Establishing Fisheries Management and Reserve Zones in Settlement Areas of Coastal British Columbia

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1997

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2351

Fisheries and Oceans Canada / Pêches et Océans Canada

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Canadian Manuscript Report of Fisheries and Aquatic Sciences

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Fisheries and Aquatic Sciences 2351

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ESTABLISHING FISHERIES MANAGEMENT AND RESERVE ZONES IN SETTLEMENT AREAS OF COASTAL BRITISH COLUMBIA

By

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Cat. No. Fs 97-4/2351E ISSN 0706-6473

Correct citation for this publication:

Millar, J., N. Page, M. Farrell, B. Chilibeck, and M. Child. 1997. Establishing fisheries management and reserve zones in settlement areas of coastal British Columbia.

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ABSTRACT

The purpose of this document is to re-examine the nature and extent of the interaction between aquatic and riparian areas and to present an approach for designating fisheries management and reserve zones in urban / suburban settlement areas of coastal British Columbia. The dimensions of the Fisheries Management and Reserve Zones recommended in this document are based on distances required to protect various habitat features and functions. The methodology is stratified and proposes the establishment of two zones. The scale and timing for establishing the zones are linked to community and settlement planning processes. The first zone – a Fisheries Management Zone (FMZ) is established on the basis of existing broad scale map information and data on watercourses, floodplains, vegetation and topography for the catchment area or watershed. The FMZ is a high level planning boundary. It provides a proactive and strategic habitat management and land use planning tool to ensure appropriate consideration can be given to protecting features and processes that occur in this area during subsequent development. The second zone – the Fisheries Reserve Zone (FRZ) - is the immediate area adjacent to watercourses or wetlands which represents the critical zone of functional interaction between the aquatic feature and adjacent land-based features. The FRZ boundary is a local refinement of the FMZ and is based on site specific assessments which generate information on fish use, vegetation community structure, geomorphic processes and features, and local hydrology and topography. Identification of the FRZ can occur at any time where this detailed site specific information is available, but is generally initiated later in the development process when an impact assessment or statement is required. Where both zones are established the site specific FRZ will vary the alignment of the previously established large scale FMZ boundary in order to capture local features or address site specific risks that would not be apparent at the broad scale or general information stage. In highly developed areas which have been historically impacted the FRZ identifies priority areas for enhanced protection and restoration.

RÉSUMÉ

Millar, J., N. Page, M. Farrell, B. Chilibeck, and M. Child. 1997. Establishing fisheries management and reserve zones is settlement areas of coastal British Columbia.

Ce document a pour objet de réexaminer la nature et l'étendue de l'interaction entre les zones aquatiques et riveraines et de présenter une approche en vue de désigner les zones de gestion des pêches et les zones de réserve le long des écosystèmes aquatiques, dans les secteurs de peuplement de la côte de la Colombie-Britannique.

Ce document recommande que l'espace occupé par les zones consacrées aux réserves et à la gestion des pêches soit basé sur les distances nécessaires pour protéger les divers processus qui contribuent à l'habitat des poissons. La méthodologie pour délimiter ces limites consiste en un processus en deux étapes qui tient compte des divers stades de planification de l'utilisation du sol qui marquent l'aménagement. Au cours de la première étape, on fixe une limite à la zone de gestion des pêches (ZGP) en se basant sur des photos ou des cartes aériennes à une échelle convenant à un inventaire des zones écosensibles, un plan officiel de la collectivité ou d'autres plans stratégiques de l'utilisation du sol. Ces limites sont établies au moyen de l'information existante sur les cours d'eau, le périmètre d'inondation, la végétation et la topographie. La limite de la ZGP fournit un outil stratégique de gestion de l'habitat et de planification urbaine pour s'assurer qu'on tient suffisamment compte, par la suite, au cours de la planification de l'utilisation et du lotissement, de la nécessité de protéger les processus et les caractéristiques existant dans ce secteur et qui contribuent à l'habitat des poissons. Par ailleurs, la zone de réserve des pêches (ZRP) est le secteur limitrophe des cours d'eau et d'autres entités aquatiques qui comprend notamment la zone critique d'interaction fonctionnelle entre le cours d'eau et sa zone riveraine. La limite de la ZRP constitue un raffinement de la ZGP et repose sur une information particulière aux sites concernant l'utilisation par les poissons, la composition de la végétation, les processus géomorphologiques ainsi que les caractéristiques hydrologiques et topographiques. La ZRP fera varier au besoin les limites de la ZGP pour englober les caractéristiques du site non répertoriées précédemment et susceptibles d'augmenter le potentiel de répercussion de l'aménagement sur les écosystèmes aquatiques adjacents. Dans les secteurs ou il y a eu une dégradation des cours d'eau ou des zones riveraines, la ZRP fournit l'occasion de restaurer les processus naturerl du cours d'eau et l'habitat des poissons. Les limites finales de la ZRP intègrent des facteurs biologiques (p. ex. présence du poisson et utilisation, composition de la végétation, présence d'espèces rares ou en péril ou utilisation), des caractéristiques du paysage (p. ex. suintements, sources, périmètres d'inondation, habitats des chenaux principaux, terres humides, zones pourvues de sols érodables ou de pentes instables, zones a haut relief comme des ravins et des escarpements) et des processus liés aux bassins hydrographiques (p. ex. mouvement de terrain, alimentation d'une nappe souterraine, déracinement par le vent et apport de débris organiques de grande taille, déplacement lateral du chenal dans le périmètre d'inondation). Cette approche fonctionnelle pour déterminer les zones de réserve des pêches reflète les processus et les caractéristiques qui contribuent à l'habitat des poissons. Elle sert aussi, dans les zones de peuplement, à justifier les dimensions des zones de protection des cours d'eau et des marges d'isolement fixées pour l'utilisation des terres le long des réseaux aquatiques.

ACKNOWLEDGEMENTS

The authors are sincerely grateful to the many people who contributed to this project. We would like to thank in particular those people who, at an early workshop, contributed suggestions on approaches which helped guide the research and development of the methodology. We would also like to thank those that provided scientific and technical review comments on the document, including Bob Beschta, Gordon Hartman, Steve Macdonald, Andy Castelle, Otto Langer, Bruce Reid and Marissa Byrne. Information and comments from land use planners, consultants and municipal staff were also particularly helpful to the authors for refining the methodology for application of fisheries management and reserve zones in human settlement areas. Editorial and formatting assistance was provided by Sean Standing and Fern Hietkamp, and is very much appreciated.

EXECUTIVE SUMMARY

This document presents an approach to protecting fish habitat in urban and rural areas of coastal British Columbia that relies on the establishment of Fisheries Management and Reserve Zones adjacent to streams, wetlands and other sensitive aquatic features. As fish habitats are a product of hydrologic, geomorphic and biological processes that occur at a watershed scale, and most impacts to watersheds are a result of large-scale changes in land and water use, this approach is directly linked to land use planning. This document and the recommended approach have intentionally focused on privately owned lands in urban or agricultural areas because of the significant fisheries resources at risk in rapidly urbanizing areas of the province and the lack of comprehensive strategic planning processes to address aquatic and riparian protection in these areas. Large non-settlement areas of the province are already subject to strategic and hierarchical land use planning processes and in the case of working forests are expected to comply with site specific watercourse protection and riparian management requirements in the Forest Practices Code.

The recommendations in this report for Fisheries Management Zone widths have been derived from the existing scientific literature on aquatic ecosystems in the Pacific Northwest. Based on the relevant literature the following default management zone distances are proposed to protect habitat features, functions and processes:

- **actively fish bearing and potentially fish bearing permanent streams** – 50 m on both sides of the stream channel (from bankfull width);
- **ephemeral and intermittent streams** – 30 m on both sides of the stream channel (from bankfull width);
- **lakes and wetlands** – 30 m from the extent of seasonal inundation and/or hydrophilic plant community;
- **contemporary floodplain (>1 in 30 year recurrence interval)** – any portion of the floodplain that is partially included in the Fisheries Management Zone should be completely encompassed within the Fisheries Reserve Zone; and,
- **ravines, escarpments, or other steeply sloped area**s – steep slopes (> 30% slope) and any high relief features that are partially encompassed within 50 m of fish bearing permanent streams and 30 m of non-fish bearing permanent, ephemeral or intermittent streams should be wholly encompassed within the Fisheries Reserve Zone. An additional setback at the crest of the slope may be required (as necessary) to ensure geotechnical and vegetation stability.

The alignment of the Fisheries Reserve Zone relative to the Fisheries Management Zone will vary depending on information collected at the site level respecting landscape and drainage features, local fish use and risk. In many heavily urbanized watersheds, existing developments already occupy large portions of the Fisheries Management Zone. In these impacted situations existing land uses and site alterations are considered in arriving at a feasible setback or habitat protection prescription for these sites. Management zones that could be established in these areas would be compromised and should therefore be considered priority areas for reclamation, restoration or acquisition.

The approach proposed in this document focuses extensively on the riparian / aquatic interface and does not attempt to address many of the watershed scale, fluvial, geomorphic or biological processes which are critical to the creation and maintenance of fish habitat. Much larger reserve zones would be required to maintain many of these processes which would include: mass wasting, natural riparian forest succession, groundwater recharge and changes in channel morphology.

1.0 INTRODUCTION

Rivers, streams, lakes, wetlands, floodplains and their associated riparian areas provide a network of critical habitats for fish, wildlife and vegetation throughout coastal British Columbia. Together these areas support a high proportion of the region's biodiversity including at least thirty species of fish and twelve species of amphibian, in addition to the many species of birds, mammals, insects and plants that are dependent on aquatic and riparian habitats (Westwater 1993; Meidinger and Pojar 1992). Coastal rivers and streams are of particular importance to British Columbia salmon stocks. Recent estimates of the production suggest that approximately 80% of the chum (*Oncorhynchus keta*), 65% of the coho (*O. kisutch*), and 100% of the cutthroat trout (*O. clarki*) stocks are produced in tributaries located downstream from Hope, B.C. (DFO 1994). Small streams in coastal British Columbia also sustain genetic and stock diversity which is considered fundamental to species survival. In addition, several endangered fish species and populations such as Salish sucker (*Catostomus sp.*), Nooksack dace (*Rhinichthys sp.*), and Enos and Paxton lake three-spine sticklebacks (*Gasterosteus spp.*) occur in streams and lakes of coastal British Columbia (MELP 1995).

The network of aquatic habitats formed by streams, lakes, and wetlands in combination with their floodplains and adjacent riparian areas are commonly referred to as the Fisheries Sensitive Zone. This zone encompasses permanent and seasonal aquatic areas as well as that portion of the riparian margin which serves a critical function in sustaining aquatic habitat for fish. While many factors influence fish escapement, declining populations (in particular coho) and persistent increases in the rate of fish habitat loss in settlement areas strongly suggests that current urban land use and development practices are failing to adequately protect this zone from serious impacts. Given the commercial, recreational, and cultural importance of fisheries resources in coastal B.C., there is an urgent need to improve protection of fish habitat. The establishment of Fisheries Management Zones (FMZ) and subsequently Fisheries Reserve Zones (FRZ) serve this purpose. These zones are not only critical for fish habitat protection; they also serve other ecological functions and provide a variety of community benefits. These include providing an unbroken connection between high elevation and valley bottom ecosystems for wildlife, dissipating flood energy during wet periods, retaining water in soil during drought periods, filtering non point sources of pollution, providing buffers and transition zones between different land uses, providing wildlife viewing and nature interpretation opportunities in urban settings, accommodating pathways and trails for recreational use, and protecting surface water supplies for domestic consumption or agricultural use.

Although this report focuses on the nature and extent of biological interactions between an aquatic system and its riparian margin, it is important to note that watershed scale management is essential to sustain hydrologic functions that produce and sustain aquatic habitats and fish populations in urban and rural areas. In urbanized watersheds, dramatic changes to channel morphology, water quality, and stream temperature have resulted from increases in impervious surface area beyond 15% by area (City of Olympia 1995; Booth 1990). In many cases, large streamside buffers have failed to mitigate the impacts of increased stormflow intensity and poor water quality that result from urbanization. This is particularly common where expansive areas of hard surfaces (i.e. roads, parking areas, and building roofs) within a watershed collect surface water and convey it directly to the stream through storm sewers and outfalls.

During recent years, a number of local governments and agencies throughout coastal British Columbia have completed Environmentally Sensitive Areas (ESAs) studies which inventory and rate the sensitivity of biological, geological, hazard, and heritage lands within their study area (Abs et al. 1990; Berris et al. 1995). Where aquatic or Fisheries Sensitive Zones were established in these studies they were typically based on the stream setback distances recommended in the Land Development Guidelines for the Protection of Aquatic Habitat (Chilibeck et al. 1993). These guidelines require a minimum 15 – 30 meter fixed width leave strip between aquatic areas and low and high density development areas respectively. While this approach attempted to standardize leave area requirements and establish minimums, it has not been consistently attained and will not adequately protect many aquatic / riparian interactions. In addition variances are common in urban settings where land owners and managers argue that the application of the minimum prescribed setbacks would render many sites undevelopable. Relaxations have also been entertained on sites that have been historically impacted by land development. In these circumstances, rehabilitation and stewardship activities on the remaining land base have been required in an attempt to achieve "no-net-loss" in the productive capacity of fish habitat.

Difficulties in achieving compliance with leave area requirements are due in large part to historic land use zoning in settlement areas. In the majority of cases zoning implied uses and densities which were not sensitive to aquatic features or ecological function. As a result, incompatible land uses and dense developments have occurred immediately adjacent to many sensitive aquatic areas Riparian habitats in many settlement areas have also been significantly altered and compromised. These problems are further compounded by claims of private property rights, and allegations of land "sterilization". Given these impediments, significant changes to land use and settlement planning processes are required to proactively protect fish habitat on private property if fishery resources dependent on these habitats are to be sustained. A first step is to incorporate fishery management and reserve zones into local government's community planning processes. In fact, unless fisheries management and reserve zones are identified prior to zoning and subdivision, and protected through innovative site planning, density bonusing, land trusting, development right transfers, greenways planning, land use or environmental bylaws, or other proactive mechanisms, protection of sensitive aquatic habitats in urban settlement areas will not be achieved.

Specific objectives of this report include:

- Reviewing the body of scientific literature, unpublished reports, monographs, and proceedings which discuss the features and functions of aquatic and riparian ecosystems;
- Recommending dimensions for a broad scale ‘management zone’ to protect key functions and features of fish habitat and a site specific ‘reserve zone’ which would preserve direct interactions between aquatic habitats and riparian zones;
- Identifying fish habitat features that require protection in order to sustain fish populations; and
- Presenting a community planning based approach to delineating Fisheries Management Zones at the strategic community planning level and Fisheries Reserve Zones at the neighbourhood or site development level.

This report is divided into three sections.

- **Section 1** – provides an introduction to this project and an overview of the fisheries resources of coastal British Columbia.
- **Section 2** – summarizes information on specific fish habitat features provided by streams, floodplains, lakes and wetlands, hydrologic elements, and riparian areas.
- **Section 3** – presents a methodology for establishing fisheries management and reserve zone boundaries in association with local government land use planning processes.

1.1 FISHERY RESOURCES OF COASTAL BRITISH COLUMBIA

This document addresses urban and rural areas of coastal British Columbia which includes much of the Georgia Basin, the lower Fraser Valley, as well as portions of the north and west coasts of Vancouver Island and the fjords and islands of the central coast. Coastal British Columbia encompasses two ecoregions, the Coast and Mountains Ecoregion, and the Georgia Depression Ecoregion. In addition to providing productive habitat for up to ten salmonid species, many of British Columbia's coastal streams, lakes and wetlands are also inhabited by non-salmonid species that are critical to the ecology and biodiversity values of the region. Native fish species occurring in streams and rivers of coastal British Columbia are listed in Table 1 (from McPhail and Carveth 1993a; 1993b).

