchasers.

10.10.2 **Multi-owner developments.** For apartments, layouts and gated communities, the declaration shall name the association or body responsible after handover by the developer. The developer remains responsible until that body is legally constituted and has accepted the declaration in writing.

10.10.3 **Annual declaration.** Every owner of a facility in a Tier A area, and of any pumped facility, tide gate or regional facility anywhere, shall submit an **Annual Maintenance Declaration and Inspection Report (Form 10-7)** by **15 June** each year. The report shall be signed by the owner and, for facilities under Clause 10.6.1(c) and (d), by an empanelled professional. It shall state that the pre-monsoon inspection of Clause 10.12 has been done and any defects corrected.

10.10.4 **Transfer.** On sale or transfer, the seller shall disclose the declaration and the latest Form 10-7. The purchaser takes on the obligations from the date of transfer.

> Commentary. Singapore requires owners of pumped detention systems to file yearly declarations and documents with PUB (PUB Detention Tank Guide, citing Code of Practice §13.2). Addendum No. 3 to the Code of Practice (16 Apr 2025) introduced annual maintenance declarations for flood barriers and pumped detention tanks, following amendments to the Sewerage and Drainage Act. APWA 5600 (2006, §5608) required easements and maintenance provisions for detention facilities. A registered declaration matters in Rajasthan because detention tanks under podiums and in basements are easy to convert to parking or storage once the building is occupied. The 15 June date is set by this Manual to fall before the south-west monsoon (June–September), when most Rajasthan extreme rainfall occurs.

10.11 O&M plans

10.11.1 Every stormwater facility shall have an O&M plan, approved at Stage 2 and finalised at Stage 4. The plan shall include:

- (a) an inventory and a plan drawing of each facility, with design levels, volumes and outlet details;
- (b) routine tasks and their frequency: inspection, debris and sediment removal, vegetation care, screen cleaning;
- (c) the trigger for sediment removal, stated as a depth or a percentage of design volume;
- (d) inspection checklists matching Form 10-7;
- (e) for pumped systems, gates and valves: the operating rules, test schedule, standby power, and actions on a cyclone or heavy-rainfall warning;
- (f) actions to prevent standing water and mosquito breeding, consistent with the drawdown times of Chapter 4;
- (g) safety measures for confined spaces, deep water and public access;
- (h) access routes and equipment needed (Clause 10.13);
- (i) an annual cost estimate and who pays it; and
- (j) the records to be kept, and for how long.

10.11.2 **Public facilities.** For facilities owned by a ULB or department, the O&M plan shall be included in the asset register (Clause 10.14.3) and funded in the annual maintenance budget.

> Commentary. Rajasthan runs its monsoon season through State and district control rooms, which the Disaster Management, Relief and Civil Defence Department ordered to work round the clock from 15 June (2026, as reported), when WRD was also told to inspect and repair the gates of its dams before the monsoon (as reported), and through the gate operations of WRD and of the custodians of the lakes. For the urban drains the orders found are local: Jaipur's corporations have run nala-cleaning drives without a stated date, and in July 2026 the Chief Minister directed that every drain be cleaned (as reported); no order of the LSG Department or UDH setting a statewide deadline for desilting the nalas was found. Several city outfalls are governed by gates: Ana Sagar in Ajmer is held at its full gauge by opening the gates of its escape channel, which floods the colonies along the channel (as reported); the Udaipur lakes spill from one to the next through gated links; and at Kota the river level is set by releases from the Kota Barrage and the dams above it. No operating rule for any lake escape channel, sluice, flap gate or pumping station in a Rajasthan city, linking it to a lake level, a river stage or a rainfall warning, was found in the public domain. Every gate and pump in this Manual needs a written rule for what happens when a warning is issued.

10.12 Inspection frequencies

10.12.1 **Owner inspections.** Owners shall inspect facilities at least as set out in Table 10.3:

Table 10.3 — Minimum owner inspection frequencies

Facility type	Routine	Pre-monsoon (by 15 June)	After a heavy-rainfall event
Retention / infiltration (soakaways, trenches, bioretention, permeable paving)	Every 6 months	Yes	Yes
Surface detention basin or multi-use open space area	Every 6 months	Yes	Yes
Underground or podium detention tank, gravity outlet	Every 6 months	Yes	Yes
Pumped detention, pumps and controls	Monthly test run	Yes, with full duty test	Yes
Flap / tide gate, non-return valve	Every 3 months	Yes, with seal test	Yes
Gross pollutant trap / first-flush device	Every 3 months	Yes	Yes
Private drains and inlets	Every 6 months	Yes	—

A heavy-rainfall event, for this Clause, is a day on which the nearest approved gauge records rainfall at or above the IMD "heavy rainfall" category, or a day for which a red alert is issued for the district. In Rajasthan, the pre-monsoon inspection of sluices, flap gates, non-return valves, lake escape-channel gates and pumped facilities, including the gates on outfalls to lakes, talabs and reservoirs, with the pump duty and gate seal tests, shall be completed by **15 June**; these facilities, with their standby generators, shall be certified ready by **20 June**, as the normal onset reaches the State (24 June at Jhalawar to 6 July at Bikaner and Pokaran), with every gate on an outfall to a river or lake, and every escape-channel gate, operated through its full travel. Pumps, their standby power and the gates shall then be kept on monsoon standby, with the monthly test run, until **30 September**, and at an outfall to the Chambal or another river regulated by a dam or barrage upstream until the river at the governing gauge has fallen below its danger level and the releases have ended, if that is later.

10.12.2 **Authority inspections.** The Authority shall inspect:

- (a) every facility on a site of 1,000 m² or more, or under Clause 10.6.1(c) or (d), at least once every 2 years, and every year in a flood-sensitive catchment; and
- (b) a random sample of at least 10% of other facilities each year.

10.12.3 The results of Authority inspections shall be entered in the facility register (Clause 10.17).

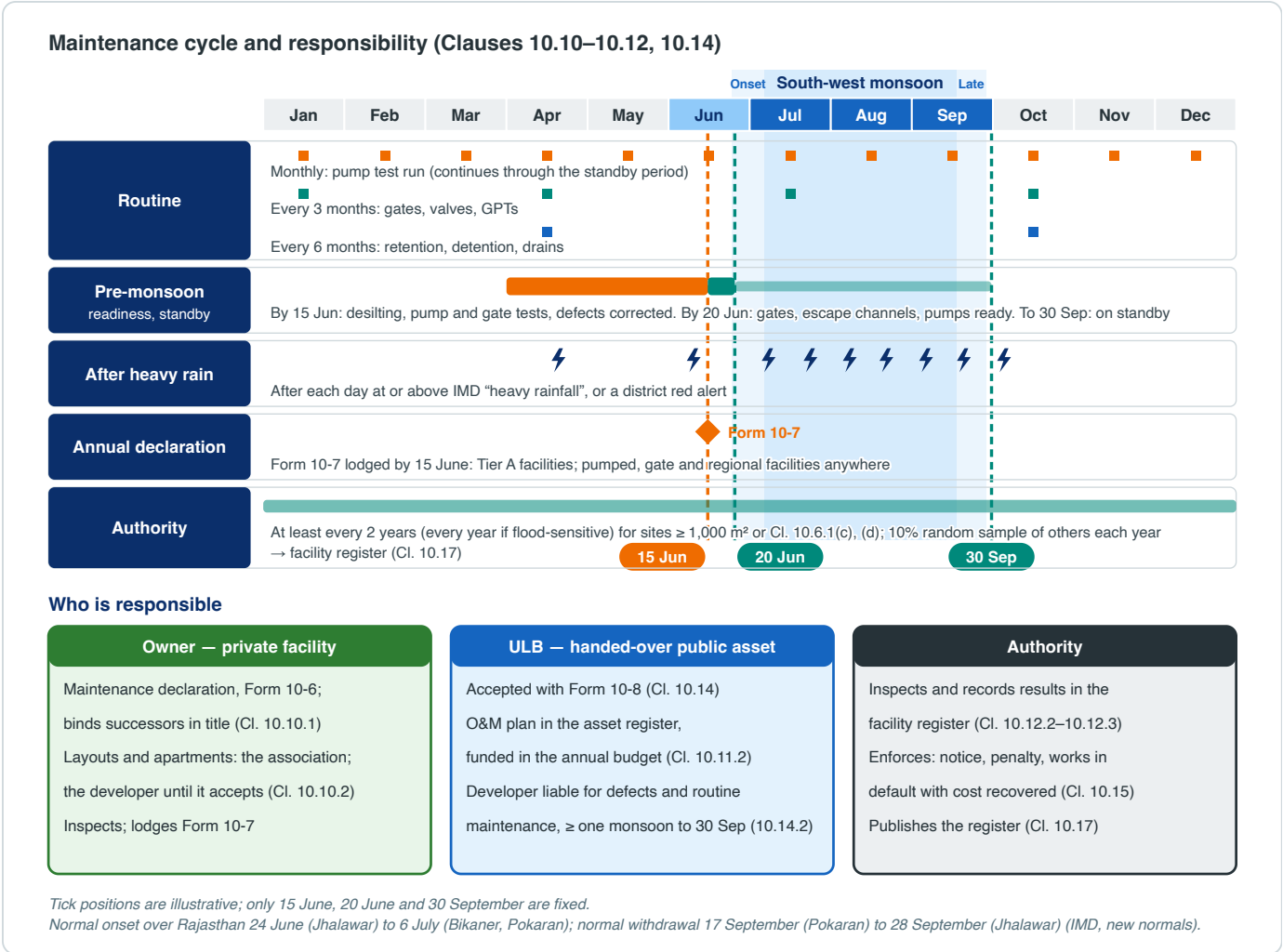

Figure 10.3 — Annual maintenance cycle and who is responsible: routine, pre-monsoon (by 15 June) and post-event inspections, the annual declaration (Form 10-7) and Authority inspections (Clauses 10.10–10.12 and 10.14). Original drawing for this Manual. The timing follows the south-west monsoon (June–September); tick positions within the year are illustrative.

Commentary. The split in Clause 10.12.2 follows the MBBL 2016 inspection regime for RWH, which requires 100% monitoring of buildings over 1,000 m² and a 10% random check below that (MBBL 2016, §9.6). The inspection intervals in Table 10.3 are set by this Manual. The 15 June deadline is set by this Manual for the onset of the south-west monsoon in the last week of June and the first week of July, and is the day on which the State and district control rooms begin to work round the clock (as reported); no order of the LSG Department or UDH setting a statewide desilting deadline was found. The normal onset is 24 June at Jhalawar, 25–26 June at Udaipur and Kota, 29 June at Jaipur, 1–2 July at Ajmer and Jodhpur and 6 July at Bikaner and Pokaran (IMD, 1961–2019 normals), and large falls have been recorded before it, 412.3 mm at Ajmer on 10 June 2002 (IMD). NDMA (2010) sets 31 March for pre-monsoon desilting nationally; this Manual allows until 15 June so that dry-season work can be finished, and keeps 15 June for the annual declaration. Sluices, gates, lake escape channels, pumps and their standby generators must in addition be certified ready by 20 June, as the onset reaches the south-east. The normal withdrawal runs from 17 September at Pokaran to 28 September at Jhalawar (IMD), so pumps and gates are kept on standby to 30 September (Figure 10.3), and at an outfall to the Chambal or another river regulated by a dam or barrage until the river has fallen below its danger level and the releases have ended, if that is later. October storms do occur, 500.0 mm at Nasirabad on 5 October 1989 and 350.0 mm at Jhalawar on 5 October 1997 (IMD), and the post-event inspections of Table 10.3 cover storms at any time of year.

10.13 Maintenance access

10.13.1 Every facility shall have permanent access for inspection and maintenance, shown on the approved drawings and protected by the maintenance declaration or, for public facilities, by an easement or land transfer.

10.13.2 **Surface facilities.** Basins, ponds and open channels shall have a vehicle access route to the inlet, the outlet and the base, and a maintenance strip along at least one side. Ramps into basins shall be suitable for the plant needed to remove sediment.

10.13.3 **Underground facilities.** Tanks shall have:

- (a) an access opening over the inlet, the outlet and each chamber;
- (b) fixed ladders or steps, and ventilation for confined-space entry;
- (c) a sump or low point for sediment removal; and
- (d) headroom sufficient for manual cleaning.

10.13.4 **Outlets.** Orifices and screens shall be reachable for cleaning without entering a full facility.

10.13.5 Access routes shall not be built over, fenced off or used for parking in a way that prevents access.

> Commentary. APWA 5600 (2006, §5608) required a 15-ft (about 4.5 m) maintenance access strip for detention facilities. Plot sizes in Rajasthan cities make a fixed width hard to apply to every site, so this Manual sets functional requirements. Annex 10C covers maintenance access dimensions.

10.14 Handover of public assets to the ULB

10.14.1 Drains, roads, open space facilities, regional facilities and other stormwater assets that a developer builds for transfer to a ULB shall be handed over only when:

- (a) the as-built certificate (Clause 10.9) has been accepted;
- (b) the facility has been cleaned, and pipes and culverts have been inspected internally (for example by CCTV or manual entry), with the record handed over;
- (c) the land, or an easement over it, has been transferred to the ULB;
- (d) the O&M plan, drawings, GIS data and warranties have been handed over; and
- (e) the **Asset Handover Certificate (Form 10-8)** has been signed by both parties.

10.14.2 **Defects liability.** The developer shall remain responsible for defects and for routine maintenance for a defects liability period that includes at least **one full monsoon season, from 15 June to 30 September,** after handover. The ULB may hold a security deposit for this period.

10.14.3 **Asset register.** On acceptance, the ULB shall enter the asset in its GIS drainage asset register and in the facility register of Clause 10.17.

10.14.4 **Private facilities.** A private facility remains the owner's responsibility under its maintenance declaration unless the ULB formally accepts it under this Clause.

> Commentary. NDMA (2010) calls for a GIS inventory of drains. Requiring the developer's GIS data at handover builds that inventory as the city grows, at no cost to the ULB. The defects period spans one monsoon because many defects in Rajasthan drainage show up only in the first SW monsoon.

10.15 Enforcement

10.15.1 **Offences.** The following are contraventions of this Manual:

- (a) building without an approved drainage design where one is required;
- (b) building a facility other than as approved;
- (c) removing, filling, covering, reducing or changing the use of a facility without approval;
- (d) failing to maintain a facility, or to submit Form 10-7;
- (e) a sewage connection to a storm drain;
- (f) building or filling in a waterbody setback or no-fill zone (Chapter 7);
- (g) obstructing a natural drainage path or major-system flow path; and
- (h) false or negligent certification.

10.15.2 **Graduated response.** The Authority shall respond in the following order, moving to a later step where an earlier one fails or where the contravention is serious (Table 10.4):

Table 10.4 — Graduated enforcement response

Step	Action
1	Written notice stating the contravention, the clause breached, the remedy and a compliance period.
2	Stop-work order, or withholding of the completion certificate, for development not yet complete.
3	Penalty under the applicable Act or rules.
4	Works in default by the Authority, with the cost recovered from the owner.
5	Disconnection of the private drain connection to the public system, where this causes no hazard to others.
6	Report of the certifying professional to the registering authority, and suspension from the empanelled list.

10.15.3 **Immediate action.** Where a contravention puts life or property at risk during a monsoon, the Authority may carry out works in default at once and recover the cost later.

10.15.4 **Security deposits.** For sites under Clause 10.6.1, the Authority may require a security deposit or bank guarantee, released after the as-built certificate is accepted, to cover works in default.

10.15.5 **Record.** Every notice and action under this Clause shall be entered in the facility register.

> **Commentary.** Penalties are referred to generically. This Manual cannot itself create offences or fines, and the powers come from the Acts under which the Model Rajasthan Building Regulations 2025 are made and from the municipal Acts. The graduated steps are set by this Manual. In Rajasthan the courts have become the working regulators of catchments, natural channels, lakes and river corridors. The High Court ordered the catchment of the Ramgarh dam, about 769.20 km² over four tehsils, cleared of construction and encroachment (*Abdul Rahman*, D.B.C.W.P. 1536/2003, 2 August 2004), and in a suo motu case barred allotments in the catchments of "Johar, Nala, Tank, River, Pond" (S.B.C.W.P. 11153/2011, orders of 23 August 2011 and 29 May 2012); the Supreme Court found the lake "still bone dry" and nothing substantive achieved on the ground, awarded costs and ordered a demolition on catchment land (*NIMS University v. State of Rajasthan*, 9 November 2017). The High Court has held that master plans cannot disturb rivers, lakes, nalas and their catchments (*Gulab Kothari*, D.B.C.W.P. 1554/2004, 12 January 2017), that land recorded as gair mumkin nala is a natural channel that may not be diverted or built on even for a public purpose (*Ramji Lal Saini*, 7 May 2026), and that no wetland or its catchment may be filled, built on or receive untreated sewage while a statewide survey is made (suo motu, 1 June 2026). Udaipur's lakes have a no-construction zone under a notification of 1997, and a project within 200 m of the high flood level of Udai Sagar was held void (as reported); at Ana Sagar the National Green Tribunal ordered structures built in the wetland removed (2023), the Supreme Court refused to stay or modify the order (2023–2025), and demolition began on 12

September 2025 (as reported). On the Jojari the Supreme Court has directed a High Flood Line and ecological buffer for every river system in the State, frozen fresh permissions in the identified river corridors meanwhile and ordered a River Commission or River Rejuvenation Authority (7 August 2026), and has barred construction within 100 m of the river's edge pending demarcation (24 August 2026, as reported). The statutes carry real powers: the Municipality may require a building put up over a drain vested in it without consent to be pulled down (Municipalities Act 2009, s.213(2)), an owner who does not provide rainwater harvesting is liable to a fine of ₹10,000–20,000 and a new building gets no public water connection without the Municipality's certificate (s.238), and the Lakes Development Authority may remove an obstruction in the protected area or the flow area of a lake (Lakes Act 2015, s.6(2), as read from the Bill). No audit by CAG of urban drainage, of AMRUT drainage works or of the lakes in Rajasthan was found; CAG's Rajasthan audits found cover solid waste management in the urban local bodies (Report No. 4 of 2025, as reported) and land revenue. This shows that a rule without routine enforcement does little, and that where the State has not drawn a line the courts have. Professional accountability (step 6) is often more effective than fines on owners, because it acts on the person who signs the design.

10.16 Monitoring and post-event review

10.16.1 **Monitoring network.** Tier A authorities shall maintain, or have access to, recording rain gauges and water-level gauges at their main outfalls and regional facilities. Data shall be archived at intervals of 15 minutes or less.

10.16.2 **Event reports.** After any event that floods buildings within a ULB area, the ULB shall prepare a short event report within **3 months**, recording:

- (a) rainfall at the nearest approved gauges, by duration, compared with the design depths of Chapter 2;
- (b) the level of the receiving river (the Chambal at Kota or Dholpur, the Banas, the Luni or another river) at the nearest CWC or WRD gauge, or of the receiving lake or reservoir (in Udaipur, Pichola, Fateh Sagar or Udai Sagar; in Ajmer, Ana Sagar; in Jodhpur, Kailana or Takhat Sagar), and, where it is gauged, at the outfall, each on a named datum, with lake gauge readings in feet converted to metres; for a catchment with no outfall, the peak level in the terminal basin or depression and the time it took to empty; the state of every sluice, flap gate, escape-channel gate, interception structure and pumping station on the outfall and on the drain upstream of it, with the hours each pump ran and any loss of power; and the gate openings and releases of any lake, dam or barrage that sets the receiving level, such as the Kota Barrage or the escape-channel gates of Ana Sagar;
- (c) flooded locations, depths and durations, with flood marks surveyed where possible;
- (d) the performance of public and inspected private facilities, including any blocked outlets, failed pumps or closed gates; and
- (e) recommended actions.

10.16.3 **Post-event review.** Where an event exceeds the 1% AEP 24-hour or 72-hour design depth at two or more approved gauges in the State (Clause 2.14.1), RSDMA, with the State Stormwater Technical Committee, shall lead a post-event review within **12 months**. It shall assess whether the criteria of this Manual were adequate, and shall feed into the review of Clause 1.12.

10.16.4 **Facility performance sampling.** The Authority shall, at least every 5 years, monitor a sample of private retention and detention facilities through a monsoon, to test whether they perform as designed.

Commentary. The post-event trigger is the review trigger already set in Clause 2.14.1. Rajasthan's urban floods have been examined by the courts and the press rather than by technical reviews. On 18–20 July 1981 Jaipur city recorded 82 cm of rain in three days and 35 cm in the 24 hours of 19 July, a low having formed over the region and stagnated, and the city was cut off (Gupta and Jindal 1987); IMD's station record for the day is 326.0 mm, against a 50-year 24-hour depth on the CWC plate of about 200 mm. On 19–21 August 2006 about 577 mm fell in three days around Kawas in Barmer district, more than twice the annual normal, and parts of Kawas were

reported still under water months later; the reported deaths range from about 50 to more than 300 (as reported), and in the same week Udaipur's lakes overflowed into the colonies below them (as reported). In September 2019 the Chambal reached its high flood level of 248.68 m at Kota City while the Kota Barrage released through 18 or 19 of its gates (CWC; as reported). In July 2022 Jodhpur received about 119 mm in 24 hours, most of it in about five hours, reported as its highest July rain since 1943, and more than 30 colonies were flooded (as reported). On the night of 31 July 2024 three members of one family died in a flooded basement in Jaipur's Vishwakarma Industrial Area (as reported), and in September 2024 and July 2025 the opening of the Ana Sagar escape channel waterlogged colonies in Ajmer (as reported). No technical review of any of these events was found, and no record of flood extents, depths or durations kept by any Municipal Corporation or development authority was found. NDMA (2010) called for automatic rain gauges at "1 in every 4 sq km" in Class I, II and III cities. Clause 10.16.1 asks only for gauges where they serve design and review. The report and sampling intervals are set by this Manual.

10.17 Data publication

10.17.1 Each Authority shall publish, on a public website, and update at least quarterly:

- (a) a **facility register**: location, type, design volume, release rate, owner, date of as-built acceptance, and the latest inspection result for every facility approved under this Manual;
- (b) a summary of each approved drainage report, with Forms 2-1 and 10-2;
- (c) the register of variances and waivers (Clause 1.10);
- (d) the alternatives adopted under the Policy Supplement (Clause 1.7);
- (e) enforcement actions (Clause 10.15.5); and
- (f) event reports and post-event reviews (Clause 10.16).

10.17.2 The State Stormwater Technical Committee shall publish the compliance calculator, all Annexes, the flood-sensitive catchment maps and the State-level summary of facility registers as open data.

10.17.3 Personal data other than the name of a corporate owner or association shall not be published. Security-sensitive details of critical infrastructure may be withheld, with the reason recorded.

10.17.4 Published data shall be machine-readable (for example CSV and GeoPackage) and released under the Government Open Data Licence – India or an equivalent open licence.

Commentary. Transparency is a design criterion in its own right here. Some of Rajasthan's drainage records are public: the Building Regulations 2025 (in a third-party copy) and the JDA 2020 regulations in their Gazette text, the judgments of the High Court and the Supreme Court on Ramgarh, natural channels, wetlands and the Jojari, the EIA chapter of the Dravyavati project, RUIDP's Circular No. 8 and ADB's project documents, CGWB's groundwater assessments, and the river bulletins of CWC. Much else could not be found in the public domain: the Gazette publication of the Building Regulations 2025 by each city and authority, and the full text of their environmental schedule; the design discharge, rainfall and method of the Dravyavati channel; the return period and model of JDA's 2025 drainage upgrade; the initial environmental examination of the Jodhpur storm water drains; an inventory of the sluices, flap gates, escape channels and pumping stations of any city, with their capacities and operating rules; the operating rules of the Ana Sagar escape channel and of the gates of the Udaipur lakes; the level above mean sea level of the gauge zeros of the Udaipur and Ajmer lakes; any notification of lake boundaries or protected areas under the Lakes Act 2015; an urban flood plan of RSDMA; the list of wetlands notified under the Wetlands Rules 2017; any audit by CAG of urban drainage; and the full text of the Supreme Court's order of 24

August 2026 on the Jojari. Publishing inputs and facility records lets the public, researchers and other agencies check that the city's growing stock of private storage actually exists. The open-format requirement is set by this Manual.

10.18 Review of this chapter

10.18.1 This chapter shall be reviewed with the Manual under Clause 1.12. The forms and the compliance calculator may be revised by the State Stormwater Technical Committee between reviews, under Clause 10.5.3.

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Annexes and forms

Annex / Form	Content
10A	Compliance calculator and user guide
10B	GIS data specification and attribute schema
10C	Maintenance access dimensions
10D	Model O&M plans by facility type
10E	Empanelment criteria for Stormwater Design Professionals and reviewers
Form 10-1	Drainage Report Checklist
Form 10-2	Compliance Calculator Summary
Form 10-3	Professional Design Certificate
Form 10-4	Hold-Point Inspection Record
Form 10-5	As-built Certificate
Form 10-6	Maintenance Declaration
Form 10-7	Annual Maintenance Declaration and Inspection Report
Form 10-8	Asset Handover Certificate
Form 2-1	Design Rainfall Sheet (Chapter 2)

CHAPTER 11

Basin and City Stormwater Master Plans

11.1 Purpose and scope

11.1.1 Chapters 2 to 10 control one project at a time. This chapter sets the requirements for the plan that ties those projects together: the **Basin Stormwater Master Plan (BSMP)**. A BSMP is prepared for each drainage basin of a city or urban area. A city's set of BSMPs makes up its **City Stormwater Master Plan**.

11.1.2 A BSMP shall:

- (a) map flood hazard for the basin under existing and future conditions;
- (b) set the level of service each part of the drainage system must achieve (Clause 11.6);
- (c) identify the works, storage and land needed to reach that level of service, and rank them (Clauses 11.7 and 11.8);
- (d) reserve land for regional storage, talab and tank restoration, and major flow paths in the statutory land-use plan (Clause 11.9);
- (e) set the basin-specific inputs that site designs under Chapter 4 depend on: regional facilities, the fee-in-lieu unit rate, and any basin release rate stricter than Chapter 4 (Clause 11.8.3); and
- (f) recommend catchments for notification as flood-sensitive (Clause 4.5.4).

11.1.3 **Relationship to site design.** Site criteria (Chapters 4 to 8) apply whether or not a BSMP exists. A BSMP may make the site criteria **stricter** for its basin. It shall not relax them, except through the regional detention and fee-in-lieu routes of Clauses 4.13 and 4.5.6.

> Commentary. Rajasthan's cities are spending on their drains and channels, but no city drainage master plan with a design standard has been published. The largest work is JDA's **Dravyavati River Project** in Jaipur, which rebuilt the Dravyavati, a river that had become a storm and sewage channel (the Amanishah nala), over 47.5 km, in two phases of 34.84 km and 12.66 km, from the Nahargarh hills to its outfall to the Dhund; it collects the Naharika, Ambabari, Ganda and Jawahar nalas, was designed "to make the river section capable of safely passing the hundred year flood", and includes treatment plants of 170 MLD (JDA EIA; Supreme Court, 2026). Its cost is given as ₹1,676 crore, including ten years of maintenance, by the contractor (Tata Projects) and as ₹1,490.85 crore for the two phases in the EIA, and it was inaugurated on 2 October 2018 (as reported); its design discharge was not found. JDA began a monsoon drainage upgrade of about ₹80 crore in May 2025 built on an integrated storm water model, the first in Jaipur (as reported), whose return period and consultant were not found. In Jodhpur RUIDP, with ADB finance, is building the 13.1 km Bhairav nala and the 7.0 km RTO nala and Mata ki Than drain to the Jojari (ADB, 2023), with no design return period stated; RUIDP's own guidance of 2008 allowed 1–2 years for town drains. Udaipur's lakes, Ajmer's Ana Sagar and Kota's outfalls to the Chambal are managed by gate operation and, at Udaipur and Ana Sagar, by court orders on their margins, not by a drainage plan; for Ana Sagar the State engaged NEERI and MNIT after the Supreme Court's orders (as reported). The drainage chapter of the Master Development Plan of the Jaipur Region was not found. No published document sets a design return period for the storm drain network of any Rajasthan city; the only design standard found for any urban channel is the 100-year flood of the Dravyavati. This chapter supplies the design storm, levels of service, storage and buffer criteria that such a plan needs, with the design storms of Chapter 2 and the levels of service of Clause 11.6; it has not been adopted by UDH, the LSG Department, any Municipal Corporation, development authority or Urban

Improvement Trust, or any other body. A site-level manual cannot fix basin-level problems: lost tank storage, nalas and natural channels recorded as gair mumkin nala built over or diverted, city outfalls to lakes held at their full level by gates and escape channels and to the Chambal, which barrage releases can hold high for days, nalas that carry sewage and industrial effluent into the Dravyavati, the Jojari and the Udaipur lakes, catchments in the west with no outfall at all, single drains split between a Municipal Corporation, a development authority or Urban Improvement Trust, RIICO and WRD, and drains that are adequate on their own but overload the next reach. Comparable manuals pair site criteria with basin planning:

- Denver's Mile High Flood District prepares major drainageway master plans that set regional facilities and release rates.
- The Kansas City APWA criteria rest on regional watershed studies (MARC).
- England's Surface Water Management Plans (Defra, Surface Water Management Plan Technical Guidance, 2010) set a phased method of preparation, risk assessment, options and implementation.
- Malaysia's MSMA requires drainage master plans for urban areas.

This chapter adapts that method to Rajasthan: to city outfalls on lakes whose levels are held by gates and escape channels, as at Ana Sagar in Ajmer and in the chain of lakes at Udaipur, and on the Chambal at Kota, which releases from the Kota Barrage and the dams above it can hold high for days; to the west of the State, where about 60% of the land drains inland and many catchments have no outfall at all, so that storage, infiltration and evaporation take the place of an outfall; to nalas that carry sewage, industrial effluent and solid waste into the Dravyavati, the Jojari and the lakes; to drains and public tanks vested in the Municipalities, scheme drains of the development authorities and Urban Improvement Trusts, industrial drains of RIICO, rivers and dams held by WRD, natural channels recorded as gair mumkin nala that the High Court protects, and lakes under the Lakes Act 2015, without an order that divides the nalas between them; to a State where the courts, not a floodplain law, draw the lines along rivers and lakes, and the Supreme Court has ordered a High Flood Line for every river system; to a State with no published design return period for the drains of any city except the 100-year Dravyavati channel; to aquifers over-exploited across most of the State but rising beneath the old city of Jodhpur and the canal plains; and to a south-west monsoon whose recorded days far exceed the 50-year depths of the CWC plates, 326.0 mm at Jaipur on 19 July 1981 and 653.0 mm at Mount Abu on 8 September 1992 (IMD).

11.2 Definitions

Term	Meaning in this Manual
Basin	The land draining to one outfall to the sea, a river, or a major waterbody, as delineated under Clause 11.3.
Basin Stormwater Master Plan (BSMP)	The plan for one basin prepared under this chapter.
Lead Authority	The body responsible for preparing a BSMP (Clause 11.4).
Level of service (LoS)	The flood performance a part of the drainage system must achieve, expressed as an AEP and an outcome (Clause 11.6).
Flood hazard map	A map of flood extent, depth, velocity and hazard class (H1–H6, Chapter 6) for a stated AEP and scenario.
Regional facility	A storage, conveyance or outfall work serving more than one development, identified in a BSMP.
Capital Improvement Programme (CIP)	The ranked, costed list of works in a BSMP (Clause 11.8.4).

11.3 Planning unit: the basin, not the ward

11.3.1 BSMPs shall be prepared **by hydrological basin**, not by ward, zone or local-body boundary. Where a basin crosses local-body boundaries, one BSMP shall cover the whole basin.

11.3.2 Basin boundaries shall be delineated from the digital elevation model of Clause 11.5.2, checked against the drain network, road embankments, canals and tank supply channels. Diversions between basins, whether by canal, drain or surplus course, shall be mapped and represented in the model.

11.3.3 No basin delineation has been published for any Rajasthan city. For the urban areas where the evidence identifies them, the basins are at least the following:

- **Jaipur, Dravyavati:** the catchment of the **Dravyavati** from the Nahargarh hills to its outfall to the **Dhund**, with the **Naharika**, **Ambabari**, **Ganda** (walled city) and **Jawahar** nalas and the Sanganer area as sub-basins, the rebuilt channel and its fall structures in the 1D network, and its interception works and treatment plants mapped (Clause 8.9.5);
- **Jaipur, Man Sagar:** the catchment of **Man Sagar (Jal Mahal)**, reported as 23.5 km², with the **Brahmapuri** and **Nagtalai** nalas, and the lake level as the boundary condition of every drain that enters it;
- **Jaipur, Ramgarh:** the catchment of the **Ramgarh dam**, about 769.20 km² over four tehsils, in the parts that the city and the JDA region reach, with the catchment line drawn under the High Court's orders shown;
- **Jodhpur, Jojari:** the catchments that drain south and south-east to the **Jojari**, among them the **Bhairav nala** and the **RTO nala**, with **Kailana** (full reservoir level 273.7 m) and **Takhat Sagar** (269.75 m) as storage linked by gated conduits, the rising water table of the old city as a design condition, and the High Flood Line and buffer of the Jojari, once demarcated, shown;
- **Udaipur, lakes:** the catchments of **Pichola** and **Fateh Sagar**, fed by **Bada Madar**, and of the **Ayad** below them to **Udai Sagar**, with the gated link between Pichola and Fateh Sagar and the lake spills to the Ayad as gated links between basins (Clause 11.3.2), and each lake's level as the boundary condition of the drains that enter it;
- **Ajmer, Ana Sagar:** the catchment of **Ana Sagar**, with the lake held at its full gauge as the boundary condition, the outfall-closed case a design case, and the **escape channel** and the colonies along it as a gated link to the basin below;
- **Kota, Chambal:** the catchments of the city that outfall to the **Chambal**, with the river level at the CWC Kota City site, which releases from the **Kota Barrage** and the dams above it govern, as the boundary condition and the outfall-closed case a design case; and
- **No-outfall towns of the west:** for **Bikaner** and the other towns whose catchments end inland, each **terminal depression** or basin with the land draining to it, tested with the 72-hour design volume of Clause 4.12.7 and no outflow other than infiltration and evaporation.

Other Tier A bodies, including Alwar, Bharatpur, Bhilwara, Sikar, Pali, Sri Ganganagar and Tonk, shall define their basins in the first BSMP that covers them. Where WRD, CWC, the custodian of a lake or a court has a high flood level, a full tank level or maximum water level, a High Flood Line or buffer, a lake protected area, or an operating rule for a dam, a barrage, a lake gate or escape channel or a pumping station, the BSMP shall take its boundary conditions from it and show those levels against its own 1% AEP map.

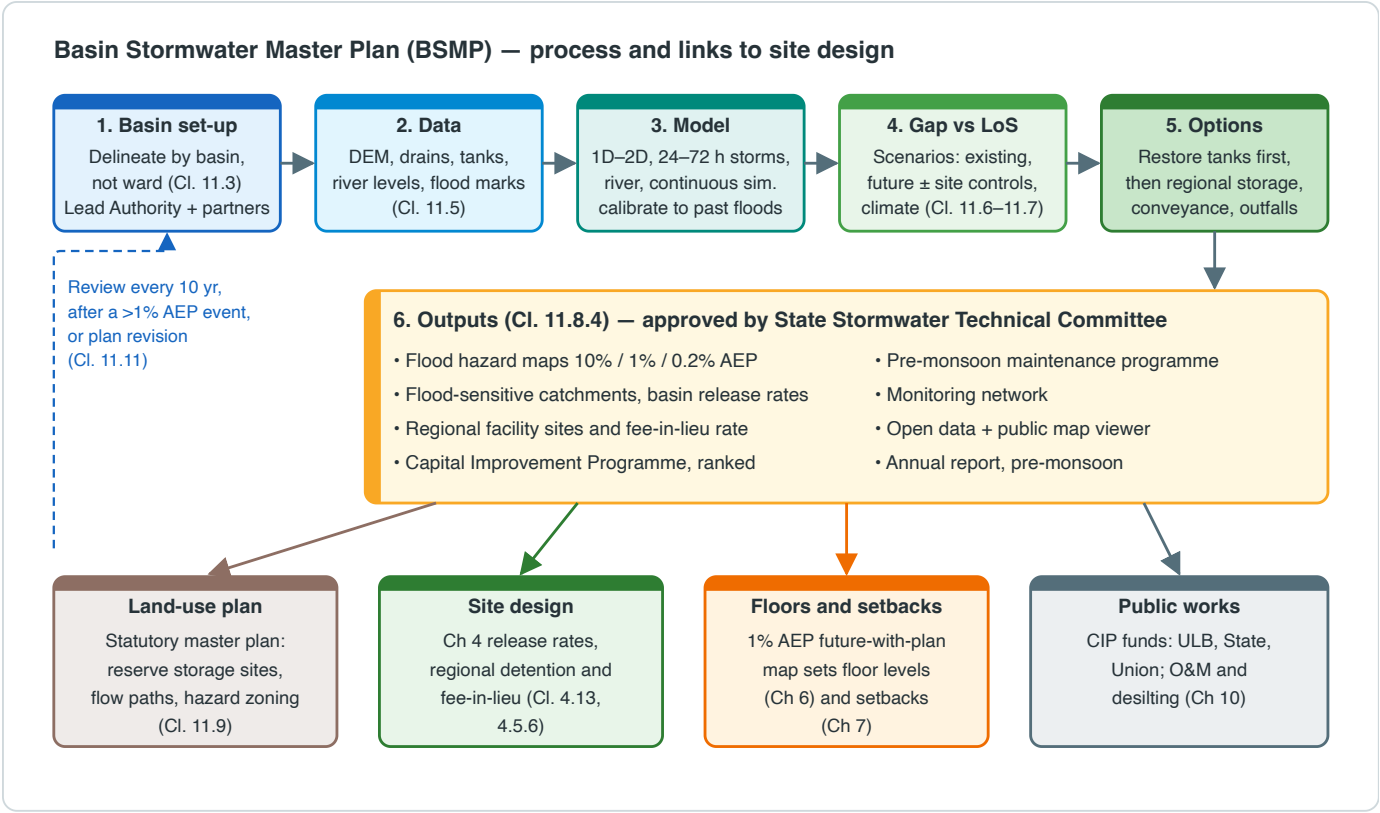

Figure 11.1 — Basin Stormwater Master Plan process and its links to site design. Original drawing for this Manual. The phase structure is adapted from Defra, Surface Water Management Plan Technical Guidance (2010), and Mile High Flood District master planning practice.

Commentary. Water does not follow ward boundaries. A ward-by-ward drain plan can pass the problem to the next ward, and to the next local body. In Rajasthan a single nala can pass through several hands on its way to a lake, a river or a depression. The Rajasthan Municipalities Act 2009 vests in the Municipality, as trustee, the public tanks and streams and the drains and watercourses in, alongside or under any street (s.68), and puts all drains within it under its survey and control (s.200); the development authorities and Urban Improvement Trusts build the drains of their schemes; RIICO runs the drains of its industrial areas, which the Supreme Court found discharging into municipal drains at Jodhpur (2026); the rivers, dams and their High Flood Lines are with WRD; natural channels recorded as gair mumkin nala are State land that the High Court has held may not be diverted or built on (*Ramji Lal Saini*, 2026); and the lakes fall under the Lakes Act 2015, though no lake boundary or protected area was found notified. No rule divides the natural nalas from the municipal drains (as this Manual reads the record), and the Supreme Court has found the Rajasthan River Basin and Water Resources Planning Authority, meant to plan by river basin, "largely defunct" (7 August 2026). The drains carry sewage across these boundaries: Jaipur's nalas reach the Dravyavati, whose project treats 170 MLD, and Jodhpur's sewage, put at about 230 MLD against treatment of about 175 MLD in 2026, and industrial effluent reach the Jojari (Supreme Court, 2025–26). This clause makes the basin the planning unit, so that one model carries each drain from its head to the lake, river or depression whoever owns each reach, and so that the interception structures are tested against the capacity of the drains they tap (Chapter 8, Clause 8.9.5).

11.4 Who prepares, and when

11.4.1 **Lead Authority.**

- For the basins of a city with a Municipal Corporation: the **Municipal Corporation** (in Jaipur, **JMC**), in which the Rajasthan Municipalities Act 2009 vests the public tanks, streams and street drains (s.68) and which must provide drainage (s.45), jointly with the **development authority** or **Urban Improvement Trust** for the city (in Jaipur, **JDA**), which prepares the master development plan into which the BSMP is carried (Clause 11.9) and builds the drains of its schemes; either may prepare the plan as UDH directs. Where a basin extends beyond the Corporation, the other local bodies and the development authority or trust in the basin are partners, and one BSMP covers the whole basin (Clause 11.3.1). The twin corporations of Jaipur, Jodhpur and Kota were reported merged again into one corporation each in 2025 (as reported); the Lead Authority is the corporation as it stands when the BSMP is prepared.
- No order dividing the natural nalas from the municipal drains, or the drains of the local bodies from the rivers and dams of WRD, was found; until one is made, this Manual assigns the reaches within each BSMP as follows, each body being Lead Authority for the reaches and works it owns or runs and for the parts of the CIP on them: **WRD** for the rivers, dams, barrages and reservoirs, their gates and releases, and their high flood levels, with the **River Commission or River Rejuvenation Authority** that the Supreme Court has directed (7 August 2026), once constituted, for the High Flood Lines and ecological buffers of the rivers; the **Rajasthan Lakes Development Authority**, with the **custodian of each lake**, for the lakes under the Lakes Act 2015, their full tank level lines, gates and escape channels, protected areas and flow areas; the **Rajasthan State Wetland Authority** for notified wetlands; the **Municipal Corporation**, **Municipal Council** or **Municipal Board** for the municipal nalas, street drains and public tanks vested in it (s.68); the **development authorities** and **Urban Improvement Trusts** for the drains of their schemes until they are handed over; **RIICO** for the drains of its industrial areas; the **Collector** for the nalas, nadis and talabs recorded as gair mumkin in the revenue records in the parts of a basin outside municipal limits; and PWD and NHAI for the drains of their roads.
- In Tier B bodies: the Lead Authority is named by UDH with the LSG Department. Basins draining to a common river reach, lake or depression may be grouped into one district-level plan.

The Rajasthan Lakes Development Authority shall be consulted on every BSMP whose basin includes a lake, since the land-use plan into which it is carried needs that Authority's prior approval (Lakes Act 2015, s.5); the Rajasthan State Wetland Authority shall be consulted on every BSMP whose basin drains to a notified wetland or a Ramsar site (Keoladeo, Sambhar, Khichan or Menar); RSDMA and the district administration on every BSMP; and the Rajasthan State Pollution Control Board on every BSMP that proposes works on a drain that carries sewage or effluent to a lake or river.

WRD shall be a partner in every BSMP that includes a river, canal or tank under its control.

11.4.2 **When a BSMP is required.**

- (a) Every Tier A body shall approve BSMPs covering its whole area within **3 years** of this Manual taking effect.
- (b) A BSMP is required before:
  - any regional detention or fee-in-lieu is accepted under Clause 4.13;
  - a fee held under Clause 4.5.6.3 is spent; and
  - a basin-specific release rate is applied under Clause 11.8.3.
- (c) A Tier B body shall prepare a BSMP where its Lead Authority, or the State Stormwater Technical Committee, finds recurrent flooding of buildings or arterial roads.

11.4.3 **Preparation.** BSMPs shall be prepared by, or under the direction of, an engineer empanelled as a Stormwater Design Professional (Chapter 10) with experience in basin-scale modelling.

11.5 Data and surveys

11.5.1 Each BSMP shall assemble and publish (Clause 11.10) the data in Table 11.1:

Table 11.1 — Minimum data and surveys for a BSMP

Data	Minimum requirement
Terrain	Digital elevation model from LiDAR or photogrammetry, with vertical accuracy of 0.15 m RMSE or better in urban areas, tied to the Survey of India datum
Drain network	Inventory of all public drains, culverts and outfalls with invert levels, sizes, condition and silt depth; private drains above 600 mm
Waterbodies	Survey of every tank, talab, pond and marsh under Chapter 7: FTL, MWL, bund level, stage–storage, sluices, surplus weirs, supply channels, encroachment
Rivers and canals	Cross-sections at no more than 200 m spacing and at every structure
Outfalls, rivers, lakes and terminal depressions	The datum of every level named, with lake gauge readings in feet above a local zero converted to metres once the zero has been surveyed; outfall invert levels against the warning, danger and high flood levels of the receiving river at the nearest CWC or WRD gauge and its recorded peaks (for the Chambal at Kota City, a danger level of 242 m and a high flood level of 248.68 m in 2019); for outfalls to lakes and reservoirs, the full tank level, maximum water level and dead-storage level from WRD or the custodian, the gate and escape-channel operating rule and any conflict between published values (for Fateh Sagar, a full gauge of 13 ft against 14 ft); for a catchment with no outfall, the stage–storage, infiltration and evaporation of the terminal depression or basin; the lines drawn under court orders where they bind, such as the High Flood Line and ecological buffer that the Supreme Court has directed for the rivers of the State, once demarcated; the sluices, flap gates, escape channels, interception structures, anicuts, check dams and pumping stations on the outfalls, with their capacities and operating rules; and releases from any dam or barrage upstream
Rainfall and levels	All available rain gauges (IMD, including its observatories at Jaipur (Sanganer), Jodhpur, Bikaner, Jaisalmer, Barmer, Ajmer, Kota, Udaipur and Mount Abu and the automatic weather stations and rain gauges reported by the Meteorological Centre Jaipur; the district and tehsil rain gauges of the State; the rain and river gauges of CWC and of WRD, including those at the dams, barrages and lakes; and any gauges kept by the Municipal Corporations, the development authorities and the Smart City companies) and water-level records, including those for the July 1981 (Jaipur), August 2006 (Barmer and Udaipur), September 2019 (Kota and the Chambal), July 2022 (Jodhpur) and July–August 2024 (Jaipur) events
Flood evidence	Surveyed flood marks and mapped flood extents from past events, including public reports
Land use	Existing land use and imperviousness; future land use from the statutory master plan
Soils and groundwater	HSG map (Annex 3A); seasonal high groundwater; aquifer and recharge zones
Sewer interaction	Known sewage cross-connections, dry-weather flow in drains, and solid-waste hotspots

Commentary. The 0.15 m accuracy has no direct precedent; this Manual sets it because on the flat interdune and canal plains of the west, around the terminal depressions in which catchments with no outfall end, on the Jaipur plain, along the Chambal at Kota, and around the margins of the lakes of Udaipur and Ajmer, where the line of the full tank level decides what may be built, a small error in ground level moves the flood edge a long way, and the 1% extent from the BSMP sets floor levels (Chapter 6) and setbacks (Chapter 7). Past flood marks matter as much as models. The July 1981 (Jaipur), August 2006 (Barmer and Udaipur), September 2019 (Kota and the Chambal), July 2022 (Jodhpur) and July–August 2024 (Jaipur) events are the best calibration data Rajasthan has, and much of the evidence is held in photographs, news reports and residents' records that should be collected before it is lost.

11.6 Levels of service

11.6.1 Each BSMP shall adopt the following minimum levels of service. A BSMP may adopt stricter levels.

Table 11.2 — Minimum levels of service

Element	Minimum level of service
Minor system	The design AEP of Chapter 6 (Table 6.1)
Habitable buildings	No flooding above floor level in the 1% AEP (100-yr) event
Critical facilities (hospitals, emergency services, substations, water and sewage plants)	No flooding of the facility in the 0.2% AEP (500-yr) event; access road passable in the 1% AEP event
Evacuation routes and arterial roads	Passable (hazard class H2 or better, Chapter 6) in the 1% AEP event
Ponding drain time	Surface water cleared from roads within **6 hours** after rain ends in the 10% AEP (10-yr) event
Tank and talab storage	No net loss of flood storage below the MWL in the basin, measured against the earliest available survey
Outfalls	Functioning under the joint and outfall-closed cases of Chapter 5

> **Commentary.** The building and road levels repeat Chapter 6, so that the basin plan and the site designs aim at the same outcome. The 0.2% AEP for critical facilities, the 6-hour ponding drain time and the no-net-loss rule for tank storage have no direct precedent and are set by this Manual. The drain time reflects what residents notice most after a storm. The no-net-loss rule reflects a loss of storage that has been reported but not measured. In law the State's lakes and tanks are protected in several layers: the Lakes Act 2015 treats as a lake any water body that had a submerged area of at least 3 ha (heritage or religious) or 10 ha (others) at any time in the fifty years before the Act, "whether it contains water or not and whether it has been recorded as such … or not", defines its "flow area" as the area through which its feeders flow, and lets the Lakes Development Authority remove obstructions in the protected area or the flow area (ss.2 and 6, as read from the Bill), though no lake boundary or protected area was found notified; within a Municipality the public tanks, and the adjacent land that is not private property, vest in it as trustee (Municipalities Act 2009, s.68); no khatedari rights accrue in tank and river beds (Rajasthan Tenancy Act 1955, s.16), and the High Court has barred allotments in the catchments of "Johar, Nala, Tank, River, Pond" (2012) and held that land recorded as gair mumkin nala keeps that character (*Ramji Lal Saini*, 2026). The losses are visible all the same: the Supreme Court found the Ramgarh dam, once Jaipur's water supply, "still bone dry" after years of orders on its 769.20 km² catchment (2017); at Fateh Sagar in Udaipur the freeboard at the main bund has been put at about 0.75 m, with water held above the design full tank level by sandbags (as reported); and Ana Sagar is still awaiting notification as a wetland after the Tribunal's orders (as reported). Keoladeo (1981), Sambhar (1990) and Khichan and Menar (2025) are Ramsar sites, and 75 wetlands were reported notified under the Wetlands Rules 2017 by January 2026 (as reported). No inventory of the talabs inside any Municipal Corporation, and no survey of the storage of any of them, was found.

11.7 Modelling and scenarios

11.7.1 **Model.** Each BSMP shall use a coupled 1D–2D hydraulic model of:

- the minor system;
- the major (overland) system;
- rivers, canals and tanks; and

- the outfalls.

Methods shall follow Chapter 3. Tidal and river boundaries shall follow Chapter 5.

11.7.2 **Design storms.** The model shall be run for the design storms of Chapter 2, including the 24-, 48- and 72-hour storms, for at least the 50%, 10%, 1% and 0.2% AEPs. Areal reduction shall be applied under Clause 2.7.3.

11.7.3 **Continuous simulation.** Basins with tank cascades shall also be run by continuous simulation (Clause 3.13), using the full IMD gridded daily record where available and at least 30 years, disaggregated by the temporal patterns of Annex 2D. This shows how full the tanks are when the design storms arrive, and how often heavy rain coincides with a closed outfall. The two-step approach of Clause 3.13.5 may be used: a simplified storage model is run for the whole record, and the coupled 1D–2D model of Clause 11.7.1 is run only for the design storms, starting from the tank levels the continuous run gives. A continuous run of the full 1D–2D model is not required.

11.7.4 **Scenarios.** Each BSMP shall model at least:

- (a) **Existing:** existing land use, network, tanks and outfalls;
- (b) **Future, uncontrolled:** future land use under the statutory master plan, with no site controls;
- (c) **Future, controlled:** future land use with the site controls of Chapter 4;
- (d) **Future, with plan:** scenario (c) plus the works of the CIP; and
- (e) **Climate:** scenarios (a) and (d), with the climate factors of Clause 2.8, used unchanged: no projection of heavy rainfall for Rajasthan with a design factor was found, and the reported increases in monsoon and heavy rainfall over west Rajasthan (Mehta and Yadav 2022; an IMD analysis as reported) are a reason to keep them, not to reduce them, although the Jaipur station extremes show no significant trend over 1970–2013 (Ghate and Timbadiya 2022).

11.7.5 **Calibration.** The model shall be calibrated and validated under Clause 3.15, using at least two of the July 1981 (Jaipur), August 2006 (Barmer and Udaipur), September 2019 (Kota and the Chambal), July 2022 (Jodhpur) and July–August 2024 (Jaipur) events where data exist.

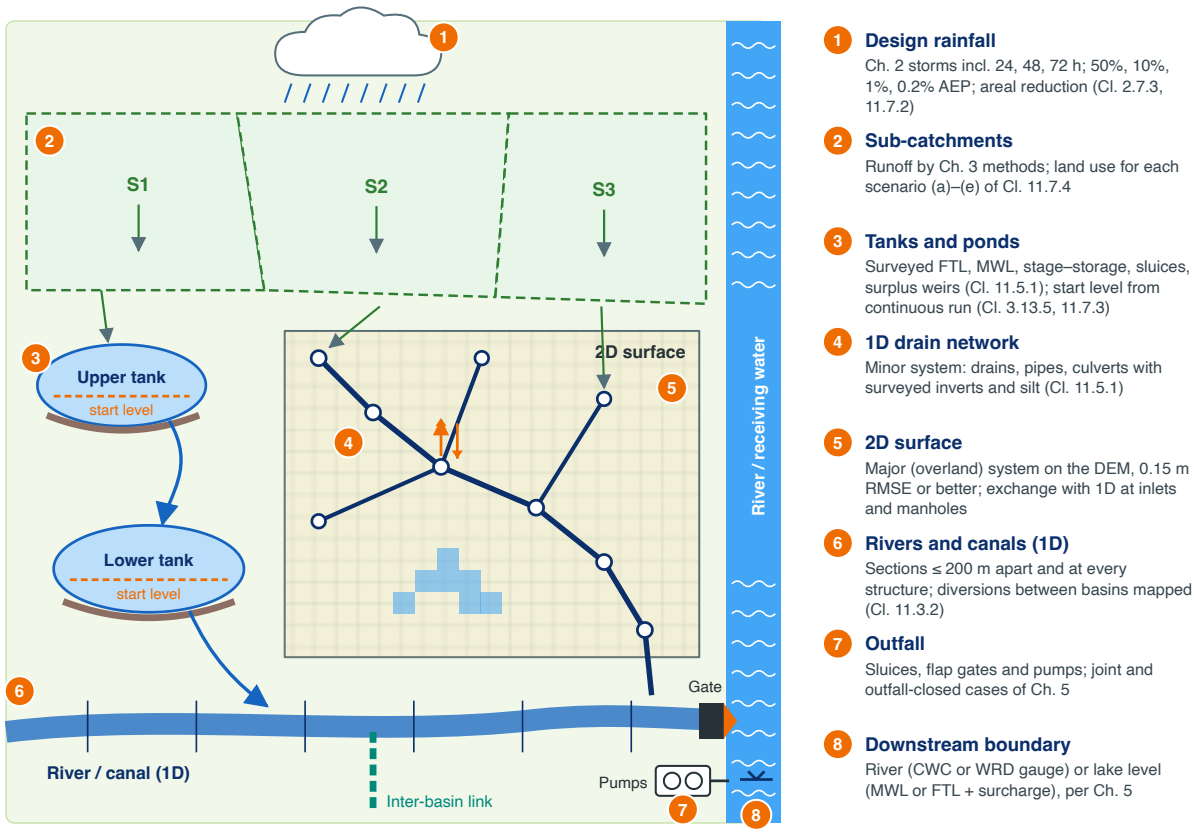

Figure 11.2 — Elements of the BSMP model required by Clause 11.7: sub-catchments, the 1D drain and channel network, the 2D surface, tanks and talabs with starting levels from continuous simulation, and the tidal or river boundary at the outfall (schematic, not to scale). Original drawing for this Manual, adapted from common coupled 1D–2D urban flood modelling practice.

> **Commentary.** Scenario (b) against scenario (c) shows what the site rules achieve on their own. Scenario (d) shows what the public works add. This comparison is also the evidence base for notifying flood-sensitive catchments (Clause 4.5.4) and for setting a stricter basin release rate (Clause 11.8.3).

11.8 Options, outputs and the Capital Improvement Programme

11.8.1 **Options hierarchy.** Options shall be considered in the following order, the basin-scale form of the hierarchy in Clause 1.2:

1. **Protect and restore storage:** talabs, tanks, marshes and floodplains, including desilting to the original bed and recovering encroached area (Chapter 7);
2. **Regional retention and detention**, sited by modelling so that releases do not coincide with the main-stem peak (Clause 4.13);
3. **Conveyance** upgrades to drains, canals and culverts;
4. **Outfall works:** sluices and flap gates on the outfalls to the rivers and lakes, pumping stations and the storage behind them where an outfall can be closed, the escape channels and gates of the city lakes, interception structures that keep the storm capacity of the drain, storage and infiltration basins at the end of catchments with

no outfall, and the operating rules of the lake, dam and barrage gates that set the receiving levels, agreed with WRD or the custodian;
5. **Property-level protection** where works cannot reach the level of service; and
6. **Non-structural measures:** flood warning (for example IMD district rainfall warnings issued by the Meteorological Centre Jaipur, CWC flood forecasts and river stages at its sites on the Chambal, the Banas and other rivers against their warning and danger levels, warnings to the localities downstream before the gates of the Kota Barrage and other dams, the escape-channel gates of Ana Sagar or the gates of the Udaipur lakes are opened, and the State and district control rooms that run round the clock from 15 June), flood-hazard zoning, emergency planning and public information.

11.8.2 **Option assessment.** Each option shall be assessed for:

- reduction in flood risk (buildings and people flooded; expected annual damage);
- capital and 30-year maintenance cost;
- land required;
- effect on groundwater recharge in the over-exploited aquifers that underlie most of the State, the rising water table and waterlogging in the old city of Jodhpur and the Ganganagar–Hanumangarh canal belt, and the quality of the groundwater, in which fluoride, nitrate and salinity are common, and of the lakes that the drains reach (Chapter 8);
- effect on downstream basins and the receiving river or lake; and
- who benefits.

11.8.3 **Basin release rates.** Where scenario (c) does not meet the level of service, the BSMP may set a basin-specific **permissible site discharge** ($m^3/s/ha$) stricter than Chapter 4, by AEP and sub-catchment. The rate takes effect under the notification procedure of Clause 4.5.4.

11.8.4 **Outputs.** Each BSMP shall produce:

- (a) flood hazard maps (extent, depth, velocity, hazard class) for the 10%, 1% and 0.2% AEPs, existing and future-with-plan. The **1% AEP future-with-plan map** becomes the reference map for floor levels (Chapter 6) and setbacks (Chapter 7);
- (b) recommended flood-sensitive catchments and any basin release rates (Clauses 4.5.4 and 11.8.3);
- (c) regional facility sites, with storage volumes, land needs and the sites they serve;
- (d) the fee-in-lieu unit rate for the basin (Clause 4.13.3);
- (e) the **Capital Improvement Programme**: works ranked by risk reduction per rupee, with cost, phasing and agency;
- (f) a pre-monsoon **maintenance programme**: desilting, gate and pump testing, and tank operating rules (Chapter 10); and
- (g) monitoring needs: new rain gauges, level sensors and flood-mark survey points.

> Commentary. Restoring storage comes first because many of the outfalls of Rajasthan's cities are lakes that are often full in the wettest weeks, and many catchments have no outfall at all. Ajmer's Ana Sagar is held at its full gauge by opening its escape-channel gates, so faster conveyance into the lake only floods the colonies along the channel sooner; the Udaipur lakes spill from Pichola and Fateh Sagar to the Ayad and Udai Sagar; and at Kota the Chambal's high flood level stands about 6.7 m above its danger level (CWC), with barrage releases holding it high for days. About 60% of the State drains inland (as reported), where the drained water has nowhere to go but into storage, the ground and the air. The State's tanks are old and public: no khatedari rights accrue in tank beds (Rajasthan Tenancy Act 1955, s.16), and within a Municipality the public tanks vest in it as trustee (Municipalities Act 2009, s.68). The storms are large for drains with no stated design basis: IMD has recorded 326.0 mm in a day at Jaipur (19 July 1981), 412.3 mm at Ajmer (10 June 2002) and 653.0 mm at Mount Abu (8 September 1992), far above the 50-year 24-hour depths of the CWC plates there (IMD; this Manual's reading), and about 577 mm was reported in three days around Kawas in Barmer district in August 2006, more than twice the district's annual normal (as reported). Conveyance upgrades on their own move water faster to an outfall that the Chambal in

flood or a lake held at its full level by its gates may close, or that is limited by the capacity of its sluice, escape channel, interception structure or pumping station, and, where a catchment has no outfall, to the lowest ground of the terminal depression. Groundwater in Rajasthan calls for recharge almost everywhere and forbids it in a few places. The State's stage of extraction was 149.86% in 2024, with 214 of 302 assessment units over-exploited and 27 critical (CGWB), so recharge is the default. But the water table under the old city of Jodhpur has risen since canal water arrived in 1997, to within about 1–1.5 m of the surface in places, with basements pumped daily (as reported; NIH, 2025), and the Ganganagar–Hanumangarh canal plains have pockets within 2 m of the surface (CGWB); there, recharge adds to waterlogging. Quality limits recharge too: of CGWB's samples in 2024, 43.2% exceeded 1.5 mg/L of fluoride, 49.5% exceeded 45 mg/L of nitrate and 48.6% exceeded 3,000 µS/cm of electrical conductivity. The law asks for recharge without regard to either: the Building Regulations 2025 require a rainwater harvesting structure or rooftop storage tank on plots of 225 m² or more (reg. 8.3), with no sizing or pre-treatment rule, and exempt only waterlogged areas once the local body has marked them. This is why recharge, waterlogging and groundwater quality are all assessment criteria. This Manual ranks projects by risk reduction per rupee so that limited budgets go first where most people are protected.

11.9 Integration with land-use planning

11.9.1 An approved BSMP shall be incorporated into the statutory land-use plan: the master development plans and zonal development plans of the development authorities, made under their Acts (JDA 1982, JoDA 2009, AjDA 2013, KDA 2023, UDA 2023 and the Bikaner and Bharatpur Development Authority Acts 2025), among them the Master Development Plan of the Jaipur Region, the master plans of the other towns prepared through UDH and the Urban Improvement Trusts under the Rajasthan Urban Improvement Act 1959, and the layouts and schemes approved under them; and, for a plan that covers a lake, with the prior approval of the Lakes Development Authority (Lakes Act 2015, s.5). In particular:

- (a) regional facility sites, restored tank flood storage, and major flow paths shall be **reserved** in the plan;
- (b) the 1% AEP hazard map shall be shown, and Chapter 7 setbacks applied to it;
- (c) land in hazard classes H5–H6 in the 1% AEP event shall not be zoned for new habitable development; and
- (d) the open space of layouts within a basin should be located, where possible, to form part of the major flow paths or regional storage shown in the BSMP.

11.9.2 Where a land-use plan is revised before a BSMP is approved, the planning authority shall use the best available flood mapping and record the BSMP as pending.

Commentary. Rajasthan draws its water lines by court order rather than by rule. The Building Regulations 2025 set no setback from a nala, river or lake, and keep only the natural drainage inlets and outlets of large projects. The lines come from the courts: the Supreme Court has directed a High Flood Line and ecological buffer for every river system in the State, with no fresh permissions in the identified river corridors meanwhile (7 August 2026), and on the Jojari has barred construction within 100 m of the river's edge and hazardous industry within 500 m of the flood line or flow path (24 August 2026, as reported); the High Court has held that master plans may not disturb rivers, lakes, nalas or their catchments (*Gulab Kothari*, 2017) and that land recorded as gair mumkin nala may not be diverted or built on (*Ramji Lal Saini*, 2026), and has barred construction in wetlands and their catchments (2026) and in the catchment of Fateh Sagar (November 2025, as reported); and Udaipur's lakes have a no-construction zone under a notification of 1997, and a project within 200 m of the high flood level of Udai Sagar was held void (as reported). The Lakes Act 2015 provides for a protected area around each lake, by notification, but none was found notified. Notified wetlands carry a 50 m line from the mean high flood level (Wetlands Rules 2017). No State floodplain zoning law or order was found. These are river, lake and waterbody lines, not drainage-flood lines; the hydraulic corridor and setback zones of Chapter 7 are this Manual's proposal, and where a court line binds and is wider, it applies. A BSMP gives the land-use plans the 1% AEP drainage-flood map, and the buffer widths of Chapter 7, that they need. Using open space land as storage or flow path has no

direct precedent; this Manual adopts it because the Building Regulations 2025 already require a green area of 10–20% on non-commercial plots of more than 750 m², at least half of it on natural ground with no slab below (reg. 8.1), and for projects of 5,000–20,000 m² built-up require that the natural drainage inlet and outlet points be kept as they are and that at least 20% of the open space be left unpaved (environmental conditions of the regulations' schedule, as in Annexure 4 of the JDA Building Regulations 2020), but set no detention or pervious-area rule; storage placed in a layout's open space builds on these duties, and because that land still serves as open space, the storage must stay usable as one. Placing it on the flow path costs the developer nothing extra and gives the basin storage it would otherwise have to buy.

