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Regional Council
TE RAUHITANGA TAIAO

Framework for Assessment and Management of Urban Streams in the Auckland Region

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"Good"

natural channel and floodplain
natural channel shape (meandering)
excellent aquatic habitat
natural riparian vegetation, natives
stream connection to floodplain
stream connection to groundwater

"Fair"

natural channel and floodplain
natural channel shape (meandering)
fair aquatic habitat, aquatic weeds
modifed riparian vegetation, weedy
(remove exotics, plant natives)
stream connection to floodplain
stream connection to groundwater

"Poor"

channelised, poor habitat quality, aquatic weeds
modified riparian vegetation, weedy (needs shade palnting)
development in ½ floodplain, restricted stream connection
stream connection to groundwater

"Very Poor"

artificial channel and banks
channelised
poor aquatic habitat
modified riparian vegetation
(needs shade planting)
no connection to floodplain
no connection to groundwater

Preface and Acknowledgements

This document provides a framework for implementation of Chapter 3.5 (Urban Rivers and Stream Management Areas) of the Auckland Regional Plan; Air, Land, and Water (ARC 2004a). The purpose of this document is to promote consistent application of Chapter 3.5 across the Auckland region. Other elements of the Plan affecting urban stream management include Chapters 2, 5, 6, 7, and 12. The target audience includes engineers designing developments and stormwater control devices, planners preparing catchment management plans and structure plans, scientists conducting ecological assessments, and managers and staff of government agencies responsible for aquatic resource assessment and management.

The focus is on streams and wetlands that are often the first aquatic resources to receive urban discharges. Their enhancement and protection are important in their own right, and are necessary to protect and enhance estuarine and marine resources downstream. The overall intent is to provide Territorial Local Authorities (TLAs) with a technically sound framework they can use to develop specific assessment methods and management actions. This is an initial effort to standardise the assessment and management of urban streams in the Auckland region, and we recognise that there are many different ways to meet the overall objectives described in the Plan. Minimum requirements for assessment, classification, and management of urban streams are provided, while selection of specific methods is the responsibility of the TLAs. We encourage the TLAs to retain ecological, engineering, and planning expertise to assess and manage their streams and wetlands, and to develop GIS-based systems for reporting, managing, and mapping data. In the future, we will review the progress made and provide additional specificity as needed to further promote consistency and enhance urban stream and wetland quality and management.

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1 Introduction and Scope

The Auckland Regional Plan; Air, Land, and Water (ARC 2004a), hereafter referred to as the Plan, acknowledges that urban rivers and streams are impacted by the nature of their surroundings, locally and on a catchment scale. Most importantly, they provide many functions and values that can be maintained, restored, and enhanced with improved management. This Framework extends the information given in the Plan by providing a process for stream assessment, categorisation, and management that:

- enables specific urban stream reaches to be assessed and managed according to their existing and potential uses and functions, and
- incorporates a catchment-wide management approach to maximise the uses and functions of urban streams.

This document provides a framework for assessing stream quality and functions, and implementing regulatory (e.g., consents) and non-regulatory (e.g., riparian planting) management actions. The ARC has identified a need to develop methods for the assessment and management of urban streams that recognise and balance the wide range of functions they provide. Primary stream functions considered include the following:

<u>Ecology</u> - Urban streams provide living and breeding space for freshwater fish, invertebrates and plants. Stream functions are affected by catchment-scale (e.g., land use) and local-scale (e.g., physical habitat) factors.

<u>Connectivity</u> - Stream functions are determined in large measure by their connectivity between reaches from the headwaters to the sea. For example, many native aquatic species (e.g., fish) require access to the sea to complete their life cycles. Stream functions are also directly affected by connectivity with the riparian zone, the floodplain, and groundwater. For example, insects are an important food source for fish and birds, and have both aquatic (larva) and terrestrial (adults) life stages.

<u>Water Quality</u> – Good water quality is necessary to support ecosystem functions and human uses in streams and coastal areas. Streams provide for the physical, chemical, and biological processing of contaminant inputs, including those related to wastewater and stormwater.

<u>Flood Management</u> - Streams and their surrounding floodplains are the drainage network for a catchment and are an important part of the flood management system. Many urban streams have been highly modified (piped and channelised) to convey flood flows and protect property from flood damage. Conveying flood flows in upper reaches can lead to more severe flooding downstream.

<u>Amenity / Cultural</u> – Streams in urban areas have a number of values related to human use. These values are often interrelated and include:

- Amenity - Streams flowing through reserves (or private land) may include walkways or picnic areas and are valued for their visual appeal.
- Recreation - Paths along streams are popular for walkers and joggers. Non-contact recreational uses include kayaking in the lower reaches of larger urban streams, although

full contact recreation such as swimming and playing are generally discouraged in urban streams to protect public health.

- Cultural/Community - Significant cultural and/or community values are attached to a number of Auckland's urban streams. Waicare groups, local Iwi, or other community organisations may have special connections to particular streams, and often participate in protecting and improving their condition.
- Economic – Streams provide a variety of indirect economic benefits related to tourism, commercial and business uses, and property values. In addition, streams provide for the treatment, processing, and attenuation of contaminants at no direct cost.

Managing public health in urban areas is important due to the high population density and levels of contaminants, including pathogens, in urban streams. Direct contact with urban streams is not recommended. The collection of aquatic plants (e.g., watercress) and animals (e.g., koura, eels) for human consumption is not recommended due to the high potential for exposure to contaminants and pathogens.

The primary focus of this document is on streams that have year-round aquatic habitat and hydrology defined as "Category 1" (e.g., perennial) streams in Chapter 12 of the Plan. It is important to also recognise that "Category 2" (e.g., ephemeral) streams and wetlands that do not meet the Category 1 criteria are also ecologically important freshwater resources, and management techniques developed for Category 1 streams may also apply to them. Research is currently underway on the extent, function, and management options for Category 2 streams, and the results of this work will be considered in future updates of this Framework.

The stream categorisation and assessment methods outlined here provide a framework for the preparation of a wide range of investigative reports and planning documents related to urban development including Integrated Catchment Management Plans (ICMP), Network Management Plans (NMP), Structure Plans (SP), and Assessments of Environmental Effects (AEE). This document provides the technical basis for consistent application of assessment and management actions for urban streams throughout the Auckland region.

2 Guiding Principles

Urban streams are those contained within urban areas as defined in the Plan and shown on map Series 1, and include the Auckland metropolitan urban area and urban zones of rural and coastal settlements (ARC, 2004a). They are generally characterised as having high density urban land uses, and the streams, riparian areas, and floodplains have undergone substantial modifications to accommodate development and convey flood flows. The vast majority (approximately 90%) of streams in the Auckland Region are short (first or second order) narrow (channel width < 2 metres), and contained within small (< 100 ha) catchments (ARC 2004b). The success of efforts to manage Auckland streams will be determined largely by how these small streams are managed.

