Papakura Stream Assessment and Management Study

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1 Executive Summary

The wider Papakura Stream Catchment has come under increasing pressures from intensifying land-use (particularly agricultural) and residential development. For instance, continuous forest cover now only occurs in the upper headwaters of the catchment, with the extent of forest vegetation cover reducing through the course of the Papakura Stream. This is evidenced by the diminishment of the stream corridor and natural habitat within the residential and industrial urban environments of Manurewa and Takanini.

This study was undertaken to quantify and assess the physical characteristics and ecological values of the waterways within the wider Papakura Stream Catchment, and to identify management options and prioritise activities that can maintain / improve the stream water quality and ecological values within that catchment. One of the main objectives of this study was to test the use of a combined River Environment Classification (REC) / Stream Ecological Valuation (SEV) approach to assist with Integrated Catchment Management Plans (ICMPs). While considerable emphasis was placed on the freshwater component of the study, additional avenues of investigation included estuarine and terrestrial ecology (riparian vegetation, avifauna, and herpetofauna), landscape and amenity values, and socio-cultural values.

An analysis of overland flowpaths (flow accumulation model) using LIDAR point source topographical information was used to verify the REC streams. From this, considerable differences were found in both the Papakura Catchment boundary and total stream length calculated using the two methodologies. Consequently, it was demonstrated that LIDAR-based models have potential uses in catchment management planning and reconciling inconsistencies in existing information.

The REC formed the basis for the selection of the 32 SEV sampling sites (comprising six different REC classes) within the Papakura Stream Catchment. These sites represented an appropriate spread within the catchment (upper, mid and lower), across a range of habitat (land-use) types, and included both the main stem and a number of tributaries. Based upon an analysis of all the data, the majority of sites surveyed along the Papakura Stream were found to be of Moderate to Moderate-Low ecological health. Comprehensive water quality testing at the 32 SEV plus 10 additional sites found high levels of nutrients and bacteria, indicating agricultural runoff as an issue throughout the catchment. Nitrate concentrations were relatively high in the urban catchment under dry weather conditions. Cadmium, copper and lead were relatively high at specific sites, while high zinc concentrations were widespread.

Only two SEV sites displayed attributes suggestive of better ecological quality and health, and both were located in the upper catchment area of the main stem, set within mature kanuka forest upstream of the Brookby Quarry and adjacent to mature pine plantations. This suggests that both of these sites (and the stream reaches above and immediately below them) are generally free from the causal factors that degrade the quality and ecological values of the rest of the stream system. The more significant of these causal factors absent from these sites are most likely to be farming practices (fertilizer application, herbicide application, pesticide application, stock pugging the stream banks and overland flows containing bacterial loads), and point source discharges (from either urban or industrial activities and from roads). It also suggests that these two sites have attributes that contribute positively to stream health; the most obvious being the presence of the mature kanuka bush along their riparian margins.

With regards to the estuarine sediment quality, although a wide range of potentially harmful contaminants was detected throughout the sampling site, few were present in concentrations that exceeded either ANZECC or ARC guideline values. Furthermore, the concentrations of common stormwater heavy metals reported in this study were similar to those in previous ARC surveys. Estuarine water quality tests showed *E. coli* concentrations in all samples exceeding the guideline value. This single survey indicates that the source of the recorded contaminants may be the water and sediment discharged from Papakura Stream rather than water and sediment circulating within the harbour.

Three Environmental Management Areas (EMAs) were identified within the Papakura Catchment, based largely on discrete topographical systems of varying geology and valley slope, land-cover and contributing land-use. The Brookby Valley and Alfriston-Ardmore Valley EMAs were located within rural and forested areas of the catchment, while the Takanini Valley EMA largely corresponded to the MUL. A number of factors were investigated to ascertain the potential effects of stormwater quality and quantity on the Papakura Stream and its tributaries within these EMAs, as well as identifying issues and environmental management recommendations accordingly.

It is important to note that the management objectives and recommendation of this report require further evaluation in ICMPs for individual projects, with consideration of district and regional plan policies and objectives, capital and maintenance costs, efficacy, ancillary benefits, environmental effects, and stakeholder buy-in.

2 Background

The Papakura Stream study was initiated by Auckland Regional Council (ARC), Papakura District Council (PDC) and Manukau City Council (MCC) to "*Identify management options and prioritise activities that can maintain / improve the stream water quality, ecological and socio-cultural values and use*". While the emphasis of this study is on freshwater (testing the use of a combined SEV/REC approach to ICMP), additional avenues of investigation included terrestrial ecology (riparian vegetation, avifauna, herpetofauna), landscape and amenity values, and socio-cultural values.

This publication comprises two documents. The first is the Technical Publication which outlines the methodologies, results and discussion, identifies the site values within the catchment, and suggests the ways that these sites can be managed so that the associated values are protected and enhanced. The second document is a map book which visually presents the results of the study. Relevant maps within the map book are referred to throughout this Technical Publication, and as such should be cross-referenced in order to gain a greater appreciation of their implications within a catchment-wide context.

This report includes both technical aspects (in relation to the methodology for the field investigations and the analyses involved in interpreting the data collected) as well as a discussion on management options. The latter should not be construed as representing officially adopted ARC policy.

2.1.1 Catchment Context

The Papakura Stream Catchment is shared between the Manukau City and Papakura District Councils, forming the boundary between the two. The catchment covers an area of approximately 4,100 ha, with a total stream length of approximately 63 kilometres. The land-use within the catchment is predominantly rural, with the urban area being located in the lower catchment. Commercial and native forests are located in the upper catchment, along with the Brookby Quarry operation. While indigenous forest cover is limited, there are two QEII covenants in the mid-catchment.

The geology of the catchment is mainly hard sedimentary rock, with soft sedimentary rock in the mid and lower catchment to the north of the main stream. Smaller areas of volcanic-acidic geology and alluvium also occur within the catchment. The valley-landform is predominantly low gradient, with some medium and high gradient sections in upper tributaries and headwaters.

2.1.2 Landscape Context

The south-east flow of the Papakura Stream towards the Manukau Harbour extends from within the base of the Whitford forest, just north of the rural settlement of Clevedon. The approximate 16 km course of the stream descends over 200 m down to sea level between Clevedon and Manurewa and in so doing experiences significant contrasts in rural-urban environments.

The alignment of the Papakura Stream coincides with the juxtaposition of a series of geological fault lines, which largely account for the elevated ridgelines associated with its catchment boundaries. In its rural upper valley, the main stream is largely contained between parallel south-west/north-east ridgelines in the vicinity of Clevedon and Brookby. The southern ridge above Clevedon forms the watershed between the neighbouring catchment of the Wairoa River, which flows in an opposite north-east direction into the Hauraki Gulf.

In its mid-reaches, the Papakura Stream valley shallows and broadens into extensive productive flatlands in the vicinity of Ardmore in the south-east, whilst the landform remains elevated to the north, coincident with the Drury fault line. The course of the Papakura Stream largely meanders along the base of this northern hillside face, which is being rapidly developed for new housing on the outskirts of Manurewa, to the east of SH1.

The lower reaches of the Papakura Stream pass through a mix of residential and industrial development before entering the Manukau Harbour via the Pahurehure Inlet - in close proximity to a local golf course.

Although no outstanding landscapes have been identified within the Papakura Stream Catchment by the ARC Regional Growth Strategy Landscape Assessment (Plan Change 8, 2005), outstanding landscape values have been attributed to the wider Maraetai Hills Forest and adjacent Clevedon Scenic Reserve. The scenic qualities of the elevated hillsides to the north of the catchment are also recognised by both the ARC and also MCC in their identification of landscape sensitivity in this area.

2.1.3 Ecological Context

The Papakura Catchment spans both the Hunua and Manukau Ecological Districts, the boundaries between the two being largely determined by topography, associated with the configuration of geological fault lines in this area. Approximately one third of the catchment at the upper eastern end falls within the Hunua Ecological District. Much of the district is composed of greywacke and argillite basement rock. The Maraetai Forest is one of a few large native forest blocks now dissociated with the Hunua Forest Ranges. It extends through to the Clevedon fault line at the head of the Papakura Catchment. The original indigenous forest types in this area are based on kauri-taraire-tawa associations. The wildlife values provided by this forest habitat would include the more common native forest birds.

The remainder of the Papakura Stream Catchment falls within the Manukau Ecological District, which is more broadly associated with lowland habitats down to the alluvial Ardmore Flats and Manukau Harbour. Prior to being settled and modified for productive agricultural land-use activities, the area was covered with kahikatea swamp forest which included rimu and kauri (Tyrell *et al.* 1999). There were also extensive flaxlands associated with the course of the Papakura Stream and its tributaries. Much of these original habitats and their associated values have been lost through modern agricultural practices (including land drainage), with few forest remnants remaining.

The Manukau Harbour at the mouth of the Papakura Stream is a significant natural habitat for wildlife in terms of roosting wading bird species.

3 Programme Objectives

The overarching management objectives of Papakura Stream Assessment and Management study were to:

1) Identify existing areas of higher ecological value within the stream system which should be protected from degradation;
2) Identify existing areas of sub-optimal / degraded ecological value; and
3) Identify management options and prioritise activities that can maintain / improve the stream water quality, ecological and socio-cultural values and use.

These objectives were achieved through the ancillary subset of objectives listed below and employing a combination of field, laboratory and desktop (particularly GIS) analyses which incorporated a number of disciplines including ecology (terrestrial, freshwater and estuarine), landscape architecture and geo-spatial.

1) Identifying areas of high ecological value within the stream system which should be protected from degradation;
2) Identifying areas where ecological values are compromised, including the nature of the causal factors and the severity of the problem(s);
3) Characterising the existing stream environments that are compromised and assessing the potential for their enhancement (i.e. improvement and/or restoration).
4) Where applicable, identify distinct sets of restoration options appropriate to each of the identified compromised stream "types".
5) Distinguishing between remedial restoration actions that can be undertaken quickly versus those that are more complicated and hence will take longer.
6) Identifying opportunities to improve ecological corridors (both terrestrial and freshwater).
7) Identifying opportunities for potential improvements to community benefits involving the catchment waterways and stream mouth, including
   - Recreational (including walkway linkages)
   - Visual/amenity (landscape)
   - Socio-cultural.

4 Methodology

4.1 Desktop Investigations

The initial step of this project was to undertake a desktop compilation and assessment of available environmental data relevant to the Papakura Stream Catchment. While database information was incorporated into the investigation analyses, an annotated bibliography was produced summarising all the information gathered from this desktop analysis (see Appendix 1).

4.2 Geographical Information System

A Geographical Information System (GIS) was used to manage, analyse and map the data associated with this project. The GIS software was ESRI ArcGIS 9.2 (ArcView), used in conjunction with the 3D analyst and ArcHydro extensions.

4.2.1 Source Data

Data from various organisations was used for the base mapping and analysis, as follows:

Auckland Regional Council; Roads, streams, aerial photography, cultural heritage places and zones, open space, 2 m regular grid Digital Elevation Model (DEM).

It should be noted a number of corrupt DEM tiles were supplied for the project area and were unusable. The solution to this issue was use of the contour information supplied to fill in the gaps.

Manukau City Council; District Plan zones, open space, open channels, stormwater detention features, flooding, and stormwater reticulation.

Papakura District Council; District Plan zones, open space, open channels, stormwater detention features, flooding and stormwater reticulation.

Boffa Miskell Limited in-house resources; Land Cover Data Base Version 2 (LCDB2), New Zealand River Environment Classification (NZREC) and New Zealand Land Resource Inventory (NZLRI).

4.2.2 Derived Data

The following are the main layers derived or interpreted from the above source data and digitised.

Hillshade: Derived from the 2m DEM supplied by the Auckland Regional Council. Standard 3D analyst tools/processes within ArcView were used to generate this layer.

Potential Stream Barriers (culvert mapping): The streams and roads supplied by the Auckland Regional Council were intersected to provide point locations that were assumed to be a likely location of culverts and therefore potential barriers to fish passage. They were assumed as culverts rather than bridges because of the low water flows. A sample of these locations was validated by field inspection.

Riparian Vegetation: Interpreted from aerial photography and digitised into the GIS.

Sampling Site Locations; The sampling sites were located by using a handheld Global Positional System (GPS) with an approximate accuracy of ±15m, which is significantly better than the accuracy of the stream network provided by the Auckland Regional Council (based on NZMS260 map series with an accuracy of ± 50m).

In some cases the sampling sites in the mapbook (and Appendix 2) may not appear to be located on a stream (e.g. site 18). This is because of the better locational accuracy of the sampling sites from GPS.

Slope Analysis: Derived from the 2 m regular Digital Elevation Model (DEM) supplied by the Auckland Regional Council. Standard 3D analyst tools/processes within ArcView were used to generate this layer.

Urban stormwater network classification: The classification of the piped stormwater network was done based on the same methodology as used in the NZREC classification.

4.2.3 NZREC Validation Based on LIDAR Data

The use of LIDAR to verify NZREC information was outside the scope of this project. However it was considered useful to compare the NZREC data (based on 20 m contours) against the now available LIDAR based 2m Digital Elevation model (DEM).

The LIDAR based model was investigated in order to demonstrate its potential use in catchment management planning and to reconcile inconsistencies in existing information.

The Environmental Systems Research Institute (ESRI) ArcHydro model was used to determine catchment boundaries and stormwater flowpath information using the Auckland Regional Council 2m DEM. A peak flow accumulation of 0.25% was used.

The results of the ArcHydro based model were similar to NZREC. However in the flatter parts of the study area the ArcHydro based model produced significantly different catchment boundary definitions (see Map 1 'Flowpath Analysis'). This is believed to be the result of the LIDAR data having significantly more accurate vertical levels than the NZREC, which uses 20 m contours as the basis for deriving the 3-Dimensional surfaces. As validation, the ArcHydro based model was visually inspected against the hillshade raster to confirm the model interpolation of flowpaths.

Notwithstanding the above, it is emphasized that the LIDAR Flowpath/Catchment model is a draft analysis only. Although it would appear to be a significant improvement on the accuracy of the NZREC, it is indicative only. In order to reproduce the methodology of the NZREC (in position alone) a number of additional processing steps would need to be taken.

4.2.4 GIS Data

In addition to the hardcopy map book, the following digital outputs are supplied:

1. The derived datasets supplied as an ESRI file geodatabase.
2. A complete GIS project as an ESRI ArcReader document (free to view).

4.3 Freshwater

4.3.1 Scope

Freshwater investigations included the following:

- Stream Ecological Valuation (SEV) analyses of stream function, which includes physical habitat quality, fish communities and aquatic macro-invertebrate communities;
- Aquatic plant communities;
- Stream cross-sectional profiles and erosion;
- Identification of barriers to fish passage;
- Stream water quality;
- Stream sediment quality.

All field work was undertaken between March and June 2008.

4.3.2 Selection of Sampling Sites

The River Environment Classification (REC) system groups rivers according to several environmental factors that influence or cause the rivers' physical and ecological characteristics (Snelder *et al.* 2004). Each of the REC's six hierarchical classification levels is defined by one of six controlling factors: climate, source-of-flow, geology, land-cover, network-position and valley-landform (gradient). The similarity among rivers within a class means that REC classes can be used to stratify monitoring sites within a region. As such, the REC formed the basis for the selection of the SEV sampling sites within the Papakura Stream catchment.

Three REC factors were selected for the analysis in this study - geology, valley-landform and land-cover. Of the excluded factors, climate and source-of-flow did not discriminate greatly at the catchment scale, while network-position was addressed adequately via the distribution of selected sites. This gave a total of six stream classes each representing at least 4.9% of stream length. Initially two sampling sites were assigned to each class, which provided good coverage of small classes (one sample site approximately every 1.6km or 2.5% of stream length) but relatively low sampling effort on the larger classes. This level of sampling intensity was then applied to all REC stream classes. The high intensity of sampling was desirable to provide data for the research aspects of the study, in particular the evaluation of variability in SEV scores at the catchment scale.

A total of 32 SEV sites were sampled within the Papakura Stream Catchment (see Map 2 'Site Location Plan'). These sites represent an appropriate geographical spread within the catchment (upper, mid and lower), across a range of habitat (land-use) types, and include both the main stem and a number of tributaries. Site coordinates are provided in Appendix 3.

4.3.3 SEV Methodology

SEV surveys were performed according to Rowe *et al.* (2006). A 50 m reach of the stream was sampled at each of the 32 SEV sites, and parameters relating to hydrology, biogeochemistry, habitat quality and biodiversity were recorded. These included assessments of floodplain and groundwater connectivity, water quality, organic matter input, particle retention, decontamination of pollutants, habitat quality and invertebrate, fish and riparian communities. Assessments involved recording data (i.e. floodplain widths, channel depths/widths, substrate etc) at 10 transects spaced at 5 m intervals (total 50 m); categorizing variables according to descriptors (i.e. 'marginal' dissolved oxygen demand) or according to prevalence (i.e. proportion of various vegetation types); and sampling of in-stream fauna (see section 4.3.4).

Data were analysed using the SEV calculator version 8.2 (Rowe *et al.* 2006). Scores were tabulated and/or graphed to identify trends between sites and to identify key factors responsible for scores. The results obtained from these SEVs were compared against those from high quality reference streams in the Papakura region (the Hay's and Symond's Streams). Scores for these reference sites are available in the calculator (Rowe *et al.* 2006).

4.3.4 Biota

4.3.4.1 Macroinvertebrate Communities

Macroinvertebrate samples were collected following the methodology outlined by Stark *et al.* (2001). One composite sample was collected per site, using Protocol C2 (soft-bottomed, semi-quantitative). Processing of the samples followed Protocol P1, while Quality Control followed Protocol QC1. Stark & Maxted (2007) was followed with regards to assessing the Macroinvertebrate Community Index (MCI).

4.3.4.2 Fish

Where practicable, fish were sampled using a backpack electro-fishing machine. At each site, approximately 30 m^2 of habitat was surveyed during a single pass. At those sites where the stream was too deep (>1m) to permit electro-fishing, eight box traps baited with burley pellets and marmite and two unbaited fyke nets were deployed overnight. All traps were checked the day following deployment. In all instances, captured fish were identified, measured, counted and released.

Further information regarding the distribution of fish species previously recorded in the Papakura Stream Catchment was collected from records in the New Zealand Freshwater Fish database (held by NIWA).

4.3.4.3 Macrophytes

Macrophyte abundance was assessed by estimating the percentage of stream bed cover of submerged and emergent macrophytes at each SEV sampling site. This involved recording the presence/absence of each group at 0%, 25%, 50%, 75% and 100% of stream width at each of the 10 transects spaced at 5m intervals.

4.3.5 Stream Cross-sectional Profiles and Erosion

A representative cross sectional profile was recorded at each SEV site. This was done by measuring vertical distance from a horizontal datum at regular intervals across the stream. Estimates were made at sample sites that were not wadeable.

Bank erosion was assessed by estimating the proportion of eroded bank within each 50 m SEV reach. At each of the 10 transects spaced at 5 m intervals, erosion on each bank was categorized according to the following scale:

- Low: <10% of bank length affected by erosion
- Moderate: 11-60% of bank length affected by erosion
- High: >60% of bank length affected by erosion

The prevalence of different erosion types ('bank failure' (slumps and cracks), 'bank undercutting', 'surficial' or 'no erosion' was also recorded according to the above scale.

4.3.6 Stream Water Quality

Water quality samples were collected from a total of 42 sites, made up of the 32 SEV sites (labeled 1–32) plus an additional 10 sites (labeled A–I) of special interest (such as point source discharges) (see Map 2 'Site Location Plan'). Three water quality runs were conducted, comprising of one dry run and two wet runs. The dry weather run was undertaken after 72 hours of no rain, while the wet weather runs were undertaken following a >10mm rainfall event within a 24 hour period. All water quality samples for each run were collected on the same day.

A total of 17 parameters were measured during each of the water quality surveys, and were consistent with those parameters measured by the ARC in their regional monitoring program (as identified in Table 3 of TP 327). These parameters were measured either using portable meters (water temperature, dissolved oxygen, conductivity, salinity and pH) or by laboratory analyses (coliforms, ammonia, nitrate, nitrite, phosphorus, chloride, biochemical oxygen demand, copper, cadmium, lead, zinc and copper). All samples collected for laboratory analyses were kept cool and transported in chilly bins to Watercare Services Laboratory on the day of collection. Analytical methods and laboratory accreditation are listed in Appendix 4.

The dry weather water quality survey of 42 sites was undertaken on 7 April 2008. The first wet weather run was undertaken on 15 April 2008 and the second on 23 June 2008.

To evaluate this data, an assessment was undertaken based on a system employed by Environment Waikato (Environment Waikato 2008). Values for selected key parameters were classified as Excellent, Satisfactory and Unsatisfactory by comparison with predetermined ranges. Six parameters were assessed, these being dissolved oxygen saturation, pH, ammonia, temperature, total phosphorus and total nitrogen.

An overall site index was also produced based on the number of Unsatisfactory values for the six parameters, with one or no Unsatisfactory scores classified as Good overall water quality, two or three as Poor, and four or more as Very Poor.

Water quality data was further evaluated to identify unusual values and to compare with ANZECC (2000) trigger values for the protection of aquatic ecosystems. Results from both a dry weather survey (7 April 2008) and wet weather survey (15 April 2008) were assessed.

4.3.7 Stream Sediment Quality

Stream sediment sampling was undertaken to determine the possible presence of new (emerging) contaminants in the stream. The selection of a single site in each of the urban (SEV site 2), peri-urban (SEV site 10) and rural (SEV site 21) areas enabled a comparison of each of these land-use zones within the Papakura Stream Catchment (see Map 2 'Site Location Plan'). Due to the extensive suite of parameters to be tested, it was necessary to obtain the services of three laboratories (see Table 1 for parameters tested by each laboratory). Consequently, multiple samples were collected at each of the three sites, with sample collection methods being consistent with the protocols specified by each laboratory. All samples were held on ice and couriered to the laboratories immediately following their collection. All sediment sampling was undertaking on the same day.

Table 1.
Stream sediment parameters tested by individual laboratories.

CSIRO via NIWA	Asure-Quality	Hill Laboratory	
• Nonylphenol	• BDE 47	• Di-n-octyl phthalate	• TOC
• Octylphenol	• BDE 99	• Bis(2-ethylhexyl)phthlate	• Chlorpyrifos
• Estradiol	• BDE 100	• Glyphosphate	• Carbaryl
• Estrone	• BDE 153	• 2,4-D	• Permethrin
• Ethynyl estradiol	• BDE 154	• Terbuthylazine	• Malation
	• BDE 183	• Triclopyr	• Copper
		• Acetochlor	• Lead
		• Isoproturon	• Zinc
		• Diuron	• Cadmium
		• Diazinon	• PAH
		• TPH	

Analytical methods and laboratory accreditation are listed Appendices 5 (Hill Laboratories), 6 (Asure Quality) and 7 (CSIRO).

4.3.8 Fish Passage

Sections of stream containing potential fish passage barriers were identified using GIS analysis to highlight where sections of road crossed streams. A sample of these potential barriers was then surveyed in the field to verify the nature of the structures present. The primary structures identified included culverts (submerged, stepped or perched), weirs and bridges. The potential impairment of native fish passage was assessed using ARC TP131 guidelines.

4.3.9 Stock Access

The access of stock to riparian margins was assessed during both SEV sampling and fish passage verifications. The possibility of stock access to streams was evident from site 4 (on the urban limit) to site 31 (the quarry site). Where possible, observers noted the extent of access (e.g. true left bank), evidence of effects and the identity of stock present (e.g. cattle, sheep, horse). The extent of any fencing present was also noted.

4.4 Estuarine

4.4.1 Scope

The marine receiving environment for the Papakura Stream is the Pahurehure Inlet. The estuarine investigations included:

- Sediment quality;
- Water quality;
- Shellfish contamination; and
- Benthic communities.

Sampling was undertaken at four locations on the afternoon of 13 March 2008 (see Map 2 'Site Location Plan', and Appendix 2: Estuarine Sampling Sites). The results of the sampling, in aggregate, provide an understanding of the current state of the estuarine environment and how it is being influenced by the quality of the stream environment.

4.4.2 Estuarine Sediment Quality

Surface sediment samples (from the top 2cm), weighing approximately 100g, were collected from three areas (approximately 1m apart) within sites Q1 and Q2. The three samples collected from each site were combined to form a composite sample, held on ice and sent to Cawthron Institute for sediment grain size analysis. Additional surface sediment samples were collected in the same manner from the stream mouth (SM), Q1 and Q2, held on ice and sent to Hill Laboratories to test for contaminants (copper, zinc and lead, cadmium, organochlorine pesticides, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and petroleum hydrocarbons). The heavy metals were analysed in both the <63μm and <500μm grain size fraction. Analytical methods are provided on page 7 and 8 of the Hill Laboratories report in Appendix 8.

4.4.3 Estuarine Water Quality

Samples of estuarine water were collected from three sample sites (stream mouth, Q1 and Q2) and tested by Cawthron Institute for the presence of faecal indicator bacteria (faecal coliforms and *Escherichia coli*). Two replicate samples were taken at each site.

The results were compared against the Microbiological Guidelines for Shellfish-Gathering Waters as set out in the New Zealand Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas 2003.

4.4.4 Shellfish Contamination

A single composite sample of 50–100 *Amphibola crenata* (mud snail) were collected from the stream mouth and Q2, stored on ice and sent to Hill Laboratory for analysis of body burden of metals, organochlorine pesticides, PAHs, PCBs, and petroleum hydrocarbons. No shellfish were available to be collected from Q1.

Upon receipt of the samples, in order to remove as much sediment as possible, laboratory staff washed the organisms under running water. Shellfish were shucked, the flesh collected in a small plastic colander, rinsed with deionised water for approximately 1 minute, blotted dry with paper towels to remove excess water and homogenised in a blender.

4.4.5 Benthic Communities

In order to quantitatively assess the epifauna, three replicate 0.25 m^2 quadrats were undertaken at each of the stream mouth, Q1, Q2 and Q3 sites. In addition, three replicate sediment cores (13 cm diameter, 15 cm depth) were collected at the four sample locations. Sediment cores were sieved through a 0.5 mm mesh, and the retained organisms extracted, identified and counted.

4.5 Terrestrial

4.5.1 Scope

Terrestrial investigations included a general characterisation of the terrestrial ecology (avifauna and herpetofauna) of the wider catchment area and an assessment of habitat quality, and observations of riparian communities undertaken at each of the 32 SEV sites.

4.5.2 Herpetofauna

Prior to undertaking field searches for this study, previous distribution records of herpetofauna within the Papakura Stream Catchment were obtained from the Department of Conservation Herpetofauna Database.

Herpetofaunal habitat assessments were conducted at the 32 SEV sites. The assessment was restricted to the area visible from or passed on the way to the SEV site. The area was described as Low, Moderate or High-quality habitat for terrestrial lizards and arboreal geckos. Key determinants of habitat quality were the availability of refugia (e.g. thick, low-lying vegetation, deadwood, corrugated iron) and basking sites for terrestrial lizards; and the availability of suitable tree species for arboreal geckos (e.g. manuka, kanuka, mingimingi, native bush).

Possible terrestrial lizard refuges were searched when encountered in an attempt to locate individuals. Captured lizards were identified and released. Chance lizard encounters outside of the SEV sites were also recorded.

No frog surveys were undertaken due to the absence of suitable habitat for native species.

4.5.3 Avifauna

Prior to undertaking field searches for this study, previous distribution records of the Papakura Stream Catchment avifauna were obtained from the Ornithological Society of New Zealand's Atlas Scheme records (1999-2004).

Birds were then surveyed within the Papakura catchment primarily by 5-minute point counts (two per SEV site) and roaming searches. Counts preceded the commencement of SEVs and were typically conducted at a spacing of 200 m, adjacent to the stream bank. All species heard or seen within the 5-minute period were noted, including those seen traversing overhead. Double counting was avoided by appropriately spacing counts and disregarding individuals that had obviously been previously surveyed.

The duration of each SEV averaged approximately two hours. During this period any birds not recorded during 5-minute counts were noted by the same observer. This combination provided a good balance between obtaining fixed quantitative data and taking an inventory of species present at each site. In addition to these methods, any unusual or noteworthy sightings obtained while traversing the catchment were also recorded.

The nature of the available habitat was also characterised to determine the sites overall habitat quality and to gauge the likelihood of the area supporting other avian inhabitants. Habitat quality was judged on the basis of factors such as food availability (e.g. fruiting trees, ground cover characteristics), presence of nests or suitable nest sites, habitat linkages with nearby areas, and vegetation matrix (e.g. dense, open).

Three scores were used to characterise the bird community at each site. Both the Total Species Number (including introduced species) and Total Native Species Number were taken from the species noted during point counts and roaming searches at each site. The diversity at each site was characterised using the Shannon Index of Diversity, which was calculated using the combined totals from the two point counts. This index identifies communities that are similar based on both the diversity of species present (including introduced species) and the population abundance of each species. Communities with greater numbers of species will score higher, as will populations that have an even abundance of representatives across species. The overall rating for each SEV site (Good, Moderate, Poor) is a direct reflection of the site's diversity score. Although the rating only reflects relative community health for each site within the catchment, it also provides a good indication of each site's habitat quality in a more general sense.

4.6 Stormwater

4.6.1 Scope

A broad scale assessment of hydrology in the Papakura Catchment was undertaken through extensive desktop compilation and GIS based analysis. This included potential impacts on stormwater quality and quantity arising from land-use activities in the catchment. Verification occurred through targeted field visits, SEV and water quality testing.

The purpose of these assessments was to describe stormwater sources, methods of conveyance and detention, and the nature of outfalls to the receiving environment or main stem of the Papakura Stream channel.

4.6.2 Desktop Analyses

Stormwater related issues were recognised from previous studies, with particular reference to the Papakura flood management study (Beca Carter Hollings & Ferner Limited 1993) and water quality baseline information from the ARC long-term monitoring.

Drainage patterns were described using GIS datasets made available by PDC, MCC and ARC. Information layers included sub-catchment boundaries, land-use activity, open space, streams and open channels, stormwater detention features, flooding, stormwater reticulation, and network consents and discharges. Further information was inferred from land-use capability, slope analysis, erosion, and drainage layers from Land Environments New Zealand (LENZ). Minor digitization supplemented any incomplete datasets, utilizing cadastral, hillshade analysis and aerial photography as base information.

The hydrological patterns and preliminary stream characterization for the Papakura Catchment was based on the REC system. The REC was also interrogated for valley-landform using LIDAR slope analysis, and for land-cover using additional digitization of vegetation from aerial photographs and field verification.

Drainage patterns within the metropolitan urban limit (MUL) were also adjusted to take account of reticulated stormwater systems. Reticulated systems extend outside the catchment boundaries of overland flowpaths through underground pipes, culverts and dedicated overland flowpaths.

4.6.3 GIS Analyses – Environmental Management

Environmental Management Areas (EMAs) were derived from grouping of REC stream classifications (based on land-cover and valley gradient), dominant landscape typologies based on derived landscape units, and the dominant contributing land-use.

Based on these criteria, the study discerned three EMAs: two within the predominantly rural areas of the catchment and a third encompassing the urban section (roughly equivalent to the MUL). The rural catchments were investigated by slope analysis, existing vegetation cover and the related erosion potential. Specific land-uses were also identified to ascertain the potential effects of stormwater quality and quantity on the Papakura Stream and its tributaries, and to identify issues and environmental management recommendations accordingly.

Within the urban EMA, sub-catchments were defined according to the extent of reticulation (pipe networks). These pipes were classified according to open or closed systems, along with pipe diameter, to reveal the character and pattern of flow within the urban hydrology. Subsequently, this pipe information was overlaid with district planning provisions/land-use categories to determine where overland flowpaths and/or pipes coincided with institutional, transportation (road and rail), or public open space. This approach was used to reveal where opportunities exist for stormwater treatment utilising surface watercourses, wetlands and low impact design approaches.

4.6.4 Field Verification

As described above, site visits conducted for SEV, water quality and culvert surveys provided verification of flow accumulation within the catchment. In addition, a more detailed assessment of erosion was conducted at each SEV site (as detailed in Section 4.3.5). The land-use adjacent to watercourses and in-stream modification was recorded during SEV surveys. This information provided 'snapshots' of representative locations in the catchment to interpret existing and likely contamination sources of stormwater and in-stream flows.

Ten water quality sampling sites were selected and used to augment the 32 SEV sites. These additional water quality sites were located downstream of stormwater outlets in the MUL, and within REC tributaries that were unrepresented by SEV sites. Furthermore, these water quality sampling sites occurred downstream of the 'zone of mixing' (determined to be 30 m, or a minimum of 10 times the width of the stream) and in areas that were readily accessible and recognizable for repeat testing.

4.6.5 Broadscale Assessment to Inform ICMPs

The intention of this current study was to provide broadscale assessment of potential stormwater contamination issues and therefore to inform a further level of analysis to be undertaken for integrated catchment management plans (ICMPs). Hydrologic modeling investigates the overland flow and pipe system dynamics of individual sub-catchments, providing for their existing capacities and drainage efficiencies associated with existing and future development scenarios. This is provided for in the report

‘Papakura Stream Flood Hazard Mapping’, currently being prepared by OPUS and DHI in coincidence with the Papakura Stream Assessment and Management Study.

ICMPs prepared by individual territorial authorities, to follow these baseline reports, would augment information through public consultation, a ‘stream walk’ for at least all of the main reach and second order tributaries, and hydrologic and hydraulic investigations utilizing stormwater modeling tools. Public consultation would provide additional anecdotal evidence as well as pinpointing specific areas of public concern to provide for wider community objectives. Engagement could extend to catchment residents through surveys, and/or be directed to ratepayer groups and protection societies.

ICMPs would also benefit from the assessment of groundwater flow to determine drainage potential within the catchment and, if applicable, ‘breakout areas’ from aquifers. The water quality results and broadscale assessment of sub-catchments presented in this report may require further analysis in ICMPs by way of impervious percentage modeling or up-pipe water quality sampling to pinpoint potential sources of contamination.

The environmental management objectives and recommendation of this report (refer to Section 6) require further evaluation through the ICMP process with consideration of efficacy, planning provisions, costs, ancillary benefits, environmental effects, and stakeholder perspectives. In addition, project selection could consider coincident project work to combine construction costs and prioritise aging infrastructure.

4.7 Landscape, Socio-cultural and Heritage

4.7.1 Scope

Information regarding the landscape, socio-cultural and heritage values were compiled in order to understand and identify the current issues influencing the future management of the Papakura Stream Catchment at a landscape scale.

4.7.2 Landscape Analysis and Mapping

The landscape and terrestrial ecological values of the Papakura Stream Catchment were established using a combination of desktop and field verification methods. Following a detailed review and interrogation of available GIS mapping layers, a series of eight Landscape Units were identified from within the catchment boundaries, taking account of the wider context. Physical factors such as topography, geology, hydrology and land-cover have informed the preliminary delineation of landscape areas in addition to land-use and settlement patterns in relation to the Papakura Catchment.

These component landscape units were subsequently ground proofed through field investigations focused on representative sites for individual stream sections, which include the SEV monitoring sites. At the same time, these field observations were used to record the relative extent and types of vegetation cover in relation to the Papakura Stream, in combination with digital mapping from aerial photographs.

Social-cultural and heritage values have been largely determined by desktop investigations involving ARC databases, representative mapping and background reports.

5 Results and Discussion

5.1 Freshwater

Comparative calculations of total stream lengths were made using the NZREC classification, the LIDAR flowpath analysis and the ARC stream data (which is based on the NZSM 260), for the Papakura Stream catchment areas identified by the NZREC and LIDAR methodology (Table 2).

Table 2.

Total stream lengths within the Papakura Catchment based on using NZREC, LIDAR and NZMS 260 data.

Data set	LIDAR boundary	NZREC boundary
NZREC	78.06 km	62.41 km
LIDAR flowpath	121.13 km	90.70 km
NZMS 260	93.00 km	82.12 km

Summary data and ratings for all parameters measured at each site (SEV, water quality and estuarine) are provided in Appendix 2. A photo of each site is included, along with a catchment map and aerial photograph.

