EA 1555

MISSION CREEK
HABITAT RESTORATION FEASIBILITY

submitted to:

Ministry of Water, Land and Air Protection
Unit 201-3547 Skaha Lake Rd.
Penticton, BC
V2A 7K2

March 2003

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prepared by:

Marc Gaboury[1] and Pat Slaney[2]

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[1] **LGL Limited, environmental research associates, 9768 Second St., Sidney, BC V8L 3Y8**

[2] **P. Slaney Aquatic Science Inc., 214 Nelson St., Coquitlam, BC V3K 4M4**

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INTRODUCTION

Most portions of lower Mission Creek were dyked for flood control in the 1950's. The dyking impaired natural stream processes and negatively impacted spawning, rearing and overwintering habitat for native rainbow trout, kokanee and other non-salmonids.

This report explores the feasibility of restoring fish habitat in the lower 12 km of Mission Creek between Okanagan Lake and the Hasse property above East Kelowna Road (Figure 1). This section of creek was chosen because of impacts to channel morphology, watershed processes and aquatic and terrestrial habitat as a result of the historic flood protection works constructed along the channel. The channel upstream of East Kelowna Road remains in a relatively natural state.

Within the selected area we investigated the possibility of returning the creek to a more original configuration by:

- setting back dykes to widen selected portions of the river;
- constructing riffle-pool sequences; and
- realigning portions of the channel in a more natural and meandering route.

The rationale for undertaking restoration work in Mission Creek is based on its relative contribution to Okanagan Lake fish production. Restoration of Mission Creek is one of the major components in a multi-faceted plan to restore depressed kokanee and rainbow trout stocks and recover a viable sports fishery in Okanagan Lake. The urgency of implementing restorative measures on the spawning and rearing habitats of kokanee and rainbow trout is due to the continuing declines in Okanagan Lake wild fish stocks over the past 30 years.

Restoration of Mission Creek will involve the cooperation and commitment from all levels of government as well as local community groups within the Kelowna area. A coalition made up of the City of Kelowna, Regional District of Central Okanagan, Friends of Mission Creek, and Ministry of Water, Land and Air Protection in conjunction with First Nations and community groups is envisioned to oversee and champion the long term restoration of Mission Creek. If in support, the coalition will use this report as a working document to discuss and refine the conceptual restoration options, and, over time, implement the approved projects.

Status and Trends of Okanagan Lake Fishery

Although Okanagan Lake supports 18 species of fish, kokanee and rainbow trout are the primary species targeted by anglers. Kokanee have historically dominated the salmonid catch by about five fold owing to their much greater abundance than rainbow. A few other species including whitefish, burbot and perch are reported to be of minor (1%) interest by anglers (Shepherd 1990). Angler effort on Okanagan Lake was estimated at 188,000 angler hours in 1971, resulting in an estimated catch of 178,000 kokanee (Andrusak 2001). Angler effort in the late 1980's was estimated at 310,000 angler-hours or 72,000 angler-days per year (Shepherd 1990), although effort and particularly catch had declined by the early 1990's (Andrusak 2001). The fishery in the 1980's was economically valued at $2 million per annum, with fishery-related expenditures of $5 million per year (Shepherd 1990).

Unfortunately, Okanagan kokanee, of both stream and lake-shore spawning stocks, have declined substantially from a total of 600,000-1,000,000 spawners in the 1970's to 300,000 in the 1980's to about 100,000 in the 1990's, collapsing to a low of only several thousand spawners in the late 1990's (Sebastian et al. 2002; Figure 2). The cause of the decline has been linked largely to loss of stream habitat and low survival during the lake rearing phase resulting from modifications to lake habitat. One of the identified contributors to low in-lake survival is the ill-advised introduction of mysid shrimp in the mid 1960's which are now confirmed to compete directly with kokanee for zooplankton (rather than act as an alternative larger prey source for kokanee).

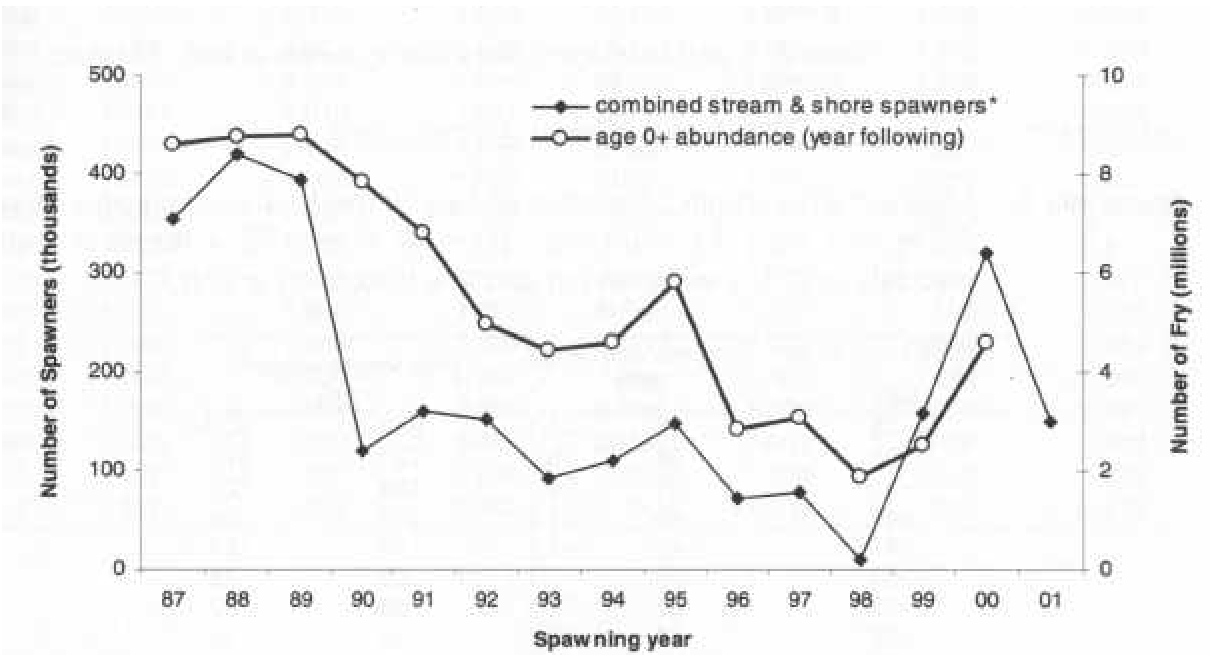

Figure 2. Trends in combined stream and shore spawner abundance counts (expanded by 1.5x to estimate total numbers) and the estimated kokanee fry population in Okanagan Lake based on annual acoustic surveys from 1987 to 2001 (Sebastian et al. 2002).

The precipitous decline in kokanee in the mid-1990's as depicted in Figure 2 has resulted in considerable media attention, curtailment of kokanee fishing, and establishment of the Province's Okanagan Lake Action Plan (OLAP) (Andrusak et al. 2001). Fisheries managers, researchers and concerned members of the public assembled to summarize what was known on productivity and trophic levels of Okanagan Lake, as well as the historical and existing status of fish stocks. A strategic

20-year direction from the Plan involves conserving native fish stocks (through restrictive fishery regulations), protecting habitat, and collecting priority information over the first five years. Over the next five years the focus is to be directed at priority remedial measures including restoring stream flows, curtailing habitat degradation, reducing Okanagan Lake level fluctuations, and increasing in-lake survival of salmonids.

By comparison, the status of rainbow trout is more difficult to ascertain because there are no long-term spawner counts as there are for kokanee. However, catch per unit effort (CPUE) in the fishery provides a useful trend indicator of stock status. Catch per unit effort for kokanee declined from >1 per hr to 0.3 per hr or a 70% decline from 1971 up to 1989 (Shepherd 1990). Catch per unit effort of rainbow has been more resilient with a more moderate decline to 0.5 catch per day from an earlier 0.7 catch/day over the same period of time. Some of the same constraints on productivity and energy transfer in the lake, as discussed above, can impact growth and survival of rainbow trout.