A comprehensive study of the ecological conditions in Auckland's urban streams has been completed (Allibone et al., 2001). The report contains details on urban stream condition using data collected at 65 urban sites, and suggests methods of categorisation and management to maximise ecological functions and human uses. Urban streams were found to be severely degraded, although relatively natural stream reaches in steep bush covered catchments were found. Suren (2000) summarised the adverse effect of urbanisation on New Zealand stream invertebrates. Invertebrates are ubiquitous, and research has shown that they are good indicators of stream ecological health (Collier and Winterbourn 2000). Fish also provide an integrated measure of stream ecological health.

Poor water quality including depressed dissolved oxygen and elevated levels of temperature, organic compounds, metals, and bacteria have been documented from a network of monitoring sites in Auckland urban streams (Wilcock and Stroud, 2000). Nevertheless, available research and monitoring indicate that even the most degraded urban streams provide important functions and values that can be enhanced with improved management.

The following principles derived from the available research and monitoring guided the development of this Framework. This information is provided as an interpretive summary of relevant scientific concepts and principles rather than an exhaustive review and summary of the literature.

<u>Tidal Influence</u>

Biological quality and stream uses are affected by the tides. The lower reaches of urban streams are utilised by native fauna that are dependent upon access to the sea, and provide important spawning habitats for inanga (*Galaxias maculatus*). These lower reaches are also utilised for recreation such as kayaking, swimming, and whitebaiting.

<u>Land Use and Catchment Impervious Cover</u>

The quality and functions of streams vary along their course, and are related to reach-specific and catchment-specific factors. Reach-specific measures include the condition of the stream channel and riparian zone. Catchment-scale variables such as land use largely determine the quality of a stream. Data collected throughout the region found water quality (Wilcock and Stroud 2000) and biological quality (ARC 2004c) related to catchment land use, and can be ordered from best to worse as follows:

native bush > exotic forest > rural > urban

While the quality of even the best urban streams is poorer than those in native bush, exotic forest, and many rural catchments, urban streams provide important ecological functions, and in many cases their condition can be improved. The quality of urban streams has been found to be related to the density of urban development. The percentage of the contributing catchment with impervious surfaces (e.g., roadways, carparks, and rooftops, %IC) has been shown to be related to stream quality in the Auckland region (Allibone et al., 2001) and overseas (Schueler 1994). Auckland's urban stream quality was highest at < 10 %IC, declined between 10-25 %IC, and was consistently poor at > 25 %IC. Adverse effects to the biota are due to multiple factors in urban areas including reduced water quality, altered hydrology, and reduced physical habitat quality.

Physical Habitat (local scale)

Biological quality was found to be positively correlated with riparian habitat conditions in Auckland streams across all major land uses, including urban land use (Allibone et al., 2001; ARC 2004c). Allibone (2001) identified the following factors as major contributors to aquatic habitat in urban streams; site slope and stream gradient, elevation, stream size (wetted perimeter and channel width), extent and quality of riparian planting (stream canopy and understory), and barriers. The importance of riparian habitat in supporting stream function has been documented in New Zealand (Collier, et al., 1995, Rutherford, et al., 1999) and overseas, and summarised in regional guidelines (ARC 2001).

Activities causing disturbance of habitat conditions in urban streams include the following:

- Loss of riparian shade – Elevated temperature is a major stressor in urban streams due to lack of shade and impervious surfaces that heat runoff. Native NZ fauna have been found to be more sensitive to elevated temperature than the fauna from other parts of the world (Richardson et al., 1994). The removal of shade vegetation also promotes the growth of nuisance aquatic plants (e.g., algae and exotic macrophytes) leading to dissolved oxygen levels that are unable to sustain healthy native aquatic communities.
- Reduction of channel length - Channelisation and straightening of stream channels reduces the total length of stream channel, leading to a proportional loss of habitat and function. The percentage loss depends on the degree of meandering, but generally ranges from 10-50%. Channelisation and piping are common practices in urban areas to promote drainage and transmit flood flows.
- Loss of bank habitat - Channel banks are often armoured with concrete, treated timber, or gabian baskets to reduce erosion of the banks and to protect adjacent properties. Channel erosion is a natural process, particularly on the outside of bends, and is accelerated by changes in hydrology due to urbanisation. Bank modifications can eliminate productive aquatic habitats.
- Loss of functions from piping and culverting – Piping and culverting represent the complete loss of natural functions of streams (except the conveyance of flow). Many functions are dependent upon sunlight driven processes (i.e., primary and secondary production) and the

interconnections between land and water (e.g., riparian zones) and between surface and groundwater, and are eliminated by piping.

Riparian System (catchment scale)

The functions of aquatic and terrestrial ecosystems are effected by the connectedness of the stream network and riparian corridor from the headwaters to the sea. The River Continuum Concept (RCC) is a fundamental tenant of stream ecology, and provides evidence that stream functions are defined by conditions along the full length of a stream network (Vannote et al., 1980). In other words, the condition of a stream at any one point is affected by conditions upstream and downstream from that point. This is particularly relevant to streams in the Auckland region with short distances from the headwaters to the sea and freshwater fauna dependent upon access to the sea.

A fundamental principle of landscape ecology is that the quality of the system is determined by the size of a patch and its position in the landscape (Harris 1984). The highest quality natural resources in urban areas are often isolated bush blocks surrounded by urban development (i.e., parks or reserves). Many of these blocks include streams and floodplains because these areas were more difficult to developed than upland areas. Connecting these isolated blocks together through improved riparian management will substantially improve and enhance the quality of aquatic and terrestrial ecosystems on a catchment scale.

Floodplain Connections

Modification of floodplains with stop banks, buildings, carparks, roads, culverts, and stormwater control devices affect the ability of the floodplain to accommodate flood flows. Locating buildings in floodplains increases the potential for flood damage. Placing urban land uses in floodplains also increases the input of contaminants to the drainage system affecting streams, estuaries, and coastal resources downstream. In general, the best option for protecting aquatic resources and minimise flood damage is to allow stream channels and floodplains to function naturally with minimal physical modification, rather than rely on engineered intervention after damage has occurred. This option may not be possible in fully developed areas.

Groundwater Connections

Many of the functions of streams and wetlands are affected by connections between surface and groundwater. These functions include enhanced flows during dry periods, contaminant processing, temperature attenuation (i.e., cooling), and a variety of biotic functions. The connection to groundwater is particularly important for small streams and wetlands that depend upon groundwater during dry periods. Artificial materials (e.g., concrete, timber) used to armour the channel bed and banks reduce or eliminate this connection and the related functions.

