HAWKE'S BAY WATERWAY GUIDELINES

+ LOW IMPACT DESIGN

HAWKE'S BAY
REGIONAL COUNCIL

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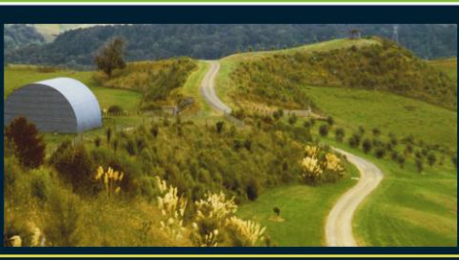

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Hawke's Bay Waterway Guidelines

Low Impact Design

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Acknowledgement
This document for the Hawke's Bay Region is based primarily on the Auckland Regional Council's Technical Publication No. 124 "Low Impact Design Manual for the Auckland Region". The ARC gave permission to use their document and that permission is greatly appreciated.

Modifications to the ARC document have been made to account for advances in the approach and to reflect local conditions.

Note
This document is a living document and may be reviewed from time to time as industry standards change and best practice evolves. Please contact Hawke's Bay Regional Council to ensure the latest version is used.

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Contents

1 Introduction

"Low Impact Design" *is a design approach for site development that protects and incorporates natural site features into erosion and sediment control and stormwater management plans.*

1.1 Purpose

The primary purpose of this guideline is to present an alternative approach to site design and development from a stormwater management context. It is very applicable to residential development but can also be used on commercial and even on industrial development. Its basis is founded in the recognition that the volume of stormwater discharged from a site may be of equal importance to limiting contaminant discharge. The low impact design approach is another stormwater management tool for reducing the adverse impacts of stormwater runoff.

It is not intended that the approach will become mandated by the by the Hawke's Bay Regional Council at this time. There may be development situations where it will be difficult for other approaches to provide the same level of protection for downstream receiving waters, but the decision as to the stormwater management approach rests with the site developer as long as there is an approach to stormwater management which can provide similar benefits and protection to receiving waters.

Stormwater management issues relate primarily to providing guidance for site and catchment design, which incorporates natural site features into land development. The intention is to advise land developers on the benefits of retaining and incorporating these natural features into the site development process and thereby reducing or, in very limited situations, eliminating the need for structural stormwater management controls. Other benefits are also realized through natural site feature utilisation, such as more closely approximating the predevelopment water budget, protection of habitat, and reduced overall impact to the receiving system.

Site features include:

- Wetlands,
- Watercourses,
- Floodplains,
- Forested areas with emphasis on native vegetation,
- Riparian buffers,
- Soils,
- Steep slopes, and
- Other natural features.

Design procedures are provided which allow site designers to incorporate practices, inherently known to be good, but which have not had a sound rational basis to ensure plan approval. That rational basis will be provided in this guideline for a variety of situations. The design approach will be flexible enough to allow for various low impact practices to be combined on one site and quantify the benefits of that combination.

It must be emphasized that structural controls will still be essential on many sites. A heavily vegetated site having a significant portion of the tree canopy removed will still have a significant increase in sediment yield and stormwater runoff, even with aggressive planning efforts related to erosion and sediment control and stormwater management. The practices detailed in this guideline are provided as additional tools in the erosion and sediment control and stormwater management toolbox. They may supplement structural control practices and may, in some situations, replace or reduce the need for structural practices while providing attractive site amenities.

1.2 Audience

The guideline can be used on residential, commercial or industrial sites, especially in the context of a treatment train approach when considering multiple contaminants. Clustering may be more appropriate for residential subdivisions and catchment level implementation than it would be for commercial or industrial sites but issues such as water reuse, green roofs or biofiltration are equally possible on all types of land use activities.

1.3 Background

When discussing the background of this guideline, it is beneficial to recognise the evolution of efforts related to erosion and sediment control and stormwater management and their relationship to the Resource Management Act. These programmes are continually evolving as we learn and this evolutionary process will have to continue as long as water quantity, water quality and aquatic ecosystem problems exist.

The Hawke's Bay Regional Council has its duties, powers and functions specified in the RMA, which was enacted in 1991. The purpose of the Act is defined in Section 5 of the Act.

> "Section 5. Purpose:
>
> 1. The purpose of the Act is to promote the sustainable management of natural and physical resources.
> 2. In this Act, sustainable management means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while.
>
>   (a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and
>   (b) Safeguarding the life supporting capacity of air, water, soil, and ecosystems; and
>   (c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment."

Under the RMA Regional Councils and Territorial Authorities (TA's) have different duties, powers and functions. The Hawke's Bay Regional Council has the function of "the establishment, implementation, and review of policies and methods to achieve integrated management of the natural and physical resources of the region" and "the control of discharges of contaminants into or onto land, air, water, and discharges of water into water". The RMA is enabling, rather than a prescriptive act. The Hawke's

Bay Regional Council can implement management of natural and physical resources through the adoption of policies and rules.

Under Section 32 of the RMA, the Hawke's Bay Regional Council has a duty to consider alternatives and assess the benefits and costs before adopting policies and rules. An urban runoff quality control programme must therefore consider all the tools available for reducing environmental degradation from urban runoff and establish a strategy that passes the tests provided for in Section 32 of the Act.

1.4 Problem Statement

When considering problems, there are a number of aspects that can be considered. One approach is to consider problems from a temporary (erosion and sediment control) and permanent (stormwater management) perspective. From a temporary context, there is the importance of site disturbance on sediment yields during construction. There are some basic statements that can be made.

Estuarine Sedimentation from Site Development

- The greater the area of site disturbance, the greater the sediment yields.
- The longer the area remains disturbed, the greater the sediment yields.
- The greater the slope, the greater the sediment yields.
- Disturbed land has a greater runoff potential than vegetated surfaces.
- The closer the site disturbance is to a receiving environment (watercourse, estuary, marine area), the greater the potential impact.

When considering the permanent impacts of urbanisation, there is the historic recognition that flooding can be a problem. There is also increased recognition that other water-related problems are associated with land development. The most obvious, is stream channel erosion with subsequent impacts on the stream biota. The creation of impervious surfaces increases the total volume of water running off the land during a rainfall event. This increased volume of stormwater runoff results during all storm runoff events and increases the potential for stream channels to erode. The channel capacity is increased (wider, deeper, or both) and results in the loss of private and public property and significant habitat degradation. There is documentation indicating that channel erosion in a catchment that is completely developed is the single largest source of sediment delivered downstream. Channel instability results in public expenditures to reduce property loss and necessitates channel works such as stone armouring or channel lining.

Other impacts associated with land development include the generation and discharge of contaminants carried off the landscape by stormwater runoff. These contaminants include:

- Sediment,

- Oxygen-demanding substances (decomposition of organic materials),
- Nutrients (predominantly nitrogen and phosphorus),
- Metals (many different ones but zinc, copper, lead are generally found),
- Oil and grease,
- Microorganisms (human or animal waste), and
- Organics (pesticides, herbicides, etc.)

Typical Urban Contaminants

Contaminants build up in a catchment, and are delivered to a receiving system during storm runoff and may accumulate over time. Their impacts tend to be chronic rather than acute or episodic, and increase over time. Examples of impacts associated with contaminant loadings include increased water supply treatment costs, destruction of aquatic plants and animals, beach and shellfish area closures from bacterial contamination, and bioaccumulation of chemical pollutants. More subtle impacts can include reduced harvesting or landings of fish and shellfish.

Another emerging concern is the reduction in low stream flow as catchments develop. Streams which had water flowing in them all year frequently become ephemeral as groundwater recharge is reduced. As a general comment, if a stream is flowing when it is not raining, then the flow is groundwater generated. If groundwater levels drop lower than the stream invert, baseflow ceases and the stream loses its biologic values unless aquatic organisms can exist in pools until the time when the stream flows again. All of us live in catchments that have been impacted as a result of our activities on the land.

For all of these reasons, the Hawke's Bay Regional Council requires erosion and sediment control and stormwater management to implement temporary and permanent practices and strategies for water quantity and water quality purposes. Consent requirements for erosion and sediment control are detailed in the Erosion and Sediment Control Guidelines for the Hawke's Bay Region. Existing stormwater management requirements are detailed in the Stormwater Management Guidelines for the Hawke's Bay Region.

The guidelines place heavy emphasis on structural practices such as filters and ponds to minimise, to some extent, the adverse impacts of stormwater runoff both during and post-construction. When intending land development, the land developer must consider both the quantity of water leaving the site and the quality of that water both during and post-construction. Criteria are specified in the various Hawke's Bay Regional Council Guidelines that must be followed.

1.5 Limitations of Existing Practices

Most stormwater management programmes place a heavy reliance on implementation of structural practices. These practices include ponds, both wet and dry; flow diversion systems; filtering practices; and other variations. The implementation of stormwater management practices is necessary for their water quantity and water quality benefits and is expected to remain integral to programme implementation, but there should not be an over reliance on them. These practices, in and of themselves, cannot eliminate adverse impacts that urban development has both during and post-construction. In addition, there are a number of limitations to structural facilities.

A stormwater management programme relying solely on structural practices has a number of weaknesses. The existence of these weaknesses has been recognized for some time, but there has been little information available on alternative approaches that would justify their inclusion in programmes. In addition, clear guidance must be available on alternative design approaches or practices that can be used by plan designers and approval agencies. The guidance must also lend itself to effective field implementation. The following items and their discussion present some of the weaknesses of programmes based on structural controls.

1.5.1 **Lack of Flexibility in Site Design**

A lack of flexibility in what a site developer can do for stormwater management will have an impact on how the site is developed. The requirement to construct ponds will necessitate that site drainage be routed to the ponds. This would mean that runoff which can travel through sheet flow across vegetated areas must be conveyed to the pond. This will normally entail conversion of the water from sheet flow into concentrated flow through a reticulation system.

The existing approach detailed in the Stormwater Management Guidelines for the Hawke’s Bay Region is presented as a “cookbook” of practices. The approach does not mandate one practice over another, but rather provides a framework by which one practice is used over or in conjunction with another one. Practices and approaches have limitations to their use and those limitations will determine, to a large extent, which ones are used. Some flexibility does exist but that flexibility is only as broad as the interpretation of the individuals designing or approving the stormwater management plan. In reality, there is a perception, for the most part valid, that the preference for ponds is too often a mandate. In addition, design consultants must deliver an approvable plan to the site developer. The expense associated with that plan is dependent on the consultant being reasonably comfortable that their cost estimate for design will provide for their time and expense in doing the site design. An innovative site design may receive a poor reception from the consenting agency and necessitate a redesign with a more traditional approach to site control. Innovation is very difficult to budget for when monetary resources are limited.

1.5.2 **Altered Site Hydrology**

The only structural practices that attempt to mimic predevelopment site hydrology are practices that take stormwater out of the runoff stream. Infiltration, water reuse and evapotranspiration practices reduce the total volume of stormwater runoff. Unfortunately, these practices are not appropriate everywhere, Other practices, such as stormwater management ponds, only reduce, to an extent, the adverse impacts of land development. The volumes of stormwater runoff are increased immediately upon site clearance, and consequently the duration of storm flows from these ponds is considerably longer than that which would have occurred prior to site development. From a water quantity standpoint, the intention is to hold the site's stormwater long enough to allow the catchment's storm flows to pass the site, and thus reduce downstream flooding. They also provide water quality treatment primarily through settling processes that are designed into the practice. However, it needs to be recognised that flows can also modify ambient water quality so as to make it unsuitable for downstream biota.

The use of ponds is a recognition and acceptance that site hydrology has drastically been modified, and an increase in the volume of stormwater runoff is inevitable. In the same regard, groundwater levels will drop and base stream flow will be reduced. The pond's purpose is to reduce, to the extent possible, the adverse impacts of contaminant discharge and altered site hydrology. If the site hydrology were not altered to the degree that is normally accomplished, downstream impacts would be reduced.

1.5.3 Expense

In addition to design costs, there is the greater expense associated with the construction of ponds and filtering practices. These practices can be expensive. Too often in stormwater design the sizing of stormwater management practices is based on the generic land use draining to the practice and does not consider that portions of the site, if left undisturbed, would not generate the amount of runoff that results from the developed portion of the site.

Ponds, as generally implemented, are structural practices. They must have properly designed structural components such as a core trench, anti-seep collars, a riser assembly with a trash rack, a barrel, and structural fill. These components are expensive and require care in their proper installation and performance.

For the most part discussion in this guideline will address ponds as the current primary means for stormwater management in site development. Ponds have been preferred historically as a result of their applicability for water quantity use in addition to their proven water quality performance values. There are a number of other practices and these other practices are also structural practices. Other practices include infiltration trenches and dry wells, biofiltration practices such as swales or filter strips and filtration practices that rely on the movement of water through a filter media, usually sand, to provide a water quality benefit.

1.5.4 Loss of site area

Stormwater management practices take up site area. When a land developer decides to develop a given piece of property, an initial consideration is how many housing units can be placed on that property, and their potential sale prices. A factor in this determination includes how much of the site must be devoted to the stormwater management practice, maintenance access to the practice and drainage components that convey water to it. All of these features limit what the land developer can do on the remainder of the property. Low impact design practices will also utilize site area, but they can more easily be blended into the overall site development and required open space plan than can stormwater management ponds, for example.

1.5.5 Potential increased impacts to site and catchment natural resources

Generally, the lowest elevation of the site will be where the stormwater management pond is to be located. This will ensure gravity flow throughout the site to the pond. If this portion of the site is bush or a wetland, construction in this area could adversely impact on those resources.

Even if wetlands or other natural features are avoided by the stormwater management practice, getting a reasonable financial return on the project may necessitate disturbance in those areas for another aspect of site development. This could occur because housing densities may necessitate filling wetlands or cutting down more trees to get the minimum number of lots needed.

Increased disruption of natural site features can have impacts off-site. Downstream wetlands or estuarine areas may have greater sedimentation as a result of increased site disturbance or increased disturbance of steep slopes, or erodible soils, etc. New Zealand has lost approximately 90 percent of its nontidal wetlands. Those wetlands were not lost overnight or as the result of one activity. Adverse sediment and stormwater impacts are cumulative in nature and result from numerous activities, each having a minor catchment-wide individual impact.

1.5.6 Configuration of Development

Typical Form of Urban Development

The traditional approach to stormwater management seems to also fit with the traditional approach to site development. The site design approach allocates a portion of the site to sediment control and stormwater management in conjunction with a “cookie cutter” approach to site layout. Site development is configured in a traditional pattern that easily goes through the territorial authority approval process. Traditional structural stormwater management requirements are now well understood and are just incorporated in an overall site plan with little consideration of the need to protect existing site resources.

1.5.7 Connection of Impervious Areas

Conventional storm drains usually link impervious areas on most sites. Storm drains are efficient water conveyance systems that collect and quickly pass runoff into a structural stormwater management practice. Rapid travel through an enclosed storm drain system eliminates any potential for contaminants to be removed from the stormwater conveyance system prior to its entry into the stormwater management practice. This results in the stormwater management practice being the only means of treating the runoff water quality and providing for water quantity control.

1.5.8 Disregards Site Resource Conservation Benefits

There is little incentive, under the existing approach to site development, to leave trees in a given location, to establish native vegetation in open space, or to maintain low areas as wetlands. All of these practices reduce the total volume of runoff and provide water quality benefits. There is no incentive if structural stormwater management is still required for the land development and the volume and areal extent of the practice cannot be reduced.

Protecting and preserving natural site features requires a greater effort during the land development process. At present, there is little incentive for the land developer to take additional natural feature protection efforts, especially if public perception indicates that site buyers might prefer a more manicured site. The land developer must receive an economic benefit by leaving natural features if that individual is to “sell” eventual property owners on the rationale for leaving natural features.

1.5.9 Maintenance Obligations

Operation and maintenance of structural stormwater management practices is a significant responsibility if ongoing adequate performance of the practices is to occur. Structural practices require routine and periodic inspections to ensure proper function and all system components need to be checked. Individuals conducting these inspections need to be trained to recognize when a problem exists and what steps need to be taken to rectify them. Inspection report forms need to be completed and given to those individuals responsible for maintenance of the practice.

Actual maintenance of the structural practice is generally divided into two categories: routine and non-routine. Routine maintenance needs to be ongoing, such as mowing or maintenance of terrestrial vegetation, debris removal, lubrication of any moving parts to the practice, etc. Non-routine maintenance is done on an “as-needed” basis and can include sediment removal, aquatic weed removal, replacement of worn parts, needed structural repairs, and other activities associated with a particular structural practice. Maintenance activities represent a significant commitment of time and resources to ensure long-term function of the sediment control and stormwater management practices.

Also, the issue of who is responsible for operation and maintenance can be a problem. This can exist where stormwater practices such as ponds have been installed in new subdivisions. Local authorities or maintenance organizations may not have the expertise, awareness, or inclination to address operation and maintenance obligations or problems. There may also be a potential safety or liability problem in the event of stormwater practice failure.

When maintenance is not accomplished, the results can range from increased downstream flooding and increased contaminant discharge to potential loss of life and property. Maintenance is a major expense associated with structural stormwater management practices.

1.6 Low Impact Design (LID) Approach

Low impact design (LID) approaches reflect a totally different philosophy towards site design that integrates stormwater management into the very core of site design, as opposed to being considered an afterthought to site design with a conventional approach. These approaches can include an almost endless universe of practices, strategies, planning and common sense. This guideline cannot include all potential components but will provide guidance and information on many that are currently recognized where data exists or can be generated to substantiate their benefits from a water budget perspective.

It is important to develop an ethic that treats stormwater runoff as a “resource” rather than a “waste-product” of development. As such, there are a number of key site design components to consider:

- Reducing site disturbances,
- Reducing impervious surfaces,
- Constructing biofiltration practices,
- Water reuse,
- Creating natural areas, and
- Clustering development

Low impact approaches will be discussed through the guideline but some are briefly discussed here to provide an initial awareness of the range of options that will be discussed later in greater detail.

1.6.1 **Reducing site disturbances**

Many sites have existing resources that, in addition to other values, have soil retention and stormwater management benefits. These natural systems include forested areas, wetlands, and other areas of natural value and are discussed in greater detail in Section 3.

Forested areas provide for rainfall interception by leaf canopy. In addition, an organic forest litter develops on the forest floor that acts very much as a sponge to capture the water and prevent overland flow. Trees provide for uptake and storage of nutrients. They also moderate temperatures during the summer and provide wildlife habitat, thus providing other environmental benefits.

Wetlands are valuable resources and provide numerous benefits including flood control, low stream flow augmentation, erosion control, water quality and habitat. They are very productive ecosystems whose maintenance would have significant water quantity and quality benefits. Where they exist on a development site, they could become an important element in site design.

From a construction standpoint, leaving areas in natural ground cover can have a significant benefit by reducing downstream sediment delivery. Sediment yield from disturbed soils can be 2000 times greater than yields from forested areas. Leaving site areas undisturbed is an important low impact approach component.

1.6.2 Reducing impervious surfaces

Impervious surfaces (roads, roofs, footpaths) prevent the passage of water through their surface into the ground. Water must then be transported across the surface to a point of discharge. Residential subdivisions can reduce the width of roadways, or design the roadways to limit the total length needed to service individual properties. In conjunction with imperviousness, roof down drains may be directly connected to streets or reticulation systems when providing splash blocks and discharging the water across grass and away from impervious surfaces (footpaths, streets) will allow for a greater amount of water to infiltrate into the ground.

An important factor in limiting impervious surfaces and separating roof drains from direct connection to streets is the need for education of home owners regarding their awareness and responsibility to ensure continued function of these practices. Homeowners often change or otherwise redirect lot drainage to impervious surfaces, which undoes a lot of low impact design, benefits. Community education and involvement is integral if implementation of LID is to be effective.

1.6.3 Constructing biofiltration practices

The use of vegetative swales, buffer strips and rain gardens can provide a significant water quality benefit in addition to reducing the total volume of stormwater runoff. The primary processes involved in their performance are filtering of pollutants contained in stormwater runoff, evapotranspiration and infiltration of runoff into the ground.

Even with kerbs being needed to prevent traffic movement off of paved surfaces, kerb cuts or openings can be placed in the kerb to allow water to pass off the paved surface into a biofiltration practice. This would allow for both objectives (traffic control and stormwater) to be attained.

1.6.4 Water reuse

Using stormwater generated from roof areas or even from impervious surfaces for domestic or industrial purposes can reduce the total volume of stormwater being discharged, as water being reused will be separated from catchment stormwater delivery. Water reuse is potentially a very valuable tool in reducing stormwater runoff volumes and would have other beneficial effects such as reduced use of groundwater and reduced potable water needs.

Water Reuse at a Hospital Site

1.6.5 Creating natural areas

In many site development situations, the predevelopment condition may be pasture or other highly modified hydrological condition. Re-establishment of native bush as riparian cover, steep slope protection or general site revegetation as open space would have significant stormwater management benefits for both water quantity and water quality. The area, if well designed and constructed, could become an attractive amenity to a community and enhance the value of the properties.

1.6.6 Clustering development

How a site is developed and to what degree the entire site must be utilized will have a significant impact on sediments and stormwater runoff from the site. Conventional land development encourages sprawl, while other approaches to land development can provide significant sediment reduction during construction and post-construction stormwater benefits. Cluster development encourages smaller lots on a portion of a site, allowing the same site density, but leaving more site area in open space and disturbing less of the natural ground cover. Clustering entails designing residential neighbourhoods more compactly, with smaller lots for narrower single-family homes, as are found in traditional villages and small towns. Cluster development can provide for protection of site natural areas, while at the same time reducing total site imperviousness by reducing the areal extent of roads.

House Clustering Schematic for a Residential Subdivision

1.7 Catchment Wide Approaches

Catchment-wide considerations, from a broad perspective, are important and should be the context from which many resource-based land development decisions are made. This Guideline strongly supports catchment-based approaches to land use decisions and Section 6 focuses entirely on catchment-wide implementation of LID. This context is important from a number of perspectives.

- Catchment approaches allow for a recognition and consideration of where growth distribution should occur.
- Consideration of land use from a catchment perspective allows for a greater awareness of the cumulative impacts of catchment development. Impervious surfaces are important to consider if downstream areas are to be protected.
- A comprehensive approach to resource protection can be developed and implemented based on consideration of catchment specific issues such as steep slopes, erodible soils, existing bush retention, high water table, the need for aquifer recharge, etc.
- A catchment approach allows for developers and the general public to understand the basis by which land use decisions were made in a rational format that can be easily understood.

- Land use decisions based on catchment wide analyses provide the local authority a basis for making decisions that can be defended.

As desirable as catchment-wide approaches are, it must be recognized that significant “up front” resources and costs may be needed to accomplish these efforts. Depending on the goals of the effort, significant data needs may exist. From a long-term perspective, catchment approaches represent the most economical approach if resource protection is to be considered in conjunction with land development.

1.8 Organisation of Guidelines

The guideline is organised along the following chapters.

Section 1 - Introduction to LID

The context of LID is presented here along with a discussion of problems that occur from implementation of conventional development and conventional approaches to stormwater management. LID concepts are briefly discussed to familiarise the reader with information presented in later sections.

Section 2 - Importance of Water Cycle in Stormwater Management

Various aspects of the water budget are discussed. Rainfall and its relationship to site stormwater runoff are components of the water cycle. Data that relates to ecological response to urbanisation and that relationship to water quantity and quality are also presented. A final element mentioned is natural mechanisms for stormwater pollution removal.

Section 3 - Site Resources

Site resources will be discussed in terms of their inclusion as components of overall site design. This will include a discussion of ecology and landscape form, wetlands, floodplains, riparian buffers, forests, soils, steep slopes, and other natural features. Consideration of these site components may have a significant impact on reducing adverse stormwater related impacts.

Section 4 - Low Impact Design Approach

A low impact design approach will be presented that considers an array of nonstructural low impact techniques. These techniques include: reduction of site imperviousness, use of swales appropriately, reduction in use of kerbing, clustering to reduce site disturbance and imperviousness, lengthening stormwater flow paths, preservation and enhancement of native bush, and other concepts.

Section 5 - Detailed Design Procedures

A design procedure is provided for minimising adverse impacts related to earthworks during construction and minimising impacts on a long-term basis relating to permanent stormwater management. Checklists are provided to assist in site design.

Section 6 - Catchment -wide considerations

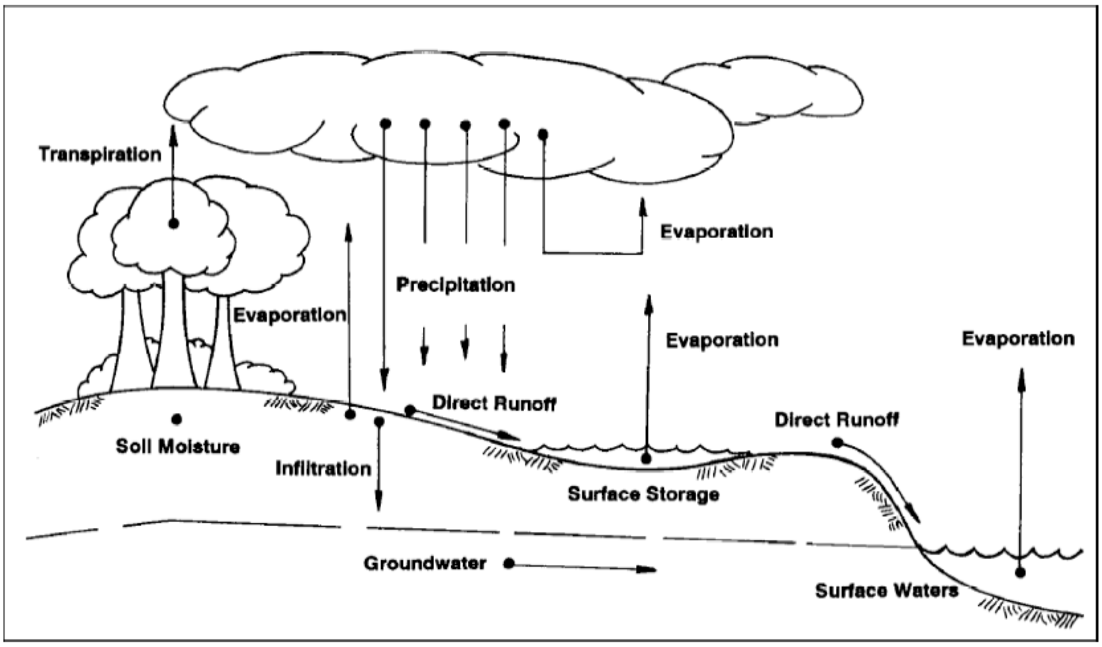
The concept of approaching LID from a catchment-wide perspective is presented in this Section to demonstrate that approaching resource protection from a catchment perspective is the most effective way to consider it. Issues such as fitting development to the land, avoidance of development on steep slopes or in wetlands, setting target densities and consideration of stormwater impacts on receiving systems are integral elements in consideration of development potential in a sustainable context.

2 The Water Cycle

2.1 The hydrologic cycle

Any discussion on stormwater related issues must begin with a discussion of the hydrologic cycle. Understanding the hydrologic cycle concept is essential if there is to be any understanding of cause and effect as it relates to stormwater management. Figure 2-1 illustrates, in a very simplistic form, the essential elements of the hydrologic cycle. The water cycle arrows make the point of continuous movement and transformation. Of all aspects of the water cycle, its dynamic quality - the never ending cycling from atmosphere to the land and then to surface and groundwater and back again to the atmosphere, must be emphasized. That we drink the same water today that the Maori drank hundreds of years ago is a graphic example of the continuous cycling and recycling of water. The concept of continuous movement is essential in order to understand the hydrologic cycle system.

Figure 2-1
The Hydrologic Cycle



Source: Fundamentals of Urban Runoff Management.

When looking at those components of the hydrologic cycle for the Hawke's Bay Region, the following information contained in Table 2-1 can be approximated for undeveloped and urbanised catchments. This information must be placed in the context of being generally applicable for the Region as Hawke's Bay rainfall is very locationally specific.

