MANUKAU CITY COUNCIL

KENDERDINE CATCHMENT

COMPREHENSIVE STORMWATER CATCHMENT MANAGEMENT PLAN

VOLUME I

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MANUKAU CITY COUNCIL

KENDERDINE CATCHMENT

COMPREHENSIVE STORMWATER CATCHMENT MANAGEMENT PLAN

EXECUTIVE SUMMARY

GENERAL

This report comprises a comprehensive stormwater catchment management plan (CCMP) for the Kenderdine Catchment, located in Papatoetoe, South Auckland.

Studies have been undertaken for the Kenderdine Catchment with the aim of identifying stormwater issues, management plan options and recommendations in relation to water quantity, quality and ecological issues in accordance with the Auckland Regional Council's Integrated Catchment Management Plan (ICMP) Guidelines so as to mitigate the adverse effects of urbanisation in the catchment.

This study provides information to support an application for a Comprehensive Stormwater Catchment Discharge Consent (CCDC) for the Kenderdine Catchment to the Auckland Regional Council (ARC). This includes addressing the following issues of concern in this catchment:

- Inadequate capacity of the primary drainage system in some areas for a 5-year ARI rainfall event
- Localised flooding throughout the catchment
- Gentle terrain with possible backwater effects in the drainage system
- Ponding and potential flood hazards in the Kohuora Crater and Malaspina Place area
- Obstruction of stormwater flows in the open channel along Hillside Road
- Erosion and stability of some open channels
- Maintenance of open channels

THE CATCHMENT

The Kenderdine Catchment is located within the Papatoetoe Ward of Manukau City and covers approximately 318 ha of land. The topography is dominated by the Kohuora Crater area to the north and a central valley running east to west at a slope of about 0.1-0.8% towards a tributary of the Waokauri Creek. This catchment is one of the oldest settlement areas in Manukau City and is fully urbanised. It mainly comprises residential zoned areas, together with commercial areas around the St George Streetrett shopping centre, several schools (Aorere College, Papatoetoe West and South Primary Schools), and some recreational areas, particularly the Kohuora Crater, the eastern portion of which contains the former Kohuora Landfill. The crater floor is also designated for use for stormwater management purposes. The NIMT Railway and southwestern motorway both pass through the catchment.

The average catchment imperviousness is 38.4% (parcels only), or approximately 42% with the southwestern motorway, primary and secondary roads, and railways included.

Essentially, the Kenderdine Catchment comprises a valley tributary of the Waokauri Creek. The valley bottom, historically and currently, provides the main trunk drainage system for the catchment. About 1.4 km of its upper reaches has been piped (east of Kenderdine Road), while a number of significant crossings have been constructed over the unpiped lower reaches (open stream) including Wyllie Road, Hillside Road, Ferndown Avenue, and the southwestern motorway. There is also a waterway that runs along the western and southern boundaries of the Kohuora Crater, before entering a large culvert and discharging into the main open stream. The primary piped system is extensive throughout the catchment, except for a small area upstream of Hill Road, and discharges into the open stream. Overland flowpaths generally comprise roads, waterways, and the open stream. The flow along the longest drainage path is about 3.5 km. The open stream flows under the southwestern motorway into the Waokauri Creek and out into the Manukau Harbour.

MODELLING OUTLINE

The software package used was MOUSE, which fulfils the requirements to incorporate both hydrological and hydraulic capabilities. This programme is widely used within New Zealand by a number of Territorial Authorities.

The catchment was subdivided into 380 sub-catchments reflecting the configuration of the existing reticulation, as displayed on Fig A2 in the HMS report. Perviousness and imperviousness within each sub-catchment was taken into account to yield appropriate curve numbers.

Analysis of the maximum probable development (MPD) situation has allowed for an increase in the imperviousness of individual sub-catchments of +5% or to a maximum value of 54%, whichever is less. The one exception is the upper Kohuora Crater area between Malaspina Place and Station Road. This is zoned main residential and is largely undeveloped at present. Several residential developments are in various stages of planning or construction in this area. Hence, the MPD scenario has assigned the maximum assumed imperviousness to this area of 54%.

In discussions with MCC it was agreed that three principle scenarios should be investigated:

- Option 1: An upgrade of the entire network as necessary to meet the MCC minimum standard of capacity for stormwater reticulation, viz, capacity to carry the 20% AEP storm event.
- Option 2: Modifications to the inlet and outlet arrangements from the Kohuora Crater to test the effectiveness of utilising the crater for storage, and the subsequent effects on flows and levels in the main stream

- Option 3: A combination of pipe upgrades, and purchase of properties vulnerable to flooding, to reduce flood risk throughout the catchment generally.

MODELLING RESULTS

Flooding

An indicative Flood Hazard map for the 1%AEP event in the existing catchment has been developed based on the assessment of water levels for this case, and has been mapped as shown on Fig A4 in the HMS report. This flood hazard map provides information that compares well with the LIR information provided by MCC, as shown on Fig A9 in the HMS report. It also confirms that flooding will continue to occur in locations previously identified by landowners complaints and consultation questionnaires, and by earlier studies.

The principal areas at risk continue to be:

- The length of the main stream between Hillside Road and Wyllie Road
- The area upstream of the railway line
- The area identified by Narada Avenue, and the northwest end of Ferndown Road
- The western side of the Kohuora Crater

Option 1

The model was run to determine the extent of pipe upgrades required to convey the MCC standard reticulation flow rate for the 20%AEP storm event throughout the existing stormwater reticulation system. Table 15 shows the pipe upgrade information, but has been expanded to include cost information for the upgrade of the pipes based on MCC standard rates, and has been sorted by a priority category (see below).

It should be noted that in running the model for this option, a significant restriction at the culvert at 36 Hillside Road has been identified. This culvert displays a head loss of approximately a metre during the 1% AEP event, which is significantly more than any other culvert in the system.

The cost of the overall system upgrade, for the MPD catchment and the 20%AEP storm event, as presented from the information shown in Table 15 is $6.61M approximately. This has been allocated into the three priorities set out above, as follows:

Priority 1	Upgrade the culvert at 36 Hillside Road, to improve the hydraulics of the main pipeline and reduce current flooding risk on all properties upstream, particularly those immediately upstream.	$42,000
Priority 2	Upgrade the main pipeline to reduce the flooding risk on all properties upstream of the Railway Line, and in the Narada Place/Claude Avenue area.	$2.66M

Priority 3 All the remainder of the system $3.95M

Map 11 shows the distribution of upgrade priority in the system.

Option 2

Option 2 has three sub-options for utilising the Kohuora Crater:

- Option 2(a): restrict the crater outlet
- Option 2(b): 1800mm dia inflow and 600 mm dia outflow from the crater
- Option 2(c): separate the crater into two storage ponds

None of these options provides a significant improvement over the current situation, particularly in the main stream, and in the case of Option 2(a), worsens the situation in regard to both water levels in the Crater and the main stream.

Option 3

The upper reach of the main stream upstream of the railway line is fully piped, and is under capacity. Overland flow occurs along the valley floor, mostly through private property. There is a flood risk in the 1%AEP event, as indicated by the Flood Hazard Map.

The alternatives available for solving this problem would be:

- take these properties out of private ownership;
- take these properties out of private ownership, and by so doing provide an opportunity to construct a detention dam in the valley with the aim of reducing water levels and flows downstream;.
- build a duplicate line down the valley floor which, when combined with the existing system, would provide capacity to carry the 1% AEP storm event flows, and eliminate overland flow.

Both of the first two options are clearly unrealistic when compared to the pipe upgrade option because of the high cost of the necessary property purchase ($19M) and the potential difficulties and expense of obtaining landowner agreement to sell. The third alternative also costs an additional mailto:$@M$2M cost over and above the Option 1 pipe upgrade through this area.

Other Property Purchase Alternatives

Reference to Map 9 appended to this report shows that the properties at greatest risk of flooding are those off Malaspina Place on the west side of the Kohuora Crater. Numbers 9 and 11 Malaspina Place are particularly vulnerable. There may be merit in Council purchasing these and incorporating them into the Crater Reserve. MCC Property Department have provided estimated valuations for all of the properties in Malaspina Place and Lendenfeld Drive which have been affected by flooding in the past (refer Appendix E). These range from $240,000 to $300,000.

The cost to Council of acquiring the four worst-hit properties (7-13 Malaspina Place), and possibly 24-26 Lendenfeld Drive, would be of the order of $1.7M, but would immediately relieve Council of any need to carry out further work in the crater. It would not avoid, however, the necessity of allocating capital to upgrade the rest of the stormwater reticulation system in the catchment.

The merits of purchasing property in the Narada Place/Claude Avenue area were considered in order to eliminate the negative effects of the modelled floodplain for the 1% AEP storm event in this area, but was not considered cost-effective for reasons similar to those given for the area east of the railway line.

The other significant location which has historically been vulnerable to flood nuisance and the source of complaint is 74 Hillside Road, immediately upstream of the Hillside Road culvert. Although the culvert itself is apparently adequate, the low-lying nature and proximity of this dwelling to the stream have caused problems of inundation in the past. Purchase of this property to relieve this situation would cost about $400,000.

ECOLOGICAL ASSESSMENT

The Ecological Assessment (refer separate report) classified the Kenderdine Catchment into nine distinct stream sections, based on instream and riparian habitat information gathered during field work for this study, involving assessments at 33 sites, with more detailed habitat assessments based on modified ARC habitat assessment methods being undertaken at a further six sites. Key results are summarised below:

- Its waterways are typical of Auckland urban stream catchments, being characterised by small catchments less than 4 km in length, with narrow channels (<3 m wide) and the presence of fine sand/clay/silt sediments, abundant macrophytes, pool and run flow regimes.
- Instream and riparian habitat characteristics are diverse. Habitat conditions ranged from modified wooden reinforced concrete channels (Section 1), well-shaded meandering sections (Section 2), peaty drains (Section 4), piped sections (Section 5), poorly shaded macrophyte choked channelised sections (Section 7 and 8), and hydrologically diverse sections with good instream habitat (Section 9). No waterways within the catchment were in their natural state and thus natural heritage values were poor.
- The instream habitats ranged from poor to moderate ecological quality, typical of Auckland urban catchments that have had varying degrees of channel modification including streambank reinforcement, channel straightening and piping.
- The riparian vegetation and macrophyte communities of the Kenderdine Catchment were comparable to those found in urban catchments elsewhere in the Auckland region. All plant species encountered are relatively common and no rare species or species of conservation interest were found.
- The water and sediment quality results indicate that the health and abundance of aquatic life in the catchment could be potentially

affected, due to contamination from untreated urban stormwater runoff. However, the results are similar to that of waterways in Waitakere City urban catchments.

- The macroinvertebrate communities recorded from waterways are considered to be of poor-moderate quality, but typical of those recorded from urban streams.
- Fish diversity was low in the waterways of the Kenderdine Catchment with four fish species recorded. Indigenous fish included large numbers of shortfin eel and inanga (whitebait species) throughout most of the catchment and a single redfin bully in the lower catchment. Overall, the fish community is considered typical of open lower gradient streams.
- The catchment is considered to have high ecological value as adult inanga fish habitat and supporting Auckland's urban fish stocks and ensuring continuity between stocks north and south of the city.
- Fish passage did not appear to be an issue within the Kenderdine Catchment, as indigenous fish species, including inanga, which are not renowned for their climbing ability and are diadromous, were recorded throughout the catchment. The artificial structures and natural features were only considered "potential" barriers, with the biggest issue being the excessive growth of emergent macrophytes (willow weed) that completely choked the stream channel in areas with poor riparian vegetation.
- The majority of the stream sections were classified as being Type 4 (highly disturbed natural channels, with greater than 25% of the catchment area being in impervious cover). Exceptions were the upper wooden lined Section 1 (Type 5 = modified channel, >50% artificial lining) and Section 5 (Type 6 = modified channel, >50% piped). The extent of the survey did not cover Type 1 (stream mouth) habitats.

MANAGEMENT STRATEGIES AND RECOMMENDED OPTIONS

Ecological Management Strategies and Recommendations

The following are derived from the KML Ecological Report in Volume 2 to which reference should be made:

1. Maximise opportunities for habitat restoration, increased habitat diversity and naturalisation of stream channels. This includes the potential removal of the wood lined streambanks in Section 1, the prevention of further channelisation and straightening of the stream channel in Section 9, and consideration of soft engineering options as opposed to concrete/wood for Sections 2, 3, 4, 6, 8, and 9.

2. Minimise barriers to fish and invertebrate passage by following ARC culvert design guidelines when renewing or installing new culverts. This is relevant throughout the entire Kenderdine Catchment as inanga, which are not particularly strong swimmers or climbers are found throughout the catchment.

3. Manage the emergent aquatic macrophyte *Persicaria hydropiper* (willow weed) within Sections 1, 3, 7, and 8. This may be in the form of mechanical

removal and long-term management through active restoration of shading riparian vegetation in accordance with ARC TP148 (2001). It is not recommended that the submerged macrophyte *Egeria densa* be mechanically removed from waterways, as the stems are brittle, fragmenting and rooting easily, meaning small plant fragments floating downstream may propagate to presently uninfested areas.

4. Establish (Sections 3, 4, 6, 7, and 8) and maintain (Sections 1, 2, and 9) riparian vegetation, preferably with native trees in accordance with ARC TP148 (2001). Some of the direct benefits that an intact, well vegetated riparian zone will have on waterways within the Kenderdine Catchment will include:

    (a) Water quality improvements including filtration of sediments and removal of nutrients.
    (b) Reduction in stream temperatures through shading to maintain conditions capable of sustaining aquatic life.
    (c) Stabilising streambanks and reducing accelerated erosion and sedimentation.
    (d) Interception of rain that inhibits surface runoff, reducing erosion and sedimentation of aquatic ecosystems.
    (e) Increases instream habitat values through the addition of large woody debris and leaf litter.

5. Remove "large" debris dams in Section 1 and 2, however trying to minimise streambed disturbance and the removal of detritus and "small" debris jams, as they provide important habitat and food for macroinvertebrates and fish.

6. Minimise further drainage and lowering of the water table, specifically in the upper catchment (vicinity of Catchment 1) as lower baseflows reduce the amount of water and habitat in the channel, increase temperatures, decrease DO concentrations and concentrate contaminants, all of which affect aquatic life.

7. Minimise the increase in impervious area where possible. This is most relevant to Section 4 in the Kohuora Crater and the lower catchment Sections 4 and 9, which have undeveloped land adjacent to the stream.

8. Erosion control of streambanks in Section 4 through riparian restoration using native plants.

Hydraulic and Hydrological Strategies and Recommended Upgrade Options

The following is derived from the HMS Hydraulic Modelling report in Appendix 1, to which reference should be made, and to the discussion of options in Section 5.3 above.

Given the level of accuracy discussed in Section 1.3 of the HMS report, it is strongly recommended that sufficient field surveys be undertaken to support the design of any capital works in the catchment, and to confirm the results of the modelling. In particular, there would be merit in allocating funding to undertake more comprehensive and accurate survey of the Kohuora Crater in order to more closely determine the available storage in the crater, and improve the ability to assess the effects of modifications to the crater outlet conditions. Given the current state of crater data in the model, undertaking works to better utilise the storage available in the crater does not appear worthwhile. Even if such data were obtained and more effective use of the storage in the crater were able to be demonstrated, it is likely that the vulnerability of properties on the west side of the crater, particularly those in Malaspina Place, would not necessarily be reduced, and Council may wish to purchase these properties to avoid the potential flooding risk.

Without taking action of any kind, it is likely that flooding of private property will continue to occur in the following locations during larger storm events:

- The valley floor upstream of the railway line
- Adjacent to the main stream between Wyllie Road and Hillside Road
- Low-lying properties on Malaspina Place adjacent to the crater floor
- Daphne Road adjacent to the main stream
- Claude Avenue, Narada Place

Upgrading the pipe network to provide capacity for the 20%AEP event will reduce, but not eliminate, flooding in the valley floor upstream of the railway line, and in the Claude Avenue and Narada Place during larger events. Upgrading these pipes will, however, increase peak water levels in the crater and main stream.

The effect of this is particularly pronounced at the 36 Hillside Road culvert. Upgrading this culvert to 2.1 m diameter, which is sufficient to pass the 1%AEP event without creating a significant head loss, was included in the pipe network upgrade model, and is proposed as the Priority 1 activity in the overall pipe upgrade process.

It is known that the water level in the main stream peaks before the water level in the crater and backflow into the crater occurs. This is confirmed by the modelling. This effect helps to attenuate peak flows and water levels in the main stream downstream of the crater outlet. However, the various options tested to better utilise storage in the crater have a minimal effect on the water levels in the main stream. The effect is insufficient to offset the increase in water levels in the main stream during the 1%AEP event, which result from upgrading the pipe reticulation to the 20%AEP event capacity.

The only exception to this is upstream of the 36 Hillside Road culvert where all modelled mitigation options result in a drop in water level, as these options include upgrading this culvert.

Upgrading the pipe network in the valley floor upstream of the railway line to cater for the 1%AEP event (Priority 2) will result in an increase in water level downstream in the main stream, necessitating the upgrade of the culverts at 36 Hillside Road and Wyllie Road. Even with the upgrade to the Wyllie Road culvert the water level upstream of the culvert will increase.