Fish Passage

The majority of Auckland fish depend on access to the sea to complete their life cycle (McDowall 1990, 2000). Barriers to the free passage of these organisms upstream include any structures, natural or constructed, that cause the water to “free fall”, often referred to as “drop structures”. Potential barriers include weirs, dams, and culverts. Even a drop of as little as 10-20 mm may be a barrier because most native fish and invertebrates cannot jump out of water to traverse such obstacles. Some fish species have the ability to climb steep wetted surfaces (e.g., eels, banded kokopu) while others cannot (inanga, giant kokopu). Other factors that adversely affect fish passage include velocity and depth. Some species have adapted to survival in stream reaches isolated above obstacles such as waterfalls, but are more limited in their ability to expand their populations and recolonise after pollution events. Consequently, the greatest diversity and abundance of native fish are found at low elevations where there is direct access to the sea (Allibone et al. 2001).

Pipes and culverts are common barriers in the urban environment, and can serve to prevent the movement of fish to suitable habitats in upper catchments. A smooth concrete invert does not provide the protection needed by fish and aquatic biota for breeding and resting. Flows in pipes and culverts often have higher velocities than natural channels, and commonly exceed the swimming ability of many native fish. Channel length can also have adverse effects where there are no resting areas (low velocity zones). Fish passage can thus be restricted through a combination of slope, depth, velocity, and culvert length. Guidelines for fish passage have been developed nationally (Boubée, et al., 1999) and for the Auckland region (ARC 2000b).

On-line Ponds

The Plan discourages the placement of ponds, including stormwater treatment ponds, within Category 1 stream channels and floodplains (i.e., perennial), and encourages their location off-line or on Category 2 (e.g., ephemeral) streams. Research in the Auckland region found poor water quality conditions in rural and bush ponds (including elevated temperature and depressed dissolved oxygen), and adverse effects extended for hundreds of metres downstream (Maxted 2004, in review). On-line ponds are often a barrier to fish passage. Contaminants stored in large on-line stormwater ponds within large catchments are more likely to be transmitted downstream during severe storms than small off-line ponds within small catchments.

The Plan includes procedures for the consenting of stormwater treatment ponds, including those proposed as part of ICMPs, and the ARC has developed guidelines on the design of stormwater treatment devices (ARC 2003). Efforts to control the adverse effects of stormwater on rivers, estuaries, and harbours should endeavour to also protect and enhance the functions, values, and uses of streams within their catchments.

Development Design

The density and layout of urban areas are described in regional and local planning documents (e.g., catchment management plans, structure plans). Many of the most effective methods of protecting aquatic resources are available only during the design phase of development. It is more difficult and costly to address problems after development occurs. These include, for example, flooding, piping, riparian disturbance, fish passage, and the overall ecological affects related to impervious surfaces. Guidelines have been developed for the Auckland region on methods to minimise the impact of urbanisation on aquatic resources using Low Impact Design concepts (ARC 2000a).

3 Assessment and Management Framework

Guidance is provided in this section on the extent, assessment, categorisation, and management of urban streams. It is recommended that local authorities (TLAs) develop GIS-based maps and databases to support the work and manage the data. A GIS-based system for data recording and management provides the basis for tracking stream conditions and changes over time across large geographic areas. Data management systems have been developed by Auckland City Council and North Shore City Council (NSCC). TLAs should establish expertise or seek advice from qualified experts in freshwater ecology and fish passage when undertaking this work.

Streams are assessed on a 'reach' basis, where a reach is defined as a relatively homogeneous stream section bounded by upper and lower sections with significantly different stream, riparian, and catchment characteristics; e.g., where land use changes from residential to commercial, where the stream changes from an open channel to a piped section, or at the junctions with major tributaries. A reach-based approach ensures that all sections of the stream network are managed to the highest quality possible. A reach approach was also selected because impacts occur at local scales, and research has shown that substantial improvements in ecological conditions can be achieved at local scales. In a recent survey of 55 Auckland streams, biological conditions across all land use classes (e.g., rural, forestry, and urban) were significantly correlated with local habitat quality; i.e., the better the habitat, the better the biology (ARC 2004c). These results indicate that even the most degraded streams can be enhanced and improved.

A combination of on-site investigations of specific locations, and mapped and computer-based data sources may be used to asses and categorise urban streams. Integrated management requires detailed knowledge of stream characteristics, particularly where significant adverse effects occur at specific locations (e.g., pipes, discharges, culverts, unshaded channels, concrete channels). The most comprehensive method of assessment, but also the most time consuming and costly, is to walk the entire length of all streams as has been done in NSCC (NSCC 2003). The results were used to assess (NSCC 2004a) and categorize their streams (NSCC 2004b).

3.1 Stream Extent

The assessment and management of urban streams is dependent upon the determination of stream extent as defined in Chapter 12 of the Plan. Category 1 streams (formerly called "perennial") have permanent surface hydrology, and are the primary focus of this Framework. TLAs should map all Category 1 streams. Category 2 streams (formerly called "ephemeral") and wetlands that do not meet this definition provide many of the functions and values of Category 1 streams. Assessment and management options for Category 2 streams and wetlands are the subject of on-going investigations by the ARC, and may be included by way of variation or plan change in the future. Protecting Category 2 streams and wetlands may be necessary to fully protect the functions and values of Category 1 streams downstream.

The National Institute of Water and Atmospheric Research (NIWA) has developed the River Environment Classifcation (REC) that may be useful in assessing and mapping stream extent (Snelder et al., 2002); also see NIWA web site at "http://www.niwa.co.nz/ncwr/rec/". This GIS-based system provides data on stream extent (length), substrate type (based upon physical factors such as rainfall, geology, and slope), elevation, and distance from the sea. Modeling has been used to predict the extent of the drainage system, and may be particularly useful in estimating the extent of historic channels that have been piped (Reach Type 6, see Section 3.3).

3.2 Floodplain Extent and Uses

Topography may be used to estimate the perimeter of the 100-year floodplain, but may be highly variable and affected by local conditions such as geology and land use. The most accurate method of estimating the perimeter of the 100-year floodplain involves catchment hydrologic modelling to determine stormwater flows (ARC 1999). Hydraulic modelling and local topography are used to determine the area of inundation for various flood event frequencies.

Land uses and structures allowed in floodplains should be specified in planning documents. Appropriate uses in floodplains may include parks and sports fields, but buildings, roads, carparks, and stormwater control devices should, as far as possible, be excluded from floodplains. Note that contaminants stored in stormwater and wastewater control devices within stream channels and floodplains may be released and discharged downstream during flood events.

