



INFORMATION BULLETIN

Minor Stormwater System Standards for Residential Areas

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Department	Development Services	SP003
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1 Purpose of this Information Bulletin

To inform the industry of the proposed reduction of the minor residential stormwater system design standard as part of the Engineering Design Guidelines, including issuing a copy of the Draft discussion paper, requesting feedback on the proposal and inviting members of the industry to attend an information session.

2 Details

The minor residential stormwater system design standard is proposed to be reduced from the current 18% AEP (Q_5) to 39% AEP (Q_2) to align with the QUDM recommendations, and to achieve more of a balance between level of service, economy and growth.

Attached is a Draft discussion paper on the proposal, which will be presented to industry in a briefing session. Feedback will be requested before a final proposal is presented to Council for adoption later in the year. Information on the proposed method of adoption will be given at the presentation.

The industry briefing will be held at 9:30am, 24 August 2015 in the Reception Room at Mackay Regional Council's Administration Building in Gordon Street. Members of the local engineering and development industry are invited to attend to find out more and to provide feedback. Please RSVP to Yevonne Sullivan at strategic.planning@mackay.qld.gov.au (or phone 4961 9129) with the name and number of people in your organisation who will be attending.

Feedback on the proposal is to be received via email to strategic.planning@mackay.qld.gov.au by 4 September 2015.

3 Date of Effect

Refer above

4 Enquiries

Please direct enquiries concerning this information bulletin to Strategic Planning at strategic.planning@mackay.qld.gov.au (or phone 4961 9129).

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Minor Stormwater System Standards for Residential Areas

Discussion Document - Draft

**Strategic Planning, Development Services
10 August 2015**

Mackay Regional Council
Minor Stormwater System Standards for Residential Areas
Discussion Document

Revision History

Revision Date	Version	Revised By	Description of Revision
10 August 2015	Draft	Caitie Becker	Draft for industry comment

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1. Introduction

Mackay Regional Council has identified the importance of achieving a balance between growth, level of service and financial sustainability moving into the future. As part of working towards a greater balance, areas of improvement have been identified. One area of focus is the stormwater system standards, particularly achieving balance between the whole of life costs and the level of immunity the system provide.

The stormwater system comprises two parts:

- the minor system (for the convenience and safety of pedestrians and vehicles, generally underground including pits and pipes); and
- the major system (providing immunity from flooding, generally within a road reserve or open drain).

Mackay Regional Council (MRC) and its predecessors have traditionally utilised the *Queensland Urban Drainage Manual* (QUDM) to set the standards for stormwater system design in the region, with specific amendments outlined in various design standards. One such amendment that has consistently been applied is the requirement for the minor stormwater system for residential developments to cater for an event with 18% Annual Exceedance Probability (AEP), or a 1 in 5.5 chance of occurring each year (also referred to as the Q₅ event), rather than the QUDM recommended standard of an event with 39% AEP, or a 1 in 2.5 chance of occurring each year (the Q₂ event). Please refer to Section 1.1 below for further explanation of the terminology.

Therefore, the minimum standard for underground stormwater systems has been identified as a possible candidate for a level of service reduction, to achieve a greater balance with economy – both up front capital cost, and renewal cost over the whole-of-life. Reducing the current standard from a Q₅ system underground to the current QUDM recommendation for Q₂ will have both benefits and disadvantages, which are investigated in this discussion paper. The minor stormwater system comprises underground pipes and pits, where the size and number of both is dependent on various design criteria.

QUDM also makes a distinction between several different residential density categories, requiring that underground systems be designed to cater for an event with a 10% AEP, or 1 in 10 chance of occurring every year (a Q₁₀ event) for densities of 20 dwellings per hectare (dwlgs/ha) or greater. The *Draft Residential Densities Strategy 2011* (DRDS) outlines MRC's vision for more compact residential living and densities greater than 20 dwlgs/ha are encouraged in some areas. A recent publication by the Urban Development Institute of Australia (UDIA), *The UDIA (Qld) Industry Insights Report 2015*, reports that there has been an 18% reduction in the median lot size in Mackay since 2009, which is expected to continue to decline. Higher density living presents unique challenges with regards to stormwater drainage, thus the design standards for this category need to be reviewed in comparison with QUDM. This discussion paper focusses on lower density development less than 20 dwlgs/ha, but comment will be made on the application of the QUDM standard to high density.

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This discussion paper aims to investigate current industry best practice, and critically assess it against local practice to determine the most appropriate way to strike a balance between economy and levels of service specifically related to stormwater system design standards.

1.1 Terminology

There has been a shift in how floods and storm events are referred to, particularly when dealing with the public. Table 1 below outlines the ‘old’ and the ‘new’ terminology, and how they relate to one another.

TABLE 1: TERMINOLOGY

Reference to design storm event (Q_x)	Percentage chance of a flood occurring in any year (AEP – annual exceedance probability)	Chance of a flood occurring annually (1 in x)	Annual Recurrence Interval (ARI)	Description
	New terminology	Old terminology		
Q_2	39%	2.54	2	A common flood likely to be experienced every couple of years or so.
Q_5	18%	5.52	5	A small flood event which will mostly be contained within the stormwater pipe system (in new areas)
Q_{10}	10%	10	10	A small flood where flooding in the street is likely to occur
Q_{50}	2%	50	50	A medium sized flood
Q_{100}	1%	100	100	A large uncommon flood event that is rarely observed but still possible

For the purpose of this discussion paper, reference will be made to the design storm event (Q_x) or the percentage chance of a flood occurring in any year (AEP %).

2. Background

2.1 History

The history of stormwater system standards in the region is largely based on the history behind the various Council amalgamations. The current Mackay Regional Council was formed by the amalgamation of the Mackay City, Sarina Shire and Mirani Shire Councils in 2008. Prior to this, in 1994, the Mackay City Council was formed with the amalgamation of the Pioneer Shire Council and Mackay City Council.

The requirement for residential stormwater system design within the Pioneer Shire Council was Q_5 for minor systems and Q_{50} for major flows, while the Mackay City Council is thought to have been Q_2 or lower for minor with little or no consideration given to major flows. QUDM was originally released in 1992, and recommended Q_2 for minor systems and Q_{100} for major systems within urban residential developments. Both Councils adopted Q_5 for minor flows, Pioneer Shire maintained Q_{50} for major flows and Mackay City considered major flows on a case by case basis. After amalgamation in 1994, the Mackay City Council Development Manual was created in 1998 to set the standards for infrastructure design in the area. Councillors were satisfied with the apparent reasonable immunity provided by the Q_5 system, and were reluctant to downgrade the standards. Therefore, a Q_5 minor system requirement was maintained (with the major system requirement being Q_{50}). Provision was made for a reduction of the underground system to Q_2 where the volume of flows in a major event were above $10m^3/s$, with prior agreement.

In 2006, an increase to Q_{100} for the major system design requirement was adopted in the new Engineering Design Guidelines (which superseded the Development Manual). The minor system requirement remained at Q_5 .

The Sarina Shire Council referred largely to the Mackay City Council Development Manual for their design standards, and thus also adopted Q_{50} major/ Q_5 minor design standard.

The Mirani Shire Council differentiated between higher density residential and lower density residential, and required Q_2 for densities less than 15 dwlgs/ha, and Q_{10} otherwise. The major system design requirement was Q_{100} .

2.2 Current policy

Since amalgamation into the current Mackay Regional Council, the three planning schemes of the former Councils have remained current. The existing stormwater system design standards are shown in Table 2 below:

TABLE 2: CURRENT MACKAY REGION STORMWATER SYSTEM STANDARDS FOR RESIDENTIAL AREAS

Former Council	Minor System	Major System
Mackay City	Q ₅	Q ₁₀₀
Sarina Shire	Q ₅	Q ₅₀
Mirani Shire	Q ₂	Q ₁₀₀
QUDM	Q ₂	Q ₁₀₀

2.3 Proposal

The *Draft Mackay Region Planning Scheme* (DMRPS) was submitted to the Minister for Infrastructure, Local Government and Planning in December 2014 seeking approval to adopt the scheme. Once adopted, it will bring the three former Council areas together under the one set of standards. This includes the Engineering Design Guidelines, which in the current Draft edition are based on the Mackay City standards. It is expected that the recommendations from this discussion paper will inform an amended PSP SC6.12-10 Engineering Design Guideline – Stormwater Drainage Design.

The proposed reduction of the minor system underground design standard from Q₅ to Q₂ and the possible introduction of a new category of higher density residential development greater than 20 dwlgs/ha requiring Q₁₀ needs to be balanced with an acceptable level of service, with minimal impact on residents. If adopted, the reduced standard should only be applied to new developments and new ‘greenfield’ capital works, to ensure a decreased level of service is not experienced by existing residences. Renewal of existing systems needs to continue based on the original design, or if the existing system is designed to a much lower level (such as parts of the CBD or South Mackay) it can be brought up to meet the standard at Q₂. The recommendations in QUDM should generally be adopted, unless there are compelling or locality-specific reasons not to.

Due to complexities and issues surrounding interallotment drainage systems, it is proposed that the current requirements for these systems remain in place until a thorough review of interallotment drainage can be undertaken.

2.4 Desired outcomes

As a result of this investigation into the possible reduction of the minor stormwater system standards, the following key outcomes have been identified, seeking a balance between the key areas of level of service, growth and economy:

1. Maintain an acceptable level of service to the community with regards to the level and frequency of inundation and nuisance during minor and major storm events (*Level of Service*);
2. Ensure there is a ‘no worsening’ effect on existing areas (*Level of Service*);
3. Reduce capital and asset renewal costs (‘whole of life’ costs) of stormwater pit and pipe infrastructure (*Economy*);
4. Reduce maintenance costs of stormwater pit and pipe infrastructures (*Economy*);
5. Align the region with current industry practices for the design storm events and standardise the design standards across the region (*Growth*);
6. Assist with reducing the impacts of increased density within new developments on stormwater infrastructure costs (*Growth and Economy*).