5.1.1 SEV

Details of SEV calculations and scores for each site are provided in Appendix 9. Overall SEV scores were similar within the catchment, ranging from 0.29–0.71 (mean = 0.49) (Table 3). According to Rowe *et al.* (2006), scores from 0–0.4 represent streams of low functional value, 0.4–0.8 represent streams of medium functional value, and >0.8 represent streams of high functional value. Under this system, all SEV sites were of medium value, except for sites 16, 18 and 19 (all tributaries) which were low value (range = 0.29–0.36) (see Map 3 'Overall SEV Ratings at Sampled Sites'). The highest scoring sites were 28, 31, 32, and 23 (range = 0.63–0.71). These sites typically had a high dissolved oxygen availability, high canopy cover, high water quality and desirable physical habitat characteristics. There were no obvious trends in any of the functions and distance upstream. However, habitat provision and biodiversity functions were generally lower on the tributaries than on the main stem.

Overall functional class scores were generally much lower than at the Papakura reference sites (see Table 3, Appendix 2 and Figure 1). Hydraulic and biogeochemical functions were generally relatively high (Figures 2 and 3), habitat provision functions were moderate (Figure 4), and biodiversity functions were poor (Figure 5). Factors contributing to relatively high hydraulic scores included low levels of catchment imperviousness, few dispersal barriers and high channel naturalness. However, mean scores were reduced by variations in floodplain connectivity between sites.

Factors contributing to relatively high biogeochemical scores included high retention of in-stream debris, low velocities and high macrophyte densities. However, it is noted that high macrophyte densities may reduce the ecological value of streams, and the high score observed here may reflect the lack of a 'cut-off' point in the SEV calculator after which scores decrease. Mean biogeochemical scores were reduced by low dissolved oxygen availability, high variability in floodplain connectivity and also canopy cover. Factors contributing to moderate habitat provision functions included generally high quality galaxid spawning grounds, low quality bully spawning grounds, and very poor water quality at most sites. Poor biodiversity function scores reflected a lack of pollution-sensitive macroinvertebrates and suboptimal fish and riparian communities.

Results suggest that the major parameters reducing the ecological value of streams in the Papakura Catchment are low water quality and dissolved oxygen availability, and poor riparian and macroinvertebrate communities.

Table 3.

Summary of 32 Papakura Stream catchment SEV scores

	Minimum	Maximum	Mean	Reference mean
Hydraulic function	0.26	0.82	0.58	0.84
Biogeochemical function	0.39	0.87	0.55	0.89
Habitat provision function	0.11	0.87	0.45	0.88
Biodiversity function	0.13	0.57	0.33	0.98
Overall SEV score	0.29	0.71	0.49	0.90

Phillips *et al.* (2006) undertook SEV surveys at 20 sites in the Papakura District, including four sites on the Papakura Stream all in the lower catchment. Overall SEV scores at test sites (not reference sites) in that study ranged from 0.39 to 0.79, with an average score of 0.54, while the Papakura Stream site scores ranged from 0.39 to 0.56 (average of 0.49). A comparison of these values with those obtained from the current investigation (Table 3) indicates that SEV scores were similar overall, although both the minimum and maximum scores were slightly lower in the latter. A comparison of scores for the three sites located in the same stream sections is provided in Table 4 (Phillips Oakleigh Ave Site 22 was not comparable to any sites within the current study). Function scores varied somewhat but overall SEV scores were similar at two of the sites. In the Boffa Miskell study the concrete-lined channel at Frangipani Ave was scored lower for all functional categories. Differences will be due to differences in specific sampling locations within stream sections, seasonal timing of sampling, and observer bias. Although only tentative conclusions are possible from this limited data set, the results suggest that the SEV assessment is a reasonably robust and repeatable assessment methodology.

Table 4.

Comparison of SEV results from Phillips *et al.* (2006) and the current study for three sites on the Papakura Stream.

	Maphona Road		Phillip St bridge		Frangipani Ave Park	
	Phillips *et al.* (2006)	This study	Phillips *et al.* (2006)	This study	Phillips *et al.* (2006)	This study
	Site 1	Site 3	Site 2	Site 10	Site 4	Site 1
Hydraulic function	0.70	0.71	0.78	0.51	0.73	0.64
Biogeochemical function	0.55	0.44	0.51	0.58	0.62	0.43
Habitat provision function	0.57	0.63	0.58	0.62	0.52	0.23
Biodiversity function	0.25	0.34	0.25	0.39	0.34	0.30
Overall SEV score	0.51	0.54	0.51	0.52	0.56	0.42

Figure 1.

Overall SEV scores at the 32 sites sampled within the Papakura Stream Catchment. Ref = Papakura reference sites from SEV calculator (Reference sites 7, 9, Symonds stream, plus reference site mean value). T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

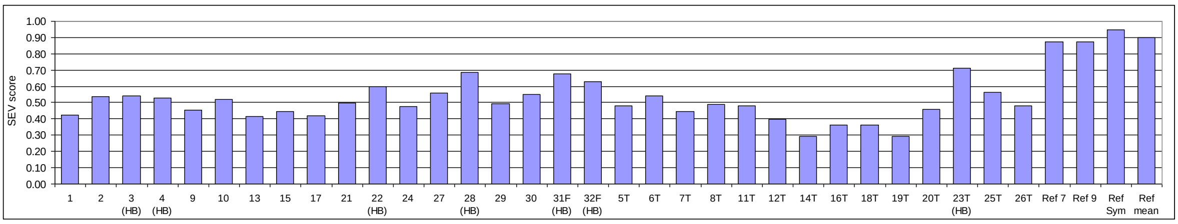


Figure 2.

Hydraulic function scores at the 32 sites sampled within the Papakura Stream Catchment. Ref = Papakura reference sites from SEV calculator (Reference sites 7, 9, Symonds stream, plus reference site mean value). T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

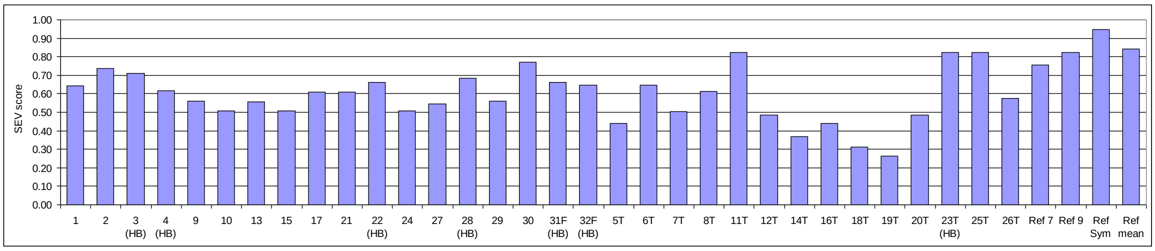


Figure 3.
Biogeochemical function scores at the 32 sites sampled within the Papakura Stream Catchment. Ref = Papakura reference sites from SEV calculator (Reference sites 7, 9, Symonds stream, plus reference site mean value). T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

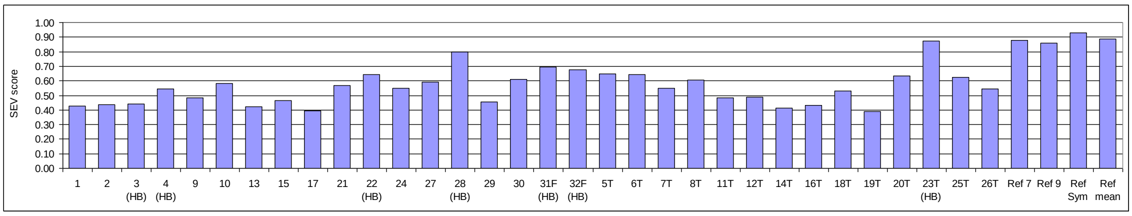


Figure 4.
Habitat provision function scores at the 32 sites sampled within the Papakura Stream Catchment. Ref = Papakura reference sites from SEV calculator (Reference sites 7, 9, Symonds stream, plus reference site mean value). T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

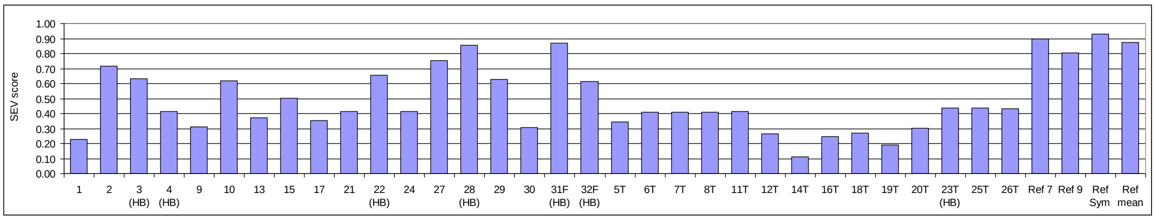
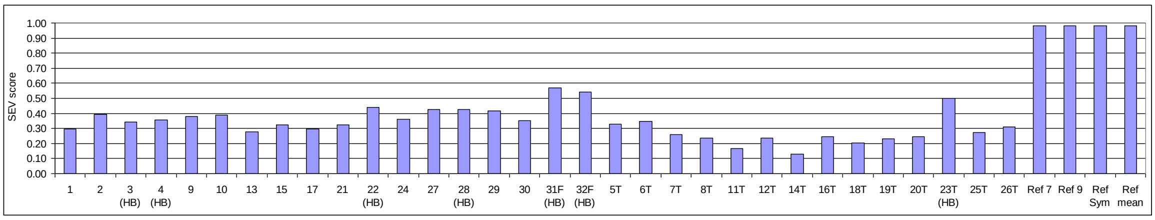


Figure 5.
Biodiversity function scores at the 32 sites sampled within the Papakura Stream Catchment. Ref = Papakura reference sites from SEV calculator (Reference sites 7, 9, Symonds stream, plus reference site mean value). T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).



5.1.2 Biota

While discussed individually in the following sub-sections, Table 5 provides a summary of the biological indices that were measured at each of the SEV sites.

5.1.2.1 Macroinvertebrate Communities

Results of the Quality Control Assessment are provided in Appendix 10. A total of 62 macroinvertebrate taxa were recorded at the 32 SEV sites (Table 6). In the lower main stem, the dominant fauna were snails, with worms and leeches sub-dominant (sites 1 to 4; Figure 6). In the middle main stem (sites 9 to 21) snails were dominant, and amphipods and ostracods (*Crustacea*) sub-dominant. In the upper stream, mayflies and caddisfies were relatively abundant. The tributary sites generally had fewer snails and more worms and leeches, flies and crustaceans, and also more OHC taxa (*Odonata, Hemiptera* and *Coleoptera* – mainly damselflies and water boatmen) (Figure 7).

Most samples had relatively low macroinvertebrate abundance (Figures 8 and 9). Taxonomic richness was also generally low, with only 10 sites having more than 10 taxa, and only four sites having more then 15 taxa (Figure 10). Sensitive EPT (*Ephemeroptera, Plecoptera, Trichoptera*) taxa were only recorded at nine sites (Figures 11 and 12). Macroinvertebrate Community Index (MCI) values were generally very low, with 11 sites scoring less than 60 and only three sites scoring >100 (Figures 13 and 14) (see Map 4 'Macroinvertebrate Values for Each SEV Site').

Sites 8, 18 and 25 had mosquito larvae, indicative of stagnant water. Sites 22, 23 and 27–32 had mayflies, generally indicative of cool, well-oxygenated water.

Table 5.

Summary of Biological Indices measured at the Papakura Stream Catchment SEV Sites

SITE	FISH				MACROINVERTEBARTES		PLANTS % COVER	
	No. of fish spp.	No. of pest fish	Fish IBI score	Fish IBI rating	Taxonomic Richness	MCI	Submerged	Emergent
1	4	1	20	Poor	9	52	56	0
2	5	1	30	Fair	11	42	48	2
3	5	1	30	Fair	6	50	50	0
4	5	0	30	Fair	7	51	82	12
5	2	0	20	Poor	13	63	12	0
6	2	0	28	Fair	9	72	0	0
7	2	1	10	Very Poor	8	85	0	50
8	2	1	10	Very Poor	9	67	0	0
9	5	1	30	Fair	8	44	0	100
10	5	1	30	Fair	5	57	20	0
11	2	0	10	Very Poor	0	65	0	0
12	4	1	14	Very Poor	8	41	0	60
13	3	1	14	Very Poor	0	95	10	80
14	2	0	10	Very Poor	0	67	12	66
15	3	1	24	Poor	8	45	20	54
16	2	1	10	Very Poor	7	84	0	12
17	3	1	24	Poor	6	34	18	36
18	2	1	10	Very Poor	8	44	0	38
19	2	1	10	Very Poor	10	61	0	34
20	3	1	20	Poor	7	57	10	0
21	6	1	40	Good	7	63	90	0
22	3	0	28	Fair	14	94	0	2
23	3	0	32	Fair	19	104	0	0
24	4	0	32	Fair	11	67	70	0
25	0	0	0	No Natives	9	82	0	0
26	1	0	14	Very Poor	11	77	56	28
27	3	0	28	Fair	11	100	14	16
28	2	0	20	Poor	15	88	0	0
29	4	1	36	Good	17	73	36	12
30	3	1	24	Poor	10	65	100	0
31	2	0	22	Poor	21	102	0	0
32	2	0	26	Poor	21	135	0	0

Table 6.

Composition of the total freshwater macroinvertebrate taxa recorded at 32 SEV sites within the Papakura Stream Catchment.

Taxonomic group	Common name	No. of taxa
Ephemeroptera	mayflies	6
Plecoptera	stoneflies	1
Trichoptera	caddisflies	13
Odonata	dragonflies	4
Hemiptera	water bugs	3
Coleoptera	beetles	4
Diptera	true flies	16
Megaloptera	dobsonflies	1
Arachnida	spiders	1
Lepidoptera	moths	1
Crustacea	shrimps, crayfish, hoppers	5
Mollusca	snails and clams	5
Hirudinea	leeches	1
Oligochaeta	worms	1
Total		62

Figure 6.

Macroinvertebrate Community Composition – Main stem. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

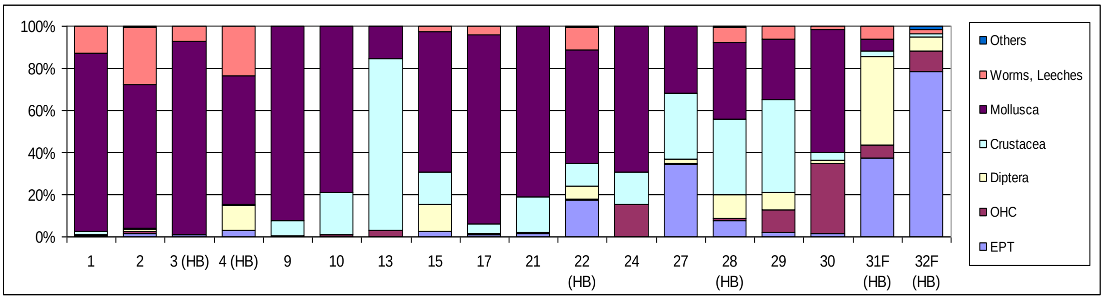


Figure 7.

Macroinvertebrate Community Composition – Tributaries (T).

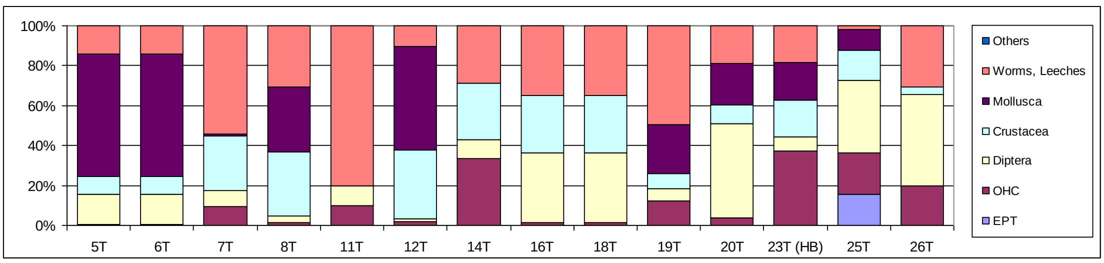


Figure 8.
Total coded abundance. T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

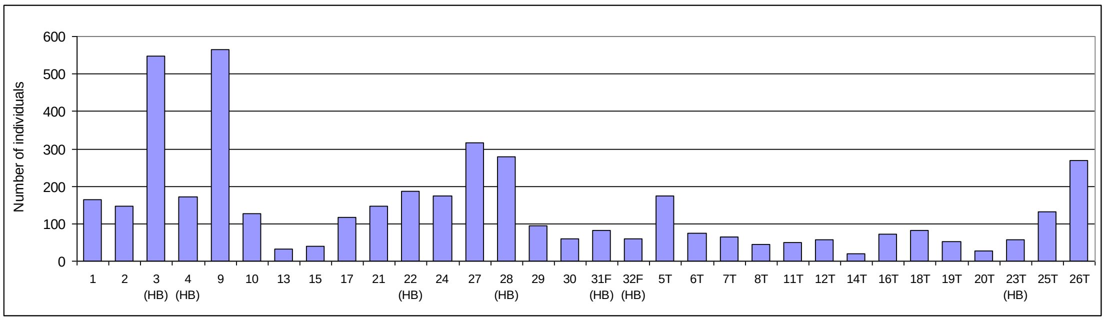


Figure 9.
Number of insect taxa recorded at each site. T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

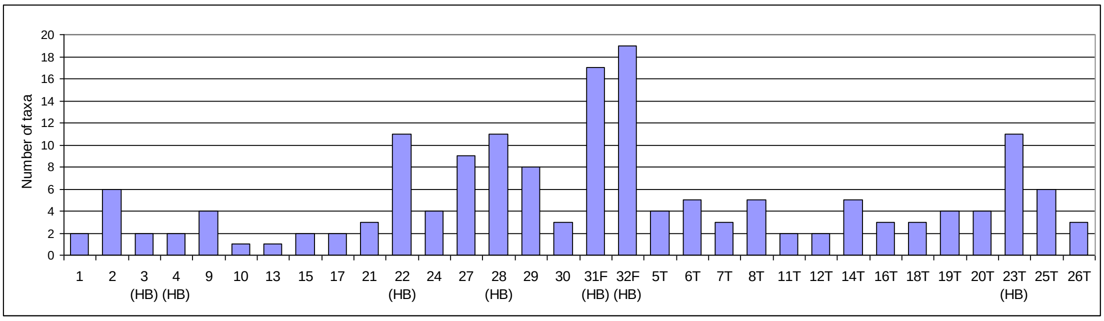


Figure 10.
Taxonomic richness recorded at each site. T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

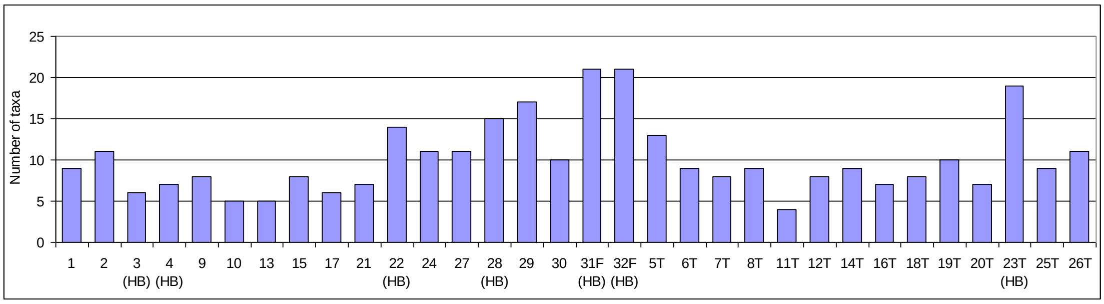


Figure 11.

Number of EPT taxa recorded at each site. T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

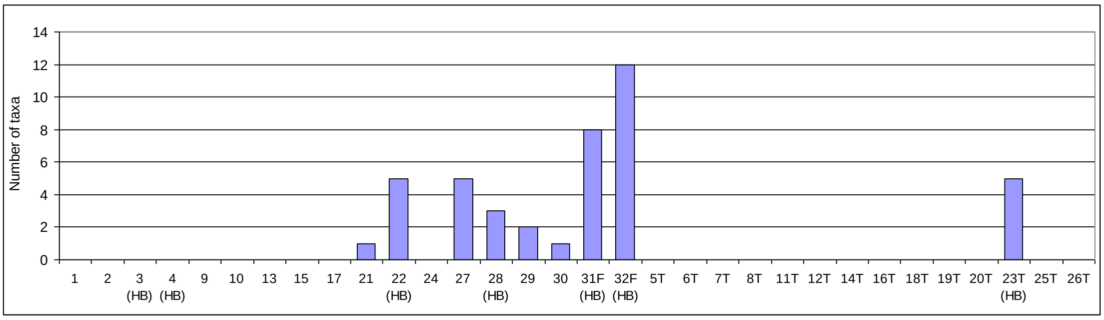


Figure 12.

Percent of EPT abundance recorded at each site. T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

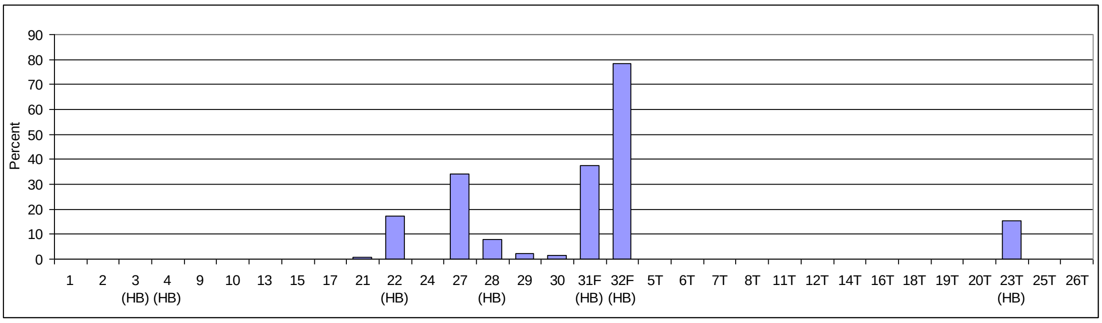


Figure 13.

Macroinvertebrate Community Index score recorded for each site. T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

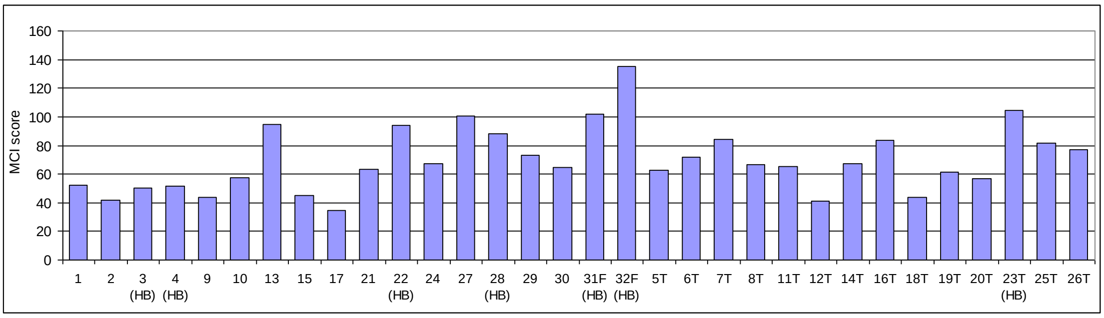
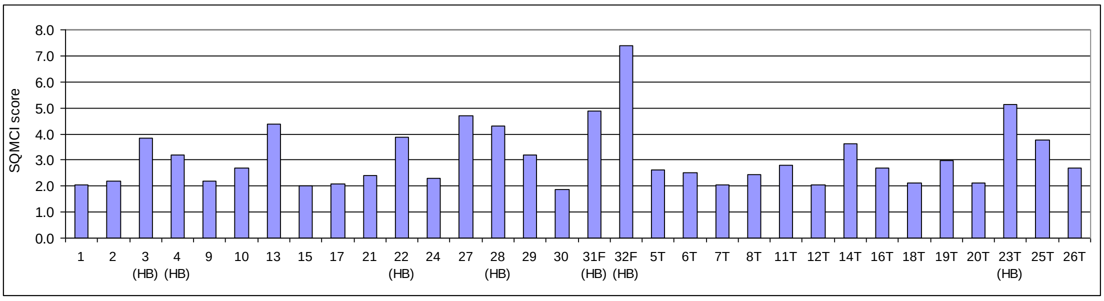


Figure 14.

SQMCI score recorded for each site. T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).



5.1.2.2 Fish

A total of 10 fish species (seven native and three exotic) were recorded in the SEV surveys (Table 7). Shortfin and longfin eels and mosquitofish were the most commonly occurring species, followed by inanga, Cran's and common bullies. Banded kokopu and goldfish were uncommon, and common smelt and brown trout were rare.

An average of three fish species per SEV site was recorded (range = 0–6). The number of species generally declined with distance upstream, and was lower in the tributaries compared to the main stem (Figure 15). Shortfin and longfin eels were recorded throughout the main stem, inanga and mosquitofish in the lower reaches, with all other species being recorded intermittently and not exhibiting any strong longitudinal patterns. Fish IBI scores, which allow for altitude and inland distance (Joy & Henderson 2004), only declined slightly with distance upstream, but were again generally lower in the tributaries (Figure 16). Higher IBI scores were recorded at sites 21 and 29, and in the tributaries at sites 6 and 23. Lower scores were recorded at site 13, and in the tributaries at sites 7, 8, 16, 18, and 19.

Table 7.

Occurrence of fish species sampled from the SEV sites

Species	Common name	Status	No. of sites	% of sites
Anguilla australis	Shortfin eel	Native	26	81
Anguilla dieffenbachii	Longfin eel	Endemic	15	47
Galaxias fasciatus	Banded kokopu	Endemic	4	13
Galaxias maculatus	Inanga	Native	7	22
Gobiomorphus basalis	Cran's bully	Endemic	7	22
Gobiomorphus cotidianus	Common bully	Endemic	9	28
Retropinna retropinna	Common smelt	Endemic	1	3
Carassius auratus	Goldfish	Introduced	4	13
Gambusia affinis	Mosquitofish	Introduced	18	56
Salmo trutta	Brown trout*	Introduced	1	3

*observed only, not confirmed

Most sites were rated as Very Poor, Poor or Fair according to their fish IBI scores, with no sites rated as Very Good or Excellent (Table 8) (see Map 5 'Fish IBI Ratings for Each SEV Site'). The fish IBI scores generally indicated a high level of environmental impact on freshwater fish communities within the Papakura Stream Catchment.

Figure 15

Number of fish species recorded for each site. T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

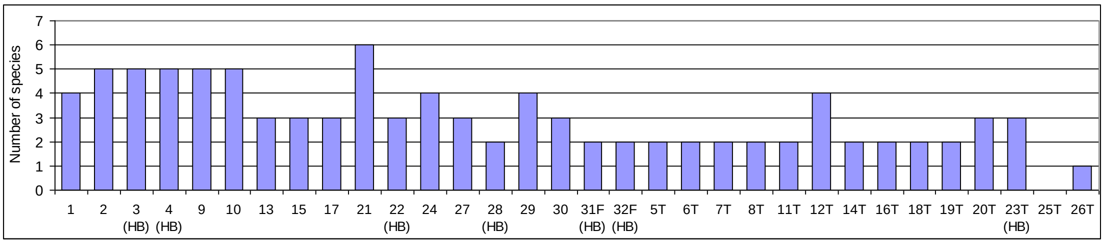


Figure 16

Fish IBI scores for each site. T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).

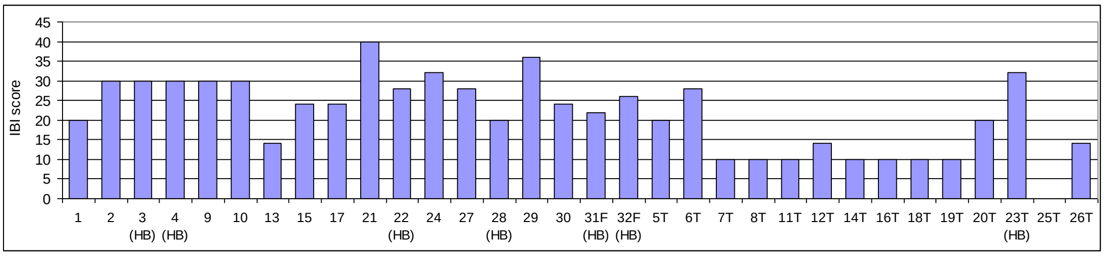


Table 8.

Papakura Catchment Fish IBI Scores and Interpretation

% of sites	Integrity class	Attributes
10	No fish	Site grossly impacted or access non existent.
25	Very Poor	Site impacted or access almost non-existent.
28	Poor	Score is below 50th percentile for Auckland region, site severely impacted
31	Fair	Score above 50th percentile, site significantly impacted.
6	Good	Score above 70th percentile, species richness slightly reduced.
0	Very Good	Score above 90th percentile, species richness slightly less than best in region.
0	Excellent	Score above 97th percentile, comparable to best situations without human disturbance.

Only one pest fish, *Gambusia affinis*, was recorded from the data collected at the SEV sites. This species is widespread in lowland waterways around Auckland.

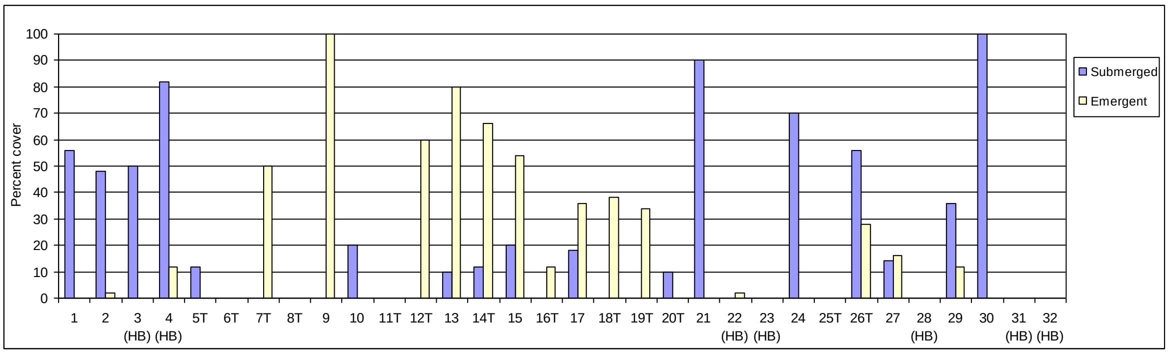
The New Zealand Freshwater Fish Database (NZFFDB) contained 24 site records for streams within the Papakura Stream catchment, including sites in both the lower and upper catchment. Koaro (*Galaxias brevipinnis*) and redfin bully (*Gobiomorphus huttoni*) were recorded in the NZFFDB but were not in the present SEV survey. The full records are presented in the Appendix 11.

5.1.2.3 Macrophytes

The abundance of submerged and emergent macrophytes at SEV sites is presented in Figure 17. Macrophytes were recorded at 24 sites, typically covering >50% of the streambed. Their high prevalence and abundance may reflect the open, nutrient-enriched, soft-bottomed and sluggish nature of most streams within the Papakura Catchment. Indeed, sites with low macrophyte densities were fast-flowing, hard-bottomed and/or well-shaded (sites 22, 23, 28, 31 and 32), or were boggy and grass-choked (sites 6, 8, 11 and 25).

Figure 17

Percent stream bed cover of submerged and emergent macrophytes at SEV sites. T = Tributary site (default is main stem site). F = forest vegetation as defined in the River Environment Classification. (HB) = Hard-Bottomed site, i.e. hard-bottomed sampling protocol used to collect macroinvertebrates (default is soft-bottomed).



5.1.3 Erosion and Sedimentation

Stream channel cross-sections for each SEV site are presented in Appendix 2, along with a summary of the severity of erosion observed at each site. The prevalence of different erosion types across all SEV sites is presented in Table 9. Erosion was highest at sites 12, 16, 18 and 19, where 90–95% of the bank was affected. In total, eight sites suffered from 'High' (>60% of bank affected) levels of erosion, 20 sites from 'Moderate' erosion (11-60% of bank affected), and four sites from 'Low' (<10% of bank affected) erosion (see Map 6 'Overall Erosion at Each SEV Site'). 'Low' scores typically occurred at small streams with poorly defined banks.

Within a given stream, the most commonly recorded erosion category was 'no erosion' (mean = 58%), followed by bank failure (mean = 19%), surficial erosion (mean = 14%), and bank undercutting (mean = 9%) (see Table 9).

The relatively common occurrence of erosion observed here probably reflects concentrated flows during precipitation events associated with clearance of the catchment's vegetation (Beca Carter Hollings & Ferner Ltd 1993). Low levels of stabilizing riparian vegetation and prevalent stock access are also likely to reduce bank stability.

Table 9.

Mean, minimum and maximum prevalence of different erosion types on stream banks at SEV sites.

Erosion type	Mean percentage affected	Minimum percentage affected	Maximum percentage affected
Bank failure	19	0	95
Bank undercutting	9	0	55
Surficial	14	0	95
Total erosion	42	0	95
No erosion	58	5	100

5.1.4 Stream Water Quality

Details of the laboratory water quality results are present in Appendix 4.

The original location of SEV site 11 was found to have low flows during the dry weather water quality run, and as such no sample was obtained. Consequently, an alternative SEV site 11 was sampled in a different reach of the stream but within the same REC class (Airfield Road, GPS co-ordinate 1773861, 5899859) during the first wet weather run. This site was later regarded as not being optimal for undertaking the required SEV work, and as such was moved to the location that is marked as SEV site 11 on Map 2 'Site Location Plan', and was the site at which the second wet weather water quality sample was taken.

5.1.4.1 General characterisation of water quality within the catchment

The results of the single dry weather run were used to obtain an understanding of the typical stream conditions within the Papakura Catchment, from which it was found that the water quality was generally poor. The results of the individual SEV sites water quality samples obtained during the dry weather run are presented in Appendix 2, and on Map 7 'Overall Water Quality at Sampled Sites – Dry Weather Sample'. Nutrient levels were consistently high, with over 80% of sites having Unsatisfactory concentrations of both nitrogen and phosphorus. Dissolved oxygen saturation was Unsatisfactory at 48% of the sampled sites and temperature at 33% of sites. Values for pH and ammonia were both Unsatisfactory at 13% of sites (Table 10). On the basis of the number of Unsatisfactory values for the six key parameters (Table 10), overall site water quality was classified as Good at six sites, Poor at 26 sites, and Very Poor at 10 sites.

Table 10.

Water quality classification and the percentage of survey sites with Excellent, Satisfactory or Unsatisfactory values.

Water quality variable (units)	Relevance	Excellent	Satisfactory	Unsatisfactory	%E	%S	%U
Dissolved oxygen (% of saturation)	Oxygen for aquatic animals to breathe	>90	80–90	<80	40	13	48
pH (acidity)	Can affect plants and fish	7–8	6.5–7 or 8–9	<6.5 or >9	68	20	13
Ammonia (g N/m^3)	Toxic to fish	<0.1	0.1–0.88	>0.88	75	13	13
Temperature (°C)	Fish health (Oct-Apr)	<16	16–20	>20	18	50	33
Total phosphorus (g/m^3)	Causes nuisance plant growth	<0.01	0.01–0.04	>0.04	0	18	83
Total nitrogen (g/m^3)	Causes nuisance plant growth	<0.1	0.1–0.5	>0.5	0	13	88

The following patterns were evident within the Papakura Stream catchment:

- Nitrogen concentrations were high at most sites and satisfactory at the forest and three mid-catchment main stem sites. Agriculture is likely to be the main source of nitrogen.
- Phosphorus was high throughout the stream, including the upper native forest sites, suggesting high natural levels.
- Temperature was generally excellent or satisfactory, except in the lower catchment below site 3, and tributaries at sites 6 and 7. This suggests that shade planting targeted at specific reaches may be sufficient to manage water temperature.
- Low oxygen levels were evident in the mid and upper stream. This may indicate high oxygen demand (caused by enrichment) throughout the stream, which may be off-set at some of the lower catchment sites by macrophyte oxygenation.
- Ammonia levels were relatively high at sites 6, 10, 21, 22 and 25.