3.3 Reach Categorisation

There are 6 reach types specified in Chapter 3.5 of the Plan, and are based upon studies undertaken on behalf of the ARC by NIWA (Allibone et al., 2001). The quality and functions of streams vary depending upon reach-specific (e.g., riparian condition) and catchment-specific (e.g., land use) variables. Percent impervious cover (%IC) is the primary catchment-specific variable used to define reach Types 2, 3, and 4. Habitat quality and condition of the stream channel are the primary reach-specific variables used to define highly modified channels (Types 5 and 6). A decision tree illustrating this categorisation appears in Figure 1, and an example of reach types applied to a fictitious urban catchment appears in Figure 2.

<u>Estimating Percent Impervious Cover</u>

There are a variety of methods for estimating the percentage of land in the catchment that is covered by impervious surfaces (%IC). Estimates of %IC for each reach may be derived from land use data where estimates of %IC are available for each land use (e.g., low, medium, and high density residential, commercial, and open space). However, these estimates are often highly variable because %IC is often highly variable within land use classes and land use data may not reflect current conditions. Directly connected impervious cover (i.e., the proportion of the impervious cover that is connected to the drainage system) is best but the data are often not available. The most accurate estimates are derived from computer assisted interpretations of aerial photographs that directly measure all impervious (e.g., roads, rooftops, walkways, carparks) and pervious (parkland, bush, yards, gardens, sports fields) surfaces. Impervious surfaces are identified from visual signatures on digitised aerial photographs, and summed for the catchment using GIS software.

This method was used by NSCC, and is recommended because it uses % cover estimates derived from current aerial photographs. All impervious surfaces, excluding roads, are "captured" (digitally delineated) from aerial photography using the "heads-up" digitising software. This data layer is then imported into the NSCC corporate GIS system by property parcels, including the area and %IC of each parcel. The %IC for each stream reach is then determined by delineating the catchment area above the reach and "clipping-out" and summing the parcel data for the catchment.

NCSS made two adjustments to the catchment %IC estimates. First, large areas containing one land use class (e.g., golf courses, hospitals, and schools) were assessed and adjusted individually. Second, roads were determined to be 100% impervious. An investigation of the average %IC of roads including road reserves and footpaths was carried out. %IC estimates were calculated for 10 random road right-of-way locations within the city, and found to be 89% impervious in residential areas and 99% impervious in commercial areas. Based upon this analysis, all road right-of-ways were given an impervious value of 100% because the percentages were high (> 89%) and road reserves and footpaths are generally well compacted and likely to be relatively impermeable.

<u>Stream Mouths (Type 1)</u>

Type 1 reaches include all reaches influenced by the tides, and segments immediately upstream that would be suitable for inanga spawning. The interface with the marine receiving environment at the stream mouth is a particularly important habitat for inanga spawning. Disturbance of inanga spawning sites should be avoided and habitats protected or enhanced through the appropriate maintenance of grasses or native vegetation on banks along upper and lower tidal zones. Type 1 reaches are often used for recreation.

Assessing the extent of Type 1 reaches is complicated by multiple physical (topography, elevation, barriers) and hydrologic (tidal flow, upstream freshwater flow) factors. Consideration should be given to both the head of tidal influence and upstream freshwater reaches suitable for inanga spawning. Topography, changes in elevation, and the presence of natural (e.g., waterfalls) and constructed (e.g., dams, weirs, culverts) barriers can provide the basis for initial mapping of Type 1 reaches. Initial mapping using these physical measures should be confirmed with field observations of the channel profile, emergent and submerged wetland plants, aquatic invertebrates, and of course the presence of inanga during the spawning season. No detailed mapping of inanga spawning areas has been done in the Auckland region, and therefore professional advice should be sought.

<u>Natural Channels (Types 2, 3, and 4)</u>

Catchment-scale estimates of % IC are used to categorise natural stream channels. Type 2 reaches (highest value natural channels), characterised by a low degree of impervious cover (< 10 %IC) in the catchment, have limited bank erosion, and are relatively unimpacted by urban development. They are particularly well preserved where there is also significant riparian and bush vegetation. Water quality, biodiversity, and habitat values in these streams would be expected to be relatively high, and thus warrant the highest degree of protection and management control.

Type 3 reaches (moderately disturbed natural channels) have a moderate degree of impervious cover (10-25 %IC) and have been affected by their surroundings, but are often not highly modified. There often remains significant riparian cover, but the streams may suffer from bank erosion. Natural values are somewhat degraded, however, these reaches offer the best prospects for restorative actions such as riparian planting to provide shade. Moderately disturbed natural channels are likely to be important for fish passage and have relatively high ecological values.

Type 4 reaches (highly disturbed natural channels) have a high degree of impervious cover (> 25 %IC), are severely degraded, and often suffer significant channel erosion. In many cases, the banks of the stream have been modified, but the channel is natural. Bank modification may include short (< 20 m) sections with concrete walls, gabions, and battering. These stream reaches have low natural values, but may allow fish passage to any higher quality reaches upstream. Restorative actions are more limited than in Type 3 reaches, but all management options should be considered, including riparian planting to provide shade.

Modified Channels (Types 5 and 6)

On-site investigations are used to categorize modified channels, which include concrete and piped channels. These modified channels are common in highly urbanized settings. However, there may be cases where the upstream catchment has a low degree of impervious cover (< 25 %IC) and high ecological values, but the channel may have been lined for flood control. These cases should be assessed and managed on a case-by-case basis utilizing assessment and management actions applicable to natural channels.

The reach is categorized as an "artificial/concrete channel" (Type 5) if > 50% is composed of artificial materials such as concrete or timber. It is most likely that these reaches are in catchments that are highly urbanized where channel modifications are the result of works to manage flooding and erosion. Often the natural floodplain has also been confined by development or infilling, and the opportunities for riparian restoration works are limited.

Modified channels using pipes, culverts, and concrete provide a lesser quantity and quality of aquatic habitats because the natural variations in stream pattern (i.e., meandering) and profile (e.g., depth) have been eliminated or reduced. The more uniform channel shape also reduces or removes the variety of features that fish and other aquatic biota need for shelter including pools, undercut banks, submerged wood, and other instream cover. Modified channels often have higher and more uniform velocities than natural channels that may restrict fish passage. A smooth concrete base also limits habitat diversity and food sources, and interrupts natural surface and groundwater interactions. Limited riparian cover is common in modified urban channels, and these unshaded reaches exacerbate the adverse effects of elevated stream temperatures. Type 5 reaches have higher natural values than Type 6 (piped channels) reaches because they support the full range of functions related to exposure to sunlight, including primary (plant growth) and secondary production.