All of the fish species listed in Table 1 rely on stream or lake habitats for one or more phases of their life history including spawning / incubation, rearing, overwintering, and migration. A generalized life history diagram for anadromous salmonid species is shown in Figure 1. Table 2 summarizes specific habitat elements necessary during each of these various life phases.

2.0 FRESHWATER FISH HABITAT FEATURES

Critical fish habitat is provided by rivers, streams, lakes, wetlands, floodplains, hydrologic contribution areas, and riparian areas. These features need to be adequately protected if fish habitat and fish populations are to be maintained or restored. Fisheries Management Zones can be established and refined to a Fishery Reserve Zone to encompass the full extent of critical stream and riparian features and functional interactions. The following section discusses the nature, extent, and function of these interactions.

2.1 RIVERS AND STREAMS

Rivers and streams are often the central features of freshwater aquatic ecosystems and are characterized by flowing surface water within a defined channel. Rivers are generally large, perennially wetted features that are the product of many coalesced lower order streams. Streams can be separated into two classes based on flow regime: i)permanent or perennial and ii) ephemeral or intermittent. Permanent streams flow year round over bedrock or substrates deposited by alluvial processes. Ephemeral streams flow in direct response to intense precipitation and are located above the ground water table. During periods of channel flow they may be indistinguishable from permanent

Table 1. Native Freshwater Fish Species of Coastal British Columbia.

Common Name	**Species Name**
Salmonids	
Coho salmon	*Oncorhynchus kisutch*
Chum salmon	*Oncorhynchus keta*
Chinook salmon	*Oncorhynchus tshawytscha*
Sockeye Salmon	*Oncorhynchus nerka*
Pink salmon	*Oncorhynchus gorbuscha*
Rainbow trout / Steelhead	*Oncorhynchus mykiss*
Cutthroat trout	*Oncorhynchus clarki*
Dolly Varden	*Salvelinus malma*
Bulltrout	*Salvelinus confluentus*
Mountain whitefish	*Prosopium williamsoni*
Non-salmonids	
Three-spine stickleback[1]	*Gasterosteus aculeatus*
Western brook lamprey	*Lampetra richardsoni*
Pacific lamprey	*Lampetra tridentata*
Brassy minnow	*Hybognathus hankinsoni*
Peamouth chub	*Mylocheilus caurinus*
Redside shiner	*Richardsonius balteatus*
Northern squawfish	*Ptycocheilus oregonesis*
Salish sucker	*Catostomus sp.*
Nooksack dace	*Rhinichthys sp.*
Largescale sucker	*Catostomus macrocheilus*
Prickly sculpin	*Cottus asper*
Coastrange sculpin	*Cottus aleuticus*
River lamprey	*Lampetra ayresi*
Green sturgeon	*Acipenser medirostris*
White sturgeon	*Acipenser transmontanus*
Cowichan lamprey	*Lampetra macrostoma*
Longfin smelt	*Spirinchus thaleichthys*
Eulachon	*Thaleichthys pacificus*
Leopard dace	*Rhinichthys falcatus*
Bridgelip sucker	*Catostomus columbianus*

[1] Taxonomists have reported that several distinct species of three-spine stickleback may occur in Georgia Basin lakes, although they have not yet received official designation.

Figure 1. Generalized life history diagram for anadromous salmonid species (from Adams and Whyte 1990).

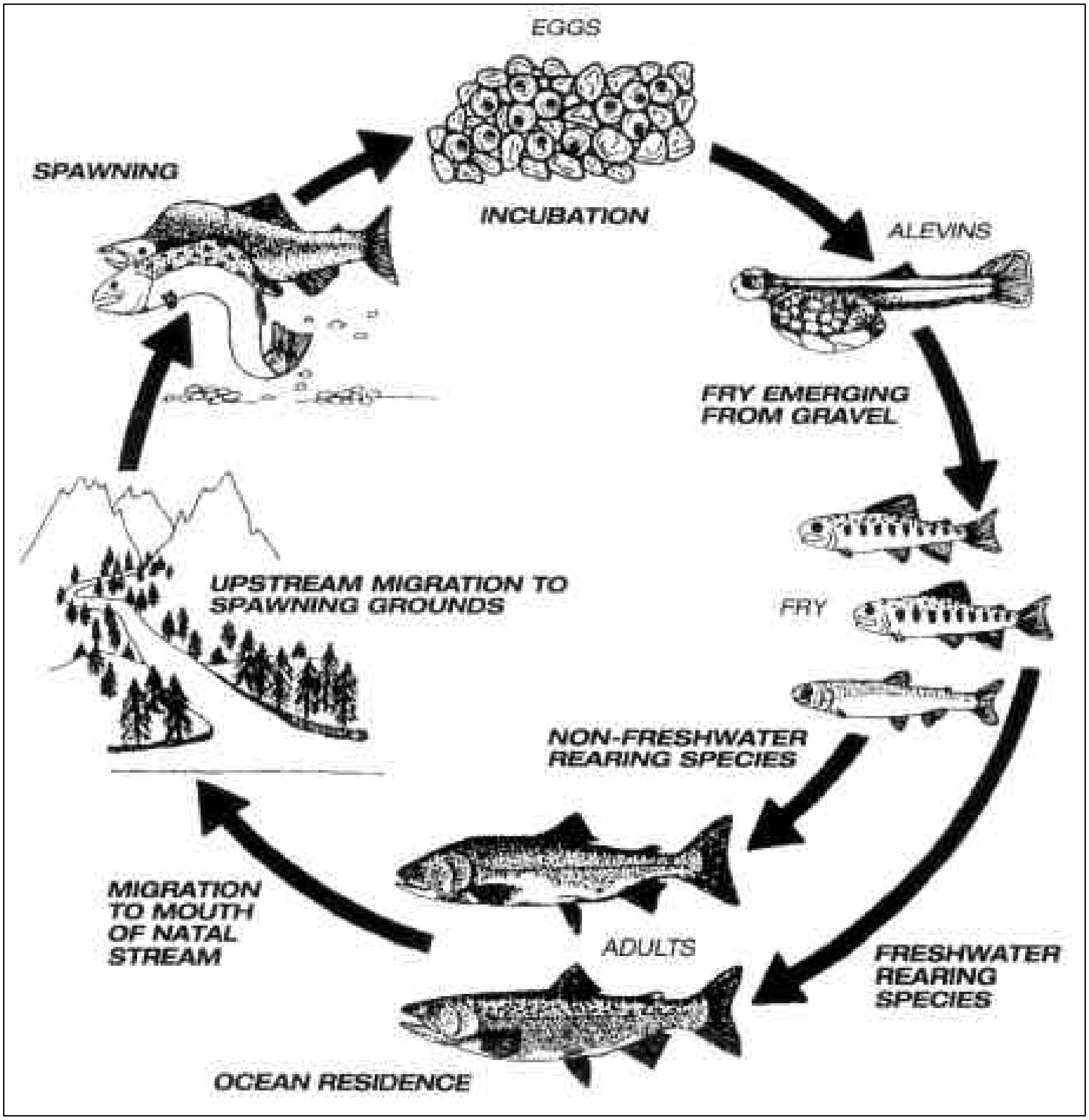


Table 2. Salmonid Life Cycle Stage and Important Habitat Requirements.

Life Cycle Stage	Habitat Requirements
Spawning / Incubation	· gravel of suitable size and quality · subsurface or intergravel flow of suitable quantity, quality and temperature · stable channel and stream bed characteristics · unobstructed access to spawning grounds during spawning periods · sustained flow volumes and velocities during incubation · continuous sources of gravel (mass wasting) · continuous source of baseflow (wetlands, headwater areas, and groundwater sources)
Rearing / Overwintering	· instream cover (i.e. large woody debris (LWD), undercut banks, boulders, cobbles) · optimum ratio of riffle, run, and pool habitats · overhanging riparian vegetation (i.e. shade and temperature regulation, insect drop and leaf litter) · high water refuge areas (i.e. off channel areas, ephemeral tributaries) · adequate water quality (dissolved Oxygen, temperature, pH, absence of contaminants) · suitable flow volumes and velocities · allochthonous or autochthonous food production
Migration	· suitable water volumes and velocities for juveniles and adults during migration · absence of impassable barriers or partial obstructions to fish migration (i.e. hanging culverts, dams, low flows, etc.)

streams; however, they typically become dry on an irregular or seasonal basis. Intermittent streams differ from ephemeral streams in that they are located near the ground water table and flow when snowmelt, precipitation, or groundwater seepages raise the level of the water table above the bed of the channel. When they are not flowing, ephemeral and intermittent streams can often be identified by the presence of terrestrial plant species such as grasses and quick growing annual species growing within their wetted perimeter. During the summer, ephemeral streams are often very difficult to locate or identify, particularly when they are overgrown with vegetation. Shallow swales or channels and alluvial deposited substrates can also indicate the location of ephemeral or intermittent streams. Despite the major difference in flow regimes between permanent, ephemeral and intermittent streams, they all provide important fish habitat.

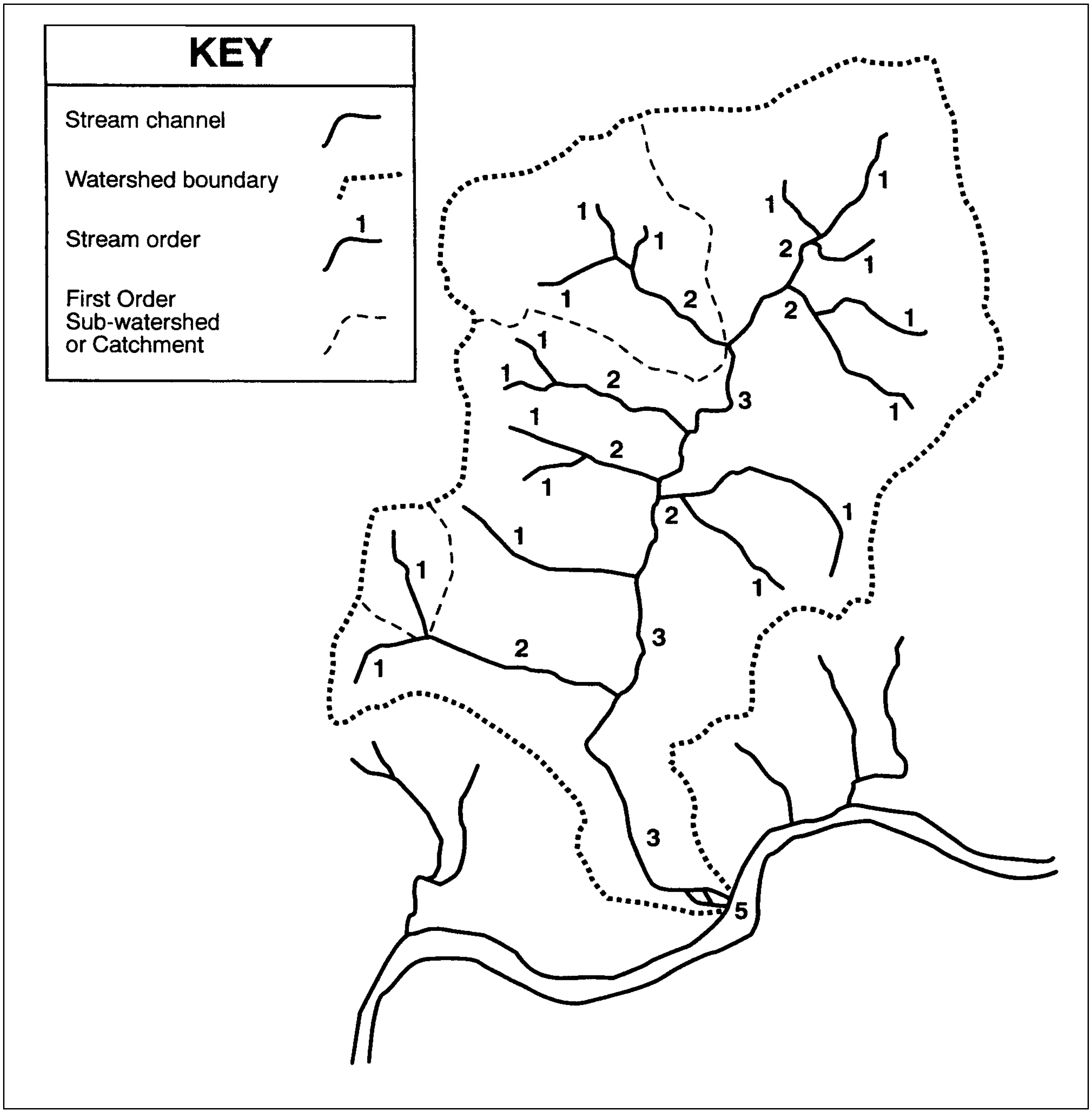
Stream channels are commonly classified into orders. Initial undivided headwater stream channels are designated as first-order streams. Two first-order streams combine to form a second-order stream. A third-order stream is formed by the union of two second-order streams (Everest et al. 1985), and so on (Figure 2). Many coastal first-order streams are generally small, high gradient ephemeral streams found in the headwater areas of a watershed. Second-order streams may also be ephemeral although they are more often characterized by permanent flow. Third to fifth-order streams generally provide productive salmonid rearing and spawning habitat. Fifth, sixth and seventh-order streams are generally larger systems with shallow gradients and serve as important migration corridors and summer rearing areas for salmonids.

2.1.1 Permanent Rivers and Streams

Permanent rivers and streams provide direct spawning, rearing, and migration habitat for many fish species in coastal British Columbia. Important habitat elements include:

- ***pools*** – pools are deeper habitat areas formed by localized streambed erosion with slower current velocities. In the field, pools are identified by the lack of surface turbulence attributable to stream bed substrates. Pools provide important juvenile rearing and adult holding areas;
- ***riffles*** – riffles are shallow, turbulent sections with higher gradients than pools or glides. Riffles usually provide spawning and summer rearing areas and are important areas of benthic food production. Riffles are often found at the outlet or tailout of pools in meandering gravel bed dominated rivers;
- ***stream banks*** – river or stream banks confine water conveyance to the channel under normal flow regimes and prevent unconfined lateral movement of the channel. Stream banks also provide important cover features and lower velocity areas for rearing and feeding. Undercut banks, which commonly occur at bends or in areas where a riparian plant root mass is undermined, are used by both juveniles and adults of most salmonid species for cover, summer rearing, and winter refuge;

Figure 2. Generalized coastal watershed showing the hierarchy of stream orders.



- ***large organic debris (LOD)*** – instream LOD results when downed trees, snags or rootwads fall into the stream channel. Large organic debris serves many functions including increasing stream channel complexity and roughness elements, recruiting and stabilizing spawning gravels and providing instream cover for fish;
- ***gravel bars*** – gravel bars occur in depositional areas and along banks where water velocities are reduced. Point bars are situated at the inside of meander bends. Gravel bars provide a source of spawning gravel during scour events;
- ***bed substrate*** – well graded uncompacted gravel substrates provide spawning habitat for adult salmon and trout, incubation areas for eggs and support invertebrate and algae communities which provide fish food; whereas cobble / boulder substrates can provide overwintering habitat for both juvenile and adult fish;
- ***subsurface and intergravel water flow*** – intergravel flow maintains a steady source of cool, oxygenated water for incubating eggs. Shallow subsurface flow from upslope areas or groundwater into the stream channel provides a source of baseflow that is a consistent temperature;
- ***live trees and root systems*** - live trees and root systems stabilize channel structure and are sources of LOD for rivers and streams. In addition, overhanging vegetation provides cover and a source of terrestrial insects (fish food items); and
- ***obstructions and barriers to fish migration*** – instream barriers and obstructions can interfere with natural upstream and downstream migrations of fry, smolt, and adults. Barriers prevent fish passage under all flows while obstructions (sometimes called partial barriers) typically prevent upstream migration only under specific flow levels (i.e. low summer flows). Natural barriers and obstructions include falls and inclines, rock slides, log / debris jams, and beaver dams. Anthropogenic modifications to the stream channel, stream bed elevation or composition of substrate by construction of dams, culverts, instream weirs or dykes or as a result of dredging and bar scalping also restrict or impede fish passage.