High nutrient levels in rural stream water are often indicative of agricultural inputs from animal waste and/or unutilised fertiliser. These unutilised nutrients represent unrealised agricultural production. Upon entering waterways these nutrients are used by aquatic plants. In lakes they can cause algal blooms, in stony streams a proliferation of filamentous algae and in soft-bottomed streams an increase in the biomass of aquatic macrophytes (such as the oxygen weed *Egeria densa*). Aquatic plants were generally not at nuisance levels in the Papakura Stream. It is therefore likely that a significant proportion of the nutrient load is not taken up by aquatic plants and is exported to the Manukau Harbour.

Insufficient dissolved oxygen and extreme water temperatures can stress aquatic fauna and make habitats unsuitable for sensitive species. Water is oxygenated by surface gaseous exchange (especially in turbulent water) and by aquatic plants, which have a net production of oxygen by day and consumption by night. Oxygen is mainly depleted by the respiration of plants at night and by bacteria and other microbes consuming organic matter in the stream. The oxygen-holding capacity of water is also inversely related to water temperature. Sites with low dissolved oxygen are often slow-flowing, warm and nutrient rich. While water velocity is a natural characteristic dependant on stream gradient, water temperature and nutrients are affected by removal of shade vegetation and by agricultural runoff. Results indicate that these are significant issues in many parts of the catchment.

While pH and ammonia were not Unsatisfactory at most sites, these parameters are indicative of potentially more serious water quality issues. While many New Zealand fish are tolerant of a range of pH values (West *et al.* 1997), pH can increase the toxicity of metals and thereby have secondary effects. Furthermore, pH is usually well-buffered in the natural environment so unusual values may indicate other issues. Ammonia is a toxic form of nitrogen often associated with animal wastes. It tends to break down rapidly in the environment, so high concentrations may indicate a concentrated source nearby. Further analysis of water quality results is required at sites with unusual pH or ammonia.

5.1.4.2 Assessment of specific water quality parameters

The results of the water quality data obtained from both the dry and wet weather surveys were evaluated to identify unusual values and to compare with ANZECC (2000) trigger values for the protection of aquatic ecosystems. Each of the analysed parameters is discussed below.

BOD

Streams with BOD levels >5 mg/L are considered polluted (ARC 2004). Only a few sites exceeded this value, with sites 6, 7 and 16 having levels indicating pollution in both the dry and wet surveys (probably indicating a local source of organic pollution).

BOD levels >5 mg/L were recorded at sites 6, 7, 16 and 25 under dry weather conditions. One extreme value of 52 was recorded at site 12.

Under wet weather conditions, values >5 mg/L were recorded at sites 5, 6 and 7 on 15 April, and an elevated value of 88 was recorded at site 16 (the value at site 12 was 3.1). On 23 June, values exceeding the criteria were only recorded at sites 16 and 19.

Chloride

Chloride values at all sites exceeded the ANZECC (2000) trigger value for slightly-moderately degraded systems of 0.003 mg/L. High levels occur in coastal environments, but may indicate the presence of other contaminants in freshwater. The major natural source of chloride is from groundwater, which in the Auckland Region ranges from 17–40 mg/L depending on the geology concerned (ARC 2004). The extreme values recorded at sites A and B and site 1 may be attributed to a saline influence. Apart from one measurement at site 6 (143 mg/L on 7/4/08), all other samples were within the normal range or only moderately elevated.

Chloride ranged from 23 mg/L to 47 mg/L at most sites under dry weather conditions. Higher values were 112 at site 1, 143 at site 6 and 60 at site 8. Extreme values were recorded at sites A (3232) and site B (1978).

Chloride values were generally slightly lower under wet weather conditions. On 15 April concentrations ranged from 13 to 44 at most sites with higher values at site 16 of 66, site 18 of 51 and 819 at site A. On 23 June, values ranged from 17.6 to 41.5 mg/L. Only five sites (11 and 12, and 16, 18, and 19) had values exceeding 25 mg/L.

Ammonia

The ANZECC (2000) trigger level for total ammonia (NH3-N + NH4-N) is 0.9 mg/L. This was exceeded at sites 6 and 25 (both 0.98 mg/L) under dry weather conditions.

Under wet weather conditions on 15 April, the trigger level was exceeded at site 16 (6.3 mg/L) and site 19 (1.3 mg/L). On 23 June most values were under 0.1mg/L, although the trigger was again exceeded at sites 16 (1.6mg/L) and 19 (2.4 mg/L).

Nitrite

Nitrite nitrogen is usually short-lived in the presence of oxygen and therefore indicates a source of nitrogenous waste in the immediate vicinity of the sampling site (ARC 2004).

Concentrations were below the detection limit of 0.002 mg/L at most sites under dry weather conditions, and were slightly above at sites 25, 26 and E.

Most samples were above the detection limit under wet weather conditions. Relatively high values above 0.1mg/L were recorded at sites 16 and 18 on 15 April, while all sites were below this level on 23 June.

Nitrate

Nitrate concentrations were below 1.0 mg/L at most sites under dry weather conditions. Concentrations over 1.0mg/L were recorded at sites 27, 29, A, E, F and H. Concentrations exceeding the updated ANZECC (2000) guideline of 7.2 mg/L were recorded at sites 28 (9.16 mg/L), G (9.89 mg/L) and I (7.91 mg/L).

Under wet conditions on 15 April, concentrations above 1.0 mg/L were recorded at sites 2, 6, 11, 19, 20, 23, 24, C and J., though none exceeded 7.2 mg/L. On 23 June, only three sites had concentrations <1.0 mg/L and none exceeded 7.2 mg/L. Those sites for which the values exceeded 5.0 mg/L were sites 2, 5, 10, 16, and 19.

Under dry weather conditions high levels of nitrate were largely associated with drainage from urban areas in the lower catchment, sometimes exceeding the trigger level for potential toxic effects. Under wet conditions no trigger levels were exceeded and moderately high levels were more widespread in the catchment. Nitrate is not particularly toxic to aquatic life (ARC 2004). The recommended limit for potable water is 10 mg/L and for stock water is 100 mg/L.

Total Nitrogen

Total nitrogen is the combination of nitrate, nitrite and Total Kjeldahl Nitrogen (TKN), and is used to assess the nutrient enrichment or trophic status of waterways. The ANZECC (2000) trigger value for slightly disturbed lowland rivers is 0.614 mg/L.

Concentrations exceeded 0.614 mg/L at most sites under dry weather conditions. Concentrations exceeded 8.0 mg/L at sites 25 (8.36), 28 (9.48), G (10.84) and I (9.46).

Total nitrogen exceeded 0.614 mg/L at most sites under wet conditions. Concentrations exceeded 8.0mg/L at sites 16 (23.23) and 19 (10.55) on 15 April, and sites 16 (9.25) and 19 (10.36) again on 23 June.

Abundant nitrogen was available for plant growth in the streams. High levels occurred in the lower (urbanised) catchment under dry weather conditions. Sites 16 and 19 are located in the same tributary, indicating a high concentration source here under wet weather conditions.

Soluble Reactive Phosphorus

Soluble Reactive Phosphorus (SRP) is the bio-available fraction of phosphorus. The ANZECC guideline for New Zealand lowland rivers is 0.01 mg/L. Note that SRP is also known as Dissolved Reactive Phosphorus and Filterable Reactive Phosphate.

Concentrations exceeded 0.01 mg/L at nearly all sites under dry weather conditions. In addition to being the trigger level, this was also the detection limit. No samples exceeded 0.1 mg/L, the highest being 0.089 mg/L at site 16.

Under wet conditions, concentrations at all sites exceeded 0.01 mg/L on 15 April, and at all but seven sites on 23 June. Concentrations of 0.1 mg/L were exceeded at sites 11, 12, 14, 16 and 19 on 15 April,and at sites 16, 18, and 19 on 23 June.

Total Phosphorus

The ANZECC (2000) guideline for total phosphorus is 0.033 mg/L for lowland rivers, and the average annual concentration indicating eutrophic status for lakes is >0.05 mg/L.

Most samples exceeded 0.05 mg/L under dry conditions, and concentrations of >0.2 mg/L were exceeded at sites 7 (0.423), 8 (0.381), 12 (1.21), 16 (0.477), 18 (0.24), 19 (0.415) and 25 (1.20).

Under wet weather conditions, on 15 April all sites exceeded 0.05mg/L and 15 sites exceeded 0.2 mg/L. The highest values were at sites 16 (4.32) and 19 (1.95). On 23 June, all but one site exceeded 0.05 mg/L, and five sites exceeded 0.2 mg/L. As was the case in the first wet weather run, the highest values were recorded at sites 16 (0.55 mg/L) and 19 (0.795 mg/L).

Suspended solids

Concentrations were less than 10 mg/L at 23 sites, and exceeded 500 mg/L at sites 6 (978), 16 (601), 19 (768) and 25 (576) under dry conditions.

Under wet weather conditions on 15 April, concentrations were <10 mg/L at 12 sites, but only exceeded 500 mg/L at site 19 (523). On 23 June, values <10 mg/L were recorded at nine sites, and values at all sites were below 37 mg/L except for site 25 which recorded a value of 104 mg/L.

Heavy metals

Cadmium concentrations exceeded the ANZECC (2000) trigger level guideline of 0.0002 mg/L at sites 4 and 6 in the dry weather survey, and sites 16 and 19 in the wet survey on 15 April. On 23 June the trigger was exceeded at 13 sites, with values more than an order of magnitude greater than the guideline value being recorded at sites 1 (0.0021 mg/L), 14 (0.0027 mg/L), 24 (0.0029 mg/L) and E (0.0081 mg/L).

Copper concentrations exceeded the ANZECC guideline of 0.0014 mg/L at sites 6, 12, 16 and 19 during the dry survey. In the wet survey on 15 April, this guideline was exceeded at 33 sites, with the highest levels being recorded at sites 3 (0.011 mg/L), 4 (0.013 mg/L), 16 (0.014 mg/L) and 19 (0.016 mg/L). In the wet survey on 23 June, the guideline value was exceeded at all sites, with high values being recorded at sites 14 (0.0053 mg/L), 16 (0.0086 mg/L), 19 (0.0081 mg/L), E (0.0062 mg/L) and G (0.067 mg/L).

Lead concentrations exceeded the ANZECC guideline of 0.0034 mg/L at sites 6 (0.013) and 25 (0.0085) in the dry weather survey, and sites 3 (0.0069), 4 (0.0081), 5 (0.0053), 19 (0.0047) and F (0.0038) in the wet weather survey on 15 April. During the second wet weather survey on 23 June, all sites recorded values below the guideline level.

In the dry weather survey, zinc concentrations exceeded the ANZECC guideline of 0.008mg/L at sites 1, 6, 7, 8, 12, 16, 19, 20, 24, 25, and A–E. Of these sites, the highest value was recorded at site 6 (0.14). Under the wet weather conditions on 15 April the guideline was exceeded at 27 sites, the highest being at site 19 (0.089). On 23 June, the guideline was exceeded at all but three sites, with the values >0.003 mg/L being recorded at sites 1, 3, 16, 18, A, B, and E. Of these sites, the highest value was recorded at site 16 (0.084 mg/L).

E. coli

The Action/Red mode for recreational waters of >550 cfu/100ml (MfE 2002) was exceeded at 29 sites in the dry weather survey, at all sites in the wet weather survey on 15 April, and all but three sites on 23 June. Concentrations were higher in the wet surveys, with the highest values being recorded at sites 7 (237,000), 16 (2,000,000) and 19 (388,000) on 15 April, and at sites 4 (71,000), 16(52,000) and 19 (61,000) on 23 June.

Conclusions

High levels of nutrients and bacteria indicated agricultural runoff was an issue throughout the catchment. Nitrate concentrations were relatively high in the urban catchment under dry weather conditions. Cadmium, copper and lead were relatively high at specific sites. High zinc concentrations were widespread, but were particularly high in the lower catchment. Sites 6, 12, 16, 19, and 25 frequently exceeded water quality guidelines for a range of contaminants. This indicates a specific source of pollution. Examination of aerial photographs indicates that some large buildings are present north of site 19, which may be intensive farming facilities. Follow-up by ARC environmental inspectors may be appropriate. Sites 16 and 19 were located on the same watercourse, indicating a pollution source here. Other high results will also indicate local sources.

5.1.5 Stream Sediment Quality

Full reports from the laboratory analyses of the stream sediment samples are provided in Appendices 5, 6 and 7. The analytes detected in sediment samples collected from the three sites (periurban, rural and urban) reflect the types of landuse in the catchment.

Common metals in stormwater discharges (copper, lead, zinc and cadmium) were detected in low concentrations at all three sites, in both the sediment size fractions analysed (Table 11). As anticipated, given their affinity to bind with fine particles, metals were detected in higher concentrations in the <63µm fraction compared to the <500µm fraction. Concentrations were below ANZECC Interim Sediment Quality Guidelines (ISQG) low trigger levels and below ARC green traffic light threshold at all sites. The concentrations of metals detected constitute approximately 50% of the ISQG low trigger level and 75% of the ARC green threshold.

In the <63 µm fraction, the urban site had the highest concentration of zinc and copper, whereas the periurban site had the highest concentration of lead and the rural site had the highest concentration of cadmium. This pattern was similar for the <500 µm fraction, excluding zinc, which was slightly highest in the rural site.

Table 11.

Concentrations of metals in the urban, periurban and rural stream sediment samples taken from Papakura Stream.

ANALYTE	UNIT	Rural (<63um Fraction)	Periurban (<63um Fraction)	Urban (<63um Fraction)	Rural (<500um Fraction)	Periurban (<500um Fraction)	Urban (<500um Fraction)	ISQG (Low)	ARC Green Threshold
Cadmium	mg/kg dry wt	0.28	0.21	0.25	0.17	0.11	0.11	2	-
Copper	mg/kg dry wt	12	11	14	8.3	6.2	10	65	<20
Lead	mg/kg dry wt	19	23	19	13	15	13	50	<30
Zinc	mg/kg dry wt	89	75	99	67	49	66	200	<125

Herbicides, pesticides, phthlates and total petroleum hydrocarbons were below detection level for the majority of individual analytes (Table 12). Petroleum hydrocarbons between C15 and C36 were measured above detection limits in the urban sample (Table 12). However, the concentration is very low. Some individual PAHs were detected in very low concentrations, with a weak pattern of higher concentrations in samples collected from the urban site (Table 12). However, the concentrations of individual PAHs detected are very low, generally between 3 and 4 orders of magnitude lower than the ANZECC ISQG low trigger concentration.

Polybrominated diphenyl ethers (PBDEs) are organic compounds that are used as flame retardants in a range of products including building materials, electronics, motor vehicles, furnishings, plastics and textiles. Bioaccumulation of these compounds in humans has been linked to reproductive and neurological effects on health. The concentrations detected in samples were very low, but were generally higher in the urban sample (Table 13). However, all sample concentrations were not vastly different from the blank, which can be considered as a background concentration. PBDEs have become ubiquitous in many environments, and the blank sample may have accumulated very low concentrations of these compounds from the reagents, glassware, human handling and the laboratory atmosphere.

Table 12.

Concentrations of hebicides, pesticides, phthlates and total petroleum hydrocarbons in the urban, periurban and rural stream sediment samples taken from Papakura Stream.

ANALYTE	UNIT	RURAL	PERI-URBAN	URBAN
Total Organic Carbon (TOC)	g/100g dry wt	1.6	0.92	1.9
Glyphosphate	mg/kg dry wt	0.7	< 0.040	0.69
Acid herbicide				
2,4-D	mg/kg dry wt	< 0.021	< 0.017	< 0.022
Triclopyr	mg/kg dry wt	< 0.021	0.017	< 0.022
Organonitro & phosphorus pesticides				
Acetochlor	mg/kg dry wt	< 0.014	< 0.011	< 0.014
Carbaryl	mg/kg dry wt	< 0.014	< 0.011	< 0.014
Chlorpyrifos	mg/kg dry wt	< 0.014	< 0.011	< 0.014
Diazinon	mg/kg dry wt	< 0.0069	< 0.0053	< 0.0067
Diuron	mg/kg dry wt	< 0.014	< 0.011	< 0.014
Malation	mg/kg dry wt	< 0.014	< 0.011	< 0.014
Permethrin	mg/kg dry wt	0.14	< 0.0075	< 0.0094
Terbuthylazine	mg/kg dry wt	< 0.0069	< 0.0053	< 0.0067
Polycyclic Aromatic Hydrocarbons (PAH)				
Acenaphthene	mg/kg dry wt	0.0054	< 0.0021	< 0.0025
Acenaphthylene	mg/kg dry wt	< 0.0027	< 0.0021	< 0.0025
Anthracene	mg/kg dry wt	< 0.0027	< 0.0021	< 0.0025
Benzo[a]anthracene	mg/kg dry wt	< 0.0027	< 0.0021	0.0047
Benzo[a]pyrene (BAP)	mg/kg dry wt	< 0.0027	< 0.0021	0.0035
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.0078	0.004	0.0097
Benzo[g,h,i]perylene	mg/kg dry wt	0.0042	0.0029	0.0048
Benzo[k]fluoranthene	mg/kg dry wt	0.0044	0.002	0.0054
Chrysene	mg/kg dry wt	0.0038	0.0022	0.0068
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.0027	< 0.0021	< 0.0025
Fluoranthene	mg/kg dry wt	0.0051	0.0042	0.013
Fluorene	mg/kg dry wt	< 0.0027	< 0.0021	< 0.0025
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	< 0.0027	< 0.0021	0.0025
Naphthalene	mg/kg dry wt	< 0.014	0.029	0.017
Plasticisers				
Bis(2-ethylhexyl)phthlate	mg/kg dry wt	< 0.88	< 0.68	< 0.85
Di-n-octyl phthalate	mg/kg dry wt	< 0.44	< 0.34	< 0.43
Total Petroleum Hydrocarbons				
C7 - C9	mg/kg dry wt	< 13	< 8.9	< 13
C10 - C14	mg/kg dry wt	< 20	< 20	< 20
C15 - C36	mg/kg dry wt	< 30	< 30	37
Total hydrocarbons (C7-C36)	mg/kg dry wt	< 60	< 60	< 60

Table 13.

Concentrations of plybrominated diphenyl ethers (PBDEs) in the urban, periurban and rural stream sediment samples taken from Papakura Stream. (ND = not detected)

	Rural (ng/g)	Peri-urban (ng/g)	Urban (ng/g)	Blank (ng/g)
BDE 47	0.039	0.022	0.058	0.02
BDE 99	0.034	0.02	0.065	0.021
BDE 100	0.0066	0.0043	0.011	0.0046
BDE 153	0.0036	0.0019	0.0063	0.0022
BDE 154	0.0032	0.0017	0.006	0.0013
BDE 183	ND	ND	ND	ND
BDE 209	ND	ND	ND	ND

Endocrine disrupting compounds are present in sediment from the periurban and urban sites (Table 14). Of the three tests performed to detect estrogenic and androgenic activity in sediment samples (GCMS, YES/YAS, ELISA), the only one that performed particularly well was the ELISA.

The YES/YAS showed no estrogenic and no androgenic response, but the presence of the anti-estrogenic response indicates that we cannot fully rely upon the below detection (<LOQ) results. Other protein binding compounds can interfere with the receptor site not allowing the estrogenic compounds to bind to yeast assay. Environmental sediment samples can contain a range of compounds that may interfere with the assay. In summary, there could be estogenic activity in the three samples which is not detected in this analysis. The test, in this instance, should be considered inconclusive for estrogen but conclusive for androgen.

The GCMS directly analysed for concentrations of endocrine disruptors and compounds that behave like endocrine disruptors. Nonylphenol compounds, which are not endrocrine disruptors, but behave in a similar chemical manner, were detected in the urban sample at concentrations that are towards the lower end of that typically found in urban sediment samples. Therefore, while the GCMS did not detect the presence of endocrine disrupting chemicals, the detection limits used were most likely too high (see also Stewart *et al.* 2008).

ELISA is an immunoassay technique that is very specific to the compound being tested. Compounds that behave like endocrine disruptors are not detected by this assay, only the estrogenic compounds themselves are able to bind with the receptor. Estrone was detected at 2.2 μg/kg at the peri-urban site and 0.64 μg/kg at the urban site. The concentration at the periurban site is towards the upper end of concentrations reported in the literature in sediment samples collected adjacent to sewage outfalls. Estrone is known to remain in sediment longer than other estrogenic compounds, which may explain the higher concentration. In addition, estradiol was present at the periurban site.

Table 14.

Levels of endocrine disrupting compounds present in the urban, periurban and rural stream sediment samples taken from Papakura Stream. (LOQ = Limit of Quantitation)

Test and Analytes	Rural	Peri-urban	Urban	Acid washed & furnaced sand
GCMS				
4-tert-octylphenol (4-t-OP)	<100	<100	<100	<100
4-nonylphenol (4-NP)	<100	<100	280	<100
Nonylphenolethoxylates (12 NPEOs in total)	<100	<100	230	<100
Bisphenol-A (BPA)	<50	<50	<50	<50
Estrone (E1)	<5	<5	<5	<5
17b-estradiol (E2)	<5	<5	<5	<5
17a-ethynylestradiol (EE2)	<20	<20	<20	<20
Estriol (E3)	<20	<20	<20	<20
Triclosan (TCS)	<100	<100	<100	<100
4-n-nonylphenol (4-n-NP)	<100	<100	<100	<100
YES				
Estrogenic Response - E2 Equivalents (EEQ)	<LOQ	<LOQ	<LOQ	<LOQ
Anti estrogenic response	yes	yes	yes	no
Anti estrogenic response ranking	medium	medium	medium	-
YAS				
Androgenic Response - Testosterone Equivalents (TEQ)	<LOQ	<LOQ	<LOQ	<LOQ
Anti Androgenic response	no	no	no	no
Anti Androgenic response ranking	-	-	-	-
ELISA				
Estrone (E1)	<LOQ	2.2	0.64	<LOQ
17b-estradiol (E2)	<LOQ	0.72	<LOQ	<LOQ
17a-ethynylestradiol (EE2)	<LOQ	<LOQ	<LOQ	<LOQ

Whilst there have been very few studies of estrogenic compounds in sediment undertaken and therefore little data to compare these results to, the relatively high concentration of estrone is noteworthy and may suggest that monitoring over a larger area over time may be warranted.

Based on the three analyses used for detection of endocrine disrupting compounds, it can be concluded that ELISA gave the most reliable results. If additional sediment monitoring was to be undertaken, it is recommended that only ELISA be used.

In summary, stream sediment from the sites sampled contained low concentrations of contaminants which are typical for the types of surrounding land use. The concentration of contaminants is below that which is likely to cause adverse ecological effects. It is likely that contaminants bound to fine sediment are periodically flushed from the stream system during high flow storm events into the wider estuary area where they may be accumulate in settling zones.

5.1.6 Fish Passage

The sections of streams containing potential fish barriers that had been identified using GIS analyses are shown in Map 8 'In-stream Structures'. The main stem of the Papakura Stream is crossed by bridges at all public road crossings and consequently fish passage was found to be unimpaired at these locations. Seven low weirs located downstream of site 4 do not appear to be obstructing fish passage into upper reaches and may be submerged during high waters. The concrete lining of the lower section is likely to have some effect on fish passage. However, this was not able to be determined from the results on fish distributions within the catchment.

Of approximately 39 culverts examined throughout the catchment, 32 (82%) were identified as submerged. Most of these would be amenable to fish passage during normal flows. As not all submerged structures were sunk below the streambed, fish passage may be impeded during low flows. The smooth concrete lining of most culverts (increasing the velocity of water flow) may also impede passage at these times. The remaining culverts were either stepped (n=3) or perched (n=4). While these stepped culverts are probably passable by moderate-good climbing species, perched culverts may only be passable during high water flows.

No stepped or perched culverts were found situated on the main stem. However four perched culverts were found on tributaries of the main stem (at site 5 and upstream of sites 10, 21 and 22). A stepped culvert was located on a tributary of the main stem at site 26 and on upper tributaries downstream of site 31 and upstream of site 16. Given the presence of species with poor climbing ability, such as inanga, downstream of the culvert at site 5 (i.e. at site 4) and their absence upstream (sites 6 and 7), this may be a potential barrier to this species. Similarly, the presence of inanga on the main stem at site 24 but not on the tributary at site 23 may indicate that the stepped culvert in-between is impassable by this species. The possible effects of other aforementioned culverts are more difficult to assess due to an absence of recently fished sites up- and downstream of these particular potential barriers. In any case, absence of species alone does not necessarily indicate the presence of barriers, and the presence of species upstream may only indicate older specimens or those few that have managed to pass the obstacle.

Numerous farm culverts on small streams may also be a widespread problem, although some will be short and passable by species with good climbing abilities. Within the NZREC Papakura Stream Catchment boundary, approximately 78 additional culverts identified from GIS analysis were not examined due to inaccessibility. As these were not assessed, their impact on fish migration can not be determined, however, it is likely that some of these will present barriers to fish passage.

5.1.7 Stock Access

Stock access to stream margins was widespread. At most sites this consisted largely of cattle, although grazing by sheep and horses were also widespread. Over 50 sites were visited between sites 4 and 31. Approximately 90% of sites were currently accessible, at least to some degree, to stock. Most sites were accessible from both banks of the stream, although some were fenced, or partially fenced on a single bank.

Most of the fencing that was present was inadequate to exclude stock long-term. Most fenced streams were protected by 1-3 wire fences or a single electric wire. At many of these, evidence of recent streamside grazing (e.g. pugging, grazed edges) was seen beyond the current fence line. Standard stock exclusion fences generally consist of at least 5-7 wires and often incorporate additional electric wires. Very few examples of this standard of fencing were found during this survey.

5.2 Estuarine Investigations

The Papakura Stream mouth discharges into a shallow estuarine habitat typical of many New Zealand upper harbour environments. The stream appears to be tidal for a short distance upstream of the mouth, and the riparian vegetation comprises of plants consistent with tidal or salt marsh conditions such as Batchelors button (*Cotula coronopifolia*), glasswort (*Sarcocornia quinqueflora*), toatoa (*Haloragis erecta*), orache (*Atriplex australasica*), sea rush (*Juncus krausii*), oioi (*Apodismia similis*), mangrove seedlings (*Avicennia resinifera*), slender clubrush (*Isolepis cernua*), and sea primrose (*Samolus repens*).

The estuary margins near the stream mouth are vegetated with small patches of mangroves that are mature (around 3 m tall) at the edge of the stream channel grading into seedlings (around 0.5 m tall) toward the shore. In places, mangroves have been cut down or poisoned. Other vegetation consists of weed plants and garden escapees such as pampas (*Cortaderia* spp.), garden succulents, woolly nightshade (*Solanum mauritianum*), black nightshade (*Solanum nigrum*), saltwater paspalum (*Paspalum vaginatum*) and *Yukka* spp. Garden waste and pine trees have been disposed of into the mangroves and along the banks of the stream.

5.2.1 Estuarine Sediment Quality

Sediment grain size analyses indicated that site Q1 was dominated by medium to very fine sand (40% wet weight (ww) <500µm->63µm) and silt and clay (56.4% ww <63 µm). Larger grain sizes comprised the remainder of the sediment composition at site Q1. In contrast, sediment collected from Q2 was almost entirely composed of silt and clay (96.1% ww >63µm), with medium to very fine sand (<500µm->63µm) making up 3.8% ww of the composition and coarse sand 0.1% ww (see Appendix 8 for raw data).

Table 15 presents a summary of the results compared with the ANZECC guidelines for sediment quality (ISQG-Low) and the ARC's Environmental Response Criteria (ERC – Green) (TP 168). In this table, the results for pesticides, PAHs and PCBs are only recorded where they were detected, and the full contaminant results are provided in Appendix 8.

While each of the metals analysed was detected at all three sample locations (stream mouth, Q1 and Q2), none exceeded the ANZECC ISQG-Low trigger value for sediment or ARC ERC for sediment.

DDT, DDE and dieldrin were detected in the fine sediment at Q1, with the dieldrin concentrations exceeding the ANZECC guidelines. DDT was also detected at Q2 in coarse sediment, and in this case the concentrations exceeded the ANZECC guideline.

Eleven PAHs were detected at all three sampling locations. Ten of these were detected in both fine and coarse sediments, while fluorene was only detected in fine sediment at the stream mouth and Site Q1. None of the PAH concentrations exceeded ANZECC guidelines.

A combined total of 11 PCB congeners were detected across the three sites, predominantly in the fine sediment samples. The stream mouth and Q2 sites were similar in their contaminant profiles, with the same six PCB congeners being detected at both sites. A total of 10 PCB congeners were detected at the Q1 site, five of which were not detected at the stream mouth or Q2 sites. Concentrations of total PCBs at the stream mouth exceeded the ANZECC and ARC guidelines.

Low concentrations of petroleum hydrocarbons were detected in the fine sediment at sites Q1 and Q2.

In summary, although a wide range of potentially harmful contaminants was detected throughout the site, few were present in concentrations that exceeded either ANZECC or ARC guideline values.

ARC's estuarine and marine sediment survey results for 2002 (Kelly 2007) and 2005 (McHugh & Reed 2006) reported similar concentrations of common stormwater heavy metals in both the silt and total sediment fractions (see Table 16). It is not possible to statistically compare the data between sampling times due to differences in the location that samples were collected, the method of collection and the number of replicates analysed among the three studies, which may account for some of the variability.

Table 15.

Summary of estuarine sediment testing where they were recorded at three sample sites (stream mouth, Q1 and Q2). Values exceeding ANZECC and/or ARC guidelines are highlighted yellow.

Analytes (all units mg/kg)	ARC TP168 Sediment ERC-Green	ANZECC Guidelines	BML Results – Papakura Stream					
			Mouth		Q1		Q2	
			500µm	63µm	500µm	63µm	500µm	63µm
Total recoverable metals								
Total cadmium	-	1.5	0.048	0.071	0.090	0.062	0.075	0.053
Total copper	<19	65	8.3	14	9	11	9.6	9.1
Total lead	<30	50	11	18	15	17	14	13
Total zinc	<124	200	62	100	77	87	79	74
Organochlorine Pesticides								
4,4'-DDE	<0.0021	0.0022	BDL	BDL	BDL	0.001	BDL	BDL
4,4'-DDT	<0.0032	0.0016	BDL	BDL	BDL	0.0014	0.0021	BDL
Dieldrin	<0.0072	0.00002	BDL	BDL	BDL	0.0011	BDL	BDL
Polycyclic Aromatic Hydrocarbons								
Benzo[a]anthracene		0.261	0.0045	0.0086	0.0062	0.0085	0.0048	0.0065
Benzo[a]pyrene		0.430	0.0055	0.0096	0.0086	0.012	0.0071	0.0076
Benzo[b]fluoranthene + Benzo[j]fluoranthene		-	0.014	0.022	0.024	0.02	0.016	0.015
Benzo[g,h,i]perylene		-	0.0069	0.016	0.011	0.016	0.0084	0.011
Benzo[k]fluoranthene		-	0.0056	0.0066	0.009	0.0087	0.006	BDL
Chrysene		0.384	0.0092	0.018	0.017	0.02	0.012	0.014
Fluoranthene		0.6	0.0084	0.027	0.016	0.023	0.01	0.016
Fluorene		0.019	BDL	0.0091	BDL	0.0067	BDL	BDL
Indeno(1,2,3-c,d)pyrene		-	0.004	0.009	0.0061	0.0096	0.0053	0.0069
Phenanthrene		0.240	0.0025	0.051	0.006	0.037	0.0036	0.024
Pyrene		0.665	0.0082	0.028	0.061	0.024	0.01	0.018
LMW-PAH	-	0.552	0.0025	0.0601	0.006	0.0437	0.0036	0.024
HMW-PAH	<0.66	1.7	0.0358	0.0912	0.0638	0.0875	0.0439	0.0621
Polychlorinated Biphenyls								
PCB-28+PCB-31	-	-	BDL	0.0068	BDL	BDL	BDL	0.0035
PCB-44	-	-	BDL	0.0031	BDL	0.0018	BDL	0.0014
PCB-49	-	-	BDL	0.0028	BDL	0.0018	BDL	0.0015
PCB-52	-	-	BDL	0.0049	BDL	0.0029	BDL	0.0023
PCB-101	-	-	BDL	0.0031	BDL	0.0027	BDL	0.0022
PCB-105	-	-	BDL	BDL	BDL	0.0014	BDL	BDL
PCB-110	-	-	BDL	BDL	BDL	0.0015	BDL	BDL
PCB-118	-	-	BDL	BDL	BDL	0.0014	BDL	BDL
PCB-121	-	-	BDL	0.002	BDL	0.0014	BDL	0.001
PCB-126	-	-	BDL	BDL	0.003	0.0012	0.0064	BDL
PCB-149	-	-	BDL	BDL	BDL	0.0011	BDL	BDL
Total PCBs	<0.022	0.023	-	0.0227	0.003	0.0172	0.0064	0.0119
Total Petroleum Hydrocarbons								
Total hydrocarbons	-	-	BDL	BDL	BDL	160	BDL	140

Table 16.

Comparison of concentration of heavy metals in estuarine sediment from Papakura Stream mouth and Pahurehure Inlet.

Analytes (all units mg/kg)	ARC TP168 Sediment ERC-Green	ANZECC Guidelines	Average results for this study (2008 data)		McHugh & Reed 2006 (2005 data)		Kelly 2007 (2002 data)	
			500µm	63µm	500µm	63µm	500µm	63µm
Total recoverable metals								
Total copper	<19	65	8.97	10.05	7.00	8.31	10.10	6.00
Total lead	<30	50	13.33	15.00	13.00	17.93	15.70	13.10
Total zinc	<124	200	72.67	80.50	66.10	78.00	76.00	51.30

5.2.2 Estuarine Water Quality

Detailed results of the estuarine water quality laboratory tests are provided in Appendix 12. Concentrations of *E. coli* ranged from 79MPN/100ml to 1.6x103MPN/100ml. While the lowest concentrations were recorded at Site Q1, the *E. coli* concentrations in all samples exceeded the guideline value of 14MPN/100ml. Potential sources of faecal bacteria include general runoff and stormwater, water birds, domestic animals, and septic system failures.

5.2.3 Shellfish Contamination

Each of the metals analysed was detected in shellfish samples collected at both the stream mouth and Q2 sites. When analysed as a percentage of the concentration detected in the sediment, concentrations of copper accumulated in these shellfish were at around 70% of the concentration found in sediment. Cadmium and zinc were present in shellfish at around 20% and 13% respectively of the concentration found in sediment. Lead was present in shellfish at less than 2% of the concentration found in sediment. This indicates that copper is bioaccumulates in *Amphibola* more readily than other metals.

DDE and dieldrin were detected in shellfish from the stream mouth, but not in the sediment collected from this location. DDT, DDE, DDD and dieldrin were detected in shellfish from site Q2, but dieldrin was not detected in sediment. Given that dieldrin and DDT derivatives were detected in sediment at site Q1, these shellfish contamination results may indicate that *Amphibola* are more mobile than expected, or that sediment contaminant profiles are more variable than can be shown without undertaking intensive grid sampling. Concentrations of these organochlorine pesticides found in the shellfish were consistently higher than that found in the sediment regardless of location, confirming the strong tendency for these contaminants to bioaccumulate in biota.

Fluoranthene and pyrene were detected in shellfish from the stream mouth site, and phenanthrene and pyrene in shellfish from site Q2. These contaminants were also detected in sediment at these sites. When analysed as a percentage of the concentration detected in the sediment, all three of these PAHs was present in the shellfish at 3–6% of the concentration detected in the sediment.

One PCB congener was detected in shellfish from site Q2 at a similar concentration to that detected in the fine sediments taken from the same site.

Petroleum hydrocarbons were not detected in the shellfish.

5.2.4 Benthic Communities

The quadrat samples revealed that estuarine snails (*Potamopyrgus estuarinus*) dominate the assemblage at the stream mouth. At site Q1, estuarine snails were abundant (>100s per m^2), with occasional mud snails (*Amphibola crenata*) and mud crab holes (<1 per m^2). At site Q2, estuarine snails and mud crab holes were less abundant, with mud snails being dominant. At site Q3, only mud crab holes were present.