11.10 Consultation and publication

11.10.1 A draft BSMP shall be published for public comment for at least **60 days**, with public meetings in each affected local body.

11.10.2 After approval, the following shall be published as open data:

- the model files;
- the flood hazard maps;
- the data of Clause 11.5.1, except security-sensitive asset details; and
- the CIP.

They shall also be shown on a public map viewer.

Commentary. Publishing the maps lets buyers, lenders, insurers and residents see flood hazard before they build or buy. Publishing the model lets designers use the same boundary conditions as the Authority, so site designs and the basin plan stay consistent. This matches the publication approach of Chapter 10.

11.11 Approval, review and reporting

11.11.1 **Approval.** BSMPs shall be approved by the State Stormwater Technical Committee (Chapter 1), after review of the model and of the public comments.

11.11.2 **Review.** Each BSMP shall be reviewed:

- every **10 years**;
- within **2 years** of an event exceeding the 1% AEP design depth in the basin (Clause 2.14); and
- when the statutory land-use plan is revised.

11.11.3 **Annual report.** The Lead Authority shall publish an annual implementation report before each SW monsoon (by 15 June). The report shall show:

- CIP progress;
- the fee-in-lieu ledger (Clause 4.13.4);
- maintenance completed; and
- any flooding against the levels of service.

11.12 Interim arrangements

11.12.1 Until a BSMP is approved for a basin:

- (a) all site criteria of Chapters 4 to 8 apply in full;
- (b) regional detention and fee-in-lieu under Clause 4.13 are not available, except the holding of fees under Clause 4.5.6.3;
- (c) floor levels and setbacks use the best available mapping, and the methods of Chapters 6 and 7 where no mapping exists; and
- (d) public drain projects shall include a basin-level check that their outfall and downstream reaches can take the design flow under the Chapter 5 tailwater cases.

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Annexes and forms

Annex / Form	Content
11A	BSMP terms of reference template
11B	Basin lists and boundaries for Tier A bodies
11C	Depth–damage curves for Rajasthan building types
11D	BSMP data and model publication standard
Form 11-1	Annual implementation report

ANNEXES TO CHAPTER 1

Policy, Applicability and Adoption

These annexes support Chapter 1. They hold the lists and maps that define where the Manual applies, the model text of the Policy Supplement and of the legal instruments that would give the Manual effect, and the two forms an Applicant files under Chapter 1. The Manual is a draft; it is not adopted by any government or agency: model legal text is offered for consideration by a competent authority and is not in force, and the forms are draft forms. An annex marked "To be prepared" states the data it needs and the rule to use until it is published (Clause 1.11.5).

Annex 1A — List of Tier A authorities, with the boundaries of the Municipal Corporations and of the regions of the development authorities

Supports Clauses 1.6.1 to 1.6.5 of Chapter 1.

1A.1 Clause 1.6.1 defines Tier A by class of authority. Table 1A.1 sets out the classes, and the authorities named in the clause, as Chapter 1 defines them. Every authority not in Table 1A.1 is Tier B (Clause 1.6.2).

Table 1A.1 — Tier A authorities as defined in Clause 1.6.1

Item	Tier A authority	Clause
(a)	Jaipur Municipal Corporation (JMC), and JDA and every other Approving Authority within the Jaipur Region of JDA	1.6.1(a)
(b)	Every other Municipal Corporation constituted under the Rajasthan Municipalities Act, 2009	1.6.1(b)
(c)	Every other development authority constituted by an Act of the State (JoDA, AjDA, KDA, UDA and the Bikaner and Bharatpur Development Authorities), with every Approving Authority within its region	1.6.1(c)
—	A Tier B authority that opts into Tier A by council resolution, or that the Government notifies as Tier A	1.6.4

1A.2 Whatever the tier, the design-aid route and the alternatives of Clause 1.7 are not available in a flood-sensitive catchment (Clause 1.6.5; Annex 1B).

To be prepared. This annex will contain the full list, by name, of every Municipal Corporation and every development authority in the State, and of every Approving Authority within the region of each development authority, with the date from which each is Tier A, and the boundaries of those areas as a map and as a GIS layer. It needs the regions of the development authorities as notified under their Acts, and the bodies that approve building plans and layouts in each (UDH, JDA and the other development authorities, and the Urban Improvement Trusts); the current list and boundaries of the Municipal Corporations, Municipal Councils and Municipal Boards, after the reported re-merger of the twin corporations of Jaipur, Jodhpur and Kota in 2025 and the reported reversion of some municipalities to gram panchayats in 2026 (the Local Self Government Department; neither notification seen, and the number of Municipal Corporations not verified [TBC]); and the district and tehsil boundaries after the reorganisation of districts in 2023–24 (Revenue Department, Survey of India). Until it is published, the tier is decided by the classes in Clause 1.6.1 and recorded on Form 1-1, and the Authority confirms it at the pre-application stage (Clause 1.5.9).

Table 1A.2 — Register of Tier A authorities (layout)

No.	Authority	Class (Municipal Corporation / Municipal Council / Municipal Board / development authority / Urban Improvement Trust / other)	District	Basis (Clause 1.6.1(a), (b), (c) or 1.6.4)	Tier A from (date)	Notification or resolution reference
1						
2						
3						

1A.3 The Municipal Corporation and development-authority region boundary map shall be published as open data in a machine-readable format (Clause 10.17.4), with the date of the notification it shows.

Annex 1B — Maps of flood-sensitive catchments

Supports Clauses 1.4, 1.6.5 and 1.10.3(d) of Chapter 1, and Clauses 4.5.3 and 4.5.4 of Chapter 4.

1B.1 The flood-sensitive catchments are listed in Clause 4.5.3.2. Table 1B.1 repeats that list. The maps of this annex and the boundaries of Annex 4A are the same data set and shall be issued together.

Table 1B.1 — Flood-sensitive catchments listed in Clause 4.5.3.2

Item	Catchment	Extent as described in Chapter 4
(a)	Jaipur on the Dravyavati	The catchment of the Dravyavati river (the former Amanishah nala) and of the nalas that join it, among them the Naharika and Ambabari nalas, the walled-city Ganda nala, the Jawahar nala and the nalas of Sanganer town, with the low-lying colonies of the city that drain to them; JDA rebuilt about 47.5 km of the river as a channel to pass the 100-year flood (JDA EIA; design discharge not found [TBC]), and three people died in a flooded basement in the city in August 2024 (as reported)
(b)	Jodhpur on the Jojari and the old city	The catchments of the Jojari through the city and of the Bhairav and RTO nalas and the other city nalas that drain to it, and the old city, where the water table has risen since canal water arrived in 1997 to about 1–1.5 m below ground in places (as reported); more than 30 colonies flooded on 18–19 July 2022 (as reported), and the Jojari's corridor is being demarcated under the Supreme Court's orders (2026)
(c)	Udaipur's lake chain	The land that drains to the Pichola, Swaroop Sagar, Fateh Sagar, the Ayad (Ahar) and Udai Sagar, whose outfalls are held up when the lakes are full and their gates are open; the lake levels are kept on gauges in feet above an unknown zero (Pichola full at 11 ft, Fateh Sagar at 13 ft, Udai Sagar at 24 ft, as reported), and their levels in metres are to be confirmed [TBC]
(d)	Ajmer on Ana Sagar and its escape channel	The catchment of Ana Sagar and the land along its escape channel, which floods when the escape gates are opened to hold the lake at its full gauge of 13 ft (as reported; level in metres [TBC]), as on 11 September 2024 and 18–20 July 2025 (as reported)
(e)	Kota on the Chambal	The land that drains to the Chambal through the city, where the river is raised by releases from Gandhi Sagar, Rana Pratap Sagar, Jawahar Sagar and the Kota Barrage (full reservoir level 260.3 m); the CWC site at Kota City has a danger level of 242 m and a highest flood level of 248.68 m (16 September 2019) (CWC)
(f)	Barmer and Balotra on the Luni	Balotra town and the land that drains to the Luni there, where the highest flood level is 108.755 m (18 July 1979) (CWC list, as reported); and Barmer town and the low ground of its district, such as Kawas, where water stood for months after about 577 mm fell in three days in August 2006 (as reported)
(g)	Notified catchments	Any catchment notified under Clause 4.5.4

To be prepared. This annex will contain a map of each catchment in Table 1B.1 at a scale fit for deciding whether a plot lies inside it, and the same boundaries as a GIS layer. It needs catchment boundaries drawn from a digital elevation model and the drain network (the Municipal Corporations of Jaipur, Jodhpur, Udaipur, Ajmer and Kota, the Municipal Councils of Balotra and Barmer, the development authorities, Survey of India); the city drains with their outfalls and interception works and their levels on a stated datum (the local bodies, JDA and RUIDP); the full levels, maximum water levels and gate and escape-channel operating rules of Pichola, Fateh Sagar, Udai Sagar and Ana Sagar, on a datum in metres, and of the Kota Barrage (WRD, the Lakes Development Authority, the custodians of the lakes); the high flood lines and buffers being demarcated under the Supreme Court's order of 7 August 2026, beginning with the Jojari; the CWC levels on the Chambal at Kota City and on the Luni at Balotra; the depth to groundwater in the old city of Jodhpur (CGWB, the Ground Water Department); and the land flooded in 1981, 2006, 2019, 2022, 2024 and 2025 (the Collectors, RSDMA, the local bodies). Bharatpur, where the Gambhir and Banganga floods of 1981 endangered the Ajan bund; Tonk on the Banas; Sri Ganganagar and Hanumangarh on the Ghaggar; Bikaner; Alwar; and Mount Abu and Abu Road on the West Banas are candidates for notification under Clause 4.5.4 once their catchment boundaries and flood record are documented. The river corridors and the lake and wetland buffers set by the courts are governed by Chapter 7 and by the orders that bind there rather than by this list. Until it is published, the Authority decides at the pre-application stage whether a site lies in a listed catchment, from the best boundary available, and the decision and its basis are recorded on Form 1-1 and in the drainage report (Clauses 1.5.9 and 1.11.5).

Table 1B.2 — Attributes of the flood-sensitive catchment layer (layout)

Field	Content	Unit or format
catchment_id	Unique identifier	text
name	Catchment name	text
basis	Clause 4.5.3.2 item (a) to (f), or the notification under Clause 4.5.4	text
notification_ref	Gazette notification number, where notified	text
notified_on	Date of notification	date
applies_from	Date from which the rule applies to applications (Clause 4.5.4.2, step 5)	date
boundary_source	Source and date of the boundary	text
area_km2	Catchment area	km²

Annex 1C — Policy Supplement: text of alternatives S-1 to S-5 and model council resolution

Supports Clauses 1.6.3, 1.6.5 and 1.7.1 to 1.7.3 of Chapter 1.

Model text for consideration by a competent authority. Not in force. The text below shows how the Policy Supplement of Clause 1.7 could be written. It has no effect unless and until it is issued by the Government and adopted by an Approving Authority under Clause 1.7.3.

Part 1 — General provisions

P1.1 **Scope.** This Supplement sets out alternatives S-1 to S-5 to the requirements of the Rajasthan Stormwater Design Manual (the Manual) named in each alternative. An alternative applies within the area of an Approving Authority (the Authority) only from the date on which the Authority adopts it under P1.3.

P1.2 **No lower criterion.** No alternative lowers any criterion of the Manual. S-1 and S-2 are simplified methods for meeting the same criterion (Clause 1.7.3(a)).

P1.3 **Adoption.**

- (a) A Tier B authority adopts an alternative by council resolution in the form of Part 3, and sends a copy to the State Stormwater Technical Committee (the Committee) within 30 days of the resolution.
- (b) A Tier A authority adopts an alternative only after the Committee has concurred in writing.
- (c) The Authority publishes the alternatives it has adopted on its website and in the register of Clause 10.17.

P1.4 **Retention.** No alternative replaces the retention requirement (Annex 2E depth), except where fee-in-lieu under S-5 funds equivalent retention in the same basin (Clause 1.7.3(d)).

P1.5 **Tables.** The tables used by S-1, S-2 and S-3 are those issued by the Committee, and are reviewed with Chapter 2 of the Manual (Clauses 1.7.3(e) and 2.14). An alternative that depends on a table cannot be used until that table is issued.

P1.6 **Record.** An Applicant who uses an alternative states it on Form 1-1 and in the drainage report, with the resolution or concurrence under which it was adopted.

Part 2 — The alternatives

S-1 — Design-aid route for storage

S-1.1 *Replaces:* storage sized by a hydrograph method under Chapter 3.

S-1.2 *Alternative:* retention and detention volumes may be taken from the unit-storage tables issued for Annex 4B (m³ per ha, by rainfall zone, hydrologic soil group and impervious fraction) and the compliance calculator, by the method of Clause 4.14.2.

S-1.3 *Eligibility:* sites of 2 ha or less outside flood-sensitive catchments, and of 0.5 ha or less within them (Table 1.2; Clause 4.14.1).

S-1.4 *Conditions:* the post-development imperviousness used shall be that shown on the approved plans; the outlet, spillway, RWH accounting and safety provisions of Clause 4.14.2 apply; the compliance calculator may be the sole calculation (Table 1.1).

S-2 — Permissible site discharge (PSD)

S-2.1 *Replaces:* the release rate $Q_{post}(T) \le 0.9 \times Q_{pre}(T)$ computed for the site (Clause 2.11.2).

S-2.2 *Alternative:* the release rate for each AEP may be taken as the tabulated unit-area release rate for the site's zone and AEP, multiplied by the site area. The tabulated rates are derived from the $0.9 \times Q_{pre}$ rule (Table 1.2).

S-2.3 *Eligibility:* any site outside a flood-sensitive catchment.

S-2.4 *Conditions:* storage is then sized to hold every duration of Clause 2.5.2 at the PSD; drawdown, minimum orifice and spillway rules of Chapter 4 apply unchanged.

S-3 — Fixed-width waterbody setback

S-3.1 *Replaces:* the waterbody setback extended to the mapped 1% AEP flood extent plus margin (Chapter 7).

S-3.2 *Alternative:* where no 1% AEP extent is mapped, the setback shall be the fixed width for the class of waterbody in the table of Clause 7.4.6 (and Annex 7B), measured as in Clause 7.4.3.

S-3.3 *Eligibility:* waterbodies with no mapped 1% AEP extent.

S-3.4 *Conditions:* no setback under this alternative is less than the Zone 1 minimum of Clause 7.4.7 (Clause 1.10.3(c)); the no-fill zone of Chapter 7 applies; where a 1% AEP extent is later mapped and adopted, the mapped setback applies to new applications.

S-4 — Downstream screening checklist

S-4.1 *Replaces:* downstream analysis by hydraulic model under Chapter 5.

S-4.2 *Alternative:* the Applicant completes a screening checklist of downstream capacity and known flooding, covering at least the conditions of Clause 5.3.4: that the receiving public drain has documented capacity for its minor-system design flow (Chapter 6), and that no flood-prone location is recorded within 500 m downstream. A hydraulic model under Chapter 5 is required only where the screen fails.

S-4.3 *Eligibility:* sites of less than 1 ha, outside flood-sensitive catchments, not discharging to a tidal outfall.

S-4.4 *Conditions:* the checklist is signed by the registered professional who signs the drainage report (Clause 10.6); flood-prone locations are those recorded by the local body, the Collector and the District Disaster Management Authority, RSDMA, the State and district control rooms, or WRD (Clause 5.3.3(d)).

S-5 — Fee-in-lieu toward regional storage

S-5.1 *Replaces:* on-site detention under Chapter 4.

S-5.2 *Alternative:* all or part of the detention requirement may be met by a fee-in-lieu toward a regional detention facility or restored talab or tank storage identified in the basin plan (Clause 4.13.1).

S-5.3 *Eligibility:* sites in a basin for which a basin plan has been notified (Table 1.2).

S-5.4 *Conditions:*

- (a) the conditions of Clause 4.13.2 apply, including interim on-site detention until the regional facility or restored tank is operational, and retention and WQv treatment on site;
- (b) the fee is computed under Clause 4.13.3 and held in the ring-fenced basin account;
- (c) the volume credited and the fee are entered in the public ledger of Clause 4.13.4; and
- (d) in a flood-sensitive catchment, fee-in-lieu is available only as allowed by Clause 1.10.3(d).

Part 3 — Model council resolution

> **Model text for consideration by a competent authority. Not in force.**

Resolution No. _____ of _____ (name of Municipal Corporation (Nagar Nigam) / Municipal Council (Nagar Parishad) / Municipal Board (Nagar Palika)), dated _____

Subject: Adoption of alternatives under the Policy Supplement to the Rajasthan Stormwater Design Manual.

The Council, having considered the report of the Commissioner / Executive Officer dated _____, and noting that:

- (i) the Rajasthan Stormwater Design Manual and its Policy Supplement have been given effect by _____ (instrument and date);
- (ii) this local body is a Tier B / Tier A authority under Clause 1.6 of the Manual; and

- (iii) for a Tier A authority, the State Stormwater Technical Committee concurred on _____ (reference _____),

resolves:

1. to adopt the following alternatives of the Policy Supplement within its area, under the conditions of Clause 1.7.3 of the Manual:

Table 1C.1 — Alternatives adopted by this resolution

Alternative	Adopted (Yes / No)	Area to which it applies (whole area, or wards / zones)	Applies from (date)
S-1 Design-aid route			
S-2 Permissible site discharge			
S-3 Fixed-width setback			
S-4 Downstream screening checklist			
S-5 Fee-in-lieu			

2. that no adopted alternative shall apply within a flood-sensitive catchment except as the Manual allows (Clause 1.6.5);
3. that a copy of this resolution be sent to the State Stormwater Technical Committee within 30 days;
4. that the adopted alternatives be published on the local body's website and entered in the register of Clause 10.17; and
5. that this resolution be reviewed when the tables of Clause 1.7.3(e) are revised.

Mayor / Chairperson: _____ Commissioner / Executive Officer: _____ Date: _____

Annex 1D — Model Building Regulations 2025 amendment and model ULB bye-law

Supports Clauses 1.3.1, 1.3.4, 1.11 and 1.12 of Chapter 1.

> **Model text for consideration by a competent authority. Not in force.** The text shows one way the instruments of Clause 1.3.1 could be drafted. Rule and section numbers are left blank.

> **Drafting note D1D.1.** The rule numbers of the Model Rajasthan Building Regulations 2025 at which the new rule and the conditions would be inserted, and the enabling sections of the Rajasthan Urban Improvement Act, 1959, the Acts of the development authorities (Jaipur 1982, Jodhpur 2009, Ajmer 2013, Kota and Udaipur 2023, Bikaner and Bharatpur 2025) and the municipal and panchayat Acts, are to be confirmed by the Government's legal advisers. None is stated here.

Part A — Model amendment to the Model Rajasthan Building Regulations 2025

A.1 **Short title and commencement.**

- (1) These rules may be called the Rajasthan Building (Stormwater Management) Amendment Regulations, _____.
- (2) They shall come into force on the date six months after their publication in the Rajasthan Gazette (Clause 1.11.1).

A.2 **Insertion of a new rule.** After rule [_____] of the building regulations that each urban local body and development authority brings into force, by publication in the Rajasthan Gazette, on the model issued by the Urban Development and Housing Department with its order of 12 May 2025, the following rule shall be inserted:

> **Rule [_____]. Stormwater management.**
>
> (1) *Definitions.* In this rule, "the Manual" means the Rajasthan Stormwater Design Manual as notified by the Government, with its annexes and amendments; other words have the meanings given in Clause 1.4 of the Manual.
>
> (2) *Application.* This rule applies to every development for which planning permission, building permit or layout approval is required under these rules.
>
> (3) *Runoff control.* Where a development, over its common plan of development, involves land disturbance of 0.1 ha or more, or new or replaced impervious area of 500 m² or more, the development shall comply with Chapters 4 and 5 of the Manual (retention, detention, downstream and tailwater analysis).
>
> (4) *Provisions for every development.* Every development, whatever its size, shall comply with Clause 1.5.4 of the Manual: no sewage connection to a storm drain; floor levels; waterbody setbacks and the no-fill zone; and no obstruction of a drainage path.
>
> (5) *Exemptions.* A single dwelling on its own plot below the thresholds of sub-rule (3), and linear road resurfacing that adds no impervious area, are exempt from sub-rule (3) but not from sub-rule (4) or the rainwater harvesting provisions of these rules.
>
> (6) *Conditions of approval.* The competent authority shall not grant:
>
> - (a) planning permission or layout approval, unless a preliminary drainage report under the Manual has been accepted;
> - (b) a building permit, or permission to commence, unless the final drainage design has been accepted; or
> - (c) a completion certificate, unless the as-built certificate has been accepted and the maintenance declaration has been registered, or the public assets have been handed over,
>
> for a development to which sub-rule (3) applies (Manual, Clause 10.3).
>
> (7) *Certification.* Drainage reports and designs shall be signed by a registered professional, and, where Clause 10.6.1 of the Manual so requires, by an empanelled Stormwater Design Professional.
>
> (8) *Rainwater harvesting.* Nothing in this rule alters the rainwater harvesting provisions of these rules.
>
> (9) *Variances and waivers.* The competent authority may grant a variance or waiver only on the grounds and by the procedure of Clause 1.10 of the Manual, and shall publish each decision.
>
> (10) *Transition.* Applications filed complete before the commencement of this rule, and Tier B authorities, are governed by Clause 1.11 of the Manual.

Part B — Model ULB bye-law

B.1 **Title and commencement.** These bye-laws may be called the _____ (name of local body) Stormwater Management Bye-laws, _____. They come into force on _____.

B.2 **Adoption of the Manual.** The Rajasthan Stormwater Design Manual, as notified by the Government, applies to:

- (a) every development approved by the local body; and

- (b) every drainage, road, culvert, waterbody and flood-mitigation work executed by the local body, including its own drains and roads (Clause 1.3.1(b)).

B.3 **Public works.** Every detailed project report and contract for a work under B.2(b) shall require compliance with the Manual, from the dates in Clause 1.11 (Clause 1.3.4).

B.4 **Tier and alternatives.** The local body is a Tier _____ authority under Clause 1.6 of the Manual. The alternatives of the Policy Supplement adopted by the local body are listed in the Schedule, with the resolution under which each was adopted.

B.5 **Submittals and review.** Submittals shall be made in the stages of Clause 10.3 of the Manual and reviewed within the periods of Clause 10.7.

B.6 **Maintenance, inspection and enforcement.** Maintenance declarations, inspections, handover of public assets and enforcement shall follow Clauses 10.10 to 10.15 of the Manual.

B.7 **Publication.** The local body shall publish the registers and reports of Clause 10.17 of the Manual.

B.8 **Review.** These bye-laws shall be reviewed whenever the Manual is amended under Clause 1.12.

Table 1D.1 — Schedule: alternatives adopted (layout)

Alternative	Resolution number and date	Committee concurrence (Tier A only)	Applies from	Area

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Form 1-1 — Applicability Determination

Supports Clauses 1.5.1 to 1.5.9 and 1.6 of Chapter 1, and Clause 10.3 of Chapter 10.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Lodged at the pre-application meeting (Stage 0) or with the preliminary drainage report (Stage 1), as Clause 10.3.2 requires.

Table 1F.1 — Form 1-1: Applicability Determination

No.	Item (clause)	Entry
	A. Applicant and site	
A1	Applicant (owner, developer or department)	_____
A2	Site address and survey numbers	_____
A3	Site coordinates (latitude, longitude)	_____
A4	Approving Authority (Clause 1.4)	_____
A5	Tier of the Authority: A / B (Clause 1.6; Annex 1A)	_____
A6	Approval sought: planning permission / building permit / layout approval / public work (DPR)	_____
A7	Type of development: building / layout / sub-division / road / paving / land-use change / other (Clause 1.4)	_____
A8	Stage at which this form is lodged: Stage 0 / Stage 1 (Clause 10.3)	_____
	B. Coverage (Clause 1.5.1)	
B1	Development requiring approval under the Model Rajasthan Building Regulations 2025 — 1.5.1(a): Yes / No	_____
B2	Public work by a ULB, State department, board or State undertaking — 1.5.1(b): Yes / No	_____
B3	Work by a Central agency needing the Authority's approval or no-objection — 1.5.1(c): Yes / No	_____
	C. Areas over the common plan of development (Clauses 1.4, 1.5.5)	
C1	Phases, plots and sub-divisions included (one layout approval or one ownership)	_____
C2	Total site area (ha)	_____
C3	Land disturbance (ha)	_____
C4	Existing impervious area (m²)	_____
C5	New impervious area (m²)	_____
C6	Replaced impervious area, removed to subgrade and rebuilt (m²)	_____
C7	New plus replaced impervious area, C5 + C6 (m²)	_____
C8	Plot area for the RWH mandate (m²) (Clause 1.5.3)	_____
	D. Thresholds and exemptions	
D1	Land disturbance 0.1 ha or more — 1.5.2(a): Yes / No	_____
D2	New or replaced impervious area 500 m² or more — 1.5.2(b): Yes / No	_____
D3	Redevelopment (existing impervious cover on the site) — 1.5.6: Yes / No	_____
D4	Constrained redevelopment route of Clause 4.5.6 proposed: Yes / No	_____

No.	Item (clause)	Entry
D5	Linear public work: added impervious area per drainage catchment crossed given in Table 1F.2 — 1.5.7: Yes / No / not applicable	_____
D6	Exemption claimed — 1.5.8(a) single dwelling below the thresholds / 1.5.8(b) resurfacing with no added impervious area / none	_____
D7	RWH mandate applies (Building Regulations 2025, reg. 8.3: plot of 225 m² and more, except in a waterlogged area marked by the local body; RIICO industrial plots: its own regulations [TBC]) — 1.5.3: Yes / No	_____
	E. Site conditions	
E1	Site in a flood-sensitive catchment (Annex 1B; Clause 4.5.3): No / Yes — name	_____
E2	Source of the catchment boundary used	_____
E3	1% AEP level mapped or determinable for the site (Clause 1.5.4(b)): Yes / No; source	_____
E4	Waterbody on or adjoining the site (Clause 1.5.4(c); Chapter 7): No / Yes — name	_____
E5	Natural drainage path or major-system flow path crossing the site (Clause 1.5.4(d)): No / Yes	_____
E6	Site drains to a tidal outfall (Clause 10.3.2(d)): Yes / No	_____
E7	Variance, waiver, regional facility or fee-in-lieu proposed (Clause 10.3.2(c)): No / Yes — Form 1-2 attached	_____
	F. Determination	
F1	Result: (i) Chapters 4 and 5 apply, with Clause 1.5.4 and the RWH mandate; (ii) Clause 1.5.4 and the RWH mandate only (below thresholds); (iii) exempt under 1.5.8, Clause 1.5.4 and the RWH mandate still apply	_____
F2	Stage 0 mandatory under Clause 10.3.2: Yes (state item (a) to (d)) / No	_____
F3	Storage method: hydrograph method (Chapter 3) / design-aid route S-1 (Clause 1.7, where adopted and eligible)	_____
F4	Other Policy Supplement alternatives relied on (S-2 to S-5), with the adopting resolution	_____
F5	Tier B phased start applies (Clause 1.11.3): Yes / No	_____
	G. Declaration	
G1	I declare that the information above is correct and covers the whole common plan of development. Applicant: name, signature, date	_____
G2	Prepared by (registered professional, Clause 1.4): name, registration number, signature, date	_____
	H. For the Authority (Clause 1.5.9)	
H1	Determination confirmed / corrected	_____
H2	Corrections and reasons	_____
H3	Officer: name, designation, signature, date	_____

Table 1F.2 — Form 1-1: added impervious area by drainage catchment, linear works (Clause 1.5.7)

Drainage catchment crossed	Chainage from – to	Added impervious area (m²)	500 m² or more (Yes / No)	Storage location: right of way / regional facility

Form 1-2 — Variance / Waiver Request

Supports Clause 1.10 of Chapter 1.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Lodged with the preliminary drainage report (Clause 1.10.4(a)), with one form for each requirement concerned.

Table 1F.3 — Form 1-2: Variance / Waiver Request

No.	Item (clause)	Entry
	A. Applicant and site	
A1	Applicant	_____
A2	Site address and coordinates	_____
A3	Form 1-1 reference and date	_____
A4	Tier of the Authority: A / B	_____
A5	Site area (ha)	_____
A6	Site in a flood-sensitive catchment: Yes / No	_____
	B. Request	
B1	Type: variance from a numeric requirement (1.10.1) / waiver of Chapter 4 detention (1.10.2)	_____
B2	Clause of the Manual concerned	_____
B3	Value required by the Manual	_____
B4	Value or arrangement proposed	_____
	C. Matters that cannot be varied or waived (Clause 1.10.3) — confirm that the request does not concern any of them	
C1	(a) a sewage connection to a storm drain	Not concerned: _____
C2	(b) the lowest habitable floor level of Chapter 6	Not concerned: _____
C3	(c) a waterbody setback below the Zone 1 minimum of Clause 7.4.7, or fill or construction in the no-fill zone of Chapter 7	Not concerned: _____
C4	(d) retention in a flood-sensitive catchment, except by fee-in-lieu under Clause 1.7	Not concerned: _____
	D. Variance: grounds (Clause 1.10.1(a))	
D1	Site condition: high groundwater table / contaminated soil / rock / site too small for the required facility / other	_____
D2	Evidence (tests, surveys, plans), with references	_____
D3	Options assessed and why each is impracticable	_____
	E. Variance: equal performance or make-up (Clause 1.10.1(b))	
E1	Downstream point used (Chapter 5)	_____
E2	Performance at that point with full compliance and with the variance (peak flows, water levels)	_____

No.	Item (clause)	Entry
E3	Or: shortfall made up by fee-in-lieu or off-site works in the same catchment — volume (m³), works or fee	_____
	F. Waiver of detention: grounds (Clause 1.10.2)	
F1	Site discharges directly to the sea / to a tidal reach with no flood-prone property downstream	_____
F2	Analysis showing that undetained flow does not worsen the outfall-closed condition of Chapter 5 — reference	_____
F3	Retention still provided in full: Yes	_____
	G. Attachments (Clause 1.10.4(a))	
G1	Report certified under Clause 10.6	_____
G2	Preliminary drainage report	_____
	H. Certification and declaration	
H1	Certified by (registered professional; empanelled professional where Clause 10.6.1 applies): name, registration or empanelment number, signature, date	_____
H2	Applicant: name, signature, date	_____
	I. For the Authority (Clause 1.10.4)	
I1	Referred to the State Stormwater Technical Committee (Tier B, site 1 ha or more): Yes / No; date	_____
I2	Decision: granted / granted with conditions / refused	_____
I3	Reasons and conditions	_____
I4	Entry number in the public register (Clause 10.17)	_____
I5	Note: a variance runs with the approval and lapses if the approval lapses (Clause 1.10.4(d))	—
I6	Officer: name, designation, signature, date	_____

ANNEXES TO CHAPTER 2

Design Rainfall and Design Storms

These annexes support Chapter 2. Annexes 2A to 2E will hold the statewide rainfall tables that Chapter 2 refers to: the benchmark checks and zone map, sub-daily ratios, grid-to-point factors, temporal patterns and retention depths. Each needs analysis of NIH-DHAARA and IMD records that has not yet been done for this Manual, so each is marked "To be prepared" and gives its intended layout and the rule to use until it is published (Clause 1.11.5). Form 2-1 is a draft form for the Design Rainfall Sheet that every hydrologic submittal must include (Clause 2.13). The Manual is a draft; it is not adopted by any government or agency.

Annex 2A — NIH-DHAARA vs IMD station and IMD gridded checks at benchmark points; zone map

Supports Clauses 2.3.1 to 2.3.5 of Chapter 2.

To be prepared. This annex will compare, at benchmark points across the State, the NIH-DHAARA design depths with frequency analyses of long IMD daily station records and of IMD gridded daily data (converted to point values with Annex 2C), for 24 hours and longer and for the AEPs of Table 2.1. It will also contain the map of rainfall zones used by Annexes 2B, 2C and 2E and by the Tier B tables of Chapter 4. It needs NIH-DHAARA values at the benchmark coordinates (NIH), IMD daily and recording-gauge station records and IMD gridded rainfall (IMD), State rain-gauge records (the tehsil and dam-site rain gauges whose readings IMD and the State report, the gauges of WRD, and any network of RSDMA [TBC]), and district and basin boundaries (Survey of India, WRD). Until it is published, design depths are taken from NIH-DHAARA under Clause 2.3.1, the cross-checks of Clause 2.3.3 are reported on Form 2-1, and the zone of a site is the one agreed with the Authority and recorded on Form 2-1.

Table 2A.1 — Benchmark comparison of design depths (layout)

Benchmark point	IMD station ID	Latitude, longitude	Years of record	Duration (h)	AEP	NIH-DHAARA (mm)	IMD station analysis (mm)	IMD gridded, point value (mm)	NIH-DHAARA / IMD station	Remarks
				24						
				48						
				72						

2A.1 The zone names below are the working names used in the Tier B table template of Chapter 4 (Clause 4.14.2). Their boundaries, and whether further zones are needed, are to be set by the analysis of this annex.

Table 2A.2 — Rainfall zones (layout)

Zone (working name)	Extent (districts, basins)	Representative stations	Notes
RJ-Z1 Arid west and north	The west and north of the State, west of the Aravallis, in CWC subzone 1(a) (Luni), except the Abu cell (RJ-I): the Thar, the Luni basin, Shekhawati and the Ghaggar–canal plains (Clause 2.3.6(c)); Jhunjhunu and the Ghaggar strip of Hanumangarh lie on the 1(e) line; catchments that cross a zone line take the higher zone value	Jodhpur 10202 (daily record 1901–2012), Bikaner 42165 (1901–2008), Phalodi 42237 (1901–2012), Barmer 42435 (1931–2012), Jaisalmer 42328 (1949–2012), Sriganganagar 42123 (1951–2012), Sikar 42249 (1946–2012), Churu 42170 (1956–2012), Jalore 42439 (1968–2012)	District annual normals about 170–500 mm (Jaisalmer 172.9, Ganganagar 243.4, Barmer 251.7, Bikaner 258.5, Jodhpur 320.7, Nagaur 391.2, Sikar 459.6, Pali 498.9 mm; IMD, 1951–2000). FER 50-yr 24-h about 120–200 mm, and about 240–280 mm on the Pali–Jalore–Sirohi plains; 1-h ratio 0.36 (10-yr basis). Records far above the plates: Sam (Jaisalmer) 540.0 mm (17 Aug 1973), Sachor (Jalore) 511.8 mm (16 Sep 1893), Desuri (Pali) 381.0 mm (31 Jul 1952), Pachpadra (Barmer) 370.0 mm (12 Aug 1992), Nagaur 310.6 mm (23 Jun 1996), Jodhpur 215.9 mm (12 Sep 1924), Jaisalmer 204.0 mm (16 Aug 1973) (IMD). Parbatsar 780.3 mm (16 Sep 1900) in *Climate of Rajasthan* conflicts with the 306.8 mm of the FER and is not used [TBC]. NIH-DHAARA 50-yr 24-h low here (Bikaner 89, Jaisalmer 94, Barmer 123, Jodhpur 153 mm). No storm-drain outfall over much of the zone; the 72-hour volume check of Clause 2.3.6(i) applies throughout
RJ-Z1 Arid west and north: RJ-A Thar core	Jaisalmer and Barmer (with Balotra west of the Luni), Pokaran, Phalodi and west Bikaner; boundaries [TBC]	Jaisalmer, Barmer, Phalodi	The lowest normals in the State (Jaisalmer 172.9 mm) and the highest relative variability: annual totals of 280–299% of normal (Jaisalmer 1973, Barmer 1990), and 14 excess years each at Barmer and Jaisalmer in 1951–2000 (IMD). Dune and hummocky sands, with calcrete (petrocalcic) pans and saline depressions; water tables deep. About 577 mm in three days in Barmer district on 19–22 August 2006 (as reported). FER 50-yr 24-h about 120–160 mm at Jaisalmer and Pokaran and 180–200 mm at Barmer. Receiving waters: mostly none; the Luni at Balotra (highest flood level 108.755 m, 1979, CWC list, as reported) and the inland depressions
RJ-Z1 Arid west and north: RJ-B Marwar and Luni basin	Jodhpur, Pali, Jalore, south Nagaur, Balotra and the Sirohi plains; boundaries [TBC]	Jodhpur, Jalore, Erinpura (Jawai Bandh) 42441 (1955–2012)	Grey-brown desert soils and sandy loams, with Aravalli rock to the east; a rising water table in the old city of Jodhpur. FER 50-yr 24-h about 200 mm at Jodhpur and about 240–280 mm on the Pali–Sirohi plains, where the worked example of the 1(a) report reads 25.0 cm; CAZRI's 50-year 1-day values are 170 mm at Jodhpur, 190 mm at Pali and 260 mm at Jalore (Singh et al., 1992). About 714 mm fell at Bali (Pali) in six days in July 1990 (Singh et al., 1992). Receiving waters: the Jojari and the Luni; Kailana (full reservoir level 273.7 m) and Takhat Sagar (269.75 m) at Jodhpur (NIH, 2025)
RJ-Z1 Arid west and north: RJ-C Shekhawati and Bikaner	Bikaner (east), Churu, Sikar, Jhunjhunu and north Nagaur; Jhunjhunu lies on the 1(a)/1(e) line; boundaries [TBC]	Bikaner, Sikar, Churu, Pilani 42174 (1958–2012)	Sandy plains and dunes; water tables more than 40 m deep in Jhunjhunu, Sikar, Nagaur and Bikaner (CGWB). FER 50-yr 24-h about 160–200 mm (Bikaner about 180). Records: Taranagar (Churu) 319.0 mm (22 Jul 1978), Khetri (Jhunjhunu) 281.4 mm (13 Jul 1908), Sikar 236.0 mm (13 Jul 1968), Bikaner 165.6 mm (25 Sep 1945) (IMD). Receiving waters: inland drainage, with no major drainage at Bikaner (CGWB, as reported)

Zone (working name)	Extent (districts, basins)	Representative stations	Notes
RJ-Z1 Arid west and north: RJ-D Ghaggar–IGNP canal plains	Sri Ganganagar and Hanumangarh, with Anupgarh and Suratgarh, in the Ghaggar plain and the command of the Indira Gandhi canal; on the 1(a)/1(e) line; boundaries [TBC]	Sriganganagar	Ghaggar alluvium and calcareous soils; canal seepage has raised the water table to within 2 m in pockets, with waterlogging (CGWB). FER 50-yr 24-h about 160 mm. Records: Sriganganagar 251.7 mm (31 Aug 1928) (IMD). Receiving waters: the Ghaggar, in flood in 1976, 1981, 1993, 2004, 2010 and 2023 (as reported), and the canal escapes
RJ-Z2 East and central	The east and centre of the State, east of the Aravallis, in CWC subzone 1(b) (Chambal), with the north-east in subzone 1(e) (Clause 2.3.6(c)); Jaipur and Ajmer lie on the 1(a)/1(b) line; catchments that cross a zone line take the higher zone value	Jaipur (Sanganer) (A) 42348 (1901–2012), Ajmer 42343 (1879–2012), Kota 42451 (1901–2008) and Kota (A) 42452 (1961–2012), Jhalawar 42555 (1930–2012), Tonk 42349 (1959–2012), Alwar 42255 (1956–2000), Bharatpur 42258 (1974–2012), Sawai Madhopur 42453 (1977–2012), Dholpur 42354 (1955–2012)	District annual normals about 450–920 mm (Ajmer 454.9, Jaipur 596.8, Alwar 618.6, Bharatpur 622.4, Kota 758.7, Jhalawar 921.2 mm; IMD, 1951–2000). FER 50-yr 24-h about 180–320 mm (Ajmer 180–200, Jaipur and Alwar about 200, Bharatpur 220–240, Kota and Tonk 240–280, Jhalawar and Sawai Madhopur 280–320); 1-h ratio 0.35 (1(b)) and 0.34 (1(e)). The Jaipur station analysis gives 93 mm in 1 hour at 50 years, about a third above the plates and ratios (Ghate & Timbadiya, 2022); the floors of Clause 2.3.6(h) apply. Records: Bharatpur 630.0 mm (25 Aug 1996), Kanota (Jaipur) 589.2 mm and Dausa 550.0 mm (19 Jul 1981), Bamanwas 505.0 mm (19 Jul 1981), Nainwa (Bundi) 502 mm (23 Aug 2025), Nasirabad 500.0 mm (5 Oct 1989), Ajmer 412.3 mm (10 Jun 2002), Jaipur (Sanganer) 326.0 mm (19 Jul 1981) (IMD). NIH-DHAARA 50-yr 24-h low at Jaipur (151) and Ajmer (127 mm), high at Kota (318) and Tonk (270 mm)
RJ-Z2 East and central: RJ-E Dhundhar–Ajmer central	Jaipur, Ajmer, Tonk, Dausa, Kishangarh, Beawar and the Sambhar–Phulera side; the west of Jaipur and Ajmer districts lies in subzone 1(a); boundaries [TBC]	Jaipur (Sanganer) (A), Ajmer, Tonk	Alluvium and sandy loams over Aravalli schist and quartzite; water tables more than 40 m deep at Jaipur (CGWB). The only station analysis of short storms in the State (Jaipur, Clause 2.3.6(b)). The storm of 18–20 July 1981, 82 cm in three days at Jaipur, is the reference event (Gupta & Jindal, 1987). Receiving waters: the Dravyavati to the Dhund (a 100-year channel); Man Sagar (Jal Mahal), whose full level was not found [TBC]; Ana Sagar at Ajmer (full at 13 ft on its gauge, as reported [TBC]); the Banas at Tonk (highest flood level 262.05 m, 1973, CWC list, as reported); Bisalpur (full reservoir level 315.5 m); and Sambhar, a salt lake with no outfall
RJ-Z2 East and central: RJ-F Mewat–Braj north-east	Alwar, Bhiwadi, Behror, Bharatpur and Deeg, in subzone 1(e); boundaries [TBC]	Alwar, Bharatpur	Alluvium of the Yamuna side; fluoride in groundwater (CGWB). FER 50-yr 24-h about 200 mm at Alwar and 220–240 mm at Bharatpur; 1-h ratio 0.34. Records: Bharatpur 630.0 mm (25 Aug 1996) and 269.4 mm (11 Jul 2003), Mandawar (Alwar) 350.5 mm (3 Oct 1891), Alwar 219.6 mm (10 Sep 1969) (IMD). Receiving waters: the Sahibi, which flows on to Haryana and Delhi, the Ruparel, the Banganga and the Gambhir, with the Ajan bund and Keoladeo at Bharatpur

Zone (working name)	Extent (districts, basins)	Representative stations	Notes
RJ-Z2 East and central: RJ-G Hadoti and the Chambal	Kota, Bundi, Baran, Jhalawar, Sawai Madhopur, Karauli and Dholpur; boundaries [TBC]	Kota and Kota (A), Jhalawar, Sawai Madhopur, Dholpur, Rawatbhata 42552 (1956–2012)	Medium and deep black soils (vertisols), which take in water at about 1–3 mm/h once closed in the Chambal series (as summarised); the CWC loss rate of the Chambal subzone is 1.7 mm/h; water tables within 20 m over much of the south-east (CGWB). FER 50-yr 24-h about 240–320 mm. Records: Hindoli (Bundi) 413.3 mm (22 Aug 1942), Bairam (Baran) 413.2 mm (13 Aug 1967), Nainwa (Bundi) 502 mm (23 Aug 2025), Jhalawar 350.2 mm (17 Aug 1969) and 350.0 mm (5 Oct 1997), Kota (A) 251.7 mm (2 Jul 2001) (IMD; CWC FER 1(b)). Receiving waters: the Chambal at Kota City (danger level 242 m, highest flood level 248.68 m, 2019, CWC) below the Kota Barrage (full reservoir level 260.3 m), whose releases follow those of Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar; the Chambal at Dholpur (danger level 130.79 m, highest flood level 145.54 m, 23 Aug 1996, CWC); the Parwan, the Kalisindh, the Parbati and the Chandralohi
RJ-Z3 South and the Abu hills	The south of the State: Mewar and Vagad in CWC subzones 1(b) and 3(a), and the Abu hills in the closed 1(a) cell around Mount Abu (Clause 2.3.6(c)); Udaipur lies on the 1(b)/3(a) line; catchments that cross a zone line take the higher zone value	Udaipur City 42543 (1898–2012) and Udaipur (Dabok) (A) 42542 (1965–2010), Mount Abu 42540 (1901–2012), Banswara 42655 (1964–2012), Chittorgarh 42546 (1973–2012), Dungarpur 42652 (1970–2012), Bhilwara 42447 (1962–2011)	District annual normals about 550–880 mm (Rajsamand 556.5, Bhilwara 592.8, Udaipur 697.2, Dungarpur 699.6, Chittorgarh 793.9, Banswara 882.2 mm), and 1,677.0 mm at Mount Abu (IMD, 1951–2000). FER 50-yr 24-h about 200–320 mm, and 440–480 mm and more in the Abu cell; 1-h ratio 0.35 (1(b)), 0.36 (3(a) and 1(a)). Records: Mount Abu 653.0 mm (8 Sep 1992; 700.0 mm in *Climate of Rajasthan* [TBC]), Pindwara 635.0 mm (1 Sep 1973), Banswara 558.8 mm (23 Jul 1959) and 371.2 mm (26 Aug 1987), Sahara (Bhilwara) 440.0 mm (8 Jul 1984), Udaipur City 292.0 mm (30 Jun 1983) (IMD). Chittor 802.9 mm (14 Jul 1982) in *Climate of Rajasthan* conflicts with the Chittorgarh station record of 227.0 mm and is not used [TBC]. NIH-DHAARA 50-yr 24-h low at Udaipur (175 mm) and Mount Abu (407 mm), close at Banswara (249 mm)
RJ-Z3 South and the Abu hills: RJ-H Mewar and Vagad	Udaipur, Rajsamand, Chittorgarh, Bhilwara, Pratapgarh, Banswara and Dungarpur; the south of Udaipur district, south Pratapgarh, Banswara and Dungarpur lie in subzone 3(a); boundaries [TBC]	Udaipur City and Udaipur (Dabok) (A), Chittorgarh, Banswara, Dungarpur, Bhilwara	Red loams, mixed red-and-black soils and thin soils over Aravalli rock; hard-rock aquifers. FER 50-yr 24-h about 200–220 mm at Udaipur, about 280 mm at Chittorgarh and 280–320 mm at Banswara and Dungarpur. Receiving waters: the Udaipur lake chain, Pichola (full at 11 ft), Fateh Sagar (13 ft, one report 14 ft) and Udai Sagar (24 ft), on gauges whose zero has not been found (as reported [TBC]), spilling to the Ayad and on to the Berach and the Banas; the Gambhiri at Chittorgarh; the Mahi Bajaj Sagar (full reservoir level 281.5 m, as reported)
RJ-Z3 South and the Abu hills: RJ-I Mount Abu and the Sirohi hills	Mount Abu, Abu Road, Pindwara and Sirohi; inside subzone 1(a), but in its closed high cell; boundaries [TBC]	Mount Abu, Erinpura (Jawai Bandh)	Granite and rhyolite hills with thin soils; the steepest rainfall gradient in the State, from a normal of 1,677.0 mm at Mount Abu to about 560 mm on the Sirohi plains (IMD). FER 50-yr 24-h 440–480 mm and more in the closed cell, and more than 560 mm at 100 years; the 1(a) report's own annex gives Mount Abu 560.0 mm on 1 Sep 1973. Receiving waters: the West Banas at Abu Road (highest flood level 265.4 m, 31 Aug 1973, CWC list, as reported) and Nakki lake

Annex 2B — Sub-daily ratios P(t)/P(24h) by zone: NIH-DHAARA (hourly-based) vs the one-third rule

Supports Clauses 2.6.1 to 2.6.4 of Chapter 2.

To be prepared. This annex will tabulate, for each zone of Annex 2A, the ratios of the t-hour to the 24-hour design depth from NIH-DHAARA, which are derived from hourly records, against the ratios implied by IMD Das et al. (2022) and by the one-third rule. It needs NIH-DHAARA depths for each duration at representative points in each zone (NIH), IMD recording-gauge data and the IDF values of Das et al. (2022) (IMD). Until it is published, sub-daily depths are read directly from NIH-DHAARA or an approved station IDF (Clause 2.6.1). Where only daily depths are available, the ratios used are those agreed with the Authority, which in Rajasthan are those of Clause 2.3.6: the CWC Flood Estimation Report ratios for the site's subzone in Table 2B.1, raised at 1 and 3 hours in RJ-Z2 and RJ-Z3 to the floors of Clause 2.3.6(h) for the 10-yr and rarer storms, and, in RJ-E, with the 1-hour depth of Clause 2.3.6(b) for Jaipur (Clause 2.6.2), and are recorded on Form 2-1. The one-third rule is not used (Clause 2.6.4).

2B.1 The first row of Table 2B.1 gives the ratios of the one-third rule P(t) = P(24)·(t/24)^(1/3), for comparison only. The 1, 3, 6 and 12 h values are those stated in the commentary to Clause 2.6; the 2 h value is computed from the same formula. The rule shall not be used for design unless this annex confirms it for the zone concerned (Clause 2.6.4).

Table 2B.1 — Ratios P(t)/P(24h) by zone (layout)

Zone	Source	1 h	2 h	3 h	6 h	12 h	24 h
All (reference only, not for design)	One-third rule	0.35	0.44	0.50	0.63	0.79	1.00
RJ-Z1 (RJ-A to RJ-D), and RJ-I in the 1(a) Abu cell	CWC FER 1(a), 10-yr basis (interim design ratios, Clause 2.3.6(g))	0.36		0.58	0.72	0.85	1.00
RJ-Z2 (RJ-E, RJ-G) and the 1(b) part of RJ-Z3 (RJ-H north)	CWC FER 1(b), 50-yr (interim design ratios, Clause 2.3.6(g))	0.35		0.53	0.67	0.80	1.00
RJ-Z2 (RJ-F)	CWC FER 1(e), 50-yr (interim design ratios, Clause 2.3.6(g))	0.340	0.475	0.560	0.680	0.840	1.00
RJ-Z3 (RJ-H south: Banswara, Dungarpur, south Udaipur and south Pratapgarh)	CWC FER 3(a), 50-yr (interim design ratios, Clause 2.3.6(g))	0.36		0.57	0.70	0.85	1.00
RJ-Z2 and RJ-Z3	Ratio floor of Clause 2.3.6(h)(i), 10–100 yr	0.37		0.56			1.00
RJ-Z2 (RJ-E): Jaipur	Ghate & Timbadiya (2022), the authors' suggested 25-yr design values, 70 mm in 1 h and 190 mm in 24 h (comparison only)	0.37					1.00
RJ-Z2 (RJ-E): Jaipur	Station 1-h depth of Clause 2.3.6(b) at 50 yr (93 mm), as a ratio to the 1(b) plate value of about 200 mm (comparison only)	0.47					1.00
RJ-Z2 (RJ-E): Jaipur	NIH-DHAARA, 50-yr, Jaipur cell (comparison only; 3- and 6-hour values not queried)	0.31	0.45			0.81	1.00
RJ-Z2 (RJ-G): Kota	NIH-DHAARA, 50-yr, Kota cell (comparison only; 3- and 6-hour values not queried)	0.21	0.36			0.79	1.00
RJ-Z1 (RJ-B): Jodhpur	NIH-DHAARA, 50-yr, Jodhpur cell (comparison only; 3- and 6-hour values not queried)	0.29	0.44			0.81	1.00

Zone	Source	1 h	2 h	3 h	6 h	12 h	24 h
RJ-Z3 (RJ-H): Udaipur	NIH-DHAARA, 50-yr, Udaipur cell (comparison only; 3- and 6-hour values not queried)	0.28	0.42			0.84	1.00
RJ-Z3 (RJ-I): Mount Abu	NIH-DHAARA, 50-yr, Mount Abu cell (comparison only; 3- and 6-hour values not queried)	0.16	0.26			0.77	1.00

2B.2 Depths from fixed observation windows are converted to true-interval depths with the factors of Clause 2.6.3, repeated in Table 2B.2. They are the standard WMO (Hershfield) values and are not provisional.

Table 2B.2 — Fixed-interval adjustment factors (Clause 2.6.3)

Number of fixed observation intervals in the duration	Factor
1	1.13
2	1.04
3–4	1.02

Annex 2C — Grid-to-point factors

Supports Clauses 2.7.1 and 2.7.4 of Chapter 2.

To be prepared. This annex will give the factors that convert grid-average design depths (for example from 0.25° cells) to point depths, by zone, duration and AEP. It needs paired frequency analyses of IMD gridded rainfall and of the IMD and State gauges inside each cell (IMD, WRD and the tehsil rain gauges whose readings the State reports [TBC]), the benchmark points of Annex 2A, and a stated method for deriving the factors. Until it is published, design depths are taken as point values from NIH-DHAARA or an approved station IDF (Clauses 2.3.1 and 2.3.2). Grid-average values are not used as design depths unless a conversion agreed with the Authority is recorded on Form 2-1 (Clause 1.11.5).

2C.1 The commentary to Clause 2.7 shows why the factors matter, and in Rajasthan the reanalysis cells err mostly low. At Jaipur the IMDAA cell of NIH-DHAARA (about 12 km) gives a 50-year 24-hour depth of about 151 mm and a 100-year depth of about 170 mm, while the CWC plate gives about 200 mm, the station analysis of Ghate & Timbadiya (2022) 194.6–249.9 mm at 50 years, and the Sanganer gauge recorded 326.0 mm on 19 July 1981; at Ajmer the cell's 50-year value, about 127 mm, is below a third of the station's record of 412.3 mm (10 June 2002); at Bikaner about 89 mm, against a plate value of about 180 mm; and at Jaisalmer about 94 mm, against a station record of 204.0 mm and the 540.0 mm recorded at Sam in the same storm of August 1973. At Kota the cell's value, about 318 mm, is above the plate value of about 240–280 mm and the Kota (A) record of 251.7 mm (2 July 2001). The cells' 50-year 1-hour depths, about 33–68 mm, are 0.16–0.45 of their 24-hour depths, and at Jaipur 46.3 mm, half the 93 mm of the station analysis (NIH-DHAARA, queried 6–7 Nov 2026; IMD; CWC). Values of this kind are grid-average values and need these factors before any use as point depths; under Clause 2.3.6 they are not used as design depths in Rajasthan until this annex and Annex 2A are published.

Table 2C.1 — Grid-to-point factors (layout)

Zone	Grid product and cell size	Duration (h)	AEP	Factor (point / grid)	Stations used	Years of record
		24				

Zone	Grid product and cell size	Duration (h)	AEP	Factor (point / grid)	Stations used	Years of record
		48				
		72				

Annex 2D — Rajasthan temporal patterns (Huff curves)

Supports Clauses 2.9.3 and 2.9.4 of Chapter 2, and Clause 11.7.3 of Chapter 11.

To be prepared. This annex will give dimensionless time-distribution (mass) curves of Rajasthan storms, in the form introduced by Huff (1967), by zone, storm-duration class and quartile, at stated probability levels. It needs storm hyetographs from recording gauges and automatic weather stations (IMD, its automatic weather stations and automatic rain gauges in the State, under the Meteorological Centre Jaipur, and any recording gauges of WRD and of the city command centres [TBC]), separated into independent storms by a stated rule, and the Jaipur storm of 18–20 July 1981, the storm of 16–17 August 1973 at Jaisalmer and Sam, the Mount Abu storm of 8 September 1992, the Ajmer storm of 10 June 2002, the Barmer storm of 19–22 August 2006, the Jodhpur storm of 18–19 July 2022, the Jaipur storm of 31 July–1 August 2024 and the Nainwa (Bundi) storm of 23 August 2025 among them. Until it is published, design storms use the alternating-block pattern of Clause 2.9.1 and the 48- and 72-hour pattern of Clause 2.9.2; for catchments of 25–5,000 km², the CWC Flood Estimation Report curves may be used with a sensitivity run under Clause 2.9.1 (Clause 2.9.4). SCS Type distributions are not used (Clause 2.9.3). For the disaggregation of daily records in continuous simulation (Clause 11.7.3), the method is agreed with the Authority and recorded (Clause 1.11.5).

Table 2D.1 — Cumulative fraction of storm depth against cumulative fraction of storm time (layout, one table per zone, duration class and quartile)

Fraction of storm time	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
10% probability curve	0										1.0
50% probability curve	0										1.0
90% probability curve	0										1.0

2D.1 Each table shall state the zone, the duration class, the quartile (the quarter of the storm in which most rain fell), the number of storms analysed and the period of record.

Reference: Huff, F.A. (1967). Time distribution of rainfall in heavy storms. *Water Resources Research* 3(4), 1007–1019.

Annex 2E — Retention percentile depths by zone

Supports Clauses 2.8.3 and 2.10.1 to 2.10.2 of Chapter 2, Clause 4.4 of Chapter 4 and Chapter 8.

To be prepared. This annex will give, for each zone of Annex 2A, the retention design depth P_R: the 24-hour rainfall depth not exceeded on 90% of days with rain (≥ 2.5 mm) in the long-term record (Clause 2.10.1). It needs long daily records at stations in each zone (IMD, WRD and the tehsil rain gauges whose readings the State reports [TBC]) and IMD gridded data with the factors of Annex 2C where stations are sparse. Until it is published, P_R is computed by the definition of Clause 2.10.1 from the long-term daily record of a station agreed with the Authority, by the steps in 2E.1, and recorded on Form 2-1 (Clause 1.11.5).

2E.1 **Computing P_R from a daily record.**

1. Take the daily (24-hour) rainfall series of the station for its full record.
2. Keep only the days with rain of 2.5 mm or more (wet days).
3. Rank the wet-day depths and take the depth not exceeded on 90% of them (the 90th percentile).
4. Do not apply the climate factor (Clause 2.8.3) or the fixed-interval factor; P_R is a statistic of everyday rainfall, not an AEP design depth.
5. Record the station, the period of record, the number of wet days and P_R on Form 2-1.

Table 2E.1 — Retention depth P_R by zone (layout)

Zone	Stations or grid cells used	Period of record	Number of wet days (≥ 2.5 mm)	P_R, 90th percentile (mm)	Issued on
RJ-Z1 Arid west and north					
RJ-Z2 East and central					
RJ-Z3 South and the Abu hills					

Form 2-1 — Design Rainfall Sheet

Supports Clauses 2.3 to 2.13 of Chapter 2, and Clause 10.4.1(d) of Chapter 10.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. One sheet for each hydrologic submittal. The steps follow Figure 2.3 of Chapter 2.

Table 2F.1 — Form 2-1: site, source and storms

No.	Item (clause)	Entry
	A. Site (Clause 2.13, item 1)	
A1	Project and site	_____
A2	Site coordinates (latitude, longitude, decimal degrees)	_____
A3	Rainfall zone (Annex 2A, or as agreed with the Authority)	_____
A4	Contributing catchment area (km²) (Clause 2.7)	_____
A5	Design life: more than 25 years / temporary works, 5 years or less (Clause 2.8.2)	_____
A6	Outfall under tidal or river backwater influence: Yes / No (Clauses 2.5.3, 2.12)	_____
	B. Source (Clauses 2.3, 2.3.5; item 2)	
B1	NIH-DHAARA: version or access date	_____
B2	Coordinates queried	_____
B3	Screenshot or export of the values extracted attached: reference	_____
B4	Station IDF used (Clause 2.3.2): No / Yes — station, ID, distance from site (km)	_____
B5	Station IDF: years of recording-gauge data (30 or more); published or approved by	_____
B6	Station IDF: change of terrain or coastal exposure between gauge and site: None / describe	_____
	C. AEPs and durations (Clauses 2.4, 2.5)	
C1	Elements designed and their AEPs (Table 2.1)	_____
C2	Conveyance: Tc and design duration (not less than 10 min) (Clause 2.5.1)	_____
C3	Storage: durations checked from {1, 2, 3, 6, 12, 24, 48, 72 h}; 24, 48 and 72 h included (Clause 2.5.2)	_____
C4	Critical duration found for each storage element	_____
	D. Conversions	
D1	Sub-daily depths: read directly / from Annex 2B ratios / from ratios agreed with the Authority (Clauses 2.6.1, 2.6.2)	_____
D2	Fixed-interval factor applied: none (true-interval source) / 1.13 / 1.04 / 1.02 (Clause 2.6.3)	_____
D3	Grid-to-point factor: not needed (point source) / Annex 2C / agreed value (Clause 2.7.1)	_____
D4	ARF: 1.0 (10 km² or less; single-site storage) / CWC curve / interpolated (Clauses 2.7.2–2.7.4)	_____
D5	Climate factor: 1.20 (≤ 6 h) and 1.10 (> 6–72 h) / 1.0 temporary works / projected depths under Clause 2.8.4	_____
	E. Cross-checks (Clause 2.3.3; item 4)	
E1	IMD Das et al. (2022) values for 1–24 h: reported in Table 2F.2	_____

No.	Item (clause)	Entry
E2	CWC subzone 1(a) / 1(b) / 1(e) / 3(a) 24-hour point value, catchments of 25–5,000 km²: subzone used	_____
E3	CWC floor governs for any AEP: No / Yes — AEPs	_____
	F. Retention depth (Clause 2.10)	
F1	P_R (mm) and source: Annex 2E zone value / computed under Annex 2E, 2E.1 — station and period	_____
F2	No climate factor applied to P_R (Clause 2.8.3): confirmed	_____
	G. Design storms (Clauses 2.9, 2.11, 2.12; items 5 and 6)	
G1	Storms up to 24 h: alternating block, peak at 50%; time step (≤ Tc/3 and ≤ 15 min)	_____
G2	48 and 72 h storms: built under Clause 2.9.2 (Table 2F.3)	_____
G3	Other pattern used: none / Annex 2D / CWC FER with sensitivity run (Clauses 2.9.3, 2.9.4)	_____
G4	Hyetographs attached as a table and a plot for each design storm: reference	_____
G5	AMC: III for every design storm of 15 August–15 September in RJ-G and RJ-H and on black soil anywhere, whatever its duration; at any other time and place, III for a storm that follows or contains a 5-day total of more than 53 mm; II otherwise (Clause 2.11.4)	_____
G6	Pre-development condition: greenfield, open land in good condition for the mapped HSG (Clause 2.11.5)	_____
G7	Release criterion: standard, Q_post ≤ 0.9 × Q_pre (Clause 2.11.2) / flood-sensitive, mixed-frequency rule (Clause 2.11.3)	_____
G8	Tailwater joint cases run (Clause 2.12): case (a) MHWS + sea-level allowance; case (b) 10% AEP 48 h storm with 1% AEP still-water level + sea-level allowance; governing case	_____
	H. Prepared by	
H1	I confirm that the values above are those extracted and used in the submittal. Name, registration number, signature, date	_____

Design depth = source depth × fixed-interval factor × grid-to-point factor × ARF × climate factor. Where the design depth is lower than the CWC floor for the same AEP, the floor is adopted (Clause 2.3.3).