Of 46 named tributaries to Okanagan Lake, 17 are known kokanee and/or trout producers, with 6-7 classified as major kokanee producers and three as major rainbow producers, including Mission, Powers, Peachland, Kelowna, and Trepanier creeks. The largest tributary, Mission Creek, has historically dominated estimated production of kokanee and rainbow trout (Shepherd 1990). During the 1980's, seven tributary streams (Mission, Kelowna, Lambly, Peachland, Powers, Shorts, and Trepanier creeks) were surveyed to estimate spawning capacity for kokanee and rearing capacity for juvenile rainbow trout. Of an estimated spawning capacity of 219,000-405,000 kokanee, Mission Creek accounted for 186,000-330,000 of stream capability for kokanee (Shepherd 1990). Based on historical stream spawner surveys, Mission Creek has accounted for >80% of the kokanee counts. However, by 1992, average kokanee escapement at Mission Creek was 50,000 or about 17% of estimated capacity, and by 1998 to 1999 abundance had collapsed to an estimated 1700 spawners, although numbers have increased to several thousand recently (Appendix 1; Andrusak 2001). Counts of rainbow trout migrants at a temporary fishway from 1975 to 1979 indicated an average escapement of 421 rainbow spawners, and a range of 245 to 573 (Shepherd 1990). As well, juvenile rearing capacity of rainbow trout from the seven tributaries was estimated at 5700-9200 parr, of which 3700-6000 was estimated to be produced in Mission Creek (Tredger 1989). As the primary rearing stream for rainbow trout, it is estimated 65% of the trout originate from this pivotal stream. Thus, it is apparent that Mission Creek is the dominant salmonid stream in the Okanagan basin.

Additive to in-lake constraints for supporting a viable fishery within Okanagan Lake is a 100 year history of alteration of streams and lake shores by human intervention. Restoration of streams with long-standing impacts to stream spawning habitat of kokanee and stream rearing habitat of rainbow trout is a remedial action of considerable merit. In degraded and prime habitats, survival of salmonids can be reduced and increased, respectively, at each stage of their life history from egg to adult; and those stocks with highest survival at each stage have the greatest "stock productivity" from a stock-recruitment perspective (Slaney and Martin 1997).

"Productive stocks" are most resilient at maintaining their historical abundance through periods of negative environmental change, and thereby they are much more resilient to fishing pressure. Further, kokanee also serve as a "keystone species" in the Okanagan basin, the same ecological function that Pacific salmon provide elsewhere. As a keystone species, they re-distribute nutrients as well as energy in the form of eggs and carcass flesh to the streams and riparian areas, which also have profound benefits to many aquatic-dependent wildlife. Thus, restoring conditions in the nursery environments is as important as restoring limnological conditions in the lake, and together both actions from OLAP can accelerate recovery over that which would occur by focusing on a singular course of action (Andrusak et al. 2001). Owing to Mission Creek's overriding importance to kokanee recruitment to Okanagan Lake, and because salmonid habitats in the lower 12 km of the creek have been historically degraded, lower Mission Creek must be considered a priority target for restoring productive habitat conditions.

HYDROLOGY AND HABITAT OF MISSION CREEK

Mission Creek has a watershed area of 858.8 km^2, with elevations ranging from 342 m at Okanagan Lake to 2171 m at the Little White Mountain summit (Anonymous 1997). Annual total precipitation averages 329.7 mm for lower Mission Creek and 702.6 mm at the McCulloch Station (elev. 1250 m) (Anonymous 1997). Mission Creek is designated a community watershed.

Analysis of historic flow data (1949-2000) for Mission Creek at East Kelowna (WSC Stn. 08NM116) indicates a mean annual discharge of 6.81 cms, with a recorded peak daily discharge of 87.5 cms. Higher discharges typically occur during the snowmelt period in May and June with the lowest mean monthly flows occurring from December to March (Figure 3). The instantaneous peak flow with a recurrence interval of 100 yr is estimated at 98 cms (Figure 4). Bankfull discharge (instantaneous flow with a recurrence interval of 1.5 yr) is estimated at 52 cms. Discharges in the creek are regulated as a consequence of several lakes being developed as storage reservoirs for irrigation needs.

Mission Creek has a stream length of 74.3 km but a falls barrier located at 19 km upstream of the river mouth limits access for adfluvial species from Okanagan Lake. Known fish species recorded in the creek include rainbow trout, kokanee, brook trout, burbot, longnose dace, peamouth chub, redside shiner and sucker (sp.) (Fish Wizard website: pisces.env.gov.bc.ca).

Historically, the channel in 1938 was meandering and appeared to have significant aggradation of sand and gravel downstream of the East Kelowna Road bridge crossing (Map 1). Active channel width, including gravel bars, averaged 60 to 80 m between KLO Road and the present-day Regional Park. Overall channel length was 29.9 km between East Kelowna Road crossing and the lake as compared to 10.8 km currently. Channel gradient over this overall channel length averaged about 0.2% in

1938 versus 0.6% today. Overflow streams are apparent on the 1938 air photo mosaic near the present-day location of Ziprick Road. The photos show that riprap dykes had been constructed to contain floodwaters but appear to have breached and allowed flooding to the north. Abandoned mainstem channels are also apparent to the north and northwest of the 1938 channel alignment below KLO Road indicating that Mission Creek actively migrated on its alluvial fan. The potential for widespread flooding by Mission Creek on its alluvial fan was described by Bergman (1995) as “If not contained by dykes, during high flow events Mission Creek could flow anywhere over an approximately 30 km^2 area and enter Okanagan Lake anywhere over an 8 km distance, from Okanagan Mission to downtown Kelowna”.

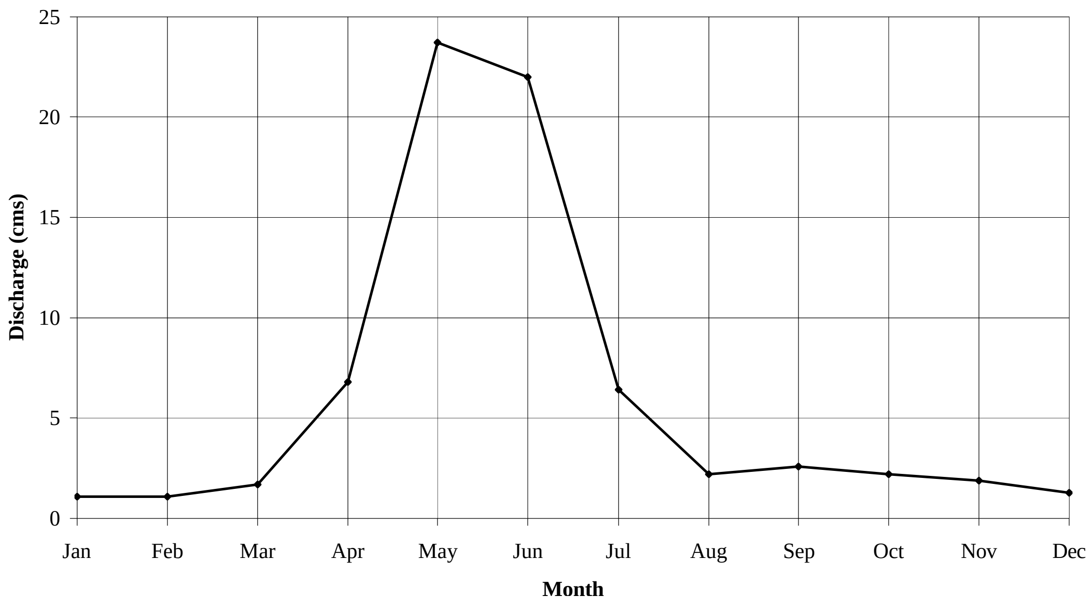

Figure 3. Average annual hydrograph for Mission Creek, 1949 to 2000.

Although no engineering level survey of the channel was conducted in this project, cross sections from 1980, 1983 and 1992 were available from BC Ministry of Sustainable Resource Management (MSRM) (B. Edward, MSRM pers. comm.). A channel profile plot based on thalweg streambed elevations from each cross section, indicated gradients of 0.2 to 1.0% between Okanagan Lake and the falls barrier (Figure 5). The gradient is lowest at 0.2% between KLO Road and the lake. Bankfull widths, estimated from cross sections between 1 and 96 (Map 2), ranged between about 22 and 43 m. The bankfull width for the channel between KLO and East Kelowna roads averaged about 31 m. This is similar to an expected width based on a formula, $W = 4.5 \cdot Q^{0.5}$ developed by Kellerhals and Church (1989) that relates bankfull discharge (Q) to bankfull width (W). With an estimated bankfull discharge of 52 cms for Mission Creek, the expected bankfull width was calculated to be 32.4 m.

The length of the Mission Creek mainstem examined in this project was approximately 12 km, extending from the Hasse property (located about 0.5 km upstream of the East Kelowna Road bridge crossing) to the Mission Creek confluence with Okanagan Lake. Most of the lower 7 km of channel, extending from the Regional District Park to the lake, was dyked for the purpose of flood control in the early 1950's. However, there is a section at Casorso Marsh (immediately upstream of Casorso Road) where the dyke is absent from the left bank allowing overbank flows to occur. In this lower reach there are more mature trees, primarily large cottonwood. The 3 km reach above the Park was less altered, but the lower half of this reach has been flood-protected by rip-rap armoring which has been incrementally increased over time. Upstream of this reach to the Hasse property has had limited dyking activity and appears to have had some channel re-alignment and habitat simplification.

