B2
Stormwater

Guiding principles

Access and equity: Stormwater infrastructure plays a significant role in maintaining access to communities and in protecting assets such as buildings and houses. Stormwater infrastructure also reduces flooding.

Health and safety: Stormwater can have health and safety impacts that are not immediately obvious. Fast-flowing water is particularly dangerous; children may be at risk of drowning if they play in open drains. If left lying, stormwater can cause ground saturation and loss of strength in load-bearing structures, damaging road pavements, buildings and their foundations, water towers and their footings.

Environmental health: Excess stormwater can pose serious environmental health risks, including:

- Water ponding or lying for extended periods of time may become stagnant, leading to health problems such as increased numbers of mosquitoes.
- The ground can become saturated, effectively raising the subsurface water level to a height where it renders septic systems unusable. Effluent then leaches into the ground water, contaminating the water ponding on the surface.
- If septic systems become unusable, people use facilities in other buildings. This may lead to overcrowding within houses, and subsequent overuse of other dwellings and their septic systems.

Appropriateness: Infrastructure solutions typically capture stormwater or divert it away from assets (for example, houses, landfill sites, roads, community buildings) and discharge it into natural watercourses. Infrastructure design must be functional but not cost-prohibitive, and should be able to cope with regular rainfall and unusual events (such as one-in-ten-year floods).

Affordability and sustainable livelihoods: Most communities will have limited funding for stormwater infrastructure. Remote areas require simple solutions to stormwater problems that can be maintained by the community's equipment and people. Use of existing structures, features and natural watercourses is the best approach.

Systems overview

The range of stormwater infrastructure options for remote communities includes:

- culverts
- floodways
- open drains
- V-drains
- table drains
- cut-off drains
- catch drains
- kerbing or kerb and channelling
- concrete V-drains
- holding ponds.

Current service delivery arrangements

Stormwater is generally part of internal civil infrastructure or access road civil infrastructure. Access roads may be managed by the state or territory authority, the local government authority, or the community. Internal infrastructure is usually managed by the local government authority or the community.

Communities in Western Australia, South Australia, the Northern Territory, Queensland and New South Wales rely on outside consultants to provide professional advice on stormwater requirements and design, and to supervise construction. State governments may use their own departments for advice (such as main roads departments), but this is rare.

Relevant Australian standards

Each agency managing stormwater infrastructure must comply with the relevant town planning, transport, or local government Act. Some communities will have their own planning scheme, including conditions for stormwater systems and structures. Water (of any type) cannot be moved from one property to another without the owner's written consent.

Each state government has a policy and guideline for stormwater management.

Involving the community

When working with a community on stormwater infrastructure, contact the relevant elders before visiting a site. Walk with them around the community, discuss any concerns they might have and discuss the preliminary work to be done before implementing the final design.

Once all the information has been gathered and agreement about the design has been reached, return to the community and present the design to them — they may have valuable ideas to contribute.

Although professional contractors will undertake the construction, there should be opportunities for community members to learn new skills, such as operating and maintaining equipment, using boning rods for level control, and maintaining drainage structures and systems.

Ensure that:

- discussions with the community are included from the very beginning; community members will have vital information about stormwater trends, flows, depths, directions, changes and past attempts to resolve these concerns.

Consider:

- the skills and equipment available in the community for maintaining the stormwater system.

Appraising community requirements

When appraising the community's stormwater management needs, it is important to find the source of the water flow and to investigate the adequacy of current stormwater structures and any related maintenance issues. Stormwater will always flow along the route of least resistance: often along natural creek lines or along lower areas through or around a community. Additional drains and infrastructure may be necessary to divert or to cope with the excess water.

A number of factors will determine the community's stormwater infrastructure requirements.

Culverts, open drains and pipes and stormwater holding ponds must be designed to take into account the peak rainfall rates in the area, the surface area of the catchment (which includes both building roofs and open land from which rainfall run-off contribute to the total flow towards the lowest point), the porosity or slickness of the surfaces (sandy soil 'soaks up' rain while building roofs, pavement and sheet rock do not), the slope or fall of the land, and objects such as existing watercourses, fences, tanks and dams that may impede, capture or redirect flow.

Design calculations to size these structures are normally carried out by a civil engineer. Sources of this design information include topographical maps, the community's existing and future development plans, historical rainfall data and geological information.

The location of underground or above-ground services (such as optic fibre cabling, telecommunications lines, water supplies, sewerage systems and underground or above-ground power supplies) may also influence the decision-making process.

Consider:

- the likely future development of a community, and how this will affect the load on a stormwater system.

Cultural issues

Water, rainfall, and creek or river flows are important features in Aboriginal culture, beliefs and storytelling. Most river or creek systems and waterholes have several sacred sites or sites of significance to Aboriginal people.

Ensure that:

- local elders are contacted about the location of sites of significance to Aboriginal people when appraising stormwater requirements.

