Chapter 3
Site Resources

Introduction

The site resources 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 benefits.

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 which should be recognised and considered in site development and use. In terms of this Chapter, the following site resources are important due 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 form part of a riparian buffer. In this Chapter, they are discussed individually although their benefits may be, and generally are, cumulative.

Terrestrial Ecology and Landscape Form

It is often said that the three principal economic factors that drive real estate prices are: location, location, 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 detailed in Table 3-1 apply to all site resources.

Table 3-1
Principles to Improve the Quality of Receiving Environments

- 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 naturalness 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)

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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, brid dispersal processes active, level of weeds and pests and outside influrences 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 esturarine 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 Chapter 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).

<u>Representativeness</u>

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 which are good examples of the character of a district or region. Protection of substantial parts of ecosystems are 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.

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 impct. 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).

Generally, the ecological value of a natural area increases with its diversity and the complexity of its ecological patterns

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. The development of ecosystem complexity and function over time can be seen in the following example of transition from a pasture to a mature forested area.

The initial land use of pasture, and a severely degraded wetland is shown in the first picture and is typical of land use conditions for much of New Zealand. The second picture shows an example of regeneration where grasses are replaced by native shrub/scrub vegetation. The second picture shows this process after approximately five years.

This first transition stage tends to be to a fairly simple ecosystem. Changes occur rapidly and little organisation exists. Colonising native plants are typically suited to soil that is low in organic content and fertility, able to withstand harsher conditions, and require direct sunlight to survive.

Typical pasture

Early reversal period to native vegetation

The second pair of pictures provides another time period with the first picture being later in the process than the second picture in the first series. Where the time period in the second picture is approximately five years, the third picture represents approximately a 15 year time period to achieve that level of growth. The fourth picture shows a mature forested area and may take a hundred or more years to achieve the level of growth shown.

Later successional stage

Mature woodland

With the passage of time, distinct clumps or patterns appear. Groups or assemblages of species appear that partition the environment into layers or strata that begin to increase the complexity of the system. The increased complexity is most easily seen by the displacement of grasses and herbaceous plants by woody shrubs and small trees. The organic content of the soil increases as leaf litter builds up and as the vegetation decays.

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.

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<u>Size and Shape</u>

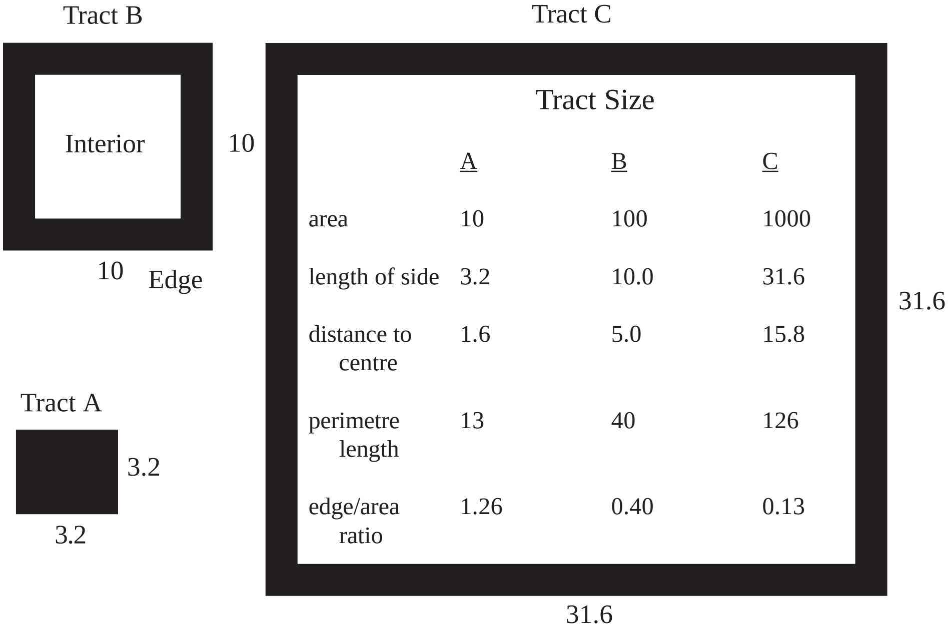
Size and shape of the area affect the long term viability of a natural area’s ecological components and functions. With increase in size, the diversity and resistance to disturbance of an area generally increases. The shape of a natural area influences its resistance to external effects (e.g. a compact 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 natural systems are fragmented by roads and urban development. 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 Auckland 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) as shown in Figure 3-1. 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.

