# Application of Low Impact Design to Brownfields Sites

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# Application of Low Impact Design to Brownfield Sites

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Prepared for
Auckland Regional Council

This document has been prepared by Pattle Delamore Partners Ltd in conjunction with Boffa Miskell Ltd.

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# Glossary of Terms and Abbreviations

| | |
|---|---|
| ARC | Auckland Regional Council |
| ARI | Average Recurrence Interval. Refers to the average period between exceedances of a given flow rate or rainfall |
| Benkelman beam | a device used to measure surface deflections of roading/pavement surfaces |
| Geo grid | a flexible plastic soil reinforcing mesh |
| ICMP | Integrated Catchment Management Plan |
| LID | low impact design |
| Site scale | within the boundary of the site being considered |
| Solar gain | increases in the extent and time of sunlight exposure |
| Subsoil | an intermediate layer between topsoil and the underlying soil with some organic content and partially porous because of root intrusion |
| TP10 | Auckland Regional Council Technical Publication 10, 2003. Stormwater Management Devices: Design Guidelines Manual |
| TSS | total suspended solids |
| WCC | Waitakere City Council |
| WDP | Waitakere District Plan |
| WQV | Water Quality Volume – used in TP10 to size treatment device |

# 1 Executive Summary

## 1.1 General

This report summarises the application of stormwater low impact design (LID) principles for sites in the urban environment, and in particular provides a toolbox of methods to assist with the implementation of LID methods on brownfields sites. The report uses quantitative stormwater design objectives for LID methods where they are available so that designers and developers can clearly identify when design objectives have been met.

Information for this report is drawn from both the Auckland Regional Council's Low Impact Design Manual for the Auckland Region, Technical Publication 124 (TP124) and Auckland Regional Council's Stormwater Management Devices: Design Guideline Manual, Technical Publication 10 (TP10). TP124 promotes low impact design as an alternative stormwater management approach for residential land development in greenfield areas. TP10 provides a design method and construction, operation and maintenance guidance for a range of stormwater management devices. The information provided here does not fully replicate the information contained in either of those documents, but rather applies that information in the context of brownfields development to assist the implementation of LID.

The report includes:

1. Discussion of particular issues that face the implementation of LID methods in a brownfields context (Section 3).
2. A flow chart for choosing LID methods within the urban environment (Figure 1).
3. A summary of LID methods applicable to an urban environment (Section 5), using those described in TP124, as well as new tools that have not been widely used in the Auckland region (eg green roofs, tree-pits).
4. A table summarising the issues and constraints relating to the use of LID methods in an urban environment (Table 17).
5. Quantitative measures of hydrological and contaminant removal effectiveness (where available) to assist in choosing appropriate LID methods. In particular a spreadsheet Calculator is provided to assess the hydrological effect of different combinations of LID methods (Section 6).
6. Qualitative measures to determine the relative benefits of LID methods to ecology, landscape amenity, and urban design (Section 6).
7. Case studies from sites that form part of the New Lynn East ICMP-LID study (Section 7).

### 1.1.1 Application of LID to an urban environment

TP124 defines LID as being an alternative approach to site design and development that "protects and incorporates natural site features into erosion and sediment control and stormwater management".

This report relates to the stormwater management component of LID and, specifically, its use in an urban environment.

LID methods replicate processes such as capture and infiltration of stormwater by vegetation, rather than relying on engineering structures and reticulated systems. By changing the types of surfaces that contribute to stormwater runoff or directing stormwater to purpose-built treatment systems that emulate natural processes, LID can mitigate the stormwater effects of impervious areas – with resulting benefits to the receiving environments. There are also potential cost savings where the construction of physical infrastructure is avoided. In an urban environment LID methods, and the natural processes they utilise, may need to be constructed, but even so they have the potential to achieve a more sustainable form of urban development.

TP124 sets out five basic principles associated with effective LID stormwater management. Table 1 below amends these for an urban context.

**Table 1 LID Principles in an urban context**

| | **TP 124 principle (application to greenfields)** | **Application to brownfields** |
|---|---|---|
| 1 | Achieve multiple stormwater management objectives<br>– stormwater management techniques should seek to achieve multiple stormwater management objectives, including both run-off peak-rate and volume control as well as water quality control. | Recognise the catchment, implement locally<br>– the stormwater management methods used on a site should achieve site stormwater objectives and if possible, any catchment wide objectives. The site stormwater objectives primarily relate to; changes to peak run-off rates, water quality control and the introduction of natural systems to the urban environment. |
| 2 | Integrate stormwater management and design early in the site planning process<br>– stormwater management techniques should be designed early and integrated into the conceptual site planning as part of the overall design process. This provides the greatest opportunity for integrating LID into the site design, rather than attempting to retrofit after the fact. | Identify constraints early and integrate design<br>– the scope of re-development and existing constraints may limit the extent to which stormwater management techniques can be integrated into the site. Constraints should be identified early and LID methods integrated into the re-development as part of the overall design process. |

| | TP 124 principle (application to greenfields) | Application to brownfields |
|---|---|---|
| 3 | Prevent rather than mitigate<br>– the most effective stormwater management approach is where a site can be designed so as to reduce impermeable areas, and thus reduce the amount of stormwater generated. | Prevent and mitigate<br>– the functional needs of the site are likely to require some hard surfaces. It may therefore not be possible to fully prevent adverse effects in a brownfields context and therefore prevention and mitigation may both be used. |
| 4 | Manage stormwater as close to the point of origin as possible: minimise collection and conveyance<br>– developing a more natural hydrology for a site can help to reduce the concentration of stormwater and its conveyance in pipes, which can be economically more cost effective (by reducing pipe diameter or eliminating the need for pipes altogether). | Reduce the run-off potential of hard surfaces: use common collection systems where possible<br>– modifying the hydrology of an existing brownfields site may be partially achieved through the use of LID methods that change run-off characteristics. An above ground drainage system may be difficult to achieve given space limitations and the proximity of buildings, but where possible a drainage system should serve multiple buildings. |
| 5 | Rely on natural processes within the soil mantle and the plant community<br>– this recognises the importance of the soil mantle in providing contaminant removal functions through physical processing (filtration), biological processing (microbial action) and chemical processing (cation exchange capacity, other chemical reactions). It also recognises that plants can also provide pollutant uptake/removal functions. | Introduce natural systems and processes<br>– the introduction of natural vegetation provides multiple benefits in terms of contaminant removal and amenity values. Constructed vegetative systems can re-introduce a level of naturalness to the urban environment. |

To achieve catchment objectives, LID methods must be implemented on a site scale and at a sufficient density across the catchment in order to achieve an overall change to catchment hydrology and contaminant loading.

### 1.1.2 Design imperatives

The environmental effects that ARC seek to address through the use of LID methods are wide ranging. They include:

- Water quantity effects such as flooding, drainage system capacity, groundwater recharge.
- Improved aquatic habitat of the receiving environment – through maintenance of physical habitat such as pools and riffles in streams, improved forage and refuge opportunities for wildlife, and enhanced water quality.

- The introduction and preservation of natural character values (green space) in an urban environment along with good urban design.
- Indirectly, reducing effects on water quality in the marine environment.
- The introduction of a greener environment to the city

Urban environments have greater extents of impervious areas (at a site and catchment scale) than greenfields areas, which causes significantly modified hydrology. A fundamental component of a LID approach is to manage the hydrology of the proposed development, so that if possible it matches the pre-development or greenfields hydrology. The extent to which this can be achieved in an urban context varies significantly. However within urban constraints, the general aims for LID should still be to:

- Extend the time that water takes to run off the site and catchment.
- Reduce the overall run-off volume and peak flow rate of stormwater by encouraging the interception of stormwater run-off via processes such as evapo-transpiration and infiltration.
- Manage stormwater contaminants on-site.
- Rehabilitate natural features, including enhancement of landscape amenity values, landscape connectivity, ecological values and urban design.

The normal application of LID methods provides for fewer connections between impervious surfaces and reticulated systems and therefore less concentrated flows to the receiving environment. It also provides for greater use of pervious surfaces and less impervious surfaces overall so that the peak-flow rate, volume of run-off, and the time of concentration after development is maintained at (or as close as possible to) pre-development levels. Methods in the brownfields context include:

- Minimising the use of impervious surfaces – by clustering buildings, stacking building spaces, placing them underground and sharing vehicle accessways.
- Maximising contact with pervious surfaces – infiltration capacity may be limited by compacted soils and/or the reduced time for stormwater to move between a run-off and pervious surface, but can be improved by re-constructing pervious areas of vegetation and planters next to run-off sources and the introduction of larger vegetation to improve evapo-transpiration.
- Rehabilitating the characteristics of existing pervious surfaces – eg soil remediation and revegetation of compacted fill which had limited infiltration and depression storage capacity.
- Modification of impervious surfaces to surfaces that promote depression storage and infiltration – eg localised depressions, pervious pavements and green roofs.

## 1.2 Objectives

In order to meet the design imperatives listed above and measure the effectiveness of a stormwater LID design approach, five stormwater design objectives have been put forward in this report, as follows:

Objective 1: Implementing LID methods that complement overall catchments objectives, if present (eg integrate with ICMP objectives and requirements).

Objective 2: Implementing LID methods that match the 2- and 10-year ARI post-development peak flows to the pre-development peak flows.

And, if downstream flooding is an issue which requires management of larger flows, the 100-year ARI peak flows should also be managed to 80 per cent of the pre-development 100-year peak flow.

Objective 3: Implementing LID methods that reduce the volume of stormwater run-off generated from a site.

Objective 4: Implementing LID methods that reduce contaminant loading from a site (preferably equivalent to 75 per cent removal of Total Suspended Solids).

Objective 5: Providing practical guidance to optimise landscape amenity and natural character values, urban ecology and urban design aspects of LID implementation.

## 1.3 Objective 5

Stormwater management is often seen as a technical subject, but it and LID in particular offer the potential to improve the landscape and amenity values of the community. To encourage this, the report uses Objective 5:

**Providing practical guidance to optimise landscape amenity and natural character values, urban ecology and urban design aspects of LID implementation.**

This objective recognizes the multiple benefits of a LID approach to stormwater management. This is especially the case if LID is adopted in early stages of design when there are opportunities to integrate stormwater infrastructure with the overall design intentions for the site. The ancillary benefits of LID discussed in this report are grouped into recognised areas of practice where there are publicly available sources of information, and practitioners or specialists in the area. They include:

- Urban design
- Crime Prevention Through Environmental Design ("CPTED")
- Energy efficiency
- Ecology
- Landscape amenity.

These areas of practice are discussed in general terms below and a checklist of potential ancillary benefits is provided in Section 5 of this report. For further guidance on these aspects please refer to the ARC's Breathing Space: creating memorable places with living infrastructure.

### 1.3.1 Urban design

The New Zealand Urban Design Protocol is a central government initiative to improve the quality of the urban environment. It sets out seven essential design qualities, known as the "Seven Cs", to initiate quality urban design.
Signatories to the Protocol include central and local government agencies, developers, and design professionals. Further information on the Urban Design Protocol, including the Urban Design Toolkit, is available on the Ministry for the Environment's website, (www.mfe.govt.nz/publications/urban/design-protocol-mar05).

### 1.3.2 Crime Prevention Through Environmental Design

The Ministry of Justice has released a national guideline for Crime Prevention Through Environmental Design in New Zealand (CPTED www.lgnz.co.nz/projects/SocialandCommunityIssues/CPTED/). This guideline sets out seven qualities for well-designed, safer places. The active operation and maintenance of LID methods is also important as it creates the perspective of active community involvement which tends to deter crime.

### 1.3.3 Energy efficiency

Central government has provided two resources to promote the consideration of long-term energy use in development, namely the "Smarter Homes" website for home owners (www.smarterhomes.org.nz/ ) and the "Level" website for developers (www.level.org.nz/).

Householders face increasing costs associated with running a household such as water supply, stormwater and wastewater disposal and electricity charges. Designing households to minimise these issues will become an increasingly key component of marketing a successful development.

On-site stormwater control is a fundamental component of LID practice. Methods which enable a household to collect stormwater provide an additional source of water to the public water supply, and possibly reduce local authority charges to dispose of stormwater.

### 1.3.4 Ecology

An LID approach requires the comprehensive assessment of a development site to determine those areas that are significant natural resources or that perform important functions as ecological systems or processes such as aquifers, areas of vegetation, and wetlands.

Intact ecological systems provide an effective buffer to the receiving environment from peak stormwater flows and stormwater contaminants. They also provide a suite of ancillary benefits such as moderation of dust and noise, landscape amenity, and ecological connections to the wider urban environment.

### 1.3.5 Landscape amenity

A landscape is generally a broad area which has a unique combination of natural elements, such as landforms, vegetation and waterways, and human elements such as buildings and roads. Landscapes can be defined, or discerned by their elements (natural and physical features) and their landscape character (the more intangible "feel" of the landscape).

During re-development a landscape's character will inevitably change. LID provides an opportunity to maintain key landscape amenity values through integrating the built form with natural resources, protecting scenic values through enhancement of an open space framework, and conserving the predominant natural elements that define the character and ultimately the "sense of place" of a site. For example, a rehabilitated natural stream can provide stormwater treatment functions, while also providing for connected open space and natural character values.

If LID methods are constructed with landscape amenity and the overall design values in mind then they are more likely to become a permanent, well maintained feature of developments as landowners are more likely to take pride and stewardship over these facilities.

## 1.4 Structure of this report

This report is divided into sections to match the process used to develop a site development concept. This process is illustrated on the flow chart in Section 4.

Sections 3 and 4 outline the information required to produce a site development concept and the typical constraints to development in a brownfields area.

Section 5 provides an overview of LID methods and how these can be used within a brownfields context.

Opportunities become apparent through the design process including connections with neighbouring properties (eg access, pedestrian paths, parks), optimum solar aspects, infiltration to groundwater, and integrating LID methods with existing and proposed vegetation.

Section 6 provides a means of calculating the trade off between the impervious area of the built form with pervious areas associated with open space and LID infrastructure. In addition, use is made of ARC's Contaminant Load Model and a checklist for Objective 5 is provided. This checklist provides guidance for integrating LID stormwater management with other design objectives to achieve a better quality outcome and added value to the project.

Once the proposed methods have been assessed, a check should be made to see if the design objectives have been achieved. Further iterations of the methods proposed may then occur where the design objectives have not been met.

Section 7 presents two case studies with examples of concept layout designs.

## 1.5 Applicability

This report puts forward concepts for the integration of LID into brownfields site development. While typical issues and opportunities associated with LID methods and potential ways to address and incorporate these into developments have been identified; site owners, developers and professional advisors need to consider the specific issues and opportunities for their particular sites. Professional advice should therefore be sought with respect to the implementation of LID methods on a particular site and detailed design undertaken to ensure all potential issues are addressed.

# 2 Introduction

## 2.1 General

This report summarises the application of stormwater low impact design (LID) principles for sites in the urban environment, and in particular provides a toolbox of methods to assist with the implementation of LID methods on brownfields sites. The report uses quantitative stormwater design objectives for LID methods where they are available so that designers and developers can clearly identify when design objectives have been met.

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# 3 Site Assessment

The first stage of the design in any development or subdivisional project is to identify the major constraints and opportunities of the project.

These will generally fall into:

- Existing natural and built environment.
- Social and cultural environment.
- Regulatory provisions.

A comprehensive assessment of the physical resources of the site (infrastructure, buildings, geology, hydrology and ecology), when coupled with regulatory provisions and any wider constraints for the area provides a base-level of information. These issues must be balanced against the site owner's or developer's objectives to form the preliminary development concept.

There are many issues which may impact on cost in a brownfields context, for example; restricted space, building over services, services relocation, soil disposal, geotechnical stability. These items are highly site specific and therefore the cost of them may vary significantly. This report therefore does not specifically consider costs – as only generic costs would be possible at best and it is considered better to prepare specific costs with knowledge of the specific constraints for a site.

One of the major causes of problems in design development is the failure to identify all of the issues and opportunities early in the design process. "Constraints mapping" is useful to carry out prior to preparing draft concepts. This process allows different site constraints to be identified and overlaid to identify areas on-site which are most suitable for development (due to there being the least number of constraints). This process may also illustrate potential opportunities for the site eg integrating site uses and connections to external community facilities.

Once concepts have been through initial iterations, project viability decisions are made and the selected concept is divided into detailed design packages. The addition of further constraints or objectives in later design stages can affect project viability and result in a sub-optimal design and time delays. This can substantially increase the cost of a project.

Consideration should be given to the statutory and planning framework to ensure that foundations are laid at pre-design stage for a development proposal which will meet statutory requirements. Regulators have an important role to play at this stage. It is important regulators are able to clearly identify regulatory constraints early in the concept design phases and any is ambiguity is clarified. Early discussions with regulators – before the development of concept plans and lodging consent applications – is vital.

Developing a concept development plan requires; information to be gathered to identify constraints and opportunities (refer Sections 3 and 4, a knowledge of the appropriate LID methods available (refer Section 5) and a means of combining them to identify a preferred suite of methods (refer Section 6). As shown on the flow chart in Figure 1, this process of integrating LID methods into the concept design is likely to be iterative because it requires compromise between competing objectives and constraints.

## 3.1 Existing natural and built environment

The re-development of urban sites is usually more complex than greenfields sites because of historic land uses and existing modifications to the environment.

Some of the common environmental issues associated with re-development projects are listed below:

- Services – the levels and positions of existing drainage systems may conflict with the desired position and depth of new infrastructure and the development.
- Access to the site (eg width, gradients).
- Not exceeding the capacity limits of existing stormwater and wastewater drainage.
- Providing for floodplains and overland flow paths.
- Slope stability and geotechnical issues.
- Contaminated soils.
- Maintaining the quality and recharge of aquifers.
- Maintaining landscape character elements and existing landscape amenity.
- Significant/protected landscapes, geological features, and landforms.
- Protecting existing vegetation and habitats, including ecological connections through the landscape.
- Retaining and enhancing existing watercourses and wetland environments.

Table 2 (below) provides a list of site specific information that is useful to identify such potential environmental issues. Specific site investigation and analysis may then be required to check these at a more detailed level.

**Table 2**

Sources for site specific information

| Information | Possible sources | Used for |
|---|---|---|
| Topography | District LIDAR data, specific survey. | Slope, aspect, contributing catchment, flow paths, time of concentration and detention sites. |
| Aerial photographs | District GIS databases. Photographs available commercially from Terralink, New Zealand Aerial Mapping Ltd, Aerial Surveys. | Extent of existing vegetation and impervious surfaces. |
| Terrestrial environments | Site surveys, regional and District Plan maps, Protected Natural Area surveys, management plans, district ecological surveys, conservation management strategies. | Potential for overland flow to vegetation, potential ecological effects and landscape connections. |
| Freshwater environments | Site surveys, freshwater fish databases, Regional Plan: Air, Land & Water, ARC State of the Environment reports. | Important aquifers, potential effects to freshwater ecology, and potential enhancement of freshwater resources to detain and treat stormwater. |
| Coastal environment | Regional Plan: Coastal, Regional Discharges Project sediment quality and ecological monitoring, ARC State of the Environment reports. | Identifying the need for contaminant reduction objectives. |
| Landscape character | Regional Policy Statement maps, District Landscape Assessments, District Plan maps, Open Space Strategy. | Protection and enhancement of landscape character values and visual amenity. Potential landscape and visual effects. |
| Drainage systems | District service sheets and GIS databases. | Identifying tie-in points and existing stormwater or wastewater capacity. |
| Catchment management | Integrated Catchment Management Plans, Catchment Management Plans, network discharge consents. | Setting site objectives, identifying catchment wide constraints. |
| Existing services | Local authority and utility service sheets. | Identifying physical constraints. |
| Infiltration rates | Site specific tests. | Potential for infiltration LID methods to complement stormwater detention. |
| Soils | Land Information New Zealand, geological maps, site boreholes. | Identifying areas that are ideal for development or re-vegetation. |
| Hazards (eg flooding, stability, contamination etc .) | District hazard registers. | Miscellaneous constraints. |
| Catchment hydrology (peak flows, flood levels) | Integrated Catchment Management Plans, flood studies, user specific assessment. | Identifying potential effects on the downstream environment, drainage systems, drainage capacity. |
| Overland flow paths | Integrated Catchment Management Plans, flood studies, site inspections. | Identifying restrictions to development. |

## 3.2 Existing social and cultural context

The re-development of urban sites occurs within the context of existing land use and is usually more complex than greenfield sites because of additional constraints, and perceptions of the existing community. Re-development is often constrained by community expectations for specific land use types and building forms. Construction phases can be restricted by effects to roading networks and adjacent land parcels.

Awareness of the existing social and community context will allow the development form to pre-empt community planning objectives, respond to any potential community concerns, and optimise market demand for the product and/or service that re-development seeks to provide. Some of the common social and cultural issues associated with re-development projects are listed in Table 3 below.

**Table 3**

Social and cultural context

| **Issue** | **Possible information sources** | **Used for** |
|---|---|---|
| Community facilities | District Plan maps and websites. | Potential to augment community services or to utilise existing facilities. |
| Educational facilities | Ministry of Education, Education Review Office, District Plan maps. | Community planning for connectivity to schools while protecting private property. |
| Useable open space | District Plan maps, Open Space Strategy, and District GIS databases. | Open space planning. Landscape amenity values. |
| Landscape character values | Regional Policy Statement maps, District Landscape Assessments, District Plan maps, Open Space Strategy. | Protection and enhancement of landscape character values and visual amenity. Potential landscape and visual effects. |
| Neighbourhood character values | Community perception studies. LTCCP Neighbourhood Plans. | Neighbourhood context for density and building form. Correlation with existing community planning objectives. |
| Transportation | District and Regional transport planning documents. District Plan maps and Structure Plans. | Coincidence of the site with future proposed roading networks, potential future changes to roading hierarchies, mass transit systems, and pedestrian and recreational open space corridors. |
| Heritage sites | Local authority GIS databases, New Zealand Historic Places Trust (pre 1900), Local authority iwi liaison. Engagement with Tangata Whenua. | Identifying potential effects on protected features and taonga. Potential design responses to heritage character elements. |
| Demographics | Statistics New Zealand and District community planning. | Determines community composition including job sector, levels of employment, and age cohort to guide the product of the re-development based on community requirements and |

| Issue | Possible information sources | Used for |
|---|---|---|
| | | market demand. |
| Land values | Council websites. Current valuations and rate prices | Determines target market and minimum yields for break-even. |
| Future potential projects | District LTCCP, annual plans, District Plans and Structure Plans. Discussions with planning officers. | Potential reverse sensitivity issues from future proposed land use. Also possibilities to integrate within proposed future urban structure |
| Community objectives | LTCCP Neighbourhood Plans. Engagement with Tangata Whenua and Community Boards, neighbours and local community groups. | Pre-empt community concerns and fulfil community aspirations. |
| Crime Prevention Through Environmental Design (CPTED) | CPTED guidelines as they relate to district planning provisions or to specific structure or area plans. | Provide for crime prevention within the interior of the site and the potential for passive surveillance to and from the site to deter crime. |

## 3.3 Regulatory Provisions

The re-development of an urban site requires careful analysis from a regulatory perspective, due to both the rehabilitative component of the work and the context of intensive human activity which characterises existing urban areas, particularly where these areas are being intensified.

Regardless of the LID approach to the project, the policy and regulatory framework of the project should be thoroughly understood during the concept design phase. This involves review of growth strategies, policy statements, the district plan and other planning and urban design guidelines. The documents are likely to indicate the direction of the approach.

Local Authority Engineering Codes of Practice and other technical and engineering documents will provide more detailed guidance on the requirements of infrastructure and are often a "how to" guide for the more strategic statutory planning documents. These requirements, may however, conflict with the requirements of LID methods- and, if so, it will be necessary to find a compromise between the two.

A key factor is to have early and regular discussions with regulatory authority staff to reduce the risk of consenting issues delaying the design process. Minutes should be kept and circulated of all such meetings particularly when technical guidance or regulatory interpretation is provided.

Table 4 provides an overview summary of common regulatory issues that may arise in formulating a LID approach for a brownfield site.

**Table 4 Potential Regulatory Issues**

| Issue | Possible sources |
|---|---|
| The impact of the LID approach on development controls to prevent effect to neighbouring properties (eg side yards widths, height in relation to boundary, noise). | District Plan. |
| Compliance with rules regarding overall lot configuration (eg minimum lot sizes and accessway widths). | District Plan rules or Local Authority Code of Subdivision/Infrastructure Standards. |
| Overall density provisions – noting that in a brownfield area subject to intensification this may be a minimum number of lots/units rather than a maximum number. | District Plan rules. |
| Provision of sufficient parking spaces (again noting that in some brownfield areas rationalisation of carparking spaces and provision for alternative modes of transport may be desired by the regulatory authority). | District Plan rules. |
| Complying with minimum permeable to or maximum impermeable surface standards. | District Plan rules. |
| Providing for adequate amenity and privacy in areas of residential intensification, particularly outdoor amenity areas. | District Plan rules. |
| Servicing (ie water supply, sewage and stormwater systems). | District Plan or Local Authority Code of Subdivision/Infrastructure Standards. |
| Site contamination and rehabilitation (often required to be resolved before development work can commence). | Regional Plan. |
| Providing for the passage of flood flows and overland flow paths; addressing natural hazard issues. | Building Code, Regional Plan, District Plan, Local Authority Code of Subdivision/Infrastructure Standards. |
| Protecting existing buildings (eg heritage) and site features (eg trees) | District Plan rules. |
| Stormwater discharges. | Regional Plan. |
| Traffic volume increase. | District Plan. |
| Construction issues such as earthworks and sediment control. | District Plan, Regional Plan. |

# 4 LID Concept Design

Following a comprehensive site assessment (detailed in Section 3), the design team will have sufficient information to accurately describe the opportunities and constraints inherent for the subject site.

This section of the document outlines the subsequent approach to progress a site assessment to concept design:

1. Determine the project/development objectives.
2. Map the constraints of the subject site.
3. Prepare a "Spatial Development Framework'.

## 4.1 Determine project/development objectives

Engaging in open discussions between the client and consultants will provide a common understanding of the individual and collective objectives to the project team members. In this way, the clients' objectives for the development are met, the environmental objectives regulated by regulators are attained, and there is scope for innovative design solutions from the project team. Example objectives may include:

**Table 5**

Example objects

| **Client objectives** | **Regulatory environmental objectives** | **Project team's LID objectives** |
|---|---|---|
| Sustainable development. | Protection of the environment. | Innovative solution that conforms to guidelines. |
| Minimum number of residential units (or equivalents) required for the project to be viable. | Clustered units with minimum impervious cover. | Efficient and appropriate use of space and layout. |
| Vision or legacy for the project. | Responsive to community, district, and regional plan objectives. | Sustainable and innovative designs. |

There are a wide range of outcomes a client may seek to achieve, but primary objectives tend to relate to project viability and operational need. Most other objectives then relate to the form and staging of the development.

There are usually opportunities to incorporate a "sustainable" design approach aimed at adding value to individual sites and providing for an integrated proposition for the site as a whole. "Sustainable development" may have a marketing advantage through providing for efficient use of the site and/or achieving multiple objectives to reduce operational costs (eg re-use of stormwater reduces water supply costs, and open space requirements may be combined with stormwater treatment).

## 4.2 Map constraints

The constraints mapping process involves extracting the various layers described in Section 3 above, to provide a means to interpret the site and represent its development potential. Absolute constraints such as protected watercourses, geotechnically unstable areas, archaeological sites of merit, protected trees etc are identified. In some instances constraints could vary according to district plan requirements relating to things like building setbacks and access road widths. Likewise the requirements for stormwater management will vary according to the level of imperviousness etc that results from design iterations.

The constraints mapping process provides for those constraints that are absolute or that require a specific design approach (eg specific architectural and engineering responses to building on steep sites).

## 4.3 Prepare a Spatial Development Framework

The "Spatial Development Framework" is a way of representing the built development pattern supported by an integrated framework of unbuilt landscape elements.

The Spatial Development Framework should be of a sufficient level of detail to determine the potential form and locations of LID methods and how these will be integrated into the master plan of future development. The process to follow is:

1. Identify dominant features that determine development form

   In some circumstances there are features that define and/or connect the various elements of a site and therefore dictate a distinct development form. For example, dominant landforms or stream corridors are often associated with a specific development form or open space type; aspect and slope may lead to distinct patterns of roading and built development. These features often contribute to a "sense of place" that contributes to a unique environment for a development.

2. Determine relative density/building coverage from constraints mapping

   The constraints mapping process will determine those areas that are optimal for development, those that have partial constraints and those that have absolute constraints. For example, flat areas of land with good aspect and existing access may be ideal areas to cluster development, whereas gullies or steep slopes may require a more expensive design approach relating to earthworks or building form responses. In these cases, density or building coverage may be lessened in order to provide for a different product, relating to larger lots or areas of landscape enhancement.

It is important to consider community stakeholders at an early stage to ensure their concerns are adequately addressed and project viability is not compromised.

3. Integrate the site through an environmental enhancement framework

   Within the Spatial Development Framework, some areas of a site may clearly be optimal for development, while others may have to be retired (eg capping a contaminated site, planting a steep hillside, or buffering a high value natural area such as the Waitakere Foothills). There are further areas that represent neither optimal development locations nor absolute constraints. These areas represent opportunities for infrastructure, particular the provision of "ecological infrastructure" and LID approaches. For example, a gully that acts as an overland flow path may connect open spaces within the site, provide for landscape amenity when planted, and treat stormwater through a series of LID methods.

   In this way, stormwater management areas can be based in marginal land areas (gullies, ephemeral streams, roadside verges, lower catchment slopes) yet contribute to the overall environmental enhancement framework of the proposed development, including streetscapes, mitigation planting, and structure planting.

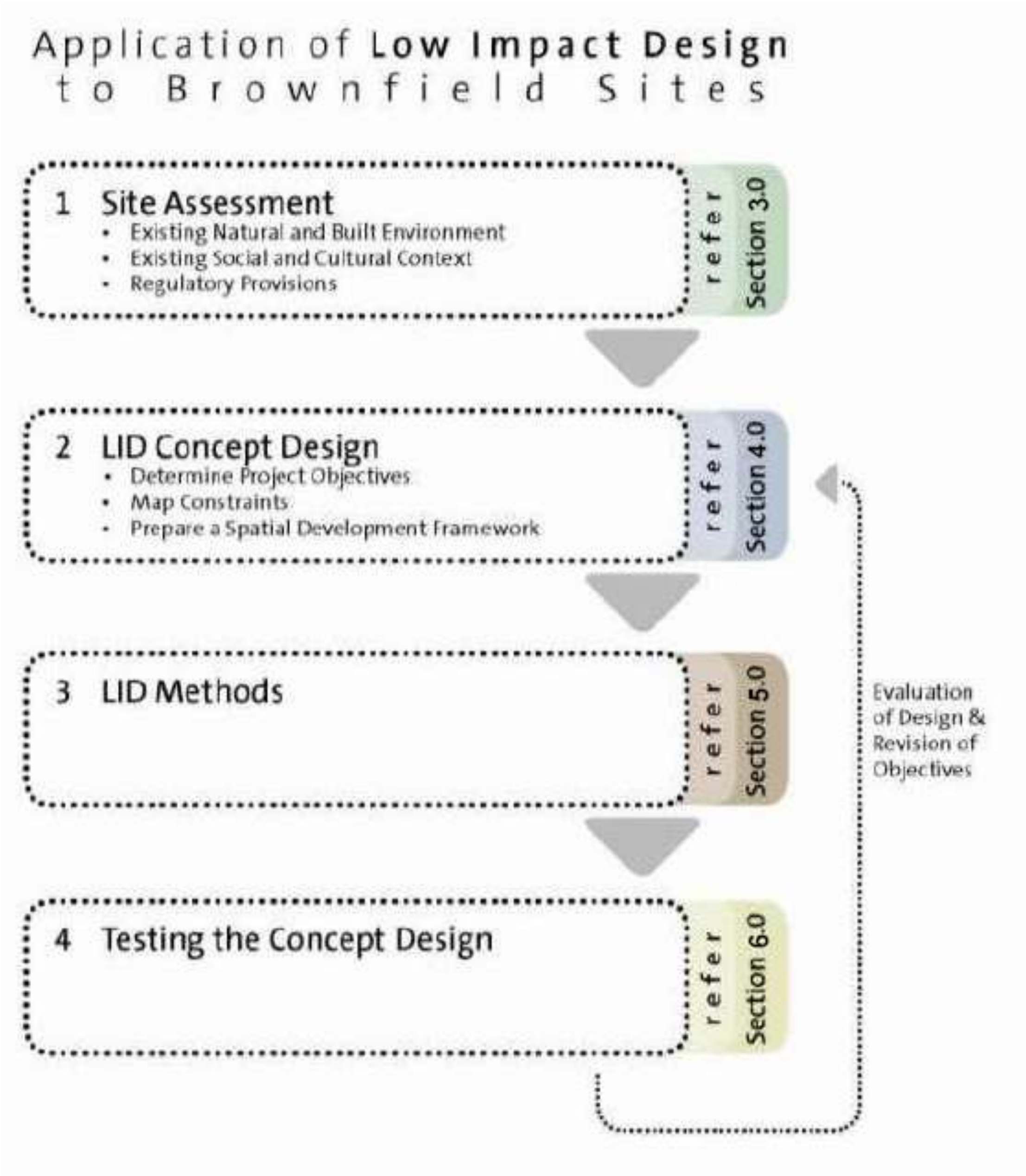
4. Design iterations and their relationship to LID methods

   With the Spatial Development Framework providing preliminary layout options, design iterations can provide for the yield of units/buildings and requirement for access and parking. This will start to define the "footprint" of development and the expectant impervious surfaces that will result.

   LID methods can be applied as appropriate to reduce the extent of impervious area within specific land use activities, including development and transport infrastructure. These will also contribute to the environmental enhancement framework of the site and the ultimate character of the development.

   Through design re-iterations, the proposed development form and the extent of impervious surfaces will vary. This will modify the potential post-development hydrology. Selection of the most appropriate LID method will depend on specific constraints, hydrologic requirements, proposed "treatment trains', and overlap with other objectives for the project. Description of LID methods and their applicability to specific situations is provided in the following Section 5.

**Figure 1 Implementing LID for Brownfield sites**



# 5 LID Methods

## 5.1 Overview

The following sub-sections provide an introduction to different LID methods and their application to a brownfields environment. Key issues and opportunities associated with each method are summarised in a table and at least one case study is presented relating to their implementation. In most cases the case studies use examples of the methods implemented in Auckland and illustrate issues such as project initiation, construction and operation. Often two case studies are presented to illustrate different aspects of implementation.

Design issues have been summarised rather than addressed in detail. For further assistance in design procedures, the reader is referred to relevant local design guidelines. This avoids repetition and it is intended that existing design guidelines continue to be updated and republished rather than replacing selected methods with this document. ARC's TP10: Stormwater Management Devices: Design Guidelines Manual (2003) provides the majority of guidance in this regard but other key documents include the NSCC/RDC/WCC Permeable Pavements Design Guidelines (2004) and NSCC's Bioretention Guidelines (2008).

Table 6 summarises the types of LID methods included in this guideline.

Case studies for each type of LID method are presented in Appendix 1 and a conceptual standard drawing for each method except Reducing Impervious Area is included in Appendix 2.

Table 6 LID methods utilised in this guideline

| **LID methods** | **Definition** | **Stormwater management benefits** | **Quantification** |
|---|---|---|---|
| Minimising building footprints and impervious areas | Reducing impervious area to a practical minimum – eg the use of smaller building footprints and reduction in road widths . | Limits soil disturbance and allows storm flows to more closely approximate the natural hydrological regime. Maximises open space areas and landscape amenity values. | Reduced impervious area and hence flow/volume in hydrological calculations. |
| Clustering developments | Placing buildings together or amalgamating impervious areas so as to reduce overall impervious area. | Minimises site disturbance, infrastructure, and impervious surfaces, and maximises open space areas. Allows for natural infiltration and reduces stormwater run-off rates. | Reduced impervious area and hence flow/volume in hydrological calculations. |
| Green roofs (extensive and intensive) | Roofs supporting a soil media and plants.<br>An extensive roof is defined as less than 150 mm thick, and an intensive roof is greater than 150 mm thick. | Reduces stormwater run-off rate, and provides stormwater quality treatment. Can have landscape and ecological benefits, as well as providing insulation (heating/cooling and noise) benefits for the building. | Hydrological benefits of green roofs are still being quantified as curve number (CN) values can vary significantly depending upon the size of the storm. Auckland University is investigating this aspect on behalf of the ARC. It is hoped that more accurate CN values will become available in the medium-term. |
| Permeable paving | Permeable paving infiltrates water through gaps between the pavers which are filled with aggregate a low fines aggregate.<br>Porous paving infiltrates water through pores in the surface material itself (i.e. the paver/ surface is constructed using a “no fines” coarse granular material). | Provides for infiltration, and increases the time of concentration thereby reducing stormwater run-off rates. Improvement to detention can also be made by incorporating aggregate with a high void ratio or detention cells below the pavement. | A curve number of 92 is used for permeable paving. (NSCC/WCC/RDC, 2004). |

| LID methods | Definition | Stormwater management benefits | Quantification |
|---|---|---|---|
| Rehabilitating soil structure and density | Conditioning and dis-aggregation of compacted surficial soils to reduce density and improve infiltration characteristics. | Improves infiltration, and reduces stormwater run-off rates. Improves soils pollutant adsorption and bio-filtration rates, and provides for improved plant growth and robustness. | A curve number equivalent to pre-development pervious soils. |
| Bio-retention areas (tree-pits/planter boxes, rain gardens, swales/vegetative filter strips) | A pervious area which stores or ponds water and then filters it through organic media.<br>Swales convey, rather than store, water. Some infiltration occurs through the base of the swale while water is present. | Reduced stormwater run-off rates, increased time of concentration, replaces pipe infrastructure with surface water flows, and provides stormwater quality treatment. Provides landscape amenity, ecological benefits, and ancillary benefits including dust interception and temperature moderation. | Contaminant benefits are assessed using design methods in ARC TP10.<br>If specific storage is included some hydrological benefit can be obtained- this requires specific hydrological modelling. |
| Detention (rain tanks, above ground) | An area or device which receives and stores water and then releases it at a slower rate. | Reduces stormwater run-off rate. Allows fornon-potable water re-use on site, eg irrigation, toilet flushing, laundry. | Hydrological benefits are modelled using standard flood routing techniques. |

## 5.2 Reducing impervious areas

### 5.2.1 Description

Reducing impervious areas can be achieved in many places across a development by combining usable spaces, or changing the type of surface to reduce the run-off generated and allow for natural infiltration rates.

The method can be applied to all types of development. It simply requires careful thinking about the need for, and size of, a given impervious surface – can it be reduced while maintaining its functionality?

**Figure 2**: Reduced street width at Talbot Park

Reduced impervious area reduces peak run-off flow rates and volumes from the site, allows infiltration to occur and potentially reduces the amount of contaminants in run-off. This can have a range of benefits by reducing potential flooding, required pipe sizes and treatment devices.

Reducing impervious area requires consideration of the footprint size of buildings, verandahs, paved areas and road widths. Some common methods for reducing the extent of impervious area are:

- designing buildings with smaller setback distances from roads to reduce driveway lengths;
- reducing road widths;
- increasing the number of storeys a building has instead of increasing the building footprint;
- providing garaging underneath a building to reduce roof areas; and
- sharing driveways and access lanes.