Climatic factors

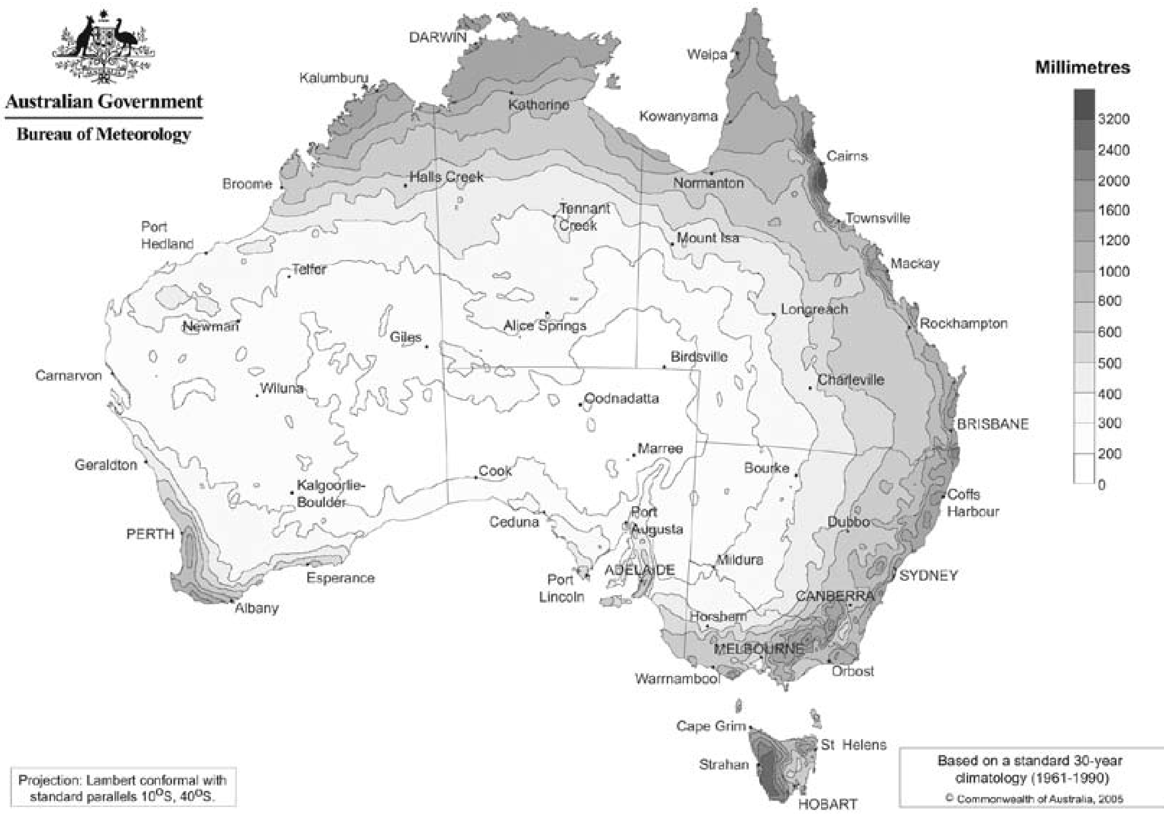
Climatic conditions vary greatly across Australia. Effective stormwater management must account for the circumstances and problems specific to each region (Table B2.1).

Table B2.1: Stormwater management on a regional basis

Region	Stormwater management	Problems
Wet tropical regions have two seasons — the wet (January to April) and the dry (the remainder of the year); a community may receive a yearly rainfall of > 1200 millimetres in only a few weeks	Stormwater and drainage systems generally cannot be designed to cope with tropical deluges	Stormwater can flood and scour community assets and services within communities (eg roads, parks, dwellings, septic systems)
Tropical regions have four seasons; rainfall is scattered throughout the year with an increase during summer months	Stormwater systems should be designed to cope with summer rains	Silt and debris can build up in stormwater systems in a short period of time if a series of small rainfalls is followed by a larger rainfall Assets in tropical regions are generally better protected by stormwater systems than those in the wet tropics
Dry desert regions have rain in short bursts or for short periods, followed by prolonged dry periods	Stormwater systems should be designed and maintained to cope with sand and silt build-up, and with peak rainfall bursts	Wind-blown sand, silt and debris can fill open and underground drains during long periods of time without rain; if drains are not cleared, stormwater systems may fail during times of heavy rain
Southern regions have rain scattered throughout the year with an increase during winter months	Stormwater systems should be designed and maintained to cope with increased rain during the winter months	In these areas, stormwater systems are often designed to cope with regular rainfall in small quantities; however, larger downfalls can cause system failure and infrastructure damage

Although forecasting tools such as weather maps and extreme weather warnings are available (such as from the Bureau of Meteorology; Figure B2.1), using these to predict storms or heavy rain events is often difficult. Consequently, stormwater infrastructure must be regularly maintained to prevent damage to the stormwater system, and prevent other hazards to the community.

Figure B2.1: Average annual rainfall in Australia



Source: Australian Bureau of Meteorology (2005)

In areas with tropical storms, designers should consider open drainage, rather than underground drainage, in conjunction with the road design. Open drainage systems allow for high volume and high velocity flows for extended periods of time. Wherever possible, residential properties should remain higher than road surfaces, so roads can collect and direct stormwater to the nearest watercourse. When designing roads within a community, consider the levels throughout the entire community. Roads are designed to create service access networks, and so should also be considered when creating stormwater drainage networks.

Consider:

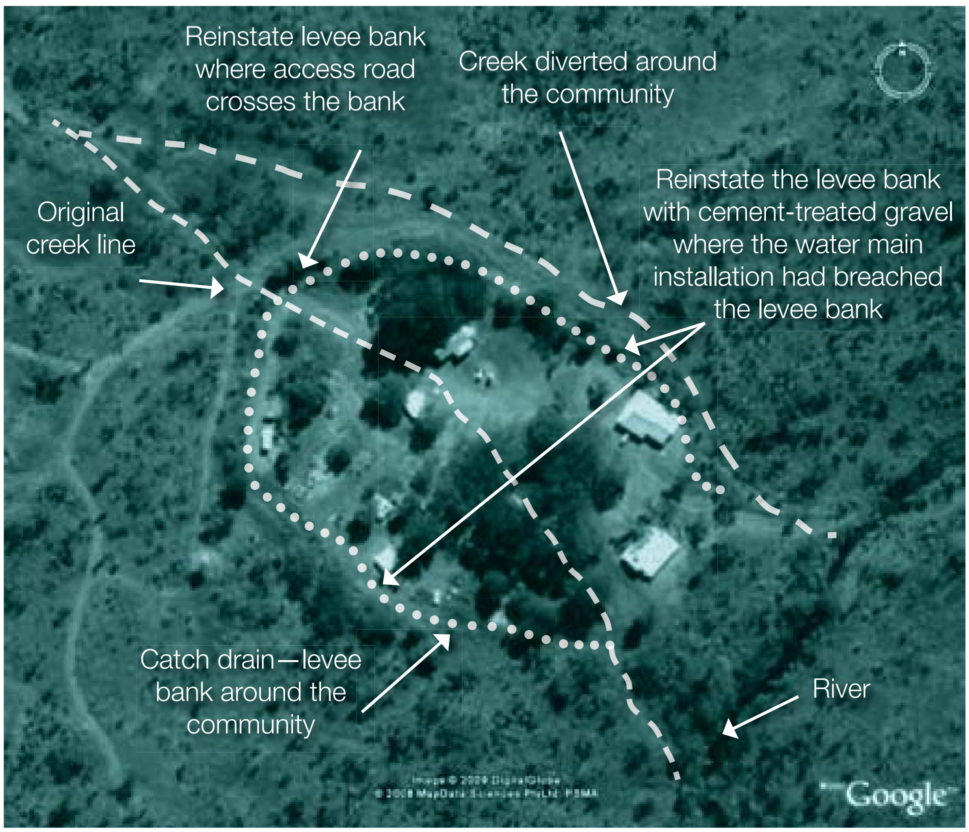
- using kerb and channelling in tropical areas, rather than just kerbing; channelling will make it easier to maintain internal roads and will prolong the life of the pavement
- using infrastructure such as underground drainage as part of the internal road designs in non-tropical areas.