Table 2F.2 — Form 2-1: depth table (Clause 2.13, item 3)

AEP (T-yr)	Duration	Source depth (mm)	Fixed-interval factor	Grid-to-point factor	ARF	Climate factor	Design depth (mm)	IMD Das et al. (2022) (mm)	CWC floor (mm)	Adopted depth (mm)

Table 2F.3 — Form 2-1: 48- and 72-hour storm construction (Clause 2.9.2)

AEP (T-yr)	Duration (h)	Total design depth (mm)	24 h design depth, final 24 h (mm)	Remainder (mm)	Hours before the final 24 h	Uniform intensity before the final 24 h (mm/h)
	48				24	
	72				48	

ANNEXES TO CHAPTER 3

Hydrologic Methods

These annexes support Chapter 3. Annex 3C sets out benchmark test problems for software acceptance, and Forms 3-1 and 3-2 are the submittal forms required by Clause 3.17. Annexes 3A, 3B, 3D and 3E need survey, gauging or published report data that this draft does not yet contain; each gives the intended layout and the interim rule of Chapter 3 that applies until it is published. The forms are draft forms and have no statutory status.

Annex 3A — Rajasthan soil series to HSG lookup; seasonal high water table map

Supports Clauses 3.7 and 3.10 of Chapter 3.

To be prepared. This annex will contain (a) a lookup from each soil series mapped in Rajasthan to its hydrologic soil group (HSG), in both the drained and the undrained state, and (b) a map of the depth to the seasonal high groundwater table in the south-west monsoon (June–September). It needs NBSS&LUP and Central Arid Zone Research Institute (CAZRI, for the arid zone) or the Rajasthan Department of Agriculture (soil survey) [TBC] series maps with their scales, measured saturated hydraulic conductivity and depth to an impermeable layer for each series, and observation-well records from the Central Ground Water Board and the Ground Water Department, supplemented by piezometers in the Ghaggar–canal plains of Sri Ganganagar and Hanumangarh, the old city of Jodhpur, the floodplains of the Chambal, the Banas, the Luni and the Ghaggar, the black-soil plains of Hadoti, and the foreshores of the lakes and talabs of Udaipur, Ajmer and Jaipur. Until it is published, use the interim rules of Chapter 3: assign HSG from measured saturated hydraulic conductivity and depth to an impermeable layer or water table by the criteria of NEH Part 630, Ch. 7 (Clause 3.7.2); verify it by site infiltration tests wherever retention relies on infiltration (Clause 3.7.3); take the seasonal high water table from site piezometers, trial pits or the nearest observation well (Clause 3.10.2); and assign HSG D wherever that level is within 0.6 m of the ground surface (Clause 3.10.1).

Table 3A.1 — Soil series to HSG lookup (layout)

Soil series	District(s)	Taxonomic class	Surface texture	Saturated hydraulic conductivity (mm/h)	Depth to impermeable layer (m)	HSG, drained	HSG, undrained	Source map and scale

Table 3A.2 — Seasonal high water table, by mapping unit (layout)

Mapping unit or grid cell	Observation wells used	Years of June–September record	Highest June–September level below ground (m)	Within 0.6 m of ground (Clause 3.10.1)?	Data source

Mapping unit or grid cell	Observation wells used	Years of June–September record	Highest June–September level below ground (m)	Within 0.6 m of ground (Clause 3.10.1)?	Data source

Annex 3B — Rajasthan CN calibration and supplementary land covers (dune and hummocky sand, calcrete pans and saline depressions, cracked black-soil fallow, talab, johad, nadi and khadin beds, Aravalli rock and thin soils, desert scrub and grassland)

Supports Clauses 3.8 and 3.15 of Chapter 3.

To be prepared. This annex will contain (a) curve numbers calibrated against observed rainfall and runoff in Rajasthan catchments, compared with the TR-55 values of Table 3.5, and (b) curve numbers for land covers that Table 3.5 does not list: the dune and hummocky sands of the Thar, shifting or stabilised, bare or under sparse grass; the calcrete (kankar) and petrocalcic pans and the saline and gypsum depressions of the arid zone, which shed water from a few centimetres of soil; the black-soil fallow of Hadoti while it is still dry and cracked early in the monsoon; the beds of talabs, johads, nadis and khadins and the foreshores of lakes such as the Pichola, Fateh Sagar and Ana Sagar that are dry or cultivated at the start of a storm; the bare or nearly bare rock and thin soils of the Aravalli hills, from Mount Abu and Udaipur to Ajmer, Jaipur and Alwar; and the desert scrub and grassland of the west and the dry forest of the Aravallis. It needs paired rainfall–runoff records for small gauged catchments of known cover and soil, from WRD gauging sites, agricultural research stations and tank gauges, analysed by event and by antecedent moisture. Until it is published: the pre-development reference stays open space in good condition for every site (Clause 3.3.2), so these covers do not enter the pre-development run; for off-site existing conditions, use the nearest Table 3.5 or TR-55 cover row, including the cultivated rows (Clause 3.8.3(c)), and state the row chosen and the reason on Form 3-1; land under standing water at the start of the design storm is modelled as water surface with no losses (Table 3.5; Clause 3.10.4(b)). Any departure from these defaults requires calibration under Clause 3.15 (Clause 3.15.1(d)).

Table 3B.1 — Supplementary land covers, AMC II (layout)

Cover type	HSG A	HSG B	HSG C	HSG D	Ia ratio	Basis (catchments, events, years)
Dune and hummocky sand of the Thar, shifting or stabilised, bare or under sparse grass						
Calcrete (kankar) or petrocalcic pan, gypsum layer or saline depression of the arid zone						
Black-soil fallow of Hadoti, dry and cracked at the start of the storm (before 15 August)						
Talab, johad, nadi or khadin bed, or lake foreshore, dry or cultivated at the start of the storm						
Bare or nearly bare Aravalli rock and thin soils						
Desert scrub and grassland of the west, and dry forest of the Aravallis						
Other (state)						

Table 3B.2 — CN calibration catchments (layout)

Catchment	District	Area (km²)	Dominant HSG and cover	Events used	Table 3.5 CN	Calibrated CN	Calibrated ÷ Table 3.5

Annex 3C — Benchmark test problems for software acceptance

Supports Clauses 3.5, 3.6, 3.8, 3.9, 3.11, 3.12 and 3.16 of Chapter 3.

Purpose. Software not listed in Clause 3.16.1 shall reproduce the results of the five problems below (Clause 3.16.3). Each problem is fully specified and uses only the methods and tables of Chapter 3, so every answer can be checked by hand. The acceptance tolerance is ±5% on each tabulated result, the equivalence threshold of Clause 3.16.2; for closed-form results (Problems 3C-1 to 3C-4), software should agree to the rounding shown. The submittal shall report the software result next to each answer below.

Illustrative — not design values. The inputs (areas, intensities, rainfall depths, slopes and the basin) are chosen for testing only. They are not design data for any site.

Problem 3C-1 — Rational Method peak (Clause 3.5)

Inputs. A 2.0 ha catchment draining to one inlet: 1.2 ha concrete paving and roofs, C = 0.90 (Table 3.2, upper half of 0.80–0.95); 0.8 ha lawns on sandy soil, average slope, C = 0.15 (Table 3.2, upper half of 0.10–0.15). Design AEP 1% (100-yr). Rainfall intensity at Tc, including the climate factor: i = 120 mm/h.

Part (b): a separate 0.5 ha fully paved catchment, C = 0.90, design AEP 1%, i = 150 mm/h.

Table 3C.1 — Problem 3C-1 solution

Step	Calculation	Result
Composite C (Clause 3.5.4)	(1.2 × 0.90 + 0.8 × 0.15) / 2.0	0.60
Frequency factor (Table 3.3)	1% AEP	Cf = 1.25
C · Cf (≤ 1.0)	0.60 × 1.25	0.75
Peak flow (Clause 3.5.1)	0.75 × 120 × 2.0 / 360	**Q = 0.500 m³/s**
Part (b): C · Cf	0.90 × 1.25 = 1.125, capped at 1.0 (Clause 3.5.3)	1.00
Part (b): peak flow	1.00 × 150 × 0.5 / 360	**Q = 0.208 m³/s**

Problem 3C-2 — Time of concentration by the segment method (Clause 3.6)

Inputs. Pre-development flow path: sheet flow over greenfield, n = 0.15 (Clause 3.6.3), L = 30 m, S = 0.01; P2 (50% AEP 24-hour rainfall, no climate factor) = 80 mm. Shallow concentrated flow, unpaved, L = 200 m, S = 0.01. Channel flow, L = 400 m, bank-full velocity V = 1.0 m/s (given).

Table 3C.2 — Problem 3C-2 solution

Segment	Calculation	Travel time
Sheet flow (Clause 3.6.2(a))	0.091 × (0.15 × 30)^0.8 / (80^0.5 × 0.01^0.4) = 0.2138 h	12.83 min
Shallow concentrated (Clause 3.6.2(c))	V = 4.918 × 0.01^0.5 = 0.4918 m/s; 200 / (3,600 × 0.4918) = 0.1130 h	6.78 min
Channel (Clause 3.6.2(d))	400 / (3,600 × 1.0) = 0.1111 h	6.67 min
Tc (Clause 3.6.1; ≥ 10 min)	12.83 + 6.78 + 6.67	**26.27 min**
Lag (Clause 3.6.5)	0.6 × 26.27	15.76 min

Problem 3C-3 — SCS-CN runoff depth, AMC and Ia sensitivity (Clause 3.8)

Inputs. Pre-development reference on HSG C: CN = 74 at AMC II (Table 3.5), all pervious. Cumulative rainfall P = 100 mm; second case P = 25 mm.

Table 3C.3 — Problem 3C-3 solution

Case	S (mm)	Ia (mm)	Runoff Q (mm), P = 100 mm	Runoff Q (mm), P = 25 mm
(a) AMC II, Ia = 0.2S: S = 25,400 / 74 − 254	89.24	17.85	**39.38**	**0.53**
(b) AMC III, Ia = 0.2S: CN(III) = 23 × 74 / (10 + 0.13 × 74) = 86.75	38.80	7.76	**64.93**	—
(c) AMC II, Ia = 0.05S: S0.05 = 25.4 × 1.33 × (89.24 / 25.4)^1.15	143.31	7.17	**36.49**	**1.97**

Runoff is $Q = (P - Ia)^2 / (P - Ia + S)$. Case (c) gives less runoff than case (a) at 100 mm but more at 25 mm, as Clause 3.8.5 and Figure 3.3 describe.

Problem 3C-4 — Separate vs composite impervious representation, and SCS unit hydrograph peak (Clauses 3.9 and 3.11.2)

Inputs, part (a). A site that is 50% directly connected impervious (CN 98) and 50% open space on HSG B (CNp = 61), AMC II, Ia = 0.2S, P = 25 mm.

Inputs, part (b). A sub-area of A = 2.5 km² with Tc = 1.0 h and computation interval Δt = 0.1 h.

Table 3C.4 — Problem 3C-4 solution

Step	Calculation	Result
(a) Impervious half (Clause 3.9.2)	S = 5.18 mm, Ia = 1.04 mm; Q = 23.96² / (23.96 + 5.18)	19.70 mm
(a) Pervious half	S = 162.39 mm, Ia = 32.48 mm > P	0 mm
(a) Area-weighted runoff, separate sub-areas	0.5 × 19.70 + 0.5 × 0	**9.85 mm**
(a) Composite CN (Clause 3.9.4)	61 + 0.50 × (98 − 61)	79.5
(a) Runoff with composite CN	S = 65.50 mm, Ia = 13.10 mm; Q = 11.90² / (11.90 + 65.50)	**1.83 mm**
(b) Interval check (Clause 3.11.3(a))	0.133 × 1.0 = 0.133 h ≥ Δt = 0.1 h	satisfied
(b) Lag and time to peak (Clause 3.11.2)	tL = 0.6 × 1.0 = 0.60 h; tp = 0.1 / 2 + 0.60	tp = 0.65 h
(b) Unit hydrograph peak, Q = 1 mm	0.208 × 2.5 × 1 / 0.65	**qp = 0.800 m³/s per mm**

Part (a) reproduces the comparison in the commentary to Clause 3.9 (about 9.9 mm vs 1.8 mm).

Problem 3C-5 — Level-pool (modified Puls) storage routing (Clause 3.12.1)

Inputs. A detention basin with vertical sides and plan area 500 m², with the stage–storage–discharge relationship of Table 3C.5. Triangular inflow hydrograph: 0 at t = 0, rising linearly to 0.50 m³/s at t = 30 min, falling linearly to 0 at t = 90 min. Basin empty at t = 0. Routing interval Δt = 10 min (600 s). No tailwater.

Table 3C.5 — Problem 3C-5 stage–storage–discharge relationship

Stage (m)	Storage S (m³)	Outflow O (m³/s)
0.0	0	0.00
0.5	250	0.05
1.0	500	0.10
1.5	750	0.15
2.0	1,000	0.20
2.5	1,250	0.25

Method. The storage-indication equation is (I1 + I2) + (2S1/Δt − O1) = (2S2/Δt + O2). The table gives O = S / 5,000 (S in m³, O in m³/s), so 2S/Δt + O = 17.667 O and 2S/Δt − O = 15.667 O, and each step is O2 = [(I1 + I2) + 15.667 O1] / 17.667. Software interpolating linearly in Table 3C.5 shall give the same result.

Table 3C.6 — Problem 3C-5 routed outflow

Time (min)	Inflow I (m³/s)	Outflow O (m³/s)	Storage (m³)	Stage (m)
0	0.0000	0.0000	0.0	0.000
10	0.1667	0.0094	47.2	0.094
20	0.3333	0.0367	183.3	0.367
30	0.5000	0.0797	398.4	0.797
40	0.4167	0.1226	612.8	1.226
50	0.3333	0.1511	755.7	1.511
60	0.2500	0.1670	835.2	1.670
70	0.1667	**0.1717**	**858.6**	**1.717**
80	0.0833	0.1664	832.1	1.664
90	0.0000	0.1523	761.5	1.523
120	0.0000	0.1062	531.1	1.062
180	0.0000	0.0517	258.3	0.517

Results. Peak outflow 0.172 m³/s at 70 min; peak storage 859 m³; peak stage 1.72 m. The inflow peak of 0.50 m³/s is reduced to 34% of its value.

Table 3C.7 — Benchmark results to be reported by the applicant

Problem	Result	Benchmark	Software result	Difference (%)	Within ±5%?
3C-1	Q, main case (m³/s)	0.500			
3C-1	Q, part (b) (m³/s)	0.208			
3C-2	Tc (min)	26.27			
3C-3	Q, case (a), P = 100 mm (mm)	39.38			
3C-3	Q, case (b), P = 100 mm (mm)	64.93			
3C-3	Q, case (c), P = 100 mm (mm)	36.49			
3C-3	Q, case (c), P = 25 mm (mm)	1.97			
3C-4	Runoff, separate sub-areas (mm)	9.85			
3C-4	Runoff, composite CN (mm)	1.83			
3C-4	qp (m³/s per mm)	0.800			
3C-5	Peak outflow (m³/s)	0.172			
3C-5	Peak storage (m³)	859			

Annex 3D — Peak rate factor study for flat coastal land

Supports Clauses 3.11.5 and 3.15 of Chapter 3.

> **Not required in Rajasthan.** Rajasthan is landlocked and has no flat coastal plain, so no land in the State meets Clause 3.11.5(a), and the standard factor 484 (PRF' = 0.208) applies to all land (Clause 3.11.5). The interdunal plains of the Thar, the canal command of Sri Ganganagar and Hanumangarh and the Sambhar basin are flat in places but are not coastal plain, and much of that land has no defined outfall; its slow response is represented by storage and backwater (Clauses 3.10.4 and 3.12.4) and by the volume rule of Clause 4.12.7, not by a lower peak rate factor. The annex and the layout of Table 3D.1 are kept only so that the annex numbering is unchanged.

Table 3D.1 — Calibrated peak rate factors (layout)

Catchment	Area (km²)	Mean slope (m/m)	Drainage condition	Events used	Calibrated PRF (US customary)	PRF' (SI)	Range of applicability

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Annex 3E — CWC SUH parameters for subzones 1(a), 1(b), 1(e) and 3(a), with worked example

Supports Clauses 3.4.3 and 3.11.4 of Chapter 3.

To be prepared. This annex will tabulate, for CWC subzones 1(a) (Luni), 1(b) (Chambal), 1(e) (Upper Indo-Ganga Plains) and 3(a) (Mahi and Sabarmati), the regression relationships for the synthetic unit hydrograph parameters, the design storm duration, loss rate, base flow, areal reduction and time distribution, each with its reference to the Flood Estimation Report, and a worked example for one catchment. It needs the four CWC Flood Estimation Reports that cover Rajasthan: the Luni subzone 1(a) (L/20/1992; the cover reads L-20/1993), of whose 205,624 km² some 202,422 km² lie in Rajasthan, about 59% of the State, covering the Thar, the Luni basin and Shekhawati, including Jodhpur, Bikaner, Jaisalmer, Barmer, Balotra, Pali, Jalore, Sirohi and Mount Abu, Nagaur, Churu, Sikar and Sri Ganganagar and the west of Ajmer and Jaipur districts; the Chambal subzone 1(b) (C/16/1988), which covers Jaipur, Ajmer (east) and Nasirabad, Tonk, Bhilwara, Chittorgarh, Rajsamand, the north of Udaipur, Kota, Bundi, Baran, Jhalawar, Sawai Madhopur, Karauli and Dholpur; the Upper Indo-Ganga Plains subzone 1(e), approved at the 40th meeting of the Planning and Co-ordination Committee on 23–24 July 1984, whose design-office report number is not on the scanned copy read for this Manual [TBC], and which covers the eastern border of the State, including Alwar, Bhiwadi, Bharatpur and Deeg; and the Mahi and Sabarmati subzone 3(a) (MS/13/1986, printed "M5/13/1986"), which covers Banswara, Dungarpur and the south of Udaipur and Pratapgarh (see the References of Chapter 3); with the time-distribution and areal reduction tables of subzone 1(a), which are garbled in the copy read, the names and areas of the seven bridge catchments on which the 1(a) unit hydrograph rests, the printing conflicts listed in the note to Table 3E.1, and the subzone boundaries within Rajasthan, including those at Jaipur and Ajmer (1(a)/1(b)), Udaipur (1(b)/3(a)) and Jhunjhunu, Sri Ganganagar and Hanumangarh (1(a)/1(e)), still to be confirmed on the reports' page images and index maps [TBC], transcribed and checked against the published reports, and a catchment with physiographic parameters measured from survey or a DEM. Until it is published, take all SUH inputs directly from the applicable Flood Estimation Report (Clause 3.11.4(a)), apply the 24-hour design rainfall of Clauses 2.3.3(b) and 2.7.3 with the climate factor of Clause 2.8 (Clause 3.11.4(b)), report the SUH result alongside the HEC-HMS or SWMM result for the existing natural condition (Clause 3.11.4(c)), and, where the hydrograph model gives a lower 1% AEP peak, either justify it by calibration under Clause 3.15 or adopt the SUH peak (Clause 3.11.4(d)).

Table 3E.1 — SUH relationships by subzone (layout)

Parameter	Symbol	Unit	Subzone 1(a) relationship	Subzone 1(b) relationship	Subzone 1(e) relationship	Subzone 3(a) relationship
Time from centre of unit rainfall to peak	tp	h	tp = 0.257 A^0.409 S^0.432, as printed, with A in km² (the positive exponent on S lengthens the lag on steeper catchments; see the note) [TBC]	tp = 0.339 (L/√S)^0.826	tp = 1.858 qp^−1.038	tp = 0.433 (L/√S)^0.704
Peak discharge per unit area	qp	m³/s per km²	qp = 2.165 tp^−0.893	qp = 1.251 tp^−0.610 (relationship table; the step-by-step text prints 1.215 [TBC])	qp = 2.030 (L/√S)^−0.649	qp = 1.161 / tp^0.635
Width of UH at 50% of peak	W50	h	W50 = 2.654 qp^−0.921	W50 = 2.215 qp^−1.034	W50 = 2.217 qp^−0.990	W50 = 2.284 / qp^1.00
Width of UH at 75% of peak	W75	h	W75 = 1.672 qp^−0.816	W75 = 1.191 qp^−1.057	W75 = 1.477 qp^−0.876	W75 = 1.331 / qp^0.991
Width of rising limb at 50% of peak	WR50	h	WR50 = 1.245 qp^−0.571	WR50 = 0.834 qp^−1.077	WR50 = 0.812 qp^−0.907	WR50 = 0.827 / qp^1.023

Parameter	Symbol	Unit	Subzone 1(a) relationship	Subzone 1(b) relationship	Subzone 1(e) relationship	Subzone 3(a) relationship
Width of rising limb at 75% of peak	WR75	h	WR75 = 0.816 qp^−0.559	WR75 = 0.502 qp^−1.065	WR75 = 0.606 qp^−0.791	WR75 = 0.561 / qp^1.037
Base width of UH	TB	h	TB = 6.299 tp^0.612	TB = 6.662 tp^0.613	TB = 7.744 tp^0.779	TB = 8.375 tp^0.512
Unit duration	tr	h	1	1	2	1
Design storm duration	TD	h	Trial durations from 1.1 tp to TB; the one giving the highest peak is adopted (the report finds it "not possible to recommend adoption of design storm duration due to scanty data")	TD = 1.1 tp, or TD = 0.539 (L/√S)^0.724, rounded to the nearest hour (p. 40)	TD = 1.1 tp, limited to 24 h	TD = TB = 5.452 (L/√S)^0.360, rounded to the nearest whole hour
Design loss rate	—	mm/h	5 (printed "0.5 cm/hr"; modal value 0.41 cm/h of 48 events)	1.7 (printed "0.17 cm/hr"; modal value)	3.0	4.5 (printed "0.45 cm/hr", modal value of 148 events); or, for average conditions, I = 0.56 R^0.66 / TD^0.59, with I in cm/h, TD in h and R the storm rainfall in cm as defined in the report [TBC]
Design base flow	—	m³/s per km²	0.05	qb = 0.207 A^−0.290, read by optical character recognition only [TBC]	0.05	qb = 0.109 / A^0.126, A in km²
Ratio of t-hour to 24-hour rainfall	—	—	10-yr, adopted for all return periods: 1 h 0.36; 3 h 0.58; 6 h 0.72; 9 h 0.79; 12 h 0.85; 15 h 0.89; 18 h 0.94; 24 h 1.00	50-yr: 1 h 0.35; 3 h 0.53; 6 h 0.67; 9 h 0.74; 12 h 0.80; 15 h 0.85; 18 h 0.90; 24 h 1.00 (independent of return period from 5 years)	50-yr: 1 h 0.340; 2 h 0.475; 3 h 0.560; 4 h 0.607; 5 h 0.647; 6 h 0.680; 9 h 0.770; 12 h 0.840; 15 h 0.890; 18 h 0.930; 24 h 1.000	50-yr: 1 h 0.36; 3 h 0.57; 6 h 0.70; 9 h 0.78; 12 h 0.85; 15 h 0.89; 18 h 0.93; 24 h 1.00
Time distribution of 24-hour rainfall	—	cumulative fraction	Fig. 12 and Annex 4.1 of the report (average of 18 station curves for storms of 2–3, 4–6, 7–12, 13–18 and 19–24 hours); garbled in the copy read and not transcribed [TBC]	Fig. 12 of the report; not transcribed [TBC]	Average curves of Fig. 12; not transcribed [TBC]	[TBC]
Conversion of 1-day to 24-hour rainfall	—	factor	1.15	1.15	1.15	1.15

Parameter	Symbol	Unit	Subzone 1(a) relationship	Subzone 1(b) relationship	Subzone 1(e) relationship	Subzone 3(a) relationship
Areal reduction factor	ARF	—	Annex 4.2 and Fig. 11(a) of the report; the worked example interpolates 0.664 for 414 km² and TD = 5 h; the annex is garbled in the copy read [TBC]	ARF table of the report (p. 60), read by optical character recognition only: for 200 km², 66, 75, 81, 87 and 91%, and for 300 km², 60, 69, 76, 84 and 89%, with the durations of the columns not identified; to be read from the page image before use [TBC]	Table 6 of the report [TBC]	Table-6 of the report: 1 h, from 100% down to 60%; 3 h, to 68%; 6 h, to 74%, with increasing area, for areas up to 1,100 km² extrapolated to 2,500 km² [TBC]
50-yr 24-hour point rainfall at Rajasthan towns	—	mm	Plate 9: Jodhpur about 200; Barmer about 180–200; Bikaner about 180; Sikar about 160–200; Sri Ganganagar and Nagaur about 160; Jaisalmer about 120–160 and Pokaran about 120; the Pali–Sirohi plains about 280; Mount Abu in a closed cell of about 440–480	Plate 9: Jaipur about 200; Ajmer about 180–200; Udaipur about 200–220; Dholpur about 200; Kota, Tonk and Bhilwara about 240–280; Chittorgarh about 280; Jhalawar and Sawai Madhopur about 280–320	Plate 9: Alwar about 200; Bharatpur about 220–240	Plate 10: Udaipur City about 200 (on the subzone boundary); Banswara, Dungarpur and Deolia (Pratapgarh) about 280–320
Catchment area for which the relationships apply	A	km²	Derived from seven gauged bridge catchments of 18–682 km² on the Aravalli fringe; not to be used outside that range or on dune or flat interdunal terrain (see the note)	25–2,500; up to 5,000 "based on sound judgement"	25–2,500, for "reasonably free catchments"; a "suitable increase" for steep foothill catchments	25–1,500; up to 5,000 with judgement
Report reference	—	—	Table on p. 15, §3.5 and §3.6; worked example pp. 18–20; Annex 4.3	Relationship table (p. 20), pp. 21–23, design storm (p. 40), §5.3, Table 7	§3.9 (p. 42), §3.11 and §3.12 (p. 57), text table (p. 61)	Table-4 (p. 29), §3.11 and §4.1

Note: relationships as printed in the four CWC reports that cover Rajasthan (References of Chapter 3), read from scanned copies and checked against the page images except where marked as read by optical character recognition only; L is the length of the main stream in km, Lc the length to the point nearest the catchment centroid in km, S the equivalent slope in m/km and A the catchment area in km². The 50-yr point rainfalls were read by eye from the isopluvial plates and are good to about one contour. **Subzone 1(a) is the weakest of the four, and it covers about 59% of the State.** Its unit hydrograph rests on seven gauged bridge catchments of 18 to 682 km², with one to nine years of record each, all on the Aravalli fringe in Pali, Sirohi, Jalore and the Ajmer–Marwar railway sections; none of them lies in dune terrain, and the report's rain-gauge network "is very sparse, particularly over the north-western parts of the subzone". Its time-to-peak relationship carries a positive exponent on the slope, so that a steeper catchment is given a longer lag, which is physically odd, and the report does not recommend a design storm duration. Its worked example is the Mithri, a tributary of the Luni, at the Kherwa–Bhumadra road section (A = 414.00 km², L = 52.80 km, Lc = 28.00 km, S = 3.178 m/km): the relationship gives tp = 4.98 h, which the report adopts as "say 4.5 hrs" without explanation, with qp = 0.565 m³/s per km², TB = 15.92 h ("say 16 hrs") and a unit-graph peak of 233.91 m³/s; with a 50-yr 24-hour point rainfall of 25.00 cm, a 5-hour ratio of 0.680, an ARF of 0.664, a loss of 0.50 cm/h and a base flow of 20.70 m³/s it builds a design storm of TD = 5 h, and its figure prints a design flood peak of 1,950.16 m³/s, read by optical character

recognition only [TBC]. This Manual therefore requires that the 1(a) relationships be used only for catchments of 18 to 682 km² with a defined channel on the Aravalli fringe, such as the Luni tributaries of Pali, Sirohi and Jalore and the nalas that enter Jodhpur from the hills; they **shall not be used** for dune or hummocky-sand terrain, for flat interdunal or canal-command land without a defined channel, or for the inland basins of the Thar, Shekhawati and Bikaner, where no FER method has been calibrated. There, Clause 3.11.4 has no FER benchmark: the catchment is modelled by the methods of Clause 3.4, its design rainfall is that of Chapter 2, and where it has no defined outfall its storage is set by the volume rule of Clause 4.12.7. In subzone 1(b) the relationship table gives qp = 1.251 tp^−0.610, but the step-by-step procedure in the text prints 1.215 (p. 21); the two differ by about 3% in qp, and this Manual uses the table. Subzone 1(e) uses a 2-hour unit graph, unlike the other three. The 3(a) report number is printed "M5/13/1986", probably a misprint for MS/13/1986. The design loss rates, 5 mm/h in 1(a), 4.5 in 3(a), 3.0 in 1(e) and 1.7 in 1(b), are φ-indices fitted to the floods of whole rural catchments, not soil infiltration capacities; the 1(a) value is a modal value from gravel and sand catchments on the Aravalli fringe, not from dunes, and the 1(b) value describes the black soils of Hadoti and the rest of the Chambal basin near saturation. They are not used to assign HSG (Clause 3.7) or to size infiltration practices (Chapter 4), and each rate shall be used only within its own subzone. The reports were derived from gauged rural catchments at railway and road bridges, none of them urban. In Rajasthan they apply to the rural nalas and streams that enter city limits, such as the Dravyavati and its feeders from the Nahargarh hills above Jaipur, the nalas that reach Jodhpur from the hills (within the 1(a) limits above), the Ayad and the feeders of the Udaipur lakes, the Chandralohi near Kota and the feeders of Ana Sagar at Ajmer; they are not a model of city catchments. Where a city catchment lies within 25–5,000 km², the SUH is computed only as the benchmark of its natural condition (Clause 3.11.4), and the catchment itself is designed by the methods of Clause 3.4 with the design rainfall of Chapter 2. The Chambal at Kota and Dholpur, the Banas, whose basin within the subzone is 48,577 km², and the Luni at Balotra, with a basin of 36,527 km², are far larger than the catchments of any report and are outside Clause 3.11.4 (Clause 3.4.5). Subzone boundaries, to be confirmed on the index maps of the reports [TBC]: Jaipur city lies on the 1(a)/1(b) boundary and drains south by the Dravyavati to the Dhund and on to the Banas, so its catchments are in 1(b), while the Sambhar, Phulera and Dudu side, which drains inland, is in 1(a); Ajmer straddles the Aravalli watershed, with Ana Sagar and the east draining to the Banas (1(b)) and Pushkar and the west to the Luni (1(a)); Udaipur lies on the 1(b)/3(a) boundary, its lake chain draining by the Ayad to the Berach and the Banas (1(b)) and its southern suburbs to the Som and the Mahi or to the Sabarmati (3(a)); Mount Abu and the Sirohi hills lie in 1(a) but carry its steepest rainfall gradient; Jhunjhunu, Sri Ganganagar and Hanumangarh lie at the 1(a)/1(e) boundary, and 1(a) values are used there only with a check against 1(e); Alwar and Bharatpur are in 1(e), and Dholpur and Karauli in 1(b). The subzone is chosen by the catchment's outfall, not by its district. Where a catchment drains across the boundary between two subzones, or its outfall lies within 5 km of one, as at Jaipur, Ajmer and Udaipur, this Manual requires the SUH to be computed with the parameters of each subzone and the higher 1% AEP peak to be adopted, unless calibration under Clause 3.15 supports the other. The plates are old and are exceeded at many stations: the heaviest 24-hour falls on record include 326.0 mm at Jaipur (Sanganer) on 19 July 1981, against a 100-yr plate value of about 240 mm, 412.3 mm at Ajmer on 10 June 2002, against about 220 mm, and 204.0 mm at Jaisalmer on 16 August 1973, against about 140–180 mm (IMD), and many of the records were set after the reports were published. The short storms are also stronger than the ratios suggest in the east: the 50-yr 1-hour depth fitted to 44 years of hourly IMD data at Jaipur, 93 mm (Ghate and Timbadiya, 2022), is about a third above the 50-yr 1-hour depth that the 1(b) plate and ratio give, about 70 mm, so Chapter 2 uses a checked station record of 25 years or more where one exists, and the plates and the ratios with the floors of Clause 2.3.6 elsewhere.

Table 3E.2 — Worked example outline (layout)

Step	Content	Clause
1	Catchment area, main stream length, length to centroid and equivalent slope, from survey or DEM	3.11.4(a)
2	SUH parameters from Table 3E.1 and the plotted unit hydrograph	3.11.4(a)
3	Design storm duration, point and areal 24-hour rainfall with climate factor, time distribution	3.11.4(a), (b)
4	Effective rainfall after the design loss rate; convolution with the SUH; base flow added	3.11.4(a)
5	1% AEP peak compared with the HEC-HMS or SWMM peak for the existing natural condition	3.11.4(c), (d)

Form 3-1 — Hydrologic Calculation Summary

Supports Clauses 3.4, 3.6, 3.7, 3.8, 3.10–3.13, 3.15–3.17 of Chapter 3.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. One form per submittal. Attach the documents listed in Section H.

A. Project

Table 3F.1 — Form 3-1: project

Field	Entry
A1. Project name and applicant	
A2. Location (village or ward, survey numbers, district)	
A3. Site area (ha) and number of points of comparison (POCs)	
A4. Catchment class: standard (Clause 2.11.2) or flood-sensitive (Clause 2.11.3)	
A5. Design Rainfall Sheet reference (Form 2-1)	

B. Method and software (Clauses 3.4, 3.11, 3.12, 3.16)

Table 3F.2 — Form 3-1: method and software

Field	Entry
B1. Purpose of each calculation (conveyance, storage, comparison, catchment study)	
B2. Contributing area for each purpose (ha or km²)	
B3. Method used and the row of Table 3.1 that permits it	
B4. Reason for the choice of method	
B5. Software and version; engine and version for packages built on SWMM or HEC (Clause 3.16.1, 3.16.2)	
B6. For other software: benchmark results of Annex 3C attached (Table 3C.7) and the 5% comparison of Clause 3.16.2	
B7. Runoff transform (Clause 3.11.1)	
B8. Computation interval Δt (h), with 0.133 Tc of the smallest sub-area and the hyetograph time step (Clause 3.11.3(a))	
B9. Storage routing and channel routing methods (Clauses 3.12.1, 3.12.2)	
B10. Dynamic-wave routing required? If yes, which condition of Clause 3.12.4	
B11. CWC SUH benchmark required (25–5,000 km², Clause 3.11.4)? Result reference	
B12. Continuous simulation required (Clause 3.13.1)? Record used and starting tank levels (Clause 3.13.5)	
B13. Calibration required (Clause 3.15.1)? Calibration report reference	

C. Soils and groundwater (Clauses 3.3.3(b), 3.7, 3.10)

Table 3F.3 — Form 3-1: soils and groundwater

Field	Entry
C1. HSG source map, scale and lookup used (Clause 3.7.1, Annex 3A) or NEH Part 630, Ch. 7 assignment (Clause 3.7.2)	
C2. Infiltration tests: number, locations, depths, results (Clause 3.7.3)	
C3. Seasonal high water table: depth below ground and source (Clause 3.10.2)	
C4. Areas within 0.6 m assigned HSG D (Clause 3.10.1)	
C5. Disturbed pervious areas and HSG downgrade applied (Clause 3.3.3(b))	

D. Parameters by sub-area and condition (Clauses 3.3, 3.5, 3.8, 3.9; Clause 3.17 item 4)

Table 3F.4 — Form 3-1: parameters by sub-area and condition

Sub-area	Condition (pre / post)	Area (ha)	Impervious: roofs / paved / roads (ha)	DCIA (ha)	Disconnected (ha)	HSG	CN, AMC II	CN, AMC III (pervious part)	C and Cf (if Rational)	Tc (min)

E. Time of concentration worksheet (Clause 3.6)

One worksheet per sub-area and condition.

Table 3F.5 — Form 3-1: time of concentration worksheet

Segment	Flow type	Surface and n (Table 3.4)	L (m)	S (m/m)	P2 (mm)	V (m/s)	Tt (min)
1	Sheet					—	
2	Shallow concentrated				—		
3	Channel or pipe				—		
	Tc (not less than 10 min)						

E1. Is the post-development Tc shorter than the pre-development Tc? If not, explain (Clause 3.6.6): _____

F. Rainfall and losses (Clauses 3.8.4, 3.8.5, 3.11.5, 3.12, 3.3.5)

Table 3F.6 — Form 3-1: rainfall, losses and starting levels

Field	Entry
F1. AEPs and durations run; climate factor applied (Chapter 2)	
F2. AMC used for each duration (Clause 3.8.4)	
F3. Ia ratio for design runs; Ia = 0.05S sensitivity run made (Clause 3.8.5)	
F4. Peak rate factor used; if lower than 484, the Annex 3D value and the land it applies to (Clause 3.11.5)	
F5. Starting water level of each tank or waterbody, and its basis (Clauses 3.12.5, 3.13.5)	

Field	Entry
F6. Off-site run-on: land use assumed for conveyance and for the comparison (Clause 3.3.5)	
F7. Incidental storage counted? If yes, the authority's acceptance (Clause 3.12.3)	

G. Departures

Table 3F.7 — Form 3-1: departures from Chapter 3

No.	Clause departed from	Value used in place of the Chapter 3 value	Justification
1			
2			

H. Attachments (Clause 3.17)

Table 3F.8 — Form 3-1: attachments

Item	Attached (yes / no / not applicable)	Reference
H1. Catchment maps, pre- and post-development, with sub-areas, Tc flow paths, POCs and off-site run-on		
H2. HSG map, water-table data and infiltration test results		
H3. Parameter tables (Section D) and Tc worksheets (Section E)		
H4. Design Rainfall Sheet (Form 2-1) and hyetographs		
H5. Hydrograph tables and plots; stage–storage and stage–discharge tables; routed outflows; peak water levels		
H6. Form 3-2 for each POC		
H7. Calibration report (Clause 3.15)		
H8. Native model input and output files (Clause 3.16.4)		

I. Statement by the responsible engineer (Clause 3.17 item 10)

I state that the methods and parameters of Chapter 3 of the Rajasthan Stormwater Design Manual (Draft v1.0) have been used in this submittal, and that every departure is listed and justified in Section G.

Table 3F.9 — Form 3-1: statement by the responsible engineer

Field	Entry
Name	
Qualification and registration number	
Organisation	
Signature	
Date	

Form 3-2 — Pre- vs Post-Development Comparison

Supports Clauses 3.8.5, 3.11.5 and 3.14 of Chapter 3.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. One form for each point of comparison (POC). Flows in m^3/s, volumes in m^3.

A. Point of comparison (Clause 3.14.2)

Table 3F.10 — Form 3-2: point of comparison

Field	Entry
A1. POC identifier and location	
A2. Area draining to the POC: site (ha) and off-site run-on (ha)	
A3. Off-site run-on passes through site storage? (Clause 3.14.2(c))	
A4. Catchment class: standard (Clause 2.11.2) or flood-sensitive (Clause 2.11.3)	
A5. Tailwater applied, including joint cases of Clause 2.12 (Clause 3.14.9(c))	
A6. Flood-sensitive only: largest 10% AEP pre-development peak over all durations, the cap of Clause 2.11.3 (Clause 3.14.7)	
A7. Flood-sensitive only: 50% AEP pre-development peak at the pre-development critical duration (Clause 2.11.3)	

B. Peak flows (Clauses 3.14.7–3.14.10)

Limit: standard catchments 0.9 × Q_pre for the same AEP and duration (Clause 3.14.10(a)); flood-sensitive catchments the caps A6 (for 1% AEP) and A7 (for 50% AEP) (Clause 3.14.10(b)).

Table 3F.11 — Form 3-2: peak flows by AEP and duration

AEP	Duration (h)	AMC	Q_pre	Q_post, uncontrolled	Q_post, routed	Limit	Met?
50% (2-yr)	1	II					
50% (2-yr)	2	II					
50% (2-yr)	3	II					
50% (2-yr)	6	II					
50% (2-yr)	12	III					
50% (2-yr)	24	III					
50% (2-yr)	48	III					
50% (2-yr)	72	III					
10% (10-yr)	1	II					
10% (10-yr)	2	II					
10% (10-yr)	3	II					
10% (10-yr)	6	II					

AEP	Duration (h)	AMC	Q_pre	Q_post, uncontrolled	Q_post, routed	Limit	Met?
10% (10-yr)	12	III					
10% (10-yr)	24	III					
10% (10-yr)	48	III					
10% (10-yr)	72	III					
1% (100-yr)	1	II					
1% (100-yr)	2	II					
1% (100-yr)	3	II					
1% (100-yr)	6	II					
1% (100-yr)	12	III					
1% (100-yr)	24	III					
1% (100-yr)	48	III					
1% (100-yr)	72	III					

C. Volumes and storage (Clauses 3.14.8–3.14.10)

Table 3F.12 — Form 3-2: volumes and storage

AEP	Governing duration (h)	Runoff volume, pre	Runoff volume, post uncontrolled	Retention volume	Detention storage required	Peak water level in storage (m)
50% (2-yr)						
10% (10-yr)						
1% (100-yr)						

C1. Governing duration for storage, and the 24, 48 and 72 h results (Clause 3.14.10): _____

D. Sensitivity runs (Clauses 3.8.5, 3.14.11)

Table 3F.13 — Form 3-2: sensitivity runs

Run	Governing storm (AEP, duration)	Change in Q_post, routed (%)	Change in required storage (%)	Retention volume or WQv governing (Clause 3.8.5(c))
Ia = 0.05S				
Standard peak rate factor (only where a lower factor is used)				—

E. Associated checks (Clause 3.14.12)

Table 3F.14 — Form 3-2: associated checks

Check	Result	Reference in submittal
Drawdown times (Chapter 4)		
Minimum orifice and trash screen (Chapter 4)		
Emergency spillway (Chapter 4)		
Outfall-closed storage check (Chapter 5)		
Downstream analysis (Chapter 5)		

F. Statement by the responsible engineer

I state that this comparison has been made by the procedure of Clause 3.14, with the same design storms in the pre- and post-development runs, and that no runoff has been diverted from one natural catchment to another to meet the criterion (Clause 3.14.2(b)).

Table 3F.15 — Form 3-2: statement by the responsible engineer

Field	Entry
Name	
Qualification and registration number	
Signature	
Date	

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0.

ANNEXES TO CHAPTER 4

Site Runoff Control: Retention and Detention

These annexes support Chapter 4. Annex 4C is a complete Tier A worked example with routing tables, built on the illustrative example of Clause 4.6.7. Annex 4B sets out the structure of the Tier B tables, the provisional fixed release coefficients and a standard orifice table computed from the Chapter 4 orifice equation; the values that need NIH-DHAARA depths are still to be derived. Annex 4A needs GIS and groundwater data that this draft does not yet contain; it gives the intended layout and the interim rules of Chapter 4. Forms 4-1 to 4-3 are the submittal forms required by Clause 4.17. They are draft forms and have no statutory status.

Annex 4A — Flood-sensitive catchment boundaries (GIS); shallow-groundwater zone map

Supports Clauses 4.5.3, 4.5.4 and 4.12 of Chapter 4.

4A.1 **Flood-sensitive catchment boundaries.** The catchments are those listed in Clause 4.5.3.2, with any catchment notified under Clause 4.5.4. Their maps and GIS layer are the same data set as Annex 1B, which lists the catchments and gives the attribute layout of the layer. The two annexes shall be issued together.

4A.2 **Shallow-groundwater zone map.** This map shows the areas where Clause 4.12 applies: the Ghaggar–canal plains of Sri Ganganagar and Hanumangarh, the old city of Jodhpur, the floodplains of the Chambal, the Banas, the Luni and the Ghaggar, and the foreshores of the lakes and talabs of Udaipur, Ajmer, Jaipur and the other cities, and any area where the groundwater table lies within 3 m of the surface at any time of year (Clause 4.12.1).

To be prepared. This annex will contain (a) the boundaries of the flood-sensitive catchments as a GIS layer and as maps at a scale fit for deciding whether a plot lies inside them, and (b) a map of the shallow-groundwater zone of Clause 4.12.1, with the seasonal high groundwater depth during and after the SW monsoon. It needs basin and sub-basin boundaries from a digital elevation model and the drainage network (WRD, NRSC, Survey of India), the full levels of the lakes, talabs and reservoirs, with the lake boundaries, protected areas and flow areas to be notified under the Rajasthan Lakes (Protection and Development) Authority Act 2015 (none found), the no-construction zone of the Udaipur lakes of 1997, the high flood lines and ecological buffers of the river systems to be demarcated under the Supreme Court's order of 7 August 2026 and the 100 m line from the edge of the Jojari (as reported), the land recorded as gair mumkin nala, nadi or talab in the revenue records, the Ramgarh dam catchment, the dams, gates and canals of WRD and the Indira Gandhi Canal command, and the boundaries of the four Ramsar sites and of any wetland notified under the Wetlands (Conservation and Management) Rules 2017, town boundaries (UDH, the development authorities and Urban Improvement Trusts, the Directorate of Local Bodies, and the Municipal Corporations, Municipal Councils and Municipal Boards), flood maps held by RSDMA, observation-well records of the CGWB and the Ground Water Department, and the extent of the dune and hummocky sands, the calcrete pans and the saline depressions of the arid zone, the black soils (vertisols) of Hadoti, the Aravalli rock and thin soils, and the alluvium of the eastern plains and the Ghaggar from soil survey maps (NBSS&LUP, the Central Arid Zone Research Institute (CAZRI, for the arid zone) or the Rajasthan Department of Agriculture (soil survey) [TBC]). Until it is published: (a) the catchments named in Clause 4.5.3.2 apply, and whether a site lies in one is decided and recorded as set out in Annex 1B; and (b) every site to which Clause 4.12.1 may apply establishes its design groundwater level from site piezometer readings over one June–November season or, failing that, from the nearest CGWB or State observation well plus 0.5 m and the design flood level of any adjacent river, nala or talab, or the full tank level of an adjacent lake (Clause 4.12.1(b)). For the flotation check in the Ghaggar–canal plains of Sri Ganganagar and Hanumangarh and the old city of Jodhpur without piezometer readings, the design groundwater level is existing ground level (Clause 4.12.1).

Table 4A.1 — Attributes of the shallow-groundwater zone layer (layout)

Field	Content	Unit or format
zone_id	Unique identifier	text
zone_class	Ghaggar–canal plain (Sri Ganganagar, Hanumangarh); old city of Jodhpur; river floodplain (Chambal, Banas, Luni, Ghaggar or other); lake or talab foreshore (Udaipur, Ajmer, Jaipur or other); other area with groundwater within 3 m of the surface (Clause 4.12.1)	text
shgw_depth_m	Seasonal high groundwater depth below ground, SW monsoon season	m
shgw_basis	Wells or piezometers used, and period of record	text
tidal_influence	Whether the groundwater level follows an adjacent tidal water body (Clause 4.12.1(b))	yes / no
source	Source agency and date of the data	text
geometry	Zone boundary	polygon

Annex 4B — Tier B tables: PSD and SSR (Table 4.3), retention credit factor C_R, standard outlet sizes; confirmed fixed release coefficients (Table 4.3A)

Supports Clauses 4.4.6.3, 4.14.1, 4.14.2 and 4.14.4 to 4.14.6 of Chapter 4.

4B.1 This annex will hold four tables. Their status in this draft is:

Table 4B.1 — Contents of Annex 4B and their status

Table	Content	Clause	Status in this draft
4B.2	Tier B permissible site discharge (PSD) and site storage requirement (SSR), the values of Table 4.3	4.14.2	To be prepared
4B.3	Retention credit factor C_R	4.4.6.3	To be prepared; C_R = 0 until published
4B.4	Standard outlet sizes	4.14.2 step 4, 4.14.6	Computed in this annex from the orifice equation of Clause 4.6.5.2
4B.5	Fixed release coefficients C_10 and C_2 (Table 4.3A)	4.14.4	Provisional values of Table 4.3A; confirmed values to be prepared

4B.2 PSD and SSR (Table 4.3)

To be prepared. This table will give, for each rainfall zone, hydrologic soil group and post-development imperviousness, the PSD for the 2-yr and 100-yr stages and the SSR, for standard and flood-sensitive catchments, in the layout of Table 4.3. It needs NIH-DHAARA design depths with the climate factor for each zone (Chapter 2, Annex 2A), the sub-daily ratios of Annex 2B, and routing of a set of standard sites by the full method of Clause 4.6 for every AEP and duration of Table 4.1. Each PSD shall be the governing release cap and each SSR the governing storage per hectare, with a margin so that the simplified method is never cheaper than routing. Until it is published, Tier B sites use Clause 4.6, or the fixed-coefficient route of Clause 4.14.3 where the site is 1 ha or less (Clauses 4.14.1 and 4.14.3).

Table 4B.2 — Tier B PSD and SSR (layout of Table 4.3)

Zone (Annex 2A)	HSG	Imperviousness	PSD 2-yr (L/s/ha)	PSD 100-yr (L/s/ha), standard	PSD 100-yr (L/s/ha), flood-sensitive	SSR (m³/ha), standard	SSR (m³/ha), flood-sensitive
RJ-Z1 Arid west and north: RJ-A Thar core	A / C / D	50% / 70% / 90%	—	—	—	—	—
RJ-Z1 Arid west and north: RJ-B Marwar and Luni basin	A / B / D	50% / 70% / 90%	—	—	—	—	—
RJ-Z1 Arid west and north: RJ-C Shekhawati and Bikaner	A / B / C	50% / 70% / 90%	—	—	—	—	—
RJ-Z1 Arid west and north: RJ-D Ghaggar–IGNP canal plains	B / C / D	50% / 70% / 90%	—	—	—	—	—
RJ-Z2 East and central: RJ-E Dhundhar–Ajmer central	B / C / D	50% / 70% / 90%	—	—	—	—	—
RJ-Z2 East and central: RJ-F Mewat–Braj north-east	B / C	50% / 70% / 90%	—	—	—	—	—
RJ-Z2 East and central: RJ-G Hadoti and the Chambal	C / D	50% / 70% / 90%	—	—	—	—	—

Zone (Annex 2A)	HSG	Imperviousness	PSD 2-yr (L/s/ha)	PSD 100-yr (L/s/ha), standard	PSD 100-yr (L/s/ha), flood-sensitive	SSR (m³/ha), standard	SSR (m³/ha), flood-sensitive
RJ-Z3 South and the Abu hills: RJ-H Mewar and Vagad	C / D	50% / 70% / 90%	—	—	—	—	—
RJ-Z3 South and the Abu hills: RJ-I Mount Abu and the Sirohi hills	C / D	50% / 70% / 90%	—	—	—	—	—

4B.3 Retention credit factor C_R

To be prepared. This table will give C_R for each rainfall zone, hydrologic soil group and design infiltration or drawdown rate of the retention practice (Clauses 4.4.3 and 4.4.6.3). It needs routing of the full duration set of Clause 2.5.2 with NIH-DHAARA depths, with the retention practice modelled as in Clause 4.4.6.2, and the credit expressed as the reduction in governing storage per cubic metre of retention provided. Until it is published, **C_R = 0** (Clause 4.4.6.3).

Table 4B.3 — Retention credit factor C_R (layout)

Zone (Annex 2A)	HSG	Design infiltration or drawdown rate (mm/h)	C_R (–)

4B.4 Standard outlet sizes

4B.4.1 Table 4B.4 gives the largest circular orifice, in 5 mm steps, whose discharge does not exceed a stated permissible discharge at a stated head. It is computed from the orifice equation with the discharge coefficient of Clause 4.6.5.2:

> $Q = 0.60 \times (\pi d^2 / 4) \times \sqrt{(2 g H)}$

where Q is the discharge (m³/s), d the orifice diameter (m), g = 9.81 m/s² and H the head from the water level to the centre of the orifice (m). Sizes are rounded **down**, so that the orifice never passes more than the permissible discharge. Where the computed size is below 50 mm, the 50 mm minimum of Clause 4.8.2 is shown; it is deemed to comply under Clause 4.5.5.1.

4B.4.2 The table assumes free discharge. Where the tailwater can rise above the orifice (Clause 4.6.6), H is the difference between the upstream and downstream water levels and the orifice shall be checked by routing. The State Stormwater Technical Committee may replace this table when it issues Annex 4B.

Table 4B.4 — Largest orifice diameter (mm) for a permissible discharge at a given head (Cd = 0.60, free discharge)

Permissible discharge (L/s)	H = 0.5 m	H = 1.0 m	H = 1.5 m	H = 2.0 m
5	55	50	50	50

Permissible discharge (L/s)	H = 0.5 m	H = 1.0 m	H = 1.5 m	H = 2.0 m
10	80	65	60	55
15	100	80	75	70
20	115	95	85	80
30	140	115	105	100
50	180	150	135	130
75	225	185	170	155
100	260	215	195	180
150	315	265	240	225
200	365	305	275	260
300	450	375	340	315

Check: for 50 L/s at H = 1.0 m, the area is 0.050 / (0.60 × √(2 × 9.81 × 1.0)) = 0.0188 m², so d = √(4 × 0.0188 / π) = 0.155 m, rounded down to 150 mm.

4B.5 Fixed release coefficients (Table 4.3A)

4B.5.1 Table 4B.5 repeats the provisional coefficients of Table 4.3A. They may be used now under the fixed-coefficient route (Clause 4.14.4).

Table 4B.5 — Fixed release coefficients C_10 and C_2 (provisional, Table 4.3A)

Hydrologic soil group	C_10	C_2	Clause	Status
A (sandy, well drained)	0.05	0.02	4.14.4	Provisional
B	0.08	0.03	4.14.4	Provisional
C	0.15	0.08	4.14.4	Provisional
D (clay, poorly drained)	0.25	0.15	4.14.4	Provisional

To be prepared. The confirmed coefficients will replace Table 4B.5. They need NIH-DHAARA depths for each zone and the greenfield curve numbers of Clause 3.3, as described in the commentary to Clause 4.14. Until they are published, the provisional values of Table 4.3A apply.

Annex 4C — Worked example (Tier A) with full routing tables

Supports Clauses 4.4 to 4.9, 4.15 and 4.17 of Chapter 4.

Illustrative — not design values. This example continues the illustrative example of Clause 4.6.7. Its inputs are invented to be plausible for a colony on a Dravyavati tributary nala in south Jaipur; they are not NIH-DHAARA values and must not be used for design. Part 1 sets out the inputs, hydrographs and routing step by step, for a trial outlet. Part 2 finds

that the trial outlet fails the drawdown check with the blockage of Clause 4.8.3, and revises it to the outlet reported in Table 4.2. Part 3 completes the spillway, outlet, safety and retention checks. The outfall-closed check of Chapter 5 for the same facility on an outfall to a Dravyavati tributary nala in south Jaipur is in Annex 5C.

Part 1 — Inputs, hydrographs and routing (Clauses 4.6.1 to 4.6.4)

4C.1 **Inputs.**

Table 4C.1 — Inputs (Illustrative — not design values)

Item	Value	Basis
Site area A	2.0 ha (0.02 km²), one outfall	Clause 4.6.7
Catchment class	Flood-sensitive (Clause 4.5.3)	Clause 4.6.7
Land cover and curve numbers, AMC II	Pre-development: all pervious, CN 70. Post-development, as two sub-areas: directly connected impervious 1.57 ha at CN 98, and pervious open space 0.43 ha at CN 70 (same soil as pre-development). Impervious fraction f = (92 − 70) / (98 − 70) = 0.786, so the area-weighted CN is 92	Clauses 3.9.2, 4.6.7
AMC III conversion	Pervious areas only, for storms of 12 h and longer: CN_III = 23·CN / (10 + 0.13·CN) = 84.3. The impervious CN 98 is not converted	Clause 3.8.4
Initial abstraction	Ia = 0.2S; Ia = 0.05S as a sensitivity run	Clause 3.8.5
Time of concentration Tc	45 min pre-development; 15 min post-development, used for both sub-areas, because the open space is small and drains through the same site system	Clause 4.6.7
Unit hydrograph	SCS triangular; tL = 0.6 Tc; tp = Δt/2 + tL; base 2.67 tp	Clauses 3.6.5, 3.11.2
Time step Δt	5 min (= Tc/3 of the post-development site)	Clause 4.6.2, step 8
24-h depths, 2-, 10-, 100-yr	110, 200, 350 mm, taken as including the climate factor	Clause 4.6.7
Shorter durations	P(t) = P24 · (t/24)^0.40 (assumed ratio set, not Annex 2B)	Clause 4.6.7
48-h and 72-h depths	1.25 and 1.40 × P24, with the 24-h depth on the last day	Clauses 4.6.7, 2.9.2
Storage	Open, vertical-walled, 2,500 m² plan area, excavated, no embankment, not publicly accessible	Clause 4.6.7
Trial outlet	Stage 1: 120 mm orifice at the floor. Stage 2: 470 mm orifice, invert 0.533 m above the floor. No Stage 3	Trial for this annex; Part 2 revises it
Outfall	Free outfall to a receiving drain whose level stays below the outlet invert	Illustrative input

The example follows Clauses 3.8.4 and 3.9.2: the runoff of each sub-area is computed separately and the two are added before routing.

4C.2 **Design rainfall.** Table 4C.2 gives the depths. For example, the 100-yr 6-hour depth is 350 × (6/24)^0.40 = 350 × 0.574 = 201.0 mm.

Table 4C.2 — Design rainfall depths, mm (Illustrative — not design values)

Duration (h)	1	2	3	6	12	24	48	72
50% AEP (2-yr)	30.9	40.7	47.9	63.2	83.4	110.0	137.5	154.0

Duration (h)	1	2	3	6	12	24	48	72
10% AEP (10-yr)	56.1	74.0	87.1	114.9	151.6	200.0	250.0	280.0
1% AEP (100-yr)	98.2	129.5	152.3	201.0	265.3	350.0	437.5	490.0

4C.3 **Hyetographs.** Storms up to 24 h use the alternating-block method in 5-minute blocks with the peak block at mid-storm (Clause 2.9.1). The 48- and 72-hour storms spread the depth in excess of the 24-hour depth uniformly over the first 24 or 48 h and place the 24-hour alternating-block storm on the last day (Clause 2.9.2). For the 100-yr 72-hour storm: (490.0 − 350.0) / 576 blocks = 0.243 mm per 5 minutes for the first 48 h; the peak 5-minute block on the last day is 350 × (5/1440)^0.40 = 36.3 mm, at 60:00–60:05 h.

4C.4 **Losses.** Table 4C.3 gives S = 25,400/CN − 254 (mm) and Ia = 0.2S. The runoff depth for a rainfall depth P is Q = (P − Ia)² / (P − Ia + S) for P > Ia, and zero otherwise.

Table 4C.3 — Curve numbers and abstractions (Illustrative — not design values)

Condition	AMC	CN	S (mm)	Ia = 0.2S (mm)
Pre-development	II (durations ≤ 6 h)	70	108.9	21.8
Pre-development	III (durations ≥ 12 h)	84.3	47.3	9.5
Post-development pervious open space (0.43 ha)	II (durations ≤ 6 h)	70	108.9	21.8
Post-development pervious open space (0.43 ha)	III (durations ≥ 12 h)	84.3	47.3	9.5
Post-development directly connected impervious (1.57 ha)	All durations (not converted)	98	5.2	1.0

Check: 100-yr 24 h, post-development. Impervious: Q = (350.0 − 1.0)² / (350.0 − 1.0 + 5.2) = 343.9 mm. Pervious, AMC III: Q = (350.0 − 9.5)² / (350.0 − 9.5 + 47.3) = 299.0 mm. Site: 0.786 × 343.9 + 0.214 × 299.0 = 334.2 mm. The post-development columns of Table 4C.4 are these area-weighted site depths.

Table 4C.4 — Storm runoff depth Q, mm (Illustrative — not design values)

Duration (h)	AMC	2-yr pre	2-yr post	10-yr pre	10-yr post	100-yr post
1	II	0.7	20.1	8.2	41.3	79.2
2	II	2.8	28.2	16.9	57.2	108.5
3	II	5.1	34.2	24.5	69.0	130.2
6	II	11.4	47.5	42.9	94.7	177.1
12	III	45.0	70.5	106.6	137.2	249.9
24	III	68.4	96.4	152.6	185.1	334.2
48	III	93.5	123.3	201.0	234.7	421.5
72	III	108.9	139.6	230.3	264.5	473.9

The runoff volume is 10 × Q × A = 20 × Q m³ for this 2.0 ha site: for example 9,478 m³ for the 100-yr 72-hour storm. The routed hydrographs carry up to 0.5% less, because the 5-minute alternating-block storm places 349.5 mm rather than 350.0 mm on the last day.

4C.5 **Unit hydrographs.** The runoff in each 5-minute block (for the post-development site, the sum of the two sub-areas) is convolved with the triangular unit hydrograph of Table 4C.5. The peak is qp = 0.208 × A × Q / tp, with A in km² and Q = 1 mm (Clause 3.11.2).

Table 4C.5 — Unit hydrograph parameters (Illustrative — not design values)

Condition	Tc (h)	tL = 0.6 Tc (h)	tp = Δt/2 + tL (h)	Base 2.67 tp (h)	qp (L/s per mm of runoff)
Pre-development	0.75	0.45	0.492	1.313	8.5
Post-development	0.25	0.15	0.192	0.512	21.7

4C.6 **Release caps (Clause 4.5.3).** The site is flood-sensitive, so the mixed-frequency rule applies. The 100-yr cap is the largest pre-development 10-yr peak over all durations: **356 L/s** (72 h; Table 4.2). The 2-yr cap is the largest pre-development 2-yr peak: **180 L/s** (72 h). Each cap applies to every post-development duration (Clause 4.5.3.1).

4C.7 **Stage–storage–discharge.** The basin is vertical-walled, so storage S = 2,500 × h (m³), where h is the stage above the floor (m). Outlet discharge follows Clause 4.6.5.2 with Cd = 0.60:

- Stage 1, for h ≥ d: Q1 = 0.60 × A1 × √(2g (h − d/2)). For h < d (orifice part-full), the head is taken as d/2 and the result is multiplied by h/d.
- Stage 2 is counted once the water is above its centre: Q2 = 0.60 × A2 × √(2g (h − z2 − d2/2)), where z2 is its invert. Below its centre its flow is ignored, which slightly over-states storage.

Table 4C.6 — Stage–storage–discharge, trial outlet (Illustrative — not design values)

Stage h (m)	Storage (m³)	Stage 1, 120 mm (L/s)	Stage 2, 470 mm (L/s)	Total (L/s)
0.00	0	0.0	0.0	0.0
0.06	150	3.7	0.0	3.7
0.12	300	7.4	0.0	7.4
0.20	500	11.2	0.0	11.2
0.30	750	14.7	0.0	14.7
0.40	1,000	17.5	0.0	17.5
0.50	1,250	19.9	0.0	19.9
0.60	1,500	22.1	0.0	22.1
0.70	1,750	24.0	0.0	24.0
0.80	2,000	25.9	83.0	108.9
0.90	2,250	27.5	167.8	195.3
1.00	2,500	29.1	222.3	251.4
1.10	2,750	30.7	265.8	296.5
1.20	3,000	32.1	303.2	335.3
1.30	3,250	33.5	336.4	369.9
1.40	3,500	34.8	366.7	401.5

Check at h = 1.00 m: Q1 = 0.60 × 0.01131 × √(19.62 × 0.94) = 0.0291 m³/s; Q2 = 0.60 × 0.1735 × √(19.62 × (1.00 − 0.533 − 0.235)) = 0.2223 m³/s.