Results of the sediment cores are presented in Table 17. Although the taxonomic groups present at each location vary slightly, the diversity of the benthic communities is similar at the stream mouth, Q2 and Q3 sites. At these sites, the average number of taxa ranged from 11–15 and the average number of individuals ranged from 102–134. The benthic community at Q1 was somewhat less diverse, with an average of eight taxa and 53 individuals recorded.

The species present at all sites are typical of Auckland's inner harbour habitats, with abundance and diversity largely influenced by physical parameters such as sediment grain size and salinity gradient.

5.2.5 Estuarine Environment

Based on results from the sampling location at the stream mouth compared to results from Q1 and Q2, it appears that there is a trend of decreasing concentrations of contaminants with distance away from the mouth of Papakura Stream. This single survey indicates that the source of contaminants in sediment, water and biota may be the water and sediment discharged from Papakura Stream rather than water and sediment circulating within the harbour.

Remedial measures to protect the stream mouth focus predominantly on reducing the volume of suspended sediment to which most contaminants are likely to be adsorbed. A principal method for achieving this should be point source measures targeting stormwater discharges from industrial sites and roads. However, the presence of PCB congeners and DDT derivatives indicates a possible source of historic contamination (rather than current activities) such as landfill leachate, disused industrial facility or agricultural practices.

5.3 Terrestrial

5.3.1 Vegetation Cover

Information regarding the extent and composition of vegetation within the Papakura Stream Catchment is provided in Map 9 'LCDB2 – Vegetation' and Map 10 'Riparian Vegetation'. Maps 10a-10c are enlargements of Map 10 for the lower, mid and upper catchment areas respectively.

Table 17.

Benthic communities sampled at four estuarine sites.

			Mouth			Site	Q1			Site	Q2			Site	Q3			Site
Group	**Taxa**	**Common Name**	**S1**	**S2**	**S3**	**Total**	**S4**	**S5**	**S6**	**Total**	**S7**	**S8**	**S9**	**Total**	**S10**	**S11**	**S12**	**Total**
Anthozoa	*Anthopleura aureoradiata*		1			**1**				**0**				**0**				**0**
Nemertea	*Nemertea*	Proboscis worms				**0**				**0**	1			**1**			1	**1**
Gastropoda	*Amphibola crenata*	Mud Snail			1			1								1	2	
Gastropoda	*Potamopyrgus estuarinus*	Estuarine snail				**1**				**1**	3	2		**5**				**3**
Bivalvia	*Arthritica bifurca*	Small bivalve									1						1	
Bivalvia	*Perna canaliculus Spat*	Green-lipped mussel juveniles				**0**				**0**				**1**	1			**2**
Oligochaeta	*Oligochaeta*	Oligochaete worms	13	22	44	**79**	19	4	2	**25**	37	5	3	**45**	14	8		**22**
Polychaeta: Spionidae	*Polydora sp.*	Polychaete	2	19			6	2			2	1			2	1		
Polychaeta: Spionidae	*Prionospio sp.*	Polychaete									1							
Polychaeta: Spionidae	*Scolecolepides sp.*	Polychaete	1	3	4		2	5			1	4	1		2	1		
Polychaeta: Capitellidae	*Heteromastus filiformis*	Polychaete					1		2		1	2	7		9	28	18	
Polychaeta: Nereidae	*Nereidae*	Rag worms	1		1				1		3	3	2		3	5	1	
Polychaeta: Eunicidae	*Eunicidae*	Polychaete	1	2		**34**				**19**				**28**				**70**
Amphipoda	*Amphipoda A*	Amphipods										3	3					
Amphipoda	*Amphipoda B*	Amphipods	2															
Amphipoda	*Amphipoda C*	Amphipods				**2**				**0**	1			**7**				**0**
Decapoda	*Alpheus sp.*	Snapping shrimp											2			2		
Decapoda	*Helice crassa*	Tunneling mud crab		2	3		1	4	1		2	5	3		2			
Decapoda	*Macrophthalmus hirtipes*	Stalk-eyed mud crab	4	1	1	**11**	2			**8**	1	1		**14**	7	4	1	**16**
Copepoda	*Copepoda*	Copepods	2	1	3	**6**				**0**		1		**1**	1	1	1	**3**
		Number of groups				**7**				**4**				**8**				**7**
		Number of taxa		**Mouth**		**11**		**Q1**		**8**		**Q2**		**15**		**Q3**		**13**
		Number of individuals				**134**				**53**				**102**				**117**

The extent of forest vegetation cover diminishes along the course of the Papakura Stream towards the suburban fringes of Manurewa. Continuous forest cover only occurs in the upper headwaters of the catchment, to the north of Clevedon and representing the southern extension to the Maraetai Hills forest. The regenerating forest within both Beacon Bush and Clevedon Scenic Reserves include Kauri, taraire, puriri, rewarewa and tawa. There are, in addition, younger stands of kanuka-manuka scrub on the slopes above the Klimptons Road Quarry in association with commercial plantation pine.

Smaller fragments of regenerating native forest also continue along the parallel ridgelines of the catchment north and south of Brookby, amongst pockets of plantation pine forest. Their connections with the wider Maraetai Forest provide important ecological connections. The upper hillsides that define the Brookby Valley are also associated with pockets of regenerating vegetation within the gullies, in conjunction with older forest remnants. The series of scattered forest remnants occurring on the hillsides to the north of Brookby include taraire, puriri, totara, rewarewa and pukatea and are collectively identified as Sites of Ecological Significance (see Map 11 'Vegetation of High Ecological Value').

The base of the Brookby valley, representing the upper floodplain of the Papakura Stream, includes a few isolated pockets of kahikatea swamp forest. However, the majority of the stream course in the vicinity of Brookby is also associated with a mixed vegetation cover of predominantly planted exotic species, including poplars, oaks, willows and macrocarpas. Exotic weeds also feature amongst this mixed vegetation cover.

As the land flattens in the vicinities of Alfriston and Ardmore, there is little natural tree cover remaining amongst the productive land-use activities. Exotic shelterbelts and horticultural plantings are the dominant vegetation types of the extensive wider landscape. The course of the Papakura Stream is depicted by a discontinuous cover of predominantly willow trees. Kahikatea and totara specimens occur in isolation within this floodplain landscape.

The lower reaches of the Papakura Stream catchment in the west have been largely developed for residential and commercial industrial land-uses extending right up to the immediate stream corridor and coastal marine edge. Little native vegetation has survived in this context, including alongside the immediate stream course. Street and parkland trees are the key vegetation type within this area, which incorporates a network of small areas of public open space. However, a collection of native forest remnants have survived amongst residential development in the vicinity of Hill Road. These collectively include a diversity of notable alluvial forest species such as kahikatea, totara, taraire, karaka, pukatea, puriri and kohekohe and titoki. The surviving forest remnants are separated from the Botanic Gardens and Totara Park beyond by SH1.

5.3.2 Herpetofauna

The Department of Conservation Herpetofaunal Database was searched in order to obtain background information regarding herpetofauna previously recorded within the Papakura Catchment. The results of this search revealed that one endemic gecko (*Hoplodactylus pacificus*), one introduced skink (*Lampropholis delicata*), one introduced frog (*Litoria raniformis*) and one unidentified skink had been recorded within the catchment.

A summary of overall terrestrial lizard and arboreal gecko habitat quality as determined in this study are provided for each SEV site in Appendix 2. This information is also presented in Map 12 'Terrestrial Lizard and Arboreal Gecko Habitat Quality at Each of the SEV Sites'.

5.3.2.1 Terrestrial lizard habitat quality

Most SEV sites consisted of low-quality grazed/mown grassland interspersed with small patches of high-quality thick, low-lying vegetation (i.e. long grass, weedy shrubs). These occurred as riparian vegetation, or under hedgerows, shelterbelts or fence lines. Farm debris (i.e. sheet metal, pieces of wood, concrete blocks) was also common on some properties, and again conferred high quality refugia in otherwise low quality surroundings. Such isolated high quality refugia may support individuals/populations despite low overall habitat quality. When averaged across each site, overall high scores were only observed at SEV sites 7 and 28. This reflected the presence of thick, long grass and a high abundance of deadwood/fallen epiphytes, respectively.

Excluding narrow riparian belts, bush/forest was only present at a few sites (22, 23, 28, 31, and 32). While refugia may be common in bush, high shading reduces habitat quality by limiting basking opportunities. However, bush edges are often highly desirable as they allow basking whilst providing an abundance of refugia in the form of thick ground-tier vegetation.

Terrestrial lizard habitat quality increased marginally with distance up the catchment. However, high quality areas were patchy and localized. This suggests that habitat quality for a given sampling site may not reflect the quality of the wider area/stream.

5.3.2.2 Arboreal gecko habitat quality

Most SEV sites were of low-quality arboreal gecko habitat (see Appendix 2), reflecting the low abundance of trees (especially natives). Five sites (20, 22, 27, 28 and 32) were moderate-quality due to the presence of mixed or native bush, and two sites (23 and 31) were of high quality due to the presence of relatively intact native bush, including kanuka. Kanuka was also present at sites 21 and 27, but occurred as isolated clusters of just a few trees. Similarly, bush patches at other sites were often small and isolated (i.e. at sites 20 and 27), and the capacity of these sites to support viable gecko populations is questionable. Habitat quality increased with distance up the catchment due to an increase in total (and native) tree cover.

5.3.2.3 Refuge search

Table 18 presents the results of the refuge searches. The intensity of the search varied between sites based upon the availability of potential refugia. A total of four lizards were observed during these searches (Table 18): one copper skink (*Cyclodina aenea*), two unidentified native skinks (*Cyclodina* sp.) and one unidentified skink. In addition, the introduced rainbow skink (*Lampropholis delicata*) was observed at two localities in the lower catchment. Based on habitat requirements and local abundance, the unidentified native skinks were likely to be copper or possibly ornate (*C. ornata*) skinks.

Given a high degree of between-site similarity and the availability of high-quality refugia at many sites, the lack of skinks located within the catchment are more likely a reflection of the low sampling effort and cryptic behaviour, as opposed to their actual absence.

Table 18.

Results of the terrestrial lizard natural refuge search at SEV sites. SW, MW and LW = small, medium and large wood, respectively.

Site	Date	Time	Weather	Objects turned	Lizards found
1	08/03/08	1230	Sunny, hot, still	0	0
2	10/03/08	1445	Overcast, hot, dry	0	0
3	11/03/08	1000	Overcast, mild, wet from dew	1 x rock, 1 x sack	0
4	11/03/08	1230	Sunny, hot, dry	0	0
5	02/04/08	1030	Cloudy, mild, wet underfoot, moderate wind	3 x MW, 10x LW, 1 x concrete slab.	0
6	03/04/08	1400	Cloudy, intermittent showers, warm, still	0	0
7	18/03/08	1200	Hot, still, dry	Approx. 25 x LW	1 x copper skink
8	02/04/08	1300	Hot, moderate wind, mostly dry underfoot	1 x MW	1 x unidentified native skink
9	18/03/08	1430	Hot, sunny, dry, still	2 x MW	0
10	11/03/08	1500	Overcast, warm, still, dry	0	0
11	17/04/08	1300	Intermittent showers, humid, warm	1 x MW	0
12	04/04/08	1200	Cloudy, mild, damp underfoot	1 x MW, 1 x LW	0
13	16/04/08	1500	Overcast, showers, mild, recent heavy rain	0	0
14	16/04/08	1415	Overcast, showers, mild, recent heavy rain	0	0
15	17/03/08	1130	Sunny, hot, dry	1 x LW	0
16	26/03/08	1100	Sunny, hot, dry	0	0
17	01/04/08	1300	Overcast, mild, wet underfoot, light-moderate breeze	8 x MW	0
18	08/04/08	1300	Cloudy, moderate breeze, mild, damp underfoot	1 x large sheet metal, 2 x large jib board	0
19	26/03/08	1300	Hot, sunny, dry, moderate breeze	1 x pile of sheet metal, 1x SW, 1 x MW, 3 x LW	1 x unidentified native skink
20	09/04/08	1100	Sunny, mild, mostly dry	0	0
21	12/03/08	1000	Sunny, hot, dry, still	0	0
22	12/03/08	1030	Overcast, dry, warm	3 x LW	0
23	08/04/08	1200	Cloudy, mild, damp underfoot	2 x LW	0
24	13/03/08	1500	Sunny, dry, hot	0	0
25	13/03/08	1400	Overcast, hot	1 x concrete pipe	0
26	09/04/08	1330	Sunny, warm, mostly dry	0	0
27	13/03/08	1015	Sunny, warm, wet with dew	3 x LW	0
28	03/04/08	1130	Showers, cool, light breeze	1 x rock, 3 x MW, 8 x LW, 7 x fallen epiphyte	1 x unidentified skink
29	14/03/08	1300	Overcast, hot, dry	0	0
30	14/03/08	1100	Sunny, hot, dry	0	0
31	25/03/08	1100	Cloudy, warm, dry	0	0
32	25/03/08	1400	Cloudy, warm, dry	12 x MW, 1 x LW	0

5.3.3 Avifauna

A total of 39 species were identified during survey (Table 19), 19 of which are indigenous and 20 introduced. Of the 10 most commonly recorded species, starling were most numerous, followed by pukeko, mallard, silvereye, myna, welcome swallow, house sparrow, goldfinch, blackbird and spur-winged plover.

Table 19.
Bird species recorded during surveying.

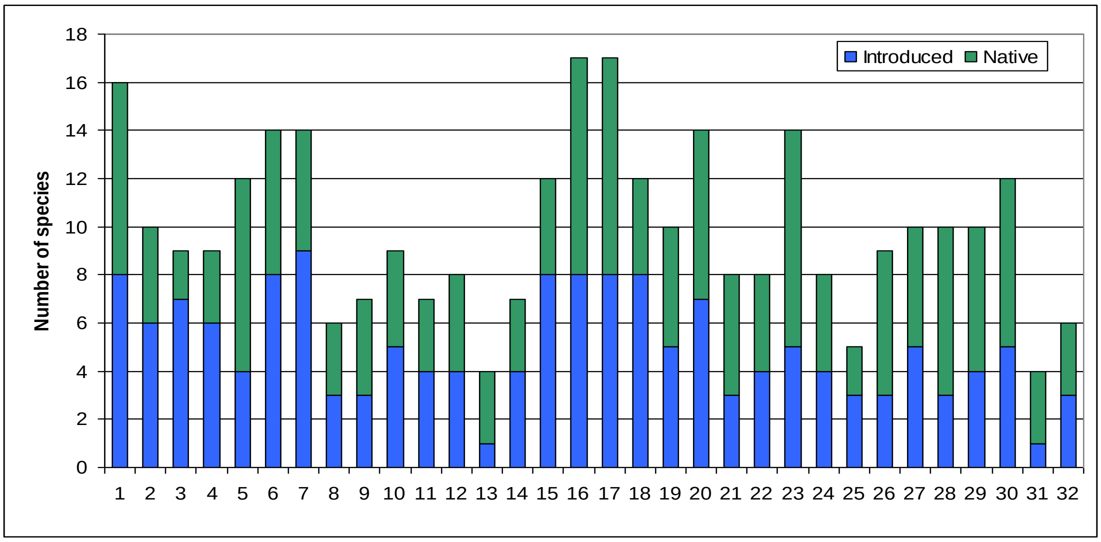
Species	Status	NZ Threat Classification[1]
Blackbird	Introduced	
Chaffinch	Introduced	
Dove, Barbary	Introduced	
Dove, Spotted	Introduced	
Fantail, New Zealand spp	Native	Not threatened
Goldfinch	Introduced	
Goose, Feral	Introduced	
Greenfinch	Introduced	
Gull, Red-billed	Native	Gradual Decline
Gull, Southern Black-backed	Native	Not threatened
Harrier, Australasian	Native	Not threatened
Heron, White-faced	Native	Not threatened
Kingfisher, New Zealand	Native	Not threatened
Magpie, Australian	Introduced	
Mallard	Introduced	
Myna	Introduced	
Pheasant, Ring-necked	Introduced	
Pigeon, New Zealand	Endemic	Gradual Decline[RF]
Pigeon, Rock	Introduced	
Pipit, New Zealand spp	Endemic	Not threatened
Plover, Spur-winged	Coloniser	
Pukeko	Native	Not threatened
Redpoll	Introduced	
Rosella, Eastern	Introduced	
Shag, Black	Native	Sparse[SO]
Shag, Little	Native	Not threatened
Shelduck, Paradise	Endemic	Not threatened
Shoveler, New Zealand	Native	Not threatened
Silvereye	Native	Not threatened
Skylark	Introduced	
Sparrow, Hedge	Introduced	
Sparrow, House	Introduced	
Starling	Introduced	
Swallow, Welcome	Coloniser	
Thrush, Song	Introduced	
Tomtit, New Zealand spp	Endemic	Not threatened
Tui	Endemic	Not threatened
Warbler, Grey	Endemic	Not threatened
Yellowhammer	Introduced	

[1]Hitchmough *et al.* (2007) classification with qualifiers. RF=Recruitment Failure; SO=Secure Overseas.

A summary of the overall rating of bird diversity for each SEV site is provided in Appendix 2 (also see Map 13 'Bird Species Diversity at Each of the SEV Sites'). Species diversity varied enormously between sites, from a minimum of four to a maximum of 17 species (mean = 10). The composition of native and introduced bird species recorded at each of the SEV sites is shown in Figure 18. Native diversity (including colonisers) ranged from two to nine (mean = 5). The mean Shannon Diversity rating was 1.59, with a maximum of 2.30 and a minimum of 0.59. In most instances, the rating closely mirrors the number of species present. However, at a small number of sites this was skewed downwards due to an overabundance of a single species. This was particularly evident at sites 4 (mallard), 11 (starling), 12 (pukeko), and 18 (starling).

Figure 18

Composition of native and introduced bird species recorded at SEV sites.



Avian feeding habitat varied enormously over the course of the catchment. Resident species through the lower catchment sites 1 to 4 benefit from the diversity of shrubs and small trees found in residential gardens. These sites were also frequented by wandering coastal species. Sites 5 through 30 support expansive grassland feeding areas punctuated by regular stands of shelterbelts and remnant native forest. Sites 31 and 32 are situated within or adjacent to mature secondary kanuka forest and an extensive pine plantation. Additional feeding resources within the catchment included farm ponds and long roadside swales.

Many areas within the catchment provided good, dense streamside nesting habitat for species such as pukeko and mallards. Arboreal nest sites were provided by a mix of streamside amenity plantings, in concert with discrete pockets of kahikatea or kanuka forest/treeland. Many of the larger bridges crossing the stream provided habitat for welcome swallows that nest under these structures.

Three threatened species were observed during the surveys: red-billed gull, black shag and kereru. Red-billed gulls are primarily a coastal species and were recorded only at sites 1-4. Large flocks of this species were also noted feeding on mudflats at the stream outlet at Hills Beach. Similarly coastal, black shag were recorded only at site 1 and would not usually travel any further up stream than sites 2 or 3. The many large, established trees at Manukau Golf Course would provide excellent coastal roost sites for this species. During point and roaming counts kereru were recorded at sites 23 and 28. Both of these areas are bordered by larger areas of contiguous bush, which would increase the likelihood of sightings. However, while traversing the catchment several kereru were seen at a range of sites indicating that the species' actual distribution was probably not adequately reflected in the data. Although some native trees such as puriri and karaka provide a substantial portion of the species diet, many naturalised species are also frequently visited.

Distribution of bird species is likely to be a reflection of habitat features rather than stream health. Foremost among these features would be the vegetation matrix. Most species prefer low to moderate tree densities with a diversity of ages, especially those including mature specimens with large spreading limb structures. Predation pressure, both within sites and from surrounding areas, is also likely to play a large part in determining bird distributions.

Most of the species recorded by the OSNZ were noted during this survey, with the exception of many coastal species unlikely to be seen frequently inland (e.g. shorebirds and waders). However, a few discrepancies are worth mentioning. These include shining cuckoo, morepork, pied stilt and Australasian bittern.

Shining cuckoo are seasonal migrants and occur throughout Auckland during spring and summer. The autumnal timing of this survey precluded the identification of this species. Similarly, morepork, being nocturnal, were unlikely to be recorded. This species is widespread and common year round. Pied stilt frequently feed on inundated pasture in inland areas and may be common during periods of sustained rain. Areas of raupo identified in roadside swales throughout the catchment are common habitat for Australasian bittern. This species is highly cryptic and rarely recorded outside of the breeding season. However, due to the restricted extent of most of this habitat, numbers of this species are probably very low in the Papakura Stream Catchment. In addition, other wetland species including waterfowl and occasional grebes may be regular vagrants to farm ponds in the area.

5.4 Stormwater

5.4.1 Flow Accumulation Modeling

SEV site selection based on REC river environments were verified by an analysis of overland flowpaths (flow accumulation model) using LIDAR point source topographical information. While only minor discrepancies occur between the REC and revised flowpath model, the southern catchment does extend significantly beyond the REC catchment boundary (see Map 1 'Flowpath Analysis'). This difference reflects the subtle topography of Alfriston-Ardmore Valley lowland environments.

These results demonstrate the relevance of LIDAR information available to councils to provide for a comprehensive drainage pattern and to assure that SEV site selection is based on true stream order. The 'finer grained' topographical information accompanied by digitisation of vegetation and LIDAR slope analysis has the potential to provide accurate base mapping and to more accurately determine representative field survey sites and characterise the hydrological patterns and boundaries of stream environments.

In addition, the stormwater catchment of the MUL extended further southward than the REC catchment boundary to take into account reticulated stormwater systems. Urban sub-catchments were further refined within the study to include only those pipe networks that flow to the Papakura Stream, omitting pipe networks that flow directly to the Pahurehure inlet.

5.4.2 Drainage (LENZ)

As indicated on Map 14 'LENZ Level 4 - Drainage', LENZ drainage layers for the Papakura Stream Catchment indicate Poor to Very Poor drainage within soil layers. This is largely expected for the properties of the poor draining clay mantle and heavily weathered sedimentary rock of the Waitemata Group of soils (Firth 1930).

The alignment of the Papakura Stream essentially divides Waitemata group soils in the north and alluvium soils in the southern catchment. Alluvium is covered by 'Takanini Peat' layers in the mid to lower southern catchment, which is described as silt with a high organic content, rather than true fibrous peat material (Beca Carter Hollings & Ferner 1993). In terms of stormwater management outcomes, the planned drainage of the peaty soils reduces groundwater levels and leads to the drying and consolidation of these horizons. This can reduce the surface permeability of this soil group and lead to surface ponding and increased overland flow.

5.4.3 Erosion Potential (LRI)

Erosion potential of soils within the catchment was derived from soil classifications of the New Zealand Land Resource Inventory (NZLRI), a national database developed to improve land-use based on soil properties. Erosion is based on a scale of 1 to 5 in terms of intensity. In the Papakura Catchment, identified erosion is generally areal (sheet and wind) although the data indicates only slight erosion (<10% of bare ground or area eroding) (see Map 15 'NZLRI Erosion'). These areas of erosion within the catchment are forms of accelerated erosion that are likely to be the result of rural land-use and overstocking in steeper areas. This is supported by the strong correlation between potential erosion areas and moderately steep to very steep unvegetated slopes (see Map 16 'Slope Analysis').

5.4.4 Flooding (ARC)

Due to poor drainage and low gradient valley slopes, prolonged flooding can frequently occur in the Papakura Catchment. Notable flooding has occurred as recently as 1953, 1965 and 1985.

In the 1% AEP (Annual Exceedence Probability) event (100 year flood) over 590 ha of the catchment is inundated (equating to between 10-15% of the overall catchment). The vast majority (80%) of this flooding occurs east of Mill Road (Beca Carter Hollings & Ferner 1993) (see Map 17 'Flooding'). This floodplain area within the mid-catchment detains stormwater behind roadway nick points, and consequently prevents deleterious flooding effects within the MUL west of Porchester Road. These areas can be flooded for a 24-hour period before draining to the harbour.

5.4.5 Environmental Management Areas (EMAs)

Three EMAs were identified were indentified within the Papakura Stream Catchment (see Map 18 'Environmental Management Areas'): two within rural and forested areas (Brookby Valley and Alfriston-Ardrmore Valley) of the catchment and one within the MUL (Takanini Valley).

5.4.5.1 Brookby Valley

The Brookby Valley EMA, located at the eastern extent of the upper catchment, is a discrete valley system with the greatest incidence of steep valley landforms and forested cover within the Papakura Catchment (see Figure 19). The stream environments within this EMA are largely unmodified in their reaches except by the inputs of adjacent land-use. The Papakura main stem originates in the base of the valley, meandering between extending north-south ridges. The outlets to the valley are by way of a narrow gorge system between two of these ridges, upstream of Fitzpatrick Road.

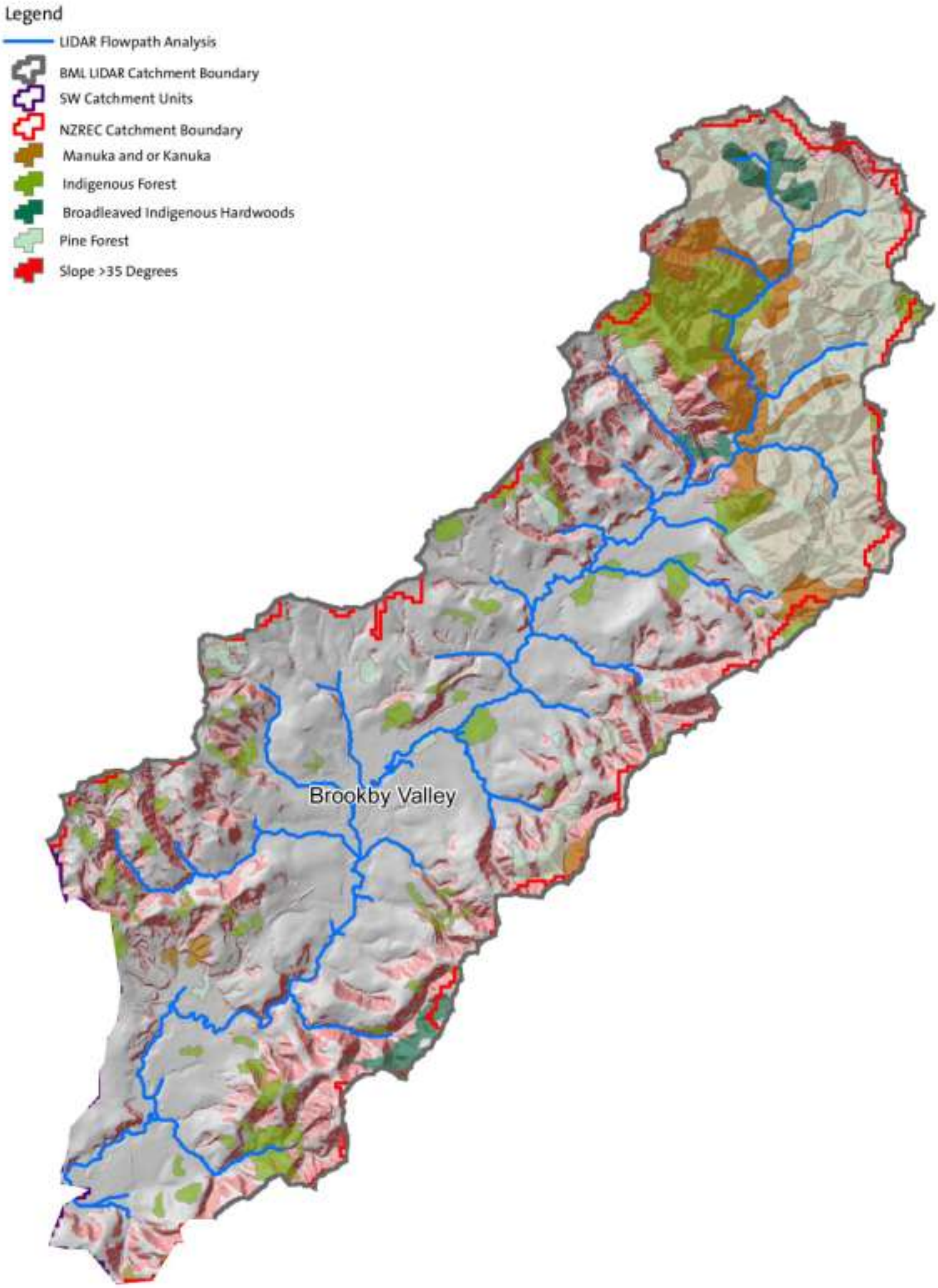
Land-use within the catchment is primarily rural (including equestrian), with significant areas of commercial forestry (e.g. Whitford Forest Block) and large stands of native vegetation at the head of the valley and in the upper tributaries. Brookby Quarry is also at the head of the valley, representing a long-term extractive land-use.

5.4.5.2 Alfriston-Ardmore Valley

The mid-Papakura main stem flows through a wide valley system that attenuates the majority of flood flows during high rainfall events (see Figure 20). The Papakura Stream meanders across the valley floor, in the direction of moderate slopes to the north, with oxbows and back-wetlands beside the stream. To the south there are only subtle topographical boundaries between the Papakura Catchment tributaries and the stream series that drain to Drury Creek and into the Manukau Harbour. In lowland environments there have been modifications to natural drainage patterns to accommodate pastoral land-use, a prevalence of horticulture, and the Ardmore Aerodrome.

The southern portion of this EMA is overlain by Takanini peat soils, with a defined drainage pattern to the Papakura Stream or through interflow to the Pahurehure Inlet and the Manukau Harbour. The gentle slopes and engineered drainage has limited the areas of swampy ground and/or wetlands still existing. Though the remaining ephemeral and perennial wetlands are not indicated on the existing GIS layer, the potential exists to improve this information, using localized depressions indicated on LIDAR as a preliminary reference.

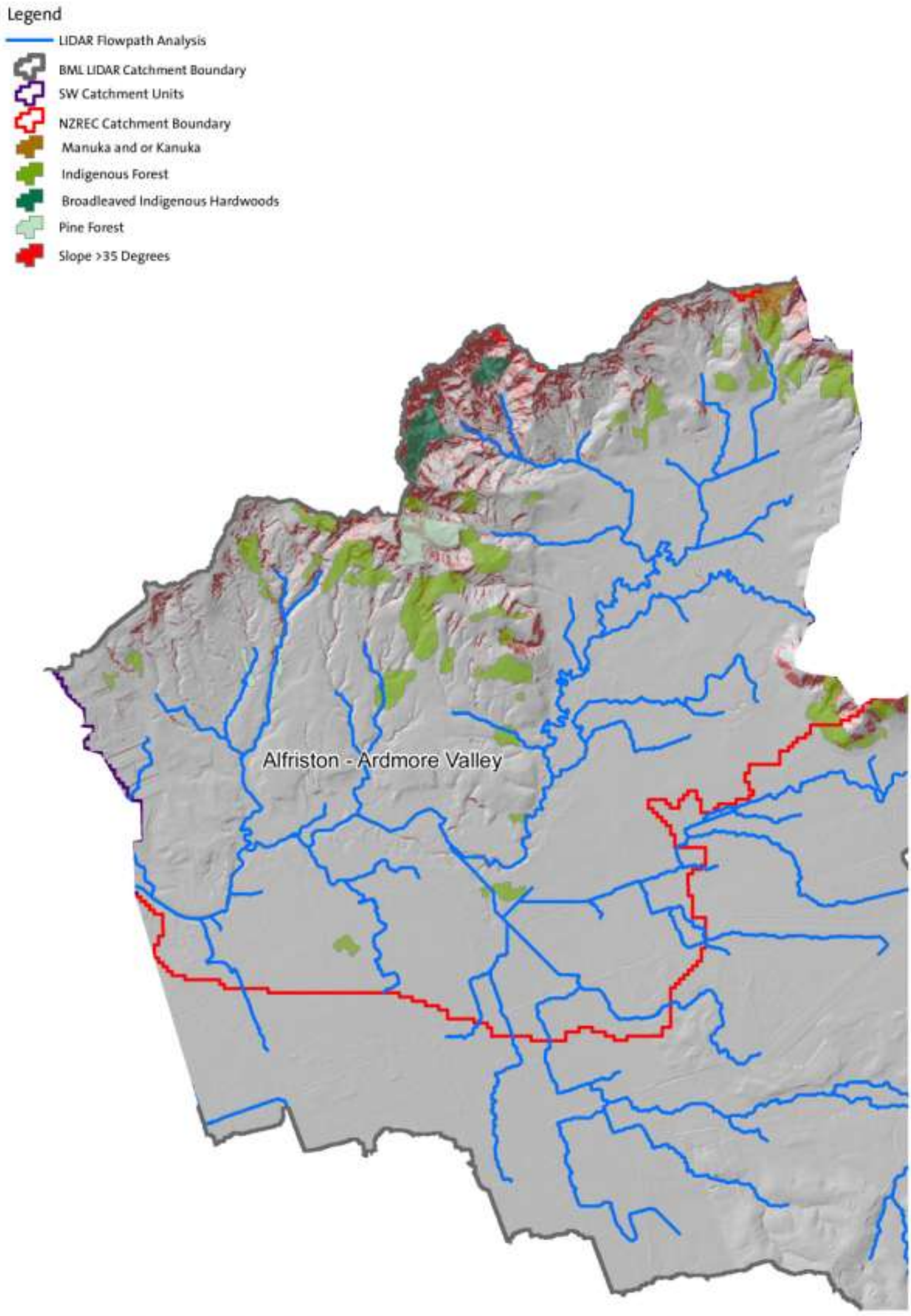
Rural residential areas increase in density towards the MUL, especially within the foothills to the north of this valley. This development leads to culverting and filling of overland flowpaths, as well as examples of restoration of surface watercourse and implementation of in-line stormwater ponds and standing water features in association with rural-residential subdivision.



PAPAKURA STREAM ASSESSMENT AND MANAGEMENT STUDY
Figure 19: Brookby Valley Environmental Management Area
Date: 17.06.08 Drawing: A4_brookby.jpg Scale: 1: 34,600@A4 Author: MDa

Auckland Regional Council

Boffa Miskell



PAPAKURA STREAM ASSESSMENT AND MANAGEMENT STUDY
Figure 20: Alfriston-Ardmore Valley Environmental Management Area
Date: 17.06.08 Drawing: A4_alfriston.jpg Scale: 1: 34,000@A4 Author: MDa

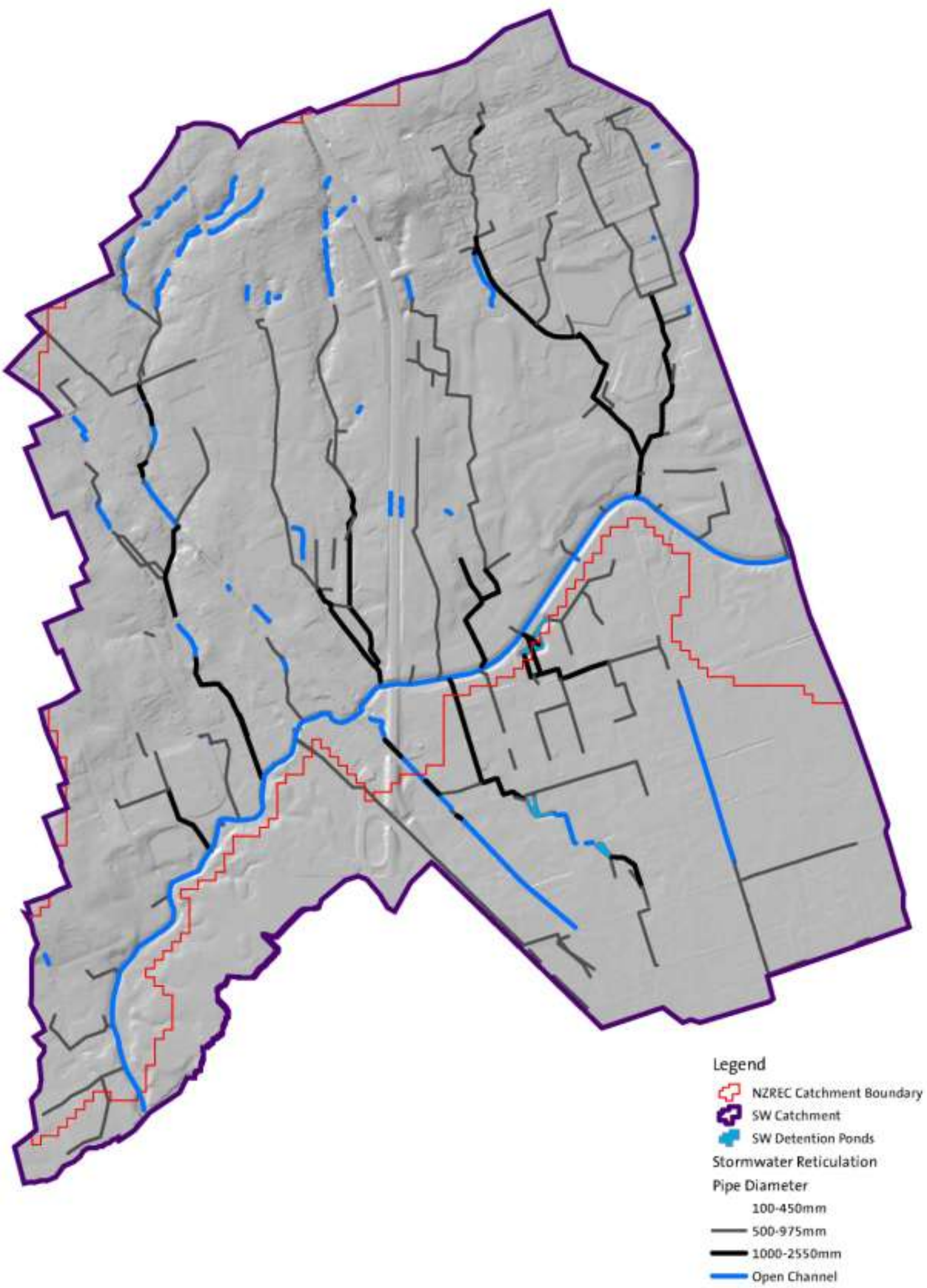
5.4.5.3 Takanini Valley

The complex nature of the Takanini Valley EMA (see Figure 21) necessitates its division in to seven sub-catchments (Neild Road, Greenmeadows, Manurewa East, Takanini North, Papakura, Clayton, Lincoln - see Figure 22).