Hence, the recommended sequence for pipe upgrades in the catchment as a whole, together with their associated estimated costs, is:

Priority 1	Upgrade the culvert at 36 Hillside Road, to improve the hydraulics of the main pipeline and reduce current flooding risk on all properties upstream, particularly those immediately upstream, (32 and 32A Hillside Road, amongst others)	$42,000
Priority 2	Upgrade the main pipeline to reduce the flooding risk on all properties upstream of the Railway Line, and in the Narada Place/Claude Avenue area.	$2.66M
Priority 3	All the remainder of the system	$3.95M

With the upgrades in place, there may still be merit in Council undertaking purchase of vulnerable properties to alleviate further potential risk of flooding and complaint from landowners. This could only take place after a willingness to sell is expressed by the landowners and a negotiation is successfully completed. At this stage, the recommended properties for purchase are:

No.74 Hillside Road, (current estimated and indicative market value:- $400,000).
Nos.79 and 11 Malaspina Place (current estimated and indicative market value of $580,000 for both).

It is recommended that survey manhole invert and lid levels and cross-section information be captured into MCC's GIS for future use.

Stormwater Treatment Options

Under normal circumstances, the selection of treatment options and methods within a catchment requires detailed examination of sub-catchment configurations, identification of sites for installation of devices, and design of appropriate devices suitable for the sub-catchment areas being served. The range of options likely to be suitable would include devices and facilities such as:

- Detention ponds or engineered wetlands
- Vegetated swales in suitable locations
- On-line litter removing devices
- Cesspit bags, litter traps, and other devices for road runoff treatment
- Riparian plantings adjacent to open watercourses

However, in the Kenderdine Catchment, with the exception of the Kohuora Crater, options for installation of stormwater quality devices capable of dealing with large segments of the catchment are limited, if non-existent, without the purchase of extensive areas of private land.

In the absence of currently identified sites, that are both located appropriately at the bottom of the catchment and are large enough to treat stormwater runoff comprehensively from large areas of the catchment, retro-fitting of devices onto existing pipelines, and into existing road reserves and open space reserves are a possibility. This will require detailed examination of the sub-catchments in relation to the configuration of the reticulation systems and topography within them. Council may wish to undertake this process as part of its operational activities in managing the stormwater systems.

Attention should also be paid to the treatment of stormwater runoff from those major roads in the catchment which are currently carrying large volumes of traffic (George Street and Station Road; Portage Road, Pah Road and Wyllie Road; Ferndown Avenue, Claude Road and Kenderdine Road). The southwestern motorway presumably remains the responsibility of Transit New Zealand. Opportunities for installation of water quality devices for these roads are constrained, given the maturity of development in the catchment, and will be confined to such activities as improved street sweeping if necessary, and possibly the installation of Enviropods, Storm Filters, or similar in cesspits. There seems little opportunity for the installation of swales or other "soft engineered" facilities in relation to the roads. Council may also wish to investigate this process further as part of its operational activities in managing the stormwater systems for the roading.

Improvements to the riparian margins of the main stream channel in order to improve water quality from the ecological viewpoint are set out in 8.1 above.

Monitoring

An effective monitoring programme is fundamental to improving water quality. Benefits that result from improvement works can be quantified with the use of monitoring data and also similar improvement works can be implemented in other areas with more confidence in the results to be achieved.

In its State of the Environment Report (1999), Manukau City Council has identified its proposed monitoring work programme for the City's Urban and Rural freshwater Streams, Lakes, and Estuaries. The monitoring is to include:

- Physical, chemical, and biological parameters in high priority and representative catchments
- All activities impacting on water quality
- Riparian vegetation and modifications to the natural channels

The following is an outline of MCC's monitoring methodology:

- Select priority and/or representative streams and appropriate sites for monitoring
- Develop monitoring programmes in conjunction with the ARC
- Liaise with appropriate parts of Manukau City Council, as well as external organisations for data on development activities in certain catchments

MCC is also proposing to monitor water quality in marine waters at selected representative sites and to monitor the water quality and quantity of groundwater.

MCC's monitoring work programme, whilst not developed in detail on this report, would provide additional data to access the water quality improvement measures proposed for the Kenderdine Catchment.

MCC also has a WAI CARE Stream Monitoring programme underway in Manukau.

MANUKAU CITY COUNCIL

KENDERDINE CATCHMENT

COMPREHENSIVE STORMWATER CATCHMENT MANAGEMENT PLAN

1.0 INTRODUCTION

1.1 BACKGROUND

Manukau City Council (MCC) is developing a comprehensive stormwater catchment management plan (CCMP) for the Kenderdine Catchment, located in Papatoetoe, South Auckland.

Fraser Thomas Limited (FTL) was commissioned by MCC to undertake the preparation of this CCMP, with assistance from Hydraulic Modelling Services (catchment modelling) and Kingett Mitchell Ltd (ecological assessment).

This CCMP includes addressing the following issues of concern in this catchment:

- Inadequate capacity of the primary drainage system in some areas for a 5-year ARI rainfall event
- Localised flooding throughout the catchment
- Gentle terrain with possible backwater effects in the drainage system
- Ponding and potential flood hazards in the Kohuora Crater and Malaspina Place area
- Obstruction of stormwater flows in the open channel along Hillside Road
- Erosion and stability of some open channels
- Maintenance of open channels

The information in support of the CCMP is presented in two volumes:

- Volume 1: The Kenderdine Catchment Comprehensive Stormwater Management Plan
- Volume 2: Appendices
  - Appendix 1: Hydraulic Modelling Services Ltd (HMS): Stormwater Modelling and Upgrade Option Assessment
  - Appendix 2: Kingett Mitchell Ltd (KML): Aquatic Ecology and Management Objectives for the Kenderdine Catchment, August 2005

1.2 PURPOSE

This Comprehensive Stormwater Catchment Management Plan (CMP) has been developed:

- To fulfil the stormwater objectives and statutory responsibilities of the Manukau City Council (MCC) and the Auckland Regional Council (ARC) in relation to stormwater
- To identify stormwater issues, management plan options, and recommendations
- To provide information to support an application for a Comprehensive Stormwater Catchment Discharge Consent (CCDC) for the Kenderdine Catchment to the Auckland Regional Council (ARC)[1].

1.3 MCC'S STORMWATER MANAGEMENT OBJECTIVES

MCC's stormwater management objectives for the catchment are summarised in Table 1.

Table 1 : MCC's Stormwater Management Objectives

Item	Objectives
Quantity	• To manage stormwater volumes and peak flows to avoid flood risk and limit stream erosion. • To maintain base flows and sustain the life supporting capacity of streams. • To minimise the impact of development on stormwater runoff.
Quality	• To achieve water quality outcomes consistent with regulatory requirements. • To manage the discharge of contaminants and protect the receiving environment by applying best management practices that are recognised within the industry.
Aquatic Habitat	• To maintain unobstructed fish passage in streams. • To protect and enhance the capacity of watercourses to support life.
Land Use	• To ensure that the effects of urbanisation can be managed in a sustainable manner.
Riparian Management	• To protect streams and riparian corridors that have ecological and amenity value. • To promote and enhance riparian areas to provide habitat with a diversity of species.
Development and Maintenance	• To provide for appropriate development controls and ongoing operation and maintenance of assets related to stormwater management.
Implementation	• CMP to provide guidelines for Council and developers to assist in land development.

[1] The Kohuora Catchment (380 ha), which essentially includes the Kenderdine Catchment, does have a CCDC, as described in Section 3.3.

2.0 CATCHMENT DESCRIPTION

2.1 LOCATION

The Kenderdine Catchment is located within the Papatoetoe Ward of Manukau City and covers approximately 318 ha of land. Its location, general features, and an aerial of the catchment are shown on Maps 1, 3, and 4 appended to this report (Appendix F). The existing stormwater reticulation system is displayed in accordance with the Map Grid on Map 1 and presented in the series of Maps 2-A2 to 2-E3 in Appendix F.

In general terms, the catchment is bounded by the southwestern motorway to the west, and Portage Road, Station Road, Dunnotar Road, and Glen Avenue to the north. In the east its boundary runs from near the St George Street/Scott Road intersection across a series of roads including Central Avenue, Maunu Road, Grande Vue Road, and Wallace Road to near the corner of Cambridge Terrace and Bridge Street. Its southern boundary lies at varying distances to the north of Puhinui Road, approximately following Chestnut Road, Pah Road, and Hillside Road.

Technical Report No.2 of the ARC-TA's Regional Urban Stormwater Strategy (SLG, 1997) identifies the Kenderdine Catchment as lying within Catchment No 439000-375C (Pukaki & Waokauri Creeks), which has a total area of 490 ha and overall runoff coefficient of 49.7%, based on an analysis of current land use.

2.2 TOPOGRAPHY

The catchment topography is dominated by the Kohuora Crater area to the north and a central valley running east to west at a slope of about 0.1-0.8% towards a tributary of the Waokauri Creek.

The central valley has gentle slopes (1-2%) in the upper reaches of the catchment, east of the North Island main trunk (NIMT) railway line. West of the railway line, the valley features an open (unpiped) stream from approximately Kenderdine Road. Either side of the stream, the slopes are fairly steep, ranging from 15-20% for a distance of up to 30m from the stream, and then becoming more gentle (4-8%).

The Kohuora Crater lies in the middle of the northern side of the catchment. It has a very flat and marshy base, surrounded by steeper side slopes ranging from 15-20%.

Topography of the catchment is shown in Map 3 in Appendix F.

2.3 EXISTING DRAINAGE SYSTEM

The existing drainage system is displayed on Maps 2-A2 to 2-E3. Stormwater drainage systems are categorised into trunk, primary, and secondary systems. The primary system is the stormwater pipe system designed to handle frequent storms, in this case the 20% AEP storm in all urban areas. The secondary system is the overland flowpath, this being the route the excess stormwater (up to the 1% AEP storm) takes when the primary system's capacity is exceeded. The trunk system is where the primary and secondary systems are not physically separated. This includes the natural and artificial channels, as well as hydraulic structures, culverts, and road crossings, naturally occurring ponding, and artificial detention storage.

Essentially, the Kenderdine Catchment comprises a valley tributary of the Waokauri Creek. The valley bottom, historically and currently, provides the main trunk drainage system for the catchment. About 1.4 km of its upper reaches has been piped (east of Kenderdine Road), while a number of significant crossings have been constructed over the unpiped lower reaches (open stream) including Wyllie Road, Hillside Road, Ferndown Avenue, and the southwestern motorway.

There is also a waterway that runs along the western and southern boundaries of the Kohuora Crater, before entering a large culvert and discharging into the main open stream.

The primary piped system is extensive throughout the catchment, except for a small area upstream of Hill Road.

Overland flowpaths generally comprise roads, waterways and the open stream.

This piped stormwater network discharges into this open stream. The flow along the longest drainage path is about 3.5 km. The open stream flows under the southwestern motorway into the Waokauri Creek and out into the Manukau Harbour.

Map 3 shows the topography and other general features within the Kenderdine Catchment. An aerial photograph of the catchment is displayed on Map 4.

2.4 GEOLOGY AND SOILS

Information on the geology of the Kenderdine Catchment area has been obtained from the New Zealand Geological Map, Auckland Urban Area, Sheet R11, scale 1:50,000. The geology information is reproduced in simplified form in Map 5 in Appendix F.

This map indicates that the catchment, except for the Kohuora Crater area and along the western boundary, is underlain with pumiceous mud, sand, and gravel, with some organic-rich alluvium of the Puketoka formation.

The Kohuora Crater floor comprises dark brown to black, organic rich mud, while its higher slopes are made up of lithic tuff, comprising comminuted pre-volcanic materials with basaltic fragments, both from the Auckland volcanic field. Most of the eastern branch of the Kohuora Crater used to be the

Kohuora Landfill, which is described in more detail in Section 4.2.2 of this report.

The area along the western boundary comprises a mixture of basaltic ash and lapilli, red to red-brown to dark grey, vesicular, pebble to boulder sized ejecta of basaltic or basanitic composition and lithic tuff, all from the Auckland Volcanic field.

The entire catchment geology is of Pleistocene-Holocene age.

The soil everywhere within the catchment, except for the crater floor, is well compacted yellow brown earth with a relatively high clay content. In contrast, the crater floor is very organic, spongy, and saturated.

Overall, the infiltration rate of soils in the catchment can be considered to be slow to very slow.

2.5 OPEN WATERCOURSES INVENTORY

The Environmental Management section of MCC has compiled an inventory of open watercourses covering the urban areas of Manukau (MCC, February 2000). The inventory is part of a policy formulation exercise for open watercourses and will assist in identifying problems early and providing options and recommendations and prioritisation for solutions to some of the more common problems encountered in the open watercourses in Manukau.

The inventory is based on field survey information without chemical and biological testing although colour and odour are included in the assessment. As part of the inventory, photo points were established at different locations along the open watercourses and an assessment system was developed to gauge the condition of the open watercourses, from which they were categorised as "good", "fair", "poor", or "very poor". The assessed condition of the open watercourses in urban Manukau (covering 11 identified watercourse areas) range from poor to very poor.

The "poor" rating (28 to 33 points) applies to open watercourses which have more than one problem that needs to be addressed in the medium (1-2 year) future. These problems could be related to flooding, instability, water quality, etc.

The "very poor" rating (34 points and above) applies to open watercourses which have many problems such as flooding, erosion, weed growth, poor water quality and drainage, human impacts, etc.

The Papatoetoe area was included in this inventory, including five locations within the Kenderdine Catchment: 2-17 Romford Road, along Hookers Place, Hillside Road, Alabaster Drive, and Hillcrest Road. There was considerable variability in the condition scores obtained by these five sections, which ranged from 28 to 38 points.

The overall condition of the Papatoetoe area was assessed as poor, with an average score of 33.2, which ranks it 8th (fourth lowest) out of the 11 watercourses surveyed, just above Harania Creek and Tamaki River (34.6) and the Otara Creek (upper part) (34.8). All other watercourses scored 28.9 to 31.3.

Relevant details of the Papatoetoe Area stream assessment are set out in Appendix B.

2.6 PRESENT LAND USE AND DEVELOPMENT POTENTIAL

2.6.1 Present Land Use

Map 6 in Appendix F shows the current District Plan zoning and land use for the Kenderdine Catchment. An approximate breakdown of present land use is set out in Table 2.

Table 2 : Breakdown of Land Use in the Kenderdine Catchment

Land Use		**Area (ha)**		**Area (%)**
Residential	Main residential	201.14	214.30	67.4
	Designated main residential (refer note 2)	13.10		
	Residential heritage 3	0.06		
Business	Business 1	0.23	5.75	1.8
	Business 2	5.43		
	Designated Business 2 (Police)	0.09		
Rural	Designated rural 1	1.00	14.25	4.5
	Puhinui rural	13.25		
Public Open Space	POS 2	8.30	28.97	9.1
	POS 3	15.28		
	POS 4	3.49		
	POS 2 (flood management)	1.91		
Roads	Designated primary (NW motorway)	10.99	51.60	16.2
	Primary	5.62		
	Secondary	34.99		
Rail	Designated rail (NIMT)	2.69	2.69	0.8
Water	Rivers	0.35	0.48	0.2
	Streams	0.13		
Unzoned		0.16	0.16	0.0
Total		**318.20**	**318.20**	**100.0**

Note: Land use area data supplied by MCC GIS section.

The Kenderdine Catchment is one of the oldest settlement areas in Manukau City and is fully urbanised. It comprises mainly residential zoned areas, together with commercial (Business 2) areas around the St George Street shopping centre. Designated land use areas include schools (Aorere

College, Papatoetoe West, and South Primary Schools), railways (NIMT line), roading (southwestern motorway), and some recreational areas, particularly Kohuora Park in the Kohuora Crater, the eastern portion of which contains the former Kohuora Landfill. The crater floor is also designated for use for stormwater management purposes.

The average catchment imperviousness is 38.4% (parcels only), or approximately 42% with the southwestern motorway, primary and secondary roads and railways included[2]. Catchment imperviousness is shown in Map 7 in Appendix F, from which can be seen the relatively even distribution of impervious areas throughout the residential areas of the catchment, reflecting its general maturity.

2.6.2 Development Potential

Development potential within the catchment was assessed by reviewing District Plan requirements, Manukau Consultants Flood Management Study (1995/96) and the MCC Revitalisation Project Report for Old Papatoetoe, as summarised in Table 3.

Table 3 : Development Potential Review

Item	Requirements/Comments
District Plan	• Permits a maximum of 35% building coverage in residential zoned areas, excluding other paved areas on-site • Allows subdivision to a minimum of one house per 400m² net site area in residential zoned areas.
MCL Flood Study	• About 60% of existing lots are more than 750m² in area. • They considered it highly unlikely that more than 50% of these lots are in a position to consider more housing units. • A large number of lots in and around St George Street already have multiple flats and units. • However, those that are still capable of sustaining further development are going to be put under greater pressure to do so because of their proximity and convenient linkage to MCC and its main activities.
MCC Revitalisation Project	• Regional growth strategy aims to achieve residential densities of 20-25 dwellings/ha supportive of public transport. • Need 910-1900 new dwellings in old Papatoetoe area to achieve 20-25 dwellings/ha density. • Infill housing potential under current rules appears to be of order 600 extra dwellings. Concept plan indicates opportunities (primarily within business zone of Old Papatoetoe) that could yield in the order of 750 additional dwellings, making a total of 1350 dwellings, within the target range.

Analysis of the above data indicates that there should be little if any change in imperviousness in those areas likely to be developed under the Revitalisation project. Hence, the Manukau Consultants findings concerning future potential development are considered to still be applicable, assuming the District Plan zoning rules for this area remain unchanged.