Figure 3-1
Effect of Edge versus Area



Tract Size

	A	B	C
area	10	100	1000
length of side	3.2	10.0	31.6
distance to centre	1.6	5.0	15.8
perimetre length	13	40	126
edge/area ratio	1.26	0.40	0.13

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

Hidden elements and scientific uncertainty

Obviously, we, as stewards for the environment, 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

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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 Auckland 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 50 years. In a few years it is likely that we will look back on how little we knew in 1999. 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.

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.

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There can be few other vegetation classes which 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.

An Example of a Wetland in the Auckland Region

The problem with wetlands is that they are rarely seen as being a valuable resource.

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.

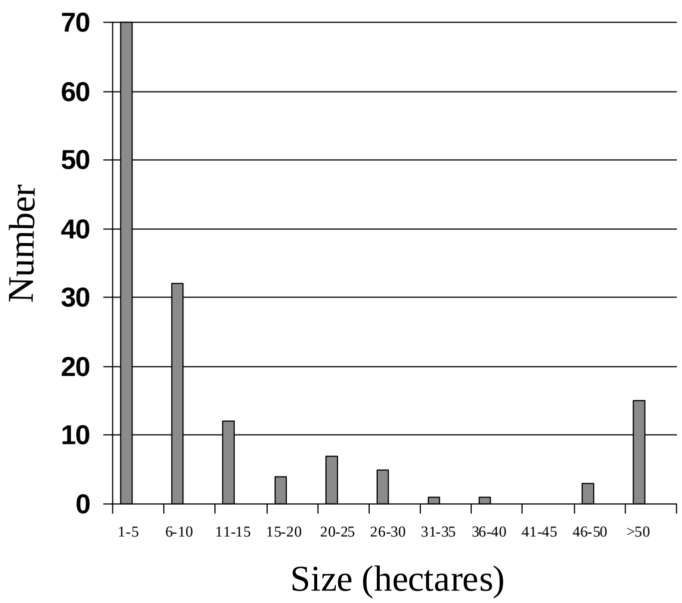
Nationwide, freshwater wetlands covered at least 670,000 hectares before European settlement, but have now been reduced by drainage for pasture to around 100,000 hectares. Although several thousand wetlands still survive, most are very small and have been modified by human activities and invasive species. 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. The Auckland Regional Council, as detailed in Figure 3-2 have done a broad inventory of wetlands in the Region which provides information on how many larger wetland areas are in the Region (Myers, January, 1997). The term "larger" is important here as the survey only identified wetlands whose areal extent exceeds one hectare. There are many wetlands smaller than this size which are not identified. The survey identified 152 wetlands with a total surface area of 2561.67 hectares.

The vast majority of wetlands are in the 1 - 5 hectare size. It is reasonable to expect that there are many more wetlands in the less than one hectare category, but they have not been reported. This is especially true in headwater areas of catchments where wetlands may be present which are very small in extent.

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.

Figure 3-2
Wetlands in the Auckland Region and Their Size Breakdown (Myers, 1997)



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

Table 3-3
Summary of Wetland Functions and Values

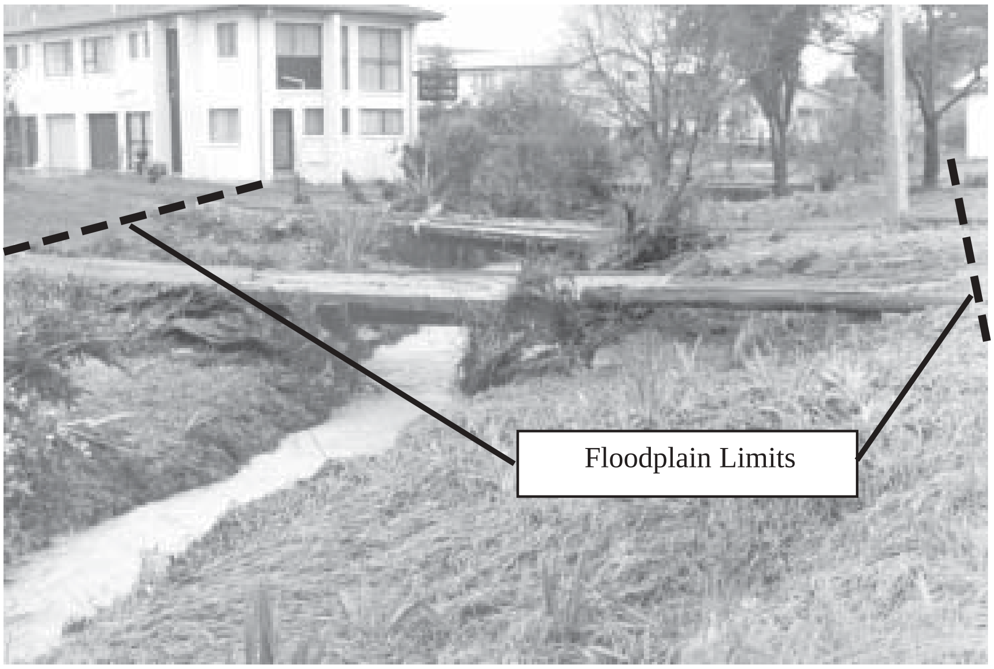
Function/Value	Description
flood control	attenuation of peak flows storage of water absorption by organic soils infiltration to groundwater
Flow augmentation	maintenance of stream flow during drought
Erosion Control	increased channel friction reduction in stream velocity reduction in stream scour channel stability by vegetative roots dissipation of stream energy
Water qualitymaintenance	sedimentation burial of pollutants 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 (koura)
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
- volatilisation

