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SC6.4.9.1 Introduction

(1) Objectives of stormwater drainage design and construction

(a) Objectives

The objectives of stormwater drainage design and construction are as follows:

(i) to ensure that inundation of private and public buildings located in flood prone areas occurs only on rare occasions and that, in such events, surface flow routes convey floodwaters below the prescribed velocity/depth limits;

(ii) to provide convenience and safety for pedestrians and traffic in frequent stormwater flows by controlling those flows within prescribed limits; and

(iii) retain within each catchment as much incidental rainfall and runoff as is possible and appropriate for the planned use and the characteristics of the catchment.

(b) Principles

In pursuit of these objectives, the following principles apply:

(i) New developments are to provide a stormwater drainage system in accordance with the "major/minor" system concept set out in QUDM (Fourth Edition 2017) ; that is, the "major" system shall provide safe, well defined overland flow paths for infrequent storm runoff events while the "minor" system shall be capable of carrying and controlling flows from frequent runoff events.

(ii) Redevelopment - where the proposed development replaces an existing development, stormwater must be managed in a way that does not exacerbate flooding, and /or adversely impact on neighbouring land or road. The level of drainage provided must be consistent with new development.

(iii) The work to be executed under this section consists of the design of stormwater drainage systems for urban and rural areas.

(2) Consultation and planning

(a) Consultation with Council

Designers are encouraged to consult with the Council and other relevant authorities prior to and during the preparation of the stormwater design. Designers should, in addition to requirements of this section, ascertain the specific requirements of these authorities as they relate to the designs in hand.

(b) Existing service plans

The designer must obtain service plans from all relevant public utility authorities and organizations whose services may exist within the area of the proposed development. These services are to be plotted on the relevant drawings including the plan and cross-sectional views.

SC6.4.9.2 Reference and source documents

Reference and source documents that must be read in conjunction with this section are as follow:

(1) SC6.4 Development manual planning scheme policy sections:

Section SC6.4.2 Development application guidelines
Section SC6.4.3 Standard drawings
Section SC6.4.8 Stormwater management
Section SC6.4.10 Stormwater quality
Section SC6.4.17 Structures
Section SC6.4.18 Concrete works
Section SC6.4.23 Construction management, quality management, inspection and testing

Section SC6.4.24 Acceptance of completed works
Section SC6.7 Flood hazard planning scheme policy.

(2) Australian Standards:

AS/NZS 1254	*PVC-U pipes and fittings for stormwater and surface water applications.*
AS/NZS 2032	*Installation of PVC pipe systems.*
AS/NZS 2566.1	*Buried flexible pipelines, Part 1: structural design.*
ASNZS 3725	*Design for installation of buried concrete pipes.*
AS/NZS 4058	*Precast concrete pipes (pressure and non-pressure).*
AS 4139	*Fibre reinforced concrete pipes and fittings.*

Institute of Public Works Engineering Australasia, *Queensland Urban Drainage Manual – Fourth Edition 2017.*

(3) Department of Transport and Main Roads:
Road Planning and Design Manual (2nd edition)

(4) Other:

Australian National Conference on Large Dams (ANCOLD)	*Guidelines on the Consequence Categories for Dams, 2012.*
Austroads	*Guide to Road Design Part 5: Drainage – General and Hydrology Considerations*
Chanson, H	*Hydraulic Design of Stepped Cascades, Weirs and Spillways, Pergamon, Oxford 1994.*
Chanson, H	*Hydraulics of Nappe Flow Regime Above Stepped Chutes and Spillways, Australian Civil Engineering Transactions, IEAust Volume 1 CE36 No. 1, January 1994.*
Concrete Pipe Association of Australia	*Hydraulics of Precast Concrete Conduits (Pipes and Box Culverts) 2012.*
Concrete Pipe Association of Australia	CPAA Technical Publications as a general reference
Commonwealth of Australia (Geosciences Australia) Australian Rainfall & Runoff (AR&R)	*A Guide to Flood Estimation 2019.*

SC6.4.9.3 Major and minor system design AEPs

(1) The Annual Exceedance Probability (AEP) is the probability of exceedance of a given rainfall intensity or discharge within a period of one year.

(2) The major system design AEP is the Defined Flood Event, being the 1% AEP, unless altered by the Part 8.2.6 Flood hazard overlay code.

(3) The Minor system design AEPs must be in accordance with Table SC6.4.9.1 below.

Table SC6.4.9.1 - Minor System Design AEP and Average Recurrence Interval (ARI)

Development Category	ARI (yrs)	AEP
Residential	2	39%
Commercial - Lower order (district centre and below)	2	39%
Commercial - Other (excluding Lower order commercial and Principal centre)	5	18%
Industrial	5	18%
Principal Centre (CBD)	10	10%
Rural Residential	20	5%
Parks and recreation areas (excluding community facilities)	1	1EY

(4) The Minor system design AEP for streets is as per the adjacent development category listed in Table SC6.4.9.1 above.

SC6.4.9.4 Hydrology

(1) Design rainfall data

Design rainfall data can be obtained from one of the following methods:

(a) Design intensity, frequency, duration (IFD) rainfall - IFD relationships shall be derived in accordance with Australian Rainfall & Runoff (AR&R 2019) for the catchment under consideration; and

(b) Design IFD rainfalls can be obtained from the Bureau of Meteorology website for specific locations, and these are to be submitted to Council.

(2) Catchment area

(a) The total area of land, both internal and external to the area of interest, contributing stormwater runoff to the point under consideration. Consideration must be given to likely changes to individual catchment areas and catchment parameters caused by the full development of the catchment in accordance with the zonings in the Townsville City Plan.

(b) Where no detailed survey of the catchment is available, datasources used to determine the catchments and to measure areas can be sourced in the form of digital elevation models from Council, Qld Open Data Portal or ELVIS for digital methods, otherwise contour maps produced from Council's GIS .can be used. A suitable scale shall be chosen for contours.

(c) Catchment area land use shall be based on current available zoning information or proposed future zonings, where applicable.

(3) Rational method

(a) Rational method calculations to determine peak flows shall be carried out in accordance with QUDM.

(b) All calculations shall be carried out or supervised by a qualified engineer (RPEQ certified) who is experienced in hydrologic and hydraulic design.

(c) The rational method is not appropriate for use in catchments with floodplain storage, timing effects due to multiple flow paths, and detention basins.

(d) Coefficients of discharge shall be calculated as per QUDM~~)~~. and full details of coefficients utilised shall be provided to Council.

(e) Details of fraction impervious for individual zonings are given in Table SC6.4.9.2 below.

(f) The time of concentration of a catchment is defined as the time required for storm run off to flow from the most remote point on the catchment to the outlet of the catchment. Most catchments will have multiple lengths of flow paths and gradients. The longest length flow path may not always govern the critical flow path. The hydrologic design should analyse several paths to assess any sensitivity to the catchment's time of concentration.

(g) Where the flow path is through areas having different flow characteristics or includes property and roadway, then the flow time of each portion of the flow path shall be calculated separately.

(h) The minimum time of concentration shall be taken as 5 minutes in urban and 10 minutes in rural catchments.

(i) Flow paths to pits must be designed to accommodate the flows from the fully developed catchment and provide for anticipated obstructions such as fences, building pads, buildings, and other likely obstructions. Any proposed changes to flow paths must be undertaken on a catchment wide basis to ensure flow paths are not diverted onto other land parcels which may result in damage or loss of enjoyment of the adjoining lands.

(j) Horton's roughness coefficient "n*" shall generally be derived from information in QUDM Section 4.6.. Values applicable to specific zoning types and overland flow path types are given below on the flow across:

(i)	Parks	0.35
(ii)	Rural residential land (vegetated)	0.3
(iii)	Rural residential land (short prairie grass)	0.15
(iv)	Residential low density	0.21
(v)	Residential high-density / industrial	0.06
(vi)	Commercial	0.04
(vii)	Paved areas and asphalt roads	0.01
(viii)	Gravel areas	0.02

(k) The design and analysis of stormwater drainage is to be based on the peak runoff flows from sub-catchments and from accumulated catchments. Designers are to show, by the assessment of partial catchment areas, that the peak flows have been identified.

(l) The fraction impervious for different types of land use zones is shown in Table SC6.4.9.2 below.

Table SC6.4.9.2 - Design AEPs and Fraction Impervious for Land Use Zones

Development Category	Land use	Fraction impervious (fi)
Residential zones category	Low density residential	0.65
	Medium density residential	0.7
	High density residential	0.9
	Rural residential	0.6

	Character residential	0.55
Centre zones category	Neighbourhood centre	0.9
	Local centre	0.9
	District centre	0.9
	Major centre	1.0
	Principal centre (CBD)	1.0
	Specialised centre	0.9
	Mixed use	0.9
Community facilities and Open space zone category	Sport & recreation	0.2
	Open Space	0.2
	Community facilities	0.95
	Environmental management & conservation	0.4
Industry zones category	Low impact industry	0.9
	Medium impact industry	0.9
	High impact industry	0.9
Rural zones category	Rural	0.1
Other zones category	Emerging community	-
	Special purpose	-

(4) Hydrological models

(a) Council has carried out flood modelling for most areas across Townsville. Hydrological models are available on request. The information from these models, such as peak flows, should be used during the design of the stormwater system.

(b) Other hydrological models may be used providing the requirements of Australian Rainfall & Runoff (AR&R) are met, summaries of calculations are provided and details are given of all program input and output.

(c) Details on the modelling requirements should be obtained from Section SC6.7 Flood hazard planning scheme policy.

(d) Where computer analysis programs are used, copies of the final data files shall be provided on submission of the design to Council and with the final drawings after approval by Council.

SC6.4.9.5 Hydraulics

(1) Hydraulic grade line

(a) Hydraulic calculations shall generally be carried out in accordance with Australian Rainfall & Runoff (AR&R) and shall be undertaken by a qualified person experienced in hydrologic and hydraulic design. The calculations shall substantiate the hydraulic grade line adopted for design of the system and shown on the drawings. Summaries of calculations are added to the plan and details of all calculations are given including listings of all programme input and output.

(b) The “major” system shall provide a safe, well defined overland flow path for larger storm events up to the maximum defined flood event. The “minor” system shall be capable of carrying and design flows from the lesser nominated flood events based on the land zoning of the area.

(c) Downstream water surface levels are to be obtained from Council’s existing flood studies. If flood study information is not available, the most appropriate of the below is to be used:

(i) known hydraulic grade line level from downstream calculations including pit losses at the starting pit in the design event;

(ii) where the downstream starting point is a pit and the hydraulic grade line is unknown, details of the downstream system shall be obtained, and further analysis performed to determine the hydraulic grade line;

(iii) where the outlet is an open channel and the design storm is the minor event, details of the downstream system shall be obtained, and further analysis performed to determine the hydraulic grade line. The top of the outlet pipe or the hydraulic grade line, or mean high water springs shallbe the downstream control, whichever is higher;

(iv) where the outlet is an open channel, the design storm is the major event and downstream flood levels are not known, details of the downstream system shall be obtained, and further analysis performed to determine the hydraulic grade line. The top of the outlet pipe or the hydraulic gradeline shall be the downstream control whichever is the higher;

(v) where the outlet is an open channel, the design storm is the major event and downstream flood levels are known, the downstream control shall be the highest of all duration events for the definedflood event;

(vi) mean high water springs (MHWS) where discharges are to river or creek systems within the intertidal zone;

(vii) In some instances, the downstream water surface level may need to be determined with the development of a flood study. Details on the flood study requirements should be obtained from Section SC6.7 Flood hazard planning scheme policy; and

(viii) the downstream water surface level used in the calculations should be provided to Council.

(2) Major/minor system

(a) Design of the drainage system should be in accordance with the major/minor flood management concept which recognises the dual requirements of the drainage system to provide for convenience and the protection of life and property for all storm events up to the defined flood event.

(b) All design work undertaken should follow the guidelines set down in the *Queensland Urban Design Manual* (QUDM) unless otherwise instructed in this section.

(3) Minor system criteria

(a) Minimum conduit sizes shall be as follows:

(i) pipes 375 mm diameter; and

(ii) box culverts 600 mm wide x 300 mm high.

(b) Maximum velocity of flow in stormwater pipelines shall be 4 m/sec. Minimum velocity shall be determined by ensuring self-cleansing velocity is achieved. This requirement shall be deemed to be satisfied providing the product of slope and diameter (S x D) is not less than 0.0008 m where S = slope (m/m) and D is pipe diameter (m).

(4) Roadway flow width and depth

(a) Flow width and depth criteria for major and minor storm events must comply with QUDM section 7.4.

(5) Inlet pits and manholes

(a) Inlet pits and manholes must be provided:

(i) to enable access for maintenance;

(ii) at changes in direction, grade, level, or class of pipe; and

(iii) at junctions.

(b) The maximum recommended spacing of pits and manholes where flow widths are not critical should be spaced every 80 m for ease of maintenance purposes. Kerb inlets shall be constructed in accordance with Section SC6.4.3 Standard drawings SD-200.

(c) Pit entry capacity calculations must be undertaken to provide for adequate spacing of pits, and to ensure flow capture has been adequately analysed. Flow under weirs and/or orifice conditions must be carefully considered. Information on pit entry capacities is available in the following sources:

(i) *Queensland Urban Drainage Manual* (QUDM);

(ii) Pit relationships given in Section 5.5, Book 9 of Australian Rainfall & Runoff (AR&R); and

(iii) Manufacturers' design specifications.

(d) Blockage factors to be applied to theoretical inflow capacities of inlet pits are given in Table SC6.4.9.3 below.

Table SC6.4.9.3 - Allowable Pit Capacities

Condition	Inlet Type	Blockage factor
Sag	Side entry	20%
Sag	Grated	50%
Sag	Combination	Side inlet capacity only Grate assumed completely blocked
Sag	"Letterbox"	50%
Continuous Grade	Side entry	20%
Continuous Grade	Grated	50%
Continuous Grade	Combination	90%
Field inlet	Flush	80%
Field inlet	Raised grate	50%

(6) Hydraulic losses

(a) Pressure change co-efficient "K" shall be determined from the appropriate charts given in QUDM Appendix 2.

(b) Allowable reduction in "K" due to benching is given in QUDM section 7.16.8.

(c) Computer program default pressure change co-efficient “K” shall not be acceptable unless they are consistent with those from the charts in QUDM. The chart used and relevant co-efficients for determining“K” value from that chart shall be noted on the hydraulic summary sheet provided for plan checking and included on the final design drawings.

(d) Bends may be permissible in certain circumstances and discussions with Council regarding their use isrequired prior to detailed design. Appropriate values of pit pressure change co-efficient at bends are givenin QUDM.

(e) The design must avoid clashes between services. However, where unavoidable clashes occur within the existing network, then the pressure change co-efficient “Kp” must be determined from the chart given in QUDM section 7.16.11.

(f) Requirements for private pipes entering Council’s system are given below:

(i) all pipe inlets, including subsoil pipes, must where possible, enter the main pipe system at junction pits. These must be finished off flush with and be grouted into the pit wall; and

(ii) if a junction has to be added then a junction pit shall be built at this location in accordance with this section.

(g) Construction of a junction without a structure should be avoided where possible. Permission to do this is required from Council prior to detailed design. Where this is unavoidable, the pressure-change coefficients Ku, for the upstream pipe and Kl, for the lateral pipe, must be determined from the chart given in QUDM.

(h) Going from larger upstream to smaller downstream conduits is not permitted without approval of Council prior to detailed design. In going from smaller to larger pipes benching must be provided in pits to enable a smooth flow transition. Losses in sudden expansions and contractions are given in QUDM.