2.1.2 Ephemeral and Intermittent Streams

Ephemeral and intermittent streams provide seasonal rearing and high water refuge habitat for fish, and function as important water quality and discharge moderators. In addition, they can provide critical salmonid holding and spawning habitat particularly when flood events displace adult spawners out of the main channel because of high flow velocities. Permanent streams are generally fed by a large number of ephemeral and intermittent streams in headwater areas. Therefore, first-order tributaries are critical areas which require protection. Important fish habitat elements of ephemeral and intermittent streams include:

- ***wetted area*** – under seasonal high water conditions following periods of heavy precipitation or snowmelt, surface flow can be established in ephemeral or intermittent channels, thereby flushing water, nutrients and food sources to downstream fish-bearing waters, or providing direct access to additional habitats; and
- ***high water refuge*** – ephemeral and intermittent channels provide important refuge areas for fish during high water precipitation events. Fish will move into ephemeral channels when flow volumes, water velocities or sediment loading become excessive in the main permanent channel.

2.2 LAKES AND WETLANDS

Wetlands are areas of permanently or intermittently standing water that lack significant channel flow. Runka and Lewis (1981) defined them as: “lands that are wet enough or inundated frequently enough to develop and support distinctive natural vegetative cover that is in strong contrast to the adjacent matrix of better drained lands.” The Canadian Wetland Classification System (National Wetlands Working Group 1987) recognizes several classes of wetlands including bog, fen, marsh, and swamp, each of which are defined below. Wetland areas contribute directly to fish habitat by maintaining stream baseflows and water quality. As well, fish accessible open water wetlands are used extensively by some fish species for rearing and spawning.

Bogs are peatlands where the water table (sustained largely by precipitation) is low in nutrients and is at or near the surface. Bogs may be treed or treeless but are usually covered with Sphagnum moss.

Fens are peatlands where the water table (derived from mineral soils) is nutrient rich and is usually at or a few centimetres below the surface. Fens are dominated by vegetative communities consisting of sedges, grasses, reeds and brown mosses with some shrubs and, at times, a sparse tree cover.

Marshes are mineral wetlands that are permanently or seasonally inundated up to a depth of two meters by standing or slowly moving water. The waters are nutrient rich and the substrate is usually mineral soil. Marshes are characterized by vegetation that includes emergent rushes, grasses and reeds, and submerged or floating aquatic plants in open water areas.

Swamps are wooded mineral wetlands or wooded peatlands with standing or gently flowing water in pools and channels. The water table is generally at or very near the surface. Waters are nutrient rich. Vegetation is a dense cover of deciduous or coniferous trees or shrubs, herbs and some mosses.

Important habitat elements of wetlands include:

- ***Open water*** – accessible open water areas are used for rearing, spawning, and overwintering by a variety of fish species;
- ***Flow regulation*** – wetland areas can store significant volumes of water during high water periods, gradually releasing it during drier periods. Wetlands also serve to dissipate flow energy;
- ***Recharge areas*** – wetland areas occurring in natural depressions can be recharged by local precipitation or by regional groundwater flows and serve to augment stream baseflows;
- ***Food source*** – wetlands are important insect, invertebrate and detritus production areas which support the aquatic food chain. Fish food produced in wetlands can be exported by water movements or consumed directly by fish where direct access to the wetland is available; and
- ***Water quality*** – is often maintained or enhanced by wetlands which can filter water-borne pollutants and fine sediments, and bioaccumulate other contaminants.

2.3 FLOODPLAINS

Floodplains are relatively flat areas within the stream valley that lie adjacent to stream channels and are periodically inundated when the stream overtops its banks in response to heavy rainfall or snowmelt. They are ecologically and geomorphologically dynamic areas that are actively modified by erosion and deposition processes during flood events. Floodplain vegetation communities are often more diverse than upland areas, which reflects the chronic flooding regime, high productivity, and range of soil moisture conditions that characterize these areas. Floodplains provide direct (although often seasonal) rearing and high water refuge habitat for salmonids and other fish species. Most importantly they are areas in which natural stream channels migrate laterally in response to flows and stream processes. This natural process is fundamental for the creation and rejuvenation of riverine fish habitats.

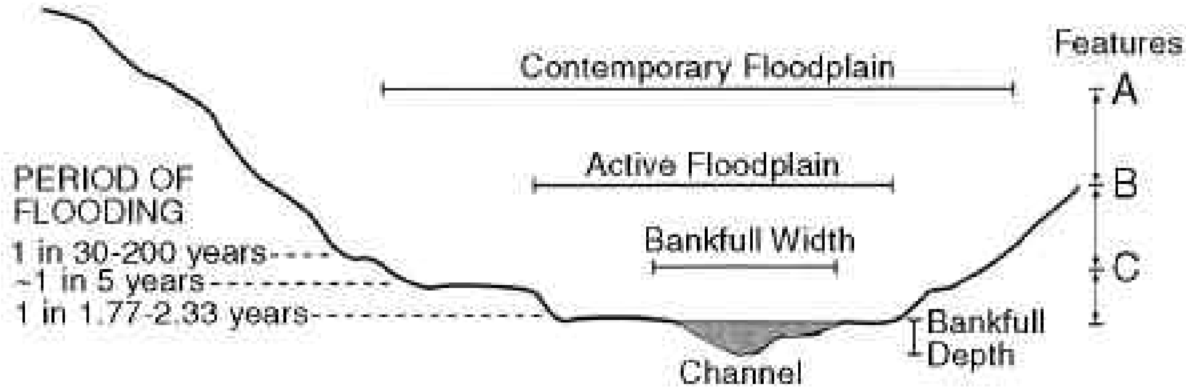
Floodplains are commonly classified according to flooding frequency. This report has adopted the floodplain classification scheme outlined by the Clayoquot Sound Scientific Panel (1995). Their report divided floodplain areas into two classes based on frequency of inundation: i) active floodplain, and ii) dry floodplain. Together, these areas were included within a single unit designated as the contemporary floodplain. A generalized cross section showing the relationship of floodplain class and recurrence interval is shown in Figure 3.

The ***active floodplain*** is the area adjacent to the stream channel that is occupied by flowing or standing water on average once in five years (1 in 5 year recurrence interval) (Clayoquot Scientific Panel Report 1995). Its lower elevational extent is defined by the bankfull discharge level, an elevation that is reached when stream water begins to overtop the banks of the channel and inundate the adjacent floodplain (Leopold 1994); Leopold et al. 1964). In largely undisturbed systems with uniform hydrology the recurrence interval of the bankfull discharge level is typically assumed to be between 1 and 2.5 years with an average of approximately 1.5 years. This dominant discharge level is important because it coincides with the maximum sediment transport capability of channels in low gradient streams which significantly influences channel form via erosion, and sediment transport and deposition.

An estimate of bankfull elevation can often be determined in the field from the following features (Harrison et al. 1994; Leopold 1994):

- the upper elevational extent of gravel and cobble point bars on the inside of meander bends (point of active floodplain formation);
- well defined points of undercutting or bank erosion;
- a marked change in vegetation such as the change between unvegetated gravel bars and terrestrial shrub and herbaceous species as well as visible signs of erosion at tree roots;
- visible change in the size distribution of surface sediments such as the change from sand to gravel, or fine gravel to cobble;
- prominent changes in slope between the banks of the stream channel and adjacent floodplain areas; and
- lines of sediment, lichen, or mosses on stable substrates and bedrock banks.

Figure 3. Generalized cross-section showing relationship of floodplain class and recurrence interval.



Features:

A

- Soils and vegetation representative of occasional disturbance and deposition due to flooding.

B

- Mineral to organic soils
- Flood-tolerant vegetation
- Presence of off-channel fluvial features (side channels, oxbows, ponds)

C

- Routinely wetted shrubs and water-tolerant vegetation
- Transition to larger bank materials
- Undercut with eroding banks

The **active floodplain** has been described by Kistritz and Porter (1993) as: riparian woods or seasonal wetlands with mineral-rich soils that were formed by fluvial or lacustrine processes. Inundation occurs during periods of flooding (return period less than five years), induced by peak river flows, rising lake levels, or periods of intense precipitation. Saturation or inundation is seasonal with occasional periods of severe flooding during years of extreme run-off. Soils are well aerated mineral to organic in composition. The vegetation is characterized by dense cover of flood-tolerant trees and shrubs which can be deciduous (e.g. cottonwood, willows, alders, red-osier dogwood) or coniferous (e.g. western red cedar, hemlock, various spruces).

Above the active floodplain is the ***dry floodplain*** which is subject to only occasional inundation caused by heavy continuous rainfall from major storms or rain-on-snow events. The recurrence interval for flooding of the dry floodplain is between 1 in 5 and 1 in 30 years. The upper elevational extent of the dry floodplain is typically 60 to 80% of bankfull height (the height between the stream bed and bankfull elevation) (Leopold, 1994),

The ***contemporary floodplain*** is "the valley bottom adjacent to a stream channel that is subject to inundation in the contemporary streamflow regime and that, consequently, has soils composed of recently deposited sediments" (Clayoquot Sound Scientific Panel 1995). This area encompasses both the active and dry floodplains and is therefore defined by a flood recurrence frequency of greater than once in thirty years (up to 1 in 200 years).

Identifying floodplain areas in the field can be extremely difficult. As the Clayoquot report (1995) states: "In practice, frequency of inundation on many floodplains cannot be precisely determined: the presence of water tolerant understory plants may be the best indicator of water sources. Dry floodplain areas may be best distinguished by the presence of overbank stream sediments deeper than in the active floodplain, on which a substantial litter layer (LFH horizon) has accumulated." Professional hydrologists or geomorphologists should be consulted where it proves difficult to precisely determine the location and extent of floodplain areas.

Fish habitat elements which typically occur in the contemporary floodplain include:

- ***side and groundwater channels*** – run through the floodplain connected to the main channel and are generally maintained by natural surface flow diversions, through gravel seepage or groundwater sources. These areas often provide important spawning, rearing and high water refuge areas;

- ***off-channel pools*** – off-channel pools in the floodplain often provide good refuge and rearing habitat for fish. They may be sustained by groundwater flow and are often inundated during flood events;

- ***sediment storage areas*** – once permanent streams overtop their banks and inundate a floodplain, flow velocities are reduced and sediment settles out of suspension onto the floodplain;
- ***channel migration corridor*** – floodplains provide areas for the stream channel to migrate over time and therefore play an important role in the natural evolution of a stream system and maintenance of natural stream processes;
- ***point mid channel, and side bars*** – point bars are located in the depositional area on the convex side of meander bends and represent the point of active floodplain formation, while mid channel and side bars may be formed by avulsions, bank sediment sources or depositions from tributary streams;
- ***high water refuge areas*** - include off-channel ponds, backwaters, avulsions and smaller tributaries which are inundated during flood events and where water velocities and sediment loads are lower than the main channel;
- ***vegetation communities*** – vegetation in floodplain areas is usually diverse and vigorous due to high soil productivity and the lack of a long-term summer moisture deficit. This results in dense growth with higher than average nutrient filtering capacity. The disturbance regime contributes to the high structural diversity of these areas which is comprised of snags, downed logs, and a multilayered canopy;
- ***LOD development areas*** – are provided by growth and supply large trees and wood in the riparian or forested areas of the floodplain; and
- ***food source*** – floodplain vegetation provides an important source of insects and invertebrates that become prey items for downstream fish populations.

2.4 WATERSHED ELEMENTS

There are critical factors that extend beyond site specific features to the watershed level. These features, individually small in size and nature, can cumulatively have an overwhelming effect on the very functioning of a stream’s hydrology and ecology. Hydrology and ecology are inextricably linked. A critical component of an ecologically healthy stream system is a fully functioning hydrological regime that provides water quality and quantity and supporting habitat elements from year to year.

Watershed elements that are important for the maintenance of fish habitat include:

- ***first order drainage*** – coastal headwater areas or first order streams are often characterized by many small surface runoff areas, rivulets, gullies, small unconfined channels, springs and groundwater seeps which are cumulatively the source of both surface flows and baseflows for the watershed’s streams;
- ***Landscape level features*** – features at a landscape level that are often not included due to their anonymity within the watershed. For example, the amount of developed area, cleared or harvested forest or “green space” within a watershed can

have a direct and pronounced impact on the hydrology and water-dependent resources within that watershed;

- ***groundwater recharge areas*** – various areas in a watershed including headwater areas can be associated with local (<1 ha) or regional (1 to 10 ha) scale depression, glaciofluvial outwash areas or other permeable surficial geological features which act as groundwater recharge areas which sustain baseflows (i.e. groundwater flows sustaining streamflows during times of no runoff from precipitation or snow melt);
- ***groundwater discharge areas (springs and seepage sites)*** – provide important baseflow components to flows throughout the watershed. These features provide critical spawning, incubation and summer rearing areas for salmonids;
- ***sources of substrate and sediment*** – headwater areas of coastal streams are typically characterized by rugged high gradient terrain. Natural mass wasting processes in these areas often provide an important source of sediments required for stream processes and important biological functions (i.e. spawning cobbles and gravels for salmonids); and
- ***ephemeral non-connected areas*** – ephemeral catchments capture precipitation and moderate watershed hydrology by intercepting, detaining and infiltrating water during periods of heavy precipitation.

Many of the impacts of development on or near streams stem from inadvertent changes or interruptions to surface and subsurface drainage patterns that can lead to reduced summer flows, poor water quality, and higher and more frequent peak flows.

Simple clearing of forested watersheds cause significant changes in the hydrology of these basins. Studies by Jones and Grant (1994) have showed that 25% patch clearcutting and associated road systems induce a 50% increase in the magnitude of all runoff events in watersheds less than 100 hectares in size. Continuous hydrological simulation of a small watershed in North Vancouver (Currie et al. 1995) showed that for small 1 in 2 year storms, development of roads and storm drainage systems increased peak flows by 50%. Current levels of building development increased peak flows by 150%.

Urban development leads to the creation of effective impervious area (EIA) which is a measure of the total area where water does not infiltrate into the soil and that is connected directly to the drainage network (i.e. storm drain and trunk system). Recent studies in Puget Sound watersheds indicate that instability of stream systems become apparent at an effective impervious area of 10% in the watershed (Booth and Reinelt 1993). A summary of studies showed that stream degradation and aquatic resource impacts increase dramatically after approximately 10 – 15% EIA development in a watershed (Watershed Protection Techniques 1994). Recent surveys of the Lower Mainland indicate that watershed EIA coverage in many urban areas exceeds 30% (Rood and Hamilton 1994). Analysis of effects of urbanization and development of EIA on a watershed is fundamental to understanding the effects of hydrological changes on stream systems and aquatic resources.

Groundwater recharge and discharge area are hydrologically important areas and should be managed for the protection of flows and water quality for fish and fish habitat. Recharge can occur in headwater areas characterized by unconsolidated, pervious soils. Effective rainfall, depth of soil horizon, area, location of these soils relative to deep and shallow aquifers, aquifer depth, and topography determine the potential groundwater yield and influence on surface-flowing streams. Groundwater discharge areas such as springs and seepage sites are often located directly adjacent to stream channels and are therefore typically encompassed within the protection zone for floodplains, wetlands, and steeply sloped areas. Common field indicators of groundwater discharge include:

- hydrophilic plant species such as skunk cabbage, devil’s club, sedges, and rushes that are not directly associated with streams, floodplains, or wetlands with surface inflow;
- saturated soils and presence of surface water outside of precipitation periods; and
- localized areas of erosion slumping, and/or soil creep.