A reach is categorized as a "piped channel" (Type 6) if greater than 50% of it is piped. Piped channels are usually located in highly urbanized areas and were often installed historically for flood protection and to maximize development extent and density. Piped sections have little or no natural values apart from providing for the passage of native fauna to upper reaches. They provide some cooling because they are underground and fully shaded.

Locating and mapping piped channels may be difficult, particularly in headwater areas where there are no upstream open channels that meet the Category 1 definition. Engineering plans may be needed to identify the course and extent of piped channels. The REC may be useful in mapping piped sections because it predicts the locations of stream channels based upon physical factors independent of land use. Considering piped sections as part of the stream network is necessary to achieve many catchment scale functions (e.g., fish passage), and may lead to important enhancements such as daylighting (restoration to open channels) and the removal of barriers.

3.4 Fish Passage (reach and catchment scales)

Assessments of barriers within specific reaches and across entire catchments are needed because barriers can affect the entire network of aquatic habitat, particularly if located in lower reaches of a catchment. Various sources of existing information should be augmented by field observations. Road crossings are the most common potential barriers in urban areas, and can be assessed rapidly by car. Barriers within piped sections may be particularly difficult to locate and assess. Each barrier identified should be given a severity ranking assessed across different flow conditions. Factors to be considered in the ranking include contributing catchment area, position in the catchment (e.g., distance from tide), habitat and land use upstream, structure type (e.g., constructed, natural, culvert, pipe, weir, waterfall), and physical features (height, slope, length, velocity). Guidelines for maintaining and enhancing fish passage have been developed for the Auckland region (ARC 2000b).

3.5 Public Health Hazard

Most urban streams have the potential to adversely affect human health. Public health is of particular concern where people regularly come into direct contact with urban streams. This may be through recreation (e.g. children playing, boating, swimming), food gathering (e.g. eels, watercress, koura), water supply (e.g. irrigation and non-potable household use), and community activities (e.g. monitoring, education, clean-ups). Accidental or purposeful consumption of contaminated water is probably the most significant route by which infection occurs, but infection is also possible through inhalation, and through contact with ears, eyes, nasal passages, or wounds.

The primary management approach with regard to public health is the prevention and control of faecal contaminants entering stream systems. Food gathering is also not recommended in urban areas due to the potential for the transmission of disease, and exposure to contaminants from collection and consumption. Essential information that needs to be provided in ICMPs includes combined stormwater/wastewater discharge points and volumes, sewer overflow points and frequency of overflows and volumes, and areas where human contact with urban streams is high. Public health is the responsibility of the relevant TLA and district health boards under the 1956 Health Act.

3.6 Amenity, Community, and Cultural Values

The amenity value of streams varies according to the location of the stream, surrounding land use and ownership. Amenity values are also linked to other stream functions such as habitat quality and human health. Reaches flowing through public or private open space generally have a high amenity value, while reaches flowing through industrial or commercial parks will typically have reduced amenity value. Characterisation of the surrounding land use is therefore an important component in the assessment of current and potential amenity, community, and cultural value. Information to be collected might include public open space, private open space (e.g. golf courses), publicly owned riparian margins that allow access to stream reaches, areas of high and recreational value, and areas used frequently for food gathering. A combination of information provided by stream care groups, public surveys, consultation (e.g. with iwi), and the local knowledge of council staff may be used. Some sites with high amenity, community, and cultural value may also be listed in local and regional plans.

3.7 Management Priorities

Management priorities applicable to the six reach types are shown in Table 1. The primary focus of urban stream management is to (1) maintain or enhance the quality of all reach types, (2) optimise the connectivity between reaches within a catchment, (3) provide for public use and amenity values, (4) protect public health and safety, and (5) protect and enhance cultural values. Connectivity from the headwaters to the sea is provided by the removal of fish barriers and the establishment of a corridor of native riparian vegetation. The maintenance or enhancement of water quality is related to both habitat quality and connectivity and is therefore an issue common to all reach types.

The highest quality urban streams are at greatest risk because adverse effects from urbanisation are typically uni-directional; i.e., once adverse effect occur, it is very difficult to restore to a former condition. Therefore, the most protective management actions should be applied to the highest quality urban streams. The highest quality urban streams have < 25 %IC (Types 2 and 3) or have tidal influence (Type 1). As the density of urbanisation progresses, the emphasis shifts to providing fish passage and shade, minimising erosion, and the maintenance or enhancement of public access and amenity values. Flood hazard management is the primary function in Type 5 and 6 reaches, although keeping additional structures out of floodplains should be a priority for all reach types. Peri-urban and greenfield catchments not yet developed have the greatest opportunities for flood hazard prevention.

Establishing or maintaining shade vegetation along streams, preferably with native trees, is a priority for all reach types (except Type 6). The riparian zone provides multiple functions including contaminant retention and processing, temperature moderation, and aquatic and terrestrial habitat. Elevated water temperature is a major stressor in streams that lack shade.

Shade provided by trees and shrubs along streams is effective in preventing or reducing elevated temperatures (Rutherford et al., 1999). Shade trees and shrubs are also an effective, inexpensive, and sustainable method of biological control for aquatic and terrestrial weeds because weed growth is inhibited in shaded areas. Guidelines for the management of riparian zones are available (ARC 2001).

Human health is also given a high priority across all stream categories. It is unlikely that the health risk can be completely eliminated from urban streams, but the separation of the combined stormwater/sewer systems and the prevention of wastewater overflows are high priorities, and benefit other stream functions and the marine receiving environment. Methods of reducing the public health exposure risk, such as signage and education, should also be used in reaches where people have a high probability of direct contact with urban streams.

3.8 Management Actions

TLAs should develop management actions customized for each reach type. Examples of stream restoration actions appear in Table 2. Management actions should be defined by objective and reach type.

Objectives Applicable to All Reaches

Selected management actions will apply across all reaches and catchments to promote connectivity of aquatic resources from the headwaters to the sea. Actions include riparian management (planting trees to provide shade), removal of fish barriers, providing open natural channels and floodplains, control of wastewater and stormwater discharges, ensuring off-line stormwater management, and the maintenance of public health and safety, recreation, and amenity.

Objectives Applicable to the Highest Quality Reaches (Types 1, 2, and 3)

Selected management actions recognize the need for a higher level of protection and management for selected reaches and catchments. Preventative and remedial actions will have the highest net benefits in Type 1-3 reaches because these reaches have the highest quality and are the most susceptible to further degradation. Preventative actions might include land use controls to appropriately locate and manage development through structure plans, ICMPs, and district plans; e.g., impervious cover limits, areas set aside for flood control, and areas set aside for riparian protection. All remedial actions (e.g., removal of fish barriers, control of wastewater and stormwater discharges, planting of shade vegetation) would be a high priority in Type 1-3 reaches.