[2] Source: MCC GIS: Total parcel impervious area = 101.2 ha; total parcel area = 263.46 ha and using estimated imperviousness from MCC standard road construction details of 61% to calculate approximate roading impervious areas.

Overall, analysis of the maximum probable development (MPD) situation has allowed for an increase in the imperviousness of individual sub-catchments of +5% or to a maximum value of 54%, (43% paved and 11% supplementary paved), whichever is less. The one exception is the upper Kohuora Crater area between Malaspina Place and Station Road. This is zoned main residential and is largely undeveloped at present. Several residential developments are in various stages of planning or construction in this area. Hence, the MPD scenario has assigned the maximum assumed imperviousness to this area of 54%.

As is demonstrated in the details of the HMS hydraulic modelling report, Volume 2, Appendix 1, the effect of taking into account the MPD for the catchment is insignificant, both in terms of stream flows and volumes, and on the pipe system upgrade analysis.

3.0 CATCHMENT BACKGROUND

3.1 HISTORICAL FLOODING AND MAJOR FLOOD CONCERNS

Information on historical flooding and major flood concerns was obtained mainly from MCC's land information registry (LIR) data, plotted overland flowpaths from MCC's GIS system, flood records and informal consultation. This data is confirmed by the modelling results presented in the HMS report, Volume 2, Appendix 1.

3.1.1 Land Information Registry (LIR) Data

Current LIR data was obtained from the MCC GIS section. This gave a total of 594 entries, which were categorised into seven main categories, as shown in Table 4. This data is plotted on Map 9.

Table 4 : Categorisation of LIR Data

Code	LIR Category	No of Entries
A	Site may be subject to surface water (ponding)/overland flow	499
B	Predicted overland flow through site, causing possible flooding, that may affect consented buildings	2
C	Flooding during 24 May 1997 storm	9
D	Overland flowpath easement	4
E	Overland flowpath easement (site subject to flooding)	4
F	Ponding easement	8
G	Right to drain water easement	68
	Total	**594**

Note: Some lots come under more than one category.

3.1.2 Plotted Overland Flowpaths from MCC's GIS System

Existing overland flowpaths from MCC's GIS system are also superimposed on Map 8 in Appendix F. In contrast to the LIR data, a count of the number of properties on designated overland flowpaths yields a total of 299 lots.

3.1.3 Flood Records

The following records supplied by MCC were reviewed during this investigation:

- Stormwater Service Requests: January 2000 – 12 October 2004
- Stormwater Flooding Reports: 1998-2001
- Stormwater Flooding Reports for 1997

These records were categorised into flooding, possible ponding/overland flow, and erosion issues, with minor maintenance related problems being excluded. The raw and sorted data is included in Appendix C and summarised in Table 5. This data has also been plotted on Map 9 in Appendix F.

Table 5 : Stormwater Service Requests and Flood Record Data Summary

Address	Entry	Dates of Occurrence
	FLOODING	
22 Hillcrest Road	Flooded (1 occasion)	9 Jun 1997
32 Hillside Road	Flooded (1 occasion)	14 Mar 2000
32a Hillside Road	Flooded (approx. 4 occasions)	9 Jun 1997, 2 May 2001
74 Hillside Road	Flooded (1 occasion)	31 Mar 2004
81 Hillside Road	Flooded (1 occasion)	2 Feb 2004
17 Landscape Road	Flooded (1 occasion)	9 Jun 1997
22 Lendenfeld Drive	Flooded (2 occasions)	3 Feb 2004, 29 Feb 2004
24 Lendenfeld Drive	Flooded (2 occasions)	3 Feb 2004, 29 Feb 2004
26 Lendenfeld Drive	Flooded (1 occasion)	5 Mar 2004
5 Malaspina Place	Flooded (2 occasions)	2 Feb 2004, 29 Feb 2004
7 Malaspina Place	Flooded (2 occasions)	2 Feb 2004, 29 Feb 2004
9 Malaspina Place	Flooded (4 occasions)	10 Aug 1998, 13 Oct 2003, 2 Feb 2004, 29 Feb 2004
11 Malaspina Place	Flooded (3 occasions)	2 May 2001, 11 Mar 2003, 2 Feb 2004
13 Malaspina Place	Flooded (2 occasions)	2 Feb 2004, 29 Feb 2004
15 Malaspina Place	Flooded (2 occasions)	2 Feb 2004, 29 Feb 2004
24 Miles Avenue	Flooded (1 occasion)	
64 Park Avenue	Flooded (1 occasion)	9 Jun 1997
19 Ramsey Street	Flooded (1 occasion)	9 Jun 1997
56 Wallace Road	Flooded (1 occasion)	9 Jun 1997
57 Wallace Road	Flooded (1 occasion)	9 Jun 1997
58 Wallace Road	Flooded (1 occasion)	9 Jun 1997
	POSSIBLE PONDING/OVERLAND FLOW	
42 Chantelle Place	Overland flow	1 May 1999
42 Ferndown Avenue	Overland flow	10 Aug 1998
9 Hill Road	Overland flow	1 May 1999
91 Hillside Road	Overland flow	2 Feb 2004
104 Hillside Road	Overland flow	19 Mar 2003
36 Kenderdine Road	Ponding	13 Oct 2003
14 Lendenfeld Drive	Seepage	2 Mar 2004
6 Narada Place	Overland flow	9 Jun 1997
10 Romford Road	Overland flow	
56 Wallace Road	Ponding/overland flow (2 occasions)	1 May 1999, 9 Jun 1997
58 Wallace Road	Overland flow	9 Jun 1997
43/3 Wyllie Road	Overland flow	

Address	Entry	Dates of Occurrence
	EROSION	
32 Chantelle Place	Erosion	4 Feb 2004
15 Fenton Street	Erosion	5 Feb 2004
9 Hill Road	Erosion	1 May 1999
74 Hillside Road	Erosion	1 May 1999

3.1.4 Stormwater Liaison Group (1997) Classification

Technical Report No.2 of the ARC-TA's Regional Urban Stormwater Strategy (Stormwater Liaison Group, 1997) identifies the Kenderdine Catchment as being subject to a medium flooding risk, meaning it contains areas where increased catchment development could result in flooding problems, or require upgrading of services to avoid flooding.

3.1.5 Informal Consultation

Prior to field work investigations, letters were forwarded in February 2005 to the occupiers of 120 properties identified by Kingett Mitchell as being located alongside open watercourses to inform them that it may be necessary to pass through their property as part of this investigation. Following this, several people contacted Fraser Thomas to discuss flooding issues on their properties, as summarised in Table 6.

Table 6 : Flooding Issues from Informal Consultation

Name	Contact Details	Comments
Delwyn Tewhata	74 Hillside Road; Tel 278 1975, 027 253 1863	• Feb: Bought property in Dec 2004, backs on to stream; have since found out by talking to neighbours that bad flooding affects their site. • Jul: Stream banks overtopped, flooding property on 24 Jul around 1:30 am, affecting lawn area but not buildings; Council staff in attendance. Doug Johnston (Manukau Water) advised this was the only problem of any significance associated with this storm in the Kenderdine Catchment.
Terry Mayhy	32A Hillside Road; Tel 277 7139	• Feb: Lived there 14 yrs; runs small hydraulic company on-site; lost three vehicles to floods during that time; knee deep water 2-3 times per yr (May-Jun worst); believes Council should clean out stream.
Gareth Milne	30A Hillside Road; Tel 2786764; 021 257 0149	• Feb: Major flooding of his property; believes caused by insufficient capacity of three downstream culverts; infilling has worsened problem; emailed many photos of flooding.

3.2 PREVIOUS INVESTIGATIONS AND EXISTING DISCHARGE CONSENTS

3.2.1 Comprehensive Catchment Discharge Consents (CCDC)

A comprehensive water right (No 761020) was granted to Manukau City Council for the Kohuora Crater catchment area (290 ha) in March 1976 for a period of 35 years, permitting the discharge of 23-28m^3/s of stormwater into the Waokauri Creek at the discharge point, map reference N42 – 354440. This water right was granted at the time of installing the main culvert from Kohuora Crater. It recommended the floor level for buildings around the Kohuora Crater to be RL 8.0 m and elsewhere in the catchment to be 1 m above the 1 in 50-yr ARI flood level. It also fixed a maximum outflow from the crater to 2.2 m^3/s from the 50-yr, 2-hr ARI storm.

In December 1978, MCC applied to extend this water right a further 500 m downstream to map reference N42 350436[3] to allow for the proposed Tidal Road to Puhinui Expressway works to be within the comprehensive catchment drainage area. This water right was granted at the time of installing the culvert under the motorway. It suggested that this culvert be designed to fully pass at least the 10-yr ARI storm and allow for passing the 100-yr ARI storm with headwater up to about 3.5 m to elevation RL 6.0 m. This extension increased the catchment area to 380 ha. The enlarged catchment covers the area bounded by Portage Road, Station Road, Carruth Road, and Manukau Harbour. This catchment essentially includes the Kenderdine Catchment and an additional area west of the southwestern motorway, where the crematorium is located.

3.2.2 Stormwater Related Consents

A total of 11 stormwater related consents relevant to this study were identified. Four of these relate to stormwater discharges, three to the drilling of groundwater bores, one to a groundwater take (bowling club for irrigation purposes), two to the Kohuora Crater (leachate discharge, sediment control), and one for earthworks associated with a cleanfill. Key details are summarised in Table 7.

[3] Approximately 500 m downstream of the southwestern motorway.

Table 7 : Relevant Discharge Consents

No	Consent No File Ref)	Consent Holder	Address	Purpose	Status
1	22116 (12783)	BP Oil NZ Ltd	96-98 Station Road, Papatoetoe	To divert and discharge stormwater from a redeveloped existing service station with stormwater from refuelling areas being discharged via a stormwater treatment device.	Granted 1999; Expires 31 Dec 2033
2	2985 (BR802466)	Transit NZ		Stormwater discharge	Lodged ~1980; archived
3	13383 (C512-12-1453)	Pattle Delamore Partners Ltd	South Auckland Cemetery, Puhinui Road	Land use consent to construct seven bores to approximately 5 m depth for groundwater level and/or chemistry investigations.	Granted Nov 1994; expired 18 Nov 1995
4	10932 (14/17/694)	Papatoetoe RSA Bowling Club (Inc)	Cambridge Terrace, Papatoetoe	Permit to construct a bore for the extraction of groundwater for irrigation purposes.	Granted Sep 1991; expired 19 Sep 1992
5	7978 (AG917919)	Papatoetoe RSA Bowling Club (Inc)	Cambridge Terrace, Papatoetoe	To take up to 22 m^3/day of groundwater for irrigation of two 36.4 m^2 bowling greens.	Lodged Nov 1991; expires 31 Dec 2006
6	29300 (C512-12-3322)	Caltex New Zealand Ltd	26 Rangitoto Rd, Papatoetoe	To construct four 100 mm diameter bores to a depth of approximately 5 m.	Commenced May 2004; expired 28 May 2005
7	15708 (CG9611468)	Manukau City Council	Kohuora Park, Station Road, Papatoetoe	To discharge leachate from an old sanitary landfill at an average annual rate of 36 L/min into the ground and groundwater beneath the site.	Lodged ~1996; expires 31 Dec 2017
8	15707 (SC9611469)	Manukau City Council	Kohoura Park, Station Road, Papatoetoe	Land use consent to carry out approximately 5 ha of earthworks associated with the rehabilitation and development of the Kohuora Crater landfill.	Lodged ~1996; expired 30 May 1999
9	1763 (BR761020)	Manukau City Council	Area bounded by Portage Rd, Station Road, Carruth Road and Manukau Harbour	Extension to comprehensive water right to allow the discharge of up to 42 m^3/s for a 1% storm from a catchment area of 380 ha.	Lodged Oct 1979; expires 16 Mar 2011
10	29168 (17472)	Vuksich and Borich Ltd	246 Portage Rd, Mangere	To authorise approximately 13.4 ha of earthworks associated with a cleanfilling operation.	Lodged 2004; expires 30 April 2015
11	2518 BR781902)	Manukau City Council	South Auckland Crematorium, Pah Rd, Papatoetoe	To discharge stormwater from a 7.6 catchment, including a 6.9 ha development (Hillside Road area near Puhinui Road and South Auckland Crematorium) into the Waokauri Creek; works include stormwater reticulation system and associated outfall structure.	Lodged Sep 1978; expires 22 Nov 2013

Notes:

1. Consents 10 and 11 lie partially outside the catchment.
   Limited consent information was obtained for consent No 2. This consent is believed to relate to sediment control works associated with runoff from earthworks during construction of the Tidal Rd-Puhinui Expressway.

3.2.3 Manukau Consultants Comprehensive Flood Management Study

Manukau Consultants undertook a Comprehensive Flood Management Study of the Kenderdine Catchment, Papatoetoe, in 1995/96. This report was peer reviewed by Babbage Consultants in 2000, who recommended some minor modifications.

This study involved review of relevant documentation and statutory requirements, a survey of about 2,000 households, hydrologic/hydraulic modelling, and the development of management options to address significant issues of concern. Stormwater drainage information used in the model was based on existing drainage data (mainly manhole invert depths), estimation of manhole lid levels from digital terrain modelling of aerials (1 m contour intervals), and surveying of a limited number of manhole lids to verify this data.

Some of the concerns identified by residents included:

- Overloading of the stormwater pipe upstream of Evelyn Street
- Flooding in the open channel between Kenderdine and Hillside Roads
- Flooding and overland flow on and upstream of Hill Road
- Flooding at Narada Place on Ferndown Avenue

Manukau Consultants found that hardly any major flooding was likely to occur in storms with a 1 in 5-year ARI or less. However, for events with 5-yr ARI or more, the following problems are likely to occur:

- More widespread overland flow along 60 m north of Evelyn Street
- Flooding in the open channel upstream of 36 Hillside Road
- Possible ponding upstream of Wallace and Landscape Roads
- Overland flow risk in flood plains

4.0 WATER QUALITY

4.1 THE RECEIVING ENVIRONMENT

The freshwater and coastal receiving environments for stormwater discharges from the Kenderdine Catchment are the Waokauri Creek and the Pukaki Creek and Waokauri Creek Inlet of the Manukau Harbour (SLG, 1997).

This section provides an overview of the Waokauri and Pukaki Creeks and the Manukau Harbour receiving environments and their water quality.

4.1.1 The Waokauri Creek (Freshwater Section)[4]

The Waokauri Creek is classified as a Category 1 stream (ie perennial stream) and described as having high naturalness (<20% of channel length piped or channelised), high riparian vegetation (>50% riparian vegetation remaining on watercourse margin) and with 83% of the stream being bounded by reserves, including the Puhinui Heritage Rural zone. No instream values were reported.

An ecological assessment of the open stream running through the catchment that drains into the Waokauri Creek is summarised in Section 6 of this report, and set out in detail in Volume 2, Aquatic Ecology, and Management Objectives for the Kenderdine Catchment, Kingett Mitchell, August 2005.

4.1.2 Pukaki and Waokauri Creeks (Coastal Marine Area)

(a) <u>Location and Reserve/Legal Status</u>

The Pukaki-Waokauri Creeks are located on the northern shore of the Manukau Harbour and are part of the Coastal Marine Area. Their confluence is near the causeway on Puhinui Road at the eastern end of the Auckland International Airport complex, with water flowing under the causeway and past Wiroa Island into the Upper Manukau Harbour.

Under the "Coastal Plan" (Operative Regional Plan: Coastal (October 2004), the Pukaki-Waokauri Creek Area is both a Conservation Protection Area 2 and a Tangata Whenua Management Area, being a Maori Reservation established under the Te Ture Whenua Maori Act 1993. Section 2.10.2 of the Coastal Plan states:

"The Waitangi Tribunal has recommended that the Creek be reserved for the exclusive use of the Pukaki Marae... an application to the Maori Land Court resulted in the establishment in 1992 of Pukaki-Waokauri Creek as a Maori Reservation for the purpose, inter alia of a place of significance for the common use and benefit of the Hapu of Te Akitai

[4] From Technical Report No.2 of the ARC-TA's Regional Urban Stormwater Strategy, SLG (1997).

and Te Ahiwaru o Waiohua. The local Tangata Whenua are Kaitiaki of the lands in question, and have maintained the natural and ecological values over several centuries, despite significant development pressures over the last century. These Tangata Whenua Management Areas recognise this, and the customary rights, responsibilities and relationships of the Tangata Whenua with their ancestral taonga".

The water area downstream of this (south and east of existing runway) is part of the Airport Management Area. This is identified as a Coastal Protection Area 2 in the Coastal Plan, except for much of the seaward side of Wiroa Island which is classified as a Coastal Protection Area 1.

Pukaki and Wiroa Island are both zoned as habitat zones under the 1993 Manukau Harbour Maritime Planning Scheme.

The Department of Conservation has selected the bird roosts and saltmarsh at Puhinui along with the closely adjacent intertidal banks as an Area of Significant Conservation Value.

(b) Habitat Types, Plant and Animal Life

This area consists of intertidal banks, shell banks and sandflats, which form a complex habitat for a variety of animal and plant communities. The extensive gently graded sand flats (27a[5]) support dense populations of intertidal sand flat organisms and are an excellent feeding ground for thousands of international migratory and New Zealand endemic wading birds including a number of threatened species (eg kingfishers, shags, ducks, and pukeko are common in the area, while the threatened banded rail, spotless crake, brown bittern, fernbird and marsh crake also use this area (SLG, 1997)).