In conjunction with this, consider clustering buildings, conveying run-off from existing impervious surfaces to pervious areas, and changing the characteristics of the paving (refer to sections on Porous Paving and Green roofs) to reduce run-off.

Reducing impervious areas allows for more open space – with the result being an increase in natural character and landscape amenity values. Less impervious area also reduces a potential source of reflectant heat and dust.

Further guidance on reducing impervious areas is available in the ARC's TP124 Low Impact Design Guidelines for the Auckland Region. Note that each local authority in Auckland has an Engineering Code of Practice that sets out minimum standards for subdivision and engineering design. These codes often include minimum road widths.

### 5.2.2 Use within a brownfields context

Most impervious surfaces in brownfields area serve a function or meet a need- buildings, parking and access ways. It can be difficult to imagine how to actually reduce impervious area in a city. But, it is important to remember that often structures and impervious areas have been gradually added to a site over time and just because they are there, doesn't mean that they are still needed. Site re-development and building alterations offer a chance to consider which parts of a site or building are still required for the current and future uses. If existing impervious areas are no longer required for their original use, they can be redeveloped into pervious areas and used for landscaping and amenity purposes. If they are needed, but only infrequently, it may be acceptable to try an alternative impervious surface such as a reinforced grass parking area or permeable pavement – preserving their function, but reducing their hydrological impact.

Certain soils can limit water infiltration. Clayey soils, such as the East Coast Bays formation and Tauranga Group alluvium around much of Auckland do not have high infiltration rates. Prior to development, these sediments were overlain by topsoil and subsoil (an intermediate layer between topsoil and the underlying substratum with some organic content and can be partially porous because of root intrusion). Topsoil and subsoil act as a sponge to store infiltrate water. An important part of rehabilitating impervious areas is to try and recreate topsoil and subsoil layers to promote infiltration.

When rehabilitating impervious areas, remember that there may be foundations for nearby structures, compacted basecourse for roads or simply compacted soils below the impervious area. It may be useful to re-condition the soil at the same time (refer Section 4.4). This usually consists of loosening the soil with a rotary hoe or ripper and adding compost to improve water retention. When rehabilitating soils adequate set back distances from existing structures should be used to prevent damage.

### 5.2.3 Implementation issues and opportunities in a brownfields context

The particular issues and opportunities related to reducing impervious areas are summarised in Table 7 below.

Table 7 Issues with reducing impervious area

| Issue | Solution |
|---|---|
| **General** | |
| Why should I not use (or remove) impervious surfaces from my site? The soil is clay and nothing's going to soak into it. | Clay soils do limit the amount of infiltration that can occur – but, originally there would have been layers of topsoil and subsoil over the clay which would have acted as a sponge to store some water while a degree of infiltration occurred. This subsoil layer can be recreated by removing impervious areas and reconditioning the soil. |
| Emergency services access, rubbish trucks all need wide streets to operate on. | The main obstacles for these vehicles are wide turning requirements and problems if parking is allowed on the reduced width road.<br>Use no parking restrictions on the road itself. Try a one way system to allow the road to loop and avoid the need for turning.<br>Remember that narrow streets play an important role in traffic calming and this is an important part of making a pedestrian friendly neighbourhood. |
| Narrow roads mean there is no parking available for visitors. | Install intermittent parking bays for visitors to be shared among the residents. |
| Engineering standards are often prescriptive and prevent the use of reduced road widths. | Remember that narrow streets play an important role in traffic calming and this is an important part of making a pedestrian friendly neighbourhood. A reduced road width is a key method of calming traffic<br>Identify a council champion for LID who will assist in the development process |
| Impervious area creep – following subdivision and development new owners often want to make the place their own, adding new paved areas, paths, sheds. | It's important to try and identify the needs of the future occupiers as well as possible and meet those needs. If outside living areas are carefully designed, integrated and built up front with the development, some impervious creep can be avoided.<br>For future occupiers – try and identify what you really want up front and if possible get these needs incorporated into the design.<br>If impervious areas are added, try grouping (clustering) them). |
| Hard shoulders for impervious areas extend beyond edge of the impervious area to form a foundation – the foundations can easily cover parts of the "pervious areas" on a site. | This effect is reduced if impervious areas are grouped together – as in the clustering approach. |
| Impervious areas are required because they service a functional need. | Try the clustering approach of stacking units and putting carparking underground.<br>Try changing the surface type – eg using permeable paving for low traffic volume roads or a green roof instead of a standard roof (refer Sections 4.5 and 4.6).<br>Remember to protect the green areas that have been created from future development or impervious area creep. |

| Issue | Solution |
|---|---|
| **Retrofitting** | |
| Existing impervious surfaces have a functional need – such as driveways, roofs. | Try changing the surface type – eg using permeable paving for low traffic volume roads or a green roof instead of a standard roof (refer Section 4.5 and 4.6).<br>Try other methods such as rain tanks or filter strips. |
| Existing impervious areas are insufficient – people already park on the grass. | Grass areas can become compacted by frequent vehicle use. If parking is allowed to occur, try changing the grass areas to a reinforced grass area or granular pervious pavement.<br>If parking is not meant to occur, try using bollards as barriers or changing the grass to landscaping to prevent parking occurring. |
| Even small areas can present a chance to reduce impervious areas. | Try things like:<br>Driveways made of two strips of concrete instead of the full width;<br>pebble pathways;<br>stepping stone pathways; and<br>designing new impervious areas to integrate close to the existing impervious area of the house (intra site clustering). |

## 5.3 Clustering

### 5.3.1 Description

Clustering is a form of development where buildings are sited close together or are combined. This is different to conventional lot layouts that use standard sizes, setbacks and are widely spaced. Clustering allows for preservation of existing site resources, provision of larger communal open spaces, and reduction in the extent of impervious areas.

A comprehensive site assessment, including constraints mapping, identifies the most appropriate location for built form and increased density, and recognises the site resources with existing values for stormwater management such as aquifers, gullies, and floodplains. The combination of natural drainage patterns and a larger balance of open space (areas outside of clustered building envelopes) provide for increased opportunities for stormwater quality treatment, infiltration, dispersed overland flow, and extended detention. The use of larger open space areas instead of multiple smaller ones also promotes wider landscape and amenity values and improves community involvement.

Hydrological benefits are modelled according to reduced impervious areas, resulting in decreased stormwater run-off and an increase in the time of concentration for flow from the site.  Clustering reduces the amount of roof and paved area, and the contaminant load is reduced in proportion to this.  Clustering can also protects existing soil surfaces by limiting the extent of earthworks.

### 5.3.2 Use within a brownfields context

Clustering is one method that can be used to reduce impervious surfaces on a subdivision scale.  , By clustering lots, there is an opportunity to design shared driveways, have shorter road-lengths and reduced setbacks.  This can then lead to a reduction in stormwater run-off.  Clustering also promotes the design of subdivision layouts to take account of natural features, thereby ensuring buildings are placed in appropriate locations and natural hydrological systems (such as streams, wetlands and overland drainage patterns) are retained to the extent possible.

As well as closely spacing and appending to existing built forms, clustering may also mean building upwards, instead of outwards, or re-development within existing building footprints to limit potential effects to the local hydrology.  The ancillary benefits of clustering include shared infrastructure, common foundations and exterior walls, combined access, and efficiency of combined thermal mass.  Often buildings are sited in existing development to take advantage of solar exposure, access, views etc.  Increasing density in these locations can optimise the existing advantages of a site.

Re-development may require enhanced open space to mitigate increased building form.  Clustering retains large open spaces on a site to fulfil open space potential and provide opportunities to integrate discrete development areas into an enhanced landscape and visual amenity framework.

### 5.3.3 Implementation issues in brownfields areas

**Table 8 Issues with implementing clustering**

| ISSUE | SOLUTION |
|---|---|
| **General** | |
| The amassed buildings will be perceived as too dense and will have a cumulative effect on the receiving environment. | The perceived density is often related to building façade, rather than overall mass. Appropriate treatment of architecture as well as designing landscape to integrate the built form, can avoid, remedy, and mitigate for these potential effects. |

| **ISSUE** | **SOLUTION** |
| --- | --- |
| It will be more difficult to sell a subdivision with smaller individual lots. | Ultimately clustering would seek to achieve the placement of built form in the most appropriate location of the site, thereby increasing the value of individual lots through their favoured location. Often clustering requires a more comprehensive design approach utilising specific architectural responses to the landform and providing for larger open spaces to integrate building form. This will ultimately provide for a site with "added value', through retaining the qualities of the site, providing for a unique local and site-specific appeal.<br><br>In order to provide for smaller lots but allow collective ownership and use of the balance of land there are legal mechanisms available such as incorporated societies. |
| Clustering will centralise stormwater systems leading to large detention ponds. | Clustering reduces impervious surfaces and thereby reduces the overall design requirements for attenuation and treatment of stormwater. Clustering may also provide collective stormwater management methods that are more effectively maintained. |
| Increased density will reduce privacy and increase disturbance between lots. | Density is often perceived as desirable, especially in developed areas, representing a heightened sense of community, a recognisable human scale, neighbourhood security, and critical mass for public transportation (on a larger scale). Site design can effectively provide for both increased density and privacy through the careful handling of private to public transitions through intermediate spaces, and recognisable design elements eg fence heights, small versus large spaces, internal vs external spaces, landscape areas etc. Infill development and land use practice is a product of zoning provisions eg land use practices for mixed-use zoning will be different from commercial sites. |
| **Retrofitting** | |
| Re-development near existing buildings will provide for a confused built form. | This can be handled by integration of the local architecture into new designs, adding onto existing building façade in a sympathetic manner. However, potential effects to heritage structures should be assessed where necessary to provide for appropriate architectural treatment. |
| Construction near existing buildings may affect existing infrastructure. | Avoidance of infrastructure effects can be achieved through comprehensive survey work and piloting before construction. LID retrofits may provide for long-term improvements for existing owners/tenants. |

## 5.4 Soil rehabilitation

### 5.4.1 Description

Soil rehabilitation is the reinstatement of compacted or low organic content soil to near-natural soil conditions, to improve water infiltration and support plant growth. The re-establishment of plants will further refine soil structure through penetration of root systems into sub-soils and augmentation of leaf litter and humus layers at the surface. This allows stormwater to be retained and percolate through soil layers, providing stormwater quality remediation, attenuation of flows, and groundwater recharge. Soil rehabilitation is applicable following mass earthworks or to restore consolidated soils (where they have been devoid of vegetation, compacted, or previously built on).

Soil rehabilitation can be applied to any site, with limitations for the depth and extent of rehabilitation based on access for machinery, and proximity of infrastructure and buildings. There are a variety of methods for soil rehabilitation; dependant upon surficial and parent geology, topography, slope, aspect, and the condition of existing soils and availability of soil additives. Where bulk earthworks machinery can get access, soil rehabilitation methods involve deep tillage or chisel plowing, which breaks up deep soil layers to about 900mm without mixing in surface soil layers. These methods disaggregate and aerate compacted soils. In other areas, such as around existing buildings or on small sites, it may be possible to do shallow soil remediation using tractor mounted or hand operated equipment such as a rotary hoe.
The standard detail for Soil Rehabilitation (Drawing A01825302-008 in Appendix A) illustrates the different soil rehabilitation methods.

Much of the urban Auckland area is underlain by silt and clay soils of either weathered Waitemata Group siltstones and sandstones or Tauranga Group Alluvium. There are some areas of volcanic soils, particularly around the central Auckland isthmus. In terms of soil science, the Waitemata Group soils are typically of moderate to poor structure with high clay content. Therefore in many instances additional drainage layers may be required to prevent soil saturation, compaction or weakening of the soil structure. Inclusion of organic compost at a ratio of 2:1 soil to compost, or the use of gypsum is also recommended to improve soil structure. Gypsum (calcium sulphate di-hydrate) is an abundant natural mineral found in Australia used as a soil conditioner and fertiliser, improving soil texture, drainage, and aeration. Gypsum is appropriate for the remediation of compacted soils, exposed subsoils, or soils affected by salinity (eg. estuarine berms, dairy effluent disposal areas). Gypsum has an advantage over certain other minerals, being pH neutral.

Clay soils can also be rehabilitated for improved plant establishment through shallow ripping of surface layers (150-200mm depths), followed by mixing and filling with additional topsoil. This topsoil layer (to vary in depth for specified plant species) can also be augmented with compost or gypsum. The addition of a further layer of mulch will reduce the saturation of these soil layers and prevent surficial erosion, and consolidation. The mychorrhizae fungi can also be incorporated (through inoculation by spray) into topsoil horizons to accelerate soil biodiversity and productivity.

Clearly, the most appropriate means to preserve soil structure on a site is to limit disturbance of existing pervious areas through site design, erosion controls, and

defining areas from which machinery is prohibited. This protects many of the soil processes in–situ, which may take years to recover naturally if removed, even temporarily.
Where removal of and stockpiling topsoil is essential, it should be stripped following site clearance, weed removal, and the installation of silt controls. Backfilled areas should be free of stumps, branches and construction debris and compacted in layers no greater than 200mm, ideally to be track rolled using a wide tracked dozer fitted with swamp tracks. Slopes need to be maintained in a stable condition and inspected prior to soil rehabilitation, to check for wet areas and shear surfaces that may require specific stability treatments.

For ideal planting conditions, imported topsoil should be good quality medium, well-drained loam, with a neutral pH (5.5-7.5), free from stones and debris (greater than 20 mm) and weed seeds. Topsoil should contain as little clay, sand and lime as possible. The soil should be carefully handled to ensure the maintenance of soil aeration and drainage properties, kept in a slightly moist condition to yield the greatest structural stability, yet not worked in a plastic condition. Soils should be track rolled using a wide swamp-tracked or balloon-tyred dozer.
Topsoil can be between 100 and 300mm for newly planted areas, depending on proposed planting schemes. Final light grading (of the top 100mm) is carried out to avoid depressions forming where water may collect. The application of a mulch layer following soil rehabilitation is important for preventing surficial erosion and weed infestation. Wood chip mulch has better properties than straw or other light mulches for attenuating surface water and reducing soil saturation and rilling. Permanent weed mats should be avoided as they prevent contact between surface litter layers and native soils.
Once implemented, minimal operation and maintenance is required of rehabilitated soil surfaces, other than that required of a standard lawn area or revegetated site (namely weeding, mowing, pruning and exclusion of vehicles).

### 5.4.2 Use within a brownfields context

In a brown-fields context, existing soils may be contaminated due to existing commercial or industrial land use, or from historical fill or land use practices. This can be checked using contaminated site soil investigation procedures. Where soil is contaminated, it is possible that soil surfaces cannot be broken, or excavation must be treated as hazardous material with appropriate health and safety protocols. It may then be necessary to excavate and appropriately dispose of soils and replace these with suitable sub-soils. It may also be possible to use underground water storage cells beneath the surface layers to provide drainage and infiltration to the underlying uncontaminated soil horizons. Another possible solution is the application of phyto-remediation processes, which utilises plants to capture, metabolise and transform contaminants to innocuous forms or that are readily transported as coppice or leaf litter. In any circumstances, where positive drainage passes through contaminated soil layers, due consideration should be given to the effects on groundwater and leaching to the receiving environment. Professional advice is therefore required in relation to the investigation and management of contaminated soils.

Soil rehabilitation can also be used following mass earthworks or the removal of old buildings and structures. Weathered upper soils are often completely removed during mass earthworks operations and these compacted soils are then generally only covered with about 100mm of topsoil. Rehabilitation can only be undertaken away from buildings, structures and services. It is likely that only smaller scale rehabilitation methods will be able to work around the identified constraints.

### 5.4.3 Implementation issues in brownfields areas

**Table 9**

Issues with implementing soil rehabilitation

| ISSUE | SOLUTION |
|---|---|
| **General** | |
| Waitemata clays do not provide sufficient drainage to make soil rehabilitation worthwhile. | Where subsoils do not provide adequate drainage, there is still potential for attenuation and treatment of stormwater, through the amended soil profile. Some “infiltration” (water movement into the soil) is still possible where “deep percolation” (movement into groundwater) may not be possible. |
| Interfering with contaminated soils may lead to contaminants being exposed, entering the atmosphere as dust, or being available to leach to the surrounding environment. | Where soils are contaminated, specialist knowledge of hazardous materials is required. Options may include capping the site and importing soils to provide for infiltration at the surface, incorporating drainage or organic matter without excavating soils, or excavating and reworking the site as appropriate, to reduce the concentration and availability of contaminants. |
| Saturated soils may lead to settlement or geotechnical issues. | It is necessary to undertake geotechnical assessment of any areas that may attenuate stormwater, especially if they are on slopes and are likely to undergo wetting and drying cycles. .Specialist geotechnical advice should be obtained in these circumstances. |
| Soil rehabilitation is expensive. | Soil rehabilitation retrofits existing open space to provide a stormwater management function, thereby using existing resources more efficiently. Rehabilitated soils can be part of site preparation for landscape amenity planting, since it allows for enhanced plant establishment and growth.<br>Where budgets are limited soils can be rehabilitated via natural succession. Manuka and other colonist species can establish open soils, fixing nitrogen and creating microclimates for other species. More complex plant systems introduce humus layers to the soils, while roots and microrhizzae penetrate the soils and introduce organic matter. |
| The slope is too great on the site. | Geotechnical treatments such as geotextile layering, retaining structures, check dams, and terracing may respond to slope constraints. Appropriate planting schemes will also bind soils into a cohesive material and assist stability. |

## 5.5 Green roofs

### 5.5.1 Description

Green roofs consist of a lightweight growing media (usually a mixture of bark/compost and an inert substance such as pumice, crushed brick or "expanded[1]" clay) planted with a range of hardy vegetation on top of a drainage layer laid over a roof. The vegetation and media encourage evapo-transpiration and slow down rainfall response times thereby reducing peak run-off volumes and flows. There are two types of green roofs:

1. Shallow green roofs (extensive) have a maximum depth of 150 mm and are planted with sedums[2] or grasses.
2. Deeper green roofs (intensive) are over 150 mm deep and can support larger plants and can be used as an amenity area.

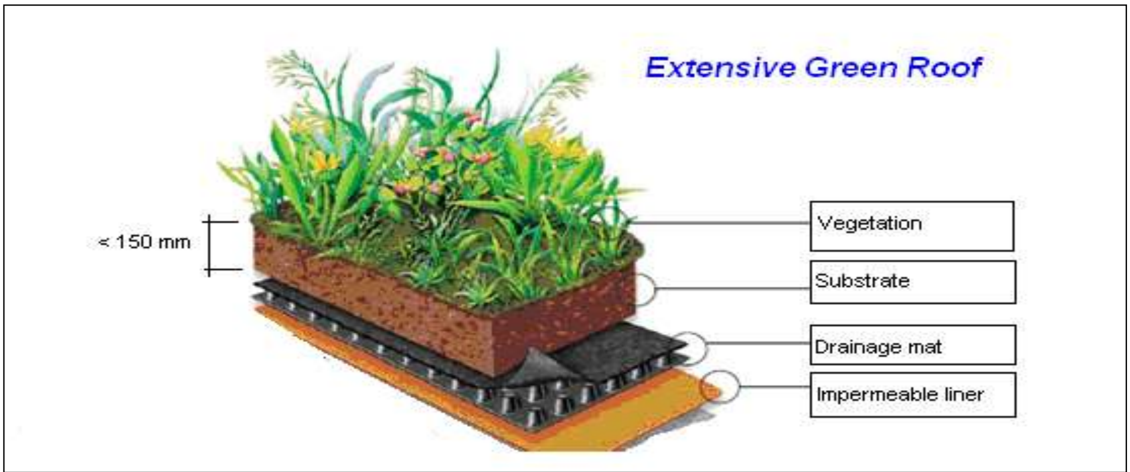
**Figure 3:** The green roof at Waitakere City Council

Green roofs are used as a LID source control method, with lower peak-flow rates and run-off volumes than equivalent impervious roofs. They may also prevent contaminants from becoming suspended or dissolved in the run-off (depending upon the amount of organic matter present in the media).

Green roofs are generally applied to roofs with a gradient of 2-3 degrees, although construction can be applied to steeper slopes by incorporating stabilising design features.

Figure 4

Cross-section of an extensive green roof (adapted from Sarnafil Roofing)




[1] "Expanded clay" is clay which has been heated to a high temperature so that the moisture particles are boiled off producing a lightweight, porous material.

[2] Sedums are "leaf succulents", ranging in size from annual groundcovers to shrubs. The plants have water-storing leaves and the typical blossom has five petals.

Figure 4 indicates the components of a green roof. A waterproof membrane beneath the green roof protects the supporting structure from moisture. A drainage layer is situated on top of the waterproof membrane allowing for the removal of any run-off that passes through the media during a rain event. Vegetation grown in the media provides evapo-transpiration, and stability for the lightweight media.

Intensive green roofs include a deeper media, but otherwise have the same profile as an extensive green roof. The structural support of the roof is a key issue to be checked in both cases.

The design procedure for green roofs is outlined in Extensive Green Roofs for Stormwater Mitigation, Part 1: Design and Construction. (ARC, 2010)

### 5.5.2 Use within a brownfields context

The easiest roofs to retrofit with a green roof will be in good condition, relatively flat and strong enough to support the additional weight. Extensive roofs are therefore more applicable: these often aim for a total additional weight of no more than 100 kg/sq.m. Steeper roofs that have previously supported concrete or clay tiles may also offer a retrofit opportunity as they should have originally been designed for the additional weight of tiles (which equates to about 40 to 50 kg/sq.m). In any case, structural checks are the important first step to carry out.

The use of a green roof within an urbanised environment offers a number of specific benefits:

- The potential for retrofitting and introducing green spaces where there were previously impervious areas. Many urban areas are now only roads and roofs with green spaces completely gone – green roofs offer a chance to incorporate green space with a building's functions.
- The use of these green spaces as amenity areas for people. Green roofs allow for green open space areas for people living and working in ultra-urban environments.
- Alternative means of achieving District Plan requirements. Where the building footprint is maximised, an intensive green roof can offer an alternative location for achieving open space requirements in District Plans.
- The reduction of peak run-off where the surface was previously impervious. Green roofs offer a way of reducing flows over time (individual flows will gradually reduce as plant growth proceeds and the number of green roofs in the catchment increases). Where there is limited space for detention ponds on-site, green roofs offer an alternative method of reducing a portion of peak run-off.
- The use of these green spaces to promote ecology through such means as creation of an ecological corridor between existing green spaces. The roofs can act as habitat islands for birds and insects usually absent from city environments.

- The potential for building insulation, reduction of heat island effect  and noise reduction.  For example, the National Research Council of Canada reported an average 26 per cent reduction in heat loss in winter and a 75 per cent reduction in heat gain during summer when comparing a green roof to a reference roof (Liu et al. 2003).

### 5.5.3 Implementation issues in brownfields areas

The particular issues and opportunities facing the introduction and retrofitting of a green roof are summarised in Table 10.  The ARC has initiated a field project at the University of Auckland's Engineering School trialling the hydrological and contaminant removal benefits of green roofs which will address a number of the matters below.

**Table 10 Issues with implementing green roofs**

| ISSUE | SOLUTION |
|---|---|
| **General** | |
| The cost of a green roof. | Cost needs to be specifically analysed.  Consider savings associated with energy usage and insulation and other amenity benefits also. |
| The council has never authorised one before and it may be difficult to get a consent. | WCC has recently installed a green roof on its new council building as a demonstration project.  Identify potential champions within the council. |
| Potential water leaks. | Careful testing of water proof liners is required.  TP10 outlines a water test procedure. |
| Conflict between requirements for plant health and infiltration characteristics.  A good free draining media may not have enough fine material to support plant growth, but the addition of fines increases peak run-off. | Results of the University of Auckland trial will recommend a media that will balance the competing demands of water retention and plant health suitable for extensive roofs. |
| | |
| Access to the roof.  Many roofs have no barriers and are therefore unsuitable for regular access. | Where access is to be incorporated, use barriers that comply with the Building Code. |
| Commercially available compost is often supplemented with nitrogen and phosphorus which can leach from the media. | Specify a "clean" compost and supplement this with slow release fertilisers. |
| **Retrofitting** | |

| **ISSUE** | **SOLUTION** |
|---|---|
| Existing roofs may not be able to support the weight of a green roof. | Extensive green roofs can sometimes be retrofitted on to existing roofs following structural checks. The selection of a light weight media of minimum depth is the key to resolving this. The University of Auckland roof has been constructed in two shallow depths generally suitable for retrofitting – 50 mm and 70 mm thick. The 70 mm thick media is better able to support plant growth.<br>Note that where tile roofs have previously been used on buildings, the roof structure has more closely spaced purlins to support tiles and may therefore be more likely to be able to support additional roof weight .<br>Use stronger parts of the roof to support a green roof – for example the section of a roof directly over walls and columns are more likely to be able support additional weight. |
| Green roofs are most easily fitted on to flat roofs of about 2-3 degrees. Most corrugated roof profiles require roof slopes of at least 10 degrees to suit manufacturer's requirements for good drainage. These roofs are typically used for many residential and industrial properties. | TP10 notes that retention methods (such as vertically mounted boards running across the roof) would need to be incorporated for roofs steeper than approximately 20 degrees. |
| Construction access to the roof. In retrofitting situations any machinery required will need to be brought in to site and other parts of the site may need to keep operating while the green roof is being constructed. | Plan ahead – a crane may be required. Allow time to obtain permits such as road opening notices to be obtained. If required, plan the roof construction work around other activities on-site. |
| Water proofing the roof. Special care needs to be taken to ensure the waterproof membrane is in fact waterproof. Any debris on the roof may puncture liners. | An inspection of the roof, prior to laying the liner, should be carried out to identify and remove any projections and possible puncture sources. Check the life expectancy of the existing roof membrane if a new liner is not being used. The existing roof substrate needs to be completely clear of objects which could puncture the liner. Protrusions need to be carefully sealed around and a water test carried out once soils and plants are in place. |
| Plant establishment may be difficult for the shallow soil media depths often required in retrofitting situations. | Consider the best time of year for plant establishment. Plant establishment is usually better in spring or autumn and provide irrigation as required. Plants should be chosen for different zones to suit the conditions. Pre-formed mats of media and plants can be used to improve plant establishment and achieve hydrological benefits more quickly. |
| The plants can be affected and die because of shading and wind from other buildings. In retrofitting situations, there is no scope to change the design or aspect of the roof to improve conditions for plants. | Particular care needs to be taken to assess the potential for shading, wind direction. Plants should be chosen for different zones to suit the conditions. |

## 5.6 Permeable pavement

### 5.6.1 Description

Permeable pavement is used to reduce the amount of surface water run-off that occurs from impermeable surfaces such as parking areas and roads. Some of the water that would otherwise run-off an impermeable surface is allowed to pass into the pavement structure where it either infiltrates into the ground or it slowly seeps out through subsoil drainage into the reticulated system. This has the effect of reducing the amount of surface run-off and increasing the overall length of time that water takes to discharge to the receiving environment. While water passes into and is held in the pavement structure, sediment in the run-off is also filtered and trapped.

**Figure 5:** Permeable paving at Shore Rd reserve

There are two types of paving used for stormwater management:

- Permeable paving – namely solid paving blocks with gaps between the pavers which allow water to flow down past the sides of the blocks.
- Porous paving – that allows the water to flow through the structure of the paving.

A range of products which can reinforce grass areas for occasional traffic use are also available. These products may be constructed from concrete or plastic in a lattice type pattern. Figure 5 is an example of a concrete lattice type pattern. They are typically used for "overflow" type parking at venues such as sports fields and parks.

Permeable paving can be used to both change the hydrological characteristics of a pavement and improve run-off water quality. It is typically used as part of suite of LID methods on a site but can be designed as a stand-alone water quality treatment device by providing below ground storage for the water quality volume within the basecourse layers. The Permeable Pavement Design Guidelines (NSCC/RDC/WCC, 2004). provide a design method to achieve a stormwater treatment level of 75 per cent removal of sediment as required by ARC's TP10.

The infiltration rate of the pavement is a key consideration in its design and maintenance. In permeable pavements infiltration must occur through the jointing sand or aggregate. Field verification of the actual infiltration rate must occur – design processes (eg NSCC/RDC/WCC, 2004) often make assumptions that the infiltration rate will reduce over time as sediment can blind the jointing sand. When permeable paving is used as a stand alone treatment device, its catchment is limited to no more than double the area of the pavement itself (NSCC/RDC/WCC, 2004).

Conventional paving blocks usually rely on a well graded basecourse layer and jointing sand to achieve their structural integrity. In the design of a permeable pavement, the basecourse is often a "no-fines" material (of about 30-40 per cent void space) to allow for storage. The basecourse layer may therefore be thicker than a standard block pavement both to achieve the required water storage volume and achieve required structural performance. Careful selection of the aggregate layers and confirmation of the materials used during construction is required to ensure the pavement will meet both infiltration and structural performance requirements.

Maintenance typically involves cleaning the surface to ensure that water can infiltrate through the pavement and topping up paver joints with aggregate to maintain structural integrity. A loss of integrity can occur where the pavement basecourse fails or pavers become unconfined and joints unravel: in these cases, the paver surface may need to be re-laid.

Paving comes in a variety of colours, block shapes and textures and can often be useful to demarcate boundaries between different road users and activities. For example, coloured paving adjacent to normal asphaltic seal can help to identify bus stops, pedestrian areas and carparks.

Design of permeable pavements is outlined in both ARC's TP10 Chapter 8 (ARC, 2003) and Permeable Pavement Design Guidelines (NSCC/RDC/WCC, 2004).

### 5.6.2 Use within a brownfields context

Permeable pavement is most suitable where there is limited sediment entrained in stormwater, such as for low traffic volume situations and where there is no overland flow from sediment sources such as gardens.

When retrofitting LID methods to a site, permeable pavement provides a useful alternative to a fully sealed impervious parking area and can be used as a "half-way house" when parking is only used occasionally. It can also be useful to use for treatment where it is difficult to catch and treat diffuse run-off – for example sites with accessways and ramps which are below the rest of the stormwater management system and therefore cannot be conveyed to a central treatment device. Permeable paving can also usually be retrofitted relatively easily as little or no additional pavement footprint is required.

Applications include:

- Parking areas with occasional use.
- Vehicle and equipment storage areas.
- Demarcation of parking bays, lay-bys and traffic calming measures within higher traffic volume roads.

### 5.6.3 Implementation issues and opportunities in a brownfields context

The particular issues and opportunities relating to the introduction and retrofitting of a permeable pavement are summarised in Table 11 below.

**Table 11**

Issues with implementing permeable paving

| ISSUE | SOLUTION |
|---|---|
| **General** | |
| Many Auckland soils are clay based and infiltration is limited. | In clay soils, infiltration to ground may not be appropriate. However, the basecourse could be lined and used as an extended detention reservoir which would drain to the stormwater system. |
| Basecourse strength and permeability must be carefully evaluated. | A greater depth of basecourse, geo-grid and filter fabric may be used to achieve structural integrity requirements. |
| Availability of basecourse and jointing sand – standard basecourse or sand may not meet the infiltration rate and void requirements. | Careful review of available materials should be undertaken during the design phase. An appropriate particle size distribution for the basecourse should be specified and allowance made for testing any alternative materials supplied. |
| The surface can become blocked with sediment once in service due to normal operation – this can be worse with higher traffic loadings and sediment coming on to the pavement from adjacent land uses. | In general, permeable paving should not be used in high traffic volume areas, i.e. greater than 3000 vehicles per day).<br>Mechanical brushing combined with vacuuming can be applied to the surface. Water blasting can cause aggregate in the joints to be displaced and should be avoided. |
| Where wider gaps between pavers are used, fine aggregate and sand can be washed out of the paver. | Maintenance inspections are required to identify when and if cleaning and topping up of aggregate is required. |
| The total cost is perceived to be higher than standard roading due to increased construction and maintenance costs. | Construction costs should be evaluated on a case by case basis. As more use of the product is made by designers and contractors, some of the discrepancy may reduce.<br>Maintenance can be reduced by limiting silt from off site areas to be deposited on the pavement. |
| **Retrofitting** | |
| Sediment discharges from adjacent construction activities onto the permeable surface can clog the surface, the voids within the basecourse and the subgrade layer. | Order construction so that earthworks upstream have appropriate erosion and sediment controls, and if possible, are completed prior to construction of the permeable paving. |
| Installation of permeable paving at the top of slopes could cause groundwater levels to rise and potentially reduce ground stability. | Carry out checks for slope stability, use drainage of the basecourse/subgrade layer and consider the use of impermeable liners. |
| The slope of the paving needs to be relatively flat to keep water within the basecourse for the required design time. | Limit retrofit application to relatively flat areas or consider creating flat areas with steps in kerbs/gardens. |
| Application of permeable pavement is limited to catchment with slopes no greater than 15%. | Consider using an alternative LID method or a combination of LID methods in series to form a treatment train. |

| ISSUE | SOLUTION |
|---|---|
| Not suitable for contaminant hotspots such as industrial sites, marinas, commercial nurseries etc. | Choose industry or site specific best practice stormwater management technique. |

## 5.7 Planter boxes and tree-pits

### 5.7.1 Description

Tree-pits and planter boxes are forms of bio-retention, similar to rain gardens, but are usually discrete from surrounding soils and often include increased drainage to assist tree establishment. This allows for above-ground encapsulated systems and for bio-retention systems to be used in the midst of infrastructure constraints. In most cases, these systems receive concentrated flows such as roadway run-off from grates or back-entry cesspits to tree-pits, and downpipes directed to planter boxes. Planter boxes and tree-pits may be the sole stormwater treatment device before the receiving environment, or form part of a treatment train. These devices are relatively new initiatives for New Zealand, but have been utilised successfully overseas for the last ten years

Systems are constructed using a similar media to rain gardens, i.e. a drainage layer and permeable soils. However, there is generally less exfiltration to the surrounding soils to avoid potential effects to infrastructure, building foundations, basement floors, and roadway sub-bases. Tree-pits have larger quantities of soil and increased drainage than planter boxes to accommodate tree root growth. There may also be additional structures to protect infrastructure within the tree-pits from root growth. After filtering through upper soil horizons of the tree-pit, stormwater is collected in a gravel layer at the base and directed to an approved outlet via perforated pipes.

**Figure 6:** Tree-pit at Waitakere City Council

Tree-pits and planter boxes can be designed to capture the water quality volume. However, in a retrofit situation it is more likely that only the first flush will be treated. This would still improve an the exiting situation where there would otherwise be no treatment of stormwater. Sizing tree-pits will depend on the hydraulic conductivity of available soil media, the extended detention capacity and freeboard for above ground storage.

TP10 (ARC, 2003) notes that planter boxes are appropriate for a smaller impervious catchment area 1000 $m^2$, such as a portion of a roof. However, more typically the catchment area would be 50 to 100 $m^2$. A planter box sized to accommodate the water quality volume for a 50 $m^2$ catchment in the Auckland region would have a surface of approximately 2.5 $m^2$ for an individual tree.

Tree-pit catchments vary considerably, with those in a roadway verge varying in size and number of tree units depending on road hierarchy (arterial or collector), and roadway cross-slope and longitudinal slope.

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The plants in these systems assist conductivity of stormwater through soils via root zones (rhizosphere) and utilise interactive soil-plant systems to intercept, metabolise and transform contaminants through a combination of physical filtering, chemical transformation and biological processing. The tree canopy intercepts and captures much of the initial precipitation before it comes in contact with impermeable surfaces, and this is directed to tree-pits via stem-flow down the trunk. Water may also be detained in soil layers and in above-ground storage, allowing settling of sediment and reduction of total stormwater volumes through evapo-transpiration.

Suggested planting lists are available in the TP10,(ARC, 2003) WCC's Stormwater Solutions for Residential Sites November 2004 and NSCC's Bio-retention Guidelines 2008. The plants usually specified for planter boxes and tree-pits are floodplain or upper riparian bank species. They should be able to tolerate inundation for at least a 24-hour period as well as the dry conditions found in free draining soils and adjacent to impervious surfaces. Trees are often highly exposed in streetscape situations and are required to be hardy species or planted in protective groups to create a microclimate.

Soil media is required to provide permeability rates of >300 mm per day. This is achieved through providing a uniform mix free from stones, stumps etc and augmentation by sand and compost as appropriate. Whilst soil specifications are the same as for rain gardens, they may vary depending on the optimal growth media for the tree species.

Ponding on the surface of planter boxes and tree-pits is designed to dissipate over a period of less than 24 hours as a function of soil permeability. Often some freeboard is required to direct larger storm events to designed overflow points, and to avoid flooding of adjacent buildings from planter boxes, or flooding through grates to sidewalks from tree-pits. Tree-pits may require increased drainage such as perforated coil pipes to draw water away from root zones and aerate soils.

A joint research paper by the University of Melbourne and Ecological Engineering, entitled Street Trees as Stormwater Treatment Measures (Breen et al. 2004), outlined the relationship between stormwater treatment and the horticultural requirements for successful street tree growth (Breen et al. 2004). Results indicated that stormwater provided for faster growth rates than tap water, possibly due to higher levels of nutrients in stormwater than tap water. The study also showed that it is feasible to use under-pavement tree-pits as a stormwater treatment method and that tree growth was satisfactory in soils with a range of infiltration characteristics. Even at a very young age, plants appeared to modify the hydraulic conductivity of tree-pit systems. Added phosphorus was fixed in soil columns and preliminary results indicated organic nitrogen was also being retained (longer-term results are pending).

Tree-pits add significant landscape value to a streetscape, with the potential to transform a wide and open paved urban corridor into an attractive public space that is cool, shaded, and has human-scale proportions. A planter box that has been located and planted to provide for landscape amenity is more likely to be maintained by landowners, who will take pride and stewardship over these facilities. Planter boxes represent an opportunity to integrate bio-retention and stormwater treatment with architecture, acting as a transition between built form and landscape context (natural elements, systems and processes). There are a suite of ancillary benefits associated with vegetation in developed areas including intercepting dust, reducing temperatures and improving air quality. Tree-pits and planter boxes can also help reduce wind tunnel effects in modified urban environments.

**Figure 7**

Waitakere Central – amenity and interception from trees within impervious areas

As a rule of thumb soil media should be 300-500 mm for ornamental grasses, 500-750 mm for shrubs and 1000-2000 mm for canopy trees. The minimum recommended surface area to accommodate medium size canopy trees to achieve a reasonable root zone is 6 $m^2$, represented as a minimum width of 2.5 m for a square bioretention facility and approximately 3 m diameter for a circular facility. Trees can be planted in smaller areas but their growth rates and vitality are likely to be affected. Input from an arborist or tree supplier is ultimately required to determine the minimum or optimum soil conditions for any given tree species.

### 5.7.2 Use within a brownfields context

In many locations where conventional planter boxes are placed on building facades, courtyard spaces, or rooftops, they can be utilised for the capture of localised stormwater or receive gutter drains and rooftop downspouts. The nature of these systems allow them to be elevated above the ground, acting as building facades, edges to spaces, or seating walls. Their location often requires them to have an impervious liner between the planter box and building foundation or other structures, and care must be taken to ensure that the foundations and structural components of the planter box and any structures beneath it can support the weight of the saturated soil layer, plants, and ponding depth of water.