The recommendations in Section 8 are based on these five outcomes.

DRAFT

3. Literature Review

A review of QUDM and current standards of other Councils with similar climatic conditions was undertaken to compare MRC's current practice with industry standard.

3.1 Queensland Urban Drainage Manual (QUDM)

QUDM is the acknowledged industry standard for stormwater system design throughout Queensland and forms the basis of the standards of many Councils. It was originally issued in 1992 after being developed by the State Government to inform stormwater design across the state. At the time of writing this discussion paper, the current revision is 2013 Provisional. It is currently being updated and is expected to be released at the end of 2015, however instruction from the Minister is to utilise it as a complete document in the meantime. Caution should be used in referencing QUDM in any new policies, to ensure the reference remains valid even in future revisions.

QUDM states that the local authority may vary the design AEPs from the recommendations in QUDM to suit local conditions, taking into consideration the required level of service for hydraulic performance, construction and operating costs, maintenance requirements, risk assessments, safety, aesthetics, regional planning goals, legal and statutory requirements and convenience/nuisance reduction. It is not recommended that design standards less than those in QUDM be adopted.

QUDM recommends Q_{100} for the major system, and Q_2 for the minor system in residential areas where the density is less than 20 dwlgs/ha. For densities greater than 20 dwlgs/ha, QUDM recommends Q_{10} for the minor system. This discussion paper has included basic analysis of this category by comparing the current Q_5 criteria with the QUDM-recommended Q_{10} and discusses when this criteria applies (ie when the site is considered to have a density of more than 20dwlg/ha). Further analysis is excluded, and it is recommended that this topic be the subject of further investigation and discussion, for inclusion into any future amended engineering design guidelines.

Upon undertaking this literature review, it has become apparent that the existing engineering design guidelines don't reflect the current QUDM standard in a number of areas. Whilst further investigation hasn't been undertaken within the scope of this discussion paper, it is recommended that a review of the current engineering design guidelines be completed with the aim of reviewing the guidelines for a more broad adoption of QUDM (albeit with specific departures for the Mackay region).

3.2 Other Queensland councils

A review of the design guidelines for other Councils in a similar geographical area and which experience similar climatic conditions was undertaken. Councils included in this review were members of Far North Queensland Regional Organisation of Councils (FNQROC - Cairns

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Regional, Mareeba Shire, Croydon Shire, Hinchinbrook Shire, Tablelands Regional, Cassowary Coast Regional, Douglas Shire, Cook Shire and Wujal Wujal Aboriginal Shire Councils), Townsville City Council, Burdekin Shire Council, Whitsunday Regional Council, and those which utilise the Capricorn Municipal Development Guidelines (Rockhampton Regional, Livingstone Shire, Gladstone Regional, Banana Shire and Central Highlands Regional and Maranoa Regional Councils).

The minor stormwater system standards for residential areas were reviewed, and the design rainfall intensities compared with Mackay to ensure similar climatic conditions during the peak wet season. Intensities for a 1 hour, Q₁₀ event (¹I₁₀) and a five minute, Q₁ event (⁵I₁) were utilised to look at the design event utilised in QUDM for the Rational Method, and the short intense events. The results are included in Table 3 below

TABLE 3: COMPARISON OF COUNCIL STORMWATER SYSTEM DESIGN STANDARDS FOR RESIDENTIAL AREAS UP TO 20 DWLGS/HA

Council/Region of Councils	⁵ I ₁ intensity (mm/hr)	¹ I ₁₀ intensity (mm/hr)	Minor system	Major system
Mackay	125	80-90	Q ₅	Q ₁₀₀
Sarina	110-120	80	Q ₅	Q ₅₀
Mirani	120-140	70-80	Q ₂	Q ₁₀₀
FNQ ROC	100-140	60-90	Q ₅	Q ₁₀₀
Townsville*	110-130	70-80	Q ₂	Q ₁₀₀
Burdekin	110-120	70-80	unknown	unknown
Whitsunday	120-130	70-85	Q ₂	Q ₁₀₀
Capricorn ROC	95-120	60-70	Q ₅	Q ₁₀₀

* Townsville City Council have advised that the current standards within their 2014 City Plan are onerous and difficult to achieve and that the industry has reverted back to utilising the previous Thuringowa City Council standards, which are represented in Table 3 above. They have also advised that large changes will be made to the document to enable industry to achieve the criteria moving forward. The current Townsville City Plan standards are dependent on zoning of the land being serviced, along with the road classification the underground system is within. For residential developments of all densities, the standard is Q₁₀ for arterial roads, Q₅ for Collectors and Q₂ for Local and rural streets.

3.3 Observations

Based on a comparison of QUDM, MRC standards and those of other Councils, the following basic observations were made:

1. Intensities:
 - a. The rainfall intensity in the Mackay Region is very similar to the regions used in the comparison for both $^1I_{10}$ and 5I_1 events and the comparisons are therefore reasonable to be used.
 - b. The Capricorn ROC experiences slightly lower intensities than Mackay but is still similar enough to be included in the comparison.
 - c. The Councils in FNQROC experience the most similar intensities to those in the Mackay Region.
2. Major event:
 - a. All Councils except the former Sarina Shire Council require Q_{100} for the major design event.
 - b. The major design event requirement in Mackay of Q_{100} is consistent with the QUDM requirement.
3. Minor event:
 - a. Mirani Shire, Townsville City and Whitsunday Regional Councils require Q_2 for the minor design event. All other Councils require Q_5 .
 - b. The minor design event requirement in Mackay of Q_5 is higher than the QUDM requirement of Q_2 , but fairly consistent with the comparison Councils.

Representatives of some of the above Councils were contacted and asked to provide background as to how their current standards came into practice. The responses included:

- Rockhampton Regional Council:
 - The increase from QUDM Q_2 to Q_5 was as a result of industry pushing for it;
 - From Council's perspective the larger pipe size is only slightly more expensive and gives more room for error;
 - Southern Councils that have adopted Q_2 have a major focus on overland flow, which isn't always able to be achieved in some areas so any flow in excess of Q_2 that can be captured underground is an advantage.
- Townsville City Council
 - The current TCC standards are difficult to design for and to achieve, as they have different immunity requirements for the underground system depending on the classification of road which results in designers having to run different scenarios within the one development;
 - Council will be making large changes to the standards;
 - Currently designers are reverting back to previous standards, which utilises Q_2 for standard residential;
 - Commercial/industrial systems were reduced from QUDM's recommended Q_{10} to Q_5 some years ago to reduce infrastructure cost
- No reply was received from other Councils.

4. Design Considerations

Stormwater drainage systems are complex, and rely on much more than the design AEP to determine the pipe and pit sizes. Factors impacting on the design include topography, land use (zoning and resulting physical constraints), external catchments and standards for safety and effectiveness.

Case studies have been undertaken (refer Section 6 below) that will encompass the major considerations to ensure a rounded view of the possible advantages and disadvantages.

4.1 Topography

Very flat sites – such as those in likely future growth areas of Ooralea, Bucasia, Shoal Point, Mirani and Paget – are often challenging to drain adequately for both minor and major flows. Major flow design criteria can impact on the minor system design. It is sometimes more effective (or necessary) to convey parts of the major flow underground in order to limit the earthworks required to restrict the major flow to the road reserve, or to achieve major system criteria (such as flow depth or width) within the road reserve. Further, downstream drainage levels and required depth of cover to stormwater pipes can be physically difficult, and trunk open drains can become very large and deep. It is this balance between pipe systems and earthworks that needs to be achieved to ensure a development is economical.

In a standard situation, approximately 45% of the Q_{100} flow is captured underground in a Q_5 system. When reduced to a Q_2 , that reduces to approximately 30%. The additional 15% needs to be accommodated within the above ground system, which may be difficult in topography where the road reserve has limited capacity due to flat grades. In these flat areas of the region, the systems are generally drowned systems where the design is elevation-head driven and the full capacity of the pipe is being utilised; however, if the major storm criteria is the driving force behind the sizing of underground pipes a reduction to Q_2 will have little positive impacts.

Conversely, sloping or free draining sites (such as those in the areas of Richmond and Rural View) can sometimes be drained with ease and comparatively little cost; however, large upstream catchments flowing through the site can dramatically impact on the stormwater drainage philosophy. The high velocity of the flowing water in steep sites can also result in significant stormwater pit bypass, needing additional pits to capture the flow, rather than the pits being necessary for volumetric or configuration reasons. Underground pipe systems in these situations are often sized based on velocity requirements rather than capacity, with pipes only flowing partially full in the design storm.

The case studies undertaken in Section 6 below include both a flat and a free-draining site.

4.2 Land Use

The density of developments in Mackay over the last 5 years has been increasing. This has been encouraged in the *Draft Residential Densities Strategy* and in the *Draft Mackay Region Planning Scheme*. The *UDIA (Qld) Industry Insights Report* states that the median lot size in the Mackay local government area was 643m² in 2014, a reduction of 18% in five years since 2009. The trend is expected to continue to smaller lot sizes and increased densities.

The 2006 planning scheme had a standard lot size of 800-1000m² with 40% imperviousness. The current Draft planning scheme is closer to 400-600m² with 70% imperviousness.

The following graphic, extracted from the *UDIA (Qld) Industry Insights Report* shows the trend:



- Median lot size has trended downwards most notably since 2009, from 785sqm to 643sqm in 2014. This is an 18% reduction in median lot size in the past 5 years.