4C.8 **Routing.** Each storm is routed by level-pool continuity (Clause 4.6.1): over each 5-minute step, the change in storage equals inflow volume minus outflow volume. The computation used six 50-second sub-steps per 5-minute step. Each row of Table 4C.7 can be checked by hand as ΔS ≈ (I − Ō) × 300 s, where I is the mean inflow over the 5-minute

step ending at the time shown and $\bar{O}$ is the mean of the outflows at the start and end of the step. For example, between 60:15 and 60:20: $\Delta S = 2{,}853.0 - 2{,}613.3 = 239.7$ m³, and $(1.0891 - (0.2655 + 0.3069)/2) \times 300 = 240.9$ m³.

Table 4C.7 — Routing of the 100-yr 72-hour storm through the trial outlet, around the peak (Illustrative — not design values)

Time (h:min)	Rainfall in step (mm)	Inflow I (L/s)	Outflow O (L/s)	Storage S (m³)	Stage h (m)
60:00	8.44	286.3	169.5	2,164.0	0.866
60:05	36.33	354.2	184.1	2,216.9	0.887
60:10	11.61	703.3	218.0	2,367.1	0.947
60:15	6.88	1,066.0	265.5	2,613.3	1.045
60:20	5.23	1,089.1	306.9	2,853.0	1.141
60:25	4.34	897.5	334.8	3,025.0	1.210
60:30	3.77	653.2	349.9	3,117.6	1.247
60:35	3.36	403.6	353.8	**3,132.9**	**1.253**
60:40	3.05	301.5	352.3	3,117.3	1.247
60:45	2.81	254.8	348.6	3,088.7	1.235
60:50	2.61	224.9	343.7	3,052.4	1.221
60:55	2.45	203.3	337.9	3,011.3	1.205

Storage is greatest at the end of the step ending at 60:35. In the next step the mean inflow (302 L/s) is below the outflow (about 352 L/s), so storage falls.

Table 4C.8 — Routing of the 100-yr 72-hour storm through the trial outlet, hourly (Illustrative — not design values)

Time (h)	Cumulative rainfall (mm)	Inflow (L/s)	Outflow (L/s)	Stage (m)	Storage (m³)
12	35.0	14	8	0.130	325
24	70.0	15	12	0.215	536
36	105.0	16	14	0.264	660
48	140.0	16	15	0.294	736
54	181.7	47	19	0.469	1,172
57	213.5	69	23	0.623	1,559
59	248.5	120	91	0.789	1,971
60	293.3	286	170	0.866	2,164
61	378.0	187	332	1.187	2,967
62	399.3	106	237	0.968	2,421
63	414.5	80	142	0.829	2,072
66	446.9	51	52	0.771	1,927
72	489.5	33	33	0.768	1,920
84	489.5	0	18	0.405	1,012

Time (h)	Cumulative rainfall (mm)	Inflow (L/s)	Outflow (L/s)	Stage (m)	Storage (m³)
96	489.5	0	10	0.167	418
108	489.5	0	4	0.058	146

The routed outflow volume equals the inflow volume (about 9,470 m³): detention delays the volume but does not remove it.

4C.9 **Results, trial outlet.** Table 4C.9 gives the peaks, maximum stages and drawdown times for the trial outlet.

Table 4C.9 — Results for the trial outlet (120 mm and 470 mm orifices) (Illustrative — not design values)

Duration (h)	2-yr detained (L/s)	2-yr max stage (m)	10-yr detained (L/s)	10-yr max stage (m)	100-yr detained (L/s)	100-yr max stage (m)	100-yr storage (m³)	10-yr 90% drawdown, clean (h)	10-yr 90% drawdown, 50% blocked (h)
1	9	0.15	15	0.30	22	0.59	1,468	27.2	54.2
2	11	0.20	18	0.42	89	0.79	1,966	28.3	57.0
3	13	0.24	20	0.50	135	0.82	2,058	29.3	59.1
6	15	0.31	23	0.64	190	0.89	2,229	31.1	63.4
12	17	0.40	49	0.77	279	1.06	2,647	36.2	69.2
24	19	0.45	87	0.79	334	1.20	2,991	42.8	75.4
48	20	0.51	144	0.83	353	1.25	3,129	42.5	72.7
72	20	0.52	147	0.84	354	1.25	**3,133**	42.5	71.9

The drawdown time is measured from the time of maximum 10-yr storage until 90% of that storage has been released (Clause 4.7.1).

Part 2 — Checks and revision of the outlet (Clauses 4.5, 4.7 and 4.8)

4C.10 **Release caps.** Every 100-yr detained peak is at or below 356 L/s, and every 2-yr detained peak is far below the 2-yr cap of 180 L/s. Both caps are met. The 2-yr peaks are not compared duration by duration with the pre-development peaks: for a flood-sensitive site the 2-yr cap is the single largest pre-development 2-yr peak (Clause 4.5.3.1).

4C.11 **Drawdown.** Clause 4.8.3 requires the low-flow orifice to be assumed **50% blocked** when drawdown is checked. With the 120 mm orifice at half its area, 90% of the 10-yr storage takes 54 to 75 h to drain (Table 4C.9), against the 48-hour limit of Clause 4.7.1. **The trial outlet fails.** With a clean orifice it would drain in about 42 h.

4C.12 **Revised outlet.** The low-flow orifice was increased in 10 mm steps until the blocked drawdown met 48 h for every duration, and Stage 2 was then re-sized so that the 100-yr cap was still met. The result:

- Stage 1: **170 mm** orifice at the floor;
- Stage 2: **460 mm** orifice, invert 0.53 m above the floor (centre at 0.76 m);
- no Stage 3.

The larger low-flow orifice releases more in frequent storms. That is acceptable here because the 2-yr cap of a flood-sensitive site is the largest pre-development 2-yr peak (Clause 4.5.3.1). The WQv is assumed to be treated in a separate practice upstream (Chapter 8), so Stage 1 is not required to hold the WQv for 24–48 h (Clause 4.6.5.1); where Stage 1 also releases the WQv, Clause 4.7.2 must be checked as well.

Table 4C.10 — Stage–storage–discharge, revised outlet (Illustrative — not design values)

Stage h (m)	Storage (m³)	Stage 1, 170 mm (L/s)	Stage 2, 460 mm (L/s)	Total (L/s)
0.00	0	0.0	0.0	0.0
0.085	213	8.8	0.0	8.8
0.17	425	17.6	0.0	17.6
0.30	750	28.0	0.0	28.0
0.40	1,000	33.9	0.0	33.9
0.50	1,250	38.9	0.0	38.9
0.60	1,500	43.3	0.0	43.3
0.70	1,750	47.3	0.0	47.3
0.76	1,900	49.6	0.0	49.6
0.80	2,000	51.0	88.3	139.3
0.90	2,250	54.5	165.3	219.7
1.00	2,500	57.7	216.4	274.1
1.10	2,750	60.8	257.5	318.3
1.17	2,925	62.8	282.8	345.6
1.20	3,000	63.7	293.0	356.7
1.30	3,250	66.5	324.6	391.1

Table 4C.11 — Results for the revised outlet (170 mm and 460 mm orifices) (Illustrative — not design values)

Duration (h)	2-yr detained (L/s)	2-yr max stage (m)	10-yr detained (L/s)	10-yr max stage (m)	10-yr storage (m³)	100-yr detained (L/s)	100-yr max stage (m)	100-yr storage (m³)	10-yr 90% drawdown, 50% blocked (h)
1	15	0.14	28	0.29	734	42	0.57	1,426	31.3
2	20	0.19	34	0.40	990	79	0.76	1,911	32.1
3	22	0.22	37	0.46	1,147	139	0.80	1,999	32.8
6	25	0.26	41	0.56	1,386	194	0.86	2,154	34.2
12	30	0.33	46	0.68	1,692	276	1.01	2,512	39.0
24	32	0.37	49	0.75	1,870	320	1.11	2,766	45.3
48	34	0.40	82	0.77	1,913	343	1.17	**2,913**	44.8
72	34	0.41	84	0.77	1,915	343	1.16	2,911	44.7

Findings:

- **100-yr cap:** largest detained peak 343 L/s ≤ 356 L/s. Met.
- **2-yr cap:** largest detained peak 34 L/s ≤ 180 L/s. Met.
- **Drawdown:** longest blocked drawdown 45.3 h ≤ 48 h (Clause 4.7.1). Met.

- **Governing storage: 2,913 m³** (100-yr, 48 h), at a maximum stage of **1.17 m**. The larger low-flow orifice releases more water early in the long storms, so the revised outlet needs about 220 m³ less storage than the trial outlet. Table 4.2 in Clause 4.6.7 reports this revised design.
- **Governing storms (Clause 4.6.2, step 12):** storage, the 100-yr 48-hour storm; Stage 1, the 10-yr 24-hour storm (drawdown); Stage 2, the 100-yr 48-hour storm (cap).

Part 3 — Sensitivity, retention, spillway, outlet details and safety

4C.13 **Ia = 0.05S sensitivity (Clause 3.8.5).** With S converted as S0.05 = 25.4 × 1.33 × (S0.20 / 25.4)^1.15, the governing 100-yr 48-hour run gives 2,898 m³ of storage and a 341 L/s peak, slightly below the default run. The pre-development 10-yr peak, and so the 100-yr cap, falls to 344 L/s. The design is based on the default run (Clause 3.8.5(c)); the sensitivity results are reported on Form 3-2.

4C.14 **Retention and retention credit (Clauses 4.4.2 and 4.4.6).** With an illustrative retention depth P_R = 40 mm, Q_R is computed for each sub-area at AMC II, because a composite CN is not used for retention (Clause 3.9.4). Impervious, CN 98: S = 5.2 mm, Ia = 1.0 mm, Q_R = (40 − 1.0)² / (40 − 1.0 + 5.2) = 34.4 mm. Pervious, CN 70: S = 108.9 mm, Ia = 21.8 mm, Q_R = (40 − 21.8)² / (40 − 21.8 + 108.9) = 2.6 mm. RRV = 10 × (34.4 × 1.571 + 2.6 × 0.429) = **552 m³**. The retention is modelled as a store that is empty at the start of the storm and captures all runoff until full, with no infiltration during the storm (Clause 4.4.6.2).

Table 4C.12 — Retention credit by routing, revised outlet (Illustrative — not design values)

100-yr storm	Storage without retention (m³)	Storage with retention (m³)	Reduction (m³)
24 h	2,766	2,628	138
48 h	2,913	2,906	7
72 h	2,911	2,911	0

The governing storage falls from 2,913 to 2,906 m³, so the retention credit is 7 m³, about 1% of the RRV. The retention is still required in full for its own purposes (Clause 4.4.1, Chapter 8).

4C.15 **Emergency spillway (Clause 4.9).** The facility is excavated, with no embankment, so Clause 4.9.7 applies: the overflow route is treated as the spillway and must meet Clause 4.9.1.

- Design flow: the 1% AEP peak inflow, 1,089 L/s, with the outlet blocked and the basin full to the crest.
- Crest: the 1% AEP maximum water level with the outlet working is 1.17 m; with the recommended 0.15 m clearance (Clause 4.9.3) the crest is set at **1.35 m**.
- Crest length: a broad-crested weir with Q = C × L × H^1.5, C = 1.7 (an illustrative coefficient for a broad-crested weir in SI units; Clause 4.6.5.2 requires a coefficient suited to the shape). With L = 4.0 m: H = (1.089 / (1.7 × 4.0))^(2/3) = 0.295 ≈ **0.30 m**.
- Maximum level with the spillway flowing: 1.35 + 0.30 = 1.65 m. With 0.3 m freeboard (Clause 4.9.1), the top of the walls is at least **1.95 m** above the floor.
- The spillway discharges to the 1% AEP overland flow path, away from buildings (Clause 4.9.4).

4C.16 **Outlet details (Clause 4.8).**

Table 4C.13 — Outlet checks, revised outlet (Illustrative — not design values)

Item	Requirement	Value	Result
Minimum orifice	≥ 50 mm (Clause 4.8.2)	170 mm	Met

Item	Requirement	Value	Result
Rack bar spacing	≤ half the smallest opening and ≥ 25 mm (Clause 4.8.3)	≤ 85 mm	Set at 75 mm
Rack open area	≥ 10 × area protected (Clause 4.8.3)	10 × (0.0227 + 0.1662) m² = 1.89 m² for one rack around both orifices	Provide ≥ 1.89 m²
Anti-vortex, Stage 1	Needed if head > 1.5 d (Clause 4.8.4)	Head up to 1.08 m > 0.26 m	Required
Anti-vortex, Stage 2	Needed if head > 1.5 d (Clause 4.8.4)	Head above centre up to 0.41 m < 0.69 m	Not required
Isolation	Facility serving > 1 ha (Clause 4.8.6)	Serves 2.0 ha	Stop-log slot or penstock, normally open
Outlet barrel	≥ 300 mm (Clause 4.8.5)	Sized under Chapter 9 for 343 L/s	To be designed

4C.17 **Safety (Clause 4.15).** The 10-yr depth (0.77 m) exceeds the 0.45 m limit for publicly accessible storage (Clause 4.15.1(a)), so the facility is not open to the public. It has vertical walls higher than 0.6 m and a depth of more than 1.2 m when the spillway flows, so a non-climbable fence at least 1.2 m high with a lockable gate is required (Clause 4.15.3). Signs and a depth marker are provided (Clause 4.15.5).

4C.18 **Summary of the design (Illustrative — not design values).**

Table 4C.14 — Summary of the revised design (Illustrative — not design values)

Item	Value
Storage	2,500 m² plan area; 2,913 m³ at the 1% AEP maximum level of 1.17 m
Stage 1	170 mm orifice at the floor, with trash rack and anti-vortex plate
Stage 2	460 mm orifice, invert 0.53 m
Spillway	Crest 1.35 m, length 4.0 m, maximum level 1.65 m
Top of walls	≥ 1.95 m above the floor
100-yr peak release	343 L/s (cap 356 L/s)
2-yr peak release	34 L/s (cap 180 L/s)
10-yr drawdown, 50% blocked	45.3 h (limit 48 h)
Retention	RRV 552 m³ provided in addition; credit 7 m³
Still to be checked	Outfall-closed check on an outfall to a Dravyavati tributary nala in south Jaipur (Annex 5C); downstream analysis (Chapter 5); groundwater and flotation (Clause 4.12); WQv (Chapter 8)

Form 4-1 — Site Runoff Control Report

Supports Clauses 4.3 to 4.17 of Chapter 4.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. One form for each site. Where the site drains to more than one outfall, complete Sections E to J for each outfall (Clause 4.5.1.3). Tier B sites using Clause 4.14.2 attach Form 4-2 in place of Sections F and G; sites using the fixed-coefficient route attach Form 4-3 in place of Sections F and G (Clause 4.17).

A. Site and route

Table 4F.1 — Form 4-1: site and route

Field	Entry
A1. Project name and applicant	
A2. Location (village or ward, survey numbers, district)	
A3. Approving Authority and tier (Tier A / Tier B)	
A4. Site area, land disturbance and new or replaced impervious area (ha, ha, m²) (Clause 4.1.2)	
A5. Number of outfalls (Clause 4.5.1.3)	
A6. Sizing route: full method (Clause 4.6) / Tier B tables (Clause 4.14.2) / fixed-coefficient route (Clause 4.14.3)	
A7. Constrained redevelopment route used (Clause 4.5.6)? If yes, attach the Constraint Statement, the existing-condition model and the shortfall and fee computation	

B. Inputs (Clause 4.17, item 1)

Table 4F.2 — Form 4-1: inputs

Field	Entry
B1. Design Rainfall Sheet reference (Form 2-1)	
B2. Hydrologic Calculation Summary reference (Form 3-1)	
B3. HSG of each sub-area and the tests that confirm it (Clause 4.6.2, step 1)	
B4. Pre-development condition and CN (Clause 4.5.1.2)	
B5. Post-development CN of each sub-area, and Tc pre and post	
B6. Routing method and software, with version; time step (Clauses 4.6.1, 4.6.2)	

C. Order of measures (Clause 4.3.1; Clause 4.17, item 2)

Table 4F.3 — Form 4-1: order of measures

Step	What the design does	Why this step cannot do more
1. Preserve		
2. Retain		

Step	What the design does	Why this step cannot do more
3. Detain		
4. Convey		

D. Retention (Clause 4.4; Clause 4.17, items 3 and 4)

Table 4F.4 — Form 4-1: retention

Field	Entry
D1. Retention depth P_R (mm) and zone (Annex 2E)	
D2. Runoff depth Q_R (mm) by sub-area and RRV (m³) (Clause 4.4.2)	
D3. Retention practices and volume provided (m³)	
D4. Infiltration tests: number, locations and depths, measured rates (mm/h) (Clause 4.4.3(a))	
D5. Design infiltration rate (mm/h), not more than half the measured rate (Clause 4.4.3(b))	
D6. Seasonal high groundwater depth below the base of each practice (m), at least 1.0 m (Clause 4.4.3(c))	
D7. Reuse demand calculation, where retention is by reuse (Clause 4.4.3)	
D8. Retention drawdown time (h), not more than 72 h (Clause 4.4.5)	
D9. Shortfall in RRV (m³), if any, treated as WQv (Clause 4.4.4.2)	
D10. Governing storage without and with retention, and the retention credit (m³) (Clause 4.4.6)	
D11. Preservation credit areas and covenant reference (Clause 4.4.7)	

E. Release criteria (Clause 4.5; Clause 4.17, item 5)

Table 4F.5 — Form 4-1: release criteria

Field	Entry
E1. Catchment class: standard (Clause 4.5.2) or flood-sensitive (Clause 4.5.3), with the Annex 4A map extract	
E2. Release caps by AEP (L/s), and the duration that sets each cap	
E3. Clause 4.5.5 used (50 mm orifice deemed to comply, or the short-duration 2-yr relief)? Report any 2-yr exceedance	

F. Results (Clause 4.6; Clause 4.17, item 6)

Complete one row for each duration, in the format of Table 4.2. Mark the governing case for storage, for each outlet stage and for the spillway (Clause 4.6.2, step 12).

Table 4F.6 — Form 4-1: results by duration (L/s; m³)

Duration (h)	2-yr pre	2-yr post, detained	10-yr pre	10-yr post, detained	100-yr post, uncontrolled	100-yr post, detained	100-yr storage used
1							
2							

Duration (h)	2-yr pre	2-yr post, detained	10-yr pre	10-yr post, detained	100-yr post, uncontrolled	100-yr post, detained	100-yr storage used
3							
6							
12							
24							
48							
72							

G. Facility, drawdown and outlet (Clauses 4.7, 4.8, 4.10; Clause 4.17, items 7 to 9)

Table 4F.7 — Form 4-1: facility, drawdown and outlet

Field	Entry
G1. Facility type (Clause 4.10) and storage provided (m^3)	
G2. Stage–storage and stage–discharge tables and plots; inflow and outflow hydrographs for the governing cases (attach)	
G3. 10-yr drawdown: time to release 90% of the maximum stored volume (h), with the low-flow orifice 50% blocked (Clauses 4.7.1, 4.8.3)	
G4. WQv release time (h), 24 to 48 h (Clause 4.7.2)	
G5. Tidal outfall: drawdown with the tidal tailwater, and any pumped drawdown (Clause 4.7.4)	
G6. Each outlet stage: type, size (mm), invert level (m)	
G7. Trash racks: clear bar spacing (mm) and open area (m^2) (Clause 4.8.3)	
G8. Anti-vortex devices (Clause 4.8.4); outlet barrel diameter and seepage control (Clause 4.8.5); isolation (Clause 4.8.6)	
G9. Proprietary devices: certified head–discharge curve and minimum clear opening (Clause 4.6.5.3)	

H. Spillway, freeboard and embankment (Clause 4.9; Clause 4.17, item 10)

Table 4F.8 — Form 4-1: spillway and freeboard

Field	Entry
H1. Hazard classification, with reasons (Clause 4.9.2)	
H2. 1% AEP peak inflow (L/s); 0.2% AEP peak inflow for high-hazard facilities (L/s)	
H3. 1% AEP maximum water level with the outlet working (m); spillway crest level (m) (Clause 4.9.3)	
H4. Spillway or overflow route: type, dimensions, maximum level with the outlet blocked (m)	
H5. Freeboard to the embankment crest or wall top (m), at least 0.3 m (Clause 4.9.1)	
H6. Spillway location and discharge path (Clause 4.9.4)	
H7. Embankment height (m); geotechnical report where more than 2 m (Clause 4.9.6)	

I. RWH accounting, groundwater and flotation (Clauses 4.11, 4.12; Clause 4.17, items 11 and 12)

Table 4F.9 — Form 4-1: RWH, groundwater and flotation

Field	Entry
I1. RWH storage provided (m³), assumed full at the start of every storm (Clause 4.11.2)	
I2. Combined RWH and detention tanks: zone levels and the detention orifice level (Clause 4.11.3); attach tank sections	
I3. Design groundwater level and its basis (Clause 4.12.1)	
I4. Lined or unlined storage; volume below the design groundwater level not counted (Clause 4.12.2)	
I5. Flotation factor of safety, at least 1.2 (Clause 4.12.3)	

J. Downstream, tailwater, safety and maintenance (Clause 4.17, items 13 and 14)

Table 4F.10 — Form 4-1: downstream, tailwater, safety and maintenance

Field	Entry
J1. Downstream and Tailwater Report (Form 5-1) or Simplified Downstream Statement (Form 5-2) reference	
J2. Tailwater used in routing, and flap gate where tailwater governs (Clause 4.6.6)	
J3. Public access, depths in the 10% and 1% AEP storms, slopes, fencing, grates, signs and depth markers (Clause 4.15)	
J4. Draft maintenance declaration reference (Chapter 10)	

K. Statement by the registered professional (Clause 10.6)

I state that this report has been prepared under Chapter 4 of the Rajasthan Stormwater Design Manual (Draft v1.0), that the results reported are reproduced by the models submitted, and that every departure from Chapter 4 is listed with its reason. The Professional Design Certificate (Form 10-3) is attached.

Table 4F.11 — Form 4-1: statement by the registered professional

Field	Entry
Name	
Qualification and registration number	
Empanelment number, where Clause 10.6.1 requires it	
Organisation	
Signature	
Date	

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0.

Form 4-2 — Tier B Site Sheet

Supports Clauses 4.4.6.3, 4.14.1 and 4.14.2 of Chapter 4.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. This sheet replaces items 6 and 7 of the Site Runoff Control Report (Form 4-1) for Tier B sites using Clause 4.14.2. It can be used only after Table 4.3 is published in Annex 4B; until then, Tier B sites use Clause 4.6 or, for sites of 1 ha or less, the fixed-coefficient route (Clauses 4.14.1 and 4.14.3).

A. Eligibility (Clause 4.14.1)

Table 4F.12 — Form 4-2: eligibility

Field	Entry
A1. Local body (Tier B)	
A2. Site area A (ha): 2 ha or less outside flood-sensitive catchments; 0.5 ha or less inside them	
A3. Catchment class: standard or flood-sensitive (Annex 4A)	

B. Table 4.3 values (Clause 4.14.2, step 1)

Table 4F.13 — Form 4-2: values read from Table 4.3

Field	Entry
B1. Rainfall zone (Annex 2A)	
B2. Hydrologic soil group	
B3. Post-development imperviousness (%)	
B4. PSD 2-yr (L/s/ha)	
B5. PSD 100-yr (L/s/ha), for the catchment class	
B6. SSR (m³/ha), for the catchment class	

C. Storage and release (Clause 4.14.2, steps 2 and 3)

Table 4F.14 — Form 4-2: storage and release

Line	Quantity	Computation	Value
C1	RRV provided (m³)	Clause 4.4	
C2	C_R	Annex 4B; 0 until published	
C3	V_credit (m³)	C2 × C1 (Clause 4.4.6.3)	
C4	Required storage V (m³)	B6 × A − C3	
C5	Storage provided (m³)	From drawings	
C6	Q_PSD,2 (L/s)	B4 × A	

Line	Quantity	Computation	Value
C7	Q_PSD,100 (L/s)	B5 × A	

D. Outlet and other provisions (Clause 4.14.2, steps 4 and 5)

Table 4F.15 — Form 4-2: outlet and other provisions

Field	Entry
D1. Low-flow orifice: diameter (mm) from the Annex 4B outlet table, head (m), at least 50 mm	
D2. Upper control: type, size and level	
D3. Spillway or overflow (Clause 4.9)	
D4. RWH accounting (Clause 4.11)	
D5. Safety provisions (Clause 4.15)	

E. Statement

I state that the values above are taken from Annex 4B for the site's zone, soil group, imperviousness and catchment class, and that the storage and outlets shown on the drawings match them.

Table 4F.16 — Form 4-2: statement

Field	Entry
Name	
Qualification and registration number	
Signature	
Date	

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0.

Form 4-3 — Fixed-coefficient Route Sheet (Clauses 4.14.3 to 4.14.7)

Supports Clauses 4.14.3 to 4.14.7 of Chapter 4.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. This sheet replaces items 6 and 7 of the Site Runoff Control Report (Form 4-1) for sites using the fixed-coefficient route. Complete it for each point where runoff leaves the site (Clause 4.14.4). Figure 4.3 shows the method.

A. Eligibility (Clause 4.14.3)

Table 4F.17 — Form 4-3: eligibility

Check	Yes / No
A1. Site area 1 ha or less	
A2. The design does not count tank or waterbody storage (Clause 4.14.3(a))	
A3. No part of the site lies within a waterbody setback (Clause 4.14.3(b))	
A4. The site does not drain to a tank cascade whose storage is counted in a downstream design (Clause 4.14.3(c))	

B. Release caps (Clause 4.14.4)

Table 4F.18 — Form 4-3: release caps

Line	Quantity	Source or computation	Value
B1	Site area A (ha)	Survey	
B2	Area of each hydrologic soil group (ha)	Clause 3.7	
B3	C_10 and C_2, area-weighted	Table 4.3A	
B4	i_10 and i_2 (mm/h), 15-minute duration, with the climate factor	Form 2-1; Clause 2.8	
B5	Q_cap,10 (L/s)	2.78 × C_10 × i_10 × A	
B6	Q_cap,2 (L/s)	2.78 × C_2 × i_2 × A	
B7	Discharge of a 50 mm orifice at the corresponding stage (L/s), where a cap is smaller (Clause 4.5.5.1)	Orifice equation, Clause 4.6.5.2	

C. Volumetric coefficient (Clause 4.14.5)

Table 4F.19 — Form 4-3: volumetric coefficient C_v

Line	Quantity	Value
C1	Composite C of Table 3.2 (upper half of each range)	
C2	Cf of Table 3.3 for the 1% AEP	
C3	C_v for durations below 12 h (C1 × C2)	
C4	C_v for durations of 12 h or more, with C for every pervious surface not less than 0.50	

D. Storage (Clause 4.14.5)

For each duration: inflow = 10 × C_v × P(d) × A (m³); release = 1.8 × Q_cap × d (m³); difference = inflow − release. V_100 and V_2 are the largest differences; V is the larger of the two.

Table 4F.20 — Form 4-3: storage by duration

d (h)	P_100(d) (mm)	100-yr inflow (m³)	1.8 × Q_cap,10 × d (m³)	100-yr difference (m³)	P_2(d) (mm)	2-yr inflow (m³)	1.8 × Q_cap,2 × d (m³)	2-yr difference (m³)
1								
2								
3								
6								
12								
24								
48								
72								

Table 4F.21 — Form 4-3: storage required and provided

Line	Quantity	Value
D1	V_100 (m³) and governing duration	
D2	V_2 (m³) and governing duration	
D3	V = larger of D1 and D2 (m³)	
D4	Storage provided (m³)	

E. Outlet, retention and other checks (Clauses 4.14.3, 4.14.6, 4.14.7)

Table 4F.22 — Form 4-3: outlet, retention and other checks

Field	Entry
E1. Low-flow orifice: diameter (mm) and invert; discharge (L/s) with the storage holding V_2 full, not more than Q_cap,2	
E2. Upper orifice or weir: size and level; total release (L/s) at the top of V, not more than Q_cap,10	
E3. Retention volume of Clause 4.4 provided in addition to V (m³); no retention credit taken	
E4. Drawdown (Clause 4.7), trash racks (Clause 4.8), spillway (Clause 4.9): reference to Form 4-1 Sections G and H	
E5. Downstream and tailwater checks (Chapter 5) and water quality (Chapter 8): references	

F. Statement

I state that the site meets the eligibility conditions of Clause 4.14.3 and that the caps, storage and outlets above have been computed by Clauses 4.14.4 to 4.14.7.

Table 4F.23 — Form 4-3: statement

Field	Entry
Name	
Qualification and registration number	
Signature	
Date	

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0.

ANNEXES TO CHAPTER 5

Downstream and Tailwater Analysis

These annexes support Chapter 5. Annex 5C is a worked example of the outfall-closed check of Clause 5.10, for the illustrative facility of Annex 4C. Annexes 5A and 5B need tidal, surge, survey and river data that this draft does not yet contain; each lists what the chapter already sets, gives the intended layout and states the interim rule of Chapter 5 that applies until it is published. Forms 5-1 and 5-2 are the submittal forms required by Clause 5.14. They are draft forms and have no statutory status.

Annex 5A — Tidal datums (MSL, MHWS, HAT vs CD and Survey of India datum), surge allowances and 1% still-water levels by coastal segment

Supports Clauses 5.7, 5.9, 5.10, 5.11 and 5.12 of Chapter 5.

5A.1 Table 5A.1 shows how the values of this annex enter the design tailwater levels of Table 5.1. The sea-level allowance is set by Clause 5.7.4 and does not depend on this annex.

Table 5A.1 — Use of the Annex 5A values in the design tailwater (Table 5.1)

Design case	Tailwater	Annex 5A values used	Chapter value
Minor-system design	MHWS + SLA	MHWS	SLA ≥ +0.3 m (Clause 5.7.4)
Major-system and storage design	HAT + surge + SLA	HAT; 10% AEP surge (Clause 5.7.3(a))	SLA ≥ +0.3 m
Joint case (Clause 2.12(b))	1% AEP still-water level + SLA	1% AEP still-water level (Clause 5.7.3(b))	SLA ≥ +0.3 m
Datum conversion	Chart datum to project datum	Offset from chart datum to the Survey of India datum (Clause 5.7.2(b))	—

Not prepared for Rajasthan. Rajasthan has no coast, so no outfall in the State has a tidal tailwater, and this annex has no Rajasthan content (Clause 5.1.4). Its tables are kept, empty, so that the annex and table numbers match the other editions of this Manual. Rows F1 to F7 of Form 5-1 are entered as "not applicable", and the tailwater is derived under rows F8 to F10; for a site with no defined outfall, row F10 records the 72-hour design volume and the overflow path instead (Clause 5.8.5(a)).

Table 5A.2 — Tidal datums, surge and still-water levels by coastal segment (layout)

Coastal segment	Reference port and tide-table edition	MSL (m CD)	MHWS (m CD)	HAT (m CD)	CD to Survey of India datum (m)	10% AEP surge (m)	1% AEP still-water level (m CD)	Wave set-up (m), open-sea outfalls	Sources

Coastal segment	Reference port and tide-table edition	MSL (m CD)	MHWS (m CD)	HAT (m CD)	CD to Survey of India datum (m)	10% AEP surge (m)	1% AEP still-water level (m CD)	Wave set-up (m), open-sea outfalls	Sources

Annex 5B — Major drains, riverine outfall reaches, and river mouths subject to sand-bar closure; map

Supports Clauses 5.2, 5.3, 5.8 and 5.13 of Chapter 5.

5B.1 Table 5B.1 lists the water bodies that Chapter 5 already names. It is not complete: the annex will add the extents of each reach, the other rivers, canals and mouths of the State, and a map.

Table 5B.1 — Water bodies named in Chapter 5

Water body	Region	Listed as	Clause
Chambal at Kota City, below the Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar dams and the Kota Barrage	Kota	Riverine outfall reach; dam-release river; design river level not below the transferred 248.68 m (16 September 2019); danger 242 m (240 m in 2019), warning 239 m; largest recorded release (up to 7.9 lakh cusec, as reported, September 2019) included; gauge position relative to the barrage and datum [TBC]; lock of at least 72 hours	5.8.1, 5.8.3, 5.8.5
Kota Barrage pond	Kota	Lake outfalls; FRL 260.3 m; MWL 260.9 m or 261.2 m (261.2 m applies until WRD confirms [TBC]); WRD's consent	5.8.3, 5.8.5
Chambal at Dholpur	Dholpur	Riverine outfall reach; design river level not below the transferred 145.54 m (23 August 1996); danger 130.79 m (129.79 m in 2019); releases of the Chambal dams included; datum [TBC]	5.8.1, 5.8.3, 5.8.5
Banas at Tonk below the Bisalpur dam	Tonk	Riverine outfall reach; danger 262.8 m above the highest recorded level, 262.05 m (9 September 1973), so 262.8 m is the floor of both cases; Bisalpur releases (FRL 315.5 m) included; datum [TBC]	5.8.1, 5.8.3, 5.8.5
Luni at Balotra	Balotra, Barmer	Riverine outfall reach; flash floods; design river level not below the transferred 108.755 m (18 July 1979); no danger level found [TBC]	5.8.1, 5.8.5
West Banas at Abu Road; Gambhiri at Chittorgarh	Sirohi; Chittorgarh	Riverine outfall reaches; design river level not below the transferred 265.4 m (Abu Road, 31 August 1973) and 409.24 m (Chittorgarh, 24 July 1992); danger 259 m and 407.9 m; datum [TBC]	5.8.1, 5.8.5
Dravyavati (the former Amanishah nala) and the Dhund below it	Jaipur	Major drain and riverine outfall reach; channel designed for the 100-year flood (JDA), design discharge and levels not found [TBC]; JDA's design profile or a model required	5.2, 5.8.1, 5.8.5
Naharika, Ambabari, Ganda, Jawahar, Brahmapuri and Nagtalai nalas and the other nalas of Jaipur	Jaipur	Major drains	5.2

Water body	Region	Listed as	Clause
Jojari and Bandi, and the Bhairav, RTO and other nalas of Jodhpur	Jodhpur	Major drains and riverine outfall reaches; no gauge level found [TBC]; modelled or surveyed level required; 100 m from the edge of the Jojari (Supreme Court, interim, as reported; Chapter 7)	5.2, 5.8.1, 5.8.5
Pichola, Swaroop Sagar and Fateh Sagar, the Ayad (Ahar) and Udai Sagar	Udaipur	Lake outfalls in a chain; full levels only as gauge readings (Pichola 11 ft, Fateh Sagar 13 or 14 ft, Udai Sagar 24 ft, as reported), metres [TBC]; survey tie of the gauge zero required; tailwater MWL, or FTL + 0.5 m and not below the highest recorded level; Ayad a riverine outfall reach with no gauge level found [TBC]; no-construction zone (Chapter 7)	5.2, 5.8.1, 5.8.5
Ana Sagar and its escape channel	Ajmer	Lake outfalls; full gauge 13 ft, highest reported reading 15 ft 11 in (July 2025), metres [TBC]; survey tie required; four escape gates; channel below the gates with the largest opening on record; wetland orders (Chapter 7)	5.8.1, 5.8.3, 5.8.5
Kailana and Takhat Sagar	Jodhpur	Lake outfalls; FRL 273.7 m and 269.75 m above MSL (NIH, 2025); tailwater 274.2 m and 270.25 m where no MWL is published; fed by the Rajiv Gandhi Lift Canal; custodian's consent [TBC]	5.8.5
Man Sagar (Jal Mahal) and the Ramgarh dam	Jaipur	Lake outfalls; FTL not found [TBC]; custodian's consent; Ramgarh catchment orders (Chapter 7)	5.8.5
Ghaggar at Hanumangarh and Sri Ganganagar	Hanumangarh, Sri Ganganagar	Riverine outfall reach; no gauge level found [TBC]; modelled or surveyed level required	5.8.1, 5.8.5
Sambhar Lake and the closed depressions of the inland drainage	The Sambhar basin, the Thar, Shekhawati and the canal command	No outfall; 72-hour design volume (Clause 4.12.7); Sambhar a Ramsar site	5.8.5
Drains and canals of WRD, the Indira Gandhi Canal (IGNP), its distributaries and escapes, irrigation and lift canals receiving storm water, and drains of Municipal Corporations, Municipal Councils, Municipal Boards, development authorities, Urban Improvement Trusts and RIICO 1.0 m wide or more	Rajasthan	Major drains; owner's consent, design water level and flap gate; a supply canal or an IGNP escape is not a drainage outfall without WRD's written consent	5.2, 5.8.5
Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar dams and the Kota Barrage; Bisalpur dam; Panchana dam; Ana Sagar escape gates; the gates of the Udaipur lakes	Chambal; Banas; Karauli; Ajmer; Udaipur	Releases and gate operation to be included in river and lake levels (operating rules and release records [TBC])	5.8.3, 5.8.5
River mouths subject to sand-bar closure	None in Rajasthan	Not applicable (Clause 5.1.4)	5.13.1

To be prepared. This annex will list and map (a) the major drains of each basin plan, (b) the riverine outfall reaches where backwater shall be modelled, with their upstream and downstream limits and the source of their design flood levels, and (c) the river mouths and creek inlets subject to seasonal sand-bar closure, with the most recent pre-monsoon bar crest levels and any WRD mouth-maintenance programme. It needs WRD river and canal records, design and recorded flood levels, reservoir operating rules, mouth-condition, dredging and bar-cutting records and pre-monsoon bar surveys (WRD), the drain inventories of JMC and other local bodies, basin stormwater master plans (Chapter 11), and base mapping from the Survey of India and NRSC. Until it is published: every river, WRD canal, the Dravyavati (the former Amanishah nala) of Jaipur and the Dhund to which it discharges, the Naharika, Ambabari, Ganda, Jawahar, Brahmapuri and Nagtalai nalas and the other nalas of Jaipur, the Jojari and the Bandi and the Bhairav, RTO and other nalas of Jodhpur that drain to the Jojari, the Ayad (Ahar) at Udaipur, the escape channel of Ana Sagar at Ajmer, the nalas of Kota that drain to the Chambal, any drain or canal of WRD, including the Indira Gandhi Canal (IGNP) and its distributaries and escapes, any drain maintained by a Municipal Corporation, a Municipal Council, a Municipal Board, a development authority, an Urban Improvement Trust or RIICO with an internal width of 1.0 m or more, any irrigation canal that receives storm water and every tidal creek is a major drain (Clause 5.2); the water bodies of Table 5B.1 are riverine outfall reaches (Clause 5.8.1); and the mouths of the coastal States' rivers (there is none in Rajasthan) are assumed closed at the start of the SW monsoon unless WRD certifies otherwise (Clause 5.13.2).

Table 5B.2 — Attributes of the Annex 5B layers (layout)

Field	Content	Unit or format
feature_id	Unique identifier	text
name	Name of the drain, river, canal, creek or mouth	text
category	Major drain; riverine outfall reach; mouth subject to sand-bar closure	text
clause	Clause of Chapter 5 under which it is listed	text
reach_limits	Upstream and downstream limits of the reach	text
design_flood_level_source	WRD design or highest recorded flood level, or hydraulic model (Clause 5.8.2)	text
reservoir_release	Upstream reservoir or tank and its operating rule, where any (Clause 5.8.3)	text
bar_crest_level	Most recent pre-monsoon bar crest level, for mouths	m (Survey of India datum)
mouth_programme	WRD mouth-maintenance programme and certification (Clause 5.13.2)	text
source	Source agency and date	text
geometry	Line (drains and reaches) or point (mouths)	line / point

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Annex 5C — Worked example: outfall-closed check for a site on a Dravyavati tributary nala in south Jaipur

Supports Clauses 5.9, 5.10, 5.11 and 5.12 of Chapter 5 and Clause 4.6.6 of Chapter 4.

Illustrative — not design values. This example applies the outfall-closed check of Clause 5.10 to the revised detention facility of Annex 4C. The site, its levels and its receiving drain are invented to show the method. No tidal level is used: the tide enters only through the illustrative statements in Table 5C.1 about whether the receiving drain is above or below the site outlet.

Inputs

5C.1 The site is the 2.0 ha flood-sensitive site of Annex 4C. It discharges through its own outlet chamber and a flap gate to a public storm drain that joins a tributary nala of the Dravyavati in south Jaipur, whose level rises when the Dravyavati runs high in a storm, so Clause 5.10.1 applies to the facility. To show the method, this example uses the two 6-hour lock windows of Clause 5.10.3, as the coastal editions of this Manual do. In Rajasthan an outfall below the design level of a lake is closed for the whole storm, a river-locked outfall has a single lock of at least 72 hours under Clause 5.8.5, covering the whole storm, and a site with no defined outfall must hold the 72-hour design volume of Clause 4.12.7, so in each of those cases the facility must store or pump the whole storm volume (Clause 5.9.4); that needs more storage, or pumping, than this example shows. The routing, the volume balance of Clause 5.10.4 and the assessment are the same.

Table 5C.1 — Inputs (Illustrative — not design values)

Item	Value	Basis
Facility	Revised facility of Annex 4C: 2,500 m² plan area, vertical walls; 170 mm orifice at the floor; 460 mm orifice, invert 0.53 m	Annex 4C, Table 4C.14
Storm	1% AEP, 48 h, peak day last, AMC III; 72 h also run	Clause 5.10.2
Inflow	Post-development 1% AEP hydrographs of Annex 4C (48 h: 8,420 m³; 72 h: 9,468 m³)	Annex 4C
Receiving drain levels at the connection, J1, J2 and J3	Below the site outlet invert (from the drain owner's model)	Illustrative input
Receiving drain during each lock window	Backs up above the site outlet invert, so the site cannot discharge	Illustrative input; Clause 5.10.3(b)
Flap gate on the site outlet	Set 0.15 m below the orifice inverts in the outlet chamber, so that outside the lock windows its opening head and head loss do not affect the orifice control	Illustrative input; to be confirmed from the certified curve (Clause 5.11.2)
Lock windows	Two of 6 h each, starts 12.4 h apart (semi-diurnal tide)	Clause 5.10.3(a)
Pumps	None	—

5C.2 **Cases of Table 5.2.** Because the receiving drain stays below the site outlet in J1, J2 and J3 (Table 5C.1), those cases give the free-outfall results of Annex 4C: in J2 the 1% AEP maximum water level is **1.17 m** (2,913 m³), and in J3 (10% AEP, 48 h) it is 0.77 m. R1 and R2 do not apply, because the site does not drain to a river. J4, the outfall-closed check, is worked below.

Lock windows (Clause 5.10.3)

5C.3 The peak 1-hour block of the final 24 hours of the 48-hour storm is 35:35–36:35 h, with 98.2 mm (the 1-hour depth of Table 4C.2). Two runs are made:

- **Run A:** the first window is centred on that block: 33:05–39:05 h; the second starts 12.4 h later: 45:29–51:29 h.
- **Run B:** the first window starts at that block: 35:35–41:35 h; the second: 47:59–53:59 h.

For the 72-hour storm, every time is 24 h later.

5C.4 Gravity discharge is zero inside each window. Outside the windows the outlet discharges through the orifices of Table 4C.10. The routing is the same level-pool routing as in Annex 4C.

Results

Table 5C.2 — Outfall-closed check results (Illustrative — not design values)

Storm	Run	Lock windows (h:min)	Maximum stage (m)	Maximum storage (m³)	Time of maximum (h:min)	Largest release after a window (L/s)
1% AEP, 48 h	A	33:05–39:05; 45:29–51:29	2.01	5,019	39:05	566
1% AEP, 48 h	B	35:35–41:35; 47:59–53:59	**2.10**	**5,238**	41:35	584
1% AEP, 72 h	A	57:05–63:05; 69:29–75:29	2.00	5,012	63:05	565
1% AEP, 72 h	B	59:35–65:35; 71:59–77:59	2.09	5,233	65:35	584

Run B of the 48-hour storm governs. The first window closes the outlet just as the storm peak arrives, so the whole peak is stored. The second window arrives when the facility has drained to about 0.7 m, below the Stage 2 orifice, and adds little.

5C.5 **Volume balance (Clause 5.10.4).** Table 5C.3 gives the balance for Run B. The outflow in each period is found by continuity: outflow = storage at start + inflow − storage at end.

Table 5C.3 — Volume balance, 1% AEP 48-hour storm, Run B (Illustrative — not design values)

Period (h:min)	Inflow (m³)	Gravity outflow (m³)	Pumped (m³)	Storage at start (m³)	Storage at end (m³)
0:00–35:35, before window 1	3,817	2,213	0	0	1,604
35:35–41:35, window 1	3,634	0	0	1,604	5,238
41:35–47:59, between windows	941	4,423	0	5,238	1,756
47:59–53:59, window 2	28	0	0	1,756	1,784
After 53:59	0	1,784	0	1,784	0
Total	8,420	8,420	0	—	—

Check for window 1: V_inflow = 3,634 m³ ≤ V_storage available + V_pumped + V_gravity = (5,238 − 1,604) + 0 + 0 = 3,634 m³. The facility therefore needs **5,238 m³** of storage, which the routing confirms.

Table 5C.4 — Stage hydrograph, 1% AEP 48-hour storm, Run B (Illustrative — not design values)

Time (h)	Inflow (L/s)	Outlet	Outflow (L/s)	Stage (m)	Storage (m³)
24	20	Open	18	0.18	445
28	39	Open	24	0.25	621
32	59	Open	32	0.36	906
34	85	Open	37	0.47	1,166
36	286	Closed	0	0.78	1,944
38	106	Closed	0	1.73	4,321
40	66	Closed	0	1.96	4,904

Time (h)	Inflow (L/s)	Outlet	Outflow (L/s)	Stage (m)	Storage (m³)
42	51	Open	529	1.79	4,472
44	42	Open	204	0.87	2,181
46	37	Open	49	0.74	1,854
48	33	Open	47	0.70	1,756
50	0	Closed	0	0.71	1,784
54	0	Closed	0	0.71	1,784
56	0	Open	43	0.58	1,459
60	0	Open	32	0.37	921
66	0	Open	16	0.16	397
72	0	Open	7	0.06	162

Assessment

5C.6 **Clause 5.10.4(a).** The facility of Annex 4C reaches 1.17 m in J2, and its spillway crest is at 1.35 m (Annex 4C). In the outfall-closed check the stage reaches 2.10 m, so the spillway would operate. **The facility of Annex 4C fails the check.**

5C.7 **Remedy.** Pumping (Clause 5.12) does not help here: during the lock windows the receiving drain is itself closed, and pumping into it would raise its level, which Clause 5.12.3 does not permit. The remedy is more storage. Keeping the plan area of 2,500 m² and the outlets of Annex 4C:

- the facility must hold 5,238 m³, to a stage of **2.10 m**;
- the spillway crest is set above that stage, with the 0.15 m clearance recommended in Clause 4.9.3: **2.25 m**;
- with the 4.0 m spillway of Annex 4C (head 0.30 m), the maximum level with the spillway flowing is 2.55 m, and with 0.3 m freeboard the top of the walls is at least **2.85 m** above the floor.

The outfall-closed check therefore governs the storage: 5,238 m³ against 2,913 m³ from the release-rate checks, about 80% more. A larger plan area would make the facility shallower; the outlet, caps and drawdown would then have to be re-checked, because the stage–discharge relationship changes.

5C.8 **Release after the lock.** When the first window ends, the stored water is released under a head of about 2 m, at up to 584 L/s. This is above the 100-yr cap of 356 L/s. Clause 5.10.4 allows this, because the release reaches a drain that has itself just reopened, and requires it to be included in the J4 run of the downstream analysis (Clauses 5.4 and 5.9) and reported on Form 5-1, Section H.

5C.9 **Drawdown after the storm (Clause 5.10.5).** The J1 tidal curve stays below the site outlet (Table 5C.1), so the drawdown of Annex 4C applies: 45.3 h for 90% of the 10-yr storage with the low-flow orifice 50% blocked, within the 48-hour limit of Clause 4.7. In Run B, 90% of the maximum J4 storage is released 22.6 h after the maximum.

5C.10 **Other requirements.**

- The flap gate on the site outlet is inspected and operated before 20 June each year and after every event in which it closed against a storm flow (Clause 5.11.5).
- The deeper facility is checked for flotation with groundwater at the design groundwater level; in the Ghaggar–canal plains of Sri Ganganagar and Hanumangarh and the old city of Jodhpur without piezometer readings that level is existing ground level (Clauses 4.12.1 and 4.12.3).
- The fence and signs of Annex 4C apply to the deeper facility (Clause 4.15).

Table 5C.5 — Summary (Illustrative — not design values)

Item	Value
Governing case	J4, 1% AEP 48-hour storm, Run B (first window starting at the peak 1-hour block)
Storage required	5,238 m³ (Annex 4C release-rate design: 2,913 m³)
Maximum stage	2.10 m, with 2,500 m² plan area
Spillway crest	2.25 m
Top of walls	≥ 2.85 m above the floor
Largest release after a lock window	584 L/s, to be included in the downstream J4 run
Drawdown	Annex 4C result applies: 45.3 h with the low-flow orifice 50% blocked

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Form 5-1 — Downstream and Tailwater Report

Supports Clauses 5.3 to 5.14 of Chapter 5.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. One report for each project. Sites of less than 0.5 ha that meet Clause 5.3.4 may submit Form 5-2 instead, where the Authority accepts it. Attach the plans, model files and hydrographs referred to.

A. Project

Table 5F.1 — Form 5-1: project

Field	Entry
A1. Project name, applicant and location	
A2. Project type: site under Chapter 4; drainage project under Chapter 6; regional detention or tank restoration (Clause 5.1.2)	
A3. Site or project area (ha) and outfalls	
A4. Site Runoff Control Report reference (Form 4-1), where applicable	

B. Extent of the analysis (Clause 5.3; Clause 5.14, item 1)

Table 5F.2 — Form 5-1: analysis points

Point	Location	Type (Clause 5.3.3 (a) to (e))	Contributing catchment (ha)	Project area as % of it

Table 5F.3 — Form 5-1: end point

Field	Entry
B1. End point and reason: 10% point, tank or talab, or major drain or the sea (Clause 5.3.1 (a) to (c))	
B2. Where the end point is a tank or talab: change in maximum water level (m) and in surplus-weir discharge (m^3/s); continuation below the weir if the level rises (Clause 5.3.2)	
B3. Plan of the analysis extent, showing the site, each point with its contributing area and percentage, and the end point (attach)	

C. Model (Clause 5.4.4; Clause 5.14, item 2)

Table 5F.4 — Form 5-1: model

Field	Entry
C1. Software and version; hydrologic and hydraulic methods (Clause 5.4.4)	
C2. Network schematic, with the survey sources for drains and crossings (attach)	
C3. Land use and CN of off-site areas (present land use)	

Field	Entry
C4. Upstream detention included, with evidence that it is built, maintained and documented	
C5. Calibration or validation evidence, where available	
C6. Scenarios run: existing, with project, and future where the Authority requires it (Clause 5.4.1)	
C7. Storms run: AEPs and durations, AMC and areal reduction (Clause 5.4.3)	

D. Results at each analysis point (Clause 5.4.2; Clause 5.14, item 3)

Complete one row for each analysis point, AEP and duration. E = existing; P = with project.

Table 5F.5 — Form 5-1: results by analysis point

Point	AEP	Duration (h)	Peak flow E / P (m^3/s)	Time to peak E / P (h)	Maximum water level E / P (m)	Peak velocity E / P (m/s)	Duration of inundation E / P (h)

E. Acceptance (Clause 5.5; Clause 5.14, item 4)

Table 5F.6 — Form 5-1: acceptance criteria

Criterion	Met at every point?	Where not met, the remedy adopted (Clause 5.5.3)
E1. 1% AEP water level rise ≤ 10 mm at buildings, lowest openings and carriageways (Clause 5.5.1(a))		
E2. No building newly flooded; no building or road newly failing the Chapter 6 limits (Clause 5.5.1(b))		
E3. Peak flow not above existing at the minor-system AEP of each element or at 1% AEP (Clause 5.5.1(c))		
E4. Velocity in lined channels within the lining limit, 3.0 m/s maximum (Clause 5.5.1(d))		
E5. Velocity in unlined channels, 50% and 10% AEP, not increased by more than 10% (Clause 5.5.1(e))		
E6. Change in duration of road closure on arterial or emergency routes (Clause 5.5.2)		
E7. Timing exception requested (Clause 5.5.4)? Give the conditions met		

F. Tailwater derivation (Clauses 5.6 to 5.8; Clause 5.14, item 5)

Table 5F.7 — Form 5-1: tailwater derivation

Field	Entry
F1. Tide-table edition and port, or port authority source (Clause 5.7.2(a))	

Field	Entry
F2. MHWS, HAT and MSL (m above chart datum)	
F3. Connection from chart datum to the Survey of India benchmark and the project datum: offset (m) and source (Clause 5.7.2(b))	
F4. Estuary, creek or canal outfall: levels used and any evidence for a departure from open-coast levels (Clause 5.7.2(c))	
F5. 10% AEP surge and 1% AEP still-water level: values, source, method and record length (Clause 5.7.3)	
F6. Wave set-up, for outfalls facing the open sea (Clause 5.7.3(d))	
F7. SLA (m), at least +0.3 m; design life; sensitivity run at twice the SLA for design lives over 50 years (Clause 5.7.4)	
F8. Non-tidal tailwater: receiving-system level and source (Clauses 5.6.2, 5.6.3)	
F9. River levels and sources; reservoir or tank releases included (Clauses 5.8.2, 5.8.3)	
F10. Catchments with no outfall, river-locked outfalls, lake outfalls and escape gates, rivers driven by dam releases and WRD channels and canals: for a site with no defined outfall, the 72-hour design volume, the storage below its overflow and its emptying time (Clause 4.12.7), the level of any shared basin or closed depression with and without the project and its starting level, and the overflow path traced to public land, with no discharge onto a neighbour's land or into another catchment; for a river outfall, operator of each gate and pumping station identified, gate sills, bank or wall crest, installed capacity, operating levels and gate-closing level obtained, with every level tied to the datum of the nearest CWC or WRD gauge; 1% AEP river level at the outfall from a published study or a model, with the dam releases, and not below the highest recorded level at the nearest gauge transferred to the outfall (248.68 m at Kota City, 145.54 m at Dholpur, 262.8 m at Tonk), with the profile used, or, where no gauge level exists (the Dravyavati, the Jojari, the Bandi, the Ayad, the Ghaggar), JDA's design profile, a modelled or a surveyed flood level and its source; 10% AEP river level, not below the danger level transferred; the High Flood Line for the reach where the State has demarcated it, and whether the outfall lies in an identified river corridor; drain behind the gate routed with its whole catchment and present storage, pumping confirmed available (permanent pumps only, not more than installed capacity less the largest pump), pumps operable at the design river level; single river lock of not less than 72 hours covering the whole storm, and its source; gate-failure and bank-breach checks; for a lake outfall, custodian's consent, Lakes Development Authority and State Wetland Authority permission where required, MWL or FTL plus design-flood surcharge (FTL + 0.5 m where neither is published), and not below the highest recorded level, with the levelled tie of the lake gauge zero to the project datum where the level is known only as a gauge reading in feet, outfall below it treated as closed for the whole storm, lake starting at FTL, no gate operation credited without the custodian's written rule; for an outfall below a dam, gated lake or escape, the design storm with the largest recorded release, placed before, during and after the storm; WRD consent and the court lines checked; WRD or owner's consent, permitted rate, design water level or computed channel level, and flap gate (Clause 5.8.5)	

G. Joint cases (Clause 5.9; Clause 5.14, item 6)

Table 5F.8 — Form 5-1: joint-case results

Case	Rainfall	Tailwater used (m, project datum)	Applies?	Governing result (storage, level, pipe size or pump capacity)
J1				
J2				
J3				
J4				
R1				
R2				

H. Outfall-closed check (Clause 5.10; Clause 5.14, item 7)

Table 5F.9 — Form 5-1: outfall-closed check

Field	Entry
H1. Reason the check applies (Clause 5.10.1)	
H2. Storm: AEP, 48 h and 72 h, AMC III (Clause 5.10.2)	
H3. Lock duration and basis: default of two 6-hour windows, or site study (Clause 5.10.6); extension for sand-bar closure (Clause 5.13.5)	
H4. Lock windows of the two runs (start and end times) (Clause 5.10.3(d))	
H5. Maximum stage in each facility, against its 1% AEP maximum water level (Clause 5.10.4(a))	
H6. Maximum stage in the minor and major systems, against the Chapter 6 limits (Clause 5.10.4(b))	
H7. Property connections: surcharge level, or non-return valves fitted (Clause 5.10.4(c))	
H8. Stage hydrographs (attach)	
H9. Drawdown after the storm under the J1 tidal curve, and pumping where needed (Clause 5.10.5)	

Table 5F.10 — Form 5-1: volume balance for each lock window (Clause 5.10.4)

Period	Inflow (m³)	Gravity outflow (m³)	Pumped (m³)	Storage at start (m³)	Storage at end (m³)
Before window 1					
Window 1					
Between windows					
Window 2					
After window 2					

I. Gates and valves (Clause 5.11; Clause 5.14, item 8)

Table 5F.11 — Form 5-1: schedule of flap gates, tide gates and non-return valves

Location	Type	Size (mm)	Invert (m, project datum)	Certified head–discharge data (reference)	Stop-log or penstock (outfalls > 600 mm)

J. Pumped outfalls (Clause 5.12; Clause 5.14, item 9)

Table 5F.12 — Form 5-1: pumped outfalls

Field	Entry
J1. Reason pumping is needed (Clause 5.12.1)	
J2. Duty capacity (m³/s) at the static head for the J2 tailwater; standby capacity (Clause 5.12.2)	
J3. Effect on the receiving water level (Clause 5.12.3)	
J4. Power supply: two independent supplies, or standby generation with 72 h of fuel; automatic changeover (Clause 5.12.4)	
J5. Level of electrical panels, controls, generators and fuel, against the higher of the 1% AEP flood level + 0.5 m and HAT + surge + SLA + 0.5 m (Clause 5.12.5)	

Field	Entry
J6. Discharge arrangement (Clause 5.12.6); controls, alarms and logging (Clause 5.12.7); screens (Clause 5.12.8)	

K. Sand bar (Clause 5.13; Clause 5.14, item 10)

Table 5F.13 — Form 5-1: sand-bar assumption

Field	Entry
K1. River mouth or creek inlet concerned	
K2. Mouth assumed closed, or open with WRD certification attached (Clause 5.13.2)	
K3. Bar crest level from the most recent pre-monsoon survey (m) and the closed-mouth tailwater (Clause 5.13.3)	
K4. Extension of the lock duration, where required (Clause 5.13.5)	

L. Inspection and maintenance (Clause 5.14, item 11)

Table 5F.14 — Form 5-1: inspection and maintenance

Field	Entry
L1. Gate and valve inspection before 20 June and after closure events (Clause 5.11.5)	
L2. Pump test runs before 20 June (Clause 5.12.9)	
L3. Other requirements for the maintenance plan (Chapter 10)	

M. Statement by the registered professional (Clause 10.6)

I state that this report has been prepared under Chapter 5 of the Rajasthan Stormwater Design Manual (Draft v1.0), that the results reported are reproduced by the models submitted, and that every departure from Chapter 5 is listed with its reason. The Professional Design Certificate (Form 10-3) is attached.

Table 5F.15 — Form 5-1: statement by the registered professional

Field	Entry
Name	
Qualification and registration number	
Empanelment number, where Clause 10.6.1 requires it	
Organisation	
Signature	
Date	

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0.

Form 5-2 — Simplified Downstream Statement (small sites)

Supports Clause 5.3.4 of Chapter 5.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. For sites of less than 0.5 ha. The Authority may accept this statement in place of the full analysis only where every answer in Section B is "Yes". Otherwise submit Form 5-1.

A. Site

Table 5F.16 — Form 5-2: site

Field	Entry
A1. Project name, applicant and location	
A2. Site area (ha), less than 0.5 ha	
A3. Receiving public drain: name or reference, type and size	
A4. Site Runoff Control Report reference (Form 4-1)	

B. Conditions (Clause 5.3.4)

Table 5F.17 — Form 5-2: conditions

Condition	Yes / No	Evidence
B1. The receiving public drain has documented capacity for its minor-system design flow (Chapter 6)		
B2. No flood-prone location is recorded within 500 m downstream of the site outfall. Records checked: local body, JMC, RSDMA, WRD (Clause 5.3.3(d))		
B3. The site does not drain to a tidal or backwater-affected outfall		

C. Route plan

Table 5F.18 — Form 5-2: attachments

Attachment	Attached?
C1. Plan of the drainage route from the site outfall for 500 m downstream, with the receiving drain and any recorded flood-prone locations	
C2. Copy or reference of the drain capacity record	

D. Statement

I state that the site meets the conditions of Clause 5.3.4 as shown above, and that the records listed have been checked.

Table 5F.19 — Form 5-2: statement

Field	Entry
Name	
Qualification and registration number	
Signature	
Date	

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0.

ANNEXES TO CHAPTER 6

Minor and Major Drainage Systems

These annexes support Chapter 6. Annex 6A (standard inlets and their capacity curves) and Annex 6B (sediment yield) need test and survey data that are not yet available; each states what it will contain and the interim rule to use until it is published. Annex 6C gives standard drawings that carry only the dimensions Chapter 6 and Chapter 9 already set; every other dimension is marked "to be confirmed in design". Form 6-1 is a draft form: it lists what Clause 6.15 requires and does not add to it.

Annex 6A — Standard inlet types for Rajasthan with capacity curves (on grade and sag)

Supports Clauses 6.6.1 to 6.6.7 of Chapter 6 and Clause 9.11 of Chapter 9.

To be prepared. This annex will contain a short list of standard inlet types for Rajasthan streets (kerb-opening, grate and combination inlets, including the road-level wall opening into a covered drain) and, for each type, capacity curves on grade and in a sag. It needs a fixed set of standard inlet geometries agreed with the road-owning agencies, and rating tests of those geometries (laboratory or full-scale), or HEC-22 calculations for each geometry checked against tests (data and likely sources: Public Works Department (PWD), NHAI and Jaipur Municipal Corporation standard details, MNIT Jaipur, IIT Jodhpur or other hydraulic laboratories, manufacturers' tested ratings). Until it is published, compute the clean capacity of the inlet actually proposed by the methods of FHWA HEC-22 (4th edition, 2024) or from the manufacturer's tested rating for that exact geometry (Clause 6.6.2), reduce it by the clogging factors of Table 6.5 (Clause 6.6.3), and meet the interim requirements of Table 6A.1.

Table 6A.1 — Interim requirements for inlets until Annex 6A is published (from Chapters 6 and 9)

Item	Requirement	Clause
Inlet type on public streets	Kerb-opening or combination inlets, unless the Approving Authority accepts grate-only inlets for a location	6.6.1(a)
Inlet level	Openings at road level; gutter depression where practicable	6.6.1(b)
Clean capacity	FHWA HEC-22 (4th ed., 2024) or the manufacturer's tested rating for the exact geometry; CPHEEO §5.6.2 equations as a cross-check only	6.6.2
Clogging, on grade	Grate 50%; kerb opening 10%	6.6.3, Table 6.5
Clogging, in a sag	Grate 50%; kerb opening 20%	6.6.3, Table 6.5
Spacing	By sequential calculation from the top of each gutter run; not more than 30 m on kerbed roads	6.6.4
Kerb opening size	Clear height at least 100 mm; length at least 1.0 m	9.11.4
Grate pattern	Openings parallel to the direction of travel not wider than 25 mm	9.11.3(a)

Item	Requirement	Clause
Load class	D400 in carriageways and medians; C250 within 0.5 m of the kerb; B125 in footpaths and cycle tracks (or the equivalent IS class)	9.11.2
Connection pipe	At least 300 mm diameter; gradient giving at least 0.9 m/s at the inlet's design flow	6.6.6
Silt sump	At least 300 mm deep below the outlet pipe invert, cleanable from the surface	6.6.7, 9.11.6

The intended layout of the annex is given in Tables 6A.2 to 6A.4.