Case study 5 — Responding to stormwater breaches of drainage systems

A community contacted a service provider and the local Indigenous Coordination Centre because its septic systems were not working, and were filling with stormwater during the wet season.

The service provider investigated by studying an aerial view of the community and a contour map, which showed that the community had been built in a creek bed, and the creek had been diverted around the community (Figure B2.2).

Figure B2.2: Aerial view of the case study community showing water flows



Source: Centre for Appropriate Technology, 2009

Inspection carried out in conjunction with local community members revealed that the levee bank and the diversion drains around the community had not been maintained. The community members pointed out two locations where water appeared to be flowing or seeping through or under the levee bank. One location was where a water main had been installed a year before. The levee bank had not been reinstated properly after installing the water main. In another location, vehicles had been using a section of the levee bank as part of an access road.

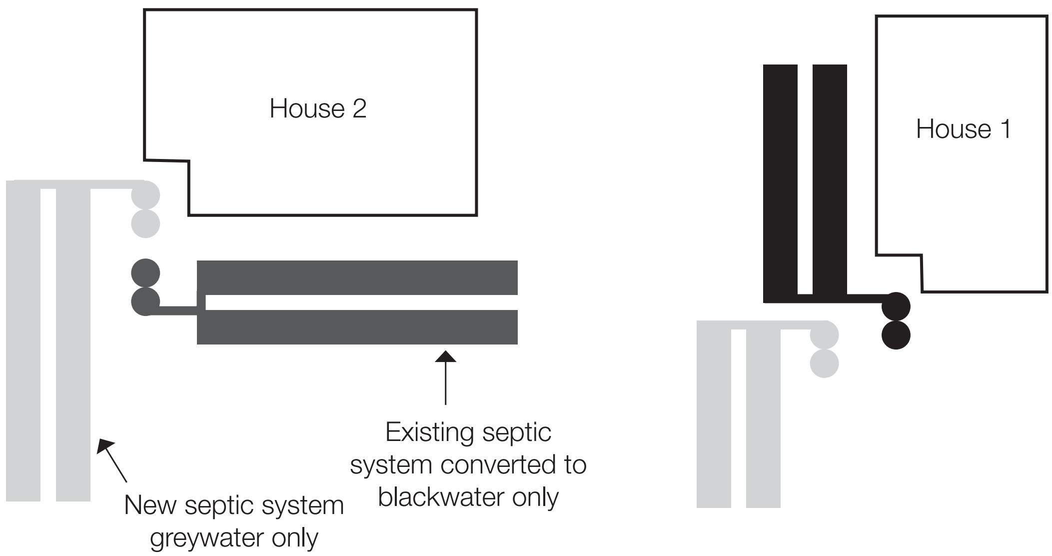
In response, the diversion drains around the community were cleaned and lowered to their original levels. The levee bank damaged by vehicles was reinstated. Where the water mains breached the levee bank, the areas were excavated, cement-treated and compacted with a roller.

(continued)

Investigating the two houses where septic systems had failed revealed that overcrowding was a major factor: the houses were designed to accommodate 4–5 people, but housed 10–12 people.

After discussions involving the community, the service provider and a company that installs wastewater gardens, a duplicate septic system was designed. The old system was kept for blackwater and a new system for greywater was installed at both houses (Figure B2.3).

Figure B2.3: Installation of septic system to cope with stormwater breaches



Source: Centre for Appropriate Technology, 2009

Wastewater gardens were mounted on top of all leach drains (including existing drains) to absorb and reduce the amount of wastewater and to prevent the wastewater from reaching the surface. The wastewater gardens were to contain water-hungry trees (such as citrus, bananas, pawpaws, chillies and custard apples) to provide fruit for the community.

The community was located in a rocky area with capstone granite only one metre below the surface, and loose rock covering the capstone. Consequently, finding the correct location for the leach drains was very important. The houses had been constructed on stumps, but the space underneath them had been filled to level the area before construction, so the new leach drains were constructed in the fill areas adjacent to the houses.

While the new system was being installed, workers found that the old septic leach drains flowed uphill. However, these old leach drains were left in place because the wastewater gardens would greatly reduce the amount of wastewater in the system, allowing the old drains to cope.

Choosing appropriate solutions

Stormwater infrastructure options

Communities generally only contact consultants when a problem arises (for example, a badly scoured access road or serious flooding). Most communities will have limited funding for infrastructure such as culverts, subsoil drainage and underground stormwater structures (such as pipes), which are very expensive and must be installed by construction professionals. A more simple or obvious above-ground system may work equally well, and have the advantage of being visible and easier to maintain with existing equipment.

Stormwater should be drained to the nearest watercourse or to a holding pond for recycling. These ponds should be located away from the community for health and safety reasons.

Culverts

Culverts are a row of pipes or boxes that allow stormwater to flow under another structure such as a road.