Groundwater discharge and recharge contribute to the ecological health of stream systems by maintaining baseflows and adequate water quality where low flow conditions may be a limiting habitat factor for fish production. Consequently analysis of development impacts on groundwater recharge and discharge in watersheds should be undertaken where baseflow maintenance is an issue.

Conversion of the watershed from natural land cover to a developed state can have dramatic effects on the cumulative water yield, timing and frequency of runoff events and quality of stream flows in a watershed. The retention of critical first order catchments, ephemeral areas and other hydraulically-connected areas is key to preserving the hydrology and fluvial processes in streams, rivers and other water bodies. Current land use and levels of development in urbanizing watersheds in B.C., combined with current stormwater management practices, will not protect the hydrological process in these streams, nor the resources that depend on those processes. Recent research indicates that improved land use practices and limits to development in watersheds are the only plausible solutions to maintaining self-sustaining processes and resources in these watersheds.

2.5 RIPARIAN AREAS

The riparian zone is recognized as an important transition zone between aquatic and terrestrial environments and serves as a link between upland and lowland ecosystems (Franklin 1992; Gregory et al. 1991; Swanson et al. 1992). Its extent is often indicated by the presence of hydric soils or hydrophilic plant communities. Unfortunately, this definition does not adequately reflect the interactions that occur between streams and riparian areas, especially along coastal streams in the Pacific Northwest (Cowardin et al. 1979). A more holistic definition recognizes the direct interactions such as microclimate regulation, LOD recruitment, and nutrient flow that occurs between these two environments (Oliver and Hinkley 1987). The dimensions of a riparian zone or the riparian zone of influence can extend a considerable distance away from the margin of an aquatic feature. Because many stream protection issues focus on riparian zones, this report provides a detailed description of their importance to fish habitat.

Typically, the coastal riparian zone supports a distinct vegetation community that is adapted to high soil moisture and light conditions, as well as to chronic episodic disturbances that characterize riparian areas (Franklin 1992). In coastal British Columbia, mature riparian areas are characterized by heterogeneous deciduous and coniferous forests dominated by western red cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)*, Douglas fir *(Pseudotsuga menziesii)*, red alder *(Alnus rubra)*, big-leaf maple *(Acer macrophyllum)*, and black cottonwood *(Populus balsamifera spp. trichocarpa)*. Common understory shrub species include salmonberry *(Rubus spectabilis)*, vine maple *(Acer circinatum)*, Indian-plum *(Oemleria cerasiformis)*, Pacific ninebark *(Physocarpus capitatus)*, devil's club *(Oplopanax horridus)* and several fern species.

In addition to interacting directly with streams and wetlands to sustain fish habit, riparian zones provide critical habitats for a wide variety of wildlife and birds (Moring et al. 1985; O'Laughlin and Belt 1995). There is no habitat type upon which birds and wildlife are more dependent (Budd et al. 1987). Reasons for this include (from Oakley 1985):

- Riparian zones contain water cover and food – the three critical habitat components.
- Riparian zones have greater diversity of plant composition and structure than uplands. There are more internal edges and strata in a short distance due to the mix of understory shrubs, deciduous trees, and coniferous trees in riparian areas compared to adjacent upslope forest stands. Where riparian zones are dominated by deciduous vegetation, the habitat types they represent will change between late fall / winter when canopy is reduced and late spring / summer when vegetation is in full leaf.
- The elongated shape of most riparian zones maximizes edge effect with the surrounding forest as well as with water This produces high edge-to-area ratios, and creates diverse and productive habitats for many species.
- Riparian zones have different microclimates than surrounding coniferous forests due to increased humidity, higher rates of transpiration, and convection which increases air movement. These conditions are preferred by wildlife during hot weather.
- Riparian zones provide permanent or temporary habitat and seasonal or daily travel corridors for many wildlife species. Abundant cover, water and food supply support

birds, small mammals and ungulates which disperse into new territories seasonally and use riparian areas as seasonal migration corridors. Strips of mature forest left along streams also serve as ‘connectors’ for wildlife to move between otherwise isolated stands of older growth or between upland and lowland habitats.

- The disturbance regime of riparian zones is generally more variable than in upslope areas, although it is significantly influenced by upslope processes. The disturbance regime of riparian areas results in a concentration of more varied habitat niches (i.e. structural elements such as snags, downed logs, and a multilayered forest canopy) that are important for wildlife species.

2.5.1 Interactions Between Stream Channels and the Riparian Zone

Streams and their associated riparian zones interact to create and sustain many elements of productive fish habitat. Direct functional interactions between stream channels and the riparian zone include (after Gregory et al. 1991; Franklin 1992; McDade 1990):

- Recruitment of large organic debris including fallen logs and snags into the stream channel;
- Addition of nutrients and organic matter (e.g. litter and insect fall to the channel);
- Stabilization of the banks and stream bed substrates(e.g. bedload movement);
- Modification of microclimate (e.g. light, temperature, and humidity); and
- Control of the flow of water, sediments, and nutrients from upslope areas into the stream channel.

The width of riparian zones required to protect various habitat features, functions, and processes are presented in Figure 4. These functional interactions are described below.

2.5.2 Recruitment of Large Organic Debris

The principal factor regulating the structural complexity of coastal streams is the addition of fallen logs and trees (large organic debris) into the channel (Bisson et al. 1987; Harmon et al. 1986; Swanson et al. 1992). Large organic debris (also commonly referred to as large woody debris (LWD) or coarse woody debris (CWD) consists of downed tree material which exceeds 10 cm in diameter and 2 m in length, and often approaches 25 cm in diameter and 5 m in length in old growth forests. The lower limits on size of large organic debris provide for the inclusion of material that is no larger than logging slash. This material may accumulate, and contribute to fish cover. However, the most significant components of LOD consist of the larger and more stable pieces of wood (i.e. full length fallen trees, tree boles and root wads). Large organic debris inputs are regulated by the dynamics of the surrounding riparian forest and landscape, which involve biotic factors such as episodes of natural forest stand thinning and abiotic processes of blowdown, mass wasting, and streambank erosion (Swanson et al. 1992).

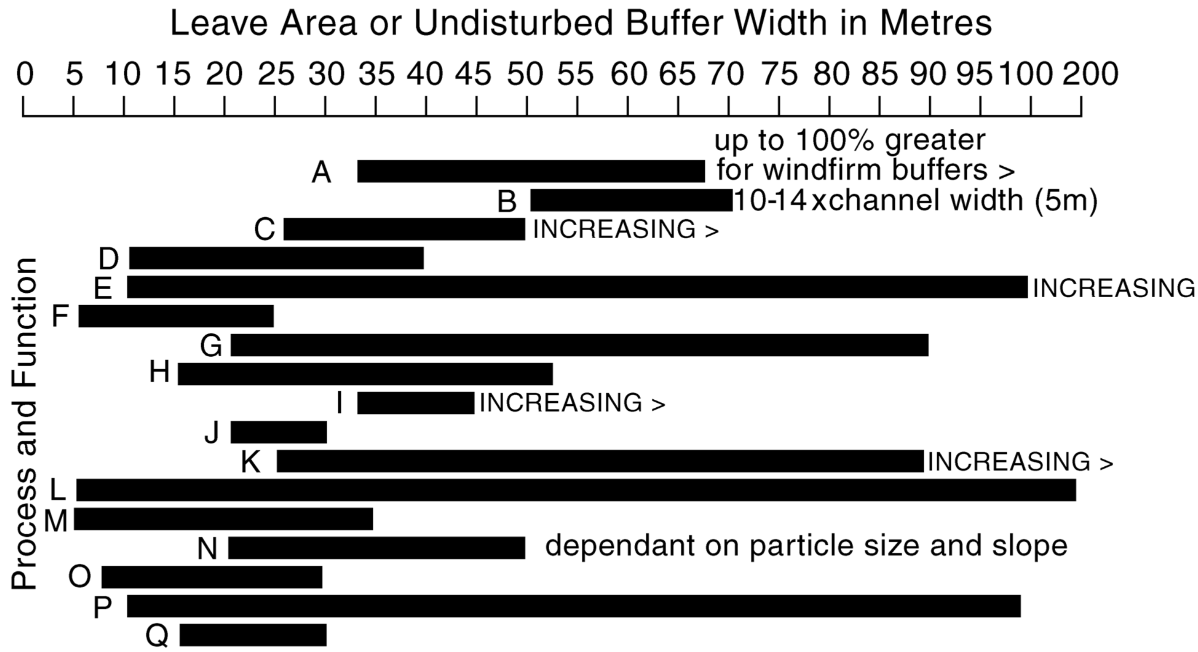


Figure 4. Riparian setback distances required to protect habitat functions, processes, and features.

Instream Processes:

A Large Organic Debris recruitment ----------- O'Laughlin & Belt 1995; McDade et al. 1990; Robison & Beschta 1990
B Floodplain processes --------------------------- Hartman et al. 1996
C Bank stability ------------------------------------- Wu 1976
D Stormwater control/water storage ------------ Johnson & Ryba 1992

Water Quality:

E Sediment removal -------------------------------- Ghaffarzadeh 1992; Gilliam 1988; SCS 1982; Lynch et al., 1985
F Chemicals/metals/nutrient removal ---------- Vanderholm & Dickey, 1978; Xu et al., 1992
G Coliform reduction ------------------------------- Grismer, 1981
H Water temperature moderation --------------- Beschta et al., 1987 Corbett & Lynch, 1985; Lynch et al. 1985

Aquatic and Riparian Habitat

I Benthic invertebrates ---------------------------- Newbold 1990; Erman 1977; Roby 1977
J Insect fall, leaf litter and debris ---------------- FEMAT 1993; Steinblum 1984
K Moderation of microclimate -------------------- Chen 1991
L Wildlife diversity and distribution -------------- Jones et al. 1988; Castelle et al. 1994; Peterson et al. 1992; Allen 1983

Other:

M Noise abatement --------------------------------- Groffman et al. 1990; Harris 1986
N Mitigation of forest harvesting ----------------- Forest Practices Code of BC Act 1995
O Local governments standard ----------------- Johnson & Ryba 1992
P Provincial and state standard ----------------- Johnson & Ryba 1992
Q Present federal standard ---------------------- Chilibeck et al. 1993

In undisturbed forested streams, LOD contributes to fish habitat complexity by creating small dams, scour pools, undercut banks, gravel bars, backwater eddies, overhead cover, and other morphological attributes that are recognized as productive fish habitat. Tree roots, trunks, and branches may account for 50% or more of the habitat diversity in small, densely forested stream reaches (Franklin 1992). Wesche et al. (1987), working with brown trout in Wyoming, found that woody debris and associated overhead cover accounted for 31% of the selection of habitat location by fish. Other cover elements such as depth and rubble size were not as significant. In Pacific coast streams of North America, LOD is a critical habitat element. In Carnation Creek, British Columbia, young of the year and one year old coho and steelhead were found to be closely associated with LOD as temperature decreased (Bustard and Narver 1975). Numbers of coho occurring in reaches of Carnation Creek (Tschaplinski and Hartman 1983), as well as in sections of Alaskan streams (Murphy et al. 1989) were positively correlated with the volume of LOD. Stream habitats that were less complex supported lower densities of cutthroat trout (Fausch and Northcote 1992), and cover that was less complex attracted fewer juvenile coho. Without LOD, provided by the riparian zone, coastal streams are severely compromised in their ability to support salmonids.

The volume and distribution of LOD is variable depending on the size of the streams, with the volume of LOD in most cases being lower in the downstream reaches of large streams. The increased transport capacity of larger streams results in the removal of wood from the channel and lessens the riparian influence in progressively larger streams (Swanson et al. 1982a). Local topography is also a significant factor as LOD recruitment will occur over greater distances where the terrain adjacent to the channel is steeply sloped. Furthermore, the spatial distribution of large debris also varies predictably from small streams to large rivers. Large organic debris is generally stable and evenly distributed across small shallow streams while it is less stable and concentrated along the banks of larger and deeper rivers. In small streams, LOD is typically large relative to channel dimensions and stream flow volumes, so it cannot be readily floated and redistributed. Therefore, its relative importance in maintaining channel stability and complex salmonid habitat is higher in small channels. However, Swanson et al. (1992) noted that the contribution of LOD to habitat complexity can also be significant along the channel banks and bars of higher-order systems.

The literature suggests that LOD recruitment extends further from the stream channel than any other interaction between the stream and riparian zone. McDade et al., (1990) investigated source distances for LOD in forested streams in western Washington and Oregon, an area that is geographically comparable to coastal British Columbia. They found that, while 70% of LOD originates from within 20 m of the stream channel, a slope distance equivalent to one mature tree height (or approximately 50 m in coastal B.C.) perpendicular to the stream is required to maintain 100% of predevelopment LOD recruitment. The requirement of one mature tree height to maintain LOD recruitment has also been recommended by other researchers (Robison and Beschta 1990; O'Laughlin and Belt 1995). Retaining a riparian buffer equal to one tree height also serves to protect trees in the riparian zone against blowdown (Hooper 1994).

The importance of the riparian zone's role as a source of LOD cannot be overemphasized. The quantity of LOD in a stream at any specific time is a result of the balance between input and output processes over a period of centuries (Swanson et al. 1992). However, immediately following removal of trees in the riparian area initial loss rates of LOD are high. In a review of the decline rates of LOD volume from streams on Vancouver Island, the Queen Charlottes, and the Olympic Peninsula, the volume was noted to decrease to approximately 50% of pre-logging levels in 20 years and to about 38% in 65 years (Scrivener and Brown 1993). In Carnation Creek on Vancouver Island the decline in LOD volumes following logging was dramatic and rapid, with a concomitant impact on fish habitat. As the volume and stability of LOD decreased the material tended to clump and local channel geometry changed significantly (Toews and Moore 1982).

2.5.3 Addition of Organic Matter

Riparian zones generate a large proportion of the food and prey items which are important to fish. Benthic invertebrates, algae, terrestrial insects, leaves, and other organic material are important food sources for fish and provide nutrients and mineral input to the water (Budd et al. 1987). Input of organic matter originating in the riparian zone provides up to 99% of the energy which is processed in small and headwater streams (Moring et al. 1985); Budd et al. 1987; Green and Kauffman 1989; Swanson et al. 1992; Tims 1994). Inputs of organic matter from the riparian forest does, however, decrease as channel width increases (Naiman 1992).

LOD in low and mid-order streams also tends to trap sediments and nutrients in the channel and store them for a longer period in the system. This allows invertebrate communities to more fully utilize organic inputs to the stream (Naiman 1992). Franklin (1992) emphasized the importance of maintaining a high diversity of vegetation in the riparian zone. Streamside zones with a more complex herbaceous, shrub and tree community generate more diverse organic inputs qualitatively and temporally than those dominated by a single species.

A buffer width of one-half the height of a site potential mature tree (approximately 25m) can provide close to maximum litter-fall effectiveness (FEMAT 1993; O'Laughlin and Belt 1995). To minimize effects on invertebrate communities, Budd et al. (1987) recommends a stream protection buffer width of 30 meters which would serve to maintain temperature and light levels conducive to invertebrate production.