The associated shellbanks at Puhinui (27c) are used as a high tide roost by many of these waders as well as a variety of coastal birds. Within this area, Wiroa Island (27b) has been developed by Auckland Airport as an artificial bird roost to encourage birds away from the flight paths of aircraft. The artificial roost is widely used by coastal birds, including waders, and it is the major roost on the Manukau Harbour for the threatened wrybill. Other threatened species likely to utilise this area include Caspian terns and Royal spoonbills (SLG, 1997).

Impounded behind the shellbanks is one of the largest, best, and least disturbed areas of saltmarsh remaining in the Manukau Harbour. The vegetation grades from the shellbank vegetation, into the saltmarsh, and then into kanuka forest with small native trees including kahikatea and rimu above Mean High Water Springs at Puhinui (27c). The saltmarsh, as well as being a habitat for a number of uncommon or threatened plants, is an important habitat for a variety of threatened secretive coastal fringe birds. Its habitat quality is enhanced by the

[5] The numbers in brackets in this section refer to those shown on Map Series 1 – Sheet 12 of the Coastal Plan and in its text.

adjoining terrestrial vegetation which provides shelter for the birds and offers potential nesting sites.

Pukaki, Tautauroa and Waokauri Creeks contain extensive dense mangrove marsh in healthy condition which is expanding. The Pukaki lagoon arm of the inlet has a marsh habitat comprising Raupo, rushes and *Cotula*. There are small areas of maritime marsh on the north-eastern side of Wiroa Island and mangroves near the causeway. This area also contains widespread but generally low density patches of the eelgrass (*Zostera*) in the upper intertidal zone (SLG, 1997).

(c) <u>Invertebrates and Fish (SLG, 1997)</u>

Invertebrate communities comprise predominantly sandy mudflat communities, with common species including wedge shells and cockles. The upper estuarine mudflats support a less diverse community dominated by the mud snail *Amphibola crenata* and the mud crab *Helice Crassa*.

Pukaki and Waokauri Creeks are likely to be used as a refuge and nursery for a number of fish species in this area, including snapper, trevally, flounder, and kahawai. Eels and yellow-eyed mullet are likely to be present in the lower tidal reaches of the freshwater streams.

(d) <u>Sediment Characteristics and Quality (SLG, 1997)</u>

Sediment classifications for this area are summarised in Table 8.

Table 8 : Sediment Classifications

Sediment dynamics	Depositional (fine materials continuously being deposited (eg sheltered, poorly flushed sites; sediments associated with such areas are typically muds.
Sediment quality	Poor
Total sediment yield	High (400,000-1,000,000 kg/year/catchment)
Sediment yield	High (300-450 kg/ha/year)
Sediment load	Medium (25,000-75,000 kg/year per km of coastline)

The Coastal Plan specifies three settling zone sampling locations within the Pukaki-Waokauri Creeks Area that will be used for monitoring the impact of stormwater and wastewater discharges in those zones. One of these is located within the Waokauri Creek branch. Settling zones are areas where most (approximately 75%) contaminants settle out of suspension and become incorporated into benthic sediments. Consequently, settling zones are prone to contaminant accumulation and some level of degradation is expected.

In TP203[6] (July 2003), the Pukaki-Waokauri Creek belongs to Regional Receiving Environment Area 17. Existing mean contaminant concentration data for the primary stormwater contaminants of concern for the urbanised Auckland region are summarised in Table 9. All contaminants were present at the "green" status level, indicative of a healthy sediment chemistry environment.

Table 9 : Mean Contaminant Concentrations in the 63 and 500 μm Sediment Fractions and Contaminant Status at the Pukaki-Waokauri Settling Zone Monitoring Site

Sediment Grain Size (μm)	Copper (mg/kg)	Zinc (mg/kg)	Lead (mg/kg)	PAHs (μg/kg)
<500	9	70	13	57
<63	6	54	13	--
Status	Green	Green	Green	Green

Notes:
1. PAHs = polycyclic aromatic hydrocarbons.
2. "Green" status criteria: Copper <19 mg/kg; zinc <125 mg/kg; lead <30 mg/kg; PAHs <0.66 mg/kg.

However, TP203 adds that some areas such as this were expected to be "amber" (indicative of degraded health), because of there being significant urban areas upstream, with further investigation of such areas being recommended.

(e) Amenity/Use Values (SLG, 1997)

This area is used for duck shooting and is a valued shellfishing area. Commercial and recreational fishing occur in this area.

4.1.3 The Manukau Harbour

The information in this section has been extracted from MCC's "State of the Environment Report" (MCC, 1999), with minor amendments and additions.

(a) General

The Manukau Harbour is a large and shallow estuarine lagoon, separating Auckland and Manukau Cities about halfway across the western side of the Auckland isthmus. The harbour covers an area of 344 km^2 with a total catchment of about 1,100 km^2 bounded by Waitakere City in the west, Auckland to the north, Manukau to the northeast and east, and Papakura and Franklin to the south.

Water circulation in the Manukau Harbour is largely tidal, dominating freshwater flows, and has a mean residence time in the Harbour of about 22 days (ARC 1994, TP No. 47). Rivers feeding into the Harbour are characteristically small, short and numerous. Several of these

[6] "Regional Discharges Project, Marine Receiving Environment Status Report 2003", Technical Publication No.203, Auckland Regional Council, July 2003

streams drain the Manukau City sub-catchment, including the Puhinui Stream in the Manurewa Ward and the Pukaki, Oruarangi, Tararata, and Harania Streams in the Mangere Ward.

The Manukau Harbour has a special place in the historic, social, spiritual, and cultural heritage of the tangata whenua. It is the source of resources that have sustained tangata whenua for centuries and was a landing place of the Tainui waka during early Maori migration.

The Harbour receives inputs from many land use types, ranging from the highly urbanised and industrialised Auckland isthmus to the rural Franklin District at the harbour mouth.

The Harbour is identified as an internationally important wetland and has been selected in its entirety as an Area of Significant Conservation Value (ASCV) by the Department of Conservation (Coastal Plan, 2004) and is considered to be subject to degradation as a result of the limited flushing characteristics of its low energy environment (ARC, March 2000).

(b) Land Uses around the Manukau Harbour

About 75% of the Manukau Catchment is rural and 25% is in metropolitan urban uses. The Harbour catchment contains the region's major industrial areas of Onehunga, Penrose, Wiri, and the Auckland International Airport.

The Mangere Wastewater Treatment Plant remains the single largest point source of pollutants for the harbour, discharging nutrients, trace metals, micro-organisms, degradable organic matter, suspended solids, and synthetic organic contaminants from its outfall near Puketutu Island in Mangere (ARC 1994, TP No. 47). It is the largest single source of fresh water to the harbour with an average daily sewage flow of more than 320,000 cubic metres.

Apart from the Mangere Wastewater Treatment Plant and a few large commercial enterprises with discharge consents, the majority of point sources for the Manukau Harbour come from small industrial units of which many do not need to hold discharge consents.

Information about the contribution of non-point source pollutants to the Manukau Harbour is largely unavailable.

(c) Monitoring Water Quality in the Manukau Harbour

The ARC has four on-going regular water quality monitoring programmes for the Manukau Harbour. They are:

- The monthly long-term baseline saline water monitoring programme, which began in 1987 and assesses trends in water quality for a range of physical, chemical and bacteriological parameters.

- The annual shellfish monitoring programme, which began in 1987 using naturally occurring Pacific oysters as biological indicators at four sites plus a control site, to assess water quality and its trends.
- The Manukau Harbour Ecological Monitoring Programme, which uses a number of naturally occurring sediment dwelling organisms to assess ecological trends in the Harbour. Monitoring is conducted once every two months.
- A Sediment Chemistry Baseline Monitoring Programme began in 1998, which monitors the status and trends in water quality based on sediment quality. In addition, the ARC has also initiated a groundwater baseline monitoring programme.

(d) <u>Water Quality in the Manukau Harbour</u>

Three broad regions reflecting different levels of pollution occur in the Harbour (ARC 1994, TP No. 37) (refer Table 10):

- The northern region from Otahuhu/Panmure, including the Mangere Inlet, to just south of Puketutu Island;
- The southern or outer region towards the Harbour entrance; and
- The central region around the Waiuku and Papakura Channels.

Table 10 : Water Quality of Manukau at about Mid-Feb, Oct- Sept 1993

Parameter	Northern Region (Mangere Bridge, Puketutu Island, Shag Pt)	Central Region (Papakura and Waiuku Channels)	Southern Region (Weymouth and Waiuku River mouths)
Salinity	31.0 – 32.7	33.6	31.9 – 33.1
Turbidity (FTU)	8.3 – 19.0	5.8 – 6.5	8.0 – 12.0
BOD (g/m^3)	1.3 – 1.9	1.0 – 1.1	1.1 – 1.4
Dissolved Oxygen (% saturation)	91 – 94	98 – 101	96 – 98
Total Phosphorus (mg P/m^3)	179 – 318	59 – 61	65 – 67
Total Inorganic Nitrogen (mg N/m^3)[a]	398 – 902	71 – 75	88 – 113
Free ammonia (mg NH_3/m^3)[a]	10 – 20	1.0 – 1.2	1.0 – 1.2
Faecal coliforms (no / 100ml)	32 – 130	<2	2 – 7
Enterococci (no / 100ml)[b]	2.8	0 - 2	3.5

Notes:

1. Data from ARC 1994, TP No. 37
2. Reported values are median values observed at sites within each region.
3. [a] = April 1989 – September 1993; [b] = August 1990 – September 1993

The northern region of the Harbour, particularly near Puketutu Island, is impacted heavily by the treated sewage outfall from the Mangere Wastewater Treatment Plant and stormwater from its intensively developed industrial and urbanised catchment. The ARC's monthly monitoring results indicate that the northern region of the Harbour has the highest levels of pollution when compared with the southern and central regions (ARC 1994, TP No.37; refer Table 10). The northern area is characterised by depleted oxygen concentrations; relatively high phosphorus, total nitrogen, ammonia and faecal coliforms; elevated biological oxygen demand (BOD_5) and bacterial levels; and is more turbid than the central and southern regions. The ARC has confirmed that the conclusions reached in ARC TP No.37 in 1994 are still valid considering more recent monitoring data to January 2000, reported in ARC TP No.132 (September 2000). However, these more recent results do indicate that turbidity and suspended solids levels are declining at nearly all Manukau sites, indicating that water clarity is improving.

The Southern Region of the Harbour out towards the Harbour entrance has the highest water quality relative to the Northern and Central Regions (refer Table 10). However, studies have noted occasional elevated levels of inorganic nitrogen and enterococci, which are probably due to sources other than the Wastewater Treatment Plant.

Shellfish quality in different parts of the Harbour have been found to closely reflect water quality. Those found close to the Mangere Wastewater Treatment Plant are considered chronically unsuitable for human use. Copper levels, in particular, have been found to exceed the Australian National Health and Medical Research Council Guidelines for human consumption (ARC 1997, TP No. 81).

Surveys have consistently shown that the levels for most trace metals, micro-organisms and organic contaminants in shellfish are higher in the northern region of the Harbour and decrease towards the southern region of the Harbour entrance. Consumption of shellfish found along the northern shores of the Manukau Harbour should be avoided.

Recreational and commercial fishing takes place in the Harbour, especially in the southern region. Swimming in the northern region, especially down-current from the Mangere Wastewater Treatment Plant and in the Mangere Inlet, is considered a health risk due to the occasional high levels of pollution. Trends in monthly water quality monitoring over the last seven years and the Ecological Monitoring programme suggest that no major harbour-wide ecological changes have occurred over recent years (ARC 1995, TP No.64).

(e) Responding to Water Quality Issues in the Manukau Harbour

In response to the degradation of water quality in the Manukau Harbour, the then Auckland Regional Authority (ARA) commissioned the Mangere Wastewater Treatment Plant in the 1960s. Given the significant increase in population and the extent of development in the Region since that time, the Plant is now nearing its full capacity. Furthermore, the oxidation pond treatment system that was once acceptable has now been superseded with more appropriate technology.

In 1997, the ARC which superseded the ARA and the MCC approved the "Waste Water 2000" project. This project involved a major upgrade of the Treatment Plant and will reduce the current levels of pollution in the Harbour. Major changes include the decommissioning of all the oxidation ponds, upgrading of the plant, and installation of a diffuse discharge outfall system. Consent conditions for the disposal of treated effluent to sea require that the receiving marine waters must comply with a set of quality conditions for values which include swimming and shellfish gathering from October 2003, except for a relatively small non-complying area (mixing zone) immediate to the outfall.

In addition, there are occasional sewage overflows into the Manukau Harbour from sewerage pump stations belonging to the surrounding local authorities and Water Care Services Ltd. The main causes of sewage overflow are infiltration, illegal connections, and vandalism. With age, increasing pressures from population, industrial and commercial growth, the need to address maintenance and upgrading of the sewerage system has become increasingly urgent. Although MCC has annually earmarked resources to deal with those issues, budgetary constraints will mean that a comprehensive solution will have to be considered along with other priority programmes over the long term.

4.2 POINT SOURCES OF POLLUTION IN THE CATCHMENT

4.2.1 Old MCC Landfill Sites

MCC has carried out extensive monitoring over a long period of time (since 1994) to identify environmental risks associated with old landfill sites in the Manukau City catchments. A report titled "Assessment of Old Landfills" (GHD, June 2000) evaluates each of the 39 closed landfill sites to determine the potential for adverse environmental effects and which of the sites may require resource consents from the ARC.

The evaluation used a number of methodologies, to ascertain actual and/or potential environmental effects from the landfills. The key criteria for assessment of environmental effects in the MCC report are mainly focused on leachate risk factor, leachate strength, and condition index values and site inspections and assessments.

The key conclusions from this evaluation are:

- No significant adverse effects from discharge of landfill leachates, were identified on the water quality of receiving waters adjacent to the respective landfills.
- Many of the old landfills mainly contain clean fill, with minimal organic content and are consequently not likely to produce any significant volumes of leachate both now and in the future.
- The environmental risk for actual or potential adverse effects, from very low levels of contaminants present in a small number of the landfill leachates, are generally considered not to be significant.

However, seven of the 39 old landfill sites in Manukau City were identified as having contaminant levels in the leachates that may pose some risk to the environment. ARC has since identified six of these sites as being of concern.

According to the MCC's landfill database, the Kenderdine Catchment contains only one of these 39 old landfill sites (Kohuora Crater landfill), which is not one of the six landfills of concern to ARC. Another old landfill (Pah Road) included in ARC's list is located slightly downstream of the catchment on land that now forms part of the Manukau Cemetery/Crematorium. The locations of these two landfills are shown on Map 10 in Appendix F. Only the Kohuora Crater Landfill is described further in this report.

One Landfill (Portage Road) is currently operating (see below).

4.2.2 Kohuora Crater Landfill[7]

The Kohuora Crater is located adjacent to Station Road and covers an area of approximately 8.5 ha, consisting of wetland (peat swamp) in the crater floor bounded by gentle slopes up to the crater rim.

From 1968-87, the then Papatoetoe City Council operated a municipal refuse and cleanfill landfill at the eastern corner of Kohuora Crater. This was capped in 1987 and converted into four sports fields (Allot 547, Manurewa Parish and Lot 3, DP114219).

From 1986-95, a private owner (McDonnell) operated a private cleanfill west of the Papatoetoe Borough Council landfill. This part of the landfill received mostly building debris (concrete, scrap metal, timber), soil material and some organic refuse (ie non-cleanfill materials). MCC purchased McDonnell's site in 1995 and established a grassed general recreation area on it.

These landfilling operations covered approximately 5 ha of the eastern portion of the crater. The western portion has remained as a natural wetland and never been used for landfilling purposes.

Both landfilling operations were established without any engineered lining systems and hence without any ground or surface water protection

[7] Most of this information comes from Kohuora Crater Compliance Monitoring, 2003/2004 Annual Report, MCC

measures. Fill levels are estimated to be about 3.6 m deep. Leachate produced at the landfill discharges to ground and surface waters via both discrete and diffuse pathways. The total estimated annual contribution to the water balance of the wetland from groundwater flows within the landfill area is estimated to be 20,000-25,000 m^3/year (GHD, 2004).

MCC was granted resource consent by ARC in 1997 to "discharge leachate from a closed sanitary landfill into the ground and groundwater beneath the site" (Consent No.7 in Table 7). Site inspections, surface water, and sediment sampling have been regularly undertaken since 1998 to ensure compliance with the conditions of the ARC consent.

Surface water sampling is undertaken at six monthly intervals at four locations: Stm 1 (upstream, near Malaspina Place), Stm 2 (mid-stream, near Lendenfeld Drive), Stm 3 (on side drain close to old landfill), and Stm 4 (discharge point, near Alabaster Drive). A sediment sample is collected annually from Stm 3. Recent water sampling results from 2004/2005 are summarised in Table 11, while graphs showing historical trends are set out in Appendix D. It should be noted that these samples were taken approximately nine years after the landfill was closed, at which time the landfill is in the early-mid range of closure.