Gravel aggradation from primarily bedload sources in the upper watershed have resulted in infrequent gravel removal operations. Gravel has been removed from a section of channel located about 0.5 km directly upstream of the Park and another section downstream of the KLO Road bridge crossing.

Fish habitat in streams is frequently assessed quantitatively to diagnose physical and biological limitations to salmonid production. For example, a procedure outlined in Johnston and Slaney (1996) was designed for assessing impacts of past logging practices by applying diagnostics for losses of large woody debris (LWD), pools, cover, spawning areas, off-channel habitats, and nutrients. The diagnostics indicate that simplified, uniform channels, resulting from losses of LWD and particularly log jams, and/or channelization, are a substantive limitation that impairs the capacity and viability of salmonid habitats. If this assessment procedure is applied to lower Mission Creek, it is evident that the channel is in "poor" condition because 8 of 12 km (67%) has been confined or channelized within dykes, and LWD structures have been removed to increase flow routing efficiency through the large Mission Creek fan (Photo 1). An instream large wood tally from kilometre 12 at the Hasse property downstream to near the mouth of Mission Creek indicates that there are only a few residual pieces of functional wood, and largely near the kokanee viewing platform in the lower reach. Consequently, natural functions of LWD including bar and bank stabilization for maintaining prime habitat conditions have been eliminated.

In addition to the loss of functional LWD, the construction and maintenance of parallel dyking has caused degradation or loss of other aquatic values in Mission Creek, such as:

- natural fluvial geomorphic processes and patterns (pool-riffle formation, meander patterns and substrate sorting/substrate diversity);
- connected floodplains and associated wetlands;
- fish spawning and incubation habitat at pool tailouts;
- diverse fish rearing habitats including juvenile rearing space (pools and cover);
- diverse fish over-wintering habitat, both instream and off-channel, particularly anchor ice refuges;

- fish habitat refuges from the high-energy spring freshet;
- connectivity between the wetted channel and the riparian area for aquatic life and wildlife; and
- wetlands for use by fish, amphibians, waterfowl and aquatic mammals.

The disconnected riparian zone along Mission Creek, with its largely immature trees, can be classified using the Proper Functioning Condition Assessment (Barrett et al. 1993). The dyked sections of the channel would be considered as non-functional. This is defined by Barrett et al. (1993) as "riparian-wetland areas that clearly are not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with high flows and thus are not reducing erosion, improving water quality, etc...The absence of certain physical attributes such as a floodplain where one should be are indicators of non-functioning conditions".

As a result of a loss of pools, the stream is likely subjected to anchor ice formation throughout the shallow open riffles that dominate Mission Creek over a distance of about 10 km. Under exceptionally low flows, the anchor ice could significantly impair kokanee survival as well as over-wintering success of any under-yearling trout that disperse into the uniform shallow reaches of lower Mission Creek.

Most kokanee spawn in the lower 8 km of Mission Creek, or from the spawning channel downstream, because this is where substrates are least coarse (Appendix 1; Wightman and Taylor 1978; Photos 2 and 3). Median diameter of the existing substrate near Gordon Road was measured at 6 cm while D_{50} near the footbridge in the Regional Park was 14 cm. In general, spawning substrates upstream of KLO Road are marginal owing to the confined nature of the channel, and a gradient that is not conducive to retaining spawning gravels. Further, there are few holding pools for kokanee in locations where there are suitable spawning substrates. Similarly, holding or resting pools are not available for rainbow spawners that are documented to migrate upstream 12 km during the spring (Wightman and Taylor 1978). Accordingly, the lower 12 km have marginal fish habitat with only sporadic habitat features conducive to either spawning of kokanee or rearing of rainbow trout.

Within Mission Creek, Black Mountain Irrigation District and South East Kelowna Irrigation District together hold licences authorizing 99% of the waterworks and storage and over 90% of the irrigation quantities (Anonymous 1990). A total of 265 licences for Mission Creek permit the use of 6738 dam^3 per year for waterworks purposes (domestic, industrial, etc.); 44218 dam^3 per year for irrigation use supported by 41300 dam^3 of storage; and 0.238 m^3/s for non-consumptive use or conservation purposes supported by 1295 dam^3 of storage. Irrigation withdrawals occur primarily between May and September, with the peak occurring in August. Licenced water withdrawals would exceed actual discharge in Mission Creek between July and September in a one in 10 year low flow. Assuming a minimum instream flow of 1.13 m^3/s in Mission Creek, trout and kokanee populations would be severely impacted in a one in 10 year low flow when licenced water withdrawals are fully utilized. Dobson Engineering recommended alternatives to improve instream flows for fish by initiating a water licence review, developing water conservation strategies, developing additional storage and obtaining storage licences (Anonymous 1990).

Water flow management in the irrigation canals is also a significant cause of rainbow trout and kokanee incubation and rearing mortality (S. Matthews, MWLAP pers. comm.). For example, in the Benvoulin Ditch, operated by the Benvoulin Water Users Community, which lies outside of the north dyke and parallels the channelized section for much of its length, higher discharges between May and September attract juvenile trout and kokanee spawners into the canal. Kokanee were observed spawning in the irrigation canal near the Regional Park in 2002 (Photo 4). The reduction in discharges in the canal during the winter is believed to cause a dewatering of habitat refugia for overwintering trout juveniles and freezing or dessication of incubating kokanee eggs. In addition, MWLAP staff have observed that the current outlet design limits fish access into and out of the Benvoulin Ditch (S. Matthews, MWLAP pers. comm.). MWLAP staff have also noted that significant fish losses occur at many irrigation off-takes as a result of inadequate screening.

There have been some intentional and incidental improvements over the past decades but, unfortunately, they do not offset the physical and biological impacts that have resulted from channel confinement. A 900 m kokanee spawning channel has been constructed on the south side of the channel in an attempt to offset losses of spawning areas (Appendix 2). However, sedimentation is an annual constraint that is currently managed at significant cost and is in the process of being resolved (S. Matthews, MWLAP pers. comm.). In addition, management agencies have cleared only limited vegetation and trees along the channelized reaches which offsets at least some of the unnatural appearance of hardened channel confinement.

RESTORATION RATIONALE

River ecosystems are based on interactions between the main channel and adjacent low velocity habitats during overbank flooding (Welcomme 1989). In comparison to a natural stream, a channelized river with parallel dyking is confined to a single thread channel with slight sinuosity and a higher flow velocity and shear stress for a given discharge. Vegetation removal from the area within the dykes in order to decrease roughness, increase velocities, and lower flood stages within the floodway channel can exacerbate sediment erosion and deposition processes. For example, increased channel bed erosion can cause channel incision and over-steepened streambanks, leading to accelerated bank erosion. However, dyking disconnects the floodplain from being inundated by floodwaters, reducing areas for sediment deposition and storage (Anonymous 2002). As occurs in Mission Creek, sediment produced by erosion of banks and from upstream sediment sources that would naturally be stored in the floodplain or channel are routed to downstream lower gradient reaches where the sediments accumulate. The aggraded sediments then need to be removed from the channel to prevent the channel bed (and water table) from being higher than the surrounding residential and agricultural lands.

Although complete recovery of geomorphic processes and ecological functions of lower Mission Creek is possible by removal of dykes, this would compromise flood protection for the City of Kelowna, as well as stream-side residents. The dykes also serve a purpose of maintenance access and provide an important component of the Mission Creek Greenway Project, functioning as trails for recreational access (Photo 2). However, recovery of stream processes and functions is still possible by re-setting the dykes where feasible as set-back dykes either on both sides or on one side of the mainstem channel. Observations of the existing channel demonstrate that even a 10 to 20 m widening of the channel, to a width of 40 to 50 m between dykes, can result in bar formation, better pool and riffle definition, some substrate sorting to improve the quality and quantity of spawning gravels, and the creation of a few small vegetated islands. In 1938, prior to channelization, the active channel widths (i.e., wetted and gravel bars) averaged between 60 and 80 m between KLO Road and the present-day Regional Park (Map 1). A greater set-back of dykes to 30 to 200 m will result in pool-riffle restoration, well-sorted substrates, braided channels with numerous islands, and ecological interfaces of pools and riparian zones to provide stream-side cover and useable energy sources for large areas of useable fish habitat (preferred depths velocities, substrates and cover). Floodplain recovery would be facilitated within the dykes, which would be beneficial to shrub and tree growth owing to deposition of nutrient-rich fine sediments, with energy (from leaf litter) and nutrients recycled more effectively in the stream ecosystem. Further, dyke protection for flooding would be more effective because a floodplain would be provided to buffer and slow hydraulic energy that would otherwise cause wear on dyke materials, requiring annual maintenance and armouring. Finally, a wider stream section would reduce depths and perching of the wetted channel above surrounding lands, thus reducing groundwater depths outside the dykes.