FIGURE 1: MACKAY VACANT LAND MEDIAN LOT SIZE 2000-2014 (EXTRACTED FROM THE UDIA (QLD) INDUSTRY INSIGHTS REPORT)

Increased housing density leads to a number of factors that impact on stormwater system design:

- Increased impervious area, leading to higher volume of runoff
- Reduced Time of Concentration, leading to an increased peak runoff
- Reduced frontage widths and more obstacles (street trees, driveways, traffic calming devices, etc) reducing possible locations for stormwater pits

The increase in runoff due to imperviousness and time of concentration would be experienced regardless of the reduction of the design AEP, and therefore the reduction in the design storm to a Q₂ will assist to counteract the cost implications of this. However, in developments where lots have narrower frontages, the constraints on the physical locations

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of inlet pits may be a factor. Whilst a theoretical reduction in pit numbers may be possible, physical constraints on their locations may require just as many, or nearly just as many. Minimum distances from traffic calming devices, street trees, street lights and driveways will still be applicable.

The following graphic, extracted from the Draft Residential Densities Study, gives a representation of various housing densities.

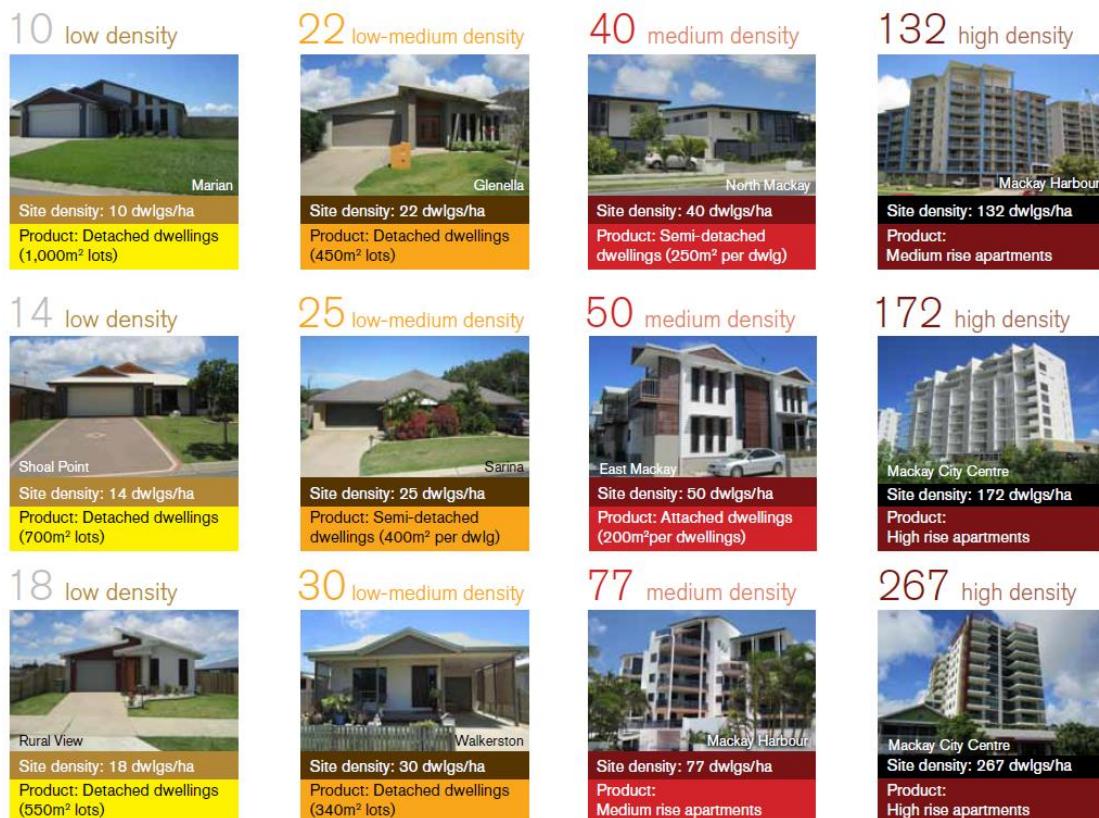


FIGURE 2: PICTORIAL REPRESENTATION OF DIFFERENT HOUSING DENSITIES AND THEIR FORMS (EXTRACTED FROM THE DRDS)

The case studies undertaken in Section 6 below are based on a density of 15-18 dwlgs/ha (approximately 600-650m² per lot), which is in line with the current median lot size but still under the 20 dwlgs/ha limit in QUDM before the Q₁₀ requirement is introduced. To represent a situation of medium density detached or semi-detached dwellings, a case study density of 30 dwlgs/ha (approximately 330m² per lot) was also included, focussing on a Q₅ and Q₁₀ comparison. A narrower lot frontage was used in the latter, considering pit locations and obstacles. Although this case study has been included for consistency and comparison purposes, further investigation should be undertaken to determine its inclusion in future amended engineering design guidelines.

Two of the most recent highest density developments in Mackay were considered, namely River's Edge development in Glenella (only 4.3ha in total, including significant parkland), and

Plantation Palms Stage 4 in Rural View (approximately 27ha in total). River's Edge achieves an overall density (excluding parkland) of approximately 24 dwlgs/ha. Plantation Palms Stage 4 achieves 18 dwlgs/ha (through a mix of high density, medium density and low density sites). These are arguably two of the densest developments in the region, one of which just exceeds the criteria, and the other doesn't. Therefore, it is not considered very likely that the overall density of 20 dwlgs/ha will be exceeded often in the foreseeable future.

4.3 External catchments

The effect of external catchments varies greatly for each specific site. In some instances, the external upstream catchment needs to be diverted around the site, or sometimes piped as a major event underground. It can either be kept separate to the underground system from the development itself, or combined.

Downstream catchment capacities may result in the need for detention systems in the development, and may impact on the lawful point of discharge.

As the impact of external catchments varies so widely from site to site, no specific example has been incorporated into the case studies. In general, it has been considered that any positive or negative impacts applicable to the reduction from Q_5 to Q_2 will apply regardless of external catchments. What will need to be considered, however, is the applicability of the proposed reduction to sites with external catchments, or where the underground system connects to an existing or lower-immunity system. These will vary on a case-by-case basis.

4.4 Safety and effectiveness

Regardless of the design AEP, various standards apply in the design of stormwater systems to ensure public safety and effective operation of the system:

- Depth/velocity product no greater than $0.4\text{m}^2/\text{s}$ for pedestrian safety;
- Flow width limitations (dependent on category of road);
- Flow depth limitations (dependent on road use, flowing or stagnant water, and adjacent property floor levels; generally no greater than 250/300mm within road reserves or 50mm above top of kerb);
- Minimum pipe size 375mm diameter to reduce blockages and allow for maintenance.

Each of these criteria impact on the location and size of stormwater pits, the size of the pipe system the pits are draining in to and the capacity of the above ground system, and will be maintained. In some cases, they might require the underground system to be increased to ensure the aboveground criteria can be met. The flow depth limitation is generally the driving factor for topographically flat sites, and with an additional 15% (approximately) of the flow aboveground, this could be worsened. In systems where the major flow is not within a road reserve (such as when it is an open drain), the major system criteria has no impact on the underground system.

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Another safety consideration is the frequency of water ponding in the roads and its impact of vehicles and pedestrians. A Q₅ storm will currently be contained in the underground system, with allowable ponding in the road (to a width depending on road classification) to still enable safe vehicle travel. A Q₅ storm in the future (if a Q₂ system is adopted) will have ponding in the road to an increased width. The worst case design storms are typically short duration storms with a higher intensity, however, so the increased time and depth of ponding will be negligible.

The case studies reviewed in Section 6 apply the above requirements as in a normal design, ensuring that the resulting system complies with the same standards as an actual design would and enabling more accurate representation of any benefits and disadvantages.

5. Benefits and disadvantages

5.1 Cost

5.1.1 Capital construction cost

The ‘Estimates and Annexures’ spreadsheet developed by Council’s Technical Services was utilised for each Case Study in Section 6 to estimate the capital construction cost of each resulting design. A simplistic view of pit, pipe and lot earthworks cost was considered and a direct comparison made between each design storm event within each case.

5.1.2 Maintenance cost

Discussions were held with Council’s Civil Operations program to determine the current maintenance issues, and how they would be impacted by the proposed change. The following summarises the discussion:

- Majority of maintenance is associated with pits and joints;
- Most common maintenance is cleaning out of pits and relining pipes;
- Relining of pipes is often required after 20-25 years in service and can give an additional 50 years of useful life before reconstruction is required;
- Relining is often the result of joint failure due to sand infiltration or incorrect/poorly constructed joints;
- An increase in damaged pipes as a result of construction loading (rather than in-service loading) is being experienced shortly after asset handover;
- CCTV of stormwater systems before asset handover would be useful in ensuring Council are handed infrastructure in good condition and without premature degradation or failures;
- Reduction in pit numbers and pipe lengths would proportionally reduce maintenance cost, even though the same maintenance on each pit and pipe would be required;
- Relining a smaller pipe is less expensive than relining a larger pipe;
- Additional flow in the major system may increase scour and prolong saturation.

Average maintenance costs were sought and provided, but it was not considered a good use of time as part of this discussion paper to quantify the costs for each case study. Considering the major points above, it is clear that a reduction in pit numbers, road crossings, pipe lengths and pipe sizes will lead to a decrease in maintenance costs.

Although not part of the scope of this discussion paper, the issue of the standard of construction of new assets handed over to Council appears to be significant, and has more of an impact on on-going maintenance costs than anything else. It is therefore recommended that this be looked into further.