2.5.4 Stabilization of the Stream Channel

In addition to the roles that the riparian zone and instream LOD play in providing and storing nutrients and increasing habitat complexity, they can also provide physical stability in many streams. Instream large organic debris acts to reduce water velocities and increase the hydraulic complexity of streams by forming a sequence of pools and riffles (Swanson et al. 1992). The soil binding properties of root systems also reduce bank erosion thereby maintaining bank stability (Groeneveld and Griepentrog 1985) and preventing sedimentation in the system (Hartman and Holtby 1982). It is important to note that some types of streams, such as bedrock confined channels, are less influenced by stable vegetated banks and instream LOD than more typical coastal stream channel forms. Notwithstanding this, the riparian zone also contributes to stream channel stabilization through other mechanisms including:

- ***Dissipation of flow energy*** **–** Riparian vegetation and its associated root systems increase channel bank and bed roughness which dissipates flow energy. Furthermore, LOD in small streams helps step the gradient such that the streambed becomes a series of long, low gradient sections separated by relatively short, steep falls or cascades in areas of LOD accumulation. This channel morphology is associated with an overall reduction in flow energy (Heede 1985);

- ***Reduction of bedload movement*** **–** Areas of LOD accumulation act as hydraulic breaks and lead to the formation of depositional silt in low velocity areas. Megahan and Nowlin (1976, in Swanson et al. 1982A) found that LOD made up 75% to 85% of the obstructions that trapped sediment which was stored in small order streams. Flow velocities are reduced upstream of each hydraulic break forming localized depositional areas. Once sediment accumulates above the LOD steps, the gradients will be reduced below those of the original bed, thereby decreasing flow velocities. Furthermore, instream LOD provides a series of invert control points that reduce channel downcutting by restricting bedload movement;

- ***Moderation of hydrology*** – Pool formation and the backwatering associated with debris jams and accumulation of LOD increases the detention time of water in a stream system. This moderates hydrology by retaining water in the stream following precipitation and snowmelt events and helps to maintain baseflows during dry (summer) periods. The riparian areas can also moderate flows by increasing the subsurface storage of water and by delaying and reducing the volume of water reaching the stream following a precipitation event; and

- ***Protection of stream structure and processes*** **–** Based on reviews of natural channel meander evolution, instream structure geotechnical stability, and assessments of the downstream implications of riprap and other bank stabilization measures a riparian setback which is equivalent to 10 - 14 times channel width has been recommended to prevent significant changes in channel morphology (Hartman et al. 1996).

2.5.5 Modification of Microclimate

The regulation of stream temperature, humidity, and light levels is also an important function of the riparian zone (Brown 1969; Beschta et al. 1987). Riparian vegetation creates a microclimate that helps maintain a more constant stream temperature (Budd et al. 1987). Other factors which help to moderate microclimate include the steepness and height of the valley walls, stream orientation, inflow of cool surface and groundwater, undercut embankments, organic debris, surface areas and stream velocity (Barton et al. 1985; Budd et al. 1987).

The maintenance of stream temperature was one of the first forestry-fisheries interactions that was comprehensively studied. Although moderate stream temperature increases resulting from riparian clearing can increase salmonid smolt production in the short term (Holtby 1982), long term salmonid production invariably decreases due to resulting channel destabilization, reduced LOD recruitment and reduced organic matter input to the system. Furthermore, extreme temperatures (above 25 C) can occur as a result of excessive riparian clearing and may lead to fish mortalities.

Studies have found that shading of the channel from direct solar radiation correlated well with stream temperatures. While the shading benefits will be determined to some extent by the type density and height of vegetation, many investigations of stream shading rely on Angular Canopy Density (ACD). This is a measure of the projection of the forest canopy at the angle direct sunlight passes through the canopy (Beschta et al. 1987). In old-growth forests, the ACD is generally between 80 and 90%. Studies of buffer strip widths required to maintain this level of shading indicate that a buffer between 22 m (Brazier and Brown 1973) and 37 m (Steinblums et al. 1984) is optimal. By comparison, a 15 m buffer provides only 40% of the predevelopment ACD level, or less than half the level of shading that occurs in old-growth streams. The importance of the riparian zone for shading is more significant in small streams than large streams as greater flow volumes in larger streams mitigate surface temperature increases due to solar radiation (Budd et al. 1987).

Air temperature (e.g. microclimate) may be an important factor regulating stream temperature (Holtby and Newcombe 1982; Cluis 1972). FEMAT (1993) acknowledges that buffers may need to be up to one site potential tree height (approximately 50 m) in order to maintain interior microclimate conditions, although this does not appear to be based on field studies and no functional explanation is provided.

2.5.6 Nutrient Flow and Sediment Storage

Riparian zones improve water quality by acting as sinks, sources, filters and transformers of polluting substances (Tims 1994). Several studies have shown that riparian zones are extremely efficient at filtering sediment and nutrients such as Nitrogen and Phosphorus, and are therefore very effective in mitigating and diffusing sources of upland pollution (Green and Kauffman 1989; Castelle et al. 1994; Gilliam 1994). Vegetated buffers can remove metals and excess nutrients from overland and subsurface flow by physically filtering water and by plant uptake (Castelle 1994). In many cases, riparian buffers convert pesticides and other toxic compounds into non-toxic forms by microbial decomposition, oxidation, reduction and hydrolysis (Tims 1994). The cleansing function of riparian buffers is especially important in agricultural areas, along golf courses, or in urban areas where input of macro-nutrients from upslope areas or stormwater can be significant.

Contaminant removal efficiencies are significantly influenced by soil composition and compaction; however, studies examining amelioration of diffuse source contaminants indicate that even relatively narrow buffers (15 m) exhibit moderate removal efficiencies (Castelle et al. 1994). In order to remove more than 80% of macronutrients however, a buffer of 50 m may be needed. Petterjohn and Correll (1984) for example found that 50 m buffers reduced nitrate and phosphate concentrations by 98% and 85% respectively. Osborne and Kovacic (1993) found that riparian forests are more efficient at removing nitrate than grass buffer zones, although phosphorus removal efficiency was greater for grass buffers.

While water quality problems in urban or rural developed areas are generally the result of non point source stormwater discharges, increasingly in urban areas stormwater is concentrated in storm drains and trunks and discharged through discrete outfalls increasing point source pollutant loadings to streams. Buffer strips can not effectively mitigate these impacts.

3.0 METHODOLOGY FOR IDENTIFYING AND DELINEATING FISHERIES MANAGEMENT AND RESERVE ZONES

Protection of streams, wetlands, riparian and aquatic habitats in urban and agricultural areas of coastal British Columbia has traditionally relied upon the establishment of setbacks or ‘leave strips’ such as those recommended in the *Land Development Guidelines for the Protection of Aquatic Habitat* (Chilibeck et al. 1993). Application of these guidelines require interpretation of physical features such as “top of bank” or “high water mark” and vary depending on the proposed land use. The guidelines specify that setbacks adjacent to aquatic areas be a minimum of 15 meters from top of bank (or defined high water mark) in low density residential areas and 30 meters in commercial / industrial or high density residential areas respectively.

Understanding of riparian / aquatic interactions has evolved considerably in the past decade due in large part of forestry supported research, and recent evidence suggests that the leave area required to support and maintain many critical stream functions is considerably larger than 15 meters. By matching specific riparian habitat value with knowledge of fish use, species habitat requirements, local features and geomorphic and fluvial processes, a scientifically derived setback can be established. This can then be integrated with local land use planing processes.

Fisheries Management and Reserve Zones

A hierarchical approach to establishing setbacks in urban / suburban areas is recommended in this document. This approach relies on the establishment of two zones – the first of which is a large scale, uniform Fisheries Management Zone (FMZ) that is delineated at the watershed or subwatershed level. As it is based on limited information it must be broad enough to capture overgrown tributaries, contiguous wetlands or other small aquatic features that may not be mapped or properly identified at the broad scale. It should also be large enough to encompass most of the critical and adjacent landscape features that contribute significantly to fish habitat. Where the management zone is large enough to provide a buffer between conservation areas and active land uses, certain ‘management’ activities may be accommodated within the management zone providing best practices are employed.

The second zone is the Fisheries Reserve Zone (FRZ) or the area immediately surrounding streams and other aquatic features where the greatest functional interaction between the stream and its adjacent riparian area occurs. The Fisheries Reserve Zone is a refinement of the broader Fisheries Management Zone and is established on the basis of site specific assessments. The FRZ is the ’leave area’ within which no disturbance is permitted.

The delineation of two zones – one strategic and the other site specific – has a number of benefits for settlement planning and environmental protection in urban or suburban areas. Uniform and broad scale Fisheries Management Zones identify areas of general concern for development and can initiate a process for information collection, assessment and boundary refinement at subsequent land use planning stages. This hierarchical approach provides options and increases flexibility by permitting this boundary to be varied in response to site conditions, sensitivity and risk.

INTEGRATION OF LAND USE PLANNING AND FISH HABITAT PROTECTION

Fisheries Management Zones

Large and uniform Fisheries Management Zones can easily be digitized onto base maps at scales appropriate for regional, municipal, neighbourhood or watershed scale planning. As they are of necessity broad scale, they are most appropriate where parcel sizes are large and undivided. The area is unzoned or undeveloped; risks are unknown; there is no local or site specific inventory information available and/or there are significant fish resource values in the watershed. Where ‘management objectives’. such as provision of recreational trails, creation of buffers between adjacent land uses, hazard tree management or routine access to utility right-of-ways are proposed next to sensitive aquatic features an FMZ must be established.

Fisheries Management Zones can also support broad scale land use designations, such as Development Permit Areas for protection of the natural environment in Official Community Plans. Where FMZs are designated as Development Permit Areas in the OCP they provide planners and subdivision approving officers with a tool to ensure that appropriate consideration is given to these areas during subsequent rezoning, subdivision or redevelopment. These designations also aid Regional Districts or municipalities which have few planning staff and map resources and limited local inventory information on areas which are to be developed. Perhaps most importantly Fisheries Management Zones are very useful in any area where, on the basis of limited information, there is a need to proactively identify sensitive fish habitats and initiate processes for protecting them in the face of increasing growth and development pressures.

The Fisheries Management Zone is a conservative estimate of the area needed to maintain most of the critical interactions between the riparian zone and the watercourse, As such it can be identified at a strategic level and provide guidance for subsequent land use planning. If established early enough in the planning process the FMZ can encourage compatible land use zoning next to sensitive aquatic areas, can influence road and infrastructure alignments and can provide landowners, prospective purchasers or developers with essential information on development constraints for an area. It also identifies riparian areas which could be priorized for incorporation into local and regional 'greenways' plans.

Fisheries Reserve Zones

The Fisheries Reserve Zone (FRZ) is a site-specific refinement of the Fisheries Management Zone. Precise delineation of the FRZ requires local knowledge of fish use and site specific information on the location and the extent of features such as streams, floodplains, wetlands, ravines and escarpments; as well as information on local hydrology and geomorphology. For this reason, the boundaries of the FRZ are not generally established until a rezoning, subdivision or development proposal triggers an area specific Environmental Impact Assessment. In addition to evaluating site conditions and factors the impact assessments must also address the following risks:

- existing site impacts and threats to fish habitat;
- status of species and stocks in the watershed;
- cumulative, watershed scale alterations; and
- overall risk to the fisheries resource.

Approaches to Establishing Management and Reserve Zones

This document presents a hierarchical approach to establishing fisheries management and reserve zones. While a hierarchical approach affords a greater level of protection to fish habitat and permits a wider range of developments over a variety of sites it also demands more sophisticated and detailed site assessments. This requires expertise in fisheries biology, hydrology, geomorphology and forest ecology. Where the expertise is not available, the expense cannot be justified, or a simplified approach is preferred a minimum FMZ can simply be adopted as a default setback.

The literature indicates that several of the most critical processes that contribute to productive fish habitat (i.e. LOD recruitment, and floodplain processes) require a minimum 50 meter setback measured horizontally from bankfull width to protect them. Accordingly this would represent the minimum FMZ or default setback on fish-bearing streams. In non fish-bearing streams, or those that discharge directly to fish habitat, the maintenance of bank stability, temperature, food production and downstream transport of food and nutrients are the most significant habitat issues. As these functions can generally be protected with a 30 meter setback measured from bankfull width this would represent the minimum FMZ or default setback on these systems.

One Step Process

Although it is generally recommended that both FMZs and FRZs be established, there may be occasions where it is not possible or necessary to establish both zones. Specifically existing footprints, land use designations, zoning and planning policies of the local government will all influence decisions regarding a stratified approach. For example in many settlement areas current zoning has already conferred uses and densities upon the management zone that are incompatible with protection of this area and in heavily urbanized areas significant alteration of the management zone may have already occurred. In these situations the retroactive establishment of a broad scale management zone would be met with considerable resistance. In these cases the objective therefore would be to establish a reserve zone which is (at a minimum) consistent with the *Land Development Guidelines* and preclude any additional or proposed ‘management’ activities in the already compromised management zone. This combination of a minimum setback with other prescriptions for these sites are necessary to conserve remaining habitats, restore values previously impacted, and protect critical watershed functions.

Where sufficiently detailed inventory information for an area exists, as a result of previous sensitive areas inventories, hazard lands assessments, watercourse mapping, master drainage plans, neighbourhood concept or local area plans or other plans and maps, it may be possible (and preferable) to proceed directly to establishment of an FRZ. This would provide several development advantages including:

- eliminating the need for numerous individual site assessments by proponents;
- reducing development application review and approval timelines

- providing the foundation for formulation of local land use regulations;
- identifying critical priority habitat areas for acquisition by local government, land trusts, and private interests; and
- encouraging early consideration of compact, land-efficient, and environmentally sensitive subdivision designs.

An FRZ can also be established without benefit of a previously delineated FMZ where:

- a Neighbourhood Concept or Local Area planning process applies to the area and will require detailed site assessments of large areas prior to subdivision; and/or
- Development Permit Areas (DPA) have been designated around all sensitive aquatic features and the associated guidelines require environmental impact assessments which can form the basis for delineating the FRZ.

Two Step Process

The alternative – a two step process, wherein a broad zone of concern (FMZ) is initially identified on the basis of limited information and is refined to a specific leave area or ‘reserve zone’ (FRZ) at subsequent land use planning stages – is more consistent with a risk averse management strategy. This approach has been adopted by several regional districts and municipalities who are experiencing or anticipating significant development and growth pressure and wish to be proactive.

The Comox Strathcona Regional District for example has established Fisheries Management Zones around all sensitive aquatic areas within their jurisdiction based on information compiled in a Sensitive Habitat Atlas. The Atlas is a series of maps which overlay orthorectified airphotos with cadastral information, aquatic features derived from TRIM (1:20,000) base maps, photointerpreted wetlands and other aquatic features. Based on this information and fish use information provided by the Department of Fisheries and Oceans (DFO) and BC Environment, the District established strategic FMZ boundaries of 100 meters on fish-bearing systems and 50 m buffers on non fish-bearing (or unknown fish use) systems. These zones highlight areas within which detailed assessments would be required to support any subsequent development applications.

Maple Ridge has also adopted a risk averse approach to fish habitat protection. Maple Ridge relies on detailed watercourse maps and inventory information compiled by a local stewardship group. Based on this mapping information the municipality has designated all known and mapped watercourses and the area 50 m either side of them as Development Permit Areas (DPA). The accompanying DPA guidelines require a comprehensive environmental impact assessment for development proposals within this area, and the identification and protection of a Fisheries Reserve Zone.

Watershed Planning

Watersheds are natural landscape units which provide an ecological foundation for land and water use planning. Watershed based planning and zoning permits establishment of overall management objectives that provide direction to subsequent settlement and development plans. For example Fisheries Management Zones identified at the watershed level could be designated conservation areas before land use and density for large areas of the watershed are established. The designation and subsequent protection of these areas could be accomplished using a combination of planning provisions, regulatory tools and incentives available to local governments. If this occurs before lands are zoned, subdivided and serviced, land value could make direct acquisition or purchase of critical habitats more feasible.