(i) Underground drainage systems must be designed as an overall system, with due regard to the upstream and downstream system and not as individual pipe lengths. Drainage system designs must clearly show the hydraulic grade line (HGL), especially in systems operating under undue pressure.

(7) Major system – minimum freeboard criteria

(a) Where floor levels of adjacent buildings are above road level there must be a minimum freeboard of 300 mm to floor level of adjacent buildings.

(b) Where floor levels of existing adjacent buildings are below, or less than 300 mm above the top of kerb, and there is at least 100 mm fall on the footpath towards the kerb, the maximum flow depth is 50 mm above the top of kerb.

(c) Where floor levels of existing adjacent buildings are below, or less than 300 mm above the top of kerb, and there is less than 100 mm fall on the footpath towards the kerb, the maximum flow depth is at the topof kerb.

(d) Wave action wash that enters properties from passing vehicles must be considered.

(e) Road capacities and major system flood levels are to be determined adopting the roadway as an openchannel. Assessment of flood impacts on adjoining properties must consider any effects of backwater from the adjacent waterway using backwater analysis techniques.

(8) Minimum grades

(a) Unlined drains must have a minimum grade of 0.5% and lined drains must have a minimum grade of 0.3%. This includes table drains and kerb and channel.

(b) Pipe and box culverts must have a minimum grade of 0.2%.

(9) Open channels

(a) Generally, open channels and swales must be designed to have smooth transitions with adequate access provisions for maintenance and cleaning. Where Council permits the use of an open channel to convey flows from a development site to the receiving water body, such a channel must comply with therequirements of this section.

(b) Design of open channels must be in accordance with Chapter 9 of QUDM. Open channels must be designed to contain the major system flow.

(c) Friction losses in open channels must be determined using Manning's "n" values. Mannings "n" roughness co-efficients for open channels must generally be derived from information in Chapter 2, Book 6 of Australian Rainfall & Runoff (AR&R). Manning's "n" values applicable to specific channel types are given in the table SC6.4.9.4 below:

Table SC6.4.9.4 – Manning's "n" Values for Specific Channel Types.

Surface Type	Manning's "n"
Concrete Pipes or Box Sections	0.011
Concrete (trowel finish)	0.014
Concrete (formed without finishing)	0.016
Sprayed Concrete (gunite)	0.018
Bitumen Seal	0.018
Bricks or pavers	0.015
Pitchers or dressed stone on mortar	0.016
Rubble Masonry or Random stone in mortar	0.028
Rock Lining or Rip Rap	0.028
Corrugated Metal	0.027
Earth (clear of weeds and debris)	0.022
Earth (with weeds and gravel)	0.028
Rock Cut	0.038

Editor's Note - For Manning's n values of grass channels refer to the *Road Planning and Design Manual (Part 5B).*

(d) Where the product of average velocity and average flow depth for the design flow rate is greater than 0.4m²/s, the design must specifically provide for the safety of persons who may enter the channel in accordance with Chapter 12 of QUDM.

(e) Maximum side slopes on grassed lined open channels must be in accordance with section 9.5.4 of QUDM. Low flow provisions in open channels (man-made or altered channels) will require low flows to be contained within a pipe system or concrete lined channel section at the invert of the main channel. The width of the concrete lined channel section must be the width of the drain invert or at least sufficiently wide enough to accommodate the full width of a tractor with an absolute minimum width of 1.5 m.

(f) Open channels should be wide and shallow in preference to narrow and deep to maintain natural invert level to reduce the expression of groundwater.

(g) Designers should also ensure that longitudinal grades are sufficient to prevent the ponding of storm water for periods of more than 2 days after a rain event.

(h) Transition in channel slopes is to be designed to avoid or accommodate any hydraulic jumps due to the nature of the transition.

(i) Drop structures must be designed in open channels where the water velocity exceeds 2 m/s. The design must address the size and location of the structure as well as details of any stilling basins and revetment works surrounding the structure.

(j) Special consideration must be given to erosion control where sodic soils occur. Details of treatment proposals prepared by a competent person must be provided and approved by Council.

(10) Major structures

(a) All major structures in urban areas, including bridges and culverts, must be designed for the 1% AEP storm event with minimal afflux. Some afflux and upstream inundation may be permitted in certain rural and urban areas provided the increased upstream flooding does not inundate private property or critical infrastructure.

(b) A minimum clearance of 0.5 m between the 1% AEP flood level and the underside of any structure is required to allow for passage of debris without blockage except where Council permits structures to be overtopped.

(c) Certified structural design must be provided for bridges and other major culvert structures and may be required on some specialised structures. Structural design must be carried out in accordance with Section SC6.4.17 Structures.

(d) Culverts (either pipe or box section) must be designed in accordance with information and charts provided in QUDM.

(e) Safety limitations – overtopping of roadways. All floodwaters overtopping a major structure such as a culvert or bridge structures within a road are to be checked for safety and stability limitations for both pedestrians and vehicles. Assessment of the waterway crossing safety and stability is to be undertaken based on criteria outlined in QUDM – Tables 7.4.3 and 7.4.4.

(11) Detention basins

(a) For each AEP a range of storm events shall be run to determine the peak flood level and discharge from the retarding basin. Storm patterns to be used are outlined in Australian Rainfall & Runoff (AR&R) and can be obtained from the AR&R data hub website (www.data.arr-software.org). The critical storm duration with the retarding basin is likely to be longer than without the basin. A graph showing the range of peak flood levels in the basin and peak discharges from the basin shall be provided for the storms examined.

(b) Flood routing should be modelled by methods outlined in AR&R. Rational method approximations of flood hydrographs are unacceptable.

(c) The high-level outlet to any retarding basin shall have capacity to contain a minimum of the 1% AEP flood event. Additional spillway capacity may be required due to the hazard category of the structure. The hazard category should be determined by reference to ANCOLD.

(d) The spillway design shall generally be in accordance with the requirements for open channel design in Clause SC6.4.9.5(9) and QUDM (Chapter 5).

(e) The low flow pipe intake shall be designed in accordance with the requirements of QUDM, section 5.8.

(f) Freeboard - Minimum floor levels of dwelling shall be 0.3 m above the Defined 1% AEP flood level in the basin.

(g) Public safety issues

Basin design is to consider the following aspects relating to public safety:

(i) side slopes are to be a maximum of 1 in 6 to allow easy egress. Side slopes of greater than 1 in 4 may require handrails to assist in egress from the basin;

(ii) water depths shall be, where possible, less than 1.5 m in the defined AEP flood event. Where neither practical nor economic, greater depths may be acceptable. In that case the provision ofsafety refuge mounds should be considered;

(iii) the depth indicators should be provided indicating maximum depth in the basin;

(iv) signage of the spillway is necessary to indicate the additional hazard;

(v) basins shall be designed so that no ponding of water occurs on to private property or roads;

(vi) no planting of trees in basin embarkment walls is allowed;

(vii) no basin spillway is to be located directly upstream of urban areas;

(viii) submission of drawings to the "Dam Safety Committee" is required where any of these guidelines are not met or Council specifically requires such submission; and

(ix) stepped spillways are used in rare instances for energy dissipation and scour control. Guidance on hydraulic design and analysis of these structures is as per Chanson 1994.

(12) Tidal barriers

The use of tidal barriers on stormwater outlets are required in areas affected by tides. The device used should meet the following criteria:

(a) limited pressure head required to allow the discharge of stormwater from the system without any manual intervention. Specifications of the device proposed to be used should be supplied to Council prior to detailed design;

(b) barriers should not be able to be wedged open to an incoming tide by litter;

(c) Council will not accept hinged flap gates as a suitable solution; and

(d) minimal requirements for repairs and maintenance of the device. Any maintenance information for thedevice should be supplied to Council prior to detailed design.

(13) Barriers at inlets and outlets

Provision shall be made for the safety of the public including children relating to the inlet and outlet of the stormwater system and should be based on the following criteria:

(a) no opening into an underground system shall be wider than 150 mm except at head walls to pipes and box culverts;

(b) headwalls on the inlets and outlets to underground drains in which the drain is longer than 30 m and hasa cross sectional area greater than 0.5 m^2 must be protected with handrails, guard rails or fencing which restricts easy access to the entry structure;

(c) trash screens or other forms of grates are not favoured across the front of inlets and are unlikely to be approved by Council unless there is a tidal barrier on the outlet of the stormwater system – this may beconsidered by Council;

(d) any grates over field inlet pits shall be set above the top of the pit to provide a 50 mm gap between the top of the pit and the bottom of the grate. In areas of open space, marker posts must be used to identify each corner of the pit; and

(e) under no circumstances, should fixed barriers or grates be placed at the end of stormwater outlet.

SC6.4.9.6 Stormwater detention

(1) Installation of stormwater detention is required on all development sites where insufficient capacity in thedownstream drainage systems exist and a minimum amount of detention will be that required to ensure no worsening of the flooding situation occurs during the defined flood event.

(2) The requirements for stormwater detention design are outlined in QUDM.

(3) The development must limit any increase in discharge rate for all storm events up to and including the defined flood event.

(4) The developed site must not discharge more stormwater than the discharge calculated for pre-developmentflows.

(5) Combined sedimentation and detention ponds must be designed in accordance with Section SC6.4.8 Stormwater management and SC6.4.10 Stormwater quality so that remobilisation of sediment is minimised.

SC6.4.9.7 Inter-allotment drainage

(1) Inter-allotment drainage must be avoided wherever possible. Where inter-allotment drainage is proposed, the Developer must demonstrate that no other drainage alternative is possible. Inter-allotment drainage is not to collect road runoff.

(2) Where inter-allotment drainage is unavoidable, it should not cover more than 2 allotments and must be contained within an easement not less than 3 m wide. The easement must be provided over the entire length of the drainage structure in favour of lots benefiting from and affected by the pipe. All inter-allotment and allotment drainage, connector pipes, and surface water collection infrastructure, remains the responsibility of the lot owner.

(3) Where inter allotment drainage is unavoidable and serves more than 5 allotments, a minimum 375 mm diameter pipe must be provided to capture the flow and must be contained within an easement not less than 3 m wide. The easement must be provided over the entire length of the drainage structure in favour of Council over the collector pipe.

(4) Inter-allotment drainage shall not be provided in commercial and industrial developments. Commercial and industrial areas shall connect directly to the Council stormwater network.

(5) Where drainage is required over more than two allotments, a drainage easement is required in favour of Council.See Clause SC6.4.9.10 Drainage easements and drainage reserves.

(6) Inter-allotment drains must be designed to accept concentrated drainage from buildings and paved areas on each allotment for flow rates having a design AEP the same as the “minor system” per Table SC6.4.9.1.

(7) The design of inter allotment drainage must make allowance for major system flows, with appropriate freeboard.

(8) In lieu of a more detailed analysis, the fraction impervious for surfaces contributing runoff to the inter-allotment drain are as shown in Table SC6.4.9.2.

(9) Pipes must be designed to flow full at the design discharge without surcharging of inspection pits.

(10) Inter allotment drainage pits must be located at all changes of direction. Pits must be constructed from an industry approved material and accepted by Council for use.

(11) The inter allotment drainage must have a minimum longitudinal gradient of 0.5% for grassed lined open channels and 0.5% for pipes less than 300 mm or if agreed by Council achieve self-cleansing velocity.

(12) The inter allotment drainage must be constructed from either fibre reinforced concrete drainage pipe, reinforced concrete pipe, or uPVC pipe which must conform respectively to the requirements of AS4139, AS/NZS4058 and AS/NZS1254 respectively.

(13) Where inter allotment drainage and sewer mains are laid adjacent to each other they must be spaced with 1.5m between pipe centrelines (where the pipe inverts are approximately equal).

(14) Where there is a disparity in level between inverts the spacing must be submitted for approval.

(15) Where sewer mains are close to inter allotment drainage lines, they must be shown on the inter allotment drainage plan.

SC6.4.9.8 Detailed design

(1) Conduits

(a) Pipe bedding and cover requirements for reinforced and fibre reinforced concrete pipes shall be determined from the Concrete Pipe Association's *Hydraulics of Precast Concrete Conduits (Pipes and Box Culverts) 2012* or AS/NZS3725. For uPVCpipes, the requirements shall be to AS/NZS2032.

(b) Conduit jointing shall be in accordance with manufacturer's specifications.

(c) Drainage lines in road reserves shall generally be located behind the kerb line and parallel to the kerb.

(d) Drop structures shall be designed on drainage lines where the pipe gradient exceeds 5 per cent or water velocity exceeds 4 m/s. The design details shall address the size, and position in the trench as well as spacing along the line.

Editor's Note - Buried flexible drainage pipes.

Situations may be identified during the design of a development for the use of buried flexible pipes instead of the pipes specified in Clause SC6.4.9.13 Pipe drainage (construction).

In such cases, the design will be required to select the flexible pipe type appropriate for the application and prepare the relevant technical specification clauses for the supply and construction with reference to AS/NZS 2566.1, Buried flexible pipelines Part1: Structural design. The proposed additional clauses would then be submitted, as an addendum to the development consent, for review and approval by Council.

(2) Design of pits

Pits shall be designed in accordance with Section SC6.4.3 Standard drawings SD-200, SD-205, SD-210 and SD-215. Safety and safe access are important in pit design and grates shall be of "bicycle safe" design.

(3) Stormwater discharge

(a) Scour protection at culvert, pipe system or kerb and channel outlets shall be designed in accordancewith the guidelines outlined in QUDM, section 8.7. Council discourages the use of any outlet structure that proposes ponding at the outlet.

(b) Where a Developer proposes to concentrate stormwater onto an adjoining property, Council will require the Developer to provide written agreement from the adjoining owner(s) granting permission to the discharge of stormwater through their property and the creation of any necessary easements.

(c) Where it is proposed to discharge runoff to an area under the control of another statutory authority, thedesign requirements of that statutory authority are also to be met.

(d) Piped stormwater drainage discharging to recreation reserves is to be taken to a point of discharge nominated by Council and in the manner nominated by Council.

(4) Trench subsoil drainage

Subsoil drainage should be designed and installed as per Section SC6.4.3 Standard drawings SD-080.

SC6.4.9.9 Documentation

(1) Drawings

(a) Catchment area plans shall be drawn to scales of 1:500, 1:1000 or 1:5000, at A1 sheet size, unless alternative scales are specifically approved by Council and shall show contours, direction of grading of kerb and channel, general layout of the drainage system with pit locations, catchment limits and any other information necessary for the design of the drainage system.

(b) The drainage system layout plan shall be drawn to a scale of 1:500 at A1 for urban areas and 1:1000 rural areas and shall show drainage pipeline location, drainage pit location and number and road centreline chainage, size of opening and any other information necessary for the design and construction of the drainage system.

(c) The plan shall also show all drainage easements, reserves, and natural water courses. The plan may be combined with the road layout plan.

(d) The drainage system longitudinal section shall be drawn to a scale of 1:500 at A1 horizontally and 1:50 vertically and shall show pipe size, class and type, pipe support type in accordance with AS/NZS 3725 or AS/NZS 2032 as appropriate, pipeline and road chainages, pipeline grade, hydraulic grade line and any other information necessary for the design and construction of the drainage system.

(e) Open channel cross sections shall be drawn to a scale of 1:100 at A1 natural and shall show the direction in which the cross sections should be viewed. Reduced levels are to be to Australian height datum (AHD),unless otherwise approved by Council where AHD is not available.

(f) Details including standard and non-standard pits and structures, pit benching, open channel designs andtransitions shall be provided on the drawings to scales appropriate to the type and complexity of the detail being shown.