The area to the west of Porchester Road is primarily reticulated for stormwater conveyance, with piped outlets to the streams in almost all cases from the Papakura and Manukau districts. Porchester Road itself and Takanini School Road support roadside swales that flow directly to Papakura Stream. There are also segments within reticulated stormwater systems that remain open channels. These are of particular ecological value in upper catchments towards the Manurewa Native Bush Reserve, which retain remnants of mature riparian podocarp-broadleaf vegetation.

Along with these open channels and vegetation remnants, the catchment also retains undeveloped land, wide areas of open space (such as the Manukau Golf Course and Randwick Park), extensive dedicated stormwater wetland areas in the Papakura District, and extensive riparian and coastal esplanade reserves. The natural stream channel is also protected to a degree by sandstone bedrock that limits direct erosion from stormwater inputs.

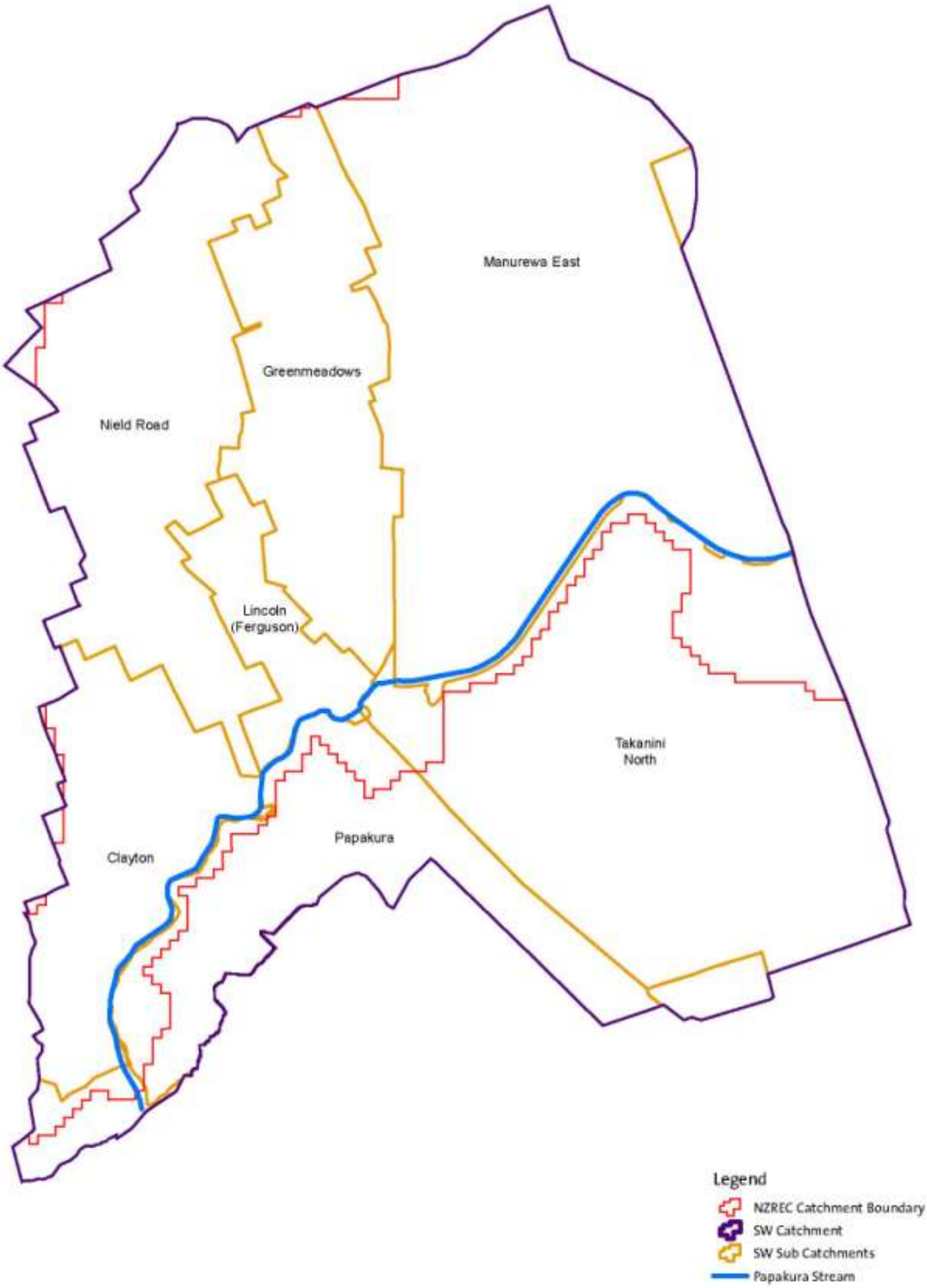
Although the MUL is open to intensified development, this also represents opportunity for appropriate stormwater source control within sub-catchments. There are additional opportunities to combine these with institutional and infrastructure land holdings within the catchment (such as schools, rail and SH1) to realise public education opportunities. Both general and specific environmental management options for the MUL (Takanini Valley) are provided for in Section 6.4.3 and 6.4.4 respectively.



PAPAKURA STREAM ASSESSMENT AND MANAGEMENT STUDY

Figure 21: Takanini Valley Environmental Management Area

Date: 17.06.08 Drawing: Catch_A4_Takanini.jpg Scale: 1: 10,000@A4 Author: MDa



PAPAKURA STREAM ASSESSMENT AND MANAGEMENT STUDY
Figure 22: Takanini Valley Environmental Management Area Subcatchments
Date: 17.06.08 Drawing: A4_Sub_Catchments.jpg Scale: 1: 16,800@A4 Author: MDa

5.5 Landscape Analysis

5.5.1 Socio-Cultural and Heritage

Sites and areas of cultural and archeological importance are shown in Map 19 'Cultural Heritage'. Much of the Papakura Stream Catchment has been highly modified by human settlement and land-uses over the ages, including pre-European occupation. The resources associated with the forest fringes and swampy flaxlands were of value to Maori and early European settlers for both timber and flax. The activities of timber milling were responsible for removing large tracts of original forest from within the wider Papakura Flats, which also supported a number of timber and saw mills.

The strong cultural associations for Maori with the wider Manukau Harbour are evidenced by a series of historic midden sites in the vicinity of the Pahurehure Inlet. Settlement by Maori within the wider catchment was focused on the forested upper hillsides in the vicinities of Clevedon and on the ridgelines to the north of Alfriston. Both areas were subsequently populated by Europeans in the early 1800's. The settlement patterns of today are centred on the coastal suburbs of Manurewa in the west of the catchment, whilst becoming increasingly rural in the direction of Brookby to the east. Ongoing residential development is progressively extending the urban fringe of Manurewa eastwards. At the same time, the cultural diversity of the residential populations has broadened.

Agricultural land-uses within the wider rural catchment have progressively removed much of the original vegetation cover from within the wider catchment. The drainage courses of a number of tributary streams within the Alfriston-Ardmore areas have also been modified for agricultural purposes, which now include modern horticultural operations alongside traditional pastoral grazing.

The wider Papakura Stream Catchment has come under increasing pressures from intensifying land-use and residential development. This is most evidenced by the diminishment of the stream corridor and natural habitat within the residential and industrial urban environments of Manurewa and Takanini.

Formalised public access to the Papakura Stream is limited to its lowermost reaches, between Porchester Road and Hills Beach, where an esplanade reserve is provided through to the harbour (see Map 20 'Public Open Space'). A deviation of this walkway links the Papakura Stream through to the Botanical Gardens and Totara Park to the north via a network of small neighbourhood parks and reserves, including Secretariat Place Reserve. The stream is only accessible inland via public road crossings, with the majority of the stream passing through private land. Shown on Map 21 'Potential Access and Restoration Concept' is one option for linking the open spaces, cultural and heritage features, and forest and riparian habitats both within the Papakura Stream Catchment and with the wider surrounding area.

5.5.2 Landscape Units

Eight landscape units were identified (see Map 22 'Landscape Units Overview'): Clevedon Headwaters, Brookby Valley Floodplain, Brookby Valley Foothills, Alfriston Basin, Ardmore Alluvial Flats, Manurewa Residential Hillside, Takanini Industrial

Corridor and Pahurehure Coastal Inlet. The following sub-sections provide a character summary of each of these units, along with management issues, management opportunities and socio-cultural opportunities. These issues and management opportunities need to read in conjunction with the environmental management options for both the rural and urban components of the Papakura Stream Catchment as are described in Section 6 of this document. Detailed information regarding the physical factors, associated values, and representative stream characteristics of each of the eight landscape units are provided in the Maps 22a-h respectively.

5.5.2.1 Clevedon Headwaters (Map 22a)

Character Summary:

The steeper headwaters of the Papakura Catchment, located above the Clevedon Fault line, are largely covered in continuous but mixed forest-and scrub vegetation. This includes plantation pine forest amongst regenerating mixed broadleaf forest and manuka-kanuka scrub. Areas of recently cleared plantation have also been rapidly colonised by gorse scrub.

Management Issues:

- This area currently provides visual amenity values as a backdrop to the wider Papakura Catchment, whilst maintaining visible connections with the wider Maraetai Hills Forest. It is however largely inaccessible to the public in terms of providing a recreational resource.
- Periodic clearing of forest areas, involving ground disturbance activities and loss of vegetation cover from within the upper catchment.
- Presence of quarry.

Management Opportunities:

- Consider stream enhancement values as part of long term rehabilitation of the quarry.
- Adopt sustainable rotation and mixed forestry practices in conjunction with establishing permanent planted stream corridors.
- Protection of indigenous vegetation through conservation covenants.

Socio-Cultural Opportunities:

- Consider providing access into the upper catchment, potentially linking in with existing access through the wider Maraetai Forest and Clevedon Scenic Reserve.

5.5.2.2 Brookby Valley Floodplain (Map 22b)

Character Summary:

The elongated valley base of the upper catchment in the vicinity of Brookby has been modified by farming. The mature amenity plantings and shelterbelts associated with this change give an established feel to the landscape, including along the course of the Papakura Stream. Isolated pockets of remnant kahikatea forest contribute to the treeland and bush copses appearance of the rural landscape, which otherwise remains largely in pastoral use.

Management Issues:

- Access to the main stream and tributary watercourses by stock, including horses, although riparian vegetation provides a natural barrier in places.
- Large number of private land-owners.
- Flooding hazard.

Management Opportunities:

- Fencing of unprotected stream sections from stock.
- Protection of existing indigenous vegetation remnants through conservation covenants.
- Riparian planting along open stream sections in conjunction with weed removal and underplanting of exotic streamside vegetation with natives.
- Restoration planting to restore linkages between indigenous forest remnants and the Papakura Stream.

Socio-Cultural Opportunities:

- Explore opportunities to provide public access through private farmland incorporating historic homesteads and heritage buildings, supported with educational material.

5.5.2.3 Brookby Valley Foothills (Map 22c)

Character Summary:

The upper valley hillsides are associated with more extensive pockets of regenerating native vegetation within the upper gullies of tributary streams, and these bush copses and larger forested remnants extend along the catchment ridgelines that define the Brookby valley. This imparts a natural "flavour" to the predominantly pastoral landscape of this unit, and provides an attractive backdrop to the valley below.

Management Issues:

- Access to the main stream and tributary watercourses by stock, including horses.
- Unprotected indigenous forest areas.
- Large number of private land-owners
- Potential for stream erosion.

Management Opportunities:

- Protection of existing indigenous vegetation remnants through conservation covenants.
- Streamside planting along tributaries to provide linkages with the Papakura Stream, whilst preventing gully erosion.
- Restoration planting to provide connections with the upper ridgeline forest blocks.

Socio-Cultural Opportunities:

- Investigate opportunities to provide public access walkways along the catchment boundaries within existing forest vegetation, incorporating cultural history and focal viewpoints. There is potential for this access to be linked with the wider Maraetai Hills Forest.

5.5.2.4 Alfriston Basin (Map 22d)

Character Summary:

This landscape unit is a discrete partially enclosed basin valley floor that has formed at the boundary of the Ardmore alluvial flats which extend to the south-west of the Papakura Stream. The stream meanders widely over the level land gradient, which has been heavily modified for both horticultural cropping and pastoral activities. With scarce original vegetation remaining, the stream is erratically associated with discontinuous riparian vegetation.

Management Issues:

- The stream remains accessible to stock in many sections, where it also lacks riparian vegetation.
- Large number of private land-owners.
- Weeds – including planted riparian willows.
- Potential for agricultural inputs (including chemicals) to the stream.
- Tributary streams have been modified for drainage purposes.
- Flooding and erosion hazards.

Management Opportunities:

- Fencing of main stem and tributary channels from stock.
- Restoration planting along main stem to provide enhanced habitat values and protection from stream erosion.
- Encourage sustainable land management practices.

Socio-Cultural Opportunities:

- Planting along the main stream would result in an increased awareness of the Papakura Stream as a key natural feature within this environment.
- Explore opportunities to provide public access through private farmland incorporating historic homesteads and heritage buildings, supported with educational material.

5.5.2.5 Ardmore Alluvial Flats (Map 22e)

Character Summary:

This landscape unit is characterised by extensive productive flatlands in the south-west of the catchment supporting mixed horticultural and pastoral land-uses, and is characterised by geometric networks of shelterbelt and amenity tree plantings.

Management Issues:

- Potential for agricultural inputs (including chemicals) to the stream through intensive horticultural activities.

- The stream remains accessible to stock in many sections, where it also lacks riparian vegetation.
- Tributary streams have been modified for drainage.
- Large number of private land-owners.
- Weeds – including planted riparian willows.
- The stream and its tributaries are crossed many times by the main road network.
- Flooding hazard.

Management Opportunities:

- Fencing of main stem and tributary channels from stock.
- Restoration planting along main stem to provide enhanced habitat values and protection from stream erosion.
- Encourage sustainable land management practices.

Socio-Cultural Opportunities:

- Planting along the main stream would result in an increased awareness of the Papakura Stream as a key natural feature within this environment.
- Explore opportunities to provide public access through private land incorporating heritage mill buildings, churches and homesteads, supported with educational material.

5.5.2.6 Manurewa Residential Hillside (Map 22f)

Character Summary:

This largely residential area defines the northern boundary of the catchment on the suburban fringes of Manurewa, with the main stem of the Papakura Stream running along its base. Residential densities decrease eastwards towards rural Alfriston, but are essentially urban to the west of SH1.

Management Issues:

- Stormwater run-off through impervious surfaces.
- Modified drainage including culverting of tributary streams.
- Progressive loss of vegetation through ongoing development pressures.
- Segregation and containment of stream corridor.

Management Opportunities:

- Daylighting sections of piped stream where appropriate.
- Focused restoration streamside planting for improved riparian habitat as well as enhanced recreational and amenity values.
- Low impact built design measures in order to reduce stormwater runoff.

Socio-Cultural Opportunities:

- Planting along the main stem would result in an increased awareness of the Papakura Stream corridor as a key natural feature within this otherwise built up environment.
- Potential to create network connections and linkages with existing areas of public open space, as part of future residential development.

5.5.2.7 Takanini Industrial Corridor (Map 22g)

Character Summary:

The industrial corridor of Takanini straddles SH1 and the Main North Line railway corridor. The course of the Papakura Stream, to the north of this area, is essentially detached from this heavily built up landscape in which planted street trees provide the main amenity values.

Management Issues:

- Stormwater run-off through impervious surfaces.
- Potential contamination from the run-off of industrial activities and air discharges.
- Lack of ground vegetation cover.
- Segregation and containment of stream corridor.

Management Opportunities:

- Daylighting sections of piped stream where appropriate.
- Focused restoration streamside planting for improved riparian habitat as well as enhanced recreational and amenity values.
- Low impact built design measures in order to reduce stormwater runoff.

Socio-Cultural Opportunities:

- Planting along the main stream would result in an increased awareness of the Papakura Stream corridor as a key natural feature within this otherwise built up environment.
- Potential to create network connections and linkages with existing areas of public open space, as part of future residential development.

5.5.2.8 Pahurehure Coastal Inlet (Map 22h)

Character Summary:

The estuarine environment of the stream mouth at the Pahurehure Inlet is associated with a range of land-uses, including residential, recreational and commercial. The Papakura Stream is accessible through to the coast by esplanade reserve walkways that continue around the Manukau Harbour.

Management Issues:

- The pressures for land development within this coastal environment are evidenced by the mixed land-uses in this area.
- Much of the existing riparian vegetation prior to the estuary mouth is exotic and includes a number of weeds.

Management Opportunities:

- Restoration planting along main stem to provide improved riparian habitat and associated recreational benefits.
- Low impact design measures.

Socio-Cultural Opportunities:

- Enhanced network connections and linkages with existing areas of public open space and the wider harbour coastline environment.
- Potential opportunities for signage and education relating to the Papakura Stream.

6 Environmental Management

6.1 Environmental Management Areas (EMAs)

Three EMAs were indentified within the Papakura Stream Catchment: Brookby Valley, Alfriston-Ardmore Valley, and Takanini Valley (MUL) (refer to Section 5.4.5 and Map 18). Because of the associated dominant land-uses of these areas, the environmental management of the rural component of Papakura Stream Catchment largely relates to the Brookby Valley and Alfriston-Ardmore Valley EMAs, while the environmental management of the urban component relates to the Takanini Valley EMA (and its seven associated sub-catchment units). Rural and urban environmental areas are discussed below in relation to relative management issues, guiding management principles and specific management options

6.2 Management Objectives

The overarching management objectives of this project were to:

1) Identify existing areas of higher ecological value within the stream system which should be protected from degradation;
2) Identify existing areas of sub-optimal / degraded ecological value; and
3) Identify management options and prioritise activities that can maintain / improve the stream water quality, ecological and socio-cultural values and use.

6.3 Areas of Higher Ecological Value within Papakura Catchment

6.3.1 Identification of Sites of Higher Ecological Value

Based upon an analysis of all of the data, the majority of the Papakura Stream sites surveyed were of Moderate to Moderate-Low ecological health. Only two sites (31 and 32) displayed attributes suggestive of better quality and health – while both of these were rated as Moderate under the SEV criteria they nevertheless scored High in terms of water quality and High in terms of their resident aquatic macro-invertebrate communities. They also scored High (site 31) and Moderate (site 32) respectively in terms of the habitat opportunities they afforded to arboreal geckos.

Both of these sites (31 and 32) were located in the upper catchment area of the main stem of the Papakura Stream, set within mature kanuka forest upstream of the Brookby Quarry and adjacent to mature pine plantations situated to the east. This suggests that both of these sites (and the stream reaches above and immediately below them) are generally free from the causal factors that degrade the quality and ecological values of the rest of the stream system. The more significant of these causal factors that are absent from these sites would most likely be farming practices (fertilizer application, herbicide application, pesticide application, stock pugging the stream banks and overland flows containing bacterial loads), and point source discharges (from either urban or industrial activities and from roads).

It also suggests that they have attributes that contribute positively to stream health. The most obvious of these is the presence of the mature kanuka bush along the riparian margins of both of these sites. Riparian strips perform a number of important ecological functions, as follows:

- They act as biological filters or buffer zones between streams and their surrounding lands, intercepting much of the nutrients that would otherwise end up in waterways. Where nutrients enter streams unchecked then eutrophication reduces water quality and degrades habitat.
- Streamside vegetation also provides shade, which regulates stream temperatures and therefore contributes to water quality. Shaded streams have lower temperatures than unshaded streams, and as a consequence have higher oxygen levels. At elevated (unshaded) temperatures the ability of streams to assimilate organic waste (without depleting oxygen to dangerously low levels for aquatic fauna) is reduced.
- Riparian vegetation and the humus it provides also store rainwater as groundwater, thereby reducing the amount of water that immediately enters streams. Instead this water is released over a longer period of time. By this mechanism run-off flows are more controlled, and as a result flood volumes are reduced and the potential for stream-bank erosion attenuated.
- In addition riparian vegetation helps maintain stable, shaded natural habitats rich in organic detritus, which are crucial to the survival of many freshwater organisms which are themselves important in aquatic food webs.

Apart from these two sites (and their upstream reaches) located in the upper-most part of the watershed, there are only a few other waterways within the Papakura Stream catchment that have a coherent forested riparian cover extending for any notable distance. Indeed, there is very little coherent forest (indigenous or otherwise) whatsoever that remains within the wider catchment area. In general the only other places where coherent native bush is present (at least as remnants of any size) are along the central-western and central-eastern ridges that form the catchment divide. In many instances these bush patches contain the upper-most headwaters of tributary waterways that feed into the main stem of the Papakura Stream.

However, many of these waterways are ephemeral in these upper reaches, while their lower (perennial) reaches do not benefit from forested riparian margins. Notwithstanding this, these headwaters do contribute in some ways to the resultant ecological character of their constituent streams, and their protection (and enhancement) would be a positive outcome in terms of steps towards the recovery of stream health within the wider catchment.

In addition to the above, there are a few instances where patches of remnant indigenous vegetation within the Papakura Stream catchment have been formally identified as being of ecological significance in either the Protected Natural Areas Programme (PNAP) report for the Hunua Ecological District (Tyrell *et al.* 1999) or the Indigenous Vegetation of the Awhitu and Manukau Ecological Districts report (Emmett *et al.* 1999). These are a single forest remnant known as Alfriston Bush 1 (site 174 –

Emmet *et al.* [1999]), and five separate remnants collectively termed the Brookby Forest Remnants (RAP #8 – Tyrell *et al.* [1999]).

These ecologically significant stands of indigenous vegetation are shown on Map 11 'Vegetation of High Ecological Value'. The majority of these remnants have streams or headwater flowpaths within them (while these are not included in REC mapped waterways they are present on the more detailed ARC Regional Waterways GIS plan). Since all of these remnants are above the closest SEV sampling sites, it is not known whether the waterways flowing through them are perennial or ephemeral. If any of them are perennial, or ephemeral but with stable pools all year round, then in view of the benefits of riparian vegetation as described above, they would provide greater habitat opportunities than would be the case with the majority of the other stream reaches within the catchment.

In view of this, these bush remnants should also be recognised as potential sites of higher ecological value, and be identified as priority sites for protection and management. This would achieve beneficial ecological outcomes in terms of conserving botanically significant bush remnants while at the same time (by virtue of such conservation) also protecting higher quality stream habitats (where they exist within these forest remnants) compared to the majority of the waterways elsewhere within the Papakura Stream catchment.

6.3.2 Management of Sites of Higher Ecological Value

Given that the only areas identified as being of higher ecological value within the entire catchment were the vegetated headwaters and tributaries of the Papakura Stream, the key management tool for these areas would be to ensure the retention of their native forest cover. This can be achieved in a number of ways, including policy provisions in Council statutory planning documents, Council purchase (for reserve purposes) or private landowner covenant.

An example of the former (i.e. policy provisions) would be the PDC Plan Change 13, which adds impetus to riparian (and other natural features) protection and restoration. The latter could be achieved either voluntarily (for purely altruistic reasons) or by way of pecuniary incentives, in particular with the use of Conservation Lot Subdivisions. These confer additional subdivision rights over and above that which the District Plan zoning of land would normally allow, in exchange for the permanent legal and physical protection of natural features associated with that land (i.e. bush or wetlands). This has proven to be a particularly successful model in the Papakura District, and is used widely by other Councils also. Some Councils allow the subdivision rights to be transferable to other land parcels distant from the parent property within which the bush to be protected is located (these are termed Transferable Development Rights – TDRs).

Other incentives in relation to landowner protection (i.e. covenanting) of areas of higher ecological value include rates relief. Where this is coupled with financial assistance in legally and physically protecting the areas (i.e. survey costs and fencing) then they can be an attractive incentive to landowners.

The physical protection of these bush remnants and their stream reaches will also require pest control, in particular the eradication of feral pigs, deer, goats and possums. All of these would impact negatively upon the coherency of the vegetation within the forest remnants and thereby exert an influence on the riparian benefits which that vegetation would bestow. Pigs, deer and goats would also directly impact upon stream-bank stability. It is recommended that as far as practicable the pest management of these higher value sites be co-ordinated with (or undertaken as part of) the regular ARC Biosecurity operations in the area.

In addition to the above, management of these sites of higher ecological value should have reference to Section 5.5 of this report in relation to their socio-cultural, landscape, visual and amenity values.

6.4 Areas of Sub-Optimal / Degraded Value : Rural

6.4.1 Identification of Areas of Sub-Optimal / Degraded Value : Rural

The rural portion of the Papakura Stream catchment encompasses SEV sites 8–32 and water quality (WQ) sites I and J. The majority of these were assessed overall as being of Moderate to Moderate-Low ecological health. This result was generally consistent across all of the aquatic variables tested, including SEV, water quality, aquatic macro-invertebrates, fish and total erosion, as follows:

- SEV - All sites were of ‘Medium’ ranking, with the exception of sites 14, 16, 18 and 19 (which were all ‘Low’) (see Map 3 ‘Overall SEV Ratings at Sampled Sites’).
- Water Quality - Seventeen sites were of ‘Poor’ ranking (8, 11, 12, 14, 16, 18, 19, 21, 22, 23, 24, 26, 27, 28, 29, 30, and WQ site J), six sites were of ‘Good’ ranking (13, 15, 17, 20, 31, 32), and four sites of ‘Very Poor’ ranking (9, 10, 25 and WQ site I) (see Map 7 ‘Overall Water Quality at Sampled Sites – Dry Weather Samples’).
- Macroinvertebrates - Fifteen sites were of ‘Medium’ ranking (8, 11, 13, 14, 16, 19, 21, 22, 24, 25, 26, 27, 28, 29, 30), seven sites were of ‘Low’ ranking (9, 10, 12, 15, 17, 18, 20), and three sites were of ‘High’ ranking (23, 31, 32) (see Map 4 ‘Macroinvertebrate Values for Each SEV Site’).
- Total Erosion - Fifteen sites were of ‘Moderate’ ranking (8, 11, 13, 14, 15, 17, 20, 21, 22, 23, 24, 26, 29, 30, 31), two sites were of ‘Low’ ranking (9, 25) and eight sites were of ‘High’ ranking (10, 12, 16, 18, 19, 27, 28, 32) (see Map 6 ‘Overall Erosion at Each SEV Site’).

The majority of the sub-optimal / degraded sites within the rural portion of the catchment are set within open pasture. These were all generally characterised by macrophytes, grasses and/or aquatic herbs (most commonly exotic but in some cases the native willow weed) to a greater or lesser degree. In some instances the streams within the sampled reach were almost totally devoid of woody riparian vegetation, and in these places aquatic plants choked much of the stream (i.e. sites 9, 11, 12, 13, 17, 18, 19). Five of the sites were characterised by the presence of a very sparse and intermittent woody riparian vegetation either on the actual stream edge or in close proximity (i.e. sites 14, 15, 16, 20 and 21), while the remainder (i.e. sites 10, 22–30) were all set within reasonably coherent copses of narrow stream-side woody vegetation (predominantly willow trees, privet and poplars, but also native trees and shrubs in some instances).

The results demonstrate that the majority of the rural sites (and the stream reaches above and immediately below them) are generally affected by degraded water quality and have compromised freshwater ecological values. The more significant of the causal factors underlying these problems are likely to be farming practices (fertilizer application, herbicide application, pesticide application, stock pugging the stream banks and overland flows containing bacterial loads), and point source discharges (from either the existing land-use practices or rural roads).

6.4.2 Key Issues for Rural Areas

The key issues identified for rural areas over the course of the study were as follows:

- Lack of riparian cover – with consequent physical and chemical changes to the stream habitat which affect its biological functionality;
- Land-use practices – including land cultivation and applications of chemicals (e.g. fertilizer, herbicides, pesticides);
- Stock access to streams – this results in direct faecal inputs from stock dung, as well as streambank erosion (both direct via pugging and streambank slumping, and indirect via intensive streambank grazing reducing the ability of the bank to resist the erosive forces of flooded streams;
- Stormwater inputs to streams – these are from diffuse sources (such as overland flows across pasture) and point sources (such as effluent discharges).

6.4.3 Guiding Management Principles : Rural

6.4.3.1 Fencing and Stream-Side Revegetation

The primary means by which the identified issues can be resolved in the rural areas of the Papakura Stream Catchment involve fencing the streams and riparian restoration. In relation to the need for fencing, Davies-Colley & Parkyn (2001) list the following types of damage that stock access has in relation to streams:

- Degraded remnant native vegetation in the riparian zone (further reducing biodiversity);
- Reduced shade and shelter (resulting in drying of soils and microclimate exposure in riparian zones, the heating of the stream water, and the growth of algae and macrophytes);
- Compacted and damaged riparian soils (with reduced infiltration capacity and reduced trapping capacity for land contaminants);
- Destabilized stream banks and channels (resulting in erosion, streambed siltation and water turbidity);
- Reduced water quality (owing to mobilization of sediment, and direct input and overland flow of nutrients and faecal microbes from animal wastes);

- Degraded stream habitat and reduced stream health (resulting from all of the above damages).

Permanent exclusion of livestock by fencing is the most obvious means of preventing these types of damage and degradation to streams, and is the only management approach that could be regarded as promoting ecological restoration.

Planting the stream-side edges of the streams within the catchment will create buffer zones that filter contaminants (in particular nutrients) and sediment from overland flows. Such buffer zones reduce diffuse and point-source pollutant transport from surrounding farmland by a variety of means, including the following:

- Enhanced infiltration by riparian soils (which reduces surface runoff and promotes deposition of particulates);
- Reduced surface flow velocities (due to increased hydraulic roughness of the buffer zone vegetation);
- Physical filtering as a result of the dense vegetation;
- Direct uptake of nutrients by plants in the buffer zone.

In addition, the establishment of woody vegetation alongside stream margins buffers the stream from water-borne processes by protecting banks from erosion, buffering channels from localised changes in morphology, and buffering the impacts of floods.

There are a number of buffer zone management options that are described in the literature. These include a mix of farming practices (such as rotational grazing) as well as the use of a variety of stream-side vegetation types, from grass filter strips to plantation trees or native bush. Literature on the subject suggests grass buffer strips are effective at filtering sediment and associated contaminants from surface runoff, but that forested buffers provide for greater removal of nitrate from subsurface flows, partly through uptake by plants (Martin *et al.* 1999).

MfE (2001) note that filter strips comprised of sedges and grasses are effective due to the following reasons:

- They typically form a dense cover over the ground which slows down the passage of water;
- Their many fine leaves are ideal filters or sieves, reducing the velocity of water and encouraging the settling out of solids;
- They grow well in saturated soils and can tolerate periods of immersion;
- They can tolerate and grow through accumulated sediment;
- They are tolerant of dry periods;
- They are generally tolerant of both low and high fertility;
- They tend to accumulate organic matter and help create anaerobic conditions, which are important steps in lowering nitrogen levels.

Trees and shrubs are less able to intercept and filter out contaminants in overland flows since they do not have dense foliage at ground level. However, there is some evidence that thick layers of forest floor organic matter (humus) can be quite effective as a contaminant filter.

Notwithstanding the above limitations, the use of forested buffer zones also has important biodiversity benefits that are not associated with the other options. Not only does the provision of trees have benefits for terrestrial biota (such as birds, herpetofauna and invertebrates), but it also provides a plethora of benefits for aquatic biota, as follows:

- It provides woody debris to the stream, providing habitat diversity and cover for fish and insects;
- It provides carbon inputs to the stream's food chain;
- It increases the amount of shading, helping to regulate water temperature and thereby associated variables such as dissolved oxygen, as well as reducing light levels and preventing nuisance plant growths;
- It reduces erosion and inputs of fine sediments, and stabilizes the stream banks; and
- It provides the terrestrial habitat required in the life stages of many aquatic invertebrates.

While the benefits associated with revegetating stream-side margins are well documented, the literature is inconclusive in terms of the necessary width of riparian buffer zones. However, it seems that the greater the width the more obvious the benefits to stream health. Parkyn *et al.* (2000) examined the following three riparian width ranges:

- 5-6 m: On-going maintenance will be required to keep a buffer of this width weed free, and natural regeneration of indigenous species is likely to be limited. This width option should only be used on very small watercourses or where there is no other option.
- 10 m: Allows for indigenous vegetation succession and should result in a relatively low maintenance riparian buffer strip. The marginal 1-2 m is likely to suffer from long-term weed infestations, which could have the potential to spread to the interior wherever canopy gaps occur. This width option should be used as a general guideline for a minimum buffer width.
- 15-20 m+: Highly likely that a buffer strip of this width would support self-sustaining indigenous vegetation with virtually no maintenance requirements.

In terms of contaminant removal, Fennessy & Cronk (1997) reported removal rates of 100% of nitrate in buffers between 20–30m width, and removal rates of over 70% where the buffers were 10 m wide. However, the effectiveness of buffers is greatly influenced by site-specific factors such as slope, soil composition, drainage patterns and the like. In view of this, Collier *et al.* (1995) provide practical guidelines to calculate the optimal filter strip width, based upon the CREAMS model (Chemical, Runoff, and Erosion from Agricultural Management Systems). Put simply, the greater the slope length and angle, the greater the clay fraction in the soil, and the lower the soil drainage capacity, then the wider the buffer zone needs to be.

In terms of in-stream communities, Davies & Nelson (1994) reported that buffers <10m in width (retained after forest harvesting) did not significantly protect streams in terms of their algal, macroinvertebrate or fish biomass and diversity; however, buffers >30 m did provide observable protection. Furthermore, while Collier *et al.* (1995) observed that a single line of trees can provide 80% shade to streams once they have achieved canopy closure, stream temperatures increase when buffer strips are <10 m wide. Quinn *et al.* (2004) noted that buffer widths (range of 8-27 m) at their Coromandel forestry sites were sufficient to enable the streams to support invertebrate community assemblages similar to those in native and mature (unlogged) plantation forests. Parkyn *et al.* (2003) also observed that a buffer strip >50 m involving 25 year old plantings demonstrated a significant improvement in the invertebrate community assemblage compared to a nearby stream flowing through pasture. Improvement in invertebrate communities appear to be most strongly linked to decreases in temperature (Parkyn 2004), suggesting that restoration of in-stream communities would only occur after canopy closure had been achieved, along with the protection of headwater tributaries.