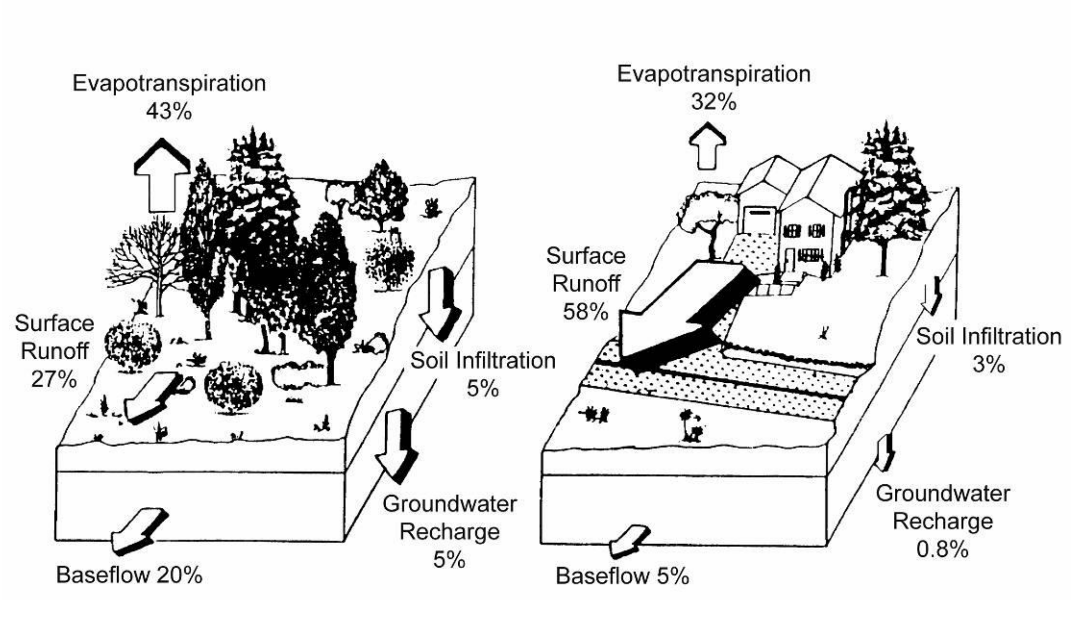
Table 2-1
Components of the Hydrologic Cycle

Component	Pre-development	Post-development
Annual rainfall	1000 mm	1000 mm
Total runoff	266 mm	580 mm
Deep infiltration	50 mm	8 mm
Shallow infiltration	250 mm	80 mm
Evaporation/transpiration	430	325

It is important to appreciate that the system itself is a closed loop. What goes in must come out. Impacts on one part of the cycle create comparable impacts elsewhere in the cycle. If inputs to infiltration are decreased by 170 mm per year, then inputs to surface runoff must be comparably increased by this amount. Stormwater programmes, which focus on one aspect of stormwater (detention or channelisation) without paying attention to the other aspects of the hydrologic cycle, will not function effectively.

Land development has come to mean a significant change in the natural landscape, including creation of impervious surfaces. When we pave areas we increase surface runoff. Figure 2-2 demonstrates that impact. The arrows in the illustration are drawn to suggest size or extent of impact (in this case, total quantities of water involved year after year). Note that when we move from the predevelopment to post-development condition, the three medium-sized arrows become one increased surface runoff arrow with both evapotranspiration and infiltration substantially reduced. Increasing surface runoff total volumes translates into significantly reduced total volumes reduced from infiltration with significant consequences later in the water cycle.

Figure 2-2
Changes to Water Direction Due to Urban Development



In the past, stormwater management programmes have focused on peak rate management or water quality treatment. Because such efforts are so partial in concept and in effect, this approach fails to acknowledge and plan for critical system wide water cycle impacts, which can mean that the stormwater management approach itself becomes a problem, rather than a solution. Only through understanding full water cycle dynamics can we hope to achieve some sort of system balance and minimise water cycle impacts when managing stormwater.

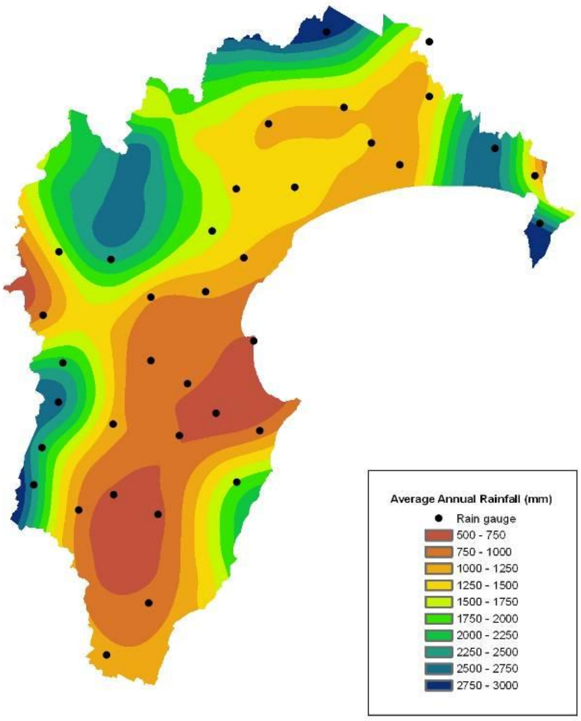
2.2 Precipitation

Hawke's Bay has a highly varied rainfall throughout the Region. The rainfall totals in western areas (3000 mm max.) can be up to three times those in eastern areas. Figure 2-3 provides information on rainfall patterns in the Region.

The following information provides some context around rainfall in the Region.

- Through 136 years of record the average dry period between storms (greater than 5 mm) during the summer is 12.9 days.
- The mean annual number of dry days in the summer is 43 days and the 5-year average is 52 dry days.
- During winter the average dry period is 11.4 days with the annual number of dry days being 36 days and the 5-year average number of dry days is 44 days.

Figure 2-3
Annual Rainfall for the Hawke's Bay Region



There is not much variation between summer and winter in terms of inter-event dry periods but there is a slightly greater seasonal rainfall in the winter months (approximately 28%) than during other times of the year.

A percentage of Hawke's Bay streams dry up completely during some summers. It is important to recognise the seasonal variability of rainfall and stream flow and the behaviour of various land use types on runoff generation. For instance, native vegetation provides a greater buffer and flow moderating influence on stormwater runoff than more modified environments. Streams are less inclined to dry up over summer months if there is abundant vegetation in a catchment as movement of water into the soil recharges groundwaters.

2.3 Groundwater Considerations

Groundwater is that part of the water cycle that has soaked into and flows through the ground. It is mainly derived from rainfall that has soaked into the ground instead of running off over the ground surface, evaporating or being used by plants. It may also be derived from water soaking into the ground from stream or lakebeds. The replenishment of groundwater in this way is called groundwater recharge.

Water that soaks into the ground moves down through soil pores or rock fractures until it hits the water table. The zone above the water table is known as the unsaturated zone. Below the water table soil pores or rock fractures are fully saturated and the groundwater mainly moves laterally through these pores and fractures.

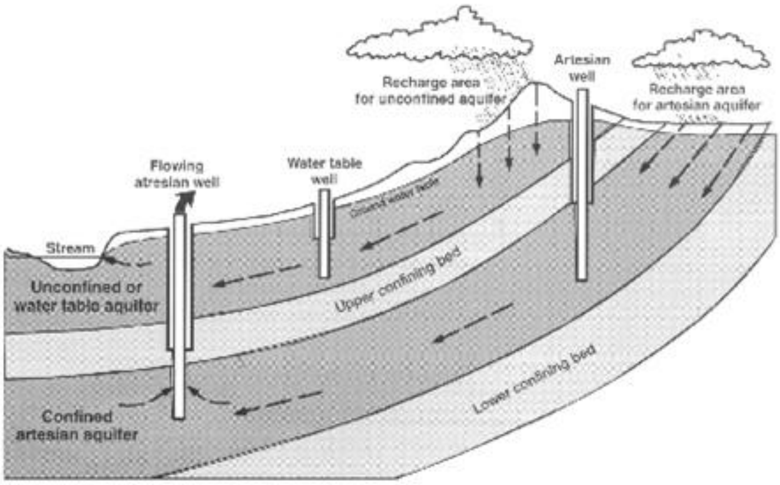
Groundwater underlies all of the Hawke's Bay Region. However, differences in geology, hydraulic properties of the soil or rock, topography, recharge rates and its relationship with surface water means that groundwater flow and bore yields are greater in some areas than others. The layers of rock that allow groundwater flow are called aquifers. There are two main types of aquifer, which are:

- Unconfined or water table aquifers. These are recharged by rainwater percolating down from the land surface (see Figure 2-4)
- Confined or artesian aquifers. These are pressurised and may give rise to artesian or free-flowing bores. They are recharged only where they are exposed at the land surface.

Confining beds or layers that don't allow groundwater flow are called aquitards.

Groundwater discharges from aquifers into the ocean, streams, lakes and springs. Aquifer discharge plays an important role in providing water to streams during dry periods. This flow to streams is called baseflow.

Figure 2-4
Common Types of Aquifers



There is a dynamic equilibrium between groundwater recharge, aquifer storage and aquifer outflow. For example recharge increases during a rainfall event and there is an increase in aquifer storage (the water tables rise) and there is a corresponding increase in aquifer outflow particularly baseflow and spring flow. This equilibrium is also changed by changes in land use. Where changes in land use reduce recharge rates there is a reduction in aquifer storage (the water table declines) and consequent reduction in baseflow in streams and in spring flow. Aquifer outflow is very important in maintaining stream ecology particularly during periods of low rainfall. During such times baseflow and spring flow is maintained from aquifer storage. If aquifer storage is not replenished by recharge a new equilibrium is reached with reduced baseflow and subsequent effects on stream ecology.

Groundwater resources in the region vary from place to place according to the characteristics of the soils and underlying rock type. Primary soils in the Region include:

Pallic Soils

Pallic soils consist of loess derived from schist or greywacke. They tend to have a slow permeability with limited rooting depth. They are susceptible to erosion due to high potential for slaking and dispersion. They tend to be dry in the summer and wet in the winter.

Podzols Soils

These soils are strongly acidic and occur in areas of high rainfall. They are associated with forest trees with an acid litter and have a slow permeability and limited root depth. Podzol soils have low biological activity.

Pumice Soils

Pumice soils are sandy or gravelly soils dominated by pumice, or pumice sand with a high content of natural glass. Drainage of excess water is rapid but the soils are capable of storing large amounts of water for plants. They have a low clay content (<10%) with low soil strength.

2.4 Stormwater Quantity

Changing the surface of the land from native vegetation or pasture to urban land use increases site and catchment impervious surfaces, by increasing rooftops, roads, driveways, patios, and pathways. Table 2-2 displays typical levels of imperviousness, which can be found for various types and levels of development.

Table 2-2
Typical Levels of Impervious Surfaces

Type of development	Percent impervious
Residential housing	
500 m^2	65
1,000 m^2	38
1,300 m^2	30
2,000 m^2	25
4,000 m^2	20
8,000 m^2	12
Commercial and Business	85
Industrial	72

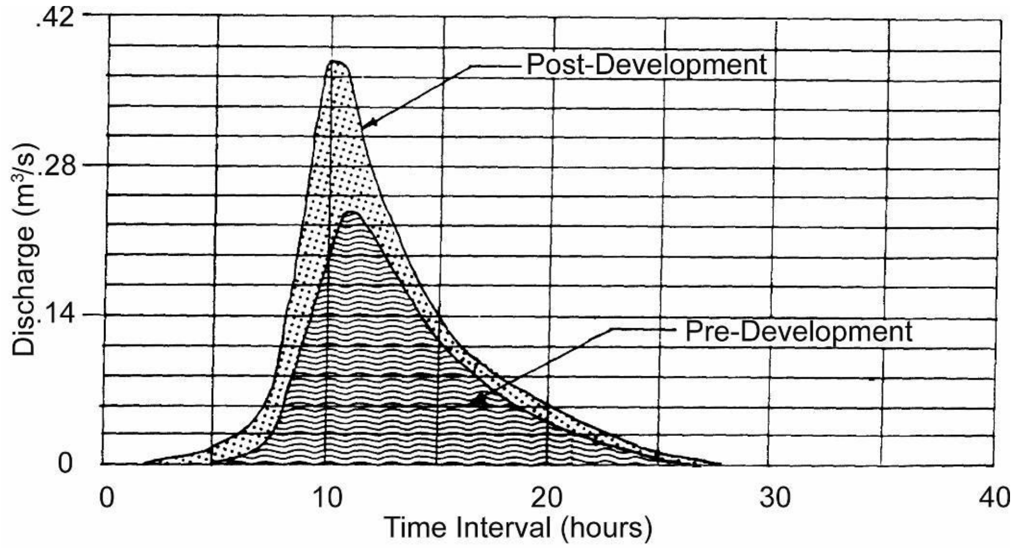
Greater levels of development in a catchment increase levels of impervious surfaces, resulting in greater runoff. Impervious surfaces, other than having a small wetting factor, directly convert rainfall into runoff.

A common means of visualising the response of stormwater runoff to rainfall is the concept of a storm hydrograph, which is a graphical comparison of runoff being discharged from any particular site (measured in cubic metres per second) versus the time that the water is being discharged. Hydrographs can be developed for sites of any size and for all different size and duration storm events. Figure 2-5 presents a hydrograph for a typical site before land development has occurred and compares that hydrograph with the post-developed runoff condition.

There are a couple of points that can be made when comparing the pre- and post development hydrographs detailed in Figure 2-5.

- The figure provides for a hypothetical development at a hypothetical site and presents a post-development hydrograph with the assumption that there is no stormwater management.

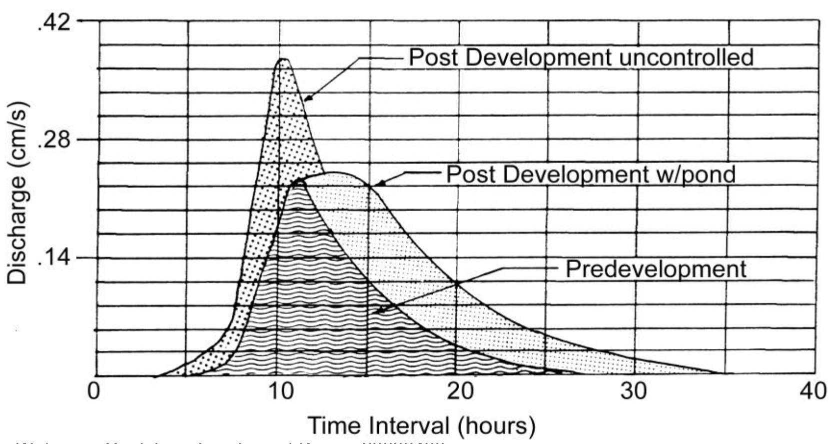
Figure 2-5
Typical Pre- and Post-Development Hydrographs



- There is a significant increase in the peak discharge from the development activity versus the predevelopment condition
- As the total volumes of the runoff are the areas under the curves, there is a significant increase in the total volume of runoff from the pre- to the post-condition.
- The post-development hydrograph rises or increases earlier in time than does the predevelopment hydrograph. Runoff starts earlier as portions of the site have been made impervious and immediately start to discharge water as rain begins.

Under existing approaches to stormwater management a developer might be required to construct a pond for water quantity peak flow control, and possibly water quality, control. Ponds provide numerous benefits but they cannot reduce the total volume of water that must pass through them. This means that water is discharged from them for a longer period of time than would have occurred under predevelopment conditions. Figure 2-6 shows hydrographs under three different

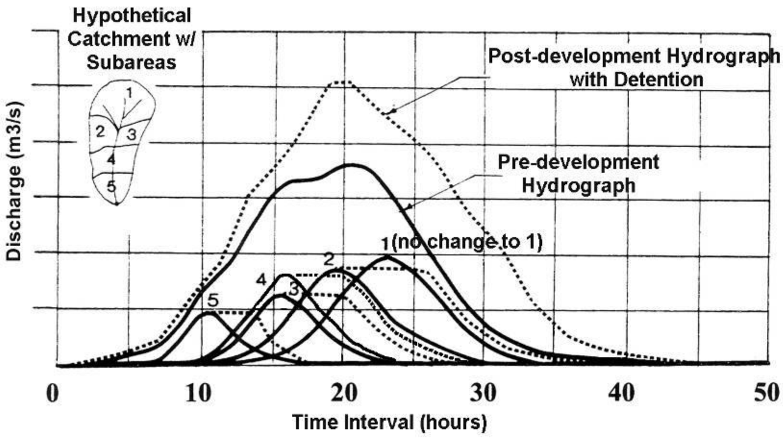
Figure 2-6
Post Development Hydrograph with Detention



scenarios now with the total volume for the uncontrolled condition being the same as the volume for the hydrograph where there is a stormwater pond. Where this situation occurs, it may not always cause problems downstream of the facility but duration of flows downstream of where a number of ponds are located on different tributaries may aggravate existing flooding problems.

Figure 2-7 illustrates the possible flooding impacts (depending on location within a catchment) that can result when a peak rate control approach is used catchment wide. Under the assumption that they illustrate five sub-catchments within a single catchment, each of which undergoes development and relies on a peak rate control approach for stormwater ponds. Under this analysis, there is a predevelopment hydrograph which sums the individual sub-catchments, five different hydrographs from sub-areas, and those five combined to provide a resultant post-development catchment hydrograph. Not surprisingly, the resultant post-development hydrograph with detention exceeds the predevelopment condition for volume (as expected) but also for the peak rate of discharge, which goes against the intent of implementing the programme to begin with. In short, flooding may worsen downstream. A programme cannot be based only on structural detention facilities. It must be supported by various approaches that can complement detention to prevent aggravating an existing catchment condition.

Figure 2-7
Possible Effects of Detention on Catchment Hydrology



Urbanisation of catchments can result in major flooding and sedimentation problems. The more important stormwater quantity effects of urbanisation which have been generated in the Hawke's Bay Region include the following:

- Complete reticulation of a catchment when urbanised will almost double the mean annual flood return period
- A fully urbanised catchment, completely reticulated and with approximately 50% impervious cover will increase the peak discharge of a two year storm by approximately four times
- Large floods of low frequency, such as 50 to 100 year events, show a relatively lesser effect from urbanisation, their peak flows increasing about 2.5 times.
- The number of bank overflows increases, perhaps doubling where the catchment is 20% storm reticulated and 20% impervious.
- Floods rise to a higher peak more quickly than under previous rural conditions and also runoff more rapidly.
- Natural baseflow may decrease as a result of reduced groundwater infiltration
- Where channel materials are erodible, the stream channel will tend to enlarge as part of the process of larger and more frequent floods.

2.5 Stormwater Quality

2.5.1 **Contaminant Types**

Urban stormwater carries with it a wide variety of contaminants from multiple sources. Representing the majority of recognised classes of water contaminants, these originate not only from land activities in the catchment but also from atmospheric deposition. Moreover, surface and groundwaters can exchange. Streams flowing during times with no rain are an indication of the surface groundwater interaction.

Contaminants commonly found in urban stormwater that can harm receiving waters and the specific measures that express them are listed in Table 2-3. Contaminants other than solids and pathogens are associated with being in a solid or in a dissolved state. In urban runoff most contaminants are associated with solids or soil or other natural particulates. This condition differs among the specific contaminants. For example, depending on overall chemical conditions, each metal differs in solubility. For instance, lead (Pb) is relatively insoluble and will generally be seen in a particulate form, while zinc (Zn) may be found in either a particulate or dissolved form. The nutrients phosphorus (P) and nitrogen (N) typically differ substantially in that phosphorus can be found either in particulate or soluble form while nitrogen is generally found in soluble form only.

Besides these contaminants, other water quality characteristics affect the behaviour and fate of materials in water. These characteristics include:

- Temperature
- pH - an expression of the relative hydrogen ion concentration
- Dissolved oxygen
- Alkalinity - the capacity of a solution to neutralise acid
- Hardness - an expression of the relative concentration of divalent cations, principally calcium and magnesium
- Conductivity - a measure of a water's ability to conduct an electrical current as a result of its total content of dissolved substances (often expressed as salinity in estuarine and marine waters or total dissolved solids (TDS))

These characteristics affect contaminant behaviour in several ways. Metals generally become more soluble as pH drops below neutral and hence become more available to harm organisms (often referred to as bioavailability). In addition, pH also affects the toxicity of some metals and ammonia. Depleted dissolved oxygen can also make some metals more soluble. Anaerobic conditions in the bottom of lakes release phosphorus from sediments, as iron changes from the ferric to the ferrous form. Elements creating hardness reduce toxicity of many heavy metals. Water quality analyses take this relationship into account by varying the allowable level as a function of hardness.

Table 2-3 Urban Contaminants	
Category	Specific Measures
Solids	Settleable solids (SS) Total suspended solids (TSS) Turbidity
Oxygen demanding substances	Biochemical oxygen demand (BOD) Chemical oxygen demand (COD)
Phosphorus	Total phosphorus (TP) Soluble reactive phosphorus (SRP) Biologically available phosphorus (BAP)
Nitrogen	Total nitrogen Total Kjeldahl nitrogen (TKN) (ammonia + organic) Ammonia-nitrogen (NH_3)
Metals	Copper (Cu), Lead (Pb), Zinc (Zn), Cadmium (Cd), Arsenic (As), Nickel (Ni), Chromium (Cr), Mercury (Hg), Selenium (Se), Silver (Ag)
Micro-organisms	Fecal coliform bacteria (FC) Enterococci bacteria (Ent) Viruses
Petroleum hydrocarbons	Oil and Grease (O+G) Total petroleum hydrocarbons (TPH)
Synthetic organics	Polynuclear aromatic hydrocarbons (PAHs) Phthalates Pesticides Polychlorobiphenols (PCBs) Solvents Etc.

2.5.2 Contaminant Sources

Now that types of contaminants have been discussed, it is important to recognise their sources. Knowing where contaminants come from can assist in developing a strategy to reduce their impact on receiving systems. Stormwater practices and approaches do not equally address contaminants and recognising the various land uses that exist in a catchment will assist in evaluating the range of pollutants that can be expected and thus the approach that needs to be taken to reduce their impact. Table 2-4 lists typical sources of contaminants.

Table 2-4 Sources of Urban Contaminants at Individual Sites	
Atmospheric deposition	From urban and rural areas: fine particles, phosphorus, ammonia, nitrate, metals, pesticides, petroleum products, toxic organics and metals
Litter and leaf fall	Personal and commercial debris discarded to roadways and parking lots such as plastics, paper, cans, and food; leaves and organic debris from roadside and parking lot trees; BOD, nitrogen, phosphorus, humic organics, metals
Residential and roadside landscape maintenance	Phosphorus and nitrogen, pesticides and herbicides, dissolved organics from soil amendments
Urban wildlife and pets	Bacteria, phosphorus and nitrogen
Transportation vehicles	Fuels, brake drum and tire wear, body rust, fine particles, metals in particular zinc, copper, cadmium, lead, and

	chromium; and petroleum products such as oil/grease and PAH
Pavement and pavement maintenance	Temperature modification, petroleum derivatives from asphalt
Pavement deicing	Chlorides, sulfates, organics from acetate deicers, coarse sediments, and cyanide
Building exteriors	Galvanised metals, chipped and eroded paints, corrosion of surfaces accelerated by acid rain, metals
Industrial businesses	Varies widely with the industry. Includes the contaminants commonly contributed by other sources but may also include those less commonly detected in general urban runoff or at concentrations greater than normally found in contaminants from inappropriate connections, petroleum products, phenols, solvents, metals.
Commercial businesses	Parked vehicles, improperly disposed refuse such as discarded food, used cooking oil and grease, and packaging materials, internal drains improperly connected to the stormwater system, metals, BOD, bacteria, phosphorus, nitrogen, oil and grease
Residential activities	Landscaping, pest control, moss control, vehicle maintenance, painting, wood preservation, pesticides and herbicides, phosphorus, nitrogen, petroleum products, zinc and bacteria
Site development	High pH from fresh concrete surfaces, petroleum products from fresh asphalt and spills, organics and particles from landscaping materials, eroded sediment and associated constituents such as phosphorus, contaminants associated with improperly disposed construction materials like fresh concrete and paints, cement from preparation of exposed aggregate concrete
Public infrastructure	Metals from galvanised stormwater drain systems, metals and petroleum products from maintenance shops, bacteria, nitrogen, phosphorus and organics from exfiltration or overflowing sanitary sewer

When considering water quality there are a number of statements that can be made.

- Stormwater's impact on the aquatic environment is due to three factors: a large increase in the volume of water that runs off impervious urban surfaces compared with more absorbent vegetated land uses, the greatly accelerated rate of runoff; and contamination of stormwater with a wide range of substances.
- Contaminants are collected by runoff from a variety of diffuse and point sources within a wide catchment area, but are often concentrated by the piped collection system at outfalls into aquatic receiving environments.
- The contaminants of most concern are suspended solids, a range of heavy metals, organochlorines, polynuclear aromatic hydrocarbons and human pathogens. Sources are widespread throughout the urban catchment and are classified as diffuse, or nonpoint sources.
- Many sources of stormwater contamination are difficult to control because of their diffuse distribution catchment-wide.
- Point sources of stormwater contaminants may be increased in industrial areas through yard and equipment washing and accidental or deliberate discharge of products and wastes from industrial processes that allow contaminants to enter the stormwater system.

- A large proportion of most contaminants are bound to particulate matter in the stormwater. A high proportion of these suspended solids pass through the drainage channels and eventually reach the marine receiving environment. In the marine receiving environment, suspended solids settle and are incorporated into marine sediments.
- Other settling processes also occur when contaminants move from freshwater to estuarine or saline waters.
- Settling occurs least along open coasts and harbour entrances as a result of wave action and littoral drift and most occurs in upper estuaries where flow velocities are reduced and salt tends to flocculate finer particles. The headwaters of most estuaries are poorly flushed because much of the water draining on the ebb tide returns on the following flood tide. In contrast, open coastal regions are well flushed by tides and contaminants can be re-mobilised into the water column by wave, current and tidal action and are widely dispersed.
- Upper estuaries are therefore regarded as highly sensitive to stormwater contamination, because they act as retention zones where suspended solids are deposited, and where contaminants continually accumulate. There is a higher rate of build-up of contaminants near stormwater outfalls. Concentrations then decrease with increasing distance from individual stormwater outfalls.
- Stormwater in New Zealand has similar concentrations and types of contaminants to those found in other developed countries.
- In urban streams, acute and chronic toxicity water quality criteria for the protection of sensitive biological species are regularly exceeded for heavy metal contaminates. Organic contaminant levels in stormwater may sometimes exceed the relevant chronic water quality criteria but the New Zealand information base is sparse. Further downstream where urban streams discharge into larger water bodies, water quality criteria are predicted to be rarely exceeded because of dilution and settling of particulates, which carry most of the contaminants.
- The impacts of urban development on small Hawke’s Bay streams have been severe. Many of these impacts have been caused by modifications to channel and riparian areas, as well as by the hydrological changes accompanying urbanisation.
- In sheltered coastal sediments there is a clear link between urban stormwater contamination and build-up of contaminants. There is strong evidence that this build-up is detrimental to animals that live in the sediment and which provide the basis of the estuarine ecosystem. Sediment contaminant concentrations in some of urban estuaries and harbours exceed North American sediment quality criteria, and there is evidence for stormwater impacts on aquatic animals in Hawke’s Bay through chronic toxic effects.
- In streams and near stormwater outfalls, many contaminants regularly exceed sediment quality criteria for the protection of sediment-dwelling animals. Many of the retention zones of Hawke’s Bay estuaries with significantly urbanised catchments exceed the criteria for the major contaminants lead, zinc, and organochlorines.
- If contaminants continue to be generated at present day rates, the rate of sediment contamination will accelerate with urban expansion, and the extent of the affected areas will increase.

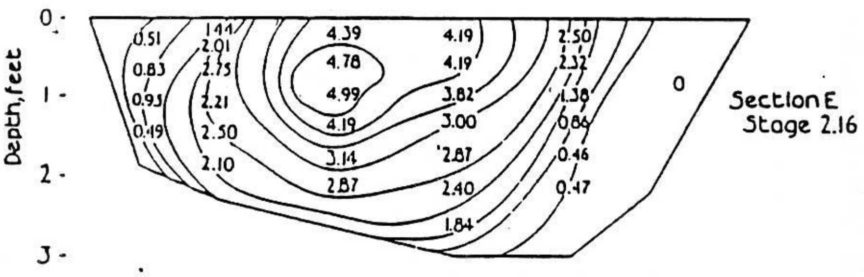
2.6 Stream Morphology

The physical appearance and function of a stream's boundaries, generally called stream morphology, is a product of the magnitude of stream flow and erosional debris produced by a catchment. The influence of channel materials, catchment slope, and other features of catchment morphology further modify the individual stream characteristics. As the catchment area increases so do the requirements of the stream to convey water and sediment.

2.6.1 Bankfull discharge

A common term used in stream morphology is "bankfull" flow. This is a term that is used to denote channel capacity. When bankfull flow is exceeded, floodplain flow initiates. Stream dimensions, patterns, and bed features are a function of channel width measures at bankfull stage. The bankfull stage corresponds to the discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels. Typical velocity distributions are shown in Figure 2-8 (Chow, 1959). It is this discharge in concert with the range of flows that make up an annual hydrograph which govern the shape and size of the channel. Bankfull discharge is associated with a momentary maximum flow that, on the average, has a recurrence interval of 1.5 years as determined using a flood frequency analysis. Although great erosion and enlargement of steep, incised channels may occur during extreme flood events, it is the modest flow regimes which often transports the greatest quantity of sediment material over time, due to the higher frequency of occurrence for such events.