(g) As constructed drawings shall be submitted to Council upon completion of the drainage construction andprior to Council's acceptance of completed works. The detailed drawings may form the basis of this information; however, any changes must be noted on these drawings.

(h) The as constructed plans must clearly identify the sections of the drainage system that will be owned byprivate residents as agreed by Council.

(2) Easements and agreements

(a) Evidence of any Deed of Agreement necessary for the diversion of runoff through an adjoining property must be submitted prior to any approval of the engineering drawings required for an Operational Works application. Easements must be created concurrently with the issue of the plan of survey.

(b) Where an agreement is reached with the adjacent landowners to increase flood levels on their property or otherwise adversely affect their property, a letter signed by all the landowners outlining what they have agreed to and witnessed by an independent person shall be submitted prior to any approval of the application.

(3) Computer program files and program output

(a) Computer program output must be submitted to Council providing summary sheets for hydrological and hydraulic calculations in accordance with this section and together with the plans submitted for checking and with final drawings.

(b) Copies of final computer data files (electronic and hard copy), for both hydrological and hydraulic models shall be provided for Council's data base of flooding and drainage information in formats agreed with Council.

SC6.4.9.10 Drainage easements and drainage reserves

(1) Specifications for new easements and reserves

(a) Easements must be of a size to enable necessary works including, but not limited to, construction,maintenance, and inspection, to be carried out.

(b) Easement widths for drainage must be no less than the greater of the criteria below.

Criteria	Type	Easement/Reserve Width
Pipe/Culvert	Pipe diameter/box culvert width ≤900 mm	Minimum 3.0 m
	Pipe diameter/box culvert width >900 mm	Easement to extend to outside diameter/box culvert width + 1m each side of external edges of pipe/culvert
Channel/Drain	Base width ≤ 5 m	Full bank width of channel/drain + 4 m wide accesspath along one bank
	Base width > 5 m	Full bank width of channel/drain + 4 m wide accesspath along both sides of channel/drain

(c) All drainage easements must be appropriately sized and located to ensure that they are not affected by, and do not impact on, an existing building's footing zone of influence, and consider any future building footings on the subject or adjoining land.

(2) Residential, commercial, and industrial areas

All major drainage is to be located within a drainage reserve with the minimum widths of that reserve being capable of containing the 1% AEP design flows plus a 4 m strip on each side for maintenance accessand safety purposes.

(3) Rural residential areas

(a) Easements must be created over all drains and natural water courses through private property unless Council determines the land is to be set aside for public use and is to be handed to Council.

(b) In rural residential areas adjacent to a major watercourse, Council may require drainage reserves or easements to be extended to cover identified areas of riparian vegetation, which may be beyond the strip required for maintenance access and safety purposes.

(4) Rural areas

(a) Easements or reserves are not required over natural watercourses. However, easements must be provided over all drains where stormwater is diverted from the natural flow path and be wide enough to contain the flows from the defined flood event plus adequate width for maintenance and safety purposes.

(b) Where the land falls away from the road, easements for drainage are required through private property over formed drains from road culverts and table drains. The location of these easements shall be fixed during design and approval of operational works for the roadworks concerned.

(5) Maintenance of easements

(a) A drainage easement over a property restricts the use of the area of land contained within the easement for drainage purposes. Council's level of service for drainage easements is restricted to ensuring the drainage easement can perform its purpose of carrying stormwater flows through the property. If an owner desires a higher order of maintenance for other reasons, this will be at the owner's ongoing cost and must not compromise the drainage function of the easement. Altering

of the drain in the easement by the owner without the approval of Council may result in action being undertaken by Council to restore the drainage path at the expense of the owner.

(b) Where subdividers are required to provide drainage easements and reserves over approved drainage paths, then these are to be acquired over the entire land at the first stage of subdivision. Where surcharge paths are terminated at the end of stages then drainage easements are required over balance lands, with such easements being released progressively with future stages that provide the surcharge path down the future roads or drainage reserves.

(6) Instrument relating to the terms – easements upon private property

Standard wording for the instruments setting out the terms for the various types of easements that can be acquired for drainage are to be utilised, with each document being cognisant of Council's needs for future grading and on-going maintenance. The document is to also ensure that the responsibility and definition of maintenance within drains is clearly defined on the instruments that accompany the easement documents. This is particularly important in rural residential areas where some residents have an expectation that Council will maintain the land (easement) to a much higher standard than is needed for drainage purposes. In relation to inter allotment drains that are not a part of the public drainage system, provision is to be made in the easement document to state that all maintenance is the owner's responsibility but with provision being made to enable the Council to carry out necessary works at the cost of the defaulting owner.

(7) Townsville City Council standard drawings for drainage

Please refer to Table SC6.4.3.2 - Townsville City Council Standard Drawings for Stormwater Drainage or Click here to obtain a copy of the drawings.

SC6.4.9.11 Construction general

(1) Introduction

Drainage works shall form a complete system carrying water through and away from the works.

This is the general section common and applicable to all types of drainage lines, open drains, kerb and channel, and drainage structures and shall be read in conjunction with drainage requirements provided below for pipe drainage, precast box culverts, drainage structures, and open drains.

(2) General scope

The work to be executed under this section consists of:

(a) preparation for stormwater drainage construction;

(b) temporary drainage during construction;

(c) siting of pipes, pipe arches and box culverts;

(d) all activities and quality requirements associated with excavation and backfilling; and

(e) all concrete work associated with stormwater drainage.

Requirements for quality control and testing, including maximum lot sizes and minimum test frequencies, are cited in Section SC6.4.23 Construction management, quality management, inspection and testing.

(3) Extent of works

Details of the work are shown on the drawings. The extent of works under this section is summarised as follows:

(a) pipe culvert stormwater drainage;

(b) precast box culvert stormwater drainage;

(c) drainage pits, headwalls, wingwalls and aprons;

(d) open concrete dish drains;

(e) scour protection of open drains at outlets to drainage structures; and

(f) demolition and removal of existing redundant pipe culverts, headwalls, and pits.

(4) Reference and source documents

Reference and source documents that must be read in conjunction with this section are as follow:

(a) SC6.4 Development manual planning scheme policy sections:

Section SC6.4.7 Clearing, grubbing, and earthworks.
Section SC6.4.18 Concrete works.

(b) Australian Standards:

AS 1289.5.4.1	*Methods of testing soils for engineering purposes - Method 5.4.1: Soil compaction and density tests - Compaction control test - Dry density ratio, moisture variation and moisture ratio*
AS 1289.5.7.1	*Methods of testing soils for engineering purposes - Method 5.7.1: Soil compaction and density tests - Compaction control test - Hilf density ratio and Hilf moisture variation (rapid method)*
AS 1597	*Precast reinforced concrete box culverts*
AS/NZS2566.2	*Buried flexible pipelines – Part 2: Installation*
AS/NZS3725	*Design for installation of buried concrete pipes*

(c) Other:

International Erosion Control Association (IECA) *Best Practice Erosion and Sediment Control*

(5) Temporary drainage during construction

(a) For each part of the drainage system, complete the erosion and sedimentation control measures before commencing the drainage works (except those parts of the drainage system forming part of the control measures). Measures for erosion and sedimentation control must be provided in accordance with the requirements of the accepted project erosion and sediment control plan and/or *Best Practice Erosion and Sediment Control* and make adequate provision for runoff flows at drainage works under constructionor at surrounding areas/structure.

(b) The Contractor shall make adequate provision for runoff flows at drainage works under construction to avoid damage or nuisance due to scour, sedimentation, soil erosion, flooding, diversion of flow, damming, undermining, seepage, slumping or other adverse effects to the Works or surrounding areas and structures because of the Contractor's activities.

(c) The Contractor shall not implement any proposals to dam up or divert existing watercourses (either temporarily or permanently) without the prior approval of Council by way of approved drawings or written instruction.

(d) The Contractor's material and equipment shall be located clear of all watercourses.

(6) Siting of culverts

(a) Before commencing construction of any culvert, the Contractor shall set out on site the culvert inlet and outlet positions to the location and levels shown on the drawings and shall present this set out for inspection by the Superintendent.

(b) The Superintendent may amend the inlet or outlet locations or designed levels or the culvert length to suit actual site conditions. Any such amendments must ensure no negative impacts on neighbouringland parcels and existing properties. Prior approval must be sought from Council.

(c) Should the Contractor propose changes to the culvert location, length, designed levels, culvert strength, conditions of installation or cover to suit the construction procedures, the Contractor shall present theproposed culvert set out in addition to the designed set out for consideration by the Superintendent and Council. No changes shall be made unless prior written approval from Council is obtained.

(7) Excavation

(a) Before undertaking stormwater drainage excavation, topsoil shall be removed in accordance with Section SC6.4.7 Clearing, grubbing and earthworks.

(b) In undertaking trench excavation, the Contractor shall provide any shoring, sheet piling or other stabilisation of the sides necessary to comply with statutory requirements.

(c) Where public utilities exist in the vicinity of stormwater drainage works the Contractor shall obtain the approval of the relevant authority/corporation to the method of excavation before commencing excavation.

(d) Excavation by blasting, if permitted by Council, shall be carried out to ensure that the peak particle velocity measured on the ground adjacent to any previously installed culvert or drainage structure does not exceed 25mm per second. The Contractor shall comply with other requirements concerning blasting operations in Section SC6.4.7 Clearing, grubbing and earthworks.

(e) Trench or foundation excavation for stormwater drainage works shall be undertaken to the planned levelfor the bottom of the specified bedding or foundation level. All loose material shall be removed by the Contractor.

(f) Any material at the bottom of the trench or at foundation level which the Superintendent deems to be unsuitable and inadequate to support the proposed drainage structure shall be removed and disposed in accordance with Section SC6.4.7 Clearing, grubbing and earthworks by the Contractor and replaced with backfill material in accordance with the requirements of this section and the sections for the culvert type. The bottom of the excavated trench or foundation, after any unsuitable material has been removed and replaced, shall be parallel with the specified level and slope of the culvert.

(g) The excavated material shall be used in the construction of embankments backfilling or spoiled in accordance with Section SC6.4.7 Clearing, grubbing and earthworks.

(8) Backfilling

Backfilling shall be carried out in accordance with the requirements of the relevant culverts or drainage structures sections and to the compaction requirements in Clause SC6.4.9.11 (9) Compaction below.

In situ concrete structures are to be backfilled in accordance with Section SC6.4.17 Structures, Clause SC6.4.17.6 (11).

The shape of the culvert must be checked by the Contractor during backfilling to ensure that on completion of backfilling the vertical and horizontal centreline dimensions of the pipe or structure do not vary from the manufacturer's specified dimensions by more than ± 2% for pipes and pipe arches.

(9) Compaction

Foundations, bedding (other than for pipe drainage) and backfilling shall be compacted to the following requirements when tested in accordance with AS 1289.5.4.1 or AS 1289.5.7.1 for standard compactive effort.

Refer to Table SC6.4.9.6 below for details of compaction and moisture tolerances.

Compaction requirements adjacent to pipe drainage for concrete, steel or UPVC pipes are set out in Clause SC6.4.9.13 (4)(d)(iv) below.

(10) Concrete work

For all concrete work, the Contractor shall comply with Section SC6.4.18 Concrete works in relation to the supply and placement of normal class concrete and steel reinforcement, formwork, tolerances, construction joints, curing and protection.

(11) Sprayed concrete

If sprayed concrete has been specified, shown on the drawings, or directed by the Superintendent, it shall comply with requirements in section SC6.4.18 Concrete works.

(12) Construction traffic

If proposing to move heavy construction plant or vehicles over pipe or box culverts structures, provide verification and certification of protective measures to the Superintendent for confirmation and approval.

(13) Limits and tolerances

The limits and tolerances applicable to the various clauses in this section are summarised in Table SC6.4.9.6 below:

Table SC6.4.9.6 - Summary of Limits and Tolerances

Item	Activity	Limits/Tolerances	Clause
(1)	**Excavation by Blasting** (a) Peak particle velocity	≤25mm/sec	Clause SC6.4.9.11(7)(d)
(2)	**Relative Compaction (Standard)** (a) Foundations or trench base to a depth of 150 mm below foundation level. (b) Material replacing unsuitable material. (c) Bedding material. (d) Selected backfill and ordinary backfill material: (i) Other than subgrade (sand 70% Density Index). (ii) Other than subgrade (other than sand). (iii) At subgrade level to 300 mm below. (iv) In a pavement zone. (e) Backfill material within the selected material zone.	95%	Clause SC6.4.9.11(9)
(3)	**Backfill** (a) Layers (b) Moisture Content	≤ 150mm >60%, <95%	Clause SC6.4.9.11(9) Clause SC6.4.9.11(9)

SC6.4.9.12 Drainage structures (construction)

(1) Scope

(a) This policy section provides standards, advice and guidelines for the construction of drainage structures.

(b) This section details the construction of headwalls, wingwalls, pits, gully pits, inspection pits, junction boxes/pits, drop structures, inlet and outlet structures, energy dissipators, batter drains and other supplementary structures.

(c) Requirements for quality control and testing, including maximum lot sizes and minimum test frequencies, are cited in Section SC6.4.23 Construction management, quality control, inspection and testing.

Editor's Note - A reference to drawings is a reference to construction drawings.

(2) Reference and source documents

Reference and source documents that must be read in conjunction with this section are as follow:

Editor's note - Documents referenced in this section are listed in full below whilst being cited in the text in the abbreviated form or code indicated.

(a) SC6.4 Development manual planning scheme policy sections:

Section SC6.4.7 Clearing, grubbing, and earthworks
Section SC6.4.18 Concrete works

(b) Australian Standards:

AS 3996 *Access covers and grates*

(3) General

(a) Drainage structures shall be constructed in concrete and in accordance with Section SC6.4.18 Concrete works.

(b) All structures shall be constructed as soon as practicable and shall be completed not later than 28 days after the construction of the associated culverts, unless otherwise approved by the Superintendent.

(4) Alignment

(a) Unless otherwise shown on the drawings, headwalls and pits shall be constructed parallel to the road centreline and wingwalls at 120º to the headwall or as shown on the drawings.

(b) Where the culvert is laid skew to the road, the wingwalls and headwalls shall be splayed so that the front edge of the wing bisects the angle between the centreline of the culvert and the headwall.

(c) Energy dissipaters shall be constructed in accordance with the drawings and with centreline on the axis of the culvert.

(5) Headwalls and wingwalls

(a) The wingwalls shall be constructed to retain the batters effectively. Where the dimensioned drawings do not satisfy this requirement, the Superintendent shall be notified before the headwalls and wingwalls are constructed. The Superintendent shall direct the Contractor as to the action to be taken. Where rock is encountered at the bottom of excavations for wingwalls and headwalls, and after approval is given by theSuperintendent, the depth of cut-off walls in uniform rock over the full width of the foundations may be reduced to less than that shown in the drawings but must be not less than 150 mm into sound rock.

(6) Pits

(a) All new pits, including access covers, gully grates and frames complying with AS 3996, shall be constructed to the details shown on the drawings. Modification of existing pits is only to be carried out if shown on the drawings.

(b) Where the full depth of the excavation is in sound rock, and the Superintendent approves, part of the concrete lining of gully pits and sumps may be omitted, provided that a neatly formed pit of the required dimensions is constructed. In all such cases the wall of the pit adjacent to and parallel to the road shall be constructed of concrete.

(c) Inlet and outlet pipes shall be integrally cast into the pit at the time of pouring the concrete for the pit walls.