Tree-pit systems are well suited to retrofit situations where streetscapes or drainage infrastructure is being upgraded. Tree-pits can be retrofitted in any situation where there are both opportunities to create feeder lines to existing stormwater systems and where constraints of existing infrastructure are not prohibitive. These may include roadsides, traffic islands, and roundabouts. As well as the landscape amenity values described above, tree-pits in sequence represent an ecological corridor in an urban environment for avifauna, lizards, and insects.

The re-design of street-trees into stormwater management devices converts a single-use amenity feature into a multiple use system. It also provides a passive watering system and therefore local-scale stormwater reuse that reduces maintenance for street trees.

### 5.7.3 Implementation issues in brownfields areas

The particular issues facing the introduction and retrofitting of a tree-pits and planter boxes are summarised in Table 12 below.

**Table 12**

Issues with implementing tree-pits

| ISSUE | SOLUTION |
|---|---|
| **General** | |
| These systems are expensive. | In general it is expected that these systems occur where trees and/or gardens are already expected and allow for cost savings in terms of regulated stormwater quality/quantity controls.<br>Cost needs to be specifically analysed. Generally, bioretention systems cost approximately $600 per square metre. There are also considerations for infrastructure protection and waterproofing as appropriate. |
| Standing water will be unsightly, have smells, and be an attraction for insects. | The system is design to drain in less than 24 hours and it is unlikely to cause smells or be an attraction for insects within this timeframe. |
| Tree-pits and planter boxes will require a great deal of maintenance. | Planter box design can allow for self maintenance after the initial establishment period, which can be covered by the planting contract. Only periodic |

| ISSUE | SOLUTION |
| --- | --- |
| | maintenance is required thereafter, eg annually. Litter cleaning and/or vacuuming may be required for tree-pit situations, as for cesspits, and appropriate access should be provided, or the primary inflow can be designed to trap initial sediments or floatables (eg a baffled riser outlet). |
| The council has never authorised one before and it would be too difficult to get a consent. | Champions within the council should be identified early. Tree-pits and planter boxes are an acceptable best practice for stormwater management and have been installed within many of the local authority districts of the Auckland region. In some instances there are grants available to promote these technologies. |
| **Retrofitting** | |
| There is no room for a planter box or tree-pit, and certainly not enough to achieve a reasonable treatment efficiency. | Planter boxes easily be modified to address weight, climate, or spatial constraints. Planter boxes can also be used inside foyers of buildings, or cantilevered as multiple systems on the outside of buildings. Tree-pits can be installed in footpaths, roadways or courtyards.<br>Their encapsulated forms allow for block walls/foundations at their edges allowing for the design of cantilevering concrete slabs, which can be paved and sustain the weight of people and vehicles. |
| The slope is too great on the site. | Encapsulated tree-pits require a single inlet from the stormwater source and these should be designed to allow for an appropriate gradient slope from the contributing catchment, and an appropriately sized inlet or ancillary structures to capture stormwater at target velocities. Planter boxes can be stepped down a slope, with the drainage pipe from a previous planter box exfiltrating to the upper soil horizons of the downhill planter – thereby providing a treatment train. |
| These systems will flood and build up rubbish and sediment. | Sufficient freeboard will allow for a preferential overflow system to have sufficient capacity for large events. Preliminary inlet systems can be designed to trap floatables and sediments and reduce erosion (eg exfiltration through pipes, spreading inflows, or using a splash pad). Litter bins should be placed nearby. |
| There is no space among the existing infrastructure. | Existing infrastructure will need to be avoided where possible. If there is an unavoidable conflict, strategies should be used to allow access to infrastructure without affecting stormwater systems. This is of particular concern for street trees, since they sit within infrastructure corridors and are more expensive to replace. Root guards, tree grates, monitoring wells, and pre-cast lids for infrastructure can avoid potential conflicts. The very nature of these systems, being encapsulated, allows work on infrastructure outside of these systems to occur without concern for root zones etc. |
| The contaminated water will affect the health of plants. | This can be addressed by species selection and appropriate soil media. In many circumstances tree growth rates will benefit from increased nutrients associated with stormwater. In many instances microbial processes within the root zone will transform |

| ISSUE | SOLUTION |
|---|---|
| | pollutants into innocuous forms. |
| There are safety issues with tree-pits in a public pathway. | Safety issues must be assessed early in a projects inception and again at detailed design and implementation phases. There are specific examples where raised and sunken tree-pits in New Zealand have lead to serious public safety concerns due to tripping and falls. Tree-pit design should incorporate visual cues to their presence, appropriate tree guards, cantilevered or continuous pavers that prevent tripping, or seating walls or similar to prevent conflicts. |

## 5.8 Rain gardens

**Figure 8:** Rain garden at Waitakere City Council

### 5.8.1 Description

Rain gardens are constructed basins backfilled with drainage layers and permeable soils, and planted. They harness the natural properties of soil and plant systems to intercept, metabolise and transform contaminants through a combination of physical filtering, chemical transformation and biological processing. Purpose-built rain gardens have been used successfully overseas and in New Zealand for the last fifteen years. These systems also represent landscape elements that enhance visual amenity values of a site.

Rain gardens detain stormwater flows, allowing filtering of sediment and reduction in the total water volumes through evapo-transpiration and infiltration. They are usually designed to capture the TP10 water quality design storm, but within a retrofit situation they may simply improve on the existing situation, or provide for stormwater treatment through a treatment train of multiple LID methods. If the stormwater entering a rain garden does not infiltrate to surrounding soils, it is collected through a gravel layer and perforated pipes at the base to an approved outlet.

Catchments up to 3 hectares can be serviced by rain gardens, but the run-off volume and available space are key factors that determine their feasibility. Slope is also an important geotechnical consideration. Design of rain gardens should be in accordance with the specifications in Chapter 7 of ARC's TP10. (ARC, 2003)

Ponding on the surface of the rain garden is called live storage and is sized to be 37 per cent of the WQV calculated for the catchment. Ponding is designed to dissipate over a period of 24 hours as a function of soil permeability and evapo-transpiration rates.

Landscape design is an important consideration for the construction of rain gardens, since attractive features encourage landowners to take pride and stewardship over the maintenance of these facilities. Rain gardens can provide for many amenity values, including improved landscape values, enhanced urban ecology values, integration with architecture, and buffering from automobile traffic.

A comprehensive list of native plants appropriate for use in rain gardens is provided in TP10 (ARC, 2003). Native plants are a good choice for rain gardens, as they have adapted to local climates and have additional biodiversity benefits. However, some exotic plants can also be suitable for rain gardens, as long as they have a suitable range of tolerance for water do not pose a biosecurity risk.

### 5.8.2 Use within a brownfields context

In many locations where conventional garden areas would occur, rain gardens can be used instead, including road side verges, traffic islands in parking areas, and retrofitted around existing catchpits. This provides for green open spaces and landscape amenity features within an already developed catchment, while still providing for the primary objectives of stormwater quality treatment. In many instances the drip line of trees may extend beyond the extent of the rain garden providing for additional interception of rainwater and direction to the garden via stemflow along the tree trunk.

Combined additional open space provides for enhanced urban ecology, including the ancillary benefits provided by vegetation; shade, inception of dust, and moderation of heat and light. Fauna that is tolerant of urban conditions, including birds and insects, will find refuge in these areas and will benefit further from a complex food-web introduced by the soil horizons and natural hydrological fluctuations. Rain gardens that are continuous with receiving environments, such as streams, will benefit from these systems as additional habitat and an ecological buffer can be provided within this "transition" area. Rain gardens within intensively developed areas act as "habitat islands" to allow movement of fauna through these areas toward larger habitats.

### 5.8.3 Implementation issues in brownfields areas

The particular issues facing the introduction and retrofitting of rain gardens are summarised in Table 13 below.

**Table 13**

Retrofitting issues for rain gardens

| ISSUE | SOLUTION |
|---|---|
| **General** | |
| Rain gardens are expensive. | Cost needs to be specifically analysed. Generally rain gardens cost approximately $600 per square metre (excluding connections to the stormwater reticulation system). |
| Standing water will be unsightly, have smells, and be an attraction for insects. | Ponding is designed to occur for a 24-hour period between rainfall events and to accommodate a 220 mm average water depth which will be screened by vegetation and/or rocks within the ponding area. |
| Rain gardens will require a great deal of maintenance. | Rain garden planting design allows for self maintenance after the initial maintenance period of the planting contract and will require only periodic maintenance (annually) thereafter. The extent of maintenance can be reduced by the incorporation of litter or sediment traps at the inlet to the rain garden and the application of mulch until planting establishes. |
| Rain gardens will modify groundwater levels and potentially affect the stability of slopes and structures. | Where infiltration to groundwater is not possible for reasons of geotechnical or structural constraints then limiting storage, increasing drainage and waterproofing lining the rain garden are possible. This will still provide for detention of stormwater and filtering through plant and soil horizons to the base of the rain garden. |
| **Retrofitting** | |
| There is no room for a rain garden. | Rain gardens can be retro-fitted into existing open space areas or integrated into impervious infrastructure (traffic islands etc). Rain gardens can be any shape, lineal or amorphic, to fit within the spatial constraints. In roading reserves, rain gardens can reduce the effective carriageway width to coincide with traffic calming designs. |
| The slope is too great on the site. | Geotechnical methods such as geotextile layers, retaining structures, check dams, and terracing may address slope constraints. |
| On-site clay soils are unsuitable for use in the rain garden media. | In general Waitemata Group type clay soils are not suitable for use in rain garden media. Living Earth make a suitable rain garden media which is available for purchase. |

## 5.9 Swales and filter strips

### 5.9.1 Description

A swale is a grassed or vegetated channel that simultaneously conveys and treats stormwater run-off. Treatment is achieved by filtering contaminants through vegetation. Swales are effective at removing metals, hydrocarbons and coarse to medium sized sediments. This method can also potentially infiltrate water, detain stormwater and decrease flow velocities.

A filter strip operates in a similar manner. It is a vegetated slope that evenly distributes and dissipates stormwater flows before they enter the receiving environment or further treatment systems. Filter strips require run-off to flow across them in a diffuse flow, potentially utilising some form of level spreader at the head of the system.

**Figure 9:** Vegetated swale at Waitakere City .Council.

Swales and filter strips may be used as part of a treatment train or a stand alone water treatment device. When used as a stand alone device, they should be sized to accommodate the water quality design storm at a velocity which achieves a minimum nine-minute residence time. Conveyance of a larger storm is also often accommodated. The "roughness" of vegetation and the use of check dams across swales and filter strips can increase residence time. Swales can be designed as "dry swales" where grass is used or "wet swales" where wetland planting is used. "Wet swales" can function partly as a rain garden where stormwater is retained and infiltrated through permeable soils and into an under-drain.

Grass in the swale needs to be a minimum of 50 mm in height. It is however, preferable to have longer grass (up to 150 mm) provided this stands up and forms a dense planting to filter the flow. Grass should be a New Zealand grown turf rye grass/fescue mix. These turf species grow slower than pasture species, requiring less maintenance and will handle inundation by water for a period of days. Wet swales use plant species selection similar to rain gardens, with typical stream-side planting within the base of the channel and typical floodplain vegetation on the upper slopes. Filter strips should accommodate plant species that are accustomed to sheet flows, such as upper bank stream vegetation.

Erosion can be a concern for swales and filter strips as preferential flow paths within the swale width reduce treatment and the re-entrainment of sediment counteracts the swales/filter strips treatment of run-off. Velocity checks, level spreaders and check-dams are used to manage this. Vegetation may require an establishment period and replanting of bare patches before the swale or filter strip becomes operational.

Design guidelines and suggested planting lists are available in TP10 and the WCC's Stormwater Solutions for Residential Sites (November 2004).

### 5.9.2 Use within a brownfields context

Typical locations for the placement of swales or filter strips are along stream boundaries or next to impervious surfaces such as parking areas and roads. Swales can take the place of conventional stormwater reticulation, replacing kerb, catchpit and pipe systems.

Herbaceous plants, tall grasses, shrubs and trees can be incorporated into filter strips and swales. Planting schemes provide for multiple benefits, such as enhancing neighbourhood character and landscape amenity, and creating opportunities for visual screening, and urban ecology.

Existing vegetation and gardens can often be used as filter strips in brownfields areas. By distributing flows along existing vegetated areas, a relatively cheap and easy retrofit can be achieved.

**Figure 10**
Orakei Rd: diffuse run-off from the parking area is filtered through existing vegetation and grass

### 5.9.3 Implementation issues and opportunities in a brownfields context

The particular issues and opportunities related to the introduction and retrofitting of a swale or vegetative filter strip are summarised in the Table 14 below.

**Table 14**

Issues with implementing swales and vegetative filters

| ISSUE | SOLUTION |
|---|---|
| **General** | |
| Soils on the surface of the swale need to be well stabilised against erosion before flows (particularly larger flood flows) are allowed into the swale. | Consider the use of stabilising geo-fabrics and diversions around the swale or filter strip while vegetation is established. |
| The length of swale is too short to get adequate retention time. | Consider the use of check dams, under-drains and longer vegetation to slow down flows.<br>Split the catchment to the swale and provide two swales.<br>Consider the use of another LID method or this method as part of a treatment train. |
| Maintenance of correct grass levels. | Education of maintenance staff and revisions to standard specifications for contractors to allow grass to be cut a higher level. |
| Swales are observed as a safety hazard to elderly and young children. | Through a good urban design plan, ensure that swales extents are formalised by bollards or plantings. Another alternative is to decrease the angle of the swale batters. |
| **Retrofitting – swales** | |
| Space is limited. | Run sheet flow off the edge of impervious surfaces onto a vegetative filter instead.<br>Consider water re-use or planter boxes for roof areas. |
| Grades are too steep for a swale and so may cause erosion or a low-flow channel to form. | Provide check dams such that the individual slope of each swale is no greater than 5%.<br>Run sheet flow off the edge of impervious surfaces onto a vegetative filter instead. |
| | |
| Existing topography or drainage system grades preclude directing flow to the swale inlet. | Flow spreaders, kerb cuts or an edge strip in place of kerbs can be used to allow distributed flow to enter the swale along its full length. |
| The soils on-site are compacted. | Consider conditioning the soil with compost and sand mix soils. |
| **Retrofitting – filter strips** | |
| Space is limited and the full filter strip size can't be accommodated. | Consider the use of a reduced catchment size to the filter strip.<br>Filter strips can be very simple to retrofit, such as by simply running water from a down pipe across existing landscaping areas or onto a garden. Use a downpipe diverter and run a pipe with perforated holes along the back of a gardening area. |
| The geotechnical stability of a slope can be reduced where water is added to the top of slope. | Avoid adding water into steep or high slopes, particularly where this is close to buildings or infrastructure. Divert water around the top of slopes. |

| ISSUE | SOLUTION |
|---|---|
| | Lowering the water table within the slope can reduce groundwater levels and improve stability. |
| Erosion can occur on the vegetated filter. | Ensure flows are evenly spread out on the top of the filter with the use of a level spreader. Planting slopes with vegetation can also stabilise the surface of the slope and prevent erosion. |
| Swales and filter strips are not generally suitable for contaminant hotspots (such as industrial sites, marinas) because of potentially high sediment and contaminant loads. | Choose an industry or site specific best practice stormwater management method.<br>Consider the use of another LID method or use this method as part of a treatment train. |

## 5.10 Rain tank detention

### 5.10.1 Description

**Figure 11:** Individual dwelling rain tank at Talbot Park

Rain tanks are containers used for storing stormwater run-off. Run-off is either stored for re-use or released at a slower rate to reduce peak run-off. Peak run-off is attenuated to reduce the frequency of drainage system overloading, reduce flood levels and/or reduce the potential for stream erosion. Tanks often combine both re-use and attenuation functions.

Down pipes from the roof direct the stormwater into the tank. Yard water is not usually re-used because of the likelihood of contaminants being present and sediment affecting the tank pipework and pumps. Run-off greater than the tanks capacity is directed to overland flow or the local reticulation system. The stored water can be reused for gardening, toilet flushing and washing machines. Where peak flows from yard areas require detention, a second tank can be used or a larger community based detention tank or pond may be constructed.

Rain tanks can be placed underground, within basements, above ground, as an architectural feature, or sometimes even in the ceiling cavities of buildings. The positioning may depend upon the building code and district plan requirements.

The size of the tank is determined from requirements for the amount of detention required to reduce peak flows (often to a pre-development situation) and the amount of water required for re-use. The size of the re-use component is determined from how often the occupier is prepared to accept that the tank could be empty, the catchment to the tank and the water demand (from the number of occupants and the number and types of appliances to be serviced). The tank supply is often supplemented by a mains top-up supply to prevent the household running out of water. Maintenance issues are typically; removal of sediment from the tank, clearing inlets and outlets and replacing filters.

ARC's TP10 (ARC, 2003) provides a detailed design procedure and charts for calculating the size of a re-use tank based on the above parameters. A procedure for sizing the detention component of a tank is given in Chapter 11 of TP10. (ARC, 2003)

### 5.10.2 Use within a brownfields context

Rain water from roof run-off is collected in tanks. Inlets to the tank require a leaf guard to prevent organic matter entering the tank. Contaminants are not specifically treated by a tank, so health authorities do not usually recommend re-using water for drinking without treatment. A first flush diverter device can be installed prior to the inlet – this diverts the initial run-off (which contains most contaminants) from the inflow. Water to be re-used should always be filtered so that there is less risk of fine sediment blocking pipe work and laundry appliances.

In urban areas, space for the tank is an important consideration. This particularly applies for medium- and high-density residential properties where outside living spaces are often limited. Rain tanks can be made of high strength plastic, corrugated iron, fibreglass or concrete and come in many colours, shapes and sizes. New designs allow them to fit in many smaller spaces or be used as features in landscapes rather than attempting to hide or disguise their presence.

### 5.10.3 Implementation issues and opportunities in a brownfields context

The particular issues relating to the introduction and retrofitting of a rain tanks are summarised in Table 15 below.

**Table 15**

Issues with implementing rain tanks

| ISSUE | SOLUTION |
|---|---|
| **General** | |
| Water user charges can be significant. | Water re-use offers an opportunity to save on both water and wastewater charges. Re-use of rain water reduces the volume of council water used. Wastewater volume charges are often calculated as a percentage of water supplied and so saving water reduces these also.<br>Several Auckland councils now offer cash-back systems for installing rain tanks. |
| Water savings by using rain tanks are made by home owners and occupiers rather than developers. This means the capital cost of | Sustainable building practices may be useful features when marketing properties.<br>Purchasers may be willing to pay extra for the |

| **ISSUE** | **SOLUTION** |
| --- | --- |
| the system is re-couped through the development cost and developers are typically unwilling to voluntarily install the systems. | incorporation of sustainable practices such as water re-use. Education on the benefits of water re-use to potential purchasers of the properties could help to stimulate demand.<br>A less extensive re-use system could be considered to service only high water demand features such as the toilet and laundry or even just installing pipework in wall cavities to allow the system to be constructed by the homeowner later. |
| The cost of tanks can be a significant proportion of the cost of a single unit or house. | If possible, communal tanks can be installed for multiple apartments or units.<br>A less extensive re-use system could be considered to service only high water demand features such as the toilet and laundry. |
| To prevent tanks running out of water a mains top-up is required. | The larger the tank, the less likelihood of running out of water. The mains-top up needs to be on an automatic system to ensure water is always available for uses such as toilets and washing. |
| Public health authorities recommend roof water is unsuitable for drinking. | Water is used for non-potable purposes. Signs on outside taps or colour coded pipes and taps may be required to remind people of this. |
| Rain tanks take up too much space. | Some rain tanks are available in a range of alternative shapes; for example they can appear to be “thick walls”, in corners of back yards, fitted into wall or floor cavities or under stair wells. |
| **Retrofitting** | |
| Space can limit the size of tank to be installed – above ground tanks take up available space for other living purposes, particularly where outdoor living space is limited. | Consider a range of tank shapes or the alternative flexible shaped containers.<br>Heavy duty flexible bags can be placed under floor cavities and are simply placed on the ground and fill up to the sub-floor level.<br>Long, low tanks can sometimes sit above ground and be disguised by a raised garden or similar landscaping.<br>Purpose designed tank shapes can fit a range of shapes – eg above ground rectangular box tanks can be disguised as seats with garden boxes on top. Alternatively pre-cast concrete products such as pipes and channels may be able to be adapted into different situations. |
| Below ground tanks may be difficult to fit in around existing buildings and infrastructure. | Consider above ground tanks or architecturally designed tanks that have amenity values. |
| Collecting water in rain tanks may require relocating down pipes and other pipes to a centrally located tank. | Where buildings are of timber construction it may be possible to run downpipes and other lines under the floor space.<br>Gutters can be re-graded to fall in the opposite direction so that downpipes can be re-located to better positions. |
| Installing the re-use supply lines to devices requires them to be fitted into existing walls/floors. The point of the connection will | Where houses are of timber construction it may be possible to run downpipes and other pipes under the floor space. |

| ISSUE | SOLUTION |
|---|---|
| only be after the mains supply has fed other appliances and uses (eg after kitchens and showers). | Re-use systems could be installed at the same time as other renovation work to minimise disruption. |
| A secure location is required for the control box – often in the garage – this requires the electricity supply and the water supply pipe from the pump being retrofitted into walls etc. | Where houses are of timber construction it may be possible to run downpipes and other lines under the floor space. |
| Access for machinery may be limited – eg diggers for excavations. | Small diggers are available at approximately 1m width where excavations are relatively shallow and small. |

## 5.11 Above ground detention

### 5.11.1 Description

**Figure 12:** Above ground detention at Myers Park, Auckland City

Detention is often an important component of an overall suite of LID methods. It can be used to provide a final reduction in the peak-flow generated by a site when other methods have not been able to meet hydrological objectives. Above ground detention (AGD) is simply the use of areas on-site that have topography suitable for the temporary storage of water. These areas invariably have primary uses such as gardens, lawns, carparks or sports-fields. To prevent disruption to these primary functions and to minimise safety issues, the ponding is usually brief and shallow: typically this might mean less than 24 hours and up to 2 m deep for community facilities down to less than 1-hour and 300 mm deep for small sites.

AGD is flexible in that it can control run-off from the whole site: gardens, yards, driveways and roofs. On smaller sites or where water re-use is practised roof water is often directed to rain tanks and AGD is left to cater for the remaining flows.

The set up is relatively simple, with site contours modified to form a ponding area or low bunds or walls constructed to form the ponding area. Outflows are controlled by an outlet structure; consisting of either a formal orifice and overflow manhole arrangement or using standard pre-cast cesspits to limit outflow to the capacity of the cesspit. In either case, a flow routing assessment of the inflows, storage and head/outflow rating curve is required. The extent of benefit to flow rates is determined through the use of various models to calculate; the volume of detention, the ponding level, normal outflow rate and overflow outflow rate. Dispersing stormwater ponding through a site can reduce the requirements for large centralized detention areas if these cannot be accommodated.

An overland flow path should be identified for extreme storms – it is important to think about what could happen if an outlet gets blocked and make sure flooding can't occur. Similarly it is important to make sure the ponding doesn't affect any adjacent upstream or downstream buildings.

Maintenance of the outflow control device is important, since small orifices can easily become blocked with debris and sediment build-up. TP10 specifies minimum orifice sizes and screening methods to reduce this risk. Maintenance is however, likely to require the regular removal of litter and the periodic clearance of sediment.

Plants within the ponding area can provide some water quality benefit but must have some tolerance to temporary inundation and dry periods.

A procedure for sizing the detention ponds (or above ground detention) and various design details are given in Chapter 5 of TP10. Detention devices require careful design and assessment of how they fit within the catchment context: the advice of an experienced stormwater professional and the local council should be sought.

### 5.11.2 Use within a brownfields context

Retrofitting AGD involves reviewing the topography and open space areas on-site through a site reconnaissance and identifying ponding opportunities. Often a small bund or wall can be used or constructed to form a temporary pond.

AGD requires careful consideration in that it is usually one of a number of uses for an area. Carparks and grassed areas provide good opportunities for ponding but they usually have existing users who should be consulted about a ponding proposal and how this may affect them. Because of the multi purpose nature of areas being used, safety is an important consideration. Property owners must understand that ponding is intended to occur and be aware of the extent and frequency of flooding of the ponding area.

### 5.11.3 Implementation issues and opportunities in a brownfields context

The particular issues relating to the introduction and retrofitting of above ground detention are summarised in the Table 16 below.

**Table 16**

Issues with implementing above ground detention

| ISSUE | SOLUTION |
|---|---|
| **General** | |
| Above ground detention can't be integrated with other uses such as carparks, sportsfields and parks. | In an urban environment multiple use of space is a benefit. However, good consultation with other park users is recommended. |

| ISSUE | SOLUTION |
|---|---|
| If the velocity or depth of water is high, crossing through the water can be hazardous. | Avoid creating overland flows with high velocity to depth ratios. Ensure there are screens around inlets to prevent access.<br>Keep ponding depths shallow. Fencing is generally required for ponds deeper than 0.4 m so this is often an appropriate maximum. |
| Water flooding other property. | Carefully define the extent of ponding so that it doesn't affect other property. Make sure there is at least 0.5 m freeboard to buildings in the 100-year ARI event.<br>Also consider the other uses of the area – if parking, limit the extent and depth of ponding so that it can't enter vehicles. |
| Maintenance of outlets. | Outlets should be carefully sized, sited and screened to minimise the risk of blockage. Regular checks should be undertaken to check the outlet isn't blocked. |
| **Retrofitting** | |
| Above ground detention can be a very effective way of reducing the peak flows from less frequent storm events. | |
| Capturing yard water means intercepting run-off from driveways and parking areas. Where these areas are not formally collected by cesspits this means placing a barrier on the low side of an existing impervious surface or re-grading the impervious surfaces to the ponding area. | Where ponding can occur on the impervious surface itself without causing significant inconvenience, a low nib wall constructed alongside the existing impervious surface is often an effective way to form a ponding area above ground. |
| Above ground ponding would cause a significant inconvenience. | Consider the use of cobble/gravel filled pits (ie significant water storage in the voids). These could help to avoid standing water issues. |
| A cesspit is used to collect yard water on the site and there is limited space for above ground detention. | Replace the pipe outlet to the existing drainage system with a larger diameter pipe online. This can then provide online storage within the system.<br>Consider the use of cobble/gravel filled pits (ie significant water storage in the voids) or pre-fabricated storage systems. |

## 5.12 Summary

Table 17 below summarises the LID methods presented in the previous sections. This includes key issues for retrofitting, catchment types and a range of physical matters. As noted previously, a conceptual drawing detail for all methods except "Reducing Impervious Area" is included in Appendix 2.

Table 17 Summary of LID methods and key issues

| | Key issues for retrofitting | Contributing Catchment area | Catchment type | Compatibility with underground structures and services | Potential geotechnical issues[3] | Compatibility of LID surface with traffic use | Under-drainage required | Soil and media requirements | Plant health requirements | Effect on existing buildings[4] | Key reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reducing impervious area** | Determine need for existing impervious area.<br>Access for machinery and removal of spoil.<br>Soils may also require rehabilitation.<br>Keeping traffic off newly created pervious area. | Not applicable. | Not applicable | Compatible.<br>Check if soil needs to be rehabilitated.<br>Allow for maintenance access of services. | Not generally applicable. | Not compatible (unless permeable pavement used instead). | Not applicable. | Soil rehabilitation may be required. | General maintenance. | Potential issue – interference with foundation support. | ARC TP124 |
| **Clustering** | Construction near or attached to existing buildings.<br>Most effective with comprehensive site assessment. | Not applicable. | Not applicable. | Check for services. | Not generally applicable. | Compatible. | Not applicable. | Not applicable. | Not applicable. | Effects of building proximity, eg solar gain, disturbance fo construction, view protection etc. | ARC TP124 |
| **Soil rehabilitation** | Access for machinery. Suitability of subsoils for drainage.<br>Potential contaminated soil issues. | Not usually designed to receive upstream flow but could infiltrate localised overland flows. | Pervious. | Check for services. | Potential issue – stability issues for slopes.<br>Cohesive soils may require additional additives or drainage. | Not compatible. | May be required in clay soils. | Compost required. | General maintenance.<br>Potential issue – choose plants suited to soil and climate. | Potential issue -- interference with foundation support and swelling of soils. | |
| **Green roofs** | Structural capacity of roof.<br>Minimum media depth.<br>Plant maintenance. | Roof area only. | Roof. | Compatible | Not applicable | Not compatible. | Usually required for positive drainage and/or a reservoir for irrigation. | Site and plant specific media selection required. | Minimum media depth.<br>Weeding.<br>Irrigation during establishment. | Potential issue – ability of roof to support the weight of the green roof. Positive effects for building insulation. | ARC TP10 |
| **Permeable pavement** | Infiltration characteristics of pavement.<br>Structural integrity of pavement.<br>Subsoil structure. | NSCC/RDC/WCC (2004) Guidelines recommend the catchment to be no more than twice the area of the pavement. | Roads, carparks. | Check for shallow services. | Not generally applicable – potential effect on subsoil strength from saturation. | Low traffic volumes. | Required | Specific media selection required. | Not applicable. | Not generally applicable. | ARC TP10;<br>NSCC/RDC/WCC Guidelines for Permeable pavement |

[3] Many of the LID methods potentially re-introduce water to soils. Geotechnical issues (eg settlement, retention, stability) may arise where LID methods are proposed near to existing buildings, services and slopes. Professional advice is recommended.
[4] Creating pervious areas near existing buildings and services may cause soils to swell and structures to move. Professional advice is recommended.

| | **Key issues for retrofitting** | **Contributing Catchment area** | **Catchment type** | **Compatibility with underground structures and services** | **Potential geotechnical issues[3]** | **Compatibility of LID surface with traffic use** | **Under-drainage required** | **Soil and media requirements** | **Plant health requirements** | **Effect on existing buildings[4]** | **Key reference** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Planter boxes, tree-pits** | Under-drainage, tree species selection, and pedestrian and vehicular movement. | Full quality treatment achieved when filter area is 5% of catchment area. | Planter boxes from roofs.<br>Tree-pits from roads, carparks, or footpaths.. | Planter boxes- compatible.<br>Tree-pits – check for services and provide for separation to root zones. | Not generally applicable except for potentially contaminated soils on excavation. | Applicable to effects during construction and driveway access and sightlines when installed. | Required | Careful media selection required<br>Avoid using in-situ clay soils for the media. | Weeding, rubbish collection, and watering through dry periods. | Potential issue – weight of planter box above buildings. | NSCC Bio-retention Guidelines |
| **Rain gardens** | Geotechnical issues.<br>Levels of inlets and outlets.<br>CPTED designs and traffic sightlines.<br>Integration with existing landscape. | Generally less than 1000 $m^2$ but up to 3 ha.<br>Full quality treatment achieved when filter area is 5% of catchment area. | Roads, roofs, carparks, pervious surfaces | Check for services. | Potential issue – stability issues where used near a slope. Ensure underdrainage is above groundwater. | Not compatible. | Required in clay soils. | Careful media selection required.<br>Avoid using in-situ clay soils for the media. | General maintenance.<br>Weeding, rubbish collection and clearance of inlets and outlets. | Potential issue-interference with foundation support. | ARC TP10;<br>NSCC Bio-retention Guidelines |
| **Swales/filter strips** | Space for the length and width of swale.<br>Geotechnical issues.<br>Construction programme. | Generally less than 2 ha. | Roads, carparks, roofs, pervious surfaces | Check for shallow services. | Potential issue - stability issues where used near a slope. Ensure under-drainage is above groundwater. | Not compatible. | Swales – preferable.<br>Filter strips – not required. | Not applicable. | General maintenance.<br>Weeding, rubbish collection and clearance of inlets and outlets. | Potential issue-swelling of soils. | ARC TP10 |
| **Rain tanks** | Size of tank versus the space available.<br>Retrofitting existing plumbing. | Generally less than 500 $m^2$ . Larger tanks are feasible with specific design. | Roof | Above ground tanks – compatible.<br>Underground tanks – check for services. | Not generally applicable. | With careful design (underground tanks only). | Not applicable. | Not applicable. | Not applicable. | Potential issue-tank weight may be significant next to foundations or retaining walls. | ARC TP10 |
| **Above ground detention** | Forming a topographical depression. | No contributingcatchment limitations, depends upon catchment area available. | Roads, carparks, roof | Check for services – if forming a depression area. | Not generally applicable. | Compatible. | Not applicable. | Not applicable. | Not applicable. | Not applicable. | ARC TP10 |

# 6 Testing the Concept Design

## 6.1 General

This section of the report sets out methods for testing the concept design (termed the Spatial Development Framework in Section 4.3) against the LID objectives identified in Section 2.2. The methods are; a "Calculator" for assessing peak run-off rates and volumes, the ARC's "Contaminant Load Model" and a checklist of the "Seven Cs" for landscape, amenity and ecological issues.

With any development retrofitted into an existing site, the final solution will be a compromise of many different factors and aims. A successful development is likely to be one in which multiple aims can be achieved and integrated.

Section 3 identified the types of issues and opportunities that should be considered in developing a concept plan for any development. Section 4 described a method for combining and representing these matters graphically on a "Spatial Development Framework" and Section 5 then summarised the LID methods available for use in retrofitting situations.

As shown on Figure 1 the process of combining the development aims, issues and opportunities is iterative. This section therefore sets out a means for trialling different LID methods and then comparing them against the LID objectives from Section 2.2. Table 18 below summarises these methods.

**Table 18**

Methods for testing LID objectives

| | **LID objective** | **Method to test objective** |
|---|---|---|
| 1 | Complement overall catchment objectives. | Include any catchment objectives by amending the requirements of the default objectives below. |
| 2 | Match the 2- and 10-year ARI post-development peak flows to the pre-development peak flows (or nominated curve number). | The "**Calculator**" included here is the primary means for assessing the different methods. |
| 3 | Reduce the volume of run-off.<br>(Note – no quantitative reduction target is given: the objective is achieved when the volume of run-off is minimised). | The "**Calculator"** also provides a estimate of the run-off volume pre- and post-development. |
| 4 | Reduce contaminant loading, preferably to 75% of pre-development load. | Once the methods have been selected using the Calculator, check the change in contaminant load using the ARC's **Contaminant Load Model.** |
| 5 | Optimise landscape, amenity and natural character values, urban ecology and urban design aspects. | A "**checklist**" is included to evaluate these matters. |

It is assumed here that catchment objectives have been considered through their inclusion in the "Spatial Development Framework" outlined in Section 4.3 and then via amendments to the default LID objectives in this document. The Calculator is the primary quantitative evaluation tool in the assessment of objectives: using it allows different scenarios to be tested against Objectives 2 and 3. Once it has been used to determine how Objectives 2 and 3 can be achieved for the layout under consideration, checks on the contaminant load and on landscape and amenity factors should be carried out. This set of results then provides the feedback to re-visit the Spatial Development Framework and refine the layout. A number of iterations may be required to achieve the best overall outcome.

## 6.2 Calculator

### 6.2.1 Introduction

The first step in this evaluation against the objectives is to identify the extent and type of the impervious and pervious areas and the suite of LID methods proposed.

Recall that the Spatial Development Framework identified matters such as:

- The number of units/extent of buildings required.
- The method and extent of access and parking.
- The minimum amount of pervious area.
- The maximum amount of impervious area.
- Features that need to be preserved (eg streams, trees).
- Space for stormwater management devices and overland flow paths.

The extent and type of these parameters and the proposed LID methods can be tested and iterated through the "**Calculator**". The implementation of LID methods will modify these parameters by reducing the extent of impervious area, maximising the extent of pervious area and changing the characteristics of the surfaces to reduce run-off.

The extent to which LID methods are used, and their footprint, is likely to depend upon how well they are integrated with other development objectives. Where LID methods are integrated extensively with the concept and the various spaces achieve multiple purposes, the overall land area required for specific stormwater management devices is likely to be reduced. For example, if bio-retention methods are also gardens, or parking areas also provide flood storage, then separate areas are not required for each use.

In going through this process it is important to consider whether the site and building layout can be developed in different ways. A series of questions, such as those which follow, may be useful to consider:

- ❑ What is the minimum amount of impervious area that is practical?
- ❑ Can buildings be grouped and clustered?
- ❑ Can carparking be underneath buildings, either at ground level or in basement parking?
- ❑ Can access be shared with neighbours?
- ❑ Can natural drainage paths, trees and vegetation be retained?
- ❑ If the site is completely modified, can pervious areas and vegetation be re-introduced?
- ❑ Can LID methods be used to mitigate existing impervious areas? (eg retrofitting extensive green roofs, using planter boxes to mitigate flows from individual down-pipes).

### 6.2.2 Methodology

The design of the Calculator is based on the ARC's TP108 methodology (Guidelines for Stormwater Run-off Modeling in the Auckland Region, April 1999). The Auckland region has been divided into regulatory zones and then into suburbs which have been allocated rainfall data based on the maps provided in ARC TP108. Use of this rainfall data, development area and soil type provides a quick estimate of pre-development run-off from the site. Note that the flows generated by this method vary from the TP108 method for sites larger than 10 ha and it is therefore not recommended for use with larger sites.

The concept layout design for the proposed development is inputted into the Calculator, using estimates for impervious areas such as roofs, carparking areas, paved areas, roadways and pervious areas. These areas constitute the initial design of the development to provide a post-development run-off rate. Sheet 2 of the Calculator allows the adjustment of the initial design by specifying construction materials used for impervious areas, and LID methods that may be required to improve the quality and change the quantity of run-off.

The various construction materials and LID methods affect the run-off curve number (CN) for the post-development run-off calculation based on the following equation:

$$CN = \frac{\Sigma CN_i A_i}{A_{tot}}$$

Where: $CN_i$ = impervious CN value

$A_i$ = impervious catchment area

$A_{tot}$ = total catchment area

### 6.2.3 Step by step guide of LID Calculator

**Step 1: evaluation of existing site**

To evaluate your existing site, on Sheet 1 ("Toolbox") enter from the drop down columns:

- The Local Authority that administers the district for the development site.
- The location that is closest to the development.
- The soil type present on the development site.
- The land area of the development site.
- The current percentage of impervious area covering the site.
- Whether pervious areas are compacted.

These six components evaluate the existing situation at the site based on ARC's TP108 for the 2-year, 10-year and 100-year ARI storms. The results are shown on Sheet 2 ("Toolbox2") under "Existing Peak Flows".

### Step 2: evaluation of proposed development

On Sheet 1 ("Toolbox"), enter the individual areas for the proposed development to calculate the percentage of impervious area covering the site. Several boxes have been allowed for each type of impervious and pervious area cover types. You must enter at least one impervious and one pervious area.

Example 1: the development may include several buildings that have different roofing materials. Combine all roof areas constructed with the same material to form a single roofing area.

Example 2: the site may be a simple subdivision consisting of construction of one or two buildings. Evaluate the entire site using each individual building as a contributor to impervious area.

Enter areas, as described above, for the carparking and paved areas.

Road areas can be entered on a length only basis if desired. The Calculator uses a default pavement width of 7 metres excluding verge width. If different road widths are being used, enter the width and length of the roadway.

Include pervious areas (as this helps in the site evaluation).

You must make sure that the values for both pervious and impervious areas sum to the previously entered Total Catchment Area.