Watershed based planning is also a prerequisite to protecting many hydrologic functions which can only be managed at the watershed level. For example, groundwater recharge which contributes to baseflows, replenishes aquifers, and regulates surface channel flows may occur in areas well removed from the riparian / aquatic interface and would therefore not necessarily be captured in the Fisheries Management Zone. Proper and early identification of recharge areas can only occur via watershed scale hydrogeological assessments. Policies that prohibit infilling of these areas, environmentally sensitive development designs that meet watershed targets for 'Effective Impervious Area' and various economic incentives / disincentives (i.e. tax assessments that are commensurate with the amount of impervious area) could then be employed to protect these features and functions.

3.1 METHODOLOGY

3.1.1 Fisheries Management Zone Delineation

Fisheries Management Zones, when used in conjunction with other habitat management and/or urban planning tools, provide the first step toward the protection of fish and fish habitat during land conversion and development processes.

3.1.2 Fisheries Management Zone Delineation Process

Information Gathering

The first step towards establishing an FMZ is the acquisition and compilation of all relevant and existing information on the streams, wetlands, hydrology, topography, and fish use of the study area. Accurate topographic and drainage mapping and reliable fish sampling information is essential for this process.

Sources of information for coastal streams, lakes, and wetlands include:

- National Topographic System Maps – 1:50,000 (Government of Canada);
- TRIM mapping – 1:20,000 (BC Government);
- Lower Fraser River Stream Inventory Atlas (Government of Canada);
- Lower Fraser Valley Fish Habitat Sensitivity Maps (Government of Canada);
- Aerial Photographs (Municipality, BC Government);
- Fraser River Estuary Management Program Foreshore habitat maps for the Lower Mainland;
- Fraser River Floodplain maps – 200 year floodplain;
- MELP Water Management Branch floodplain mapping;
- Canadian Wildlife Service Wetland Inventory (Ward et al. 1992);
- Watershed Atlas Maps (BC Government);
- Fisheries Information Stream Summary database (DFO/MELP);
- Municipal drainage mapping and stormwater management plans (Municipal Government);
- BC Conservation Data Centre Rare Element Tracking Lists (BC Government);
- Discussions with DFO / BC Environment staff, local residents, fishers, naturalist groups, and academics;
- Previous fisheries studies (DFO, BC Environment, consultant reports and local government); and

- Local Environmentally Sensitive Area Inventory or Hazard Land Assessment (Regional Districts, Municipal Governments).

Defining Fish Presence

Fisheries Management Zone delineation relies on current and reliable fish sampling to classify streams and aquatic areas. For the purposes of delineating management zone boundaries the following designations apply.

- ***Actively and Potentially Fish-bearing*** – Actively fish-bearing aquatic areas support permanent, seasonal or occasional use by fish populations. No distinction between salmonid use and non-salmonid use is made. All streams should be considered fish-bearing until, and unless, a comprehensive sampling program has been undertaken which proves otherwise. Potentially fish-bearing includes those areas where fish use is presently limited by barriers to upstream fish passage or by other limiting factors (e.g. water quality or quantity) that can be remediated or restored to allow fish use in the future. Streams that contain fish passage obstructions (i.e. improperly sized or placed culverts) should be included in this category. Before a stream is classified as non fish-bearing, the nature of the barrier and feasibility of remediation must be determined.
- ***Non Fish-bearing but with Downstream Fish Presence (or Potential)*** - This category includes all aquatic areas with no current fish presence, no historic records of fish presence, and no apparent opportunity to resolve the factor(s) limiting fish use, but which drain directly into fish-bearing waters. Fish-bearing waters, for the purpose of this report, do not include marine waters. The limiting factor for fish use (i.e. impassable falls, high summer temperatures etc.) should be noted for each reach, tributary, or stream classified as non fish-bearing.
- ***Non Fish-bearing with No Downstream Fish Presence (or Potential)*** – This category includes those streams which have no fish use potential either at, or downstream from, the site. Short, steep coastal streams which cascade into the marine environment or channels with no surface water expression fall into this category.

Sampling for Fish Presence

Recent changes to the Forest Practices Code have increased the emphasis on identifying fish-bearing streams. The Fish-stream Identification Guidebook (MOF 1995) provides a relatively simple but effective approach to determining fish presence through sampling that focuses on fish distribution, rather than population size or habitat preference. The British Columbia Resources Inventory Committee (RIC) report entitled Fish Collection, Preservation, Measurement, and Enumeration Manual, outlines a standardized approach to fish sampling. Accepted field methods to determine fish presence include:

- visual sightings;
- angling;
- pole seines;
- minnow or Gee-type traps; and
- electrofishing.

NOTE: Permits for sampling and collection of fish are required from either MELP or DFO.

Barriers and Obstructions

Identifying barriers and obstructions to fish passage is necessary in order to determine potential fish use. Natural barriers include falls, inclines and chutes, rock slides, log / debris jams, and beaver dams. Structures such as culverts, instream weirs, spillways, dykes and dams can also restrict or preclude fish passage.

The most accurate method of confirming whether a suspected barrier prevents fish passage is to sample for anadromous fish populations above and below the structure. If anadromous species are captured upstream, the passage problem is classified as an obstruction. If suitable habitat exists above the constraint but anadromous species are not present upstream, the passage problem is classified as a barrier. It is important to note that non-anadromous, resident fish species may be present above both obstructions and barriers.

Information which should be recorded includes: type and nature of barrier (permanent vs. temporary), stream gradient and local flow conditions. The feasibility of removing the barrier and opportunities to restore access to previously inaccessible habitat should also be noted.

Mapping Existing Information

The next step in the process is to transfer relevant geographically based information describing aquatic areas and fish presence onto suitable base maps. Base maps should be at a scale appropriate to the size of the areas of interest and the planning process involved. Digital TRIM maps at a 1:20,000 scale provide a convenient base for strategic or large scale planning and can facilitate the layering of other digitally derived information. They are easily manipulated in a digital environment and are currently available for most of British Columbia. However, the scale, contour interval and aquatic layer of TRIM does not typically allow for accurate identification of floodplains and wetlands. Where the level of planning is more refined and the intent is to accurately define topographic and physical features, a more detailed scale is required. Information that should be transposed onto the base map at this level includes:

- watershed boundary;
- permanent, ephemeral and intermittent streams, ditches, wetlands, contemporary floodplains, ravines, and escarpments;
- ‘grey’ areas where watercourses or wetlands are suspected but are not depicted on existing maps or where no clear drainage pattern is evident;
- fish presence and distribution information. Using fish presence information all streams and wetland areas should be separated into i) actively and potentially fish bearing, and ii) non-fish bearing. In situations where fish sampling information is unavailable or unreliable, fish presence should be assumed; and
- barriers to fish passage including natural barriers, and structures (and notations respecting opportunities to improve fish passage).

At this point in the process, the basic information required to delineate a Fisheries Management Zone boundary along aquatic areas is compiled. Recommended distances for the FMZ are presented in Table 3.

3.2 SITE LEVEL: DESIGNATING THE FISHERIES RESERVE ZONE

The Fisheries Reserve Zone, which is a site specific refinement of the FMZ, is the immediate area surrounding streams and other aquatic features that represents the critical zone of functional interaction between the stream and its adjacent riparian area. Natural processes and habitat features which occur within the FRZ must be fully protected. The spatial extent of the FRZ is determined on the basis of detailed biophysical site assessments and in highly urbanized settings the final alignment may be influenced by existing land uses and development footprints within the FMZ.

The site assessments may identify sensitive features such as unmapped tributaries and sidechannels, wetlands, seeps/springs, steep and unstable slopes, highly erodible soils, and/or unique or endangered habitats that would justify extending the FRZ beyond the FMZ. Where the FMZ has been impacted as a result of historic land use, the final alignment of the FRZ will be based on a primary objective of protecting the remaining habitat features within the FMZ and restoring the most critical functions.

Table 3. Recommended Management Zone Widths for Protection of Fish Habitat Features.

Habitat Feature	Fisheries Management Zone Widths[1]	Primary Functional Requirements
Permanent Streams		
fish-bearing / potentially fish bearing	50 meters on each bank as measured from bankfull level	100% of LOD contributions
non fish-bearing but discharges to fish habitat	30 meters on each bank as measured from bankfull level	100% of temperature, light, and nutrient control
Ephemeral and Intermittent Streams		
fish-bearing, or non-fish bearing but discharges to fish habitat	30 meters on each bank as measured from bankfull level	100% of temperature, light, and nutrient control
Lakes and Wetlands		
fish-bearing and non-fish bearing but connected to fish habitat	30 meters measured from maximum extent of hydrophilic vegetation and/or seasonal high water	100% of temperature, light, and nutrient control

Habitat Feature	Treatment	Function
Floodplains		
contemporary floodplain	complete inclusion	maintain riparian vegetation, bank stability; and retain stream meander corridor
Hydrological Elements		
ephemeral catchments, springs and seepage areas	complete inclusion	protect water sources hydraulic regime, baseflows and water quality
Geotechnical Elements		
ravines, escarpments, and other slopes > 30 percent incline	complete inclusion	protect the watercourse and riparian area from erosion or slope failure

[1] Note: distances quoted are slope distances rather than horizontal distances.

3.2.1 Fisheries Reserve Zone Designation Process

Identifying and Mapping Fish Habitat at the Site Level

Field assessments are required for the identification of important site features and the evaluation of habitat functions and risks at the site level. This information is also necessary to refine the FMZ where one has been previously established. Accurate field identification of site features and evaluations of habitat functions and risk requires expertise and knowledge of hydrology, geomorphology, soil science, fisheries biology, and forest ecology. As a result specialists in these fields may need to be consulted when delineating Fisheries Reserve Zones.

Field Assessment

Detailed investigation of physical and biological features at the site level should include:

Physical Features

1. Streams:
    - precise location and extent of permanent and intermittent streams;
    - location of bankfull width along stream channels using field indicators (see Section 2.3).
2. Floodplains
    - location identification of bankfull width;
    - location and extent of contemporary floodplain (from composition of vegetation communities, soil sampling, or hydrological analysis).
3. Wetlands
    - location and extent of wetland areas (as defined by the Canadian Wetland Classification System (National Wetlands Work Group, 1987);
    - extent of seasonal inundation and/or hydrophilic plant community.
4. Hydrological Features:
    - location of groundwater seeps or springs and local recharge areas;
    - location of surface catchments and ephemeral streams;
    - location of natural recharge areas.
5. Geomorphological Features:
    - location of slopes grater than 30% (i.e. ravines and escarpments);
    - location and extent of erodible soils.

Biological Features

6. Fish Values:

   - fish distribution;
   - demonstrated or documented fish use (spawning, rearing, overwintering, migration);
   - potential fish use (spawning, rearing, overwintering, migration);
   - location and nature of fish passage barriers and obstructions.

Note: Information on fish use and barriers has been compiled for many areas of the province and is available in the Fish Information Stream Summary (FISS) data base administered by DFO and BC Environment. This information is also available on the Internet (address: http//habitat.pac.dfo.ca). Field surveys and assessments should be designed to verify and augment this information.

7. Vegetation

   - extent and vegetative composition of riparian areas;
   - location and characterization of hydrophilic plant communities.

Risk Factors

An assessment of risk will require an evaluation of the interaction amongst processes which occur in the FMZ, the nature of proposed activities within the FMZ and the potential for negative impacts on fish habitat. Among the factors to consider when assessing risk are: windfirmness of riparian edge, risk of erosion or slope failure, potential for non point source pollution generation, alteration of natural drainage patterns, reductions in precipitation infiltration, constraints to lateral channel migration, extent and nature of existing impacts and relationship with other impacts in the watershed (i.e. cumulative impact assessment).

Designating the Fisheries Reserve Zones

After the field assessment and precise mapping of important habitat features are complete, identify the spatial extent of the Fisheries Reserve Zone using the following steps.

- Draw the 30 m or 50 m FMZ boundary parallel with the bankfull width of streams on base maps (these distances will vary depending on fish presence and flow regime).
- Ensure all contemporary floodplain areas are included.
- Completely encompass any previously unmapped or unidentified streams and drainage features.
- Ensure all steeply sloped areas (> 30% slope) which are partially included within the FMZ or immediately adjacent to the contemporary floodplain are completely

incorporated within the FRZ. Add a geotechnical buffer of 10 meters at the crest of steep slopes (> 30%) to protect against slope failure and erosion and to preserve established vegetation.

- Refine or vary the alignment to capture areas of highly erodible soils.
- Align, feather, extend, or buffer the boundary to create a windfirm riparian edge.

3.3 EXAMPLE CROSS-SECTIONS

The following cross-sections are designed to illustrate the spatial extent of the FRZ in a variety of topographic conditions and stream types. Figure 5 illustrates the spatial extent of the FRZ adjacent to fish-bearing or potentially fish-bearing permanent streams. Figure 6 illustrates FRZ boundaries adjacent to fish-bearing wetlands and lakes.

3.3.1 Example of an Application of the Methodology

The following example illustrates the process for designating fisheries management and reserve zones. The example system is a fourth-order stream on the east coast of Vancouver Island. A 380 meter section of the river's mainstem and a portion of an unnamed first-order tributary are located within the study site. The system is a significant regional producer of coho and chum salmon and cutthroat trout.

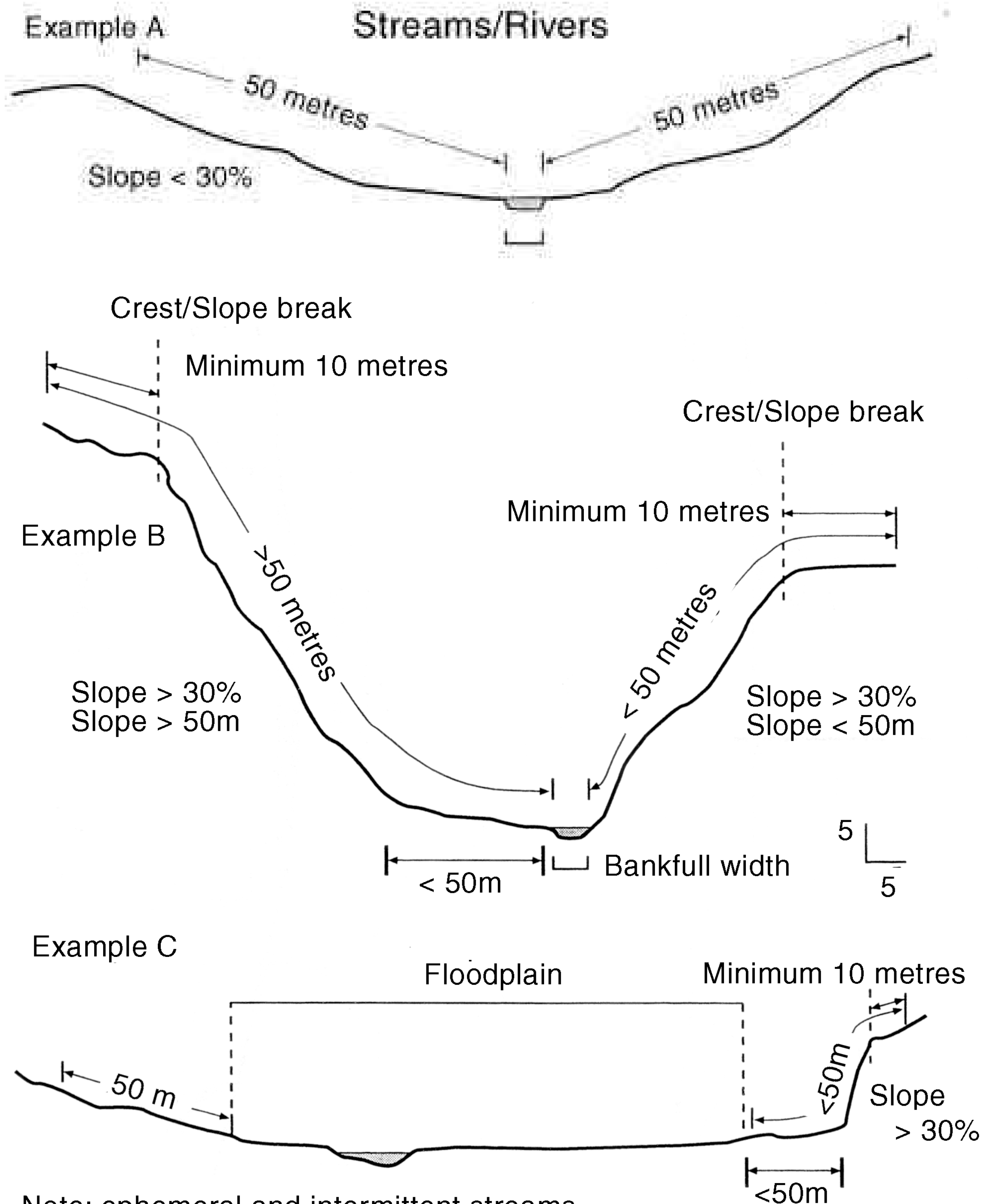
The local Municipal Government had conducted an Environmentally Sensitive Areas study the previous year and designated all watercourses and riparian areas as very high sensitivity areas. This information provided the rationale for designating these areas Development Permit Areas (DPAs) for protection of the natural environment in the OCP. In addition all steep slopes > 30% were identified as DPAs for protection against hazard.