Figure 2-8
Stream Cross-section Showing Velocity Distributions



2.6.2 Stream channel dimensions

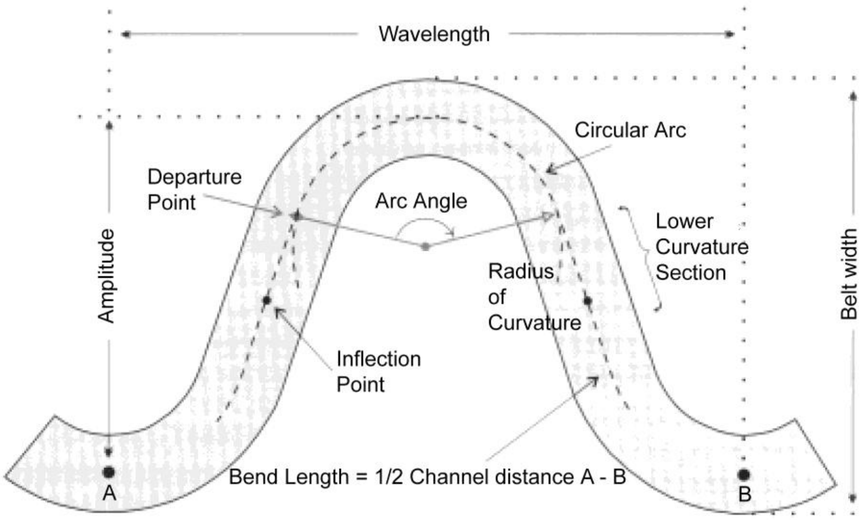
Stream width is a function of stream flow occurrence and magnitude, size and type of transported sediment, and the bed and bank materials of the channel. Channel widths generally increase downstream as the square root of the discharge. Channel width can be modified by the following influences:

- Direct channel disturbance such as channelisation
- Changes in riparian vegetation that may alter boundary resistance and increase channel erosion potential
- Changes in streamflow regime due to catchment changes such as increased impervious surfaces or increased sediment delivery resulting from construction

2.6.3 Stream channel patterns

Streams are rarely straight for any substantial distance; rather they tend to follow a sinuous course. Meander geometry is most often expressed as a function of bankfull width. An example of the relationships that exist and the various components of a meander pattern are shown in Figure 2-9. The parameters include bankfull width, meander wavelength, and radius of curvature. Stream flow regimes not only include bankfull channel widths but can also change stream patterns, depending on the magnitude and duration of flows. As catchments are urbanised, widening of streams and changes in channel patterns can be observed. These channel adjustments are brought on by an acceleration of streambank and bed erosion.

Figure 2-9
Stream Channel Geometry



The patterns of streams are naturally developed to provide for the dissipation of the kinetic energy of moving water and the transport of sediment. The meander geometry and associated riffles and pools adjust in such a way that the work expended on natural processes is minimised. Consequently, straightening stream channels ultimately leads to a state of disequilibrium or instability, often causing entrenchment and changes in morphology and stability. Over the last 150 years, numerous streams have been straightened under the assumption that their functional efficiency would increase.

The meander patterns that streams exhibit result in maintaining a slope such that the stream neither degrades nor aggrades. When reducing the natural meander changes the alignment of the stream, local stream reach slopes are changed and instability may result.

2.6.4 Stream channel profile

Generally, channel gradient decreases in a downstream direction with increases in stream flow. The shape of a longitudinal profile of a first or second order stream at the top of the catchment to the lower part of the catchment is generally concave. Since steep gradient streams are relatively straight, they dissipate energy along the longitudinal profile in relatively close spaced features, normally called riffles and pools. Their spacing is inversely related to slope and proportional to the bankfull width.

2.7 Stream Ecology

As water in streams only moves in one direction (down hill) there is a constant loss of organisms and materials to the sea, the stream community is totally dependent on materials entering the system from mostly terrestrial ecosystems, typically as particulate matter (leaves, organic and inorganic matter). As a result, different streams and reaches of streams have different aquatic communities. Upland fast-flowing streams with stony beds differ in community structure from slow-flowing lowland rivers with muddy bottoms. Looking at what lives in a stream in an undisturbed forested condition and relating that to what commonly exists in a stream that is impacted by urban development can provide a barometer of what we can expect if development was to occur in a traditional manner. A discussion of ecological issues also can provide guidance of what site resources are important to maintain if aquatic ecosystem protection is a goal.

The dynamic nature of wet-weather flow regimes and water quality make it difficult to assess the impact of urbanisation and stormwater on aquatic ecosystems. Physical habitat and biological measures reflect aquatic ecosystem conditions over months and years and thus integrate these variable conditions into a more easily understood set of measures. Physical habitat is a principal element of ecological analysis. Without the proper channel and riparian characteristics (floodplain, shade, stable channel, riffles, pools, etc.) improvements in hydrology and water quality will demonstrate little change in ecosystem function or value. Most importantly, the aquatic community (plants, invertebrates, fish) provides a direct measure of ecosystem quality and sustainability.

2.7.1 **Physical habitat**

The increased frequency and magnitude of peak flows destabilises stream banks and increases sedimentation. Sedimentation can smother stable and productive aquatic habitats such as rocks, logs, and aquatic plants. The roots of large trees are undercut and fall into the stream while new growth has less opportunity to become established. Bare soil stream banks also result from deliberate removal of vegetation and are a common feature of urban streams.

The loss of stable riparian vegetation is further accelerated by the direct removal of trees and shrubs as part of urban development. The resulting stream ecosystem is in a constant state of instability with little opportunity to become stable and more complex.

Ecosystem function and quality increases with increased complexity, and the more complex the habitat, the more complex the ecosystem functions. Forests are more complex ecosystems than pastures. Table 2-5 shows typical impacts of urbanisation on stream habitats.

Table 2-5
Impacts of Urbanisation on Stream Habitats

Adverse impacts	Stable habitats
Accelerated bank erosion	Rocks
Accelerated bank undercutting	Woody debris
Increased siltation	Aquatic plants
Elimination of meanders	Vegetated banks
Channel widening	
Reduced depth	
Reduced baseflow	
Increased flood flows	
Loss of shading	
Loss of pools	
Increased water temperature	

2.7.2 Ecological stress factors

The main factors influencing plants and animals in streams are the following:

- Physical habitat
- Temperature
- Dissolved oxygen
- Suspended solids
- Stream flow
- Nutrients
- Light
- Contaminants
- Instream barriers
- Clearance of riparian vegetation

Urbanisation results in impacts related to all of the above items. No one single item is of primary importance. If we are to reduce impacts to aquatic ecosystems, we must develop approaches to address all of the above items. Thus the LID design approaches listed in Section 4 attempt to reduce the impacts associated with each item.

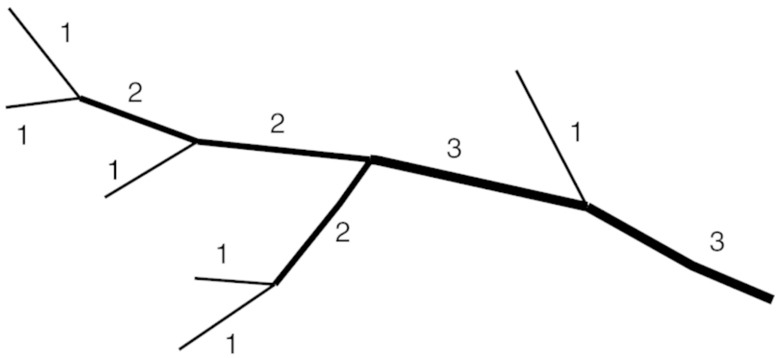
2.8 Importance of First and Second Order Streams

When considering aquatic resource protection, it is important to consider the entire catchment and to recognise that all waterways regardless of how small are integral components of the whole. To understand the relative importance of each part it is helpful to classify streams in terms of their ‘order’. Order is based upon smaller streams draining into larger ones. First order streams are catchment headwater streams. They are generally the smallest streams and flow can be perennial or ephemeral. Second order streams are those formed by the junction of two first order streams. The junction of two second order streams forms a third order stream. A schematic representation of stream order is shown in Figure 2-10.

The definition of what is a stream is not easily provided. There are a number of definitions that are not necessarily in agreement with one another. The Resource Management Act does not define a stream but does define a river as:

"River" means a continually or intermittently flowing body of fresh water; and includes a stream and modified watercourse; but does not include any artificial watercourse (including an irrigation canal, water supply race, canal for the supply of water for electricity power generation, and farm drainage canal).

Figure 2-10
Conceptualisation of a Stream Hierarchy



To provide further guidance, a stream as discussed here will be a natural body of water, which includes a free flowing area of concentrated flow, an area having stable pools of water, a spring outfall, or a wetland. In the context of a stream, the area of concentrated flow shall have defined banks and bottom. This would not include areas of sheet or shallow concentrated flow such as swales or field flow.

To provide specific information on the Auckland Region (a similar stream inventory has not been done for the Hawke's Bay Region) regarding streams and their order, including percentage of total length, a review of Auckland streams was done by NIWA (O'Brien,1999), detailed in Table 2-6, and provides the following information.

Table 2-6
Stream Inventory Table

Auckland Region Streams			Number		Length	
Order	Number of Streams	Length (m)	% of total	Cumulative %	% of total	Cumulative %
1	810	1,961,112	60.18	60.18	68.25	68.25
2	365	598,097	27.12	87.30	20.81	89.07
3	108	187,888	8.02	95.32	6.54	95.60
4	56	105,073	4.16	99.48	3.66	99.26
5	7	21,233	0.52	100.00	0.74	100.00
Total	1,346	2,873,403	100.00		100.00	

It is important to recognise that almost 70 percent of Auckland streams, in terms of total length, are first order streams. When combined with second order streams, that total increases to almost 90 percent. A similar review of U.S. streams indicates that approximately 70% of all streams are first and second order streams. It is not unreasonable to assume that between 70 - 90% of Hawke's Bay streams are first or second order streams. If it is a programme goal to protect third order or larger streams, that goal cannot be attained if first and second order streams are destroyed by mass earthworks or enclosed in pipes.

2.9 Bibliography

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3 Site Resources

3.1 Introduction

Site resources that are referred to here are those natural features or site characteristics, which, to a large extent, provide a benefit to receiving systems through their existence. They provide a benefit to the general public by their continued function to reduce peak rates and volumes of stormwater runoff, provide for water quality treatment, and prevent damage to improved or natural lands either on site where the site resources exist, or downstream of those resources.

Site resources have intrinsic and other values for habitat and biodiversity regardless of their stormwater functions. They can include a wide variety of items, but those discussed here are considered primary resources that should be recognised and considered in site development and use. In terms of this Section, the following site resources are important primarily for their stormwater management benefits. Some of the benefits are less obvious than others, but all provide a benefit.

- Terrestrial ecology and landscape form
- Wetlands
- Floodplains
- Riparian buffers
- Vegetation
- Soils
- Slopes/topography
- Other natural features
- Linkage with site development

Site resources often overlap. For example, a riparian buffer may lie within a floodplain or a forested area. In this Section, they are discussed individually although their benefits may be, and generally are, cumulative.

3.2 Terrestrial Ecology and Landscape Form

It is often said that the three principal economic factors that drive real estate prices are: location, location, and location. The same is true of natural resources and site resources. Where natural features are located on a site is just as important as the characteristics of the natural features themselves. The importance of the position of ecological features in the landscape has spawned an entire field of study called “landscape ecology”.

There are several basic principles of ecology that can be used to improve the quality of receiving environments. These principles apply to all site resources.

- Retain and protect native vegetation (native forest, regenerating native scrub and forest, wetlands, coastal forest/scrub) - these ecosystem types have important intrinsic values, and provide different habitats for native flora and fauna and different ecological functions.
- Allow natural regeneration processes to occur (e.g. pasture => scrub => forest; wet pasture => wetland)
- Undertake weed and pest control => to improve the natural values of native vegetation, allow natural processes and seed dispersal mechanisms to occur.

- Replant and restore with native plants to provide vegetation cover, which is characteristic of what, would once have been there and/or which reflects other local remnants in the area.
- Restore linkages with other natural areas or ecosystems (e.g. using waterways and riparian areas, linking fragmented forest remnants, linking wetland ecosystems and freshwater ecosystems to terrestrial forest/scrub remnants). Native species need extensive areas of vegetation to survive.
- Our knowledge is limited (Need for a factor of safety)

3.2.1 The Ecological Values of Site Resources

It is important to retain natural areas (including scrub, forest, and wetlands) on a site for their biological diversity and intrinsic values, which include the following.

- They are important for their values as characteristic examples of biodiversity in a region or district,
- The diversity of species or ecosystem types that they contain,
- Containing rare or special features or unusual ecosystem types,
- Their value as habitats for indigenous species and the level of naturalness,
- Their ability to sustain themselves over time (e.g. available seed sources, active regeneration, bird dispersal processes active, level of weeds and pests and outside influences controlled),
- Being of adequate size and shape to be viable,
- If they are buffered or they provide a buffer to habitats or natural areas, from outside influences (e.g. scrub on edges of native bush, intact sequences from estuarine to terrestrial, from freshwater to terrestrial, from gully bottom to ridge top); and provide linkages with other natural areas in an area (corridors for native birds, invertebrates).

The stormwater benefits provided by native vegetation have been detailed in Section 2. The following criteria for the evaluation of ecological significance of native vegetation provide a set of basic principles for the determination of ecosystem significance. These are paraphrased from the Protected Natural Areas Programme survey methodology (Myers et al, 1987).

3.2.2 Representativeness

It is important to protect what is common and characteristic of the ecology of an area. Natural areas that are representative of the ecological communities once formerly present in a given area (e.g. an Ecological District) are significant. It is not only rare and unusual features that are important. Most natural areas have been reduced dramatically from their former extent; so remaining representative examples of each different type of ecological community are valuable.

There has been a move away from protection of only rare species and their habitats to protecting ecosystems that are good examples of the character of a district or region. Protection of substantial parts of ecosystems is usually needed to assure the survival of their constituent parts, such as individual species.

It is easy to ignore or place less importance on elements of ecosystem functioning, which are not obvious. Many evaluations are based on visual assessment e.g. a comparison of pasture to mature forest. But there are many other important elements of ecosystem integrity that are not so readily apparent: including water cycle, chemical factors, energy flow, and biotic interactions.

3.2.3 Rarity and Naturalness

It is easy to underestimate the value of rare species. Rarity is an indicator of the scarcity of numbers of a species or other element of biodiversity. The presence of a rare or special or unusual feature in a natural area adds to its ecological value. Rare species reflect the highest degree of ecosystem complexity and function and are the most sensitive to impact. Unfortunately, their rarity makes them impractical for use with most assessment studies done as part of development projects.

Naturalness is important to the survival of species, communities and other components of biodiversity, many of which will not survive outside a natural environment. Naturalness in ecosystems is inversely proportional to the degree of disturbance by humans or introduced species (e.g. weeds).

3.2.4 Diversity and Pattern

A fundamental aim of nature conservation is to protect natural biological diversity. The diversity of a natural area refers to the species of plants and animals present as well as its communities, ecosystems, and physical features. Generally the ecological value of a natural area increases with its diversity and the complexity of its ecological patterns.

Wetlands, floodplains, and mature forests are key resources in low impact design because they are generally the oldest and least disturbed site resources. Ecosystem function increases over time.

Long-term ecological viability is the ability of natural areas to retain their inherent natural values over time. This includes the ability of a natural area to resist disturbance and other adverse effects and for its component plant and animal species to regenerate and reproduce successfully.

Complex ecosystems often have a messy or “wild” appearance to them as their complexity increases. A mature forest can take hundreds of years to develop so seeing one indicates a lack of recent disturbance.

3.2.5 Size and Shape

Size and shape of the area affect the long-term viability of a natural area’s ecological components and functions. With increase in size, the diversity and resistance to disturbance of an area generally increases. The shape of a natural area influences its resistance to external effects (e.g. a compact shaped area is less vulnerable to edge effects than a complex one).

Ecosystem function increases, as the size of the natural area gets larger. The inverse is also true that ecosystem function is reduced when roads and urban development fragment natural systems. But small fragments and patches of native vegetation are still important and may be the only remnants left of a certain type in an area. They may provide habitat for relict population, or rare species may provide seed source for local revegetation. The smaller an area of bush is, the greater the edge effects, the lack of microclimates for certain species, and the more likely weed invasion will be.

Much of the Hawke's Bay Region was covered by forest prior to human settlement. This forest had maximum ecosystem function due to its age, size, and complexity. Human influence on the land has shrunk this network of connected woodlands to a fraction of its former size.

The effect of area size on ecosystem function is, to some degree, a matter of geometry; the various dimensions of the tract change in proportion to the area of the tract. A tract reduced in area by a factor of one hundred reduces by one-tenth the distance to the centre of the tract and increases ten times the dominance of the perimeter habitat (edge/area ratio). Tract size has important implications for species that require interior habitat. The tract can become so small that the interior habitat and the species that depend on it are eliminated.

As discussed in Section 2, urbanisation causes a shift in the aquatic community from one dominated by pollution sensitive species towards one dominated by contaminant tolerant species. This ecological principle also applies to the terrestrial environment where the adverse impacts tend to be subtler in nature and more variable from site to site.

3.2.6 Hidden elements and scientific uncertainty

Obviously, we don't have all the answers. In low impact design, it is of great importance to consider the degree to which the landscape is permanently changed as a result of urban development. Safety factors are used in engineering to account for uncertainty and ensure that the "bridge doesn't collapse". This concept is even more applicable to natural resources that are considerably more complex and less well understood. Examples of safety factors that might be applicable to low impact design might include the requirement for larger riparian buffer strips or native revegetation adjacent to existing indigenous forest.

Much of the large-scale alteration of natural resources has obviously already taken place in the Hawke's Bay Region. Thus, urban development projects will have much less overall impact. The basic principles of ecology and landscape ecology still apply to minimise the impacts of future projects. Much of our knowledge of the functions and values of natural resources has developed in just the last 60 years. In a few years it is likely that we will look back on how little we knew in 2009. While it can be seen that terrestrial ecology is important for protecting intrinsic values of a given area it is also critical that we do not lose sight of the major benefits that result from retention of these areas from a hydrological standpoint.

3.3 Wetlands

Wetlands, as defined in the Resource Management Act, include permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions. They occur on land-water margins, or on land that is temporarily or permanently wet. Wetlands are a major habitat for at least eight species of indigenous freshwater fish as well as frogs, birds, and invertebrates. Wetlands have unique hydrological characteristics that can be irreversibly modified by activities such as drainage.

There can be few other vegetation classes that have suffered so severely during human times than have wetlands. The reasons for this are many, but can be attributed largely to their position on flat land, suited to agriculture, and to the generally low esteem in which such vegetation has been held by the average layperson. These changes have occurred despite the manifest value of wetlands as wildlife habitats, as regulators of flooding, their intrinsic values, for recreation, and for scientific research. Nevertheless a far larger area than remains today has been lost through drainage, fire, topdressing, and flooding.

Hawke's Bay Wetlands Creation

The problem with wetlands is that they are rarely seen as being a valuable resource. They are usually difficult to access, and therefore are rarely visited. Their wildlife is usually secretive and their plants are seldom spectacular or flamboyant. Their values as a source of mined material or as pastoral land or for horticulture are only realised after the wetland has been destroyed. Their ability to assist in water control is often only recognised after both floods and water shortages have occurred following their destruction.

Nationwide, freshwater wetlands covered at least 670,000 hectares before European settlement, but have now been reduced by drainage for pasture to around 100,000 hectares. Although several thousand wetlands still survive, most are very small and have been modified by human activities and invasive species. It is likely that some characteristic wetland types have been lost completely, while very few examples are left of others, such as kahikatea swamp forest and some kinds of flax swamp.

New Zealand's wetlands are as varied as the terrain that shapes them.

It is important to recognise that even without the presence of humans, wetlands systems are modified and eliminated by a natural ecological ageing process referred to as succession. The filling and conversion of wetlands into more terrestrial type ecosystems occurs naturally at a relatively slow rate. The intervention of man into the process vastly accelerates the conversion process.

In their natural condition, wetlands provide many important functions to man and the environment. Table 3-1 summarises the major functions and values of wetlands.

Table 3-1
Summary of Wetland Functions and Values

Function/value	Description
Flood control	Attenuation of peak flows Storage of water Absorption by organic soils Infiltration to groundwater
Flow attenuation	Maintenance of stream flow during droughts
Erosion control	Increased channel friction

	Reduction in stream velocity Reduction in stream scour Channel stability by vegetative roots Dissipation of stream energy
Water quality maintenance	Sedimentation Burial of contaminants in sediments Adsorption of contaminants to solids Uptake by plants Aerobic decomposition by bacteria Anaerobic decomposition by bacteria
Habitat for wildlife	Food Shelter/protection from weather and predators Nursery area for early life stages
Fisheries habitat	Galaxids, eels, freshwater mussels, crayfish
Food chain support	Food production from sun (primary production)
Recreation/aesthetics	Enjoyment of nature Hiking, boating, bird watching
Education	Teaching, research

In addition to the listed beneficial values, the water quality benefits of wetlands can be expanded. Natural systems have complex mechanisms and the following listing of benefits describes the major processes occurring in wetlands that allow them to provide water quality enhancement functions. These functions include:

- Settling/burial in sediments,
- Uptake of contaminants in plant biomass,
- Filtration through vegetation,
- Adsorption on organic material,
- Bacterial decomposition,
- Temperature benefits, and
- Volatilisation

3.4 Floodplains

Maraekakaho Stream at Flood Stage

Floodplains occupy those areas adjacent to stream channels that become inundated with stormwater during large rainfall/runoff events. For the most part, in the Hawke's Bay Region, rainfall (in conjunction with inadequate drainage capacity) is the main cause of flooding although surges by wind driven currents can exacerbate the problem, or in unique situations, cause the flooding problem. Flooding problems result from two main components of precipitation: the intensity and duration of rainfall, and its areal extent and distribution.

Flooding has been the most common reason for declarations of civil defence emergency in New Zealand. In the 19th century flood related drownings were dubbed “the New Zealand death”. Floods can occur in any season, and in all regions of New Zealand. The rate of flooding increased 50-150 years ago following widespread replacement of forests and scrub with shallow rooted pasture grasses. Despite extensive river and catchment control schemes, damage from flooding is estimated to cost at least $125 million a year. Many studies have shown that paving and drainage systems in urban areas increase flooding, particularly as many urban areas are located along floodplains and former wetlands.

Flooding in and of itself is not a problem. Floods have been around since the beginning of time and are a natural part of the water cycle. Problems are caused when man interacts with the floodplain. Thus, flood hazard potential relating to human health, property damage, and social disruption are strongly influenced by human activity on the floodplain. There are several key catchment characteristics which impact on flood frequency and depths.

3.4.1 Catchment size and slope

The abundance of rainfall in the Hawke’s Bay Region feeds our many small first and second order streams. These streams and their associated floodplains are the conveyance means of getting water downstream, through the catchment, and to sea level. Smaller catchments have a rapid response time to storm flows where larger catchments have a longer response time as storm flows take time to travel through

3.4.1.1 Surface conditions and land use

Until the nineteenth century, 75% of the country was covered in temperate rainforest. Replacing two-thirds of it with exotic grasses has dramatically increased the rate at which rain reaches the ground surface and flows overland into the stream system. Urbanisation, with its impervious surfaces has an even more profound effect on flood flows. Not only do flood flows increase in size and number, but also their speed of onset is increased, particularly in the first 20 percent of change from rural to impervious cover. This makes intensive, short-duration rainfalls more flood prone. In addition, time of year can impact on flood levels via intensity of rainfall and saturated condition of soils.

3.4.1.2 Floodplain topography

The channel form and associated floodplain in part determine the size of flood, particularly its depth and areal extent. A small catchment and wide floodplain will result in a shallow, but widespread flood. On the other hand, a deep channel and steep slopes will result in deeper flooding, but on a small areal extent.

The many benefits that floodplains provide are partly a function of their size and lack of disturbance. But what makes them particularly valuable ecologically is their connection to water and the natural drainage systems of wetlands, streams, and estuaries. The water quality and water quantity functions provided by the floodplain overlap with the landscape functions of tract size and ecosystem complexity to make them exceptionally valuable natural resources.

Floodplains provide a wide range of benefits to both human and natural systems. These functions and values can be broadly placed in three categories; water resources, living resources, and societal resources. Taking each of these individually provides the following:

3.4.2 Water resources

Floodplains provide for flood storage and conveyance during periods when flow exceeds channel boundaries. In their natural state they reduce flood velocities and peak flow rates by out of stream bank passage of stormwater through dense vegetation. They also promote sedimentation and filter contaminants from runoff. In addition, having a good shade cover for streams provides temperature moderation of stream flow. Maintaining natural floodplains will also promote infiltration and groundwater recharge, while increasing or maintaining the duration of stream base flow. Floodplains provide for the temporary storage of floodwaters. If floodplains were not protected, development would, through placement of structures and fill material in the floodplain, reduce their ability to store and convey stormwater when the need for floodplain storage occurs. This, in turn, would increase flood elevations upstream of the filled area and increase the velocity of water travelling past the reduced flow area. Either of these conditions could cause safety problems or cause significant damage to private property.

Table 3-2 provides values of roughness coefficients that have been established for floodplain areas for the purposes of hydraulic calculations to determine flow velocities and elevations. They indicate the value that vegetation has on the movement of flood flow and can be considered in the context of retardance factors. The higher the roughness value, the greater the retardance to flow movement through it..

Table 3-4
Values of the Roughness Coefficient n in Floodplains

Type of Ground Cover	Normal n
a. Pasture, no brush	
1. short grass	0.030
2. High grass	0.035
b. Cultivated areas	
1. No crop	0.030
2. Mature row crops	0.035
3. Mature field crops	0.040
c. Brush	
1. Scattered brush, heavy weeds	0.050
2. Light brush and trees	0.060
3. Medium to dense brush	0.100
d. Trees	
1. Heavy stand of timber, little undergrowth	0.100
2. Heavy stand of timber, flood stage in branches	0.120

As can clearly be seen, the denser and taller the vegetation, the greater the frictional resistance to stream flow.

3.4.3 Living resources

Natural floodplains are fertile and support a high rate of plant growth, which supports and maintains biological diversity. They provide breeding and feeding grounds for fish and wildlife. In addition, they provide habitat for rare and endangered species.

Ground cover in natural wetlands tends to be composed of leaf and dense organic matter. Organic soils have a lower density and higher water holding capacity than do mineral soils. This is due to the high porosity of organic soils or the percentage of pore spaces. This porosity allows floodplain soils generally to store more water than mineral soils would in upland areas.

3.4.4 Societal Resources

Floodplains provide areas for active and passive recreational use. They increase open space areas, and provide aesthetic pleasure. They also contain cultural and archaeological resources and provide opportunities for environmental and other studies. Human development historically has occurred around waterways for food and transportation. Many walkways exist in reserves and those walkways tend to be adjacent to stream channels.

3.5 Riparian Buffers

Although reduction of contaminants is a generally recognised function of riparian buffers, they also contribute significantly to other aspects of water quality and physical habitat. Habitat alteration, especially channel straightening and removal of riparian vegetation, continues to impair the ecological health of streams more often and for longer time periods than contaminants.

Stream Riparian Buffer as a Component of Subdivision Land Use

When considering riparian buffers, it is helpful to detail the variety of benefits that are gained by their protection or implementation. Riparian buffer systems provide the following benefits:

3.5.1 Temperature and light

The daily and seasonal patterns of water temperature are critical habitat features that directly and indirectly affect the ability of a given stream to maintain viable populations of most aquatic species. Considerable evidence shows that the absence of riparian cover along many streams has a profound effect on the distribution of many species of macroinvertebrates and fish.

In the absence of shading by a forest canopy, direct sunlight can increase stream temperatures significantly (up to 12^0 C), especially during periods of low stream flow in summer. Riparian buffers have been shown to prevent the disruption of natural temperature patterns as well as to mitigate the increases in temperature following upstream deforestation.

3.5.2 Habitat diversity and channel morphology

The biological diversity of streams depends on the diversity of habitats available. Woody debris is one of the major factors in habitat diversity. Woody debris can benefit a stream by:

- Stabilising the stream environment by reducing the severity of the erosive influence of stream flow,
- Increasing the diversity and amount of habitat for aquatic organisms,
- Providing a source of organic carbon, and
- Forming debris dams and slowing stream velocities.

Loss of the riparian zone can lead to loss of habitat through stream widening where no permanent vegetation replaces forest, or through stream narrowing where forest is replaced by grass. In the absence of perennial vegetation, bank erosion and channel straightening can occur. The accelerated stream flow velocity allowed by straight channels promotes channel incision as erosion of sediment from the stream bottom exceeds the sediment load entering the stream. This process can eventually lead to the development of wide, shallow streams that support fewer species.

3.5.3 Food webs and species diversity

The two primary sources of natural food energy input to streams are litter fall from streamside vegetation and algal production within the stream. Total annual food energy inputs are similar under shaded and open canopies but the presence or absence of a tree canopy has a major influence on the balance between litter input and primary production of algae in the stream.