Entering the impervious areas for the development will show the individual and cumulative percentage imperviousness on the right hand side of the screen; this value will be carried over to the next screen when you click "Next Screen".

**Figure 13**

Sheet 1 "Toolbox" of the Calculator

**LOW IMPACT DESIGN CALCULATOR FOR USE AS A PRE ASSESSMENT TOOL**

| | | | | |
|---|---|---|---|---|
| | Enter Details for proposed development & go to next screen to select treatment techniques to match pre-development flows. | | | |
| Local Authority | Auckland | | | |
| Location | Auckland City | | | |
| Soil Type | Granular volcanic loam | | | |
| Total Catchment Area ($m^2$) | 3740 | | | |
| Existing % IMPERVIOUS | 40% | | | |
| Existing Pervious area Compactio | non compacted | | | **% Impervious** |
| | **Proposed Development Design Areas** | | | |
| Roof Area A ($m^2$) | 200 | | | 5.35% |
| Roof Area B ($m^2$) | 250 | | | 6.68% |
| Roof Area C ($m^2$) | 300 | | | 8.02% |
| **Sub Total** | 750 | | | **20.05%** |
| Car Park Area A ($m^2$) | 110 | | | 2.94% |
| Car Park Area B ($m^2$) | 270 | | | 7.22% |
| Car Park Area C ($m^2$) | 0 | | | 0.00% |
| **Sub Total** | 380 | | | **10.16%** |
| Paved Area A ($m^2$) | 300 | | | 8.02% |
| Paved Area B ($m^2$) | 500 | | | 13.37% |
| Paved Area C ($m^2$) | 0 | | | 0.00% |
| **Sub Total** | 800 | | | **21.39%** |
| Roads (excluding verge) | | Length (m) | Width (m) | |
| Residential Culdesac | 0 | 0 | 0 | 0.00% |
| Residential Road | 0 | 0 | 0 | 0.00% |
| Residential Through Road | 0 | 0 | 0 | 0.00% |
| **Sub Total** | 0 | 0 | | **0.00%** |
| Pervious Area ($m^2$) | | | | |
| Pervious Area A ($m^2$) | 1810 | | | |
| Pervious Area B ($m^2$) | 0 | | | |
| **Sub Total Pervious Area** | 1810 | | | |
| **Total Area** | 3740 | | | **Total % IMPERVIOUS Area** |
| | | | | **51.60%** |
| | AREA CORRECT | Next Screen | | |

## Step 3: selection of methods to reduce run-off

On Sheet 2, for each previously entered area, select from the drop down columns the desired construction material and LID method for the corresponding area.

To the right of the "Construction Material" and "LID/treatment Method" columns are run-off numbers. These numbers relate to the amount of run-off that will come from the corresponding construction material and LID method. By changing the construction material or LID method, the run-off numbers is automatically adjusted (the user can also adjust it manually if need be). The curve numbers are used to calculate the "post-development" discharges.

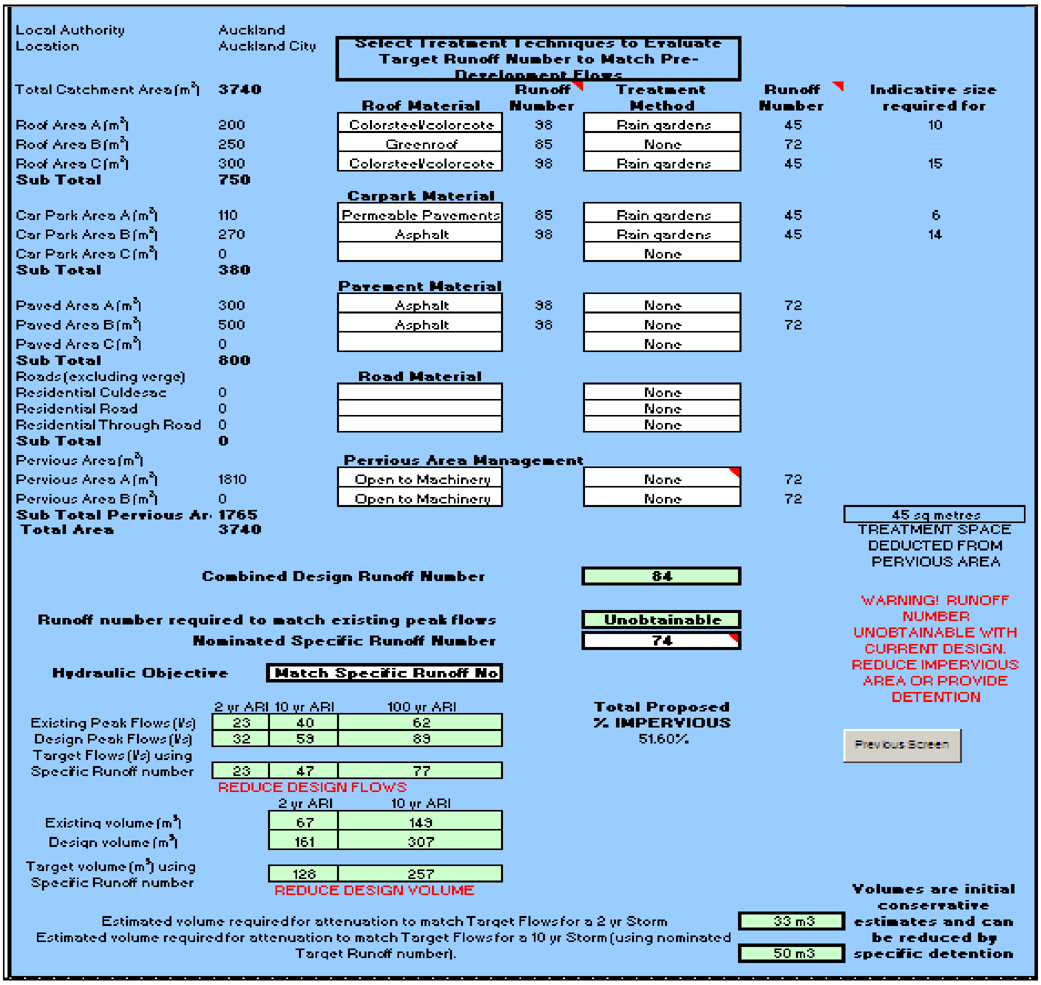
## Step 4: select target

You now need to nominate whether the design needs to "Match Existing Flow" (to the existing situation) or "Match specific run-off number". If the latter is chosen, this needs to be entered below. The chosen selection is used to calculate flows and the results shown in “Target Flows”.

The Calculator then checks whether post-development flows are less than the target flows as a result of the LID methods proposed (excluding detention). If the post-development flows are greater than the Target flows, an initial estimate of the detention tank volume required is provided. This is calculated using the difference in run-off volumes between pre- and post-development. The Calculator assumes that the pre-development scenario was native bush. Note this is not a routed flow- the volume is a conservative estimate of the storage volume to be used for initial planning purposes only. Often this method overestimates the storage volume required – but detailed modeling is required to confirm this (eg using HEC-HMS). It is therefore important that the detailed design for the LID concept should be prepared by a professional experienced in the design of stormwater management systems. HEC-HMS models are relatively easy to set up and are worthwhile to optimise detention volumes where these volumes are large or are having a significant effect on the overall site design.

**Figure 14**

Sheet 2 “Toolbox2” of the Calculator



The final screen of the Calculator also reports the run-off volumes for the 2- and 10-year ARI events for the existing, post-development and target scenarios.

## 6.3 Contaminant load assessment

### 6.3.1 Context

By using LID methods it is expected that the contaminant load from a brownfields re-development will reduce. Objective 4 uses the standard ARC TP10 objective for reduction in contaminants: 75 per cent removal of total suspended solids load on a long-term average basis. However, when processing consents for re-developments it is recognized that greater constraints often exist which may make this level of treatment difficult or expensive to achieve. In this case, the Best Practicable Option is adopted for contaminant removal.

The Best Practicable Option includes consideration of; the sensitivity of the receiving environment, the technical feasibility of an option, and financial constraints. This requires that the specific circumstances of a site are considered and that an effective and reasonable approach to contaminant management is identified. In many re-development sites this means that treatment is targeted at high risk areas and a range of management and operational practices (eg sweeping, spill containment) are also included in the contaminant management approach.

This wider context should be considered when deciding whether Objective 4 has been achieved.

### 6.3.2 ARC contaminant load spreadsheet

The contaminant load model (CLM) spreadsheet is available from the ARC's website (www.arc.govt.nz) or upon request from the Stormwater Action Team at ARC.

Inputs to the spreadsheet are:

- Areas of roofs with different roofing materials.
- Areas of roads with different traffic volumes.
- Areas of paved surfaces for different land uses.
- Pervious areas (denoted as "urban grass lands" or "stable bush").
- Treatment methods proposed.
- The suite and order of treatment devices for each sub-catchment.

Areas for the CLM will be the same as those used for the "Calculator". It is recommended that the following LID methods are represented by:

- Green roofs should be entered as "urban grass lands".
- Tree-pits and planter boxes should be entered as "bio media filtration".
- Rain tanks should be entered as "dry-detention".
- Above ground detention should also be entered as "dry detention" where it receives flows during a full range of rainfall events – ie not just during low frequency flooding events.

Because the area of roofs, paved and pervious surface will change following the implementation of most LID scenarios, it is necessary to enter two sets of data into the CLM. The first set will represent the pre-development extent of area and the second set the post-development areas and any treatment methods. The percentage reduction in contaminant load will be the difference between the two sets of data.

Results from the spreadsheet are given for total suspended sediment, zinc, copper and total petroleum hydrocarbons. Note that roof type can have a significant effect on the zinc load and traffic volume a significant effect on the copper load. Consider the contaminant load reduction holistically and individually when evaluating the results. It is possible that sediment loads could increase following the implementation of a LID scenario with significant additional pervious area: but metal loads will be much lower. This is an acceptable outcome.

The CLM spreadsheet is updated periodically by ARC to include the latest understanding of contaminant loads and treatment effectiveness.

## 6.4 Checklist – incorporating Objective 5

### 6.4.1 The checklist

The checklist is a means to ensure other benefits of LID are taken into account in the design process in order to achieve multiple objectives and added value for the development. These additional benefits (introduced in Section 2.3) are achieved by utilising existing guidelines and/or professional practices for; urban design, Crime Prevention Through Environmental Design (CPTED), energy efficiency, landscape amenity, and ecology. The checklist is provided in Table 19 below with further explanation of categories following in Section 6.4.2.

**Table 19**

The checklist

| | | |
|---|---|---|
| **URBAN DESIGN** | | |
| No. | Objectives (the "Seven Cs") | ✓ |
| 1 | Context | |
| 2 | Character | |
| 3 | Choice | |
| 4 | Connections | |
| 5 | Creativity | |
| 6 | Custodianship | |
| 7 | Collaboration | |
| **CRIME PREVENTION THROUGH ENVIRONMENTAL DESIGN** | | |
| No. | Ministry of Justice CPTED principles | ✓ |
| 1 | Access: safe movement and connections | |
| 2 | Surveillance and sightlines: see and be seen | |
| 3 | Layout: clear and logical orientation | |
| 4 | Activity mix: eyes on the street | |
| 5 | Sense of ownership: showing a space is cared for | |
| 6 | Quality environments: well-designed, managed and maintained environments | |
| 7 | Physical protection: using active security measures | |
| **ENERGY EFFICIENCY** | | |
| No. | Objectives | ✓ |
| 1 | Water use options available (roof, mains, grey water etc) | |
| 2 | Control over the amount of water use and water use options? | |
| 3 | Buildings are insulated (placed underground, green roofs, high "r" value insulation materials) | |
| 4 | Site design optimises solar exposure for living environments but allows for shading and cooling in summer months | |
| **ECOLOGY** | | |
| No. | Objectives | ✓ |
| 1 | Conservation of existing features | |
| 2 | Rehabilitation potential for ecological systems | |
| 3 | Enhanced/capitalised biodiversity of flora and fauna communities | |
| 4 | Viability of ecological systems and processes | |
| 5 | Landscape connectivity | |
| **LANDSCAPE AMENITY** | | |
| No. | Objectives | ✓ |
| 1 | Conservation | |
| 2 | View protection | |
| 3 | Coherence | |

| | | |
|---|---|---|
| 4 | Connectivity | |
| 5 | Scenic appeal | |
| 6 | Access and safety | |

### 6.4.2 Further explanation

Explanation of the items in the checklist is set out below. These should be used to assess the extent to which the overall development meets the checklist items. There is no particular "pass or fail" score of criteria for the checklist: it may not be possible to fully address each item. A successful development, in terms of the checklist, will be one that holistically integrates urban design, CPTED, energy efficiency, ecology and landscape amenity factors. It is then expected that this integration will be reflected by most criteria on the checklist being addressed.

#### 1. Urban design – the "Seven Cs"

The New Zealand Urban Design Protocol is a central government initiative to improve the quality of the urban environment. It sets out seven essential design qualities, known as the "Seven Cs", to initiate quality urban design.

Context

- ❑ Do the LID methods consider the site as a whole?
- ❑ Do the LID methods reflect an understanding of the sub-catchment and the neighbourhood?

Character

- ❑ Does the site have any existing features or features to be restored to facilitate a site specific solution?
- ❑ Do the LID methods contribute to the overall vision for the character and identity of this development?

Choice

- ❑ Do the LID methods consider the needs and decisions of the end users of the development?
- ❑ How likely is it that the LID methods will accommodate further intensification in the future?
- ❑ Do the LID methods enable end users to make choices about their energy use?

Connections

- ❑ Do the LID methods consider the natural pathways of stormwater across the site?
- ❑ How do these pathways interface with connections for people?

Creativity

- ❑ Do the LID methods implement source control in innovative yet practical solutions?
- ❑ Do the LID methods incorporate creative measures to help them succeed during operation and future maintenance?

### Custodianship

- ❑ What level of stewardship will the end users need to have to ensure the LID methods continue to operate effectively?
- ❑ How can this stewardship be promoted?
- ❑ What level of interaction (ie visibility, physical interaction) can end users of the development have with these devices?

### Collaboration

- ❑ Does the project involve engagement with others to achieve a catchment-wide approach?
- ❑ Does the design incorporate local knowledge and best practice?
- ❑ Does the project foster sharing knowledge?

### 2. CPTED – safer environments

The Ministry of Justice has released a national guideline for Crime Prevention Through Environmental Design in New Zealand (CPTED www.lgnz.co.nz/projects/SocialandCommunityIssues/CPTED/). This guideline sets out seven qualities for well-designed, safer places. CPTED principles apply to both the form of development and design of open spaces.

### Access: safe movement and connections

- ❑ Do the devices avoid dense planting alongside pedestrian routes and focus this planting in other areas?

### Surveillance and sightlines: see and be seen

- ❑ Does the design and layout of the development and any stormwater devices allow for surveillance?

### Layout: clear and logical orientation

- ❑ Does the clustering/built form design promote a good framework for the intended stormwater management approach?

### Activity mix: eyes on the street

- ❑ Do the buildings, open spaces and any LID tools within the development promote or maintain surveillance of the street?

### Sense of ownership: showing a space is cared for

- ❑ Are devices selected and located to maximize quality of space and ease of ongoing maintenance?
- ❑ Are devices designed to complement and enhance their surrounds?

Quality environments: well-designed, managed and maintained environments

- ❑ Will the physical design and operational parameters of the devices avoid these becoming poorly managed and reducing the well-kept appearance of the neighbourhood?

Physical protection: using active security measures

- ❑ Do the LID methods encourage active use of an area to promote activity and avoid security risks to their operation and longevity?

### 3. Energy efficiency

Water use options available

- ❑ Will the stormwater system enable water re-use and allow end users of the development to make choices about their water use within the site?
- ❑ Do regulators allow water re-use for a wide variety of appliances?

The amount of water use

- ❑ Will the ownership of the stormwater system enable end users of the development to control their water use?
- ❑ Is water supply metered and therefore encourage re-use?

Insulation

- ❑ Are green roofs used to reduce energy losses from buildings during winter and encourage cooler internal temperatures during summer?
- ❑ Will the stormwater design integrate with other aspects of energy efficient design (interface with electrical use, water supply, wastewater, solar aspect)?

Site design for solar gain

- ❑ Does the site design optimize solar gain during winter but allow for cooling during summer?
- ❑ Are trees utilized for shade during summer?

### 4. Ecology

Where possible, designs should attempt to mimic ecological systems and processes to achieve stormwater capture and treatment. This requires conservation of existing soil, vegetation and natural drainage structure, and enhancement of these systems to provide for biodiversity. Biodiversity improves the robustness of systems by strengthening commensurate relationships between soil, water, flora and fauna to take into account their complexities and balances in natural situations.

Conservation of existing features

- ❑ Has the proposed layout taken into account natural depressions and existing drainage patterns?
- ❑ Have wetlands, springs, and seepage areas been preserved and/or enhanced?
- ❑ Have open watercourses been retained with sufficient floodplain areas to support natural processes, including flooding?
- ❑ Has the development layout protected areas of significant vegetation and/or significant individual trees?
- ❑ Has topsoil been preserved in situ, and the limit of work minimised to preserve soil structure as far as possible?
- ❑ Has the development layout focused on protecting areas where soil classes act as natural aquifers?

Rehabilitation of ecological systems

- ❑ Have riparian areas been rehabilitated in order to receive increased stormwater quantities and potential contaminants while preserving the life supporting capacity of these systems?
- ❑ Has rehabilitation works maximised opportunities for species diversity along environmental gradients?
- ❑ Can soil structure and fertility be improved on undeveloped areas of the site, or restored in open space areas following preliminary earthworks?

Biodiversity of flora and fauna communities

- ❑ Are native species in planting areas eco-sourced and appropriate for the proposed conditions?
- ❑ Is there potential for enhancement planting to include rare or representative habitats?

Viability of ecological processes

- ❑ Is existing vegetation viable from weed incursion and other environmental effects?
- ❑ Do natural areas, proposed planting, or rain garden areas have appropriate size and shape to provide a sustainable microclimate? Is a transitional edge or planted buffer present where these conditions are not provided?
- ❑ Does the proposed hydrology account for changes to the water cycle for existing natural features and/or the contributing catchment to support enhancement planting?

Connectivity

- ❑ Does the site provide seasonal habitat for migrating species or act as a habitat island, refuge, forage or temporary habitat for native fauna?

- ❑ Has fish passage been taken into consideration?
- ❑ Is vegetation part of a larger native bush unit or linear corridor eg watercourse or coastal foreshore?
- ❑ Is riparian or terrestrial rehabilitation possible to connect to areas of vegetation off-site?
- ❑ Has the stormwater approach taken into consideration the effects of upstream land use on water entering the site?
- ❑ Has the receiving environment been sufficiently buffered from potential adverse environmental effects?

### 5. Landscape amenity

If LID methods are constructed with landscape amenity in mind, they are more likely to become a permanent, well maintained feature of development as landowners are more likely to take stewardship over these facilities.  Overall designs to incorporate LID should take into account site features that distinguish a development site with its own "sense of place'.

#### Conservation

- ❑ Have significant and/or sensitive landforms, including scarps, watercourses, and floodplain areas been protected from inappropriate development?
- ❑ Does the design of the development protect significant native vegetation or individually significant trees?
- ❑ Where there are outstanding or regionally significant landscapes within proximity to the site, has the development form considered the landscape values and sensitivities?

#### View protection

- ❑ Has the layout of the development and the positioning of public areas allowed for access to existing viewpoints and provided for potential future viewing areas?

#### Coherence

- ❑ Does the site layout make for recognisable drainage patterns through the defining elements of landforms, watercourses, and overland flow paths?
- ❑ Does the development provide for coherence within the site ie the visual unity of natural and built elements, roading and stormwater infrastructure? Do these elements of the site combine and contribute to each others function and form?
- ❑ Are representative elements repeated within the landscape eg rain gardens in connection with pedestrian crossings or public open space, or a continuous watercourse that unifies the site?
- ❑ Do LID methods such as rain gardens and swales reinforce proposed planting schemes and architecture?

- Do stormwater treatment methods near wetlands and coastal areas take into account natural character values (as defined by Section 5 of the RMA)?

Connectivity

- Does stormwater infrastructure reference and/or combine seamlessly with adjacent natural drainage patterns, open spaces and receiving environments?

Scenic appeal

- Does the development provide for the elements and characteristics which contribute to the amenity value of an area, as perceived by existing residents and the public?
- Can stormwater treatment provide for vegetation that simultaneously acts to screen undesirable views?
- Can landforms and planting associated with LID methods reinforce the design of the development (to form edges, patterns, and transitions, frame views, set backgrounds etc)?
- Can planting also enhance the natural character of the site eg rehabilitation of wetland areas and planting for erosion controls?
- Do the unique characteristics of LID methods contribute to a "sense of place" within the development?
- Can LID methods be celebrated through the expression of water-flows and eco-technological processes? Can water-play become folly and fun, diverse and rich?

Access and safety

- Do the public have physical and visual access to water bodies, reserves, or parks?
- Is there appropriate sightlines and passive surveillance of public areas?
- Do LID methods and open water systems assist in defining the orientation of the public to their surroundings?
- Is maintenance and the resulting perception of well managed areas provided for in LID design. Is the public likely to take "ownership" of these systems?

# 7 Case Studies

Two case studies for conceptual LID developments are outlined below. They demonstrate how the LID methods and Spatial Development Framework process work.

The case studies relate to a commercial development and a multi-unit residential development in the New Lynn town centre. The case studies are taken from the PDP report to the ARC and Waitakere City Council, New Lynn East ICMP – Low Impact Design Project (PDP, 2007).

Each case study includes:

- A background to the site and development opportunities.
- A set of maps illustrating the site issues and opportunities.
- Concept plans for stormwater management of the site using both conventional and LID methods.
- Plans illustrating the urban design aspects of the proposal.
- An assessment using the Calculator, CLM and the "Seven Cs" checklist.
- A comparison between the results of the Calculator and the HEC-HMS model results.

## 7.1 Ambrico Place multi-unit development

### 7.1.1 Site description

The site is approximately 3.7 ha in size, relatively flat, and located between the end of Ambrico Place and the Manawa Reserve. The location is shown on Figure 70 in Appendix 4.

The site is currently a vacant impervious lot. There are no buildings or any other structures currently on the site. The stormwater drainage system in the area does not currently service the site. However, the systems on the adjacent properties generally fall in a westerly direction, to discharge into the Rewarewa Stream (refer Figure 66 in Appendix 4).

The geological map shows the site is underlain by Tauranga Group soils. Five hand auger boreholes were drilled on the site to investigate soil types and infiltration rates in the area. Soils were described as approximately 0.40 m of compacted fill over silts and clays of the Tauranga Group. Due to the gravely, compacted nature of the material, only one of the five bore holes was able to be drilled to 1.0 m. The infiltration test carried out gave a soakage rate of 0.5 $l/min/m^2$. This rate is slightly higher than expected and probably represents infiltration into a slightly more granular material used for the fill rather than the natural soils.

### 7.1.2 Opportunities and constraints

Figures 65 to 68   in Appendix 4 give background information for geology, surface water, ecological features and District Plan zoning to build up the constraints mapping.

#### Opportunities

The site for the multi-unit residential block is located between three access ways within the Ambrico Place residential area, with the fourth aspect to the east bordering Ambrico Place itself.  This allows access to the site from all sides, potentially limiting the extent of driveways required internally within the site.  Traffic volumes are low in some of the accessways allowing potential the use for pedestrian traffic and/or opportunities for a range of permeable surfaces with less load requirements.

The surrounding area is made up of high-density multiple unit terrace homes.  The zoning in the area allows for multiple level and mixed-housing densities allowing architecture to be used creatively within the LID proposal and the concentration of building platforms to maximize open spaces.

The site is positioned lengthways east to west, facing a lane to the north.  This provides for significant solar gain, allowing for flexibility in design and greater potential for plant growth and resulting evapo-transpiration.  Views from the site are generally to accessways, but there is the Manawa Wetland Reserve to the west that provides an attractive amenity and a borrowed landscape to the development.  Access to the wetland provides opportunities for both passive recreation and demonstration of LID in the form of stormwater wetlands.  This wetland also provides the opportunity for discharge of stormwater from the system for further treatment.  The proposed development slopes gently down to the west toward this system, with sufficient slope to prevent ponding and allow the movement of water.

The residential block has access along footpaths on Ambrico Place and adjacent accessways.  The site is within 50 metres of a community centre to the north east, with potential future pedestrian connections to the New Lynn railway station.

#### Constraints

The location of the proposed multi-unit residential development is on a former hardware store and timber yard, with the possibility of contaminants in the subsoil that require further investigation.  In this case, LID designs could be required to avoid areas of contamination by using methods to treat water on the surface and minimise infiltration.  Alternatively contaminated soils may need to be removed from the site which, would then potentially allow for infiltration or soil remediation to be used.

The accessways that surround the site, while providing options for access, do create issues with privacy (eg headlights into buildings), and require consideration of existing views from Ambrico Place to the Manawa Wetland Restoration Natural Area. However, given that no alternative access is available, and WCC require the route to be a through-way, the existing traffic routes/circulation must be taken be maintained. This means many impervious surfaces on the margins of the site need to be retained or at least retained as a surface suitable for traffic.

Neighbours are in close proximity and in high-density next to the site, which allows for significant opportunities with education, but could affect views, solar gain and landscape amenity for these existing dwellings.

Although the site is currently cleared, allowing for a blank slate approach to development, there is no large established vegetation that can be utilised in site plans.

### 7.1.3 LID concepts

The site is likely to be redeveloped for residential use.  Therefore, it has been assumed that the development would comprise:

- At least 15 units on the site (1 per 230 $m^2$) similar to surrounding development densities. The final LID concept includes 19 units on the site.
- A shared driveway with the adjacent development (this can be accommodated within WCC District Plan requirements).

Two LID concepts for the multi-unit residential development on the site are shown on Figures 71 to 73 in Appendix 4.  Sections for the proposed concept are shown on Figure 74.

Concepts used to reduce the total amount of impervious area were:

- Clustering of residential units to reduce the building footprint.
- Obtaining driveway access from existing accessways on adjacent properties.
- Locating units in clusters and near the existing roads to reduce the length of new accessways.

Concepts used to reduce flows by changing the run-off characteristics of the site areas were:

- Green roofs.
- Permeable paving (flow reduction is primarily by interception of run-off and increasing the time of concentration through sub-grade material).
- Soil reconditioning of "pervious areas".
- A swale to lengthen flow paths.

Concepts used to further reduce peak flows were:

- Detention of driveway and pervious area flows with above ground detention.
- Rain detention tanks for standard roofs.

Water re-use has not been included in the detention tanks receiving roof water; however, this is a possibility and could reduce the volumes of water discharged.

### 7.1.4 Assessment

#### Hydrological modelling

Results of the hydrological modelling are given in Table 20 below. These results show that run-off from the existing site has significantly greater peak flows and volumes than the bush equivalent scenario. While stormwater detention can achieve peak-flow rates similar to the bush equivalent scenario, the proposed LID concept reduces peak-flow rates to very close to or even less than peak-flow rates in the bush covered equivalent. Stormwater volumes are increased regardless of stormwater management techniques employed; however, the proposed LID concept results in the lowest overall run-off volumes for each event modelled, and in each case are less than the existing site condition.

**Table 20**

Ambrico Place Multi-unit Residential: hydrological modelling results

| Condition | 2-year ARI | 10-year ARI | 100-year ARI |
|---|---|---|---|
| Bush covered equivalent, CN = 70 | 0.019m3/s<br>100m3 | 0.043m3/s<br>217m3 | 0.076m3/s<br>379m3 |
| Existing site (compacted fill, CN = 89) | 0.037m3/s<br>172m3 | 0.068m3/s<br>325m3 | 0.105m3/s<br>514m3 |
| Standard development, no stormwater management | 0.038m3/s<br>199m3 | 0.067m3/s<br>351m3 | 0.102m3/s<br>540m3 |
| Standard development, with stormwater detention | 0.020m3/s<br>204m3 | 0.044m3/s<br>356m3 | 0.088m3/s<br>544m3 |
| Development with LID | 0.018m3/s<br>163m3 | 0.035m3/s<br>306m3 | 0.064m3/s<br>487m3 |

Objective 2 has been achieved and the LID concept is the best option to minimise stormwater run-off volumes to achieve Objective 3.

#### Contaminant load modelling

The results of the contaminant load modelling are presented in Table 21 below. The results indicate that the proposed development with LID has greater contaminant removal (92 per cent TSS removal) compared to the proposed development with conventional treatment (75 per cent).

The results of the contaminant load modelling indicate that both the conventional stormwater treatment scenario and the LID stormwater management scenario achieve the design objective of 75 per cent TSS treatment efficiency.

**Table 21**

Ambrico Place Multi-unit Residential: contaminant modelling results

| Option | Treatment | Bottom of site out-fall loads (kg/annum) | | | Untreated TSS load | Overall TSS treatment efficiency |
|---|---|---|---|---|---|---|
| | | TSS | Zn | Cu | | |
| Existing | None | 18.3 | <0.01 | <0.01 | 18.3 | 0.0% |
| Development with conventional treatment | Sand Filter | 20.7 | 0.07 | 0.01 | 82.8 | 75.0% |
| Development with LID | Swales, detention, permeable paving | 7.3 | 0.05 | <0.01 | 90.3 | 92.0% |

## Urban design

The proposed designs provide for an effective treatment of the street edge with house fronts facing north and to the main access way, and parking generally to the side, rear, and south. The stacking of building heights from north to south allows passive surveillance of the access lane, Ambrico Place and the adjacent wetland reserve, providing greater security.

Residents are provided with a choice of housing types, some of which overlook green roof terraces and have access to shared open spaces at ground level.. The layout and aspect of the subdivision ensures that solar gain is maximised In addition, proposed parking areas at the rear and south of buildings provide light wells.

A mixture of outdoor living and community open spaces are provided in the proposed design, including private spaces in fenced yards, semi-private spaces in driveways and balconies, community spaces in shared internal landscapes, and streetscape spaces shared with the wider Ambrico Place area. Streetscapes are improved through swales and street trees, and encourage pedestrian connections from Ambrico Place to the Manawa Wetland Reserve.

## Ecology

The rehabilitation of a brownfield site and the resultant remediation of soils improves the ecology of the area and now provides possibilities for interception and treatment of stormwater. This has obvious benefits to the receiving wetland and downstream environments. The LID designs also have the potential capacity to treat overflow of stormwater from Ambrico Place, either as surface run-off, or from LID devices in the street.

As a result of the proposed development, there would be increased open green space compared to the previous development, including lawn areas, rain gardens and amenity plantings.  This includes additional trees that provide urban habitat including refuge and food sources for various urban fauna (birds, invertebrates and herpetofauna).  Green roofs, street trees, and open spaces have additional benefits of cooling ambient temperatures, intercepting dust, and improving air quality with resulting environmental enhancement.

### Landscape

The re-development of the residential area provides for significant improvement to the amenity of both the site and the wider community of Ambrico Place.  The creation of grassed areas, planted streetscapes and large trees assists in greening an area that is largely devoid of green open space and trees.  Bioretention gardens and planted swales provide additional landscape amenity.  The visibility of stormwater LID methods provides a further opportunity for the education of residents.

Views across the site to the Manawa Wetland from Ambrico Place are improved as a result of the subdivision layout and landscaping works.  .  Pedestrian and landscape connections provide thoroughfares for residents within the site and connections off-site to a neighbouring community centre, neighbourhood park on Ambrico Place and the Manawa Reserve Wetland.  Street trees, as part of improved streetscapes, provide for shade and interception of rainfall, while also creating a more intimate space within the street.  These trees additionally provide privacy to homes and break up and integrate building facades that are typically uniform elsewhere in the development.

The previous assessments have been summarised in the checklist to gauge the extent to which Objective 5 is achieved (i.e.  achieving multiple urban design benefits through a LID approach).

**Table 22**

The checklist, Ambrico Place Multi-unit development

| **URBAN DESIGN** | | |
|---|---|---|
| No. | Objectives (the “Seven Cs”) | ✓ |
| 1 | Context | ✓ |
| 2 | Character | ½ |
| 3 | Choice | ½ |
| 4 | Connections | ✓ |
| 5 | Creativity | ✓ |
| 6 | Custodianship | ✓ |
| 7 | Collaboration | ✓ |
| **CRIME PREVENTION THROUGH ENVIRONMENTAL DESIGN** | | |
| No. | Ministry of Justice CPTED principles | ✓ |
| 1 | Access: safe movement and connections | ✓ |
| 2 | Surveillance and sightlines: see and be seen | ✓ |
| 3 | Layout: clear and logical orientation | ✓ |
| 4 | Activity mix: eyes on the street | ✓ |

| | | |
|---|---|---|
| 5 | Sense of ownership: showing a space is cared for | ✓ |
| 6 | Quality environments: well-designed, managed and maintained environments | ✓ |
| 7 | Physical protection: using active security measures | ✓ |
| **ENERGY EFFICIENCY** | | |
| No. | Objectives | ✓ |
| 1 | Water use options available (roof, mains, grey water etc) | X |
| 2 | Control over the amount of water use and water use options? | ✓ |
| 3 | Buildings are insulated (placed underground, green roofs, high “r” value insulation materials) | ½ |
| 4 | Site design optimises solar exposure for living environments but allows for shading and cooling in summer months | ✓ |
| **ECOLOGY** | | |
| No. | Objectives | ✓ |
| 1 | Conservation of existing features | ½ |
| 2 | Rehabilitation potential for ecological systems | ✓ |
| 3 | Enhanced/capitalised biodiversity of flora and fauna communities | X |
| 4 | Viability of ecological systems and processes | ½ |
| 5 | Landscape connectivity | ✓ |
| **LANDSCAPE AMENITY** | | |
| No. | Objectives | ✓ |
| 1 | Conservation | X |
| 2 | View protection | ✓ |
| 3 | Coherence | ✓ |
| 4 | Connectivity | ½ |
| 5 | Scenic appeal | ✓ |
| 6 | Access and safety | ✓ |

#### Road layout

The site had to make allowance for connecting the existing road to the north of the site with the existing road to the south west corner of the site. This reduced the available site area by approximately 0.5 ha. The road is to be constructed of permeable paving materials to reduce peak run-off flows. It is not included in the above results.

### 7.1.5 Calculator assessment

To assess the usability of the LID Calculator against a more complex model such as HEC-HMS 3.1, the design has been modelled with both programmes.

The results have then been compared with the LID Calculator using the same pervious and impervious areas and curve numbers. An example of the LID Calculator spreadsheet is displayed below and shows the results from the Calculator for the proposed LID development concept for the multi-unit development.

**Figure 15a**

Example of the LID Calculator spreadsheet

**LOW IMPACT DESIGN CALCULATOR FOR USE AS A PRE ASSESSMENT TOOL**

| | | | | |
|---|---|---|---|---|
| Development | **Ambrico** | | | 18/07/08 09:46 |
| Local Authority | Waitakere | | Enter details for the proposed development. Go to the next screen to select LID methods to assess flows | |
| Location | New Lynn | | | |
| Soil Type | Weathered mud/sandstone | | | |
| Total Catchment Area ($m^2$) | 3253 | | | |
| Existing % IMPERVIOUS | 0% | | | |
| Existing Pervious area Compaction | compacted | | | |
| **Proposed** | **Development Design Areas** | | | **% Impervious** |
| Roof Area A ($m^2$) | 630 | | | 19.37% |
| Roof Area B ($m^2$) | 750 | | | 23.06% |
| Roof Area C ($m^2$) | | | | 0.00% |
| **Sub Total** | 1380 | | | **42.42%** |
| Car Park Area A ($m^2$) | 380 | | | 11.68% |
| Car Park Area B ($m^2$) | | | | 0.00% |
| Car Park Area C ($m^2$) | 0 | | | 0.00% |
| **Sub Total** | 380 | | | **11.68%** |
| Paved Area A ($m^2$) | 100 | | | 3.07% |
| Paved Area B ($m^2$) | | | | 0.00% |
| Paved Area C ($m^2$) | 0 | | | 0.00% |
| **Sub Total** | 100 | | | **3.07%** |
| Roads (excluding verge) | | Length (m) | Width (m) | |
| Residential Culdesac | 0 | 0 | 0 | 0.00% |
| Residential Road | 0 | 0 | 0 | 0.00% |
| Residential Through Road | 0 | 0 | 0 | 0.00% |
| **Sub Total** | 0 | 0 | | **0.00%** |
| Pervious Area ($m^2$) | | | | |
| Pervious Area A ($m^2$) | 1393 | | | |
| Pervious Area B ($m^2$) | 0 | | | |
| **Sub Total Pervious Area** | 1393 | | | |
| **Total Area** | 3253 | | | **Total % IMPERVIOUS Area** |
| | AREA CORRECT | | Next Screen | 57.18% |

**Figure 15b**

Example of the LID Calculator spreadsheet

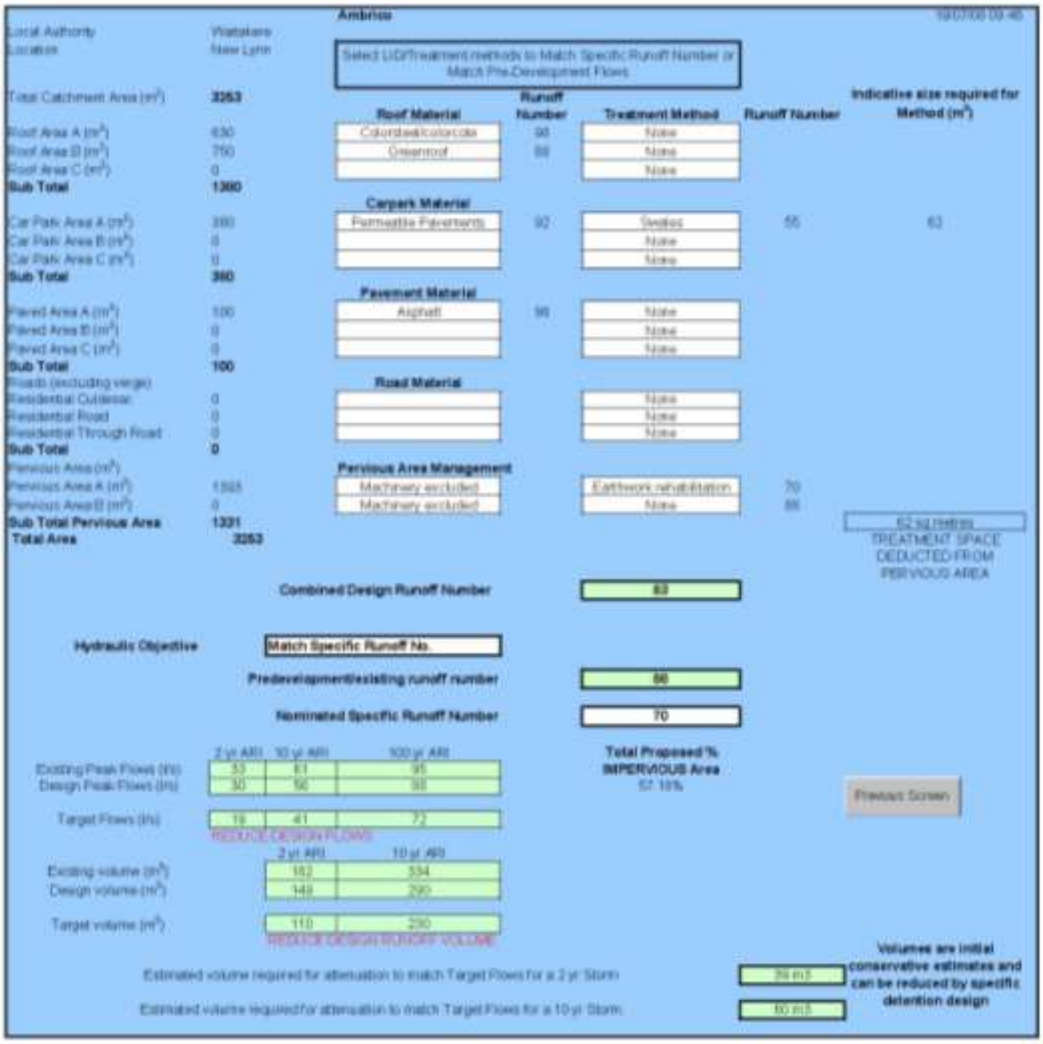


Table 23 below shows the catchment flows and volumes for the 2-year, 10-year and 100-year ARI storm events for the two models.