Table 11 : Kohuora Crater 2004/2005 Water Sampling Results

Parameter	Stm 1		Stm 2		Stm 3		Stm 4		ANZECC (1992)
	Sep 04	Feb 05	Sep 04	Feb 05	Sep 04	Feb 05	Sep 04	Feb 05	
Field Measurements									
pH	6.8	6.3	7.2	6.8	7.0	6.6	7.1	8.3	6.5 – 9.0
Temperature (°C)	13.1	19.2	14.2	21.3	15.8	21.7	15.6	28.2	
Conductivity (mS/m)	56.8	55.6	85.6	82.1	71.3	46.3	72.4	68.4	150
Lab Measurements									
pH	7.2	7.0	7.6	7.6	7.5	7.5	7.6	8.5	6.5 – 9.0
Conductivity (mS/m)	51.9	52.9	85.0	77.5	69.8	43.5	70.9	64.2	150
Chemical Oxygen Demand (COD) (g O_2/m^3)	83	73	64	48	110	<40	84	95	
Ammonia-N (g/m^3)	0.56	1.66	0.89	1.58	2.98	0.14	0.13	0.15	2.2
Chloride (g/m^3)	37.2	22.9	41.6	32.4	46.8	31.9	39.6	31.1	
Total Iron (g/m^3)	2.13	9.18	1.86	1.75	3.32	1.65	4.20	1.87	
Total Zinc (g/m^3)	0.018	0.007	0.015	0.004	0.036	0.011	0.010	0.020	0.050

Notes:
1. Guideline values are from ANZECC (1992), as approved in the consent.
2. pH, temperature and conductivity are field measurements.
3. Stm 1 and 2 sampling locations directly influenced by stormwater inputs.
4. Concentrations in excess of ANZECC guidelines are shown in bold.

Key points from the compliance monitoring undertaken to date are summarised below:

- Visual inspections have shown consistently satisfactory results.
- Six monthly surface water samples and annual sediment samples are generally in compliance with established guidelines except for isolated exceedances (eg Stm 3 – 2.98 g/m^3) and more regular exceedances for total zinc, as described further below.
- The pH of sample Stm 4 (Feb 05) was 8.30 (field measurement), which is above the expected range but within the trigger values. Sample Stm 1 (Feb 05) was 6.27 (field measurement) which is slightly below the low pH trigger value of 6.5. Historically, the pH of all samples has shown a gradual increase, except for the last three samples where a decreasing trend is generally evident.
- Water sample temperatures vary seasonally, according to the weather conditions at the time of sampling and the condition of the stream at the sampling point (shallow or deep, flowing or stagnant).
- At the compliance point (Stm 4), conductivity readings are at levels typical of most urban streams, while contaminant levels are generally at relatively low levels, except for total zinc which has frequently exceeded trigger levels until recently (February 2004). Stm 4 sampling results show a constant-decreasing trend for COD, ammonia, chloride and iron, all important leachate indicators, with ammonia consistently being below ANZECC guideline levels since December 1999. The trend in Stm 4's total zinc concentration is less clear.

Overall, these results and trends indicate that the leachate discharges from the landfill are not having a significant negative impact on surface water quality in the area, with the possible exception of zinc. However, the high zinc levels may be caused, at least in part, by stormwater runoff from the surrounding urban area.

4.2.3 Portage Road Cleanfill

Approximately 13.4 ha of earthworks associated with a cleanfilling operation at 246 Portage Road have recently been consented by ARC for an approximate 10-year period until 30 April 2015. The main potential contaminants from such an operation are silt and sediment associated with active earthworks and runoff from recently filled but yet to be stabilised areas. The location of this cleanfill is shown on Map 10 in Appendix F.

Consent conditions include the following:

- The maximum area of exposed, unstabilised earthworks at any one time shall be 5 ha.
- Erosion and sediment control measures shall be carried out in accordance with those described in the Sinclair Knight Merz Ltd Erosion and Sediment Control Plan Number C003 and in ARC TP No.90.
- Provision of perimeter controls before the commencement of earthworks.

- Construction of decanting earth bunds to provide 2 m^3 of storage for every 100 m^2 of contributing catchment area. The bunds shall have a minimum length to width ratio of 3:1 and a level impoundment area, a single perforated novacoil upstand outlet and a stabilised emergency spillway with minimum width of 2 m.
- Diversion of "clean runoff" from stabilised surfaces including catchment areas above the site away from earthwork areas via a stabilised system, so as to prevent surface erosion.
- No earthworks to be undertaken between 30 April – 1 October each year, with revegetation/stabilisation measures to be completed by 30 April each year.

The implementation of these and other measures described in the consent should help minimise the potential for runoff from the cleanfill to contaminate stormwater downstream of the cleanfill.

4.2.4 Wastewater Overflows

There are no Manukau Water pump stations and only one Watercare Services Limited pump station (No.20) within the Kenderdine Catchment, the location of which is shown on Map 10.

This pump station is a potential sources of pollution as there is always the risk of mechanical or electrical failure that could lead to pump station overflows into the nearby open channel drain. Pump station overflow data is summarised in Table 12.

There are also two known problem points within the sewer pipe system where overflows occur during heavy rainfall. Corresponding overflow data is also shown in Table 12.

Table 12 : Overflow Points and Frequency of Overflows

Location, Address	Avg. O'flow Vol. (m^3/o'flow)	O'flow Freq. (no per year)	Receiving Environment
Watercare Pump Station 20, 51 Hillside Road	10	1	Open watercourse
35 George Street	<30	<1	Stormwater system
19 Ferndown Avenue	55	Approx. 1	Overflows via MH onto private property

Notes:
1. Freq. = frequency, o'flow = overflow, vol. = volume, w/w = wastewater
2. Overflow data obtained from Manukau Water.

The locations of these wastewater overflows is shown on Map 10 in Appendix F.

Manukau Water have advised that they are currently preparing a wastewater upgrade plan as part of their global network consent which will progressively upgrade the entire wastewater system to a one year containment standard based on a one year design storm (ie no overflows for events up to a one year storm). At this stage, they are not able to advise if and when system upgrades will be undertaken to address the two known overflow points within the MCC sewer pipe system.

No information on Watercare Service Ltd's intentions with regard to potential overflows at PS 20 has been forthcoming.

4.2.5 Traffic

The Kenderdine Catchment has a number of major roads running through it. These include the southwestern motorway (approximately 1.5 km length) along the catchment's southwestern boundary and several district arterial roads either bounding the catchment (Portage and Station Roads) or running through it (St George Street and part of Carruth Road).

No specific measured traffic volume data was obtained for the southwestern motorway.

Traffic survey data obtained from MCC (refer Table 13) indicates Station Road, St George Street, and Carruth Road are subject to high traffic volumes. Both Portage and Pah Roads are subject to medium traffic volumes, while several other roads (Claude, Ferndown, Kenderdine and Wilmay) all have traffic volumes towards the upper end of the low range (ie 4,000-5,000). Almost all roads show a reduction in traffic volumes between 1998 and 2001.

Map 10 displays the major roads and traffic volumes discussed above.

Table 13 : Kenderdine Catchment Traffic Volume Data

Category	Description	Main Roads	7d Average Daily Traffic Count	
			1995-98	1999-2001
High (>10,000)	District arterials	Station Road	13,105	12,819
		St George Street	21,073	10,843
Medium (5,000-10,000)	District arterials	Portage Road	7,112	6,509
	Collector roads	Pah Road	5,811	5,644
Low (<5,000)	Collector roads	Claude Avenue	4,037	4,552
		Ferndown Avenue	5,126	4,670
		Kenderdine Road	1,604 - 5,253	3,272 – 4,382
		Wilmay Avenue	3,414	4,156
	Local roads	Hillcrest Road	3,385	Not measured
		Park Avenue	2,629	Not measured

Notes:

1. Traffic survey data was obtained from MCC and is set out in full in Appendix E. This data relates to 17 different monitoring points throughout the catchment, of which all 17 were monitored in the pre-1999 round and nine were monitored during 1999-2001. It gives reasonable coverage of the road network within the catchment except for the southeastern area around Wallace Road, Fairview Road, and Cambridge Terrace.
2. The above table lists all roads from the traffic survey data in the medium and high categories and only those roads in the low category with average daily traffic counts over 2,000.
3. Portage Road runs along part of the northern boundary of the catchment. Traffic data for this road has been included as some of the road runoff may enter the Kenderdine Catchment.
4. Comparable traffic data for Carruth Road (between Allenby and Puhinui Roads) indicates this is also a high volume road with traffic volumes of 15,964 (1998) and 14,965 (2000).
5. The Kenderdine Road data relates to two different survey points along this road.

4.2.6 Other Point Sources

No other significant point sources of pollution affecting stormwater have been identified within the Kenderdine Catchment.

4.3 EXISTING STORMWATER TREATMENT

A total of five areas provided with some form of stormwater treatment have been identified within the catchment, three of which are in operation, while one is under construction and one is proposed. These are described in Table 14. Three of these devices treat stormwater from a mixture of residential and roading areas, including the southwestern motorway, while one is a private device used for the treatment of runoff at an existing service station.

Table 14 : Treatment Devices

Location	Description
Kohuora Crater	Designated flood management area within the MCC District Plan. Previously estimated flood levels are 7.6 and 7.8 m RL for the 20% and 1% AEP events respectively, but the latter has increased to just over 8.0 m in the HMS model study, Volume 2, Appendix 1. Some stormwater quality enhancement will occur as a result of the detention of flood waters.
Manukau Memorial Gardens	Provision of water quality pond within the Memorial Gardens serving a total catchment of 16 ha, comprising a mixture of established residential, Memorial Gardens and motorway areas. The pond will have a permanent 400 mm depth (RL 14.0 m) of water to promote wetland vegetation and a water quality volume of 2,300 m^3 (RL 15.8 m). The 1% AEP water level is estimated to be 16.3 m RL. This pond is now operational.
BP Oil, 96-98 Station Road	Provision of treatment for stormwater from a redeveloped existing service station via an API interceptor tank followed by discharge to the public stormwater system. Resource consent granted by ARC in 1999 and valid until 2033.

Location	Description
42a Park Ave	Provision of two treatment and detention ponds for proposed residential development of 5.1 ha catchment to provide: Water quality treatment in accordance with ARC TP No.10 (water quality volumes = 256 m^3 (southern pond) and 203 m^3 (northern pond) at RL 7.18 m. Detention of storm flows so that the 20% AEP pre-development from the site are not exceeded (detention volumes = 344 m^3 (southern) and 283 m^3 (northern); max water level = 7.28 m RL 1% AEP storm). Additional storage volume to the crater flood volume. Approved by MCC, Nov 2004; currently under construction.
southwestern motorway	Proposed water quality pond for treatment of runoff from 2.6 ha of NW motorway. Required water quality volume = 351m 3. (GHD, 2000).

Notes:

1. 42A Park Ave data obtained from relevant excerpts of the development and engineering applications submitted to MCC in 2004.
2. MMG pond information from "Puhinui Road Water Quality Pond Design – Resource Consent from ARC", Connell Wagner, Sept 2001.
3. NW Motorway pond information from "SH20/Puhinui Road Interchange (MMG Catchment), Water Quality Treatment Requirements", GHD, Nov 2000.

5.0 WATER QUANTITY ANALYSIS

Details of the hydraulic and hydrological modelling carried out in the analysis of the catchment and its stormwater reticulations systems is to be found in Volume 2, Appendix 1, in the report by Hydraulic Modelling Services Ltd (HMS), February 2006.

5.1 METHOD OF ANALYSIS

5.1.1 Modelling Software

The software package used was MOUSE which fulfils the requirements to incorporate both hydrological and hydraulic capabilities. This programme is widely used within New Zealand by a number of Territorial Authorities. MOUSE uses rain depth distribution, catchment area, land use run-off factors to calculate flows, and accounts for the dynamic effects of sub-catchments inflows and channel storage, to produce flows, velocities, and water levels throughout the drainage system.

5.1.2 Hydrological Model

The catchment was subdivided into 380 sub-catchments reflecting the configuration of the existing reticulation, as displayed on Map A2 in the HMS report. Perviousness and imperviousness within each sub-catchment was taken into account to yield appropriate curve numbers. Curve Numbers and initial abstraction depths were derived in accordance with ARC TP 108.

In order to reflect the potential for further development in the catchment, an increase of 5% imperviousness was applied to the sub-catchments, except for those in which the imperviousness already exceeded 54%. This was to take account of the maturity of the catchment, and hence the limited potential for further modification of imperviousness in those particular sub-catchments. The resulting system represented a Maximum Possible Development (MPD) case, and was tested in addition to the exiting situation.

Synthetic design rainfall events were derived for TP108, and the 1%, 2% 20% and 50% AEP events analysed.

5.1.3 Hydraulic Model

Manhole locations, names, pipe diameters lid, and invert levels were derived from a number of sources, including:

- MCC GIS system
- Papatoetoe City Council Underground Services Plans form the 1960s
- Survey undertaken by GHD for MCC in May 1995
- Survey undertaken by Fraser Thomas Ltd for this report

Considerable interpolation of level information, using MCC 2.0 m contour plans, was necessary as a resulting of the lack of surveyed data throughout the catchment. Of the 737 manholes in the model, 437 (59% have interpolated lid and invert levels. Cross sections of the stream channel were surveyed by FTL at critical locations (refer Map A3 in the HMS report).

The Kohuora Crater is a significant hydraulic and hydrological feature in the catchment, and it contains both open channels and piped outlets, some of which were surveyed, and the rest assumed. Storage in the crater is a critical feature, but it has been found that dense vegetation and high groundwater and open surface water in the crater made survey too problematic and expensive, and was not commissioned. The storage capabilities of the crater therefore remain uncertain.

Overland flow occurs at many places in the 1% AEP storm. It has generally been assumed that overland flow occurs along roads where it is not obvious from the contours where flow would otherwise go.

Manning's M was set throughout to 30 for open channels and the main stream, and 85 for all pipes

5.2 UPGRADE OPTIONS MODELLED

In discussions with MCC it was agreed that three principle scenarios should be investigated:

- An upgrade of the entire network as necessary to meet the MCC minimum standard of capacity for stormwater reticulation, viz, capacity to carry the 20% AEP storm event
- Modifications to the inlet and outlet arrangements from the Kohuora Crater to test the effectiveness of utilising the crater for storage, and the subsequent effects on flows and levels in the main stream
- A combination of pipe upgrades, and purchase of properties vulnerable to flooding, to reduce flood risk throughout the catchment generally

The following were the options eventually modelled which has produced the results tabulated in the appendices to the HMS report, and which are discussed further below.

5.2.1 Option 1: Upgrade Pipes to Convey 20% AEP Event, but with an Upgrade of the Culvert at 36 Hillside Road to Convey the 1% AEP Event.

This upgrade option is intended to provide capacity to carry the 20% AEP storm event and to meet MCC's standard requirement for stormwater drainage capacity.

Included in the analysis is an additional upgrade to the culvert at 36 Hillside Road, because this culvert is currently presenting a significant backwater effect during larger storms. This backwater effect extends as far upstream as Wyllie Road and has the potential to exacerbate flooding of upstream properties.

The head loss through the 36 Hillside Road culvert is currently about 1.00 m. None of the other culverts in the system appear to provide this level of restriction. Hence, since it seems that a complete replacement is necessary, and in order to realise the best effect of upgrade, it was assumed that this culvert would be upgraded to carry the 1% AEP storm event, ie an upgrade to a 2.10 dia pipe or equivalent would achieve this.

5.2.2 Option 2: Utilising Storage Within the Kohuora Crater

All of the following sub-options were modelled on the basis that pipe upgrades throughout the catchment as per Option 1 had been undertaken:

- 2a: Restrict the crater outlet
- 2b: 1800 mm dia inflow and 600 mm dia outflow from the crater
- 2c: Separate the crater into two storage ponds

Apart from its natural storage function, parts of the Kohuora Crater area are suitable for development into stormwater development ponds. A set of such ponds is currently under construction in conjunction with the new residential development at the end of Malaspina Place.

A somewhat unexpected result of the current crater outflow arrangement is that during large storm events there is a backflow into the crater as water levels in the main stream exceed those in the crater. This backflow has been observed in the field, and has an attenuating effect on main stream peak water levels and flows.

Option 2a sought to restrict the outflow to 600 mm in order to reduce the peak flows from the crater. This option was aimed at allowing higher flows into the crater and restricting outflows, by assuming the existence of two pipes, each with backflow gates at the appropriate ends of the pipes. This would provide for inflow through the existing 1800 mm culvert and a restricted outflow through a 600 mm pipe.

Option 2c takes advantage of an existing embankment within the crater which separates the main crater area from the area close to the outlet currently used as a baseball field. This approach tested the effect of allowing this area to flood and store water in addition to the storage effect of the main crater.

5.2.3 Option 3: Pipe Upgrades Upstream of the Railway Line and Hillside and Wyllie Road Culverts, and Purchase of Property

This option focuses on the length of the main stream valley upstream of the railway line which is currently piped for its entire length, and downstream to Hillside Road, with its culvert restrictions, and is aimed at comparisons with the cost of purchasing properties as an alternative to pipe upgrades.

Modelling this option has also involved testing the effect of duplicating the existing pipeline through the valley upstream of the railway line, and upgrading the Wyllie Road and 36 Hillside Road culverts in an attempt to eliminate the flooding which occurs upstream of the Railway Line in the 1% AEP event.

5.3 UPGRADE OPTIONS MODELLING RESULTS

As is mentioned in the HMS report, the accuracy of the modelling results is comprised significantly by the lack of accurate survey data throughout the catchment. Many assumptions have had to be made about levels on manhole lids and inverts based on existing contour maps of large contour interval. In particular, the available storage in the Kohuora Crater has not as yet been sufficiently well measured. Whilst the supplementary surveying of stream cross-sections and specific groups of manholes carried out for this report has contributed to improving the accuracy of the model, there remains a need for more comprehensive detailed survey if the model, as a tool for future planning, is to be used with greater confidence.