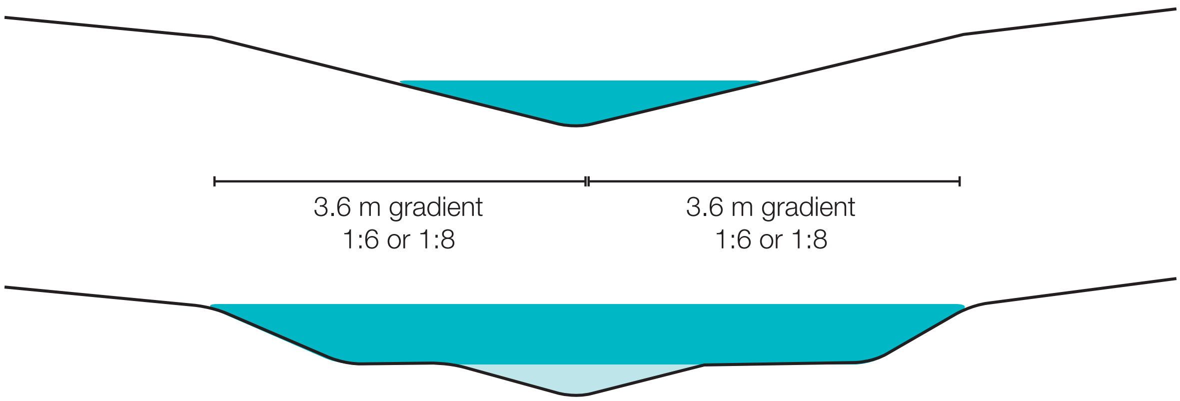
Source: Centre for Appropriate Technology, 2009

Floodways

Floodways can be designed in a number of ways to cope with different flow velocities and volumes. For low flows, a culvert can be placed under the floodway; for larger flows, the water flows over the floodway.

Open drains

Open drains carry large volumes of water from one place to another. Open drains can be constructed from material available on the site, or from concrete or upside down box culverts placed end to end. Wherever possible, avoid vertical sides as these may erode and collapse into the drain. Vertical sides can be very difficult for children to climb if they fall into drains.



Source: Centre for Appropriate Technology, 2009

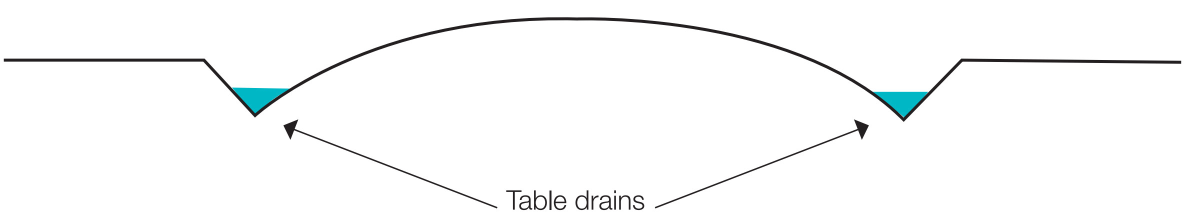
V-drains

Larger V-shaped drains reduce the velocity of the water. V-drains are easy to maintain; low vegetation cover is an advantage as it prevents erosion but should be managed by slashing when dry. In areas where large volumes of water are expected (such as the tropics and wet tropics), two-level flow drainage structures can be constructed:

- a lower, narrow drain to channel water to natural watercourses during low flows
- a higher, wider structure to channel water to natural watercourses during high flows.

Table drains

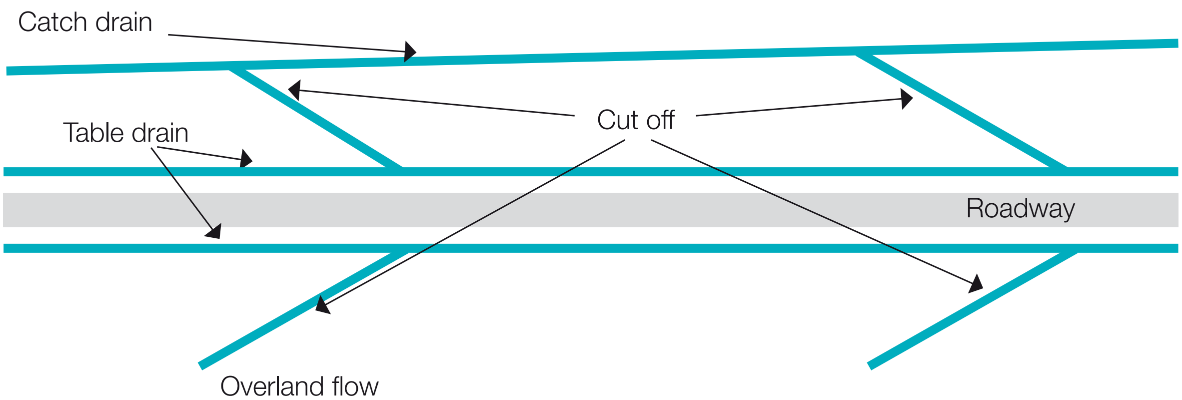
Table drains are open shallow drains constructed on either side of a road; these drains collect water and carry it to the nearest watercourse or divert it to flow overland, away from the road. Once again, sloped drains are easier to maintain than drains with vertical sides because graders and slashers can be used to clear vegetation inside the drain.



Source: Centre for Appropriate Technology, 2009

Cut-off drains

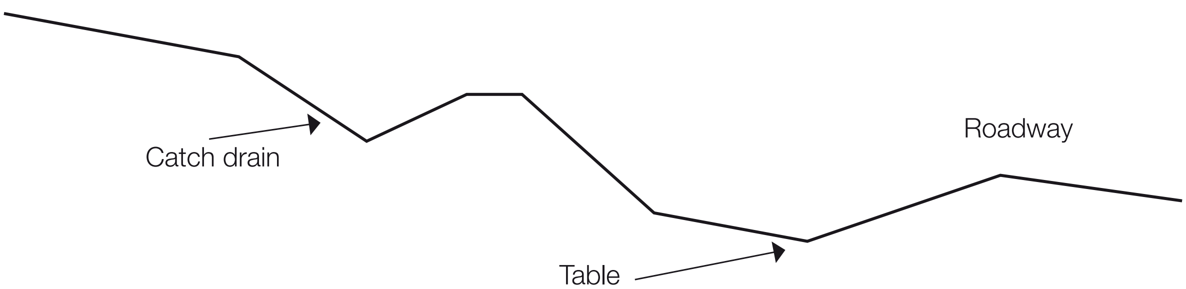
Cut-off drains are open drains used to carry stormwater from table drains into catch drains or to allow the stormwater to flow overland away from the road.