(d) Step irons are not required.

(e) A subsoil drain, where required shall be installed into the pit or headwall in accordance with the general requirements in Clause SC6.4.9.13 Pipe drainage construction.

(7) Precast units

(a) Where precast units including kerb inlet lintels, are provided in the design they shall be handled and installed in accordance with the manufacturer's instructions.

(b) If the Contractor proposes to use precast units, detailed drawings and complete details of installation procedures shall be submitted for the approval of the Superintendent.

(c) The Superintendent is required to adopt pre-cast units which are in accordance with Council's standard drawings and requirements unless otherwise agreed by Council.

(8) Jointing

Where drainage structures abut concrete paving, kerb and channel or other concrete structures, a 10 mm wide joint shall be provided between the structure and paving, or kerb and channel or other concrete structures. The joint shall consist of preformed jointing material of bituminous fibreboard.

(9) Mass concrete bedding

(a) Mass concrete bedding for reinforced concrete bases shall not be placed on earth or rock foundations until the foundations have been inspected and approved by the Superintendent. Following such approval, the surface of the foundation shall be dampened and a layer of concrete not less than 50 mm thick, shall be placed over the excavated surface and shall be finished to a smooth even surface.

(b) Unreinforced concrete bases may be cast on earth or rock foundations without the mass concrete bedding.

(10) Backfill

(a) Backfilling shall not commence until the compressive strength of concrete has reached at least 15 MPa unless otherwise approved by the Superintendent.

(b) Selected backfill shall be placed against the full height of the vertical faces of structures for a horizontal distance equal to one third the height of the structure.

(c) Selected backfill shall consist of a granular material in accordance with the requirements in Clause SC6.4.9.13 Pipe drainage construction below.

(d) Special care shall be exercised to prevent wedge action against vertical surfaces during the backfilling. Where the sides of the excavation are steeper than 4 horizontally to 1 vertically, they shall be cut in the form of successive horizontal terraces at least 600 mm in width, as the backfill is placed.

(e) Backfill on both sides of the structure shall be carried up to level alternately in layers to avoid wedge action or excessive horizontal forces. Backfilling and compaction shall commence at the wall. Compaction shall be in accordance with Clause SC6.4.9.11 (9) Compaction and SC6.4.9.13

Pipe drainage construction.

(11) Limits and tolerances

The limits and tolerances applicable to the various clauses in this section are summarised in Table SC6.4.9.7 below.

Table SC6.4.9.7 - Summary of Limits and Tolerances

Item	Activity	Limits/Tolerances	Clause
(1)	**Cut-off Walls** Depth into sound rock	>150 mm	Clause SC6.4.9.12(5)
(2)	**Mass Concrete Bedding**	>50 mm	Clause SC6.4.9.12(9)

SC6.4.9.13 Pipe drainage (Construction)

(1) Scope

(a) This section covers the supply and installation of pipe culverts and pipe arches for stormwater drainage.

(b) The work to be executed under this section consists of supply of pipes and pipe arches, bedding, installation, and backfilling.

(c) Requirements for quality control and testing, including maximum lot sizes and minimum test frequencies, are cited in Section SC6.4.23 Construction management, quality management, inspection and testing

(2) References and source documents

Reference and source documents that must be read in conjunction with this section are as follows:

Editor's note - Documents referenced in this section are listed in full below whilst being cited in the text in the abbreviated form or code indicated.

(a) SC6.4 Development manual planning scheme policy sections:

Section SC6.4.7 Clearing, grubbing, and earthworks
Section SC6.4.8 Stormwater management
Section SC6.4.10 Stormwater quality
Section SC6.4.17 Structures
Section SC6.4.18 Concrete works

(b) Australian Standards:

ISO202920-5	*Aggregates for concrete – Test methods for mechanical and physical properties*
AS 5101.4	*Methods for preparation and testing of stabilized materials – Part 4: Unconfined compressive strength of compacted materials.*
AS/NZS 1254	*PVC-U pipes and fittings for stormwater or surface water applications.*
AS 1289.3.3.1	*Methods of testing soils for engineering purposes – Method 3.3.1: Soil classification tests - Calculation of the plasticity index of a soil.*
AS 1289.5.4.1	*Methods of testing soils for engineering purposes - Method 5.4.1: Soil compaction and density tests - Compaction control test - Dry density ratio, moisture variation and moisture ratio.*
AS 1289.4.3.1	*Methods of testing soils for engineering purposes - Method 4.3.1: Soil chemical tests - Determination of the pH value of a soil - Electrometric method.*
AS 1289.4.4.1	*Methods of testing soils for engineering purposes - Method 4.4.1: Soil chemical tests - Determination of the electrical resistivity of a soil – Method for sands and granular materials.*
AS 1289.5.6.1	*Methods of testing soils for engineering purposes - Method 5.6.1: Soil compaction and density tests - Compaction control test - Density index method for a cohesionless material.*
AS 1397	*Steel sheet and strip—Hot-dip zinccoated or aluminium/zinc-coated*
AS 1646	*Elastomeric seals for waterworks purposes.*
AS 1762	*Helical lock-seam corrugated steel pipes - Design and installation.*

AS/NZS 2032	*Installation of PVC pipe systems.*
AS/NZS 2041	*Buried corrugated metal structures.*
AS/NZS 2566.1	*Buried flexible pipelines - Part 1: Structural design*
AS/NZS 2566.2	*Buried flexible pipelines - Part 2: Installation*
AS/NZS 3725	*Design for installation of buried concrete pipes*
AS/NZS 3750.9	*Paints for steel structures - Part 9: Organic zinc-rich primer.*
AS/NZS 3750.15	*Paints for steel structures - Part 15: Inorganic zinc silicate paint.*
AS/NZS 4058	*Precast concrete pipes (pressure and non-pressure).*
AS/NZS 4131	*Polyethylene (PE) compounds for pressure pipes and fittings*.
AS 4139	*Fibre reinforced concrete pipes and fittings.*
AS/NZS 4680	*Hot-dip galvanised (zinc) coatings on fabricated ferrous articles.*
AS/NZS 5065	*Polyethylene and polypropylene pipes and fittings for drainage and sewerage applications.*
AS/NZS ISO 9001 *(as amended)*	*Quality management systems - Requirements*.

(c) Department of Transport and Main Roads Technical Standards:

MRTS 25	*Steel Reinforced Precast Concrete Pipes*
MRTS 26	*Manufacture of fibre reinforced concrete drainage pipes*

(d) Other:

AASHTO Standard, M190 - *Asphalt-Coated Corrugated Metal Culvert Pipe and Pipe-Arches*

American Society for Testing and Materials (ASTM) - F2562/F2562M-08 *Specification for steel reinforced thermoplastic ribbed pipe and fittings for non-pressurised drainage and sewerage*

Safety in Design CWPHESS.

(3) Common requirements

(a) Pipes and/or pipe arches shall not be placed in position until the Contractor has produced documentary evidence to the Superintendent, that the manufacture of the products to be used in the works has complied with the Manufacturer's Quality Plan in accordance with ISO 9001.

(b) Documentation shall comprise a conformance certificate to AS 4058 or AS 4139 as appropriate for each batch of pipes or pipe arches to be included in the works, including manufacturer's installation recommendations. The above documentations certificates are to be supplied at least 24 hours in advance of dispatch to site.

Editor's Note - Table 3.6 of AS 4058 shall be replaced by Table 7A of MRTS 25 - *Asphalt-Coated Corrugated Metal Culvert Pipe and Pipe-Arches* in determining the acceptability of pipe wall and joint surface defects.

(c) Each unit shall be marked at time of manufacture with:

(i) class and size;

(ii) manufacturer's name; and

(iii) date of casting.

(d) Where a Contractor wishes to use drainage pipe other than the pipes described in Clause SC6.4.9.13, the Contractor shall submit, for agreement by the Superintendent, full details in accordance with AS/NZS 2566.1 of the characteristics of the pipe materials and embedment and design loads, together with certification from the manufacturer of its suitability and quality for use in each application. Certification of the suitability of any pipe will address the bedding requirements, deflection, strength, buckling and any other considerations appropriate to the application. Upon agreement, the Superintendent must submit an application for a variation to the development consent for approval by Council.

(e) The Contractor shall take all necessary steps to drain the excavation to allow the foundation, the bedding, and any backfilling to be compacted to the specified relative compaction.

(f) Culverts shall be installed within 10 mm of the grade line and within 50 mm of the horizontal alignment specified on the drawings. The Contractor shall relay any culvert which is not within these tolerances. Where longitudinal gradients are less than 0.5 per cent, culverts shall be installed within +/- 6 mm of the grade line.

(g) Where shown on the drawings at the discharge end of culverts terminating at pits and headwalls a 3 m length of 100 mm diameter subsurface drain shall be laid in the trench 100 mm above the invert level of the culvert and discharging through the wall of the pit or headwall at 100 mm above the invert level of the culvert or headwall. The subsurface drainage pipe shall be sealed at the upstream end and shall be enclosed in a seamless tubular filter fabric in accordance with Section SC6.4.6 Road works and traffic control, Clause SC6.4.6.3 Sub surface drainage.

(h) Excavation and backfilling for pipe drainage shall be undertaken in a safe manner and in accordance with all statutory requirements. The Contractor must present to the Superintendent the installed pipe drainage upon completion of backfill to the top side of the side zone for inspection prior completion of backfill.

(i) Where the Contractor proposes to travel construction plant in excess of 5 tonnes gross mass over pipe drainage structures, the Contractor shall design and provide adequate protective measures for the crossings and shall submit the proposals to the Superintendent for prior approval.

(j) Upon completion of installation of pipe drainage, the Contractor shall submit relevant test results to demonstrate compliance to the requirements indicated on clauses.

(4) Precast reinforced concrete pipes

(a) Pipes

(i) Precast reinforced concrete pipes shall comply with AS 4058 and shall be of the class and size as shown on the drawings.

Editor's Note - Table 3.6 of AS 4058 shall be replaced by Table 7A of MRTS 25 - *Asphalt-Coated Corrugated Metal Culvert Pipe and Pipe-Arches* in determining the acceptability of pipe wall and joint surface defects.

(ii) Fibre reinforced concrete drainage pipes shall comply with AS 4139 and shall be of the class and size as shown on the drawings.

(iii) Unless specified otherwise, joints shall be flush type with external elastomeric bands complying with AS 1646 and as recommended by the manufacturer.

(iv) Where precast pipes are to be installed into a marine or saline environment, the Contractor is to ensure and provide documentation that the supplied pipes are "fit for purpose" and are suitable for the intended site application.

(b) Excavation

(i) Unless otherwise indicated on the drawings, or approved by the Superintendent, the formation shall be completed to subgrade level and the pipes then installed in the normal trench condition.

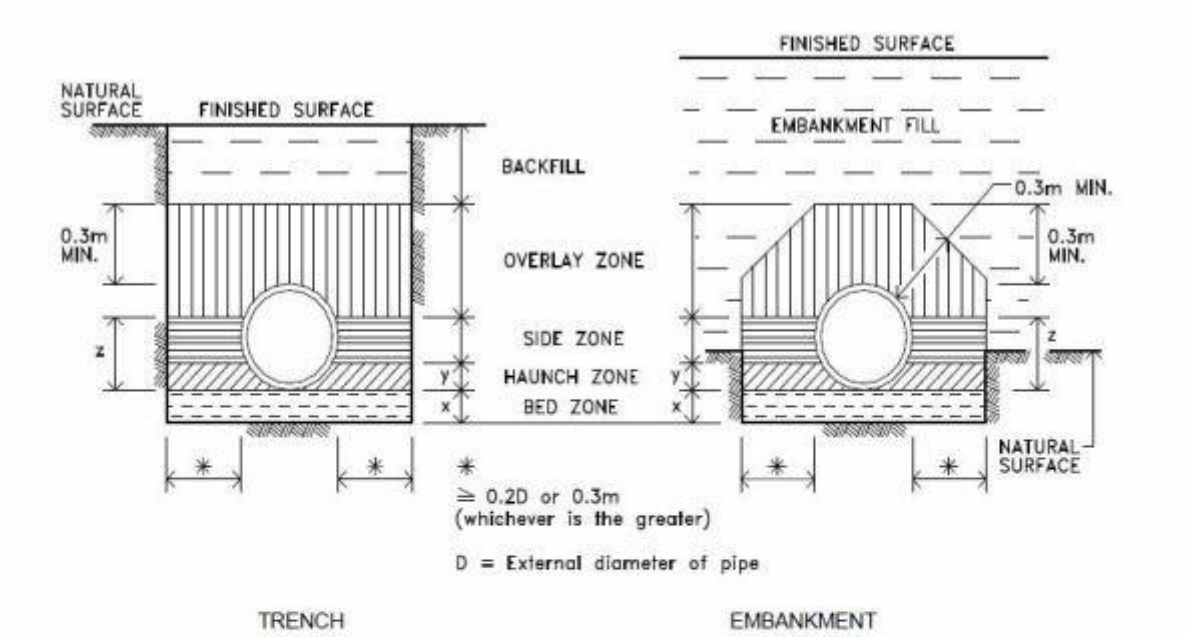
(ii) For normal trench conditions, the pipe shall be laid in an excavated trench with bedding as set out in Clause SC6.4.9.13(4)(c) below. The trench shall be excavated to a width as shown in Figure SC6.4.9.1.

(iii) Care is necessary to avoid laying pipe drainage in trenches excavated to excessive width. Pipes laid in wide trench conditions will be deemed to be in embankment conditions (positive projection). Wide trench conditions apply when, for a single pipe, the width of trench, $W \geq D + 0.6$ metre where D is the pipe diameter. For multi-cell pipes wide trench conditions apply when the width of trench, $W \geq \sum D + \sum S + 0.6$ metre where S is the square spacing between the pipelines. This definition of wide trench conditions as equivalent to embankment conditions relates to the size and geometry of the excavation utilised at construction. Pipes shown on the drawings to require trench conditions shall not be placed under embankment conditions without a design check for compliance of the pipe strength and trench support requirements in accordance with AS 3725.

(c) Bedding

(i) Bedding shall be in accordance with this sub-section, AS 3725 and AS 3725 Supplement 1 for the pipe support types as shown on the drawings. Where the pipe support type is not shown on the drawings, the support type shall be HS3 within road reserves (HS3 is recommended for high embankment fill) and H2 elsewhere.

(ii) Figure SC6.4.9.1 below and Table 5 – Bedding factors for Working Dead Loads (U, H and HS Supports) in AS/NZS 3725 indicate the dimensions of bedding and backfilling for pipes laid in trench conditions and embankment conditions for all AS 3725 pipe support types.



		Pipe Support Type						
		U	H1	H2	H3	HS1	HS2	HS3
Dimension (minimum)	x	75 on rock Nil on soil	100 for D ≤ 1500 150 for D > 1500		0.25 D but >100	100 for D ≤ 1500 150 for D > 1500		
	y	—	0.1D	0.3D	0.3D	0.1D	0.3D	0.3D
	z	—	—	—	—	≥ 0.7D		

D = External diameter of pipe

Figure SC6.4.9.1 - Pipe Installation Conditions

(iii) Bedding material for the bed and haunch zones shall consist of a granular material having a grading, determined by ISO202920-5, complying with Table SC6.4.9.8 Bedding Material Grading Limits, and a Plasticity Index, determined by AS 1289.3.3.1 of less than 6. Select fill material in the side zones, for pipe support type HS, shall also comply with Table SC6.4.9.8.