5.3.1 Flooding

Water depths and flows have been determined from the model for all of the model runs at key locations. These locations are displayed on Map A3 of the HMS report. Table 3 in the HMS report sets out water levels at these key locations for all model runs. An indicative Flood Hazard map for the 1%AEP event in the existing catchment has been developed based on the assessment of water levels for this case, and has been mapped as shown on Map A4 in the HMS report. We note that the indicative nature of this map is brought about by the coarseness of the existing contour information upon which the plotting of flood levels has had to be based.

This flood hazard map provides information that compares well with the LIR information provided by MCC, as shown on Map A9 in the HMS report. It also confirms that flooding will continue to occur in locations previously identified by landowners' complaints and consultation questionnaires, and by earlier studies. The model undertaken for this report also suggests that, in spite of pipe upgrades having been undertaken under the railway line, flooding upstream could still occur in this area.

The principal areas at risk continue to be:

- The length of the main stream between Hillside Road and Wyllie Road
- The area upstream of the railway line
- The area identified by Narada Avenue, and the northwest end of Ferndown Road
- The western side of the Kohuora Crater

5.3.2 Overland Flowpaths

Previous overland flowpath information provided by MCC has been reviewed and proved to be largely satisfactory. More detailed assessments of overland flowpaths in the existing catchment and the MPD catchment are presented on Maps A5 and A6 appended to the HMS report, which show the flow rates for the 1%AEP event. These are separated and displayed as flowpaths producing flows greater and less than 0.5 m^3/s.

5.3.3 Modelling the Upgrade Options

Section 3.2.1 of the HMS report provides the detail for this model run.

(a) Option 1 – Reticulation System Upgrade

The model was run to determine the extent of pipe upgrades required to convey the MCC standard reticulation flow rate for the 20%AEP storm event throughout the existing stormwater reticulation system. Runs were undertaken for both the existing land use in the catchment and the MPD land use situation. The upgrade details are presented on Maps A7 and A8, appended in the HMS report, and show pipe locations and upgrade diameter.

Table A4 appended to the HMS report shows the existing and required pipe diameters and other relevant detail for the MPD scenario for the catchment. Table 15 shows the same information, which has been expanded to include cost information for the upgrade of the pipes based on MCC standard rates, and has been sorted by priority category.

It should be noted that in running the model for this option, the significant restriction at the culvert at 36 Hillside Road was identified. This culvert displays a head loss of approximately 1.00 m during the 1% AEP event, which is significantly more than any other culvert in the system. Accordingly the model was run on the assumption that this particular restriction had been removed by an upgrade of this culvert to take the 1% AEP flow, and the overall upgrade result shows the situation with this in place.

The priorities allocated to the overall upgrade programme are:

- Priority 1: Replace the culvert at 36 Hillside Road with a culvert of 2100 mm dia or box section of equivalent capacity
- Priority 2: Complete the upgrade of the main valley drainage upstream of the railway line, between the railway line and St George Street, and also the main drainage at Narada Place
- Priority 3: All the rest

The cost of the overall system upgrade, for the MPD catchment and the 20% AEP storm event, as presented from the information shown in Table 15 is $6.61M approximately.

Table 15 : Pipe Upgrades to 20% AEP Capacity - Option 1

Pipe				Pipe Diameter (m)			Rate $/m	Cost	
Link ID	From Node	To Node	Length (m)	Existing	Upgrade to 20%AEP Capacity Existing Land-use	Upgrade to 20%AEP Capacity MPD Land-use	Based on MCC Standard Rates	$	
Priority 1 - 36 Hillside Road Culvert									
551852	Culvert6 inlet	Culvert6 Outlet	14	1.500	2.100	2.100	$3,010	$	41,839
						PR 1	**SUB-TOTAL**	**$**	**41,839**
Priority 2 - East of Railway Line									
325934	325934	325939	17	0.375	0.750	0.750	$1,190	$	20,761
325939	325939	345673	106	0.375	0.900	0.900	$1,390	$	147,458
345673	345673	352349	26	0.600	0.900	0.900	$1,390	$	35,651
345724	345724	345737	42	0.800	1.050	1.050	$1,570	$	65,755
345737	345737	345743	26	0.800	1.050	1.050	$1,570	$	40,679
345743	345743	345745	19	0.800	1.050	1.050	$1,570	$	30,002
345745	345745	352384	39	0.800	1.050	1.050	$1,570	$	61,903
345752	345752	345755	5	0.800	1.050	1.050	$1,570	$	8,059
345755	345755	352390	12	0.900	1.200	1.200	$1,770	$	21,791
345764	345764	345767	46	0.900	1.200	1.200	$1,770	$	80,601
345778	345778	352404	5	0.900	1.200	1.200	$1,770	$	9,236
345789	345789	352414	14	0.900	1.200	1.200	$1,770	$	24,603
345809	345809	345814	41	0.900	1.500	1.500	$2,110	$	85,758
345814	345814	345818	40	0.900	1.500	1.500	$2,110	$	85,413
345797	345797	352419	8	0.900	1.200	1.200	$1,770	$	14,462
345818	345818	345823	10	0.900	1.500	1.500	$2,110	$	21,399
345823	345823	345827	14	0.900	1.500	1.500	$2,110	$	29,233
345827	345827	345828	6	0.900	1.500	1.500	$2,110	$	12,531
345832	345832	345822	60	1.400	1.600	1.600	$2,320	$	140,282
345834	345834	345828	10	0.900	1.500	1.500	$2,110	$	21,099
345837	345837	345838	43	0.900	1.600	1.600	$2,320	$	100,667
345838	345838	345832	29	1.400	1.600	1.600	$2,320	$	66,558
352349	352349	345724	30	0.600	1.050	1.050	$1,570	$	47,285
352384	352384	345752	11	0.800	1.050	1.050	$1,570	$	17,980
352390	352390	352391	3	0.900	1.200	1.200	$1,770	$	4,891
352391	352391	345764	6	0.900	1.200	1.200	$1,770	$	10,375
352396	352396	345778	44	0.900	1.200	1.200	$1,770	$	77,922
352404	352404	352412	47	0.900	1.200	1.200	$1,770	$	83,195
352412	352412	345789	13	0.900	1.200	1.200	$1,770	$	22,441
352414	352414	345797	23	0.900	1.200	1.200	$1,770	$	40,427
352443	352443	345834	79	0.900	1.500	1.500	$2,110	$	167,211
							Sub-Total	**$**	**1,595,628**

Pipe				Pipe Diameter (m)			Rate $/m	Cost
Link ID	From Node	To Node	Length (m)	Existing	Upgrade to 20%AEP Capacity Existing Land-use	Upgrade to 20%AEP Capacity MPD Land-use	Based on MCC Standard Rates	$
Priority 2 - Narada Place								
295426	295426	295458	90	0.450	1.050	1.050	$1,570	$ 141,257
295458	295458	295467	45	0.675	1.050	1.050	$1,570	$ 70,755
295467	295467	295472	9	0.675	1.050	1.050	$1,570	$ 13,770
295472	295472	295497	96	0.675	1.050	1.050	$1,570	$ 150,077
295497	295497	295499	11	0.675	1.050	1.050	$1,570	$ 17,901
295499	295499	295511	24	0.675	1.050	1.050	$1,570	$ 38,434
295511	295511	295528	37	0.675	1.050	1.200	$1,770	$ 65,885
295528	295528	296057	59	0.750	1.050	1.200	$1,770	$ 104,081
295574	295574	295621	147	1.050	-	1.200	$1,770	$ 260,781
295621	295621	295645	63	1.050	-	1.200	$1,770	$ 111,328
296057	296057	295574	47	0.900	1.050	1.200	$1,770	$ 82,873
							Sub-Total	**$ 1,057,142**
						PR 2	**SUBTOTAL**	**$ 2,652,770**
Priority 3 - Remainder								
295410	295410	295424	55	0.375	0.600	0.600	$840	$ 46,200
295424	295424	296194	14	0.450	0.600	0.600	$840	$ 11,760
295432	295432	296196	13	0.225	0.450	0.600	$840	$ 11,314
295439	295439	295432	35	0.225	0.375	0.375	$600	$ 20,776
295487	295487	295492	28	0.225	0.300	0.300	$530	$ 15,008
295492	295492	295502	18	0.225	0.300	0.300	$530	$ 9,656
295494	295494	295511	32	0.525	0.750	0.750	$1,190	$ 38,165
295500	295500	295504	7	0.225	0.600	0.600	$840	$ 6,113
295502	295502	295541	70	0.225	0.375	0.375	$600	$ 42,032
295504	295504	295506	3	0.225	0.600	0.600	$840	$ 2,776
295506	295506	295533	98	0.300	0.600	0.600	$840	$ 82,001
295533	295533	345785	24	0.225	0.600	0.600	$840	$ 20,365
295538	295538	culv5-outlet	142	0.225	0.300	0.450	$680	$ 96,366
295541	295541	295551	11	0.225	0.450	0.450	$680	$ 7,604
295551	295551	295561	55	0.300	0.450	0.450	$680	$ 37,716
295561	295561	295583	46	0.375	0.450	0.450	$680	$ 31,363
295583	295583	295593	21	0.375	0.600	0.600	$840	$ 17,580
295593	295593	295602	30	0.450	0.600	0.600	$840	$ 25,335
295612	296237	culv5-outlet	16	0.375	0.600	0.600	$840	$ 13,274
296102	296102	296344	85	0.300	0.375	0.375	$600	$ 50,932
296139	296139	296138	11	0.400	-	0.600	$840	$ 8,847
296185	296185	295410	8	0.375	0.600	0.600	$840	$ 6,916
296237	296237	345785	125	0.375	0.600	0.600	$840	$ 105,202
296443	296443	Outlet1	32	0.600	0.750	0.750	$1,190	$ 38,163
296448	296448	296449	5	0.225	0.375	0.375	$600	$ 2,709

Pipe				Pipe Diameter (m)			Rate $/m	Cost
Link ID	From Node	To Node	Length (m)	Existing	Upgrade to 20%AEP Capacity Existing Land-use	Upgrade to 20%AEP Capacity MPD Land-use	Based on MCC Standard Rates	$
296449	296449	296461	62	0.225	0.375	0.375	$600	$ 37,330
296452	296452	296448	8	0.225	0.375	0.375	$600	$ 4,967
296530	296530	296553	47	0.225	0.375	0.375	$600	$ 28,024
296553	296553	296576	55	0.225	0.375	0.375	$600	$ 32,907
296583	296583	296592	24	0.150	0.450	0.450	$680	$ 16,529
296626	296626	296683	5	0.100	0.375	0.375	$600	$ 2,954
296637	296637	296624	39	0.100	0.375	0.450	$680	$ 26,333
296643	296643	296637	28	0.100	0.375	0.375	$600	$ 16,765
296711	296711	296707	4	0.375	0.600	0.600	$840	$ 3,487
325933	325933	325934	43	0.375	0.600	0.600	$840	$ 36,536
325936	325936	325934	43	0.225	0.450	0.450	$680	$ 29,307
325940	325940	325937	54	0.300	0.450	0.450	$680	$ 36,671
325945	325945	354185	99	0.225	0.450	0.450	$680	$ 66,990
326438	326438	326458	85	0.375	0.450	0.450	$680	$ 57,656
326458	326458	325933	92	0.375	0.450	0.450	$680	$ 62,896
327460	327460	354190	90	0.225	0.450	0.450	$680	$ 61,197
329053	329053	325940	67	0.225	0.375	0.375	$600	$ 40,464
332335	332335	332345	34	0.300	0.450	0.450	$680	$ 23,400
332345	332345	332349	21	0.375	0.450	0.450	$680	$ 14,586
332349	332349	296185	35	0.375	0.450	0.450	$680	$ 23,605
332354	332354	332362	19	0.300	0.450	0.450	$680	$ 12,882
332362	332362	295426	111	0.300	0.600	0.600	$840	$ 93,131
332705	332705	332704	10	0.300	0.450	0.450	$680	$ 6,584
332711	332711	332705	17	0.300	0.375	0.375	$600	$ 10,332
332720	332720	332711	50	0.300	0.375	0.450	$680	$ 34,280
332722	332722	332720	14	0.225	0.300	0.300	$530	$ 7,399
332762	332762	332720	67	0.225	0.375	0.450	$680	$ 45,757
332763	332764	332762	16	0.225	0.450	0.450	$680	$ 10,666
332765	332765	332762	62	0.225	0.375	0.375	$600	$ 36,915
332889	332889	XSECT19	22	0.450	0.600	0.600	$840	$ 18,559
332899	332899	332765	31	0.225	-	0.375	$600	$ 18,577
332970	332970	332971	10	0.150	0.300	0.300	$530	$ 5,054
332979	332979	332984	81	0.450	-	0.600	$840	$ 67,917
332981	332981	332982	11	0.375	0.450	0.450	$680	$ 7,699
332984	332984	332987	82	0.450	-	0.600	$840	$ 68,793
332986	332986	296139	37	0.450	-	0.600	$840	$ 31,111
332987	332987	332986	21	0.450	-	0.600	$840	$ 17,328
332988	332988	332977	16	0.225	0.375	0.375	$600	$ 9,539
345655	345655	352323	37	0.225	0.300	0.300	$530	$ 19,605
345658	345658	352334	45	0.225	0.375	0.375	$600	$ 26,734

Pipe				Pipe Diameter (m)			Rate $/m	Cost
Link ID	From Node	To Node	Length (m)	Existing	Upgrade to 20%AEP Capacity Existing Land-use	Upgrade to 20%AEP Capacity MPD Land-use	Based on MCC Standard Rates	$
345663	345663	345700	38	0.450	0.750	0.750	$1,190	$ 45,713
345665	345665	352334	1	0.225	0.300	0.300	$530	$ 693
345667	345667	345665	29	0.225	0.300	0.300	$530	$ 15,614
345670	345670	345697	31	0.225	0.375	0.375	$600	$ 18,586
345672	345672	352349	45	0.300	0.450	0.450	$680	$ 30,538
345694	345694	345755	109	0.300	0.450	0.450	$680	$ 74,372
345697	345697	345694	8	0.225	0.450	0.450	$680	$ 5,201
345700	345700	345740	51	0.450	0.750	0.750	$1,190	$ 60,528
345710	345710	345658	51	0.225	0.300	0.300	$530	$ 27,293
345723	345723	345724	10	0.225	0.450	0.450	$680	$ 6,639
345735	345735	345736	2	0.300	0.600	0.600	$840	$ 1,672
345740	345740	345750	35	0.450	0.750	0.750	$1,190	$ 41,570
345748	345748	345743	26	0.225	0.375	0.450	$680	$ 17,571
345750	345750	345787	92	0.450	0.750	0.750	$1,190	$ 109,061
345753	345753	345765	32	0.300	0.600	0.600	$840	$ 27,154
345754	345754	345748	17	0.225	0.300	0.300	$530	$ 8,832
345765	345765	345772	28	0.300	0.600	0.600	$840	$ 23,746
345767	345767	352396	3	0.900	1.200	1.200	$1,770	$ 4,676
345770	345770	345755	44	0.375	0.750	0.750	$1,190	$ 52,742
345772	345772	345788	74	0.375	0.600	0.600	$840	$ 62,107
345780	345780	345770	35	0.375	0.750	0.750	$1,190	$ 41,956
345787	345787	345806	42	0.525	0.750	0.750	$1,190	$ 49,710
345788	345788	352411	5	0.375	0.750	0.750	$1,190	$ 5,969
345790	345790	345796	6	0.225	-	0.300	$530	$ 2,941
345806	345806	345817	41	0.525	0.750	0.750	$1,190	$ 48,973
345817	345817	345827	20	0.525	0.750	0.750	$1,190	$ 24,225
345819	345819	XSECT15	29	0.225	-	0.375	$600	$ 17,466
345843	345843	345837	23	0.450	0.600	0.600	$840	$ 19,517
345844	345844	352445	14	0.450	0.600	0.600	$840	$ 11,777
345863	345863	345844	70	0.450	0.600	0.600	$840	$ 59,067
345889	345889	345871	29	0.225	0.450	0.450	$680	$ 19,843
345891	345891	345902	61	0.400	-	0.600	$840	$ 51,058
345902	345902	345904	6	0.525	-	0.600	$840	$ 4,958
345904	345904	345875	50	0.525	-	0.600	$840	$ 42,369
345914	345914	345889	76	0.225	0.450	0.450	$680	$ 51,576
345920	345920	354408	2	0.300	0.600	0.600	$840	$ 1,580
345923	345923	345902	52	0.300	0.375	0.375	$600	$ 30,942
345934	345934	345920	51	0.225	0.600	0.600	$840	$ 43,148
345952	345952	345934	55	0.225	0.450	0.600	$840	$ 46,293
345965	345965	532644	15	0.300	0.450	0.450	$680	$ 10,479

Pipe				Pipe Diameter (m)			Rate $/m	Cost
Link ID	From Node	To Node	Length (m)	Existing	Upgrade to 20%AEP Capacity Existing Land-use	Upgrade to 20%AEP Capacity MPD Land-use	Based on MCC Standard Rates	$
345971	345971	345952	55	0.225	0.450	0.450	$680	$ 37,280
345988	345988	345971	84	0.225	0.375	0.375	$600	$ 50,472
345996	345996	345994	33	0.225	0.300	0.300	$530	$ 17,401
346209	346209	346221	52	0.225	0.450	0.450	$680	$ 35,694
346221	346221	345753	55	0.225	0.450	0.450	$680	$ 37,435
352179	352179	352180	30	0.300	0.600	0.600	$840	$ 24,977
352180	352180	352182	46	0.300	0.600	0.600	$840	$ 38,344
352182	352182	352183	16	0.300	0.600	0.600	$840	$ 13,832
352183	352183	345663	54	0.450	0.600	0.600	$840	$ 44,987
352334	352334	352335	3	0.225	0.450	0.450	$680	$ 2,317
352335	352335	345663	6	0.225	0.450	0.450	$680	$ 4,014
352411	352411	345780	19	0.375	0.750	0.750	$1,190	$ 22,847
352445	352445	352429	77	0.450	0.600	0.600	$840	$ 64,834
353735	353735	352179	2	0.225	0.600	0.600	$840	$ 1,729
354185	354185	354190	35	0.300	0.450	0.450	$680	$ 23,753
354190	354190	353735	37	0.300	0.600	0.600	$840	$ 31,449
354408	354408	551660	97	0.300	0.600	0.600	$840	$ 81,069
523232	523232	345914	10	0.225	0.450	0.450	$680	$ 6,482
550307	550307	332335	24	0.300	-	0.450	$680	$ 16,145
551660	551660	345863	17	0.300	0.600	0.600	$840	$ 13,980
295533	295533	295538	11	0.150	0.375	0.375	$600	$ 6,799
296194	296194	296196	2	0.300	0.600	0.600	$840	$ 1,902
296196	296196	295426	2	0.225	0.600	0.600	$840	$ 1,707
296344	296344	296082	1	0.225	-	0.375	$600	$ 449
332357	332358	550307	57	0.225	0.300	0.300	$530	$ 30,103
333798	333798	332950	52	0.200	0.450	0.450	$680	$ 35,655
352323	352323	345672	27	0.225	0.375	0.375	$600	$ 16,156
352419	352419	345809	20	0.900	1.500	1.500	$2,110	$ 41,391
352443	352443	345837	28	0.900	1.500	1.500	$2,110	$ 59,648
532644	532644	345938	77	0.300	0.450	0.450	$680	$ 52,539
						PR 3	**SUB-TOTAL**	**$ 3,953,177**
						GRAND	**TOTAL**	**$ 6,605,947**

The prices are based on rates provided by MCC on 15 February 2006.