Having a stream exposed to sunlight for most of the day promotes algal growth and promotes proliferation of algal grazing species. This proliferation reduces species diversity. The diversity of the macroinvertebrate community in a stream protected by a riparian buffer has a much greater diversity than does a stream not having a riparian canopy. This diversity is important in that it is in such a small area that goes from low land wetter soil conditions to upland fairly rapidly and thus promoting very different vegetative types. Also, riparian buffer areas are adjacent to streams and therefore floodplains. By periodic out of bank flow, floodplains are depositional zones for fertile sediments.

3.5.4 Contaminant removal

Riparian vegetation removes, sequesters, or transforms nutrients, sediments, and other contaminants. The removal function depends on two key factors:

- The capability of a particular area to intercept surface and/or groundwater borne contaminants, and
- The activity of specific contaminant removal processes (filtration, adsorption, biological uptake, etc.).

New Zealand studies have shown that the majority of nitrate removal in a pasture catchment takes place in the organic riparian soils, which receive large amounts of nitrate laden groundwater. The location of the high organic soils at the base of gullies caused a high proportion of groundwater to flow through the organic soils although they occupied only 12 percent of the riparian zone area.

Sediment trapping in riparian forest buffers is facilitated by physical interception of surface runoff that causes flow to slow and sediment particles to be deposited. Channelised flow is not conducive to sediment deposition and can, having higher velocities, cause erosion in the riparian buffer. From a sediment deposition perspective, the following main processes occur:

- The forest edge fosters large amounts of coarse sediment deposition within a few metres of the field/forest boundary, and
- Finer sediments are deposited further into the forest, and
- The reverse occurs during out of bank stream flow where sediments carried from upstream in the catchment are deposited in the riparian buffer. The lowest velocities are at the outer edge of the buffer and the finer sediments are deposited there.

3.5.5 Importance to wildlife

- The greater availability of water to plants, frequently in combination with deeper soils, increases plant production and provides a suitable site for plants that would not occur in areas with inadequate water. This increases plant diversity.
- The shape of many riparian areas, particularly their linear meandering nature along streams, provides a great deal of productive edge.
- Riparian areas frequently produce more edge within a small area. In addition, along streams there are many layers of vegetation exposed in stair step structure. This structure provides diverse nesting and feeding opportunities for wildlife.
- Riparian areas along intermittent and perennial streams provide travel routes for wildlife.
- Although vulnerable to negative edge effects, such as weeds, riparian vegetation maintains habitat required for life cycle completion by riparian species and many instream species.
- Usually riparian margins are the remnants of more extensive natural areas, which is something to build upon for restoration.

3.5.6 Channel stability and flood flow protection

Streams are dynamic systems that are characterised by change. Instream stability and streambank erosion at a given point are heavily influenced by the land use and condition in the upstream catchment. However, vegetation is essential for stabilising stream banks, especially woody vegetation. Forested buffer strips have an indirect effect on streambank stability by providing deep root systems that hold the soil in place more effectively than grasses, and by providing a degree of roughness capable of slowing runoff velocities and spreading flows during large storm events. While slowing flood velocities may increase flood elevations upstream and in the buffer, downstream flood crest and damage may be significantly reduced. These processes are also critical for building floodplain soils.

3.6 Vegetation Cover

New Zealand's vegetation cover has changed considerably in the past 700^{+} years, with the most dramatic changes occurring in the past century. Before human settlement, the Region had a covering of native podocarp/broadleaf, beech forests with some grasslands. Maori cleared some forest for cultivation and hunting, and later European settlement had a greater impact as forests were felled or timber and pasture, and exotic animals and plants were introduced.

Only 10% of the Region remains in native vegetation.

Forests have a number of components whose characteristics determine its effectiveness in terms of water quantity and quality. These characteristics include:

3.6.1 **Stormwater runoff reduction**

As discussed in Section 2, woody vegetation and forest floor litter have a significant impact on the total volume of rainfall converted to runoff. Runoff volumes from forested areas are much less than volumes from other land uses. This lesser volume in runoff acts to minimise downstream erosion and instability problems.

3.6.2 **Soil structure**

Forest soils are generally regarded as effective nutrient traps. In New Zealand, most nutrients are retained (and recycled) in the leaf litter and shallow soil layers. Roots are usually quite shallow. The ability of a forest soil to function in removing nutrients in surface and groundwater is partially dependent on soil depth, ground slope, density of vegetation, permeability, extent and duration of shallow water table, and its function as a groundwater discharge zone.

3.6.3 **Organic litter layer**

The organic litter layer in a forest buffer provides a physical barrier to sediment movement, maintains surface porosity and higher infiltration rates, increased populations of soil mycorrhizae (a symbiotic relationship of plant roots and the mycellium of fungi - aids in decomposition of litter and translocation of nutrients from the soil into the root tissue), and provides a rich source of carbon essential for denitrification. The organic soil provides a reservoir for storage of nutrients to be later converted to woody biomass. A mature forest can absorb as much as 14 times more water than an equivalent area of grass. The absorptive ability of the forest floor develops and improves over time. Trees release stored moisture to the atmosphere through transpiration while soluble nutrients are used for growth.

3.6.4 Forested areas

Trees have several advantages over other vegetation in improving water quality. They aggressively convert nutrients into biomass. They are not easily smothered by sediment deposition or inundation during periods of high water level. Their spreading root mats resist gullying and stimulate biological and chemical soil processes. They produce high amounts of carbon needed as an energy source for bacteria involved in the denitrification process. A forest's effectiveness in pollution control will vary with the age, structural attributes and species diversity of its trees, shrubs and understory vegetation.

To consider the involvement of a forested area in water quality treatment, there are a number of functions that define that performance. These functions can be broadly defined as physical and biological functions and include the following:

- Sediment filtering

  The forest floor is composed of decaying leaves, twigs, and branches, which form highly permeable layers of organic material. Large pore spaces in these layers catch, absorb, and store large volumes of water. Flow of stormwater through the forest is slowed down by the many obstructions encountered. Suspended sediment is further removed as runoff flows into the vegetation and litter of the forest floor. This sediment is readily incorporated into the forest soil. With a well-developed litter layer, infiltration capacities of forest soils generally exceed rainfall and can also absorb overland flows from adjacent lands.

- Nutrient removal

  Forest ecosystems serve as filters, sinks, and transformers of suspended and dissolved nutrients. The forest retains or removes nutrients by rapid incorporation and long term storage in biomass, improvement of soil nutrient holding capacity by adding organic matter to the soil, reduction in leaching of dissolved nutrients in subsurface flow from uplands by evapotranspiration, bacterial denitrification in soils and groundwater, and prevention from erosion during heavy rains.

3.7 Soils

As discussed in Section 2.3, Hawke's Bay soils are predominantly:

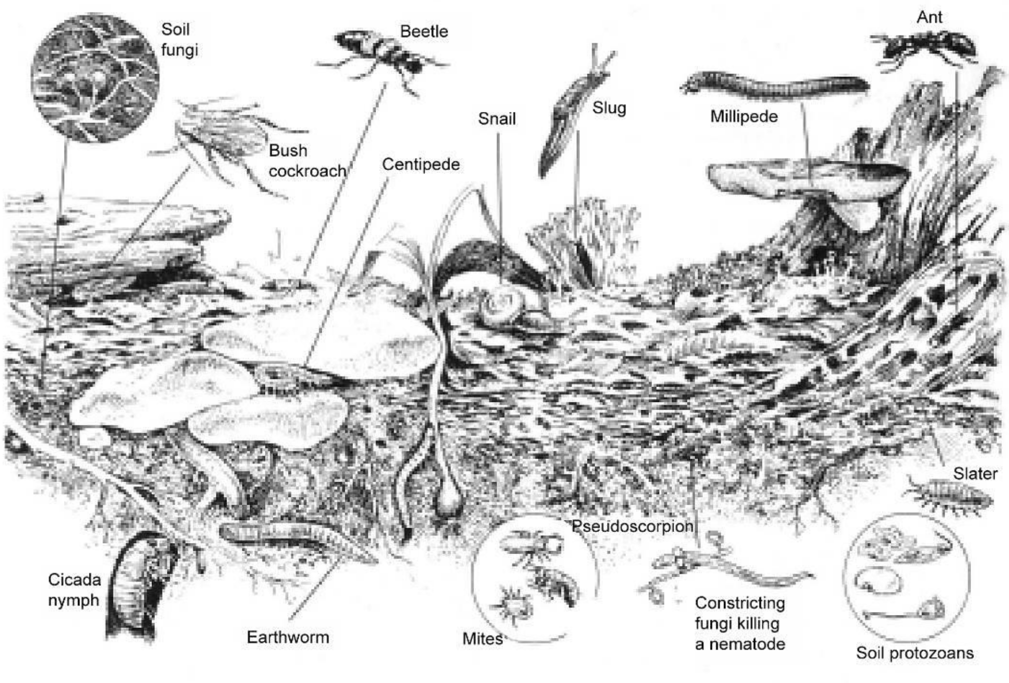
- Pallic soils have pale coloured subsoils, due to low contents of iron oxides. The soils have a weak structure and high density in subsurface horizons.
- Podzol soils are the source of aluminium and iron oxides that have accumulated, in association with organic matter, in the underlying dark or reddish coloured horizon. They occur mainly in materials from silica-rich rocks.
- Pumice soils have low fertility with low nutrient reserves and tend to be deficient in trace elements. They naturally have low levels of organic matter.

3.7.1 Biological factors influencing soil development

Soils possess several outstanding characteristics as a medium for life. It is relatively stable structurally and chemically. The underground climate is far less variable than above-surface conditions. The atmosphere remains saturated or nearly so, until soil moisture drops below a critical point. Soil affords a refuge from high and low extremes in temperature, wind, evaporation, light, and dryness. These conditions allow soil fauna to make easy adjustments to the development of unfavourable conditions. On the other hand, soil hampers movement. Except for organisms such as worms, space is important. It determines living space, humidity, and gases.

A wide diversity of life is found in the soil as shown in figure 3-1. The number of species of bacteria, fungi, protists, and representatives of nearly every invertebrate phylum found in soil is enormous. It has been estimated that approximately 50% of the earth's biodiversity occurs in soil. Dominant among the soil organisms are bacteria, fungi, protozoans, and nematodes.

Figure 3-1
Soil Life Forms



Prominent among the larger soil fauna are earthworms. Earthworm activity consists of burrowing through the soil. Burrowing involves ingestion of soil, the ingestion and partial digestion of fresh litter, and the subsequent egestion of both mixed with intestinal secretions. Egested matter is defecated as aggregated castings on or near the surface of the soil or as a semiliquid in intersoil spaces along the burrow. These aggregates produce a more open structure in heavy soil and bind light soil together. In this manner earthworms improve the soil environment for other soil organisms by creating larger pore spaces and by mixing organic matter with the mineral soil.

Biological processes in soil development are the most complex soil forming factors. Lichens secrete organic acids that dissolve rock surfaces and successions of plants add nitrogen from the atmosphere. Dead roots, stems and leaves decompose and the products are absorbed back into the soil.

The vegetative community also has a very strong impact on soil development. The microclimate of a forest is very different from that of grassland. Tree roots penetrate further into the ground than do grass roots and bring up minerals from deeper areas and thus incorporate them into the organic layer.

The total amount of soil organic material depends not only upon vegetation, but also upon topographic and climatic influences. Peat formation can occur in basin situations where the water table is high. High levels of organic matter are also found in soils in cool, wet climates.

3.8 Slopes/Topography

The presence of shallow root depths does not resist slope slippage on steeper slopes. Soil slippage is also directly related to the steepness of the slope, the type of soil and the underlying geology. Without deeper-rooted plants holding a slope, in situations where native vegetation has been replaced by grassed lawn, slopes in excess of 33% (18^0) may start to creep. Slopes greater than 45% (24^0) may see the onset of mass movement. In the case of Onerahi Chaos Breccia (Northland Allochthon where the soils are highly sheared and crushed variably calcareous and siliceous mudstones prone to slippage), slopes as flat as 1:8 can be unstable. Due to the shallow nature of the soils, most movement tends to occur in the first 1.5 metres. Leaving native vegetation on these steeper slope areas is very important to maintain slope stability.

Recent studies in New Zealand have assessed the susceptibility of different vegetation types to landslides during rainstorms. In a study north of Gisborne landslide densities were 16 times greater under pasture than indigenous forest and 4 times greater under pasture than regenerating scrub. A survey of storm damage in Tertiary sandstone/siltstone hill country reported that landslides in pasture were 3-4 times greater than in indigenous forest. Finally, in a detailed study of the relationship between slope morphology, regolith depth, and landslide incidence in eastern Taranaki hill country, identified a 10 times increase in erosion rate for modal slopes of 28-32 degrees following deforestation.

3.9 Other Natural Features

There are other natural conditions that exist on sites beyond those discussed to this point. Those discussed earlier are the primary ones in terms of overall importance but there are others and consideration of their importance is in order.

3.9.1 **Depression storage**

Of the rainfall that strikes roofs, roads, pathways, and pervious surfaces, some is trapped in the many shallow depressions of varying size and depth present on practically all ground surfaces. The specific magnitude of depression storage varies from site to site. Depression storage commonly ranges from 3 to 19 mm for flat areas and from 12 to 30 mm on grasslands of forests. Significant depression storage can also exist on moderate or gentle slopes with some estimation for pervious surfaces being between 6 to 12 mm of water and even more on forestland. Typical depths on moderate slopes can be 1 to 2 mm for impervious surfaces, 2 to 4 mm for lawns, 4 mm for pastures and 6 mm for forest litter. Steeper slopes would obviously have smaller values.

When using traditional hydrologic procedures, depression storage is contained in an initial abstraction term. The term includes all losses before runoff begins. It includes water that is ponded, retained by vegetation, evaporation, and infiltration. It is highly variable, but generally is correlated with soil and cover parameters.

Prior to urbanisation, catchments have a significant depressional storage factor. Passing through agricultural or wooded areas after significant rainfall clearly demonstrates the existence of depressional storage. The urbanisation process generally reduces that storage in addition to significantly modifying the land's surface. The combination of site compaction, site imperviousness, and reduced depression storage causes dramatic increases in downstream flood potential and channel erosion.

Information from the Mahurangi catchment north of Auckland indicates that long-term average annual predicted runoff varied from less than 300 mm (18% of rainfall) to greater than 600 mm (greater than 35% of rainfall). The 300 mm coincided with subcatchments under permanent forest cover. The 600 mm coincided with subcatchments in predominantly pastoral land use and on low infiltration soils. There is a clear statement in these statistics that significant volume reductions in runoff exist in forested catchments as opposed to volumes of runoff from pastoral land cover.

3.9.2 Natural drainage systems

Natural site drainage features exist on every site. The most common of these features is having an existing flow path for stormwater runoff. Water doesn't travel down a hill in a straight line. Straight lines are something that humans have developed to accelerate the passage of water downstream as quickly as possible. During site development, the tendency is to place water in conveyance systems, open and enclosed, which follow the shortest distance to site outfalls.

Shortening the flow distance effectively increases the slope that water travels on, accelerates the flow of water, and increases the ability of water to scour downstream receiving systems. When water travels over a meandering flow path, energy is dissipated which reduces the erosion potential. Shortening flow lengths reduces energy expended and increases the available erosion producing energy. Stream channels will meander regardless of the degree of human alteration. Replicating existing flow paths and lengths, to the extent possible, promotes channel stability and increases function and value.

The additional functions provided by meandering channels over straight channels is also simply related to the length of the aquatic resource and the time that the water is in contact with the various biotic and abiotic processing mechanisms. The additional length of meandering channels provides a greater total quantity of aquatic resource, and the associated functions and values they provide.

3.9.3 Uncompacted vegetated areas

A common approach to site development is to clear most, if not all, of the site being developed. Existing vegetated areas of the site are often cleared even when in non-essential locations. Clearing and grading of areas that will remain pervious results in significant compaction of those areas. This compaction reduces expected infiltration rates and increases overland flow.

A key issue with respect to urban development is the issue of significant soil compaction. The activity of heavy earth moving equipment on a construction site causes significant compaction of soils whose surface is designed to remain pervious. Landcare Research (Zanders, 2001) did some investigation on urban soils and found that earthworks had a significant adverse effect on water flow through soils after cut and fill operations were conducted. The earthworks allowed virtually no percolation of water through Horizon 2 soil profile. There are three options to address this concern.

1. Where cuts or fills of at least one metre are intended to facilitate site development, the expected permeability of the soil may be reduced. Stormwater management calculations that detail post construction hydrology should use a modified approach to soil classifications.
2. In areas of significant site disturbance, and where there is less than one metre of cut or fill, soil classifications are not modified, but consents should contain a construction requirement that significantly disturbed soils in areas where those soils remain pervious should be chisel ploughed. Chisel ploughing will break the surface crust of the disturbed soil and allow for a greater infiltration rate. This would then provide a good foundation for the placement of topsoil and prevent slippage of the topsoil when on slopes that become saturated.
3. Keep equipment out of areas preserved for open space.

3.10 Linkage with Site Development

The only way that site development can occur in a manner that integrates existing site resources is to identify those site resources present on the site prior to initiation of site design. The first step in site resource integration is in conducting an inventory of site resources and detailing them on a plan. A simple checklist can be developed which is based on the items presented here. The checklist could include the following items, which have been discussed throughout the Section.

- Wetlands
- Floodplains
- Riparian buffers
- Vegetative cover
- Soils
- Steep slopes
- Other natural features

A checklist should also include:

- Archaeological sites
- Cultural sites

This plan should be included as a part of the stormwater management plan submitted which is provided to the appropriate territorial authority or ARC. A narrative should also be submitted to detail what steps have been considered and/or provided to integrate existing resources into the stormwater management plan.

Plan designers and developers should also be aware of territorial authority specific criteria, which may overlap, or conflict with the natural site features items listed above.

3.11 Natural Mechanisms for Stormwater Pollution Removal

Although many stormwater related contaminates can be reduced if not eliminated through preventive design approaches driven by water quantity reduction objectives, not all contaminants can be eliminated. In such situations, an array of natural pollutant removal processes is available for use and should be exploited to the maximum. Because these processes tend to be associated with, even reliant upon both vegetation and soil processes, they can be readily incorporated into other low impact design approaches. Such natural contaminant reduction/elimination processes include:

3.11.1 Settling/deposition

The kinetic energy of stormwater washes all types of matter, particulate form and other, from land cover surfaces. Particulates remain suspended in stormwater flows as long as the energy level is maintained. Heavier particulates require more kinetic energy in order to remain in suspension. As the energy level declines - as the storm flow slows, these suspended particulates begin to settle out by gravity, with larger, heavier particulates settling out most quickly and the smallest colloidal particulates requiring considerably more time for settling. To the extent that time can be maximised, more settling can be expected to occur, holding all other factors constant. Therefore, approaches which delay stormwater movement or approaches which reduce kinetic energy in some manner (e.g., energy dissipaters) serve to maximise settling and deposition.

3.11.2 Filtering

Another natural process is physical filtration. As contaminants pass through the surface vegetative layer and then down through the soil, larger particulates are physically filtered from stormwater. Vegetation on the surface ranging from grass to underbrush removes larger contaminant particulates. Stormwater sheet flow through a relatively narrow natural riparian buffer of trees and undergrowth has been demonstrated to physically filter surprisingly large proportions of larger particulates. Both filter strips and grass swales rely very much on this filtration process. Filtration may also occur as stormwater infiltrates into the topsoil strata.

3.11.3 Biological transformation and uptake/utilisation

Although grouped as one type, this category includes a complex array of different processes that reflect the remarkable complexity of different vegetative types, their varying root systems, and their different needs and rates of uptake of different contaminants. An equally vast and complex community of microorganisms exists within the soil mantle, and though more micro in scale, the myriad of natural processes occurring within this realm is just as remarkable. Certainly both phosphorus and nitrogen are essential to plant growth and therefore are taken up typically through the root systems of the various vegetative types, from grass to trees.

3.11.4 Chemical processes

For that stormwater which has infiltrated into the soil mantle and then moves toward groundwater aquifers, various chemical processes also occur within the soil. Important processes occurring include adsorption through ion exchange and chemical precipitation. Cation exchange capacity (CEC) is a rating given to soil, which relates to a particular soils ability to remove contaminants as stormwater enters the soil mantle (through the process of adsorption). Adsorption will increase as the total surface area of soil particles increases; this surface area increases as soil particles become smaller, as soil becomes tighter and denser (clay has more surface area per unit volume than does sand).

Low impact design techniques offer an array of natural processes and techniques that substantially increase contaminant removal potential above and beyond mitigation being provided by many of the structural stormwater practices. Through a combination of vegetative-linked removal combined with using soils on a site, contaminants entrained in stormwater runoff are removed and in some cases eliminated. In this way, contaminants are prevented from making their way into either surface or groundwaters. The various design techniques are discussed in Section 4.

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4 Low impact design approach

4.1 Introduction

Stormwater management throughout the Hawke's Bay Region can be improved by approaching stormwater in a different way from past approaches, where stormwater management has been largely considered stormwater disposal. This different approach is based on a conceptual understanding of stormwater, which is more comprehensive in scope and addresses the full array of stormwater issues. These issues are important in order to maintain and protect Hawke's Bay's water resources, including maintenance of stream base flows, maintaining balance in the hydrologic cycle, reducing downstream sedimentation from construction activities, preventing flooding, and maintaining water quality and the ecological values which characterise Hawke's Bay streams and waters. This different approach is a further challenge to maximise prevention, even before stormwater becomes a problem, and to avoid the commonplace highly engineered structural solutions that are expensive to build and maintain, and possibly not effective for the purposes intended. Where feasible, this newer approach to stormwater management focuses on utilisation of natural systems and processes to achieve stormwater management objectives.

LID is intended to incorporate site resources, as discussed in Section 3, and to enhance their functioning. The end result is site design which protects and enhances existing wetlands, promotes the critical functions of floodplains, re-establishes or builds onto existing riparian buffer systems, and reduces downstream sedimentation while also satisfying sediment control and stormwater requirements.

In summary, the point of LID is to do more with less. It is a design methodology that includes an array of more area wide approaches as well as specific practices.

4.2 Low Impact Design Principles

Common to all of these approaches and practices comprising LID are five basic principles:

4.2.1 Achieve multiple objectives

Stormwater management should be comprehensive in scope, with management techniques designed to achieve multiple stormwater objectives. These objectives include both peak rate and volume control as well as water quality control and temperature maintenance. Comprehensive stormwater management involves addressing all of these aspects of stormwater. Complicated site configurations with multiple structural techniques may be required in some situations but the objective of LID is simple solutions to complex problems.

4.2.2 Integrate stormwater design early in the planning process

Stormwater management, when it is provided, is often only considered at the end of the site design process and almost always provides less than desirable results. For stormwater management objectives to be achieved, stormwater must be incorporated into site design from the outset and integrated into conceptual site planning, just as traffic considerations are. Stormwater impacts may, in some situations, even be a factor in determining the type and extent of land use that is intended at a site. Site developers and designers need to consider incorporation of LID practices into the overall site design process and attempt to not engineer them after the fact.

4.2.3 Prevent rather than mitigate

It may provide some benefit to define what is meant by prevention or mitigation. Prevention means to stop an adverse impact from happening or to make the adverse impact impossible to occur. Mitigation, on the other hand means to make an impact less intense or serious.

A key objective in an LID approach to stormwater management is minimisation of stormwater runoff and contamination occurring in the first place. This is a very different approach than the historic one. Historically, there has been a presumption that development must continue along traditional lines, and stormwater management has attempted to mitigate impacts to the greatest degree possible usually by use of a pond at the bottom of the hill or catchment.

Approaches to site design, which can reduce stormwater generation from the outset, are the most effective approach to stormwater management as they can significantly reduce impermeable surfaces. For example, clustering houses significantly reduces lengths of roads when compared to a traditional low-density similar sized lot approach. Arrangement of units with minimal setbacks reduces driveway length. Reduction in street width and other street modifications can further subtract from total impervious cover. These important elements of site design are rarely thought of as a component of conventional stormwater practices, yet they achieve significant stormwater quantity and quality benefits.

In the same regard reducing total site disturbance reduces the total amount of work required by erosion and sediment control practices during site development. Less site disturbance means less generation of sediments, which results in a lower potential for downstream sedimentation in streams and estuaries. Allowing existing vegetation to remain on sensitive areas such as steep slopes, or upstream of wetlands which may exist on site will reduce adverse impacts to downstream resources. As recognition of downstream receiving water impacts has increased, the potential for mitigation requirements to address the sediment impacts becomes more likely. Reducing the potential for sediment delivery would correspondingly reduce mitigation requirements and associated costs.

It is not being stated that mitigation practices will not be necessary as they will still be integral to site development in most cases. Rather prevention of impacts to the extent possible will lessen the reliance on mitigation practices to reduce or eliminate adverse impacts.

4.2.4 Manage stormwater as close to the point of origin as possible

From both an environmental and economic perspective, minimising the concentration of stormwater and its conveyance in pipes costs less money (by reducing pipe diameter or elimination of pipes) and helps to maintain natural hydrology. Pipes, culverts, and elaborate systems of inlets to collect and convey stormwater, work against these management objectives and generally make stormwater management more difficult as such systems concentrate flows and increase flow rates, with a result of worsening erosive potential.

4.2.5 Rely on natural soil and plant processes

The soil mantle offers critical contaminant removal functions through physical processing (filtration), biological processing (microbial action), and chemical processing (cation exchange capacity, other chemical reactions). Plants similarly provide substantial pollutant uptake/removal potential, through physical filtering, biological uptake of nutrients, and even various types of chemical interactions.

LID is based on a philosophy, a vision for the environment that is neither pro-development nor anti-development. LID is based on the positive notion that environmental values can be less adversely impacted as new communities are developed throughout catchments, if basic principles are followed. LID means understanding natural systems such as essential water resources and making the commitment to work within the limits of these systems whenever and wherever possible. As stated above, LID is based on the recognition that stormwater is ultimately a precious resource to be managed carefully, rather than a waste product in need of disposal.

4.3 Approaches and Techniques

LID can be thought of in different ways. In this discussion, a broad distinction is made between those approaches that tend to manage stormwater largely through avoidance strategies versus those that are mitigative. An example of an avoidance approach would be reduction in imperviousness. In such cases, the generation of stormwater itself is avoided or minimised. This reduction in stormwater quantity may translate into a reduction in stormwater related contaminant loading. Furthermore, the cost savings associated with preventive approaches are obvious, although not always easily calculated. Total prevention of stormwater generation is not usually possible but a stormwater management system may be designed to maximise prevention. This would achieve both quantity and quality related management objectives more cost-effectively than other approaches.

Mitigative practices, on the other hand, are designed to manage stormwater after it has been generated. As such, mitigative practices generally have to collect and control stormwater, typically with some type of structure or even a series of structures. Mitigative practices are difficult to design to control both peak rates of discharge and volume increases, as well as to remove as many contaminants as possible.

4.3.1 LID approaches

LID approaches tend, for the most part, to be preventive but this is not always true. Low impact approaches may include mitigative practices, such as swales or filter strips, which are less damaging to receiving systems than traditional approaches. LID approaches also tend to be broader in scope than traditional stormwater practices as they involve the entire site. Site design/clustering is one broad approach. Reduction in imperviousness also transcends the more focused stormwater management practice concept. The list of approaches included here includes:

- Planning/zoning (building)
- Clustering/lot configuration
- Reduced imperviousness
- Minimum site disturbance

LID avoids the basic issue of how much of what type of use is to occur at any particular site. The emphasis in this guideline is to define what we can do to improve stormwater management primarily on a site-by-site basis, assuming that development continues to occur. In those cases where conventional development programmes cannot use low impact design, density reduction is an option. Although development at the maximum allowable density has come to be the assumed norm in many cases, development at reduced densities may provide the economic use while balancing water and other ecological needs.

4.3.2 Low impact design practices

LID practices include mitigative techniques that may be more structural in implementation. They encompass an array of biofiltration and bioretention methods such as vegetated filter strips and vegetated swales. These practices can and should be used with the approaches detailed above and with one another. Variations to these themes may emerge as greater experience is gained. It is important to be aware that there are far greater options available, and yet to be developed, than have been used in the past.

4.3.3 Clustering and Alternative Lot Configuration

Stormwater management is optimised when stormwater objectives are integrated into site planning from the earliest stage. The process translates into concentrating or clustering development so that the most environmentally sensitive areas of the site are left undisturbed or are subject to minimal disturbance, although there may be aspects of site design that cannot be readily incorporated within a conventional understanding of clustering. Most of the discussion here focuses on various aspects of clustering that have evolved during recent years.