Floodplains

Floodplains occupy those areas adjacent to stream channels which become inundated



Example of a Floodplain Just After Being at Flood Stage

with stormwater during large rainfall/runoff events. For the most part, in the Auckland Region, rainfall 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.

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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. Even drought stricken Auckland was afflicted by flood damage in the midst of its 1994 water supply crisis.

Despite legislative efforts and massive investment in preventive measures, flood losses have continued to rise. The main part of the reason in Auckland is increasing urbanisation. 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.

<u>Catchment size and slope</u>

The abundance of rainfall in the Auckland 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

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 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.

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:

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 pollutants 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 low surface stream flow. Floodplains provide for the temporary storage of floodwaters. If floodplains are 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.

The following Table 3-4 provides values of roughness coefficients that have been established for floodplain areas for the purposes of hydraulic computations 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 value, the greater the retardance to flow.

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Table 3-4
Values of the roughness coefficient n 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.

<u>Living resources</u>

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.

<u>Societal Resources</u>

Floodplains provide areas for active and passive recreational use. They increase open space areas, and provide aesthetic pleasure.

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. Many walkways exist in reserves and those walkways tend to be adjacent to stream channels.

Riparian Buffers

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

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:

- 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.

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- 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 streamflow velocity allowed by straight channels promotes channel incision as erosion of sediment from the stream bottom exceeds the sediment load entering the stream.

Riparian Buffer Adjacent to Stream Boundaries

This process can eventually lead to the development of wide, shallow streams that support fewer species.

- Food webs and species diversity

  The two primary sources of natural food energy input to streams are litterfall 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 which 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.

- Contaminant removal

  Riparian vegetation removes, sequester, or transform 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.

  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, two 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 nearer the stream, 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.

- 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.

- 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 which 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.

Vegetation is essential for stabilising stream banks, especially woody vegetation.

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. The indigenous vegetation is predominantly rainforest, but a variety of other vegetation types exist too, resulting in a diverse range of land-based ecosystems.

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

<u>Stormwater runoff reduction</u>

As discussed in Chapter 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.

<u>Soil structure</u>

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.

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.

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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.

Soils

New Zealand soils can be broadly categorised into three main groupings:

- o Pumice soils which derived from volcanic rhyolite and are widespread in the central plateau and geothermal zone of the North Island.
- o Ash soils which are derived from volcanic basalt and are common in Taranaki, Waikato, parts of Northland and also western Southland.
- o Sedimentary soils which are derived from sandstones, siltstones, and mudstones, and are widespread on plains, rolling hill country and coastal areas.

Despite their diversity, most soils tend to be thin and prone to acidification, with moderate to high carbon levels and low nutrient levels. This is especially true in the Auckland Region, where kauri trees produced deep layers of highly acidic litter, which is implicated in the podzolisation and gleying processes that have contributed to the poor physical properties of many of the Region's soils. A number of other factors besides the warm, humid climate and kauri vegetation contribute to the high degree of chemical and physical weathering of the rocks of the region.

<u>Biological factors influencing soil development</u>

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.