**Table 23**

Ambrico Place multi-unit residential: hydrological modelling results comparison

| Condition | 2-year ARI | 10-year ARI | 100-year ARI |
|---|---|---|---|
| Calculator – bush covered equivalent | 0.019$m^3$/s<br>110$m^3$ | 0.041$m^3$/s<br>230$m^3$ | 0.072$m^3$/s |
| HEC-HMS model – development with LID, without detention | 0.018$m^3$/s<br>163$m^3$ | 0.035$m^3$/s<br>306$m^3$ | 0.064$m^3$/s<br>487$m^3$ |
| Calculator model – development with LID, without detention | 0.030$m^3$/s<br>149$m^3$ | 0.056$m^3$/s<br>290$m^3$ | 0.088$m^3$/s |

The difference in detention volumes (between developed and bush covered) from the Calculator model for the 2- and 10-year ARI events are 50 and 76 cubic metres. The routed storage volumes calculated by the HEC-HMS model are 14 and 29 cubic metres. The Calculator model therefore overestimates the required detention volume by 2.5 to 3 times in this case.

### 7.1.6 Summary

The 3 ha site is surrounded by multi-unit residential developments. A concept layout has been created with 19 units (slightly greater than the average surrounding development density). The development has been orientated to maximise exposure to the northern aspect by using a terraced layout and connects both to Manawa wetland to the west and Ambrico Place to the east. Landscape and amenity improvements include outdoor living areas and increased use of planting.

Impervious areas for the layout have been minimised by clustering the buildings and obtaining access from existing adjacent accessways. Green roofs, permeable pavement, soil conditioning, a swale, rain tanks and above ground detention have been used to reduce peak flows for the 2-year, 10-year and 100-year ARI storms to the equivalent of a bush covered site.

The LID stormwater management methods used provide 92 per cent removal of TSS.

## 7.2 Titirangi Road/Great North Road commercial site

### 7.2.1 Site description

This site is located on the corner of Titirangi Road and Great North Road, as shown on Figures 70 and 75 in Appendix 4.

The total site is approximately 19 ha in size including about 3.5 ha of stream and margins.  The site slopes down towards the south east, towards Scroggy Stream and the railway corridor located along the southern boundary of the site.

Apart from the stream, the commercial site considered is currently 100 per cent impermeable, with the majority of the site used for carparking.

### 7.2.2 Opportunities and constraints

Figures 65 to 68 in Appendix 4 give background information for geology, surface water, ecological features and District Plan zoning to build up the constraints mapping.

The stormwater drainage system in the area does not currently service the site. However, the site falls back towards Scroggy Stream, and it is likely that stormwater from the site currently falls in a south easterly direction to the stream.

The geological map shows the site is underlain by Tauranga Group alluvial soils

#### Opportunities

The site of the commercial case study is at the intersection of two major roads connecting suburbs north and west of the city.  The area is also within the perimeter of the New Lynn town centre and in close proximity to the railway station and arterial bus routes.

The site slopes gently to the south east where it joins with Scroggy Stream along the southern boundary.  The stream is part of a larger Restoration Natural Area, an under utilised area of public open space that has been recognised for its potential natural values and a connection point for pedestrian and cycle networks.  The open space in this location connects upstream under the railway embankment to the Manawa Wetland and downstream to the Whau River.

The site has a number of opportunities for comprehensive development due to its large size and location adjacent the existing New Lynn Town Centre.

#### Constraints

The development site is currently an area of mixed-use development with potential for contaminants in the soils underlying the site.  The area is set back off the main road, backing onto a neglected drainage reserve and a railway corridor.  The front of the area faces onto the rear of light industrial and commercial buildings and an electrical substation.

The re-development of this site as big box retail provides few opportunities for mixed-use development.  Traffic circulation through the site is limited by entrance points which have the potential to conflict with five lanes on Great North Road (limited to west bound traffic) and back up of traffic between the Titirangi Road intersection and Arawa Street.

### 7.2.3 LID concepts

It has been assumed that the site would be redeveloped for commercial purposes. Consistent with a development proposal which has been previously put to WCC, it has also been assumed that the development would comprise:

- A single big box development, approximately 6000m$^2$ in size.
- Carparking in general accordance with District Plan requirements.

Proposed LID concepts for the commercial site are shown on Figures 71 to 74 and Figure 76 (in Appendix 4) from the New Lynn Study. A simple development scenario comprising a single structure with retail, commercial and service activities was developed as Scenario A (Figure 77, Appendix 4). A more complex mixed-use design was also developed as Scenario B (Figure 78, Appendix 4) to highlight the additional opportunities. This incorporated residential properties on the upper stories. Such mixed-use development will provide for greater density, choice, community vibrancy, proximity of complementary land uses, and passive surveillance for public places and open spaces after trading hours. A further alternative with the retail development split into different buildings is shown on Figure 77.

The former was used for the detailed analysis, however the latter increases urban design benefits of the concept. Both use similar LID concepts and designs.

Concepts used to reduce the total amount of impervious area were:

- Maximising carparking underneath building, to maximise the extent of other permeable areas.
- The inclusion of swales, gardens and planting (around the pond).

Concepts used to reduce flows by changing the run-off characteristics of the site areas were:

- Green roofs.
- Permeable pavement.
- Swales to lengthen flow paths.
- Tree-pits and rain gardens.

Concepts to further reduce peak flows:

- Detention of run-off with a detention pond and detention tanks.

Water re-use was considered for the proposed development for this site. However, lack of a residential component means that opportunities for water reuse are limited to toilet facilities. This was considered to be a low demand and water re-use a relatively costly technique to implement. It is noted that the alternative design which sought to create mixed-use would present an opportunity for water reuse.]

### 7.2.4 Assessment

#### Hydrological modelling

Results of the hydrological modelling are given in Table 24 below. These flows are for the commercial site development and the Scroggy Stream area to the south combined.

These results show that run-off from the existing site has significantly greater peak

flows and volumes than the pre-development (bush covered) scenario. The proposed LID concept (with stormwater detention) reduces peak-flow rates to very close to or even less than peak-flow rates in the bush covered equivalent and therefore represents a significant improvement to the existing hydrological regime. Total run-off volumes are reduced from the existing levels when LID stormwater methods are used, but still do not match the equivalent of a bush covered site.

The standard commercial development used for comparison purposes is shown in Figure 79 in Appendix 4.

**Table 24**

Titirangi Road/Great North Road commercial site: hydrological modelling results (includes Scroggy Stream)

| Condition | 2-year ARI | 10-year ARI | 100-year ARI |
|---|---|---|---|
| Bush covered equivalent | $0.12m^3/s$<br>$590m^3$ | $0.26m^3/s$<br>$1300m^3$ | $0.46m^3/s$<br>$2260m^3$ |
| Existing | $0.25m^3/s$<br>$1230m^3$ | $0.42m^3/s$<br>$2220m^3$ | $0.63m^3/s$<br>$3340m^3$ |
| LID methods, with stormwater detention | $0.11m^3/s$<br>$950m^3$ | $0.23m^3/s$<br>$1790m^3$ | $0.48m^3/s$<br>$2860m^3$ |
| LID methods, without stormwater detention | $0.19m^3/s$<br>$950m^3$ | $0.35m^3/s$<br>$1790m^3$ | $0.56m^3/s$<br>$2860m^3$ |
| Standard development, with sand-filters | $0.19m^3/s$<br>$940m^3$ | $0.35m^3/s$<br>$1800m^3$ | $0.56m^3/s$<br>$2890m^3$ |

Objective 2 has been achieved for the "bush covered equivalent". The LID concept has a similar amount of stormwater run-off volumes to other options and therefore Objective 3 has only been partially achieved.

#### Contaminant loading

The results of the contaminant load modelling for the Titirangi Road/Great North Road Commercial Site are provided in Table 25. The results indicate that the commercial development with LID stormwater management would achieve slightly greater treatment efficiency (77.4 per cent TSS removal) as opposed to the commercial development with conventional treatment (75 per cent).

The results of the contaminant load modelling indicate that both the conventional and LID stormwater management scenarios achieve Objective 4 – 75 per cent TSS treatment efficiency.

**Table 25**

Titirangi Road/Great North Road commercial site: contaminant load modelling results

| Option | Treatment | Bottom of site out-fall Loads (kg/annum) | | | Untreated TSS load | Overall TSS treatment efficiency |
|---|---|---|---|---|---|---|
| | | TSS | Zn | Cu | | |
| Pre-development | None | 50.0 | <0.01 | <0.01 | 50.0 | 0.0% |
| Development with conventional treatment | Sand Filter | 99.4 | 0.34 | 0.10 | 397.7 | 75.0% |
| Development with LID | Swales, rain gardens, tree-pits, detention, permeable paving | 132.9 | 0.08 | 0.06 | 587.9 | 77.4% |

## Urban design

Improvements to the existing urban design could be achieved by providing connections with the stream and adjacent amenity and transportation areas. These are incorporated into both design scenarios, but more so from the alternative design (Scenario B, Figure 78 in Appendix 4).

In both designs it is preferred that a small retail or café is located in a public area to provide a node of activity on the street and overlooking the Scroggy Stream area.

In both designs the retail development is close to inter-modal nodes of public transportation, and enhances connections through dedicated bus stops, and walkways to the rail station. There are also provisions made for cycle and walkways adjacent to the site and in association with public open space. Surveillance of these public spaces is greater in the alternative design, which also provides a public view to stormwater facilities (including the green roof) and provides options and inter-visibility within the pedestrian pathways. The building in the alternative design faces directly to the open space area with its back face to the existing parking and rear of the commercial buildings along Great North Road.

Both alternatives provide green roof solutions and therefore provide thermal insulation. The potential solar gain is greatest for the mixed-use alternative, which also provides thermal regulation within the ground and directs storage and delivery facilities to the south side.  Both alternatives have potential to utilise solar energy cells or to capture and reuse roof water.

Parking areas are provided underneath the building in the concept design and additionally on the roof of the alternative design, to maximise floor space of the built area and provide access to the green roof and mixed-use buildings on the upper levels.

### Ecology

Stormwater will now receive treatment from the LID methods on-site before entering the adjacent stream and downstream reaches.  Where previously there were no connections between ecology and stormwater there are now interfaces with both soil and plant media.

In comparison to existing conditions, there is increased open space and permeable surface areas in the LID proposal.  There are also additional trees providing urban habitat and connections within the site to open space areas.  Green roofs and increased open spaces have additional benefits of cooling ambient temperatures, incepting dust and other associated environmental benefits.

The riparian buffer to the Scroggy Stream has been widened in the alternative design, including the potential to moderate the existing steep batter slope in combination with planting and weed controls and the incorporation of parallel wetland systems for stormwater treatment.

### Landscape

Where the site currently has no positive landscape values, there will now be open space in the form of water features, rain gardens, planted swales, green roofs and street trees.  This will significantly improve the amenity of the site and encourage the public to enter the space and as a result view the natural values of Scroggy Stream. Connections through the site and within the open space area will be strengthened through pedestrian/cycle networks to Great North Road and the rail system.

Parking does not compete with the building at the interface with the street, placed behind, under or on top of the building (where a green roof is not used), depending on the proposed alternative.  Intimate open spaces are instead provided along the interface with Titirangi Road, including café/retail fronts.

The previous assessments have been summarised in the checklist to gauge the extent to which Objective 5 is achieved.  This assessment considers the proposed concept (not scenario A or B) and includes the rehabilitation of Scroggy Stream.

**Table 26**

The checklist: Titirangi Commercial Centre

| **URBAN DESIGN** | | |
|---|---|---|
| No. | Objectives (the “Seven Cs”) | ✓ |
| 1 | Context | ½ |
| 2 | Character | ✓ |
| 3 | Choice | X |

| | | |
|---|---|---|
| 4 | Connections | ½ |
| 5 | Creativity | ✓ |
| 6 | Custodianship | ✓ |
| 7 | Collaboration | ✓ |
| **CRIME PREVENTION THROUGH ENVIRONMENTAL DESIGN** | | |
| No. | Ministry of Justice CPTED principles | ✓ |
| 1 | Access: safe movement and connections | ✓ |
| 2 | Surveillance and sightlines: see and be seen | ✓ |
| 3 | Layout: clear and logical orientation | ½ |
| 4 | Activity mix: eyes on the street | ½ |
| 5 | Sense of ownership: showing a space is cared for | ✓ |
| 6 | Quality environments: well-designed, managed and maintained environments | ✓ |
| 7 | Physical protection: using active security measures | ½ |
| **ENERGY EFFICIENCY** | | |
| No. | Objectives | ✓ |
| 1 | Water use options available (roof, mains, grey water etc) | X |
| 2 | Control over the amount of water use and water use options? | ½ |
| 3 | Buildings are insulated (placed underground, green roofs, high "r" value insulation materials) | ✓ |
| 4 | Site design optimises solar exposure for living environments but allows for shading and cooling in summer months | X |
| **ECOLOGY** | | |
| No. | Objectives | ✓ |
| 1 | Conservation of existing features | ✓ |
| 2 | Rehabilitation potential for ecological systems | ✓ |
| 3 | Enhanced/capitalised biodiversity of flora and fauna communities | ✓ |
| 4 | Viability of ecological systems and processes | ✓ |
| 5 | Landscape connectivity | ✓ |
| **LANDSCAPE AMENITY** | | |
| No. | Objectives | ✓ |
| 1 | Conservation | ✓ |
| 2 | View protection | ✓ |
| 3 | Coherence | ½ |
| 4 | Connectivity | ✓ |
| 5 | Scenic appeal | ✓ |
| 6 | Access and safety | ✓ |

## Road layout

The location of the site on Titirangi Road and Great North Road means that access is difficult. Both roads are heavily trafficked and cause significant constraints to traffic entering and exiting the site. The layout is similar to that provided in the draft commercial development concept to WCC.

Preliminary comment of the layout design by a traffic engineer has been sought to ensure that the proposed design provides a realistic scenario for a development on the site.

An entrance/exit point to the site has been provided from Great North Road.

Two entrance/exit points have been provided from Titirangi Road. The entrance and exit points here are constrained by the main intersection of Great North Road and Titirangi Rd and the road off Titirangi Rd opposite the south west corner of the site.

### 7.2.5 LID Calculator assessment

Modelling of the LID Calculator has also been carried out for the Titirangi Rd commercial development case study.

The same pervious and impervious areas and curve numbers have been used. An example of the LID Calculator spreadsheet is displayed below in Figures 16a and 16b, and shows the results from the Calculator for the proposed LID development concept for the development.

**Figure 16a**

LID Calculator results for the Titirangi Road commercial development

**LOW IMPACT DESIGN CALCULATOR FOR USE AS A PRE ASSESSMENT TOOL**

| | | | | |
|---|---|---|---|---|
| Development | Titirangi | | | 18/07/08 08:51 |
| Local Authority | Waitakere | | Enter details for the proposed development. Go to the next screen to select LID methods to assess flows | |
| Location | New Lynn | | | |
| Soil Type | Weathered mud/sandstone | | | |
| Total Catchment Area (m²) | 19325 | | | |
| Existing % IMPERVIOUS | 100% | | | |
| Existing Pervious area Compaction | compacted | | | |
| **Proposed** | **Development Design Areas** | | | **% Impervious** |
| Roof Area A (m²) | 6340 | | | 32.81% |
| Roof Area B (m²) | | | | 0.00% |
| Roof Area C (m²) | | | | 0.00% |
| **Sub Total** | 6340 | | | **32.81%** |
| Car Park Area A (m²) | 2820 | | | 14.59% |
| Car Park Area B (m²) | 1140 | | | 5.90% |
| Car Park Area C (m²) | | | | 0.00% |
| **Sub Total** | 3960 | | | **20.49%** |
| Paved Area A (m²) | | | | 0.00% |
| Paved Area B (m²) | | | | 0.00% |
| Paved Area C (m²) | | | | 0.00% |
| **Sub Total** | 0 | | | **0.00%** |
| Roads (excluding verge) | | Length (m) | Width (m) | |
| Residential Culdesac | 0 | 0 | 0 | 0.00% |
| Residential Road | 0 | 0 | 0 | 0.00% |
| Residential Through Road | 0 | 0 | 0 | 0.00% |
| **Sub Total** | 0 | 0 | | **0.00%** |
| Pervious Area (m²) | | | | |
| Pervious Area A (m²) | 975 | | | |
| Pervious Area B (m²) | 8050 | | | |
| **Sub Total Pervious Area** | 9025 | | | |
| **Total Area** | 19325 | | | **Total % IMPERVIOUS Area** 53.30% |
| | AREA CORRECT | Next Screen | | |

**Figure 16b**

LID Calculator results for the Titirangi Road commercial development

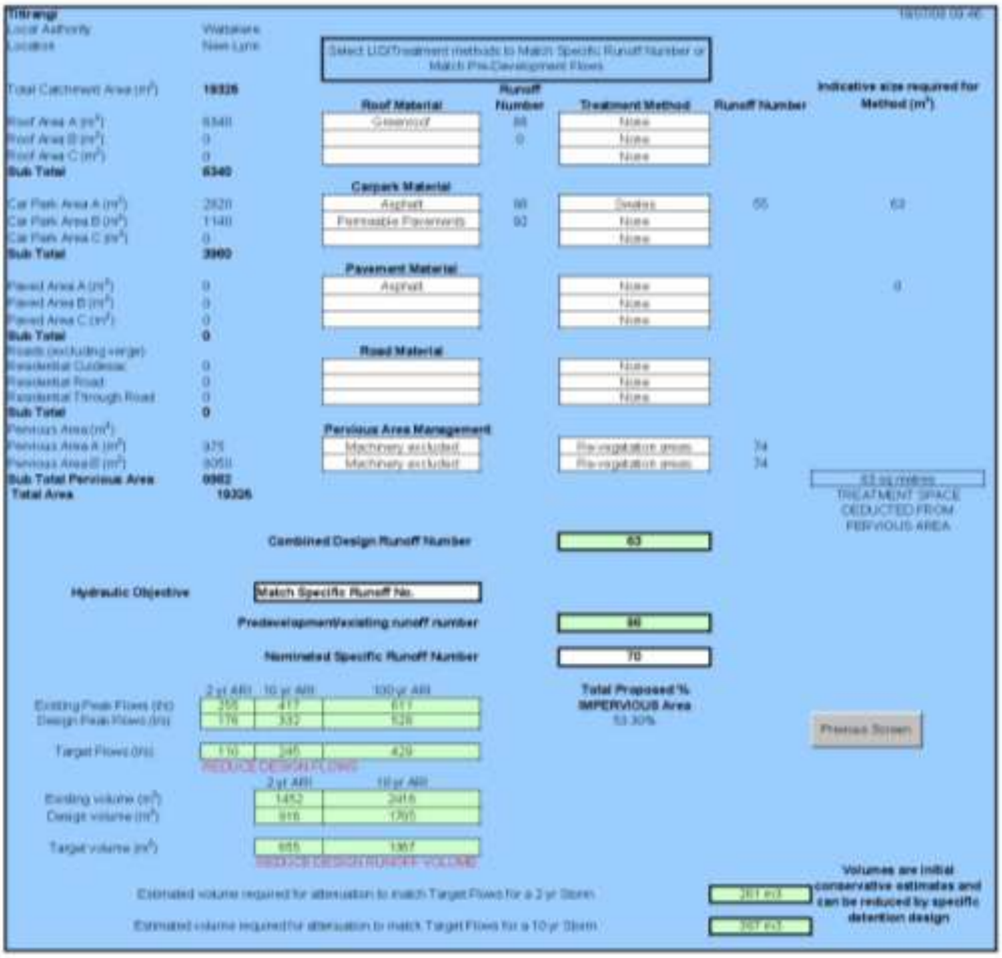


**Table 27**

Titirangi Road/Great North Road commercial site: comparison of hydrological modelling results

| Condition | 2-year ARI | 10-year ARI | 100-year ARI |
|---|---|---|---|
| Calculator model: bush covered equivalent | 0.11m$^3$/s<br>655m$^3$ | 0.25m$^3$/s<br>1367m$^3$ | 0.43m$^3$/s |
| HEC-HMS modelling: LID methods, without stormwater detention | 0.19m$^3$/s<br>950m$^3$ | 0.35m$^3$/s<br>1790m$^3$ | 0.56m$^3$/s<br>2860m$^3$ |
| Calculator modelling: LID methods, without stormwater detention | 0.18m$^3$/s<br>916m$^3$ | 0.35m$^3$/s<br>1765m$^3$ | 0.53m$^3$/s |

The data indicates that for a simple site the LID Calculator produces similar flow and volume results to the HEC-HMS model.

The detention volumes calculated by the LID Calculator are conservative – approximately 2.6 times larger than the HEC-HMS modelling in this case. Detention volumes calculated from the LID Calculator are the difference in volume produced between a pre-development and post-development 10-year ARI storm event. No account of flow through the detention tank is provided with the LID Calculator, whereas the HEC-HMS model allows for the timing effects of flows being released through the detention system during the storm event. The detention volume calculated by the Calculator model for the 10-year ARI event is 397 cubic metres while the routed storage volume calculated by the HEC-HMS model is 160 cubic metres.

### 7.2.6 Summary

The previous use of this site involved a range of commercial activities, including a car yard, and therefore almost the entire site had been sealed. Stormwater is discharged directly to Scroggy Stream without treatment. Overall the site currently has little amenity value and inhibits connections to Scroggy Stream from the surrounding land.

WCC had received a development proposal for a big box retail development, and therefore the concept layout was designed to be similar to this previous proposal. The concept reduces the overall impervious area and breaks it up with LID methods and green spaces. These include extensive green roofs, rain gardens, swales, permeable pavement and more conventionally sand filters and detention devices. The concept orientates the main development to Scroggy Stream to improve connections and amenity value.

There are two alternative designs for this concept. The solely retail/commercial development was modelled however the alternative design placed greater emphasis on urban design improvements and incorporated residential-use. These layouts incorporate elements that would be worthwhile of further consideration in the future.

Compared to the existing 100 per cent impervious surface coverage, peak flows from the LID concept (including detention) for the 2-year, 10-year and 100-year ARI storms are reduced to the equivalent of a bush covered site.

The LID stormwater management methods used provide 77 per cent removal of TSS.

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# 9 Appendix 1: LID Method Case Studies

## 9.1 Reducing Impervious Area

### 9.1.1 Case study 1: New Zealand Housing Foundation – Stage 3, Waitakere City

This subdivision of medium-density sections has been carried out by a consortium of the Waitakere Housing Trust and Housing New Zealand. The development is within the Oratia Stream catchment and located off Pyramid Drive, Glen Eden. The design includes a narrow one way road (with a layout adopted to suit the topography of the site) and a swale system to treat road run-off (running down between the two road lanes). Houses are yet to be built on the subdivision.

**Figure 17 New Zealand Housing Foundation: subdivision layout with narrow roads and parking bays**

The site topography slopes toward the stream and the design has been integrated into these levels. This has avoided the need for a fill or cut batter on respective sides of the road. Such batters may have made access into the individual lots require steeper driveways with the possible need for further earthworks. By splitting the road into a one way system with two narrow lanes around the site and stepping the roading layout, the need for more earthworks on each lot has been avoided and the impervious area of the road is reduced. A swale has also been located between the two parts of the road.

WCC officers have noted that traffic management could become an issue on the site. If there are no parking restrictions on the road, it could be used for parking and prevent access for larger vehicles such as rubbish trucks.

### 9.1.2 Case study 2: Talbot Park, Glen Innes

This case study is based on discussions with Stuart Bracey, Project Manager for the Tamaki Community Renewal Project for the Housing New Zealand Corporation (HNZC) and a paper to be presented to the 2008 NZWWA stormwater conference (Bracey et al. 2008).

The Tamaki Community Renewal project involves a 5 ha site in Glen Innes, consisting of a mixture of individual units, multi-bedroom housing and three storey apartment units. The development uses LID methods including; water re-use, rain gardens, permeable paving, creation of vegetated landscaping areas and minimising impervious areas. Other sustainable development practices such as solar water heating are also used.

Talbot Park has aimed to take a sustainable development approach and incorporate this with other social and economic objectives. A pedestrian friendly, community orientated space was designed. An important part of this was to have vehicle and pedestrian access through the site and avoid closed off or dead-end areas. Buildings were therefore orientated to encourage passive surveillance of community spaces. Walking is predominant through Talbot Park given the close proximity of public transport at Glen Innes, and many households either do not have a car, or only have one car. For example, the development houses a number of people with disabilities. In other parts of the development, large families are accommodated in houses with up to seven bedrooms. In these houses, a larger number of vehicles are present. Traffic speed was reduced by using narrow road widths. The narrow road widths also meet LID principles.

HNZC tried to reduce the number of carparks provided on-site to suit these circumstances. However, ACC considered that parking of two spaces per unit should still be provided.

**Figure 18 Talbot Park: road widths change at the entry points to the development**

The above photograph shows one of the entrances to the site with reduced road width and rain garden to the right. Traffic calming measures are incorporated to promote a pedestrian friendly environment.

## 9.2 Clustering - Talbot Park

Talbot Park is a state housing area in Glen Innes, Auckland, and was first developed in the 1960s. By the late 1970s buildings were deteriorating and the area was rife with petty crime. The internal reserve within the development resembled a wasteland and was unsafe (Bracey 2007).

Brisbane based consultant Geoffrey Walker undertook preliminary scoping and concept work for the rehabilitation and intensification of the neighbourhood, and Boffa Miskell was appointed to lead community consultation, urban design, landscape design, and statutory planning. Eight architect groups were involved, along with representatives of the Housing New Zealand Corporation (HNZC), ACC and the existing Talbot Park community. The project refurbished 108 existing "Star Flat" units, and added a further 111 homes to make more efficient use of the site.

Talbot Park was redeveloped under Auckland City Council's Residential 8 zoning with specific objectives to provide compact lifestyle in appropriate locations and to cater for future population growth. The zone supports the principal aim of Auckland City's Growth Management Strategy, which seeks to encourage more efficient use of existing urban land and infrastructure by focusing future growth around existing town centres, and close to major transport nodes.

Talbot Park is now home to 700 low income residents, representing an increase of 200 persons. Master planning sought to take advantage of solar exposure with a three storey limit, and counter criminal activity by community engagement and the incorporation of urban design and "Crime Prevention Through Environmental Design" principles (CPTED).

LID methods were integral to the site design, including the placement of buildings, the formation of open spaces, landscape, and streetscape design. Specific treatments included reduction of impervious areas, augmentation of open spaces with mulched garden areas, rain tank water capture and re-use, and rain gardens in streetscapes. Clustering of buildings provided opportunities for dedicated open space and the integration of LID methods, into communal areas, private spaces, and streetscapes. Landscape areas took account of CPTED principles to greatly improve a sense of open space and amenity, while also enhancing native biodiversity and the resident's experience of native plants.

HNZC has realised benefits for a comprehensive design approach including:

- increased demand to live in the area;
- reduced tenant turnover (reduced from 50 per cent turnover in 2001 to less than 5 per cent currently);
- a significant reduction in incidents of graffiti and other forms of property damage;
- tenants reporting they are feeling safer and happier;
- tenants coming together as a community with the formation of a Talbot Park Village residents group;
- a growing appreciation of the benefits of including environmentally sustainable design features as part of any re-development; and
- a growing community acceptance of medium-density housing as a form of housing re-development.

At a household level it has been recognised, "there are signs… of families taking pride in their new homes, tending gardens and adding their own landscaping decoration" (NZ Herald, 2007). This is encouraging given the family unit is the foundation of the Talbot Park social fabric.

## 9.3 Soil Rehabilitation - Victoria Park

Sports Surface Design and Management (SSDM) were commissioned by Auckland City Council to design, plan, and project manage the renewal of the sports fields at Victoria Park in Auckland. Issues to be considered were public amenity, active recreation, cultural and archaeological values, and the presence of contaminated soils.

SSDM were tasked with improving the sports field surfaces and their drainage with appropriate consideration of contaminated soils. In many places within the park, there were existing lateral drains, which could be utilised if excavation of contaminants could be avoided. A wide variety of uncontrolled fill material was historically placed to reclaim the site. Existing 'contamination contours' had previously been mapped by a 2004 URS survey and soil sampling strategy that utilised 152 soil pits to systematically assess the level of contamination present between the soil surface and 0.5m depth across the entire park.

SSDM devised a unique approach to rehabilitate Victoria Park's sports fields while being sympathetic to and reducing potential effects from the existing contaminated soil. The approach included:

- Retaining the existing surface but removing any undesirable turf grass species. In this instance vegetation was sprayed off and removed by intensive scarification.
- Remediation of water-collecting low spots with imported topsoil to avoid rearrangement of the existing soil.
- Use of an 'aeravator' or verti-drain machine to punch small holes into the surface to allow oxygenation and infiltration. Compacted areas are loosened with minimal surface disturbance.
- Use of a "gravel banding machine" to force open a narrow trench (rather than excavate material) and backfill immediately with aggregate (see Figure 19). This connected the soil surface to the existing lateral drainage system.
- The installation of a sand layer applied to the entire site.
- Any excavated material was handled strictly according to a soil handling methodology prepared specifically for this site.

**Figure 19 The "gravel banding machine" operating at Victoria Park. The unit has been lifted out of the soil and the expander leg is visible beneath the gravel-containing hopper (after SSDM, 2009).**

The method chosen to reconnect the soil surface to the retained lateral drainage system was pivotal to minimising excavation and preventing the spread of contaminants. SSDM opted to install gravel-filled trenches using a "gravel banding machine" (see Figure 19). This machine forced open a narrow (25mm) slot in the soil using a 350 mm long expander leg with slots installed at 0.4m spacings. The formed slot was immediately backfilled using clean gravel. Notably, no excavation of existing soil was required, which minimised the risk of contaminant spread and did not generate spoil,which had expensive disposal costs. In total, the area of the four sports fields had over 85 kilometres of gravel bands installed to assist drainage during winter. A sand layer (see Figure 20) was installed over the top of the existing surface to improve drainage of surface water but also to protect the top of the gravel bands during field use.

**Figure 20 An application of a sand followed gravel banding to protect the top of the bands during field use. The turf grass grew through the sand layer to stabilise it (after SSDM, 2009).**

While every attempt to minimise soil excavation was made in the works, re-levelling was required in places and some lateral drain sections were inconsistent or uneven due to ground movement. In these instances, new sections of lateral drains were installed using conventional machinery. Soil was handled according to the methodology prepared for this project and excavated spoil removed to a closed landfill.

## 9.4 Green Roofs - University of Auckland engineering school roof

This case study is based upon discussions with Dr Elizabeth Fassman, the project manager and leader for the University of Auckland Engineering School green roof project, and Mr Craig Mountfort who performed the original media mixing trials.

The overall project aim was to test a variety of soil media mixes and depths for their ability to support plants and then determine their effect on the volume and rate of stormwater run-off.

The planning phase of the project took some time as the green roof was a new technology in the Auckland context. The capacity of the building to support the green roof was checked and permission to construct the roof sought from University property managers. The property managers were initially hesitant about allowing a green roof to be constructed until they saw an example plot which demonstrated the depth of the roof proposed, and agreement was reached to install the roof for a four-year trial. The green roof is to be removed at the end of the trial period

Extensive roofs are generally kept to a loading range of 60 kg/m$^2$ -150 kg/m$^2$ (ARC TP10) to minimise weight on the roof. The target weight for retrofitting the green roof to the University of Auckland Engineering School building was 90 kg/m$^2$. As a comparison, the green roof on the new Waitakere City Council building has a 150 mm deep substrate and a target weight of 300 kg/m$^2$ (Simcock et al. 2005). This was constructed from new rather than as a retrofit.

To achieve the target weight, a range of media mixes were identified, mixed and tested for weight, stormwater retention and plant growth. Two trial media depths (50 mm and 70 mm) were selected to test the ability of plants to grow in limited media depths. A number of media types were also selected for testing; the primary alternatives for the light weight aggregate being zeolite, pumice and expanded clay. Once the media had been selected for the roof (in terms of weight, plant supporting requirements and soil porousity/infiltration characteristics) the constituents needed to be well mixed. Problems encountered were that the constituents were sometimes not fully mixed so a sample was not representative of the blend. Also, the mixer needed to be cleaned prior to use. Further samples had to be taken from well-mixed stockpiles and further trial mixes undertaken.

**Figure 21 The soil media being mixed**

The Engineering School roof was flat and already designed for pedestrian loadings. A bitumen type water proofing layer was also already in place, so a waterproof membrane was not required as part of the retrofit. The final green roof consisted of:

- A range of native and sedum type plants.
- Various media mixes, in six trial plots and two depths.
- An 8 mm preformed corrugated plastic drainage board under the media, with filter cloth attached.
- The existing bitumen type waterproofing layer.

Construction was relatively straightforward. Access had to be obtained using a crane parked on Symonds St. A Road Opening notice and traffic management plan was required by the Auckland City Council and the work undertaken over the weekend to avoid traffic disruption.

**Figure 22 A drainage mat was installed on the roof prior to the addition of soil media**

A range of plants were also selected for testing on the roof. These were planted at a density of 18 plants/ $m^2$. Subsequent experience suggests that a density of 25 plants/$m^2$ would be a better initial plant density. Plants used in the plots include *Sedummuralis*, *Sedum purpureum*, *Sedum reflex*, *Sedum saramentosum*, *Sedum pathulifolium* and *Sedum spurim*.

**Figure 23 These plots were planted with pre-grown mats to improve plant density and establishment**

**Figure 24 The pre-grown mats immediately after construction**

The green roof is subject to varying shading and wind effects. The lift tower partially shades the southern side of the building. This has allowed different plant species to become dominant in different sections of the roof.

**Figure 25 Plants on the southern side of the building immediately after planting**

Some plant varieties had largely disappeared from the roof 18 months after planting. In some places this reflects the shallow depths of media used, but the plants are also affected by the varying climatic conditions. The University of Auckland will recommend the most successful plant varieties at the end of the trial.

**Figure 26 The north side of the roof – where the variety of plants has also changed**

## 9.5 Permeable Paving

### 9.5.1 Case study 1: Birkdale Rd, North Shore, Auckland

The following case study has been taken from information in the paper by Fassman et al. presented to the NZWWA Fifth South Pacific Stormwater conference, May 2007.

A permeable pavement consisting of impermeable block pavers (170 mm by 80 mm) with 10 mm joint gaps has been constructed on Birkdale Rd, North Shore. The site was chosen because it is an arterial type road, with higher traffic loadings than standard permeable pavement usage. (Birkdale Rd has measured as having approximately 4500 vpd on this lane in 2003) (North Shore City Council 2008). The site was therefore expected to accelerate any potential problems, such as structural deformation or loss of infiltration. The pavement is approximately 200 m$^2$ and 0.48 m deep. A "geo-grid" (a plastic grid used to spread vertical loads) was placed over half the pavement area to check the effect of this on the structural performance.

The pavement was designed to have an infiltration rate of 1200 mm/hr, which includes a factor of safety of 10 over the infiltration rate required to provide drainage of surface water.

**Figure 27 Birkdale Rd permeable paving (Timperley M. 2008)**

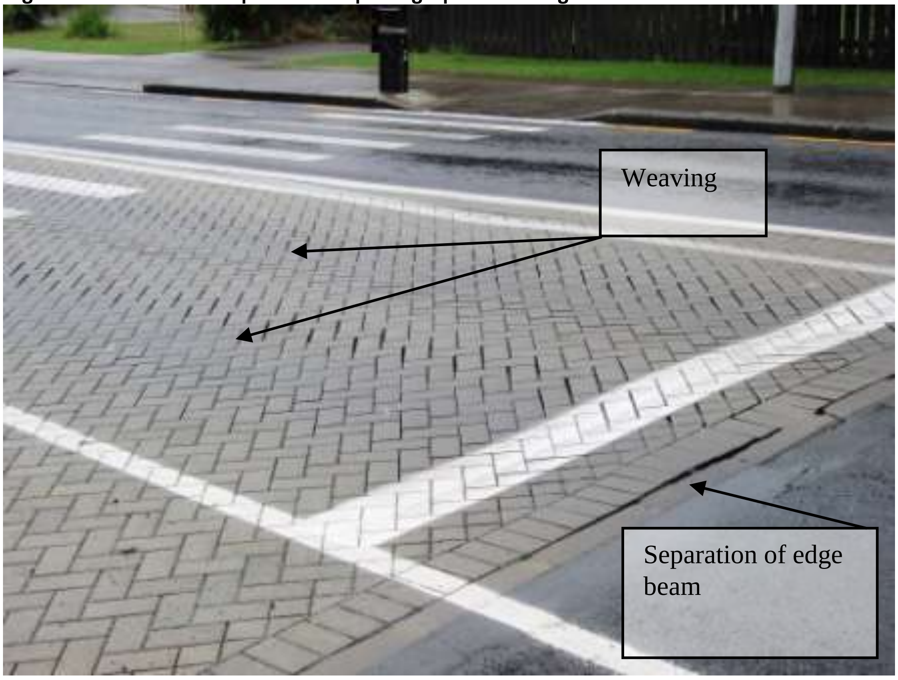
Monitoring of the permeable pavement was found to result in peak flows between 50 and 94 per cent lower than an adjacent area of asphalt pavement.

Water quality monitoring identified a TSS mass removal rate of between 30 per cent and 85 per cent for the seven storm events with sufficient monitoring data. Fassman et al. (2007) noted that silt and clay sized particles were present within the basecourse layers and could be mobilised into the stormwater system – filter cloth barriers were recommended to prevent this occurring.

The joints and block pavers were noted as moving over time – different joints were observed to be open and closed during different site visits over the time of the trial. The structural performance of the pavement has been assessed over a 12-month period using a Benkelman beam to assess pavement deflection under standard test loads. The tests indicate a deflection of 1.6 mm after 12 months. This is slightly less than the deflection at the beginning of the trial period and was expected to be as a result of slight embedment of the pavers into the bedding sand.

The blocks were laid from the top of the pavement section towards the bottom. This has allowed blocks to creep down the hill and some weaving is now apparent. It is expected that laying the blocks from the downslope end would mean they would be more tightly packed and improve the pavement's structural performance. More stress and wear was expected at the site because it has a relatively high traffic loading and includes a pedestrian crossing outside a school – where many vehicles are decelerating and turning movements occur.