5.1.3 Asset renewal/reconstruction cost

Discussions were held with Council's Civil Operations program to determine the current driving factors behind the renewal and reconstruction of stormwater systems. The following summarises the discussion:

- Reconstruction program of roads in older parts of Mackay (South Mackay, North Mackay, East Mackay and West Mackay in particular) generally leads to the reconstruction of the underground stormwater system if the system is reaching the end of its useful life, even if it doesn't require reconstruction itself at the time;
- The major cause of reconstruction (outside of being done in conjunction with road reconstruction) is complete failure of pipe joints, which is even being seen in systems that are relatively new (ie less than 50 years old);
- Reconstruction would not reduce the level of service of an existing system, and would either replace the system with the same size, or would upgrade the system for increased immunity.

As with Section 5.1.2 above, average renewal and reconstruction costs were sought and provided, but it was not considered a good use of time as part of this discussion paper to quantify the costs for each case study. Considering the major points above, it is clear that a reduction in the original system design will lead to a decrease in renewal/reconstruction costs.

5.2 Level of service

5.2.1 Major system – potentially damaging flooding

The frequency and severity of potentially damaging flooding will not change with the implementation of this policy. The major design storm event will remain at Q_{100} , so road reserves and open drains will still have to contain flows up to Q_{100} to prevent encroachment into properties. The volume of water within the above ground system will be approximately 15% higher (with approximately 30% of it being taken in the underground system as opposed to 45% with Q_5) but the impact on properties will not change, as the civil design will cater for this. Additional design documentation standards will be implemented to account for the increased volume of water in the major system.

5.2.2 Minor system – nuisance flooding

The frequency and severity of nuisance flooding will increase with the implementation of this policy. Whilst the underground system will still be designed to cater for the minor event, the chance of the minor event being exceeded will increase from 18% each year to 39% each year (ie twice as often). Nuisance flows will be more frequent, but the same level of nuisance for the new design AEP as the previous design AEP will apply. Therefore, in a Q_5

event, the level of nuisance will be higher in a new development designed to Q_2 than it would have been if that development had been designed to Q_5 . However, if this policy is only applied to new developments there will be no direct comparison, or for the replacement of systems that were designed to be less than Q_5 originally there will be an improvement. For all events below the major design event of Q_{100} , it will still not reach a damaging level, as runoff will still be contained within the major stormwater system.

It is extremely difficult to quantify the level of nuisance, as each catchment and each storm event is so different. For a typical residential street, the total rainfall received in a 20 minute Q_2 event is 32mm, while 45mm will fall in a 20 minute Q_5 event – 13mm difference. Over the course of an hour, 55mm will fall in a Q_2 event and 70mm in a Q_5 – a 15mm difference. The affect that this will have on a stormwater system varies greatly depending on recent rainfall behaviour, the rainfall pattern and where it falls within the catchment.

In general, a rainfall event that exceeds the minor system capacity will result in a depth of water at the centreline of the road; up to and including the design capacity there is to be a 0mm depth of water at the centreline of the road. As the chance of the minor system capacity being exceeded each year is increasing from 18% to 39%, there will be water over the centreline of the road more frequently, and the water will be ponded in the road for a longer period of time. The length of time for a Q_5 event to subside into the Q_2 underground system if this proposal is implemented, however, is expected to be minimal.

5.3 Other

5.3.1 Density

The increase in density experienced over the last 5 year is expected to continue leading to an increase in runoff within urban developments and an increased cost in managing stormwater. The reduction of the minor system design event to Q_2 will assist in offsetting these costs from an economics perspective, working towards a balance between cost, growth and level of service. Without this reduction, the increased density and increased runoff would continue to result in increased underground pipe sizes and pit numbers. With overall increased density, however, comes an increased volume of runoff and decreased time of concentration which is not reflected in the current engineering design guidelines.

5.3.2 Design documentation

The decreased volume of stormwater underground will lead to an increased volume above ground (in the order of 15%), requiring a greater level of confidence in the major system design. Therefore, the risk to property and residents is higher if there are errors in the design. To combat this, a minimum level and detail of documentation for Operational Works applications (and indeed renewal construction design) should be set. This will ensure MRC assessment officers are able to assess the adequacy of the design more easily, to help mitigate the risk associated with the major storm flows. The recommended documentation standards have been included in Section 8.

6. Case studies

6.1 General

To avoid the specifics of particular sites, a hypothetical situation has been developed that can be easily adjusted to focus on different considerations. The hypothetical site consists of a single street at a consistent grade with uniformly sized lots that grade to the road frontage. Traffic calming has generally been applied where required to simulate some of the physical constraints. The road was continued as a straight road to allow simplicity and consistency. It is acknowledged that this is not a desirable planning or engineering outcome; however, the focus is on the stormwater design and not the layout.

The stormwater system design was undertaken on each of the case studies, taking into account both minor and major system standards, to ensure that the resulting design mirrored that which would be required in a new subdivision being submitted for Development Approval.

The following case studies were included:

1. Low density, flat site:
15dwlg/ha (630m² lots with 18m frontages), road at 1:500 grade, lots at 1:200.
Comparing Q₅ and Q₂
2. Low density, sloping site:
15dwlg/ha (630m² lots with 18m frontages), road at 1:50 grade, lots at 1:20.
Comparing Q₅ and Q₂
3. Higher density, flat site:
30 dwlg/ha (315m² lots with 9m frontages), road at 1:500 grade, lots at 1:200.
Comparing Q₅ and Q₁₀

The Case Studies can be found in Appendix A, Appendix B and Appendix C.

The following details were adopted across all cases:

- 15m wide Access Street with standard pavement width and configuration;
- Length of road 500m (following a few model runs to test the optimum length for comparison purposes);
- Standard footpath grades, depending on the case topography;
- Road gully style grated stormwater pits, 2.4m lintels;
- Stormwater pit locations at boundaries or mid-lot;
- Free draining outlet, tailwater level at obvert of pipe;
- 600mm standard cover to pipes;
- 250mm maximum flow depth at lip of kerb for flowing water;
- 0mm depth of flow at road centreline during minor events;
- Depth.velocity product 0.4m²/s.

In a real life scenario, a 500m straight road is unlikely. Intersections and adjoining roads would have been encountered in the upper parts of the catchment, including sag points, vertical grade changes, cross-drainage and other issues which introduce complexity into the design. These are very site specific though so they were excluded for the purpose of this comparison. Whilst the modelled scenarios only really look at the top of a catchment, throughout a large-scale development there are several of these catchments working individually, before combining further downstream. Therefore, these results can be considered to emulate situations found multiple times within a larger site, before multiple catchments combine. For small- to mid-scale developments, there are generally only small numbers of catchments similar to these studies.

It is considered that the comparison results would still apply to a real-life scenario, as the focus of this discussion paper is on the differences between the Q₅ and Q₂ situation within the same site.

Mackay Regional Council's 'Estimate and Annexures' estimating spreadsheet was used to determine the construction costs for each case. Overheads, incidentals and non-stormwater based items were ignored to ensure a direct comparison was made for each case.

6.2 Case 1: Low density, flat site

For this low density scenario, lot sizes of approximately 630m² were used. The Q₅ and Q₂ events were modelled in Case 1, including the major Q₁₀₀ event to check the design criteria and its impact on the minor system. The plans showing the layout and design outcome are included in Appendix A.

Notations have been made on the plans showing the extent of earthworks required to ensure no encroachment of the major flow event occurs inside the property boundaries. Notations also show when the pipe size was increased from the minor flow requirements to cater for the major flow requirements.

6.2.1 Design criteria

The design criteria in Table 4 below were used, in accordance with QUDM:

TABLE 4: CASE 1 DESIGN INFORMATION

	Q₅	Q₂
Time of concentration	15 min	15 min
Fraction impervious	0.65	0.65
Minor runoff coefficient	0.79	0.71
Major runoff coefficient	1.0	1.0
Q₁₀₀ max road flow depth at lip of kerb	0.25m	0.25m
Q₁₀₀ max depth.velocity product	0.4m ² /s	0.4m ² /s

6.2.2 Design results

The design for each case shows that increased pit numbers are required for the Q₅ scenario, leading to increased road crossings. Pipe sizes are also consistently a size larger along nearly the entire length of road in the Q₅ scenario. However, earthworks to the lots were required sooner in the Q₂ case to prevent major flow encroachment into the lots. The design was ceased at 500m along the theoretical road where it was considered that adequate comparison results had been given and consistency in the design had been reached. The underground system had reached the point with the Q₂ design where it was necessary to increase pipe sizes to cater for some of the major flow, and both Q₂ and Q₅ scenarios required minor filling to the lots (to a maximum of 30mm) to ensure no major system encroachment occurred within the property boundaries.

The results are included in Table 5 below:

TABLE 5: CASE 1 RESULTS COMPARISON

	Q ₅	Q ₂
Pit spacings (and road crossings)	Every 2.5 lots	Every 3 lots
Pit numbers (over 500m)	22	18
Final pipe size	1200mm dia.*	1050mm dia.*
Metres down road when e/works are required to lots	325m	235m
Earthworks (to prevent major event encroachment)	250m ³	450m ³
Length of pipes:		
375mm	69m	57m
450mm	45m	54m
525mm	45m	54m
600mm	45m	108m
750mm	90m	108m
825mm	45m	54m*
900mm	81m	54m*
1050mm	90m	45m*
1200mm	45m	0m
Total length of pipes	555m	534m
Cumulative volume of pipes (to indicate overall system size)	281m ³	207m ³

* Pipe size increased from minor pipe size requirements, to cater for major flow requirements.