Table SC6.4.9.8 - Bedding Material Grading Limits

Sieve size mm	Weight passing %	
	Bed and Haunch Zones	Side Zones/Overlay Zones
75.0	-	100
19.0	100	-
9.5	-	50 - 100
2.36	50 -100	30 - 100
0.60	20 - 90	15 - 50
0.30	10 - 60	-
0.15	0 - 25	-
0.075	0 - 10	0 - 25

(iv) The Contractor shall advise the Superintendent of the source of bedding material.

(v) All material shall be compacted in layers not exceeding 150 mm compacted thickness except where explicitly approved by the Superintendent, for the first placed layer above the pipe crown in the overlay zone, to protect the pipe from construction damage. Each layer shall be compacted to the relative compaction specified before the next layer is commenced. Cohesionless materials can be compacted in one operation by saturation and vibration to achieve the minimum Density Index (DI) specified.

(vi) At the time of compaction, the moisture content of the material shall be adjusted so as to permit the specified compaction to be attained at a moisture content which, unless otherwise approved by the Superintendent, is neither less than 60 per cent nor more than 95 per cent of the apparent optimum moisture content, as determined by AS 1289.5.4.1 (standard compaction).

(vii) Compaction of select fill material in the bed and haunch zones shall be to the appropriate pipe support requirements shown in Table 5 – Bedding factors for Working Dead Loads (U, H and HS Supports) in AS/NZS 3725, when tested in accordance with AS 1289.5.6.1. H3 Pipe Support includes concrete bedding. Concrete shall be grade N20 to AS 3600. Pipe shall be suitably reinforced in accordance with AS 3725 as standard elliptically reinforced pipe may not be adequate for H3 Pipe Support. Unless specifically selected pipes are nominated for use with H3 bedding, a design check shall be required to confirm the suitability of the proposed pipes.

(viii) The top 0.100 mm of the bedding and haunch material directly under the pipe shall be placed and shaped accurately to house the pipe after compaction is achieved in the bedding and haunch zone external to the area of direct pipe support.

(ix) Where the impermeability of the natural ground and the slope of the drainage line is such that erosion of bedding material is considered by the Superintendent to be a likely problem, the Superintendent may specify cementitious stabilisation of the bedding material used in the bedding and haunch zones.

(d) Installation

(i) General

Pipes shall be laid with the socket (female) end placed upstream. Pipes which have marks indicating the crown or invert of the pipes shall be laid strictly in accordance with the markings. Unless specified, no individual length of pipe shall be shorter than 1.2m.

The Contractor is to ensure that all trenching is to conform to the requirements of *Work Health and Safety (WHS) Act* and regulations and *Excavation Work Code of Practice 2013*.

Pipes can be stiffened temporarily using timber struts, erected before filling is placed. Struts shall be of hardwood measuring at least 100 mm by 100 mm or 125 mm diameter. One strut shall be placed in a vertical position at each pipe joint, thence at a spacing not greater than 1,200 mm. Struts shall bear against a sill laid along the invert of the pipe and a cap bearing against the crown of the pipe. Both the sill and the cap shall be continuous throughout the length of the pipe. Struts shall be made to bear tightly against the pipe using wedges between the top of the struts and the cap. Struts, sills and caps shall be removed on completion of the embankment, unless removal is ordered earlier.

Lifting holes in all pipes shall be sealed with plastic preformed plugs approved by the Superintendent, or a 3:1 sand/cement mortar, before the commencement of backfilling.

Bulkheads shall be constructed on all lines where the pipe gradient exceeds 5 per cent.

The Contractor shall present the laid and jointed pipes for inspection by the Superintendent prior to commencement of trench backfilling.

(ii) Joints in reinforced concrete pipes

1. Rubber ring joints

Before making the joint, the spigot and socket and the rubber ring shall be clean and dry.

The rubber ring shall be stretched on to the spigot end of the pipe, square with the axis and as near as possible to the end, care being taken that it is not twisted. The spigot end of the pipe shall then be pushed up to contact the socket of the pipe with which it is to join and be concentric with it. The spigot end shall then be entered into the socket of the already laid pipe and forced home by means of a bar, lever and chain, or other method approved by the Superintendent.

The joint shall be tested to ensure that the rubber ring has rolled evenly into place. Where wedge shaped “skid” rubber rings are prescribed the Manufacturer’s instructions, which include the use of lubricants, shall be followed.

2. Flush or butt joints

The ends of the pipes shall be butted together to be as tight and as even as possible.

The joints shall be sealed externally with proprietary EB bands, supplied, and installed in accordance with the manufacturer’s recommendations, care being taken that the bands are not twisted.

(iii) Joints in fibre-reinforced cement pipes

1. New pipes

Joints shall be of a flexible type. Rubber rings shall be used to seal joints in both rebated and spigot and socket jointed pipes in the manner set out in Clause SC6.4.9.13 (4)(d) Installation above.

Alternatively, a jointing compound comprising plasticised butyl rubber and inert fillers may be used to seal such pipes in accordance with the manufacturer's instructions.

2. Direct side connections to other pipes

   Direct side connections to other pipes shall be as detailed on the drawings.

(iv) Backfill

1. Select fill material to the side zones shall be compacted to the requirements shown in Table 5 – Bedding factors for Working Dead Loads (U, H and HS Supports) of AS/NZS 3725 when tested in accordance with AS 1289.5.4.1 for standard compactive effort.

2. Ordinary fill to the side zones and overlay zones, for all pipe support types, except type HS shall consist of Selected Backfill as defined in Section SC6.4.7 Clearing, grubbing and earthworks or alternatively cohesionless material in accordance with Table SC6.4.9.8 Bedding material grading limits. It shall be placed around the pipe to the dimensions shown in Figure SC6.4.9.1 Pipe Installation Conditions.

3. All material shall be compacted in layers not exceeding 150 mm compacted thickness. Each layer shall be compacted to the relative compaction specified before the next layer is commenced or compacted in one operation by saturation and vibration to achieve a minimum Density Index as specified in Table 5 – Bedding factors for Working Dead Loads (U, H and HS Supports) of AS/NZS 3725.

4. At the time of compaction, the moisture content of the material shall be adjusted to permit the specified compaction to be attained at a moisture content which, unless otherwise approved by the Superintendent, is neither less than 60 per cent nor more than 95 per cent of the apparent optimum moisture content, as determined by AS 1289.5.4.1 (standard compaction).

5. The remainder of the trench to the underside of the subgrade, or selected material zone as specified in Section SC6.4.7 Clearing, grubbing and earthworks, shall be backfilled with material satisfying the requirements for embankment material as defined in Section SC6.4.7 Clearing, grubbing and earthworks. Where excavation is approved through the selected material zone, the section of trench within the select material zone shall be backfilled with selected material as defined in Section SC6.4.7 Clearing, grubbing and earthworks.

6. When compacted adjacent to culverts or drainage structures, the Contractor shall adopt compaction methods which will not cause damage or misalignment to any culvert or drainage structure. Any damage caused shall be rectified by the Contractor. Backfilling and compaction shall commence at the pipe or wall to confine remaining uncompacted material at commencement.

(5) Steel pipes and pipe arches

(a) Nestable steel pipe and drainage units

(i) Nestable steel pipes and drainage units shall be supplied in accordance with AS 2041 and shall be of the class and size as shown on the drawings.

(ii) The galvanised steel sheets used in manufacture shall comply with AS 1397 for steel base grade G250 and a minimum coating Class of Z600.

(iii) Where specified, the pipes and drainage units shall be given a protective coating over the steel, after assembly of a coal tar epoxy paint or equivalent as approved by the Superintendent, to a thickness of 400 microns.

(iv) Field cut ends shall be carefully wire brushed to remove any scale followed immediately by two coats of zinc rich organic primer complying with AS/NZS 3750.9 or two coats of inorganic zinc silicate paint complying with AS/NZS 3750.15.

(b) Helical lock seam corrugated steel pipe

(i) Helical lock seam corrugated steel pipe shall be supplied in accordance with AS 1761 and AS 1762 and shall be of the class and size as shown on the drawings.

(ii) The galvanised steel sheet used in manufacture shall comply with AS 1397 for steel-based grade G250 and a minimum coating Class of Z600.

(iii) Unless otherwise approved by the Superintendent, no part of the pipe shall incorporate steel strips which have been joined by welding. Field cut ends shall be carefully wire brushed to remove any scale followed immediately by two coats of organic zinc rich primer complying with AS/NZS 3750.9 or two coats of inorganic zinc silicate paint complying with AS/NZS 3750.15. Pipes and coupling bands shall be given a protective hot dip coating of bitumen on both sides to AASHTO standard M190 or equivalent as part of the process of manufacturing.

(c) Bolted steel pipes, pipe arches and special shapes

(i) Bolted steel pipes, pipe arches and special shapes shall be supplied in accordance with AS 2041 and shall be of the class and size as shown on the drawings. The corrugated pipe or plate shall be hot dip galvanised on both sides after fabrication in accordance with the requirements for coating thickness and mass for articles in AS/NZS 4680.

(ii) Also, after assembly, all bolted steel pipes, pipe arches and special shapes shall be given a protective coating on the outside of the steel plate, of a coal tar epoxy paint complying with AS 3887 or equivalent paint approved by the Superintendent. Invert plates shall be coated on the outside before they are placed on the pipe bed. The plate surface shall be cleaned and degreased with a cleaning solution recommended by the protective coating manufacturer. The protective coating shall be applied to give a uniform minimum dry thickness of 400 microns. Any coating damaged shall be recoated by first cleaning any grease, mud or other foreign matter from the affected area. The area shall then be recoated so that the minimum dry thickness of the coating is 400 microns.

(d) Materials and surface treatment of steel pipes and pipe arches

All steel pipes and pipe arches will require an engineer's certification that the pipe materials and surface treatments are adequate to provide for installation and in-service loading, as well as corrosion protection for a satisfactory design life of 100 years, unless indicated otherwise on the drawings. Such certification shall address the chemistry of the soil, groundwater, stream and backfill material as set out in Clause SC6.4.9.13 (5)(e) below.

(e) Materials against steel structures

(i) The severity of corrosive attack on steel structures will depend on the pH value and electrical resistivity of the soil surrounding the structure and the pH value of the water in the stream.

(ii) Besides meeting the normal requirements of the bedding, selected backfill materials and the materials used for embankment construction above the steel structures and within a horizontal distance from the structure equal to the height of the filling over the structure, the pH and resistivity limits as shown in Figure SC6.4.9.2 will determine the level of corrosion protection required.

(iii) Notwithstanding the height of fill, embankment material within 6 m of the structure shall conform to these requirements.

(iv) The pH and electrical resistivity of the material shall be determined in accordance with AS 1289.4.3.1and AS 1289.4.4.1.

(v) The Contractor shall nominate the sources of the various materials and submit documentary evidence from a NATA registered laboratory that the representative samples conform to the requirements of this clause and the protective treatment provided. The samples shall be pre-treated, if necessary, to represent the condition and grading when compacted and in service.

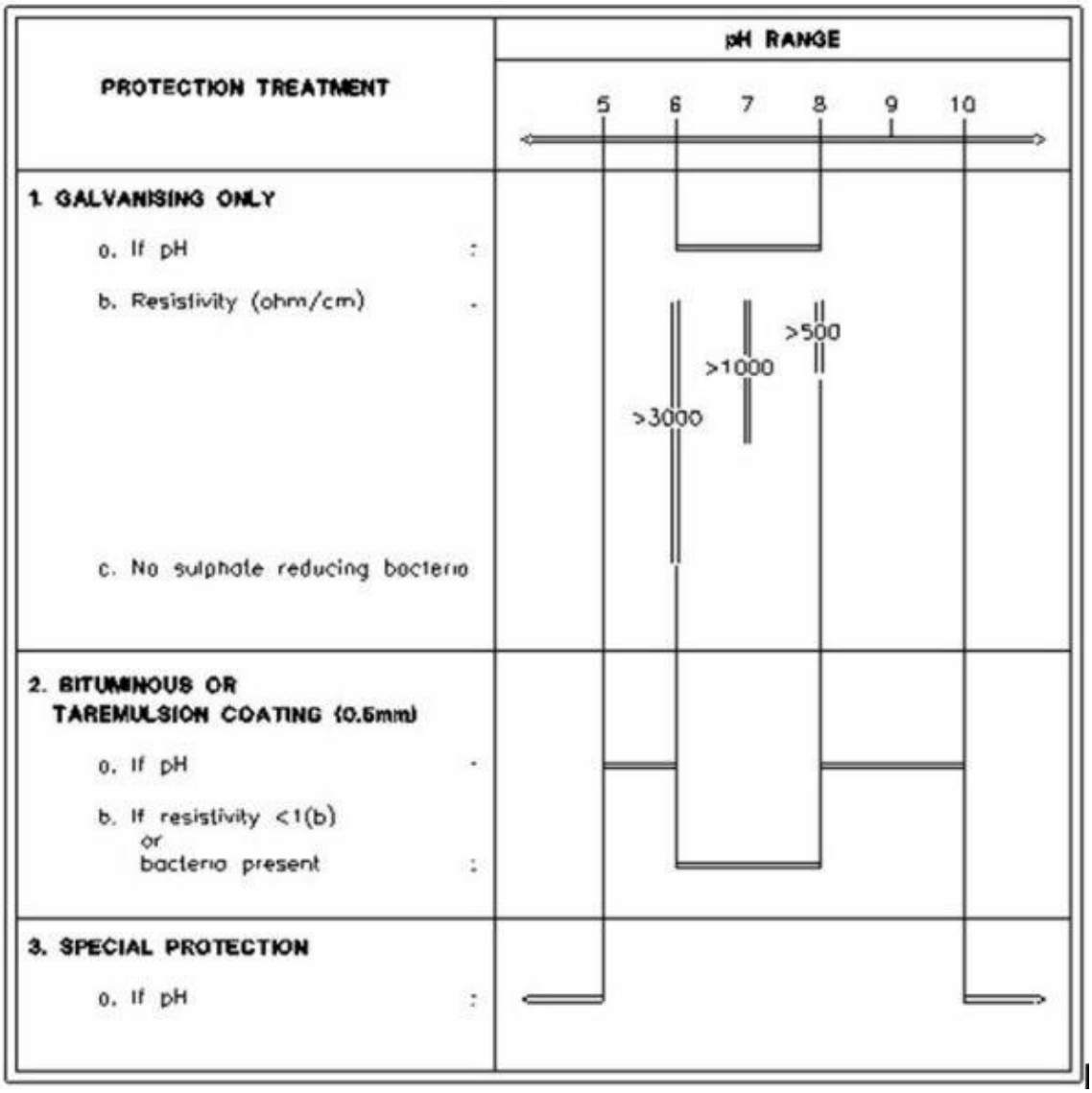


Figure SC6.4.9.2 - Corrosion Protection Requirements for Steel Structures

(f) Excavation and foundation preparation

(i) Unless otherwise indicated on the drawings or approved by the Superintendent, the formation shall be completed to subgrade level and the pipes then installed in the normal trench condition.

(ii) The trench shall be excavated to a level 75 mm below the design invert and for a minimum width of 600 mm on each side of the structure.

(iii) Where unsuitable material, as determined by the Superintendent, is encountered at the foundation level, it shall be removed to a depth approved by the Superintendent. The additional excavation shall be backfilled with material complying with, selected material as per Section SC6.4.7 Clearing, grubbing and earthworks.

(iv) Where rock is encountered at the foundation level, the foundation shall be excavated for an additional depth of 250 mm, or 0.25 times the structure width, whichever is the lesser and for a width equal to the width of the structure. The additional excavation shall be backfilled with material complying with, and compacted to, the requirements for HS3 pipe support as required in Clause SC6.4.9.13(4)(c) above.