Objectives Applicable to Severely Degraded Reaches (Types 4, 5, and 6)

Selected management actions recognise that even the most degraded waterways can be improved. Actions include replacing concrete channels with natural materials to reconnect the channel and groundwater, prevention of further channelisation and piping, providing shade vegetation (Types 4 and 5), providing for fish passage, and daylighting piped section (Type 6).

3.9 Minimum Requirements

There are a variety of measures that can be used to support stream assessment, categorisation, and management. The following is considered to be the minimum amount of information required to evaluate stream functions in an Integrated Catchment Management Plan (ICMP):

- Documentation of protocols and methods used for stream assessment, categorisation, and management.
- Mapping of Category 1 stream extent, including piped sections.
- Assigning Auckland Regional Plan: Air, Land and Water reach types (1-6) to all Category 1 stream reaches.
- Mapping of 100-year floodplain extent, including the identification of structures within the 100-year floodplain.
- Assessing and mapping pollution sources (e.g., stormwater outfalls, wastewater overflows).
- Mapping of riparian canopy extent and vegetation type (e.g., mature native trees, regenerating native trees, native scrub, exotic scrub, none).
- Mapping of privately and publicly owned riparian margins, and identification of margins with "open space" (e.g. parks, golf courses).
- Mapping of natural and constructed barriers to fish passage, including the severity of the barrier, extent of resources affected upstream, and the potential for modification or removal. Barriers within piped section should be included, particularly for reaches with large catchment areas.
- Mapping of on-line and off-line ponds, and their potential to cause adverse effects due to their size, catchment area, and extent of aquatic resources affected upstream (barrier) and downstream (elevated temperature and poor water quality).
- Assessing and mapping stream reaches that have:
    - important ecological functions and values (e.g. high biodiversity, inanga spawning);
    - been channelised;
    - active erosion and bank failure;
    - significant cultural and/or amenity value.

Geographically-based systems (GIS) will be a key platform for reporting, managing, mapping and storing stream assessment data. Systems should also be developed that allow management actions taken to address the priorities described in the Plan (and Table 1) to be tracked from planning to implementation, and where necessary, scheduled maintenance.

Much of this information can be gathered from available sources (land use, aerial photos), supplemented by targeted data collection efforts (riparian vegetation, fish barriers). In some cases, more detailed investigations may also be warranted to improve the stream evaluation and to put the quality of the stream into a broader context. The extra information gathered may include the:

- assessment and mapping of Category 2 stream reaches and wetlands;
- assessment of aquatic biota (aquatic plants, invertebrates, fish);
- assessment of aquatic habitats; and
- assessment of water quality (e.g., temperature, DO, nutrients, contaminants).

3.10 Stream Channel Design Guidance

Urban stream channels often require engineered modifications to control erosion and protect property. Many urban stream channels are highly variable in their engineered design depending upon site specific factors. The following guidance is provided on the design of urban stream channels to minimise adverse effects, and was taken from published literature on stream geomorphology (Morisawa 1968, Leopold et al.,1992, Leopold 1994, Rosgen 1996). It is based upon the fundamental principle that the cheapest and most sustainable option for urban stream channel design is to allow stream channels and floodplains to function naturally with minimal human alternation.

<u>Working with Flooding</u>

Stream flooding is a natural process that directs the energy of the flood out of the channel and onto the floodplain. Periodic flooding of driveways, yards, and structures in the floodplain during and after heavy rain may be unavoidable even with extensive engineering and management. The most effective management action to protect stream channels is to keep structures out of floodplains, and to maintain a naturally functioning stream and floodplain system.

Addressing flooding by widening and armoring stream channels is not recommended because it often requires very wide channels, exacerbates flooding downstream, and is costly to build and maintain over the long-term. Most streams in the region are small with narrow incised channels. Narrow channels are more resistant to erosion because the channel capacity is quickly exceeded during rain events, and the energy of the flood is taken by the floodplain rather than the channel. If the channel is widened to keep the flow in the channel, the erosive force against the banks is increased requiring heavy engineering. Widening and armouring may be unavoidable in fully developed catchments with buildings and structures already in the floodplain, but should be considered only after other options have been discounted (e.g., removal of blockages downstream, relocating structures, or placing structures on piles).

<u>Channel Pattern (shape) and Profile (depth)</u>

Streams naturally meander with a regular “sinuous” pattern of “bend-run-bend”. The meander is the most stable shape of a stream, and leads to a greater variety of depths and aquatic habitats than straightened channels. The degree of meandering is dependent upon several factors related to slope and topography. Natural streams in steep narrow gullies may follow topographic features rather than a regular meander pattern.

Urban developments and catchment designs should maintain or reestablish natural meander patterns. Channel straightening should be discouraged because it reduces the total length and storage capacity of the channel, reduces habitat quantity and variety, and leads to increased channel erosion due to increased velocities. Channel straightening results in the loss of stream length and a proportional amount of functions and values. The following recommendations are in order of preference from best to worse:

meandering channel > straight channel   and   variable depth > uniform depth

Minimal "Hard" Engineering

Erosion of the stream channel is a natural process, and occurs most actively on the outside of bends. Tree roots hold the channel material together and resist the erosive force of the flow. Channel engineering is often necessary to protect property, but in many cases the planting of trees may provide greater protection at lower cost over the long-term. Soft engineering (e.g., tree planting) and natural channels are preferred over hard engineering (e.g., concrete).

Use of Natural Materials

Urban stream channels are often a mixture of natural channels, armored channels, and culverts. The natural channel and streambed should be retained wherever possible. The use of natural materials for stream channels and stream banks (e.g., trees and shrubs) promotes aquatic habitat and interconnections between surface and groundwater. Armouring (e.g., concrete, timber) the stream bed should be avoided to retain the ability of the channel to form pools and other valuable aquatic habitats, and to maintain connections between surface and groundwater. The use of treated timber along water courses should be avoided due to the leaching of preservatives into the watercourse adversely affecting the biota (Weis et al., 1993). Stepped gabian baskets are preferred over concrete and timber walls because they maintain the connection between surface and groundwater, provide some aquatic habitat between the rocks, and provide horizontal surfaces for vegetation to become established along the banks. The following recommendations are in order of preference from best to worse:

roots/clay/earth/rocks > gabion baskets / rip rap > concrete > treated timber

Culverts - Necessity, Size, and Design

A single poorly designed culvert can adversely affect the functions of the entire length of aquatic habitats upstream. Advice should be sought from qualified experts for assessment of existing culverts and the design of new culverts. Assessing the need for existing and proposed culverts is a primary consideration. Development designs should require the minimum number of road crossings and culverts. Where the crossing of a stream is necessary, bridging is preferred over culverts because bridges maintain the natural streambed and provide more space for the passage of flood flows.