Table 6A.2 — Register of standard inlet types (layout)

Type code	Description	Grate size or kerb opening (mm)	Gutter depression (mm)	Load class	Standard drawing
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Table 6A.3 — Capacity on grade (layout; one table per inlet type)

Cross slope Sx (m/m)	Longitudinal slope SL (m/m)	Gutter flow Q (L/s)	Spread T (m)	Clean intercepted flow (L/s)	Design intercepted flow after clogging (L/s)	Bypass flow (L/s)
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____

Table 6A.4 — Capacity in a sag (layout; one table per inlet type)

Ponded depth at the inlet (mm)	Clean capacity (L/s)	Clogging factor (Table 6.5)	Design capacity (L/s)	Flow regime (weir, orifice or transition)
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Annex 6B — Sediment yield for silt-trap sizing and calibration of the sediment allowance

Supports Clauses 6.7.4, 6.7.8, 6.13.3 and 6.13.10 of Chapter 6.

To be prepared. This annex will contain sediment yields for urban drains in Rajasthan, by land use and drain type, for sizing the silt traps of Clause 6.13.3, and a calibration of the sediment allowance of Clause 6.7.8 against measured silt depths. It needs desilting records (volume or mass removed per drain length and per catchment area, with dates), silt-depth surveys before and after the south-west monsoon, and catchment land-use and soil data (data and likely sources: desilting records of Jaipur Municipal Corporation and other urban local bodies, WRD records for channels, land cover from NRSC, soils from the Rajasthan soil survey and NBSS&LUP, rainfall from IMD). Until it is published, size each silt trap from the designer's stated estimate of the sediment expected between scheduled cleanings, based on the desilting records of the same drain or of similar drains in the same local body, and state the cleaning interval assumed; the interval shall not be longer than the yearly pre-monsoon desilting of Clause 6.13.10. Inlet silt sumps remain at least 300 mm deep (Clause 6.6.7), and the sediment allowance of Clause 6.7.8 applies unchanged.

The intended method is a simple volume balance, with every term to be stated in the design:

> $V_{trap} = Y \cdot A \cdot t_c$

where V_{trap} is the sediment storage volume of the trap below its outlet invert (m^3), Y is the sediment yield for the catchment's land use and drain type (m^3/ha per year, from Table 6B.2 once published), A is the catchment area draining to the trap (ha), and t_c is the scheduled cleaning interval (years). The annex will state whether a safety margin is added.

Table 6B.1 — Sediment allowances already set by Chapter 6 (provisional, to be calibrated)

Element	Sediment allowance at the invert	Clause
Open and covered drains	Greater of 75 mm and 10% of the clear internal depth	6.7.8(a)
Pipes of 600 mm diameter or more	5% of the internal diameter	6.7.8(b)
Pipes below 600 mm	No allowance; minimum velocity of Clause 6.7.3(a) applies	6.7.8(c)
Drains and pipes that cannot reach the minimum velocity	Allowance doubled; mechanical desilting access provided	6.7.4(b), (c)
Inlet silt sumps	At least 300 mm below the outlet pipe invert	6.6.7

Table 6B.2 — Sediment yield by land use and drain type (layout)

Land use or catchment type	Drain type	Sediment yield Y (m^3/ha per year)	Bulk density (t/m^3)	Local body and records used	Years of record
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Table 6B.3 — Calibration of the sediment allowance (layout)

Drain or pipe ID	Clear internal depth or diameter (mm)	Allowance under Clause 6.7.8 (mm)	Measured silt depth before pre-monsoon desilting (mm)	Measured silt depth at the end of the monsoon (mm)	Ratio of measured to allowance
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Annex 6C — Standard drawings: covered roadside drain with removable covers, access chamber, inlet with silt sump

Supports Clauses 6.6, 6.7.6 to 6.7.10 and 6.13 of Chapter 6, and Clauses 9.11 and 9.12 of Chapter 9.

The drawings below are schematic standard drawings. They show only the dimensions that Chapter 6 and Chapter 9 set. Wall and slab thicknesses, reinforcement, concrete grade and cover, chamber plan sizes and frame details are to be confirmed in design: they come from the structural design (Clause 9.1.2) and the exposure class of Clause 9.13. Table 6C.1 lists the dimensions shown and their source clauses.

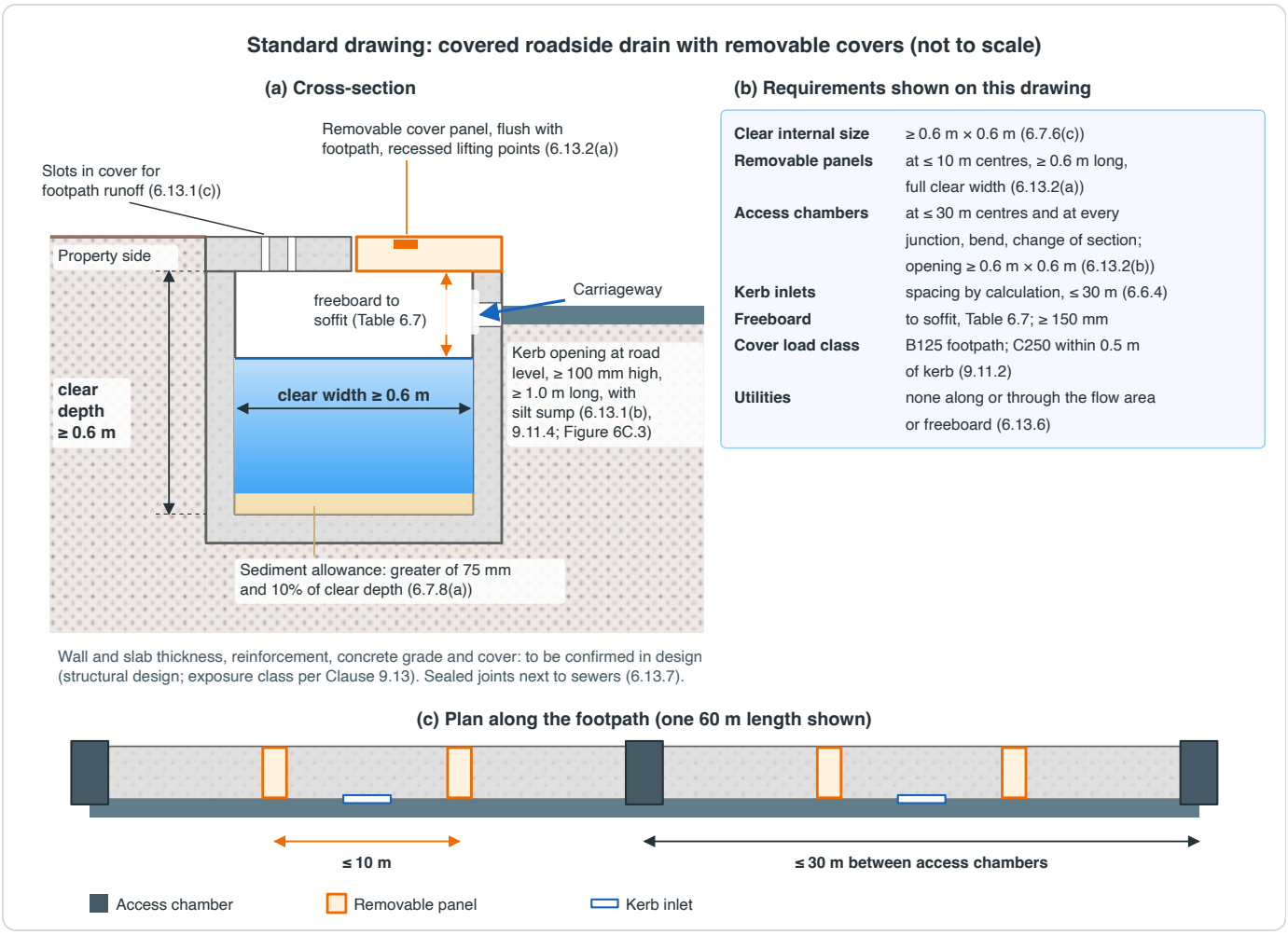

Figure 6C.1 — Standard drawing: covered roadside drain with removable covers, kerb inlets at road level, footpath slots, freeboard to the soffit and sediment allowance, with a plan of cover panels and access chambers along the footpath. Original drawing for this Manual, adapted from CPHEEO, Manual on Storm Water Drainage Systems (2019), Chapter 5, and IRC:SP:50-2013.

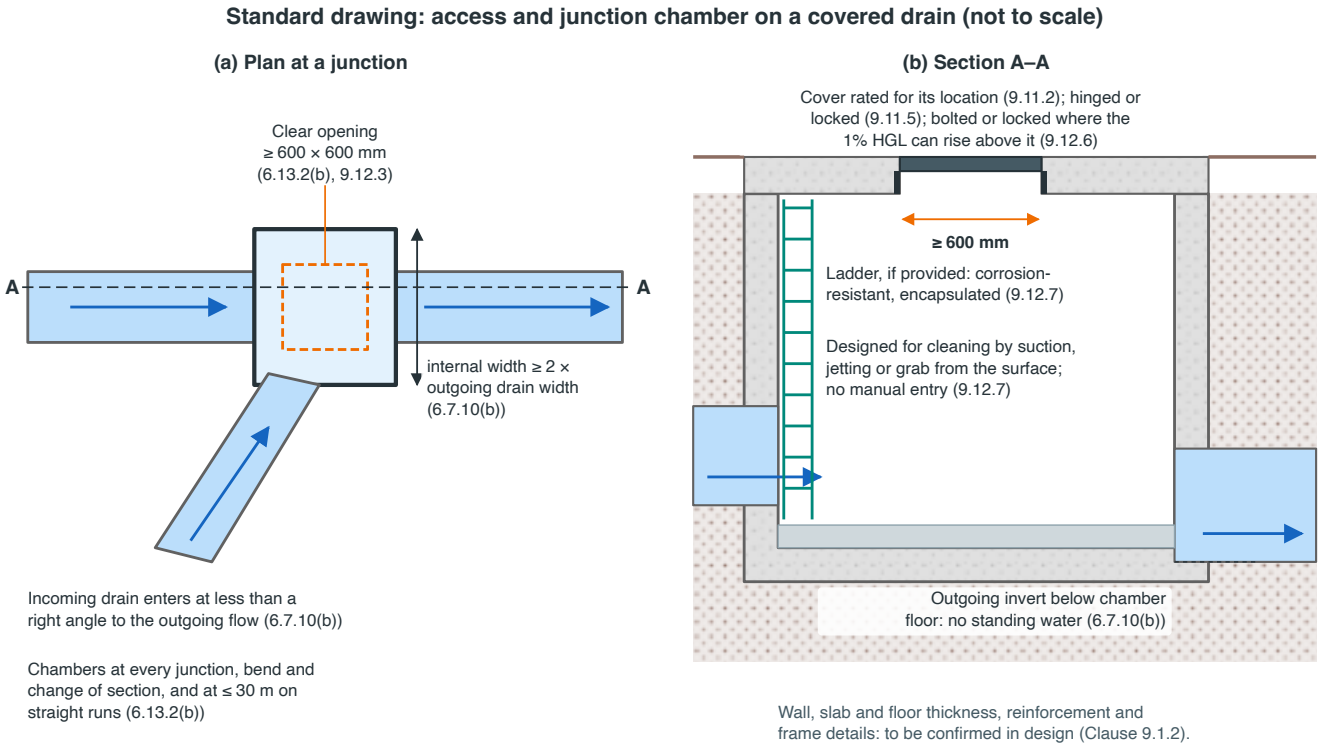

Figure 6C.2 — Standard drawing: access and junction chamber on a covered drain, with the clear opening, junction width, entry angle of the incoming drain, outgoing invert below the chamber floor, and cover requirements. Original drawing for this Manual, adapted from CPHEEO, Manual on Storm Water Drainage Systems (2019), §5.3.4 and Chapter 11.

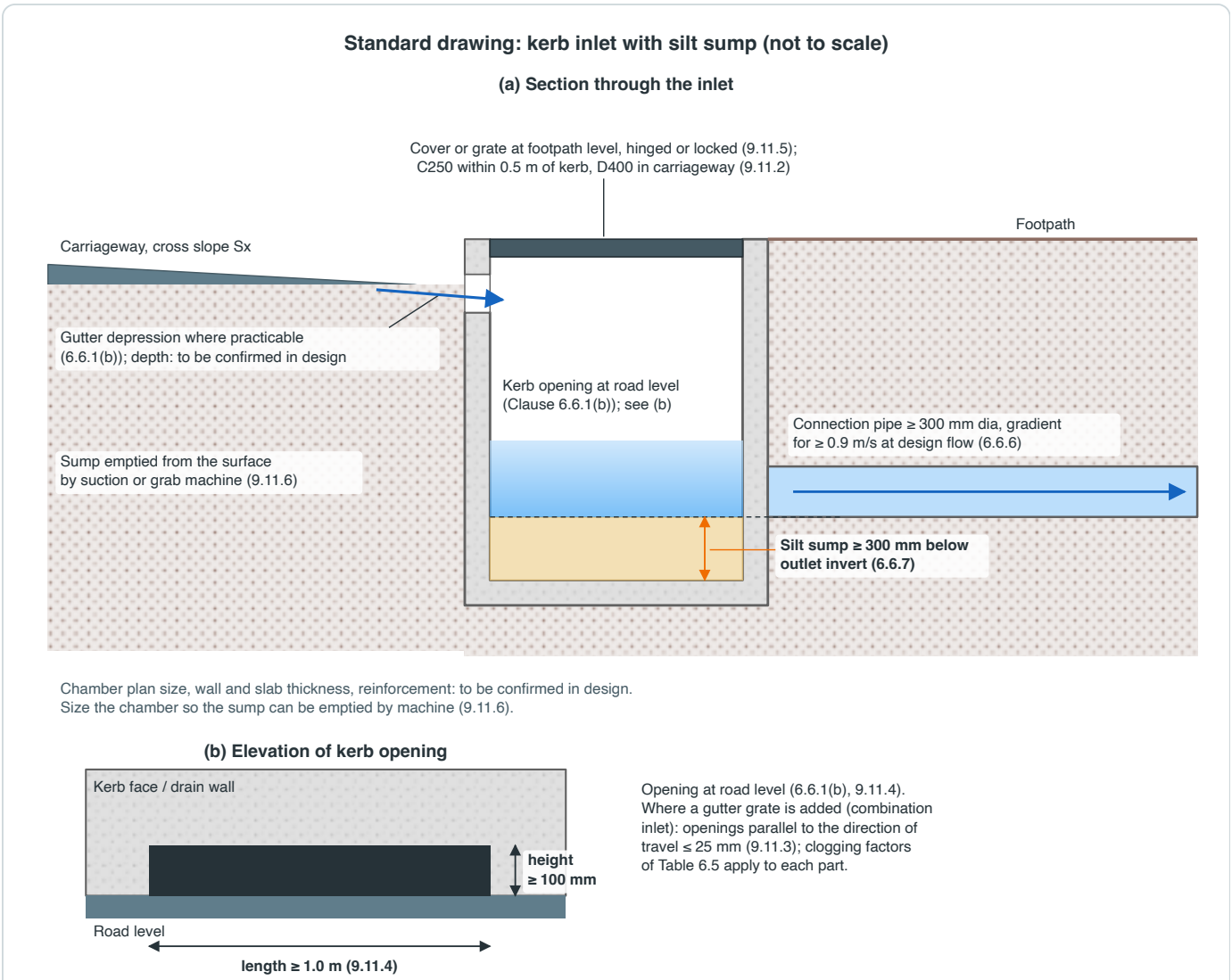

Figure 6C.3 — Standard drawing: kerb inlet at road level with silt sump, connection pipe and cover, and an elevation of the kerb opening. Original drawing for this Manual, adapted from CPHEEO, Manual on Storm Water Drainage Systems (2019), Figure 5.9, and FHWA, HEC-22 Urban Drainage Design Manual (4th ed., 2024).

Table 6C.1 — Dimensions on the standard drawings and their source clauses

Drawing	Item	Dimension or rule	Clause
6C.1	Clear internal size of a covered public drain	At least 0.6 m wide and 0.6 m deep	6.7.6(c)
6C.1	Freeboard to the cover soffit	Table 6.7; not less than 150 mm for any roadside drain	6.7.9, 6.13.1(a)
6C.1	Sediment allowance	Greater of 75 mm and 10% of clear depth	6.7.8(a)
6C.1	Removable cover panels	At not more than 10 m centres; each at least 0.6 m long and spanning the full clear width; recessed lifting points; flush with the footpath	6.13.2(a)
6C.1	Footpath runoff	Through slots or grated openings in the cover	6.13.1(c)
6C.1	Kerb inlets	Openings in the drain wall at road level, each with a silt sump; spacing by calculation, not more than 30 m	6.13.1(b), 6.6.4
6C.1, 6C.2	Access chambers	At every junction, bend and change of section, and at not more than 30 m centres on straight runs	6.13.2(b)

Drawing	Item	Dimension or rule	Clause
6C.2	Clear access opening	At least 0.6 m × 0.6 m (600 mm)	6.13.2(b), 9.12.3
6C.2	Junction chamber	Internal width at least twice the outgoing drain width; incoming drains at less than a right angle; outgoing invert below the chamber floor	6.7.10(b)
6C.2	Covers	Load class for the location; hinged or locked; bolted or locked where the 1% AEP HGL can rise above the cover	9.11.2, 9.11.5, 9.12.6
6C.2	Cleaning	By machine from the surface; ladders, where provided, corrosion-resistant and encapsulated	9.12.7
6C.3	Kerb opening	At road level; clear height at least 100 mm; length at least 1.0 m	6.6.1(b), 9.11.4
6C.3	Silt sump	At least 300 mm below the outlet pipe invert; emptied by suction or grab machine	6.6.7, 9.11.6
6C.3	Connection pipe	At least 300 mm diameter; at least 0.9 m/s at the design flow	6.6.6
6C.3	Grate in a combination inlet	Openings parallel to travel not wider than 25 mm; Table 6.5 clogging on each part	9.11.3, 6.6.3
All	Wall and slab thickness, reinforcement, concrete grade and cover, chamber plan size, gutter depression depth	To be confirmed in design	9.1.2, 9.13

Form 6-1 — Conveyance Design Report checklist

Supports Clause 6.15 of Chapter 6.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Not for statutory use.

Attach this checklist to the front of the Conveyance Design Report. For each item, enter Yes, No or Not applicable, and the drawing or page where it is shown.

Section A — Project

Table 6F.1 — Form 6-1, Section A: project

Field	Entry
Project name and location	_____
Local body, and Tier A or Tier B (Chapter 1)	_____
Applicant	_____
Designer (name and registration)	_____
Total catchment area served (ha)	_____
High-density area status for the 10% AEP minor system (Clause 6.4.4)	_____
Within the coastal band of Clause 6.11.6 (Yes / No)	_____
Date and revision	_____

Section B — Contents required by Clause 6.15

Table 6F.2 — Form 6-1, Section B: contents required by Clause 6.15

No.	Item	Clause	Provided (Yes / No / NA)	Drawing or page
1	Catchment plan: sub-catchments, minor system, inlet locations and the 1% AEP major-system overland flow paths	6.3.2		
2	Land-use and road-class AEP adopted for each element, and the high-density area status	Table 6.1, 6.4.4		
3	Design flows, with the rainfall sheet of Chapter 2 and the method of Chapter 3	6.3.4		
4	Gutter spread, depth and D·V checks for the minor, check and 1% events	Tables 6.2, 6.3		
5	Inlet schedule: clean capacity, clogging factor, design capacity and bypass flow	6.6		
6	Pipe and drain design tables: n, velocity, sediment allowance and freeboard	6.7		
7	HGL profiles for the minor and check events, with the tailwater used	6.8		
8	Sag ponding levels, including the fully-blocked check	6.10		
9	Floor-level schedule for every building	6.11		
10	Culvert and crossing calculations (with Form 9-1)	6.12, Chapter 9		

No.	Item	Clause	Provided (Yes / No / NA)	Drawing or page
11	Utilities-crossing schedule and access-opening layout for covered drains	6.13		

Section C — Design basis

Table 6F.3 — Form 6-1, Section C: design basis

Field	Entry	Clause
Minor-system design AEP adopted	_____	Table 6.1
Road class(es) and design / check AEPs for road drainage and crossings	_____	Table 6.1, 6.4.2
Rainfall source and climate factor applied	_____	6.3.4, Chapter 2
Method: Rational Method (catchment ≤ 16 ha, single element) or hydrograph method with routing	_____	6.3.4(a), (b)
Minimum time of concentration used (not less than 10 min)	_____	6.3.4(c)
Tailwater at the outfall for the HGL (MHWS + 0.3 m at tidal outfalls, or the receiving level)	_____	6.8.2
Any transfer of flow between natural catchments (none unless accepted under 6.3.5)	_____	6.3.5

Section D — Compliance checks

Table 6F.4 — Form 6-1, Section D: compliance checks

No.	Check	Limit	Clause	Complies (Yes / No / NA)
D1	Every inlet, sag, pipe, drain, culvert and storage element has a 1% AEP overland path	Shown on plan	6.3.2	
D2	Major-system flow = 1% AEP peak less the clogged minor-system capacity	Computed at each point	6.3.3	
D3	Spread in the minor event	Table 6.2	6.5.2	
D4	Depth in the check and 1% events	≤ 150 mm at the crown; ≤ 350 mm at the deepest point	Table 6.2	
D5	Flow hazard (D·V) by location	Table 6.3	6.5.3	
D6	Inlet clogging factors applied	Table 6.5	6.6.3	
D7	Inlet spacing on kerbed roads	≤ 30 m	6.6.4(a)	
D8	Sag inlet design capacity ≥ minor design flow arriving; flanking inlets where required	—	6.6.5	
D9	Inlet connection pipes and silt sumps	≥ 300 mm dia, ≥ 0.9 m/s; sump ≥ 300 mm	6.6.6, 6.6.7	
D10	Manning's n not less than the minimum design values	Table 6.6	6.7.2	
D11	Minimum velocity at the minor design flow	0.6 m/s drains; 0.9 m/s pipes	6.7.3(a)	
D12	Maximum velocity and Froude number	3.0 m/s lined drains and pipes; Fr ≤ 0.8	6.7.3(b), (d)	

No.	Check	Limit	Clause	Complies (Yes / No / NA)
D13	Where minimum velocity cannot be met: velocity reported, sediment allowance doubled, desilting access provided	—	6.7.4	
D14	Pipes sized for pipe-full capacity, not the 0.95-depth peak	—	6.7.5	
D15	Minimum sizes	Pipes 300 mm (450 mm public mains); open drain bed 0.3 m; covered public drains 0.6 m × 0.6 m	6.7.6	
D16	Cover to pipes; flotation check where groundwater is within 1 m of the crown	≥ 0.6 m; ≥ 0.9 m under carriageways	6.7.7	
D17	Sediment allowance in capacity	6.7.8 values	6.7.8	
D18	Freeboard, including superelevation at bends	Table 6.7	6.7.9	
D19	Bend radii and junction sumps	6.7.10	6.7.10	
D20	Manhole spacing on straight runs	Table 6.8	6.7.11	
D21	HGL below inlet rims and manhole covers in the minor event	≥ 0.3 m	6.8.3	
D22	Manholes that can surcharge above ground: bolted or locked covers	—	6.8.4	
D23	Soffits matched or outgoing soffit lower; outgoing invert not above the lowest incoming invert	—	6.8.6	
D24	Gate and valve losses included in the HGL; non-return valves on private connections where required	—	6.8.7, 6.8.8	
D25	Overland flow paths outside streets: width, tenure, no obstruction, continuous fall	≥ 1% top width + 0.5 m each side, ≥ 3.0 m	6.9.2	
D26	Compound walls across mapped flow paths: openings pass the 1% flow at 50% blockage	—	6.9.3	
D27	Access strip along open drains with top width ≥ 2 m	≥ 3.5 m, linked to a road at ≤ 500 m	6.9.4	
D28	Drainage reserve where required: width, separate plot, no structures, markers, services, 2 m stability check	Table 6.9	6.9.6–6.9.8	
D29	Sag ponding in the 1% event, overflow route, and fully-blocked check	≤ 350 mm at the deepest point	6.10.2, 6.10.3	
D30	Trapped sags and road underpasses	6.10.4, 6.10.5	6.10.4, 6.10.5	
D31	Floor levels	≥ 1% AEP level + 0.5 m; defaults of 6.11.3 where no level is computed	6.11.1–6.11.3	
D32	Basements and building services	6.11.4, 6.11.5	6.11.4, 6.11.5	
D33	Coastal band: floor ≥ 1% still-water level + 2 × SLA (+ wave set-up where applicable) + 0.5 m; no basement rooms or plant	—	6.11.6	
D34	Culverts: design AEP, overtopping, 50% / 20% blockage check, minimum size	≥ 900 mm	6.12	

No.	Check	Limit	Clause	Complies (Yes / No / NA)
D35	Covered drains: removable panels and access chambers	≤ 10 m; ≤ 30 m	6.13.1, 6.13.2	
D36	Silt traps, screens with bypass and 50% blockage check	—	6.13.3, 6.13.4	
D37	No building over drains; no utilities in the flow area or freeboard; existing crossings deducted with 50% blockage	—	6.13.5, 6.13.6	
D38	No sewage connections; sealed joints next to sewers; edge protection on open drains deeper than 1.0 m	—	6.13.7, 6.13.8	
D39	Outfalls: tailwater, flap gates or non-return valves below the 1% still-water level, outlet protection	—	6.14	

Section E — Variances

Table 6F.5 — Form 6-1, Section E: variances

Clause	Requirement not met	Reason and proposed alternative	Approved by and date
_____	_____	_____	_____

Section F — Signatures

The report shall be prepared and signed by a registered professional, and the Professional Design Certificate (Form 10-3) attached (Clauses 10.6.1 and 10.6.3 of Chapter 10). Where a structure stands within 2 m of the edge of a drainage reserve, the stability design shall also be signed by a qualified structural engineer (Clause 6.9.8(f)).

Table 6F.6 — Form 6-1, Section F: signatures

Role	Name	Registration or empanelment no.	Signature	Date
Designer	_____	_____	_____	_____
Structural engineer (Clause 6.9.8(f), where applicable)	_____	_____	_____	_____

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0.

ANNEXES TO CHAPTER 7

Waterbodies, Talabs (Ponds) and Setbacks

These annexes support Chapter 7. They give the inventory field specification, the fixed-width setback table, a template operating rule, the desilting and restoration specification, a glossary of Hindi and Rajasthani waterbody terms, and the three forms that Clause 7.15 requires. Where an annex cannot yet be completed it says so and gives the rule to use in the meantime. The forms are draft forms; the template and model text are for consideration by a competent authority and are not in force.

Annex 7A — Statewide waterbody GIS layer and inventory fields

Supports Clauses 7.3.1, 7.3.3 and 7.3.5 of Chapter 7.

To be prepared. This annex will contain the statewide GIS layer of waterbodies required by Clause 7.3.1, prepared by each Authority with the WRD and the Revenue Department. It needs the Revenue records and khasra maps of the Revenue Department, in which talabs, johads, nadis, nalas and rivers, and the catchments of tanks and ponds where they are recorded, are entered as gair mumkin talab, nadi or nala or in other classes of land in which no khatedari rights accrue under section 16 of the Rajasthan Tenancy Act, 1955; the public tanks, streams, reservoirs, drains and watercourses vested in a Municipality under section 68 of the Rajasthan Municipalities Act, 2009; the record of lakes, with their boundaries and flow areas, and the lake boundaries and protected areas notified under the Rajasthan Lakes (Protection and Development) Authority Act, 2015 (none was found for this Manual); the waterbodies, nalas and catchments shown in master development plans; the catchment surveys made under the directions of the High Court, such as that of the Ramgarh dam; the High Flood Line and ecological buffer of each river, once demarcated under the Supreme Court's order of 7 August 2026; the boundary of every wetland notified under the Wetlands (Conservation and Management) Rules, 2017 and of the four Ramsar sites; and the wetland survey ordered by the High Court on 1 June 2026; the WRD and Gram Panchayat tank registers with FTL and MWL; surveyed levels on a common datum; the ISRO National Wetland Inventory and Assessment (NRSC); Survey of India topographic maps; and any list of waterbodies published under court directions. Until it is published, each Applicant identifies waterbodies from all the sources of Clause 7.3.3, with the larger extent governing, and records them on the Waterbody Sheet (Form 7-1).

The field specification below is complete. It is written so that every field the chapter asks for (Clause 7.3.1(a) to (g)) has a defined name, type and source, and so that the same fields can be filled from a project's Form 7-1.

7A.1 Layers

- **WB_POLY** — one polygon per waterbody: the Revenue record boundary (Clause 7.3.1(c)).
- **WB_FTL** — the surveyed FTL contour (tanks, lakes, ponds) or top of bank (channels), as a polygon or line.
- **WB_MWL** — the MWL contour of each tank, as a polygon.
- **WB_FLOOD** — the 1% AEP flood extent, where mapped (Clause 7.3.1(f)), with the floodway where delineated (Clause 7.6.1).
- **WB_STRUCT** — points for surplus weirs, sluices, regulators, inlets and drain outfalls.

- **WB_LINK** — lines for supply channels, surplus courses and the links between tanks in a cascade (Clause 7.3.1(e)).
- **WB_ENCR** — polygons of known encroachments, each with the date recorded (Clause 7.3.1(g)).
- **WB_SETBACK** — Zone 1 and Zone 2 polygons (Clause 7.4), derived from the layers above.

All layers shall carry the waterbody identifier (WB_ID) so that they can be joined. All levels shall be stated to one datum (Clause 7.3.5), named in the layer metadata.

Table 7A.1 — Attribute fields of the waterbody inventory (WB_POLY)

Field	Type	Unit / domain	Required	Content	Clause
WB_ID	Text	District code + serial	Yes	Unique identifier, never reused	7.3.1
WB_NAME	Text	—	Yes	Name as in Revenue and WRD records, with local name	7.3.1(a)
WB_NAME_HI	Text	Hindi script	Yes	Name in Hindi	7.3.1(a)
WB_TYPE	Code	Table 7A.2	Yes	Waterbody type	7.2, 7.3.1(a)
SURVEY_NOS	Text	Village, survey and subdivision numbers	Yes	Revenue survey numbers of the waterbody	7.3.1(a)
VILLAGE	Text	—	Yes	Revenue village, tehsil and district	7.3.1(a)
CUSTODIAN	Code	Table 7A.2	Yes	Custodian body	7.3.1(b)
AREA_REC	Number	ha	Yes	Area within the Revenue record boundary	7.3.1(c)
AREA_FTL	Number	ha	Tanks	Waterspread at FTL, surveyed	7.2, 7.3.1(d)
FTL	Number	m (datum)	Tanks	Full tank level	7.3.1(d)
MWL	Number	m (datum)	Tanks	Maximum water level (Clause 7.2 definition)	7.3.1(d)
MWL_BASIS	Code	WRD record / 1% AEP computed	Tanks	Which value governs MWL	7.2
TBL	Number	m (datum)	Tanks	Top bund level, lowest point	7.3.1(d)
WEIR_CREST	Number	m (datum)	Tanks	Surplus weir crest level	7.3.1(d)
WEIR_LEN	Number	m	Tanks	Surplus weir crest length	7.3.1(d)
WEIR_TYPE	Text	—	Tanks	Surplus weir type (for example fixed crest, with shutters or falling boards)	7.3.1(d)
SLUICE_N	Integer	—	Tanks	Number of sluices; details in WB_STRUCT	7.3.1(d)
SUPPLY_CH	Text	WB_ID(s)	Tanks	Supply channel(s) feeding the tank	7.3.1(d)
SURPLUS_CS	Text	WB_ID(s)	Tanks	Surplus course(s) leaving the tank	7.3.1(d)
UPSTR_WB	Text	WB_ID(s)	Cascades	Upstream tank(s) in the cascade	7.3.1(e)
DNSTR_WB	Text	WB_ID	Cascades	Downstream tank, river, drain or sea outfall	7.3.1(e)
CATCH_AREA	Number	ha	Channels	Drainage area at the downstream end of the reach (for the 8 ha trigger of Clause 7.4.1(b) and Table 7.1)	7.4.1
DATUM	Text	—	Yes	Datum of all levels; conversion from any older WRD datum	7.3.5

Field	Type	Unit / domain	Required	Content	Clause
LEVEL_DATE	Date	—	Tanks	Date of the level survey	7.7.1(a)
SSC_DATE	Date	—	Tanks	Date of the latest stage–storage survey	7.7.1(b)
FLOOD_SRC	Code	Adopted map / site study / none	Yes	Source of the 1% AEP extent	7.3.4
FLOODWAY	Code	Delineated / whole 1% extent / below MWL	Yes	Basis of the floodway	7.6.1
ENCR_KNOWN	Code	Yes / No	Yes	Known encroachment; details in WB_ENCR	7.3.1(g)
CREDITED	Code	Yes / No	Tanks	Storage counted under Clause 7.7, with the scheme reference	7.7.1
WETLAND	Code	Notified / listed / other	Wetlands	Status under Clause 7.12.1	7.12.1
SOURCES	Text	—	Yes	Sources used, from the list in Clause 7.3.3(a) to (e)	7.3.3
UPDATED	Date	—	Yes	Date of the last edit, and by whom	7.3.1

Table 7A.2 — Code lists

Code list	Values	Clause
WB_TYPE	River or dry river bed; natural drain or nala; canal; lake, sagar or reservoir; talab or pond (talab, johad, nadi); baori or kund; taanka; khadin; salt lake, playa or inland depression; marsh or low wet land; floodplain wetland or depression; abandoned quarry or borrow pit; supply channel; surplus course	7.2
CUSTODIAN	Municipal Corporation, Council or Board (RMA s. 68); development authority or UIT; WRD (division); Lakes Development Authority (Lakes Act 2015); State Government through the Collector or Tehsildar (gair mumkin talab, nadi or nala; tank-bed land); Gram Panchayat; Rajasthan State Wetland Authority (notified wetland); RIICO; private owner; other (name)	7.3.1(b)
Structure (WB_STRUCT)	Surplus weir; sluice; regulator; inlet; drain outfall; gross pollutant trap; crossing	7.3.1(d), 7.10
Encroachment (WB_ENCR)	Building; fill; road; wall; dumping; cultivation; other — each with date recorded, area (m²) and source	7.3.1(g), 7.13

Table 7A.3 — Attribute fields of structures (WB_STRUCT)

Field	Type	Unit	Content	Clause
STR_ID	Text	—	Unique identifier	7.3.1(d)
WB_ID	Text	—	Waterbody served	7.3.1(d)
STR_TYPE	Code	Table 7A.2	Structure type	7.3.1(d)
CREST_SILL	Number	m (datum)	Weir crest or sluice sill level	7.7.1(a)
LENGTH_SIZE	Text	m	Weir crest length, or sluice opening size	7.7.1(a)
GATED	Code	Yes / No	Controllable outlet (needed for a flood cushion, Clause 7.8.2(a))	7.8.2
CONDITION	Code	Serviceable / defective	Result of the latest pre-monsoon inspection, with date	7.7.1(d), 7.14.4

Annex 7B — Fixed-width setback table (alternative S-3, with Annex 1C)

Supports Clauses 7.3.4, 7.4.3, 7.4.6 and 7.4.7 of Chapter 7, and alternative S-3 of the Policy Supplement (Annex 1C).

7B.1 When the table may be used

The fixed-width setback may be used only where all of the following apply:

- (a) the Authority has not adopted a 1% AEP flood extent map for the waterbody (Clause 7.3.4);
- (b) Clause 7.3.4 does not require the Applicant to determine the 1% AEP extent by a hydraulic study: the site is not in a flood-sensitive catchment, is not a site of 1 ha or more adjoining a waterbody, and the Authority has not asked for a study; and
- (c) the waterbody is one to which setbacks apply (Clause 7.4.1): any recorded or found waterbody, and any natural channel draining 8 ha or more at the site.

Where an Authority adopts alternative S-3 under Clause 1.7, the table below is the S-3 table. Clause 1.7.3(e) provides for the S-3 table to be issued by the State Stormwater Technical Committee. Until it is issued, the values are those of Clause 7.4.6, repeated here without change.

Table 7B.1 — Fixed-width setback by waterbody class (alternative S-3)

Waterbody class	Drainage area at the site	Total setback (Zone 1 + Zone 2)	Of which Zone 1	Measured from
Channel, small	8 ha to 65 ha	25 m	15 m	Top of bank (Clause 7.4.3)
Channel, medium	65 ha to 20 km²	40 m	15 m	Top of bank
Channel, large, and rivers	More than 20 km²	50 m	20 m	Top of bank
Tank, lake or pond	Any	MWL contour + 25 m	To the MWL contour, and not less than 15 m from FTL	FTL contour (Zone 1); MWL contour (total)
Marsh, estuary or backwater	Any	As notified by the Authority, and not less than 50 m	15 m	The waterbody boundary of Clause 7.13.1

Values from Clause 7.4.6 (Table 7.1). Zone 2 is the total setback less Zone 1.

7B.2 Rules of application

- (a) **Measurement.** Measure horizontally on plan, outward from the boundary of Clause 7.13.1: the larger of the Revenue record boundary and the surveyed FTL (or top of bank). Where FTL and top of bank both apply, use whichever gives the wider zone (Clause 7.4.3).
- (b) **Drainage area.** For a channel, use the drainage area at the downstream end of the reach that adjoins the site. Where a reach crosses a class limit within the site, apply the wider setback to the whole reach within the site.
- (c) **Both banks.** The setback applies on each bank of a channel and all round a tank, lake, pond or marsh.
- (d) **Minimum set by this Manual.** Zone 1 is never less than 15 m (Clause 7.4.7). A wider statutory or approval setback governs for the uses it restricts (Clause 7.4.5).
- (e) **Stricter of the two.** Where a hydraulic study is made voluntarily, the setback is the wider of Table 7B.1 and Clauses 7.4.3 and 7.4.4.
- (f) **Record.** The basis of the setback (fixed width) shall be stated on the Waterbody Sheet (Form 7-1) and in the approval (Clause 7.4, Disclosure).
- (g) **Review.** The table shall be reviewed within 2 years of the Authority adopting 1% AEP flood maps (Clause 7.16.1).

7B.3 Source of the channel widths

The channel widths were set by this Manual with reference to the 2006 Kansas City APWA default stream buffers, rounded up and floored at the 15 m minimum (Clause 7.4.6, commentary). The source values, as cited in the chapter, are:

Table 7B.2 — Source buffers cited in Clause 7.4.6 (KC APWA 5600, 2006, §5605.3)

Drainage area (source, acres)	Approximate SI equivalent	Source buffer
Less than 40 ac	Less than 16 ha	40 ft (12 m)
40–160 ac	16–65 ha	60 ft (18 m)
160–5,000 ac	65 ha – 20 km²	100 ft (30 m)
More than 5,000 ac	More than 20 km²	120 ft (37 m)

The 65 ha and 20 km² class limits in Table 7B.1 are the SI equivalents of 160 ac and 5,000 ac. The 8 ha lower limit is the 20-acre trigger of APWA 2025.01 (Clause 7.4.1(b)).

Annex 7C — Template tank operating rule, with flood cushion

Supports Clauses 7.7.1(c), 7.7.3, 7.8 and 7.14.4 of Chapter 7.

Model text for consideration by a competent authority. Not in force. For tanks under WRD control, the operating rule is WRD's rule (Clause 7.8.4); this template sets out the content that Clause 7.8 asks for, so that the custodian's rule can be checked against it. Text in square brackets is to be completed for each tank.

7C.1 Identification

1. Tank: [name, WB_ID of Annex 7A, village, tehsil, district].
2. Custodian: [WRD division / ULB / Gram Panchayat / other].
3. Cascade position: upstream tank(s) [ ]; downstream tank, river or drain [ ].
4. Datum: [ ]. Surveyed levels (Clause 7.7.1(a)), date of survey [ ]: FTL [ ] m; MWL [ ] m; TBL (lowest point) [ ] m; surplus weir crest [ ] m, length [ ] m; sluice sills [ ] m.
5. Stage–storage curve (Clause 7.7.1(b)): survey date [ ]; attached as Schedule 1.
6. Controllable outlets (Clause 7.8.2(a)): [gated sluice / regulator / none]; capacity at FTL [ ] m³/s.

7C.2 Purposes and priority

7. The tank serves [irrigation of a command area of [ ] ha / drinking water supply / recharge / flood storage]. Irrigation and water supply remain primary unless the custodian records otherwise (Clause 7.8.2(d)).

7C.3 Levels and dates through the year (Clause 7.8.1(a))

8. The tank shall be operated to the levels in Table 7C.1.

Table 7C.1 — Rule levels by period (to be completed for each tank)

Period	Target level (m)	Upper limit (m)	Lower limit (m)	Purpose
[1 Jan – date]	[ ]	FTL	[ ]	Holding for irrigation / supply

Period	Target level (m)	Upper limit (m)	Lower limit (m)	Purpose
[date – start of cushion period]	[ ]	FTL	[ ]	Holding
[Flood-cushion period, if any]	Cushion level [ ]	Cushion level [ ]	[ ]	Flood cushion (Clause 7.8.2)
[End of cushion period – 31 Dec]	[ ]	FTL	[ ]	Refilling

9. Where no flood cushion is adopted, the starting level for design is FTL (Clause 7.7.3) and the row for the cushion period is deleted.

7C.4 Flood cushion (Clause 7.8.2)

10. Cushion level: [ ] m, which is [ ] m below FTL, giving a cushion volume of [ ] m³ from Schedule 1.
11. Dates: the cushion applies from [ ] to [ ].
12. Drawdown: the tank can be drawn down from FTL to the cushion level through [outlet] in [ ] hours, with a release not exceeding the maximum release rate of paragraph 18.
13. Reliability: continuous simulation (Clause 3.13) over the record [years] shows that the cushion is available at the start of a design storm in [ ]% of SW monsoon seasons, which shall be at least 90%. The simulation report is Schedule 2.
14. Yield: the custodian accepts the loss of irrigation or supply yield stated in Schedule 3 [and the compensation recorded there].
15. Where the tank has no controllable outlet, this section does not apply and no flood cushion is assumed (Clause 7.8.3).

7C.5 Releases (Clause 7.8.1(b) to (d))

16. Sluice and regulator settings at each level: Table 7C.2.
17. Operator: the sluices and regulators are operated by [post]. A release above [ ] m³/s may be ordered only by [post], or, in an emergency, by [post].
18. Maximum release rate: [ ] m³/s. This rate, added to the flow from the downstream catchment, does not flood buildings downstream (Schedule 4 gives the downstream check).
19. No person shall cut, lower or breach the bund or surplus weir except under the custodian's emergency procedure (Clause 7.14.5).

Table 7C.2 — Outlet settings by level (to be completed for each tank)

Tank level (m)	Sluice 1	Sluice 2	Regulator	Expected outflow (m³/s)	Notes
Below cushion level	[ ]	[ ]	[ ]	[ ]	
Cushion level to FTL	[ ]	[ ]	[ ]	[ ]	
FTL (weir begins to spill)	[ ]	[ ]	[ ]	[ ]	
Above FTL to MWL	[ ]	[ ]	[ ]	[ ]	Check freeboard to TBL (Clause 7.7.4(b))

7C.6 Forecasts, warnings and communication (Clause 7.8.1(e) and (f))

20. The triggers and actions are in Table 7C.3.
21. Before any release under this rule, the operator shall inform the ULBs and the district administration downstream, and residents by the means stated in Schedule 5, at least [ ] hours before the release where the forecast allows.

Table 7C.3 — Triggers and actions (to be completed for each tank)

Trigger	Source	Action	By whom
IMD district heavy-rainfall warning for the catchment	IMD	Read gauges [ ] hourly; check outlets are free; confirm the tank is at or below its rule level	[ ]
IMD or RSDMA red alert	IMD, RSDMA	Begin releases needed to reach the rule level, within the maximum release rate; notify downstream bodies (paragraph 21)	[ ]
City forecast system warning, where available	[ ]	[ ]	[ ]
Tank level reaches FTL	Gauge	Record outflow hourly; inspect bund and weir	[ ]
Tank level reaches [MWL − [ ] m]	Gauge	Emergency procedure; warning to the breach area of any emergency action plan (Clause 7.14.3(c))	[ ]

7C.7 Records and review (Clause 7.8.1(g))

22. During the SW monsoon (15 June to 30 September) the operator shall record daily: the tank level, every release (time, rate and duration), and every gate setting. Outside the SW monsoon, records shall be kept [weekly].
23. Records shall be kept with the O&M plan (Chapter 10) and given to the Authority on request.
24. The tank shall be inspected before the SW monsoon (by 15 June) and after every heavy-rainfall event (Clause 7.14.4).
25. This rule shall be reviewed after any event in which the tank surplused at a level above [ ] m, after any change to the weir, sluices or bund (Clause 7.7.6), and in any case with the review of the Manual.

Schedules: 1 stage–storage curve; 2 continuous simulation report; 3 yield and compensation; 4 downstream check of the maximum release; 5 communication list.

Annex 7D — Desilting and restoration specification

Supports Clauses 7.7.1(b), 7.9 and 7.14.4 of Chapter 7.

This specification applies to every desilting, restoration or deepening of a tank, pond or other waterbody under Clause 7.9. Values are those of Chapter 7. Where the chapter does not set a value, it is marked "to be confirmed in design" and shall be stated in the works design.

7D.1 Pre-works survey (Clause 7.9.1)

- (a) **Topographic and bathymetric survey** of the waterspread, foreshore (to the MWL contour), bund, surplus weir and sluices, levelled to the datum of Clause 7.3.5. Survey grid and point density: to be confirmed in design.
- (b) **Original bed level** found by test pits or augering on a grid (grid spacing to be confirmed in design), and from historical records where available. Each pit log shall show the silt thickness, the level of the original bed, and any clay or silt layer below it.
- (c) **Silt testing** where the tank receives urban runoff or sewage: samples from the pits of (b), tested for heavy metals and other contaminants before disposal is planned. The parameters and limits shall be those the Rajasthan State Pollution Control Board (RSPCB) directs.
- (d) **Structures:** condition of the bund (seepage, slips, cracks, animal burrows, trees), surplus weir and sluices, as in Clause 7.14.4.
- (e) **Existing stage–storage curve** from the survey of (a).

7D.2 Limits of excavation (Clauses 7.9.2 and 7.9.3)

- (a) Desilting removes accumulated sediment down to the original bed level of 7D.1(b), and no deeper.
- (b) Deepening below the original bed only with a hydrogeological report showing each of Clause 7.9.3(a) to (c).
- (c) Storage created below the lowest sluice sill is not flood storage, and shall not be shown as such in the revised stage–storage curve.
- (d) Excavation shall stay clear of the bund toe by a distance to be confirmed in design, so that the bund's stability is not reduced.

7D.3 Edges and safety (Clause 7.9.4)

Where the public has access to the edge:

- (a) side slopes no steeper than **1V:4H** from **0.5 m above FTL** down to **1.2 m below FTL**; or
- (b) a level safety bench at least **3 m** wide, between **0.3 m and 0.5 m below FTL**; and
- (c) no isolated deep pit or vertical cut left in the bed. Borrow pits shall be regraded to the bed.

7D.4 Storage not reduced (Clause 7.9.5)

- (a) Islands, walkways, bund widening into the waterspread, ring roads, parking, buildings and lake-front platforms within the waterspread or foreshore are lost storage.
- (b) Lost storage shall be offset by compensatory storage at equivalent levels, band by band, using Form 7-3.

7D.5 Silt handling and disposal (Clause 7.9.6)

- (a) Desilted material shall not be placed within the setback, on the bund (except approved bund strengthening), or on any flood path.
- (b) Contaminated silt shall be disposed of as the Rajasthan State Pollution Control Board (RSPCB) directs.
- (c) Haul routes and temporary stockpiles shall meet the construction erosion and sediment control rules of Clause 8.12, including stockpiles outside Zone 1.

7D.6 Inlets (Clause 7.9.7)

Every inlet that brings urban runoff shall have a sediment forebay, a constructed wetland inlet zone or a gross pollutant trap, designed under Chapter 8 (Annex 8D).

7D.7 Timing (Clause 7.9.8)

Desilting shall be complete, and the waterbody made safe, by **15 June**. No excavation shall be left open, and no sluice or weir left dismantled, during the SW monsoon.

7D.8 Completion records

- (a) As-built survey and revised stage–storage curve. The curve is the one that Clause 7.7.1(b) requires "after the last desilting".
- (b) Volume removed, its disposal site, and the silt test results.
- (c) Photographs of the bund, weir, sluices and inlet works.
- (d) Update of the inventory record (Annex 7A: SSC_DATE, LEVEL_DATE, CONDITION).

Table 7D.1 — Hold points for desilting and restoration works

Hold point	Check	Clause
1. Before excavation	Pre-works survey, pit logs, silt tests, and hydrogeological report if deepening	7.9.1, 7.9.3
2. Original bed reached	Levels checked against pit logs; no excavation below the original bed unless approved	7.9.2
3. Edges formed	Side slopes or safety bench as 7D.3	7.9.4
4. Inlet works	Forebay, wetland inlet zone or GPT built	7.9.7
5. Completion (by 15 June)	As-built survey, stage–storage curve, silt disposal record	7.9.8, 7.7.1(b)

Annex 7E — Glossary of Hindi and Rajasthani waterbody terms and regional variants

Supports Clause 7.2 and Clause 7.3 of Chapter 7.

The terms below are Hindi, Urdu and Rajasthani words for waterbodies, catchments and drains as used in Rajasthan, given in Devanagari and, where Platts gives it, Urdu script. Rajasthan's regional speech (Marwari, Dhundhari, Mewari, Hadoti, Mewati, Wagdi and others) uses many of the same words, with regional forms, and many of the words appear in place, lake and nala names (Ana Sagar, Fateh Sagar, Pushkar Sarovar, the Amanisha nala). The name used in the Revenue, WRD or municipal record for each waterbody should be recorded in the inventory (Annex 7A) alongside the Manual's term. Only terms whose meaning was confirmed in J. T. Platts, *A Dictionary of Urdu, Classical Hindi, and English* (1884), or in Syamasundara Dasa, *Hindi Shabdasagara* (1965–1975), both as served by the Digital South Asia Library, or in a statute or court order, are listed in Tables 7E.1 to 7E.3; the meanings are Platts's English glosses, or a translation of the Shabdasagara, with the page shown by the Digital South Asia Library, and modern usage may be narrower or wider. Sitaram Lalas's *Rajasthani Sabad Kos* (1962–1988), the dictionary of Rajasthani, was not accessible for this Manual, so the Rajasthani senses of nadi, khadin, agor and payatan, among others, are not confirmed; they are listed in Table 7E.4 as not yet verified. The list is to be extended by the State Stormwater Technical Committee, with modern Revenue, WRD and municipal usage and with a Rajasthani dictionary.

The Manual's term for a tank or pond in Rajasthan is **talab (तालाब)**, with johad and nadi as regional synonyms: talab is the plain Hindi word, understood throughout the State, and glossed by Platts as "Pond, pool, tank, reservoir of water"; johad is well sourced but means an earthen pond, and is used mostly in the north-east of the State; and nadi, the Marwar word for a village pond, is not in the standard dictionaries in that sense, while in print नाड़ी reads as "artery" or "tube". Sagar, sarovar, baori, jhalra, kund, taanka and khadin keep their own meanings in this Manual.

Table 7E.1 — Waterbodies

Term	Meaning	Source of the term	Manual term (Clause 7.2)
तालाब / تالاب (tālāb; talab)	"Pond, pool, tank, reservoir of water (= talā'o ; cf. tāl)"; in the Shabdasagara, a reservoir; a lake; a pond (pokhara)	Platts, p. 306; Shabdasagara, p. 2071	Talab (tank or pond), see the definitions after Clause 7.2
जोहड़ (johaṛ; johad, "johar")	In the Shabdasagara, "कच्चा तालाब", an unlined (earthen) tank; regional word. Not found in Platts. The High Court's order of 2012 names the "Johar" among the reservoirs whose catchments are not to be allotted	Shabdasagara, p. 1806; High Court, 29 May 2012 (as quoted)	Talab (tank or pond)
सागर / ساگر (sāgar; sagar)	In the Shabdasagara (सागर १), "1. the sea … 2. a large tank; a lake; a reservoir"; in Platts, "Ocean, sea"	Shabdasagara, p. 5053; Platts, p. 626	Sagar or city lake (tank), see the definitions after Clause 7.2
सरोवर (sarovar)	In the Shabdasagara, "1. a talab; a pokhara. 2. a lake (jhil); a tal"	Shabdasagara, p. 5003	Sagar or city lake, or talab, by size (tank)

Term	Meaning	Source of the term	Manual term (Clause 7.2)
बावड़ी, बावली / باولي (bāvaṛī, bā'olī; baori, bawdi)	In the Shabdasagara, "a wide, large well with steps to go down into it; a baoli. 2. a small tank"; in Platts (*bā'olī*), "A large masonry well, generally with winding steps down to the water, and landing-places and chambers in the surrounding wall"	Shabdasagara, p. 3474; Platts, p. 128	Baori (waterbody for Clause 7.3), see the definitions after Clause 7.2
झालरा (jhālarā; jhalra)	In the Shabdasagara (झालरा २), "a wide well; a baoli; a kund"	Shabdasagara, p. 1843	Baori (waterbody for Clause 7.3)
कुंड (kuṇḍ; kund)	In the Shabdasagara (कुंड ३), "a small embanked reservoir; a very small tank"; in Platts, "… a pool, well, reservoir, spring, a basin of water especially consecrated to some holy purpose"	Shabdasagara, p. 964; Platts, p. 853	Kund (tank or pond where it receives runoff; storage for use where it is a cistern), see the definitions after Clause 7.2
टाँका, टांका / ٹانکا (ṭāṅkā; taanka, tanka)	In the Shabdasagara (टाँका ३), "1. a small kund made by raising a wall, for keeping water collected; a cistern (hauz, chahbachcha). 2. a large vessel for keeping water"; in Platts, among other senses, "a tub made of stones"	Shabdasagara, p. 1877; Platts, p. 355	Taanka (storage for use under Clause 8.11.2(a)), see the definitions after Clause 7.2. The "Rooftop Rain Water Storage Tank" of regulation 8.3 of the Model Rajasthan Building Regulations 2025 is its modern form

Table 7E.2 — Channels, catchments, embankments and parts of the system

Term	Meaning	Source of the term	Manual term (Clause 7.2)
नाला / نالا (nālā; nala, nallah, nullah)	"A watercourse; channel (for water), a ravine; a rivulet, brook, canal; a drain, gutter"; in the Shabdasagara (नाला १), a long hollow running across the ground through which rain water goes to a river; a water channel; and the water flowing in it	Platts, p. 1117; Shabdasagara, p. 2596	Natural drain or nala, see the definitions after Clause 7.2. In Rajasthan the word covers both natural watercourses and large engineered drains, and the Dravyavati of Jaipur is also called the Amanisha nala; the definition, not the word, decides which this chapter applies to
नाली / نالي (nālī; nali)	Among other senses, "a drain; … a small watercourse, or channel"	Platts, p. 1117	Drain (minor system); where it carries sewage or sullage into a storm drain, a cross-connection (Clause 8.9)
बहाव / بهاو (bahā'o; bahav)	"Flow, flood; course of a river, current, stream; flux"; in the Shabdasagara, flowing; a flowing stream	Platts, p. 180; Shabdasagara, p. 3422	Flow path (definitions after Clause 7.2, "Agor (catchment) and flow paths"). Annexure 4 of the JDA's regulations of 2020 asks for "पानी के निर्बाध बहाव", the unobstructed flow of water, at natural drainage inlets and outlets
बाँध / باندھ (bāṅdh; bandh, bund)	"Fastening; tie … embankment; dam"	Platts, p. 127	Tank bund or dam (Clause 7.14); a talab's, johad's or khadin's bund is a tank bund (Clause 7.14.2)

Table 7E.3 — Statutory and court terms

Term	Meaning
lake (Lakes Act)	"an inland water body, whether it is natural or manmade, whether it contains water or not and whether it has been recorded as such in any revenue or other official record or not, which has had, at any time during fifty years preceding the commencement of this Act, a total submerged area of not less than three hectares in case of water body having socio-cultural, heritage or religious importance and not less than ten hectares in other cases" (Rajasthan Lakes (Protection and Development) Authority Act, 2015, s. 2(x), as read from the Bill)

Term	Meaning
flow area (Lakes Act)	"the area through which streams or feeders flow to the lake for its recharge" (s. 2(viii), as read from the Bill); this Manual treats it as the agor of the lake (definitions after Clause 7.2)
protected area (Lakes Act)	A geographical area around a lake notified by the State Government, in which no construction may be undertaken without prior permission (ss. 4 and 5, as read from the Bill); no notification was found for this Manual
gair mumkin nala, nadi, talab (गैर मुमकिन)	The Revenue record class of land that cannot be cultivated because it is a nala, a nadi or a talab. "A 'Gair Mumkin Nala' constitutes a natural drainage and water flow channel forming an integral part of the ecological framework and hydrological system", which cannot be diverted, obstructed or altered for a non-conforming purpose (*Ramji Lal Saini*, High Court, 2026); see the definitions after Clause 7.2. The dictionary entries for the phrase were not checked
khatedari	The tenancy right under the Rajasthan Tenancy Act, 1955, which does not accrue in pasture land and, as reported, in river and tank beds (s. 16)
public tanks and drains (Municipalities Act)	Vested in the Municipality as trustee: "all public tanks, streams, reservoirs, cisterns, springs, aqueducts, conduits … and also any adjacent land, not being private property, appertaining to any public tank or well", and "all public sewers and drains, channels, tunnels, culverts and watercourses in, alongside, or under, any street" (Rajasthan Municipalities Act, 2009, s. 68(1)(c) and (d), as read from a third-party copy)
catchment areas (High Court)	The High Court restrained "allotment of the land falling in catchment areas of water reservoirs like Johar, Nala, Tank, River, Pond etc." (order of 29 May 2012, as quoted in *Ramji Lal Saini*, 2026)

Table 7E.4 — Terms not yet verified

The following terms are in use for Rajasthan's waterbodies, but their meaning or regional use was not confirmed in Platts, the Shabdasagara or an official source during research for this Manual. They shall not be used in a record or a drawing as defined terms until verified.

Term	Reported meaning or use	Status
नाडी, नाड़ी (nāḍī; nadi)	The village pond of Marwar and the west, usually earthen, fed by its agor	Not found in this sense: the Shabdasagara's नाड़ी means "a tube; an artery" (p. 2576), and Platts has no matching entry. Needs the *Rajasthani Sabad Kos*
आगोर, अगोर (āgor, agor; agor, agaur)	The catchment of a talab, nadi or taanka	Not confirmed: Platts gives only *agor*, "Watchman, guard; one who watches over crops" (p. 71), an unrelated sense, and the Shabdasagara has no entry; no statutory or Revenue use was found. Used in this Manual only with its gloss (definitions after Clause 7.2)
पायतन (pāyatan; payatan)	Reported as the bed or submergence area of a talab	Not found in Platts, the Shabdasagara or any statute read; not used in this Manual
खडीन (khaḍīn; khadin)	A long earthen bund across the lower edge of a sloping catchment, behind which runoff stands and soaks in before the bed is farmed; an old practice of the Jaisalmer area	Not found in Platts or the Shabdasagara; defined in this Manual from its technical use (definitions after Clause 7.2)
कुंडी (kuṇḍī; kundi)	A covered cistern fed by a saucer-shaped prepared catchment, in the Churu and Bikaner area	The Shabdasagara's कुंडी has only the senses of a stone bowl and a door-chain (p. 966); the cistern sense is not confirmed
बेरी (berī; beri)	A shallow well that draws water seeping through the sand above a hard layer	Not checked in a dictionary; Platts's *berī* is the jujube tree (p. 208)
Rajasthani forms of talab, nadi, nala and the names of parts of a talab	Regional forms of the terms of Tables 7E.1 and 7E.2, and the local words for a talab's bund, spill point and feeder channels	Not checked in a regional dictionary

Form 7-1 — Waterbody Sheet

Supports Clauses 7.3.2, 7.4 and 7.15(1) of Chapter 7.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. One sheet per waterbody. Attach the plan of Clause 7.3.2 at 1:1,000 or larger.

Table 7F.1 — Form 7-1, Section A: Project and waterbody

No.	Field	Entry	Clause
A1	Project name and Authority file number	_____	—
A2	Waterbody name (English and Hindi) and inventory ID (Annex 7A), if any	_____	7.3.1
A3	Waterbody type (Clause 7.2)	_____	7.2
A4	Position: within the site / within 100 m of the site boundary / downstream within the Chapter 5 extent	_____	7.3.2
A5	Survey numbers and village	_____	7.3.1(a)
A6	Custodian	_____	7.3.1(b)
A7	Sources checked (tick): Revenue records and khasra maps (gair mumkin talab, nadi, nala; Tenancy Act s. 16), Municipal tank and drain records (RMA s. 68), Lakes Act records and notifications, master plans, court catchment surveys and river HFLs, wetland notifications and Ramsar boundaries □; WRD / Gram Panchayat registers □; Authority inventory or court list □; historical maps and imagery, including NWIA □; site survey □	_____	7.3.3
A8	Where sources conflict: which extent governs (the larger)	_____	7.3.3
A9	Datum of all levels, and conversion from any WRD datum	_____	7.3.5

Table 7F.2 — Form 7-1, Section B: Levels and features

No.	Field	Entry	Clause
B1	FTL (tanks, lakes, ponds) or top of bank (channels), m	_____	7.2
B2	MWL (tanks), m, and basis (WRD record or 1% AEP computed)	_____	7.2
B3	TBL, lowest point (tanks), m	_____	7.3.1(d)
B4	1% AEP flood level, m, and source (adopted map / hydraulic study / not available)	_____	7.3.4
B5	Drainage area at the site (channels), ha	_____	7.4.1(b)
B6	Supply channels, surplus courses, sluices and surplus weirs shown on plan (yes / no)	_____	7.3.2
B7	Known encroachments, with date recorded	_____	7.3.1(g)

Table 7F.3 — Form 7-1, Section C: Setback

No.	Field	Entry	Clause
C1	Basis of setback: mapped extent / hydraulic study / fixed width (Annex 7B)	_____	7.15(1)
C2	Is a hydraulic study required under Clause 7.3.4 (a) / (b) / (c)?	_____	7.3.4
C3	Floodway outer edge, m from FTL or top of bank, and how delineated	_____	7.6.1
C4	Zone 1 width, m (greatest of 15 m, floodway edge, MWL contour)	_____	7.4.3

No.	Field	Entry	Clause
C5	Zone 2 width, m (to 1% AEP extent + 10 m, or 10 m)	_____	7.4.4
C6	Wider statutory or approval setback, if any, and its source	_____	7.4.5
C7	Setback applied: Manual standard / a wider statutory, court or approval line: the High Flood Line and ecological buffer of a river once demarcated under the Supreme Court's order of 7 August 2026 (no fresh permissions in an identified river corridor until then); 100 m from the edge of the Jojari (Supreme Court interim order, 24 August 2026, as reported); land recorded as gair mumkin nala, nadi or talab, or in a recorded catchment protected by the High Court; the protected area or flow area of a lake under the Lakes Act, 2015; the Udaipur lakes no-construction zone (200 m from HFL, as reported); the 50 m from the mean high flood level of a notified wetland; a WRD dam, reservoir or canal line; another court or Tribunal line; or other (state which)	_____	7.4, Disclosure
C8	Uses proposed in Zone 1 and Zone 2, and the custodian's NOC for any work in Zone 1	_____	7.5, 7.15(5)
C9	Fill proposed in the flood fringe (yes / no); if yes, Form 7-3 attached	_____	7.6.3
C10	Zone 1 marker positions shown (not more than 30 m apart)	_____	7.13.4

Table 7F.4 — Form 7-1, Section D: Prepared by

Field	Entry
Name, registration and empanelment number (Clause 10.6)	_____
Signature and date	_____
Licensed surveyor for the levels (name, licence number)	_____

Form 7-2 — Tank Storage Credit Sheet

Supports Clauses 7.7, 7.8, 7.11, 7.14 and 7.15(4) of Chapter 7.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. One sheet per tank whose storage is counted. Storage that fails any item in Section B shall not be counted (Clause 7.7.1).