This has been allocated into the three priorities set out above, as follows:

Priority 1	Upgrade the culvert at 36 Hillside Road, to improve the hydraulics of the main pipeline and reduce current flooding risk on all properties upstream, particularly those immediately upstream.	$42,000
Priority 2	Upgrade the main pipeline to reduce the flooding risk on all properties upstream of the railway line, and in the Narada Place/Claude Avenue area.	$2.66M
Priority 3	All the remainder of the system	$3.95M

Map 11 in Appendix F shows the distribution of upgrade priority in the system.

(b) Option 2 – Utilising the Kohuora Crater

Section 3.2.2 of the HMS report provides the detail for these model runs. The overall conclusion from these runs is that none of the crater sub-options have a significant beneficial effect on water levels and flows in the main stream, and tend to worsen the situation in the crater itself, as described below.

(i) Option 2(a): Restrict the Crater Outlet

The result of restricting the existing outlet to 600 mm dia leads to an increase in peak water level in the crater. The backflow that occurs from the main stream into the crater during large storm events was also reduced. Consequently, higher peak water levels occurred also in the main stream. This option therefore, worsens the existing situation.

(ii) Option 2(b): 1800 mm dia Inflow and 600 mm Outflow from the Crater

This option was aimed at testing the effect of allowing higher flows into the crater than out, by adding a 600 mm culvert outlet alongside the existing 1800 mm dia outlet. Backflow gates would be installed at the appropriate ends of each pipe to allow inflow only in the larger pipe, and outflow only in the smaller pipe.

The model shows that the main stream peaks, slightly before the crater, and water levels in the main stream are reduced, but by a negligible amount (3 mm). Hence this option makes an almost indiscernible improvement to the existing situation.

(iii) Option 2(c): Separate the Crater into Two Storage Ponds

This option tested a situation where the crater is divided into two storage areas – one to store and slowly release water from the crater catchments, and the second to store backflow from the main stream. This would be achieved by utilising the existing embankment that already separates the area to the south, currently used as a baseball field, from the rest of the crater. Flow control would be achieved by extending the existing 1800 mm culvert upstream beyond the embankment, and installing a 600 mm culvert to drain the baseball field.

This results in an increase of 0.2 m in water level in the main crater, and a reduction in flows and water levels in the main stream. Whilst the attenuation of flow in the main stream is greater than Options 2a and 2b, it is still too small to significantly reduce water levels in the main stream.

(c) <u>Option 3 – Pipe Upgrades Upstream of the Railway Line and Hillside and Wyllie Road Culverts</u>

The upper reach of the main stream upstream of the railway line is fully piped, and is under capacity. Overland flow occurs along the valley floor, mostly through private property. There is a flood risk in the 1%AEP event, as indicated by the Flood Hazard Map (Map A4 in the HMS report, Volume 2, Appendix 1).

The alternatives available for solving this problem would be:

- take these properties out of private ownership;
- take these properties out of private ownership, and by so doing provide an opportunity to construct a detention dam in the valley with the aim of reducing water levels and flows downstream;.
- build a duplicate line down the valley floor which, when combined with the existing system, would provide capacity to carry the 1% AEP storm event flows, and eliminate overland flow.

The first two of these alternatives require private property purchase. There are some 50-odd properties within the modelled 1%AEP Floodplain (refer Map A4 in the HMS report). Valuations of properties in the area have been provided by MCC Property Department, and indicate an approximate value of properties above the Railway Line at about $380,000 each (based on the figure for 56/57 Wallace Road – refer Appendix E). This yields a figure of $19M for removing entirely the threat of flooding by property purchase. Both of the first two alternatives are clearly unrealistic when compared to the pipe upgrade options, especially given the potential difficulties and expense of obtaining agreement to sell from property owners.

The model was run to test the third alternative. A length of line of approximately 1000 m, from the end of Mahon Place to the Kenderdine Road culvert was modelled, with the diameters ranging from 900 mm to 1600 mm. Aside from the difficulties of constructing such a line through private property and passing it under the railway line, there is an increase in peak flows and water levels downstream requiring the replacement and upgrading of both the culverts at Wyllie Road and Hillside Road, (not necessary under Option 1) as well as at 36 Hillside Road. The total cost of this alternative is estimated to cost an additional $2M above the cost of the Option 1 upgrade through this area, (ie $3.6M all up) based on an average of about $1800/m for the duplicate pipeline and $45,000 each for the culvert upgrades.

5.3.4 Other Property Purchase Possibilities

As mentioned above, the hydraulic analysis of the Kohuora Crater reveals that there is little that can be done to improve the hydraulics of the crater and thereby avoid flooding of vulnerable properties around its rim. Reference to Map 9 appended to this report shows that the properties at greatest risk of flooding are those off Malaspina Place on the west side of the Kohuora Crater. Numbers 9 and 11 Malaspina Place are particularly vulnerable. There may be merit in Council purchasing these and incorporating them into the Crater Reserve. MCC Property Department have provided estimated valuations for all of the properties in Malaspina Place and Lendenfeld Drive which have been affected by flooding in the past (refer Appendix E). These range from $240,000 to $300,000.

The cost to Council of acquiring the four worst-hit properties 7-13 Malaspina Place, and possibly 24-26 Lendenfeld Drive would be of the order of $1.7M, but would immediately relieve Council of any need to carry out further work in the Crater. It would not avoid, however, the necessity of allocating capital to upgrade the rest of the stormwater reticulation system in the catchment.

The merits of purchasing property in the Narada Place, Claude Avenue area were considered in order to eliminate the negative effects of the modelled floodplain for the 1% AEP storm event in this area, but was not considered cost-effective for reasons similar to those given for the area east of the railway line.

The other significant location which has historically been vulnerable to flood nuisance and the source of complaint is the vicinity of 74 Hillside Road, immediately upstream of the Hillside Road culvert. Although the culvert itself is apparently adequate, the low-lying nature and proximity of dwelling to the stream have caused problems of inundation in the past. Purchase of this property to relieve this situation would cost about $400,000.

6.0 ECOLOGICAL ASSESSMENT

This section summarises key information contained in the Kingett Mitchell Ltd (KML) Ecological Report: "Aquatic Ecology and Management Objectives for the Kenderdine Catchment" (August 2005), which was prepared as part of this Study (refer Volume 2, Appendix 2).

6.1 GENERAL

As described previously, there are two principal waterways within the Kenderdine Catchment - the main open stream that runs west along the main valley from Kenderdine Road under the southwestern motorway and into the Waokauri Creek, and the waterway that runs along the western and southern boundaries of the Kohuora Crater, before being piped into the main open stream at 86R Hillside Road.

These waterways typically flow between urban properties on private land with few stream sections open to the general public. Exceptions include the waterway in the Kohuora Crater, which is a public reserve with a walkway, an area downstream of Hillside Road and a public reserve in the lower catchment.

The Kenderdine Catchment has been classified into nine distinct stream sections, based on instream and riparian habitat information gathered during field work for this study, involving assessments at 33 sites, with more detailed habitat assessments based on modified ARC habitat assessment methods being undertaken at a further six sites. These sections form the basis of this ecological assessment. Map 2.1 in the KML report shows the sampling locations and identified stream sections, while Map 9.1 summarises the ecological values assigned to different sections of the catchment.

6.2 INSTREAM AND RIPARIAN HABITAT

The Kenderdine Catchment waterways are typical of Auckland urban stream catchments, being characterised by small catchments less than 4 km in length, with narrow channels (<3 m wide) and the presence of fine sand/clay/silt sediments, abundant macrophytes, pool and run flow regimes.

Instream and riparian habitat characteristics are diverse. Habitat conditions ranged from modified wooden reinforced concrete channels (Section 1), well-shaded meandering sections (Section 2), peaty drains (Section 4), piped sections (Section 5), poorly shaded macrophyte choked channelised sections (Sections 7 and 8) and hydrologically diverse sections with good instream habitat (Section 9). No waterways within the catchment were in their natural state and thus natural heritage values were poor.

The instream habitats ranged from poor to moderate ecological quality, typical of Auckland urban catchments that have had varying degrees of channel modification including streambank reinforcement, channel straightening, and piping.

The sections of poorest ecological value included Sections 5, 4 and 7.

- Section 5 is piped and has poor ecological value but plays an important role in the conveyance of flood flows and fish passage.
- Section 4 comprised heavily modified, drained peaty/wetland areas and was open to the public. It had poor riparian shade, no flow at the time of the survey, poor water clarity and a lack of macrophytes, possibly as a result of leaching from the peaty substrate.
- Section 7 was a macrophyte choked, open channelised section with poor riparian vegetation dominated by grass and willow saplings. The emergent/submerged macrophytes in this section provided poor habitat and are likely to significantly affect dissolved oxygen concentrations and impact aquatic life.

Areas considered to have poor-moderate ecological value included Sections 1, 3, 6 and 8.

- Section 1 has been straightened and modified through reinforced streambanks, which lowers base flow conditions and flow, increases the development of debris dams, reduces habitat area, and results in higher water temperatures and lower dissolved oxygen concentrations. These impacts are likely to limit some fish species and stress macroinvertebrate communities. However, this section also had stable coarse substrates which improved habitat diversity.
- Sections 3, 6 and 8 were impacted by urbanization through an increase in fine sediment deposition, inorganic litter, riparian removal and increased macrophyte abundance. These reaches have potential for stream enhancement.

Sections considered to have moderate ecological value included the lowermost Section 9 and Section 2.

- Section 9 was considered to have some of the better habitat conditions within the entire catchment, with good instream and riparian habitat conditions and a clear pathway for fish migration into the upper catchment. This is an important ecological feature of this catchment, as this waterway has not degenerated into a typical lower catchment urban streams smothered with fine sediment, choked with macrophytes, with poor riparian vegetation and limited aquatic flora and fauna.
- Section 2 in the mid-upper catchment also had moderate ecological values and was characterised by a meandering incised channel, moderate hydraulic diversity, moderate riparian cover, low macrophyte cover and undercut streambanks, which provided natural fish habitats and good instream conditions for macroinvertebrates.

Refer to the KML Ecological Report, Section 4 for further details.

6.3 RIPARIAN AND AQUATIC VEGETATION

Riparian vegetation and macrophyte communities of the Kenderdine Catchment were comparable to those found in urban catchments elsewhere in the Auckland region. All plant species encountered are relatively common and no rare species or species of conservation interest were found.

The riparian vegetation in the catchment has been modified through the urbanization process. Canopy and sub-canopy vegetation generally consisted of, but was not limited to *Ligustrum sinense* (Chinese privet), *Salix fragilis* (crack willow), *Xeronema callistemon* (ponga), *Melicytus ramiflorus* (mahoe), *Cordyline sp.* (cabbage trees), *Solanum mauritianum* (woolly nightshade), *Cupressus macrocarpa* (macrocarpa), *Pittosporum crassifolium* (karo), *Populus sp.* (poplar), Chinese privet and *Coprosma robusta* (coprosma). Groundcover species recorded through the catchment included *Tradescantia fluminensis* (wandering jew), *Canna sp.* (canna lily), *Zantedeschia aethiopica* (arum lily), *Tropaeolum majus* (garden nasturtium), *Calystegia silvatica* (bindweed), *Lotus pedunculatus* (lotus) and pasture grass species.

Mid-catchment sections (open, unshaded) featured dense growths of *Persicaria hydropiper* (willow weed) and *Egeria densa* (an oxygen weed), often completely choking the stream channel.

The streambanks were rarely exposed, meaning erosion and bank stability did not appear to be a major issue in the catchment. Some of the riparian plants (eg wandering jew, woolly nightshade, *Egeria densa*) are listed as pest plants by ARC.

Refer to the KML Ecological Report, Section 5 for further details.

6.4 WATER AND SEDIMENT QUALITY

Water and sediment quality sampling was undertaken on 4 March 2005 during low flow conditions (no rain for at least one week prior to sampling). This comprised taking instream measurements of water temperature, conductivity and dissolved oxygen (DO) in Section 1 (Site 1), 2 (Site 7), 3 (Site 10), 4 (Site 16), 8 (Site 29) and 9 (Site 38), and collecting water and sediment samples from Sites 1, 10 and 38. Water samples were analysed for 5-day carbonaceous biochemical oxygen demand, suspended solids, nutrients (ammoniacal nitrogen, nitrate-N, nitrite-N and dissolved reactive phosphorus (DRP) and heavy metals (arsenic, cadmium, chromium, copper, nickel, lead and zinc). Sediment samples were analysed for copper, lead, and zinc. The water and sediment sampling results are summarised below. Refer the Ecological Report, Section 6, for further details.

DO saturation at the six sites measured was 15-77%, all below the RMA minimum standard of 80% saturation required to support aquatic life, while five of these sites recorded DO concentrations below the 5 mg/L minimum level for the protection of native fish species. Low DO may therefore restrict some sensitive macroinvertebrate species such as mayfly, stonefly and caddisfly and some fish.

Nutrient levels (Nitrate+nitrite-N, DRP) concentrations were typically high, exceeding the ANZECC (2000) guidelines at the three sites sampled, which together with poor riparian cover, explains the growth of aquatic macrophytes to nuisance levels throughout the catchment, potentially impacting other aquatic life. Excessive algal growth is another potential problem.

Copper, lead and zinc were recorded in the surface water at concentrations above laboratory detection levels at all three sampling sites. Copper and lead concentrations were within USEPA guidelines but zinc concentrations exceeded the USEPA CMC and CCC guidelines[8] at one site (Site 1). Similarly, copper and lead concentrations in the sediment samples collected at the same sites were within acceptable ANZECC guidelines, while zinc levels exceeded the guidelines at Sites 1 and 10. Copper, lead and zinc are the most common heavy metals in New Zealand streams. Zinc is considered to be one of the more problematic heavy metals in streams and is derived from a combination of road runoff and poorly maintained galvanized iron roofs and fences.

Overall, the water and sediment quality results indicate that the health and abundance of aquatic life in the catchment could be potentially affected, due to contamination from untreated urban stormwater runoff. However, the results are similar to that of waterways in Waitakere City urban catchments.

Refer to the KML report, Section 6 for further details.

6.5 MACROINVERTEBRATES

A macroinvertebrate survey was undertaken in May 2005 of six sites within Sections 1-5 and 8-9 in the Kenderdine Catchment using standard procedures. The survey found that macroinvertebrate communities recorded from waterways are considered to be of poor-moderate quality, but typical of those recorded from urban streams. Key survey results are summarised below (refer the Ecological Report, Section 7, for further details).

A total of 14 macroinvertebrate taxa were recorded, the number of taxa recorded per site ranging between 5-9 taxa/3m^2 with a mean of 7.0 ($\pm$0.6) taxa/3 m^2, slightly lower than those recorded from other streams in the Auckland area (ie means of 13, 10 and 10 from Waitakere, North Shore and Auckland area streams).

The communities throughout the catchment were dominated by mollusc snails (*Gyraulus, Physa, Potamopyrgus* and *Latia*) and crustaceans

[8] CMC = criteria maximum concentration – this is an estimate of the highest concentration of a material in the surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect; CRC = criteria continuous concentration – this is an estimate of the highest concentration of material in the surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.