**Figure 28 Birkdale Rd permeable paving upstream edge**




During construction, an impermeable liner was installed under the basecourse so as to collect water for the hydrological monitoring assessment. The liner was incorrectly installed in relation to the downslope strip drain so that flow was prevented from entering the strip drain. While this will not necessarily affect the performance of the permeable pavement it affected the monitoring results and could have allowed water to enter the adjacent existing flexible pavement with possible effects on its structural integrity over time. Careful attention to design details such as this by construction supervisors and contractors is important during construction of all LID methods.

### 9.5.2 Case study 2: Parr's Park, Waitakere City

The following case study has been developed from discussions with Mr W Smith, a senior engineer with Waitakere City Council, responsible for maintenance of stormwater management devices in Waitakere City, and Mr A Lilley, a parks officer with Waitakere City.

The Waitakere City Council Parks department has installed a range of LID methods in Parr's Park as part of the development of internal road and parking areas. These include roads without kerbing that allow run-off to be directed into roadside swales and an area of permeable paving and an area of porous paving. The permeable paving is approximately 50 m long by 5 m wide. The paver area is used for parking, generally only during use of the adjacent sportsfields.

Details of the construction are unknown. From the surface, the pavement is constructed of nominally 90 mm by 180 mm pavers with some voids in the paver matrix and joints between the pavers 5 mm and 1 0mm wide. A fine aggregate (approx 6 mm) layer is beneath the pavers. The pavers slope gently toward a concrete channel which also collects flow from the adjacent park access road.

The pavers appear to be performing well. There is no evidence of structural deformation of the paver surface. The surface of the pavers and joints are generally open. The basecourse was inspected by removing one paver – while some silt was noted in the gaps between the pavers, the aggregate beneath appeared to be unblocked. Silt is visible in the paver joints for the 1 m of pavers next to the park access road. Similarly, next to the adjacent landscaping area, mulch and leaf debris has washed on to the pavers and is causing some voids to be blocked.

Figure 29 Parr's Park permeable paving showing basecourse

Figure 30 Parr's Park permeable paving adjacent garden

Areas adjacent to permeable pavement need to be managed to prevent silt and organic matter from being washed onto the pavement.

The original paving material did not perform well structurally and broke up over time. Approximately 18 months ago the pavement was rehabilitated with removal of the old blocks, relaying of part of the basecourse layer and placement of new paving blocks.

Details of the construction are unknown.  From the surface, the pavement is constructed of a plastic crate type construction with the voids in the paver matrix filled with aggregate between 5 mm and 10 mm.  Some of the original aggregate has washed out and some sand has since been placed over the area to top up the joint spaces.

**Figure 31  Parr's Park porous paving**

## 9.6 Tree Pits and Planter Boxes

### 9.6.1 Case study 1: Bourke and Collins Street extension – Victoria Harbour Wharf, Melbourne

The Docklands area is an example of a number of stormwater initiatives that are associated with the re-development of the Victoria Harbour precinct, east of Melbourne's CBD.  Docklands covers 200 hectares of land and 7 kilometres of water front, consisting of mixed residential and commercial, medium-density and high-rise development.  Stormwater designs were incorporated into the precinct at a regional, precinct and individual site scale.

The Docklands Authority had a strong commitment to sustainable design principles, including protection of receiving waterways (Port Philip Bay), stormwater recycling, and flood management.  Large areas of public open space provided an opportunity to integrate stormwater collection, storage/reuse, and treatment within a large-scale master plan.  In this way, public safety and amenity issues became important design considerations to ensure appropriate urban form and landscape values.

Tree-pits and planter boxes for stormwater treatment were used in multiple areas of the Dockland precinct re-development. The extension of Bourke and Collins Streets in particular, provided an opportunity to incorporate stormwater treatment measures into streetscape design and arose from an earlier evaluation of all landscape areas for their potential integration into stormwater systems. The Bourke Street tree-pits were the first purpose-designed and built stormwater tree-pit system in Melbourne, replacing standard side entry pits with filtration pits to treat stormwater for the 1-in-3 month storm, while providing passive irrigation to street trees. The lead designer was Ecological Engineering, a multi-disciplinary firm specialising in water sensitive urban design (WSUD).

The Bourke Street concept included tree planter bio-retention systems aligned along the street to collect run-off flows from the street catchment, infiltrate through selected media, and treat stormwater for elevated suspended solids, nitrogen and phosphorous levels. The tree-pits were part of a wider stormwater treatment train associated with the adjacent National Building, which utilised "bio-swales" and rain gardens for stormwater treatment. These systems overflowed to reticulated stormwater systems along Bourke Street, which was directed to further treatment devices in Docklands Park, before being stored underground for irrigation and other park uses.

**Figure 32 The installed tree-pits along Bourke Street, Melbourne (Haycox, M. 2005)**

### Contractor issues

The Bourke Street tree-pits were part of the extension to an existing street in the Docklands precinct and there was concern aboout the effects on pedestrian traffic, and safety conflicts between foot traffic and vehicular movements. There were also many infrastructure channels and communication cables that were mapped and then appropriated into designs and construction methodology. Both the existing services and future access rights to these systems required considerable consultation and design modification.

The long-term health of the street trees also needed to be considered, and factored into the discussion around infrastructure constraints.  There needed to be sufficient soil, potential for root growth, and positive drainage to support plant survival and growth.

The Bourke Street extension represented the first trial of street trees for stormwater treatment in Melbourne and there were no contractors in the market place with experience of this work.  A lesson learnt in this project was to communicate to contractors when a project has WSUD objectives and will require variation from conventional street tree planting.  As the project proceeded it became clear that site supervision by a representative of the design team was essential throughout the work programme.

The levels of the first tree-pits allowed the ingress of stormwater, but did not provide sufficient freeboard to allow for surface ponding.  This limited the treatment efficiency of these systems, by preventing detention/sedimentation, and infiltration of stormwater.  There was also potential for localised sedimentation at the inlet and loss of soil from the tree-pit.  Following observation by the design team, levels were resolved, and the systems have been working effectively since.  This situation reinforced the necessity of testing the devices before acceptance and sign off, including specific checks for ponding depth and unimpeded stormwater flow paths.

### Planting issues

An advantage of having street trees  connected to the stormwater network is the regular watering that occurs from rainfall events.  No tree losses were recorded in the Bourke Street project, although subsequent projects have suffered from vandalism, as occurs with ordinary street trees, with tree guards or similar responses required in less secure locations.

### Maintenance and monitoring

The self-watering aspect of stormwater tree-pits means there is potentially less maintenance required than with conventional street trees.  The Bourke Street trees have been installed for over seven years, and are in good operating order.  Tree grates have been replaced, both to meet council design standards and to provide for larger hinged grates to assist maintenance access.  Maintenance is currently on a bi-monthly basis for the removal of litter, with tree-pits acting as a catch basin.

### Social issues

The Bourke Street trees project has integrated stormwater treatment infrastructure into an urban thoroughfare while meeting the approval of local traders and the public at large.  Tree-pit design was part of an overall master plan including the street and the precinct, allowing for the integration of pedestrian access, traffic movement, public transport alighting, vehicle parking, street sweeping, waste management etc.  The combination of tree-pits and bio-swales beside the National Building have made stormwater management a key component of the landscape design and a clear demonstration of practical and cost effective environmental initiatives.

**Figure 33 Other Dockland tree-pit examples with inflow directly from the street surface and through a grate. Notice the use of a seating wall to avoid conflicts with pedestrians (right) (Haycox, M. 2005)**


## 9.6.2 Case study 2: Queen Street tree-pits, Auckland

The retrofit of the street trees along Auckland's Queen Street was part of an overall refurbishment of the streetscape by designers Architectus Ltd. Jawa Structures undertook the design of the street tree-pits, with specific input from Arb Solutions and The Specimen Tree Company. The Queen Street tree-pits are not an example of stormwater treatment applied to tree-pits, but are presented here as the successful implementation of large trees in a retrofit, highly urbanised situation, and therefore there are lessons to be applied to similar projects.

Queen Street tree-pits were of a considerable size to support large trees in a testing urban environment. The boundaries of the pits were block walls, which provided a foundation to span a cantilevering concrete slab on which paving could be laid or a tree grate inserted. The robust foundations of the structure provided for confidence in the system. A large bolted grate assisted maintenance access, and even allowed for the possibility of replacing trees if required with minimal effects to surrounding pavers. The concrete slab also allowed access by services over tree root systems, such as for street cleaning vehicles.

### Contractor issues

Street management was one of the chief concerns for the placement of large trees in Queen Street. This was a logistical issue in terms of access to site, traffic control and pedestrian movement, co-ordinating with general contractors, masons and infrastructure services, but it was also a public relations exercise in terms of perceived effects to the public of noise, time delays, and disturbance of trade.

Existing infrastructure was a significant consideration, with difficulty in determining the location of working and abandoned services. There were specific issues with avoidance of gas lines and stormwater feeders due to their parallel occurrence within the roadside verge. Coincidence with stormwater feeders would clearly have been an opportunity in the case of stormwater treatment within these pits.

To avoid infrastructure, contractors utilised cables around root-balls prior to backfill and concrete root barriers to protect adjacent infrastructure. These comprised pre-cast u-beams with a removable lid and sometimes included a monitoring well to avoid unnecessary future disturbance of the tree-pits. Much of the infrastructure in Queen Street was replaced in coincidence with the streetscape works providing for opportunities to separate tree-pits and services.

Tree-pits were constructed of imported soils encapsulated within concrete block walls. Appropriate species selection may have allowed for stormwater tree-pits in these locations and this was mooted by the project team. However, the site had significant constraints, including high public expectation of street tree survival. Therefore, Queen Street trees represented a means to test soil types and encapsulated tree-pits, providing for future incorporation of stormwater to these systems.

### Planting issues

The trees selected for Queen Street were liquidambar and nikau. Liquidambar is an attractive street tree that has featured successfully in other streetscapes within the city. Nikau were chosen as representative of the Waihorotiu Stream corridor beneath the street, in line with the design intent of the streetscape. Nikau have been transplanted successfully in other areas of the CBD, including Karangahape Road.

Trees were located or contract grown, hardened off for a specified period within the nursery, and placed in situ within their root bag. In some circumstances temporary "stays" kept trees vertical until soils had settled. Eight cubic metres of soil was specified for nikau, and ten cubic metres for liquidambars. In some locations tree-pits of three trees were connected in order to maximise the soil media available to root systems.

Perforated drainage pipes were placed around tree roots within the soil. These were utilised for watering but may provide an ancillary benefit of aerating root systems. Drainage layers were placed at the bottom of the tree-pits and around the perimeter to ensure positive drainage. To date, the trees have succeeded in their new environments, with no losses in the tree-pits discussed above. Two tree losses in upper Queen Street have been attributed to conventional tree planting in existing soils, and with no instalment of perforated pipe.

### Maintenance and monitoring

The instalment of trees into encapsulated pits allows for infrastructure outside of these pits to be maintained without any effects to their root systems. Therefore infrastructure earthworks adjacent to tree-pits has become a permitted activity.

Maintenance of the street trees includes watering through perforated pipe around their root systems. This will occur regularly through the life of the tree due to the exclusion of stormwater from road surfaces. Watering frequency will reduce over time as the canopy and stemflow increases the rainwater harvest of the tree-pit and as trees become acclimatised to their location. Maintenance of the pits also includes regular removal of litter from tree grates, which may be accomplished by machines, driven over the cantilevering concrete slab.

#### Social issues

One of the more difficult issues for the planning of Queen Street's trees was the effects, perceived or otherwise, to the general public. It is difficult to determine who the stakeholders are of Auckland's main street. This provided some difficulty in terms of engagement of appropriate stakeholders and to limit the impacts to both daily and infrequent users of the streetscape. Issues to contend with included removal and tree-work on existing trees, species selection of replacement trees, disruptions to trade, inconvenience to pedestrian and vehicular transportation, and the potential for vandalism (when the street is occupied at all hours of the night with no shortage of revellers). Some of these issues were addressed through directly informing the public with street signage, describing both the design intent, and the process for building the tree-pits to enhance tree growth and vitality.

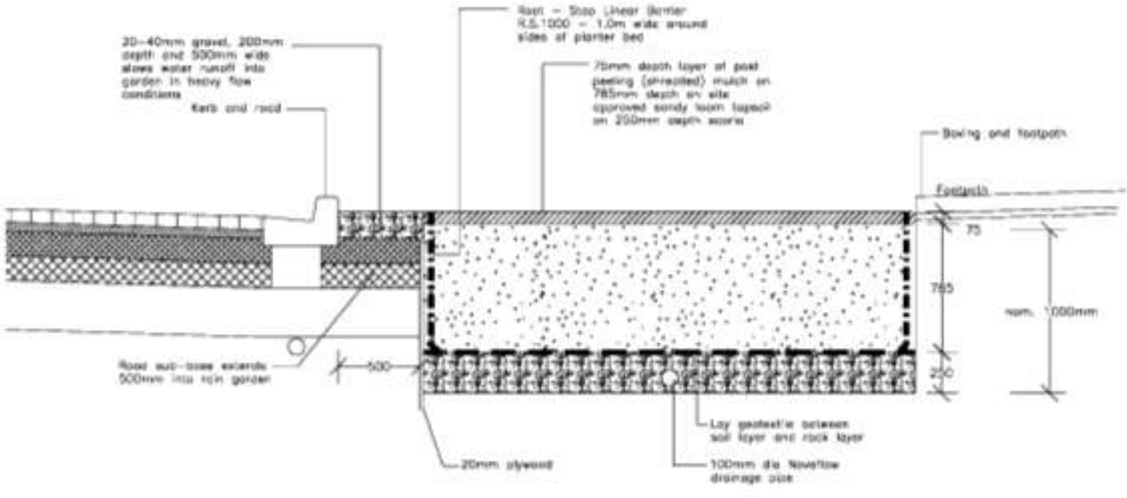
## 9.7 Rain Gardens

### 9.7.1 Case study 1: Talbot Park, Glen Innes, Auckland – a lesson in installation

Talbot Park, a Housing New Zealand Corporation (HNZC) development in Glen Innes, Auckland, has recently undergone a community renewal project based on sustainable development practices. On-site stormwater features were intended to mitigate the effects of increased imperviousness and contamination loads created by the development. A range of low impact approaches were included; minimising impervious area through narrow roads, permeable paving, retention of mature trees, and extensive mulched landscaped areas. Roof runoff was captured in rain tanks, and stormwater from roads and footpaths was directed to 14 rain gardens. Rain gardens were also expected to act as a buffer to any contamination spills (shock loads) which have caused extensive fish kills in the Omaru Stream in the past (Bracey et al. 2006).

Rain gardens were installed and landscaped in January 2006. Ponding depths were designed for 150 mm of live storage, with 75 mm of shredded mulch overlying 700 to 800 mm of "sandy loam topsoil', and a geotextile above 250 mm of scoria encasing a flexible drainage pipe. A 500 mm wide extension of the road sub-base was to continue into each garden, retained using a plywood sheet and protected from tree roots by a plastic liner. The 20-40 mm gravel proposed for this area was replaced with soil and organic mulch, as there was concern that gravel would encourage children to play in gardens and/or create a nuisance by throwing stones. Run-off was intended to enter rain gardens from roads through 0.5 m wide slots cut in one edge of the kerb, and as sheet flow from adjacent footpaths.

**Figure 34 Rain garden cross-section showing construction materials (CKL, 2005)**




Infiltration rates have increased over time, as earthworms and root growth open the soils, and integrate the decomposing mulch with underlying soil. Infiltration testing of two rain gardens in September 2006 and March 2008 by Landcare Research confirmed they exceeded TP10 permeability guidelines of 300 mm per day despite accumulation of silt, sand and debris washed from adjacent building construction sites and compaction by vehicles.

Stakeholders (HNZC, ARC, ACC, Boffa Miskell and Landcare Research) met in September 2006 to discuss and agree on retrofitting actions to respond to the issues above. Plans focused on increasing live storage by lowering the surface of the rain gardens and were approved by ARC in February 2007. Reconstruction will occur shortly.

### Contractor issues

The implementation of rain gardens will benefit from a stable and committed leadership and project co-ordinator over the term of the project and during its operational phase as a long-term community investment.

Contractors in this case had no experience in building rain gardens. Critical design specifications were generally not followed, the most important being:

- Slots in the curb were narrower at the base (200 to 300 mm) than specified, restricting flows into the gardens. Curbing was later modified using "wings" (concrete diversion baffles) to increase capture of stormwater.
- Some grates were installed too low (by approximately 50 mm), reducing the designed ponding depth, or too high, directing stormwater back to the road surface.
- Landscape contractors overfilled the rain gardens with soil and mulch, further reducing the ponding depth to the extent that run-off did not pond over the entire surface of rain gardens, causing short-circuiting and in some cases preventing run-

off from entering gardens.  This lead to accumulation of silt and debris at the kerb "cut-out" ingress points

- Completion of the rain gardens prior to construction of buildings led to rain gardens becoming clogged with sediment from building sites.  A control measure that could have been applied is part-filling (to minimise the hazard to pedestrians) and/or covering rain gardens with a filter cloth to be removed later when adjacent earthworks and building is complete. In other words, rain gardens should be commissioned (ie surfaced and planted) after construction of buildings, or at least protected from sediment loads and construction traffic.
- Devices should be tested before acceptance and sign off.  For rain gardens this would include checking ponding depth and unimpeded stormwater flow paths. General contractors also need to be alerted to the presence of LID methods and penalised if devices are adversely impacted, eg by vehicle traffic.

**Figure 35    Talbot Park rain garden inlet showing overfilling with soil and mulch, material from adjacent building sites blocking the inlet, and retrofit "wings" to improve entry of run-off (Bracey et al. 2008)**

**Figure 36 Incorrect soil and mulch levels combined with narrow kerb cuts (Bracey et al. 2008)**

Narrow curb cuts and unresolved soil and mulch levels have meant that live storage has been lost and in many instances stormwater flows to catchpits with no treatment, causing erosion within the garden or the formation of preferred flow paths that bypass the systems and exit the rain garden taking mulch and soil material.

### Planting issues

Accumulation of sediment (resulting from incorrect finished levels as previously mentioned) was implicated in the high mortality of some groundcovers in the rain gardens through physical smothering (eg *Muehlenbeckia complexa*, *Libertia peregrinans* and *Carex cultivars*) and creating anaerobic zones that starved roots of oxygen (*Arthropodium rengarenga* being particularly susceptible).

*Phormuim cookianum* (mountain flax) was the best-performing groundcover over three years with moderate to high growth rates in all 14 rain gardens in March 2008.

Plant cultivars should ensure mature heights allow clear views of children on footpaths (ie *Toetoe cultivar* were found to be too large, being 1 to 1.4 m tall). Use of a non-floating organic mulch (eg long-fibre chip) is also a lesson from the project.

### Maintenance and monitoring

HNZC employed a resident as gardener for all common areas in the development, except public parks. The work was vital for regular removing of weeds and litter to ensure functionality. An on-site gardener/maintenance person is ideal where there are many rain gardens and/or extensive landscaping. The gardener needs to be inducted into the aims and approaches of LID. Other tasks included weeding until full vegetation cover was established, and removal of sediment in and near inlets to ensure unimpeded flow into the gardens. Removal of sediment also removes many weeds that colonise exposed soils and sediment at inlets. Such maintenance is likely to decrease frequency of catchpit emptying and only took five to 15 minutes per rain garden in March 2008. The project documentation made it clear that rain garden projects require resources for adaptive management based on site-specific experience.

Monitoring is most effective if drafted during the planning phase (for stormwater) and reassessed during construction. This enables issues to be identified quickly and any remedial work to be completed early, minimizing additional costs.

**Social issues**

The Talbot Park project demonstrated the importance of building strategic relationships, particularly with planners in Auckland City Council and with Infrastructure Auckland. Local authorities need to be brought on board early in the design phase and be ready to "own" the devices on public property. This is to ensure that local authorities get what they want, know what they are getting, and are ready for the ongoing maintenance following handover.

LID was included early in the planning process, allowing discussion with the community. The general sense expressed was that the local natural environment had been degraded by urban development in Glen Innes and people were quick to recognise the value of low impact approaches in caring for the natural environment.

In addition to stormwater treatment, the rain gardens at Talbot Park act as traffic calming devices and contribute to an improved sense of safety. Narrow roads have led to safer traffic speeds and lower volumes, allowing children to safely play, walk and ride bikes on or near roads.

### 9.7.2 Case study 2: Paul Matthews Drive rain garden, North Shore City

North Shore City Council and Landcare, with the assistance of ARC, undertook the planning, design, construction and performance monitoring of the Paul Matthews Road Rain garden in 2006. The site was on a slope, similar to many localities in the North Shore, bounded by Paul Matthews Road to the south, an industrial property to the west, Alexandra Stream to the east, and the stream reserve to the north. The rain garden was intended to act as a public education demonstration project and a research tool (Smythe et al. 2007).

The average slope of the site was approximately 1 V on 4 H, with a small plateau at the top. The rain garden was lined with an impermeable liner, as shown in Figure 39, to protect the stability of the slope below the garden.

Rain gardens were designed according to specifications in TP10 but to a reduced size to meet site constraints. The rain garden treats stormwater from a commercial and industrial catchment, including an arterial road carrying a high traffic load of 16,000 vehicles per day. It was sited on steep land to represent similar constraints elsewhere in North Shore City. It also represented a retrofit situation in a developed catchment, protecting a highly valued receiving environment

To date, monitoring has indicated that the rain garden performs well as a bio-retention device by reducing the run-off volumes of smaller rain events through soil absorption and evapo-transpiration. Ongoing performance monitoring by Landcare indicates a high level of treatment efficiency, exceeding TP10 expectations.

The base capital cost for the 200 $m^2$ rain garden (assuming no requirements for infrastructure, level spreading and monitoring, and no geotechnical issues) is approximately $104,500 ex GST (or approximately $525 /$m^2$). Retrofitting rain gardens in developed areas gives little choice over site location. This can increase the overall rain garden if additional stormwater infrastructure is required.

### Contractor issues

Construction of the rain garden commenced in May 2006 and took approximately 10 weeks. It was deemed important by the project team that highly skilled, reputable contractors were engaged to undertake these works. At the tender phase, contractors were given notice that a high level of communication with the supervising consultant (WEC) and soil specialists (Landcare) would be required to ensure that the project achieved the design objectives. Allowance for this was included as a payable item in the schedule of prices. Of particular concern was maintaining infiltration rates within the planting soil by minimising compaction to the specified rates.

The successful contractor was Alexander Civil Construction Ltd. They placed the planting soil in one pass so that the excavator did not compact the planting soil. Mulch material was then applied and the rain garden left for specialist planting contractors to implement the planting plan.

The diversion of the existing stormwater flows through a bifurcation in the existing stormwater reticulation was not without problems, because of the congestion of existing services in the fully developed commercial/industrial catchment on an arterial road. During the period between design of the inlet pipeline and construction (approximately 6 months) another service provider installed significant infrastructure within the carriageway.

The main difficulty during rain garden construction was the location and procurement of 200 $m^3$ of suitable planting soil within an easily commutable distance from Albany. Landcare are presently undertaking research to identify a rain garden mix that is readily available and can maintain an infiltration rate of >50 mm/hr under “moderate” compaction.

### Planting issues

The planting of the rain garden surface caused additional compaction to the underlying planting soil, which in turn caused ponding in isolated areas of the rain garden. This was addressed by reworking the surface of these areas to achieve the desired infiltration rates. It must be noted that compaction of the planting soil may occur during future maintenance of the rain garden and due to natural consolidation over time. This must be monitored and appropriate remedial action undertaken. If remediation is not undertaken, the beneficial effects of the rain garden will be nullified due to short-circuiting of stormwater through ponding and flow out of the high level overflow.

### Maintenance and monitoring

A compacted gravel footpath was constructed above the downhill edge of the rain garden for maintenance and public access for educational purposes. NSCC also erected a signboard at the site to inform the public about the rain garden. The Paul Matthews rain garden is providing data to refine and improve rain garden designs.

Figure 37 Paul Matthews rain garden: plan (after Smythe et al.)

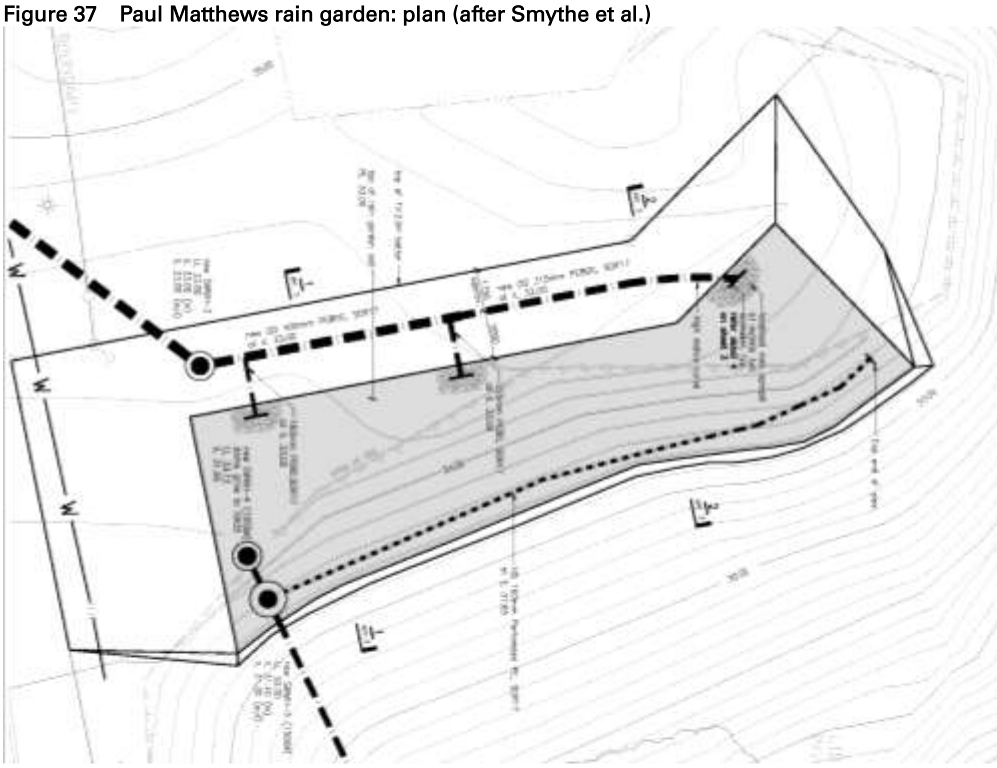


Figure 38 Paul Matthews rain garden, section (after Smythe et al.)

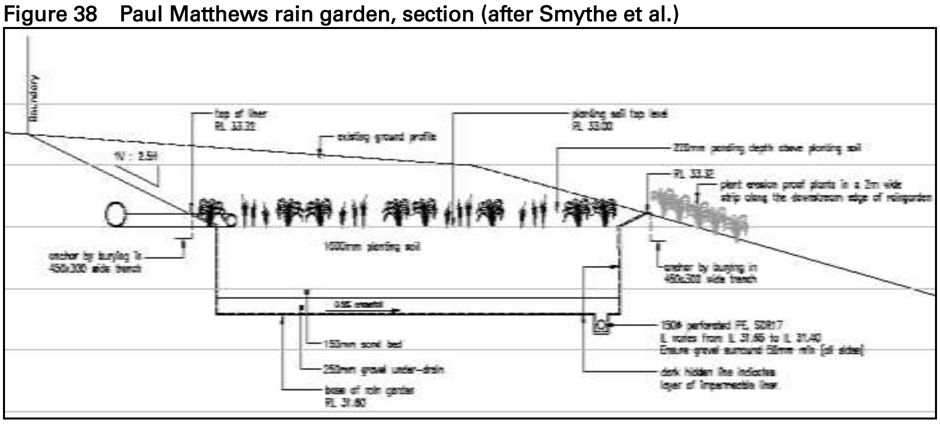


**Figure 39 Paul Matthews rain garden under construction: placement of sand (Boffa Miskell 2008)**

**Figure 40 Paul Matthews rain garden under construction: placement of sand (Boffa Miskell 2008)**

## 9.8 Swales and Filter Strips

### 9.8.1 Case study 1: New Zealand Housing Foundation – stage 3, Waitakere City

This subdivision of medium-density sections has been carried out by the New Zealand Housing Foundation. The development is within the Oratia Stream catchment and located off Pyramid Place, Glen Eden. The design includes a narrow one way road (with a layout adopted to suit the topography of the site) and a swale system to treat road run-off (running down between the two road lanes). Houses are yet to be built on the subdivision.

The swale is approximately 1.5 m wide at the base and up to about 1.5 m deep. Water enters the swale by a section of kerbless road on the road turn around area and a cesspit and drop inlet from the upper section of road. The outlet from the swale is piped under the road to the nearby stream.

Figure 41 New Zealand Housing Foundation, Pyramid Place: subdivision layout

Figure 42 New Zealand Housing Foundation, Pyramid Place: swale

Erosion has previously occurred at the outlet from the cesspit collecting water from the upper level of the road. This has been remedied by placement of bend in the outlet pipe and riprap. It also appears the contractor has installed the outlet from the cesspit at the standard outlet depth – which has meant the pipe has protruded through the retaining wall for the road from the upper level. An alternative design would have been to use a manhole with a kerb inlet, with an outlet at the swale invert level and a sump in the manhole.

The key feature of this swale is the way it has been integrated into the site levels. By splitting the road into a one way system with two narrow lanes through the site, the roading layout has been stepped and the swale located between the two parts of the road. WCC officers note that planting should also be carried out in the swale to improve water quality performance and amenity value.

WCC officers also note that traffic management could become an issue on the site. If there are no parking restrictions on the road, it could be used for parking and prevent access for larger vehicles such as rubbish trucks. Discontinuous kerbing or bollards could be used to prevent people parking on the swales.

### 4.9.5 Case Study 2: New Zealand Housing Foundation – Albionvale, Waitakere City

This development consists of medium-density terrace housing constructed for Housing New Zealand by the New Zealand Housing Foundation Ltd.

A detention pond was previously situated on-site for management of flows from an existing development upstream. Following a variation to the original ARC consent, peak flows from this site are to be released and compensated for by reducing flows from an adjacent downstream wetland detention pond system. Water quality treatment for the road is required in addition to the downstream detention. The developer has adopted a swale system to provide this treatment. This provides an example of a multi-faceted approach where different methods are used to achieve water quality and water quantity objectives for different parts of the site.

**Figure 43 New Zealand Housing Foundation, Albionvale: swale prior to planting**

**Figure 44 New Zealand Housing Foundation, Albionvale: temporary flow diversion at head of swale**

**Figure 45 New Zealand Housing Foundation, Albionvale: swale after planting**

## 9.9 Rain Tanks

### 9.9.1 Case study 1: Talbot Park, Glen Innes, Auckland

This case study is based on discussions with Stuart Bracey, Project Manager for the Tamaki Community Renewal Project for the Housing New Zealand Corporation (HNZC) and a paper to be presented to the 2008 NZWWA stormwater conference (Bracey et al. 2008).

The Tamaki Community Renewal project involves a 5 ha site in Glen Innes, consisting of a mixture of individual units, multi bedroom housing and three storey apartment units. The development uses LID methods including; water re-use, rain gardens, permeable paving, creation of vegetated landscaping areas and minimising impervious areas. Other sustainable development practices such as solar water heating are also used.

HNZC is interested in water re-use both from a sustainability and commercial view-point. As HNZC pays local authority water charges on behalf of its tenants, it is interested in ways that water costs can be minimised. Water re-use has been incorporated into the development on a trial basis to determine potential water re-use volumes and cost savings.

Water re-use has been incorporated as follows:

- 1500 L tanks have been installed for four of the one bedroom ground level units.
- 3500 L tanks have been installed for four of the three bedroom duplex houses.

- A 50,000 L tank has been installed for the three storey, 24 unit "Atrium" block.

The tanks are designed to take roof water from each of the units and re-use it in toilets and in gardens via outside taps. Catchment areas are 50 sq.m for the one bedroom units, 90 sq.m for the three bedroom duplexes and 500 sq.m for the Atrium Block.

HNZC has identified the costs of the installation of the 1500 L and 3500 L tanks as approximately $4000 per unit and the cost of the 50,000 L tank as $129,000 (about $5400 per unit). The cost of a one bedroom unit was approximately $110,000, meaning the water re-use tank is about 4 per cent of the total cost. Manaaki Whenua Landcare Research is currently monitoring the water re-use devices for HNZC to determine the effects on potable water use and water costs.

HNZC found it was difficult to get development and building consent approval for the LID methods and perceived that this was because the methods were outside the standard development details endorsed by the local authority and the LID methods were not required by conditions of a resource consent. Policy planners from the local authority were supportive of the use of LID methods and along with HNZC, invested significant time into the project to allow them to be implemented.

HNZC have noted that the circular tanks take up a significant amount of space, particularly where there are small outside spaces for each unit. These were the only above ground tanks available at the time of construction – they would prefer alternative shapes so that the usable outside space was maximised. The common 50,000 L tank serving the Atrium block is underground and avoids this issue. Consideration was also given to using underground tanks for the individual units but this was eventually rejected due to the cost involved. A mains top-up supply is provided to each of the tanks: these were originally manually operated but have since been replaced with an automatic system. The rear of one of the three bedroom units is shown below in Figure 46 – with the 3500 L tank incorporated into a garden area.

**Figure 46 Talbot Park: rain tanks for three bedroom houses**

Roof water from the Atrium apartment building and enclosed atrium is collected into a 50,000 L tank beneath the courtyard. To date (some 12 months after installation) no maintenance has had to be carried out, but the single tank is likely to require less maintenance than the multiple smaller tanks. Furthermore it contributes to the high amenity values of the enclosed courtyard by providing irrigation to the various gardens.

**Figure 47 The Atrium courtyard: large downpipes on the walls direct roof water to the underground tank**

Figure 48 Talbot Park, Atrium courtyard: planter boxes

The courtyard provides a safe enclosed amenity area. Residents have adopted the planter boxes for private use – in this case, vegetables.

### 9.9.2 Case study 2: Sonoma Crescent subdivision – Universal Homes, North Shore

The Sonoma Crescent subdivision consists of approximately 40 lots of free-standing single family homes.

ARC consent requirements were for detention of the peak flows from the 34.5 mm, 2-, 10- and 100-year ARI storms to pre-development levels. This was achieved using a stormwater detention pond for the whole subdivision. However, the size of the detention pond was allowed to be reduced as on-site detention and water re-use was also provided for each house. Each rain tank was 4500 L, of which 2200 L was live storage and 2000 L was for water re-use. A small amount of permanent storage was also provided to ensure the pump intake was always submerged.

This case study is based on the rain tank design and construction monitoring visits carried out by Pattle Delamore Partners Ltd.

Each tank received water from the roof of each house only. The tank was located under the driveway or landscaping area of each house. Re-use water was directed to the toilet and laundry of each house. Outside taps were also originally serviced, but NSCC subsequently amended requirements during construction to prevent this due to concerns about the quality of the re-use water. Water was filtered prior to use. Water was drawn from the tank when a pressure drop was measured in the plumbing – ie when a laundry tap was turned on – the pump was turned on and pressurised the re-use supply.

Where extended dry periods occur, the supply of re-use water could be exhausted. A top-up connection from the mains supply was provided to ensure water was always available. A float switch activates the top-up supply when the water level drops below 250 mm in the tank. The top-up supply also had a backflow preventer to prevent the mains supply being cross contaminated by the re-use water.

A reinforced concrete tank was used with an additional internal support for taking traffic loadings where required. The pump used was a Lowara Scuba series: various models are available, pumping up to 7 $m^3$/hour.

Three system configurations were used over the construction of the subdivision as experience with installing the tanks increased and cost reductions were sought. The initial configuration used an external filter and first flush diverter to remove contaminants. While this set up reduced the sediment load into the tank, it required all downpipes to be sealed so that water could siphon from the downpipes into the above ground filter – this potentially allows sediment to build up in the siphon pipe. The second configuration allowed downpipes to discharge directly into the tank, with the filter placed downstrea of the tank inside the garage of the house along with other controls. This reduced sediment load to the filter, but allowed construction sediment to enter the tanks: several tanks had to be pumped out to remove sediment. The third configuration was similar to the second, with external access provided to the filter via the garage wall.

Other common issues encountered during construction of the systems were; manhole covers not being cemented in place (allowing sediment to enter the tank), incorrect component diagrams mounted in the control boxes, and poor access to the control panel. The developer identified that a high degree of project management and control of staging the various trades-people involved was required to correctly install the systems.

"Do not drink" labels were required on each of the taps from which re-use water could be drawn.

Figure 49 below shows the visible parts of the system: water from the down pipe goes through the first flush diverter (attached to the fence) then into the tank (open manhole). Note the sealed downpipe in the middle of the photograph.

**Figure 49 Sonoma Crescent underground rain tanks: type 1 tank arrangement**

Figure 50 below shows the various pipe connections required for the second system configuration. Note that this installation has had an additional pipe incorrectly installed from the incoming mains supply to the internal supply – this would have had the effect of never allowing the internal pressure to drop and therefore switch on the pump. Clear design, communication to the contractor and checking are critical.

**Figure 50 Sonoma Crescent underground rain tanks: type 2 tank arrangement**

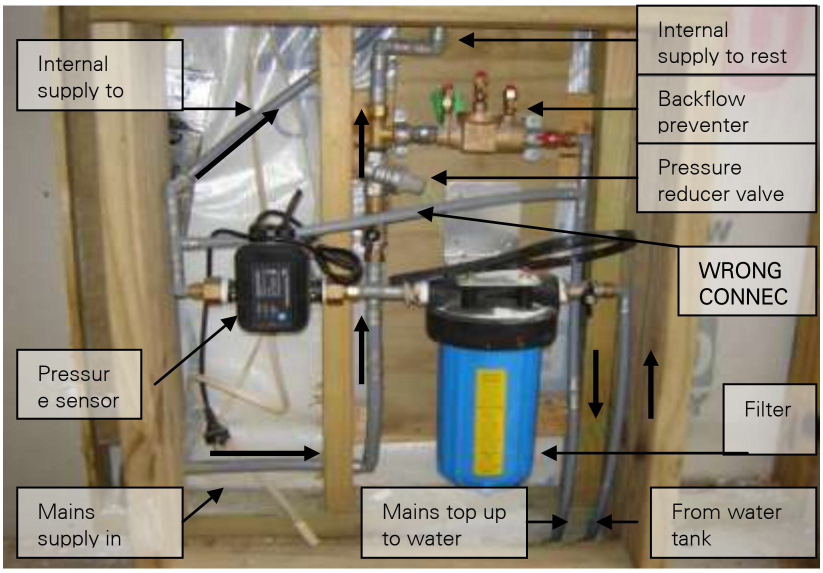


Figure 51 below shows the supply line from the pump (white pipe into blue pipe – on the far right), the power supply for the pump (black lead coming out of orange duct – on the far left) and the float switch for the top–up supply.