Example of Clustering on a Residential Development

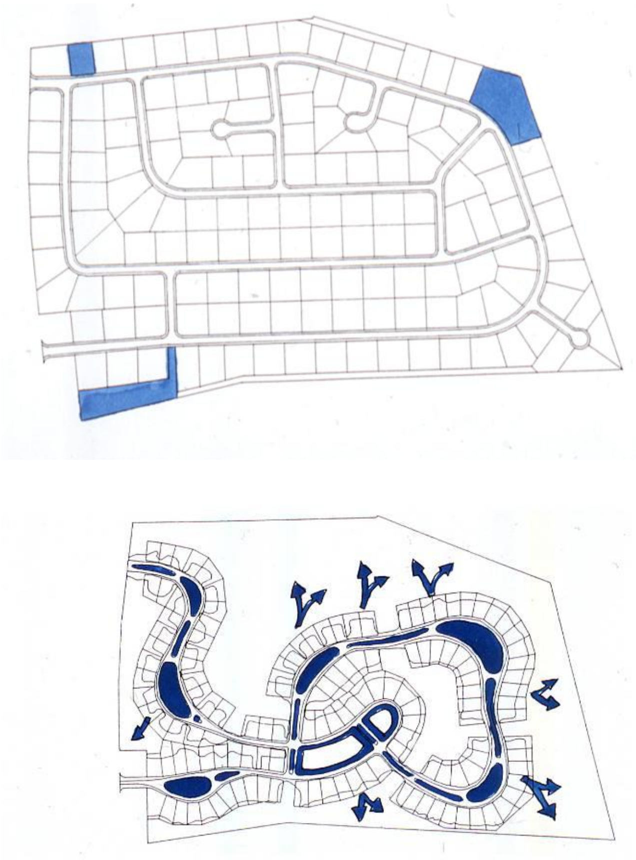
Clustering offers tremendous potential in terms of stormwater benefits and overall resource protection. While clustering is an important approach to site development it can also provide huge benefit when considered at a catchment level. The will be discussed in Section 6.

Although some density bonuses may be offered which increase density, clustering in a strict sense usually begins after the basic determination of how much of what type of use - a certain number of single-family residences, for example - already is to be permitted parcel-by-parcel. In some cases, parcels may be combined to produce a broader development pattern, but a typical clustering design should reflect the existing pattern of ownership if it is to function properly. In some cases, the clustering concept may be structured to include different types of development, including single family and apartment concepts.

As an LID approach, clustering is important. From a stormwater management perspective, clustering minimises stormwater and contaminant loading generation from the outset and therefore is preventive in nature. To maximise positive stormwater effects, clustering works well when used in conjunction with other low impact design approaches and practices. In many cases, a tight clustering approach to site design facilitates these other approaches and practices and even makes them possible.

In order to achieve maximum benefit such as shown in Figure 4-1, substantial design flexibility must be maintained. Clustering can be made to work effectively on a small site or a large one, but clearly the standards imposed on a 40-hectare site need to be different, possibly significantly different, than the standards imposed on a 4-hectare site. Clustering may involve lot design and arrangement only. Or clustering may transcend lot design and even involve changing types of residences. The challenge is to create a clustering system, which maximises clustering benefits such as open space preservation even as developer incentives are maximised as well.

Figure 4-1
Conventional Approach to Site Development versus an LID Approach (blue areas denote stormwater management areas)



If clustering is not mandated, incentives may be provided to encourage its use. Many developers perceive clustered units on smaller lots as less valuable, so a density bonus provision is needed if the option is to be used (such as an increased number of lots). Adding to the problem is the fact that the clustering option typically requires all sorts of special consent processing requirements, which invariably requires more time, energy, and resources on the part of the developer. This additional effort could result in significant cost savings during construction.

In addition, clustering may well require that a variety of provisions elsewhere in development requirements be modified. Setback provisions may have to be amended, as can be the case for any number of other dimensional requirements predicated on conventional subdivision design. Required street frontage, setback of the structure from the street, side and even rear yard setbacks become very different for cluster development then for conventional development.

Other important issues to keep in mind when considering clustering include:

- Are meaningful open space requirements established? Do these open space requirements vary with site size, type of use allowed, etc.?
- How is open space controlled and managed over the long term?
- Have water supply and wastewater provisions been incorporated?
- Have private property management systems been incorporated to the maximum extent feasible? Does the need for a private property management association discourage use of a clustering option?

Benefits achieved from clustering can be considerable.

- Reduction in imperviousness,
- Reduction in contaminant loadings,
- Preservation of special values and sensitive features,
- Habitat protection and associated wildlife benefits,
- Protection of aesthetic values,
- Passive recreation and open space maintenance, and
- Reduction in costs, both development and operational.

Although reduced imperviousness is dealt with separately later, it is such an important benefit from clustering that it deserves special mention. Holding all other aspects of the development constant (number of units, types of units), clustering significantly reduces impervious coverage. Impervious reduction is achieved mostly through reduced road construction and reduced driveway lengths. Given the direct relationship between imperviousness and stormwater generation, impervious area reduction can be expected to result in a comparable reduction in stormwater generation, both total volume and rate.

4.3.4 Costs

Clustering significantly reduces costs through reduced land clearance, reduced road construction (including kerbing), reduced pathway construction, fewer street lights, less street tree planting, less landscaping, reduced sanitary sewer line and water line footage, reduced storm sewers, reduced sizing or need for stormwater management ponds, and other related infrastructure reductions. Table 4-1 provides costs for typical land development activities. As can be seen, reduction in length or need for these activities or products can save on overall site development costs.

Table 4-1
Unit Cost Data (typical subdivision - Year 2000 $)
(Provided by Harrison Grierson Consultants Limited)

Road costs/Metre	7.5 m. width	11.0 m. width
Subgrade trimming	$12	$18
Subgrade drainage (both sides)	$30	$30
Subbase (GAP 65)	$120 (250mm)	$215 (300 mm)
Basecourse (AP40)	$60 (100mm)	$132 (150mm)
Hotmix Seal (25mm)	$90	$132
Kerbing/Edging (both sides)	$70	$70
Subtotals	$382	$597
Plus contingency	$38	$53
Totals	$420/m	$650/m
Kerbing		
Kerb and channel	$35/m	
Kerb only	$30/m	
Footpaths	$40/m	
Stormwater pipelines		
160 dia	$50/m	
225 dia	$60/m	
300 dia	$70/m	
375 dia	$85/m	
450 dia	$100/m	
600 dia	$150/m	
Manholes	$1,500 each	
Site clearing		
Difficult to cost due to possible large trees, removal of material off site.		
$5,000 - $10,000/hectare w/ some tree removal and disposal on site		
Erosion and sediment control		
$5,000 - $10,000/hectare		
Watermain		
$2,000/lot depending on main sizes		
Sanitary sewer		
$2,500/lot		

There are significant overseas data to detail significant cost savings by clustering development along with information relating to enhancement of land values. These data are not New Zealand specific and may not be applicable to local marketing conditions but they do represent relative cost differences. It is the Hawke’s Bay Regional Council belief that the same magnitude of costs and enhancements would be applicable to New Zealand. Cost data will still have to be locally generated to verify cost/benefits, and this would provide developers and territorial authorities with a confidence in the figures before widespread implementation.

4.4 Reduction in Setbacks

The issue of minimum setbacks relates to low impact design in important ways. Standard building setbacks from roads are found in most territorial housing codes, and these requirements must undergo some change if clustering is advocated. While councils specify yard setbacks there are generally opportunities for these to be relaxed.

Councils are required to take account of the New Zealand Building Code provisions for fire and other safety purposes. In residential areas, side yards may be one metre in circumstances where sufficient vehicle access is provided to beyond the rear point of each dwelling or where a garage or carport is provided for. The Code allows for some discretion for further encroachments if the building has achieved a satisfactory fire rating. Minimum separation distances of 1340 mm are required between buildings except where there is a common wall. Again, flexibility may exist and further encroachments may be allowed if Fire and Egress Officers are satisfied and the appropriate consent is obtained.

4.5 Reduction in Imperviousness

Imperviousness is an essential factor to consider in stormwater management, both from a quality and quantity standpoint. Site-by-site and catchment-by-catchment, increased impervious cover means increased stormwater generation with increased contaminant loadings as well. Consequently, actions that can be taken that reduce impervious cover become important stormwater management strategies.

A variety of specific strategies to reduce imperviousness are described here. In many cases, planning for new street systems is often based on a hierarchical system where the function and use of the particular road can be linked to width and other characteristics relating to imperviousness. These low impact design approaches, in many cases, can stand-alone and be used development-by-development, although reduction in imperviousness also can be used in tandem with other approaches and practices. As noted above, reduction in imperviousness also is achieved through other low impact design approaches, such as clustering.

Many councils have limitations on levels of imperviousness that can occur on residential developments but some see practical difficulties in monitoring/enforcement of such limits as individual property owners add impermeable structures after the building consent was issued.

A major variable in considering imperviousness is the consideration of transportation, which includes roads, kerbing, parking, and footpaths.

4.5.1 **Roads**

Numerous demands are made on the road/road reserve resource. District Plan roading provisions have to reflect public demands for safe and efficient movement of pedestrians, cyclists, and motor vehicles, and for on street parking opportunities. Other utility services such as water, electric, sewage and stormwater disposal and telephone have traditionally been placed within the road reserve.

In all local councils, minimum street widths have been established which may be excessive and which may not reflect functional needs now or in the future. Having a minimum road paving width of 7.5 metres for “first order streets” may be excessive since these streets may serve low numbers of residences. This width is excessively costly to construct, requires expensive real estate, and creates far more stormwater than otherwise would be necessary. Because of the way in which so much development is configured, these streets are often just networks of cul-de-sacs specifically designed to exclude through traffic; in most cases such streets will not receive significantly increased traffic as an area develops. Consequently, traffic levels will never increase much beyond the traffic generated by the 15 or 20 houses lining the street.

Street width reduction offers considerable potential benefit in terms of stormwater reduction. For the very smallest access street or lane with fewer than 100 vehicle trips per day, decrease street width to five metres and gradually increase road width correspondingly with traffic increases. In conventional developments with conventional lots and house design, there is no need to provide on street parking, although if tightly clustered configurations are used, on street parking may be a desirable option and included in the design.

Example of a Very Wide Street in a Subdivision

Road lengths are also an important issue. Road length should first be addressed at the District Plan, Structure Plan, Neighbourhood Unit Plan level. Obviously overall dense patterns of development result in less road construction than do low density patterns, holding net amount of development constant. High-density development and vertical development contrast sharply with the low density sprawl which has proliferated in recent years and which has required vast new highway systems in the urban fringe areas. Furthermore, the issue of concentration of development through increased density, while holding total amount of development constant, plays itself out at less macro levels of planning as well. As mentioned in the clustering discussion, road length is significantly reduced as tighter clustering occurs site-by-site. It is important to downsize streets, both their length and width, wherever possible.

Councils tend to follow engineering approaches to roads, parking, etc. with minimum road standards prescribed in their codes of practice. Potential opportunities for flexibility are not used as they could be by roading staff. A council could envisage problems with an application requiring reduced road widths; with developers wanting to reduce the road width reserve but that may cause problems for utility providers. Council staff consider the implications of locating public utility services at the back of lots but may conclude that services need to be located at the front of lots to facilitate future access for maintenance and eventual replacement /upgrading.

Reasons for not encouraging reduction in road widths include: insufficient parking, insufficient room for passing parked cars, people drive on road verges, people try to drive both ways down one-way streets and the need for emergency or refuse vehicle access. Developments with narrower streets are perceived to be inferior if they reflect less than the minimum requirements.

4.5.2 Kerbing

The requirement for kerbing has a significant impact on stormwater flows. Kerbing immediately concentrates stormwater flows along the kerb and necessitates enclosed reticulation systems to convey the concentrated flow downstream. The end destination for these conveyance systems is either a stormwater practice or a discharge directly into a receiving system. Kerbing is routinely required as a component of site development with little flexibility provided.

The provision of road drainage is generally engineering driven. Codes of practice tend to automatically assume the need for an enclosed system requiring road stormwater discharge to be managed.

It is not the intention here to advocate elimination of kerbing in all cases but rather to allow flexibility for where that option may be viable. There are other alternatives if kerbing is considered as essential in a development, such as using kerb cuts to maintain dispersed flow, which would then travel into a vegetated swale or across a buffer strip or into heavily vegetated areas. The key point is that flexibility is necessary to allow for stormwater management options.

Example of a Kerb Cut

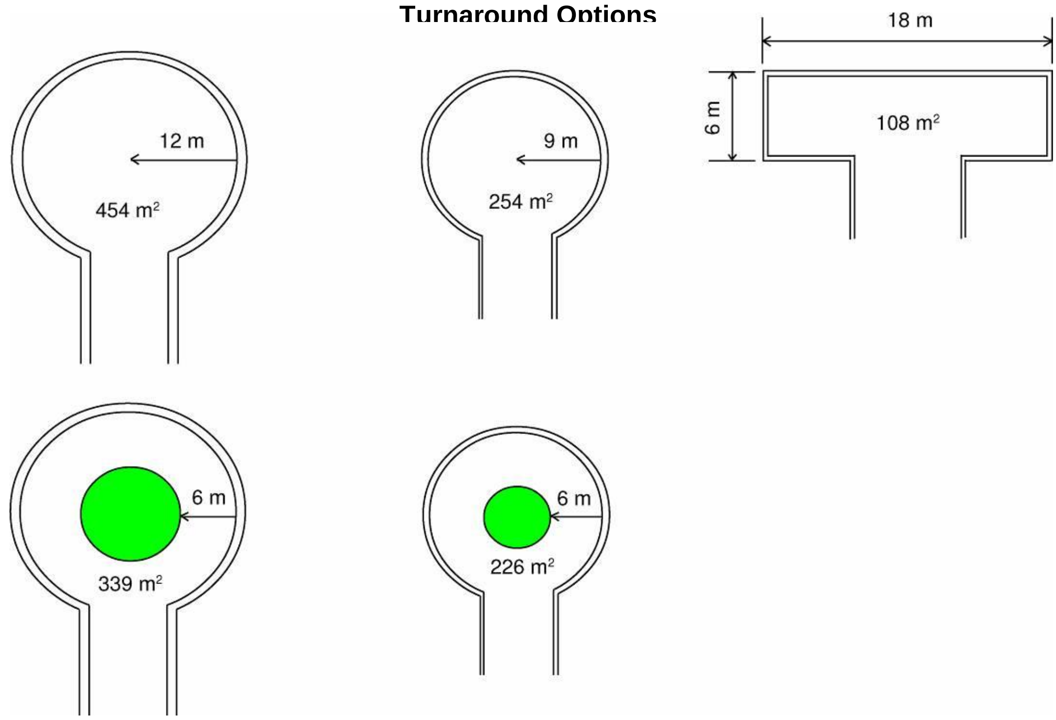
4.5.3 Turnarounds

Imperviousness can be limited in turnarounds as well. Large diameter circles at the ends of low-density cul-de-sacs simply make no sense and create much more impervious area than is necessary. Figure 4-2 indicates turnaround options, culminating in the “T” turnaround, which has the least level of imperviousness and is appropriate for low-density cul-de-sacs where traffic flows are low. Individual levels of imperviousness are shown in the turnaround options having the dimensions shown in the figure. As can be seen the “T” turnaround option has imperviousness less than 50% of the next smallest option.

4.5.4 Parking

Many different aspects of parking relate to stormwater problems, including parking ratio requirements as well as the design of parking spaces and their dimensions.

Figure 4-2
Turnaround Options



A discussion of parking as related to stormwater management links into larger planning issues quite quickly. But there are also low impact approaches to parking requirements that can minimise parking related imperviousness even where more conventional development modes are still utilised. The trend in parking ratios in recent years has been to increase these ratios, perhaps reflective of the general increase in land development and traffic associated congestion and the concern of councils to err on the conservative side. In some cases (primarily in commercial areas), minimum parking ratios are even exceeded by developers. Councils typically establish minimum parking ratios, but rarely specify maximum parking ratios.

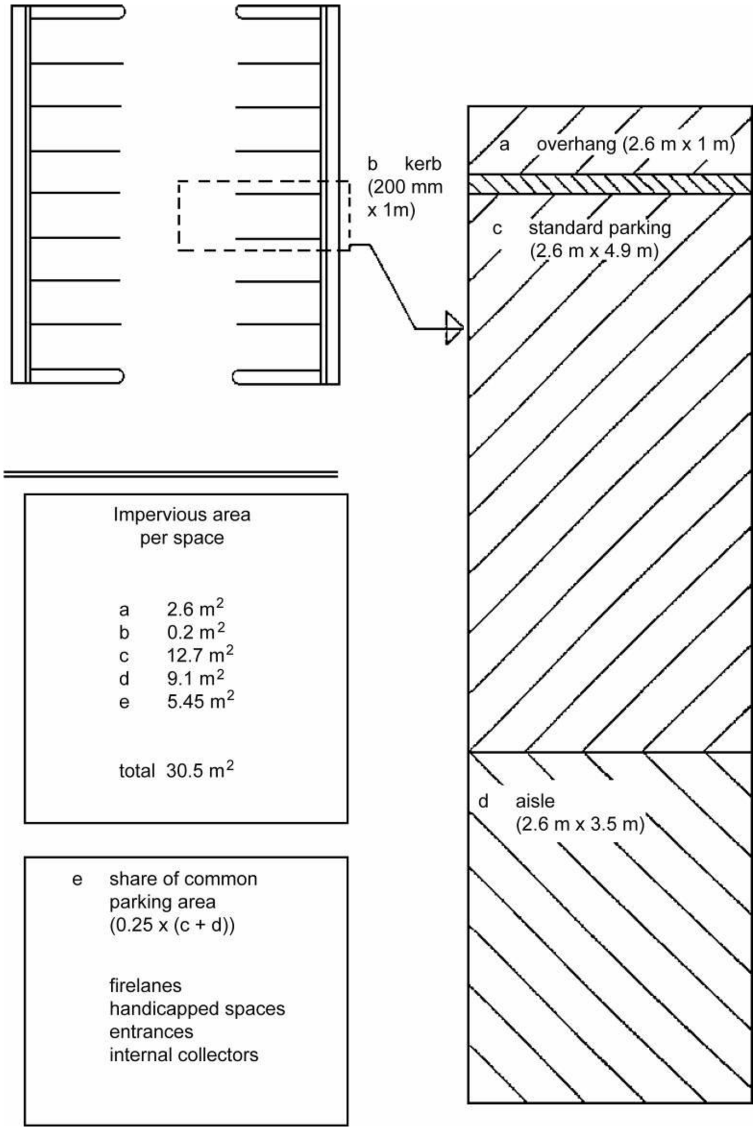
It should be noted that adjustment of ratios must be done with care. Office parks, for example, are experiencing increasing employment intensities. As companies grow, more employees are hired; ratios of employees per square metre increase; cars increase and so does the need for increased parking spaces.

In terms of parking space design standards, this can be a significant contributor of overall site imperviousness. A standard dimension parking space can be 2.6-by-5 metres having a typical kerb overhang. When including the appropriate share of the parking aisle and the share of the common parking area, that impervious space can total over 30 square metres which is over twice as much as the actual parking area itself. (Figure 4-3). Reduction in the 25% shared area or reducing the number of parking spaces can provide a significant reduction in overall site imperviousness. Larger cars having a reduced turning radius are increasing the problem of parking lot sizing increases.

A variety of other design-linked techniques should be evaluated, including altered approaches to spillover parking where less areal extent of paving is required (grass, metal, gobi blocks). Another simple technique is 1-way angled parking lot configurations, which allow for a reduction in parking aisle widths.

The first parking-related objective of low impact design is to avoid inflated parking ratios. All parking requirements should be revisited, compared with adjacent councils, and compared with actual experience. Ratios such as one space for every 35 square metres of general floor area for offices should be revisited to see if it is necessary or can be adjusted downward. Depending upon the specific use involved, ratios driven by peak demand such as shopping centres may be able to be further reduced if combined with special parking overflow provisions.

Figure 4-3
Parking Area Dimensions



Secondly, maximise sharing of parking areas by creative pairing of uses wherever possible. Developers don't attempt such sharing because of the perception that officials would simply reject such a concept. Councils need to incorporate such sharing concepts into their requirements. Councils should also consider providing positive incentives for developers to utilize sharing options.

4.5.5 Driveways

Driveways are very much linked to configuration of the development. Conventional subdivisions have setback requirements as well as front yard/side yard ratio requirements and street frontage requirements. All of these specifications translate into a development mode, which is very familiar and commonplace. Driveway length clearly must be at least equal to the house setback, plus required right-of-way. In addition, as lot sizes become large setback requirements tend to be well exceeded. Houses often sit considerable distances from the street and driveways become long. As houses have grown larger, car per house ratios have increased with larger and wider driveways again required. A standard four metre wide driveway will fan out into a two or three car garage. There may be additional paving required for out of garage parking. Although reduced density of development on any one site may give the appearance of some improved environmental benefit, the larger site imperviousness expands quickly and any benefit is impacted negatively resulting in more stormwater problems.

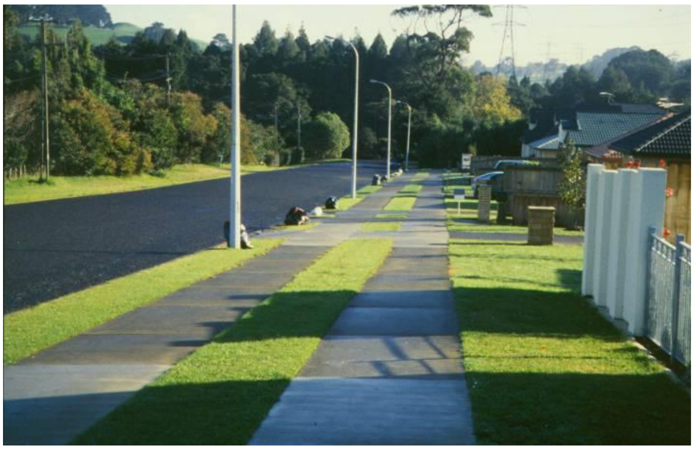
Solutions to driveway imperviousness would include reducing their length by locating the house closer to the road; using concrete strips rather than a continuous slab of concrete, or using metal strips as a substitute for concrete entirely. The metal will have a degree of compaction and still have surface runoff but the rougher surface will reduce flow velocities and will require a larger storm to initiate surface runoff than would a concrete driveway.

Twin Concrete Strip Driveway Reducing Driveway Imperviousness

4.5.6 Footpaths

Footpaths are an important element in community design and can also be a significant contributor of imperviousness generally being approximately 1.4 metres wide. Although many low-density developments may not need footpaths, they are generally required. Councils tend to rely on their own codes of practice for guidance on the requirement and sizing of footpaths.

A Dual Footpath on One Side of a Street, Further Increasing Site Imperviousness

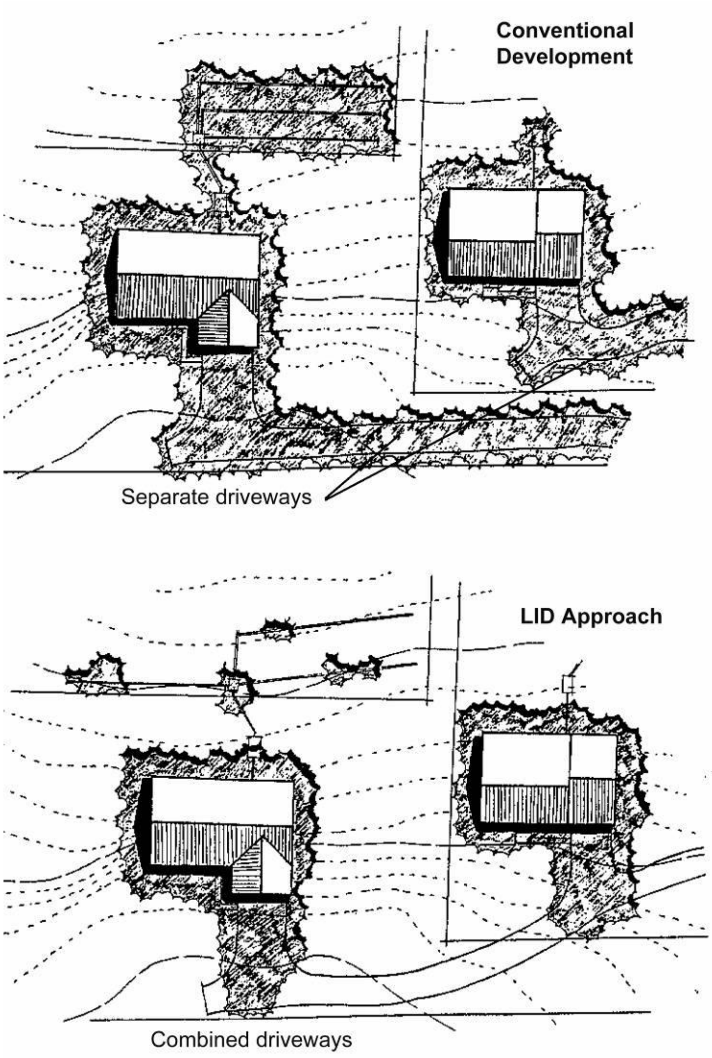


Where they are required it is possible to use more permeable materials or reduce the footpath width and provide less imperviousness to reduce the onset of stormwater runoff.

4.6 Low Impact Design Approach: Minimum Site Disturbance

Minimum site disturbance is an approach to site development where clearing of vegetation and disturbance of soil is carefully limited to a prescribed distance from proposed structures and improvements. In most cases, the concept is appropriate for sites with existing native vegetation, although existing vegetation can also be dune vegetation, pasture grasses, and coastal grasses. Tree cover need not consist solely of stands of mature native vegetation as scrub provides significant quantity and quality benefits as well. An example of minimum site disturbance is shown in Figure 4-4.

Figure 4-4
Comparison of Individual Driveways and Combined Ones



The objective of minimum site disturbance is to maximise existing vegetation and to minimise creation of an artificial landscape. At issue here are both construction phase impacts as well as the long-term operation of the development. By doing this, not only are the disturbed site impacts avoided as the result of substantial reduction in areas to be disturbed, but also natural areas of vegetation are preserved, retaining all of their functions and ecological values.

The first step in developing a minimum site disturbance programme is to establish a variety of standards and criteria that define the approach.

- Establish a "limit of disturbance" (LOD) based on maximum disturbance zone lengths; such maximum distances should reflect construction techniques and equipment needs, together with the physical situation such as slopes, as well as the building type being proposed. For example, a four-metre LOD distance may be workable in low-density residential development, where a ten-metre limit may be more appropriate for larger projects where larger equipment use is necessary. LOD distances may be made to vary by type of development, size of site, and specific development features involved. A special exception procedure should be provided to allow for those circumstances with unusual constraints.
- Integrate minimum site disturbance requirements fully into the project review process. Procedurally, the LOD should be established early on in the reviewing process.
- Require the LOD to be staked out in the field for contractor recognition.

In addition, site disturbance can be minimised by locating buildings and roads along existing contours, orienting the major axis of buildings parallel to existing contours, staggering floor levels to adjust to grade changes, allowing for steeper cuts and grades provided that proper stabilisation and erosion and sediment controls are in place, and designing structures including garages to fit into the terrain, lot by lot.

4.7 LID Practices

4.7.1 Vegetated filter strips and buffer areas

Vegetated filter strips and buffer areas are zones of vegetation, either natural/existing or planted, which are used to receive runoff in the form of sheet flow from upslope impervious areas. Strips may include vegetation ranging from grasses to forested areas. Vegetated filter strips may use existing vegetation or be planted during the course of development. Filter strips often must include some form of level spreading device to ensure an even distribution of stormwater across the vegetated area.

If filter strips can be integrated into design criteria so that small storms are controlled and properly distributed, with larger storms being redirected, the technique has excellent water quality benefits. While a filter strip may not eliminate the need for further stormwater controls downstream, it will enhance the water quality benefits by facilitating additional contaminant reduction.

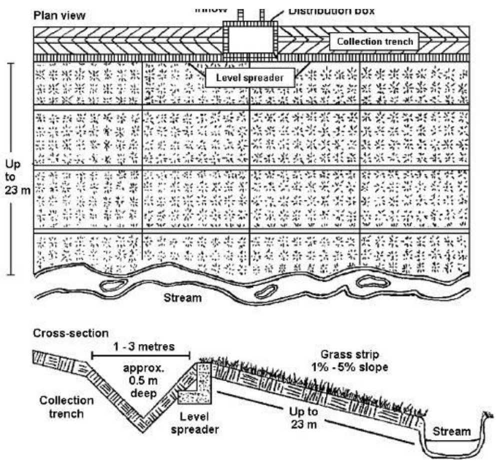
Redirecting stormwater runoff from impervious surfaces to filter strips could be termed “hydrologic disconnection”, with the objective here to minimise stormwater conveyance through wide scale distribution close to the point of origin. In these cases, pathways and driveways and other impervious features are designed to drain evenly onto adjacent vegetated areas. Such areas can be lawn areas or planted groundcover, possibly even preexisting vegetation.

In terms of this document vegetated filter strips and buffers are combined, although there are some differences. One common distinction is that filter strips are often created or planted whereas buffers utilise existing vegetation. Another distinction is that filter strips are located as close to the source of runoff as possible, while buffers are typically techniques to protect sensitive environmental features such as wetlands or streams.