Culverts should not be longer than necessary. Single lane roads may be sufficient in small residential developments that cross small streams, and fords that allow for flood flows to pass over the road may also be suitable. Flat bottomed square culverts with shallow laminar flow are substantial barriers to fish passage. Submerged culverts often avoid fish passage problems altogether. The following recommendations are in order of preference from best to worse:

open channel > bridging > short culverts > long culverts

submerged culverts > shallow culverts > perched (with free fall or drop)

Figure 1: Flow chart for assigning urban reach types as described in Chapter 3.5 of the Plan.

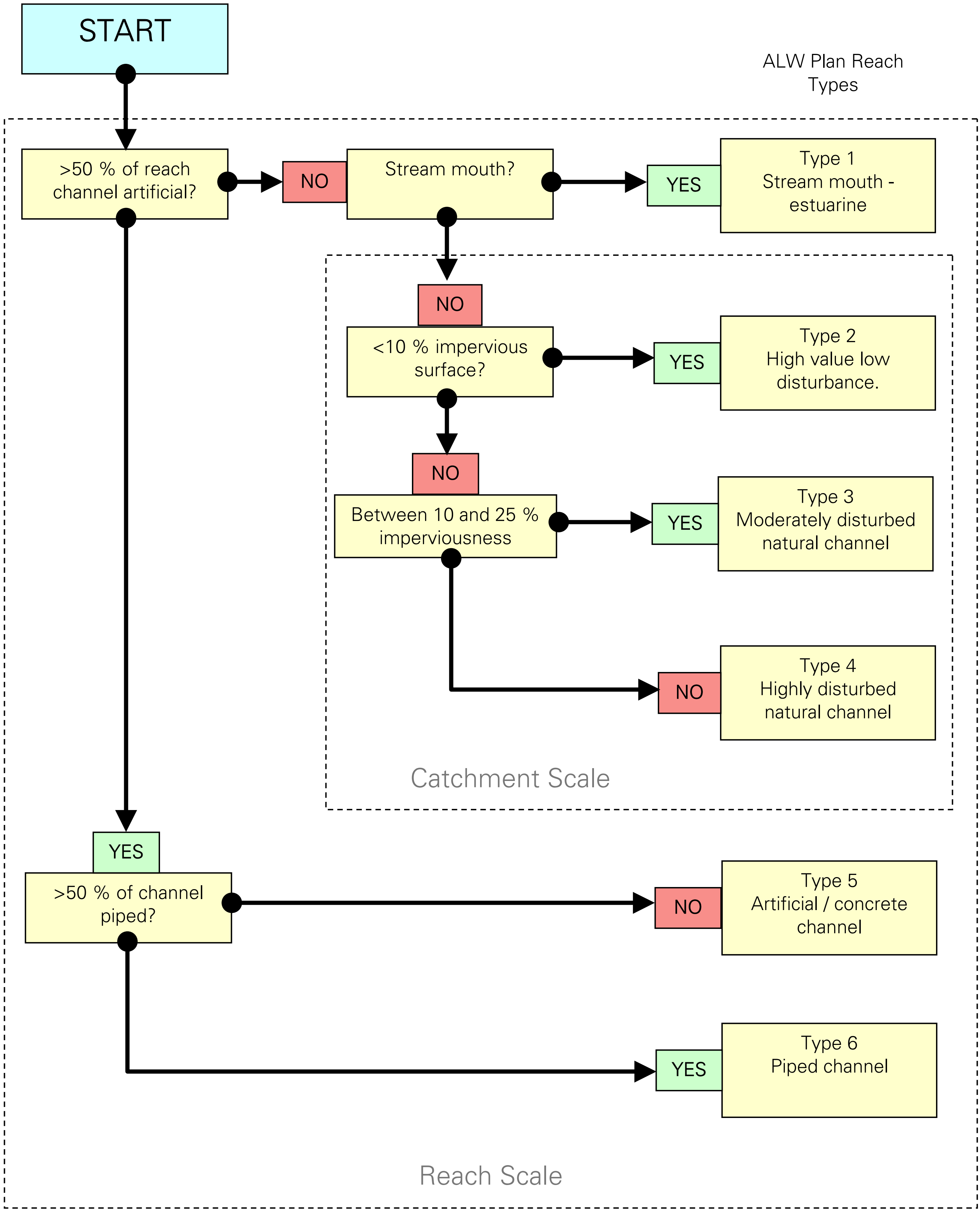

Figure 2: Example categorisation of a fictitious urban stream, considering catchment area and percent impervious cover.