6.2.3 Cost

The design was input into MRC's 'Estimates and Annexures' spreadsheet to produce an estimated construction cost of the pits and pipes. Earthworks to the lots were treated simplistically, assuming the noted depth of earthworks applied, on average, to the entire lot and a rate of \$25/m³ of imported fill was assumed. The costs are included in Table 6 below.

TABLE 6: CASE 1 CONSTRUCTION COST COMPARISON

	Q₅	Q₂
Pipe supply and install cost	\$359,800	\$288,300
Pit supply and install cost	\$106,600	\$86,000
Earthworks supply and place cost	\$6,300	\$11,300
Total	\$472,700	\$385,600

The comparison shows approximately 20% higher costs for a Q₅ minor stormwater system compared to Q₂. For this case study, with 58 lots, this is an average saving of \$1,500 per lot. As the design progressed further down the catchment, it is expected to remain similarly comparative – although possibly with a reduction in the pit number differences. (It could, however, be argued that if additional pits were required downstream for Q₂ to capture the major flow sufficiently, that longer lintels in the gully pits could be used effectively at much less cost than additional pits.)

6.3 Case 2: Low density, sloping site

For this low density scenario, lot sizes of approximately 630m² were used. The Q₅ and Q₂ events were modelled in Case 2, including the major Q₁₀₀ event to check the design criteria and its impact on the minor system. The plans showing the layout and design outcome are included in Appendix B.

Notations have been made on the plans showing when the part of the major surface flows are conveyed in the underground system in the Q₂ scenario to meet the major system criteria, although no upsizing of the pipe size was required at this point as the minor system pipe size was able to handle the additional flow. It is likely that the next pipe reach for Q₂ would require pipe upsizing, and within the next two reaches for Q₅.

6.3.1 Design criteria

The design criteria in Table 7 below were used, in accordance with QUDM:

TABLE 7: CASE 2 DESIGN INFORMATION

	Q₅	Q₂
Time of concentration	13 min	13 min
Fraction impervious	0.65	0.65
Minor runoff coefficient	0.79	0.71
Major runoff coefficient	1.0	1.0
Q₁₀₀ max road flow depth	0.18m*	0.18m
Q₁₀₀ max depth.velocity product	0.4m ² /s	0.4m ² /s

* Maximum flow depth of 180mm was driven by maintaining the d.v factor of 0.4m²/s rather than the maximum allowable depth of 250mm.

6.3.2 Design results

The designs for each case show that the same pit numbers are required for each scenario, leading to the same number of road crossings. Pipe sizes are consistently a size larger along nearly the entire length of road in the Q₅ scenario. No earthworks to the lots were required. The design was ceased at 500m along the theoretical road where it was considered that adequate comparison results had been given and consistency in the design had been reached. The underground system had reached the point with the Q₂ design where some of the major flow needed to be conveyed within the underground system, and it is expected that the size would need to increase at the next reach. It is expected that the same would be necessary for the Q₅ system two reaches along. The results are included in Table 8 below:

TABLE 8: CASE 2 RESULTS COMPARISON

	Q₅	Q₂
Pit spacings (and road crossings)	Every 5 lots	Every 5 lots
Pit numbers (over 500m)	10	10
Final pipe size	750mm dia.	750mm dia.*
Metres down road when e/works are required to lots	NA	NA
Earthworks (to prevent major event encroachment)	nil	nil
Length of pipes:		
375mm	32m	122m
450mm	90m	90m
525mm	90m	90m
600mm	90m	90m
750mm	180m	90m
Total length of pipes	482m	482m
Cumulative volume of pipes (to indicate overall system size)	142m ³	112m ³

* Pipe taking part of the major surface flows, no size increased necessary within the designed area.

6.3.3 Cost

The design was input into MRC's 'Estimates and Annexures' spreadsheet to produce an estimated construction cost of the pits and pipes. The costs are included in Table 9 below.

TABLE 9: CASE 2 CONSTRUCTION COST COMPARISON

	Q₅	Q₂
Pipe supply and install cost	\$252,900	\$212,400
Pit supply and install cost	\$46,900	\$46,900
Earthworks supply and place cost	\$0	\$0
Total	\$299,800	\$259,300

The comparison shows approximately 15% higher construction costs for a Q₅ minor stormwater system compared to Q₂. For this case study, with 58 lots, this is an average saving of \$700 per lot. The overall drainage costs are much lower than those in Case Study 1, hence the lower saving per lot. As the design progressed further down the catchment, it is expected that the pipe sizes in the Q₂ scenario would be required to be upsized to cater for the additional major flow needed to be captured underground to maintain an acceptable depth.velocity product. It is expected that one reach further on, similar would be needed in the Q₅ scenario. Due to the bypass volumes and velocities, the number of pits is expected to remain similar between both scenarios.

6.4 Case 3: Higher density, flat site

For this higher density scenario, lot sizes of approximately 315m² were used (approx. 30 dwlgs/ha), halving the road frontage of the lots in the low density cases. QUDM recommends that densities greater than 20 dwlgs/ha have an underground system designed for Q₁₀. Therefore the current requirement of Q₅ and the proposed requirement of Q₁₀ were modelled in Case 3, including the major Q₁₀₀ event to check the design criteria and its impact on the minor system. The plans showing the layout and design outcome are included in Appendix C.

Notations have been made on the plans showing the extent of earthworks required to ensure no encroachment of the major flow event occurs inside the property boundaries. Notations also show when the part of the major surface flows are conveyed in the underground system in the Q₅ scenario to meet the major system criteria, although no upsizing of the pipe size was required at this point as the minor system pipe size was able to handle the additional flow. It is likely that the next pipe reach for Q₅ would require pipe upsizing.

6.4.1 Design criteria

The design criteria in Table 10 below were used, in accordance with QUDM:

TABLE 10: CASE 3 DESIGN INFORMATION

	Q₁₀	Q₅
Time of concentration	10 min	10 min
Fraction impervious	0.85	0.85
Minor runoff coefficient	0.87	0.83
Major runoff coefficient	1.0	1.0
Q₁₀₀ max road flow depth	0.25m	0.25m
Q₁₀₀ max depth.velocity product	0.4m ² /s	0.4m ² /s

6.4.2 Design results

The designs for each case show that the same pit numbers are required for each scenario, leading to the same number of road crossings. Pipe sizes are consistently a size (or more) larger along nearly the entire length of road in the Q₁₀ scenario. Earthworks to the lots were required sooner in the Q₅ case to prevent major flow encroachment into the lots. The design was ceased at 500m along the theoretical road where it was considered that adequate comparison results had been given and consistency in the design had been reached. The underground system had reached the point with the Q₅ design where some of the major flow needed to be conveyed within the underground system, and it is expected that the size would need to increase at the next reach. It is expected that the same would be necessary for the Q₅ system further down the system, but when that was required is not immediately obvious.

The results are included in Table 11 below:

TABLE 11: CASE 3 RESULTS COMPARISON

	Q₁₀	Q₅
Pit spacings (and road crossings)	Every 2 lots	Every 2 lots
Pit numbers (over 500m)	28	28
Final pipe size	1350mm dia.	1200mm dia.*
Metres down road when e/works are required to lots	380m	270m
Earthworks (to prevent major event encroachment)	140m ³	355m ³
Length of pipes:		
375mm	88m	88m
450mm	36m	36m
525mm	0m	36m
600mm	36m	27m
750mm	54m	63m
825mm	72m	72m
900mm	36m	108m
1050mm	108m	72m
1200mm	108m	72m*
1350mm	36m	0m
Total length of pipes	575m	575m
Cumulative volume of pipes (to indicate overall system size)	378m ³	310m ³

* Pipe taking part of the major surface flows, no size increase necessary within the designed area.

6.4.3 Cost

The design was input into MRC's 'Estimates and Annexures' spreadsheet to produce an estimated construction cost of the pits and pipes. The costs are included in **Error! Reference source not found. Error! Reference source not found..**

TABLE 12: CASE 3 CONSTRUCTION COST COMPARISON

	Q₁₀	Q₅
Pipe supply and install cost	\$447,300	\$385,500
Pit supply and install cost	\$138,000	\$136,800
Earthworks supply and place cost	\$3,500	\$8,900
Total	\$588,800	\$531,200

The comparison shows approximately 10% higher costs for a Q₁₀ minor stormwater system compared to a Q₅ system but with a much higher overall cost compared to lower density

development. For this case study, with 116 lots, this is an average increase of \$500 per lot. The overall drainage costs are much higher than the other cases, as well as the minimum grade of the road; however there are twice as many lots. As the design progresses further down the catchment, it is expected that the pipe sizes in the Q₅ scenario would be required to be upsized to cater for the additional major flow needed to be captured underground to maintain an acceptable flow depth and width. It is not expected to be needed for a while in the Q₁₀ scenario and the pit numbers are expected to remain the same; however, the pit spacing for the Q₁₀ case was at the absolute limit, whilst there was still a degree of flexibility for Q₅.

6.5 Summary and Discussion

The following results can be observed from the three case studies undertaken in Table 13 below:

TABLE 13: SUMMARY OF CASE STUDY RESULTS

	Case 1 (low density, flat)		Case 2 (low density, sloping)		Case 3 (high density, flat)	
	Q ₅	Q ₂	Q ₅	Q ₂	Q ₅	Q ₁₀
Pit spacing	2.5 lots	3 lots	5 lots	5 lots	2 lots	2 lots
Pipe length	555m	534m	481.5m	481.5m	575m	575m
Cumulative pipe volume	281m ³	207m ³	142m ³	112m ³	310m ³	378m ³
Largest pipe size	1200mm dia	1050mm dia	750mm dia	750mm dia	1050mm dia	1200mm dia
Earthworks	250m ³	450m ³	nil	nil	140m ³	355m ³
Overall cost	\$472,680	\$385,576	\$299,834	\$259,315	\$531,235	\$588,781
Cost saving/increase	20% saving (\$1,500/lot)		15% saving (\$700/lot)		10% increase (\$500/lot)	

It can be seen that the most significant cost saving by reducing to Q₂ is achieved in Case 1 on flatter sites, which are traditionally more expensive and more difficult to drain. Over the course of the 58 lots, the saving amounted to an average of \$1,500 per lot. The saving per lot did decrease in Case 2 for the sloping site, where the overall drainage is generally cheaper and easier to achieve. The resulting saving was \$700/lot over the 58 lots. It is estimated that the average construction cost for lots of similar size to those in the Case Studies is in the order of \$50,000 to \$70,000 per lot, resulting in a saving of approximately 2-3% for flat sites, and 1-1.5% for sloping sites.