An excellent example of a buffer is the riparian buffer zone. This is where a sensitive stream system is buffered from stormwater runoff from adjacent developed areas. Although the full range of functions provided by the riparian buffer zone are more complex than the filter strip, conceptually the riparian buffer zone is an elaborate filter strip, as are other buffers provided around wetlands or any other protected resource.

Filter strips intercept stormwater flows before they become concentrated and then distribute the flow evenly across the filter strip. As the water travels across the filter strip it slows down due to frictional resistance of the vegetation to flow. Some portion of the runoff may infiltrate into the ground. As the flows are reduced various contaminants are removed through a range of mechanisms/processes. A schematic of a filter strip is shown in Figure 4-5.

Figure 4-5 Schematic of a Filter Strip



Most filter strips have limited stormwater management capabilities and therefore are best suited for relatively low-density development. Also, their functioning is maximised when only smaller storm events are treated. Critical to the proper design of filter strips is consideration of the following elements:

- Slope,
- Level spreading of flows,
- Proper dimensions for contaminant reduction,
- Minimisation of velocities,
- Soil permeability or suitability, and
- Avoidance of compaction and other related construction activities.

The single greatest limitation to filter strip performance is channelisation and concentration of flow. Contaminant reduction occurs as water flows through the vegetation. When flows are concentrated, the water quality function is short-circuited. Concentrated flows can also cause significant erosion of soil and vegetation, which would lead to degraded functioning of the filter strip.

Factors that can increase filter strip efficiency include:

- Low slopes,
- Permeable soils,
- Dense grass cover,
- Long filter strip lengths (greater than 60 metres) increasing contact time of flow with the vegetation,
- Smaller storm events will have greater effectiveness than larger ones, and
- Coupling filter strips with other practices.

Factors that can decrease filter strip efficiency include:

- Compacted soils,
- Short contact time of runoff to the vegetation,
- Large storm events,
- Short grass heights (less than 50 mm),
- Steep slopes (greater than 5%),
- High runoff velocities (greater than 0.8 m/sec.), and
- Dry weather flow, which would prevent grass growth and concentrate flows.

Over time, filter strips may also accumulate sediment and other solids and preferential flow paths may develop. Periodic inspection can lead to early identification and treatment of maintenance related problems.

Detailed design of vegetated filter strips or level spreaders is provided in “Stormwater Management Guidelines for the Hawke’s Bay Region” available from the Council.

4.7.2 Vegetated Swales

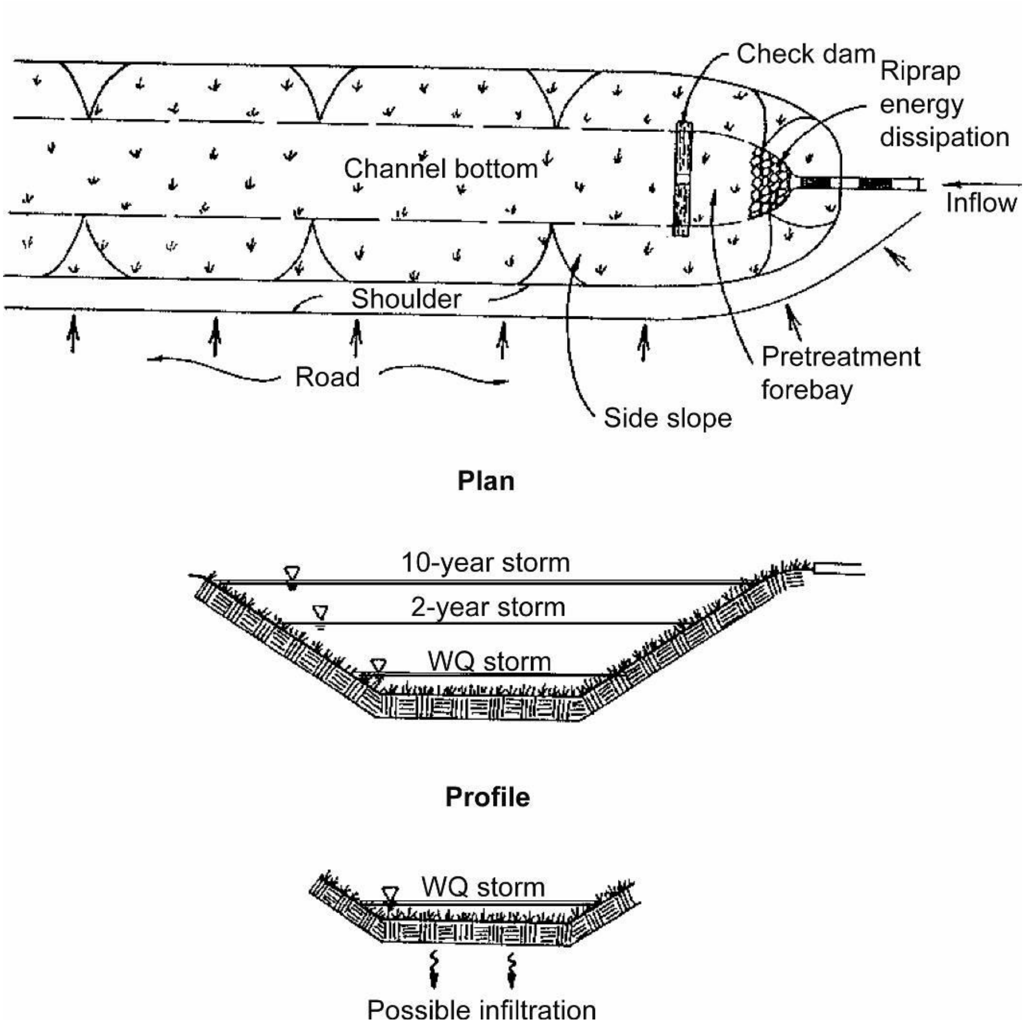
Vegetated swales are used as storm water conveyance systems. They are vegetated channels and may be located adjacent to a roadside, in a highway median, in a parking lot, or along the back or side of residential properties. Stormwater is directed into these channels and then conveyed to a stormwater treatment area or off-site.

While their function is primarily for water conveyance they can have significant water quality benefits in addition to some water quantity benefits.

Vegetated swales can take the place of conventional stormwater conveyance/piped systems. Piped systems such as kerb and channel with catchpits provide no water quality function and in effect actually worsen receiving system impacts by increasing velocities and increasing erosive forces. Although vegetated swales vary in their intended objectives and design, the overall concept of a vegetated swale is to slow stormwater flows, capture some contaminants, and allow for some reduction in the total volume of runoff.

Swales can act in two ways to affect stormwater flows. Firstly, conveyance of water in a vegetated channel causes a decrease in the velocity of flow. As the water passes over and through the vegetation, it encounters resistance. This resistance translates into increased times of concentration within the catchment and has beneficial effects on flood peaks. The result can be a reduction in habitat destruction and bank erosion that often is caused by peak flows from small storms. Some stormwater runoff may infiltrate depending on the permeability of the soil and degree of saturation. Secondly, water quality can be affected by passage through vegetation. All the physical, chemical, and biological processes previously described can reduce contaminant loadings in stormwater. Total suspended solids are reduced as a result of decreased flow velocity. Vegetation can also directly absorb nutrients and utilise them in growth. A swale schematic is shown in Figure 4-6.

Figure 4-6
Swale Schematic Plan and Profile



There are specific factors that can both positively and negatively affect swale contaminant removal performance.

Factors that can increase swale efficiency include:

- Check dams to reduce flow velocities,
- Low slopes,
- Permeable soils,
- Dense grass cover,
- Long swale lengths (greater than 60 metres) increasing contact time of flow with the vegetation,
- Smaller storm events will have greater contaminant removal effectiveness than larger ones, and
- Coupling swales with other practices.

Factors that can decrease swale efficiency include:

- Compacted soils,
- Short contact time of runoff to the vegetation,
- Large storm events,
- Short grass heights (less than 50 mm),
- Steep slopes (greater than 5%),
- High runoff velocities (greater than 0.8 m/sec.), and
- Dry weather flow that would prevent grass growth and concentrate flows.

Most sources concur that construction costs of vegetated swales are less than costs for conventional storm sewers, including kerbing, inlets, and conveyance piping. Maintenance costs for swales are relatively low. The primary objectives are to keep a dense mat of vegetation growing and to keep the swale free of obstructions such as leaf litter and significant deposits of sediment. Periodic mowing and inspection can accomplish these objectives. Occasional reseeding may be needed in areas that become bare. It is also necessary to discourage homeowners from cutting the grass too short.

It is important that swales be fully stabilised prior to accepting stormwater runoff. Swales that have been shaped but not stabilised will have greater stormwater flow velocities as a result of reduced channel roughness. Proper stabilisation will increase channel roughness and the plant root systems will reduce channel erosion potential.

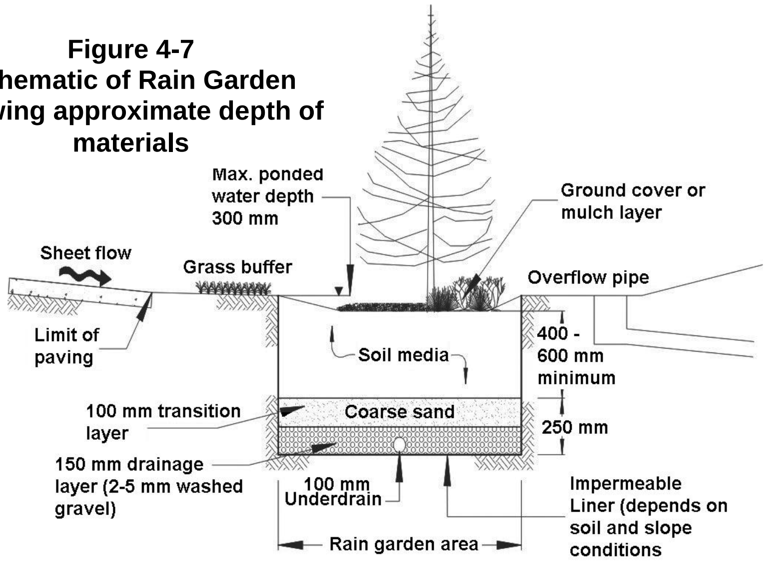
Detailed design of swales is provided in “Stormwater Management Guidelines for the Hawke’s Bay Region” available from the Council..

4.7.3 Rain Gardens

Rain garden is a relatively new name given to use of a number of processes that are used in conjunction with one another. They use the concept of bioretention, a water quality practice in which plants and soils remove contaminants. Rain gardens are created in low-lying areas, with specific layers of soil, sand, and organic mulch. These layers naturally filter stormwater. During the inter-event dry period, the soil absorbs and stores and evapotranspires the stormwater and nourishes the garden’s grasses, trees, and shrubs.

Rain gardens look and function like any other garden except they are designed to treat runoff and are designed with a layer of mulch, planting soil or media, and vegetation (trees, shrubs). Monitoring of rain gardens has shown them to be very effective in removing contaminants. A standard detail of a rain garden is shown in Figure 4-7.

Figure 4-7
Schematic of Rain Garden showing approximate depth of materials



The rain garden concept can be used on individual home sites or as a public system. The main issue on their long-term performance is the assurance of adequate maintenance responsibility. Over time, the systems may have reduced permeability that will increase surface ponding time. Another issue relates to maintenance of vegetation if the rain garden has an underdrain system, which will be the case in a number of Hawke's Bay sites. The underdrain may cause the system to dry out more completely than would a system with no underdrain. This may necessitate watering of the vegetation on an 'as needed' basis to ensure a healthy appearance.

Detailed design of rain gardens is provided in "Stormwater Management Guidelines for the Hawke's Bay Region" available from the Council..

4.7.4 Infiltration practices

Infiltration practices direct urban stormwater away from surface runoff paths and into the underlying soil. In contrast to surface detention methods, which are treatment or delay mechanisms that ultimately discharge all runoff to streams, infiltration diverts runoff into groundwater. Of all the traditional stormwater management practices, infiltration is one of the few practices (together with revegetation and rain tanks) that reduce the overall volume of stormwater being discharged.

Infiltration practices comprise a suite of different practices, including:

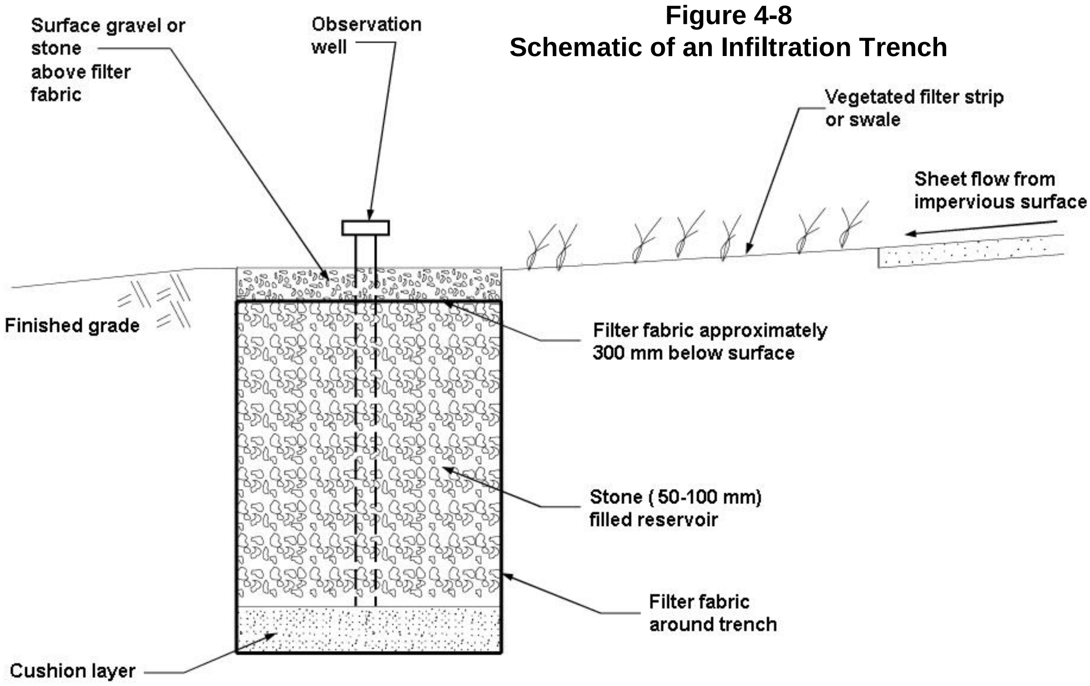
- Trenches
- Dry wells
- Modular block porous pavement
- To a certain extent, rain gardens, swales and filter strips that are considered separately.

Infiltration practices are used for three primary purposes:

- Reducing the total volume of stormwater runoff,
- Reducing the contaminant loadings downstream, and
- Low stream flow augmentation.

Especially in areas having pumice soils, infiltration of runoff could be an important tool in reducing adverse downstream impacts. A detail of an infiltration trench is shown in Figure 4-8.

Figure 4-8
Schematic of an Infiltration Trench



Detailed design of infiltration practices are provided in “Stormwater Management Guidelines for the Hawke’s Bay Region” available from the Council.

4.7.5 Use of Natural Areas Including Reforestation and Revegetation

The low impact design approach involves utilisation of existing areas of vegetation, from forested areas to scrub vegetation to pasture areas. The scale of this approach can be made to vary. In a micro sense, redirecting footpath and driveway stormwater runoff onto adjacent grassed or otherwise vegetated areas, illustrates this concept of natural area use. All such opportunities should be considered where redirection could be done without causing problems, such as concentrated flow increasing slope erosion.

For those situations where vegetation already exists use of that vegetation or enhancement of the vegetation is a good approach, significant benefits can be gained also by reforesting or revegetating portions of sites, which would improve an existing situation or expand a degraded resource.

Reforestation/revegetation includes planting of appropriate tree and shrub species coupled with establishment of an appropriate ground cover around the trees and shrubs so as to stabilise the soil and prevent an influx of invasive plants. The practice is highly desirable because, in contrast to so many other management approaches, reforestation improves in its stormwater performance over time as the vegetated area develops an organic ground cover layer of decaying leaves and vegetation.

Reforestation benefits relate closely to benefits cited in the literature on riparian stream buffer protection, although reforestation is not linear in configuration.

Plant species should be selected carefully to match indigenous species that exist in the area and care should be taken to use species reflective of the combination of environmental factors that characterise the area. This enables species that will flourish in an appropriate site, as well as improving ecological health of streams and natural areas in the wider context.

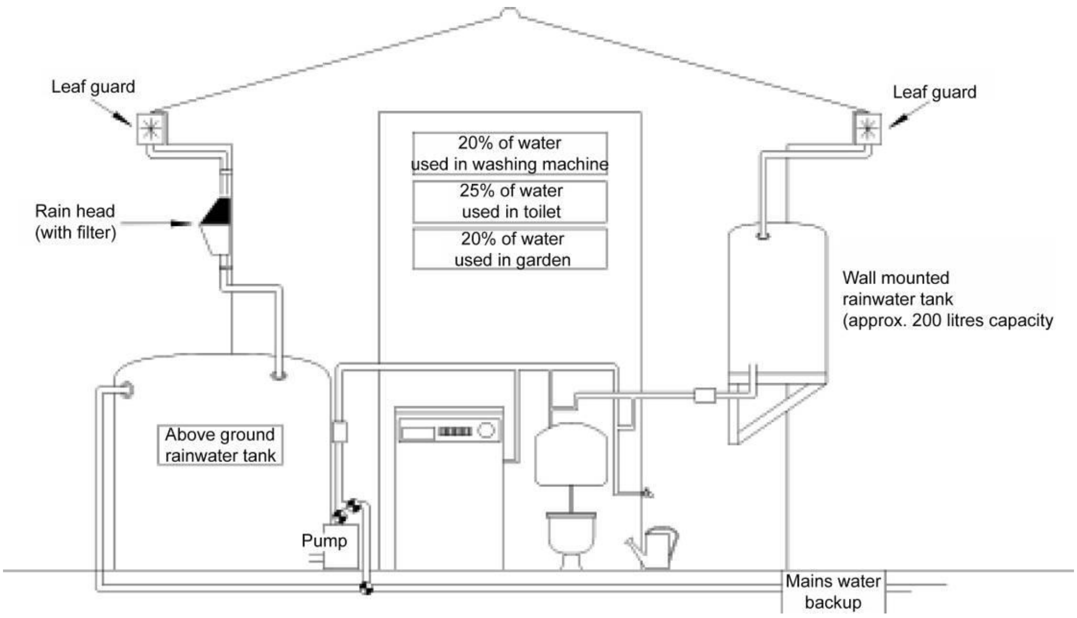
Reforestation areas need periodic management, at least for the first five years. This will ensure good survival rates for the newly planted stock. The level of management decreases as the plantings mature. During the first 2-3 years, annual spot applications of herbicide may be necessary around the planted vegetation to keep weeds from out competing the new trees and shrubs for water and nutrients.

To the extent that vegetation of different types is already established, the already stabilised natural area offers various physical, chemical, and biological mechanisms, which should further maximise contaminant removal as well as attaining water quantity objectives.

4.7.6 Water Reuse

The reuse of stormwater-generated runoff in water tanks has been integral to land development in New Zealand. Figure 4-9 provides a schematic of a household water tank. Houses have and still use roof runoff for domestic water supply when public

Figure 4-9
Schematic of a Water Tank showing Various Components



water has not been available. The effect of using roof generated runoff for domestic water supply has been to eliminate roof impervious surfaces from contributing stormwater runoff. This elimination of runoff reduces the total volume of stormwater runoff from land that has been developed downstream. If reduction in impervious surfaces is important to reduce overall site stormwater runoff volume, then water reuse can provide a significant stormwater management benefit.

To give an example of roof runoff volumes, consider a residential roof on a house covering 200 square metres. Since 1 mm of rain = 1 Litre (L) of water per square metre (m^2) of roof area, a one in ten year storm return period, 24-hour rainfall event for Napier is 103 mm. This depth of rainfall on the roof area yields 20.6 cubic metres or 20,600 litres of water. When considered on a catchment level where there may be 100 homes could yield more than 2 million litres. Reusing roof runoff for non-potable domestic water uses such as toilets, laundry, and outdoor water usage can provide a significant stormwater benefit. If roof runoff was used for non-potable domestic use, territorial authorities may require that back flow preventers be installed to avoid cross contamination of potable water supply if the two domestic uses were combined in one pipe system.

Waitakere City Eco Water distributes a brochure “How to Save Water” which provides some estimates of water usage within a household. Those estimates are shown in Table 4-2.

Table 4-2
Estimates of Water Use Within a Household

Home water use element	Percentage of water use (%)
Bathroom	28
Toilet	27
Laundry	21
Outdoors use	15
Kitchen	9

Toilet, laundry, and outdoor water use (as highlighted in the Table) use approximately 63% of all water use within the household and there is no reason why water supply for those uses cannot be provided by roof runoff. In addition to reducing the total volume of stormwater runoff, there may be economic benefits in reduced potable water consumption, and other broader benefits in reducing demand on public water supply. This would allow existing water supplies to last longer before needing to establish new sources and service a larger population base.

Water reuse is certainly beneficial from a residential consumption perspective but is also very beneficial from an industrial viewpoint. Water using industries having high levels of impervious surfaces can supplement water needs with roof runoff. Benefits of this will depend on their water demand, the ability to store water on site, and the uses for which the water is to be used.

Water reuse can and should be an important stormwater management tool. Reducing the total volume of stormwater runoff is essential if protecting the physical structure of streams is important. There are at least four possible ways to limit the total volume of stormwater runoff, and all four of these ways are important to consider on a case-by-case basis.

- Limiting land use change and limiting impervious surfaces,
- Infiltration of stormwater runoff,
- Having significant levels of evapotranspiration from vegetation, and

- Stormwater reuse.

Limiting land use change is discussed throughout this guideline and also must be considered from a catchment basis. Infiltration of runoff depends on soils, slopes, and land use, and must be considered carefully if long-term performance is to be achieved. Evapotranspiration will depend on having soils and vegetation used for stormwater treatment where evaporation and transpiration are promoted by practice design. Stormwater reuse, in becoming essential to site usage, can provide an effective long-term solution to stormwater volume reduction.

4.8 Bibliography

Natural Lands Trust, Environmental Management Handbook

Northeastern Illinois Planning Commission, Reducing the Impacts of Urban Runoff: The Advantages of Alternative Site Design Approaches, April 1997.

Center for Watershed Protection, Metropolitan Washington Council of Governments, Site Planning for Urban Stream Protection, December 1995

Delaware Department of Natural Resources and Environmental Control, Conservation Design for Stormwater Management, September, 1997

Waitakere City EcoWater, How to Save Water, undated

5 Design Procedures

5.1 Introduction

Low Impact Design (LID) presents a series of questions or checklist items that must be addressed as the site design process is done. If site designers ask these questions and consider what their responses to those questions are then LID is accomplished. The most important aspect of LID is that it achieves a new way of thinking about site design.

The approach provided here is simplistic and attempts to avoid the temptation to become overly detailed and complicated. There are thousands of variations to LID and no amount of detail will cover every situation.

In terms of approach in this Section, individual components of site design will be provided in a checklist for that component. These individual components are grouped so that an overall checklist for the LID process is followed.

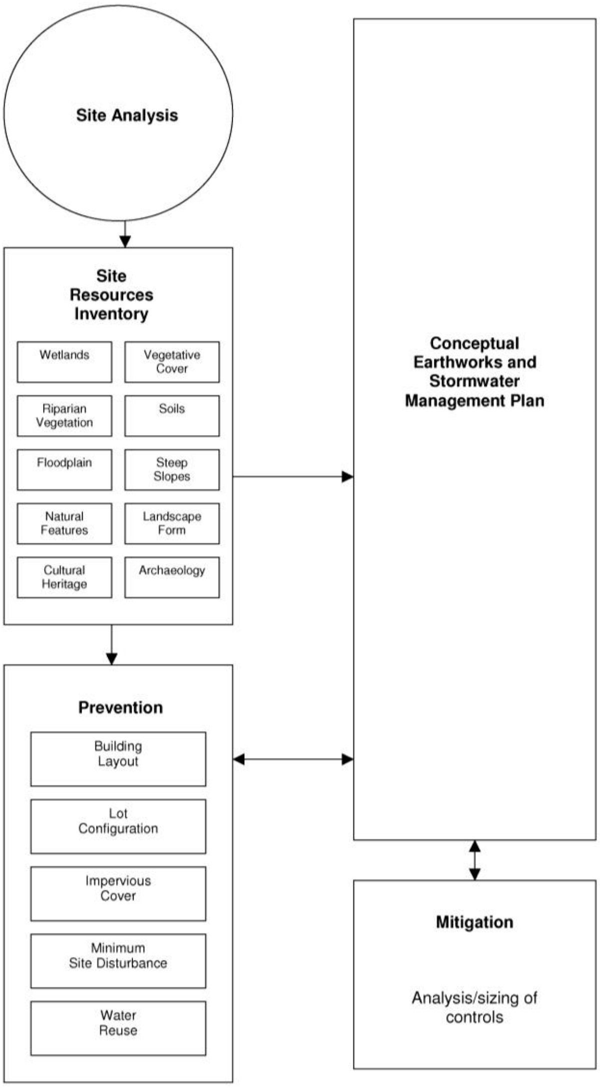
5.2 Design procedure in overview

As design procedures go, LID is simple as shown in Figure 5-1. The procedure is based on using an analysis of existing site conditions as a baseline from which to start from. These existing site conditions provide an inventory of the full range of natural systems - water, soil, geology, vegetation, and habitat - as well as cultural and archaeological factors. These systems range from the very macro in scale for resources of Region wide significance, down to micro scale site-specific conditions such as steep slopes or the presence of first or second order streams. The more this complex system is documented and understood from the start, the better the earthworks and building programme can be fitted on the site with reduced impact. Extra design effort up front will pay important dividends in the long run. LID requires a major departure from the conventional mindset of site disturbance and stormwater disposal, which is a reactive approach with an end of the line process forcibly imposed through a consent requirement. LID is based on understanding natural system opportunities, which enable us to achieve essential stormwater quantity and quality management objectives integrated into the development design from the very beginning.

LID requires that a series of questions be answered which, from an earthworks and stormwater perspective, are preventive in nature. If these questions are addressed, the reduction of stormwater runoff can be maximised. In most situations, sediment control and stormwater mitigation will still be required due to site disturbance and the increased volume and peak rates of runoff. On-site mitigation efforts in stormwater management should attempt to use less impacting forms of management such as incremental stabilisation and vegetated swales or filters where practical, but more structural forms of management such as ponds or wetlands will still possibly be required although their sizes will be reduced from the conventional site development approach.

A relevant analogy to the benefits of LID is the relationship that erosion control has to sediment control. Erosion control during construction is preventive in that it reduces the total amount of sediment generated. Sediment control attempts to reduce downstream delivery of sediment through the use of mitigative practices. LID is similar to erosion control as it is preventive. Conventional stormwater management is like sediment control in that it attempts to reduce adverse impacts rather than preventing them.

Figure 5-1
Low Impact Design Approach



The most important aspect shown in Figure 5-1 is the conceptual earthwork and stormwater management plans being done concurrently with the entire site design process. All of the preventive and mitigative steps link into the conceptual process. The building programme, site design including earthworks, and stormwater management concept are integrated and optimised. This integration of erosion and sediment control and stormwater management issues into site design from the start of the design process is essential to LID.

5.3 LID Design Approach

LID presents a series of questions or checklist items that should be answered as the design process proceeds. If you as a designer ask these questions and consider your response then LID is accomplished. The most important aspect of LID is that it achieves a new way of thinking about site design.

You do not want the process to become overly complicated as there are thousands of variations and you won't be able to cover every situation.

One key theme that permeates the overall process is to have a minimum earthworks strategy. The less site modification that occurs, the less adverse effects will occur.

There are individual sections to the process depending on the aspect of site design that is being considered. Those processes include the following items:

- General context information,
- LID ancillary benefits,
- Site natural features analysis,
- Hydrologic factors,
- Building considerations,
- Lot configuration,
- Impervious surface reduction,
- Minimisation of site disturbance,
- Calculation considerations, and
- Mitigation considerations.

These considerations are appropriate at a site or subdivision level of development. In addition, catchment development would have a number of similar factors along with some additional ones as detailed in it's own checklist that is provided in Section 6. The last checklist listed in Section 5 relates to ancillary benefits that need to be considered during the LID design process.