There is no accurate topographic, hydrologic or fish use information available for the site nor is there any floodplain mapping available for the site. On the basis of the limited information a default FMZ of 50 m is established along the mainstem and tributary (Figure 7). A rezoning and development application for the site triggered the DPA guideline for a detailed impact assessment of the site and the delineation of an FRZ.

Field Assessment Information

The following information was collected during the field assessment or from previous fisheries assessments of the river system to establish an FRZ.

Figure 5. Spatial extent of Fisheries Reserve Zone adjacent to fish-bearing or potentially fish-bearing permanent streams. Note: The extension of the FRZ in Examples B and C has been modified to incorporate the contemporary floodplain and steep slope areas.



Note: ephemeral and intermittent streams require a 30 metre boundary.

Figure 6. Spatial extent of the Fisheries Reserve Zone adjacent to fish-bearing wetlands and lakes.

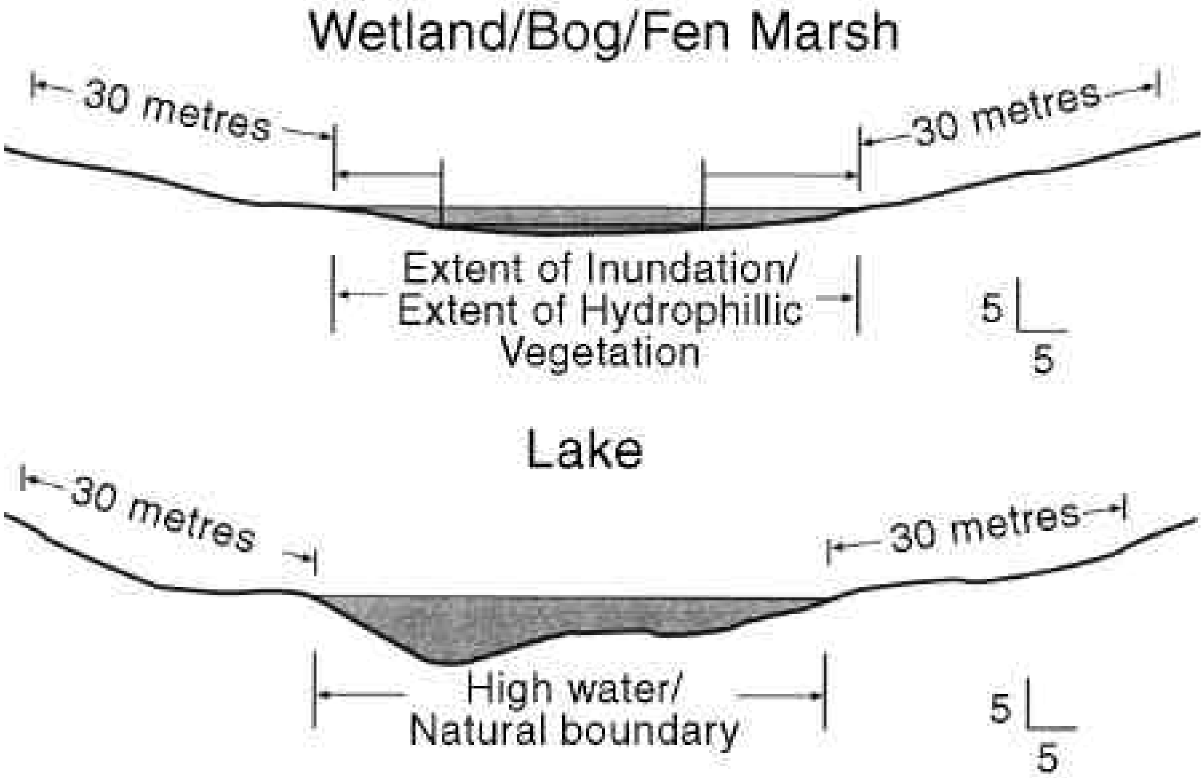
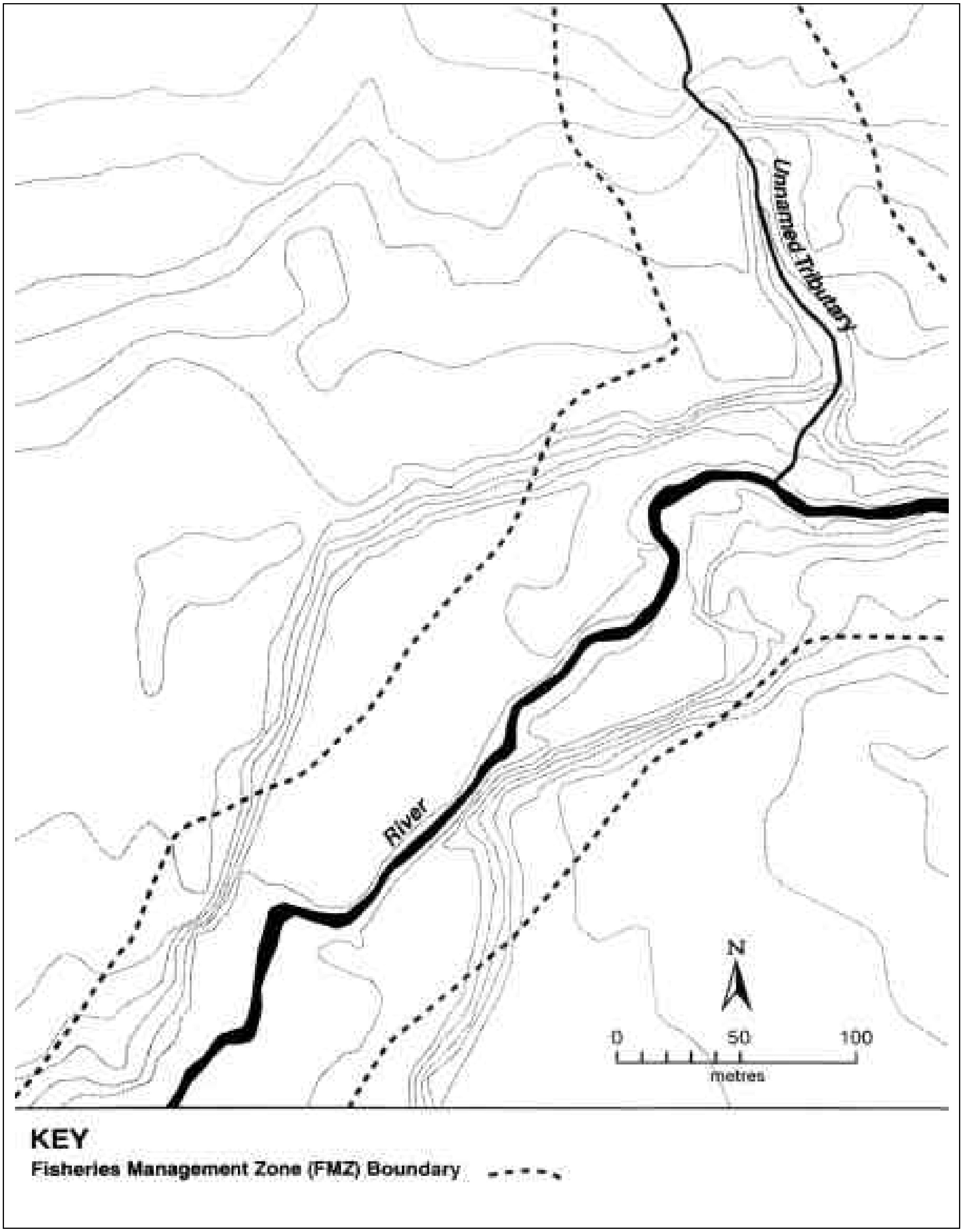


Figure 7. Location of the default Fisheries Management Zone boundary for the example site.



Physical Features

1. Streams:

   Within the study site the river is approximately 6 m wide and contains pools up to 1.5 m deep. Channel gradient is approximately 1.5% and instream habitat is primarily pools with short sections of shallow riffle. Large organic debris is largely absent due to past logging and agricultural development along the river corridor. Substrates are primarily uncompacted large gravels and cobble.

   The first-order tributary is an intermittent stream and flows in response to seasonal saturation of the surrounding soils. The channel is 0.5 to 1.7 m wide with an average depth of less than 0.1 m. Substrates are primarily sand and fines with patches of small gravels. No pools greater than 0.2 m deep were identified during the field assessment.

2. Floodplain:

   Delineating bankfull width on the mainstem is relatively easy due to the presence of a significant break in slope (> 45°) between the channel and the surrounding floodplain. The contemporary floodplain (> 1 in 30 year recurrence interval) extends to the base of the escarpment slope and several shallow linear wetlands identify abandoned overflow channel avulsions.

3. Wetlands:

   Apart from the shallow rush and reed canary grass dominated marsh areas within the active floodplain, no wetlands were identified within the study site. The marshes are not anticipated to have fish habitat value (i.e. high water refuge) except under flood levels with a recurrence interval greater than 1 in 5 years.

4. Hydrologic Features:

   Several seepage areas were identified at the base of the escarpment slope by the presence of localized slumping and saturated soils as well as surface run-off during non-precipitation periods, and hydrophilic understory species (ie. youth-on-age, skunk cabbage). The source of this subsurface flow is believed to be the forested areas to the west and east of the river corridor; however, no hydrogeology analysis has been undertaken for the area.

5. Geomorphological Features:

   The river's floodplain is confined by stable escarpment slopes on both sides. Average degree of the slope varies between 30 and 35%, and average height of the escarpment is 35 m.

Biological Features

6. Fisheries Values:

   The river is a regionally important producer of coho salmon, chum salmon, and sea-run cutthroat trout. There are both coho and cutthroat conservation concerns on this system and stringent harvest restrictions have been implemented. Coho escapements to this system have declined dramatically over the last 3 cycles and fewer than 100 spawners were reported in the previous years' stock enumeration survey. Non-salmonid species that have been documented in the system include western brook lamprey, prickly sculpin and three-spine stickleback.

   The section of the river's mainstem within the study site is important salmonid spawning and rearing (coho and chum) habitat. A fish migration barrier (2.5 meter high cascade) limits anadromous fish use of the tributary stream to a 50 m section of the tributary immediately above its confluence with the mainstem. An electroshocking survey documented no fish use, including resident species, above this natural barrier. A visual inspection of the tributary's fish habitat values indicated that it has no potential for supporting resident salmonid populations.

7. Vegetation Conditions:

   The central portion of the study area (contemporary floodplain bend) is used to pasture cattle and currently supports grass and shrub thicket vegetation (i.e. Himalayan blackberry, black hawthorn) with numerous shallow wetlands dominated by soft rush and reed canary grass. The steeply sloped floodplain escarpment that demarcates both sides of the river corridor is forested with red alder, western red cedar, big-leaf maple, and occasional black cottonwood. Understory vegetation is primarily salmonberry, sword fern, and beaked hazel. The southern portion of the floodplain is forested with a dense stand of 40 year old black cottonwood and red alder. Second-growth mixed deciduous-coniferous forest is found to the east of the river corridor while old field / pasture vegetation characterizes upslope areas to the Northwest.

8. Land Use Factors:

   The site in question is two large undivided and largely undeveloped parcels. The aquatic features on both parcels have been designated high value environmentally sensitive areas and the escarpment has been identified a high risk hazard lands following the recent Environmentally Sensitive Area Inventory undertaken by the Municipality. The area is presently zoned A2 (Upland Agricultural) and existing land use is predominantly agricultural (grazing and cash crops). As the area is not within the Agricultural Land Reserve it can be rezoned. The present landowner has applied for a rezoning to RS-1 (Single Family High Density Residential). The OCP has well enunciated policies for leave area protection, erosion prevention, sediment control and stormwater detention that would apply to any subdivision and development in the municipality. The present land use has resulted in extensive land clearing and riparian removal in certain sections of the parcels; however, there are no significant development impacts or building footprints within the default FMZ. Recreational access to the river and protection of riparian areas as part of a local 'greenway' is a municipal objective. Accordingly, portions of these parcels will need to be acquired through dedication, easement or purchase, which will require negotiations with the land owner.