Case 3 looked at the increase in cost by changing to Q₁₀ from the current Q₅, and resulted in an increase of \$500/lot over the 116 lots that are half the size of the lots in the first two cases. It is estimated that the average construction cost for lots of similar size is \$40,000 per lot, resulting in a saving of approximately 1.5%.

The majority of the cost saving for Cases 1 and 2 is in the pipework, due to the decreased sizes to cater for the lower flows (as demonstrated by the cumulative pipe volume); however, depending on lot frontages, where pit frequencies can be reduced in the Q₂ situation there are significant possible savings. It can be seen that in Case 1, the pits were able to be further apart, reducing the number of pits, the number of road crossings and ultimately the total pipe length. Pits are a comparatively large component of the cost per unit, and any reduction in pit numbers will decrease construction cost. Maintenance is also most prevalent on pits and road crossings, and so maintenance cost will also benefit from reduced pit numbers.

In real life situations intersections, alignment changes and vertical grade changes may require pits at a higher frequency than otherwise needed for hydraulic purposes. However a direct comparison in those situations between Q₅ and Q₂ – particularly for flat sites – is still expected to yield an overall pit number reduction. For sloping sites and high density sites, the difference is less noticeable, but will still depend on the specific situation.

Smaller pipe sizes have a lower capital cost, and also a lower maintenance cost when it comes to relining. Asset renewal cost is obviously also lower for smaller pipes.

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7. Applicability

The benefits of a reduction from Q_5 to Q_2 will only be appreciated if the policy is applied in the correct situations. The following considerations should be made:

1. “No worsening”:

There should be no worsening of any existing areas or systems, thereby requiring the replacement or renewal of an existing system to be done with a system of equal or greater immunity. For example, the replacement of a system in East Mackay that currently has Q_1 capacity with a new system of Q_2 capacity is appropriate; a system in Andergrove that was designed to previous Q_5 standards will need to be replaced with the same (even though that may not be to current Q_5 standards given the current fraction impervious and time of concentration figures that are used);

2. “Infill development”:

When undertaking infill development, consideration needs to be given to existing upstream and downstream systems to ensure an appropriate level of service continues to be achieved by both. The discharge location of the development will be a factor, and if a lower level of immunity for the minor system is proposed, justification needs to be provided that there will be no problems caused either upstream or downstream;

3. “Higher density” increase to Q_{10} :

As highlighted in this discussion paper, the current QUDM standard for residential densities greater than 20dwlg/ha is not currently required by MRC. It is noted that this requirement has existed within QUDM since the first volume released in 1994. Whilst included in the case studies above for the purpose of consistency and comparison, further investigation should be undertaken to determine its applicability within the Mackay region. Issues include

- determining when a development is considered to have a density greater than 20 dwlg/ha (ie is it when the average lot size is 500m² or less, or when there are more than 20 dwellings in a site greater than a hectare in size, is it not considered when the site is less than a hectare in size);
- considering the development as a whole if parts of it are higher density (considering that the underground systems will be interconnected, and that a small upstream pocket of Q_{10} would need to drain through a much larger part of the catchment of Q_5);
- how to deal with downstream systems that may only be designed to Q_5 , if part of the development will be designed to Q_{10} ;
- the benefits in applying a higher degree of immunity for higher density sites;
- increased capital and maintenance costs (thereby going against the purpose of this proposed reduction from Q_5 to Q_2);
- how to deal with detention requirements for higher density infill development, or infill development in higher density areas;
- confirming that the standard will apply to both private and public systems.

4. “Interallotment drainage systems”:

The design of interallotment drainage systems should continue per the current standards until a review of the engineering design guidelines can be undertaken.

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8. Conclusions and Recommendations

Mackay Regional Council has identified the importance of achieving a balance between the critical areas of level of service, economy, and growth. It was recognised that a greater balance between economy and level of service may be achievable within the stormwater drainage system, by reducing the design standard from the current Q₅ requirement to the QUDM recommendation of Q₂. As a result of this investigation into the possible reduction of the minor underground stormwater system standards, the following key outcomes have been identified:

1. Maintain an acceptable level of service to the community with regards to the level and frequency of inundation and nuisance during minor and major storm events (*Level of Service*);
2. Ensure there is a ‘no worsening’ effect on existing areas (*Level of Service*);
3. Reduce capital and asset renewal costs of stormwater pit and pipe infrastructure (*Economy*);
4. Reduce maintenance costs of stormwater pit and pipe infrastructures (*Economy*);
5. Align the region with current industry practices for the design storm events and standardise the design standards across the region (*Growth*);
6. Assist with reducing the impacts of increased density within new developments on stormwater infrastructure costs (*Growth and Economy*).

Whilst reviewing QUDM as part of this paper, it was found that QUDM recommends that underground stormwater drainage systems be designed to cater for a Q₁₀ event (10% AEP) for densities of 20dwlg/ha or greater. Mackay will continue to experience increased density of developments in the future, therefore this density classification needs to be considered. When considering two of the most high density developments in recent times, however, one just exceeded the 20 dwlg/ha (although was only 4.3ha in size) and one didn’t. It is therefore not considered likely that there will be a high number of developments of this density in the foreseeable future.

Following the literature review of QUDM and other local Councils, preparing a number of case studies and analysing the outcomes, and discussions with various members of Development Engineering, Strategic Planning and Civil Operations, the following recommendations are made:

1. Low density residential areas:
 - a. Reduce the minor system design storm event standard from the current 18% AEP (Q₅) to the proposed 39% AEP (Q₂);
 - b. Develop guidelines to specify when the reduction is applicable, to ensure no worsening of existing areas or systems;
 - c. Ensure infill developments are treated properly depending on the upstream and downstream situations, and the discharge location and proximity;
 - d. Develop transitional arrangements for the change with the development industry; and

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- e. Maintain current design standards for interallotment drainage systems until a review of these systems can be undertaken.
2. Higher density residential areas:
 - a. Investigate whether to apply the increased requirement for Q_{10} to densities greater than 20 dwlgs/ha;
 - b. Consider the overall purpose of requiring a higher level of immunity to more dense developments;
 - c. Develop guidelines to specify when a development is considered achieve greater than 20 dwlgs/ha for stormwater drainage purposes, considering that:
 - i. It is unlikely that this density will be achieved over an entire development site of reasonable size in the foreseeable future;
 - ii. It is not practical to apply the requirement to small ‘pockets’ of high density within a larger development, particularly when the higher density site drains through an area of lower density;
 - iii. The location of the outlet will greatly affect the applicability;
 - iv. Whether the system will discharge into an existing or lower-immunity system; and
 - v. Detention may be required in addition to a new underground system.
3. Documentation and design:
 - a. Produce guidelines or design examples showing the minimum required level of documentation to accompany a stormwater design, to allow development assessment officers to be consistent and effective. Following discussions with Engineering Assessment Officers within Development Engineering, these should include, at a minimum:
 - i. Plan view showing visual shading of flooded width, flows in the culvert and flows above ground, and depth.velocity product at critical locations;
 - ii. HEC-RAS tables, or equivalent for other programs;
 - iii. HEC-RAS cross-sections, or equivalent for other programs;
 - iv. Separate minor and major catchment plans; and
 - v. Single page stormwater design report, outlining assumptions and criteria.
 - b. Amend the Engineering Design Guidelines to accurately reflect the current recommendations of QUDM (taking care to ensure references will remain applicable in future QUDM revisions), to form PSP SC6.12-10 Engineering Design Guideline – Stormwater Drainage Design in the new Mackay Region Planning Scheme;
 - c. Revise the typical road hierarchy cross-sections to include the newly adopted standards; and
 - d. Ensure consistent terminology is used throughout the various guidelines and documents to reflect the new preferred terminology (outlined in Section 1.1).

4. Maintenance and asset renewal:

- a. Consider how to improve the quality of newly constructed stormwater systems to assist in reducing the maintenance and renewal costs, as this investigation highlighted the high cost of maintenance and asset renewal as a result of poor construction standards;
- b. Consider reviewing construction specifications for stormwater systems, focussing on pipe joints and pit connections to reduce the instances of joint and connection failures, contributing to high maintenance costs.

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UDIA (Qld) Research Foundation & The National Property Research Co., *The UDIA (Qld) Industry Insights Report*, The Urban Development Institute of Australia (Qld), Brisbane, 2015.