Meanders could be restored in some stream segments of Mission Creek where land tenures facilitate it. Restoration of meanders and pool-riffle sequences has proved to be a successful method of restoring fish habitat in channelized streams, as outlined in Newbury, Gaboury and Bates (1997) and more thoroughly in Newbury and Gaboury (1994). In lower Mission Creek, the restoration of pool-riffle sequences would provide hydraulic gradients where spawning gravels would readily deposit, particularly within pool tail-outs. These habitats would be highly utilized by kokanee spawners and provide holding areas for adult fish. It would also restore rearing areas for rainbow juveniles in the lower river. Such measures would restore much of the fish habitat in lower Mission Creek. The measures would include set-back dykes to restore meanders, pool formation, and off-channel habitats, and riffle-pool re-construction in confined sections where dykes cannot be set-back owing to private land constraints. In addition, there is a need for selected replacement of LWD in meander pools for restoring the natural process of driftwood-LWD accumulations that maintains deeper pools, cover, habitat diversity and off-channel connectivity in forested streams as described in Cederholm et al. (1997) and Slaney et al. (1997).

In the following report, restoration treatments are proposed for three channel segments as follows:

Channel Segment	**Restoration Treatment**
Gordon Road and Regional Park	Setback dykes
KLO Road and Regional Park	Meandering channel with pool-riffle sequences
Regional Park and East Kelowna Road	Riffle structures; sediment traps; re-define meandering channel

Natural landslides and extensive bank erosion on the Mission Creek mainstem upstream of the Pearson Creek sub-basin have historically contributed significant amounts of sediment to the channel (Anonymous 1998; Map 1). The Interior Watershed Assessment (IWAP) by Dobson Engineering Ltd. (Anonymous 1998) rated the landslide hazard along the mainstem of Mission Creek as high. Furthermore, the Dobson report concluded that “Landslides connected to the creek are the single most significant channel-defining event that has occurred within the watershed.” A total of 95 active and inactive landslides were identified in the watershed (Anonymous 2000). It was concluded that landslides and erosion events were part of the natural processes in the Mission Creek valley which have been ongoing since the last period of glaciation. It was observed that approximately 75% of the landslide disturbance had occurred in un-logged portions of the watershed. From this terrain stability assessment, it was concluded “As the majority of the landslides in the study area are naturally occurring and may reactivate again in the future, remediation is not recommended”. It is clear from these assessments that a high incidence of sediment delivery and transport from hillslopes are a natural condition in the Mission Creek watershed and can be expected to occur in the future. Some opportunities exist, however, to rehabilitate chronic sediment sources which have been caused by past and current land use practices.

The Mission Creek watershed is dominated by channels in a moderate and high disturbance condition. The subbasins with the highest proportion of their stream lengths in a moderate or high disturbance condition are the mainstem at 63.4%, Joe Rich Creek at 86.6% and Daves Creek at 100% (Anonymous 1998). Tributaries, such as Joe Rich Creek, can provide a significant volume of sediment as a result of poor riparian condition and extensive bank erosion (Photo 5). Based on an Interior Watershed Assessment (Anonymous 1997), high impact hazards were identified for surface erosion and riparian buffers in Mission Creek tributaries Belgo, Daves, Hydraulic, KLO, Priest, and Joe Rich creeks.

Riparian logging, cattle activity within riparian areas, high road densities within 100 m of a stream and high densities of stream crossings have all contributed to high sediment delivery to lower Mission Creek and should be addressed through active rehabilitative programs. Many forest roads that had chronic sediment production in the upper part of the watershed have been stabilized via the past Forest Renewal BC Watershed Restoration Program (P. Epp, MWLAP pers. comm.). The provincial Forest Investment Account directed to forest companies should continue to play a significant planning and financial role in forest site and road rehabilitation, and the prevention of logging-related landslides and erosion events. In addition, cooperative riparian corridor projects with private landowners on, for example Joe Rich Creek, should be considered a high priority. Investigations into the feasibility of reducing the impacts along private land should be initiated as a first step. Where candidate sites are identified, it is recommended that corridor management plans be prepared with the landowner to provide long term protection through the re-establishment and management of healthy vegetated riparian buffers. Also, integrated bank protection measures should be prepared to rehabilitate chronic sources of sediment.

Mission Creek restoration will need to not only address fish and wildlife habitat issues but other design and infrastructure components of the present channelized system, including flooding and flood routing, water withdrawal off-takes, and land drainage. Although we have acknowledged these components in our discussion, they will need to be addressed in greater detail at the design stage. The following are some conceptual designs for river restoration that, upon review by OLAP members and others, should be prioritized for further analysis and the preparation of detailed designs.

RESTORATION OPTIONS

Setback Dykes

Setback dykes are generally constructed parallel to the stream but placed far enough from the active channel to allow overbank flooding and some natural floodplain function. The degree of setback is variable, but Cowx and Welcomme (1998) suggest that the minimum setback distance should be 7 to 10 channel widths to restore the majority of floodplain functions. Clearly, a setback distance of 2 to 6 channel widths will only be feasible on Mission Creek, but we believe expanding the stream corridor to even 2 or 3 channel widths will have significant benefits to channel morphology, sediment processes, and salmonid spawning and rearing habitats.

Setting back the dykes serves many purposes including: habitat restoration, erosion reduction, water quality improvements, groundwater recharge, wildlife migration corridors, and reduction of flood hazard risks. Dykes directly affect floodplain extent and connectivity with the stream channel, which then affects habitat. Undeveloped, natural floodplains provide stream energy dissipation by reducing velocities and providing areas for sediment deposition including organic debris. These low velocity areas provide refuge areas for aquatic species during floods and are excellent habitat for a wide variety of species.

<u>Conceptual Design</u>

The section of channel near Casorso Marsh is not dyked along the left bank. This has resulted in the development of more diverse aquatic habitat, consisting of pools, riffles, gravel bars, and associated backwaters. The presence of a functional floodplain within this short section of Mission Creek has allowed for sediment sorting during floods, with deposition of finer sediments on the floodplain and less gravel scour within the main channel. As a consequence, the gravel substrate is unconsolidated or less cemented, which is preferred by kokanee who concentrate within this section during spawning (Appendix 1; Photo 3).

Our proposed restoration objective is to recreate a more functional floodplain by setting the dykes back between cross sections 9 and 49 (Map 2). The design as proposed provides a minimum separation between the setback dykes of about 50 m, with a maximum width of about 206 m. The setback design option is illustrated for four cross sections in Figure 6. In many cases, two new dykes would need to be constructed following the Provincial standard dyke design (Bergman 1995). Alternatively, for some sections of channel, the steep valley wall on the left bank could function as the setback dyke. For example, cross section 44 in Figure 6 illustrates how the valley wall might function as the dyke between cross sections 43 and 49.

Floodplains would be re-established between the dykes to allow for overtopping of the central channel banks when flows are greater than bankfull discharge, estimated at 52 cms (Figure 4). The floodplain would be constructed by excavating the existing ground level down to an elevation about 0.8 to 0.9 m above the riffle crests (Figure 7). The dykes would have top widths of 4.5 m, 2:1 side slopes, and the same top elevations as the existing dykes. The dykes would be constructed using spoil from the construction of the floodplain and the removal of the existing dykes.

Along with the setback dyke construction, restoration works would include riparian vegetation planting along the channel banks. Also, several structural components that are part of the infrastructure in the existing channel would need to be addressed in future engineering drawings of the proposed design options, including:

- existing water withdrawal off-takes. Screening of the intake pipes should be a standard practice to prevent losses of fish due to entrainment or impingement;
- gated culverts to drain excess water that accumulates locally outside of the dykes; and
- outlet pipes to connect tributaries to the river.

<u>Land Status</u>

In the section between Gordon Road and the Regional Park where setback dykes are proposed, there are about 14 affected lots in private ownership and 4 owned by the Crown, City of Kelowna, Westbank First Nation, or Regional District of Central Okanagan (CORD) (Table 1; Map 2; Appendix 2). The City's portions are road right-of-ways along the south and north streambanks as well as ‘public and institutional zones’ (P1)(City of Kelowna web site). The Regional Park is zoned ‘parks and open space’ (P3) and is owned by the Crown. The neighbouring park property to the south of the Regional Park is also zoned P3 and is owned by CORD. Much of the affected private land is within the Agricultural Land Reserve and zoned ‘agriculture 1' (A1) so the land would not only have to be acquired but it may need to be rezoned. This would require approval by the City of Kelowna Local Agricultural Advisory Committee and the Agricultural Land Commission. The concept of rezoning should be thoroughly investigated prior to any land purchases.

Table 1. Land status in the setback dyke reach. Lots identified by PID number.