Parkyn *et al*. (2000) recommended a width of 10–20 m as the minimum necessary for the development of a sustainable riparian buffer zone comprised of indigenous vegetation that would provide long-term benefits to both aquatic and terrestrial biota.

Parkyn (2004) noted that due to the different modes of particulate and dissolved contaminant transport, multi-tier or combination buffers may be effective. For water quality benefits, even a narrow combination buffer of a single row of trees alongside a grass filter strip has been shown to reduce nitrate in subsurface flows. In the USA, combination buffers often consist of an upslope grass buffer, a managed forest zone and an undisturbed forest zone next to the stream.

The managed forest zone mentioned above recognises that in some instances the growth and harvest of trees for timber can be compatible with riparian zone management, provided that a grass cover is maintained beneath them and is only ever lightly grazed (and only during Summer). The trees would provide shade to the stream as well as organic matter and would remove nitrogen from groundwater (for growth), while the grass would act as the sediment filter. This approach to riparian revegetation has the advantage that it ultimately provides some economic return to cover the costs associated with fencing and the loss of productive land. However, this approach does have potential dangers to stream health when the trees are harvested. MfE (2001) recommend the following precautions in this regard:

- Trees should neither be planted nor felled where they are likely to contribute to streambank erosion;
- Trees should be felled away from the stream;
- Avoid felling and extraction when the ground is wet and surface run-off is a threat;
- Avoid felling and extraction during times of fish spawning;
- Leave some trees standing nearest the stream, or otherwise inter-plant with alternative (non-harvest) shade trees;
- Harvest the trees in blocks over several years so that the entire stream is not left totally unshaded all at once.

The ARC has produced a Technical Publication (TP 148) that provides an easy to follow and step-by-step process for riparian planting. This includes a Strategy, Guidelines and Planting Guides for a range of planting unit types, including stream edge, flood area, back wetland or spring, clay slope, alluvial slope, volcanic slope, sandy slope, sandy stream edge and flood area, and saline stream edge and flood area. This document provides detailed advice on the "where, what and how to" aspects of any riparian revegetation programme.

In addition to the above, management of stream-side revegetation should have reference to Section 5.5 of this report in relation to their socio-cultural, landscape, visual and amenity values.

One factor that needs to be kept in mind in relation to revegetation along the riparian margins of streams is the likelihood that the stream channel will widen as a result. This is due to the increase in shading, which leads to the loss of pastoral grasses along the stream bank with a subsequent increase in the potential availability of stream bank sediments to erosion. Notwithstanding this, Parkyn *et al.* (2001) suggest that bank erosion (and therefore sediment yield) would peak about 25 years after planting, with sediment yields being approximately double the amount under pastoral grass ground cover. Following this, bank erosion and sediment yield could be expected to decline, reaching low levels when the stream has widened to its natural forest morphology by about 35–40 years after riparian planting.

6.4.3.2 Farm Management Practices

In addition to riparian zone restoration by way of fencing and the planting of stream-sides, better management of standard farming practices are likely to also have a positive effect in terms of restoring stream health. This is particularly the case in relation to the application of both nitrogen and phosphorus. Nitrogen and phosphorus inputs to streams can be reduced by applying them under the following conditions:

- when rain is less likely;
- when grass growth is active;
- when it is applied only in quantities sufficient for plant requirements;
- when it is split into smaller multiple dressings to give plants a better chance to use what is applied; and
- when it is not applied directly onto stream channels or in dry farm drains (which will become wet with rainfall events).

Better livestock management that will also decrease the input of nitrogen to waterways includes excluding stock from streams, removing stock from saturated soils, and excluding stock from wetlands, seepage zones and bogs so that a healthy cover of sedges can develop with improved capacity to denitrify nitrate inputs. In this regard, wetlands are a very important component of the equation, since they provide the only means by which nitrogen in groundwater can be treated. Provided that there is plenty of suitable organic matter, that anaerobic conditions exist and that hydraulic conditions are such that suitable retention times exist, in excess of 90% of the nitrates in the incoming water can be removed by wetlands (MfE 2001).

Loss of phosphorus is closely tied to soil erosion. Fertiliser phosphorus quickly binds to soil particles and is carried in suspension in surface run-off, so efforts to reduce soil loss in surface run-off will reduce phosphorus loss to streams as well. Once phosphorus enters surface run-off the opportunities to extract it are confined to situations where the run-off slows sufficiently for the particles to settle out of suspension. Filter strips comprised of dense swards of grasses, sedges and reeds situated on level areas offer the greatest opportunity in this regard. MfE (2001) conclude that suitable sites where this could occur include:

- Wet areas and seepage zones that are located in areas that intercept surface run-off;
- River terrace fans where surface run-off is distributed diffusely over a wide relatively level area rather than a narrow channel;
- Riparian filter strips comprising dense stands of grasses and sedges; and

- Benches or sills higher up in gullies.

MfE (2001) note that filter strips (when effectively located and constructed) can remove 90% of sediment entrained in surface run-off. The most effective such filter strips are relatively long, flat and densely covered in sedges and grasses. Collier *et al.* (1995) give details in relation to the effective use of filter strips.

Filter strips comprised of grasses and sedges are more effective at intercepting surface run-off and removing phosphorus than riparian trees and shrubs (although the latter do take up phosphorus and provide a means of storing it). Furthermore, the (eventual) closed canopy of woody vegetation would tend to shade out sedges and grasses. This needs to be factored into the design of filter strips, and when these are to be used in conjunction with the planting of woody vegetation along a stream-side, a combination buffer as suggested by Parkyn (2004) consisting of an upslope (outer-most edge) grass buffer and a forested zone next to the stream would offer a solution.

It should be noted that since sediment and phosphorus accumulate wherever they are periodically trapped, storage sites such as filter strips can become phosphorus saturated and their ability to trap phosphorus may decline over time, unless sediments or organic matter are removed from them. The means of removing phosphorus could include either mechanical or light grazing (although preferably not by heavy animals such as cattle or horses).

In addition to chemical contamination, the health of the streams in the Papakura catchment is greatly influenced by sediment inputs. The two primary means by which sediment ends up in streams is by way of sheet erosion of the hillsides (i.e. the diffuse loss of soil to surface run-off) and stream-bank erosion. Both of these mechanisms are at play within the Papakura Stream catchment. Table 9 in this report identified that 42% of the SEV sampling sites suffered from some form of erosion, with the most common form being bank failure. In some instances this affected more than 90% of the entire site. The reasons for bank failure are probably a combination of direct stock access and an absence of woody vegetation, with consequent weakening of the banks that makes them more erosion-prone, especially during periods of flood flows.

MfE (2001) observes that the loss of soil due to sheet erosion can be significantly reduced by the appropriate management of soil, pasture and livestock, as follows:

- *Reduce pasture damage:* keep stock (especially deer and cattle) off wet and saturated areas where pugging can occur, and avoid overgrazing of pasture especially during winter when surface runoff is greatest and soil moisture levels are highest.
- *Minimise and slow down surface run-off:* allow pastures to grow longer during the wet season on areas where run-off is most substantial, and establish temporary or permanent filter strips on the more level portions of hillsides to intercept and slow down surface run-off.
- *Intercept run-off before it enters streams:* utilise existing wet areas, or restore old wetlands where they lie in the path of surface run-off channels, establish filter strips on the landward edge of riparian margins and on river floodplain fans where water flow is diffuse rather than channeled, and construct sediment traps or ponds in the path of significant run-off channels.
- *Construct and maintain adequate farm drainage and crossings:* where possible, construct farm roads and tracks on stable sites and keep gradients

as low as possible, and provide plenty of cut-off drains to channel water flowing down the tracks before volume and velocity of the run-off becomes excessive.

- *Maintain the cut-offs regularly and use flumes and piping to carry run-off onto stable vegetated ground:* construct sediment traps adjacent to streams (but out of the flood channel) to collect sediment in the road run-off, and construct culverts (or bridges) at regularly used river crossings.
- *Minimise the risk of soil loss during cultivation:* use minimum tillage or zero tillage for land with a high risk of erosion due to run-off, retain a substantial well vegetated riparian strip between cultivation and streams, incorporate crop residues to increase/maintain soil permeability, on slopes cultivate cross contour rather than up and down the slope, leave gullies and areas where surface run-off is more prevalent uncultivated, avoid excessive cultivation that can result in the formation of pans, and avoid cultivation when soil moisture levels are too high or too low.

Farm drains and ditches are the most widely used mechanisms to channel surface run-off and reduce the water table on farmland. Given this role, they act to concentrate nutrients, sediment and agricultural chemicals, and are normally associated with the growth of nuisance plants. This in turn reduces their functionality, and requires that they be regularly cleaned. The two most usual means of farm drain maintenance are mechanical (i.e. with a digger) or chemical (i.e. with herbicides). Both of these can have significant adverse effects on the biota utilising the drains and on their downstream receiving environments.

MfE (2001) notes that the adverse effects of drain maintenance by mechanical means can be reduced by the following:

- Not digging out the entire length of the drain, instead alternating between 10-20m cleared and undisturbed reaches;
- Only digging out one side of the drain, so that half of the width remains undisturbed;
- Avoiding excavation during peak fish spawning and migration periods;
- Leaving spoil close to the drain bank so that fish removed in the spoil have a chance to re-enter water via the shortest route;
- Ensuring that diggers are thoroughly cleaned to reduce the risk of accidental spread of nuisance plants;
- Ensuring that exposed drain banks are seeded and re-planted soon after clearing;
- During maintenance on smaller drains, placing straw bales downstream to reduce the amount of sediment reaching streams.

MfE (2001) also notes that the adverse effects of drain maintenance by spraying can be reduced by the following:

- Not spraying the entire length of drain, instead alternating between 10-20m long reaches of spraying and not spraying;
- Only spraying the centre of the drain where faster water flows occur, so that the edges of the drain remain undisturbed to provide cover, food and habitat to aquatic biota;
- Spot spraying badly affected areas only;

- Not spraying during peak native fish spawning and migration periods;
- Using contact herbicides which only act on plant tissue.

Notwithstanding the above, there are alternative drain maintenance practices. These include creating sediment sumps (i.e. deeper and wider pools) within the drainage channel itself where sediment (and contaminants) can settle out. While these will need to be regularly maintained themselves they have the advantage of reducing the frequency that the rest of the drain will need to be cleared (i.e. they are the "sacrificial areas" within the wider drain system).

6.4.4 Specific Management Options: Rural

The rural component of Papakura Stream Catchment largely relates to the Brookby Valley and Alfriston-Ardmore Valley EMAs. These areas are examined in further detail in the following sections to provide for management options specific to land-uses in the catchment, riparian areas (including tributaries and wetlands) and the Papakura main stem.

6.4.4.1 Brookby Valley Environmental Management Area

The Brookby Valley is a discreet rural catchment, supporting largely unmodified streams of steeper valley gradients. Vegetation cover is common along riparian areas, with significant stands of native vegetation and large-scale commercial forestry in the eastern upper tributaries (refer to Figure 19). The Papakura main stem supports contiguous vegetation buffers, primarily of mixed native/exotic shrubland.

Specific management options relating to the Brookby Valley are the protection of existing native vegetation, the sustainable management of commercial forestry, the protection of steep slopes and erodible lands, management of ongoing quarry activities, and rural land management relating to the contributing catchment and drainage systems. Management options are discussed further below.

Existing Native Vegetation

Existing vegetation within the Brookby catchment includes remnant vegetation on private rural properties, with significant stands in the eastern catchment including Beacons Bush and connections to Clevedon Scenic Reserve.

Beacons Bush is 121 ha of native vegetation on private land with no formal protection. Tall kanuka (*Kunzea ericoides*) shrubland is prominent throughout this hill and gully region, with regenerating broadleaf such as taraire (*Beilschmiedia taraire*), tawa (*Beilschmiedia tawa*) and puriri (*Vitex lucens*), with kauri (*Agathis australis*) and hard beech (*Nothofagus truncata*) emerging above the canopy. The area supports common forest native birds, as well as kereru (*Hemiphaga novaeseelandiae*), green (*Naultinus e. elegans*) and forest (*Hoplodactylus granulatus*) gecko (Tyrell *et al.* 1999).

The Clevedon Scenic Reserve, including the Clevedon Stewardship Area, is steep dissected hill country supporting a mixture of kauri, tanekaha (*Phyllocladus trichomanoides*) and beech, with less abundant podocarps, coastal broadleaf species in the valleys and treefern shrublands. Kanuka forest is also evident on spurs and disturbed edges. The area contains some of the more uncommon species found in the ecological district such as manatu (*Plagianthus regius*), kaikomako (*Pennantia* *corymbosa*), king fern (*Marattia salicina*), as well as supporting rare communities such as hard beech and lowland kowhai forest. The area is known to contain kereru, morepork (*Ninox novaeseelandiae novaeseelandiae*), tui (*Prosthemadera novaeseelandiae novaeseelandiae*) and other common native birds (Tyrell *et al.* 1999).

Management options to protect vegetation remnants in the Brookby Valley include education of landowners regarding voluntary conservation covenants and/or incentives through subdivision rights or rates relief in exchange for permanent protection. Provision of funding, materials, or technical support to landowners and community groups is possible to facilitate the fencing and rehabilitation of vegetation remnants. It may also be prudent to step-up consultation with Whitford Forest Partners to provide for ecological linkages through forest blocks between Beacon Bush, the Papakura Stream and the Clevedon Scenic Reserve, and to discuss potential to purchase or effect vestment of focus ecological areas.

Priority areas for the conservation and/or rehabilitation of native vegetation remnants relate to their value and significance, ecological function (erosion controls and water quality protection), and landscape ecology function (ecological corridors, habitat islands, or buffering vegetation to other sites of significance). A first priority is to utilise the digitised vegetation layers provided in this study to identify areas for further investigation, with a view to field surveys and accurate classification of vegetation remnants coincident with landowner consultation.

Production Forestry

The eastern portion of the Brookby Valley is dominated by large contiguous stands of open canopy pine plantation as part of the Whitford Forest Partners holdings. The protection of stream values in these areas directly relates to the management of harvesting practices including (but not limited to) the following:

- Protection of streams from increased sediment and woody debris during harvesting;
- Buffering stream environments from changes to microclimates and overland flows after harvesting;
- Retaining connections between isolated native vegetation remnants through staging forest harvest and augmenting native habitat areas;
- The application of management buffer zones to stream environments. For instance, the exclusion of staging areas and reduced stem density next to a stream to limit disturbance and to provide for dense understorey growth to act as a buffer to the stream.

Assigning generic stream planting buffer widths is difficult, with the contributing valley slopes, stream morphology, and geology all likely to affect the most appropriate buffer size. The appropriate buffer width therefore relates to site specific practicalities and the bank-full proportions of the stream (generally assumed to be the annual exceedence event).

Steep banks may require protective vegetation at a distance from the crown to prevent bank failure. Point bars and riparian wetlands may require the additional protection of the natural extents of habitats and flood flows. However, smaller streams with wide floodplains and dense streamside vegetation may only require a narrow protective buffer unless there are associated spring wetlands or protected fauna in these environments.

Restoration efforts following harvest may assist with microclimate issues and weed incursions by creating a dense transitional edge to buffer the effects of climate and disturbance factors.

To ensure the protection of upper catchment streams in production forestry, it will be necessary to monitor forestry effects and consult with landowners and those vested with cutting rights, in order to set key performance indicators against forestry practices. This may be in the form of an accord, or through additional provisions for heretofore permitted activities (undertaken in the first instance through consultation with forestry stakeholders).

Brookby Quarry Activities

The Brookby Quarry is likely to continue extracting gravel from the upper catchment site over the long-term. Over-burden will continue to be removed and associated native vegetation and drainage patterns will be affected. Considering the likely sediment load of these activities, it may be more appropriate to set targets that relate to totals, rather than percentages of total suspended sediments. The removal of freshwater habitat and fish passage must also be specifically considered in ongoing consents, and monitoring for biological indices. Mitigation proposals for quarry activities may be applied off-site to provide for restoration activities to the Papakura main-stem in other areas of the catchment.

Woodlots and Land Retirement in Upper Catchment Areas

The upper catchment of the Brookby valley has incised slopes greater than 35 degrees (refer to Figure 19). The predominantly rural land-use in these upper catchment areas has the potential to result in surficial erosion. In order to limit land erosion, improve land productivity, and limit sediment loads to the Papakura tributaries, it may be of benefit to retire land susceptible to erosion, and/or provide for longer-rotation woodlots specific to steep slopes. These woodlots have the potential to provide timber, stock shelter and to contribute to the overall aesthetics of the rural setting.

Woodlots in association with steep land and riparian areas have the potential to emphasise natural variations in topography, hydrology, soils, and climate, and therefore the natural and landscape character values. As part of the working landscape, rural plantings should aim to fulfill as many functions as possible (e.g. timber, fodder, shelter, shade, erosion control). Woodlot planting has potential for:

- *Erosion control planting* focused on steep and exposed slopes.
- *Shelter planting* can enhance farm productivity in a number of ways. Pasture growth may be increased by up to 60% on exposed sites, and crop yields by 25% (Lands & Survey 1984) Animal health also benefits with fewer lambing losses and weight gains in other stock. Milk production will increase with less disruption due to stock mobbing for warmth and shelter;
- *Production woodlots* can be established to create an overall vegetation framework for a farm. Diversity of species can help diffuse regularity and provide multiple products and/or functions such as timber, fodder and bee forage. Woodlot tree species provide an opportunity to grow high-quality timber. Potential returns per cubic metre for well-tended woodlot trees are better than could be expected for *Pinus radiata*. Good returns make small woodlots viable, and small woodlots are a useful management tool for dealing with erosion-prone sites and areas not suitable for pasture

production. Opportunities exist to use small to medium sized woodlots on areas of poor soil, inaccessible areas, steep land adjacent to riparian areas and shelterbelts;

- *Longer rotation woodlots* may become a valuable resource that warrants their smaller numbers. New Zealand native timber species would be well suited to these situations, with minimal tending requirements and tolerance to local environmental conditions;
- *Amenity planting* provides opportunities to screen or soften building forms, provide deciduous colour, and celebrate entrances;
- *Planting for effluent disposal*. It is possible to apply more effluent to a coppice species than to pasture, without increasing the likelihood of nutrient leaching (NZ Grassland Association 2003);

Combining Appropriate Land Management Practices with Riparian Enhancement

Appropriate riparian management and associated land management practices in proximity to water courses and wetlands include:

- Appropriate irrigation and application of fertilizer and effluent in terms of quantities, timing, and existing buffers to the receiving environment;
- Providing for dedicated stream crossings;
- Appropriate management regimes for farm drains relating to staging, timing with fish passage and spawning, and application of restoration and silt controls;
- Exclusion of stock (including horses) from riparian areas on a permanent basis, seepage zones and bogs on a seasonal basis, and filter strips as required preventing these systems from overloading;
- Provide for combination buffer strips to include grass buffers for overland contaminant removal and forested zones for shading and uptake of contaminants from ground water flows;
- Weed controls focused on groundcover weeds on streambanks and rehabilitation of native species with stabilizing root systems.
- Erosion control of stream banks including planting at the crown of banks to prevent cracking at the 'plane of bank failure' and planting at the stream margin to prevent undercutting and fortify the toe of slope.

The most appropriate objective for stream restoration is not to merely fulfill the criteria of generic guidelines but to achieve a balance of stream function and equilibrium of stream processes. This includes (but not limited to) streambank stability, filtering and uptake of potential contaminants, habitat and ecological corridors, microclimate, sustainability of vegetation from weeds, energy input (as woody material), flood controls, water balance (and supply), and lotic (in-stream) water quality treatment. If all of these factors are considered at the scale of both the stream reach and the catchment then the purpose, extent and form of riparian buffers will vary considerably.

Implementation of riparian buffers is most likely to occur in a piecemeal fashion in the Brookby Valley. Studies have suggested an appropriate riparian management option is to restrict full planting along streams with catchments less than 200 ha (Parkyn *et al.* 2001). This prevents channel widening which can result from canopy cover restricting denser bank vegetation (Davies-Colley 1997).

Riparian tree planting programmes are therefore best placed in headwaters, such as the Brookby Valley tributaries, while still protecting the sedge/rush/grassland environments of riparian and catchment wetlands (to protect their filtering and denitrifying capacity). In this way, commencing from the upper catchment the expected impact of bank erosion on sediment yield is generally expected to be slight if whole-catchment planting is extended over 20-40 years (Parkyn *et al*. 2001).

The main stem areas of the lower Brookby Valley may require large trees for bank stabilisation and shade, additionally providing an ecological corridor and energy (in the form of woody material) to the stream.

6.4.4.2 Alfriston-Ardmore Valley Environmental Management Area

The Papakura main stem flows through the Alfriston-Ardmore Valley between the Brookby foothills to the north and the wide expanse of the alluvial valley to the south. In the flat lowland environments there have been modifications to natural drainage patterns to accommodate pastoral land-use, horticultural industries, and the Ardmore Aerodrome.

The Papakura main stem is still largely unmodified in this valley, but drainage patterns have been modified to drain lowland environments and Takanini Peats to the south. Vegetation cover is sparse along the main stem and in the tributaries, and is mostly represented by shelter belts and vegetation remnants in the headwaters.

Specific management options relating to the Alfriston-Ardmore Valley are the protection of existing native vegetation with recognized ecological significance, continuing the protection of steep slopes and upper catchment vegetation from the Brookby Valley, and management of flooding areas, particularly in relation to land-use practices within flood zones.

Existing Native Vegetation

Similar management options exist for the protection of existing vegetation remnants in the Alfriston-Ardmore Valley as those described for the Brookby Valley (refer to Section 6.4.4.1). Specific opportunities relate to remnant indigenous vegetation within the northern foothills that have been formally identified as being of ecological significance in either the PNAP report for the Hunua Ecological District (Tyrell *et al.* 1999) or the Indigenous Vegetation of the Awhitu and Manukau Ecological Districts report (Emmett *et al.* 1999) (see Map 11 – 'Vegetation of High Ecological Significance').

Woodlots and Land Retirement in Upper Catchment Areas

Woodlot and retirement planting of slopes has the potential to connect with revegetation in the Brookby Valley, thus providing connection between the mid and upper catchments of Papakura Stream, along the steeper lands of the contributing foothill environments. There are specific opportunities to connect woodlot planting and revegetation along the north-south ridgeline at the centre of the Alfriston-Ardmore Valley and connect the foothill environments to the flooding areas of the valley floor (with potential as discussed below for specific lowland habitat restoration).

Combining Appropriate Land Management Practices with Flood Protection and Riparian Enhancement

The mid Papakura main stem flows through a wide valley system that attenuates the majority of flood flows during high rainfall events. Given that 80% of the 1% AEP (100 year flood) event is stored within this EMA, there are specific management options that relate to the coincidence of specific land-use types within the floodplain. A basis for controls may be to set a minimum freeboard of 200 mm above the 100 year flood elevation of potential sources of contamination. This would potentially affect existing horticultural facilities, industrial facilities (panel beaters), and poultry farms which may require relocation, protective measures (i.e. flood berms and diversions), or elevated floor levels to prevent ongoing contamination issues.

Although flooding occurs on private property, it is partly formed behind the culverts of public roads. Furthermore, this flooding provides an important function through the extended detention of flood flows before they reach urban areas. In this respect, an important first step would be to consult with landowners within the inundation zones in order to address potential ongoing issues. This may include:

- Identification and mitigation of potential contamination sources;
- Compensation for private flood management through assistance of land improvements to protect soil resources;
- Balancing future land-use and fill with additional compensatory flood storage;
- Restoration of floodplain vegetation and wetland environments, with potential to connect these to upland environments via the tributaries of the Papakura Stream;
- Identification of remaining ephemeral and perennial wetlands not indicated on existing GIS layers;
- Potential for parallel treatment wetlands within the stream corridor of the Papakura main stem.

A further priority for riparian enhancement within the catchment is the restoration of roadside swales to enhance water quality treatment, including in-stream check-dams, dense sedge/rush/grass planting, partial shading (where this does not compromise the density of channel vegetation), and adopting a suite of potential treatment types for the outlet of swales to the Papakura Stream or its tributaries. Many of the existing rural roadways have wide grass verges that are potentially available to adopt some of these retrofit treatments.

One specific tributary of the Papakura Stream within the Alfriston-Ardmore EMA (SEV sites 14 and 16, on the northern tributary upstream of the Alfriston-Ardmore highway) was identified has having for low overall SEV ratings. These results warrant further investigation.

Protecting Natural Drainage Patterns from Rural-Residential Development in the Foothill Environments

The continued development of the Alfriston-Ardmore Valley for rural residential housing is a likely outcome, since the area does not have significant constraints, and is near to metropolitan urban areas for both MCC and PDC. To date, development has led to filling and piping of overland flowpaths, as well as restoration of surface watercourse, and implementation of stormwater wetlands.

Through the consenting process, it is important to provide for the protection of existing drainage patterns, the retention of adequate esplanade reserves for future potential restoration of stream corridors and/or implementation of stormwater management practices within the catchment. Management options to achieve this outcome may include:

- Planning controls for additional protection of both perennial surface water courses and overland flowpaths;
- Additional provisions for preservation of natural character values (represented by natural drainage patterns);
- Potential to extend subdivision rights in return for the protection and enhancement of stream corridors;
- Fast-tracking or dedicated support for resource consent processing for stormwater management outcomes that emulate pre-development hydrology, or that preserve/enhance existing drainage patterns.

6.5 Areas of Sub-Optimal / Degraded Value: Urban

6.5.1 Identification of Areas of Sub-Optimal / Degraded Value: Urban

The urban portion of the Papakura Stream catchment encompasses SEV sites 1-7 and WQ sites A-H, and includes peri-urban areas/rural residential areas in the Alfriston-Ardmore Valley. The majority of these sites were assessed as being of Moderate ecological health, with no sites recording Poor ecological health. However, ratings for fish and/or macroinvertebrate diversity were Poor/Very Poor and Low accordingly for urban locations, and overall water quality ratings were very poor for sub-catchments downstream of Great South Road and the Northern Railway Trunk Line.

In general, urban land-use has a disproportionately large effect on the health and diversity of stream biota when compared with undeveloped drainage basins (Paul & Meyer 2001). This is due to human activities altering the biological, chemical and physical processes in a stream, resulting in unstable flow patterns and altered biological structure and function of stream corridors (FISRWG 1998).

Preliminary water quality results for the Papakura urban catchment are as follows:

- **SEV** - All sites were of 'Medium' ranking (see Map 3 'Overall SEV ratings at Sampled Sites').
- **Water Quality** - Nine sites were of 'Poor' ranking (2, 3, 4, 5, A, D, F, G, H) and six sites of 'Very Poor' ranking (1, 6, 7, B, C, E) (see Map 7 'Overall Water Quality at Sampled Sites – Dry Weather Sample').
- **Macroinvertebrates** - All of the lower urban catchment SEV sites (1, 2, 3, 4) were found to have a 'Low' macroinvertebrate diversity ranking, while upper sites (5, 6, 7) outside of the MUL were of 'Medium' ranking (see Map 4 'Macroinvertebrate Values for Each SEV Site').
- **Total Erosion** - Five sites were of 'Moderate' ranking (1, 2, 3, 4, 5), and two sites were of 'Low' ranking (6, 7) (see Map 6 'Overall Erosion at Each SEV Site').

The Papakura urban catchment receives runoff from a variety of land-use types including dense residential subdivisions, the commercial centre for Manurewa, and commercial and light industrial areas in proximity to the Papakura Stream.

High faecal coliform counts have been recorded at Porchester Road Bridge (ARC 2004). The East Tamaki Dairy Factory has also allegedly detected salmonella in the Papakura stream (Beca Carter Hollings & Ferner 1993).

Urban water quality sites showed moderate levels of BOD during the dry weather water quality runs. However, results of wet weather runs may be more indicative given that 95% of the BOD in streams and rivers is from stormwater runoff during intense storm events (Pisano 1976). Catch basins can retain liquids and solids in what often becomes a septic situation with anaerobic sludge. A minor rainfall will pick up this solution, which has the BOD of over seven times that of ordinary stormwater, and carry it downstream (FWPCA 1969, Palmer 1950).

SEV sites 6 and 7 were found to have high BOD during the dry weather water quality run, possibly suggesting a local source of organic pollution. Site 6 may also require further investigation for high values of ammonia and chlorides, and greater than expected suspended sediment. This site also exceeded ANZECC (2000) trigger level guidelines for cadmium, copper, lead and zinc. Zinc occurred more frequently in urban catchment sites (1, 6 and 7), possibly due to a combination of roofing materials and runoff from roads.

As was the case for the rest of the Papakura Stream Catchment, *E. coli* levels were high; this is however not unusual for urban catchments. Bacteria are quickly metabolized when in contact with plant and soil systems, however over one third of the Papakura urban catchment has its runoff directly linked to reticulated systems (Beca Carter Hollings & Ferner 1993).

The results demonstrate that the majority of the urban sites are generally affected by degraded water quality and have compromised freshwater ecological values. The more significant of the causal factors underlying these problems are likely to be non-point source pollution from runoff of impervious surfaces.

6.5.2 Key Issues for Urban Areas

Urban streams symbolize an extreme intersection of human and ecological realms: urbanization affects the shape of stream channels, their chemical composition, primary energy sources, flow conditions and biotic interactions (Karr & Chu 2000). The primary cause of degradation to receiving waters from urban areas is the extent of impervious surfaces and/or the connection to reticulated systems.

As impervious surfaces increase, the quantity of urban runoff increases exponentially. During a storm event, an increase of 10–20% in impervious surfaces increases runoff by twofold, 35–50% increases runoff by threefold, and 75–100% increases runoff by fivefold (Paul & Meyer 2001). In urban watersheds, there is typically a shortened time period (or 'time of concentration') before runoff reaches peak flow conditions. Furthermore, these peak flows are of considerably greater volume than in non-urban watersheds. In comprehensive studies of Auckland's urban streams, it was determined that stream quality was highest at <10% impervious cover (IC), declining between 10–25% IC, and was consistently poor beyond this (Allibone *et al.* 2001).

Pollutant sources in urban watersheds generally include debris, litter and erosion of surface materials, plant and animal waste, chemical fertilizers and pesticides, household and commercial wastes, particulates, liquids and exhaust from transportation (USEPA 1993). Atmospheric pollutants collected in rainfall are more likely to reach streams in developed watersheds (Walsh 2000). It is generally accepted that urban runoff has increased loads of nutrients, metals, pesticides, and organic contaminants (Paul & Meyer 2001, Ferguson 1991). Fine-grained suspended solids seem to be indigenous to urban areas (Jones & Urbonas 1986).

Temperature is one of the most important variables in the biosphere affecting molecular movement, fluid dynamics, saturation constants for dissolved gases, metabolic rates, and life cycle cues (Hauer & Hill 1996). In general, temperature variations in urban streams show significant variation compared to those streams outside an urban catchment; an 8–10°C temperature change in streams running through metropolitan areas is not uncommon (Haslam 1990).

Pollutants accumulate within receiving waters in the fine benthic sediments, and through bioaccumulation they subsequently accumulate into the food chain. Pollutants are often compounding or have synergistic effects on surface waters. For example, algae and macrophytes may contribute to concentrated nutrient release and excessive BOD when dieback of these plants occurs.

In terms of the effect on in-stream biota, urbanization leads to a shift from external production to internal production of biological energy. Starved of vegetation from the floodplain but receiving excessive nutrient as well as increased BOD and thermal pollution, stream systems can support monocultures of algae and phytoplankton that augment high BOD conditions when they decompose.

Urban runoff can also exert a chronic toxicity to fish and macroinvertebrates (Medeiros & Coler 1982). Organochlorines get into water easily, are toxic, persist and bioaccumulate in lipid layers of higher organisms in the food chain. Heavy metal levels in runoff typically exceed the safe threshold limits for freshwater biota, increasing significantly in aquatic ecosystems over high flow periods (Ellis 1986).

The key issues identified for the urban areas of the Papakura Stream Catchment over the course of this study were as follows:

- Stormwater management – a shared responsibility by the PDC and MCC, and particularly within the urban catchment areas;
- Poor soils for drainage in the urban catchment – the loss of intercepting vegetation and detention in natural drainage patterns has lead to the increase in surface water flows to the Papakura Stream;
- Lack of riparian cover – with consequent physical and chemical changes to the stream habitat which adversely affects its biological functionality;
- Stormwater inputs to streams –from diffuse sources (such as overland flows) and stormwater outlets (both from individual lots and reticulated systems to the extent of the catchment boundary);
- Aging and undersized reticulated infrastructure and inappropriate overland flowpaths through residential homes and across brownfield environments;

- Aquatic plant growth - responding to elevated temperatures and nutrient levels, with resultant effects on channel flows, flood storage and eutrophication processes (from dieback);
- Terrestrial and aquatic-emergent weeds are displacing native vegetation, reducing flood flows and causing surficial erosion where root systems are inadequate;
- Floodplain infilling, including the construction of vertical stopbanks, fences and retaining structures in the floodplain;
- Criminal activity and lack of passive surveillance behind industrial areas and fences of housing estates that back on to the Papakura Stream;
- Takanini Peats in the southern catchment – draining of peat-like soils results in consolidation of sediments and increased surface runoff;
- Stream channelization and modification;
- Risk assessment and future proofing for climate change - sea level rise, changes to annual precipitation and extreme events, change in sediment regimes, coastal erosion etc.

6.5.3 Guiding Management Principles : Urban

6.5.3.1 Multiple Stormwater Objectives – Catchment and Greenway Planning

Stream environments can deliver multiple benefits to urban areas, and therefore urban stormwater systems should be handled with multiple stormwater management objectives in mind. This includes hydrological objectives such as control of runoff peak rates, volume control and water quality control, as well as opportunities for connected open space, enhanced urban ecology and enhanced landscape amenity values. It is also important to consider the integration of appropriate land-use with catchment drainage patterns, and to broadly promote vegetation cover within the catchment to realise an integrated planning process.

The ancillary benefits that stream restoration provides are economic, socio-cultural and environmental, including:

- Additional water quality treatment and flood storage with ease of maintenance;
- Optimised open space opportunities in association with stormwater infrastructure;
- Recreational opportunities;
- Public awareness and sense of place;
- Landscape amenity and natural character values;
- Aquatic and terrestrial habitats and ecological connections;
- Enhancement of water quality in the downstream environment.

A planning technique for integrating multiple objectives into stormwater management is the promotion of 'greenways'. Greenways also known as lineal parks, wildlife corridors and riverways are lineal open spaces linking natural, cultural and recreational areas in coincidence with streams (or other) lineal landscape features. Greenways not only form master planning objectives, but also capture the imagination of the public, environmental groups and policy-makers. Greenways provide the framework to protect, conserve and link natural resources and open spaces, including fragmented urban habitats. Connections within the stream corridor are along a central datum and natural feature that is already recognised.

The Papakura Stream supports a wide riparian esplanade area that is contiguous with a coastal walkway and is an excellent candidate for greenway planning. Papakura Stream is one of the key riparian linkages identified in Plan Change 13, and promoted as a Greenway in the Papakura Open Space Strategy. There are also specific opportunities within the Neild Road sub-catchment to connect the Papakura Stream to the Manurewa Town centre and beyond in association with open sections of the tributaries.

The Papakura Stream has been identified as an opportune area to connect open space, enhanced urban ecology and landscape amenity with hydrological objectives particularly through Takanini Structure Plan Area 6. This approach is also supported by existing Catchment Management Plan and operative Discharge Consent.

6.5.3.2 Protection of Existing Habitat Structure

The most effective stormwater management approach is to reduce impermeable surfaces through the preservation of open space as well as naturally occurring drainage patterns and vegetation, thus reducing stormwater generation from the outset. The extent and quality of existing vegetation cover in association with streams and within the contributing catchment has been shown to have a significant effect upon the water quality in the receiving environment (ARC 2001, ARC 2004, Rutherford *et al*. 1999, Allibone *et al.* 2001).

The soil mantle is important in providing contaminant removal functions through physical processing (filtration), biological processing (microbial action) and chemical processing (cation exchange capacity, as well as other chemical reactions). It also provides for plants to metabolize and transform contaminants and evapo-transpiration of intercepted rainfall.