Appendix A
Case Study 1 (low density, flat site)

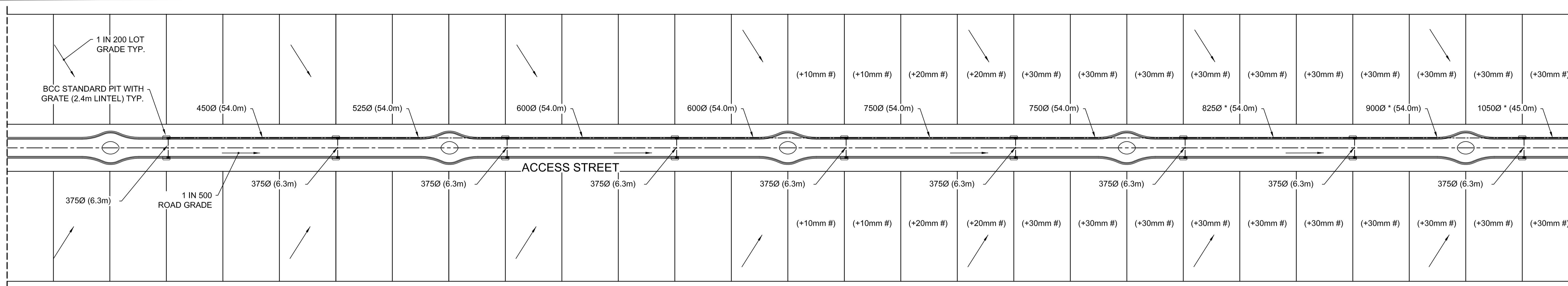
DRAFT

DRAINAGE DESIGN PARAMETERS	
DESIGN AEP (MINOR)	- 39% (1 IN 2 ANNUAL CHANCE)
DESIGN AEP (MAJOR)	- 1% (1 IN 100 ANNUAL CHANCE)
TIME OF CONCENTRATION (Tc)	- 15 min
FRACTION IMPERVIOUS (fi)	- 0.65
RUNOFF COEFFICIENT (39% AEP)	- 0.71
RUNOFF COEFFICIENT (1% AEP)	- 1.0
100 YR ARI ROAD FLOW DEPTH (MAX.)	- 250 mm
100YR ARI DEPTH x VELOCITY (d.v.)	- 0.4 m ² /s

LAYOUT DETAILS	
TYPICAL LOT SIZE	- 18m x 35m, 630m ²
SCENARIO ROAD LENGTH	- APPROX. 500m

ADDITIONAL ALLOTMENT FILLING REQUIREMENT TO CATER FOR MAJOR ROAD FLOWS (250mm MAX FLOW DEPTH)

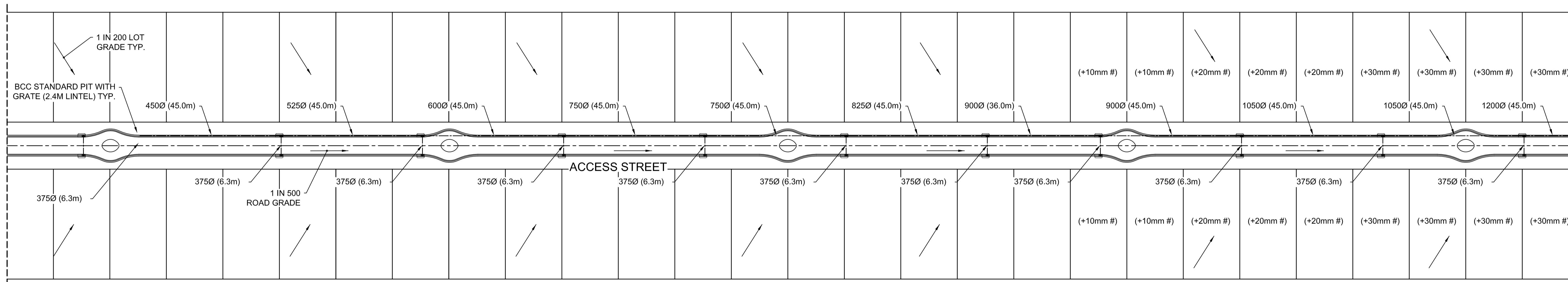
* PIPE SIZE INCREASED TO CATER FOR MAJOR FLOW REQUIREMENTS



**39% AEP (1 IN 2 ANNUAL CHANCE) DRAINAGE SCENARIO
(CURRENT QUDM)**

DRAINAGE DESIGN PARAMETERS	
DESIGN AEP (MINOR)	- 18% (1 IN 5 ANNUAL CHANCE)
DESIGN AEP (MAJOR)	- 1% (1 IN 100 ANNUAL CHANCE)
TIME OF CONCENTRATION (Tc)	- 15 min
FRACTION IMPERVIOUS (fi)	- 0.65
RUNOFF COEFFICIENT (18% AEP)	- 0.79
RUNOFF COEFFICIENT (1% AEP)	- 1.0
100 YR ARI ROAD FLOW DEPTH (MAX.)	- 250 mm
100YR ARI DEPTH x VELOCITY (d.v.)	- 0.4 m ² /s

LAYOUT DETAILS	
TYPICAL LOT SIZE	- 18m x 35m, 630m ²
SCENARIO ROAD LENGTH	- APPROX. 500m



**18% AEP (1 IN 5 ANNUAL CHANCE) DRAINAGE SCENARIO
(CURRENT MRC)**

TO BE READ IN CONJUNCTION WITH DISCUSSION DOCUMENT ON
MINOR STORMWATER SYSTEM STANDARDS FOR RESIDENTIAL
DEVELOPMENT ONLY - NOT A STAND-ALONE PLAN

NO.	DATE	DESCRIPTION	DRAWN	APPROVED	SURVEY	SCALES (A1) N.T.S.	DRAWN J. MCGARRY DESIGNED J. MCGARRY CHECKED C. BECKER MANAGER TECHNICAL SERVICES NOT APPLICABLE G. HAWES	SIGNED JPM SIGNED JPM SIGNED CMB NOT APPLICABLE G. HAWES	DATE 30/06/15 DATE 30/06/15 DATE 30/06/15 DATE 30/06/15	DIRECTOR ENGINEERING AND COMMERCIAL INFRASTRUCTURE NOT APPLICABLE JASON DEVITT DATE
					SURVEY FILE No					
A	30/06/15	ISSUED WITH DISCUSSION DOCUMENT	JPM	-						
		AMENDMENTS AND REVISIONS			FILE NAME : MISCS\SCENARIO DEVELOPMENT\A1-27741					



Q100 DRAINAGE SCENARIOS
39% AEP AND 18% AEP WITH 1 IN 500 ROAD GRADES
LOW DENSITY RESIDENTIAL DEVELOPMENT

SHEET 1 OF 3
WORKS JOB No.
DRAWING No. A1-27741 AMEND. A

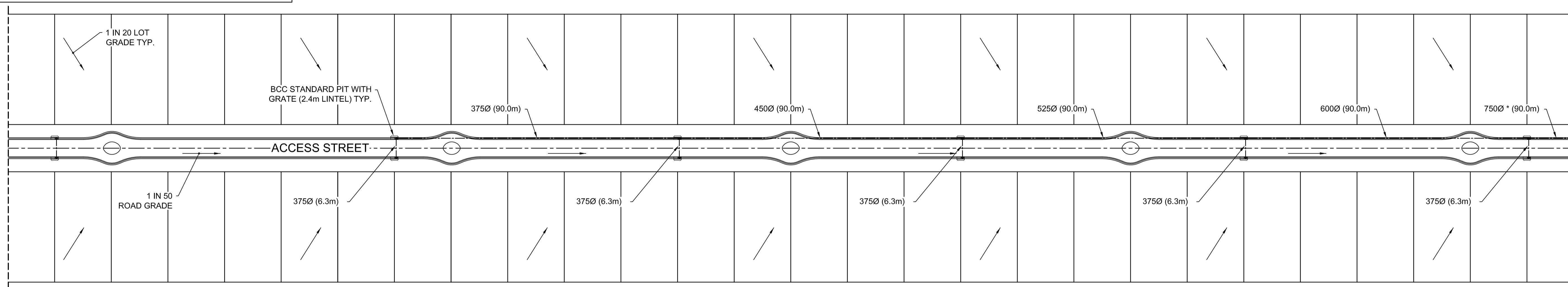
Appendix B
Case Study 2 (low density, sloping site)

DRAFT

<u>DRAINAGE DESIGN PARAMETERS</u>		
DESIGN AEP (MINOR)	-	39% (1 IN 2 ANNUAL CHANCE)
DESIGN AEP (MAJOR)	-	1% (1 IN 100 ANNUAL CHANCE)
TIME OF CONCENTRATION (Tc)	-	13 min
FRACTION IMPERVIOUS (fi)	-	0.65
RUNOFF COEFFICIENT (39% AEP)	-	0.71
RUNOFF COEFFICIENT (1% AEP)	-	1.0
100 YR ARI ROAD FLOW DEPTH (MAX.)	-	180 mm
100YR ARI DEPTH x VELOCITY (d.V)	-	0.4 m ² /s

<u>LAYOUT DETAILS</u>	
TYPICAL LOT SIZE	- 18m x 35m, 630m ²
SCENARIO ROAD LENGTH	- APPROX. 500m

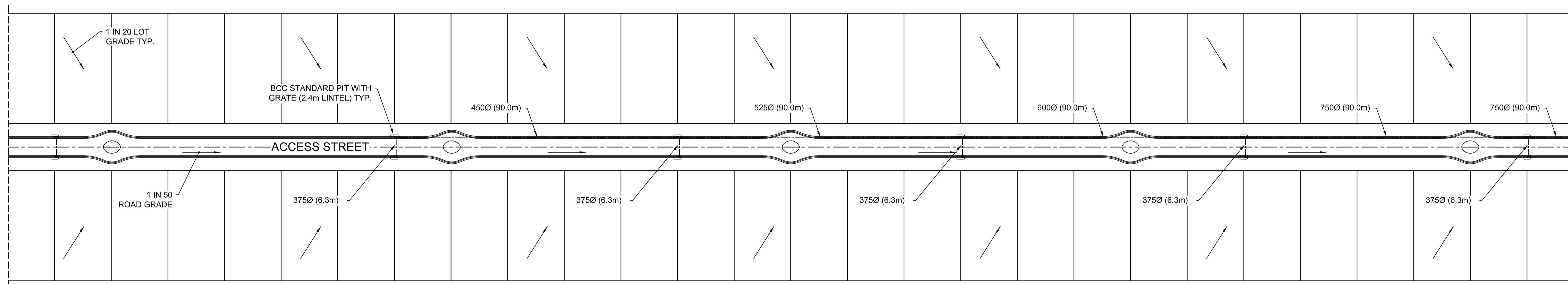
- * PART MAJOR SURFACE FLOWS CONVEYED IN PIPE SYSTEM



39% AEP (1 IN 2 ANNUAL CHANCE) DRAINAGE SCENARIO (CURRENT QUDM)