5.3.1 General Context Information

General Context Information Considered		
Information	Yes	No
The surrounding land context (rural, urban, vegetation, etc.)		
The site position in a catchment (top, middle, bottom)		
Site size		
Structure plan, district plan, network consent, code of practice indicate ranges of development for this site and adjacent ones		

5.3.2 LID ancillary benefits

Ancillary Benefits Considered		
Information	Yes	No
Urban design components		
Crime Prevention Through Environmental Design		
Energy efficiency		
Ecology		
Landscape amenity		

*Note: for a detailed breakdown please refer to the LID Ancillary Benefits Checklist in Section 5.3.12

5.3.3 Site analysis

Site Natural Features Considered		
Feature	Yes	No
Wetlands		
Streams (including intermittent ones)		
Floodplains		
Riparian buffers		
Existing site vegetative cover		
Soils		
Depth to groundwater		
Steep slopes (>33% or 18^o)		
Other natural site features		
Cultural or archaeological locations		

5.3.4 Receiving Environment

Receiving Environment Factors Considered		
Questions to Answer	Yes	No
Does the site drain directly to tidewater or the coast		
Does the receiving system have sensitivities detailed in the RPS, District Plan, Conservation Management Strategy, etc.		
Are there known downstream flooding problems		
Does the site contain 1^{st} or 2^{nd} order streams		
Are any site streams perennial		
Does the site stormwater discharge to ground		

5.3.5 Hydrological Factors Considered

Hydrological Factors Considered		
Questions to Answer	Yes	No
Have you identified the route taken by stormwater runoff from the source to the receiving environment		
Is the pathway stable enough for stormwater drainage to enter it without eroding		
Can the pathway provide for stormwater treatment		
Can site soils be used for infiltration of runoff		
Can roof or site runoff be used to reduce overall stormwater runoff volume		
Can revegetation of native vegetation be used to reduce runoff		
Do impervious surfaces drain directly to receiving waters		

Circle the appropriate "Receiving System" and "Stormwater Issue" to determine priorities:

Table 3-1 Receiving Environments and Stormwater Issues			
Receiving system	Flooding issues	Stream erosion issues	Water Quality
Streams	May be a priority depending on location within a catchment	High priority if the receiving stream is a natural, earth channel	High priority
Ground	Not an issue depending on overflow	Not an issue	High priority
Estuaries	Not an issue	Not an issue	High priority
Harbours	Not an issue	Not an issue	Moderate priority
Open Coast	Not an issue	Not an issue	Lower priority
Lakes	Not an issue	Not an issue	High priority

5.3.6 Building Considerations

Building Programme Considerations		
Consideration	Yes	No
Does the site have public sewer		
Does the site have public water		
Can the development reduce the total number of units		
Can the type of units be modified (single family to apartment)		
Is there flexibility in lot density		
Is there flexibility in individual lot requirements		

5.3.7 Lot Configuration

Lot Configuration Considerations		
Consideration	Yes	No
Have lots been reduced in size as far as practicable		
Have lots been clustered as far as practicable		
Have lots been configured to avoid important natural features		

5.3.8 Impervious Surface Reduction

Impervious Surface Reduction Considerations		
Consideration	Yes	No
Have road lengths and widths been reduced as far as practicable		
Have driveway lengths and widths been reduced as far as practicable		
Has potential for shared driveways or parking spaces been explored		
Have parking ratios and parking sizes been reduced as far as practicable		
Have cul-de-sacs roundabouts been designed to minimise imperviousness		
Has kerbing been reduced to the extent possible or have kerb cuts been used to reduce flow concentrations		

5.3.9 Minimisation of Site Disturbance

Site Disturbance Minimisation Considerations		
Consideration	Yes	No
Has maximum total site area, including both soil and vegetation been protected from clearing or other site disturbance		
Can disturbance of important natural, cultural or archaeological features be minimised		
Are areas of open space maximised		
In terms of individual lots, has maximum lot area, including both soil and vegetation, been protected from clearing or other site disturbance		
Do structures correspond to site features such as slope, both in terms of type of structure, placement on lot, elevation, etc.		
Have vegetation opportunities been maximised throughout the site		
Have revegetation opportunities been maximised in important natural areas		

5.3.10 Calculation Considerations

Design Calculation Considerations		
Consideration	Yes	No
As a result of a decrease in the total disturbed area, are numbers of sediment ponds minimised as far as practicable, and subsequently their size and areal extent also minimised		
Total sediment yield from the site during construction has been minimised as far as practicable from the conventional approach		
Could impervious cover be minimised as far as practicable from conventional development		
Have 'C' factors been reduced as far as practicable from conventional to LID		
Have total runoff volumes been affected		
Has the predevelopment time of concentration for site runoff been maintained as far as possible		

5.3.11 Mitigation Considerations

Mitigation Considerations		
Consideration	Yes	No
Has the stormwater management plan been integrated into the overall site design		
Has prevention been minimised through LID considerations		
Has mitigation been maximised through vegetative and soil based practices such as swales, rain gardens or infiltration practices		
Can unpreventable impacts be mitigated through conventional stormwater management controls		

5.3.12 LID ancillary benefits

Urban Design		
Information	Yes	No
Context: Fit within the catchment		
Character: Create vision and identity		
Choice: Range of options within the development		
Connections: Pathways through the development		
Creativity: Innovation for the future		
Custodianship: The creation of stewardship		
Collaboration: Involvement of key catchment stakeholders		
Crime Prevention through Environmental Design (CPTED)		
Information	Yes	No
Access: Safe movement and connections		
Surveillance and sightlines: See and be seen		
Layout: Clear and logical orientation		
Activity mix: Eyes on the street		
Sense of ownership: Showing a space is cared for		
Quality environments: Well-designed, managed and maintained environments		
Physical protection: Using active security measures		
Energy Efficiency		
Information	Yes	No
Water use options available (roof, mains, grey water etc)		
Control over the amount of water use and water use options?		
Buildings are insulated (placed underground, greenroofs, high ‘r’ value insulation materials)		
Site design optimises solar exposure for living environments but allows for shading and cooling in summer months		
Ecology		
Information	Yes	No
Rehabilitation potential for ecological systems		
Enhanced/capitalised biodiversity of flora and fauna communities		
Viability of ecological systems and processes		
Landscape connectivity		

Landscape Amenities		
Information	Yes	No
Conservation: Protection of significant landscape features		
View Protection: Access to existing views		
Coherence: Are existing landscape shapes maintained		
Connectivity: Seamless transitions between development and open spaces		
Scenic Appeal: Enhancement of landscapes.		
Access and Safety: Allowance for sightlines and orientation.		

5.4 Runoff calculations

Runoff calculations related to hydrologic design are critical in determining how much runoff will occur from any given site. By minimising the Rational ‘c’ factor, runoff will be minimised. Development increases the ‘c’ factor by changing site conditions and by adding impervious surfaces.

When doing hydrologic design, impervious areas should be measured from aerial photographs (for existing development) or from design plans. Within homogeneous catchments, impervious surfaces can be allowed for by using area-weighted values. Catchments containing significant impervious areas connected directly to a reticulated stormwater system should not be modelled as homogeneous. The impervious connected component will have a more rapid response time than the pervious component of the catchment. In cases where impervious surfaces are directly connected to the receiving system a more realistic representation of the catchment may be obtained by modelling the connected impervious areas and pervious areas as separate sub-catchments. As can be seen in this type of analysis, reduction in total site imperviousness will directly be reflected in downstream stormwater flows.

Many of the LID approaches have the specific aim of reducing the ‘c’ factor, and keeping it as close to the predevelopment number as possible. This is accomplished by reducing site imperviousness and disturbance in addition to implementation of control measures. These measures can considerably reduce the amount of runoff generated and thus reduce the required mitigation needed.

Clustering and reduction in road widths and driveway lengths can significantly reduce the amount of site imperviousness. Impervious surfaces have a very high ‘c’ factor (,9 or .95) and generate a significant amount of runoff. Minimising these areas helps keep the overall site runoff ‘c’ factor closer to the predevelopment condition.

Runoff can also be reduced by revegetation. Open space areas and even portions of individual lots may be revegetated to both reduce the amount of stormwater runoff generated and help mitigate the runoff that is created. Although it will take time for reforested areas to actually become fully established, they will still provide stormwater reduction as they move towards maturity.

Example of Revegetation as a Component of Site Design

LID concepts have a significant impact on hydrologic calculations. This is one of the main reasons stormwater calculations must be considered throughout the entire planning process. Decisions made early in the site planning process have significant effects on the final site runoff and thus on the amount of stormwater generated.

5.5 Time of concentration

The time of concentration relates directly to the peak stormwater flow rate. Many factors affect the time it takes water to move through a site to a point of discharge including the initial amount of water, routing of the water, and the surface that the water passes over (grass, forest, concrete). All of these factors are important considerations in the LID approach.

Stormwater must be routed through the site to avoid flooding roads, houses and other important features. The longer the flow route, the longer the time it takes water to reach the site discharge point(s). Conventional development plans often shorten the water routes through a site with piping and kerb and channel systems. Shortening the route increases the peak discharge. In LID these routes are kept as long as possible attempting to replicate the predevelopment flow paths. A longer flow path will often lower the peak rate of discharge.

Just as important as the route the water takes is the surface over which it flows. Vegetated surfaces slow water and may also provide some infiltration and water quality benefits. This is especially true during the smaller, more frequent events. The use of vegetated swales and filter strips rather than enclosed pipes or concrete channels may increase the time of concentration by both elongating the route and increasing the resistance of the flow surface.

Rational ‘c’ factors and time of concentration are the two major factors in determining the peak rate of discharge and the total volume of runoff from a site. The above discussion addresses the ways in which LID approaches can be used to meet stormwater objectives. However, the calculations don’t fully reflect the many other benefits, environmental and economic, provided by LID. These benefits are discussed throughout the guidelines and need to be considered in the greater context of regional planning and the effects of development on the catchment and the ecosystem.

5.6 Additional Stormwater Controls as Needed

The final step in LID will generally be needed although its importance will hopefully be reduced. In most cases, adverse impacts of land development will still require some form of conventional stormwater management, especially for larger storm events. It is hoped that these “conventional” approaches to stormwater management will be reduced in number and size, which will result in less site area taken up and less cost associated with design, construction, and maintenance. Those conventional stormwater management practices include ponds, wetlands, filter systems, and biofiltration. Detailed design of stormwater management practices is provided in "Stormwater Management Guidelines for the Hawke's Bay Region" available from the Council.

When considering conventional stormwater treatment or management as an overlay to LID, the integration of the practice as a component of site design should be carefully considered. LID is an approach that emphasizes a natural approach to site design. Sediment control and stormwater management treatment devices can come in many shapes and forms but design should consider how the practices are integrated with the overall development approach and with the other stormwater related approaches. Conventional sediment control and stormwater treatment devices can be designed to function effectively while, at the same time, have an attractive appearance, and minimise concerns of public safety and maintenance. Construction of a wetland pond for stormwater treatment could assist in restoration of reclaimed wetlands, minimise public concerns over safety, and have a minimal maintenance obligation. The blending of LID with conventional stormwater management could provide effective downstream resource protection while enhancing property values.

5.7 How to Measure Success

There are several obvious questions that have to be asked when doing LID.

1. What are the goals or expectations?
2. How do you know when design efforts are completed?

At this time LID does not have a performance standard associated with it. You will not get a defined answer or a specific target value that you are shooting for. The ultimate goal is to prevent change to predevelopment hydrology when site development occurs, but that mission cannot be achieved in 95% of the sites being developed. Table 5-1 summarises the general effectiveness of each of the site design approaches discussed in this guideline. It indicates that most practices are at least moderately effective at providing two or three environmental benefits. Certain practices, notably natural landscaping and cluster development are at least moderately effective in achieving all four of the desired environmental objectives. However, the table also implies that a site design should incorporate several management practices in an integrated fashion to be highly effective in controlling adverse environmental impacts.

Table 5-1
Effectiveness of LID Approaches

LID practice	Runoff rate reduction	Runoff volume reduction	Runoff contaminant reduction	Habitat Protection
Reduced street widths	Moderately effective	Moderately effective	Moderately effective	Limited effectiveness
Reduced building setback	Moderately effective	Moderately effective	Moderately effective	Limited effectiveness
Natural drainage	Moderately effective	Moderately effective	Moderately effective	Limited effectiveness
Natural detention	Very effective	Limited effectiveness	Very effective	Moderately effective
Natural	Moderately	Very effective	Very effective	Very effective

landscaping	effective			
Cluster development	Moderately effective	Very effective	Very effective	Very effective
The effectiveness of natural landscaping and cluster development will depend on how well these approaches are integrated into the overall landscape and drainage plan				

LID presents a modern approach to site design where many existing site development requirements are questioned. The realistic goal of LID is to reduce impacts to the degree possible so that mitigation is minimised while still creating desirable communities. As such, the design approach is based upon a simple question for each aspect of site development - "Why". Why do we need footpaths on both sides of a street? Why do we need streets to be as wide as they are? Why do lot sizes have to be a minimum dimension? Why do street locations have to be where they are? These questions go on and on throughout site design, and they will probably require iterations and second-guessing to get it right.

How do you know when design efforts are completed? When you have gone through the questions outlined in this chapter and completed the checklists, and addressed them to the best of your ability, you have completed the process. If you can sit back and look at your work and feel that you have blended site resources into your development approach, reduced stormwater runoff as much as possible, and delivered the best product that you can, you are finished.

What are the goals or expectations? We have to change the way we use land if we are going to have a desirable environment in the future. One tool in that effort is to change how we develop land and to bring nature more into the urban environment. As demonstrated in a number of sections, our activities have significant impacts on receiving systems in terms of contaminant entry into water and altered catchment hydrology. Our expectations are modest at this time but will certainly increase in the future with hydrologic change to catchments being minimised. Expectations are related to two areas: hydrologic change from predevelopment to post-development reduction from a conventional development approach, and site resources as detailed throughout this guideline should be protected to the extent possible. Our expectations are to see a reduced downstream impact through LID than would have otherwise occurred in a traditional site design.

5.8 Other Types of Development

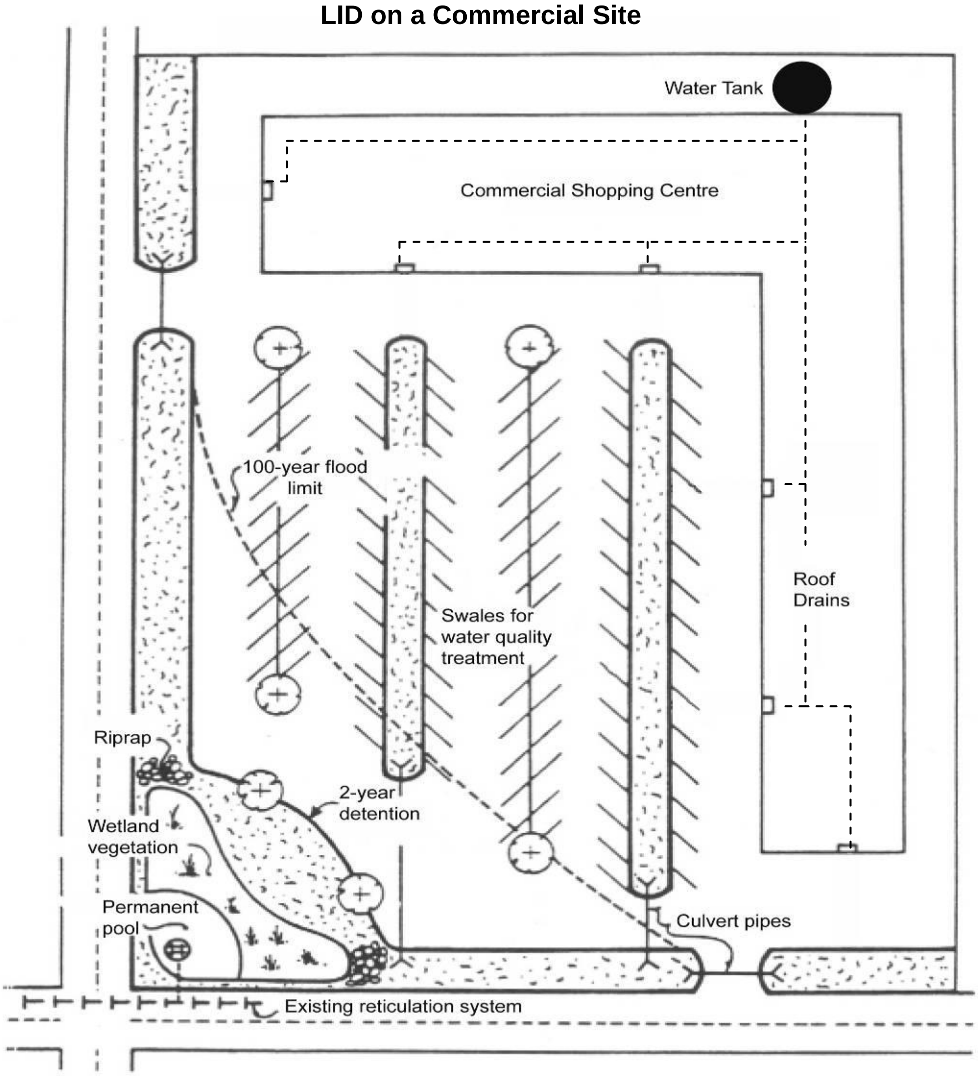
This guideline has a primary focus on residential development as residential development covers the most land area and is the most common form of site development. But commercial, industrial, and even horticultural (especially protected cropping) activities as shown in Table 5-2 can successfully apply LID to reduce their impact on receiving systems. The approach is identical to residential LID in that existing site resources are delineated, site development is integrated into the site, and LID approaches to stormwater treatment are investigated. Not all LID approaches are suited to all development types. For example, site revegetation is most easily done on larger residential lot development, but is less feasible on small commercial development.

Table 5-2
Appropriateness of LID for Selected Development Types

LID Practice	Low density residential	Medium density residential	Multi-family residential	Commercial Industrial
Reduced street widths	Generally appropriate	Generally appropriate	Generally appropriate	Occasionally appropriate
Reduced building setbacks	Generally appropriate	Generally appropriate	Occasionally appropriate	Occasionally appropriate
Natural drainage	Generally appropriate	Occasionally appropriate	Generally appropriate	Occasionally appropriate
Natural landscaping	Generally appropriate	Occasionally appropriate	Generally appropriate	Occasionally appropriate
Cluster development	Generally appropriate	Generally appropriate	Occasionally appropriate	Generally not appropriate

Any site being developed can incorporate LID. The greatest potential use of LID on commercial and industrial sites lies with use of the treatment train approach to stormwater management implementation. That is an element of LID but only one element of a broader context. The preceding example detailed in Figure 5-2 is for a small commercial development and demonstrates several LID design principles. Roof

Figure 5-2
LID on a Commercial Site



runoff reused on site and parking lot runoff enters swales, which are then directed towards a stormwater detention pond having wetland attributes. The site design promotes water reuse, water quality treatment, plus providing control of water quantity peak discharges for the 2 and 100-year storm events. As can be seen, the project does have to provide structural stormwater management control but the work done by the controls is augmented by water tanks and swales in addition to benefits provided by the wetlands vegetation.

The same issues related to residential site development requirements exist for commercial and industrial development in terms of kerbing, parking requirements, level of imperviousness, or revegetation opportunities. Almost every site can have steps taken to reduce downstream impact from conventional development approaches. One key important element is that combinations of approaches should be employed in an integrated fashion to maximise cumulative benefits.

5.9 Case studies

Several examples of LID implementation will be shown in case studies on residential subdivisions whose size and density are typical of the Hawke's Bay Region. There are any number of examples that could be used but these two were considered as typical.

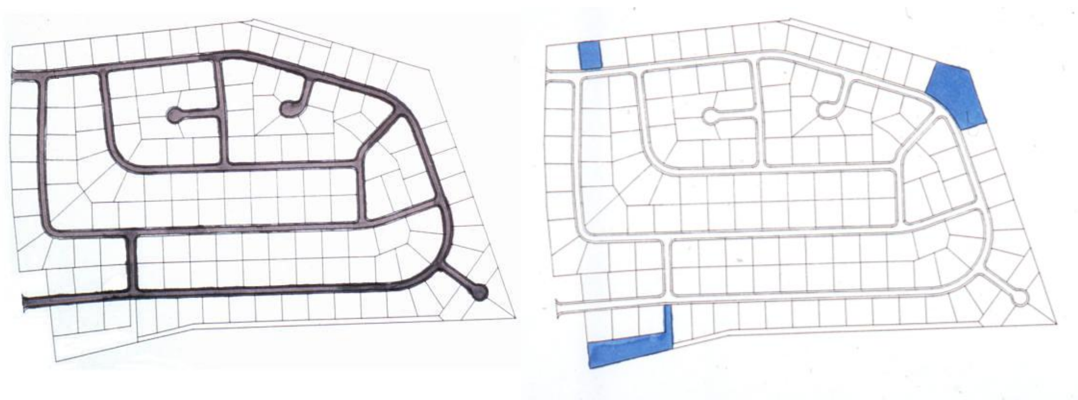
5.9.1 **Case study 1**

Residential subdivision having the following:

- 40 hectare site,
- 2,000 m^2 lots,
- 142 lots,
- Overall imperviousness 30%,
- Conventional storm drain pipe system, and
- 100% site disturbance

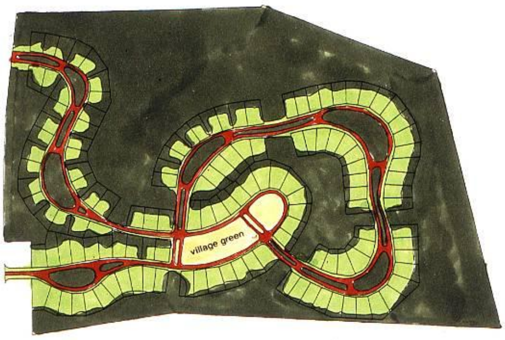
The above approach is a conventional approach that is shown on Figure 5-3.

Figure 5-3
Typical Subdivision Development Approach Showing Stormwater Management Ponds



The site was then considered from an LID context to see if benefits could be realised in terms of open space maximisation and reduced hydrological change. The following two approaches were considered in Figure 5-4.

Figure 5-4
Two Different LID Approaches to Site Development



Parkway approach

1000 m^2 lots
50% open space
15% imperviousness
60% undisturbed

Village Cluster Approach

500 m^2 lots
72% open space
17% imperviousness
67% undisturbed

When the water budget for the site is considered for the conventional development, parkway approach and village cluster approach, the following table is calculated.

Table 5-3
Subdivision Annual Water Budget (m^3)

	Pre-development	Conventional Development	LID Approach (Village)	Even Better (Parkway)
Precipitation	432,373	432,373	432,373	432,373
Runoff	18,761	249,515	82,671	67,397
Recharge	154,377	118,552	128,864	134,556
Evapo-transpiration	259,267	194,136	220,611	230,441

As can be seen, the LID approaches provide a substantial reduction in stormwater runoff being discharged on an annual basis with greater levels of groundwater recharge and evapotranspiration from the conventional approach.

These numbers only indicate runoff differences from the modified development approach. They do not consider the benefits of using water tanks for non-potable water use or rain gardens, infiltration practices, swale or filter strips as overall site stormwater management components. Using those practices in conjunction with an LID approach to site land use would result in a similar water budget to the predevelopment condition.

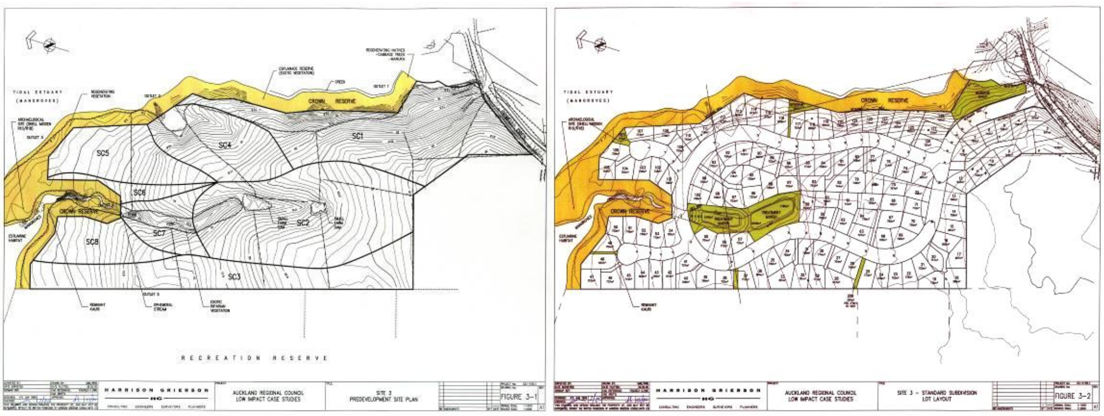
5.9.2 **Case Study 2**

Case study 2 provides for residential development in a more urban situation. The conventional development approach consists of the following:

- 14.2 hectare site,
- 128 lots,
- Average lot size 765 m^2
- Overall imperviousness 69%
- Reserve 1.09 ha,
- Earthworks area 9.5 ha,
- Earthworks volume 62,000 m^3
- Conventional storm drainage system, and
- 100% site disturbance

Figure 5-5 shows the predevelopment and conventional site development approach.

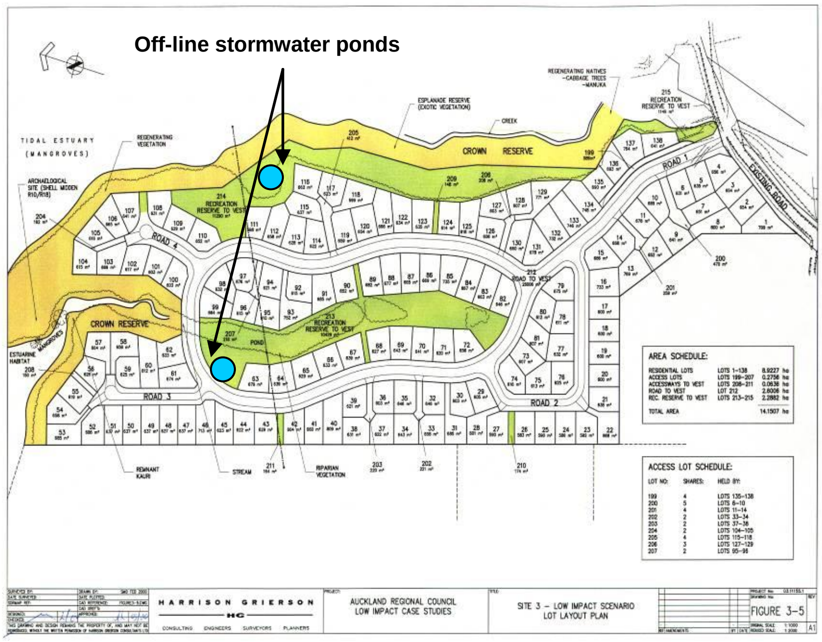
Figure 5-5
Predevelopment Site Conditions and Conventional Development Approach



The LID design approach provided for the following:

- 138 lots,
- Reserve area of 2.34 ha,
- Average lot size 650 m^2,
- Earthworks area 7.6 ha,
- Earthworks volume 53,000 m^3,
- Overall impervious ness 51%,
- Convention al storm drainage

Figure 5-6
LID Design Approach for Case Study 2



system, and
- 80% site disturbance

The LID site plan is shown in Figure 5-6.
In terms of a water budget, the following hydrological information is presented in Table 5-4.

Table 5-4
Hydrological Results

Storm	Peak flow (m^3/s)	Runoff (mm)	% increase
2-year, 24-hour storm			
Predevelopment	0.87	34	-
Conventional	1.48	59	74
Low Impact	1.37	52	53
10-year, 24-hour storm			
Predevelopment	1.89	73	-
Conventional	2.70	106	45
Low impact	2.59	97	33

Considering the water budget from an increase in total runoff and impacts on stream base flow over a given year, Table 5-5 provides the following information:

Table 5-5
Changes in Annual Storm Flow and Base Flow

Site Development status	Rainfall (m^3)	Storm flow (m^3)	Base flow (m^3)
Predevelopment	181,638	31,449	39,088
Conventional	181,638	99,160	12,254
Low impact	181,638	81,945	19,090

As can be seen, there is still a significant increase in site runoff both storm related and annually, but use of an LID approach can reduce site runoff and, in conjunction with stormwater practices, reduce downstream adverse effects.

5.10 Bibliography

Delaware Department of Natural Resources and Environmental Control, Conservation Design for Stormwater Management, September, 1997

Northeastern Illinois Planning Commission, Reducing the Impacts of Urban Runoff: The Advantages of Alternative Site Design Approaches, April 1997.

Ministry for the Environment, New Zealand Urban Design Protocol, March 2005.

Auckland Regional Council, Low Impact Design Manual for the Auckland Region, Technical Publication #124, April 2000.

6 LID catchment considerations

6.1 Introduction

While LID can be implemented at a site and subdivision level, the greatest benefit of an LID approach would be consideration from a catchment wide basis. This approach would allow land use decisions to be made based on land sensitivities, impacts to receiving systems and needed densities of population. It is considered with additional considerations than are site or subdivision developments as more consideration can be given to land use decisions rather than ways to mitigate impacts.

The ability to implement LID at a catchment level is limited in brownfields catchments but is very appropriate in catchments where new development is expected. In this situation consideration can be given to intended land use densities where an overall density can be achieved via greater intensification in some areas and reduced intensification in other areas.