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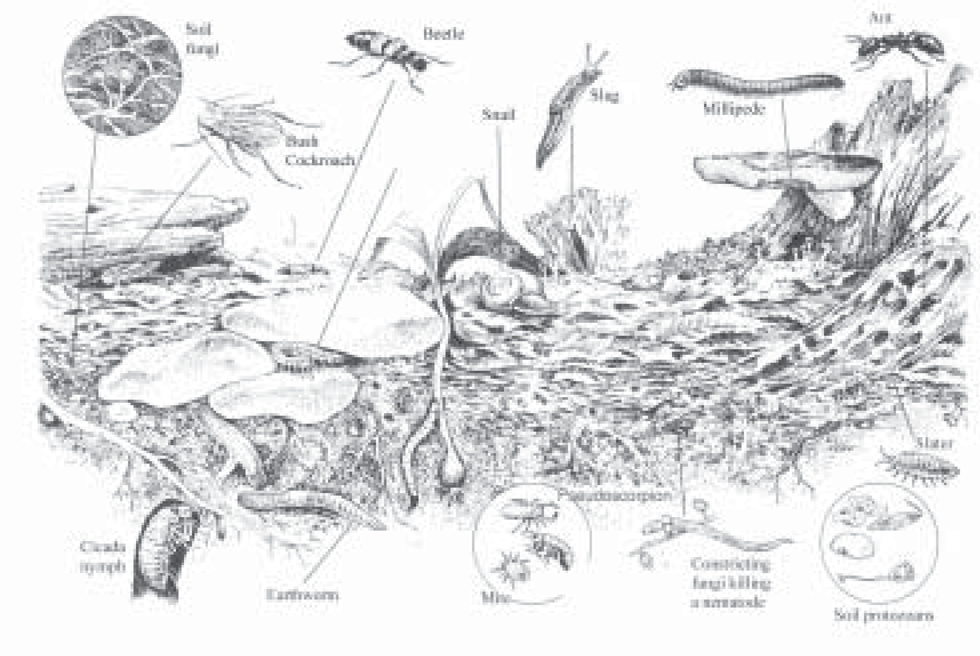
A wide diversity of life is found in the soil as shown in figure 3-3. The number of species of bacteria, fungi, protists, and representatives of nearly every invertebrate phylum found in soil is enormous. It has been estimated that approximately 50% of

Figure 3-3
Associated Soil Life Forms



the earth's biodiversity occurs in soil. Dominant among the soil organisms are bacteria, fungi, protozoans, and nematodes.

Prominent among the larger soil fauna are the 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, 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.

As there is such a strong relationship between the type of vegetation and soils, examples can be given of the type of native vegetation and its associated soil complex.

- Kauri forest tends to be on deeply weathered, clay-rich soils,
- Manuka scrubland on infertile former kauri forest sites
- Kahikatea forest is on fertile wet soils in floodplains
- Broadleaf (taraire/puriri) forests on relatively fertile soils

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.

Without deeper rooted plants holding a slope, in situations where native vegetation has been replaced by grassed lawn, slopes in excess of 33 % (18^{o}) may start to creep

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, 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.

Other Natural Features

There are other natural conditions which 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.

<u>Depression storage</u>

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 estimations for pervious surfaces being between 6 to 12 mm of water and even more on forest land. 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 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.

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 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.

<u>Natural drainage systems</u>

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.

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 which will remain pervious results in significant compaction of those pervious 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. 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 computations which 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 the approved consent should contain a construction requirement that significantly disturbed soils in areas where those soils remain pervious should be chisel plowed. Chisel plowing 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 top soil and prevent slippage of the top soil when on slopes that become saturated.
3. Avoid compaction altogether by keeping equipment out of areas preserved for open space.

The only way that site development can occur in a manner which integrates existing site resources is to identify those site resources present on the site prior to initiation of site design.

Linkage with Site Development

The only way that site development can occur in a manner which 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 Chapter.

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

A checklist should also include:

- archaeological sites
- Iwi 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.

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 pollution contaminants can be eliminated. In such situations, an array of natural pollutant removal processes are 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:

<u>Settling/deposition</u>

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.

To the extent that time can be maximised, more settling can be expected to occur, holding all other factors constant.

<u>Filtering</u>

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 blades 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.

<u>Biological transformation and uptake/utilisation</u>

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.

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 which substantially increase contaminant removal potential above and beyond mitigation being provided by many of the structural stormwater management practices being used around the Auckland Region.

Low impact design techniques offer an array of natural processes and techniques which substantially increase contaminant removal potential above and beyond mitigation being provided by many of the structural stormwater practices being used around the Auckland Region. 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 Chapter 4.

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