Setback Dyke Area	Cross Sections	Bank	Private Land Zoning	Affected Lots (Private)	Affected Lots (Crown, City, CORD)
1	9 to 20	South	A1,P1	011-099-895, 008-504-130	014-767-538, Westbank First Nation
1	12 to 20	North	A1	none	Road Right-of-Way
2	27 to 31	South	A1	009-417-770	none
2	21 to 31	North	A1	008-504-130, 024-008-168	024-008-184, Road Right-of-Way
3	39 to 50	South	A1,P3	006-909-213 & -221, 011-074-311 & -167, 007-885-482, 007-938-675, 003-979-440	Road Right-of-Way, 017-816-874
3	37 to 50	North	A1,P3	001-714-791, 011-074-132, 011-074-281 & 311, 003-979-440	Road Right-of-Way, 024-208-124, 017-816-874

Benefits, Risks and Costs

A Mission Creek corridor plan was previously proposed by BC Environment, Water Management Division that suggested the Province and City of Kelowna should partner to reconstruct dykes in the lower 7 km of the creek in a setback location (Bergman 1995). McMullen (1988) had identified that the existing dykes were not up to provincial standard, having side slopes that were too steep and crest widths which were too narrow. Bergman (1995) proposed that after the land was purchased, existing dykes would be removed and new dykes would be constructed in a setback location (Figure 8). The cost of the land purchase was estimated at $12.4 M and setback dyke construction was estimated at $3 M. No decision on an implementation schedule has been made to date because the City of Kelowna believes the Province is solely responsible for maintenance of the flood control works along Mission Creek. This responsibility was confirmed by the Premier of the Province after the City amalgamated in 1973 (H. Hall, Friends of Mission Creek pers. comm.).

It was recognized in the proposal by Bergman (1995) that the setback location would allow for the ongoing development and ownership of lands under the City of Kelowna’s Mission Creek Greenway Project. The Greenway Project is a collaborative project between the City of Kelowna, Regional District of Central Okanagan, Friends of Mission Creek, Central Okanagan Parks and Trust, Westbank First Nation, and the Ministry of Water, Land and Air Protection. As part of the overall project, an extensive hiking trail has been developed along the right bank of the creek from Lakeshore to about East Kelowna Road, along with a platform for viewing kokanee spawning near Casorso Road. However, portions of the trail are on private land which limits development and raises liability and right of access concerns.

A similar setback dyke design has also been proposed as a restoration measure for the channelized and dyked Okanagan River (Bull et al. 2000). Setback dykes were recommended for a 3 km section of the river to restore hydrological processes and floodplain function as well as improve sockeye spawning habitat. In addition, setback dykes were included in a 9.9 km long section of channel proposed for re-meandering. Implementation of setback dyke construction within the 3 km section of river upstream of Oliver is being pursued currently by the Okanagan Basin Technical Working Group (OBTWG) and the South Okanagan Similkameen Conservation Program (S. Matthews, MWLAP pers. comm.). This demonstration project will be a ‘proof of concept’ for setback dyking. The effectiveness of setback dykes in the Okanagan River will be directly relevant to decisions on the implementation of similar proposals for Mission Creek.

Setback dykes will permit controlled inundation of floodplains within their borders and allow the river to meander within a belt-width prescribed by dyke dimensions. The stability and sustained ecosystem function of large river ecosystems is dependent upon maintenance of watershed and floodplain integrity (Gore and Shields 1995). Furthermore, they state that renewal of physical and biological interactions between the main channel, backwaters and floodplains is central to the rehabilitation of large rivers. The ecological values of floodplain habitats along leveed rivers has been restored on the Danube River in the Czech Republic by constructing new setback dykes (Gore and Shields 1995).

Anticipated benefits associated with setback dykes on the Mission Creek include:

- a reduction in flood stage as a consequence of a wider stream valley with a central channel and floodplains;
- fine sediment deposition on the floodplains during flood events;
- Allows increased floodplain flows and thus floodplain channels, diversity and interaction with active channel;
- increased stability and quality of spawning gravel associated with riffle structures;
- increased shading and cover with the development of riparian areas beside the central channel;
- restores flood-flow refuge from high velocities; and
- increased diversity and abundance of various terrestrial and aquatic wildlife species resulting from the establishment of riparian areas, floodplain wetlands and sloughs.

Floodplains provide a hydrologic function by conveying and storing major floodwaters (Sparks 1995). In comparison to the existing channel, it is estimated that a wider stream valley that incorporates floodplains would lower the 1 in 200 year design flood stage of 110 cms by about 0.4 to 0.5 m (Figure 9). A shallower flood depth (similar to a natural river) would reduce the tractive force, increasing the stability of spawning gravels in the mainstem riffles.

Also, with a setback dyke design, a portion of fine sediment load (sand and silt) would be deposited on the floodplains. The increased stability of spawning gravels and reduced sedimentation should improve egg incubation success at existing and proposed riffles and tail-outs.

Planting of a diverse riparian area of trees, shrubs, grasses and forbs would be included in the setback dyke design option. The establishment of riparian areas along the existing channel will:

- provide diverse habitats for terrestrial and aquatic wildlife;
- provide corridors for wildlife movement;
- provide large woody debris and organic matter for watercourses;
- provide overhanging cover and a source for instream cover;
- stabilize the streambanks and reduce erosion;
- control temperature in the watercourse through shading; and
- enhance the visual quality and amenity of the landscape.

Many of the private land parcels in question are zoned agricultural. However, land values vary considerably based upon the size of the property, the extent of improvements made and the productive capacity of the land. Many of the parcels of land within the proposed restoration zones are productive farmland or developed as rural residences. The market value of larger acreages is considered to be about $35,000 to $50,000 Canadian per acre. For smaller parcels of land the market value (2002) can be up to $75,000 per acre (D. Parkhill, Kent-MacPherson Appraisals pers. comm.).

Risk and uncertainty for dyke setback are relatively low if appropriate analysis and modeling is completed. Risk analysis must include (1) changes to stability, (2) upstream, downstream, and floodplain hydraulic effects, (3) changes to flood hazards, and (4) stream channel response (Anonymous 2002). Hydraulic effects of setting back dykes include changes in channel and floodplain roughness and a potential change in channel length and slope, which in turn affect velocity and shear stress. Generally, velocity and shear stress will decrease causing a loss in sediment transport capability through the setback reach. The reach upstream of a levee removal project may experience increased velocity and shear stress as the backwater of the levee during flood events is eliminated. Sediment deposition on the floodplain should be expected. Hydraulic models are available to help predict these changes. Sediment transport models (HEC-6 and GSTARS) can be used to help address issues with sediment deposition in the restored reach and upstream.

An accurate determination of flood risk should be made at the detailed design stage using a backwater simulation model (i.e., HEC-RAS). An analysis should also determine the effect of riparian vegetation on the flood stage. Flood risk is usually reduced for all areas if the floodplain and channel are returned to a condition in which overbank flows are more predictable and the channel and flood stages are not super-elevated above the surrounding floodplain by being confined by parallel dykes.

The costs to purchase the necessary private land and construct setback dykes between cross sections 8 and 50 are estimated at $1.8 M (Table 2). In addition, engineering and supervision costs for dyke construction are estimated at 15% of the construction costs and would be about $149,000. In all cost estimates in Table 2, land purchase costs were assumed to be zero for lands under the jurisdiction of the City of Kelowna and Regional District of Central Okanagan.

The cost of the demonstration setback dyke project located on the north bank between cross sections 8 and 26 is estimated at $374,120. The costs include land purchase, dyke construction, and engineering and supervision.

Meander Re-establishment

An opportunity for meander re-establishment is available where sufficient belt width between the setback dykes can be obtained. In these locations, it is recommended that a meandering channel be constructed to shorten the time period and reduce downstream sediment impacts that would result if the present channelized creek were allowed to slowly evolve to a meandering state.

<u>Conceptual Design</u>

Mission Creek had a meandering channel prior to dyking in 1938, and, more specifically, was meandering within our proposed restoration section upstream of KLO Road (Map 1). Our proposed meander design for the section of channel between cross section 36 and 50 (Map 2) involves:

- purchasing land along the meander alignment;
- excavating a 31 m wide channel, where required, along the meander alignment;
- constructing dykes outside of the meanders;
- constructing 10 riffles;
- excavating 7 meander pools; and
- re-establishing a floodplain.

The proposed meandering channel would be about 1800 m long and have an average gradient of 0.5% (Map 2). In comparison, the current channel is about 1600 m long with an average gradient of 0.6%.

The meandering channel would be constructed with 2:1 side slopes, except on the inside of meanders where the side slopes would be 4:1. Bankfull width of the channel would be 31 m. The meandering channel would necessitate construction of setback dykes. The dykes would meet provincial standard designs and have top widths of 4.5 m, 2:1 side slopes, and crest elevations that protect from floods having a frequency of recurrence of 1 in 200 years. The dykes would be constructed using spoil from the construction of the floodplain and new channel, and the removal of the existing dykes. In some cases, where the depth of flow in the new channel at the design flood may be quite shallow, placing riprap along the steep valley wall may be an alternative to constructing the dykes.