Source: Centre for Appropriate Technology, 2009

Catch drains

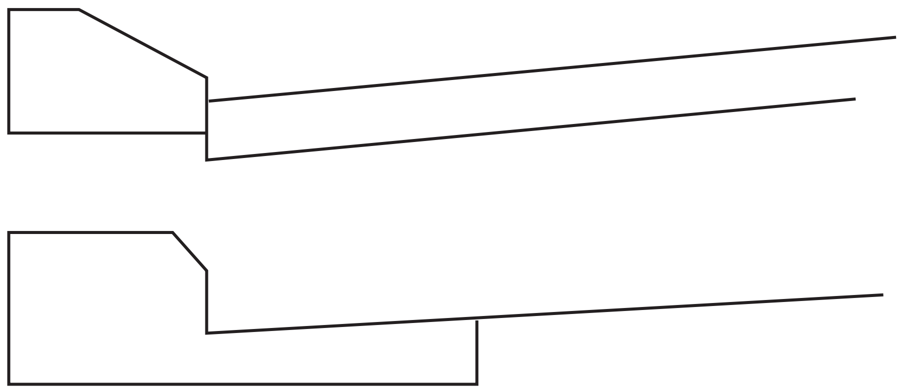
Catch drains are open drains used to collect and divert overland flow of water away from infrastructure.



Source: Centre for Appropriate Technology, 2009

Kerbing or kerb and channelling

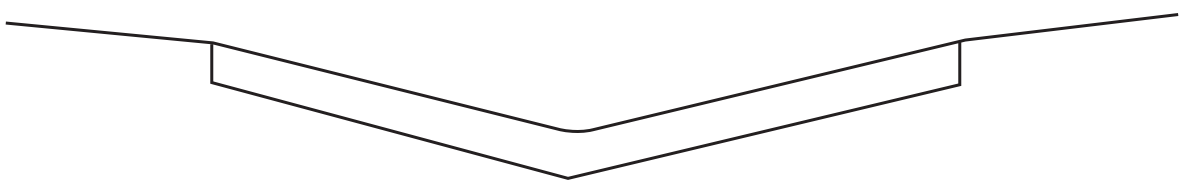
Where roads are used as drains in urban networks, kerbing or kerbs and channelling are installed to divert stormwater to underground water systems or to the nearest watercourse.



Source: Centre for Appropriate Technology, 2009

Concrete V-drains

If an area has high-velocity stormwater flows, the best option is to direct the water overland. However, consider using concrete V-drains to minimise erosion.

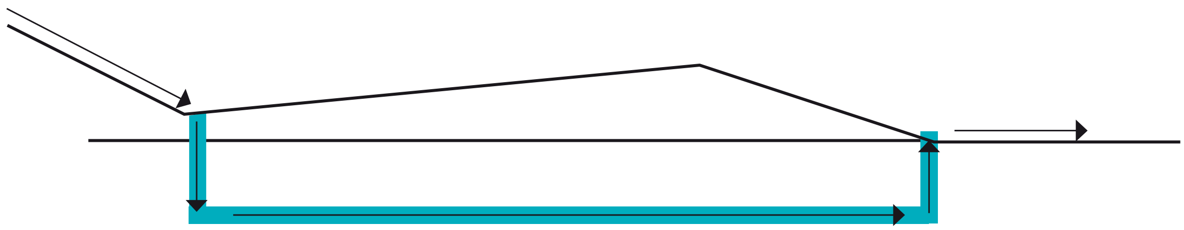


Source: Centre for Appropriate Technology, 2009

Unders and overs

Unders and overs push water from one area through a pipe and out the other end. The central section often remains full. Although unders and overs have been used in existing systems, they are not recommended for new stormwater drainage systems in remote communities because they are dangerous: children who play in them can be sucked into the piping system and drown.

Also, unders and overs can hold water all year round: stormwater can become stagnant, producing bad smells and providing a breeding ground for mosquitoes.