Table 7F.5 — Form 7-2, Section A: Tank and scheme

No.	Field	Entry	Clause
A1	Tank name and inventory ID (Annex 7A); custodian	_____	7.3.1
A2	Scheme in which storage is counted: basin plan / regional facility / fee-in-lieu (S-5)	_____	7.7.1, 7.11
A3	Cascade modelled: uppermost tank _____ to outfall _____	_____	7.7.2
A4	Datum	_____	7.3.5

Table 7F.6 — Form 7-2, Section B: Conditions for counting storage

No.	Condition	Date / reference	Met (yes / no)	Clause
B1	FTL, MWL, TBL, weir crest and length, sluice sills surveyed within the previous 5 years	_____	_____	7.7.1(a)
B2	Stage–storage curve from a bathymetric and topographic survey within 5 years or after the last desilting, whichever is later	_____	_____	7.7.1(b)
B3	Documented operating rule agreed with the custodian (Annex 7C)	_____	_____	7.7.1(c), 7.8
B4	Weir, sluices and bund under an O&M plan; latest pre-monsoon inspection found them serviceable	_____	_____	7.7.1(d), 7.14.4
B5	Custodian's written concurrence	_____	_____	7.7.1(e)

Table 7F.7 — Form 7-2, Section C: Levels and creditable volume

No.	Item	Value	Clause
C1	Starting level: FTL, or cushion level under a rule meeting Clause 7.8.2, m	_____	7.7.3
C2	If a cushion is used: controllable outlet (type) and drawdown time, h	_____	7.8.2(a)
C3	If a cushion is used: reliability from continuous simulation, % of SW monsoon seasons (≥ 90%)	_____	7.8.2(c)
C4	Computed maximum level, 1% AEP inflow with climate factor routed through the cascade, m	_____	7.7.4
C5	MWL, m; is C4 ≤ MWL?	_____	7.7.4(a)
C6	Freeboard C4 to TBL, m; WRD freeboard standard, m; met?	_____	7.7.4(b)
C7	Storage between C1 and C4, from the stage–storage curve, m^3	_____	7.7.5
C8	Volume already committed to another facility or scheme, m^3	_____	7.7.5
C9	Creditable volume = C7 − C8, m^3	_____	7.7.5
C10	Register entry under Clause 10.17 (fee-in-lieu storage)	_____	7.11.2(d)

Table 7F.8 — Form 7-2, Section D: Bund safety

No.	Item	Entry	Clause
D1	Specified dam under the Dam Safety Act, 2021? Height, crest length, capacity, maximum flood discharge	_____	7.14.1
D2	Hazard class: high / low	_____	7.14.2
D3	High hazard: weir passes 1% AEP at MWL with freeboard; 0.2% AEP check without overtopping	_____	7.14.3(a)
D4	High hazard: breach analysis and emergency action plan (references)	_____	7.14.3(b), (c)
D5	High hazard: independent check under Clause 10.6 (name)	_____	7.14.3(d)

Table 7F.9 — Form 7-2, Section E: Signatures

Role	Name and designation	Signature and date
Designer (Clause 10.6)	_____	_____
Independent checker, where Clause 7.14.3(d) applies	_____	_____
Custodian's concurrence (Clause 7.7.1(e))	_____	_____

Form 7-3 — Compensatory Storage Calculation (by elevation band)

Supports Clauses 7.6.3 to 7.6.5, 7.9.5 and 7.15(3) of Chapter 7.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0.

Method

1. Fix the **lower limit**: the normal water level of the waterbody, or the 50% AEP (2-yr) level where higher (Clause 7.6.4(b)).
2. Fix the **upper limit**: the 1% AEP flood level (with the climate factor).
3. Divide the range into **bands of not more than 0.3 m**. The top band may be thinner.
4. For each level z at a band boundary, measure on plan:
    - A_fill(z): the area of the fill footprint where existing ground is below z; and
    - A_cut(z): the area of the excavation where finished ground is below z and existing ground was above z (new flooded area).
5. For each band, by the average end-area method: V = (A(z_bottom) + A(z_top)) / 2 × band thickness. Do this for fill (volume lost) and for excavation (volume gained).
6. **Check each band:** volume gained ≥ volume lost. A surplus in one band does not make up a shortfall in another (Clause 7.6.4(b)).
7. Check the other conditions of Clause 7.6.4(c) to (f) in Section C.

Figure 7.2 in Chapter 7 shows the method.

Table 7F.10 — Form 7-3, Section A: Levels

No.	Field	Entry	Clause
A1	Waterbody, reach, and inventory ID	_____	7.6.4(c)
A2	Normal water level, m; 50% AEP level, m; lower limit (the higher), m	_____	7.6.4(b)
A3	1% AEP flood level with climate factor, m (upper limit)	_____	7.6.4(b)
A4	Band thickness, m (≤ 0.3) and number of bands	_____	7.6.4(b)
A5	Datum	_____	7.3.5

Table 7F.11 — Form 7-3, Section B: Band-by-band balance

Band	From (m)	To (m)	A_fill bottom (m²)	A_fill top (m²)	Volume lost (m³)	A_cut bottom (m²)	A_cut top (m²)	Volume gained (m³)	Gained ≥ lost?
1	_____	_____	_____	_____	_____	_____	_____	_____	_____
2	_____	_____	_____	_____	_____	_____	_____	_____	_____
3	_____	_____	_____	_____	_____	_____	_____	_____	_____
4	_____	_____	_____	_____	_____	_____	_____	_____	_____
Total					_____			_____	

Add rows as needed.

Table 7F.12 — Form 7-3, Section C: Other conditions

No.	Condition	Met (yes / no) and evidence	Clause
C1	Fill is in the flood fringe, not the floodway, and for a permitted use	_____	7.6.2, 7.6.3
C2	Excavation is in the same reach of the same waterbody, hydraulically connected, and not further downstream than the fill	_____	7.6.4(c)
C3	Excavation drains by gravity as the flood recedes; no pumping; no permanent pool below normal water level	_____	7.6.4(d)
C4	Excavation built before, or at the same time as, the fill	_____	7.6.4(e)
C5	Covenant or handover so that it is never filled (reference)	_____	7.6.4(f)
C6	Not counted as detention or retention under Chapter 4	_____	7.6.5
C7	Signature of designer (Clause 10.6) and date	_____	10.6

Worked example

Illustrative — not design values. A site in the flood fringe of a channel needs a fill pad for a permitted Zone 2 use (Clause 7.5.2). The inputs are assumed.

- Normal water level 10.00 m; 50% AEP level 9.80 m. Lower limit = 10.00 m (the higher).
- 1% AEP flood level 11.20 m. Range 1.20 m, so four bands of 0.30 m.
- The fill footprint is 1,600 m². Existing ground across the footprint rises evenly from 10.00 m to 11.20 m, so the area of footprint below each level is: 0 m² at 10.00 m; 400 m² at 10.30 m; 800 m² at 10.60 m; 1,200 m² at 10.90 m; 1,600 m² at 11.20 m.
- The excavation is a graded cut beside the channel, with its floor at 10.00 m. The new flooded area below each level (first trial) is: 300 m² at 10.00 m; 900 m² at 10.30 m; 1,100 m² at 10.60 m; 1,500 m² at 10.90 m; 1,500 m² at 11.20 m.

Step 1 — volume lost, band by band (V = average area × 0.3 m):

- Band 1: (0 + 400) / 2 × 0.3 = 60 m³
- Band 2: (400 + 800) / 2 × 0.3 = 180 m³
- Band 3: (800 + 1,200) / 2 × 0.3 = 300 m³
- Band 4: (1,200 + 1,600) / 2 × 0.3 = 420 m³
- Total: 960 m³

Step 2 — volume gained, first trial:

Table 7F.13 — Worked example: first trial (illustrative)

Band	From (m)	To (m)	Volume lost (m³)	A_cut bottom (m²)	A_cut top (m²)	Volume gained (m³)	Gained ≥ lost?
1	10.00	10.30	60	300	900	180	Yes
2	10.30	10.60	180	900	1,100	300	Yes
3	10.60	10.90	300	1,100	1,500	390	Yes
4	10.90	11.20	420	1,500	1,500	450	Yes
Total			960			1,320	

Every band passes. Note that a simple total balance would hide a failure if, for example, the cut were made deeper and narrower: suppose the designer instead offers a cut with new flooded areas of 1,400 m² at 10.00 m, 1,400 m² at 10.30 m, 1,000 m² at 10.60 m, 600 m² at 10.90 m and 200 m² at 11.20 m.

Table 7F.14 — Worked example: deeper, narrower cut (illustrative)

Band	From (m)	To (m)	Volume lost (m³)	A_cut bottom (m²)	A_cut top (m²)	Volume gained (m³)	Gained ≥ lost?
1	10.00	10.30	60	1,400	1,400	420	Yes
2	10.30	10.60	180	1,400	1,000	360	Yes
3	10.60	10.90	300	1,000	600	240	**No**
4	10.90	11.20	420	600	200	120	**No**
Total			960			1,140	

The total gained (1,140 m³) exceeds the total lost (960 m³), but bands 3 and 4 are short by 60 m³ and 300 m³. The surplus low down cannot be counted against them: the low storage fills early in every flood and is not available when the fill takes away storage near the peak. This design fails Clause 7.6.4(b) and must be regraded so that the upper bands gain at least as much as they lose, as in the first trial.

ANNEXES TO CHAPTER 8

Water Quality and Recharge

These annexes support Chapter 8. They give the layout of the water quality rainfall tables, the Level of Service and Value Rating method in detail, the layout of the BMP calibration programme, design sheets for each BMP, standard details for construction erosion and sediment control, and the two forms that Clause 8.14 requires. Annexes 8A and 8C need data that are not yet available; they say so and give the rule to use in the meantime. The forms are draft forms.

Annex 8A — 3-month ARI 24-hour depth and IDF by zone

Supports Clauses 8.2, 8.4.1 and 8.4.5 of Chapter 8.

To be prepared. This annex will contain, for each rainfall zone of Chapter 2, the 24-hour 3-month ARI depth P_3m and the 3-month ARI intensity–duration relationship used for Q_wq. It needs long-term daily and sub-daily rainfall records (IMD station and gridded data, with NIH as the Chapter 2 primary source), analysed as a partial-duration series. Until it is published, the designer shall compute P_3m from the longest available daily record for the site's zone, as the 24-hour depth equalled or exceeded on average four times a year (Clause 8.2), state the record, its length and the method on the Water Quality Sheet (Form 8-1), and use P_wq = max (P_ret, P_3m) (Clause 8.4.1). The climate factor is not applied (Clause 8.4.3).

8A.1 Method to be used in preparing the annex

- (a) Use daily records of at least 30 years where available (as for station IDF in Chapter 2).
- (b) Form the partial-duration series of 24-hour depths, with independent events separated by at least one dry day.
- (c) Choose the threshold so that the number of events above it averages four per year; P_3m is that threshold.
- (d) Derive the 3-month ARI intensities for durations from 10 minutes to 24 hours from sub-daily records, or by the Chapter 2 method of scaling from the daily value, stating which.
- (e) Do not apply the climate factor (Clause 8.4.3).

Table 8A.1 — Water quality rainfall depths by zone (layout)

Zone (Chapter 2)	Representative stations or grid	Record (years)	P_ret, Annex 2E (mm)	P_3m (mm)	P_wq = max (mm)
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Table 8A.2 — 3-month ARI intensity by duration (layout)

Zone	10 min (mm/h)	15 min (mm/h)	30 min (mm/h)	1 h (mm/h)	2 h (mm/h)	6 h (mm/h)	24 h (mm/h)
_____	_____	_____	_____	_____	_____	_____	_____

Zone	10 min (mm/h)	15 min (mm/h)	30 min (mm/h)	1 h (mm/h)	2 h (mm/h)	6 h (mm/h)	24 h (mm/h)
_____	_____	_____	_____	_____	_____	_____	_____

Annex 8B — Redevelopment LoS table and treatment-train composite VR

Supports Clauses 8.6.2 to 8.6.5 of Chapter 8.

8B.1 Required Level of Service for redevelopment

To be prepared. This part will give the required Level of Service for redevelopment sites (existing impervious cover of 20% or more of the site, Clause 8.6.2). The MARC/APWA BMP Manual (2012, Table 4.3) sets the redevelopment LoS from the percentage of impervious cover within the disturbed area; the Rajasthan values need to be set by the State Stormwater Technical Committee and checked against local redevelopment cases. Until it is published, the required LoS for a redevelopment site is **6** for the disturbed area. Where Table 8.2, applied to the change in CN from the existing condition to post-development, gives a higher LoS, that higher LoS applies. This interim value is set by this Manual. A redevelopment site that retains its whole WQv on site under Chapter 4 needs no further treatment for that area, apart from pretreatment, hotspot controls and the outfall requirements (Clause 8.4.4).

Table 8B.1 — Required LoS for redevelopment (layout)

Existing impervious cover within the disturbed area (%)	Change in impervious cover	Required LoS
_____	_____	_____
_____	_____	_____
_____	_____	_____

8B.2 Composite Value Rating: area-weighted method

The composite VR of a site is the area-weighted average of the VRs of the BMPs serving each part of the site (Clause 8.6.3):

$$VR_{site} = \Sigma (A_i \times VR_i) / \Sigma A_i + VR_{signage}$$

where:

- A_i = the area of part i of the site, ha;
- VR_i = the Value Rating (Table 8.3) of the BMP serving part i, which counts only if the BMP meets Clause 8.6.4 for the whole of A_i;
- ΣA_i = the whole site area: every part of the site is assigned to one BMP, or to preserved native vegetation; a part served by no BMP is entered with $VR_i = 0$; and
- $VR_{signage} = 0.25$ where public education signage is provided (Table 8.3), otherwise 0.

The site complies where $VR_{site} \geq$ required LoS (Clause 8.6.3).

Illustrative — not design values. A 1.0 ha site that is not redevelopment, with ΔCN = 18. Required LoS = 8 (Table 8.2).

Table 8B.2 — Worked example: composite VR (illustrative)

Part	Area A_i (ha)	BMP	VR_i (Table 8.3)	A_i × VR_i
Roofs and paving draining to bioretention	0.60	Bioretention	8.5	5.100
Car park	0.25	Permeable pavement	7.5	1.875
Preserved strip along boundary	0.15	Native vegetation (preserved)	9.25	1.388
Total	1.00			8.363

- Area-weighted VR = 8.363 / 1.00 = 8.36
- Signage provided: + 0.25
- VR_site = 8.61 ≥ 8. The site complies.

Without the permeable pavement (car park draining untreated, VR = 0): (5.100 + 0 + 1.388) / 1.00 + 0.25 = 6.74 < 8. The site would not comply.

8B.3 Treatment trains

To be prepared. This part will give the composite VR of BMPs in series (a treatment train), following the approach of the MARC/APWA BMP Manual (2012, Table 4.6), with values to be confirmed for Rajasthan by the calibration programme of Clause 8.13.4 (Annex 8C). Until it is published, each part of the site is credited with the VR of one BMP in the train that meets Clause 8.6.4 for that part, normally the last BMP before discharge, and no extra credit is given for BMPs in series. Pretreatment devices, silt traps and oil-grit separators upstream of the credited BMP earn no VR of their own (Clauses 8.6.4(c), 8.7.11(c) and 8.7.12(c)).

Table 8B.3 — Composite VR of treatment trains (layout)

First BMP	Second BMP	Composite VR	Conditions
_____	_____	_____	_____
_____	_____	_____	_____

Annex 8C — Rajasthan BMP performance calibration

Supports Clauses 8.6.3, 8.13 and 8.15.1 of Chapter 8.

To be prepared. This annex will report the BMP performance calibration programme of the State Stormwater Technical Committee (Clause 8.13.4): measured inflow and outflow concentrations and volumes for BMPs built in Rajasthan, and the revised Value Ratings that follow from them. It needs wet-weather monitoring of BMPs over several SW monsoon seasons, with laboratory analysis to the CPCB methods, and the outfall monitoring of Clause 8.13.1 published under Clause 10.17. Until it is published, the Value Ratings of Table 8.3 (MARC/APWA 2012) apply, and a proprietary device earns a VR only from verified test data (Table 8.3).

The layouts below set the minimum records the programme shall keep, so that results from different authorities can be pooled.

Table 8C.1 — Monitoring site register (layout)

Site ID	BMP type (Table 8.3)	Location and authority	Catchment area (ha)	Impervious (%)	Soil and groundwater setting	Date commissioned	Pretreatment
_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____

Table 8C.2 — Event record (layout; parameters of Clause 8.13.2)

Site ID	Event date	Rainfall (mm)	Inflow volume (m^3)	Outflow volume (m^3)	TSS in / out (mg/L)	BOD in / out (mg/L)	COD in / out (mg/L)	Faecal coliform in / out (MPN/100 mL)	TN in / out (mg/L)	TP in / out (mg/L)	Oil and grease in / out (mg/L)	Heavy metals (industrial catchments)
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____

Table 8C.3 — Performance summary and proposed VR (layout)

BMP type	Sites	Events	Volume reduction (%)	Median effluent TSS (mg/L)	Other findings	VR in Table 8.3	Proposed VR
_____	_____	_____	_____	_____	_____	_____	_____

Annex 8D — BMP design sheets, media specification, plant lists

Supports Clauses 8.5, 8.7, 8.8 and 8.11 of Chapter 8.

Each design sheet collects the requirements of Chapter 8 for one BMP. Values marked "recommended starting value" in Clause 8.7.1 may be departed from with justification. Values that the Manual does not set are marked "to be confirmed in design"; the designer shall state and justify them. Every BMP also needs: sizing for the WQv or Q_wq (Clause 8.6.4(a)), pretreatment (Clause 8.5.3), a safe bypass for flows above Q_wq (Clause 8.4.6) and maintenance access (Chapter 10).

8D.1 Design sheets

Table 8D.1 — Pretreatment (all BMPs)

Item	Requirement	Clause
Where needed	Every bioretention cell, infiltration facility, permeable pavement receiving run-on, wet pond and constructed wetland, at each concentrated inflow	8.5.3
Types	Sediment forebay, grass filter strip, silt trap or proprietary device	8.5.3
Size	Holds at least 10% of the WQv of its contributing area; or sized for Q_wq (flow-through devices)	8.5.3
Access	Cleanable without entering or disturbing the main BMP	8.5.4
Silt traps and catch pits	At every inlet receiving runoff from unpaved ground, and at the inlet of every drain discharging to a BMP or waterbody; sump at least 300 mm below the outlet invert; earn no VR	8.7.12

Table 8D.2 — Bioretention and rain gardens (Figure 8.2)

Item	Requirement	Clause
Ponding depth	≤ 300 mm above the mulch, with an overflow at maximum ponding level	8.7.2(a)
Ponding drawdown	Within 48 h	8.7.2(b)
Filter media	600–900 mm engineered sandy loam, low fines, low phosphorus (Table 8D.12)	8.7.2(c)
Mulch	50–75 mm	8.7.2(c)
Transition (choker) and gravel drainage layers	Required; thickness and grading to be confirmed in design	8.7.2(d)
Underdrain	Perforated; required where the design infiltration rate cannot meet the 48 h drawdown, or where lined; diameter to be confirmed in design	8.7.2(e)
Lining	Required where Clause 8.8 cannot be met, and at hotspots	8.7.2(f)
Plants	Native or naturalised, tolerant of waterlogging and long dry spells (Tables 8D.13 and 8D.14)	8.7.2(g)
VR	8.5 (rain garden / infiltration 9.0)	Table 8.3

Table 8D.3 — Vegetated swales

Item	Requirement	Clause
Section	Trapezoidal or parabolic; side slopes no steeper than 1V:3H	8.7.3(a)
Longitudinal slope	0.5% to 4%; check dams where steeper	8.7.3(b)
Flow at Q_wq	Depth not more than grass height; velocity ≤ 0.3 m/s	8.7.3(c)
1% AEP or bypass flow	No erosion (Chapter 9 permissible velocities)	8.7.3(d)
Underdrained ("dry") swale	Where slope < 1% or subsoil is poorly drained; filter media as Table 8D.12	8.7.3(e)
VR	4.0 (native vegetation swale)	Table 8.3

Table 8D.4 — Vegetated filter strips

Item	Requirement	Clause
Inflow	Sheet flow only; level spreader where flow arrives concentrated	8.7.4(a)
Length in flow direction	≥ 5 m	8.7.4(b)
Slope	1% to 8%	8.7.4(b)
Use	Mainly pretreatment for bioretention, infiltration and swales	8.7.4(c)
VR	5.0	Table 8.3

Table 8D.5 — Permeable pavement

Item	Requirement	Clause
Run-on	Impervious run-on area ≤ 2 × permeable area; none from unpaved or eroding areas	8.7.5(a)
Base reservoir	Clean open-graded aggregate holding its share of the WQv in its voids; void ratio confirmed by test	8.7.5(b)
Open (infiltrating) base	Only where Clause 8.8 is met; otherwise lined with underdrain and counted as filtration only	8.7.5(c)

Item	Requirement	Clause
Structure	Designed for traffic loading to the road authority's standards	8.7.5(d)
Exclusions	Not at hotspots; not where it will be resurfaced with impermeable material	8.7.5(e)
VR	7.5	Table 8.3

Table 8D.6 — Infiltration trenches and basins (Figure 8.3)

Item	Requirement	Clause
Pretreatment	Always (Table 8D.1)	8.7.6(a)
Fill	Clean washed aggregate, void ratio confirmed by test; geotextile on sides and top; sand base	8.7.6(b)
Observation well	To the base of each trench	8.7.6(c)
Storage	WQv (or Chapter 4 retention volume, if greater) held in the voids	8.7.6(d)
Drawdown	Empty within 72 h at the design infiltration rate	8.7.6(d), 8.8.7
Overflow	At grade, to the minor or major system	8.7.6(e)
Commissioning	Not in service until the contributing area is stabilised	8.7.6(f)
Criteria	All of Clause 8.8 (Table 8D.11)	8.8

Table 8D.7 — Wet ponds (extended wet detention)

Item	Requirement	Clause
Permanent pool	≥ WQv	8.7.7(a)
Extended detention	WQv above the pool, released over 24–48 h	8.7.7(a), 8.4.7
Forebay	At each inlet	8.7.7(b)
Flow path	Length-to-width ≥ 3:1; no short-circuiting	8.7.7(c)
Pool depth	1.0–2.5 m, with safety bench (Clause 7.9.4)	8.7.7(d)
Water balance	Monthly balance with IMD rainfall and pan evaporation: ≥ 50% of pool volume kept through the driest year in 10; no top-up with groundwater, potable water or sewage	8.7.8
Flood detention	Chapter 4 detention may sit above the extended detention level	8.7.7(f)
VR	5.0	Table 8.3

Table 8D.8 — Constructed wetlands

Item	Requirement	Clause
Layout	Inlet sedimentation pond (forebay), then shallow macrophyte zone	8.7.9(a)
Extended detention	WQv above normal water level, released over 24–48 h; depth ≤ 0.5 m	8.7.9(b)
Flow path	Length-to-width ≥ 3:1; deep zones across the flow path	8.7.9(c)
Bypass	High-flow bypass so that floods do not scour the macrophyte zone	8.7.9(d)
At a tank inlet	Within the tank's setback, outside its waterspread; not counted as tank storage	8.7.9(e)
Water balance	As wet ponds (minimum wetland depth kept)	8.7.8

Item	Requirement	Clause
VR	7.0 (extended detention wetland)	Table 8.3

Table 8D.9 — Gross pollutant traps and outfall screens

Item	Requirement	Clause
Treatment flow	Q_wq; all flows up to 1% AEP pass without washing out captured material	8.7.10(a)
Capture size	Down to about 5 mm	8.7.10(b)
Head loss	In the drain HGL (Chapter 9), screen 50% blocked	8.7.10(c), 8.10.3(a)
Storage	For the O&M cleaning interval; not less than 3-monthly cleaning	8.7.10(d)
Access	Vehicle access for suction or grab cleaning; safe cleaning platform	8.7.10(e), 8.10.3(d)
Blocked screen	Overflow or bypass path so that a fully blocked screen does not flood property	8.10.3(b)
Bar spacing	Chosen for the hazard: closer for litter capture, wider where blockage would cause flooding; to be confirmed in design	8.10.3(c)

Table 8D.10 — Oil-grit separators

Item	Requirement	Clause
Where	Fuel stations; vehicle workshops and washing bays; bus and truck depots; parking areas of more than 50 spaces	8.7.11(a)
Sizing	Q_wq, with high-flow bypass	8.7.11(b)
Not alone	Followed by a filtering BMP where the site needs a VR above 5; lined filtering BMP before any infiltration at hotspots	8.7.11(c), 8.8.8

Table 8D.11 — Infiltration and recharge criteria (all infiltrating BMPs)

Item	Requirement	Clause
Groundwater separation	Seasonal high groundwater ≥ 1.0 m below base (roof-only runoff in notified coastal sand: ≥ 0.5 m with mounding check, mound ≥ 0.3 m below base)	8.8.1, 8.8.9(d)
Bedrock or impermeable layer	Base ≥ 1.0 m above, unless designed for rock-aquifer recharge under Clause 8.8.10	8.8.2
Tests	Double-ring (ASTM D3385) for basins, bioretention, permeable pavement; falling-head borehole or trial-pit soakage (e.g. BRE Digest 365) for trenches, soakaways, pits, wells; ≥ 2 per facility and ≥ 1 per 100 m² of base or per 50 m of trench; Form 8-2	8.8.3
Design rate	Measured rate ÷ 2.0 (tests meet 8.8.3(c) and vary by no more than a factor of 2), otherwise ÷ 3.0	8.8.4
Minimum rates	≥ 13 mm/h full infiltration; 3–13 mm/h partial, with underdrain, credit only for volume infiltrated within 72 h; < 3 mm/h no credit	8.8.5
Setbacks (runoff from paved surfaces)	Foundations 3 m, basements 5 m; property boundary 1.5 m; drinking-water well or borewell 30 m; septic tank or soak pit 15 m; crest of slope steeper than 1V:3H 6 m	8.8.6
Expansive soils	Foundation setback doubled	8.8.11(b)

Item	Requirement	Clause
Drawdown	Empty within 72 h at design rate; tested after construction	8.8.7
Hotspots	No infiltration without treatment; none at all for waste sites and contaminated land	8.8.8
Road runoff	Never led directly into a well, borewell or recharge shaft	8.11.3(b)

8D.2 Bioretention drawdown check

The 48-hour ponding drawdown (Clause 8.7.2(b)) and the minimum rates of Clause 8.8.5 together decide whether a cell needs an underdrain.

- Rate needed to drain the maximum ponding depth in 48 h = 300 mm / 48 h = 6.25 mm/h.
- Design rate ≥ 13 mm/h: full infiltration, no underdrain, provided Clause 8.8 is met.
- Design rate from 6.25 mm/h to 13 mm/h: the ponding drains in time, but Clause 8.8.5(b) applies, so an underdrain is required.
- Design rate below 6.25 mm/h: the ponding cannot drain in 48 h by infiltration; an underdrain is required (Clause 8.7.2(e)), and below 3 mm/h no infiltration credit is given.

Illustrative — not design values. Two tests at the base of a proposed cell give 30 mm/h and 22 mm/h. The two results differ by a factor of 30 / 22 = 1.36, which is not more than 2, and the number of tests meets Clause 8.8.3(c), so the safety factor is 2.0. Taking the lower result, the design rate = 22 / 2.0 = 11 mm/h. This is above 6.25 mm/h, so the ponding drains in 300 / 11 = 27 h, within 48 h. It is below 13 mm/h, so the cell is a partial-infiltration design with an underdrain (Clause 8.8.5(b)).

8D.3 Filter media specification

Table 8D.12 — Bioretention filter media and layers

Layer	Requirement from Chapter 8	Values to be confirmed in design
Mulch	50–75 mm (Clause 8.7.2(c)); shredded hardwood or similar organic mulch that does not float away at the ponding depth	Material and source
Filter media	600–900 mm engineered sandy loam with low fines and low phosphorus content (Clause 8.7.2(c))	Particle size grading; fines (silt + clay) limit; organic matter content; phosphorus limit; saturated hydraulic conductivity of the compacted media; source and test certificate for each batch
Transition (choker) layer	Between media and gravel, to stop media washing into the gravel (Clause 8.7.2(d))	Thickness and grading, matched to the media and gravel
Gravel drainage layer	Below the transition layer, surrounding the underdrain (Clause 8.7.2(d))	Thickness, grading, washed
Underdrain	Perforated pipe where Clause 8.7.2(e) applies, with cleanouts	Diameter, slope, perforation, outlet level
Liner	Where Clause 8.7.2(f) applies (cannot meet Clause 8.8; hotspots)	Liner type and protection

Media shall be tested before placing, and placed in lifts without heavy compaction. The State Stormwater Technical Committee should set numeric limits for grading, fines, organic matter and phosphorus, with local sources of sand and compost, when it reviews this annex.

8D.4 Plant lists

The lists below are **indicative**. They name species that are native or long naturalised in Rajasthan and known to tolerate long dry spells and short wet periods; no Rajasthan source on planting for stormwater was researched for this Manual. Hindi or Urdu names are given only where J. T. Platts, *A Dictionary of Urdu, Classical Hindi, and English* (1884), or Syamasundara Dasa, *Hindi Shabdasagara* (1965–1975), both as served by the Digital South Asia Library, gives the name for the species or plant named, with its page; a dash means none was confirmed, and the common Rajasthani name, where there is one, is given in the notes only as a name in use. Platts often uses older botanical names, which are given in the notes. Final selection shall be confirmed with a horticulturist or the State Forest Department for the site's soil, salinity and water table. Sites in the arid west need species that survive years of drought and sand-blast, with no irrigation once established; sites on calcrete or saline ground species tolerant of salt; black-soil sites of Hadoti species tolerant of heavy, cracking clay that is waterlogged in the monsoon; and talab-edge and floodplain sites species tolerant of standing water. Native trees and grasses of the agor of a talab also keep its catchment from eroding and silting the talab.

Table 8D.13 — Indicative plants for bioretention, swales and filter strips

Use	Botanical name	Hindi / Urdu name	Notes
Swales, filter strips, bioretention edges	*Chrysopogon zizanioides* (vetiver)	ख़स / خس (ḵẖas)	Deep-rooted clump grass; tolerates flooding and drought; binds soil on side slopes and talab banks. Platts: "A fragrant grass, *Andropogon muricatum* (from the roots of which *taṭṭīs* are made)" (p. 489), an older name of this species
Swales and filter strips (turf)	*Cynodon dactylon* (Bermuda grass)	दूब / دوب (dūb)	Low turf; tolerates drought, traffic and short flooding. Platts: "Bent grass, panic grass, *Panicum dactylon*, or *Cynodon dactylon*" (p. 531)
Swales and filter strips in the arid west	*Lasiurus sindicus* (sewan grass)	—	Native perennial grass of the Thar sands; very drought-tolerant. Sewan, its Rajasthani name, was not found in Platts or the Shabdasagara
Swales and filter strips in the arid and semi-arid zones	*Cenchrus ciliaris* (buffel grass)	—	Native tufted grass; binds sandy soil. Dhaman, a name in use, is given by the Shabdasagara to a different plant (p. 2455), so it is not used here
Swales and banks on river sands	*Saccharum spontaneum*	कास / کاس (kās)	Native tall grass of river sands; binds banks; cut back where it would obstruct a channel. Platts: "A species of grass, of which ropes, &c. are made, *Saccharum spontaneum*" (p. 801)
Shrubs on swale banks and bioretention edges (dry)	*Capparis decidua* (syn. *C. aphylla*)	करील, कैर / کریل، کیر (karīl, kair)	Leafless thorny shrub of the desert; very drought-tolerant. Platts (*karīr*): "a thorny leafless shrub, the caper bush, *Capparis aphylla* (which grows in deserts, and is eaten by camels)" (p. 830); *kair* and *karīl* are given as forms of *karīr* (pp. 888, 831)
Shrubs on swale banks and bioretention edges (dry)	*Ziziphus nummularia*	झड़बेरी / جھڑبیري (jhaṛ-berī)	Native thorny bush of dry ground. Platts: "A wild ber or jujube bush, *Zizyphus jujuba*; the wild lote-tree" (p. 404); that the name refers to this species was not confirmed in Platts
Trees beside bioretention, swales and in the agor	*Prosopis cineraria* (khejri)	खेजड़ी (khejaṛī)	Native tree of the arid and semi-arid zones; deep-rooted, drought-tolerant, and a fodder tree. In the Shabdasagara, खेजड़ी is "the shami tree" (p. 1178), and शमी "a large tree", recorded there as found in Rajputana among other provinces (p. 4695). Not in Platts. Not to be confused with *Prosopis juliflora* (Table 8D.15)
Trees beside bioretention, swales and in the agor	*Tecomella undulata* (rohida)	—	Native tree of the arid zone; drought-tolerant; binds sand. Rohida, its Rajasthani name, was not found in Platts or the Shabdasagara

Use	Botanical name	Hindi / Urdu name	Notes
Trees beside bioretention and swales	*Ziziphus mauritiana* (ber)	बेर / بیر (ber)	Native; drought-tolerant. Platts: "The jujube tree, *Zizyphus jujuba*, or *Z. scandens*; the fruit of the jujube" (p. 208), an older name of this species
Trees beside swales and channels	*Vachellia nilotica* (syn. *Acacia nilotica*; desi babul)	बबूल, कीकर / ببول، کیکر (babūl, kīkar)	Native; tolerates both drought and seasonal waterlogging; thorny. Platts: "The gum-acacia tree, *Mimosa arabica*" (p. 130), and *kīkar*, "The tree *Acacia* (or *Mimosa*) *arabica* (syn. *babūl*)" (p. 889), older names of this species. Not to be confused with *Prosopis juliflora* (vilayati babul, Table 8D.15)
Trees on saline or calcrete ground beside swales	*Salvadora persica*	पीलू / پیلو (pīlū); जाल / جال (jāl)	Native; tolerates saline soil and drought. Platts: *pīlū*, "The tree *Careya arborea*, or *Salvadora persica*" (p. 301), and *jāl*, "the tree *Salvador indica*" (p. 371); confirm the species with the supplier
Trees beside bioretention and swales	*Azadirachta indica* (neem)	नीम / نیم (nīm)	Native or long naturalised; drought-tolerant; not for waterlogged beds. Platts: "The Nīm-tree, *Melia azadirachta*" (p. 1169), an older name of this species
Trees on talab banks and saline wet edges	*Tamarix dioica* (syn. *T. indica*)	झाऊ / جھاو (jhā'ū, jhau)	Native; tolerates salt and standing water. Platts: "A tree of the Tamarisk kind, *Tamarix gallica*, or *T. Indica* (… from its growing in marshy or sandy ground …)" (p. 402); confirm the species with the supplier
Trees beside bioretention and channels (east and south only)	*Syzygium cumini*	जामुन, जामन / جامن (jāmun, jāman)	Native in the wetter east and south (Hadoti, Mewar, Vagad); tolerates wet ground; not for the arid west. Platts: "The tree *Eugenia jambelana*, or *Syzygium jambolanum*, and its fruit" (p. 372)
Trees beside channels (east and south only)	*Terminalia arjuna*	अर्जुन / ارجن (arjun)	Native riverbank tree of the south and east; tolerates seasonal flooding. Platts: "a certain tree, *Terminalia alata glabra*" (p. 39); that the name refers to this species was not confirmed in Platts
Trees beside wet ponds and channels	*Ficus racemosa* (syn. *F. glomerata*)	गूलर / گولر (gūlar)	Native fig of stream banks. Platts: "The wild fig, *Ficus glomerata*" (p. 926). Keep roots clear of underdrains, pipes, walls and taankas

Table 8D.14 — Indicative plants for constructed wetlands and wet ponds

Constructed wetlands and wet ponds are rarely practical in the arid west, where no permanent pool survives the dry months without a feed (Clause 8.7.8); these species are for the sites where the water balance shows that one does.

Zone	Botanical name	Hindi / Urdu name	Notes
Shallow macrophyte zone	*Typha* spp. (e.g. *T. domingensis*, syn. *T. angustata*)	—	Native; tolerates some salinity; spreads quickly and needs periodic harvesting. No Hindi name was confirmed in Platts: पटेर (paṭer), sometimes used for it, is glossed by Platts as *Cyperus* (p. 229)
Shallow macrophyte zone	*Phragmites karka*	नल / نل (nal); नरसल / نرسل (narsal)	Native reed; vigorous; keep out of nalas and channels where it would obstruct flow. Platts: "A species of reed, *Amphidonax karka*, or *Arundo karka*" (p. 1152) and "A large species of reed, *Arundo karka*" (p. 1132)
Shallow macrophyte zone	*Canna indica*	—	Naturalised; tolerates waterlogging; widely used in constructed wetlands in India
Open water and deep zones	*Nelumbo nucifera* (lotus)	कमल / کمل (kamal)	Native; for permanent pools only. Platts: "The lotus, *Nelumbium speciosum*" (p. 849)
Open water and deep zones	*Nymphaea nouchali* (blue water lily)	नीलोफ़र / نیلوفر (nīlofar)	Native; for permanent pools only. Platts: "the blue water-lily, *Nymphæa cyanea*" (p. 1168), an older name of this species

Table 8D.15 — Species not to be planted

Botanical name	Hindi / Urdu name	Reason
Prosopis juliflora (vilayati babul)	—	Invasive; forms dense thickets on talab beds, in the agor of talabs, on embankments and along drains. Not to be confused with the native *Prosopis cineraria* (khejri) or *Vachellia nilotica* (desi babul) of Table 8D.13
Eichhornia crassipes (water hyacinth)	—	Invasive; chokes talabs, city lakes, nalas and screens
Ipomoea carnea	—	Invasive in ponds and channels; obstructs flow

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Annex 8E — Erosion and sediment control standard details

Supports Clause 8.12 of Chapter 8.

The details below show the arrangement of each measure. Dimensions set by the Manual are given. Dimensions the Manual does not set are labelled "to be confirmed in design" and shall be shown on the ESC plan (Clause 8.12.1). Temporary measures are designed with the rainfall of Chapter 2 and a climate factor of 1.0 (Clause 8.12.4).

Table 8E.1 — Selection of measures (Clause 8.12.3)

Situation	Measure	Detail
Sheet flow leaving a disturbed area, along its downslope edge	Silt fence	Figure 8E.1
Concentrated flow from a disturbed area of up to 2 ha	Sediment trap	Figure 8E.2
Disturbed area of more than 2 ha	Sediment basin with surface dewatering outlet	Figure 8E.2
Existing drain inlet receiving site runoff	Inlet protection	Figure 8E.4
Vehicle exit to a public road	Stabilised construction exit, with wheel washing	Figure 8E.3
Stockpiles	Outside Zone 1 of any waterbody setback; ≥ 10 m from any drain; covered in the SW monsoon	Notes to Figure 8E.1
Dewatering	Through a sediment basin, settling tank or filter bag; never pumped directly to a drain or waterbody	Notes to Figure 8E.2
Concrete washout	Lined pit; never into a drain	Notes to Figure 8E.3

8E.1 Silt fence

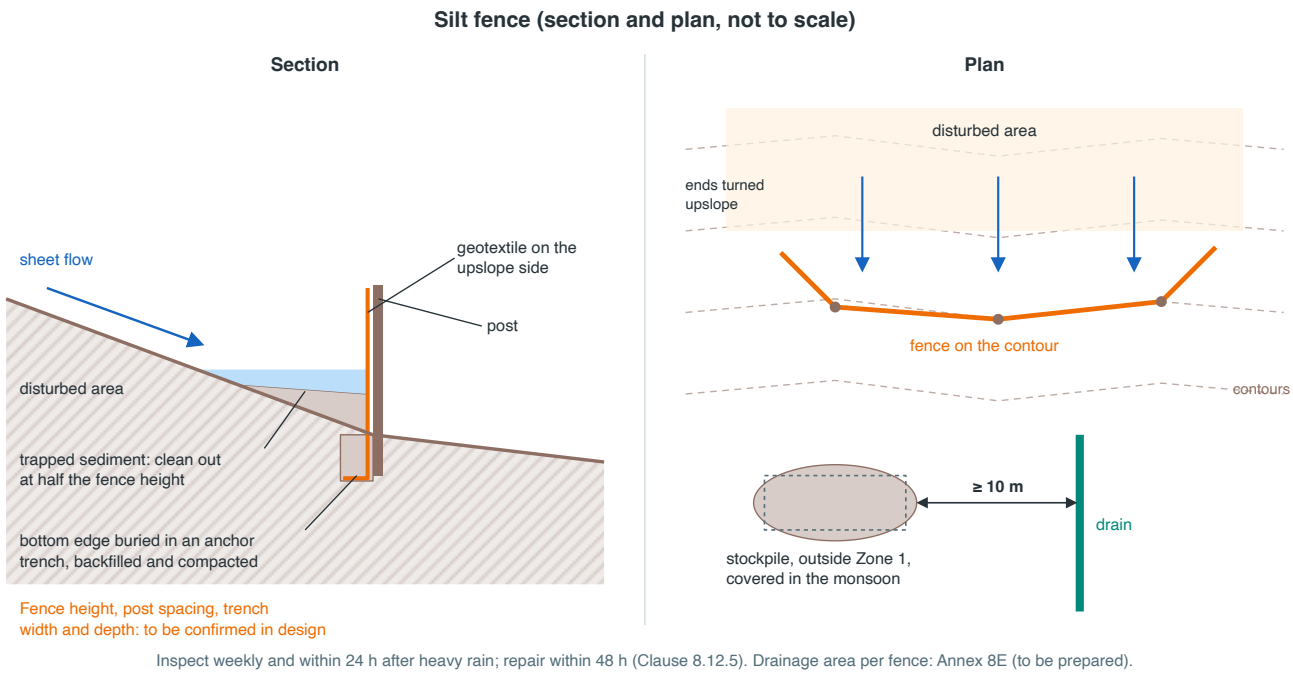

Figure 8E.1 — Silt fence: section showing geotextile on posts with the bottom edge buried in an anchor trench on the upslope side, and plan showing the fence on the contour with returns at the ends. Dimensions not set by the Manual are to be confirmed in design. Original drawing for this Manual, adapted from US EPA, NPDES Construction General Permit (2022), and CIRIA, The SuDS Manual (C753), 2015.

To be prepared. Clause 8.12.3(a) refers to this annex for the limit on the area draining to each silt fence. That limit, and the maximum slope length above a fence, need to be set by the State Stormwater Technical Committee for Rajasthan rainfall. Until they are published, the following interim limits apply, taken from common US practice (US EPA, Stormwater Best Management Practice fact sheet: Silt Fence):

- drainage area: not more than **0.1 ha per 30 m** of fence;
- slope length above the fence: not more than 30 m on slopes under 2%, 23 m at 2–5%, 15 m at 5–10%, 8 m at 10–20% and 5 m steeper than 20%;
- wherever flow arrives concentrated, or a limit cannot be met, a sediment trap (Figure 8E.2) is used instead.

The designer shall show the drainage area and slope length served by each fence on the ESC plan.

Notes:

1. Place along the contour at the downslope edge of the disturbed area, never across a concentrated flow path.
2. Turn the ends upslope so that water cannot run round them.
3. Inspect weekly and within 24 hours after every heavy-rainfall event; repair within 48 hours; remove sediment when the deposit reaches half the fence height (Clause 8.12.5).
4. Remove only after the area draining to it is stabilised (Clause 8.12.6).
5. Stockpiles: outside Zone 1, at least 10 m from any drain, and covered during the SW monsoon (Clause 8.12.3(f)).

8E.2 Sediment trap and sediment basin

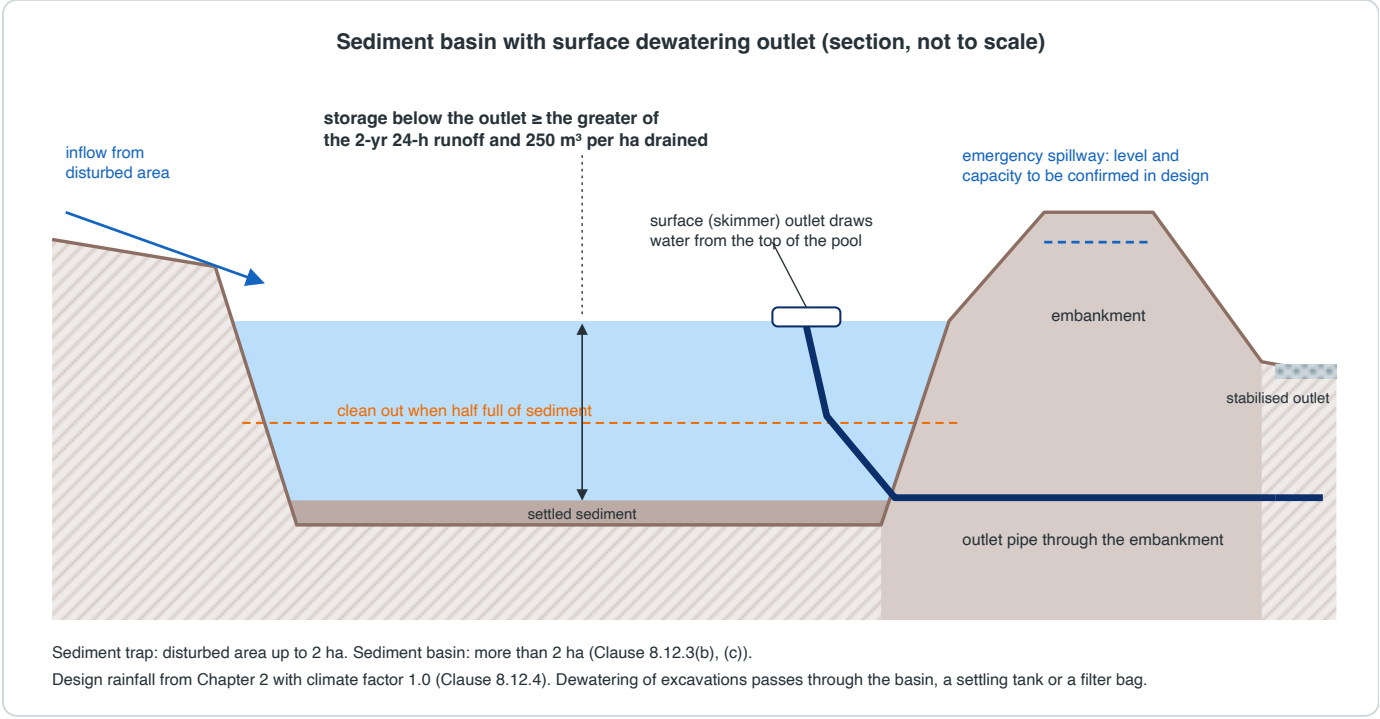

Figure 8E.2 — Sediment trap or basin in section: inflow, storage volume below the outlet, surface dewatering outlet (skimmer) drawing water from the top of the pool, emergency spillway, and sediment cleanout level at half the storage. Original drawing for this Manual, adapted from US EPA, NPDES Construction General Permit (2022).

Notes:

1. **Sediment trap:** for concentrated flow from disturbed areas of up to 2 ha (Clause 8.12.3(b)). Storage volume, depth and outlet: to be confirmed in design.
2. **Sediment basin:** for disturbed areas of more than 2 ha. Storage below the outlet ≥ the greater of (a) the runoff from the 50% AEP (2-yr) 24-hour storm and (b) 250 m³ per hectare of drainage area (Clause 8.12.3(c)).
3. The dewatering outlet draws water from the surface (Clause 8.12.3(c)).
4. An emergency spillway and its capacity: to be confirmed in design. Where the basin is also a permanent detention facility, the Chapter 4 spillway rules apply.
5. Clean out when half full of sediment (Clause 8.12.5). Remove sediment from any permanent facility before its as-built survey (Clause 8.12.6).
6. Dewatering of excavations shall pass through a sediment basin, settling tank or filter bag (Clause 8.12.3(g)).

Illustrative — not design values. A sediment basin serves 3.0 ha of disturbed land. Assume a 2-yr 24-hour rainfall of 100 mm (climate factor 1.0, Clause 8.12.4) and a curve number of 86 for bare compacted ground under the antecedent moisture condition of Chapter 2.

- $S = 25{,}400 / 86 - 254 = 41.35$ mm; $I_a = 0.2S = 8.27$ mm
- $Q = (P - I_a)^2 / (P - I_a + S) = (100 - 8.27)^2 / (100 - 8.27 + 41.35) = 8{,}414 / 133.08 = 63.2$ mm
- (a) Runoff volume = $10 \times Q \times A = 10 \times 63.2 \times 3.0 = 1{,}896$ m³
- (b) 250 m³/ha × 3.0 ha = 750 m³
- Required storage below the outlet = max (1,896, 750) = 1,896 m³. Here the 2-yr runoff governs.

8E.3 Stabilised construction exit and concrete washout

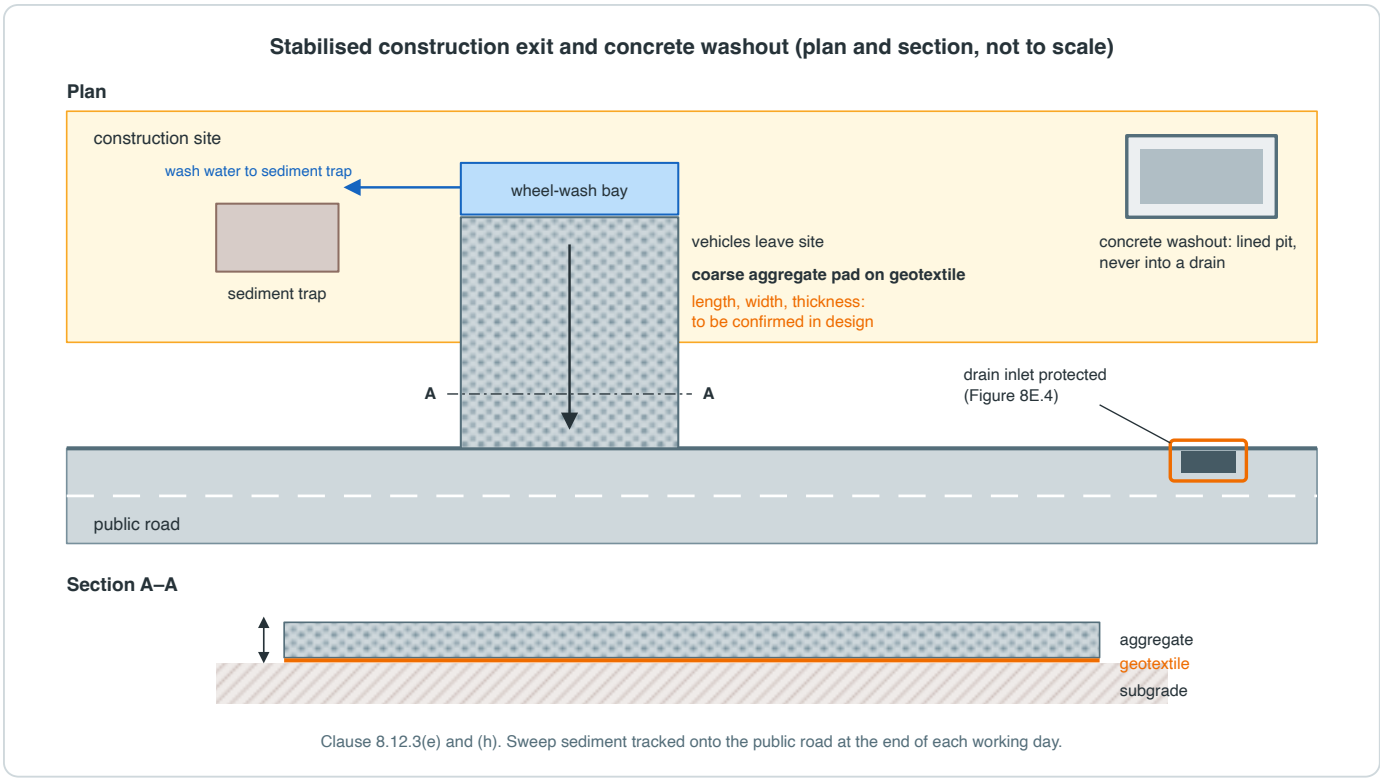

Figure 8E.3 — Stabilised construction exit: plan and section showing a coarse aggregate pad on geotextile between the site and the public road, a wheel-wash bay draining to a sediment trap, and a lined concrete washout pit. Dimensions not set by the Manual are to be confirmed in design. Original drawing for this Manual, adapted from US EPA, NPDES Construction General Permit (2022).

Notes:

1. Provide at every point where vehicles leave the site onto a public road, with wheel washing (Clause 8.12.3(e)).
2. Pad length, width, thickness and aggregate size: to be confirmed in design.
3. Wash water drains to a sediment trap or basin, never to a drain.
4. Concrete washout in a lined pit, never into a drain (Clause 8.12.3(h)).
5. Sweep any sediment tracked onto the public road at the end of each working day.

8E.4 Inlet protection

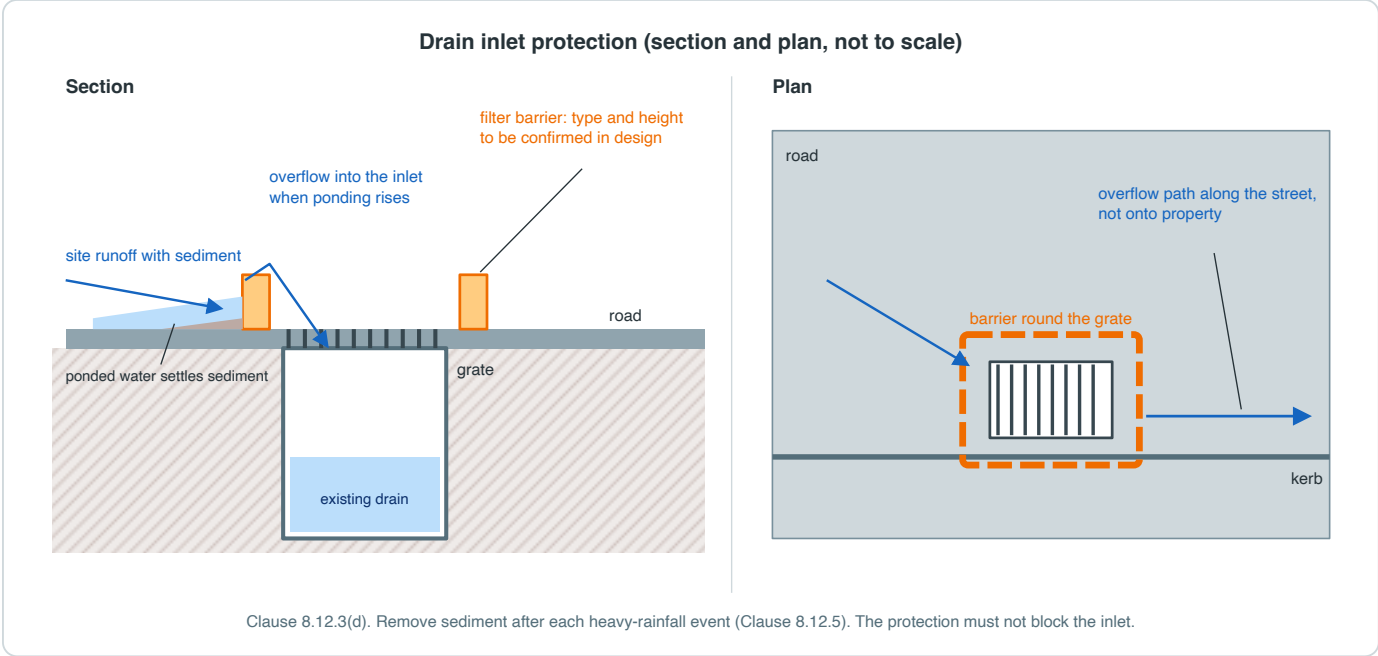

Figure 8E.4 — Inlet protection at an existing drain inlet: a filter barrier around a grate or kerb inlet, with an overflow path so that ponding does not flood the road or property. Original drawing for this Manual, adapted from US EPA, NPDES Construction General Permit (2022), and CIRIA, The SuDS Manual (C753), 2015.

Notes:

1. At every existing drain inlet that receives runoff from the site (Clause 8.12.3(d)).
2. The protection must not block the inlet: water ponding behind it must be able to overflow into the inlet or along the street.
3. Barrier type and height: to be confirmed in design.
4. Remove sediment after each heavy-rainfall event (Clause 8.12.5).

8E.5 Timing and inspection

Table 8E.2 — ESC timing and inspection (Clauses 8.12.2 and 8.12.5)

Item	Requirement
Completed earthworks	Stabilised by vegetation, mulch, matting or paving by 15 June
Area cleared between 15 June and 30 September	Sediment controls in place before clearing
Area exposed in the SW monsoon	As small as practicable
Inspection	Weekly, and within 24 h after every heavy-rainfall event (Chapter 10)
Repair	Within 48 h
Cleaning	When half full of sediment
Removal	Only after the area draining to the measure is stabilised

Form 8-1 — Water Quality Sheet

Supports Clauses 8.4, 8.6 and 8.14 of Chapter 8.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0.

Table 8F.1 — Form 8-1, Section A: Site and rainfall

No.	Field	Entry	Clause
A1	Project name and Authority file number	_____	—
A2	Tier (A / B) and site area, ha	_____	8.6.1
A3	Rainfall zone (Chapter 2)	_____	8.4.1
A4	P_ret, mm (Annex 2E)	_____	8.4.1
A5	P_3m, mm (Annex 8A, or the interim calculation: record, years, method)	_____	8.4.1
A6	P_wq = max (P_ret, P_3m), mm (no climate factor)	_____	8.4.1, 8.4.3
A7	WQv method: SCS-CN, or Rv (sites < 0.5 ha and Tier B simplified method only)	_____	8.4.2
A8	Redevelopment (existing impervious ≥ 20%)?	_____	8.6.2

Table 8F.2 — Form 8-1, Section B: Water quality volume and flow by drainage area

Area ID	Area (ha)	Impervious I (%)	Q_wq runoff depth (mm) or Rv	WQv (m^3)	Q_wq (m^3/s)	Volume retained, Chapter 4 (m^3)	WQv not retained (m^3)	BMP serving the area	Pretreatment
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
Total	_____			_____		_____	_____		

Table 8F.3 — Form 8-1, Section C: Level of Service and Value Rating (Tier A)

No.	Field	Entry	Clause
C1	CN pre-development; CN post-development; ΔCN	_____	8.6.2
C2	Required LoS (Table 8.2, or Annex 8B for redevelopment)	_____	8.6.2
C3	Composite VR (Annex 8B calculation attached)	_____	8.6.3
C4	Composite VR ≥ required LoS?	_____	8.6.3
C5	Tier B: route used under Clause 8.6.5 (a) retained on site / (b) bioretention, rain garden or infiltration	_____	8.6.5

Table 8F.4 — Form 8-1, Section D: Other submittals (Clause 8.14)

No.	Item	Attached (yes / no / not applicable)	Clause
D1	BMP designs to Clause 8.7 and Annex 8D, with pretreatment	_____	8.14(3)

No.	Item	Attached (yes / no / not applicable)	Clause
D2	Infiltration Test Record (Form 8-2), seasonal high groundwater level and source, design rate, drawdown time, setbacks	_____	8.14(4)
D3	Sewage and sullage connection plan; dye or smoke test record	_____	8.9.2, 8.14(5)
D4	GPT and first-flush design for any outfall to a waterbody	_____	8.10, 8.14(6)
D5	RWH layout separating harvesting, recharge and detention	_____	8.11, 8.14(7)
D6	ESC plan	_____	8.12, 8.14(8)
D7	Hotspot controls, where Clause 8.8.8 applies	_____	8.8.8

Table 8F.5 — Form 8-1, Section E: Prepared by

Field	Entry
Name, registration and empanelment number (Clause 10.6)	_____
Signature and date	_____

Form 8-2 — Infiltration Test Record

Supports Clauses 8.8.1 to 8.8.7 and 8.11.4 of Chapter 8.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. One record per facility. Attach a plan showing the test locations, and the readings for each test.

Table 8F.6 — Form 8-2, Section A: Facility

No.	Field	Entry	Clause
A1	Project and facility ID; facility type	_____	8.8.3
A2	Infiltration base area (m²) or trench length (m)	_____	8.8.3(c)
A3	Proposed base level of the facility, m (datum)	_____	8.8.3
A4	Runoff source: roof only / paved surfaces / mixed; hotspot (yes / no)	_____	8.8.6, 8.8.8
A5	Ground setting: sandy coastal / laterite or hard rock / delta clay or black cotton / other	_____	8.8.9–8.8.11

Table 8F.7 — Form 8-2, Section B: Tests

Test no.	Location (grid ref.)	Date	Method: double-ring (ASTM D3385) / falling-head borehole or trial-pit soakage (e.g. BRE Digest 365)	Test level, m	Groundwater level at time of test, m	Measured rate (mm/h)
1	_____	_____	_____	_____	_____	_____
2	_____	_____	_____	_____	_____	_____
3	_____	_____	_____	_____	_____	_____

Minimum number of tests: 2 per facility, and 1 per 100 m² of base area or per 50 m of trench (Clause 8.8.3(c)).

Table 8F.8 — Form 8-2, Section C: Design rate and drawdown

No.	Item	Entry	Clause
C1	Number of tests made; number required	_____	8.8.3(c)
C2	Highest and lowest measured rates; ratio (highest ÷ lowest)	_____	8.8.4
C3	Safety factor: 2.0 (tests meet 8.8.3(c) and ratio ≤ 2) or 3.0	_____	8.8.4
C4	Design rate = measured rate used ÷ safety factor, mm/h (state which measured rate was used)	_____	8.8.4
C5	Category: ≥ 13 mm/h full infiltration / 3–13 mm/h partial with underdrain / < 3 mm/h no credit	_____	8.8.5
C6	Depth of water to infiltrate, mm; drawdown time = depth ÷ design rate, h (≤ 72 h)	_____	8.8.7

Table 8F.9 — Form 8-2, Section D: Separation and setbacks

No.	Item	Entry	Clause
D1	Seasonal high groundwater level, m, and its source (Clause 3.10.2)	_____	8.8.1
D2	Separation from facility base to seasonal high groundwater, m (≥ 1.0; ≥ 0.5 for roof-only runoff in notified coastal sand with mounding check)	_____	8.8.1, 8.8.9(d)

No.	Item	Entry	Clause
D3	Depth to bedrock or impermeable layer below base, m (≥ 1.0 unless Clause 8.8.10)	_____	8.8.2
D4	Distances to: foundations / basement / property boundary / drinking-water well or borewell / septic tank or soak pit / crest of slope steeper than 1V:3H, m	_____	8.8.6
D5	Expansive soils: foundation setback doubled?	_____	8.8.11(b)

Table 8F.10 — Form 8-2, Section E: Declaration

Field	Entry
Tester: name, qualification in geotechnical testing, organisation	_____
I certify that the tests were made at the stated locations and levels, by the stated methods, and that the readings attached are complete. Signature and date	_____
Designer (Clause 10.6): name and signature	_____

ANNEXES TO CHAPTER 9

Hydraulic Design of Structures

These annexes support Chapter 9. Annex 9A gives the FHWA HDS-5 inlet-control equations in SI units, with published coefficients for common inlets, and a full worked culvert example. Annex 9B gives standard drawings that carry only the dimensions Chapter 9 and Chapter 6 already set; every other dimension is marked "to be confirmed in design". Annex 9C is a pump station design checklist with a standard control philosophy drawn from Clause 9.9. Form 9-1 is a draft form: it lists what Clause 9.14 requires and does not add to it.