<u>DRAINAGE DESIGN PARAMETERS</u>		
DESIGN AEP (MINOR)	-	18% (1 IN 5 ANNUAL CHANCE)
DESIGN AEP (MAJOR)	-	1% (1 IN 100 ANNUAL CHANCE)
TIME OF CONCENTRATION (Tc)	-	13 min
FRACTION IMPERVIOUS (fi)	-	0.65
RUNOFF COEFFICIENT (18% AEP)	-	0.79
RUNOFF COEFFICIENT (1% AEP)	-	1.0
100 YR ARI ROAD FLOW DEPTH (MAX.)	-	180 mm
100YR ARI DEPTH x VELOCITY (d.V)	-	0.4 m ² /s

<u>LAYOUT DETAILS</u>	
TYPICAL LOT SIZE	- 18m x 35m, 630m ²
SCENARIO ROAD LENGTH	- APPROX. 500m



18% AEP (1 IN 5 ANNUAL CHANCE) DRAINAGE SCENARIO (CURRENT MRC)

**TO BE READ IN CONJUNCTION WITH DISCUSSION DOCUMENT ON
MINOR STORMWATER SYSTEM STANDARDS FOR RESIDENTIAL
DEVELOPMENT ONLY - NOT A STAND-ALONE PLAN**

					SURVEY	SCALES (A1) N.T.S.
					SURVEY FILE No	
					LEVEL DATUM	
					A.H.D.	
A	30/06/15	ISSUED WITH DISCUSSION DOCUMENT	JPM	-	MERIDIAN	
NO.	DATE	DESCRIPTION	DRAWN	APPROVED	FILE NAME	\\MISC\\SCENARIO DEVELOPMENT\\A1-27742.DWG
AMENDMENTS AND REVISIONS						



Q100 DRAINAGE SCENARIOS

39% AEP AND 18% AEP WITH 1 IN 50 ROAD GRADES

LOW DENSITY RESIDENTIAL DEVELOPMENT

SHEET 2 OF 3
WORKS JOB No.
DRAWING No. AMEND
A1-27742 A

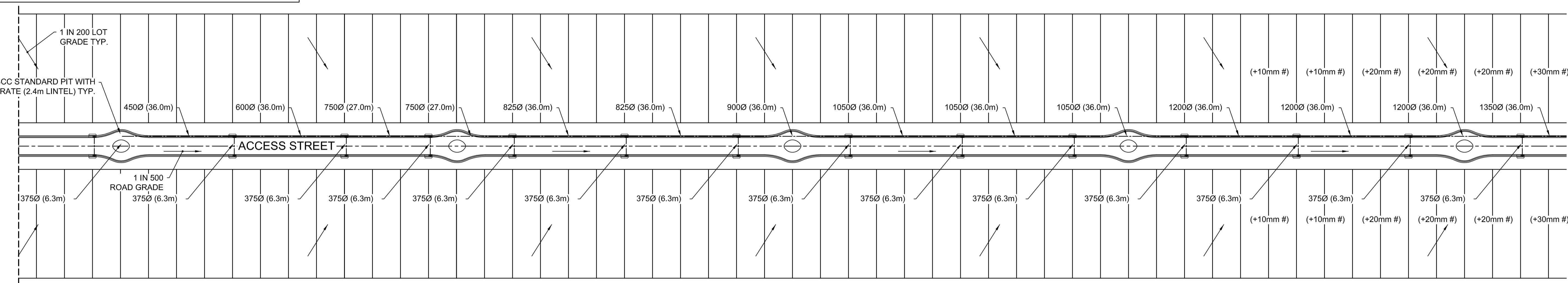
Appendix C
Case Study 3 (high density, flat site)

DRAFT

DRAINAGE DESIGN PARAMETERS	
DESIGN AEP (MINOR)	- 10% (1 IN 10 ANNUAL CHANCE)
DESIGN AEP (MAJOR)	- 1% (1 IN 100 ANNUAL CHANCE)
TIME OF CONCENTRATION (Tc)	- 10 min
FRACTION IMPERVIOUS (fi)	- 0.85
RUNOFF COEFFICIENT (10% AEP)	- 0.87
RUNOFF COEFFICIENT (1% AEP)	- 1.0
100 YR ARI ROAD FLOW DEPTH (MAX.)	- 250 mm
100YR ARI DEPTH x VELOCITY (d.V)	- 0.4 m ² /s

LAYOUT DETAILS	
TYPICAL LOT SIZE	- 9m x 35m, 315m ²
SCENARIO ROAD LENGTH	- APPROX. 500m

ADDITIONAL ALLOTMENT FILLING
REQUIREMENT TO CATER FOR MAJOR
ROAD FLOWS (250mm MAX FLOW DEPTH)



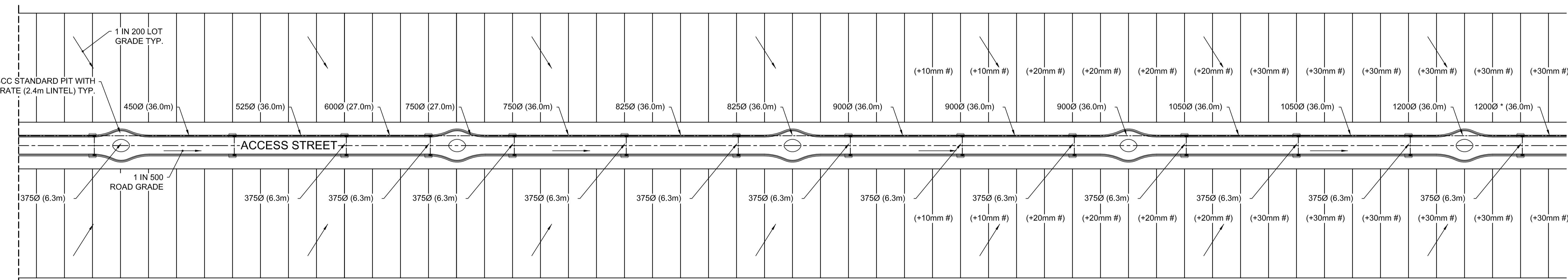
10% AEP (1 IN 10 ANNUAL CHANCE) DRAINAGE SCENARIO (CURRENT QUDM)

DRAINAGE DESIGN PARAMETERS	
DESIGN AEP (MINOR)	- 18% (1 IN 5 ANNUAL CHANCE)
DESIGN AEP (MAJOR)	- 1% (1 IN 100 ANNUAL CHANCE)
TIME OF CONCENTRATION (Tc)	- 10 min
FRACTION IMPERVIOUS (fi)	- 0.85
RUNOFF COEFFICIENT (18% AEP)	- 0.83
RUNOFF COEFFICIENT (1% AEP)	- 1.0
100 YR ARI ROAD FLOW DEPTH (MAX.)	- 250 mm
100YR ARI DEPTH x VELOCITY (d.V)	- 0.4 m ² /s

LAYOUT DETAILS	
TYPICAL LOT SIZE	- 9m x 35m, 315m ²
SCENARIO ROAD LENGTH	- APPROX. 500m

ADDITIONAL ALLOTMENT FILLING
REQUIREMENT TO CATER FOR MAJOR
ROAD FLOWS (250mm MAX FLOW DEPTH)

* PART MAJOR SURFACE FLOWS
CONVEYED IN PIPE SYSTEM



18% AEP (1 IN 5 ANNUAL CHANCE) DRAINAGE SCENARIO (CURRENT MRC)

TO BE READ IN CONJUNCTION WITH DISCUSSION DOCUMENT ON
MINOR STORMWATER SYSTEM STANDARDS FOR RESIDENTIAL
DEVELOPMENT ONLY - NOT A STAND-ALONE PLAN

				SURVEY	SCALES (A1) N.T.S.	DRAWN J. MCGARRY	SIGNED JPM	DATE 30/06/15	DIRECTOR ENGINEERING AND COMMERCIAL INFRASTRUCTURE NOT APPLICABLE JASON DEVITT							
				SURVEY FILE No		DESIGNED J. MCGARRY	SIGNED JPM	DATE 30/06/15								
A	30/06/15	ISSUED WITH DISCUSSION DOCUMENT	JPM	-	LEVEL DATUM A.H.D. MERIDIAN	CHECKED C. BECKER	SIGNED CMB	DATE 30/06/15	MANAGER TECHNICAL SERVICES NOT APPLICABLE G. HAWES							
		DESCRIPTION	DRAWN	APPROVED												
AMENDMENTS AND REVISIONS																
FILE NAME : MISCS/SCENARIO DEVELOPMENT/A1-27743																



Q100 DRAINAGE SCENARIOS
10% AEP AND 18% AEP WITH 1 IN 500 ROAD GRADES
MEDIUM DENSITY RESIDENTIAL DEVELOPMENT

SHEET 3 OF 3
WORKS JOB No.
DRAWING No. A1-27743 AMEND. A