Source: Centre for Appropriate Technology, 2009

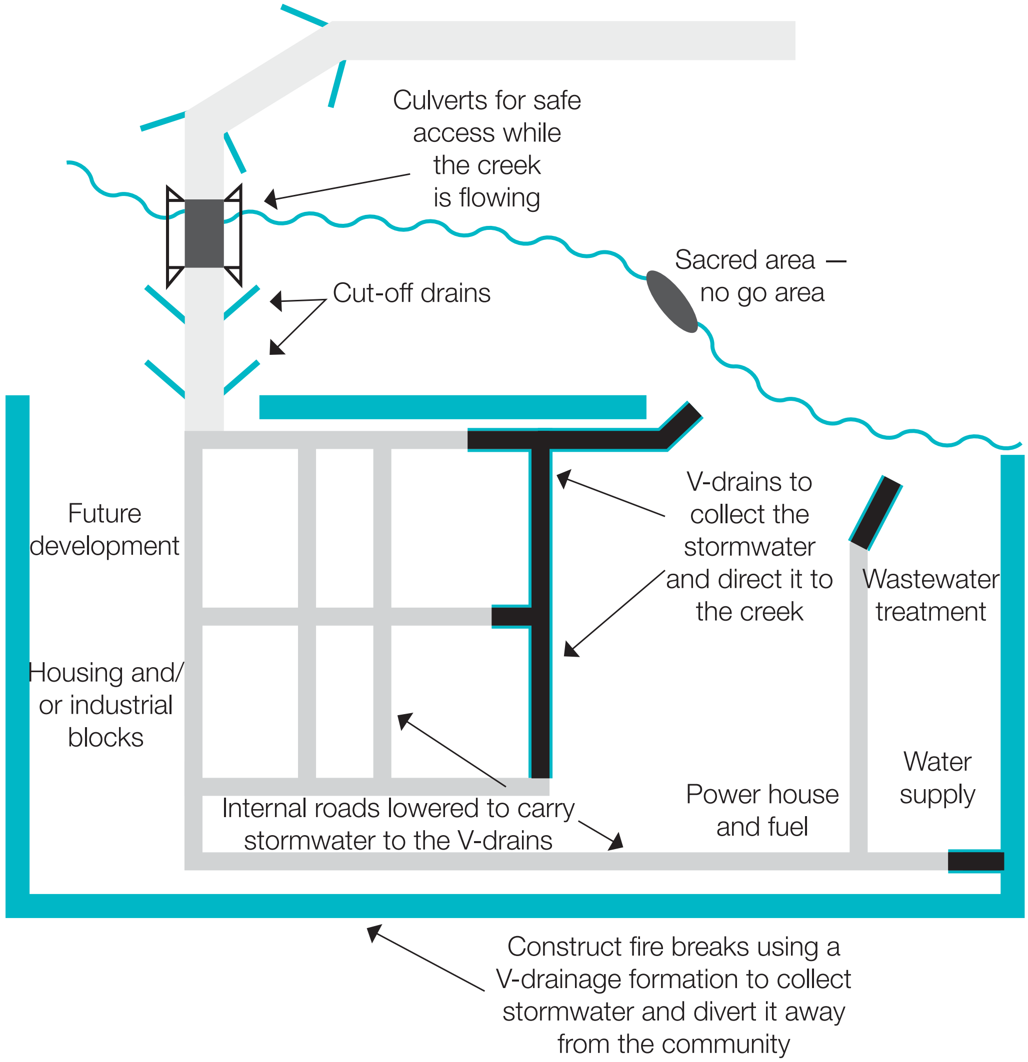
Holding pond

A holding pond is pond or dam designed to provide additional temporary storage capacity for stormwater during peak periods of rainfall, to prevent drainage systems from being overloaded. The ponded water may be harvested for reuse or allowed to drain away or evaporate slowly.

Design

A detailed feature survey of the community and surrounding land, including land contours, will assist in designing the layout, capacity, direction and distance of a stormwater system. The design should be as simple as possible, and local community members should be able to maintain the system using their own equipment (see Figure B2.4).

Figure B2.4: Example of a stormwater system design



Source: Centre for Appropriate Technology, 2009

If road designs include kerbing or channelling to divert water flow onto a sealed surface, rather than along road shoulders or unprotected table drains, water may penetrate the road pavement. This may weaken pavement strength, compromising the roads.

Ensure that:

- communities are aware that they should request external support for stormwater problems through their administration or service provider
- stormwater systems are designed, constructed and maintained by professionals with civil engineering backgrounds; this will often mean that communities need to engage consultants

- community members are consulted about water flow direction, volume and depth, and whether these features have changed in the last five years; new buildings or assets may have changed the water flow and created new problems
- community elders are consulted about previous solutions to stormwater problems, and what did and didn't work
- if community planning or layout plans include future development, the design incorporates any impact on the stormwater system
- the stormwater system does not isolate the community or any area, especially essential services, for extended periods of time
- water flows without interruption; stormwater should be collected and diverted to the nearest natural watercourse during any rainfall event
- the stormwater system protects the community and its infrastructure (such as roads, houses, buildings, essential service facilities, airstrips, barge landings) from damage from overland stormwater flow.

As the drainage system size (pipe diameter or open drain) decreases, the water velocity increases. However, if the water velocity through an open drain increases, scouring will also increase, so low grades and wide formations are best for open drains.

Small pipe diameters may be an economical design choice for short pipe runs, but long pipe drainage systems with small diameters should be avoided because such systems are costly to maintain, requiring contractors with expensive cleaning machines and techniques to clear silt, rubbish and tree roots from pipes. Units cost between $30 000 and $500 000 and necessary equipment includes ropes, tripods, harnesses, gas detectors, communication systems designed for underground work, rescue equipment and breathing apparatus. Pipes with diameters of less than 600 millimetres are associated with occupational health and safety issues.

Ensure that:

- no one enters a pipe with a diameter of less than 600 millimetres
- trained workers with special equipment are employed to clean drains with a diameter of less than 600 millimetres.

Consider:

- using roads as drains — lowering road levels will be cheaper than the cost of installing and maintaining an underground pipe drainage system with a small diameter
- using low drains where the water flows across roads; V-drains can also act as traffic-calming devices.

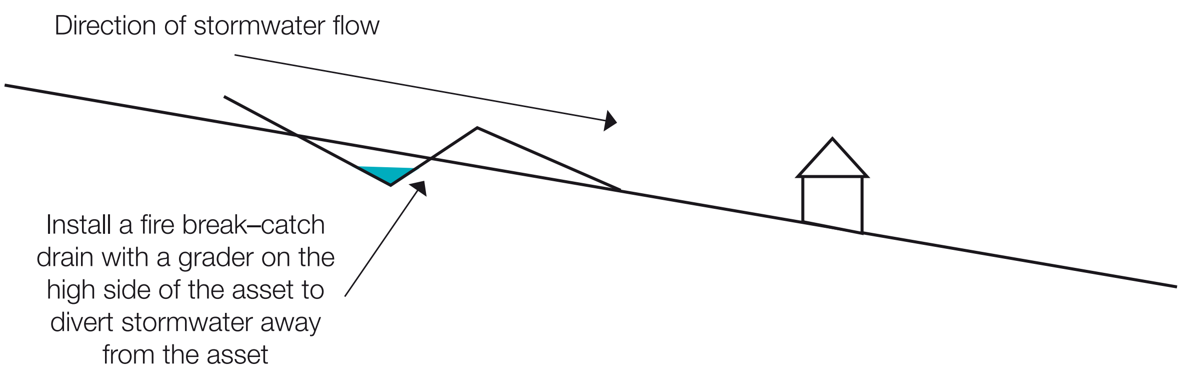
Where open drains are installed to catch overland flow and divert the water away from the community, use existing disturbed ground for the drainage.