Annex 9A — HDS-5 inlet-control coefficients and worked culvert example in SI units

Supports Clauses 9.4.1 to 9.4.7 of Chapter 9 and Clause 6.12 of Chapter 6.

9A.1 Inlet-control equations

FHWA *Hydraulic Design of Highway Culverts*, HDS-5, 3rd edition (2012), Appendix A, gives three inlet-control equations. In SI units:

> Unsubmerged, Form 1: HWi/D = Hc/D + K · [Ku · Q / (A · D^0.5)]^M + Ks · S

> Unsubmerged, Form 2: HWi/D = K · [Ku · Q / (A · D^0.5)]^M

> Submerged: HWi/D = c · [Ku · Q / (A · D^0.5)]² + Y + Ks · S

where HWi is the headwater depth above the inlet invert under inlet control (m), D is the interior height (rise) of the barrel (m), Hc is the specific head at critical depth, dc + Vc²/2g (m), Q is the discharge (m³/s), A is the full cross-sectional area of the barrel (m²), S is the barrel slope (m/m), K, M, c and Y are the constants of Table 9A.1, Ku = 1.811 in SI units (1.0 in US units), and Ks is the slope correction: −0.5, or +0.7 for mitred inlets.

Which equation applies depends on X = Ku · Q / (A · D^0.5):

- X ≤ 3.5: unsubmerged equation (Form 1 or Form 2 as listed in Table 9A.1);
- X ≥ 4.0: submerged equation;
- 3.5 < X < 4.0 (transition): use FHWA HY-8, which implements the HDS-5 transition. Where a hand calculation is used, take the higher of the unsubmerged and submerged results. This is a conservative simplification made by this annex, not an HDS-5 rule.

Table 9A.1 — HDS-5 inlet-control coefficients for common inlets

Barrel	Inlet edge	Form	K	M	c	Y
Circular concrete	Square edge with headwall	1	0.0098	2.0	0.0398	0.67
Circular concrete	Groove (socket) end with headwall	1	0.0018	2.0	0.0292	0.74
Circular concrete	Groove (socket) end projecting	1	0.0045	2.0	0.0317	0.69
Circular corrugated metal	Headwall	1	0.0078	2.0	0.0379	0.69
Circular corrugated metal	Mitred to slope	1	0.0210	1.33	0.0463	0.75
Circular corrugated metal	Projecting	1	0.0340	1.50	0.0553	0.54
Rectangular box	Wingwalls flared 30° to 75°	1	0.026	1.0	0.0347	0.81
Rectangular box	Wingwalls flared 90° and 15°	1	0.061	0.75	0.0400	0.80
Rectangular box	Wingwalls at 0° (extensions of the sides)	1	0.061	0.75	0.0423	0.82
Rectangular box	90° headwall with 19 mm (3/4 in) chamfers	2	0.515	0.667	0.0375	0.79
Rectangular box	90° headwall with 45° bevels	2	0.495	0.667	0.0314	0.82
Rectangular box	90° headwall with 33.7° bevels	2	0.486	0.667	0.0252	0.865

Source: FHWA HDS-5 (2012), Appendix A, Table A.1 (the coefficients are dimensionless and apply in SI units with Ku = 1.811). The values were checked against HIF-12-026, Table A.1 (chart and scale numbers 1/1–1/3, 2/1–2/3, 8/1–8/3 and 10/1–10/3). Where a later edition of HDS-5 differs, the later table governs. Entrance loss coefficients for outlet control are in Table 9.1 of Chapter 9.

9A.2 Worked example: pipe culvert under a collector road

Illustrative — not design values. The inputs below are invented to show the method; the results are not design values for any site.

Inputs.

Table 9A.2 — Inputs for the worked example

Item	Value	Source
Road class	Collector; design AEP 4% (25-yr), check event 2% (50-yr), and the 1% AEP check	Table 6.1, Clause 6.12.2
Design flow, 4% AEP	1.80 m³/s (including the climate factor)	Illustrative
Check flow, 2% AEP	2.20 m³/s	Illustrative
1% AEP flow	3.00 m³/s	Illustrative
Barrel	One 1,200 mm RCC pipe with collar joints, n = 0.015	Table 6.6
Inlet	Square edge with headwall: ke = 0.5; K = 0.0098, M = 2.0, c = 0.0398, Y = 0.67, Form 1	Tables 9.1 and 9A.1
Length and slope	L = 20.0 m; S = 0.005 (inlet invert 20.00 m, outlet invert 19.90 m, local datum)	Illustrative
Road levels at the inlet	Shoulder edge 22.00 m; lowest point of the road crest 22.10 m	Illustrative
Tailwater above the outlet invert, TW	0.60 m at 1.80 m³/s; 0.70 m at 2.20 m³/s; 0.85 m at 3.00 m³/s (normal depth in the downstream channel)	Illustrative; Clause 9.4.4
Receiving channel	Unlined sandy loam	Table 9.2

Minimum size: 1,200 mm ≥ 900 mm (Clause 6.12.5). The span is below 1.5 m, so the blockage check uses 50% of the inlet area blocked (Clause 6.12.4(a)).

Step 1 — Barrel properties. A = π · 1.2² / 4 = 1.131 m²; full-barrel hydraulic radius R = D/4 = 0.300 m; D^0.5 = 1.095.

Step 2 — Critical depth. For each flow, dc is found by trial from the critical-flow condition for a circular section, $Q^2 \cdot T / (g \cdot Ac^3) = 1$, where Ac and T are the flow area and top width at depth dc.

Table 9A.3 — Critical depth and specific head (D = 1.2 m)

Q (m³/s)	dc (m)	Ac (m²)	T (m)	Vc = Q/Ac (m/s)	Hc = dc + Vc²/2g (m)	Hc/D
1.80	0.737	0.728	1.168	2.471	1.048	0.873
2.20	0.817	0.820	1.119	2.683	1.184	0.987
3.00	0.952	0.962	0.972	3.118	1.447	1.206

Step 3 — Headwater under inlet control. X = 1.811 · Q / (1.131 × 1.095) = 1.462 · Q.

Table 9A.4 — Inlet-control headwater

Q (m³/s)	X	Equation	HWi/D	HWi (m)
1.80	2.631	Unsubmerged, Form 1: 0.873 + 0.0098 × 2.631² − 0.5 × 0.005 = 0.873 + 0.068 − 0.003	0.939	1.127
2.20	3.216	Unsubmerged, Form 1: 0.987 + 0.0098 × 3.216² − 0.003 = 0.987 + 0.101 − 0.003	1.085	1.302
3.00	4.385	Submerged: 0.0398 × 4.385² + 0.67 − 0.003 = 0.765 + 0.67 − 0.003	1.433	1.719

Step 4 — Headwater under outlet control (Clause 9.4.3). The friction term is 19.63 · n² · L / R^1.33 = 19.63 × 0.015² × 20.0 / 0.300^1.33 = 0.0883 / 0.2016 = 0.438, so H = (1 + 0.5 + 0.438) · V²/2g = 1.938 · V²/2g. L · S = 20.0 × 0.005 = 0.100 m.

Table 9A.5 — Outlet-control headwater

Q (m³/s)	V = Q/A (m/s)	V²/2g (m)	H (m)	(dc + D)/2 (m)	TW (m)	ho (m)	HWo = ho + H − L·S (m)
1.80	1.592	0.129	0.250	0.969	0.60	0.969	1.119
2.20	1.945	0.193	0.374	1.009	0.70	1.009	1.283
3.00	2.653	0.359	0.695	1.076	0.85	1.076	1.671

Step 5 — Governing headwater (Clause 9.4.1): the greater of HWi and HWo.

Table 9A.6 — Governing headwater and checks

Event	Q (m³/s)	HWi (m)	HWo (m)	Control	HW (m)	HW level (m)	HW/D
Design, 4% AEP	1.80	1.127	1.119	Inlet	1.127	21.13	0.94
Check, 2% AEP	2.20	1.302	1.283	Inlet	1.302	21.30	1.09
1% AEP	3.00	1.719	1.671	Inlet	1.719	21.72	1.43

Step 6 — Headwater limits at the design AEP (Clause 9.4.5):

- (a) HW/D = 0.94 ≤ 1.2. Complies.
- (b) HW level 21.13 m ≤ shoulder edge 22.00 m − 0.30 m = 21.70 m. Complies.

- (c) Water levels at upstream buildings and property boundaries are compared with the existing condition under Clause 6.12.2(d). This needs the upstream survey and is not shown here.

Step 7 — Road overtopping (Clauses 6.12.2, 6.12.3 and 9.4.6). The 1% AEP headwater level, 21.72 m, is below the lowest road crest, 22.10 m, so the road is not overtopped in the check or 1% AEP events. Had the headwater exceeded the crest, the overtopping flow Qr = Cd · L · h^1.5 (Cd ≤ 1.66) would be balanced with the culvert flow at a common headwater, and the overtopping depth checked against Clause 6.12.2(a).

Step 8 — Outlet velocity (Clause 9.4.7). Under inlet control, the outlet velocity is the velocity at normal depth in the barrel. The barrel's full-flow capacity is (1/n) · A · R^(2/3) · S^0.5 = (1/0.015) × 1.131 × 0.448 × 0.0707 = 2.39 m³/s.

- 1.80 m³/s: normal depth 0.778 m, outlet velocity 2.32 m/s.
- 2.20 m³/s: normal depth 0.908 m, outlet velocity 2.40 m/s.
- 3.00 m³/s: above the full-flow capacity, so the barrel flows full at the outlet; velocity = Q/A = 2.65 m/s.

The receiving channel is unlined sandy loam, with a permissible velocity of 0.53 m/s (Table 9.2), so outlet protection is required (Clause 9.6.1). All barrel velocities are below 3.0 m/s (Clause 6.7.3(b)).

Step 9 — Riprap apron (Clause 9.6.3; Figure 9.2). D50 = 0.2 · D · [Q / (g^0.5 · D^2.5)]^(4/3) · (D/TW), with g^0.5 · D^2.5 = 3.132 × 1.577 = 4.941.

Table 9A.7 — Riprap apron sizing

Q (m³/s)	TW (m)	Q / (g^0.5 · D^2.5)	[ ]^(4/3)	D50 (m)
1.80	0.60	0.364	0.260	0.2 × 1.2 × 0.260 × 2.00 = 0.125
2.20	0.70	0.445	0.340	0.2 × 1.2 × 0.340 × 1.71 = 0.140
3.00	0.85	0.607	0.514	0.2 × 1.2 × 0.514 × 1.41 = 0.174

Clause 9.4.7 requires the outlet to be protected for the design AEP and the 1% AEP, so the apron is sized here for the largest D50, 0.174 m. From Table 9.3, Class 2 (D50 = 150 mm) is too small, so **Class 3** (D50 = 250 mm) is used:

- apron length 5D = 5 × 1.2 = 6.0 m;
- apron thickness 2.4 × D50 = 2.4 × 0.25 = 0.60 m;
- apron width at the outlet at least 3D = 3.6 m, flaring to the downstream channel;
- stone placed on a granular filter or geotextile (Clause 9.6.4).

Step 10 — Blockage check (Clause 6.12.4(a)). Steps 3 to 7 are repeated for the 1% AEP flow with 50% of the inlet area blocked, and the results must meet Clause 6.12.2(a) and (d). This Manual does not yet set a standard way of representing a partly blocked inlet, so this check is carried out in HY-8 or by a method agreed with the Approving Authority. It is not worked here.

Table 9A.8 — Summary of the worked example (Illustrative — not design values)

Check	Result	Clause
Minimum size	1,200 mm ≥ 900 mm	6.12.5
Design HW/D	0.94 ≤ 1.2	9.4.5(a)
Design HW below shoulder edge	21.13 m ≤ 21.70 m	9.4.5(b)
Overtopping in the check and 1% events	None (21.72 m < 22.10 m)	6.12.2, 9.4.6
Outlet protection	Class 3 riprap apron, 6.0 m long, 0.60 m thick, 3.6 m wide at the outlet	9.6.1, 9.6.3
Blockage check	To be run in HY-8 or by an agreed method	6.12.4

Annex 9B — Standard drawings: headwalls, riprap aprons, drop structures, trash racks, detention risers

Supports Clauses 9.4, 9.6, 9.7 and 9.8 of Chapter 9.

The drawings below are schematic standard drawings. They show only the dimensions and rules that Chapter 9 and Chapter 6 set. Structural dimensions, reinforcement, foundations and fixings are to be confirmed in design (Clause 9.1.2). The riprap apron standard drawing is Figure 9.2 of Chapter 9, with dimensions from Table 9.3; it is not repeated here. Table 9B.1 lists the dimensions shown and their source clauses.

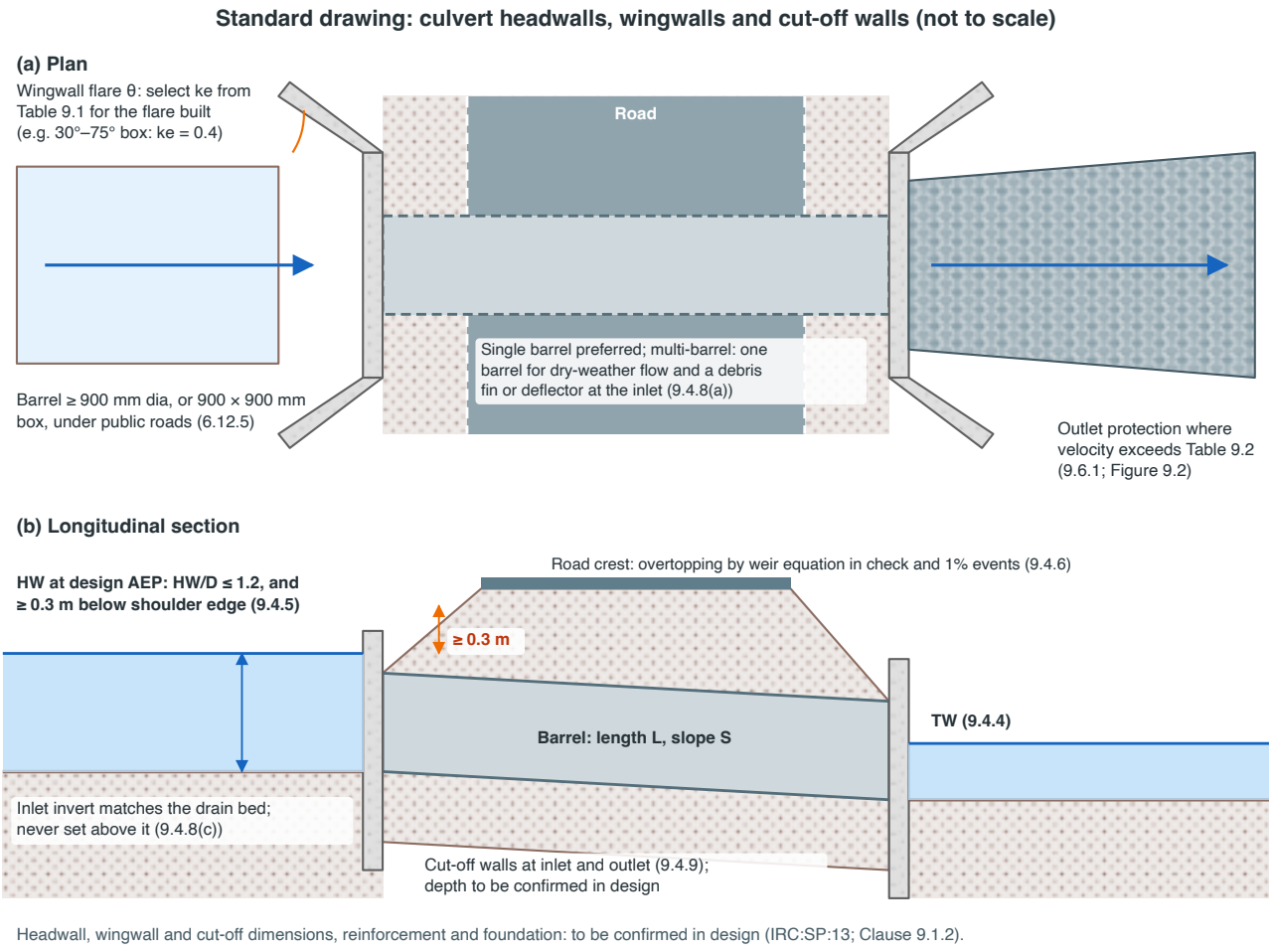

Figure 9B.1 — Standard drawing: culvert headwalls, wingwalls and cut-off walls, in plan and long section, with the headwater limits, invert rule and debris provisions. Original drawing for this Manual, adapted from FHWA, Hydraulic Design of Highway Culverts, HDS-5 (3rd ed., 2012).

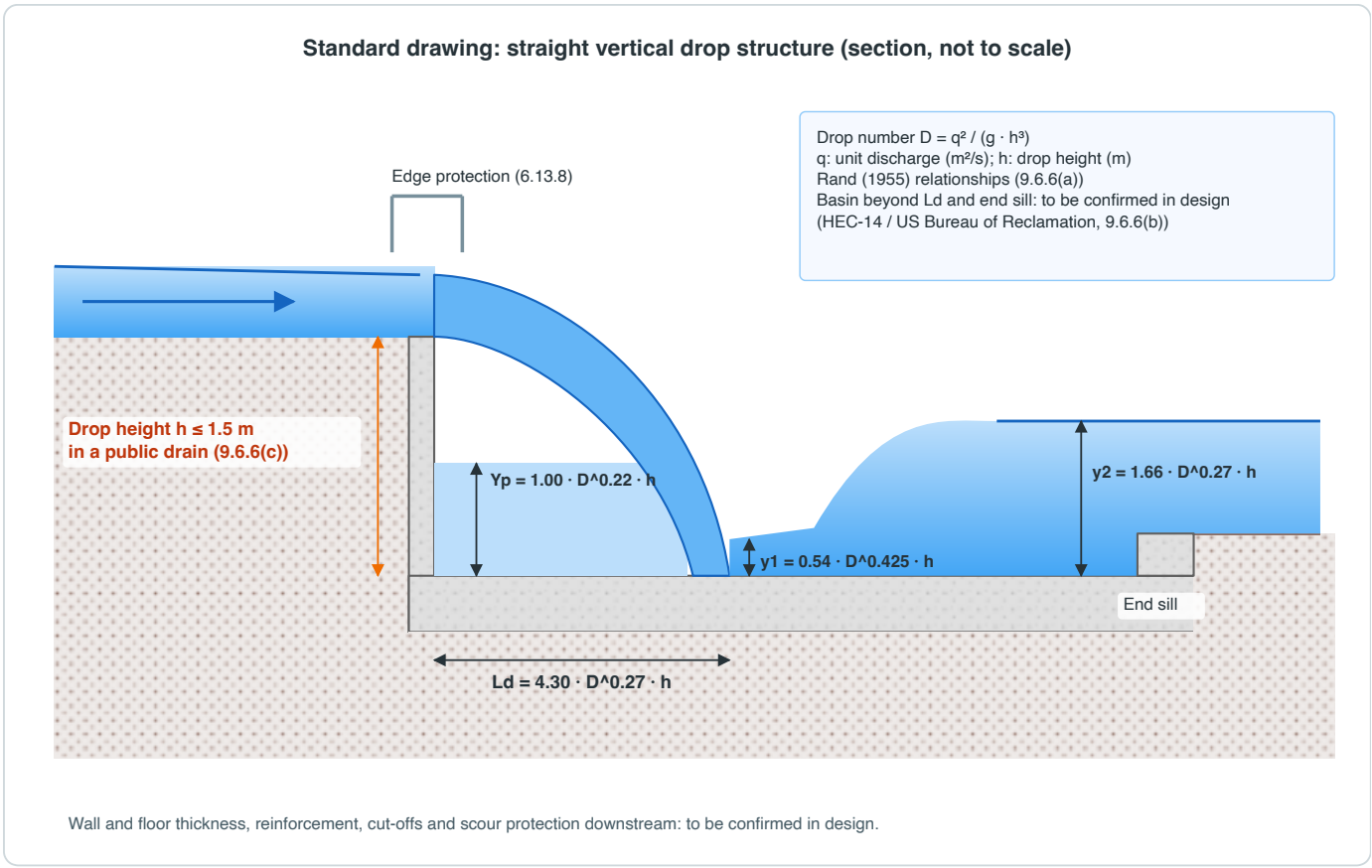

Figure 9B.2 — Standard drawing: straight vertical drop structure with the Rand (1955) pool geometry and the 1.5 m height limit. Original drawing for this Manual, adapted from Chow, Open-Channel Hydraulics (1959), and FHWA, HEC-14 (3rd ed., 2006).

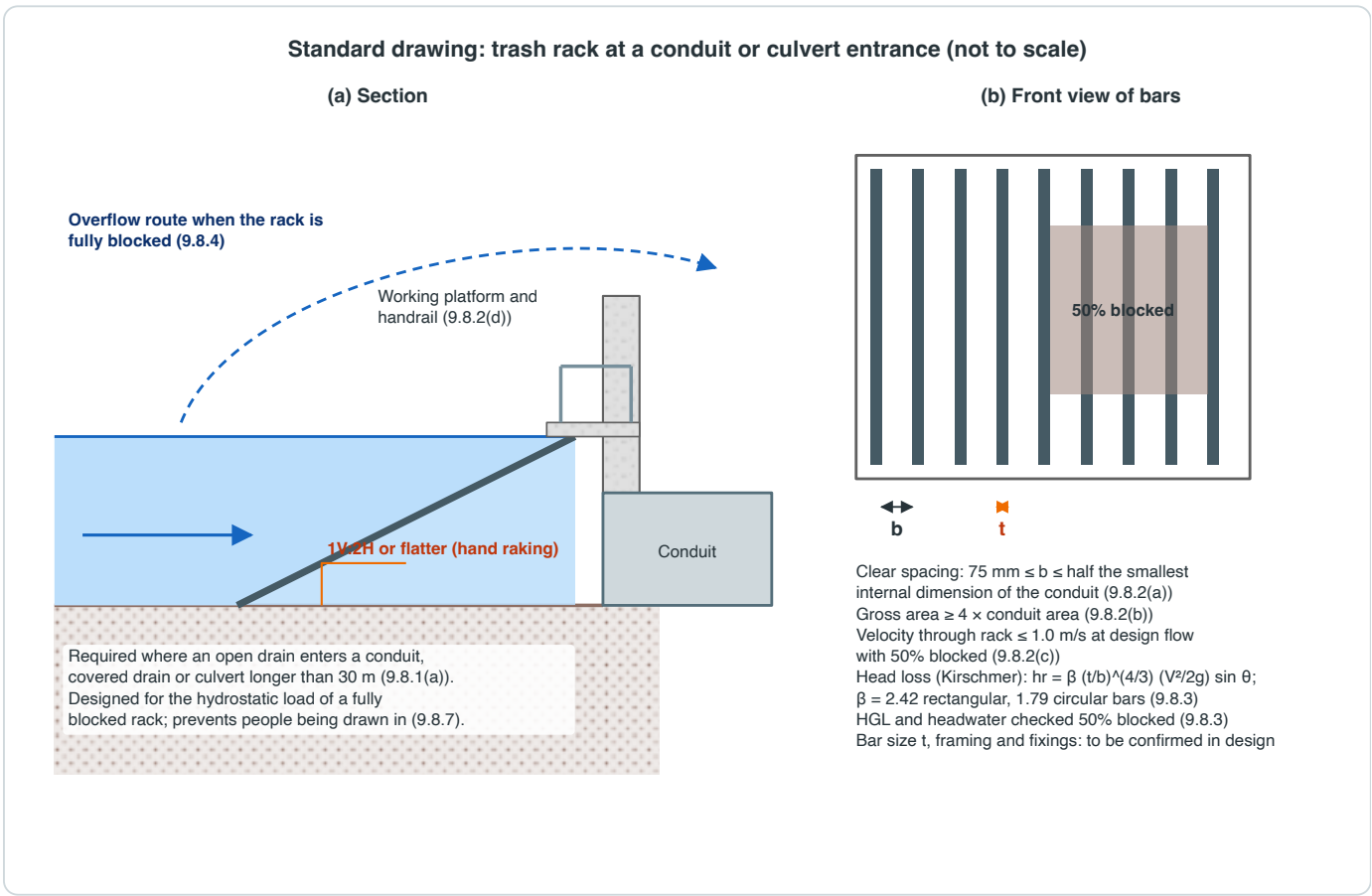

Figure 9B.3 — Standard drawing: trash rack at a conduit or culvert entrance, in section and front view, with bar spacing, area, velocity, slope and overflow requirements. Original drawing for this Manual, adapted from CIRIA, Culvert, screen and outfall manual, C786 (2019), and CPHEEO, Manual on Storm Water Drainage Systems (2019), §8.3.1.3.

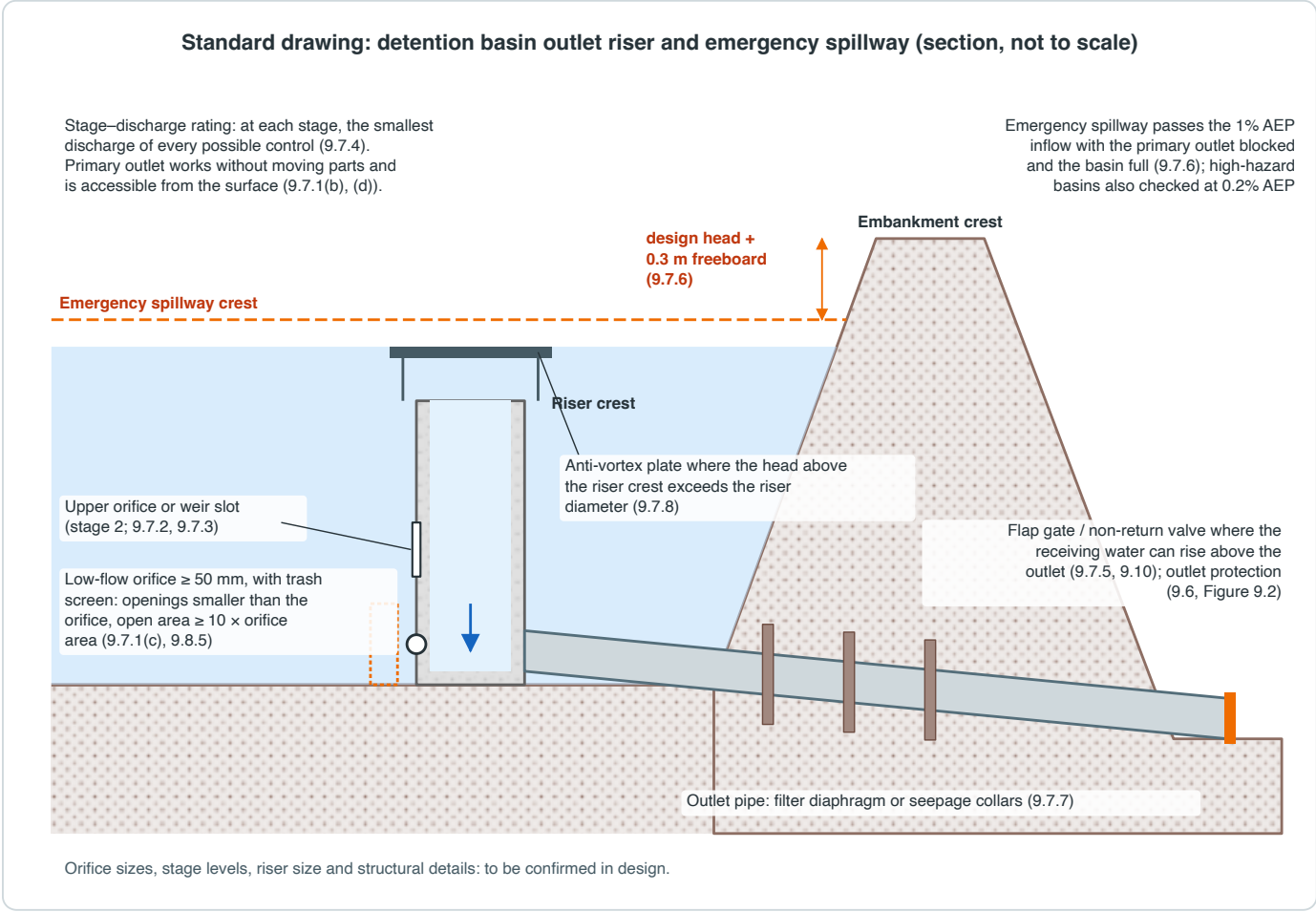

Figure 9B.4 — Standard drawing: detention basin outlet riser with low-flow orifice and screen, upper stage, anti-vortex plate, outlet pipe through the embankment, flap gate and emergency spillway. Original drawing for this Manual, adapted from Kansas City Metro APWA, Section 5600 (2006, 5608.4).

Table 9B.1 — Dimensions and rules on the standard drawings and their source clauses

Drawing	Item	Dimension or rule	Clause
9B.1	Minimum culvert size under public roads	900 mm diameter, or 900 mm × 900 mm box	6.12.5
9B.1	Headwater at the design AEP	HW/D ≤ 1.2; at least 0.3 m below the shoulder edge at the upstream face	9.4.5
9B.1	Entrance loss coefficient	From Table 9.1 for the inlet built (for example 0.4 for a box with wingwalls at 30°–75°)	9.4.3
9B.1	Inverts	Match the drain bed; never above it	9.4.8(c)
9B.1	Multi-barrel culverts	Avoided in debris-prone drains; where used, one barrel for dry-weather flow and a debris fin or deflector	9.4.8(a)
9B.1	Headwalls, wingwalls, cut-off walls	Required; dimensions to be confirmed in design	9.4.9
9B.1	Road overtopping	Qr = Cd · L · h^1.5, Cd ≤ 1.66	9.4.6
Figure 9.2	Riprap apron	Width at the outlet ≥ 3D, flaring to the channel; length and thickness from Table 9.3; filter or geotextile	9.6.3, 9.6.4

Drawing	Item	Dimension or rule	Clause
9B.2	Single vertical drop in a public drain	Height h ≤ 1.5 m; edge protection	9.6.6(c), 6.13.8
9B.2	Pool geometry	D = q²/(g h³); Ld/h = 4.30 D^0.27; Yp/h = 1.00 D^0.22; y1/h = 0.54 D^0.425; y2/h = 1.66 D^0.27	9.6.6(a)
9B.2	Basin beyond Ld, end sill	To be confirmed in design (HEC-14 or US Bureau of Reclamation)	9.6.6(b)
9B.3	Where required	Where an open drain enters a conduit, covered drain or culvert longer than 30 m	9.8.1(a)
9B.3	Clear bar spacing b	Not less than 75 mm and not more than half the smallest internal dimension of the conduit	9.8.2(a)
9B.3	Gross rack area	At least 4 times the conduit area	9.8.2(b)
9B.3	Velocity through the rack	Not more than 1.0 m/s at the design flow with 50% blocked	9.8.2(c)
9B.3	Inclination	No steeper than 1V:2H where raked by hand; working platform and handrail	9.8.2(d)
9B.3	Head loss and blocked check	Kirschmer equation; HGL and headwater checked with 50% blocked	9.8.3
9B.3	Overflow and safety	Overflow route for a fully blocked rack; designed for the full hydrostatic load	9.8.4, 9.8.7
9B.4	Low-flow orifice	Not smaller than 50 mm; trash screen with openings smaller than the orifice and open area at least 10 times the orifice area	9.7.1(c), 9.8.5
9B.4	Orifice and weir flow	Q = Cd · A · (2gh)^0.5, Cd = 0.60 sharp-edged; weir coefficients of Clause 9.7.3	9.7.2, 9.7.3
9B.4	Stage–discharge rating	Smallest discharge of every possible control at each stage	9.7.4
9B.4	Anti-vortex plate	Where the design head above the riser crest exceeds the riser diameter	9.7.8
9B.4	Outlet pipe through the embankment	Filter diaphragm or seepage collars; flared or headwalled inlet	9.7.7
9B.4	Flap gate or non-return valve	Where the receiving water can rise above the outlet	9.7.5, 9.10
9B.4	Emergency spillway	Passes the 1% AEP inflow with the primary outlet blocked and the basin full, with 0.3 m freeboard to the embankment crest; 0.2% AEP check for high-hazard basins	9.7.6
All	Structural dimensions, reinforcement, foundations, bar sizes, orifice sizes and stage levels	To be confirmed in design	9.1.2

Annex 9C — Pump station design checklist and standard control philosophy

Supports Clauses 9.8.6, 9.9 and 9.10 of Chapter 9, with Clause 6.10.5 of Chapter 6 and the outfall-closed check of Chapter 5.

9C.1 Design checklist

Submit this checklist with the pump station design report of Clause 9.14, item 6.

Table 9C.1 — Pump station design checklist

No.	Item	Requirement	Clause	Provided (Yes / No / NA)
1	Need for pumping	Gravity drainage cannot meet Chapters 5 and 6; reason stated	9.9.1	
2	Inflow	Inflow hydrograph routed through the catchment and any upstream storage	9.9.2	
3	Design standard	Design AEP of the element served; for underpasses, 2% AEP with a 1% AEP check	9.9.2(a), 6.10.5(a)	
4	Tidal outfall	Storage plus pumps hold the 48 h design volume with the outfall throttled for the tidal-lock duration (default two high tides of 6 h each)	9.9.2(b), Chapter 5	
5	Head range	Pumps selected from the lowest sump level against the lowest tailwater to the highest tailwater (HAT + surge + 0.3 m); pump and system curves submitted	9.9.2(c), 9.14	
6	Wet-well volume	Greatest of: 5 min of minimum inflow (variable speed and automatic control); 10 to 15 min of peak inflow, or the manufacturer's minimum cycle volume; $V = \Theta \cdot q / 4$ for each constant-speed pump	9.9.3	
7	Duty pumps	Same size where practicable	9.9.4(a)	
8	Standby	At least equal to the largest duty pump, and not less than 50% of the number of duty pumps	9.9.4(b)	
9	Alternation	Duty and standby roles alternate automatically	9.9.4(c)	
10	Pump type	Solids-handling (non-clog); axial-flow only behind a screen meeting Clause 9.8.6	9.9.5	
11	Sump and intake	Manufacturer's requirements and ANSI/HI 9.8; clear space 0.6 m (small and medium) or 1.0 m (large units)	9.9.6	
12	Model study	Physical model where any pump exceeds 1 m^3/s or the sump departs from ANSI/HI 9.8 geometry	9.9.6	
13	Silt trap and screen	Upstream of the wet well; screen spacing smaller than the pumps' solids size; removable modules; mechanical raking where inflow exceeds 1 m^3/s	9.9.7, 9.8.6	
14	Screen overflow	Overflow route when the screen is fully blocked	9.8.4	
15	Level control	Primary level sensor (ultrasonic, radar or pressure) with an independent float-switch back-up	9.9.8(a)	
16	Alarms	High-level and pump-fault alarms by telemetry to the local body's control room	9.9.8(b)	
17	Records	Sump levels, pump run hours and power status logged and kept at least 5 years	9.9.8(c)	
18	Power sources	Grid supply plus a standby generator or second independent feeder able to run all duty pumps at once	9.9.9(a)	
19	Fuel	At least 72 h of all duty pumps, stored above the flood level of Clause 9.9.10	9.9.9(b)	
20	Changeover	Automatic changeover to standby power	9.9.9(c)	
21	Flood protection	Electrical and control room floor, generator and transformer at least 0.5 m above the 1% AEP flood level; vehicle access usable in the 1% AEP event	9.9.10	
22	Discharge	Separate rising mains, or a non-return and an isolating valve where mains combine; delivery chamber or outfall with a flap gate or non-return valve; mains sized by a recognised friction formula	9.9.11	

No.	Item	Requirement	Clause	Provided (Yes / No / NA)
23	Gates	Flap or tide gate on outfalls below the 1% AEP still-water level; penstock or stop-log slot upstream for outfalls of 900 mm or more and every pumped outfall; head loss from tested data	9.10.1, 9.10.3, 9.10.4	
24	Sand and debris at the outfall	Gate in a chamber with surface access, or elastomeric check valves, at beach, estuary and creek outfalls	9.10.5	
25	Emergency connection	Hard-standing and quick-coupling connection for mobile pumps into the delivery chamber	9.9.12	
26	Materials	Exposure class of Clause 9.13; stainless steel grade 316, galvanised and coated steel, or non-metallic fixings within 5 km of the coast	9.13	
27	Design life	At least 50 years for civil works and 25 years for mechanical and electrical equipment	9.2.4	
28	Underpass stations	Depth markers and automatic warning or closure signals at 150 mm depth on the carriageway	6.10.5(d)	
29	Certification	Designed by an empanelled professional and checked by an independent empanelled professional	10.6.1(d), 10.6.4	

9C.2 Standard control philosophy

This is the standard control philosophy for a stormwater pump station designed under Clause 9.9. The designer adapts it to the station and submits it with the design report. Items marked "recommended" are good practice that Chapter 9 does not require; all others restate a clause.

Table 9C.2 — Control levels (values to be set in design)

Level	Rule for setting it	Clause
Pump stop	Not below the minimum submergence required by the pump manufacturer and ANSI/HI 9.8	9.9.6
Duty pump 1 start	Above the pump-stop level by at least the effective wet-well volume of Clause 9.9.3	9.9.3
Duty pumps 2, 3 … start	Staged above duty pump 1 start; spacing to be confirmed in design	9.9.2
High-level alarm	Above the highest duty-pump start level; to be confirmed in design	9.9.8(b)
Float back-up high	Independent float; starts the duty pumps	9.9.8(a)
Float back-up low	Independent float; stops the pumps	9.9.8(a)

1. **Normal (automatic) operation.** As the wet-well level rises to the duty pump 1 start level, the lead pump starts. If the level keeps rising, each further duty pump starts at its start level. The pumps stop when the level falls to the pump-stop level. The primary level sensor controls this sequence (Clause 9.9.8(a)).
2. **Duty rotation.** The lead pump changes automatically, after each pump-down cycle or by run hours as set in the design, so that duty and standby roles alternate and wear is shared (Clause 9.9.4(c)).
3. **Pump fault.** A pump that trips or fails to start is locked out. The next available pump, including the standby pump, takes its place, and a pump-fault alarm is sent by telemetry (Clauses 9.9.4(b) and 9.9.8(b)).
4. **Level-sensor failure.** If the primary sensor fails, or disagrees with the float switches, control passes to the independent float back-up: at the float-high level the duty pumps run, and at the float-low level they stop. An alarm is sent (Clause 9.9.8(a), (b)).
5. **Power failure.** Supply changes over automatically to the standby generator or second feeder (Clause 9.9.9(c)). Recommended: pumps restart one at a time after changeover, to limit the starting load on the generator.

6. **High level.** At the high-level alarm level an alarm is sent by telemetry to the local body's control room (Clause 9.9.8(b)). At an underpass, the warning or closure signals operate at 150 mm depth on the carriageway (Clause 6.10.5(d)).
7. **Outfall and gates.** Rising mains discharge to a delivery chamber or outfall fitted with a flap gate or non-return valve (Clause 9.9.11). Flap gates open and close under head difference without control action. The upstream penstock or stop logs are closed only for maintenance, or if the flap gate jams open (Clause 9.10.3). Recommended: penstock position is shown at the control panel and logged.
8. **Tide-locked operation.** Where the outfall is tide-locked, storage and pumping together hold the 48 h design volume for the tidal-lock duration (Clause 9.9.2(b) and Chapter 5). Where the station also has a gravity outfall, gravity discharge resumes through the flap gate when the tide falls.
9. **Screens.** Mechanically raked screens (required where inflow exceeds 1 m³/s, Clause 9.8.6) are run automatically. Recommended: raking is started by a timer and by the level difference across the screen, with an alarm when the difference stays high.
10. **Manual operation.** Recommended: each pump has a hand–off–auto selector at the panel, and the float back-up high-level start remains active in hand mode.
11. **Mobile pumps.** When fixed pumps are out of service or overwhelmed, mobile pumps discharge into the delivery chamber through the quick-coupling connection (Clause 9.9.12).
12. **Records.** Sump levels, pump run hours and power status are logged and kept for at least 5 years (Clause 9.9.8(c)). Recommended: alarms, pump starts and stops, and changeovers are logged as well.
13. **Testing.** The controls, floats, alarms, telemetry, changeover and generator are tested in the pre-monsoon inspection of Chapter 10 (Clause 10.12), and the results reported in the Annual Maintenance Declaration (Form 10-7; Clause 10.10.3).

Form 9-1 — Hydraulic Structures Report checklist

Supports Clause 9.14 of Chapter 9.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Not for statutory use.

Attach this checklist to the front of the Hydraulic Structures Report. For each item, enter Yes, No or Not applicable, and the drawing or page where it is shown.

Section A — Project

Table 9F.1 — Form 9-1, Section A: project

Field	Entry
Project name and location	_____
Local body, and Tier A or Tier B (Chapter 1)	_____
Applicant	_____
Designer (name and registration)	_____
Structures covered (culverts, channels, dissipators, outlets, screens, pumps, gates, inlets, manholes)	_____
Tailwater conditions used: MHWS, HAT + surge, sea-level allowance, joint case (Clause 9.2.1)	_____
Date and revision	_____

Section B — Contents required by Clause 9.14

Table 9F.2 — Form 9-1, Section B: contents required by Clause 9.14

No.	Item	Clause	Provided (Yes / No / NA)	Drawing or page
1	Culvert calculations (HDS-5 or HY-8 output) with HWi, HWo, outlet velocity, tailwater, overtopping and the blockage check	9.4, 6.12		
2	Channel water-surface profiles, velocities, Froude numbers and freeboard	9.5		
3	Outlet protection and dissipator design, with riprap sizing	9.6		
4	Detention outlet stage–discharge tables and the emergency spillway check	9.7		
5	Screen and rack design with the 50% blocked check	9.8		
6	Pump station design report: inflow hydrograph, storage, pump and system curves, wet-well volume, controls, power supply and the Chapter 5 outfall-closed check (with Annex 9C)	9.9		
7	Gate and valve selection with head-loss data	9.10		
8	Inlet, grate and cover load classes	9.11		
9	Exposure class and materials statement	9.13		

Section C — Compliance checks

Table 9F.3 — Form 9-1, Section C: compliance checks

No.	Check	Limit	Clause	Complies (Yes / No / NA)
C1	Climate factor included in design flows	Clause 2.8	9.2.2	
C2	Blocked condition checked where debris can block; safe overflow route	—	9.2.5	
C3	Pipes and box drains: design n (box drains ≥ 0.015); supercritical pipes: jump located in a structure, air venting	—	9.3.1, 9.3.4	
C4	Pipe size does not decrease downstream; joins only at manholes or junction chambers; no change of direction over 90°	—	9.3.5	
C5	Culvert design headwater = greater of HWi and HWo	—	9.4.1	
C6	Culvert headwater at the design AEP	HW/D ≤ 1.2; ≥ 0.3 m below shoulder edge	9.4.5	
C7	Road overtopping weir coefficient	Cd ≤ 1.66	9.4.6	
C8	Culvert inverts match the drain bed; headwalls, wingwalls and cut-off walls	—	9.4.8(c), 9.4.9	
C9	Channel Froude number at the design flow	≤ 0.8; none between 0.8 and 1.2	9.5.2	
C10	Channel velocity	Table 9.2	9.5.3	
C11	Channel slope in engineered channels	≤ 0.4% natural, ≤ 0.2% concrete, or drops / chute	9.5.4	
C12	Side slopes; low-flow channel where bed width ≥ 3 m; uplift or weep holes	—	9.5.6, 9.5.7, 9.5.9	
C13	Outlet protection where outlet velocity exceeds Table 9.2	Table 9.3 apron, or basin	9.6.1, 9.6.3	
C14	Single vertical drop height	≤ 1.5 m	9.6.6(c)	
C15	Detention primary outlet: no moving parts; minimum orifice	≥ 50 mm with screen	9.7.1	
C16	Emergency spillway	1% AEP, outlet blocked, basin full, 0.3 m freeboard; 0.2% AEP for high-hazard basins	9.7.6	
C17	Outlet pipe through embankment; anti-vortex plate where needed	—	9.7.7, 9.7.8	
C18	Conduit-entrance racks	Spacing 75 mm to half the smallest conduit dimension; area ≥ 4×; ≤ 1.0 m/s at 50% blocked	9.8.2	
C19	Detention orifice screens	Openings smaller than the orifice; open area ≥ 10×	9.8.5	
C20	Pump station	Annex 9C checklist complete	9.9	
C21	Gates on outfalls below the 1% AEP still-water level; secondary closure; corrosion-resistant fittings	—	9.10	
C22	Grate load classes, parallel openings ≤ 25 mm, kerb openings ≥ 100 mm × 1.0 m, locked covers	—	9.11	
C23	Manhole sizes (Table 9.4), 600 mm access openings, drops, benching, surcharge covers	—	9.12	

No.	Check	Limit	Clause	Complies (Yes / No / NA)
C24	Exposure class (Table 9.5); chloride and sulphate tests in coastal and delta areas; sulphide protection; metalwork within 5 km of the coast	—	9.13	

Section D — Variances

Table 9F.4 — Form 9-1, Section D: variances

Clause	Requirement not met	Reason and proposed alternative	Approved by and date
_____	_____	_____	_____

Section E — Signatures

The report shall be prepared and signed by a registered professional, and the Professional Design Certificate (Form 10-3) attached (Clauses 10.6.1 and 10.6.3 of Chapter 10). For a facility with an embankment, a high-hazard basin, a pumped facility, a tide gate or a regional facility, the signatory shall be an empanelled Stormwater Design Professional, and a second, independent empanelled professional shall sign as checker (Clauses 10.6.1(c), (d) and 10.6.4).

Table 9F.5 — Form 9-1, Section E: signatures

Role	Name	Registration or empanelment no.	Signature	Date
Designer	_____	_____	_____	_____
Independent checker (Clause 10.6.4, where applicable)	_____	_____	_____	_____

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0.

ANNEXES TO CHAPTER 10

Submittals, Review, Operation & Maintenance and Enforcement

These annexes support Chapter 10. They give the specification and user-guide outline of the compliance calculator, the GIS data specification, the maintenance access dimensions that the Manual sets, model O&M plans for each facility type, model empanelment criteria, and the eight forms that Chapter 10 requires. The Design Rainfall Sheet (Form 2-1) is in the annexes to Chapter 2. The forms are draft forms. The model texts are for consideration by a competent authority and are not in force.

Annex 10A — Compliance calculator and user guide

Supports Clauses 10.4.1(g), 10.5 and 10.9.1(b) of Chapter 10.

> **Status.** The compliance calculator does not exist yet. Clause 10.5.1 requires the State Stormwater Technical Committee to issue and maintain it. This annex is the specification the calculator shall meet and the outline of its user guide. Until the calculator is issued, the designer completes Form 10-2 by hand from the calculations of Chapters 4, 5 and 8, enters "not issued" as the calculator version, and attaches the calculations.

10A.1 General requirements

The calculator shall:

- (a) be a spreadsheet or web tool, published free of charge with its user guide and the source of every table in it (Clause 10.5.4);
- (b) print its version number and release date on every output page and every exported file (Clause 10.5.3);
- (c) keep a public version log. A new version applies to new submittals 6 months after release; a submittal keeps one version from Stage 1 to Stage 4 unless the Applicant elects a later one (Clause 10.5.3);
- (d) work for one site at a time, with one or more drainage areas, each draining to its own outfall (Clause 4.5.1.3);
- (e) never apply a value that the Manual has not published. Where a table it needs has not been issued (for example Table 4.3 of Annex 4B, or the S-2 discharge tables of Annex 1C), the calculator shall show that route as "not available" rather than estimate the value; and
- (f) export its inputs and results as a machine-readable file (CSV or JSON) as well as Form 10-2, so that the Authority can load them into the facility register (Clause 10.17.1(b)).

10A.2 Inputs

Table 10A.1 — Calculator inputs

No.	Input	Unit	Source
I1	Authority, tier (A or B) and file number	—	Clause 1.6

No.	Input	Unit	Source
I2	Site area; land disturbance area	ha	Clause 1.5.2
I3	New impervious area; replaced impervious area; existing impervious area before demolition	m²	Clauses 1.5.2, 1.5.6, 4.5.6.1
I4	Development type: new, redevelopment, linear public work, single dwelling	—	Clauses 1.5.6–1.5.8
I5	Flood-sensitive catchment (yes / no), and basin with an approved BSMP (yes / no)	—	Clauses 4.5.3, 4.13, 11.12
I6	Rainfall zone	—	Annex 2A
I7	Retention depth P_R; 3-month ARI 24-hour depth P_3m	mm	Annexes 2E, 8A
I8	Design rainfall depths by duration (1–72 h) and AEP, with the climate factor, as recorded on Form 2-1	mm	Clauses 2.5, 2.8, 2.13
I9	15-minute intensities i_10 and i_2, with the climate factor (fixed-coefficient route only)	mm/h	Clause 4.14.4
I10	Drainage areas: for each, area, land cover, impervious percentage, HSG and curve number, pre- and post-development	ha, %, —	Clauses 3.3, 3.7, 3.9
I11	Areas preserved under a registered covenant	ha	Clause 4.4.7
I12	Seasonal high groundwater depth below the base of each retention practice	m	Clauses 4.4.3(c), 8.8
I13	Measured infiltration rate at each practice	mm/h	Clause 4.4.3
I14	Retention volume provided, by practice; reuse demand where retention is by reuse	m³, m³/d	Clauses 4.4.3, 4.4.5
I15	Route: full hydrograph method (Clause 4.6); design-aid S-1 (Clause 4.14.2); PSD S-2 (Clause 1.7); fixed-coefficient (Clause 4.14.3); constrained redevelopment (Clause 4.5.6)	—	Clauses 1.7, 4.5.6, 4.6, 4.14
I16	For the full method: model results for each AEP and duration — pre- and post-development peaks, storage used, retention credit found by routing	m³/s, m³	Clauses 4.4.6.2, 4.6
I17	Outlet: low-flow orifice diameter or least slot dimension; drawdown times from routing	mm, h	Clauses 4.7, 4.8.2
I18	Outfall: tidal or non-tidal; outfall-closed check result	—	Chapter 5
I19	Fee-in-lieu unit rate notified for the basin, where the route applies	₹/m³	Clause 4.13.3
I20	Stage of submittal (1, 2 or 4) and, at Stage 4, the as-built values of I14, I16 and I17	—	Clauses 10.5.2, 10.9.1(b)

10A.3 Calculations, by clause

Table 10A.2 — Calculations the calculator shall perform

Step	Calculation	Clause
C1	**Applicability.** Chapters 4 and 5 apply where land disturbance ≥ 0.1 ha or new plus replaced impervious area ≥ 500 m², over the common plan of development. Report exemptions. Flag that the universal provisions apply at every size, and that RWH applies to buildings on plots of 225 m² or more, by a rainwater harvesting unit or structure, or a rooftop rainwater storage tank with a filter (Building Regulations 2025, reg. 8.3(i)), except in waterlogged areas once the local body has marked them (reg. 8.3(iii)); recharge is the default, with pre-treatment, except that in the old city of Jodhpur and the Ganganagar–Hanumangarh canal belt a groundwater-clearance check under Chapter 8 comes before any recharge is credited, no surface infiltration is credited on the black soils of Hadoti after 15 August, and road runoff is recharged only through surface infiltration with a filter.	1.5.2–1.5.8

Step	Calculation	Clause
C2	**Process flags.** Stage 0 mandatory (≥ 2 ha, flood-sensitive, variance or regional route, tidal outfall or waterbody); Stages 1 and 2 may be combined (< 1 ha, not flood-sensitive); empanelled signatory required; independent check required.	10.3.2, 10.3.3, 10.6.1, 10.6.4
C3	**Route eligibility.** Tier B simplified method: ≤ 2 ha, or ≤ 0.5 ha in a flood-sensitive catchment, and only once Table 4.3 is published. Fixed-coefficient route: ≤ 1 ha and none of the exclusions of Clause 4.14.3. Constrained redevelopment: existing ≥ 60% impervious and ≤ 1 ha. Regional detention or fee-in-lieu: only in a basin with an approved BSMP.	4.5.6.1, 4.13.1, 4.14.1, 4.14.3, 11.12.1(b)
C4	**Retention volume.** RRV = 10 × Q_R × A, with Q_R the SCS-CN runoff from P_R for each sub-area at AMC II, summed over sub-areas. The larger of the Ia = 0.2S and Ia = 0.05S results governs. The Rv form (RRV = 10 × P_R × Rv × A, Rv = 0.05 + 0.009 × I) is offered only for sites < 0.5 ha and the Tier B method. No climate factor.	4.4.2, 3.8.5(c), 2.8.3
C5	**Preservation credit.** Preserved areas are modelled at their pre-development CN in the post-development condition.	4.4.7
C6	**Retention checks.** Design infiltration rate ≤ half the measured rate; groundwater ≥ 1.0 m below the base; drawdown of the retained volume within 72 h at the design rate (or by the stated reuse demand). A practice that fails any check gets no credit; any shortfall is reported and treated as WQv.	4.4.3–4.4.5, 4.4.6.4
C7	**Water quality volume.** P_{wq} = max(P_{ret}, P_{3m}); WQv = 10 × Q_{wq} × A by SCS-CN, or (P_{wq} / 1000) × Rv × A (A in m²) for sites < 0.5 ha and the Tier B method. The retained volume counts toward the WQv in full. No climate factor.	8.4.1–8.4.4, 3.8.5(c)
C8	**Retention credit.** Tier A: the credit found by routing is entered (I16); the calculator does not compute it. Tier B: V_{credit} = C_R × RRV provided, with C_R = 0 until Annex 4B is published.	4.4.6
C9	**Design-aid route (S-1).** V = SSR × A − V_{credit}; $Q_{PSD,T}$ = PSD_T × A for the 2-yr and 100-yr stages, from Table 4.3. Shown as "not available" until Table 4.3 is published.	1.7.2, 4.14.2
C10	**Permissible site discharge (S-2).** Q = PSD (m³/s/ha) × A for each AEP, from the S-2 tables. Shown as "not available" until they are issued.	1.7.2, 1.7.3(e)
C11	**Fixed-coefficient route.** $Q_{cap,10}$ = 2.78 × C_{10} × i_{10} × A and $Q_{cap,2}$ = 2.78 × C_2 × i_2 × A (L/s); V_{100} and V_2 = max over d of [10 × C_v × P(d) × A − 1.8 × Q_{cap} × d] for d = 1 to 72 h, with pervious C ≥ 0.50 for d ≥ 12 h; V = max(V_{100}, V_2); retention added without credit. Coefficients from Table 4.3A (provisional).	4.14.4–4.14.7
C12	**Release-rate screen (full method).** For each AEP and duration: Q_{post} ≤ 0.9 × Q_{pre} (standard), or the two mixed-frequency caps (flood-sensitive). Report the governing duration and margin.	4.5.2, 4.5.3
C13	**Constrained redevelopment.** Q_{post} ≤ 0.5 × $Q_{existing}$ for 2-, 10- and 100-yr at each duration; shortfall volume = greenfield storage − storage provided; fee = shortfall × unit rate.	4.5.6.2, 4.5.6.3
C14	**Minimum orifice.** Flag any orifice < 50 mm. Where a cap is below the discharge of a 50 mm orifice at the corresponding stage, report "50 mm orifice deemed to comply".	4.5.5.1, 4.8.2
C15	**Drawdown.** Report the detention drawdown (90% of the 10-yr stored volume within 48 h), the WQv release time (24–48 h) and the retention emptying time (≤ 72 h).	4.7
C16	**Fee-in-lieu.** Fee = detention volume required on site × notified unit rate.	4.13.3
C17	**Model screen.** Where the full method is used, compare the model results (I16) with the calculator's screen values (C9 to C11, where available) and flag a difference above the tolerance stated in the user guide.	10.5.2(c)
C18	**As-built re-run.** At Stage 4, repeat C4 to C17 with the as-built values and report each change from Stage 2.	10.9.1(b), 10.9.2

10A.4 Outputs

The calculator produces:

- (a) **Form 10-2**, filled in, with the calculator version and release date on every page;
- (b) a machine-readable export of every input and result of Tables 10A.1 and 10A.2; and

- (c) a list of the flags raised (C1 to C3, C6, C14, C17), each with the clause on which it is based (Clause 10.7.7).

10A.5 Testing before release

Before each release the State Stormwater Technical Committee shall check that the calculator reproduces, within rounding, the worked examples of the Manual that use the same method, including the illustrative examples of Clauses 4.6.7 and 4.14, and the benchmark problems of Annex 3C where they apply. The test results shall be published with the version log.

10A.6 Outline of the user guide

The user guide shall contain at least:

1. Purpose, status and limits of the calculator: a summary and screening check outside the design-aid route (Clause 10.5.2(c)).
2. How to obtain the current version, and the version rule of Clause 10.5.3.
3. Each input of Table 10A.1, with where to find it in the Manual and its annexes.
4. Each calculation of Table 10A.2, with its equation and clause.
5. The tolerance used in step C17, and what the drainage report must explain where it is exceeded (Clause 10.5.2(c)).
6. How to read and sign Form 10-2, and what to attach.
7. At least one worked example for each route, labelled "Illustrative — not design values".
8. The sources of every table in the calculator (Clause 10.5.4), and the version log.

Annex 10B — GIS data specification and attribute schema

Supports Clauses 10.4.4, 10.14.1(d), 10.14.3 and 10.17 of Chapter 10.

10B.1 Format and reference systems

- (a) **Format.** One OGC GeoPackage (.gpkg) per submittal is preferred. Shapefiles are accepted, one per layer, zipped with all component files. Field names shall be as in Tables 10B.2 to 10B.6; shapefile names are limited to 10 characters, and the names below meet that limit.
- (b) **Horizontal reference.** WGS 84 geographic (EPSG:4326), or WGS 84 / UTM zone 43N (EPSG:32643) or 42N (EPSG:32642) (for this purpose a site lies in 42N if it is in Jaisalmer or Barmer district, and in 43N everywhere else in the State, including the part of Dholpur district east of 78° E; one zone is used for the whole of a project), whichever contains the site (Clause 10.4.4(c)). One system shall be used for all layers.
- (c) **Vertical reference.** All levels shall be in metres relative to a named vertical datum, stated in the metadata. The metadata shall also state the relationship between that datum and the river datums of the CWC and WRD gauges on the receiving rivers and the level datums of WRD and the lake custodians for the lakes and reservoirs that receive city drainage, with lake gauge readings in feet above a local zero converted to metres on a named datum used in Chapter 5 (Clause 10.4.4(d)).
- (d) **Accuracy.** Positions shall come from the site survey or the approved drawings. At Stage 4 and at handover, positions and levels shall come from the as-built survey (Clause 10.9.1(a)).
- (e) **File name.** `<Authority file number>_<stage>_<yyyymmdd>.gpkg` , for example `JMC-BP-2026-0123_S2_20261015.gpkg` .
- (f) **Identifiers.** Every feature has an identifier unique within the submittal (FAC_ID, OUT_ID, CAT_ID, FLP_ID). The Authority replaces them with register identifiers on acceptance and returns the mapping to the Applicant.

10B.2 Layers

Table 10B.1 — Layers

Layer	Geometry	Content	Required at
SW_SITE	Polygon	Site boundary	Stages 1, 2, 4
SW_CATCH	Polygon	Catchment boundaries draining to and through the site, pre- and post-development (Clause 10.4.1(b))	Stages 1, 2, 4
SW_FAC	Polygon (point for buried items smaller than 5 m across)	Every stormwater facility: retention, detention, water quality, pumping, gate, conveyance element designed under this Manual	Stages 2, 4; handover
SW_OUTF	Point	Every outfall from the site, and every public outfall	Stages 1, 2, 4; handover
SW_FLOW	Line	Major-system flow paths through and from the site, and natural drainage paths (Clause 10.15.1(g))	Stages 1, 2, 4
SW_CONV	Line	Drains and pipes designed under Chapter 6	Stage 4 for public works; handover
SW_META	Table (no geometry)	Metadata of Table 10B.6	Every stage

10B.3 Attribute schema

Types: T = text, I = integer, R = real, D = date (ISO 8601, yyyy-mm-dd). "Req." marks fields that shall not be empty; other fields are filled where they apply.