**Figure 51 Sonoma Crescent underground rain tanks: tank and pump arrangement**


## 9.10 Above Ground Detention

### 9.10.1 Case study 1: Maungawhau School, Mt Eden

Maungawhau School is located in Mt Eden, which is part of the Meola Catchment in Auckland City. The catchment is serviced by a combined sewer system, soakage and in some parts separated stormwater systems. A 1200 mm diametre pipe for the upstream separated stormwater system passes near the sportsfield for the school. Further downstream, the stormwater system becomes a combined sewer system. The stormwater pipe leaving the sports field area is 525 mm diameter this will prevent significant stormwater flows entering the combined system. Overloading the downstream combined system could result in localised flooding and contribute to combined sewer overflows further downstream.

In order to reduce the flow in the downstream system and prevent overland flow adjacent to the school, the sportsfield is used for stormwater detention. This could potentially occur either by water from the large stormwater pipe being unable to get into the downstream system and backing up on to the field, or by overland flows running across the field and being stored on the field until there is sufficient downstream pipe capacity to receive those flows.

**Figure 52 Maungawhau School detention area**

The detention area would not occur naturally and has been formed by a bund placed around two sides of the field.

### 9.10.2 Case study 2: Myers Park, Auckland City

Myers Park is a central city park located in a gully that runs down towards the retail area above Aotea Square and Queen St. The park is relatively steep and falls 35 m along its 400 m length. At the bottom of Myers Park, overland flows were previously able to run across Mayoral Drive and pond in low points adjacent to the Town Hall. There was no formed overland flow path out of Aotea Square. The catchment is approximately 8 ha, made up of about half from the park and half from the upstream commercial area around Karangahape Rd.

With construction of the flood wall, overland flows are prevented from running further downhill and will enter the grilled structure at the base of the flood wall. In large storm events, overland flows are stored above ground until there is sufficient capacity in the stormwater network to receive the stored water.

The design carefully integrates amenity and landscape values with the detention function. Note Figure 53 below; the flood would be contained to the level of the top of the stairs (assuming there was enough accumulated upstream flow).

Figure 53 Myers Park flood wall

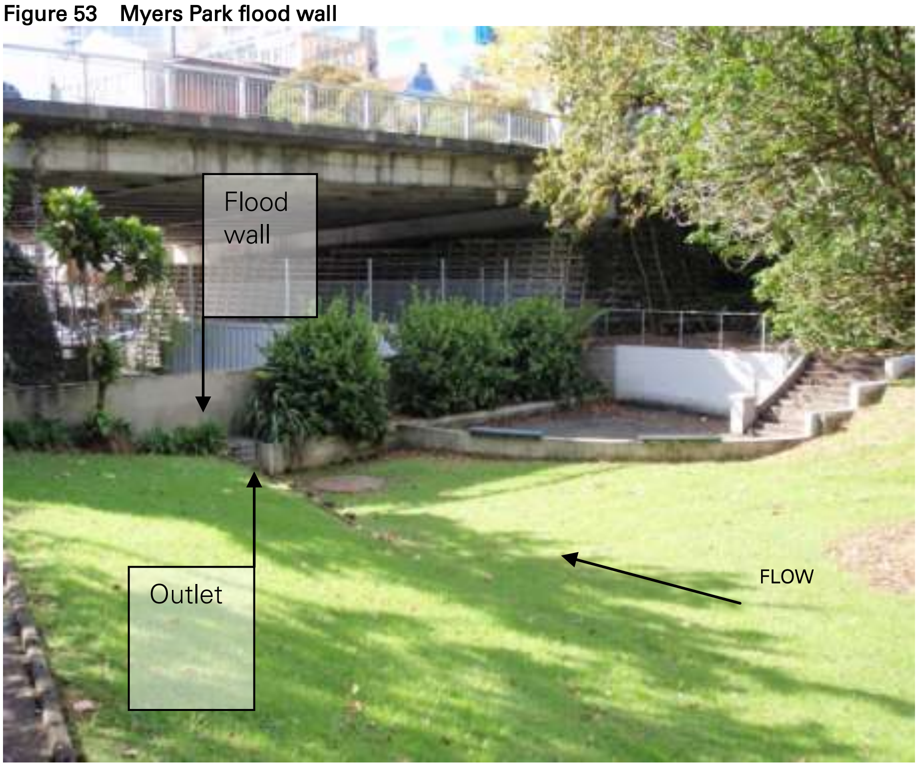



Figure 54 Myers Park: the area to the centre left of the photo could pond during a large flood event

### 9.10.3 Case study 3: Mitre 10 Mega, Glenfield

Mitre 10 has developed a site in Poland Rd, Glenfield for a large format retail development. The site is partially located within the floodplain for the Wairau Creek. The site had been previously used for warehousing with a significant adjacent open area. The open area on-site was partially pervious. The development did not incorporate LID principles but provides an example of how above ground detention can be incorporated into a commercial development.

To mitigate the potential for exacerbating downstream flooding in the Wairau Valley catchment, North Shore City Council required that stormwater detention be provided for the 100-year ARI storm event.

The site is covered by the large format retail building and associated carpark. Levels on the carpark have been set so that most of the flow from the carpark is directed towards one area. This allows flows to be treated by an underground sand filter. In large flows, water is stored within the sand filter, along with above ground ponding. The ponding area is formed by a local depression in the seal together with a speed hump across an accessway and the raised kerbs for adjacent landscaping areas. Outflow is controlled by three cesspits connected to the sand filter. This was modelled to confirm that the range of outflow and hydraulic head conditions present would not exceed the pre-development flow from the site as a whole.

**Figure 55 Mitre 10 Mega ponding area: water is contained in the low point by the kerb and speed hump**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# Appendix 2: Standard Engineering Detail

**Figure 56**
Clustering sketch

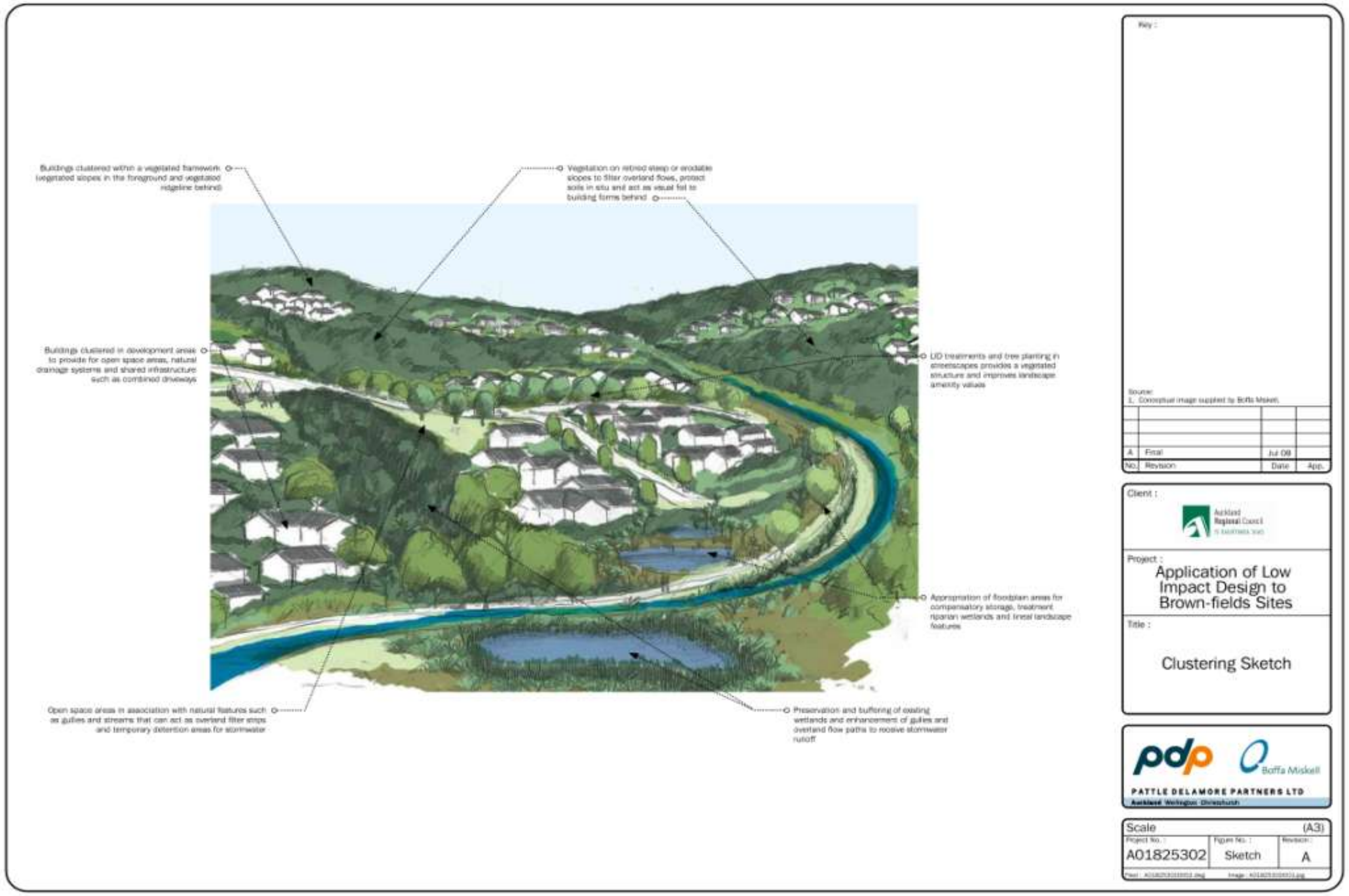


**Figure 57**
Green roof detail: standard detail

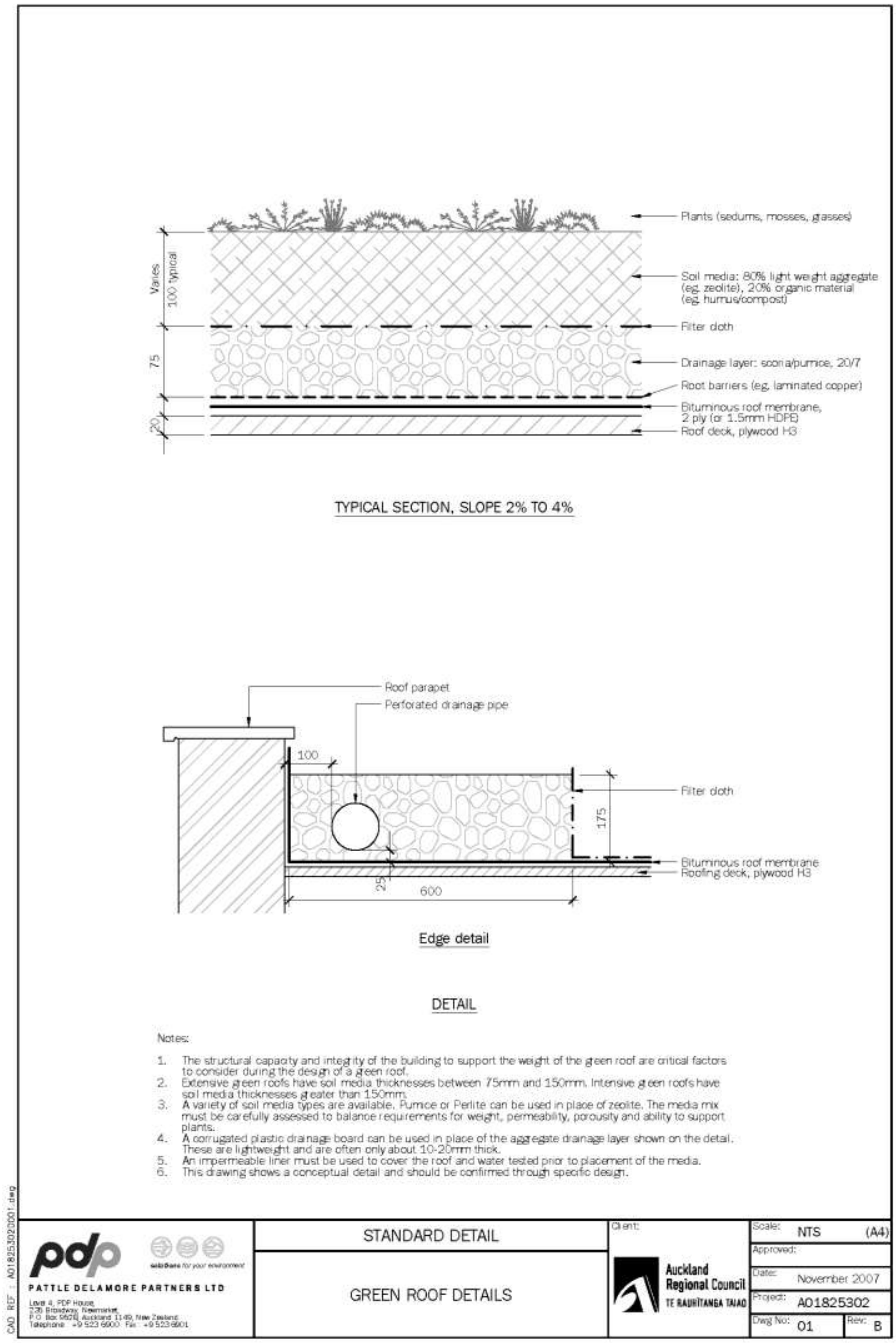


**Figure 58**
Permeable pavement detail: standard detail

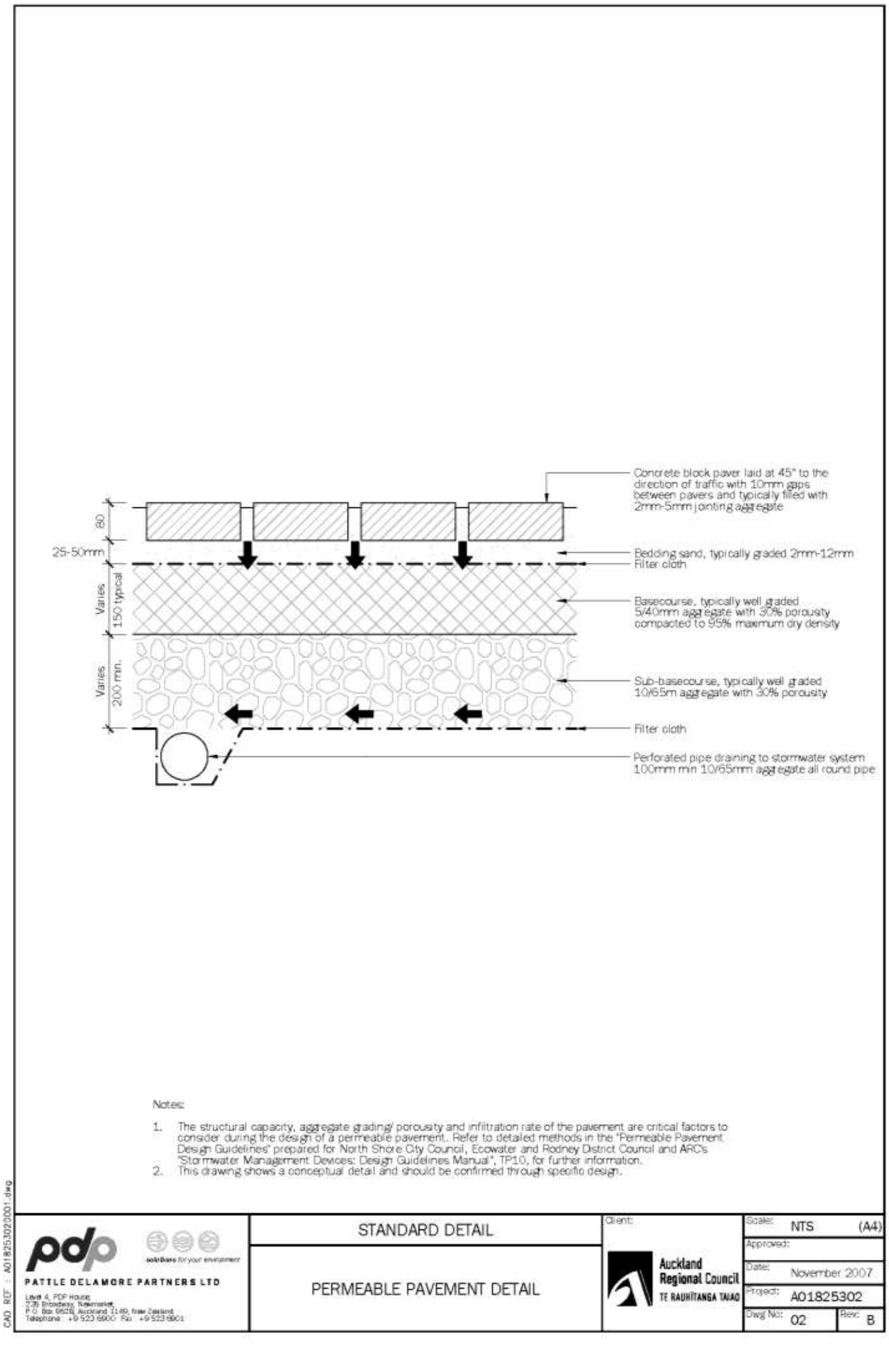


**Figure 59**
Swale detail: standard detail

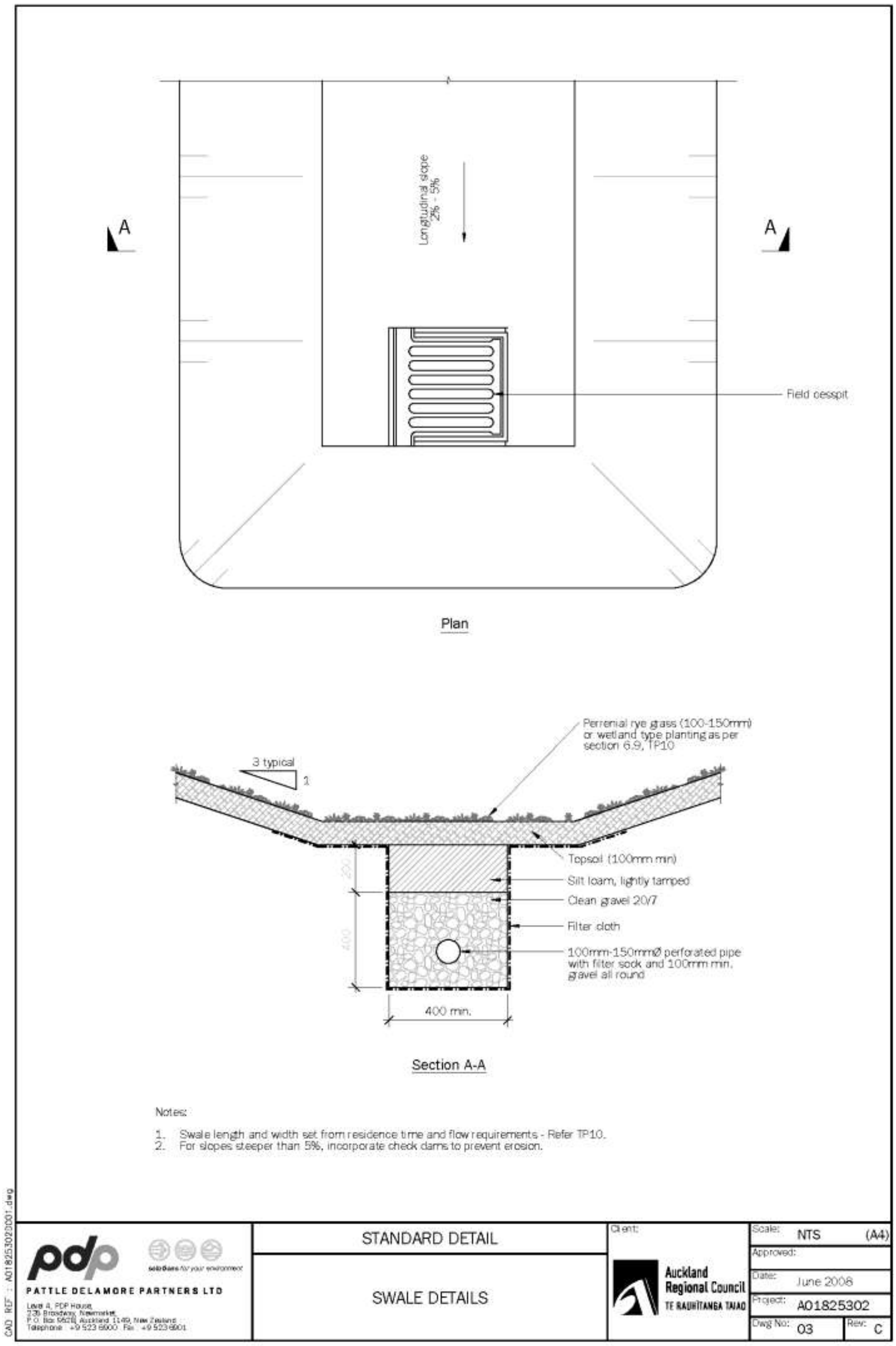


**Figure 60**
Tree-pit detail: standard detail

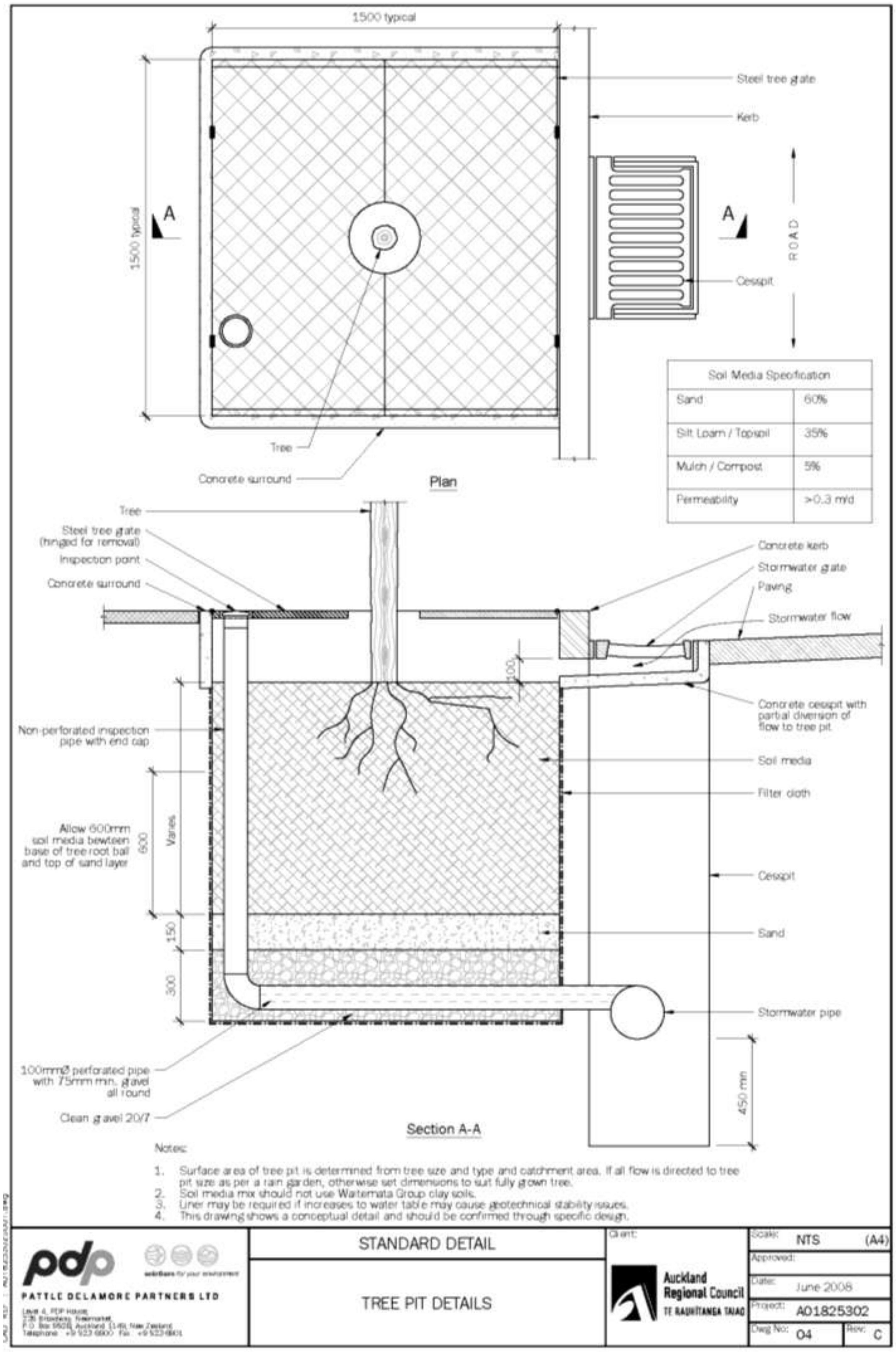


**Figure 61**

Rain garden detail: standard detail

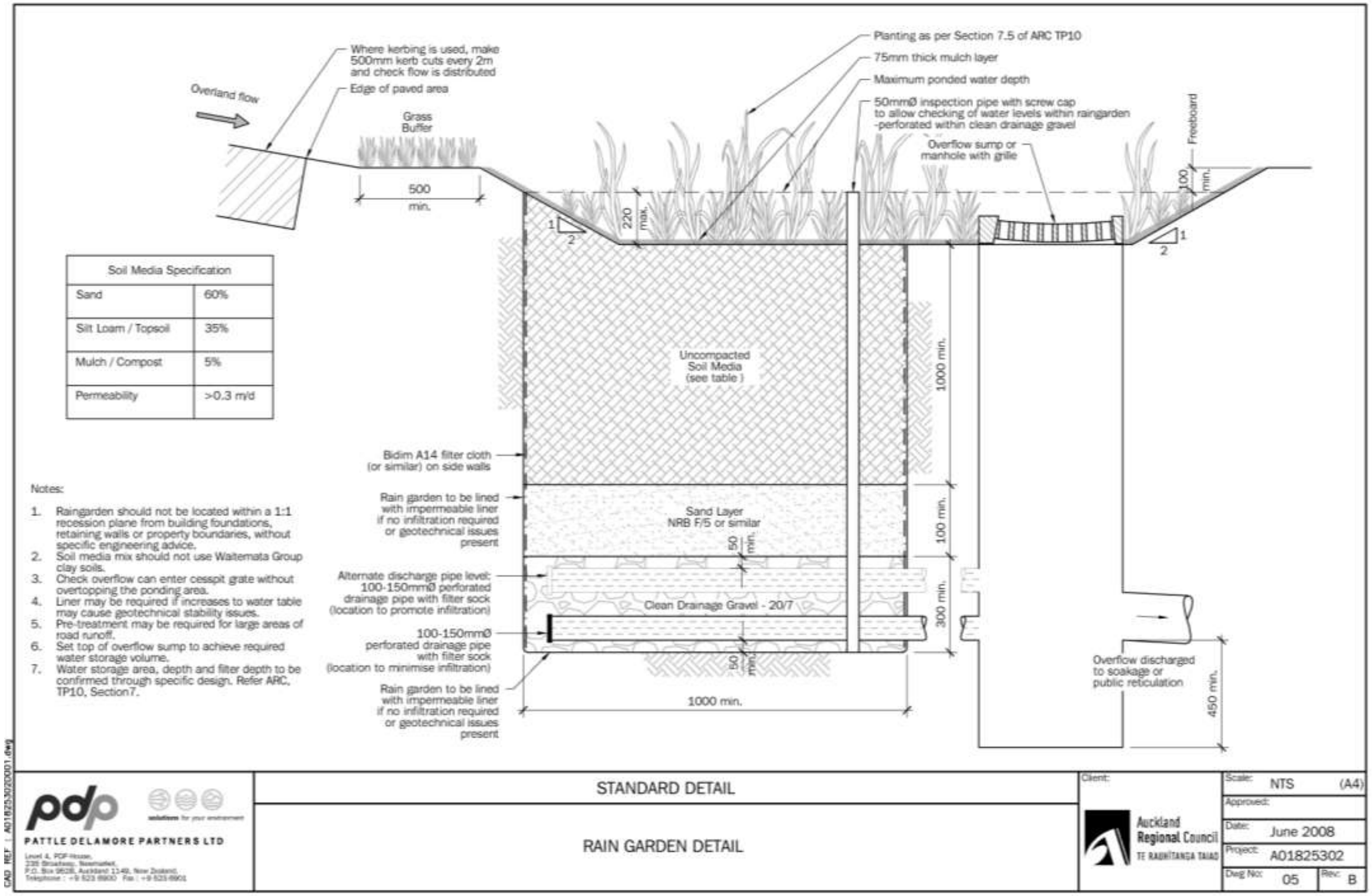


**Figure 62**
Rainwater detention tank: standard detail

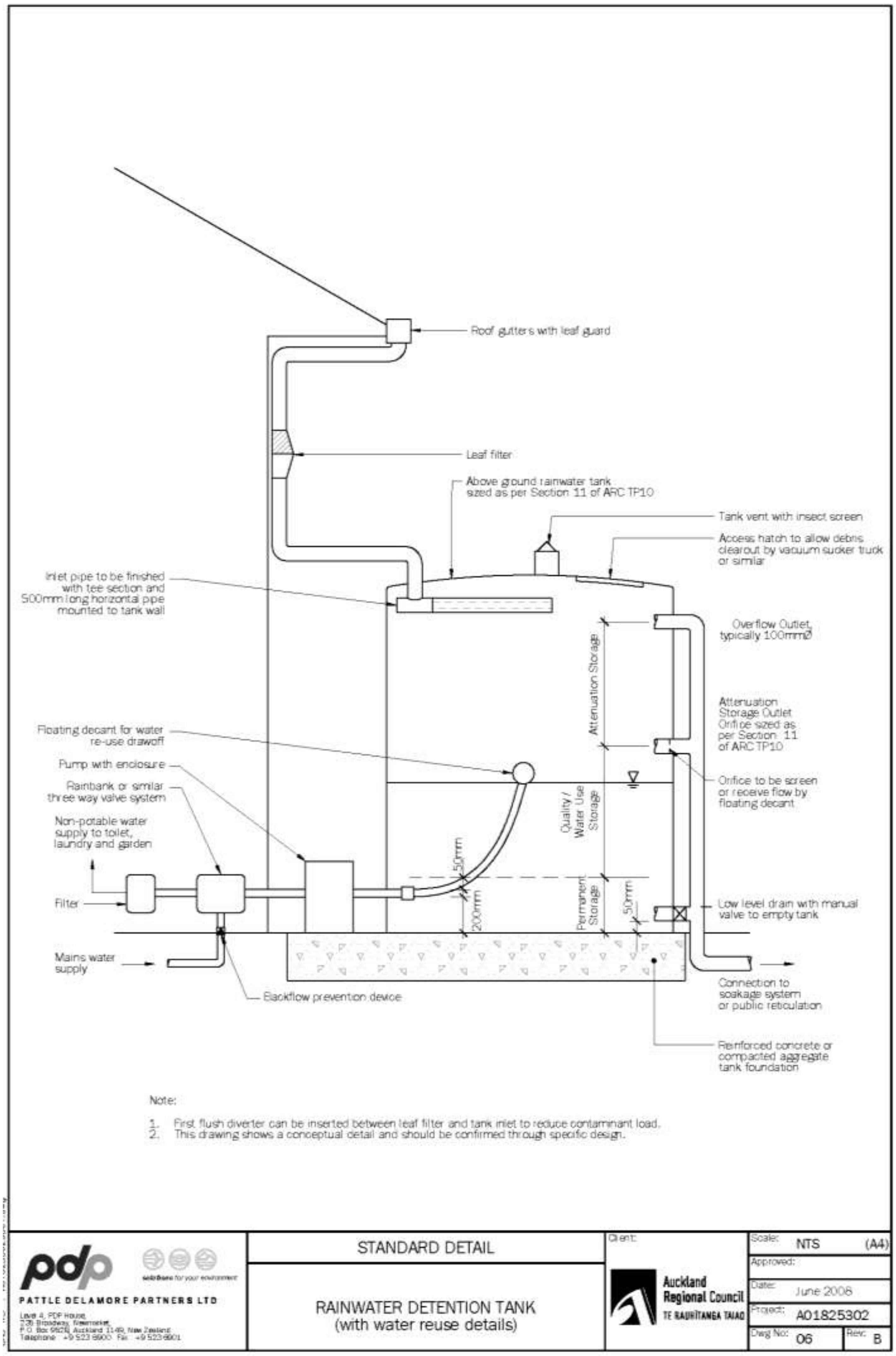


**Figure 63**
Above ground detention: standard detail

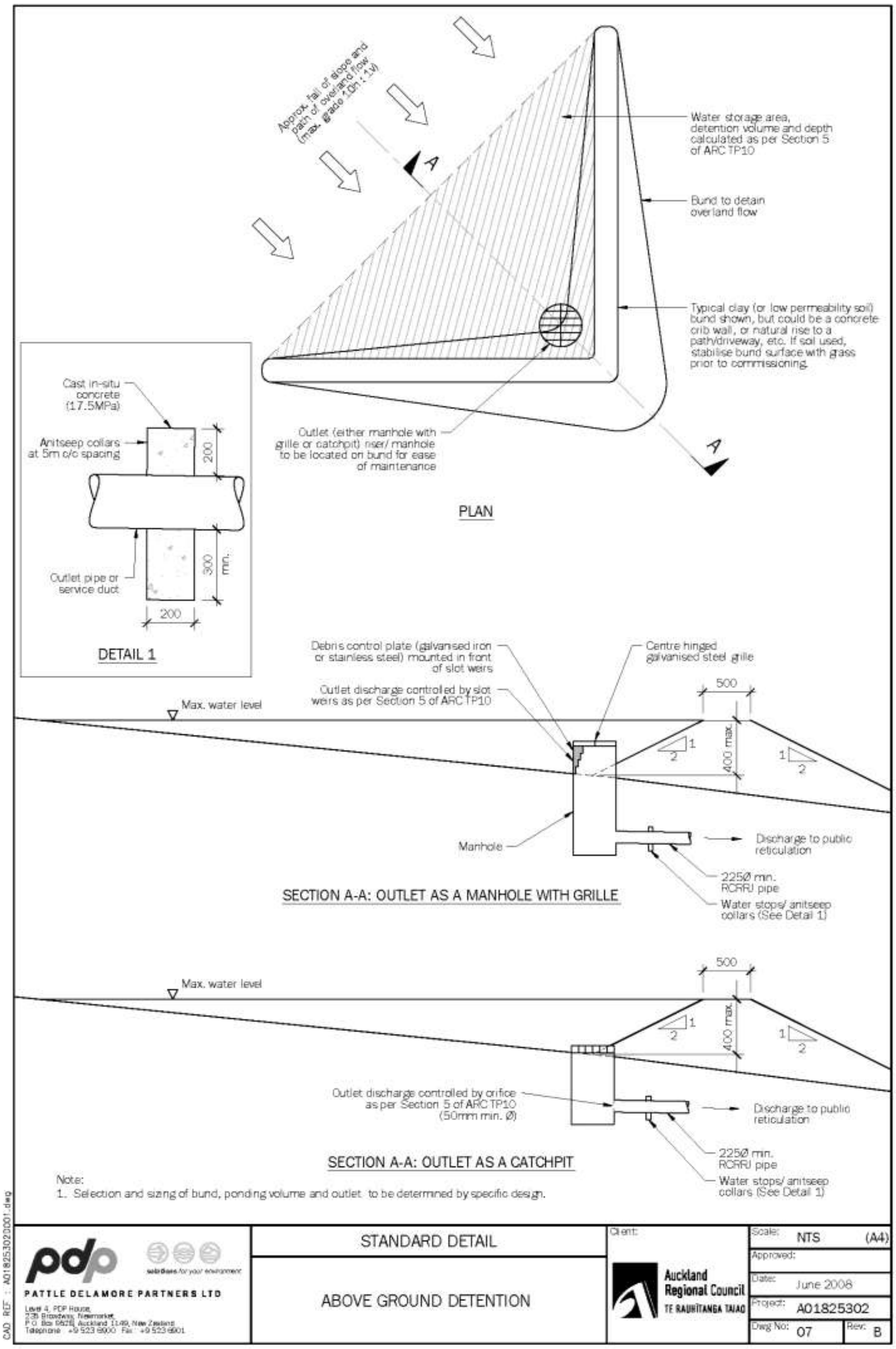
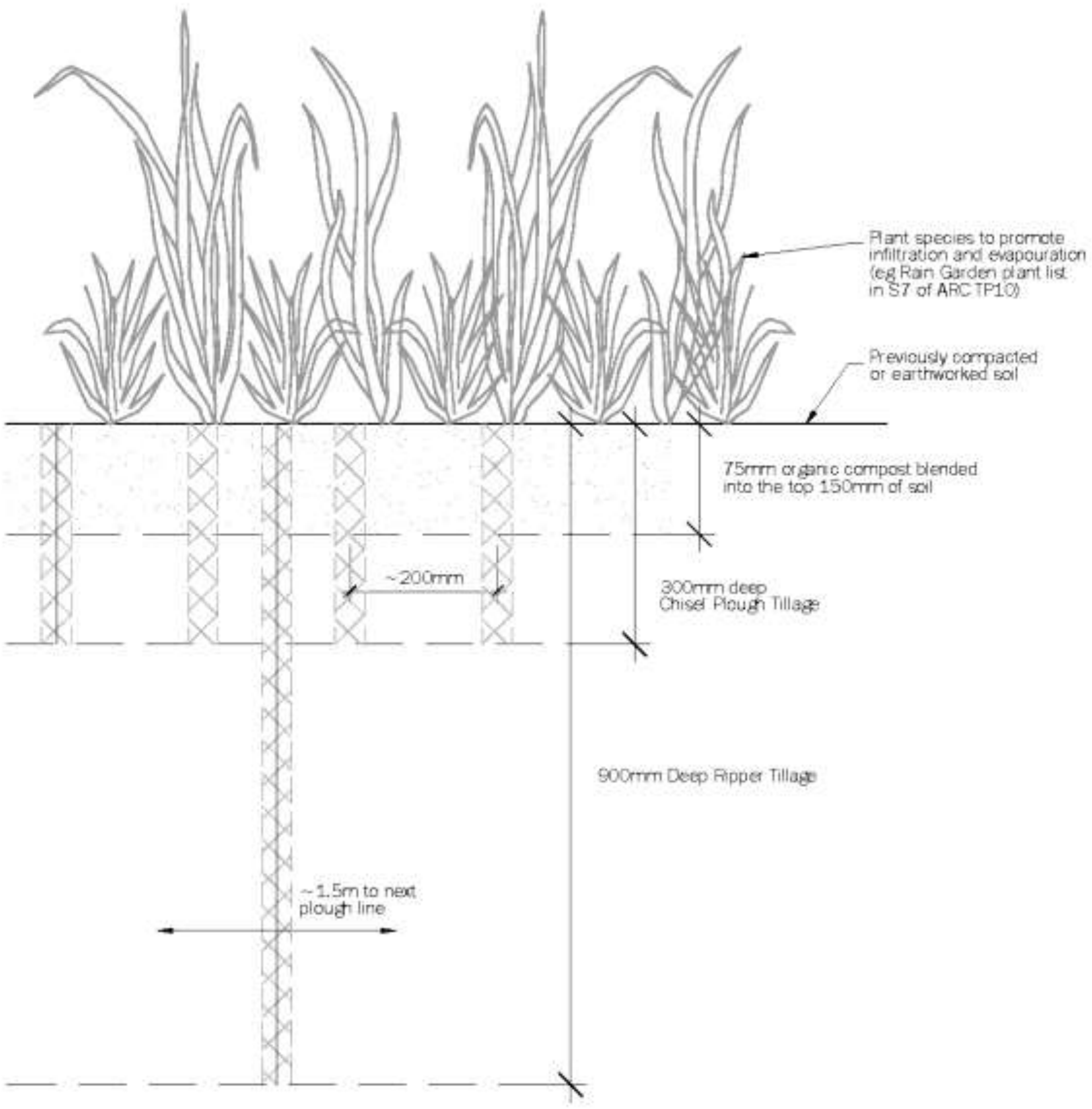