Ensure that:

- stormwater is drained to the nearest watercourse or to a holding pond for reuse (for irrigating parks, reducing dust on roads, etc)
- ponds are located away from the community for health and safety reasons, and not held in lakes or dams near the centre of the community.

Consider:

- converting fire breaks into catch drains — catch drains can be easily maintained by community members or contractors, using a grader or tractor with a blade.



Source: Centre for Appropriate Technology, 2009

Construction

Most construction companies that install drainage systems will have a quality assurance checklist for each construction task. Design drawings and specifications should also include level control. Drawings should be submitted to the principal or person in administrative control of the property, as part of the construction process.

Boning rods ('T' shapes — see Useful terms) may be used to check the grades of open drains. For underground pipes, culverts and other underground stormwater systems, use buckets of water to ensure the water flows in the right direction.

Materials

When constructing stormwater systems, consider the suitability of materials, given the climate.

Consider:

- that steel and ordinary concrete pipes will not last long in saltwater tidal areas
- whether gravel, sand and rock are available nearby; to be cost-efficient, material must be sourced from within 20 kilometres of the site.

Managing and maintaining services

Stormwater infrastructure is often forgotten because it is unseen, and it is often missed by contractors conducting maintenance checks. Currently, most communities conduct limited stormwater maintenance — planned or routine maintenance is essential so that communities are not affected by stormwater damage.

Stormwater management should include a twice-yearly maintenance program to clean, de-silt and repair drainage structures, especially where large, open stormwater drains pass through communities. In the tropics, maintenance programs should be implemented two months before each wet season and one month afterwards. Safety education for the community, especially for children, should be included in stormwater management systems.

Ensure that:

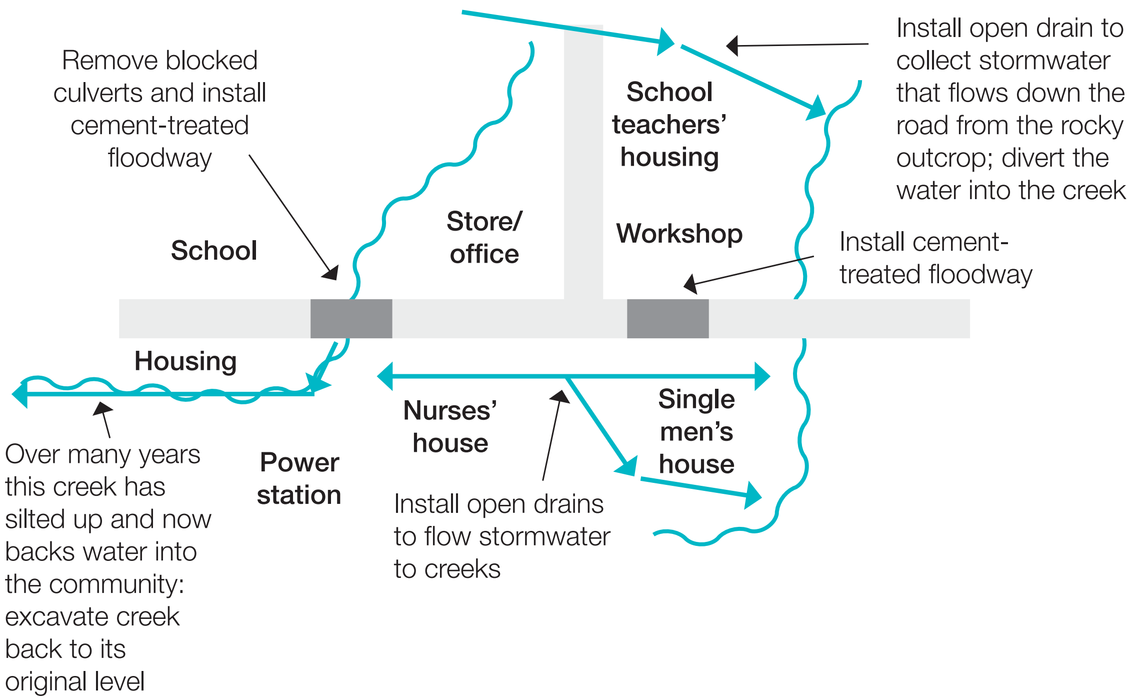
- all stormwater structures, both above and below ground, are maintained
- all drainage systems are cleaned or cleared of debris and silt before and after heavy rain
- open drains are graded and structures (such as concrete works) are repaired
- table, cut-off and V-drains are graded; material washed into the drain should be returned to the road formation, adjacent banks or batters
- gradients of drains are checked using a level; drains should be cleaned or regraded to ensure water flow
- where problems occurred during the last heavy rainfall event these are identified and remedial action taken
- a clear uninhibited path of flow exists to the nearest natural watercourse
- subsoil drains are installed to alleviate water pressure if properties and parks are affected by surface water.

Subsoil drains are essential to divert water away from structural assets (such as buildings, roads, bridges) because seepage and underground water can cause considerable damage. Subsoil drains work by pushing the water to the surface: they intercept the water flow then divert it to a natural watercourse.

Case study 6 — Addressing stormwater and seepage issues

A community was experiencing problems with stormwater and seepage from groundwater; roads, parks, verges and the airstrip were being damaged. Stormwater and subsurface water reached the ground surface level during the wet season. The community was built inside a circle of springs, and on a joint between a rocky capstone and alluvial black soil (Figure B2.5). This joint allowed subsurface water to escape to the surface when the watertable became too high, saturating the ground in the community.