Stormwater and urban drainage systems represent significant opportunities to integrate ecological infrastructure into urban environments, often in marginal locations (floodplains and overland flowpaths). These systems can be an important contributor to regional biodiversity and for passage of fauna from coastal to upland environments. Significantly, the urban reaches of the Papakura Stream still retain elements of open stream channel and associated riparian esplanade strips. In areas where the Papakura Stream remains free of stop-banks, there is frequently a wide esplanade reserve and associated floodplain. Although the stream has been modified to an extent, it still retains bedrock features, floodplains and meanders through the MUL.

Within the urban catchment there are remnant vegetation areas of some ecological (and landscape) significance. In particular this includes stream reaches of the upper Neild Road catchment connecting with the Manurewa bush reserves, and pockets and strips of vegetation in open spaces and alongside roads and roadside swales (such as

Porchester Road). Mature tree stands along the Papakura Stream also provide important habitat structure behind the commercial areas of the Lincoln sub-catchment and in association with the Manukau Golf Course. The golf course has the potential to add significant value to the stream corridor as a floodplain, riparian buffer, lowland habitat and (depending on land management practices) an important source of relatively clean water runoff.

Stormwater wetlands, in association with the Manurewa East sub-catchment in the north and the Takanini sub-catchment in the south, contribute to the ecological infrastructure of the urban drainage network. These areas not only extend the range of available habitat for both fish and macroinvertebrates, but are also potential supplementary habitats for avifauna.

Fish communities within the catchment are dependant on the retention of fish passage, which in turn is reliant on design considerations in relation to reticulated systems, rising manholes and culverts. Habitat refugia should be included in the design of stormwater management systems and should include consideration of food sources, in-stream structures for shelter, deep pools for cool water, and/or riffles for oxygenation. These provide important locations for fish to recuperate as they navigate the catchment through reaches of sub-optimal water quality.

Macroinvertebrates and planktonic organisms rely on the stream flows to perform various functions of their life cycle. The 'colonization cycle' of macroinvertebrates involves the presence of eggs and larvae in upstream reaches, drift of immature individuals to colonize suitable substrates downstream, and upstream flight of adults to complete the cycle.

Streams are recognized as highly productive habitats for threatened and endangered species (ARC 2001). Within a stream, there is an amalgamation of several distinct habitat subsystems. These vary along gradients that are longitudinal, latitudinal and hyporheic (Grimm 1996). Organisms traveling up the river exist within specific ranges of dispersive, biotic and abiotic characteristics (Townsend 1980).

Protection of existing habitat structure within the catchment could include the following actions:

- Recognise the Papakura Stream in planning documents as a landform/landscape of significant status, with formal protection of its channel, banks, floodplains and eventually its remaining tributaries as an integral system;
- Provide District planning provisions to encourage the covenanting of vegetation and open channel systems that occur on private land through rates relief, subdivision opportunity or similar;
- Provide mechanisms to reduce stormwater runoff and/or increase in publicly owned overland flowpaths and stream esplanade areas in association with redevelopment;
- Provide mechanisms to protect and enhance roadside, railway, and roadside-swale vegetation;
- Recognise opportunities to enhance inanga habitat in the coastal sections of the catchment, as well as provide for specific fish habitat enhancements at

steeper valley gradients (riffle environments) or deep gullies and bends (pool environments).

Much of Papakura District Council's existing policy supports the protection of existing habitat structure and seeks the restoration and enhancement of those degraded sections.

6.5.3.3 Restoration of Natural Systems for the Detention of Stormwater in the Mid Catchment

Natural stream environments provide stormwater attenuation and treatment of overland flows, increased hydraulic and detention capacity, and remediation of water quality. The Papakura Stream Flood Management Plan states "The use of natural attributes of water courses will be encouraged to ensure the disposal and control of stormwater" (Beca Carter Hollings & Ferner Ltd 1993).

The planting of open channels protects stream banks against erosion, provides treatment of overland and groundwater flows, increases infiltration rates, and attenuates stormwater in the floodplain. The use of native plants for vegetation leads to lower maintenance costs and enhanced long-term sustainability and biodiversity (Ferguson 1991).

It is frequently not feasible to 'restore' streams in urban watersheds to pre-runoff response conditions. Instead, the practice becomes 'rehabilitation' with integrated stormwater treatment practices. Notwithstanding this, the pressures of urbanization will sorely test rehabilitated streams. In the first year, there will likely be a range of high to low frequency flow events, and newly planted vegetation will undergo stress from sediment loading and pollution. Research in the 1970's attempted to determine if restored urban streams improved or further degraded water quality (Riley 1989). The results demonstrated that urban stream restoration projects have failed in the past and in doing so they have caused flooding and collapsed banks, and have increased turbidity, pollutant loads and sedimentation in receiving waters downstream. Urban stream restoration must therefore focus upon 'rehabilitation', as opposed to 'restoration', to ensure the sustainable recovery of stream processes in a form that is consistent with the constraints of the urban stream corridor (Pinkham 2001).

The best approach to watercourse rehabilitation is in conjunction with a well-managed catchment (FISRWG 1998). This relates to the degree of catchment imperviousness and drainage intensity (Walsh 2000). The importance of vegetation in the contributing catchment cannot be underestimated, since it intercepts overland flow and increases surface roughness and the amount of organic matter. This increases the time of concentration of runoff in the watershed before reaching the rehabilitated stream, thereby moderating quantity, velocities and erosive potential (Lawrence *et al.* 1996). Given the flood hazard risk of the Papakura Stream, any enhancement of the stream channels and banks must accommodate safe and efficient stormwater movement.

The best case scenario for stream restoration is therefore to model the stream on a rehabilitated catchment, assuming low impact design source controls and increased overall vegetation and pervious surfaces following retrofit and redevelopment. If this is a predictable end, then stream rehabilitation may be staged within the catchment and within the floodplain to limit effects of flash stormwater events.

Stream restoration is likely to follow similar principles to rural areas (previously described in Management Options for Rural Areas, see Section 6.4.3 above). Specific concerns that relate to the urban environments include:

- Reticulated stormwater infrastructure as point source inputs to the stream;
- Consideration of surface roughness as a result of riparian planting, with a view to minimising effects to hydraulic efficiency through urban areas while maximizing attenuation and flood storage;
- Consideration of principles of 'Crime Prevention through Environmental Design' (CPTED) to provide for passive surveillance of reserves and clear sight lines for walking areas;
- Provision for diversity in stream morphology, to ensure pool, riffle and run diversity occurs within the confines of the urban channel.

While dependent on vegetation type, a 10-20 m planted buffer is generally recommended (~5 m to sustain dense low planting, and 10-20 m to sustain shrubland and forested environments) (Parkyn *et al.* 2000). Christchurch City Council waterway protection programme categorised riparian buffer zones for various urban types to act as a guideline (R. Barker, pers. comm.; cited Parkyn *et al.*2000):

- Utilities waterway (piped) - 3 m
- Open utilities waterway - 5 m
- Environmental asset (natural tributary) - 7 m
- New waterway - 7 m
- Upstream river - 20 m
- Downstream river - 30 m
- Hill waterway - 10 m
- Coastline (above MHWS) - 20 m

In addition to the above discussion, management of stream-side revegetation should have reference to Section 5.5 of this report in relation to their socio-cultural, landscape, visual and amenity values.

6.5.3.4 Low impact design for stormwater attenuation/ retention

Low impact design (LID) methods replicate natural processes such as capture of stormwater by vegetation and infiltration to soil layers. The environmental effects addressed through LID methods are wide ranging, including the standard stormwater management effects considered in the ARC stormwater management programme (TP10 and TP124), and a general vision for a greener environment in metropolitan areas. The focus of LID in catchment management includes:

- Water quantity effects such as flooding, drainage system capacity and groundwater recharge;
- Improved aquatic habitat of the receiving environment;
- The introduction and preservation of natural character values in an urban environment; and

- Indirectly, reducing effects on water quality in the receiving environment.

The fundamental techniques to respond to these focus areas are:

- Reduce the overall runoff volume and peak flow rate of stormwater by encouraging the interception of stormwater runoff via processes such as evapo-transpiration and infiltration;
- Manage stormwater contaminants on–site;
- Rehabilitate natural features, including enhancement of landscape amenity values, landscape connectivity, ecological values and urban design.

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

District planning provisions can provide for both 'carrots' and 'sticks' for the retrofit of development or integration of LID treatments into redevelopment. This may take the form of rates relief, stormwater contribution reduction, pervious or landscape amenity targets, and regulation of new and replaced infrastructure. Specific LID treatments in an urban catchment include:

- Green roofs - Reduces stormwater runoff rate, and provides stormwater quality treatment. Can have landscape and ecological benefits, as well as providing insulation (heating/ cooling and noise) benefits for the building. Can also extend the life of a roof, and have benefits to air quality and ambient air temperatures.
- Minimise impervious area by clustering buildings, integrating them into existing buildings and landform, and sharing vehicle access-ways. This limits soil disturbance and allows storm flows to more closely approximate natural shallow subsurface flowpaths. Open space areas and landscape amenity are also optimized.
- Bioretention (raingardens, tree pits) – Retains and sometimes infiltrates stormwater via planted systems. Provides landscape amenity, ecological benefits, and ancillary benefits including dust inception and temperature moderation.
- Treatment wetlands - Provides stormwater quality treatment and reduces stormwater runoff rates. Provides landscape amenity, natural character values, and ecological benefits, as well providing for education and passive recreation opportunities;
- Soil rehabilitation - Improves infiltration, and reduces stormwater runoff rates. Improves soils pollutant adsorption and biofiltration rates, and provides for improved plant growth and robustness;
- Permeable paving - Provides for infiltration, and increases the time of concentration thereby reducing stormwater runoff rates;
- Revegetation of catchment - Reduces stormwater runoff rates, through interception, infiltration and evaporation as well as providing stormwater

treatment. Provides landscape amenity, biodiversity and ecology benefits, and ancillary benefits such as dust inception and temperature moderation.

A key feature of any LID within the Papakura Stream Catchment will be the need to maintain hydrological neutrality by controls on impervious area or attenuation devices.

6.5.3.5 Pollution prevention controls at flooding points and near watercourses

Papakura District is currently incorporating pollution control devices within developments in the Takanini area. These have taken the form of ponds, rain gardens and, in future, roadside swales.

Although point source contamination has been primarily removed in the Papakura Stream Catchment, including the separation of storm and sewer systems, there is still potential for intentional and/or accidental pollution to occur within the reticulated stormwater system and beside open water channels.

Prevention of spills to the Papakura Stream requires a separate study to assess risk and provide future-proofing in relation to stream environment buffers. However, immediate measures may include:

- Planting of watercourses with riparian vegetation to increase soil humus layers and provide for filtration of overland flows;
- Provide flood protection measures of habitable floors in the catchment;
- In urban and semi-urban areas provide for separate management zoning in the stream corridor, its floodplain and immediately adjacent lands;
- Require pollution prevention plans for all commercial and industrial operations in the catchment;
- Retrofit bioretention devices and/or sand filters between stream environments and adjacent land-uses. These may also be applied as primary treatment to reticulated systems in upper catchment areas; and
- Locate gully traps and sanitary fittings for sewerage infrastructure above the 1% AEP.
- A public education campaign to raise awareness of the effects of stormwater pollution.

6.5.4 Specific Management Options : Urban

The urban component of Papakura Stream Catchment largely relates to the Takanini Valley (MUL) EMA and its associated sub-catchments (Figure 22). These sub-catchments are examined in further detail in the following sections to provide for management options specific to planning, land-use, integration of LID, restoration of riparian areas (including open watercourses and wetlands), and outlets to the Papakura main stem.

The Takanini Valley EMA is a continuation of the Alfriston-Ardmore Valley, with foothills to the north and flat areas of Takanini Peats to the south. Streams are entirely reticulated barring short sections of open watercourse and open drainage channels. Native vegetation is sparse, except for mature broadleaf-podocarp remnants in association with upper tributaries toward Claude Road (in the Neild Road sub-catchment). The MUL retains wide areas of open space (such as the Manukau Golf Course and Randwick Park), extensive dedicated stormwater wetland areas in the Papakura District, and broad riparian and coastal esplanade reserves in association with the Papakura main stem.

6.5.4.1 Clayton Sub-catchment

The Clayton sub-catchment (Figure 23) is a largely built-out area of residential subdivision in lowland environments and lower foothills, and commercial and light industrial land alongside the Papakura Stream. This sub-catchment does not contain large areas of public open space or institutional land, therefore lending itself to LID retrofit for stormwater management with the potential to utilise the sizable esplanade reserves of the Papakura Stream for combination treatment wetlands and compensatory flood storage. Management options are discussed further below.

Low Impact Design Retrofit

Many of the residential areas within the Clayton sub-catchment are well established, (e.g. along Coxhead Road) or recently developed (e.g. the Glenross Drive area). There are opportunities to capture and re-use stormwater for individual homes in these areas (rain tanks).

LID retrofit is likely to have the most benefit (in terms of landscape amenity values and public awareness) adjacent to neighbourhood shopping areas or along wider roads adjacent to commercial properties and leading to the Papakura Stream (Clayton, Holmes, and McQuarrie Roads). LID retrofit in commercial properties could coincide with redevelopment, with a view to contaminant source controls prior to reticulation (e.g. sand filters, bioretention).

Floodplain Treatment Wetlands

Extensive esplanade reserves along the Papakura Stream provide opportunities for treatment wetlands to parallel the stream in coincidence with floodplain areas. These systems have the potential to dissipate outfalls to the Papakura Stream, provide water quality treatment, compensatory floodplain storage, and enhanced riparian habitat (e.g. inanga spawning habitat). Specific consideration must be given to adequate drainage of wetland systems to avoid stagnant water, appropriate surface roughness to accommodate flood flows, public amenity, public safety, and continued public access along reserves.

Potential locations for treatment wetland systems include a lineal area between the stormwater outlets upstream and downstream of Gairloch Road (see Photo 1), and opportunities to direct upper catchment pipe networks to an open expanse beside YKK NZ Limited building, where there is evidence of an existing overland flowpath or ephemeral spring (see Photo 2).

PAPAKURA STREAM ASSESSMENT AND MANAGEMENT STUDY

Figure 23: Clayton

Date: 17.06.08 Drawing: A4_Clayton.jpg Scale: 1: 6,000@A4 Author: MDa

Auckland Regional Council

Boffa Miskell

Photo 1.

Existing stormwater outlet downstream of Gairloch Road

Photo 2.

Opportunities for treatment wetlands below the YKK NZ Ltd Building

6.5.4.2 Neild Road Sub-catchment

The Neild Road sub-catchment (Figure 24) begins in lower density residential areas on the Papakura ridgeline, extending through the Manurewa town centre (see Photo 3), crossing Great South Road and the Northern Trunk Line, through dense residential areas of the Papakura lowland environments, to commercial properties adjacent to the Papakura Stream.

The sub-catchment includes the Manukau Christian School and large areas of open space, including Beaumont Park, Gallaher Park, Tadmor Park and the Manurewa Native Bush Reserve. The bush reserve is contiguous with remnant vegetation in open upper tributaries (see photo 4), which supports mature native broadleaf-podocarp remnants, with substantive native understorey.

A significant proportion of the accumulated flows in this sub-catchment are within open channel systems, through a combination of private land, public open space and transportation corridors. The extent of the open water systems lend this sub-catchment to management options for both surface watercourse restoration and stream daylighting of piped sections, specifically for the eastern most tributary (henceforth tributary 'A').

Low Impact Design Retrofit

An LID retrofit of the Manurewa Town Centre streetscapes has the potential to improve traffic calming, and enhance urban design and landscape amenity values (see photo 3). This would also link with restoration proposals for tributary 'A' which flows in piped sections south of the Manurewa Town centre and across Alfriston Road.

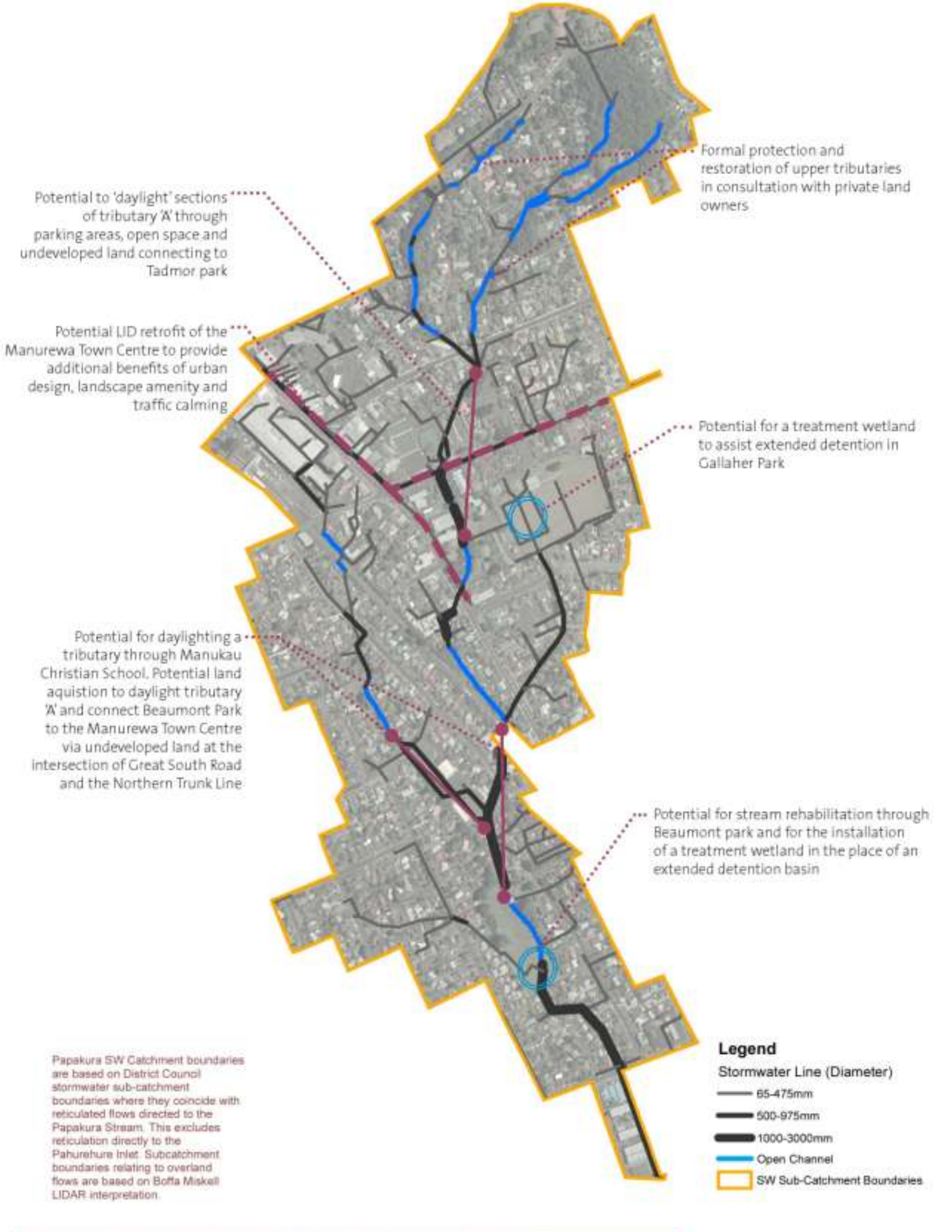
LID streetscapes could pick up again, further southward on Great South Road, through the intersection with Mahia Road, linking to LID retrofit opportunities ascribed to the Clayton sub-catchment and coincident with Great South Road crossing the Papakura Stream.

Stream Restoration and Rehabilitation

Tributary 'A' flows through a combination of public and private land, with the potential for not only streambank and floodplain restoration, but also the creation of additional surface watercourse through the process of 'daylighting' of pipes. This would require a comprehensive planning document, to provide for a vision of an open water course and its associated values in the urban catchment, and to allow for effective public consultant and feasibility studies.

Stormwater Wetland Detention

Surface watercourses and reticulated streams that currently flow across existing open space have the potential to be detained in stormwater wetland and extended detention areas to provide for ecological restoration and landscape enhancement. Specific opportunities to be investigated include Beaumont Park (see photo 5) and Gallaher Park. Stormwater wetland detention is also possible within the narrow floodplain bar of the Papakura Stream, similar to the floodplain treatment wetlands discussed in the Clayton sub-catchment (refer to Section 6.5.4.1).



PAPAKURA STREAM ASSESSMENT AND MANAGEMENT STUDY

Figure 24: Nield Road

Date: 17.06.08 Drawing: Catch_A4_Nield.jpg Scale: 1:9,000@A4 Author: MDa

Photo 3.

Manurewa Town Centre.

Photo 4.

Podocarp-Broadleaf forest remnants on private land in the upper tributaries.

Photo 5.

Existing modified watercourse and treatment wetland through Beaumont Park

6.5.4.3 Lincoln Sub-catchment

The Lincoln sub-catchment (Figure 25) is comparatively small, centered around the intersection of Great South Road and the Northern Trunk Line, incorporating residential areas at its periphery and commercial/industrial areas at its core, and adjacent to the Papakura Stream. Due to the lack of open space within this sub-catchment, the main opportunities are with regards to LID retrofitting and/or utilizing transportation corridors for stormwater management.

Low Impact Design Retrofit

LID retrofit opportunities exist at the intersection of Mahia and Great South Roads, through the linking in with those ascribed for the Clayton and Neild Road sub-catchments (refer to sections 6.5.4.1 and 6.5.4.2 respectively).

Industrial areas (including a dairy factory) would benefit from LID treatments to prevent accidental spills and provide a treatment of 'first flush' contaminants in the localized catchment.

Stream Restoration and Rehabilitation

Surface water flows occur alongside the Northern Trunk Line and as overland flowpaths within industrial areas. There may be sufficient flow in these areas to warrant rehabilitation of surface water courses along the railway lands, before linking into Great South Road and the Papakura Stream. This could be formed as an ecological corridor within the 'left over spaces' of the Northern Trunk Line and Great South Road rights-of-way (see photo 6).

The interface between lowland commercial areas and the Papakura Stream consists of stop-banks and fences overrun with weed species (see photo 7). There are opportunities here to replace engineered 'hard' structural measures with stablised streambanks and reinforcing vegetation. This has the potential to restore the natural morphology of the stream and increase floodplain capacity and riparian habitat.

Restoration of the Papakura esplanade area could be integrated with LID retrofit of commercial areas, ideally placed at the transition to the stream, and potentially including trees to shade the northern banks from the crown. In this way, overland flow from commercial areas could be directed to riparian banks and by-pass reticulated systems.

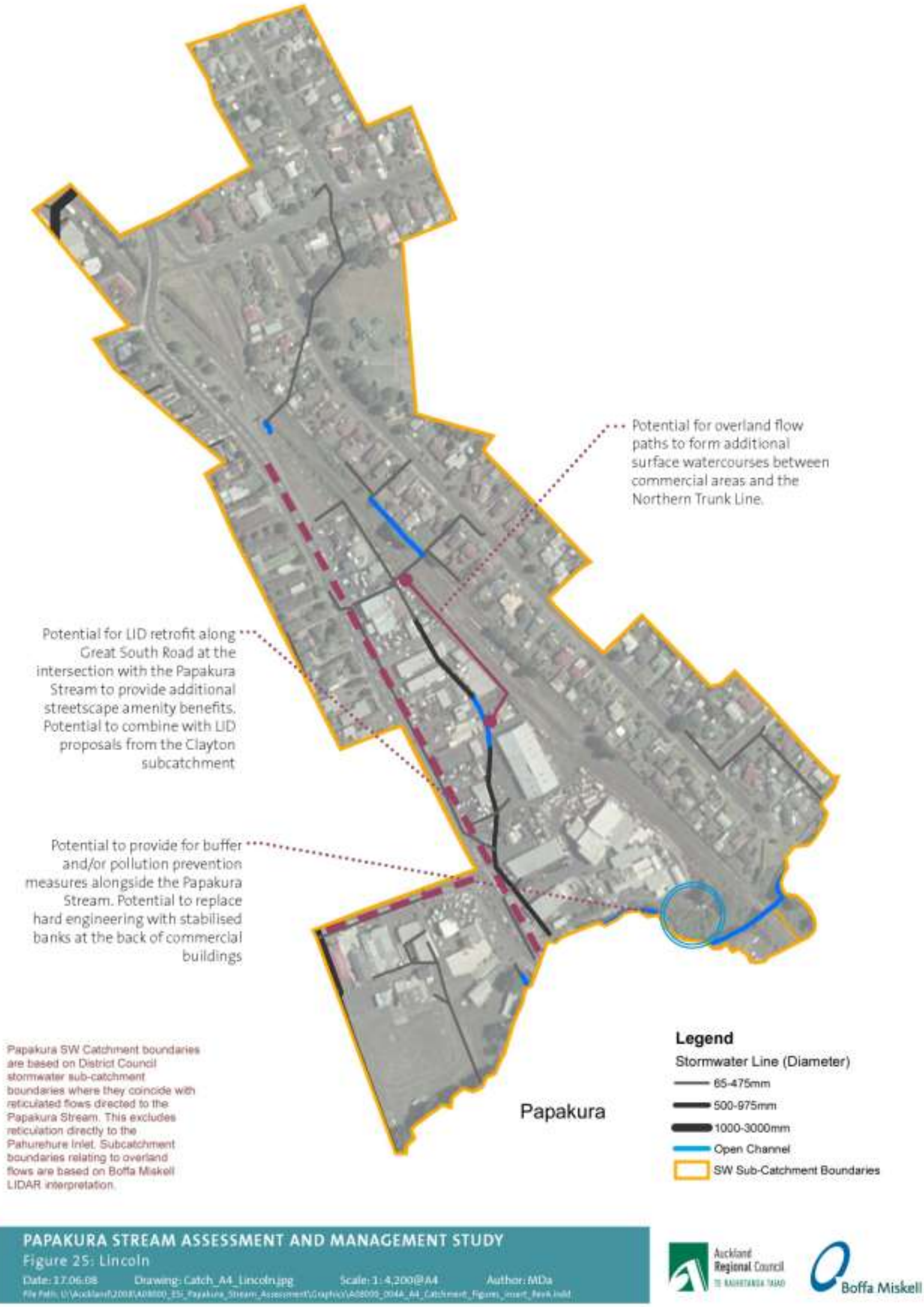

Potential for overland flow paths to form additional surface watercourses between commercial areas and the Northern Trunk Line.
Potential for LID retrofit along Great South Road at the intersection with the Papakura Stream to provide additional streetscape amenity benefits. Potential to combine with LID proposals from the Clayton subcatchment
Potential to provide for buffer and/or pollution prevention measures alongside the Papakura Stream. Potential to replace hard engineering with stabilised banks at the back of commercial buildings
Papakura SW Catchment boundaries are based on District Council stormwater sub-catchment boundaries where they coincide with reticulated flows directed to the Papakura Stream. This excludes reticulation directly to the Pahurehure Inlet. Subcatchment boundaries relating to overland flows are based on Boffa Miskell LIDAR interpretation.
Papakura
Legend
Stormwater Line (Diameter)
65-475mm
500-975mm
1000-3000mm
Open Channel
SW Sub-Catchment Boundaries
PAPAKURA STREAM ASSESSMENT AND MANAGEMENT STUDY
Figure 25: Lincoln
Date: 17.06.08
Drawing: Catch_A4_Lincoln.jpg
Scale: 1:4,200@A4
Author: MDa
Auckland Regional Council
Boffa Miskell

Photo 6.

Railway embankments and associated right of ways support open channel in degraded forms.

Photo 7.

A confined channel directs stream flows past commercial areas.

6.5.4.4 Greenmeadows Sub-catchment

The Greenmeadows sub-catchment (Figure 26) includes reticulated systems and open water courses west of State Highway One (SH1), and includes Manurewa East School and Greenmeadows Intermediate. Land-use is predominantly residential, barring Yokoya Limited buildings, toward the lower sub-catchment on Sterling Avenue. As for the Neild Road sub-catchment, there are opportunities in Greenmeadows for the restoration of upper sub-catchment tributaries and the daylighting of piped watercourses that coincide with open space and institutional public land.

An existing overland flowpath east of the sub-catchment (and west of Manurewa East School) is of concern in terms of conflicts with residential homes. Hydrological modeling may determine a need for additional extended detention above this tributary or upsizing of existing pipe networks. If reticulation is to be replaced, or augmented, there would be a benefit in stormwater diversion under Scotts Road, Myers Road and Sterling Avenue to coincide with potential LID retrofit of these streetscapes.

Low Impact Design Retrofit

As discussed above, there is potential for the retrofit of streetscapes with LID along Scotts Road, Myers Road and Sterling Avenue. This would link the upper sub-catchment tributaries with the lower sub-catchment pipe networks, and link the two schools in this sub-catchment to the Papakura Stream Esplanade, providing for traffic calming and landscape amenity values.

Stream Restoration and Rehabilitation

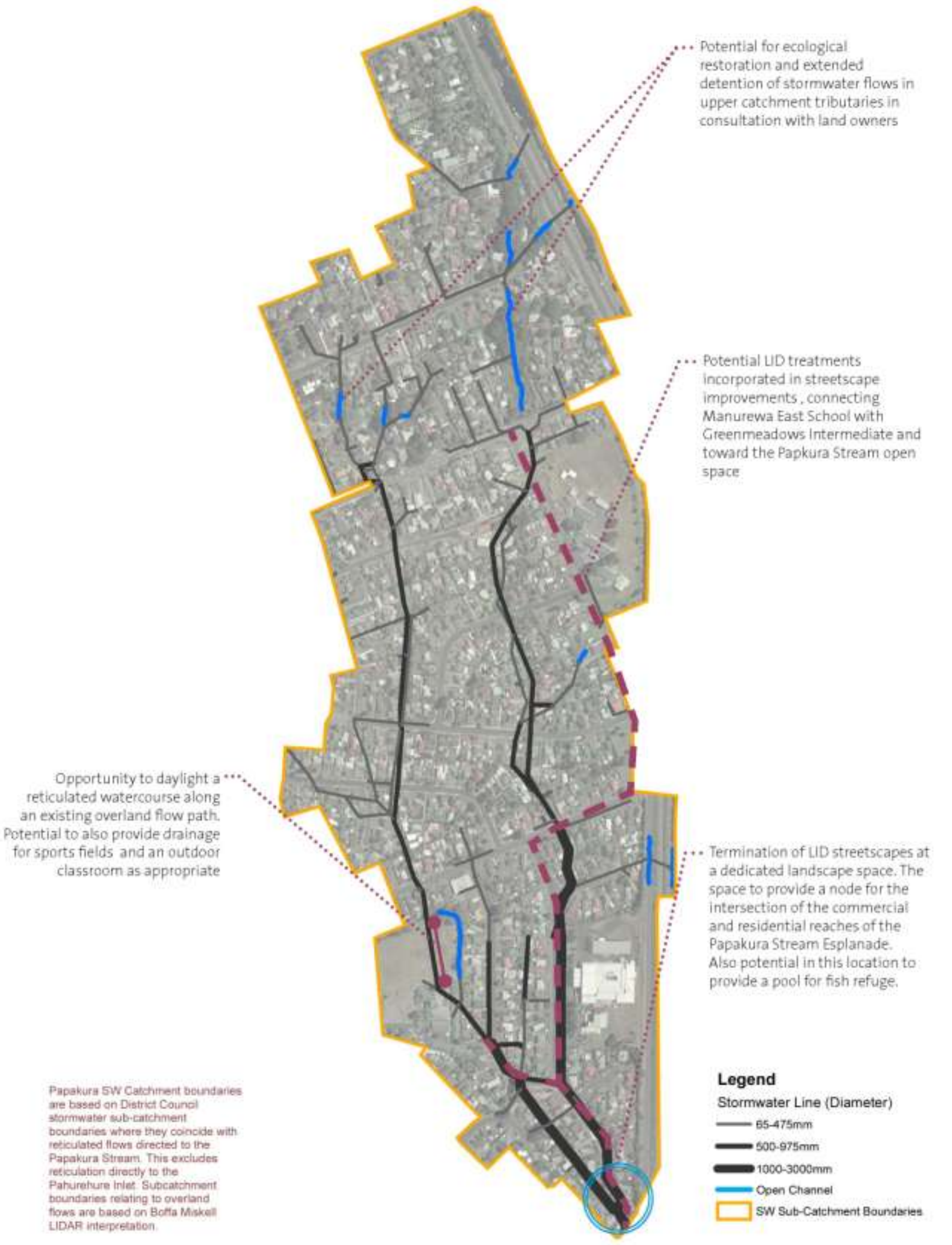
Upper catchment tributaries are intermittently piped and impacted by weed species. There are opportunities to restore these systems to provide for extended detention, stormwater treatment and habitat enhancement.

An overland flowpath crosses the eastern extent of Greenmeadows Intermediate, while a larger order pipe flows under the sports grounds. There is a potential to daylight a section of this stormwater pipe and/or divert flow to the existing overland flowpaths for stormwater treatment, extended detention, habitat enhancement and associated educational opportunities.

Restoration of Papakura Stream has the potential to take advantage of an outside bend and high banks at the outlet of the Greenmeadows sub-catchment to provide a pool habitat to assist fish passage through the less amenable reaches of the MUL. There is potential to provide for a dedicated landscape space in this location, at the intersection of residential and commercial reaches of the Papakura esplanade.

Stormwater Wetland Detention

There may be an opportunity for a treatment wetland in the mid catchment at the confluence of piped systems, and at the intersection of Greenmeadows and Sterling Avenue. This location would also be at the confluence of potential LID streetscapes. A wetland in this location would take advantage of a natural low point in the catchment and combine with existing open space between Greenmeadows Road and Barnard Road. This option would however require land purchase.



PAPAKURA STREAM ASSESSMENT AND MANAGEMENT STUDY

Figure 26: Greenmeadows

Date: 17.06.08 Drawing: Catch_A4_Greenmeadows.jpg Scale: 1:7,500@A4 Author: MDa

Auckland Regional Council Boffa Miskell

Photo 8.

Upper tributary to Greenmeadows with mature totara and mixed exotic vegetation.

Photo 9.

The Papakura Stream and SH1 over-bridge with Greenmeadow outlet to the lower left.

Photo 10.

The overland flowpath at Greenmeadows Intermediate

6.5.4.5 Manurewa East Sub-catchment

The Manurewa East sub-catchment (Figure 27) is the largest MUL sub-catchment, comprising primarily of residential areas and schools, and incorporates the majority of SH1 within the Papakura Stream Catchment. Residential development has been built-out for the most part, with older subdivision and streetscapes in the south-west and ongoing development in the west and foothills.

Low Impact Design Retrofit

LID retrofit is likely to provide the most benefit in streetscapes in association with schools along Magic Way, and along Hyperion Drive following the Papakura Stream and linking open spaces. In many instances roadway networks have been constructed recently. The planting of street trees for the interception of rainfall is a minimal LID response to avoid impact to these newly installed assets.

Stream Restoration and Rehabilitation

Large open spaces in the catchment provide opportunities for additional surface watercourses, specifically within the non-descript Randwick Park, and recently vested open space areas in the upper sub-catchment (see photos 11 and 12). Randwick Park is of considerable size and already contains overland flowpaths on the western edge. Pipe networks in other parts of the sub-catchment could be directed to this open space to provide a natural surface water feature to enhance landscape amenity values and provide for ecological enhancement in this under-utilised green space.