Riffles would be constructed at the crossover points in the channel profile (Map 2). The design approach would be to construct the riffle crests so that the bankfull flood is just contained within the banks, which then allows floods with greater return periods to overtop the banks and inundate part of the floodplain. The floodplain would be constructed at an elevation about 0.8-0.9 m above the riffle crests (Figure 6). A series of stable riffle crests would step the channel profile by 0.1 to 0.3 m drops. The riffles would be constructed of boulders (60 to 90 cm in diameter) with a placement of oversized (1-1.2 m diameter) boulders on the downstream face to create localized pocket pool habitat. All riffle structures would have a 20:1 downstream face (minimum length of 20 m), and would be constructed following the guidelines in the schematic pool and riffle construction drawing (Figure 10).

Pools in the meander bends would be excavated to a residual depth of 1.0 m and at this depth for a pool area of approximately 10 m wide by 25 m long. Suitably sized cobbles and boulders extracted from the pool sites could be used to construct the riffle structures. Large woody debris would be anchored to boulders or buried in the streambanks to provide overhead and instream cover in the pools. Similar design specifications would be used to re-define a meandering channel between cross sections 71 and 78 (Map 2).

Similar to the construction conditions for the setback dykes, several physical components that are part of the infrastructure in the existing channel will need to be addressed in the engineering drawings for the new meandering channel. These include:

- existing water withdrawal off-takes;
- flap-gated culverts to drain excess water that accumulates locally outside of the dykes; and
- outlet pipes to connect tributaries to the river.

<u>Land Status</u>

The proposed meander section between KLO Road and the Regional Park includes all the land parcels identified within the setback dyke area #3 (Table 1; Map 2; Appendix 3). In this section there are about 10 affected lots in private ownership and 2 owned by the provincial Crown and Regional District of Central Okanagan (CORD). The Crown portions are often road right-of ways along the south and north streambanks. Much of the affected private land is zoned 'agriculture' and lies within the Agricultural Land Reserve. Re-zoning prior to construction of the restoration works may be necessary. As mentioned previously, the City of Kelowna Local Agricultural Advisory Committee and Agricultural Land Commission should be consulted on zoning amendments prior to any land purchases.

Benefits, Risks and Costs

Although meandering alignments may be expensive to construct, environmental benefits and reduced maintenance costs may offset high construction costs over the life of the project (Brookes 1989). Also, well-designed meandering channels are more stable and provide a greater variety of flow conditions and aquatic habitat diversity (Keller and Brookes 1984). Meandering channels have been reconstructed in some channelized rivers of Denmark (Anonymous circa 1997), Germany (Glitz 1983) and the U.S. (Gore and Shields 1995) over the past 20 years. In addition to recreating a former meandering watercourse, the projects included restoration works, such as, substituting concrete weirs with gravel and cobble riffles, re-establishing floodplains, and adjusting the streambed so that meadows were inundated during floods. The restoration projects have improved habitats and production of aquatic insects, fish and wildlife. Response to the restoration works was predominantly positive from the public. Landowners in Denmark, surveyed through a questionnaire, indicated that restoration of the river had enhanced the value of the area's landscape, and that the biological value of the area and its value for outdoor life had increased.

Reconstruction of historic meanders has also been proposed for the Okanagan River (Bull et al. 2000). They suggested that restoring a meandering channel with setback dykes in the Okanagan River would re-establish the physical characteristics and processes found in a natural stream, and continue to ensure flood protection to the adjoining properties. Construction of a 2 km demonstration remeander project was proposed to test and evaluate the effectiveness of this restoration approach.

During spawner surveys between 1989 and 2002, kokanee spawners were found to be more concentrated between Gordon and KLO roads than above KLO Road (Appendix 1). This is attributed to the higher channel gradient and lack of gravel accumulation upstream of KLO Road. Construction of riffles in the proposed meandering section will improve local gravel accumulations near the riffle face and tail-out, thereby creating appropriate spawning habitat for kokanee. Mountain whitefish and rainbow trout will also use the riffles and tail-outs within the meandering section for spawning. The meandering restoration option will also benefit the rearing of rainbow trout and mountain whitefish through the re-establishment of pools, riffles and the addition of instream LWD cover.

As setback dykes are part of the constructed meanders, the benefits described for the setback dyke option above also apply to the meandering option. These benefits relate to a reduction in flood stage, establishment of riparian vegetation, sediment deposition on the floodplain, and more abundant and diverse wildlife habitat.

There is a risk of sediment release during excavation of the floodplain and removal of the existing dykes during construction. Also, sediments could be generated from the floodplain if there is significant flooding before the new vegetation is well established. This risk would be minimized by working under low discharges during the fisheries work window, completing the excavation of meanders and floodplains outside of the existing dykes before connecting through the dykes, and using cofferdams to divert the flow away from the work area.

The costs associated with the recommended meandering project between cross sections 36 and 50 are estimated at $1.5 M (Table 2). The costs include land purchase, channel, dyke and riffle construction, and engineering and supervision.

Riffle Enhancement

Conceptual Design

Riffle construction and strategic boulder placements on the downstream face of 19 riffles are proposed for a section between cross sections 50 and 78 (Map 2). The restoration objective is to better define riffle-pool sequences by spacing riffles approximately six times the bankfull width or about 186 m apart. The design approach would be to raise the existing riffle crests only slightly, less than 0.5 m above the existing streambed. The design concept is similar to a riffle constructed recently in Mission Creek near cross section 57 (Photo 6; Appendix 4) where the crest elevation is essentially the same as the existing streambed. The riffle section would have a gradient of 0.19% with drops of 0.35 m between riffle crests (Figure 10). The riffles would be constructed of boulders (60 to 90 cm in diameter) with a placement of oversized (1-1.2 m diameter) boulders on the downstream face to create localized pocket pool habitat, as shown in this example of an enhanced riffle (Photo 7). All riffle structures would have a 20:1 downstream face, and would be constructed following the guidelines in the schematic pool and riffle construction drawing (Figure 10). A scour pool with a residual depth of 0.8 to 1.0 m would be excavated on the downstream side of each riffle.

Land Status

Riffle enhancement will occur within the existing channel and dykes and, consequently, should not adversely affect properties along Mission Creek.

Benefits, Risks and Costs

Under summer low flow conditions much of the creek upstream of cross section 50 is a shallow riffle habitat (Photo 1). However, holding areas for larger juveniles (i.e., parr) and adults appears quite limited. The riffle enhancement measures proposed would establish a riffle-pool habitat, expanding and diversifying habitat for juvenile and adult fish that rear in the creek.

Spawning gravel accumulations of a size suitable for rainbow trout and kokanee are very limited between cross sections 50 and 78, and proportionally fewer kokanee have been observed spawning in the mainstem upstream of the lower footbridge in the Regional Park (Appendix 1). Increasing the crest elevation above the existing bed will cause some aggradation of fine gravels on the front face of each riffle. Also, excavation of a scour pool downstream will cause gravel accumulation on the tail-outs of the riffles. These areas will be quite suitable for salmonid spawning. Also, the sequence of pool-riffle habitats will more evenly distribute gravel throughout this section of channel and reduce gravel accumulations in the lower gradient reaches downstream, where gravel removal from the channel has been necessary. In addition, sediment traps can be incorporated into the pool-riffle sequences to increase gravel accumulations. This option is discussed below.

The risks of riffle construction within the proposed section of Mission Creek relate to riffle stability under flood flows, their impact on increasing flood water elevations, and potential increases in groundwater levels on the outside of the dykes. To assess the implications of riffle construction, an accurate determination of water surface profiles over the range of discharges should be made at the design stage using a backwater simulation model (i.e., HEC-RAS). Groundwater levels could be assessed by monitoring outside of the dykes using piezometers. Similar groundwater and structure stability assessments are being undertaken in the Okanagan River where four demonstration riffles were constructed in 2001.

The cost of constructing 19 riffle structures between cross sections 50 and 78 is estimated at $10,000 per riffle plus engineering and supervision, for a total of $218,500 (Table 2).

Additional Restoration Measures

Mission Creek is subject to high sediment loads, both historically and in its current condition. Sediments have historically been removed from the higher quality spawning habitats in the lower gradient reach downstream of KLO Road. Sediment traps are a means to confine excessive sediment accumulations to a localized area and reduce the impact that gravel extraction can have on higher quality fish habitats. It is proposed that sediment traps be constructed in conjunction with pool-riffle sequences between cross sections 66 and 71 (Map 2; Figure 11). Three riffles should be constructed to obtain a local reach gradient of about 0.6%. This will improve sedimentation of gravels upstream of each of the riffles. Over-excavation of the pools by about 2 m between the riffles would provide a potential storage volume in the three pools of about 31,000 m^3. The accumulated gravels can be removed as required from these sediment trap pools. However, it will be important when scheduling the frequency of gravel extractions to balance the need for spawning gravel in the downstream reaches with the desire to reduce excessive accumulations in the lower gradient section below KLO Road.