Figure B2.5: Map showing infrastructure and drainage patterns of case study community



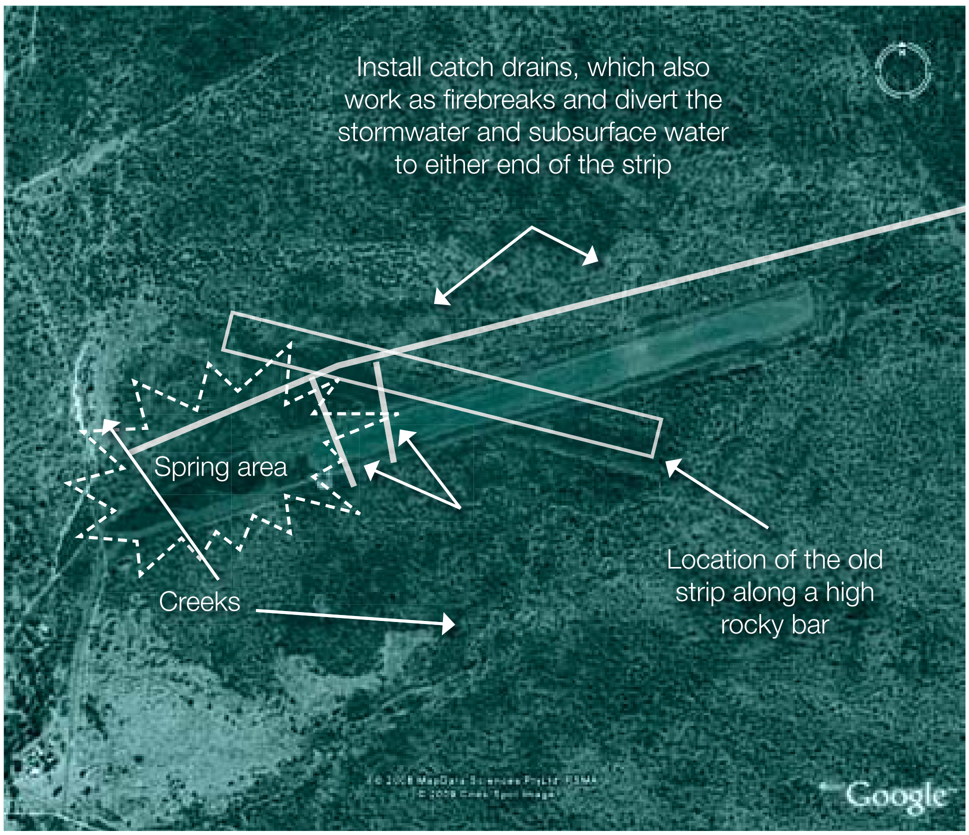
Source: Centre for Appropriate Technology, 2009

An engineer talked to community members and administration staff, and decided to divert the stormwater into existing creeks. The community was also concerned because large numbers of snakes were breeding in the area and using the culverts under the road as a home. An inspection revealed that the culverts were installed too high and had silted up; water could not flow through them. Removing the culvert and installing a cement-treated floodway would lower the water flow level and decrease the number of snakes in the community.

(continued)

The community's airstrip presented a further problem: during the wet season, only 60% of the airstrip was serviceable, limiting the types of aircraft that could use the airstrip. The airstrip had a high point in the centre that sloped to either end; this should have been good for drainage but springs appearing on the high side of the strip during the wet season caused water to flow across the airstrip (Figure B2.6). Aircraft had eroded the gravel on the airstrip and the black soil underneath had been exposed to water, rendering the airstrip unusable. The aircraft parking area was also in the middle of a spring, and could not be used at all for four months of the year.

Figure B2.6: Aerial view of airstrip described in the case study



Source: Centre for Appropriate Technology, 2009

The engineer sat down and talked with the elders of the community. He found that the old airstrip had followed a rocky ridge perpendicular to the current airstrip. The old airstrip had been used by the Royal Flying Doctor Service all year round without any threat of closure.

(continued)

To repair the airstrip to an all-weather standard, the following changes were required:

- *installation of open drains down the high side of the strip to collect and divert any run-off stormwater and any subsurface water that was coming to the surface at either end of the airstrip, so the water could run into existing watercourses*
- *installation of subsoil drainage where springs were appearing in the runway and in the aircraft parking area, so the outlets could divert the water to flow overland to the nearest watercourse*
- *gravel re-sheeting of the entire runway with 150 millimetres of well-graded material and a small amount of clay for binding.*

The total cost of these repairs would be $512 000. In contrast, reopening the old airstrip and building a new 1.2-kilometre runway would cost approximately $800 000. Funding constraints have prevented further progress on this project to date.

Useful terms

Boning rods	A trio of equal-sized 'T' shapes set temporarily into the ground surface along the line of a drain under construction. A change in slope is gauged by sighting along the cross-arms of the first pair to the third rod.
Capstone	A layer of impervious sheet rock.
Catch drain	An open drain used to collect and divert overland flow of water away from infrastructure.
Culvert	A row of pipes or boxes that allows stormwater to flow under another structure (eg a road).
Cut-off drain	An open drain that carries stormwater away from the table drain.
Groundwater	Subsurface water.
Holding pond	A pond or dam designed to provide additional temporary storage capacity for stormwater during peak periods of rainfall, to prevent drainage systems from being overloaded. The ponded water may be harvested for reuse or allowed to drain away or evaporate slowly.
Leach drain	Typically associated with a septic tank system: a drain excavated and refilled with gravel or other material that allows treated greywater to slowly filter into the soil.
Sheeting	A construction process where a sheet or layer of material such as gravel or rubble is laid onto a road or other formed surface.
Table drain	The shallow open drain parallel to a road on its edge.

Further reading

Australian rainfall charts and guides are essential to determine rainfall volumes. Information about regional climates is available from the Australian Government Bureau of Meteorology.
www.bom.gov.au

Austroads, main roads departments and civil engineering reference books for stormwater design are available at engineering bookshops. These reference books should be used with local input when calculating catchment capacity, soil types, run-off calculations and final pipe, open drain design capacity.

Austroads (2003). *Guidelines for Treatment of Stormwater Runoff from the Road Infrastructure*, Austroads, Sydney.

Pilgrim DH (ed) (1987). *Australian Rainfall and Runoff — A Guide to Flood Estimation*, Institution of Engineers, Australia, Barton, Australian Capital Territory.