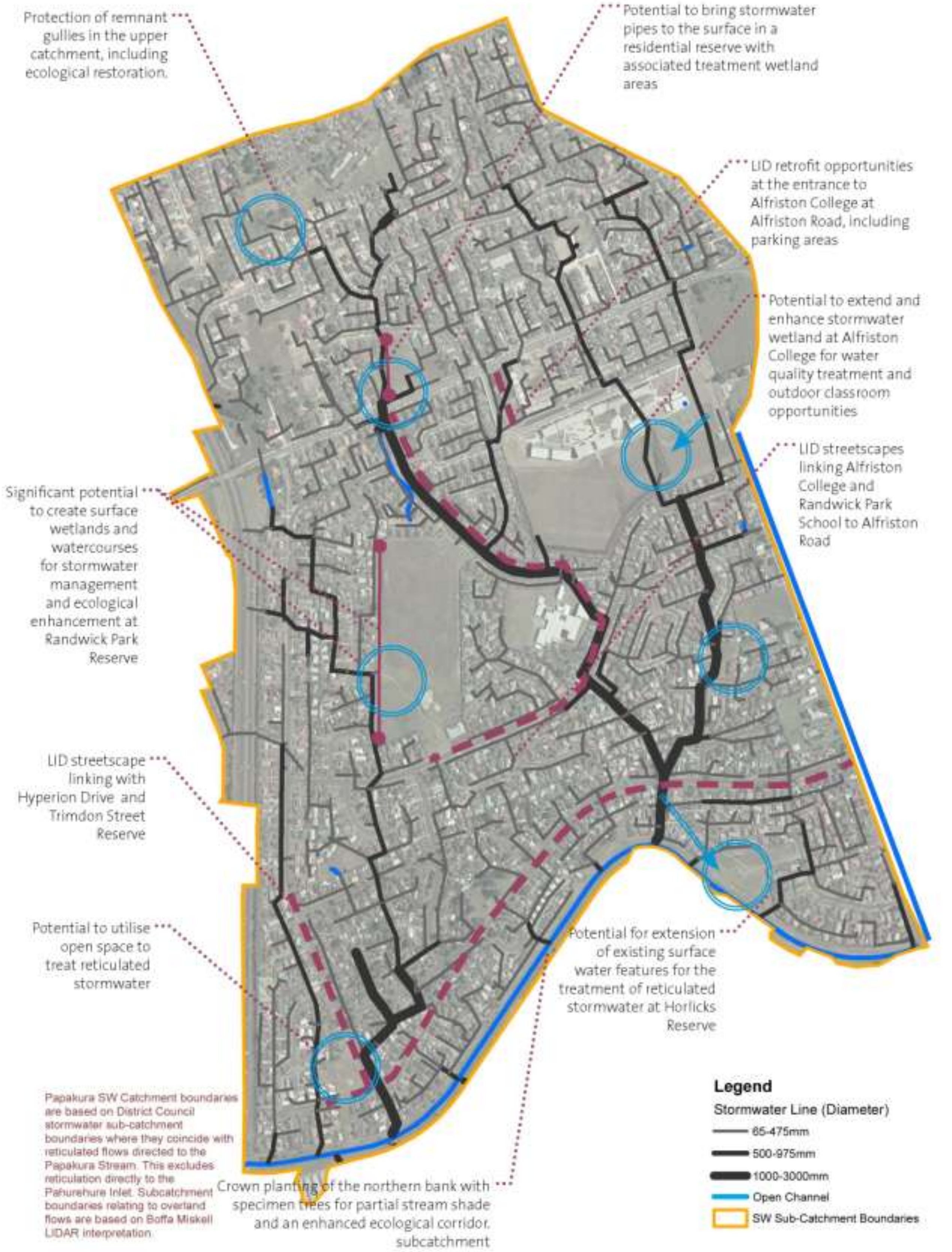
The Papakura Stream below Manurewa East is a bedrock channel set in wide and uniformly sloped flood banks. The planting of canopy trees along the streambank would provide for shade, with due consideration for CPTED principles and hydraulic efficiency of the channel.

Stormwater Wetland Detention

There may be an opportunity for treatment wetlands within Randwick Park in combination with a surface water course as above.

Existing water features have been provided for in Horlicks Reserve beside the Papakura Stream. These could be augmented to link into reticulated systems for water quality treatment.

Existing stormwater wetlands have the potential to be enhanced, specifically a small gully on Norm Pellow Road and a wetland at Alfriston School. The Alfriston School wetland has the potential to integrate other pipe networks and be enhanced for ecological values and educational opportunities/outdoor classroom activities.



PAPAKURA STREAM ASSESSMENT AND MANAGEMENT STUDY

Figure 27: Manurewa East

Date: 17.06.08 Drawing: Catch_A4_Manurewa.jpg Scale: 1: 9,500@A4 Author: MDa

Auckland Regional Council

Boffa Miskell

Photo 11.

Randwick Park overland flowpath

Photo 12.

An overland flowpath coincides with a residential reserve above Alfriston Road.

Photo 13.

The stream corridor with open flood plain, similar in character from Porchester Road to SH1.

6.5.4.6 Papakura Sub-catchment

The Papakura sub-catchment (Figure 28) as it flows to the Papakura Stream includes the northern half of the Manuka Golf Course and areas east of Great South Road. The remainder flows through reticulated systems to the Pahurehure Inlet and Manukau Harbour.

Low Impact Design Retrofit

Specific opportunities exist for LID treatments along Great South Road (see photo 14) and connecting with ascribed potential LID retrofits in the Lincoln sub-catchment. The Great South Road artery is wide and generally lacking in streetscape vegetation, with ample opportunities for an improved pedestrian experience associated with street trees and bioretention gardens.

Stream Restoration and Rehabilitation

Stream daylighting has the potential to occur along the Great South Road frontage of the Manukau Golf Course (see photo 15), by combining an existing overland flowpath with underground piping.

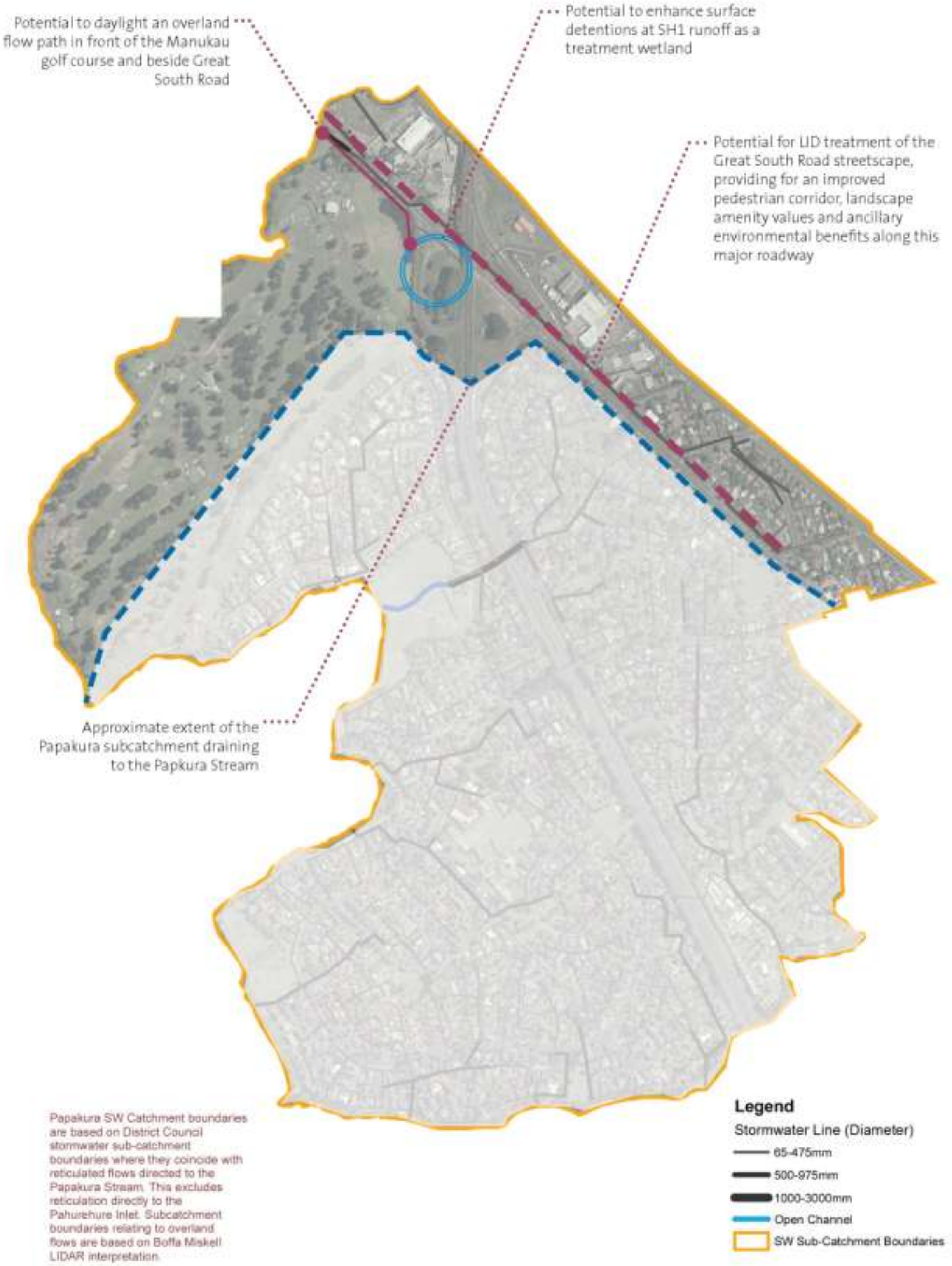
An existing surface water course along the Northern Trunk Line has significant restoration potential. This channel would be contiguous with a moderately sized vegetated area (weed dominated) and open water course that enters the Papakura Stream in the Takanini North sub-catchment.

The Papakura Stream is similar on the true left bank to the Lincoln sub-catchment on the true right, with an outlet from the sub-catchment to a constructed floodplain above the main channel (see photo 16). There is likely to be benefits to flow capacity and downstream velocities if retaining structures in this area are battered back and reinforced with planting. This may also go some way to addressing weed issues in this location.

Stormwater Wetland Detention

A large area of undeveloped land currently exists at the eastern intersection of the Papakura Stream and Great South Road. There is potential for stormwater treatment in this area adjacent to the Papakura Stream, and at the gateway between Papakura District and Manukau City.

The golf course adds significant value to the stream corridor as a floodplain, riparian buffer, lowland habitat and (depending on land management practices) an important source of relatively clean water runoff.



PAPAKURA STREAM ASSESSMENT AND MANAGEMENT STUDY

Figure 28: Papakura

Date: 17.06.08 Drawing: Catch_A4_Papakura.jpg Scale: 1: 10,500@A4 Author: MDa

Auckland Regional Council

Boffa Miskell

Photo 14.

Opportunities for LID retrofit and streetscape improvement along Great South Road.

Photo 15.

The overland flowpath above a pipe system between Manukau Golf Course and Great South Road

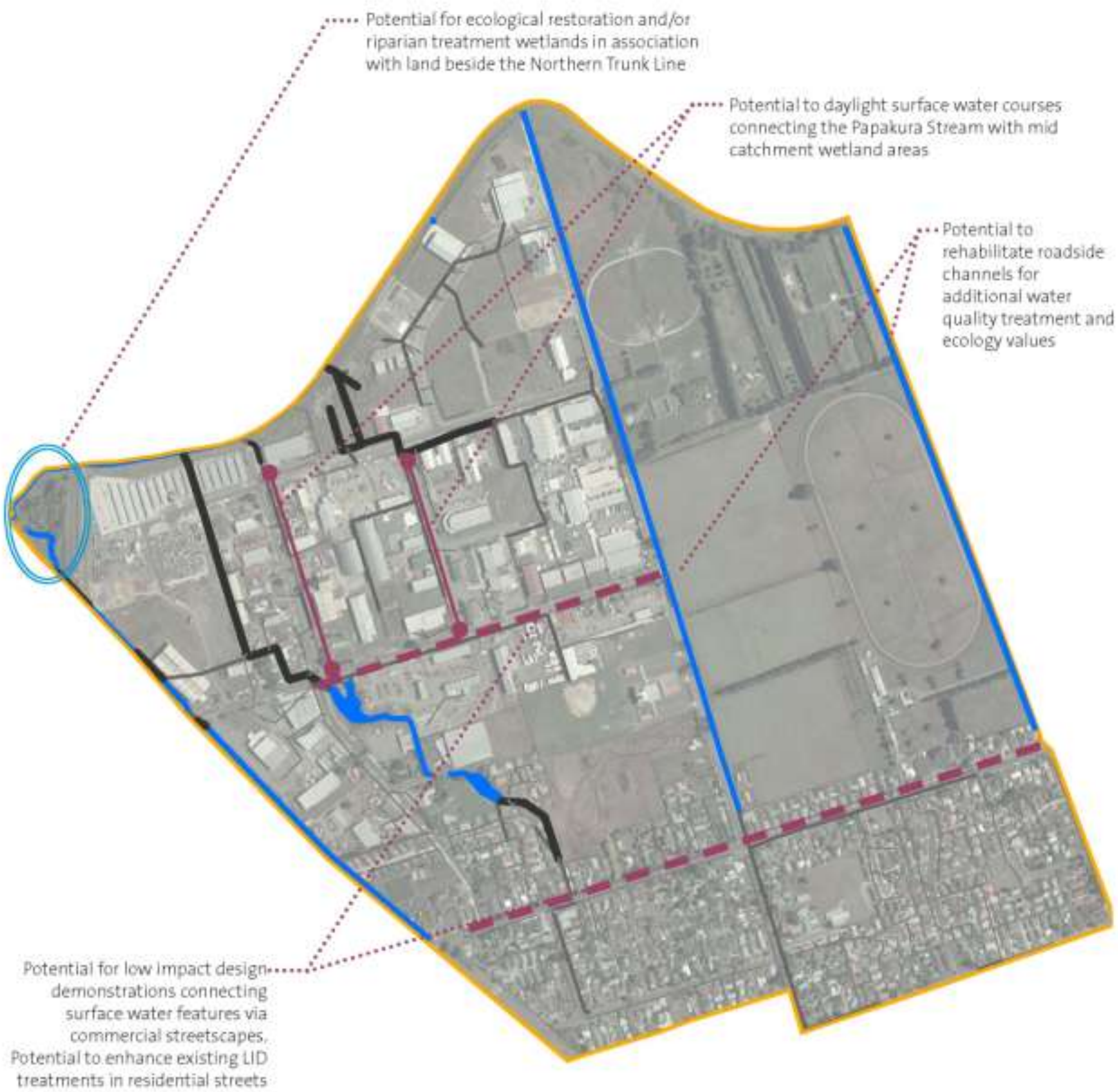
Photo 16.

Outlet of the Papakura sub-catchment to the Papakura Stream.

6.5.4.7 Takanini North Sub-catchment

The Takanini North sub-catchment (Figure 29) comprises the commercial and residential land to the west of the Northern Trunk Line. Much of the land remains undeveloped. Low impact treatments have been articulated in residential areas, such as swales and permeable paving, but these have been executed without a robust streetscape design. More recent development has omitted these features (see photo 17).

The catchment sits above the drained and consolidated Takanini peats and therefore surface water runoff occurs in significant quantities. A string of stormwater wetlands connect through the mid-catchment to provide for flood attenuation and primary treatment for both residential and commercial land-uses. There are opportunities to combine these centralised locations with open channel conveyance systems associated with wide commercial streets (see photo 18).



Papakura SW Catchment boundaries are based on District Council stormwater sub-catchment boundaries where they coincide with reticulated flows directed to the Papakura Stream. This excludes reticulation directly to the Pahurehure Inlet. Subcatchment boundaries relating to overland flows are based on Boffa Miskell LIDAR interpretation.

Legend

Stormwater Line (Diameter)

- 65-475mm
- 500-975mm
- 1000-3000mm
- Open Channel
- SW Sub-Catchment Boundaries

PAPAKURA STREAM ASSESSMENT AND MANAGEMENT STUDY

Figure 29: Takanini North

Date: 17.06.08 Drawing: Catch_A4_Takanini.jpg Scale: 1: 10,000@A4 Author: MDa

Auckland Regional Council
Boffa Miskell

Photo 17.

New residential development adjacent to commercial land-use (no evident LID treatments).

Photo 18.

Wide commercial streets represent opportunities for surface water conveyance

Photo 19.

Constructed stormwater wetland at Oakleigh Avenue borders commercial and residential areas.

7 Concluding Remarks and Recommendations

The Papakura Stream Catchment supports a mix of rural, peri-urban and urban land-uses. For the most part, its freshwater values have been degraded through historic land clearance and present-day land-uses, to the extent that the majority of the sites sampled over the course of this study were of Moderate to Moderate-Low health. There were only two sites within the wider catchment that were identified as having attributes suggestive of better quality and health. Both of these were in the headwaters area of the main stem in the north-eastern portion of the catchment; both were in forested land cover.

Management options for restoring the health of the catchment streams were discussed in the preceding sections of this report, from which it was recommended the implementation of stream-friendly land-use practices (in both the urban and rural areas) as well as the revegetation of the riparian margins of the streams involved.

In relation to point source contaminants, the issue needs to be addressed on a discharge by discharge basis, with discharges that are obviously affecting water quality being identified and rectified (as far as practicable). In addition, all newly consented point source discharges should utilise best practice in relation to reducing the levels of the contaminants involved.

In relation to diffuse source discharges, this largely occurs in the rural part of the catchment, and the resultant stream health is a direct reflection of the link between streams and the land-uses in the catchment. Diffuse source discharges are an issue that can only be addressed on a landowner-by-landowner basis, but needs to be done so across the entire catchment. As an issue, it can best be resolved by a combination of better farming practices together with riparian revegetation. Both of these management approaches will require a combination of education, advocacy and incentives by both the ARC and the territorial local authorities. This is likely to require an on-going commitment from the Councils, and be part of a collaborative approach with the landowners concerned.

With respect to the revegetation of riparian margins, it is important that a targeted and integrated catchment-wide approach be applied that recognises the inter-relationships between the variables that collectively determine stream health. In this regard, given that the tributaries and upper reaches of a catchment all end up influencing the main stream stem(s),then it is logical that revegetation should at least be initially focused on the headwater areas. In many instances these headwater areas are within the top ends of gullies, which co-incidentally are normally where remnant patches of forest or regenerating native bush are to be found. These bush patches with their headwater streams are likely to support healthy aquatic communities that will provide a source for the recolonisation of downstream areas once they have been revegetated and are providing habitats conducive to the survival of the colonists.

With specific reference to the Papakura Stream Catchment, the supposition that headwater streams with established bush margins support healthy communities is borne out by the results of the SEV sampling, where sites 31 and 32 were the only two that achieved a “High” ranking in relation to their macroinvertebrate communities. Additionally, the supposition that the gullies of headwater tributaries generally support native bush remnants also holds true for the Papakura Stream Catchment, where the great majority of the remaining indigenous forest cover is restricted to such areas. In particular the uppermost reaches of the catchment in the north-eastern corner are covered in native bush, but so too are the western and eastern “spines” that contain the catchment in its central and northern area. While not all of these bush patches have waterways within them, it appears that a majority do (as defined on the LIDAR flowpath plans and the ARC’s Streams of the Auckland Region GIS plan). Given this, there is room for optimism that a reliable source of macroinvertebrate colonists already exists in the wider catchment area, which would be able to disperse over time as freshwater habitat conditions improved as a result of the successful revegetation of the riparian margins downstream of these source areas.

In light of the above discussion, one of the priorities in the rural part of the catchment should be to protect and/or manage the copses and remnants of native bush (and mixed native-exotic bush) where they contain waterways. Where these stands of bush are grazed, then incentives should be provided for their fencing. Some of the more obvious candidate sites in this regard are the coherent and large stands of native bush at the end of Ranfurly Road. These include two sites identified in the Hunua PNAP survey, and a third site identified in the Indigenous Vegetation of the Awhitu and Manukau Districts, as being significant natural areas.

In the context of the Papakura Stream Catchment there are also many instances where a treeland exists in the general vicinity of streams, and in many instances such treeland vegetation is located in between larger more coherent stands of bush that contain streams. These treeland areas provide a good basis for streamside revegetation, and simply require either a greater density (achieved through underplantings) or a greater width (achieved through buffer planting). There are multiple good examples of this type of patch-work vegetation within the central western and central eastern spines that contain the wider catchment. On both the eastern and western sides this vegetation is contiguous with or in close proximity to other large stands of native bush in the neighbouring catchments. These provide a far larger source area of birds and herpetofauna to colonise the revegetated riparian zones in the longer term, as well as providing a wider source area of aquatic invertebrates that require bush habitats in their adult life stages.

There are other areas of the catchment that presently support a treeland cover alongside streams. For the most part however, this vegetation cover is exotic and dominated by streamside willows. While this type of cover may bestow some benefits to the streams involved in terms of carbon inputs and provision of shade, as a general rule, it is intermittent (keeping any benefits very localised) and not fenced, and surface run-off from the surrounding farmland is unabated and untreated. In the short-term these areas may well benefit from the provision of filter strips on the landward margins of the narrow exotic tree cover. In the long-term it would be of benefit to gradually replace these willows and the like with native species. However, this is not a priority.

In addition to the privately owned rural areas, opportunities for revegetating the riparian margins of the Papakura Stream exist within some of the parks and reserves administered by the local Councils. In the main, these have very little in the way of existing riparian vegetation. While these are all in the lower end of the catchment and would do little to influence the overall water quality of the wider stream the revegetation of the riparian zone here would likely have some local benefits to in-stream biota. It could also be a rallying point for the local community, providing an impetus on Council-owned and managed land that could (hopefully) spread across the wider catchment.

While perhaps not a priority, another potential avenue for exploration would be the creation of wetlands in appropriate places to hold water in the rural catchments and provide a nitrogen stripping service. While this is likely to be of most benefit if it is implemented on multiple farms throughout the catchment, there may be some merit in investigating whether some of the more flood-prone areas within the catchment would also be suitable candidates (i.e. creating large off-line wetlands in these areas to capture and treat large volumes of stormwater). However, it is noted that this concept would require a lot more work and discussion.

7.1 Recommendations on Priorities for Implementation

The broad-scale assessment work of this study is a means to determine focus issues within the Papakura Catchment and to provide a number of tools to meet the catchment management objectives (refer to Section 6.2). Potential actions both in the immediate and long-term are expected to follow from further survey work, planning review, and the production of technical documents and practice notes to guide implementation as well as instruct District Plan Rules.

7.1.1 Completion of Assessment work

7.1.1.1 GIS and Survey Work

The outputs from this current study were the production of an interactive GIS package alongside the written report. Information was presented in this format to instruct ongoing planning processes with interactive mapping capability. As for all mapping exercises, the usefulness of the information is directly related to the accuracy of data and the interrogation of data sets.

There are opportunities to provide the following areas of detailed information to instruct future catchment management planning:

- A full interrogation of flow modeling and catchment extents, including field verification to determine perennial streams and identify localized gully systems;
- Slope and aspect analysis derived from LIDAR point source data;
- Comprehensive digitisation of all existing vegetation within the Papakura Stream Catchment into appropriate categories;
- Identification of perennial and ephemeral wetlands;
- Erosion hot spots;
- Comprehensive fish passage surveys.

7.1.1.2 ICMPs

In order to test the feasibility of urban management options and to determine the channel flows and extent of flooding in the rural sector, it will be necessary to undertake detailed hydrologic and hydraulic investigations of the Papakura Catchment. This may be undertaken as part of the 'Papakura Stream Flood Hazard Mapping' study which is currently under preparation by OPUS and DHI, or as part of individual ICMPs. These studies are likely to provide for the following information:

- Overland flow and pipe system dynamics including capacities and drainage efficiencies;
- Flooding extents;
- Existing and future development scenarios;
- Overland flow paths and flow velocities;
- Age of infrastructure;
- Public consultation and engagement of specific stakeholders;
- Groundwater modeling, including break-out areas;
- Capital and maintenance costs of management options;
- Cost-benefit feasibility analysis of management options.

7.1.1.3 Site Specific Surveys

Immediate priority surveys are recommended for those SEV sites identified as having lower overall SEV scores and/or water quality scores than expected. SEV scores which justify additional response are located on the tributary including SEV sites '6' and '7' and the tributary including SEV sites '14' and '16'.

7.1.2 Planning Review

The Papakura Stream Assessment and Management Study and the 'Papakura Stream Flood Hazard Mapping' (in prep.) provide an opportunity for the review of planning documents with more detailed survey information. Management options appearing in these reports can be interrogated in relation to the wider context (embedded in regional and district-wide planning documents), as well as providing more detailed information in relation to likely thresholds for the implementation of management options (e.g. optimum uptake of conservation lots for desired density). Alignment with existing planning provisions and conflicts with existing planning rules will be important in determining immediate priorities and areas that require further investigation or public consultation. Planning documents to be reviewed may include:

- The Regional Growth Management Strategy
- District Plans
- Asset Management Plans
- Long Term Council Community Plan
- Codes of Practice
- Southern Sector Agreement
- Development contribution policies
- Papakura Open Space Strategy

- Plan Change 13 of the Papakura District Plan
- Takanini Structure Plan 2000
- Pahurehure Inlet Management Plan

7.1.3 Technical and Guideline Publications

The preparation of technical documents/practice notes can provide guidance to planning provisions, consenting issues and implementation works by council employees and consultants. Guidelines can act as an education tool and a means of engagement for public consultation and stakeholder working groups. Follow on guideline documents to this current study may include:

- Catchment-wide ecological survey and planning document
- Land Management Practices for Rural Environments
- Restoration Planting Guidelines
- LID practice notes

7.1.4 Future Strategy

This study has been instrumental in understanding the issues that are present within the Papakura Catchment. These have included the following:

- Ecology – Water quality, poor riparian zone management practices, inadequate buffer zones, limited range of habitats, limited ecological knowledge, degraded stream habitat and reduced stream health.
- Stormwater / drainage – Protection of natural floodplains and ponding areas, water quality and sources of pollution, poor drainage and low gradient valley slopes, lack of riparian vegetation, stream channelization and modification.
- Landscape – Increasing pressure from urbanization, limited protection of natural landforms and regenerating native plants.
- Recreation – Limited access along stream margins, quality of the stream environment is central to the recreation experience, need to manage both wildlife and recreation values.
- Cultural – Sustainable management of native plant and wildlife species and historic sites.
- Heritage – Lack of on site and written interpretative material.

The study has also provided an indication of the value of developing a strategy for the Papakura Catchment using a values-based approach (landscape, drainage, ecology, recreation, culture and heritage) to manage its surface water environment. Such a strategy would include the development of visions (involving public consultation) and associated key actions by which each vision can be implemented and achieved. Following this, financial considerations, timeframes and levels of services can then be determined from these long-term visions and aspirations.

Though future works involved with such a strategy may be undertaken by individual territorial authorities, an over-arching guiding strategy would facilitate a catchment-wide approach to its management that meets the public and council's vision.

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9 References

Allibone, R., J. Horrox & S. Parkyn (2001). *Stream categorization and instream objectives for Auckland's Urban Streams*. Prepared by the National Institute of Water and Atmospheric Research for the ARC.

ANZECC (2000). Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

ARC (1992). Design Guideline Manual for Stormwater Treatment Devices. *Auckland Regional Council Technical Publication No. 10.*

ARC (2000). Low Impact Design Manual for the Auckland Region. *Auckland Regional Council Technical Publication No. 124.*

ARC (2000). Fish Passage Guidelines for the Auckland Region. *Auckland Regional Council Technical Publication No. 131*

ARC (2001). Riparian Zone Management: Strategy, Guideline, planting Guide. *Auckland Regional Council Technical Publication No. 148.*

ARC (2002). Blueprint for Monitoring Urban Receiving Environment*. Auckland Regional Council Technical Publication No. 168*

ARC (2004). Framework for Assessment and Management of Urban Streams in the Auckland Region. *Auckland Regional Council Technical Publication No. 232.*

ARC (2004). Baseline water quality: Stream, lake and saline waters - Annual Report January-December 2003. *Auckland Regional Council Technical Publication 234.*

ARC (2007). Rivers and Streams Water Quality Data Report 2005. *Auckland Regional Council Technical Publication 327.*

Beca Carter Hollings & Ferner Ltd (1993). Papakura Stream flood management study. Report prepared for ARC Environment. 143p.

Collier, K.J., A.B. Cooper, R.J. Davies-Colley, J.C. Rutherford, C.M. Smith & R.B. Williamson (1995). *Managing Riparian Zones: A contribution to protecting New Zealand's rivers and streams.* Volume 2: Guidelines. Department of Conservation, Wellington.

Davies, P.E., & M. Nelson (1994). Relationships between riparian buffer widths and the effects of logging on stream habitat invertebrate community composition and fish abundance. *Australian Journal of Marine & Freshwater Research 45:* 1289–1305.

Davies-Colley, R.J. (1997). Stream channels are narrower in pasture than in forest. *New Zealand Journal of Marine & Freshwater Research 31:* 599-608.

Davies-Colley, R., & S. Parkyn (2001). Effects of livestock on streams and potential benefits of riparian management: Issues and options in the Auckland Region. *Auckland Regional Council Technical Publication 351*.

Ellis, J.B. (1986). *Pollutional Aspects of Urban Runoff.* Proceedings of the NATO workshop on Urban Runoff Pollution, Heidelberg FRG.

Emmett, D.K., M.C. Smale, B.D. Clarkson, J.R. Leathwick, M.R. Jessen & P.T. Whaley (1999). *Indigenous Vegetation of the Awhitu and Manukau Ecological Districts.* Auckland Regional Council, Auckland. 179 p.

Environment Waikato (2008). River Water Quality. http://www.ew.govt.nz/enviroinfo/indicators/inlandwater/riversandstreams/riv1/techinfo.htm. Referenced 5 June 2008.

Fennessy, M.S., & J.K. Cronk (1997). The effectiveness and restoration potential of riparian ecotones for the management of nonpoint source pollution, particularly nitrate. *Critical Reviews in Environmental Science & Technology 27:* 285–317.

Ferguson, B.K. (1991). Urban Stream Reclamation. *Journal of Soil & Water Conservation 46:* 324-328.

Firth, C.W. (1930). The geology of the north-west portion of Manukau County, Auckland. *Transactions & Proceedings of the Royal Society of New Zealand 31:* 85–137.

FISRWG (1998). *Stream Corridor Restoration: Principles, Processes, and Practices.* By the Federal Interagency Stream Restoration Working Group GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN3/PT.653. ISBN-0-934213-59-3.

FWPCA (1969). Water Pollution Aspects of Urban Runoff: Final Report on the causes and remedies of Water Pollution from Surface Drainage of Urban Areas. Research Project No. 120. Federal Water Pollution Control Administration, US Dept. of the Interior.

Gill, B., & T. Whitaker (1996). *New Zealand Frogs & Reptiles.* David Bateman Limited, Albany.

Grimm, N. (1996). *Surface-Subsurface Interactions in Streams.* IN: Hauer, R. & G. Lamberti, Methods in Stream Ecology. Academic Press, San Diego, California.

Haslam, S. (1990). River Pollution: An Ecological Perspective. Belhaven Press, New York.

Hauer, R., & W. Hill (1996). *Temperature, Light and Oxygen*. IN: Hauer, R., & G. Lamberti, Methods in Stream Ecology. Academic Press, San Diego, California.

Hitchmough, R., L. Bull & P. Cromarty (2007). *New Zealand Threat Classification Systems List – 2005.* Department of Conservation, New Zealand. 194 p.

Jones, E., & B. Urbonas (1986). *Conference on Urban Runoff Quality - Objectives.* IN: Urbonas, B., & L. Roesner, Urban Runoff Quality - Impact and Quality Enhancement Technology. Proceedings of an Engineering Foundation Conference. American Society of Civil Engineers, New York.

Joy, M., & I. Henderson (2004). A Fish Index of Biotic Integrity (IBI) for the Auckland Region. Report and User Guide. IN: Rowe *et al.* 2008. Stream Ecological Valuation (SEV): a method for scoring the ecological performance of Auckland streams and for quantifying environmental compensation - 2nd Edition, January 2008. Auckland Regional Council Technical Publication No. 302.

Karr, J.R., & E.W. Chu (2000). Sustaining living rivers. *Hydrobiologia 422:* 1-14.

Kelly, S. (2007). Marine receiving environment stormwater contaminants: status report 2007. Auckland Regional Council Technical Publication No. 333.

Lands & Survey (1984). Rural Landscape Guidelines. Lands & Survey Publication, Wellington.

Lawrence, A., J. Marsalek, J.B. Ellis & B. Urbonas (1996). Stormwater detention and BMPs. *Journal of Hydraulic Research 34:* 799-813.

Martin, T.L., N.K. Kaushik, J.T. Trevors, & H.R. Whiteley (1999). Review: denitrification in temperate climate riparian zones. *Water, Air & Soil Pollution 111:* 171–186.

McHugh, M. & J. Reed (2006). Marine sediment monitoring programme – 2005 results. Auckland Regional Council Technical Publication No. 316.

Medeiros, C., & R. Coler (1982). A Laboratory/ Field Investigation into the Biological Effects of Urban Runoff. Water Resources Research Center, Amherst, MA.

MfE (2001). Managing Waterways on Farms: A Guide to Sustainable Water and Riparian Management in Rural New Zealand. Ministry for the Environment, New Zealand.

MfE (2002). Microbiological Water Quality Guidelines for marine and Freshwater Recreational Areas. Ministry for the Environment, New Zealand.

NZ Grassland Association (2003). Using trees on farms. *Grassland Research & Practice Series No. 10.*

Palmer, C. (1950). The pollutional effects of stormwater overflows from combined sewers. *Sewage & Industrial Wastes 22:*154-65.

Parkyn, S.M. (2004). Review of Riparian Buffer Zone Effectiveness. *MAF Technical Paper No. 2004/05.*

Parkyn, S., R. Davies-Colley, K. Collier, P. Reeves & B. Cooper. (2001). Issues for riparian management in the Auckland Region: Analysis of trade-offs between benefits and impacts. *Auckland Regional Council Technical Publication No. 349.*

Parkyn, S.M., R. Davies-Colley, N.J. Halliday, K.J. Costley & G.F. Croker (2003). Planted riparian buffer zones in New Zealand: do they live up to expectations? *Restoration Ecology 11:* 436-447.

Parkyn, S., W. Shaw & P. Eades (2000). Review of information on riparian buffer widths necessary to support sustainable vegetation and meet aquatic functions. *Auckland Regional Council Technical Publication No. 350.*

Paul, M.J., & J.L. Meyer (2001). Streams in the urban landscape. *Annual Review of Ecology & Systematics 32:* 333-365. .

Pinkham, R. (2001). Stream Restoration and Daylighting: Opportunities in the Pittsburgh Region. Studio for Creative Inquiry Pittsburgh PA.

Pisano, M. (1976). Nonpoint sources of pollution: A Federal Perspective. J*ournal of the Environmental Engineering Division 102:* 555-565.

Rutherford, J.C., R.J. Davies-Colley, J. M. Quinn, M.J. Stroud & A.B. Cooper (1999). *Stream Shade: Towards a Restoration Strategy.* Prepared by the National Institute of Water and Atmospheric Research

Quinn, J.M., I.K.G. Boothroyd & B.J. Smith (2004). Riparian buffers mitigate effects of pine plantation logging on New Zealand Streams 2: Invertebrate communities. *Forest Ecology & Management 191:* 129-146.

Snelder, T., B. Biggs, & M. Weatherhead (2004). *New Zealand River Environment Classification User Guide*. Ministry for the Environment.

Stark, J.D., I.K.G. Boothroyd, J.S. Harding, J.R. Maxted & M.R. Scarsbrook (2001). Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report No. 1. Prepared for the Ministry for the Environment. Sustainable Management Fund Project No. 5103. 57p.

Stark J.D., & J.R. Maxted (2007). *A user guide for the Macroinvertebrate Community Index.* Prepared for the Ministry for the Environment. Cawthron Report No.1166. 58 p.

Stewart, M., M. Ahrens & G. Olsen (2008). Analysis of Chemicals of Emerging Environmental Concern in Auckland Aquatic Sediments. *DRAFT Auckland Regional Council Technical Publication.*

Townsend, C. (1980). *The Ecology of Streams & Rivers.* Camelot Press, Southampton Great Britain.

Tyrell M., M. Cutting, C. Green, G. Murdoch, K. Denyer & A. Jamieson (1999). Hunua ecological district – survey report for protected natural areas programme. New Zealand protected Natural Areas Programme Survey Report No. 17, Auckland Regional Council, Auckland.

USEPA (1993). *Results of the Nationwide Urban Runoff Program.* NTIS PD#84-18-5545. United States Environmental Protection Agency.

Walsh, C.J. (2000). Urban impacts on the ecology of receiving waters: A framework for assessment, conservation and restoration. *Hydrobiologia 431:* 107-114.

West, D.W., J.A.T. Boubée & R.F.G. Barrier (1997). Responses to pH of nine fishes and one shrimp native to New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 31:* 461-468.