**Figure 64**
Soil rehabilitation: standard detail




| Definitions | |
|---|---|
| Deep Ripper Tillage | A single or two arm plough that rips the soil to a depth of 900mm with a spacing of ~1.5m depending on the tractor's wheel span |
| Chisel Plough Tillage | Tillage with a chisel plough to a depth of 300mm, with plough shank spacing of ~200mm |
| Compost Blended | Addition of a 75mm layer of organic compost which is then hand raked to blend with the top 150mm of soil |

Note:

1. Chisel Plough not to be used within 1.0m of buildings or property boundaries, and deep ripper not to be used within 3.0m of buildings, property boundaries or underground services

**Titirangi** 10/31/2008 11:31

| | |
|---|---|
| Local Authority | Waitakere |
| Location | New Lynn |

Select LID/Treatment methods to Match Specific Runoff Number or Match Pre-Development Flows

| | | Roof Material | Runoff Number | Treatment Method | Runoff Number | Indicative size required for Method ($m^2$) |
|---|---|---|---|---|---|---|
| Total Catchment Area ($m^2$) | **19325** | | | | | |
| Roof Area A ($m^2$) | 6340 | Galvanised unpainted | 98 | None | | |
| Roof Area B ($m^2$) | 0 | | 0 | None | | |
| Roof Area C ($m^2$) | 0 | | | None | | |
| **Sub Total** | **6340** | | | | | |
| | | **Carpark Material** | | | | |
| Car Park Area A ($m^2$) | 2820 | Asphalt | 98 | None | | |
| Car Park Area B ($m^2$) | 1140 | Asphalt | 98 | None | | |
| Car Park Area C ($m^2$) | 0 | | | None | | |
| **Sub Total** | **3960** | | | | | |
| | | **Pavement Material** | | | | |
| Paved Area A ($m^2$) | 0 | Asphalt | | None | | 0 |
| Paved Area B ($m^2$) | 0 | | | None | | |
| Paved Area C ($m^2$) | 0 | | | None | | |
| **Sub Total** | **0** | | | | | |
| Roads (excluding verge) | | **Road Material** | | | | |
| Residential Culdesac | 0 | | | None | | |
| Residential Road | 0 | | | None | | |
| Residential Through Road | 0 | | | None | | |
| **Sub Total** | **0** | | | | | |
| Pervious Area ($m^2$) | | **Pervious Area Management** | | | | |
| Pervious Area A ($m^2$) | 975 | Machinery excluded | | None | 88 | |
| Pervious Area B ($m^2$) | 8050 | Machinery excluded | | None | 88 | |
| **Sub Total Pervious Area** | **9025** | | | | | 0 sq metres |
| **Total Area** | **19325** | | | | | TREATMENT SPACE DEDUCTED FROM PERVIOUS AREA |

**Combined Design Runoff Number** **93**

**Hydraulic Objective** **Match Specific Runoff No.**

**Predevelopment/existing runoff number** **93**

**Nominated Specific Runoff Number** **93**

| | 2 yr ARI | 10 yr ARI | 100 yr ARI |
|---|---|---|---|
| Existing Peak Flows (l/s) | 231 | 398 | 596 |
| Design Peak Flows (l/s) | 231 | 398 | 596 |
| Target Flows (l/s) | 229 | 396 | 595 |

**Total Proposed % IMPERVIOUS Area**
53.30%

Previous Screen

DESIGN FLOWS ACCEPTABLE

| | 2 yr ARI | 10 yr ARI |
|---|---|---|
| Existing volume ($m^3$) | 1260 | 2204 |
| Design volume ($m^3$) | 1260 | 2204 |
| Target volume ($m^3$) | 1248 | 2190 |

DESIGN RUNOFF VOLUME ACCEPTABLE

| | | |
|---|---|---|
| Estimated volume required for attenuation to match Target Flows for a 2 yr Storm | 12 m3 | **Volumes are initial conservative estimates and can be reduced by specific detention design** |
| Estimated volume required for attenuation to match Target Flows for a 10 yr Storm | 14 m3 | |

# Appendix 4: New Lynn Case Study Figures

**Figure 65**
Geology

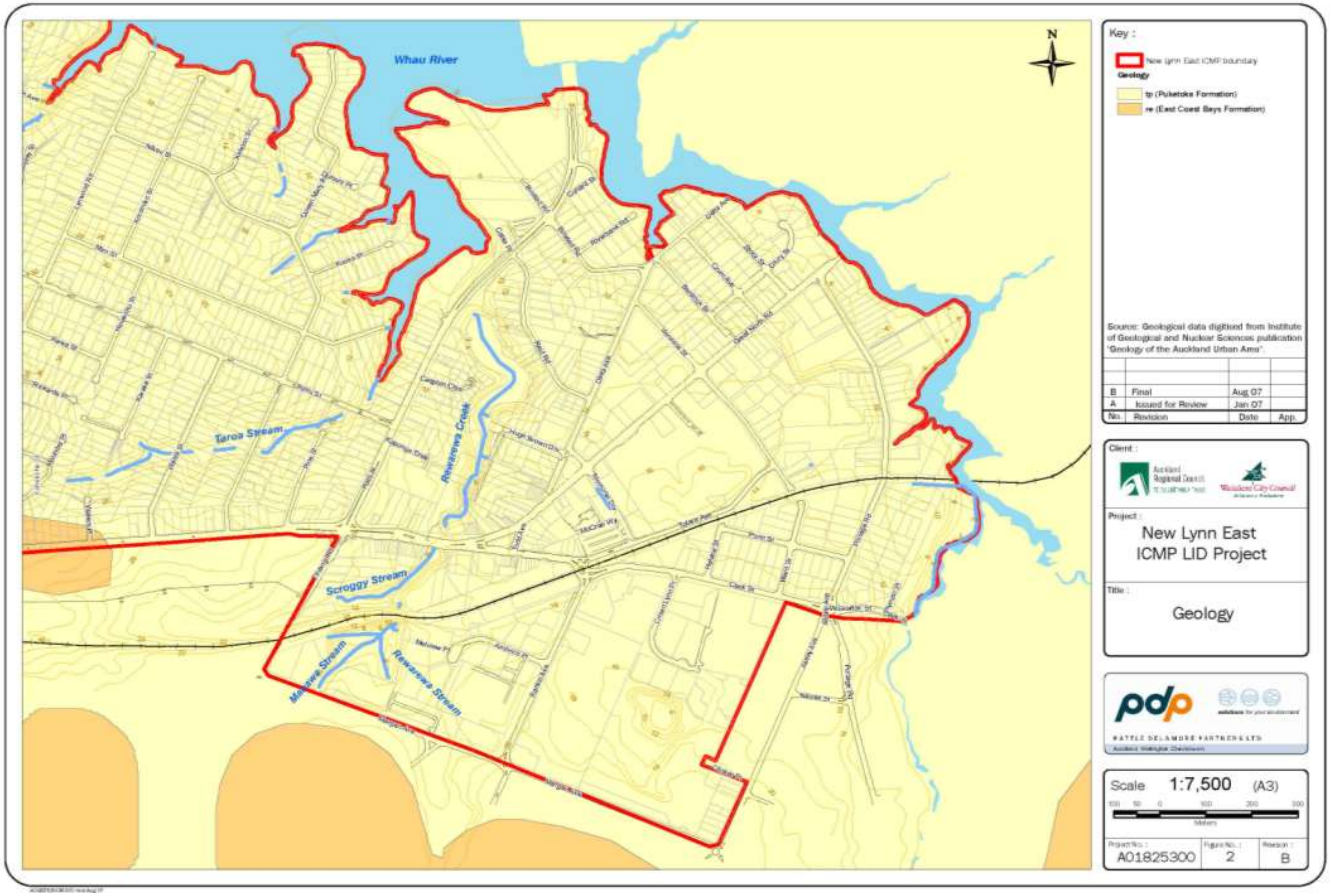


**Figure 66**

Surface water and stormwater network

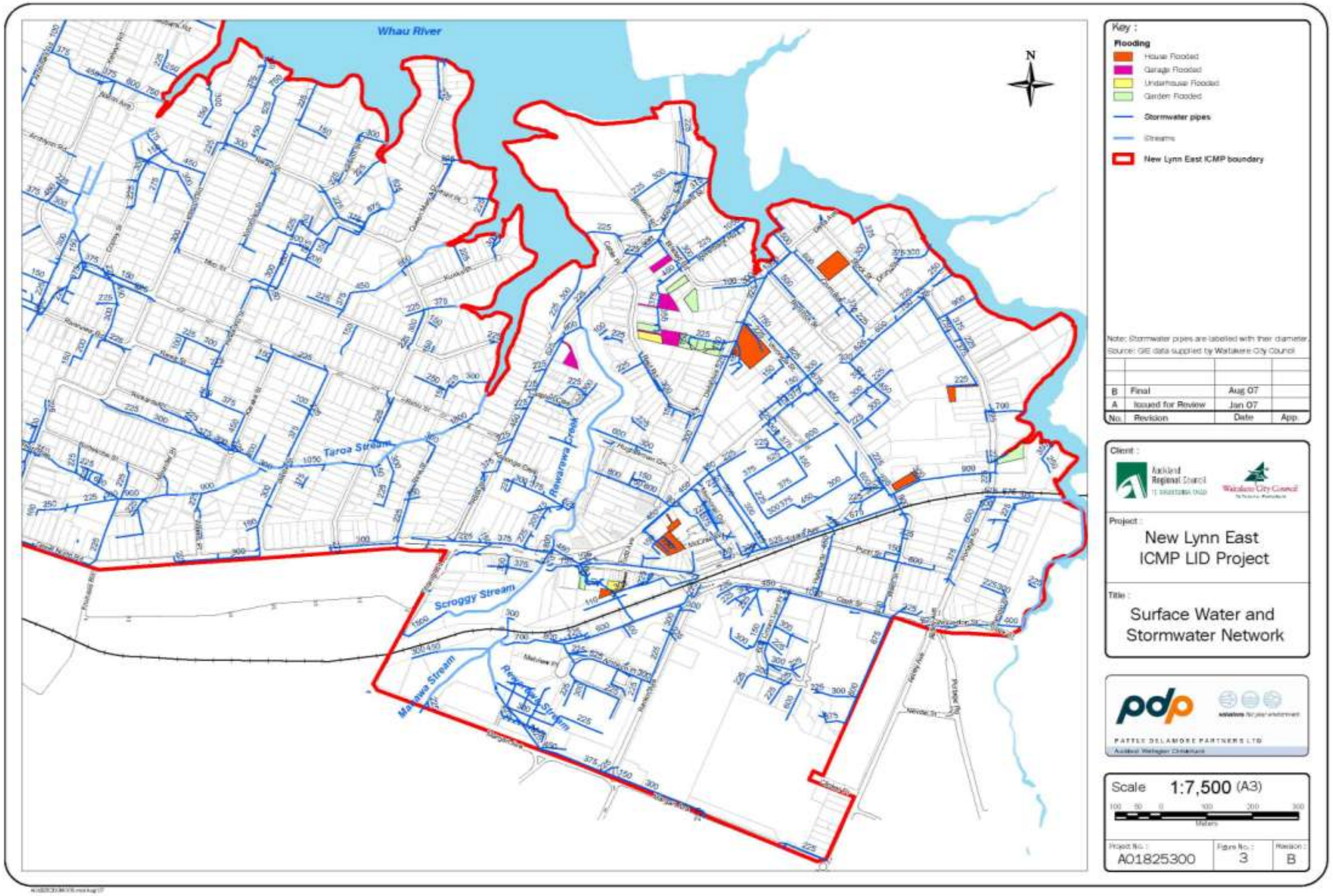


**Figure 67**
Ecological features

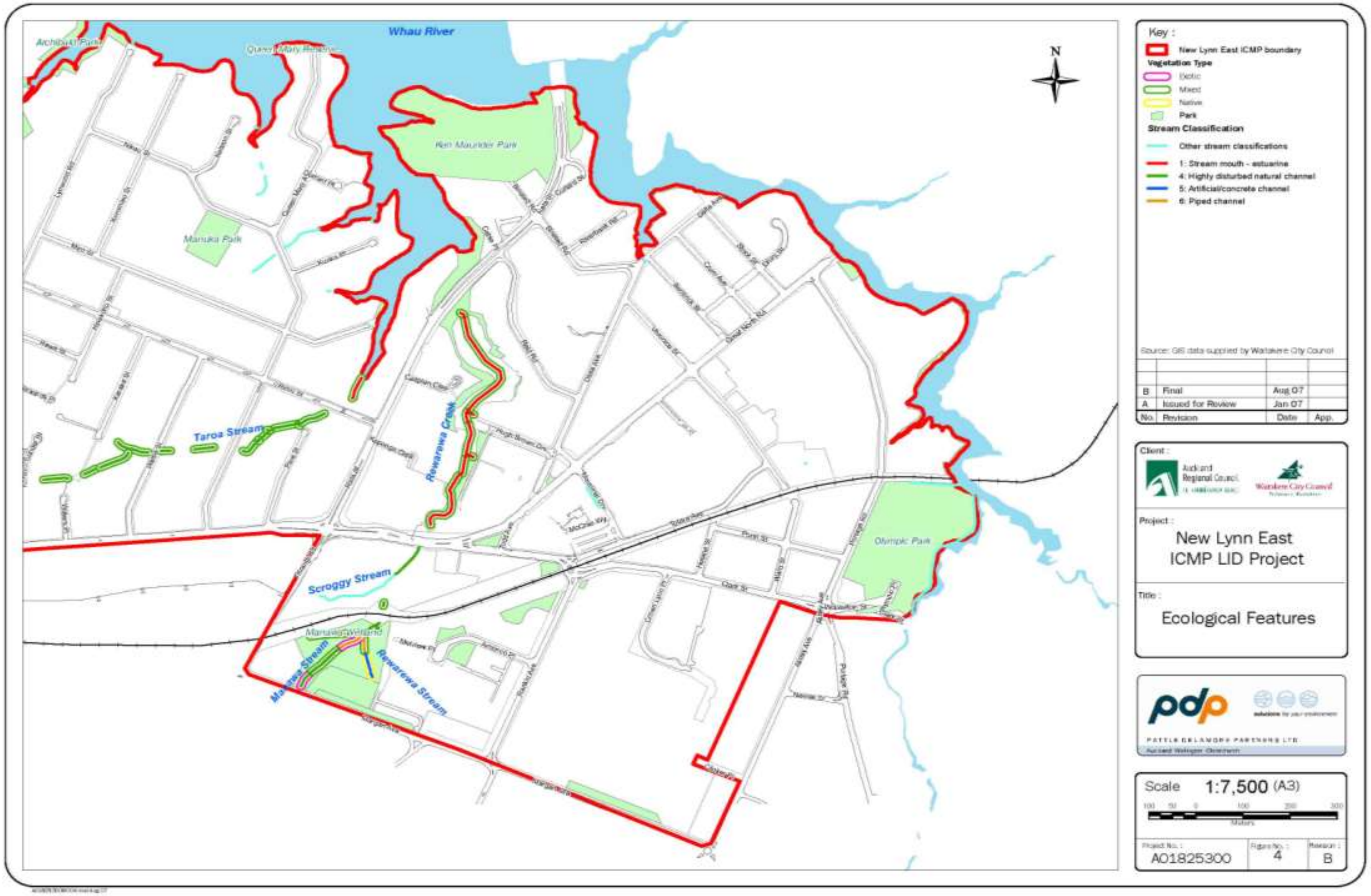


**Figure 68**
Proposed plan change 17

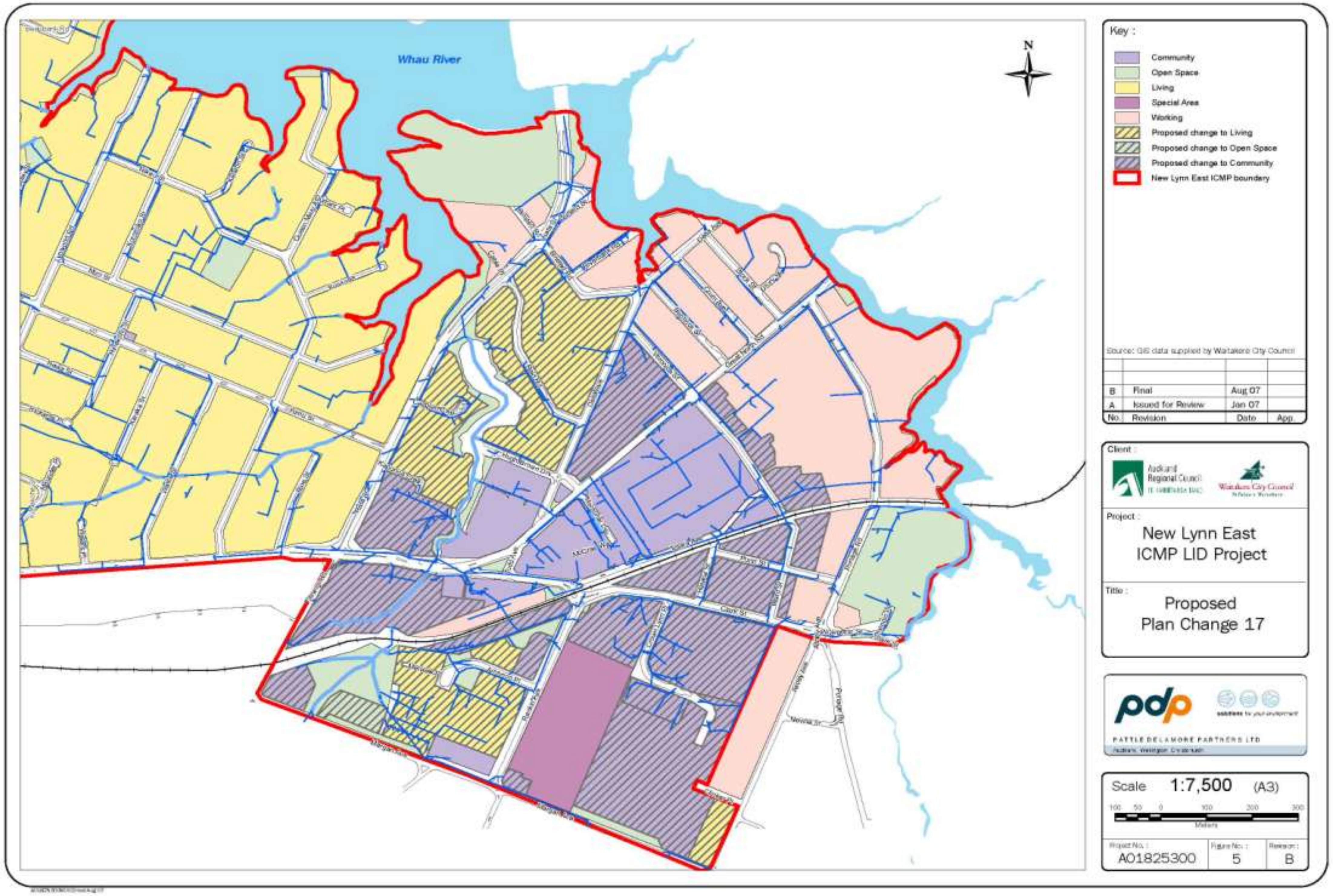


**Figure 69**
Location of sites

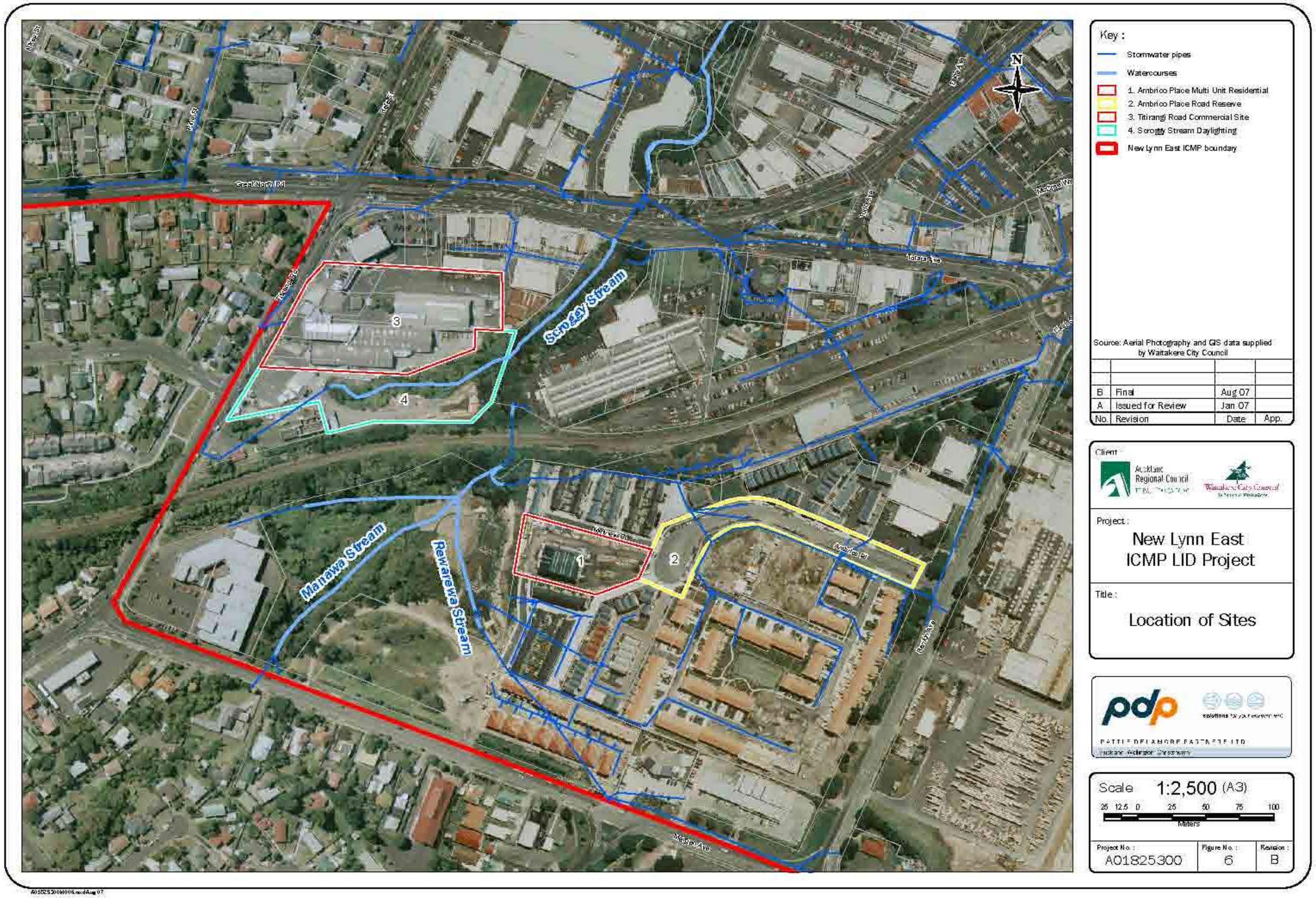


**Figure 70**
Case study 1: Ambrico Place multi-unit residential – existing layout

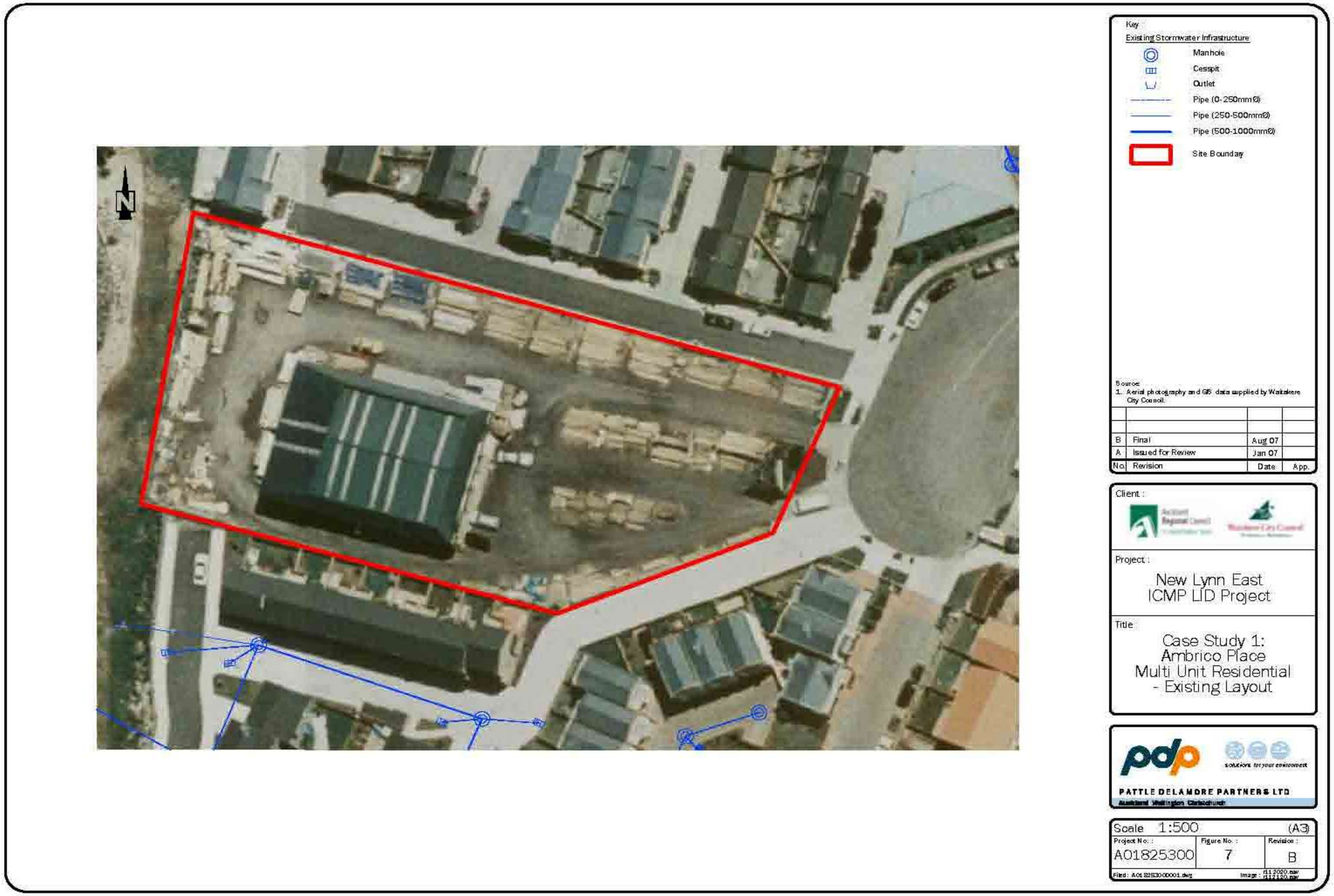


**Figure 71**

Case study 1: Ambrico Place multi-unit residential – proposed LID concept layout

**Figure 72**

Case study 1: Ambrico Place multi-unit residential – proposed LID concept engineering layout

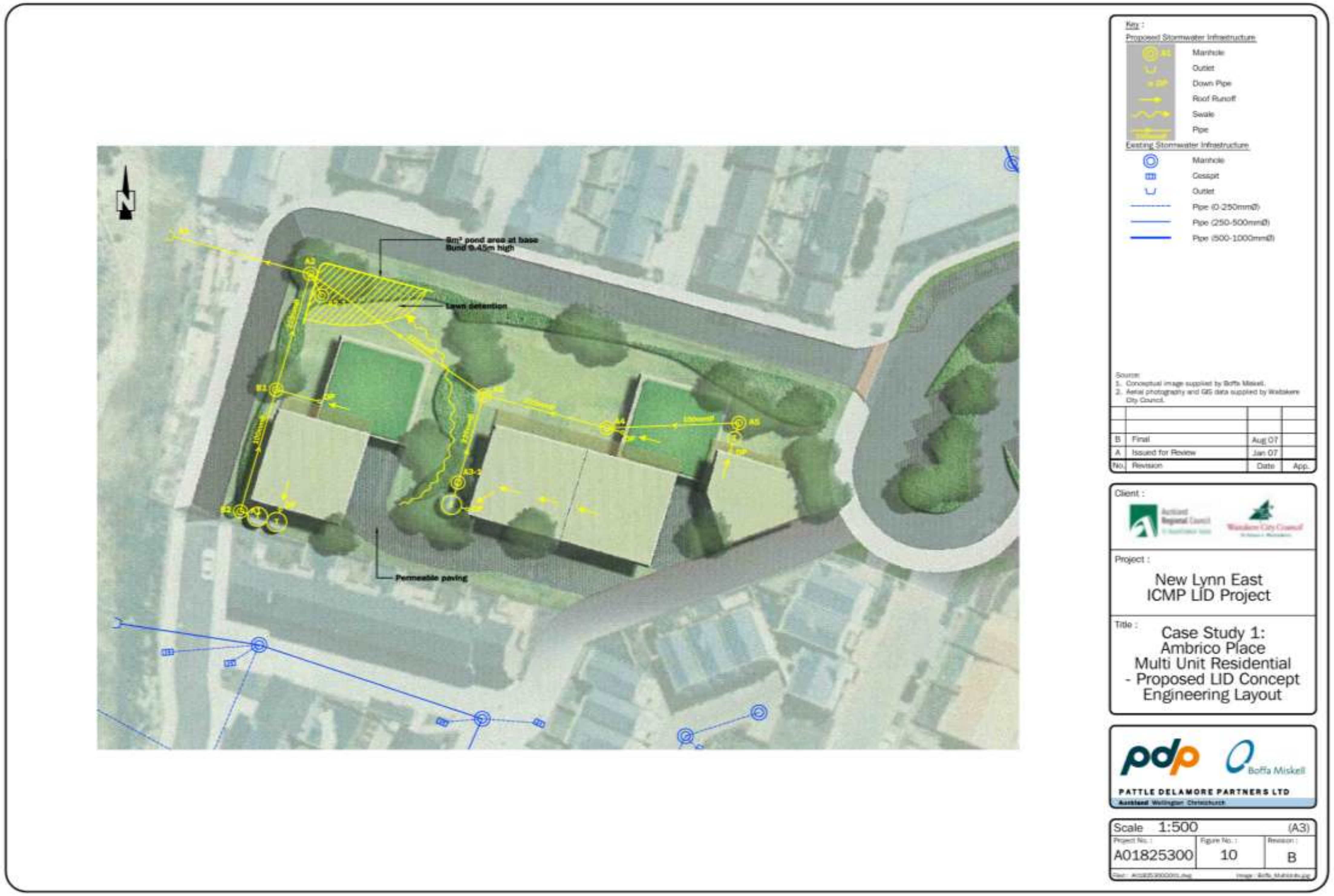


**Figure 73**
Case study 1: Ambrico Place multi-unit residential – alternative LID concept landscaping layout

**Figure 74**

Case study 1: Ambrico Place multi-unit residential – proposed LID conceptual sections

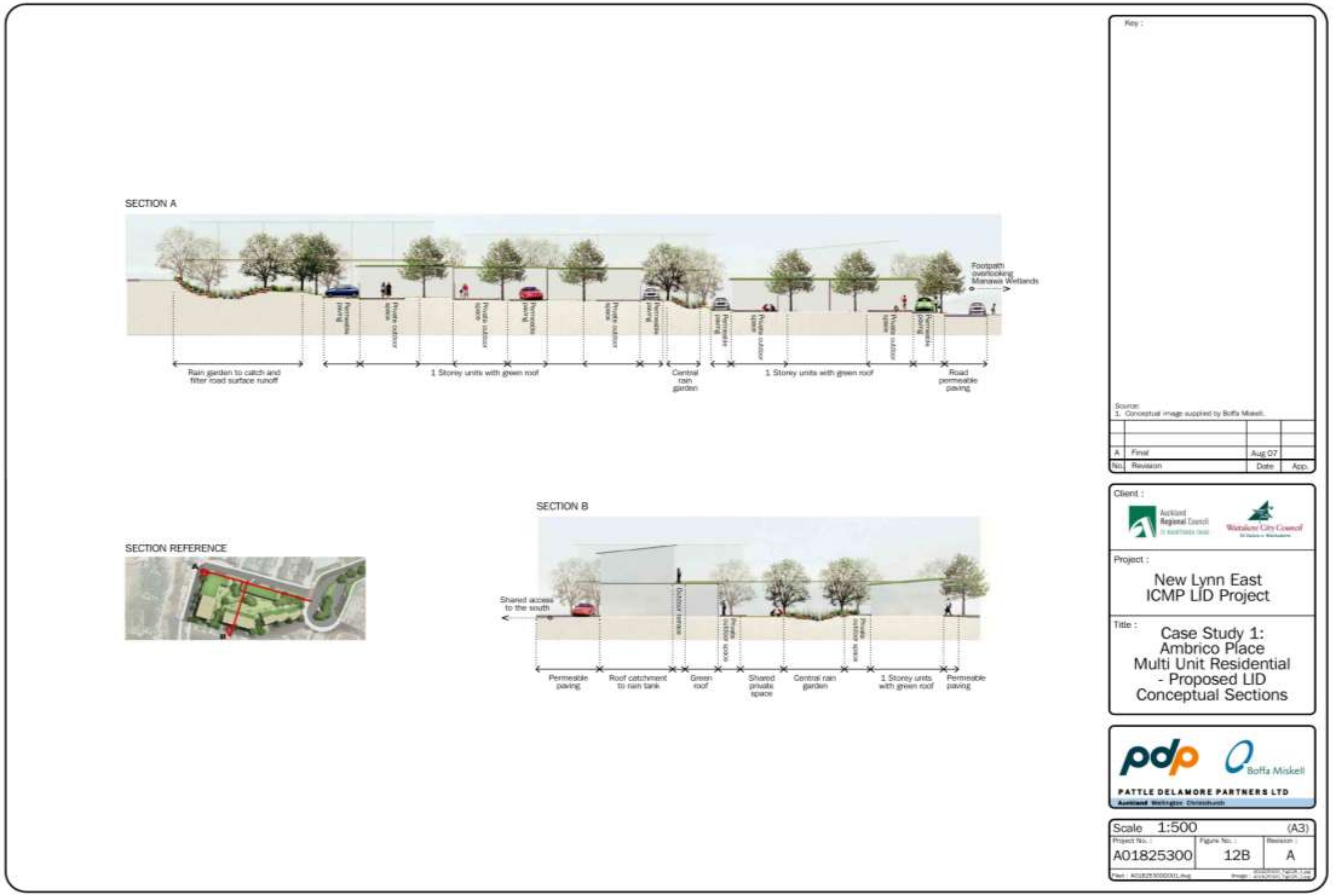


**Figure 75**

Case study 3: Titirangi Road commercial site – existing layout

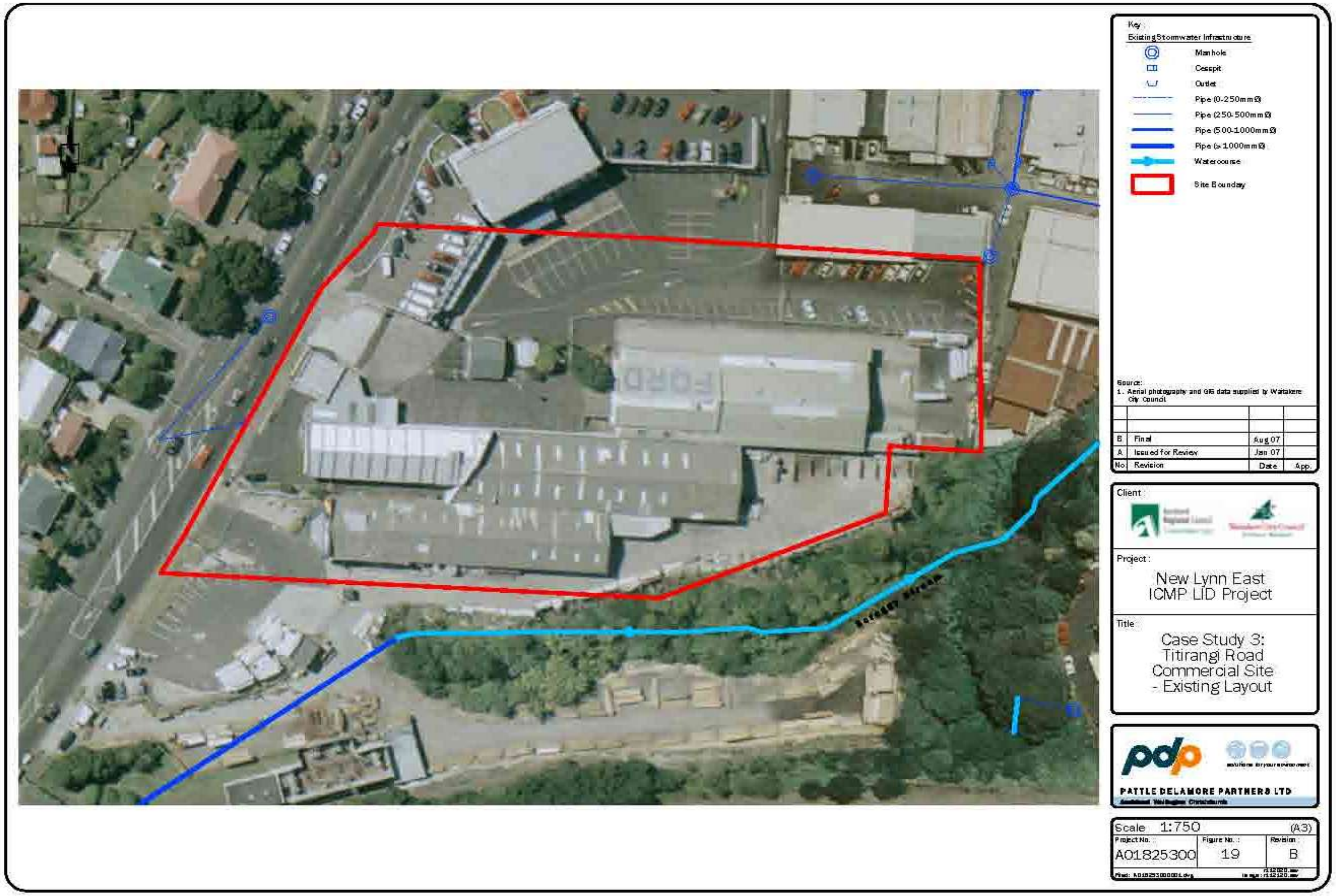


**Figure 76**

Case study 3: Titirangi Road commercial site – proposed LID concept landscaping layout

**Figure 77**
Case study 3: Titirangi Road commercial site – alternative LID concept, layout A

**Figure 78**

Case study 3: Titirangi Road commercial site – alternative LID concept, layout B

**Figure 79**

Case study 3: Titirangi Road commercial site – standard development engineering layout