This Section consists primarily of a checklist and several case studies to demonstrate LID at a catchment level.

6.2 Catchment checklist

The following checklist shown in Table 6-1 should be completed in conjunction with the checklists provided in Section 5. It will become obvious which questions are pertinent from those checklists with the catchment checklist being an overlay.

Table 6-1
Catchment Planning Considerations

Consideration	Yes	No
Greenfields		
Have all perennial and intermittent streams been identified		
Has catchment geology been done and are areas with instability identified		
Has a topographical map of the catchment been done		
Have overall development densities been assigned		
Can development occur on the contour to limit earthworks		
Can development clustering be done to protect streams and reduce earthwork requirements while achieving development densities		
Can headwater streams be protected from hydrological change		
Can total volumes of runoff be reduced from a conventional approach to reduce impacts on receiving systems		
Brownfields		
Have all perennial streams been identified		
Has the storm drain system been identified and capacities determined		
Can redevelopment within the catchment provide opportunities for reduction in		

impervious surfaces		
Has consideration been given to source control of contaminants		
Can redevelopment provide for stream rehabilitation or daylighting		
Can redevelopment provide for vertical growth and create additional open space		

6.3 Case studies

There are two case studies that provide an evolutionary path for LID at a catchment level in New Zealand. The two case studies are the following:

- Flat Bush catchment in Manukau City, and
- Long Bay catchment in North Shore City.

The Flat Bush catchment is discussed first as that catchment study and consent were done prior to the Long Bay catchment, which has just been through the Environment Court.

6.3.1 Flat Bush catchment

It needs to be reiterated that the Flat Bush Catchment Management Plan predates the Long Bay one.

As such, there are aspects of the Flat Bush approach that would be changed today but this approach was an evolutionary step prior to the Long Bay Plan. It would be expected that the next catchment management approach would be an evolutionary step beyond the Long Bay one as it is a step beyond the Flat Bush Plan.

Specifics to the Flat Bush Catchment:

- Predevelopment land use was predominantly rural
- Catchment area 1735 ha.
- Drains into Otara Creek and discharges to Otara Lake and then the Tamaki River
- Existing streams below headwater streams have been degraded and somewhat modified by farming activities
- The district plan was changed to accommodate urban development of approximately 50,000 people
- The receiving environment is depositional and the development should be designed to achieve the best practicable reduction in sediment and contaminant discharge.

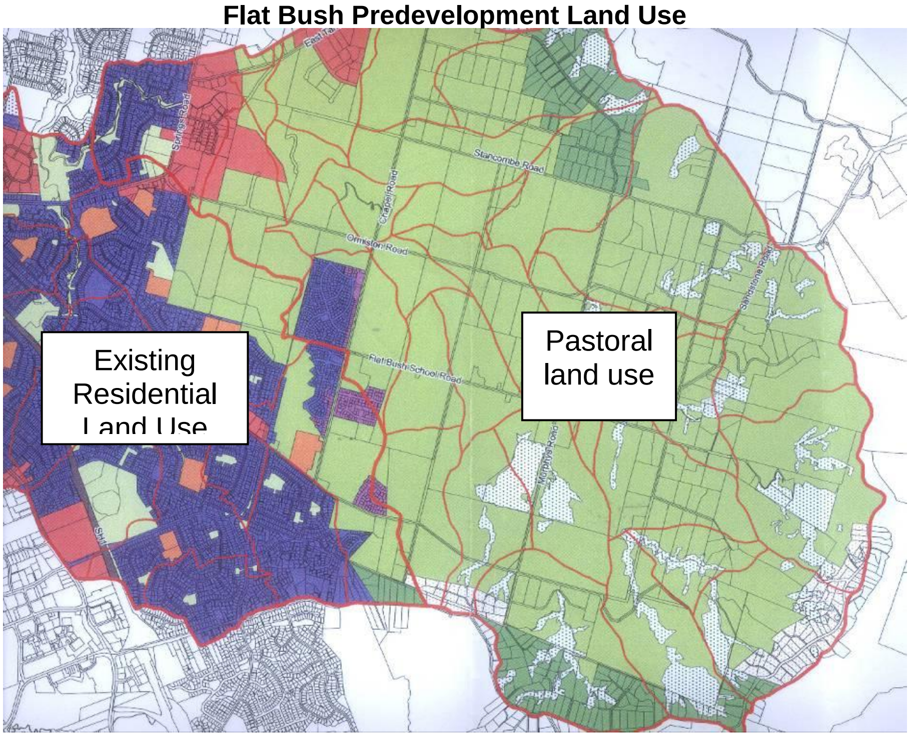
Stormwater management objectives:

- Manage the volume and peak flow rate and the passage of stormwater runoff to limit stream erosion
- Manage the peak flow rate of stormwater runoff to avoid increased flood risk within the catchment
- Manage the discharge of contaminants as far as practicable to avoid those contaminants reaching high value receiving environments

- Maintain stormwater in the catchment to assist in retaining dry season stream flows
- Provide for ongoing operation and maintenance of stormwater management assets
- Maintain fish passage
- Protect high value waterways

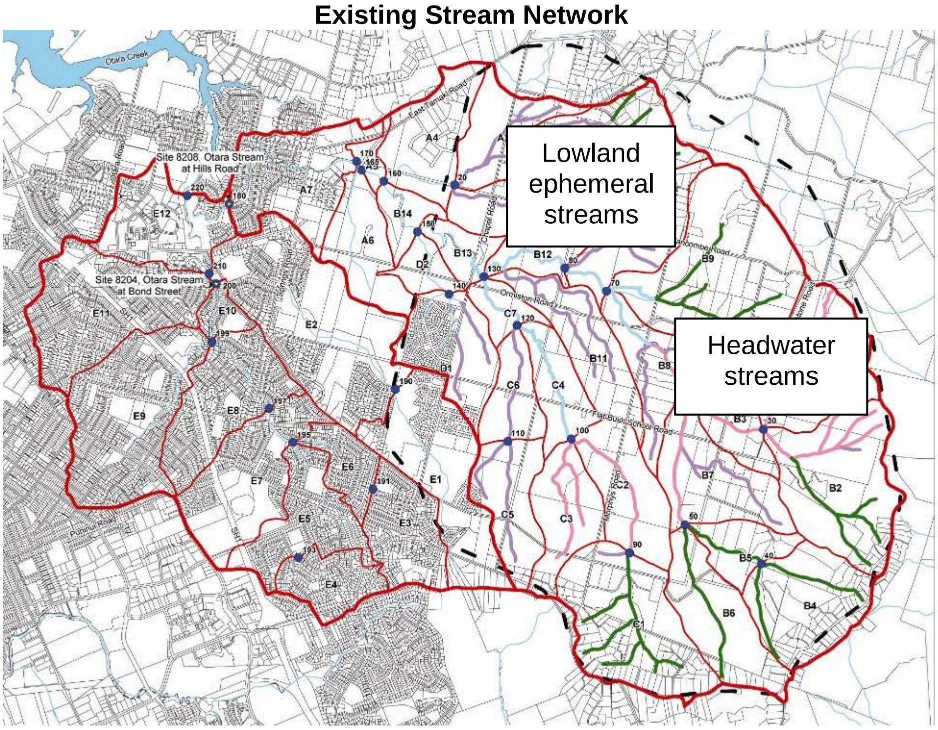
The predevelopment land use is shown in Figure 6-1.

Figure 6-1
Flat Bush Predevelopment Land Use



The existing stream network is shown in Figure 6-2.

Figure 6-2
Existing Stream Network



6.3.1.1 Upper catchment general approach:

- Revegetation (general and riparian)
- Dispersal of stormwater by dissipation over a broad area
- Water tanks
- Treatment and flow control

Middle and lower catchment general approach is a sub-catchment based approach, which relies on stormwater collection in ponds before discharge into protected streams, is necessary to meet the stormwater quality, extended detention and flood peak attenuation criteria.

6.3.1.2 Design concepts:

- Discharge through pond systems is the most appropriate method in most situations and indicative locations are shown on a following slide
- Where practicable, overland flow paths should be directed to ponds to attenuate larger floods
- Floodplains and stormwater pond locations must be retained
- Discharge to the stormwater management areas should be through a vegetative filter strip, limited to 5 m in width

6.3.1.3 Stream strategy:

There are 3 types of stream status:

- Fully protected streams in stormwater management areas, which are linked to headwater streams and on which there shall be no on-line ponds
- Streams in stormwater management areas which are not linked to headwater streams and where on-line ponds are permitted, and
- Lowland ephemeral streams, which may be modified or piped

6.3.1.4 Floodplain strategy:

As an underlying principle, as far as practicable, the full existing extent of flood plains should be retained. This achieves a range of objectives including:

- Flood peak attenuation,
- Provision of riparian planting and protection of stream habitat, and
- Protection of streams from channel erosion

6.3.1.5 Impervious coverage assumptions

Impervious coverage assumptions are shown in Table 6-4:

Table 6-4 Typical Impervious Area Assumptions			
Land use type	Coverage range (%)	Additional impervious (%)*	Total impervious area (%)
Flat Bush town centre	80	20	100
Flat Bush neighbourhood centre	80	15	95
Flat Bush Residential 1	35-55	20-25	55-80
Flat Bush Residential 2	40-45	20-25	60-70
Flat Bush countryside transition	15	0-5	15-20
* Additional impervious surfaces include an allowance for driveways, paths and patios			

6.3.1.6 Stormwater management pond considerations

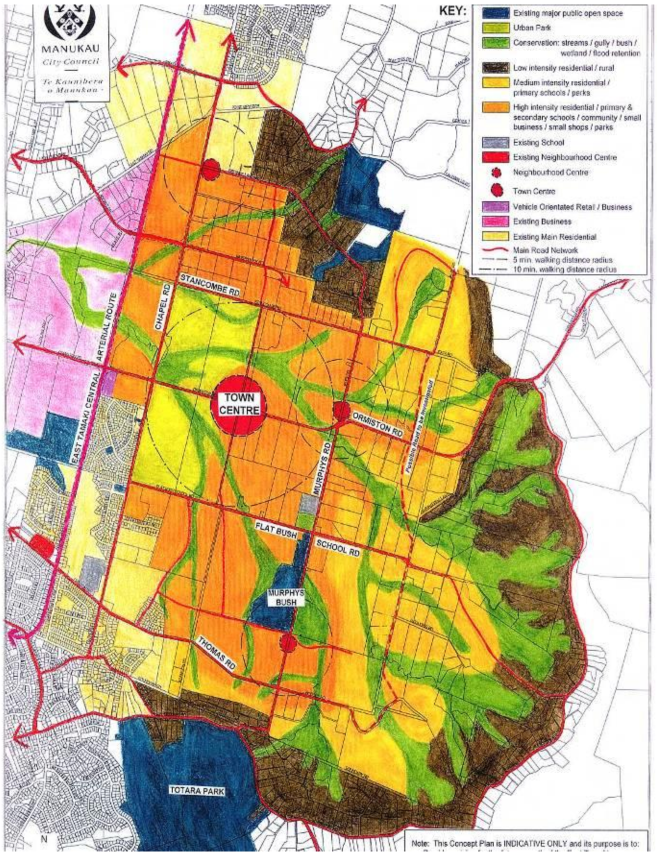
Stormwater management ponds:

Stormwater management ponds are the primary method of management and are designed to achieve three principal objectives:

- Protection of water quality through removal of contaminants by wet ponds, extended detention, filtration and passage through wetlands vegetation,
- Extended detention via release of rainfall from 34.5 mm rainfall over a 24-hour period,
- Attenuation of the 100-year flood at 80% of the predevelopment flood peak.

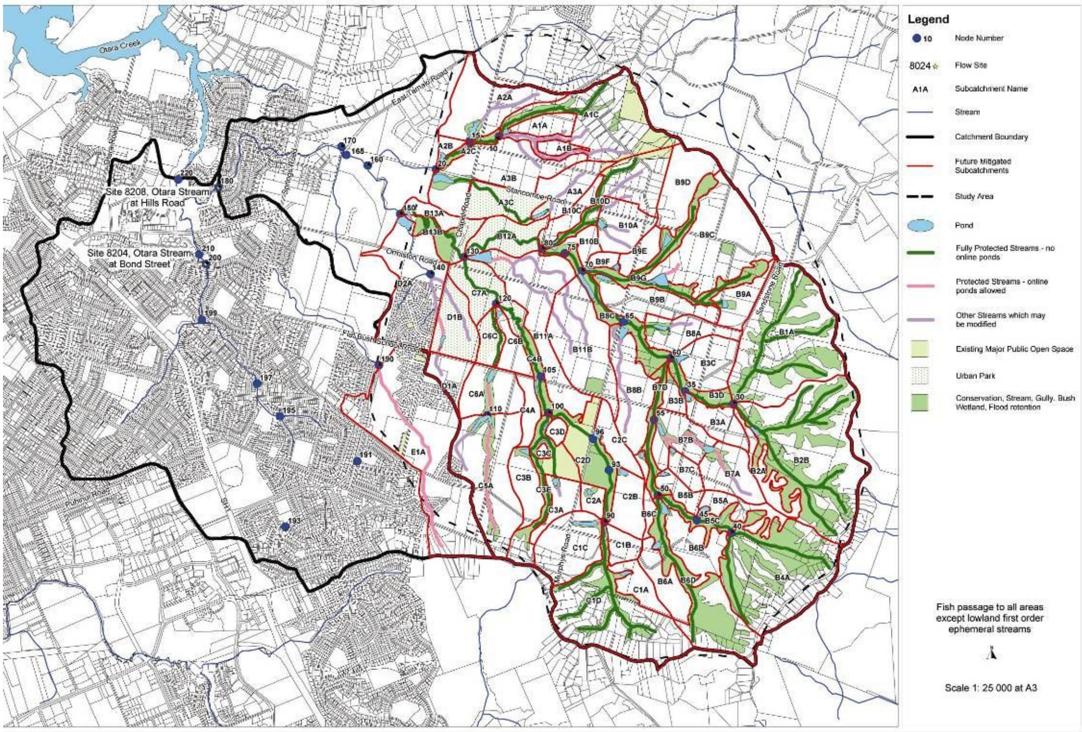
Proposed catchment land use is shown in Figure 6-3.

Figure 6-3
Proposed Catchment Land Use



There are 47 proposed wetlands detailed in the catchment management plan. Those wetlands are shown in Figure 6-4.

Figure 6-4
Location of Stormwater Wetlands in the Catchment

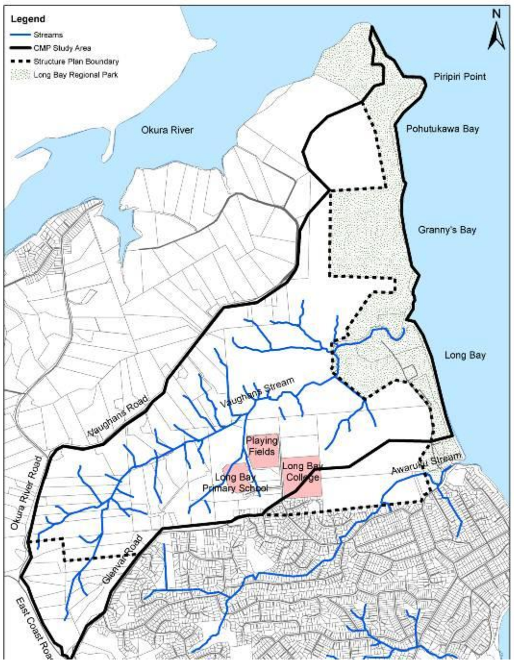


The Flat Bush catchment is being developed at this time.

6.3.2 Long Bay catchment

The Long Bay Catchment boundaries are shown in Figure 6-5.

Figure 6-5
Long Bay Catchment Boundaries

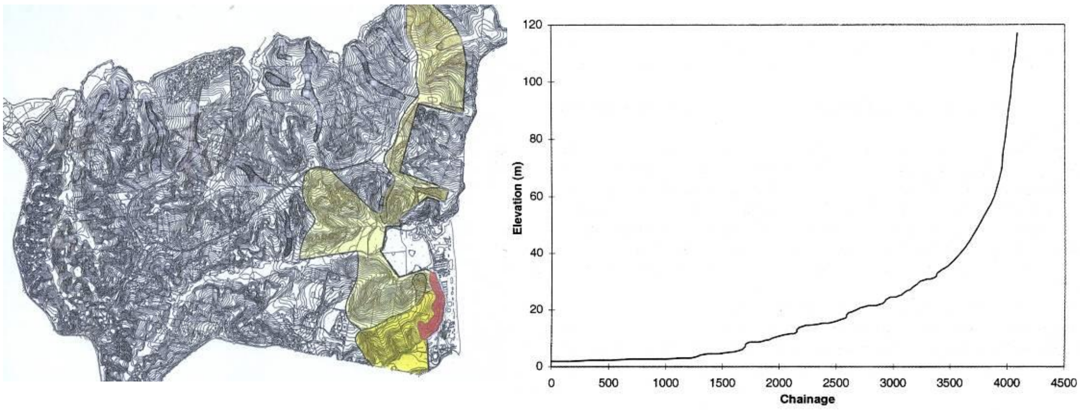


The Long Bay catchment development approach is a more recent evolutionary step in an LID approach to catchment development. The genesis of the approach is based on North Shore City Council (NSCC) desire to allow urbanization to occur in this catchment. The Auckland Region has a Metropolitan Urban Limit (MUL) that reduces sprawl potential outside of accepted urban limits and the NSCC won the right to shift the MUL and allow urbanization by decision of the Environment Court.

Receiving system concerns related to stream channel physical structure protection and water quality impacts to receiving systems (Vaughan's Stream and marine reefs off the coast). The catchment is very steep with geotechnical issues throughout the catchment and there was a major concern that intensification in the headwater areas would cause significant stream stability issues that could not be mitigated for if overall imperviousness was high. Figure 6-6 shows overall catchment topography and stream long sections. As can be seen in the long section, the stream slope becomes very steep as the top of the catchment is approached.

The catchment topography was extremely important in determining an overall

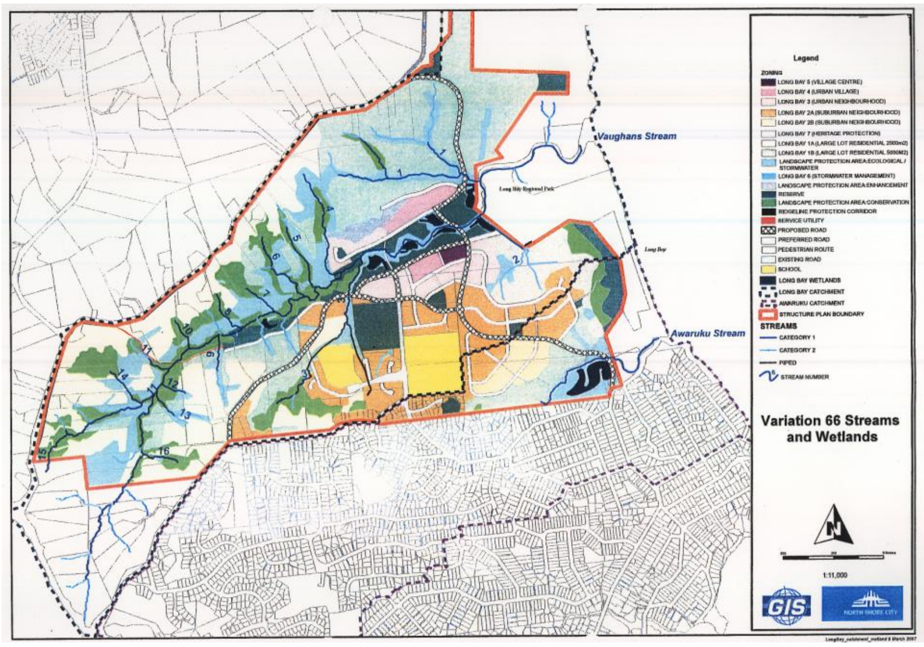
Figure 6-6
Catchment Topography and Stream Long Section



catchment land use as urbanization in the headwater areas was kept to a low level for which mitigation could be provided, while more intensive development was prioritised in the lower catchment where more conventional stormwater management could be implemented.

A key element in protection of streams was their identification and the establishment of riparian corridors around all the perennial streams as shown in Figure 6-7. There was limited stream enclosure proposed in the high intensity development area, but

Figure 6-7
Stream Tributaries and their Associated Riparian Zones



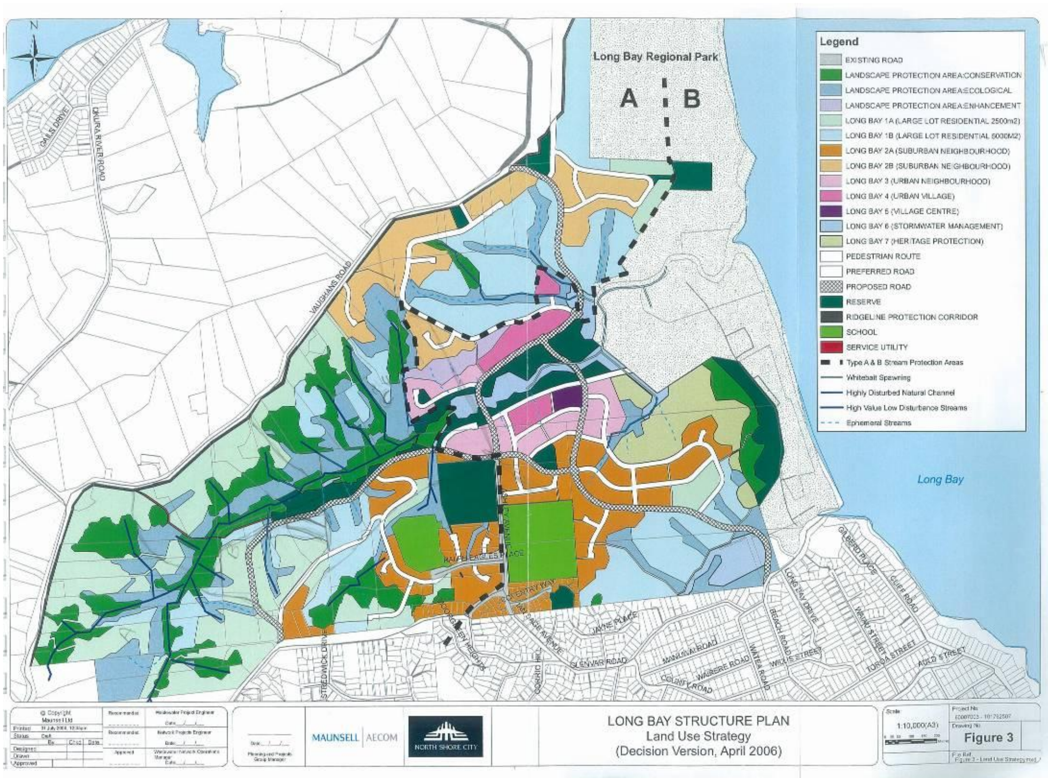
for the most part streams were identified and protected in riparian corridors.

The ultimate land use plan selected for the catchment by NSCC had an interesting approach where NSCC established to zones in the catchment: A and B where Zone A is used to maintain low density urban development to reduce mass earthworks and minimise increased impervious surfaces in that Zone. Streams and watercourses are retained in their natural state in this zone. Maximum impervious surfaces cannot exceed 15% of the site or 500 m^2, whichever is greater and impervious areas are to be fully mitigated by on-site management. Fully mitigated includes managing runoff volumes as far as practicable to predevelopment levels.

Zone B comprises the lower catchment where more conventional stormwater management and higher density development are proposed. The area contains urban neighbourhoods, an urban village and a village centre. Imperviousness will be high in these areas. The stream protection B areas are required to provide a level of on-site treatment in conjunction with off-site measures. These would include primarily rain tanks and off-site wetlands.

The zones and catchment land use are shown in Figure 6-8.

Figure 6-8
Catchment Development Zones and Land Use



Land use in the catchment was the following as shown in Table 6-5.

Table 6-5 Long Bay Land Use Designations	
Long Bay 1 Zone	Minimum site areas

Long Bay 1A	2500 m^2
Long Bay 1B	5000 m^2
Long Bay 2 Zone	Minimum site areas
Long Bay 2A Zone	600 m^2
Long Bay 2B Zone	1000 m^2
Long Bay 3 Zone	
Minimum Net Site Area	220 m^2
Maximum Net Site Area	350 m^2
Long Bay 4 Zone - Urban Village	1500 m^2 (intended for apartment buildings of four stories
Long Bay 5 Zone - Village Centre	1500 m^2 (small scale business, mixed use and apartments)

Table 6-6 shows imperviousness associated with the land use is the following:

Table 6-6
Impervious Percentages for Individual Land Uses

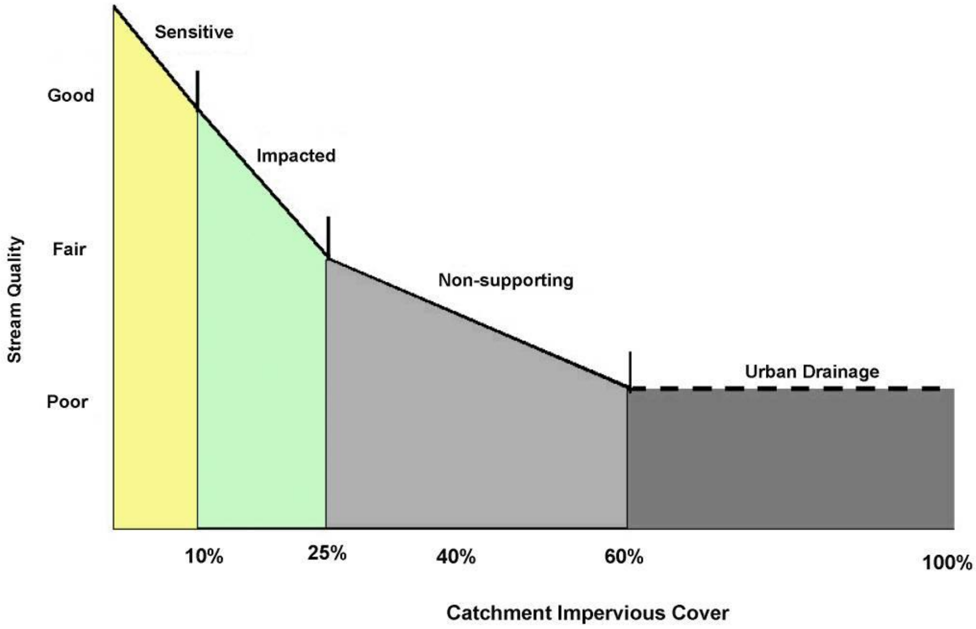
Landuse	Fully developed (ultimate) impervious area percentage
Community Centre (Long Bay 5 Zone)	100%
Community facilities	100%
Urban village (Long Bay 4 Zone)	90%
Urban neighbourhood (Long Bay 3 Zone)	70%
Suburban neighbourhood (Long Bay 2 Zone)	50% (to a maximum of 500 m^2)
Large lot (2500 m^2) (Long Bay 1A Zone)	15% or 500 m^2, whichever is greater
Large lot (5000 m^2) (Long Bay 1B Zone)	15% or 500 m^2, whichever is greater
Landscape protection	0%
Reserve	0%
Ridgeline protection corridor	0%
Stormwater management area	0%
Landscape protection after earthworks	0%
Arterial road reserve	75%
Subdivision road reserve	61%

Another interesting component of the catchment-wide approach was the consideration of effective imperviousness in relation to stream protection. NSCC used international literature to determine stream health if direct connection of impervious surfaces to stream was limited. While the approach has not been proven based on field evaluation, it is a logical approach and one that will provide greater protection to the streams than not having the approach.

Effective imperviousness is based on the concept that stormwater runoff should pass through stormwater management practices such as water tanks, rain gardens, swales, filter strips or wetlands prior to being discharged into streams. This would slow the delivery of water down and reduce adverse effects to the physical structure of streams. The concept is shown in Figure 6-8. As the concept is relatively recent there has been little opportunity to investigate its effectiveness but it is a logical approach.

The Long Bay approach to urban development has several evolutionary aspects that are important in consideration of future catchment management plans.

Figure 6-8
Catchment Imperviousness versus Stream Quality



1. Urban development areas were determined by catchment sensitivities,
2. Streams were considered as important natural features,
3. Natural areas of bush were protected,
4. Water quantity and quality issues were considered on a catchment-wide basis, and
5. Levels of imperviousness, including effective imperviousness, were considered in the context of protection of stream health.

The catchment-wide LID approach taken by NSCC was challenged by a developer and was taken to the Environment Court. The Court affirmed the approach taken by NSCC, which was an important step in verifying that LID was a valid approach to catchment development in other situations.

6.4 Bibliography

Manukau City Council, Flat Bush Catchment Management Implementation Plan, Version A6, June 2004.

North Shore City Council, Long Bay Catchment Management Plan, prepared by Maunsell/Aecom, August 2006.