(g) Bedding

Bedding shall meet the requirements of Clause SC6.4.9.13 (4)(c)(vii) above. The thickness of uncompacted bedding material between the foundation and the outer surface of corrugation shall not be less than 75 mm. The uniform blanket of loose material which provides the minimum 75 mm thick bedding, shall be placed on the shaped, compacted selected material foundation to allow the corrugations of the structure invert to bed in and become filled with the material.

(h) Installation

(i) General

The assembly of all corrugated steel pipes and pipe arches as well as helical lock seam corrugated steelpipes shall be carried out in accordance with the manufacturer's recommendations. These recommendations shall be submitted to the Superintendent before assembly or laying of the culverts iscommenced.

If deemed necessary after consultation with the manufacturer, temporary bracing of corrugated steel pipes or pipe arches shall be carried out in accordance with the manufacturer's recommendations.

(ii) Joints

Corrugated steel pipes or pipe arches shall be joined in accordance with the manufacturer's recommendations and AS 2041.

Where helical lock seam corrugated steel pipes are to be joined, both ends of the join shall be rerolled with four annular corrugations of pitch 68 mm. Coupling of the re-rolled ends shall be made in accordancewith AS 1761 by using semi corrugated bands. Rubber ring joint seals shall be used in conjunction with the coupling bands except where specifically indicated otherwise in the drawings.

All joints or lap joints in pipes or pipe arches (excluding rubber ring joint coupling bands) shall be covered with strips of non-woven geotextile material, of minimum 250 mm width and of minimum mass 270 grams per square metre in accordance with the requirements for geotextile in Section SC6.4.6 Roadworks and traffic control, Clause SC6.4.6.13(2)(d) Geotextile to prevent loss of sand backfill or bedding into the pipe.

(i) Backfill

(i) Compaction of the material in the side support and overlay zones shall comply with the requirements of Clause SC6.4.9.13(4)(c)(vii) above, except that the required relative compaction in the side support and overlay zones shall be 95 per cent (AS 1289.5.4.1 standard compaction). Backfill shall be placed around the steel pipe or structure, to a minimum dimension equal to the pipe width, on both sides.

(ii) All material shall be compacted in layers not exceeding 150 mm compacted thickness. Each layer shall be compacted to the relative compaction specified before the next layer is commenced.

(iii) At the time of compaction, the moisture content of the material shall be adjusted to permit the specified compaction to be attained at a moisture content which, unless otherwise approved by the Superintendent, is neither less than 60 per cent nor more than 95 per cent of the apparent optimum moisture content, as determined by AS 1289.5.4.1 (standard compaction).

(iv) The remainder of the trench to the underside of the subgrade, or selected material zone as specified in Section SC6.4.7 Clearing, grubbing and earthworks, shall be backfilled with material satisfying the requirements for embankment material as defined in Section SC6.4.7 Clearing, grubbing and earthworks. Where excavation is approved through the selected material zone, the section of trench within the select material zone shall be backfilled with selected material as defined in Section SC6.4.7 Clearing, grubbing, and earthworks.

(v) The Contractor shall check the shape of the culvert during backfilling to ensure that on completion of backfilling, the vertical and horizontal centreline dimensions of the pipe or structure shall not vary from the manufacturer's specified dimensions by more than plus or minus 2 per cent for pipes and pipe arches.

(j) Invert protection of corrugated steel pipes and pipe arches

(i) Where shown on the drawings, the invert of corrugated steel pipes and pipe arches shall be protected using sprayed concrete.

(ii) The sprayed concrete shall be placed to a thickness of not less than 100 mm over the crest of the corrugations and to a width such that the bottom third of the pipe circumference is covered symmetrically about the invert of the pipe.

(iii) All foreign material shall be removed from the surface to be protected. Where corrosion has occurred, all loose scale shall be removed.

(iv) The production, application and curing of sprayed concrete shall be in accordance with Section SC6.4.18 Concrete works.

(v) The sprayed concrete shall be reinforced with a fabric of hard drawn steel wire 4 mm diameter with 200 mm square mesh. The fabric shall be securely supported at a central location within the sprayed concrete by non-metallic supports.

(vi) Laps in fabric shall be 300 mm and a cover of 50 mm of sprayed concrete shall be provided to the fabric at all edges.

(vii) Immediately after placement of the sprayed concrete, all free water shall be removed, and the surface coated with cement slurry.

(viii) No water shall be allowed to flow over the surface of the sprayed concrete for twenty-four hours after the placement of sprayed concrete.

(6) UPVC pipes

(a) Materials

(i) Un-plasticised PVC (UPVC or similar material) pipes and fittings shall be manufactured in accordance with AS/NZS 1254 and shall be of the type and size as shown on the drawings. Where pipes with an external diameter equal to, or greater than, 450 mm (375 mm nominal internal diameter) are proposed, a separate approval from the Superintendent and Council is required.

(ii) Embedment material in the bedding, side support and overlay zones shall be in accordance with bed and haunch zone material in Clause SC6.4.9.13 (4)(c)(vii) above.

(iii) Trench backfill material shall satisfy the requirements for embankment material as defined in Section SC6.4.7 Clearing, grubbing and earthworks.

(b) Excavation and bedding

(i) Unless otherwise indicated on the drawings or approved by the Superintendent, the formation shall be completed to subgrade level and the pipes then installed in the normal trench condition.

(ii) Figure SC6.4.9.3 and Table SC6.4.9.9 indicate the dimensions of bedding and backfilling for pipes laid in trench conditions and embankment conditions, unless otherwise indicated on the drawings.

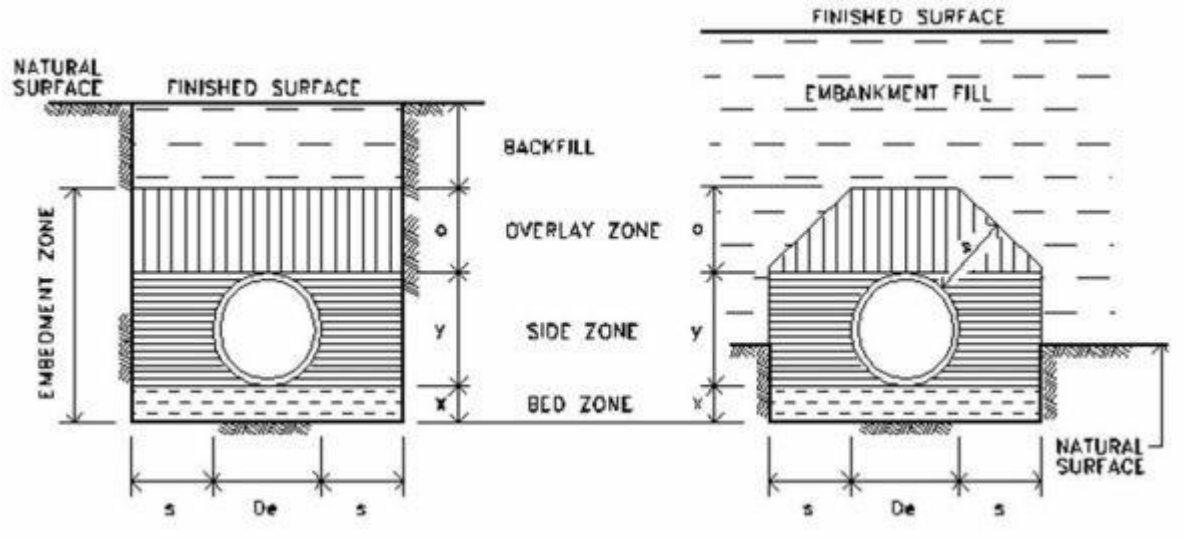


Figure SC6.4.9.3 - Pipe Installation Conditions

Table SC6.4.9.9 - Trench and Embedment Dimensions

Extreme External	Minimum Dimensions (mm)			
Dia (De)mm	x	S	o	y
³75≤150	75	100	100	Pipe dia.
>150≤300	100	150	150	Pipe dia.
>300≤450	100	200	150	Pipe dia.

Editor's Note - Where multiple pipes are laid side by side the minimum distance between the pipes shall be dimension "s" for the larger of adjacent pipes.

(c) Excavation and foundation reparation

(i) Bedding zone material shall be placed and compacted in accordance with the requirements in Table 5.5 of AS/NZS 2566.2.

(d) Installation

(i) Embedment of the UPVC pipe shall be in accordance with the requirements of AS/NZS 2566.2 and to the dimensions shown in Figure SC6.4.9.3 and Table SC6.4.9.9.

(ii) Pipe laying shall be in accordance with Part 7 of AS 2032 and solvent cement pipe jointing shall be in accordance with Part 3 of AS 2032. Jointing may be performed with the pipes either in the trench or at ground level. All pipes, or jointed pipelines, shall be lowered into the trench without being dropped. Pipelines shall be placed so that joints are not strained.

(e) Backfill

(i) Compaction of the material in the side support and overlay zones shall comply with the requirements of Clause SC6.4.9.13 (4)(d)(iv) above for HS3 support type.

(ii) All material shall be compacted in layers not exceeding 150 mm compacted thickness. Each layer shall be compacted to the relative compaction specified before the next layer is commenced or compacted in one operation by saturation and vibration to achieve a minimum Density Index as specified in Table 5.5 of AS/NZS 2566.2 – Buried Flexible Pipelines – Installation.

(iii) At the time of compaction, the moisture content of the material shall be adjusted to permit the specified compaction to be attained at a moisture content, which, unless otherwise approved by the Superintendent, is neither less than 60%, nor more than 95 per cent of the apparent optimum moisture content, as determined by AS 1289.5.4.1 (standard compaction).

(iv) The remainder of the trench to the underside of the subgrade, or selected material zone as specified in Section SC6.4.7 Clearing, grubbing and earthworks, shall be backfilled with material satisfying the requirements for embankment material as defined in Section SC6.4.7 Clearing, grubbing and earthworks. Where excavation is approved through the selected material zone, the section of trench within the select material zone shall be backfilled with selected material as defined in Section SC6.4.7 Clearing, grubbing and earthworks.

(7) Limits and tolerances

The limits and tolerances for materials and product performance related to the various clauses in this section aresummarised in Table SC6.4.9.10 Summary of Limits and Tolerances below:

Table SC6.4.9.10 - Summary of Limits and Tolerances

Item	Activity	Limits/Tolerances	Clause
(1)	**Culvert Position** (a) Grade Line (b) Grade line <0.5% (c) Horizontal Alignment	 ± 10 mm ± 6 mm ± 50 mm	Clause SC6.4.9.13 (3)(e)
(2)	**Bedding** (a) Bed and Haunch Zone Compaction	Table 5 – Bedding factors for Working Dead Loads (U, H and HS Supports) of AS/NZS 3725	Clause SC6.4.9.13 (4)(c)(vii)
(3)	**Backfill - Concrete Pipes** (a) Side and Overlay Zone Compaction	Table 5 – Bedding factors for Working Dead Loads (U, H and HS Supports) of AS/NZS 3725	Clause SC6.4.9.13 (4)(c)(ii)
(4)	**Backfill - Steel Pipes** (a) Side and Overlay Zone Compaction	Table 5 – Bedding factors for Working Dead Loads (U, H and HS Supports) of AS/NZS 3725	Clause SC6.4.9.13 (5)(i)
(5)	**Pipe/Structure** (a) Horizontal and Vertical Variation	< 2% of specified dimensions	Clause SC6.4.9.13 (5)(h)
(6)	**Sprayed Concrete** (a) Over crest of corrugations over bottom third of pipe circumference	> 100 mm	Clause SC6.4.9.13 (5)(j)
(7)	**Bedding Zone Compaction**	DI 70	Clause SC6.4.9.13 (6)(c)(i)
(8)	**Backfill - UPVC Pipes** (a) Side and Overlay Zone Compaction	[3]95%, DI 70	Clause SC6.4.9.13 (6)(e)(iii)

SC6.4.9.14 Precast box culverts

(1) Scope

(a) This section covers the installation of precast concrete box culverts.

(b) The work to be executed under this section consists of:

(i) preparation of foundations;

(ii) provision of bedding;

(iii) construction of base slabs;

(iv) installation of precast culvert units;

(v) headwalls and wingwalls;

(vi) backfilling against structures;

(vii) provision and removal of coffer dams; and

(viii) excavation of inlet and outlet channels.

(c) Requirements for quality control and testing, including maximum lot sizes and minimum testfrequencies, are cited in Section SC6.4.23 Construction management, quality management, inspection and testing.

(2) Reference and source documents

Reference and source documents that must be read in conjunction with this section are as follow:

Editor's note - Documents referenced in this section are listed in full below whilst being cited in the text in the abbreviated form or code indicated.

(a) SC6.4 Development manual planning scheme policy sections:

Section SC6.4.6 Road works and traffic control
Section SC6.4.7 Clearing, grubbing and earthworks
Section SC6.4.18 Concrete works

(b) Australian Standards:

AS1597.1	*Precast reinforced concrete box culverts - Part 1: Small culverts (not exceeding 1200 mm width and 900 mm depth).*
AS1597.2	*Precast reinforced concrete box culverts - Part 2: Large culverts (from 1500 mm span and up to and including 4200 mm span and 4200 mm height)*
AS/NZS ISO 9001	*Quality management systems - Requirements.*

(c) Other:

Austroads *Guide to Pavement Technology - Part 4G: Geotextiles and Geogrids*

Department of Transport and Main Roads
MRTS05 *Unbound Pavements*
MRTS24 *Manufacture of precast concrete culverts*

(3) Materials

(a) Culvert units, link and base slabs

(i) The supply and testing of precast reinforced concrete box culvert units, link and base slabs shall be in accordance with AS 1597 with the following alterations or additional requirements:

1. proof load testing must be arranged by the Contractor in batches as specified in either AS 1597.1 or AS 1597.2 as appropriate;
2. proprietary lifting anchors must be provided in the culvert units, link, and base slabs;
3. delivery and unloading is the Contractor's responsibility; and
4. the supplier must implement and maintain a quality system in accordance with ISO 9001 to ensure materials, manufacture and proof load testing conform to the appropriate standards.

(ii) A conformance certificate, to AS 1597 must be submitted to the Superintendent at least 3 working days prior to dispatch.

(iii) Each unit must be marked at time of manufacture with:

1. type and size;
2. casting date;
3. manufacturer's name; and
4. inspection pass and date.

(b) Handling, delivery and storage

(i) Ensure adequate equipment and load shifting machineries are available for safe handling and unloading.

(ii) Upon delivery of precast units, ensure that the following criteria have been achieved:

1. 70% of the minimum concrete strength;
2. small culvert units: Cured to AS 1597.1 clause 2.6.3; and
3. large culvert units: Cured to AS 1597.2 clause 2.7.

(iii) Prior inspection of the stored precast box culvert units is to be undertaken for dimensional accuracy and defects following delivery. Results of the inspections must show that the units conform to the following:

1. small culvert unit: To AS 1597.1; and
2. large culvert unit: To AS 1597.2.

(c) Concrete

The concrete and reinforcement for cast-in-situ base slabs shall comply with Section SC6.4.18 Concrete works

(d) Selected backfill

The quality of selected backfill shall comply with the requirements in AS 1597.2, or alternatively comply with the requirements of side/overlay zone materials in Figure SC6.4.9.1 and Table SC6.4.9.8.