The riprapped mainstem channel through Kelowna is occasionally in need of maintenance as a result of channel bed erosion and subsequent destabilization along the toe of the riprap. Often, a deeper pool is associated with channel bed erosion near the bank and, in conjunction with instream woody debris, provides important refugia and rearing areas for trout, mountain whitefish and kokanee. When rehabilitation of these armoured banks occurs, the constructed works should be designed to ensure both bank stability and good habitat quality for aquatic fauna. For example, one possible maintenance option that provides bank protection along with a deeper pool and instream cover is shown in Figure 12. The boulder groynes re-align the flow so the thalweg is away from the base of the existing bank, thereby reducing erosion at the toe of the riprap. The boulders and LWD hydraulically create a deeper pool on the outside face of the structures and also provide good quality instream cover for fish rearing and holding. During the rehabilitation work, additional cover over the pool can be provided by maintaining the existing woody vegetation on the bank that overhangs the channel. In addition, a maintenance plan should be developed between Fisheries agencies, Water Management and the City of Kelowna that outlines a protocol for maintaining the channel banks and instream woody debris.

Current habitat limitations in lower Mission Creek could be mitigated to some extent with the implementation of additional restoration measures. A 640 m groundwater-fed side-channel could be constructed above East Kelowna Road crossing on the Hasse property as an over-winter refuge for juvenile trout (Appendix 5). The groundwater channel would mitigate the impacts of shallow water and riffle anchor ice on juvenile trout. The channel would be 6 m wide and should have boulder riffles to provide summer rearing habitat for trout. The cost of construction is estimated at $20 per m^2 (M. Foy, Fisheries and Oceans Canada pers. comm.) for a total cost of $88,320 (Table 2).

The Benvoulin Ditch on the right bank near the Regional Park is currently used for spawning by kokanee (Photo 4) and rearing by juvenile salmonids. Improving the water flow management regime to provide flows throughout the year would benefit native fish production. An instream flow analysis is required as a first step, however, to determine the requirements for the Ditch and if sufficient volumes are available from Mission Creek to provide these flows without jeopardizing mainstem fish survival and production. If the frequency of availability of the required flows is considered favourable, the Ditch channel should be redesigned with pool-riffle sequences and suitable spawning substrate for trout and kokanee. Cover should be added in the form of boulders and LWD to the riffles and pools, respectively. The stream's proximity to the Regional Park makes it ideal for showcasing a functioning small stream. However, the public access on adjacent trails should be kept to a minimum so that the riparian connectivity with the wetted channel can be maintained and a diverse vegetation community is established. In addition, the outlet of the Benvoulin Ditch should be re-designed to provide consistent fish access.

IMPLEMENTATION PLAN

Prioritization of Works

The following outlines a prioritized set of restoration activities for Mission Creek. It is recognized that these priorities may change as a consequence of land acquisition, funding and partnership opportunities.

The highest priority would be to construct the riffle structures and sediment traps between cross sections 66 and 71. This would confine the maintenance work done on the mainstem during gravel removal operations to this section of channel, limiting the amount and location of habitat alteration to a reach that is used to a much lower extent by kokanee and trout.

The next highest priority would be to initiate a demonstration project that would establish setback dykes and a broad floodplain, and then monitor the effectiveness of the constructed works at meeting restoration objectives. Setback dykes could be constructed on the right bank along a 1420 m section of channel between Gordon Road and cross section 26 upstream of Casorso Road (Map 2). Land purchase costs would be quite low as a significant portion (78%) of the setback corridor is under the jurisdiction of the City of Kelowna as either road allowance or dyke right-of-way. The remaining portion is privately owned, but a long term lease or conservation easement with the affected landowner may only be required. Effectiveness monitoring of the setback dyke demonstration section would determine if re-establishment of a minimum 50 m wide stream valley with a well-defined central channel allowed for fine sediment deposition on the broader floodplain and a reduction in flood stage during major floods. Monitoring would also evaluate the effects of setback dykes on the spawning and/or rearing habitat of rainbow trout, kokanee, and mountain whitefish.

After monitoring of the setback demonstration site was completed and the results were deemed favourable, the next highest priority would be to complete setback dyke construction on both banks of the creek between Gordon and KLO roads. This would involve 3.5 km of channel and would establish a stream corridor having widths between 40 and 110 m.

Construction of meanders, riffle-pools and setback dykes between KLO Road and the Regional Park would follow. Initially, it may be prudent to construct a demonstration section of the meander concept within the Benvoulin Woods on the right bank. The remainder of the meandering project should be completed if the demonstration project is shown to be effective.

A defined riffle-pool profile should then be completed from cross section 50 at the Regional Park to cross section 78, downstream of East Kelowna Road. Riffle construction will cause spawning gravel aggradation on the faces and tail-outs of the riffles, and pocket-pool habitat on the downstream face of each riffle. These changes to the bedform of Mission Creek will improve hydraulic and habitat diversity for salmonid spawning and rearing.

Several other projects are considered a high priority and could be implemented concurrently with the above recommendations. Screening of irrigation off-takes to prevent significant losses of juvenile fish should be undertaken as soon as possible. An instream flow analysis should be done to assess the feasibility of providing a year-round flow regime in Benvoulin Ditch that would maintain fish populations. If results from the flow analysis are favourable, regrading and pool-riffle construction in the Ditch could follow after a restoration design is prepared and funding for construction has been acquired. Also, the outlet structure for the Ditch should be re-designed to improve access into and out of the canal. The design for the groundwater channel on the Hasse property should be reviewed again by MWLAP, and upon approval, funds should be sought for its construction.

For the watershed as a whole, projects that improve land use management or can feasibly rehabilitate chronic sediment sources should be considered a high priority. Funding from the provincial Forest Investment Account should continue to be directed at the prevention and rehabilitation of logging-related landslides and erosion events. In addition, stream corridor management plans should be prepared with private landowners to provide long term protection through the re-establishment and management of healthy vegetated riparian buffers. For example, investigations into the feasibility of reducing impacts along private land on Joe Rich Creek should be considered as the first step.

Land Negotiation

About 14 privately owned properties would be affected by the proposed plan for setback dykes. All lots are zoned for agricultural use and are within the agricultural land reserve. Thus, discussions on the need for rezoning with the City of Kelowna Agricultural Advisory Committee and the Agriculural Land Commission are mandatory. Five additional land parcels are owned by the City of Kelowna, Westbank First Nation, or Regional District of Central Okanagan. Other lands that are not identified with a specific PID number are typically right-of-ways under City of Kelowna ownership.

Plan implementation must be preceded by an intensive investigation of what land is needed and how it can be rezoned and acquired. Proposed restoration works should be coordinated with ongoing infrastructure improvement planning by the City of Kelowna (B. Watson pers. comm.) and the Greenway Project committee (H. Hall pers. comm.). At a minimum, negotiations will involve individual land owners, Regional District of

Central Okanagan, City of Kelowna, Agricultural Land Commission, City of Kelowna Local Agricultural Advisory Committee, Westbank First Nation, Ministry of Water, Land and Air Protection, Canada Department of Fisheries and Oceans, and Greenway Project committee.

The logical steps would include:

1. Determine portions of plan to be implemented;
2. Identify sources of funding;
3. Obtain approval-in-principle from government agencies;
4. Retain the services of a local certified land appraiser/negotiator;
5. Identify essential properties;
6. Investigate possibility of subdivision or alteration of property boundaries;
7. Determine whether rezoning is required;
8. Determine whether rezoning is possible;
9. Determine owner’s willingness to sell;
10. Appraise land value;
11. Commit funding; and
12. Negotiate sale.

To assist in the process of landowner contact we have identified the lots in question, and listed their zoning and legal status (Table 1; Appendix 3). Names and addresses of owners are reported in a separate confidential document. This was necessary to ensure privacy and comply with the rules under which the information was obtained.

No individual meetings were held with property owners within the setback and channel realignment areas to assess their reception of the proposed restoration plans. Property owner survey work is warranted as soon as portions of the plan are accepted in principle and implementation appears probable.