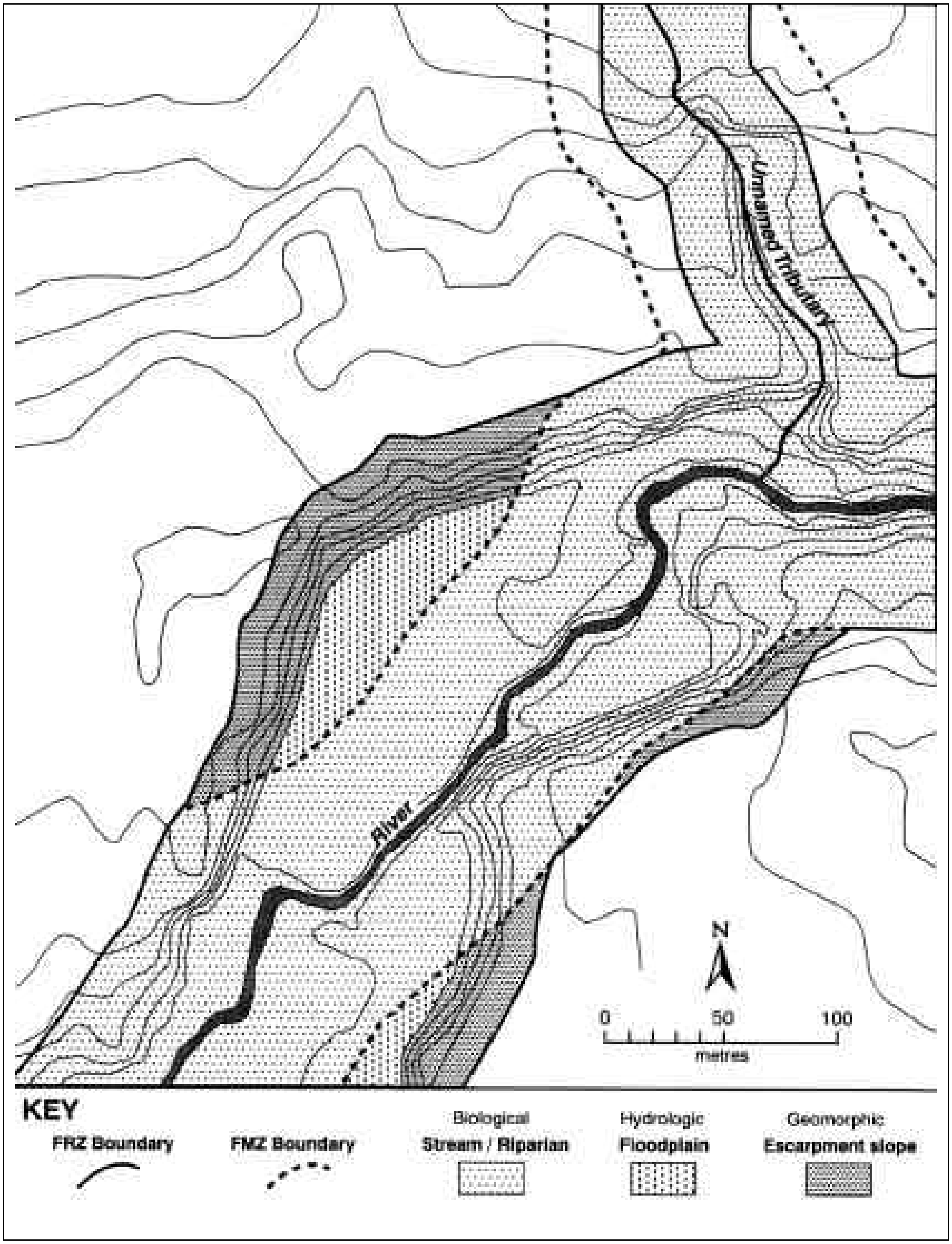
9. Risk Factors:

   Coho salmon escapements and cutthroat trout enumerations indicate that these stocks are approaching extinction in this watershed, and stringent harvest and habitat conservation measures are required. Present land use has resulted in extensive clearing and riparian removal on the parcels and further riparian removal should be opposed. The groundwater seeps, wetland complexes and active off channel habitats located within the floodplain are representative of a very complex hydrologic regime. The relief on this site is significant and soils on the crest of the escarpment are erodible and easily mobilized once disturbed. As the escarpment is located immediately above very sensitive fish habitat and the risk of erosion and slope destabilization from development on the edge of the escarpment is high, a broad geotechnical setback on the escarpment is required. As the entire watershed is approaching 15% Effective Impervious Area it is desirable to maintain compact cluster development with significant open space on this site to maintain natural infiltration capacity.

Land use factors will not affect the final alignment of the FRZ boundaries in this case; however, risk factors dictate that the FRZ should not be reduced beyond that justified by fish use. Establishment of an initial FMZ in this case was very beneficial as it encourages more compact development and greater open space for stormwater infiltration and also preserves the opportunity to accommodate and design passive recreation trails and viewpoints through the management area that will not impact critical riparian / aquatic features

The location and precise dimensions of hydrologic and geomorphic features such as the contemporary floodplain and escarpments were not identified at the ESA stage and use of the tributary by fish was not known until field assessments and sampling were conducted. As a result, an initial FMZ was established at 50 meters (measured from the bankfull width) on both the mainstem and the tributary (Figure 7). This boundary was then refined based on site specific biophysical information and analyses. The final FRZ boundary needed to be expanded to include both the contemporary floodplain and steeply sloped (> 30%) escarpments that are adjacent to the mainstem but were not fully encompassed within the default FMZ. The final FRZ boundary also reduced the initial FMZ from 50 to 30 meters on the tributary as a result of fish sampling and field investigations which revealed that the tributary was not fish-bearing and the barrier was a permanent feature (i.e. falls). The difference between the preliminary Fisheries Management Zone boundary and the refined Fisheries Reserve Zone boundary in this example is shown in Figure 8.

Figure 8. Comparison of preliminary Fisheries Management Zone boundary and final refined Fisheries Reserve Zone boundary for the example site.



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Appendix 1: Glossary

Abiotic: Inert, not alive or consisting of plant, micro-organism or animal matter (i.e. climate).

Active Floodplain: that portion of the floodplain that is inundated more often than once in five years (>1 in 5 year recurrence interval).

Anadromous: Ascending rivers from the sea to spawn. Anadromous fish include pacific salmon, sea-run cutthroat trout steelhead, sea-run dolly varden, and oolichans.

Angular canopy density: Streamside vegetation that projects over the stream channel and that is greater than 2 m above water surface. Also called crown closure or canopy closure.

Aquatic: Associated with or taking place on or in water.

Bankfull elevation: The surface water elevation corresponding to a discharge stage at which banks overtop and adjacent floodplains are inundated.

Barrier: An instream feature which creates a hydraulic condition which prevents fish passage. Total barriers are impassable to all species and size classes of fish under all flow conditions while partial barriers are passable under certain flow conditions.

Baseflow: Flow rate for a given stream that is not directly the result of surface runoff from precipitation or snowmelt. Usually the contribution that is derived from groundwater and/or percolation into ground, and base flows from lakes, swamps or wetlands. Also called sustaining, normal, ordinary or groundwater flow.

Bedload: Stream transported materials, such as sediments and small rocks, transported along the stream bed in the lower layers of streamflow by dragging, rolling or saltation.

Benthic invertebrates: Organisms without backbones that reside on or in the bottom of rivers, streams, lakes, wetlands and other aquatic areas.

Bioaccumulate: The ability of an organism to accumulate substances (i.e. toxins) within its tissues thereby removing them from the environment.

Biodiversity: The array of plants, animals and other living organisms in all their forms and level of organization and the evolutionary and functional processes that link them.

Biome: A major regional ecological community of organisms usually defined by the habitat in which they occur and determined by interaction of substrate, climate, fauna, and flora.

Biotic community: All organisms living on and contributing to a specific region.

Biotic factor: The influences that occur on both the physical environment and biological community as a result of the activities of living organisms.

Bog: Wetlands with organic soils and a water table that is at or near the surface. Soils are predominantly poorly to moderately decomposed sphagnum moss peats. The bog surface is usually unaffected by groundwaters and waters are therefore generally acid and low in nutrients. Bogs are usually carpeted by sphagnum mosses and ericaceous shrubs. They may be treed or treeless. Bogs with an open growth of scrubby trees are commonly referred to as muskeg.

Channel morphology: The shape, size and configuration of the bed and banks of a river or stream as defined by its flow, sediments and geological setting.

Contemporary floodplain: That portion of the valley floor adjacent to a stream channel that has a flood recurrence interval that is greater than once in 30 years (i.e. between 1:30 and 1:200 year events). It encompasses both the active and dry floodplain.

Dam pool: Water impounded by a complete or nearly complete channel blockage, typically caused by a log jam, beaver dam, rockslide, or stream habitat improvement device (boulder berm, gabion, log sill, etc.).

Dry floodplains: That portion of the floodplain which is subject to only occasional inundation by heavy continuous rainfall from major storms or rain-on-snow events. The recurrence interval for flooding of the dry floodplain is between 1 in 5 and 1 in 30 years.

Environmentally sensitive areas (ESAs): Areas defined to manage and protect special, rare, outstanding or endangered natural resource values, systems, functions or processes. ESAs have also been broadly defined by some to included areas of scenic, historic or cultural value.

Ephemeral stream: Stream that flows briefly only in direct response to precipitation in the immediate locality and whose channel is at all times above the water table.

Erosion: Detachment and transport of soil particles by water, wind, ice, gravity or the activity of organisms.

Fen: Wetlands with organic soils and a water table at or above the surface. Soils are primarily moderately to well decomposed sedge and non-sphagnum moss peats. Waters are mainly nutrient rich with a near neutral to slightly acid pH. The vegetation consists primarily of sedge, grasses, reeds, mosses, and some shrubs. Scattered trees may be present.

Fisheries Management Zone (FMZ): A broad based habitat planning tool that identifies a general zone of concern for fish and fish habitat protection. The Fisheries Management Zone is delineated at the strategic land use planning stage using existing information on topography, drainage, hydrology, geomorphology and fish presence.

Fisheries Reserve Zone (FRZ): The Fisheries Reserve Zone is the “leave area” around rivers, streams, wetlands and other aquatic features that includes the area of greatest functional interaction between the stream and its adjacent riparian area. Except in very urbanized settings where the FRZ may of necessity be the minimum recommended in the Land Development Guidelines for Protection of the Aquatic

Environment the FRZ is typically a refinement of the more strategic FMZ. It is designated following a detailed site assessment of biological (i.e. fish presence and vegetation communities) and physical features (i.e. streams, floodplain areas, and wetlands) in the area, and an assessment of cumulative watershed impacts and risk to the stock.

Floodplain: Level or very gently sloping surface bordering a river or stream that is formed of fluvial sediments and is subject to flooding.

Flow energy: Energy generated by the movement of a stream of water and/or other substances from place to place.

Gravel bar: An accumulation of gravel formed in the channel, along the banks, or at the mouth of a stream where a decrease in velocity or an obstruction in flow induces deposition.

Groundwater discharge: The portion of streamflow derived from the water table or other aquifers which have stored precipitation that has migrated into underlying geological strata from the surface soil layers.

Groundwater recharge: Augmentation of subsurface aquifers with water that has infiltrated surfical materials.

Heterogeneous: Unlike, dissimilar, not uniform in character.

High water refuge habitat: Low velocity bank associated with or off-channel habitat used by juvenile and adult fish during periods of high flow in the mainstem channel.

Hydric soils: Soils characterized by an abundance of moisture (i.e. saturated soils).

Hydrologic regime: The natural cycle of water movement from the atmosphere to the earth and back to the atmosphere, via precipitation, condensation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration. The cycle involves the movement of water between the atmosphere and terrestrial, aquatic or ocean environments.

Hydrology: The scientific study dealing with the occurrence, circulation, and distribution of the waters of the earth.

Hydrophilic plant communities: Plant communities growing in water or on very wet soils deficient in Oxygen at least part of the time (i.e. water tolerant).

Incubation: The process by which suitable conditions are maintained for the development and hatching of fertilized eggs.

Intergravel flow: The portion of the surface water that infiltrates the stream bed and moves through the substrate pores.

Intermittent stream: Streams that flow in contact with the ground water table at certain times of the year when the ground water table is high and/or when it receives water from springs or a surface source such as snowmelt. It ceases to flow above the stream bed when water table drops or losses from evaporation or seepage exceed precipitation inputs. Syn: Seasonal stream.

Inundation: A regime that exhibits periodic flooding, characterized by submergence and subsequent emergence of the land surface and supported vegetation.

Large organic debris (LOD): Any entire trees or large pieces of relatively stable organic material having a minimum diameter greater than 10 cm and a length greater than 1 m in the stream channel that provides channel stability or creates fish habitat diversity in the channel. Syn: Large woody debris (LWD).

Macroinvertebrate: An animal without a backbone that is large enough to be seen without magnification.

Marsh: Wetlands with mineral or sometimes well decomposed peat soils. When peat soils are present they are often enriched with mineral materials. Waters are nutrient rich with near-neutral to basic pH. Surface water levels typically fluctuate seasonally with declining levels exposing matted vegetation or mudflats. Emergent vegetation includes grasses, cattails, sedges, rushes and reeds which cover more than 25% of the wetland surface.

Microclimate: The climate conditions (wind, temperature, humidity, etc.) of a local area The area may range from a few centimetres (e.g. for microorganisms in the forest floor) to several tree heights in diameter.

Migration: Fish movements required to complete life cycles. This includes upstream adult migration from the ocean to natal streams, movement by juveniles within streams, movement of juveniles / subadults downstream to estuaries and the ocean and movements within the ocean.

Obstruction: Any structure or natural formation which blocks or prevents fish movement.

Off-channel pool: (Also secondary channel, side channel). Relatively small, sometimes isolated pools in a smaller braid of the mainstem and usually associated with gravel bars.

Overwintering habitat: Physical instream feature, often complexes of large woody debris, rock / cobble substrates and pools, that provide cover, refuge and food for fish during winter periods

Peak flow: The highest discharge recorded over a specified period of time, often annually, resulting from spring snowmelt or large storm events. Also called freshet flow.

Permanent stream: Stream that flows continuously throughout the year Syn: perennial stream.

Plunge pool (Also falls pool, plunge basin): A pool created by water passing over or through a complete or nearly complete channel obstruction, and dropping vertically, scouring out a basin.

Pool: (a) A deeper area of the streambed with reduced current velocity, and which is frequently used by fish for resting and cover. (b) A small body of standing water (e.g. on the floodplain).

Ravine: A long, deep, narrow hollow or valley, usually formed by a torrent or watercourse deepening its bed.

Rearing habitat: Areas in which fish actively feed, rest, seek refuge from predation and continue growth and life cycle processes.

Riffle: Shallow rapids where the water flows swiftly over completely or partially submerged obstructions to produce surface agitation, but standing waves are absent.

Riparian zone: The area between a stream or other body of water and the adjacent upland identified by soils that exhibit some wetness characteristics during some portion of the growing season and by distinctive vegetation that is acclimated to saturated conditions. It includes wetlands and those portions of floodplains and valley bottoms that support vegetation.

Salmonid: Fish belonging to the family Salmonidae including salmon, trout, char and allied freshwater and anadromous fishes.

Scour pool: Deeper section of the channel formed by the scouring action of stream flow as it is directed laterally or obliquely to one side of the stream by a partial channel obstruction, such as a gravel bar or wing deflector.

Sediment: Fragmented material that originates from weathering of rocks and decomposition of organic material that is transported by, suspended in, and eventually deposited by water or wind.

Sediment storage areas: Areas where suspended sediments have settled and are being stored either temporarily or permanently depending on stream flow, channel morphology and channel hydraulics.

Seepage sites: Areas of minor groundwater discharge generally smaller than springs

Setback: Areas of land and riparian vegetation adjacent to watercourses or aquatic water bodies that are to remain in an undisturbed state, throughout and after the development process. Syn: Leave area or reserve zone.

Shallow open water: Wetlands which are intermittently or permanently flooded with open expanses of standing or moving water up to 2 m deep. Open water with no emergent vegetation covers 75% or more of the wetlands surface. Commonly termed ponds or pools.

Site potential tree: A tree that has attained maximum height possible given the site conditions where it occurs

Spawning: Active deposition and fertilization of eggs.

Spring: A surface water drainage feature that derives most of its flow from groundwater and has relatively constant flow and temperature.

Stormwater flow: The portion of streamflow that is provided by surface water runoff.

Strategic planning level: A high level planning stage which focuses on formulation of a broad plan with general policies, objectives and goal statements.

Stream: A natural watercourse containing flowing water, at least part of the year, and supporting a community of plants and animals within the stream channel and the riparian vegetation zone.

Stream bed: The substrate plane, bounded by the stream banks, over which water flows. Syn: stream bottom.

Structural elements: (a) Any large object in the stream channel that controls water movement. (b) The diversity of physical habitat within a stream. (c) When applied to a biological community, the organization of taxa into various functional or trophic groups.

Substrate: The mineral and/or organic material that forms the bed of the stream.

Subsurface drainage: The portion of streamflow that is below ground.

Surface drainage: The portion of streamflow that is expressed above ground.

Swamp: Wetlands with mineral or occasionally peat soils and a water table at or near the surface. Pronounced internal water movement from adjacent mineral areas, make the waters nutrient-rich. If peat is present, it is predominantly well decomposed wood and occasionally sedges. The vegetation is typically dominated by coniferous and deciduous trees or dense shrubs and herbaceous species.

Terrestrial: Consisting of, living on, or growing on land.

Undercut bank: A bank that has had its base cut away often as a result of erosion.

Wetlands: An area subject to periodic inundation, usually with soil and vegetative characteristics that separate it from adjoining non-inundated aeras. Includes fens, swamps, marshes and bogs.

Wetted width: The width of the water surface measured at right angles to the direction of flow and at a specific discharge. Widths of multiple channels are summed to represent total wetted width.

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