(e) Ordinary backfill

Ordinary backfill is material obtained from culvert excavations, cuttings and/or borrow areas which are in accordance with the requirements for the upper 0.3 m of embankment construction as detailed in Section C6.4.7 Clearing, grubbing and earthworks.

(4) Construction

(a) Coffer dams

(i) At some sites it may be expedient for the Contractor to construct a coffer dam. The construction of coffer dams shall be the responsibility of the Contractor.

(ii) Coffer dams shall be sufficiently watertight to prevent damage of the concrete by percolation or seepage through the sides and shall be taken sufficiently below the level of the foundations to prevent loosening of the foundation materials by water rising through the bottom of the excavation. Coffer dams shall be adequately braced and shall be so constructed that removal will not weaken or damage the structure.

(iii) A coffer dam may be constructed to the actual size of the reinforced concrete invert slab and used as side forms for the concrete. The details of the coffer dam and formwork, and the clearances proposed shall be subject to the approval of the Superintendent, but the Contractor shall be responsible for the successful construction of the work.

(iv) Coffer dams which have tilted or have moved laterally during sinking, shall be righted, or enlarged to provide the clearances specified. This work will be at the Contractor's expense.

No timber or bracing shall be left in the concrete or in the backfill of the finished structure. Coffer dams, including temporary piles, shall be removed at least to the level of the invert after completion of the structure. Upon completion of works, remove coffer dams, including temporary piles, at least to the level of the culvert invert after completion of the structure. Ensure that no material associated with the coffer dam or dewatering can enter the culvert.

(b) Excavation

Excavation shall be carried out in accordance with the provisions in. Clause SC6.4.9.11 (7).

(c) Foundations

(i) Rock foundations shall be neatly excavated to the underside of the mass concrete or selected fill bedding shown on the drawings. All minor fissures shall be thoroughly cleaned out and refilled with concrete, mortar, or grout. All loose material shall be removed.

(ii) Where rock is encountered over part of the foundation only or lies within 300 mm below the underside of the mass concrete or selected fill, all material shall be removed to a depth of 300 mm below the mass concrete or selected fill for the full width of the foundation over the length where the rock is encountered.This additional excavation shall be backfilled with ordinary backfill material.

(iii) Over excavation or uneven surfaces shall be corrected with mass concrete to provide a uniform surface at least 50 mm above the highest points of rock.

(iv) Earth foundations shall be finished to line and level to the underside of bedding shown on the drawings.Care shall be taken to avoid disturbing material below this level.

(v) All soft, yielding, or unsuitable material shall be removed and replaced with ordinary backfill material as directed by the Superintendent and backfilled in accordance with Clause SC6.4.9.11(8).

(d) Bedding

(i) Cast-in-situ base slabs

No bedding material shall be placed until the foundations have been inspected and approved by theSuperintendent.

Bedding shall be either mass concrete or lightly bound paving material which complies with the requirements of at least a Type 3, Subtype 3.3 material as defined in the Specification MRTS05,whichever is shown on the drawings.

Mass concrete bedding blinding layer shall be 20 mPa compressive strength and shall not be less than 50 mm thick over any point in the foundation. It shall be laid to the line and level of the underside of the base slab to a tolerance of ±10 mm in level and ±50 mm in line. The bedding shall be finished to a smooth surface. Where longitudinal gradients are less than 0.5 per cent, concrete blinding layers shall be installed with +/- 6 mm of the grade line.

(ii) Precast base slabs

Precast base slabs, U shaped culvert units and one-piece culvert units shall be supported on a bed zone of selected backfill of minimum compacted depth 150 mm in accordance with AS 1597.2.

If suitable compaction of the trench subgrade cannot be achieved, it will be the responsibility of the Developer to recommend an alternate solution to Council to achieve the desired bearing capacity for the structure prior to construction.

(e) Cast-in-situ slabs

(i) Cast-in-situ base slabs shall be constructed to the dimensions shown on the drawings and in accordance with the requirements of Section SC6.4.18 Concrete works. The invert levels shall be within -10 mm to +10 mm of the design level, grade 5 mm in 2.5m (1 in 500) and plan position ± 50 mm. Where longitudinal gradients are less than 0.5 per cent cast insitu base slabs shall be installedwithin +/- 6 mm of the grade line.

(ii) Recesses or nib walls to accommodate the walls of the precast crown units shall be formed in the base slab to the dimensions shown on the drawings.

(f) Installation of precast units

(i) Precast units shall not be installed until the base slab has attained a minimum compressive strength of 20 MPa.

(ii) Precast crown units shall be placed on a bed of mortar either on the slab or in the recesses in the base slab. Any gaps between the side walls and the sides of the recesses shall be packed with cement mortar. Lifting holes and butt joints between units shall be packed or sealed with cement mortar or grout or flexible joint filler.

(iii) Before placement of top slabs on U shaped units or link slabs on adjacent crown units, the bearing areas of the supports shall be thoroughly cleaned and covered with a bed of mortar of minimum thickness 5 mm after placement of precast unit.

(iv) Lifting anchor recesses shall be filled to the surface with cement mortar.

(v) In the case of multi-cell culverts, a nominal 50 mm gap shall be provided between adjacent cells. This gap shall be filled with cement mortar or grout.

(vi) All mortar joints shall be protected from the sun and cured in an approved manner for not less than 48 hours.

(vii) All external surfaces of vertical joints between precast crown units, shall be covered full length, a minimum 100 mm width with strips of Denso tape or similar as an

alternative to joint filling.

(g) Backfill

(i) All bracing and formwork shall be removed prior to backfilling. Prior to backfill placing, present to the Superintendent for inspection all seals, joints and levels.

(ii) Selected backfill shall be placed in the side zones of the box culverts and wingwalls, and to a depth of 300 mm in the overlay zone of the culverts, in layers with a maximum compacted thickness of 150 mm in accordance with the backfilling and compaction requirements of AS 1597.2. Alternatively, cohesionless materials can be compacted in one operation by saturation and vibration to achieve a minimum Density Index of 70. The remainder of the excavation shall be backfilled with ordinary embankment fill in accordance with Section SC6.4.7 Clearing, grubbing and earthworks.

(iii) Backfill shall be placed against wingwalls, headwalls and retaining walls in accordance with Section SC6.4.18 Concrete works.

(iv) Backfill layers shall be placed simultaneously on both sides of the culvert with a maximum 600 mm level difference to avoid differential loading. Backfilling and compaction shall commence at the wall and proceed away from it.

(v) Where the slopes bounding the excavation are steeper than 4:1, they shall be cut in the form of successive horizontal terraces of at least 1 m width before the backfill is placed.

(h) Excavation of inlet and outlet channels

Excavation of inlet and outlet channels shall be carried out as shown on the drawings and shall extend to join the existing stream bed in a regular manner as detailed in Clause SC6.4.9.16 below.

(i) Construction loadings on culverts

(i) Construction vehicles and plant shall not pass over the culvert until 28 days after the casting of the base slab or until the cylinder compressive strength of the base slab concrete has reached 32 MPa.

(ii) Construction vehicle loads on culverts for various design fill heights shall be in accordance with AS 1597.2.

(5) Limits and tolerances

The limits and tolerances applicable to the various clauses in this section are summarised in Table SC6.4.9.11 Summary of Limits and Tolerances below:

Table SC6.4.9.11 - Summary of Limits and Tolerances

Item	Activity	Limits/Tolerances	Clauses
(1)	**Mass Concrete Correction**		
	(a) Over highest points of rock	50 mm	Clause SC6.4.9.14(4)(c)(iii)
(2)	**Mass Concrete Bedding**		
	(a) Level	± 10 mm	Clause SC6.4.9.14(4)(d)(i)
	(b) Level where grade line <0.5%	+/- 6 mm	
	(c) Line	± 50 mm	)
(3)	**Culvert Location**		
	(a) Invert Level	±10 mm	Clause SC6.4.9.14(4)(d)(i)
	(b) Invert where grade line is <0.5%	+/- 6mm	
	(c) Grade	5 mm in 2.5 m (1 in 500)	
	(d) Plan Position	± 50 mm	

SC6.4.9.15 Drainage mats

(1) Scope

(a) The purpose of this policy section is to provide standards advice and guidelines for the use and installation of drainage mats.

(b) Drainage mats shall be constructed where and as shown on the drawings or as directed by the Superintendent.

(c) This section should be read in conjunction with Section SC6.4.6 Road works and traffic control Clause SC6.4.6.13.

(d) Requirements for quality control and testing, including maximum lot sizes and minimum test frequencies, are cited in the Section SC6.4.23 Construction management, quality management, inspection and testing.

(2) Terminology

Type A drainage mats	Refer to SC6.4.9.17
Type B drainage mats	Refer to SC6.4.9.17

(3) Reference and source documents

Reference and source documents that must be read in conjunction with this section are as follow:

Editor's note - Documents referenced in this section are listed in full below whilst being cited in the text in the abbreviated form or code indicated.

(a) SC6.4 Development manual planning scheme policy sections:

Section SC6.4.6 Road works and traffic control, Clauses SC6.4.6.12 and SC6.4.6.13.

(b) Australian Standards:

AS 1289.5.4.1 *Methods of testing soils for engineering purposes - Method 5.4.1: Soil compaction and density tests - Compaction control test - Dry density ratio, moisture variation and moisture ratio.*

(4) Order of construction

(a) Type A drainage mats shall be constructed after the site has been cleared and grubbed and before commencement of embankment construction.

(b) Type B drainage mats shall be constructed after completion of the subgrade construction and before construction of the pavement.

(5) Construction

(a) Type A Drainage Mats

(i) Type A drainage mats shall be constructed under embankments as and where shown on the drawings or as directed by the Superintendent.

(ii) After the embankment foundation has been trimmed and any necessary trench drains installed, a geotextile complying with the requirement of Section SC6.4.6 Road works and traffic control, Clause SC6.4.6.13 Subsurface drainage, shall be laid on the embankment foundation. The area of geotextile laid shall be sufficient to cover the area of the Type A drainage mat and an additional amount for enclosing the sides of the drainage mat after the filter material has been placed. Laps of minimum width of 500 mm shall be provided at each join in the geotextile.

(iii) Type C filter material or Type D filter material, as shown on the drawings or as determined by the Superintendent, shall be placed on the geotextile, and compacted to the satisfaction of the Superintendent. The minimum thickness of the compacted filter material shall be 300 mm plus an allowance for the expected consolidation of the embankment foundation under the embankment load or 500 mm if the amount of the expected total consolidation of the embankment foundation is not known. The filter material shall be placed in two or more layers so that no layer, when compacted, has a thickness greater than 250 mm.

(iv) After completion of placement and compaction of the filter material, geotextile shall be placed on top of and around the sides of the filter material so that the filter material is completely enclosed by geotextile. The geotextile shall be secured in such a manner as to prevent movement of the geotextile by wind or by construction plant placing subsequent layers of filter material or earth filling over the drainage mat.

(v) An additional layer of geotextile shall be placed on the drainage mat under the base of any rock facing which may be placed as part of the embankment construction. The additional layer of geotextile shall extend beyond the outside and inside faces of the bottom layer of rock.

(vi) Care shall be taken not to damage the geotextile during the construction of the drainage mat or during placement of subsequent layers of filter material, earth filling or rock facing. Any geotextile so damaged shall be repaired or replaced by the Contractor to the satisfaction of the Superintendent. The cost of repairing or replacing such damaged geotextile shall be borne by the Contractor.

(vii) Type A drainage mats shall extend 2 m beyond the toes of embankments and such extensions shall be covered by a 300 mm thick layer of Type C filter material or Type D filter material, as determined by the Superintendent. This protective layer shall be placed immediately after completion of construction of each drainage mat.

(viii) Outlets from Type A drainage mats may be surface outlets at the toes of embankments or piped outlets connected to other drainage systems. Where piped outlets are constructed, they shall conform to the requirements of Section SC6.4.6 Road works and traffic control, Clause SC6.4.6.3 Subsurface drainage.

(b) Type B Mats

(i) Type B drainage mats shall be constructed in cuttings as and where shown on the drawings or as directed by the Superintendent. Type B drainage mats shall be constructed for the full width of cuttings and for the pavement width in other locations.

(ii) After the subgrade material has been compacted and trimmed, a geotextile complying with the requirements of Section SC6.4.6 Road works and traffic control, Clause SC6.4.6 3 Subsurface drainage, shall be laid on the subgrade. Laps of minimum width of 500 mm shall be provided at each join in the geotextile.

(iii) Slotted thick-walled un-plasticised PVC pressure pipe complying with AS 1477, shall be laid on the geotextile 200 mm from and parallel to the longitudinal edges of the drainage blanket as shown in the drawings. Details of slot sizes and spacings are shown in Section SC6.4.6 Road works and traffic control, Clause SC6.4.6.13.

(iv) Type A filter material shall be placed on the geotextile and compacted to achieve a relative compaction,determined by AS 1289.5.4.1, of at least 100 per cent (standard compaction). Alternatively, the Superintendent may approve the use of a coarser filter material having a maximum particle size of 75 mm and a maximum D90/D10 ratio of three.

(v) The thickness of the compacted filter material shall be as shown on the drawings or as directed by theSuperintendent. If the required thickness of compacted filter material is greater than 250 mm, the filter material shall be placed in two or more layers so that no layer, when compacted, has a thickness greater than 250 mm.

(vi) After completion of placement and compaction of the filter material, geotextile shall be placed on top of and around the sides of the filter material so that the filter material is completely enclosed by geotextile. The geotextile shall be secured in such a manner as to prevent movement of the geotextile by wind or by construction plant placing pavement layers over the drainage mat.

(vii) Outlets from Type B Drainage Mats shall conform to the requirements of Section SC6.4.6 Road works and traffic control, Clause SC6.4.6.3 Subsurface drainage.

(6) Limits and tolerances

The limits and tolerances applicable to the various clauses in this section are summarised in Table SC6.4.9.12 Summary of Limits and Tolerances Drainage Mats below:

Table SC6.4.9.12 - Summary of Limits and Tolerances Drainage Mats

Item	Activity	Limits/Tolerances	Clause
(1)	**Filter Material**		
	(a) Layer thickness	250 mm max	Clause C6.4.9.15(5)(a)(iii)
	(b) Compaction (Relative)	100% Standard	Clause SC6.4.9.15(5)(b)(iv)
	Type A filter material		
(2)	**Type B Mats**		
	(a) Design level at top of mat	+0, -40 mm	Clause SC6.4.9.15(5)(b)(v)

SC6.4.9.16 Open drains

(1) Scope

(a) This policy section provides standards, advice, and guidelines for the construction, lining and protection of all types of open drains including the construction of rock filled wire mattresses and gabions associated with stormwater drainage infrastructure.

(b) Requirements for quality control and testing, including maximum lot sizes and minimum test frequencies, are cited in Section SC6.4.23 Construction management, quality management, inspection and testing.

Editor's Note - A reference to drawings is a reference to construction drawings.

(2) Terminology

Open Drains Refer to SC6.4.9.17

(3) Reference and source documents

Reference and source documents that must be read in conjunction with this section are as follow:

Editor's Note - Documents referenced in this section are listed in full below whilst being cited in the text in the abbreviated form or code indicated.