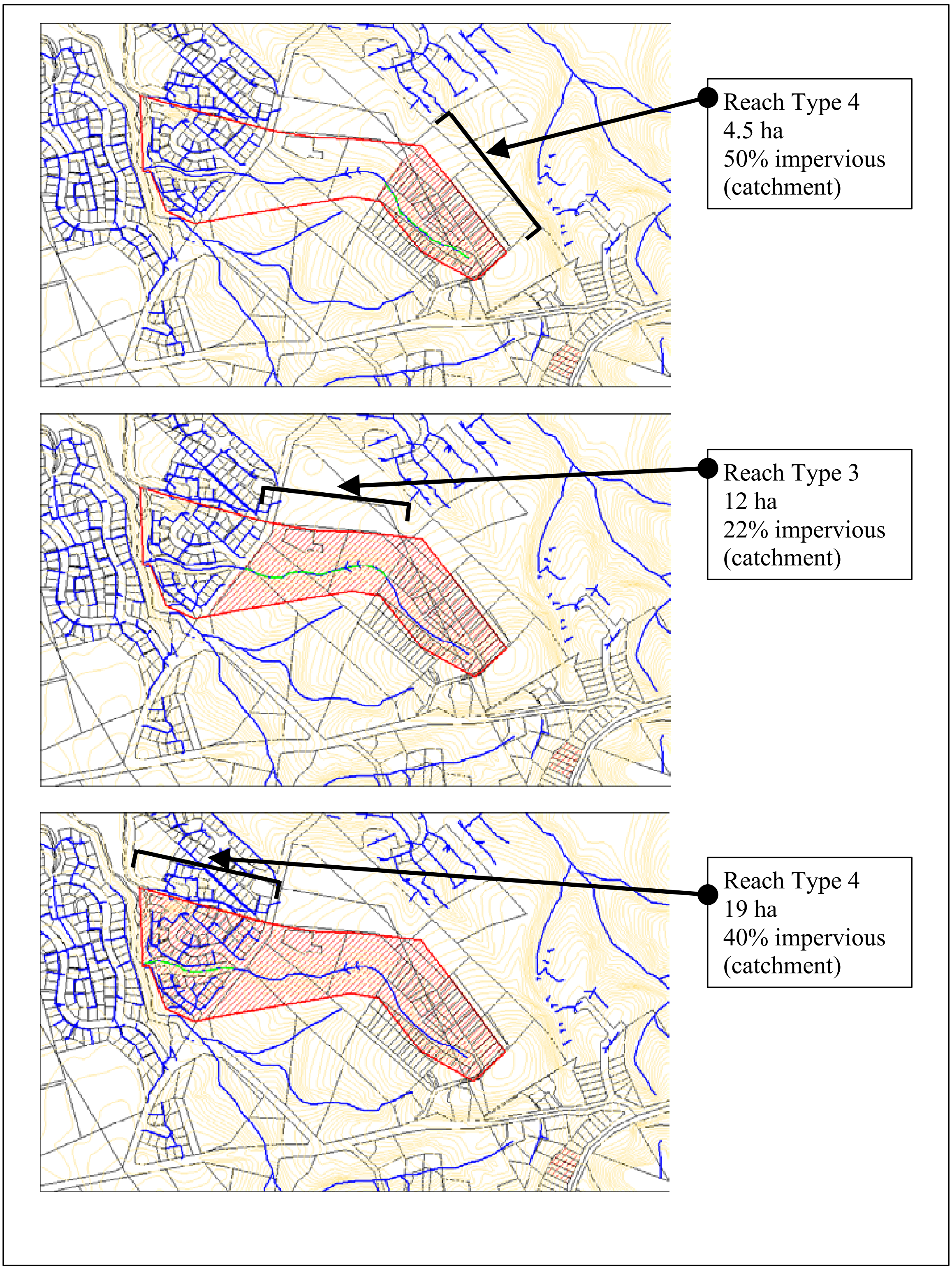

Table 1: Management priorities for urban streams types 1-6. The relative emphasis for setting priorities is given by: Twelve management priorities for reach types 1 – 6, with relative emphasis given as high (H), medium (M), or low (L); not applicable (–).

Urban Rivers and Stream Management Priorities	Reach Classification Type					
	1	2	3	4	5	6
1. Maintain or enhance amenity values (aesthetics, recreation, culutral/community, economic).	L	L	H	H	–	–
2. Maintain or enhance instream values.	H	H	H	M	–	–
3. Maintain or enhance public access to and along rivers, lakes and wetlands.	L	L	H	H	–	–
4. Maintain high water quality by avoiding, remedying or mitigating contaminant inputs.	H	H	H	H	H	H
5. Improve degraded water quality by avoiding remedying or mitigating the adverse effects of contaminant inputs.	–	–	H	H	H	H
6. Stabilise and protect stream banks from erosion.	L	L	M	M	–	–
7. Restore the pre-development hydrology to the fullest practicable extent.	–	M	H	H	–	–
8. Reduce instream temperatures and improve reach connectivity by planting or enhancing riparian vegetation.	H	H	H	H	H	–
9. Protect and enhance inanga spawning areas.	H	–	–	–	–	–
10. Maintain or enhance fish passage for appropriate species by avoiding, remedying or mitigating effects of artificial barriers.	H	H	H	H	H	H
11. Minimise flood risk to humans and property through the application of best management practices.	–	L	M	M	H	H
12. Protect human health	H	H	H	H	H	H

Table 2: Categories of management actions according to the Priority Areas list in Table 1.

Priority Area (Table 1)	Action Categories
General	Implement district and regional plan rules to address a variety of objectives (e.g., vegetation clearance, earthworks, sediment controls, impervious surface limits, avoid building in floodplains, avoid piping and infilling of streams and wetlands, minimise culverts and design fish friendly stream crossings).
	Develop guidelines for subdivision and urban developments (e.g., stormwater management, road improvements, re-vegetation, and weed control).
	Minimise and manage impervious cover in all catchment, and especially in catchments with < 25% IC, through low impact designs options.
	Locate structures out of floodplains, and locate stormwater devices off-line.
1. Amenity Values	Protect and enhance parks and reserves.
	Facilitate community-led stream monitoring programmes.
	Facilitate community-led stream and catchment protection/restoration projects.
2. Instream Values	Protect and enhance the biota and physical habitat of existing streams, lakes, and wetlands.
	Restore wetlands and other fish breeding areas.
	Daylight buried (piped) stream channels
3. Public Access	Manage public access to streams, lakes, and wetlands. This may include restricting access to some streams to protect their ecological functions and minimise human health risk, and enhancing access to other streams to increase amenity values.
4/5. Water Quality	Identify sewage overflow points, and reduce their frequency and severity. Minimise the discharge of these pollutants to streams, lakes, and wetlands.
	Identify stormwater and other non-point source discharges. Minimise the discharge of these pollutants entering streams, lakes, and wetlands.
	Install stormwater treatment devices off-line.
	Replace stormwater pipes in poor condition or under capacity to meet design requirements.
	Maintain or improve base flows – recharge to groundwater.
6. Stream Channels	Maintain and enhance the variety of channel depths (e.g., pools, riffles, runs) and substrates (e.g., rocks, wood and other organic material).
	Restore or maintain natural channel pattern (i.e., meander pattern); minimise channel straightening.
	Stabilize eroding banks with vegetation or bioengineering measures.
	Remove artificial stream bank and bed armoring/linings, where practicable.
7. Hydrology	Reduce the adverse effect of urbanization on stream hydrology without compromising other stream functions (e.g., fish passage).

Priority Area (Table 1)	Action Categories
8. Riparian Connectivity and Shade	Maintain or restore vegetation cover (preferably with natives) in the catchment to intercept rainfall and achieve a more natural hydrologic pattern.
	Revegetate riparian margins – establish woody vegetation along streams to reduce stream temperatures and provide organic matter delivery to streams. Use native trees and reduce/remove exotics.
	Halt or reduce the mowing of grass that occurs in the floodplain or within at least 10 metres of the stream bank.
	Remove invasive exotic species in the catchment that threaten the survival and regeneration of native vegetation, including in riparian margins. Control exotic aquatic plants (macrophytes) through shading rather than physical removal or herbicide use.
9. Inanga Spawning	Identify, map, protect, and enhance inanga spawning areas.
10. Fish Passage	Identify and map barriers.
	Prioritise barriers and remove or modify in priority order.
11. Flooding	Remove blockages to stream flow that can increase flooding downstream.
	Restore wetlands/create stormwater treatment-detention wetland systems.
	Restrict building of additional structures within floodplains.
12. Human Health	Improve and enhance public health by reducing contaminant inputs and human exposure to contaminants.
	Restrict activities (e.g., swimming, food gathering) in contaminated areas. Educate through signage and other means to reduce exposure to contaminants.

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