(amphipods *and Paratya* shrimp), with taxa recorded in lower numbers including the damselfly *Xanthocnemis,* Orthocladiinae chironomids, *Paroxyethira* caddisflies (typically associated with nutrient enriched waters), oligochaetes, leeches and flatworms. Abundance was significantly greater at downstream sites as a result of large numbers of *Potamopyrgus* snails and *Paracalliope* amphipods, both of which are widespread and typically abundant in weedy urban streams. The waterway in Section 4 draining the Kohuora Crater contained taxa typically associated with heavily degraded water and habitat quality, including flatworms, leeches, oligochaetes, *Chironomus* chironomids and *Physa* snails. There were no macroinvertebrate taxa recorded in the Kenderdine Catchment of conservation significance, while sensitive mayfly, stonefly, and caddisfly taxa were absent. Thus, the macroinvertebrate communities within the catchment are dominated by pollution-tolerant species that are typical of Auckland urban streams.

The biological indices (MCI and QMCI) indicated that the water and habitat quality was of poor-moderate quality, comparable with those recorded for other Auckland urban catchments. MCI values ranged from 43 in the northern catchment to 89 in the lower catchment, with a mean overall catchment score of 69. Section 4 had the lowest values of these indices, while Sections 1-3 had similar, slightly higher values and Sections 8 and 9 had the highest values, indicating improved instream conditions at downstream sites. However, it must be noted that these indices typically understate ecological health in soft-bottomed streams.

Channel shade was positively correlated with invertebrate abundance, water temperature and negatively correlated with DO concentration. It was also positively correlated with MCI and QMCI values but this was not statistically significant. This confirms the value of stream shade and its influence on stream temperature and DO concentrations on aquatic ecosystems. Temperatures recorded in the main tributary (18.4-19.3°C) were within the ranges of more robust macroinvertebrate species.

Refer to the KML report, Section 7 for further details.

6.6 FISH

Information on fish distributions within the Kenderdine Catchment was collected from five selected sites using standard techniques in March 2005 and through a review of the New Zealand Freshwater Fish Database. An assessment of potential artificial and natural barriers to fish passage within the catchment was also made. Key results are summarised here (refer the Ecological Report, Section 8 for further details).

Fish diversity was low in the waterways of the Kenderdine Catchment with four fish species recorded. Indigenous fish included large numbers of shortfin eel and inanga (whitebait species) throughout most of the catchment and a single redfin bully in the lower catchment. Adult inanga were common throughout the majority of the catchment (excluding Section 4) in areas that were not choked with emergent macrophytes. No inanga spawning sites were identified in the catchment above the southwestern motorway. Shortfin eels were also present throughout the catchment, with large numbers aggregating below the piped section in the upper eastern catchment. The only introduced fish recorded were mosquito fish, which were very abundant in Section 4 and are considered an unwanted organism by the Department of Conservation. Existing fish data indicates that fish diversity in adjacent catchments is also relatively low. No fish species of conservation significant were recorded.

Water temperature may be a limiting factor in the distribution of fish in the Kenderdine Catchment. The water temperature recorded in Section 4 (25°C) is likely to restrict fish species including inanga, common bully, and banded kokopu. The range of water temperature recorded in sections of the main tributary (18.4-19.4°C) was typically within these limits.

Map 8.1 in the KML report shows the locations of culverts and potential barriers to fish passage. Fish passage did not appear to be an issue within the Kenderdine Catchment, as indigenous fish species, including inanga, which are not renowned for their climbing ability and are diadromous, were recorded throughout the catchment. The artificial structures and natural features were only considered "potential" barriers, with the biggest issue being the excessive growth of emergent macrophytes (willow weed) that completely choked the stream channel in areas with poor riparian vegetation. Hence, factors other than barriers to migration are most likely responsible for the low number of fish species recorded in the catchment.

Overall, the fish community is considered typical of open lower gradient streams. The catchment is considered to have high ecological value as adult inanga fish habitat and supporting Auckland's urban fish stocks and ensuring continuity between stocks north and south of the city.

Refer to the KML report, Section 8 for further details.

6.7 ARC URBAN STREAM CLASSIFICATION

The urban waterways within the Kenderdine Catchment were classified using the criteria outlined in ARC TP232 (2004). The majority of the stream sections were classified as being Type 4 (Highly disturbed natural channels, with greater than 25% of the catchment area being in impervious cover). Exceptions were the upper wooden lined Section 1 (Type 5 = modified channel, >50% artificial lining) and Section 5 (Type 6 = modified channel, >50% piped). The extent of the survey did not cover Type 1 (stream mouth) habitats.

Refer to the KML report, Section 9.5 for further details.

6.8 ECOLOGICAL MANAGEMENT OBJECTIVES AND RECOMMENDATIONS

Ecological management objectives and recommendations set out in the KML report are based on the objectives and policies of the ARC Proposed Air, Land and Water Plan (October 2004) and TP232. Specific recommendations are:

1. Maximise opportunities for habitat restoration, increased habitat diversity and naturalisation of stream channels. This includes the potential removal of the wood lined streambanks in Section 1, the prevention of further channelisation and straightening of the stream channel in Section 9 and consideration of soft engineering options as opposed to concrete/wood for Sections 2, 3, 4, 6, 8, and 9.

2. Minimise barriers to fish and invertebrate passage by following ARC culvert design guidelines when renewing or installing new culverts. This is relevant throughout the entire Kenderdine Catchment as inanga, which are not particularly strong swimmers or climbers are found throughout the catchment.

3. Manage the emergent aquatic macrophyte *Persicaria hydropiper* (willow weed) within Sections 1, 3, 7, and 8. This may be in the form of mechanical removal and long term management through active restoration of shading riparian vegetation in accordance with ARC TP148 (2001). It is not recommended that the submerged macrophyte *Egeria densa* be mechanically removed from waterways, as the stems are brittle, fragmenting and rooting easily, meaning small plant fragments floating downstream may propagate to presently uninfested areas.

4. Establish (Sections 3, 4, 6, 7, and 8) and maintain (Sections 1, 2, and 9) riparian vegetation, preferably with native trees in accordance with ARC TP148 (2001). Some of the direct benefits that an intact, well vegetated riparian zone will have on waterways within the Kenderdine Catchment will include:

    - Water quality improvements including filtration of sediments and removal of nutrients.
    - Reduction in stream temperatures through shading to maintain conditions capable of sustaining aquatic life.
    - Stabilising streambanks and reducing accelerated erosion and sedimentation.
    - Interception of rain that inhibits surface runoff, reducing erosion and sedimentation of aquatic ecosystems.
    - Increases instream habitat values through the addition of large woody debris and leaf litter.

5. Remove "large" debris dams in Sections 1 and 2, however trying to minimise streambed disturbance and the removal of detritus and "small" debris jams, as they provide important habitat and food for macroinvertebrates and fish.

6. Minimise further drainage and lowering of the water table, specifically in the upper catchment (vicinity of catchment 1) as lower baseflows

reduce the amount of water and habitat in the channel, increase temperatures, decrease DO concentrations and concentrate contaminants, all of which affect aquatic life.

7. Minimise the increase in impervious area where possible. This is most relevant to Section 4 in the Kohuora Crater and the lower catchment Sections 4 and 9, which have undeveloped land adjacent to the stream.

8. Erosion control of streambanks in Section 4 through riparian restoration using native plants.

7.0 CONSULTATION

No consultation other than that described in Section 3.1.5 of this report has been undertaken for this CCMP. The consultation process and outcomes is expected to be undertaken by MCC, will be reported on in due course.

8.0 MANAGEMENT STRATEGIES AND RECOMMENDED OPTIONS

8.1 ECOLOGICAL MANAGEMENT STRATEGIES AND RECOMMENDATIONS

The following are derived from the KML Ecological Report in Volume 2 to which reference should be made:

1. Maximise opportunities for habitat restoration, increased habitat diversity and naturalisation of stream channels. This includes the potential removal of the wood lined streambanks in Section 1, the prevention of further channelisation and straightening of the stream channel in Section 9 and consideration of soft engineering options as opposed to concrete/wood for Sections 2, 3, 4, 6, 8, and 9.

2. Minimise barriers to fish and invertebrate passage by following ARC culvert design guidelines when renewing or installing new culverts. This is relevant throughout the entire Kenderdine Catchment as inanga, which are not particularly strong swimmers or climbers are found throughout the catchment.

3. Manage the emergent aquatic macrophyte *Persicaria hydropiper* (willow weed) within Sections 1, 3, 7, and 8. This may be in the form of mechanical removal and long-term management through active restoration of shading riparian vegetation in accordance with ARC TP148 (2001). It is not recommended that the submerged macrophyte *Egeria densa* be mechanically removed from waterways, as the stems are brittle, fragmenting and rooting easily, meaning small plant fragments floating downstream may propagate to presently uninfested areas.

4. Establish (Sections 3, 4, 6, 7, and 8) and maintain (Sections 1, 2, and 9) riparian vegetation, preferably with native trees in accordance with ARC TP148 (2001). Some of the direct benefits that an intact, well vegetated riparian zone will have on waterways within the Kenderdine Catchment will include:

    (a) Water quality improvements including filtration of sediments and removal of nutrients.
    (b) Reduction in stream temperatures through shading to maintain conditions capable of sustaining aquatic life.
    (c) Stabilising streambanks and reducing accelerated erosion and sedimentation.
    (d) Interception of rain that inhibits surface runoff, reducing erosion and sedimentation of aquatic ecosystems.
    (e) Increases instream habitat values through the addition of large woody debris and leaf litter.

5. Remove "large" debris dams in Sections 1 and 2, however trying to minimise streambed disturbance and the removal of detritus and "small" debris jams, as they provide important habitat and food for macroinvertebrates and fish.

6. Minimise further drainage and lowering of the water table, specifically in the upper catchment (vicinity of catchment 1) as lower baseflows reduce the amount of water and habitat in the channel, increase temperatures, decrease DO concentrations and concentrate contaminants, all of which affect aquatic life.

7. Minimise the increase in impervious area where possible. This is most relevant to Section 4 in the Kohuora Crater and the lower catchment Sections 4 and 9, which have undeveloped land adjacent to the stream.

8. Erosion control of streambanks in Section 4 through riparian restoration using native plants.

8.2 HYDRAULIC AND HYDROLOGICAL STRATEGIES AND RECOMMENDED UPGRADE OPTIONS

The following is derived from the HMS Hydraulic Modelling report in Appendix 1, to which reference should be made, and to the discussion of options in Section 5.3 above:

Given the level of accuracy discussed in Section 1.3 of the HMS report, it is strongly recommended that sufficient field surveys be undertaken to support the design of any capital works in the catchment, and to confirm the results of the modelling. In particular, there would be merit in allocating funding to undertake more comprehensive and accurate survey of the Kohuora Crater in order to more closely determine the available storage in the crater, and improve the ability to assess the effects of modifications to the Crater outlet conditions. Given the current state of crater data in the model, undertaking works to better utilise the storage available in the crater does not appear worthwhile. Even if such data were obtained and more effective use of the storage in the crater were able to be demonstrated, it is likely that the vulnerability of properties on the west side of the crater, particularly those in Malaspina Place, would not necessarily be reduced, and Council may wish to purchase these properties to avoid the potential flooding risk.

Without taking action of any kind it is likely that flooding of private property will continue to occur in the following locations during larger storm events:

- The valley floor upstream of the railway line
- Adjacent to the main stream between Wyllie Road and Hillside Road
- Low-lying properties on Malaspina Place adjacent to the crater floor
- Daphne Road adjacent to the main stream
- Claude Avenue, Narada Place

Upgrading the pipe network to provide capacity for the 20%AEP event will reduce but not eliminate flooding in the valley floor upstream of the railway line, and in the Claude Avenue and Narada Place during larger events. Upgrading these pipes will, however, increase peak water levels in the crater and main stream.

The effect of this is particularly pronounced at the 36 Hillside Road culvert. Upgrading this culvert to 2.1 m diameter, which is sufficient to pass the 1%AEP event without creating a significant head loss, was included in the pipe network upgrade model, and is proposed as the Priority 1 activity in the overall pipe upgrade process.

It is known that the water level in the main stream peaks before the water level in the crater and backflow into the crater occurs. This is confirmed by the modelling. This effect helps to attenuate peak flows and water levels in the main stream downstream of the crater outlet. However, the various options tested to better utilise storage in the crater have a minimal effect on the water levels in the main stream. The effect is insufficient to offset the increase in water levels in the main stream during the 1%AEP event, which result from upgrading the pipe reticulation to the 20%AEP event capacity.

The only exception to this is upstream of the 36 Hillside Road culvert where all modelled mitigation options result in a drop in water level, as these options include upgrading this culvert.

Upgrading the pipe network in the valley floor upstream of the railway line to cater for the 1%AEP event (Priority 2) will result in an increase in water level downstream in the main stream, necessitating the upgrade of the culverts at 36 Hillside Road and Wyllie Road. Even with the upgrade to the Wyllie Road culvert the water level upstream of the culvert will increase.

Hence, the recommended sequence for pipe upgrades in the catchment as a whole, together with their associated estimated costs, is:

Priority 1	Upgrade the culvert at 36 Hillside Road, to improve the hydraulics of the main pipeline and reduce current flooding risk on all properties upstream, particularly those immediately upstream, (32 and 32A Hillside Road, amongst others)	$42,000
Priority 2	Upgrade the main pipeline to reduce the flooding risk on all properties upstream of the Railway Line, and in the Narada Place/Claude Avenue area.	$2.66M
Priority 3	All the remainder of the system	$3.95M

With the upgrades in place, there may still be merit in Council undertaking purchase of the most vulnerable properties to alleviate further potential risk of flooding and complaint from landowners. This could only take place after a willingness to sell is expressed by the landowners and a negotiation is successfully completed. At this stage, the recommended properties for purchase are:

No.74 Hillside Road, (current estimated and indicative market value: $400,000).

Nos. 9 and 11 Malaspina Place (current estimated and indicative market value of $580,000 for both)

It is recommended that survey manhole invert and lid levels and cross-section information be captured into MCC's GIS for future use.

8.3 STORMWATER TREATMENT OPTIONS

Under normal circumstances, the selection of treatment options and methods within a catchment requires detailed examination of sub-catchment configurations, identification of sites for installation of devices, and design of appropriate devices suitable for the sub-catchment areas being served. The range of options likely to be suitable would include devices and facilities such as:

- Detention ponds or engineered wetlands
- Vegetated swales in suitable locations
- On-line litter removing devices
- Cesspit bags, litter traps and other devices for road runoff treatment
- Riparian plantings adjacent to open watercourses

However, in the Kenderdine Catchment, with the exception of the Kohuora Crater, options for installation of stormwater quality devices capable of dealing with large segments of the catchment are limited, if non-existent, without the purchase of extensive areas of private land.

In the absence of currently identified sites, that are both located appropriately at the bottom of the catchment and are large enough to treat stormwater runoff comprehensively from large areas of the catchment, retro-fitting of devices onto existing pipelines, and into existing road reserves and open space reserves are a possibility. This will require detailed examination of the sub-catchments in relation to the configuration of the reticulation systems and topography within them. Council may wish to undertake this process as part of its operational activities in managing the stormwater systems.

Attention should also be paid to the treatment of stormwater runoff from those major roads in the catchment which are currently carrying large volumes of traffic (St George Street and Station Road; Portage Road, Pah Road, and Wyllie Road; Ferndown Avenue, Claude Road, and Kenderdine Road). The southwestern motorway presumably remains the responsibility of Transit New Zealand. Opportunities for installation of water quality devices for these roads are constrained, given the maturity of development in the catchment, and will be confined to such activities as improved street sweeping if necessary, and possibly the installation of Enviropods, Storm Filters, or similar in cesspits. There seems little opportunity for the installation of swales or other "soft engineered" facilities in relation to the roads. Council may also wish to investigate this process further as part of its operational activities in managing the stormwater systems for the roading.

Improvements to the riparian margins of the main stream channel in order to improve water quality from the ecological viewpoint are set out in 8.1 above.

8.4 MONITORING

An effective monitoring programme is fundamental to improving water quality. Benefits that result from improvement works can be quantified with the use of monitoring data and also similar improvement works can be implemented in other areas with more confidence in the results to be achieved.

In its state of the Environment Report (1999) Manukau City Council has identified its proposed monitoring work programme for the City's Urban and Rural freshwater Streams, Lakes, and Estuaries. The monitoring is to include:

- Physical, chemical and biological parameters in high priority and representative catchments
- All activities impacting on water quality, and
- Riparian vegetation and modifications to the natural channels

The following is an outline of MCC's monitoring methodology:

- Select priority and or representative streams and appropriate sites for monitoring
- Develop monitoring programmes in conjunction with the ARC
- Liaise with appropriate parts of Manukau City Council as well as external organisations for data on development activities in certain catchments

MCC is also proposing to monitor water quality in marine waters at selected representative sites and to monitor the water quality and quantity of groundwater.

MCC's monitoring work programme, whilst not developed in detail on this report, would provide additional data to access the water quality improvement measures proposed for the Kenderdine Catchment.

MCC also has a WAI CARE Stream Monitoring programme underway in Manukau.

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Appendix A

Open Watercourses – Kenderdine Catchment Assessment

Appendix B

MCC Stormwater Service Requests and Flooding Reports

Appendix C

Kohuora Crater Landfill Monitoring Data

Appendix D

Kenderdine Catchment Traffic Volumes

Appendix E

Property Values in the Kenderdine Catchment

Appendix F

Maps

1. Map Grid and Location Diagram
2. Stormwater Services 2-A2 to 2-E3
3. General Features
4. Aerial
5. Geology
6. Zoning and Land Use
7. Imperviousness Areas
8. Flood Records and Overland Flowpaths
9. LIR Information
10. Contaminant Sources and Existing Treatment Devices
11. Pipe Upgrade Priorities