(a) SC6.4 Development manual planning scheme policy sections:

SC6.4.6 Road works and traffic control

SC6.4.12 Landscaping and open space

SC6.4.17 Structures

SC6.4.18 Concrete works

(b) Australian Standards:

AS 1141.22	*Wet/dry strength variation*
AS 1289.5.4.1	*Methods of testing soils for engineering purposes - Method 5.4.1: Soil compaction and density tests – Compaction control test – Dry density ratio, moisture variation and moisture ratio*
AS 1289.5.7.1	*Methods of testing soils for engineering purposes - Method 5.7.1: Soil compaction and density Tests - Compaction control test Hilf density ratio and Hilf moisture variation (rapid method)*
AS 2758.4	*Aggregate for gabion baskets and wire mattresses*

	AS 2876	*Concrete kerbs and channels (gutters) – Manually or machine placed*
	AS/NZS 4534	*Zinc and zinc/aluminium alloy coatings on steel wire.*
	AS/NZS 4680	*Hot dip galvanized (zinc) coatings on fabricated ferrous articles*

(c) Other:

Austroads	*Guide to Pavement Technology, Part 4B – Asphalt (AGPT04B)*
Austroads	*Guide to Pavement Technology, Part 4G – Geotextiles and Geogrids (AGPT04G)*
ASTM International	ASTM A975 - *Standard specification for double twisted hexagonal mesh gabionsand revet mattresses (metallic coated steel wire or metallic coated steel wire with PVC coating)*
International Erosion Control Association (IECA),	*Best Practice Erosion and Sediment Control.*

(4) General

Open drains shall be designed and constructed in accordance with the relevant clauses in Chapter 9 of QUDM 2013. Locate and construct open drains to avoid recharging groundwater, a shallow water table and salinity degradation of adjacent land.

Any unsuitable material must not be used for the bed and banks of the drain and must be removed from the site. Where a tree is marked for preservation, any drain must be diverted around it with sufficient clearance to avoid damage to the tree's root system.

Where open drains pass through private property, drainage easements of sufficient width to contain the flow and vehicular access for maintenance must be provided and registered as an encumbrance on the title of the land through which the drain passes.

Prior to works commencing, temporary drainage measures must be implemented in accordance with the requirements of *Best Practice Erosion and Sediment Control*.

(5) Types of open drains

Catch drains shall be provided above the top and at the toe of embankments as part of the construction of the adjacent roadway. The edges of catch drains shall be positioned not less than 2 m from the tops of cuttings or the toes of embankments nor more than is necessary to maintain the fall of the drains unless otherwise approved.

Minor diversion and contour drains shall be constructed where shown on the construction drawings. Minor diversion drains shall have the same capacity as the nearest pipe culvert on the line of the drain unless otherwise approved by the Superintendent.

Table drains, swales and depressed medians shall be constructed to the line and level shown or calculated from the drawings. Their construction is deemed to be part of the earthworks.

(6) Inlet, outlet, and diversion drains

Inlet, outlet, and diversion drains shall extend to join the existing stream bed and be of sufficient size to accommodate the design flows from the upstream catchment. The drain shall be excavated to the full width of the structure and care must be taken to ensure the stream bed can accommodate the additional flow with only minimal disturbance.

(7) Excavated materials

Construction material excavated from drains shall be placed on the lower sides of the drains and formed as banks with slopes graded in accordance with QUDM Third edition 2013 – Provisional. This material shall be compacted in accordance with AS 1289.5.4.1 and shall be not less than 95 per cent for standard compactive effort.

The Contractor shall ensure that none of the activities associated with the work disturbs any watercourse outside the site. Any excavation below the level of the natural channel shall be backfilled with suitable material compacted to a density equal to and compatible with that existing naturally.

Any excess material shall be legally and responsibly disposed of by the Contractor.

Unlined drains and areas adjacent to open drains shall be treated and revegetated immediately after the drains are complete, in accordance with Section SC6.4.12 Landscaping and open space.

(8) Lined open drains

(a) Proprietary lining materials

The Contractor must only use proprietary products which are suited to the terrain and have been approved for use by Council. This would include the use of:

(i) organic fibre and vegetation mats installed in accordance with the manufacturer's instructions;

(ii) rock filled wire mattresses; or

(iii) concrete where there is insufficient width to accommodate the required water way area, or the flow velocity in the drain will exceed the non-scouring velocities or where the trail is likely to be used as a bikeway or footpath during dry periods. Lining shall conform to the profile of the drain and shall be provided as soon as possible after forming the drain.

Before placing any lining material, the foundation material shall be shaped and compacted to not be less than 95 per cent for standard compactive effort as determined by AS 1289.5.7.1 or AS 1289.5.4.1.

Unless shown on the drawings, proprietary products may only be used with the approval of the Superintendent. Where specified, they must be used strictly in accordance with the manufacturer's instructions.

This section does not include kerb and channel.

(b) Concrete lining

Concrete lining for open drains shall be cast-in-situ or sprayed concrete supplied and placed to a minimum thickness of 100 mm measured at right angles to the surface of the lining in accordance with Section SC6.4.18 Concrete works.

Poly-fibres must not be used in marine environments, or where there is risk of fibres escaping into the environment, without approved controls to capture loose poly-fibre strands.

Weepholes shall be provided in the concrete at intervals of 2 m spacing with non-horizontal elements or as determined by the Superintendent.

Contraction joints in concrete lining, consisting of narrow transverse and vertical grooves, 5-10 mm in width, 20 mm deep, shall be formed neatly in the surface of the freshly placed concrete at intervals of 3 m unless otherwise specified by the Superintendent.

Expansion joints shall be placed at intervals not more than 15 m with a minimum width of 15 mm and shall consist of preformed jointing material of bituminous fibreboard or alternate approved material and shall be of sufficient depth to fill the joint.

(c) Stone pitching

Stone pitching shall consist of sound durable rock not less than 100 mm thick, properly bedded on approved loam or sand and mortared to present a uniform surface. The exposed surface of each stone or block shall be generally flat and not less than 0.05 square metres in area. Spaces between adjacent stones or blocks shall not exceed 20 mm in width.

(d) Batter drains

Batter drains shall be constructed using either half round steel pipes or precast nestable concrete units as shown and detailed on the drawings.

The units shall be installed in carefully excavated and template-controlled trench to produce an even rim line of +0 mm to – 50 mm from the batter line at the underside of topsoil.

Any over excavation and undulations in the batter line shall be backfilled and both sides of the drain compacted over the full length to form a firm shoulder against the rim of the batter drain.

When topsoil is placed it shall be tapered over a width of 1 m to zero thickness at the rim of the drain. Both sides of the drain shall then be turfed for minimum width of 1 m and pinned down as provided in Section SC6.4.12 Landscaping and open space.

(9) Rock filled wire mattresses and gabions

(a) General

Prior to installation of rock filled wire mattress or gabion, excavate so the mattresses finish flush and level with the surrounding ground. Rock filled wire mattresses and gabions shall be placed at the locations shown on the drawings. Installation shall be in accordance with the manufacturer's instructions. A geotextile, as shown on the drawings, shall be placed between the wire cage and the material being protected.

Foundations of floors of gabions should ideally be within cut material, however if in fill areas or embankments then material must be compacted in layers not greater than 150 mm thick, to a relative compaction of 95 percent when tested in accordance with AS 1289.5.4.1, for standard compactive effort.

(b) Materials

For wire mattresses and gabions, the galvanising requirements for wire of circular cross section cited in this Clause as "heavily galvanised", shall comply with the coating mass requirements for round wire, Class W10, in AS/NZS 4534. The Contractor must submit for approval the type of mattress/gabion proposed along with confirmation of compliance to ASTM A975 and a schedule of installation locations.

(i) Gabions

The gabions shall be of the sizes shown on the drawings and fabricated of woven heavily galvanised wire mesh and PVC coated where specified on the drawings. Each gabion shall be divided by diaphragms into cells whose length shall not be greater than the width of the gabions plus 100 mm. Gabions shall have a nominal mesh size of 80 mm x 100 mm and body wire shall be a minimum diameter of 2.7 mm heavily galvanised with an additional thickness of 0.4 mm PVC coating where specified on the drawings. The minimum core diameters of heavily galvanised selvedge wire and lacing wire shall be 3.4 mm and 2.2 mm respectively.

(ii) Wire mattresses

Unless specified otherwise, the wire mattresses shall be supplied in units having dimensions of 6 m x 2 m x 230 mm and shall be cut to suit areas as shown on the drawings. The mattresses shall be divided by diaphragms into cells of length not exceeding 600 mm. Unless otherwise specified, they shall be fabricated of woven heavily galvanised wire and PVC coated where specified on the drawings.

Mattresses shall have a mesh size of 60 mm x 80 mm and body wire shall be a minimum diameter of 2.0 mm heavily galvanised with an additional minimum thickness of 0.4 mm PVC coating where specified on the drawings. The minimum core diameters of heavily galvanised selvedge wire and lacing wire shall be 2.7 mm and 2.2 mm respectively.

(iii) Geotextile

A chemically and biologically stable geotextile with a minimum strength rating (G) of 1350 and minimum mass of 180 grams per square metre, in accordance with Guide to Pavement Technology - Part 4G: Geotextiles and Geogrids, shall be used.

Samples, manufacturer's specification, and instructions on installation shall be submitted to the Superintendent seven days before the intended use of geotextile.

(iv) Rock fill material

The rock fill shall consist of clean hard rock complying with the requirements of AS 2758.4.

Rock fill for gabions shall have particle sizes between 100 mm and 250 mm. Rock fill material should be placed by hand and only when approved by the superintendent shall they be placed using a suitable mechanical device to ensure fill is tightly packed with a minimum of voids. Fill material shall be levelled off 25 mm to 50 mm above the top of the mesh to allow for settlement.

When the mattress is on a slope, rock fill material shall be placed into the units starting from the low end. Units shall be filled slightly overfull by 25 mm to 50 mm to allow for settlement and to provide an even tight and smooth surface of the required contour.

(c) Assembly and erection

Before laying out the gabions or wire mattresses, geotextile shall be placed on the founding material and against any surface that will be in contact with either drainage course or earth backfill.

Adjust the position of the diaphragms so that the sides hinge up on the thicker wire woven in the mesh. Lace the gabion boxes along all diaphragm points and edges at to all adjacent boxes. Internal bracing wires 4 per metres at 330 mm centres to prevent distortion. Face bracing wires 4 per metres of face.

Ensure star pickets are either driven or cut off level with the top of the mattress.

After tying diaphragms and adjacent units of mattresses/gabions on all three adjacent corners (rear, floor, and front face), leave top edge untied to allow for securing along with the lid section. The end corners of wire mattress/gabion tied sections shall be firmly tied after galvanised star pickets are driven and stretched in place a minimum of 900 mm into the surrounding ground in the final location at one end.

Carefully secure the opposite end of the gabions without damaging or distorting the dimensions of the units to a suitable mechanical device and apply a stretching force to the assembled mattress/gabion section to be filled.Whilst under tension, secure each corner of each unit using galvanised star pickets driven into foundation ensuring each unit is stretched tight in all directions.

(d) Filling

Fill whilst the gabion boxes are under tension. Place the rocks at the front face and other exposed faces byhand to produce a neat face free of excessive bulges, depressions, and voids.

Redistribute the filling materials by hand to ensure that all diaphragm compartments are fully filled to produce aneat and level top surface. Overfill by 25 to 50 mm to allow for subsequent settlement.

Mechanical filling equipment may be used with caution ensuring to protect any PVC or galvanized coatings from abrasion. Release the tension on the mattress/gabion boxes only when fully laced to prevent anyslackening.

The upstream edge of wire mattresses shall be folded down into a trench of minimum depth 300 mm and filled with rock fill. This edge shall be tied to star pickets.

Final lacing should be undertaken as soon as practicable after filling particularly if there is a storm or floodexpected. Stretch lids tightly over the filling and lace down securely. The works should be inspected uponcompletion of lacing.

(10) Limits and tolerances

The limits and tolerances applicable to the various clauses in this section are summarised in Table SC6.4.9.13 below.

Table SC6.4.9.13 - Summary of Limits and Tolerances Rock Filled Wire Mattresses and Gabions

Item	Activity	Limits/Tolerances	Clause
(1)	**Open Drains - General**		
	(a) Grading	Grade - QUDM 2013 Table 9.5.2	Clause SC6.4.9.16(4)
	(b) Depth	Based on hydraulic capacity of the channel	Clause SC6.4.9.16(4)
			Clause SC6.4.9.16(4)
	(c) Freeboard	QUDM 2013 table 9.3.1 & Fig 9.8	Clause SC6.4.9.16(4)
	(d) Channel Side Slopes	QUDM 2013 Section 9.5.3	
	(e) Compaction	> 95% (standard compaction)	Clause SC6.4.9.16(7)
(2)	**Open Drains – Lining**		
	(a) Compaction of Foundation	>95% (standard compaction)	Clause SC6.4.9.16(8) (a)
(3)	**Stone Pitching**		
	(a) Rock Dimensions	> 100 mm thickness	Clause SC6.4.9.16(8)(c)

	(b) Exposed surface area (c) Spaces between stones	> 0.05 sq m < 20 mm width	Clause SC6.4.9.16(8)(c) Clause SC6.4.9.16(8)(c)
(4)	**Batter Drains** (b) Rim line	 + 0, - 50 mm from batter line	 Clause SC6.4.9.16(8)(d)
(5)	**Kerb and Channel** (a) Compaction of foundation (b) Level of gutter surface (c) Alignment (d) Surface uniformity (e) Contraction joints (i) Area (ii) Groove width (f) Expansion joint interval (g) Backfill behind kerb (i) Layer thickness (ii) Compaction	 To AS 2876 Level ≤ ± 6 mm of design level Level ≤ ± 50 mm of design alignment Deviation of kerb and channel surface from 3 m straight edge ≤ 5 mm ≥ 50% of CS area ≥ 5 mm at all gully pits and associated structures ≤150 mm >95% (standard compaction)	
(6)	**Rock Fill for Gabions and Wire Mattresses** (a) Wet strength (b) Wet/dry strength variation (c) Particle size for gabions (d) Fill level (e) Particle size for wire mattresses	 > 100 kN < 35% >100 mm <250 mm and preferably not greater than 200 mm > 25 mm < 50 mm above top of mesh Between 75 mm and two thirds of the mattress thickness, or 250 mm, whichever is the lesser	 Clause SC6.4.9.16(9)(b) Clause SC6.4.9.16(9)(b) Clause SC6.4.9.16(9)(b) Clause SC6.4.9.16(9)(b)
(7)	**Erection of Gabions and Wire Mattresses** (a) Star pickets for ties (b) Trench depth from upstream edge	 Depth in ground > 900 mm. Spacing < 1 m Depth >300 mm	 Clause SC6.4.9.16(9)(d)

SC6.4.9.17 Terminology

AEP	Annual Exceedance Probability
IFD	Intensity-Frequency-Duration
QUDM	Queensland Urban Drainage Manual
MHWS	Mean High Water Springs
ANCOLD	The Australian National Committee on Large Dams
IECA	International Erosion Control Association
DI	Density Index
WHS	Work Health & Safety
AASHTO	American Association of State Highway and Transportation
NATA	National Association of Testing Authorities
Type A Drainage Mats	are intended to ensure continuity of a sheet flow of water under fills, to collect surface seepage from a wet seepage area or for protection of vegetation or habitat downstream of the road reserve where a fill would otherwise cut the flow of water. are intended to ensure continuity of a sheet flow of water under dfills, to collect surface seepage from a wet seepage area or for protection of vegetation or habitat downstream of the road reserve where a fill would otherwise cut the flow of water.
Type B Drainage Mats	are constructed to intercept water which would otherwise enter pavements by capillary action or by other means on fills and to intercept and control seepage water and springs in the floors of cuttings.
Open Drains	are all drains other than pipe and box culverts and include catch drains, contour drains, diversion drains, table drains, batter drains, swales, channels, gutters and kerb and channel.