Table 10B.2 — Attributes of SW_FAC (facilities)

Field	Type	Unit	Req.	Content	Source
FAC_ID	T	—	Yes	Facility identifier	10B.1(f)
FAC_TYPE	T	—	Yes	Code from Table 10B.7	Clause 4.10, Table 10.3
FAC_NAME	T	—		Name on the drawings	—
OWNER_TYP	T	—	Yes	PRIVATE / ASSOC / DEVELOPER / ULB / DEPT	Clauses 10.10, 10.14
OWNER_NM	T	—	Yes	Name of a corporate owner or association only; for an individual, "private individual" (Clause 10.17.3)	Clause 10.17.3
CTRL_AREA	R	ha	Yes	Area draining to the facility	Clause 4.5.1.3
V_RET	R	m³		Retention volume provided	Clause 4.4
V_WQ	R	m³		Water quality volume provided	Clause 8.4
V_DET	R	m³		Detention volume at the top design level	Clause 4.6
Q_2	R	L/s		Release at the 50% AEP (2-yr) design level	Clause 4.5
Q_10	R	L/s		Release at the 10% AEP (10-yr) design level	Clause 4.5
Q_100	R	L/s		Release at the 1% AEP (100-yr) design level	Clause 4.5
ORIF_MM	R	mm		Low-flow orifice diameter or least slot dimension	Clause 4.8.2
INV_OUT	R	m		Outlet invert level	Clause 10.9.1(a)

Field	Type	Unit	Req.	Content	Source
TWL_DES	R	m		Top design water level	Clause 10.9.2(a)
SPILL_LV	R	m		Spillway or overflow crest level	Clause 4.9
PUMPED	T	—	Yes	Y / N	Clause 10.10.3
REGIONAL	T	—	Yes	Y / N	Clause 4.13
EMPANEL	T	—	Yes	Y / N: facility under Clause 10.6.1(c) or (d)	Clause 10.6.1
STATUS	T	—	Yes	Code from Table 10B.8	Clause 10.17.1(a)
APPR_DATE	D	—		Date of Stage 2 approval	Clause 10.3
ASB_DATE	D	—		Date the as-built certificate was accepted	Clause 10.9
DECL_REF	T	—		Registration reference of the Maintenance Declaration (Form 10-6)	Clause 10.10.1(e)
HAND_DATE	D	—		Date of the Asset Handover Certificate (Form 10-8)	Clause 10.14
LAST_INSP	D	—		Date of the latest inspection	Clause 10.12
INSP_RES	T	—		Code from Table 10B.9	Clause 10.17.1(a)
OUT_ID	T	—	Yes	Outfall to which the facility discharges	—

Table 10B.3 — Attributes of SW_OUTF (outfalls)

Field	Type	Unit	Req.	Content	Source
OUT_ID	T	—	Yes	Outfall identifier	10B.1(f)
RECEIVER	T	—	Yes	Receiving drain, channel, waterbody or sea, by name	Clause 4.5.1.3
RECV_TYPE	T	—	Yes	PUBLIC_DRAIN / CANAL / RIVER / TANK / SEA / OTHER	Chapter 5
INV_LEVEL	R	m	Yes	Outfall invert level	Clause 10.9.1(a)
SIZE_MM	R	mm	Yes	Diameter, or width × height written in the drawing	Chapter 6
TIDAL	T	—	Yes	Y / N	Chapter 5
GATE_TYPE	T	—		NONE / FLAP / TIDE / DUCKBILL / PENSTOCK / NRV	Clauses 5.11, 9.10
GATE_REQ	T	—	Yes	Y / N: invert below the 1% AEP still-water level	Clause 5.11.1
GPT	T	—		Y / N: gross pollutant trap fitted	Clause 8.10.1
Q_100	R	L/s		Design 1% AEP discharge	Chapter 5

Table 10B.4 — Attributes of SW_CATCH (catchments)

Field	Type	Unit	Req.	Content	Source
CAT_ID	T	—	Yes	Catchment identifier	10B.1(f)
CONDITION	T	—	Yes	PRE / POST / EXTERNAL (land outside the site draining through it)	Clause 10.4.1(b)
AREA_HA	R	ha	Yes	Area	—
IMPERV_PC	R	%	Yes	Impervious percentage	Clause 3.9
HSG	T	—	Yes	A / B / C / D, or mixed with area shares in NOTES	Clause 3.7
CN	R	—		Curve number, AMC II	Chapter 3

Field	Type	Unit	Req.	Content	Source
OUT_ID	T	—	Yes	Outfall to which it drains	Clause 4.5.1.3
FLOODSENS	T	—	Yes	Y / N	Clause 4.5.3
NOTES	T	—		Free text	—

Table 10B.5 — Attributes of SW_FLOW and SW_CONV (flow paths and conveyance)

Field	Type	Unit	Req.	Content	Source
FLP_ID	T	—	Yes	Line identifier	10B.1(f)
LINE_TYPE	T	—	Yes	OVERLAND / NATURAL / OPEN_DRAIN / COVERED_DRAIN / PIPE / CULVERT	Chapter 6
US_LEVEL	R	m		Upstream invert or ground level	Chapter 6
DS_LEVEL	R	m		Downstream invert or ground level	Chapter 6
SIZE_MM	R	mm		Pipe diameter, or drain width (depth in NOTES)	Clause 6.7.6
Q_DES	R	L/s		Design discharge	Chapter 6
AEP_DES	T	—		Design AEP, for example "10%" or "1%"	Clause 6.4
RESERVE_M	R	m		Drainage reserve width, where one applies	Clause 6.9.7
NOTES	T	—		Free text	—

Table 10B.6 — Metadata (SW_META)

Field	Content
FILE_NO	Authority file number
STAGE	1, 2, 4 or HANDOVER
H_CRS	EPSG code of the horizontal reference system
V_DATUM	Name of the vertical datum
TIDE_REL	Relationship of the vertical datum to the Chapter 5 river datums of the CWC and WRD gauges on the receiving rivers and the level datums of WRD and the lake custodians for the lakes and reservoirs that receive city drainage, with lake gauge readings in feet above a local zero converted to metres on a named datum (for example, MSL = x.xx m on the site datum)
SURVEYOR	Name and licence number of the surveyor
SURV_DATE	Date of the survey
PREP_BY	Name and registration number of the certifying professional
CALC_VER	Compliance calculator version (Annex 10A), or "not issued"
DATE	Date the file was prepared

10B.4 Code lists

Table 10B.7 — Facility type codes (FAC_TYPE)

Code	Facility	Inspection row of Table 10.3
RET_SOAK	Soakaway, recharge pit or shaft	Retention / infiltration

Code	Facility	Inspection row of Table 10.3
RET_TRENCH	Infiltration trench or basin	Retention / infiltration
RET_BIO	Bioretention or rain garden	Retention / infiltration
RET_PERM	Permeable pavement	Retention / infiltration
RET_REUSE	Retention by reuse (tank with demand)	Underground or podium detention tank, gravity outlet
DET_BASIN	Surface detention basin	Surface detention basin or multi-use open space area
DET_OSR	Multi-use detention in open space, park or playfield	Surface detention basin or multi-use open space area
DET_ROOF	Rooftop detention	Underground or podium detention tank, gravity outlet
DET_PODIUM	Podium or landscape-deck detention	Underground or podium detention tank, gravity outlet
DET_PARK	Parking-lot detention	Surface detention basin or multi-use open space area
DET_TANK	Underground tank or vault, gravity outlet	Underground or podium detention tank, gravity outlet
DET_PUMP	Pumped detention or pump station	Pumped detention, pumps and controls
WQ_POND	Wet pond or constructed wetland	Surface detention basin or multi-use open space area
WQ_SWALE	Swale or filter strip	Private drains and inlets
WQ_GPT	Gross pollutant trap, first-flush device or oil-grit separator	Gross pollutant trap / first-flush device
GATE	Flap or tide gate, non-return valve	Flap / tide gate, non-return valve
CONV	Private drain, inlet or culvert	Private drains and inlets

Table 10B.8 — Status codes (STATUS)

Code	Meaning
PROPOSED	In a Stage 1 or Stage 2 submittal
APPROVED	Stage 2 approved; not yet built
ASBUILT	As-built certificate accepted (Clause 10.9)
HANDEDOVER	Accepted by the ULB (Clause 10.14)
ALTERED	Changed with the Authority's approval (Clause 10.3.5)
REMOVED	Removed with the Authority's approval

Table 10B.9 — Inspection result codes (INSP_RES)

Code	Meaning
OK	Working as designed; no defect
MINOR	Defect found and corrected; date in the inspection record
MAJOR	Defect affecting storage, outlet or safety; notice issued (Clause 10.15.2, step 1)
NOACCESS	Inspection could not be made
NOTFOUND	Facility missing, filled, covered or changed in use (Clause 10.15.1(c))

10B.5 Facility register extract

The public facility register of Clause 10.17.1(a) is an extract of SW_FAC: FAC_ID, FAC_TYPE, location (centroid), V_DET (and V_RET, V_WQ), Q_100 (and Q_2, Q_10), OWNER_NM, ASB_DATE, LAST_INSP and INSP_RES. It is published as CSV and GeoPackage under the licence of Clause 10.17.4. Personal data are not published (Clause 10.17.3).

Annex 10C — Maintenance access dimensions

Supports Clause 10.13 of Chapter 10.

Clause 10.13 sets access by function. This annex collects the access dimensions that the Manual already sets in other chapters, and lists the dimensions that it does not set. Where a dimension is not set by the Manual, the designer shall state it on the drawings, show that it suits the plant and equipment named in the O&M plan (Clause 10.11.1(h)), and mark it "to be confirmed in design".

Table 10C.1 — Access dimensions set by the Manual

Element	Requirement	Clause
Open drains with a top width of 2 m or more	Maintenance access strip at least 3.5 m wide along one bank, connected to a public road at intervals of not more than 500 m	6.9.4
Drainage reserves	Width not less than Table 6.9, based on the required drain size; where the access strip of Clause 6.9.4 is wider, the wider governs	6.9.7
Covered drains, minimum section	0.6 m × 0.6 m clear	6.7.6
Covered drains, removable covers	Panels at not more than 10 m centres, each at least 0.6 m long and spanning the full clear width, liftable by two workers or a hand-operated device	6.13.2(a)
Covered drains, access chambers	Clear opening at least 0.6 m × 0.6 m at every junction, bend and change of section, and at not more than 30 m centres on straight runs	6.13.2(b)
Manholes and access chambers on public drains	Clear access opening at least 600 mm	9.12.3
Inlet chambers on public roads	Silt sump at least 300 mm deep below the outlet pipe invert, cleanable from the surface	6.6.7
Underground tanks and vaults	Access openings over the outlet chamber and over every inlet; in tanks over 500 m², not more than 30 m apart; floor falling at least 1% to a sump at the outlet	4.10.2(b), (c)
Detention outlets serving more than 1 ha	A means of isolating the outlet (stop-log slot or penstock)	4.8.6
Outfall gates	Stop-log slot or penstock upstream on outfalls larger than 600 mm (Chapter 5) and on outfalls of 900 mm or more or serving a pumped or storage system (Chapter 9); the gate chamber accessible at all tides, with its access above HAT + surge + sea-level allowance	5.11.3(d), (e); 9.10.3
Pump stations	Maintenance vehicle access usable in the 1% AEP event; hard standing and a quick-coupling connection for mobile pumps; clear space between adjacent pumps or motors of 0.6 m (small and medium units) or 1.0 m (large units)	9.9.6, 9.9.10, 9.9.12
Pretreatment devices	Cleanable without entering or disturbing the main BMP	8.5.4
Screens at outfalls, culvert inlets and pump sumps	Cleanable from a safe platform, with vehicle access	8.10.3(d)

Element	Requirement	Clause
Infiltration trenches	Observation well to the base of each trench	8.7.6(c)
Publicly accessible storage	Side slopes no steeper than 4H:1V, with at least a quarter of the perimeter at 6H:1V or flatter	4.15.1(c)
Wet basins	Safety bench at least 3 m wide, no more than 0.3 m below normal water level	4.15.2
Fencing	At least 1.2 m high, non-climbable, with a lockable gate, where Clause 4.15.3 requires it	4.15.3

Table 10C.2 — Access dimensions not set by the Manual (to be confirmed in design)

Element	What the designer shall state	Clause setting the function
Vehicle access route to the inlet, outlet and base of a basin, pond or open channel	Width, gradient, turning space and design load for the plant in the O&M plan	10.13.2
Maintenance strip beside a basin or pond	Width along at least one side	10.13.2
Ramp into a basin	Width, gradient and surface for the sediment-removal plant	10.13.2
Access openings of private tanks	Clear size of each opening over the inlet, outlet and each chamber	10.13.3(a)
Ladders and steps	Type and spacing; ventilation for confined-space entry	10.13.3(b)
Headroom in underground tanks	Clear height for manual cleaning	10.13.3(d)
Reach to orifices and screens	How the outlet is cleaned without entering a full facility	10.13.4

> **Commentary.** APWA 5600 (2006, §5608) required a maintenance access strip of 15 ft (about 4.5 m) for detention facilities. The Manual did not adopt a fixed width for private sites, because plot sizes in Rajasthan cities vary widely (Clause 10.13, Commentary). The State Stormwater Technical Committee may add standard values to Table 10C.2 when it issues the standard drawings of Annexes 6C and 9B.

Annex 10D — Model O&M plans by facility type

Supports Clauses 10.11, 10.12 and 10.13 of Chapter 10.

The model plans below are starting points. The designer adapts them to each facility and completes the items marked "_____". Inspection frequencies are the minimum frequencies of Table 10.3; a plan may set more frequent inspection, never less. Where this annex leaves a value to the designer, the Manual does not set it.

10D.1 Contents of every O&M plan

Every plan shall contain the items of Clause 10.11.1:

Table 10D.1 — Contents of an O&M plan

Item	Content	Clause
1	Inventory and plan drawing of each facility, with design levels, volumes and outlet details (from SW_FAC, Annex 10B)	10.11.1(a)
2	Routine tasks and their frequency (Tables 10D.2 to 10D.8)	10.11.1(b)
3	Trigger for sediment removal, as a depth (mm) or a percentage of design volume: _____	10.11.1(c)
4	Inspection checklist matching Form 10-7	10.11.1(d)
5	For pumps, gates and valves: operating rules, test schedule, standby power, and actions on a cyclone or heavy-rainfall warning	10.11.1(e)
6	Actions against standing water and mosquito breeding, consistent with the drawdown times of Clause 4.7	10.11.1(f)
7	Safety: confined spaces, deep water, public access	10.11.1(g)
8	Access routes and equipment (Annex 10C)	10.11.1(h)
9	Annual cost estimate (₹ _____ per year) and who pays it	10.11.1(i)
10	Records to be kept, and for how long: _____ years (pump records at least 5 years, Clause 9.9.8(c))	10.11.1(j)

10D.2 Model plans

Table 10D.2 — Retention and infiltration (soakaways, trenches, bioretention, permeable paving)

Task	Frequency	Standard or trigger	Clause
Inspect surface, inlets, pretreatment and overflow	Every 6 months; before 15 June; after each heavy-rainfall day	No blockage; overflow clear	Table 10.3
Check drawdown at the observation well or surface	At each inspection after rain	Empties within 72 h of the end of rain; if not, investigate clogging	4.4.5, 8.7.6(c)
Clean pretreatment (forebay, filter strip, silt trap)	When the sediment trigger (item 3) is reached	Pretreatment cleaned without disturbing the main BMP	8.5.3, 8.5.4
Bioretention: mulch, plants, ponding	Every 6 months	Ponding drains within 48 h; dead plants replaced; mulch 50–75 mm	8.7.2
Permeable paving: surface	Every 6 months	Sweep or vacuum; no resurfacing with impermeable material	8.7.5(e)
Keep the contributing area stable	Each inspection	Bare soil stabilised; no sediment washing in	10.8.3(b)
Keep the facility in place and in use	Each inspection	Not filled, covered, paved or built over without approval	10.10.1(d)

Table 10D.3 — Surface detention basin or multi-use open space area

Task	Frequency	Standard or trigger	Clause
Inspect inlets, outlet, orifice, trash rack and spillway	Every 6 months; before 15 June; after each heavy-rainfall day	Orifice and rack clear; spillway unobstructed	Table 10.3, 4.8, 4.9
Remove debris and sediment	When the sediment trigger is reached, and after events	Design volume restored	10.11.1(c)
Check that the basin drains	After rain	No low point ponds for more than 72 h	4.15.7
Vegetation	As set in the plan	Grass cut; no woody growth on embankments or in the outlet zone	10.11.1(b)

Task	Frequency	Standard or trigger	Clause
Safety features	Every 6 months	Signs in Hindi and English and a depth marker in place; fences and gates sound where required	4.15.3, 4.15.5
Embankment (if any)	Every 6 months and after events	No cracks, slips, seepage or animal burrows	4.9.6

Table 10D.4 — Underground or podium detention tank, gravity outlet

Task	Frequency	Standard or trigger	Clause
Inspect from the access openings: inlets, outlet, orifice, screen, sump, vents	Every 6 months; before 15 June; after each heavy-rainfall day	Clear; vents open	Table 10.3, 4.10.2
Clean the sump and floor	When the sediment trigger is reached	Floor falls freely to the sump	4.10.2(c)
Inlet silt trap or GPT	Every 3 months (Table 10.3 row for GPTs)	Cleaned	4.10.2(e)
Overflow route	Each inspection	Operates when the outlet is blocked; route to the overland path unobstructed	4.9.5
Confined-space entry	Each entry	Entry procedure stated in the maintenance declaration followed; covers locked after	4.15.6
Use of the space	Each inspection	Not used for parking or storage; volume not reduced	10.10.1(d)

Table 10D.5 — Pumped detention, pumps and controls

Task	Frequency	Standard or trigger	Clause
Test run of each pump, duty and standby	Monthly	Each pump starts on level control; roles alternate	Table 10.3, 9.9.4(c)
Full duty test	Before 15 June	Station meets its design duty point	Table 10.3, 10.9.3
Standby power	Monthly with the test run; full test before 15 June	Automatic changeover works; fuel for at least 72 h of all duty pumps on site	9.9.9
Level sensors, float back-up, alarms, telemetry	Monthly	High-level and fault alarms reach the control room	9.9.8
Screens and silt trap	Every 3 months and after events	Clean	9.9.7
Records	Continuous	Sump levels, run hours and power status logged; kept at least 5 years	9.9.8(c)
Warning actions	On an IMD heavy-rainfall or cyclone warning	Actions written in the plan: _____ (for example staff on site, fuel topped up, mobile pump connection checked)	10.11.1(e), 9.9.12

Table 10D.6 — Flap or tide gate, non-return valve

Task	Frequency	Standard or trigger	Clause
Inspect and operate	Every 3 months; after each heavy-rainfall day	Opens at a small head; no debris, sand or growth holding it	Table 10.3, 9.10.4

Task	Frequency	Standard or trigger	Clause
Seal test	Before 15 June	Seals against the receiving water	Table 10.3, 10.9.3
Beach, estuary and creek outfalls	After every high-tide or surge event in the monsoon season	Sand and debris cleared	9.10.5(b)
Isolation	Before 15 June	Stop-log slot or penstock operable	9.10.3
Hinges, pins and fixings	Before 15 June	No corrosion that would stop the gate working	9.10.6
Property non-return valves	Every 3 months	Cleaning eye accessible; valve seals	5.11.4

Table 10D.7 — Gross pollutant trap or first-flush device

Task	Frequency	Standard or trigger	Clause
Inspect and empty	Every 3 months; before 15 June; after each heavy-rainfall day	Emptied before the capture chamber is full; bypass clear	Table 10.3, 8.4.6
Screens	Each inspection	Clean; overflow path clear	8.10.3(b)
Disposal	Each cleaning	Material taken to an authorised solid-waste facility	—

Table 10D.8 — Private drains and inlets

Task	Frequency	Standard or trigger	Clause
Inspect and clean drains, inlets and silt sumps	Every 6 months; before 15 June	Free of silt and debris	Table 10.3
Check for sewage connections	Each inspection	None; any cross-connection removed	1.5.4, 8.9
Overland flow paths	Each inspection	Not obstructed by walls, fill or stored material	6.9.2, 10.15.1(g)

Annex 10E — Empanelment criteria for Stormwater Design Professionals and reviewers

Supports Clauses 10.6, 10.7.4 and 11.4.3 of Chapter 10.

> *Model text for consideration by a competent authority. Not in force.* Clause 10.6.2 assigns the issue of empanelment criteria to UDH. The text below is a model. Values shown as "[ ]" are for the competent authority to set; the Manual does not set them.

10E.1 Model criteria

1. **Lists.** The competent authority shall keep three public lists:
    - (a) **Stormwater Design Professionals**, who may sign designs under Clause 10.6.1 and act as independent checkers under Clause 10.6.4;
    - (b) **Empanelled Reviewers**, who may review submittals for an Authority under Clause 10.7.4; and

    - (c) a **basin modelling endorsement**, held by a Stormwater Design Professional who may prepare or direct a BSMP under Clause 11.4.3.
2. **Eligibility for list (a).** An applicant shall:
    - (a) hold a degree in civil engineering, or an equivalent qualification recognised by the competent authority (Clause 10.6.2);
    - (b) be registered as a professional under the Model Rajasthan Building Regulations 2025 (Clause 1.4);
    - (c) have at least [ ] years of experience in drainage design after graduation, shown by a list of at least [ ] projects with the applicant's role in each (Clause 10.6.2); and
    - (d) have completed a training course on this Manual, with an assessment, within the [ ] years before application (Clause 10.6.2).
3. **Eligibility for list (b).** As for list (a), with at least [ ] years of experience, of which at least [ ] years in the design or review of drainage under this Manual or an equivalent standard.
4. **Basin modelling endorsement (c).** A Stormwater Design Professional who shows experience in basin-scale 1D–2D modelling, including calibration, on at least [ ] studies (Clause 11.4.3).
5. **Independence of a checker.** A checker under Clause 10.6.4 shall not be employed by, or a partner of, the designer's firm or the Applicant, and shall not have worked on the design.
6. **Conflict of interest of a reviewer.** An Empanelled Reviewer shall not review a site on which the reviewer, or the reviewer's firm, has worked in any capacity (Clause 10.7.4), and shall declare any other interest before accepting a review. The Authority remains the decision-maker (Clause 10.7.4).
7. **Application.** The application shall include proof of degree and registration, the project list with references, the training certificate, and a signed declaration that the information is true.
8. **Term and renewal.** Empanelment is valid for [ ] years. Renewal requires evidence of continuing practice and of any refresher training issued after a revision of the Manual (Clause 1.12).
9. **Suspension and removal.** The competent authority may suspend or remove an empanelled person after a false or negligent certificate (Clause 10.6.5), on a report under step 6 of Table 10.4, or on loss of registration. The person shall be given notice and an opportunity to be heard. Every suspension and removal shall be published on the list.
10. **Publication.** The lists shall be published and kept current, with each person's name, registration number, list, endorsement and validity date.

Form 10-1 — Drainage Report Checklist

Supports Clauses 10.4.1 to 10.4.4 and 10.7.1 of Chapter 10.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Lodge with every Stage 1 and Stage 2 submittal. For each item give the page or sheet where it is addressed, or the reason it does not apply. The Authority does not start technical review without a completed Form 10-1 (Clause 10.4.3).

Table 10F.1 — Form 10-1, Section A: Submittal

No.	Field	Entry
A1	Authority and file number	_____
A2	Site name and address; survey numbers	_____
A3	Stage: 1 / 2 / combined 1 and 2 (Clause 10.3.3) / public work DPR or tender (Clause 10.3.4)	_____
A4	Applicant	_____
A5	Certifying professional (name, registration and empanelment number)	_____

Table 10F.2 — Form 10-1, Section B: Stage 1 contents (Clause 10.4.1)

No.	Item	Clause	Page / sheet	Not applicable: reason
B1	Form 1-1; Form 1-2 where a variance or waiver is sought	10.4.1(a)	_____	_____
B2	Site plan: existing and proposed levels, impervious areas, catchment boundaries to and through the site	10.4.1(b)	_____	_____
B3	Soils (HSG), seasonal high groundwater, infiltration tests or test plan	10.4.1(c)	_____	_____
B4	Design Rainfall Sheet (Form 2-1)	10.4.1(d)	_____	_____
B5	Pre-development condition and hydrologic method	10.4.1(e)	_____	_____
B6	Order of measures: areas preserved, retention method, detention concept, conveyance	10.4.1(f)	_____	_____
B7	Preliminary retention, WQ and detention volumes and release rates, with Form 10-2	10.4.1(g)	_____	_____
B8	Downstream extent and tailwater case	10.4.1(h)	_____	_____
B9	Waterbodies, setbacks and the 1% AEP level	10.4.1(i)	_____	_____
B10	Land reserved for facilities and maintenance access	10.4.1(j)	_____	_____
B11	Professional Design Certificate (Form 10-3)	10.4.5	_____	_____

Table 10F.3 — Form 10-1, Section C: Stage 2 contents (Clause 10.4.2)

No.	Item	Clause	Page / sheet	Not applicable: reason
C1	Updated Stage 1 contents (Section B)	10.4.2	_____	_____
C2	Final calculations for every storage duration and AEP, with the outfall-closed check	10.4.2(a)	_____	_____

No.	Item	Clause	Page / sheet	Not applicable: reason
C3	Stage–storage–discharge tables; emergency spillway design	10.4.2(b)	_____	_____
C4	Hydraulic design of conveyance, inlets and structures	10.4.2(c)	_____	_____
C5	Water quality design; first-flush device or GPT where required	10.4.2(d)	_____	_____
C6	Construction drawings, details and specifications of every facility	10.4.2(e)	_____	_____
C7	Construction sequence, with protection of retention and infiltration areas	10.4.2(f)	_____	_____
C8	Hold-point schedule (Form 10-4, Section A)	10.4.2(g)	_____	_____
C9	Draft O&M plan and draft Maintenance Declaration (Form 10-6)	10.4.2(h)	_____	_____
C10	Model input files and GIS data	10.4.2(i)	_____	_____
C11	Certificates (Form 10-3, signed by designer and, where required, checker)	10.4.2(j)	_____	_____

Table 10F.4 — Form 10-1, Section D: Digital submittal (Clause 10.4.4)

No.	Item	Clause	Provided (yes / no)	Detail
D1	Reports and drawings as searchable PDF	10.4.4(a)	_____	_____
D2	Models in native, runnable format; software name and version	10.4.4(b)	_____	_____
D3	GIS data to Annex 10B; horizontal reference system (EPSG code)	10.4.4(c)	_____	_____
D4	Vertical datum named; relationship to the Chapter 5 river datums of the CWC and WRD gauges on the receiving rivers and the level datums of WRD and the lake custodians for the lakes and reservoirs that receive city drainage, with lake gauge readings in feet above a local zero converted to metres on a named datum	10.4.4(d)	_____	_____

Table 10F.5 — Form 10-1, Section E: Declaration and completeness check

Field	Entry
I confirm that this checklist is complete and correct. Certifying professional: name, signature, date	_____
For the Authority: date received	_____
Date of completeness check (within 5 working days, Clause 10.7.1)	_____
Result: accepted for review / returned	_____
Missing items, if returned	_____
Officer: name, designation, signature	_____

Form 10-2 — Compliance Calculator Summary

Supports Clauses 10.4.1(g), 10.5 and 10.9.1(b) of Chapter 10.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Produced by the compliance calculator (Annex 10A) with Stage 1, 2 and 4 submittals. Until the calculator is issued, complete it by hand and enter "not issued" in A3. One column per drainage area where the site has more than one outfall.

Table 10F.6 — Form 10-2, Section A: Site and route

No.	Field	Entry	Clause
A1	Authority, file number, stage (1 / 2 / 4)	_____	10.5.2(a)
A2	Site area, ha; land disturbance, ha; new + replaced impervious area, m²	_____	1.5.2
A3	Calculator version and release date	_____	10.5.3
A4	Tier (A / B); flood-sensitive (yes / no); approved BSMP for the basin (yes / no)	_____	1.6, 4.5.3, 11.12
A5	Route: full method / S-1 / S-2 / fixed-coefficient / constrained redevelopment / regional or fee-in-lieu	_____	1.7, 4.5.6, 4.13, 4.14
A6	Flags raised by the calculator (list)	_____	Annex 10A.4

Table 10F.7 — Form 10-2, Section B: Rainfall and soils

No.	Field	Entry	Clause
B1	Rainfall zone; Form 2-1 reference	_____	2.13
B2	Retention depth P_R, mm; 3-month ARI depth P_3m, mm	_____	2.10, 8.4.1
B3	Climate factor applied (≤ 6 h; > 6–72 h)	_____	2.8
B4	HSG by sub-area; seasonal high groundwater, m below base	_____	3.7, 4.4.3
B5	Measured and design infiltration rates, mm/h	_____	4.4.3

Table 10F.8 — Form 10-2, Section C: Volumes

No.	Quantity	Required (m³)	Provided (m³)	Clause
C1	Retention volume (RRV)	_____	_____	4.4.2
C2	Water quality volume (WQv)	_____	_____	8.4.2
C3	Retention credit against detention	_____	—	4.4.6
C4	Detention volume	_____	_____	4.6, 4.14
C5	Fee-in-lieu or regional volume, and fee (₹)	_____	_____	4.5.6.3, 4.13.3

Table 10F.9 — Form 10-2, Section D: Release rates (each outfall)

AEP	Q_pre or cap (L/s)	Q_post (L/s)	Governing duration (h)	Meets criterion (yes / no)	Clause
50% (2-yr)	_____	_____	_____	_____	4.5
10% (10-yr)	_____	_____	_____	_____	4.5

AEP	Q_pre or cap (L/s)	Q_post (L/s)	Governing duration (h)	Meets criterion (yes / no)	Clause
1% (100-yr)	_____	_____	_____	_____	4.5

Table 10F.10 — Form 10-2, Section E: Outlets, drawdown and stage comparison

No.	Field	Entry	Clause
E1	Low-flow orifice, mm (minimum 50 mm)	_____	4.8.2
E2	Detention: time to release 90% of the 10-yr stored volume, h (≤ 48 h)	_____	4.7.1
E3	WQv release time, h (24–48 h)	_____	4.7.2
E4	Retention emptying time, h (≤ 72 h)	_____	4.7.3
E5	Model result differs from the calculator screen by more than the guide tolerance? If yes, report section that explains it	_____	10.5.2(c)
E6	Stage 4 only: changes from the Stage 2 values (list), and whether every criterion is still met	_____	10.9.2
E7	Prepared by (name, registration number), signature, date	_____	10.6.3(b)

Form 10-3 — Professional Design Certificate

Supports Clauses 10.6.1 to 10.6.5 of Chapter 10.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Signed by the designer with every Stage 1 and Stage 2 submittal, and by an independent checker for facilities under Clause 10.6.1(c) and (d).

Table 10F.11 — Form 10-3, Section A: Project and signatory

No.	Field	Entry	Clause
A1	Authority, file number, stage	_____	—
A2	Site and facilities covered by this certificate	_____	—
A3	Designer: name, qualification, Building Regulations 2025 registration number	_____	10.6.1
A4	Empanelment number, where required, and the reason: Tier A ≥ 1 ha / flood-sensitive / embankment or high-hazard basin / pumped, tide gate or regional facility	_____	10.6.1(a)–(d)
A5	Variances or waivers approved (Form 1-2 references), or "none"	_____	10.6.3(a)

Table 10F.12 — Form 10-3, Section B: Certificate of the designer

No.	I certify that:	Initials
B1	the design complies with the Rajasthan Stormwater Design Manual, except for the variances listed at A5, which have been approved	_____
B2	the rainfall, soils and tailwater inputs are as recorded on Form 2-1 and Form 10-2	_____
B3	the models submitted reproduce the results reported	_____
B4	I understand that a false or negligent certificate is a contravention under Clause 10.15	_____

Table 10F.13 — Form 10-3, Section C: Certificate of the independent checker (Clause 10.6.4)

No.	Field or statement	Entry
C1	Checker: name, registration and empanelment number	_____
C2	I am independent of the designer and the Applicant and have not worked on this design	_____
C3	I have checked the facilities listed: _____, and agree with the certificate in Section B	_____
C4	Matters on which I do not agree, if any	_____

Table 10F.14 — Form 10-3, Section D: Signatures

Role	Name	Signature	Date
Designer	_____	_____	_____
Independent checker (where required)	_____	_____	_____

Form 10-4 — Hold-Point Inspection Record

Supports Clauses 10.4.2(g), 10.8 and 10.9.3 of Chapter 10.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Section A is the hold-point schedule, approved at Stage 2. Section B is completed at each hold point, with dated, geotagged photographs (Clause 10.8.2). Work shall not proceed past a hold point until Section B is signed. See Figure 10.2.

Table 10F.15 — Form 10-4, Section A: Hold-point schedule

Hold point	Facility (FAC_ID)	Stage of work	Planned date	Notice to Authority sent (date)*	Authority attended (yes / no)
(a) Excavated base, before media, liner or structure	_____	_____	_____	_____	_____
(b) Outlet structure, orifice and trash screen, before backfill or first filling	_____	_____	_____	_____	_____
(c) Infiltration and verification tests (Clause 10.9.3)	_____	_____	_____	–	_____
(d) Outfall, flap or tide gate and non-return valve, before downstream connection	_____	_____	_____	–	_____
(e) Pumps and controls, at commissioning	_____	_____	_____	–	_____
Other hold points added by the Authority	_____	_____	_____	_____	_____

* For sites under Clause 10.6.1, at least 3 working days' notice of hold points (a) and (b) (Clause 10.8.2).

Table 10F.16 — Form 10-4, Section B: Inspection record (one per hold point)

No.	Field	Entry
B1	Hold point and facility	_____
B2	Date and time of inspection; weather	_____
B3	Inspected by (certifying professional); others present	_____
B4	Approved drawing and revision checked against	_____
B5	Levels, dimensions and materials found, against approved values	_____
B6	For (a): retention and infiltration areas protected from traffic and stockpiles (Clause 10.8.3(a))	_____
B7	For (b): orifice size and invert; screen in place	_____
B8	For (c): infiltration test result and emptying time (≤ 72 h); pump duty point; gate opening and sealing	_____
B9	For (d) and (e): gate type, seating and test; pump commissioning record	_____
B10	Photograph references (dated, geotagged)	_____
B11	Result: released / not released; corrective work required	_____
B12	Corrective work checked (date, by)	_____
B13	Signature of the certifying professional, date	_____

Form 10-5 — As-built Certificate

Supports Clauses 10.9 and 10.3.5 of Chapter 10.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Lodged before the completion certificate. The Authority shall not issue the completion certificate until this form is accepted (Clause 10.9.4).

Table 10F.17 — Form 10-5, Section A: Project and survey

No.	Field	Entry	Clause
A1	Authority, file number; Stage 2 approval reference and date	_____	—
A2	Licensed surveyor: name, licence number, date of survey	_____	10.9.1(a)
A3	Vertical datum	_____	10.4.4(d)
A4	GIS data to Annex 10B, as built (file name)	_____	10.4.4(c)

Table 10F.18 — Form 10-5, Section B: Approved against as built (one block per facility)

Item	Approved	As built	Accepted (yes / no)	Clause
Storage volume at each design level, m³	_____	_____	_____	10.9.2(a)
Outlet dimensions (orifice, weir), mm	_____	_____	_____	10.9.2(b)
Outlet and outfall inverts, m	_____	_____	_____	10.9.2(b)
Spillway or overflow level, m	_____	_____	_____	4.9
Retention volume, m³	_____	_____	_____	4.4

Table 10F.19 — Form 10-5, Section C: Re-run and tests

No.	Field	Entry	Clause
C1	Compliance calculator re-run with as-built values: version, and Form 10-2 (Stage 4) attached	_____	10.9.1(b)
C2	Model re-run with as-built values (where a model was used): file name	_____	10.9.1(b)
C3	Every criterion of Chapters 4 and 5 met on re-run (yes / no; list any not met)	_____	10.9.2(c)
C4	Infiltration retention: measured emptying time, h (≤ 72 h)	_____	10.9.3
C5	Pumps: duty point achieved (flow at head)	_____	10.9.3
C6	Tide gates and non-return valves: shown to open and seal	_____	10.9.3
C7	Deviations, and how corrected or re-certified under Clause 10.3.5	_____	10.9.2

Table 10F.20 — Form 10-5, Section D: Attachments and certificate

No.	Field	Entry
D1	Completed hold-point records (Form 10-4)	_____
D2	Final O&M plan	_____
D3	Executed Maintenance Declaration (Form 10-6) or handover documents (Form 10-8)	_____

No.	Field	Entry
D4	I certify that the facilities listed were built as approved, except as stated at C7, and perform as designed. Certifying professional: name, registration number, signature, date	_____
D5	For the Authority: accepted / returned; officer, date	_____

Form 10-6 — Maintenance Declaration

Supports Clauses 10.10.1, 10.10.2, 10.10.4 and 10.13.1 of Chapter 10.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Model text for consideration by a competent authority. Not in force. Executed by the owner of every private stormwater facility before the completion certificate is issued, and registered so that it runs with the land.

> **Drafting note D10A.1.** The instrument under which this declaration is registered, and the Act that gives the Authority its right of entry and its power to carry out works in default, are to be confirmed by the competent authority. This form does not cite statute sections.

Table 10F.21 — Form 10-6, Section A: Parties and land

No.	Field	Entry
A1	Owner (the declarant): name and address; for a company or association, its registration number	_____
A2	Authority	_____
A3	Land: survey numbers, village, tehsil, district; extent	_____
A4	Approval reference (file number, Stage 2 approval date)	_____
A5	For multi-owner developments: the association or body that takes over after the developer (Clause 10.10.2)	_____

Table 10F.22 — Form 10-6, Section B: Schedule of facilities

Facility (FAC_ID)	Type	Location on the attached plan	Design volume (m³)	Outlet	O&M plan reference
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Model declaration. I/We, the owner named in Section A, declare and undertake, for myself/ourselves and for every successor in title to the land:

1. to operate, inspect and maintain each facility in Section B under the approved O&M plan, and to make the inspections of Clause 10.12 (Clause 10.10.1(b));
2. to give the Authority, its officers and its contractors a right of entry to inspect each facility and the access route shown on the plan, and to carry out works in default under Clause 10.15, with the cost recoverable from the owner (Clause 10.10.1(c));
3. not to remove, fill, cover, reduce or change the use of any facility, or obstruct its access route, without the Authority's written approval (Clauses 10.10.1(d), 10.13.5);
4. where Clause 10.10.3 applies, to lodge an Annual Maintenance Declaration and Inspection Report (Form 10-7) by 15 June each year;
5. for underground tanks, to follow the confined-space entry procedure stated here: _____ (Clause 4.15.6);
6. on sale or transfer of the land or any part of it, to disclose this declaration and the latest Form 10-7 to the purchaser, who takes on these obligations from the date of transfer (Clause 10.10.4); and
7. for a multi-owner development, that the developer remains responsible until the body named at A5 is legally constituted and has accepted this declaration in writing (Clause 10.10.2).

Table 10F.23 — Form 10-6, Section C: Execution and registration

Field	Entry
Owner: signature, name, date	_____
Witness 1: signature, name, address	_____
Witness 2: signature, name, address	_____
Acceptance by the association or body at A5 (when constituted): signature, date	_____
Registration: office, document number, date	_____
For the Authority: received and recorded in the facility register; officer, date	_____

Form 10-7 — Annual Maintenance Declaration and Inspection Report

Supports Clauses 10.10.3, 10.11.1(d) and 10.12 of Chapter 10.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Due by **15 June** each year from every owner of a facility in a Tier A area, and from every owner of a pumped facility, tide gate or regional facility anywhere (Clause 10.10.3). See Figure 10.3.

Table 10F.24 — Form 10-7, Section A: Owner and facilities

No.	Field	Entry
A1	Reporting year (1 June to 31 May)	_____
A2	Owner or association; Maintenance Declaration registration reference	_____
A3	Facilities covered (FAC_ID and type)	_____
A4	Any facility under Clause 10.6.1(c) or (d) (yes / no). If yes, Section E is required	_____

Table 10F.25 — Form 10-7, Section B: Inspections made during the year (Table 10.3)

Facility	Routine inspections (dates)	Pre-monsoon inspection (date)	After heavy-rainfall events (dates)	Monthly pump test runs (number)
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Table 10F.26 — Form 10-7, Section C: Pre-monsoon checklist (one per facility)

No.	Item	Condition (OK / defect)	Defect and date corrected
C1	Inlets, pretreatment and silt traps clear	_____	_____
C2	Orifice, trash screen and outlet clear; orifice size unchanged	_____	_____
C3	Sediment below the trigger in the O&M plan	_____	_____
C4	Storage volume not reduced; no filling, covering or change of use	_____	_____
C5	Overflow and spillway route clear	_____	_____
C6	Retention drains within 72 h (observation well or surface)	_____	_____
C7	Pumps: full duty test; standby pump and standby power tested; fuel for 72 h on site	_____	_____
C8	Alarms and telemetry tested	_____	_____
C9	Flap or tide gates and non-return valves: operated and seal tested	_____	_____
C10	Safety: covers locked, fences, signs and depth markers in place	_____	_____
C11	Access routes clear and not used for parking	_____	_____

Table 10F.27 — Form 10-7, Section D: Declaration of the owner

Field	Entry
I/We declare that the pre-monsoon inspection of Clause 10.12 has been made, that the defects found have been corrected as listed in Section C, and that the facilities are maintained under the approved O&M plan. Owner: name, signature, date	_____

Table 10F.28 — Form 10-7, Section E: Empanelled professional (facilities under Clause 10.6.1(c) and (d))

Field	Entry
I have inspected the facilities listed and confirm Section C. Name, empanelment number, signature, date	_____

Table 10F.29 — Form 10-7, Section F: For the Authority

Field	Entry
Date received; on time (by 15 June) yes / no	_____
Entered in the facility register (Clause 10.17), date	_____
Follow-up action, if any (Clause 10.15)	_____

Form 10-8 — Asset Handover Certificate

Supports Clause 10.14 of Chapter 10.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Signed by the developer and the ULB when drains, open space facilities, regional facilities or other stormwater assets built by a developer are handed over.

Table 10F.30 — Form 10-8, Section A: Asset and parties

No.	Field	Entry
A1	Developer: name and address	_____
A2	ULB	_____
A3	Layout or project, approval reference	_____
A4	Assets handed over (FAC_ID, type, length or volume), with a plan	_____

Table 10F.31 — Form 10-8, Section B: Conditions of handover (Clause 10.14.1)

No.	Condition	Met (yes / no)	Reference or date
B1	As-built certificate (Form 10-5) accepted	_____	_____
B2	Facility cleaned; pipes and culverts inspected internally (CCTV or manual entry), record handed over	_____	_____
B3	Land, or an easement over it, transferred to the ULB	_____	_____
B4	O&M plan, drawings, GIS data (Annex 10B) and warranties handed over	_____	_____

Table 10F.32 — Form 10-8, Section C: Defects liability and register

No.	Field	Entry	Clause
C1	Defects liability period: from _____ to _____ (includes at least one full monsoon season, from 15 June to 30 September, after handover)	_____	10.14.2
C2	Developer responsible during the period for defects and routine maintenance	_____	10.14.2
C3	Security deposit held by the ULB, ₹, and release date	_____	10.14.2
C4	Entered in the ULB GIS drainage asset register and the facility register: date	_____	10.14.3

Table 10F.33 — Form 10-8, Section D: Signatures

Party	Name and designation	Signature	Date
Developer	_____	_____	_____
Certifying professional	_____	_____	_____
ULB	_____	_____	_____

ANNEXES TO CHAPTER 11

Basin and City Stormwater Master Plans

These annexes support Chapter 11. They give a terms of reference template for a Basin Stormwater Master Plan (BSMP), the layout of the basin list and boundary layer, the layout and method for depth–damage curves, the standard for publishing BSMP data and models, and the annual implementation report form. Annexes 11B and 11C need data that are not yet available; they say so and give the rule to use in the meantime. The template and the form are a model and a draft form for consideration by a competent authority, and are not in force.

Annex 11A — BSMP terms of reference template

Supports Clauses 11.1 to 11.12 of Chapter 11.

> *Model text for consideration by a competent authority. Not in force.* The Lead Authority adapts this template for each basin. Items in "[ ]" are for the Lead Authority to complete. Clause references are to this Manual, which the consultant shall follow in full.

11A.1 Background and purpose

1. The [Lead Authority] intends to prepare a Basin Stormwater Master Plan for the [name] basin under Chapter 11 of the Rajasthan Stormwater Design Manual.
2. The BSMP shall (Clause 11.1.2):
    - (a) map flood hazard for the basin under existing and future conditions;
    - (b) set the level of service for each part of the drainage system;
    - (c) identify, cost and rank the works, storage and land needed to reach that level of service;
    - (d) identify land to be reserved in the statutory land-use plan for regional storage, talab and tank restoration and major flow paths;
    - (e) set the basin inputs for site design: regional facilities, the fee-in-lieu unit rate, and any basin release rate stricter than Chapter 4; and
    - (f) recommend catchments for notification as flood-sensitive.
3. The BSMP may make the site criteria of Chapters 4 to 8 stricter for the basin. It shall not relax them, except through the regional detention and fee-in-lieu routes of Clauses 4.13 and 4.5.6 (Clause 11.1.3).

11A.2 Client, partners and study area

1. **Client:** [Lead Authority] (Clause 11.4.1).
2. **Partners:** WRD, wherever the basin includes a river, canal or tank under its control, and [other local bodies, JDA or UDH, RSDMA] (Clause 11.4.1).
3. **Study area:** the whole of the [name] basin, draining to [outfall], as delineated under Clause 11.3, including the parts outside the client's limits (Clause 11.3.1). The provisional boundary is in [Annex 11B / attached map]. The consultant shall confirm it in Task 2.

4. **Links to other basins:** [for example the receiving river or lake corridor]. Diversions between basins by canal, drain or surplus course shall be mapped and represented in the model (Clause 11.3.2).

11A.3 Team

1. The study shall be led by an engineer empanelled as a Stormwater Design Professional with the basin modelling endorsement of Annex 10E (Clause 11.4.3).
2. The team shall include at least: [a hydrologist; a hydraulic modeller; a coastal or tidal specialist where the basin has a tidal outfall; a GIS and survey lead; a planner; a cost engineer; a community engagement lead]. The client sets the minimum qualifications and experience of each.

11A.4 Tasks

Task 1 — Inception. Review existing studies, data and projects in the basin. Prepare a data inventory against Table 11.1, a gap list, a survey plan, a consultation plan, and the work programme. Deliver the inception report.

Task 2 — Data and surveys. Assemble, survey where missing, and quality-check every item of Table 11.1 (Clause 11.5.1):

- (a) terrain: DEM from LiDAR or photogrammetry with vertical accuracy of 0.15 m RMSE or better in urban areas, tied to the Survey of India datum, with the accuracy test reported;
- (b) drain network: every public drain, culvert and outfall, with invert levels, sizes, condition and silt depth; private drains above 600 mm;
- (c) waterbodies: every tank, talab, pond and marsh under Chapter 7: FTL, MWL, bund level, stage–storage, sluices, surplus weirs, supply channels and encroachment, in the fields of Annex 7A;
- (d) rivers and canals: cross-sections at no more than 200 m spacing and at every structure;
- (e) outfalls, rivers, lakes and terminal depressions: outfall invert levels, on a named datum, against the warning, danger and high flood levels of the receiving river at the nearest CWC or WRD gauge (the Chambal, the Banas, the Luni or another river) and its recorded peaks; for outfalls to lakes and reservoirs, the full tank level, maximum water level and dead-storage level from WRD or the custodian, with lake gauge readings in feet converted to metres, the gate and escape-channel operating rule and any conflict between published values; for a catchment with no outfall, the stage–storage, infiltration and evaporation of the terminal depression or basin; the lines drawn under court orders where they bind; sluices, flap gates, escape channels, interception structures, anicuts, check dams and pumping stations on the outfalls, with their capacities and operating rules; and releases from any dam or barrage upstream;
- (f) rainfall and water levels: all available records (IMD, including its observatories at Jaipur (Sanganer), Jodhpur, Bikaner, Jaisalmer, Barmer, Ajmer, Kota, Udaipur and Mount Abu and the automatic weather stations and rain gauges reported by the Meteorological Centre Jaipur; the district and tehsil rain gauges of the State; the rain and river gauges of CWC and of WRD, including those at the dams, barrages and lakes; and any gauges kept by the Municipal Corporations, the development authorities and the Smart City companies), including the July 1981 (Jaipur), August 2006 (Barmer and Udaipur), September 2019 (Kota and the Chambal), July 2022 (Jodhpur) and July–August 2024 (Jaipur) events;
- (g) flood evidence: surveyed flood marks and mapped extents of past events, including public reports, photographs and residents' records;
- (h) land use: existing land use and imperviousness; future land use from the statutory master plan;
- (i) soils and groundwater: HSG map (Annex 3A or Clause 3.7.2), seasonal high groundwater, aquifer and recharge zones; and
- (j) sewer interaction: known cross-connections, dry-weather flow in drains, solid-waste hotspots.

Confirm the basin boundary and the inter-basin diversions (Clause 11.3.2). Deliver the data report and the data in the formats of Annex 11D.

Task 3 — Model build. Build a coupled 1D–2D hydraulic model of the minor system, the major (overland) system, rivers, canals and tanks, and the outfalls (Clause 11.7.1; Figure 11.2). Use the methods of Chapter 3 and the tidal and river boundaries of Chapter 5. Run the design storms of Chapter 2, including the 24-, 48- and 72-hour storms, for at least the 50%, 10%, 1% and 0.2% AEPs, with areal reduction under Clause 2.7.3 (Clause 11.7.2). Where the basin has tank cascades, run continuous simulation under Clause 3.13 with the full IMD gridded daily record where available, and at least 30 years, disaggregated by the temporal patterns of Annex 2D. The two-step approach of Clause 3.13.5 may be used: starting tank levels and antecedent conditions from the continuous run are passed to the design-storm runs (Clause 11.7.3).

Task 4 — Calibration and validation. Calibrate and validate the model under Clause 3.15, using at least two of the July 1981 (Jaipur), August 2006 (Barmer and Udaipur), September 2019 (Kota and the Chambal), July 2022 (Jodhpur) and July–August 2024 (Jaipur) events where data exist (Clause 11.7.5). Report the performance measures of Clause 3.15.4 and the reasonableness check of Clause 3.15.6.

Task 5 — Scenarios and hazard maps. Model the scenarios of Clause 11.7.4: (a) existing; (b) future, uncontrolled; (c) future, controlled; (d) future, with plan; and (e) climate, applied to (a) and (d). Produce flood hazard maps of extent, depth, velocity and hazard class (H1–H6, Chapter 6) for the 10%, 1% and 0.2% AEPs, existing and future-with-plan (Clause 11.8.4(a)).

Task 6 — Level-of-service assessment. Compare scenarios (a), (c) and (d) with the levels of service of Table 11.2 and any stricter levels the client adopts (Clause 11.6.1). Map every shortfall.

Task 7 — Options. Develop options in the order of Clause 11.8.1: protect and restore storage; regional retention and detention, sited by modelling; conveyance; outfall works; property-level protection; non-structural measures. Assess each option for the criteria of Clause 11.8.2: reduction in flood risk (buildings and people flooded, and expected annual damage using Annex 11C); capital and 30-year maintenance cost; land required; effect on groundwater recharge in the over-exploited aquifers that underlie most of the State, the rising water table and waterlogging in the old city of Jodhpur and the Ganganagar–Hanumangarh canal belt, and the quality of the groundwater, in which fluoride, nitrate and salinity are common, and of the lakes that the drains reach; effect on downstream basins and the receiving river or lake; and who benefits.

Task 8 — Basin inputs for site design. Where scenario (c) does not meet the level of service, propose basin release rates (m³/s/ha) by AEP and sub-catchment (Clause 11.8.3). Recommend catchments for notification as flood-sensitive, with the evidence of Clause 4.5.4.1. Identify regional facility sites, with storage volumes, land needs and the sites they serve, and compute the fee-in-lieu unit rate, including land, construction and 10 years of maintenance (Clauses 4.13.3, 11.8.4(c), (d)).

Task 9 — Capital Improvement Programme. Rank the works by risk reduction per rupee, with cost, phasing and responsible agency (Clause 11.8.4(e)).

Task 10 — Maintenance and monitoring. Prepare the pre-monsoon maintenance programme: desilting, gate and pump testing, and tank operating rules (Clause 11.8.4(f); Chapters 7 and 10). Specify monitoring needs: new rain gauges, level sensors and flood-mark survey points (Clause 11.8.4(g); Clause 10.16.1).

Task 11 — Land-use integration. Prepare the material for the statutory land-use plan required by Clause 11.9.1: sites to be reserved; the 1% AEP hazard map with the Chapter 7 setbacks; land in hazard classes H5–H6 in the 1% AEP event; and open space locations that can form part of flow paths or regional storage.

Task 12 — Consultation. Publish the draft BSMP for public comment for at least 60 days, with public meetings in each affected local body (Clause 11.10.1). Keep a log of comments and responses.

Task 13 — Final BSMP and publication. Revise the BSMP after consultation. Prepare the package for approval by the State Stormwater Technical Committee, including the model for review (Clause 11.11.1). Publish the data, models, maps and CIP under Annex 11D (Clause 11.10.2).

11A.5 Deliverables

Table 11A.1 — Deliverables

No.	Deliverable	Task	Due (months from start)
D1	Inception report, data inventory and survey plan	1	[ ]
D2	Data report and data sets (Annex 11D)	2	[ ]
D3	Model build report and model files	3	[ ]
D4	Calibration and validation report	4	[ ]
D5	Scenario results, hazard maps and level-of-service assessment	5, 6	[ ]
D6	Options report, with basin inputs for site design	7, 8	[ ]
D7	Draft BSMP with draft CIP, for consultation	9–12	[ ]
D8	Final BSMP, consultation log, approval package and open-data release	13	[ ]

11A.6 Ownership and publication

All data, models, maps and reports produced under these terms are owned by the Lead Authority and shall be published under Annex 11D. The consultant shall not use any software licence, data licence or format that prevents publication, or that prevents a third party from re-running the model with the stated software version.

Annex 11B — Basin lists and boundaries for Tier A bodies

Supports Clauses 11.3 and 11.4 of Chapter 11.

To be prepared. This annex will contain the list of basins for every Tier A body, with a GIS layer of basin boundaries delineated under Clause 11.3.2. It needs the list of Tier A bodies (Annex 1A), a DEM of the accuracy of Clause 11.5.1, the drain network of every drain-owning body (the Municipal Corporations, the development authorities' and Urban Improvement Trusts' scheme drains, RIICO's industrial-area drains and the interception works on the nalas), the lakes, reservoirs and talabs with their full tank levels, maximum water levels, gauge datums and gate and escape-channel rules (from WRD and the lake custodians), the sluices, flap gates, anicuts, check dams and pumping stations on the outfalls, the terminal depressions of the catchments with no outfall, the nalas, nadis and talabs recorded as gair mumkin in the revenue records, the lines drawn under court orders, and the catchments used for the Dravyavati project, JDA's storm water model and the RUIDP drainage works (other likely sources: Survey of India, CWC, CGWB and the Lakes Development Authority). No basin map of any Rajasthan city was found. Until the annex is published, the basins of Jaipur, Jodhpur, Udaipur, Ajmer, Kota and the no-outfall towns of the west named in Clause 11.3.3 are at least those named there; other Tier A bodies define their basins in their first BSMP (Clause 11.3.3); and the interim arrangements of Clause 11.12 apply in every basin without an approved BSMP.

Table 11B.1 — Basins named in Clause 11.3.3 (provisional)

Tier A body or area	Basin	Note from Chapter 11
Jaipur (JMC, JDA)	Dravyavati, from the Nahargarh hills to the Dhund, with the Naharika, Ambabari, Ganda and Jawahar nalas	Rebuilt channel and fall structures in the 1D network; interception works and treatment plants mapped (Clause 8.9.5)
Jaipur (JMC, JDA)	Man Sagar (Jal Mahal), reported as 23.5 km², with the Brahmapuri and Nagtalai nalas	Lake level as boundary
Jaipur region (JDA)	Ramgarh dam catchment, about 769.20 km², in the parts the city and the JDA region reach	Catchment line under the High Court's orders shown
Jodhpur (Municipal Corporation, JoDA)	Catchments draining to the Jojari, among them the Bhairav and RTO nalas	Kailana and Takhat Sagar as storage; rising water table of the old city; Jojari High Flood Line and buffer shown once demarcated
Udaipur (Municipal Corporation, UDA)	Pichola and Fateh Sagar, fed by Bada Madar, and the Ayad to Udai Sagar	Gated link and lake spills as links between basins; lake levels as boundaries
Ajmer (Municipal Corporation, AjDA)	Ana Sagar catchment	Lake at full gauge as boundary; outfall-closed case a design case; escape channel as a gated link
Kota (Municipal Corporation, KDA)	City catchments draining to the Chambal	Level at the CWC Kota City site, governed by the Kota Barrage releases, as boundary; outfall-closed case a design case
Bikaner and other no-outfall towns of the west	Each terminal depression or basin and the land draining to it	72-hour design volume (Clause 4.12.7) with no outflow other than infiltration and evaporation
Other Tier A bodies, including Alwar, Bharatpur, Bhilwara, Sikar, Pali, Sri Ganganagar and Tonk	To be defined in the first BSMP	Clause 11.3.3

Table 11B.2 — Attributes of the basin boundary layer (layout)

Field	Type	Content
BASIN_ID	Text	Basin identifier
NAME_EN, NAME_HI	Text	Basin name in English and Hindi
TIER_A	Text	Tier A body or bodies in the basin
OUTFALL	Text	Outfall to the sea, river or major waterbody (Clause 11.2)
AREA_KM2	Real	Basin area, km²
LEAD_AUTH	Text	Lead Authority (Clause 11.4.1)
PARTNERS	Text	Partners, including WRD where it applies
LINKS	Text	Diversions to and from other basins (Clause 11.3.2)
BSMP_STAT	Text	None / in preparation / draft published / approved
BSMP_DATE	Date	Date of approval of the current BSMP
REVIEW_DUE	Date	Date of the next review (Clause 11.11.2)

Annex 11C — Depth–damage curves for Rajasthan building types

Supports Clause 11.8.2 of Chapter 11.

To be prepared. This annex will contain depth–damage curves for the main building types of Rajasthan cities, for structure and contents, for use in computing expected annual damage under Clause 11.8.2. It needs a building-type classification and building stock data (Census housing tables, property-tax records, Lead Authority GIS), damage surveys and claims from the July 1981 (Jaipur), August 2006 (Barmer and Udaipur), September 2019 (Kota and the Chambal), July 2022 (Jodhpur) and July–August 2024 (Jaipur) floods (Revenue Department and RSDMA damage assessments, insurers), and replacement costs (PWD schedules of rates). Until it is published, each BSMP shall state the depth–damage relations it uses and their source, and shall report the reduction in buildings and people flooded for every option (Clause 11.8.2), which does not depend on the curves.

Table 11C.1 — Depth–damage curve (layout, one table per building type)

Depth of water above floor level (m)	0	0.25	0.5	1.0	1.5	2.0	3.0
Structure damage (% of replacement cost)	_____	_____	_____	_____	_____	_____	_____
Contents damage (% of contents value)	_____	_____	_____	_____	_____	_____	_____
Building type, source and year of costs	_____						

11C.1 Use in option assessment

Expected annual damage (EAD) is computed for each scenario from the damages at the modelled AEPs. With damages $D_1, D_2, \ldots$ at annual exceedance probabilities $P_1 > P_2 > \ldots$, using at least the 50%, 10%, 1% and 0.2% AEP results of Clause 11.7.2:

$$EAD \approx \Sigma \tfrac{1}{2} \times (D_i + D_{(i+1)}) \times (P_i - P_{(i+1)})$$

The reduction in EAD between scenario (c) and scenario (d), or between options, is the risk-reduction benefit used to rank works per rupee (Clause 11.8.4(e)). The BSMP shall state how damages beyond the 0.2% AEP and below the 50% AEP were treated.

Annex 11D — BSMP data and model publication standard

Supports Clauses 11.5.1 and 11.10 of Chapter 11, and Clause 10.17 of Chapter 10.

11D.1 What is published, and when

Table 11D.1 — Items to be published

Item	Format	At draft (Clause 11.10.1)	At approval (Clause 11.10.2)
BSMP report, with the level-of-service assessment and options	Searchable PDF	Yes	Yes, final

Item	Format	At draft (Clause 11.10.1)	At approval (Clause 11.10.2)
Flood hazard maps: extent, depth, velocity, hazard class, for each AEP and scenario of Clause 11.8.4(a)	GeoTIFF rasters; extents also as GeoPackage polygons	Yes	Yes
Capital Improvement Programme	CSV and PDF	Draft	Yes
Basin release rates, recommended flood-sensitive catchments, regional facility sites, fee-in-lieu unit rate	GeoPackage and CSV	Yes	Yes
Data of Table 11.1 (terrain, drains, waterbodies, cross-sections, river and lake levels, terminal depressions and outfall structures, rainfall and levels, flood evidence, land use, soils and groundwater, sewer interaction)	GeoTIFF (terrain); GeoPackage (features); CSV (tables and time series)	Summary	Yes, except security-sensitive asset details
Model files: native, runnable, with all boundary-condition, rainfall and control files, the software name and version, and a run log	Native format, zipped	No	Yes
Calibration and validation report	Searchable PDF	Yes	Yes
Consultation log of comments and responses	PDF or CSV	—	Yes

11D.2 Formats and references

- (a) Raster data shall be GeoTIFF, preferably cloud-optimised, with the cell size stated. Vector data shall be GeoPackage. Tables and time series shall be CSV in UTF-8, with a header row and units in the column names.
- (b) Horizontal and vertical references shall be as in Annex 10B.1(b) and (c). The vertical datum and its relationship to the Chapter 5 river datums of the CWC and WRD gauges on the receiving rivers and the level datums of WRD and the lake custodians for the lakes and reservoirs that receive city drainage, with lake gauge readings in feet above a local zero converted to metres on a named datum shall be stated in every data set that carries levels.
- (c) Times shall be in Indian Standard Time, written as ISO 8601 (yyyy-mm-ddThh:mm+05:30). Units shall be SI.
- (d) Hazard map files shall be named `<basin>_<scenario>_<AEP>_<variable>.tif`, where scenario is a to e of Clause 11.7.4, AEP is written as 50, 10, 1 or 0p2, and variable is depth, velocity, hazard or extent; for example `dravyavati_d_1_depth.tif`.
- (e) Waterbody data shall use the fields of Annex 7A. Facility and outfall data shall use the fields of Annex 10B.

11D.3 Metadata

Every published data set shall carry: title; description; Lead Authority; source and method; date of capture; accuracy (for the DEM, the measured vertical RMSE); horizontal and vertical reference; scenario and AEP, where relevant; BSMP version; licence; and a contact.

11D.4 Withholding and personal data

- (a) Security-sensitive details of critical assets may be withheld, with the reason recorded and published (Clauses 10.17.3, 11.10.2). The flood hazard maps and the model shall still be published; only the sensitive attributes are removed.
- (b) Personal data shall not be published (Clause 10.17.3). Flood evidence collected from residents shall be published without names or contact details unless the person consents.

11D.5 Licence, viewer and versions

- (a) Published data and models shall be released under the Government Open Data Licence – India or an equivalent open licence (Clause 10.17.4).
- (b) The hazard maps, regional facility sites and CIP shall also be shown on a public map viewer (Clause 11.10.2).
- (c) Each approved BSMP shall carry a version number and date. Superseded versions shall stay available, marked as superseded, so that designs approved under them can be checked.
- (d) The published model package shall allow a third party with the stated software version to reproduce the published results. Designers may use its boundary conditions for site designs in the basin (Clause 11.10, Commentary).

Form 11-1 — Annual implementation report

Supports Clause 11.11.3 of Chapter 11, with Clauses 4.5.6.3 and 4.13.4 of Chapter 4.

Draft form — Rajasthan Stormwater Design Manual, Draft v1.0. Published by the Lead Authority for each basin with an approved BSMP before each south-west monsoon, by **15 June** (Clause 11.11.3).

Table 11F.1 — Form 11-1, Section A: Basin and plan

No.	Field	Entry
A1	Basin; Lead Authority; partners	_____
A2	BSMP version and date of approval	_____
A3	Reporting year (1 June to 31 May)	_____
A4	Date of publication (by 15 June) and web address	_____

Table 11F.2 — Form 11-1, Section B: CIP progress

CIP rank	Work	Agency	Cost in CIP (₹)	Spent this year (₹)	Spent to date (₹)	Status	Expected completion
_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____

Table 11F.3 — Form 11-1, Section C: Fee-in-lieu ledger (Clauses 4.5.6.3(c) and 4.13.4)

Regional facility or tank	Volume credited to sites (m³)	Volume delivered (m³)	Fees received (₹)	Fees spent (₹)	Fees held, with year received
_____	_____	_____	_____	_____	_____
Basin total: volume owed and delivered	_____	_____	_____	_____	_____

Table 11F.4 — Form 11-1, Section D: Maintenance completed (Clause 11.8.4(f))

No.	Item	Planned	Done	Date completed
D1	Desilting of drains and canals (length, km; volume, m³)	_____	_____	_____
D2	Tank and talab desilting and restoration (tanks, number; storage restored, m³)	_____	_____	_____
D3	Gate tests (number of gates)	_____	_____	_____
D4	Pump station duty tests (number of stations)	_____	_____	_____
D5	Tank operating rules reviewed with the custodian (number)	_____	_____	_____
D6	Monitoring added: rain gauges, level sensors, flood-mark points (Clause 11.8.4(g))	_____	_____	_____

Table 11F.5 — Form 11-1, Section E: Flooding against the levels of service

Event (dates)	Rainfall compared with the design depths (Clause 10.16.2(a))	Level-of-service element (Table 11.2)	Location	Met (yes / no)	Event report reference (Clause 10.16.2)
_____	_____	_____	_____	_____	_____

Table 11F.6 — Form 11-1, Section F: Review triggers and sign-off

No.	Field	Entry
F1	Event exceeding the 1% AEP design depth in the basin this year (yes / no). If yes, review due within 2 years (Clause 11.11.2)	_____
F2	Statutory land-use plan revised this year (yes / no) (Clause 11.11.2)	_____
F3	Next 10-year review due (date)	_____
F4	Officer of the Lead Authority: name, designation, signature, date	_____