Agency Approvals

Approvals will be required from the agencies listed in the following table:

Agency	Legislation	Description
DFO	Fisheries Act	Approval for activities that affect fish habitat
MELP (Regional Operations)	Fisheries Act Fish Protection Act	Approval for activities that affect fish habitat
MELP (Water Mgt)	Water Act	Water license. Approval for alteration and work in and about a stream (Section 9)
Transport Canada	Navigable Waters Protection Act	Permit for activities around navigable waters.
BC Health	Health Act	Approval of construction camp, sewage disposal and potable water supply
BC Municipal Affairs, Recreation & Housing: Archaeology Branch	Heritage Conservation Act	Approval to excavate and alter sites of archaeological significance.
BC Assets and Lands		Permission to use Crown Land
City of Kelowna		Permission to construct setback dykes (e.g., right-of-ways)
Regional District of Central Okanagan	Municipal Act Regional Bylaws	Approval of zoning. Permits for construction
Westbank First Nation	Case Law	Mandatory Consultation

Community Support and Awareness

Stewardship of riparian areas is fostered and prompted by all levels of government. Community support is especially important in the Kelowna area where numerous stewardship and restoration initiatives are underway. Friends of Mission Creek, along with the City of Kelowna and Regional District of Central Okanagan, have championed the Mission Creek Greenway Project and have completed a significant portion of the trail and recreational infrastructure adjacent to the creek (H. Hall, Friends of Mission Creek pers. comm.). Coordinating and reviewing proposed channel work with the managers of the Greenway Project will facilitate acceptance of the restoration plan by the community and improve the overall restoration design.

In addition, informing interested parties and liaison with the “community-at- large” is desirable. When government approval and financial backing appears likely, “town hall” meetings should be held in Kelowna. Articles should also be prepared for local newspapers, radio and television.

Pre- and Post-Construction Monitoring

Assuming construction is initiated on priority works, as outlined above, monitoring should determine the effectiveness of the restoration works at meeting the restoration objectives.

The restoration objectives for the priority works are:

1. to maintain flood protection up to the design flow of 110 cms;
2. to maintain existing drainage networks and water withdrawal off-takes;
3. to increase the quantity and quality of spawning and rearing habitat for salmonids;
4. to improve the stability of salmonid spawning substrates;
5. to improve aesthetics and wildlife habitat;
6. to increase and maintain biodiversity within the river corridor; and
7. to re-establish some of the physical structure, and hydraulic and geomorphic processes that are characteristic of natural rivers.

Monitoring of the proposed restoration works should occur prior to and after construction and pertain to: the native fish populations and habitat; water levels; extent and impact of flooding on lands outside of the dykes; and sediment transport and deposition. The target fish species for the effectiveness monitoring should include kokanee, rainbow trout and mountain whitefish. A holistic monitoring program should also include wildlife species that would be affected by the restoration projects. The evaluation of these monitoring results will guide the implementation of further restoration activities.

Monitoring parameters to determine fish utilization, particularly for spawning and rearing, should involve spawner counts, and determining fry, juvenile and adult densities. Egg incubation success should, where feasible, be evaluated for the target species. Egg incubation success should be related to the characterization of the spawning habitats of kokanee, rainbow trout and mountain whitefish. This should include velocity, depth, substrate size analysis and slope measurements. To assess the impact of riffle construction on water levels at flood and low flow stages, continuous water level recorders should be installed in the riffle section and in the demonstration meander section. Regular engineering level surveys of the channel and floodplain will monitor sediment transport and deposition rates, and stability of the constructed streambed and channel.

Concluding Statement

This report has outlined several ways of restoring fish habitat in the Mission Creek. Implementation will require considerable effort to ensure widespread support and funding. Time is of the essence since restoration options are quickly disappearing as new initiatives for land development arise.

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TABLES

Table 2. Estimated cost of restoration options for Mission Creek.

Section of River	Location Based on Cross Sections	Restoration Options	Land Purchase Cost ($50,000/ha)	No. of Hectares	Channel Construction (@$3/$m^3$)	Channel Length (m)	Dyke Construction (@$5/$m^3$)	Dyke Length (m)	Riffle Construction (@$10,000 each)	Number of Riffles	Engineering and Supervision (15% of construction cost)	Total Cost
Gordon Road to KLO Road	8 to 26	Construct setback dykes on the north bank (demonstration site)	$145,500	2.91			$198,800	1420			$29,820	$374,120
	8 to 26	Construct setback dykes on the south bank	$94,000	1.88			$142,800	1020			$21,420	$258,220
	26 to 34	Construct setback dykes on north and south banks	$18,500	0.37			$187,600	1340			$28,140	$234,240
KLO Road to Regional Park	36 to 50	Construct setback dykes on north and south banks; construct meandering channel with pools and riffles	$530,500	10.61	$302,250	1300	$463,400	3310	$100,000	10	$129,848	$1,525,998
Regional Park to East Kelowna Road	50 to 78	Construct riffle structures and sediment traps; re-define a meandering channel between cross sections 71 and 78			$81,375	350			$190,000	19	$40,706	$312,081
Hasse Property	86	Construct a groundwater channel on the right bank (@$20/$m^2$)			$76,800	640					$11,520	$88,320
		Totals	$788,500	15.77	$460,425	2290	$992,600	7090	$290,000	29	$261,454	$2,792,979

FIGURES

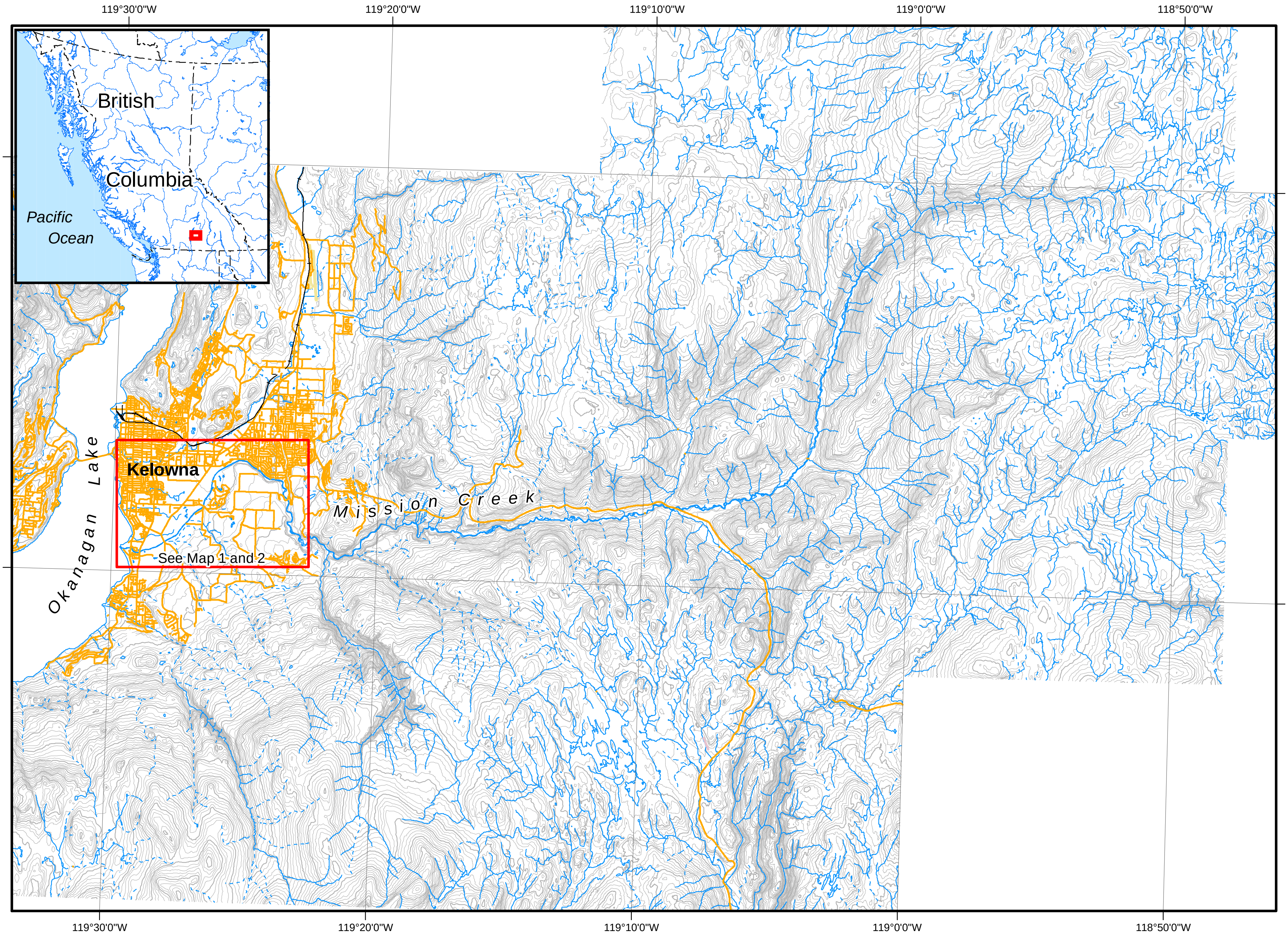


Figure 1. Index map of Mission Creek watershed, restoration area, and location within British Columbia.

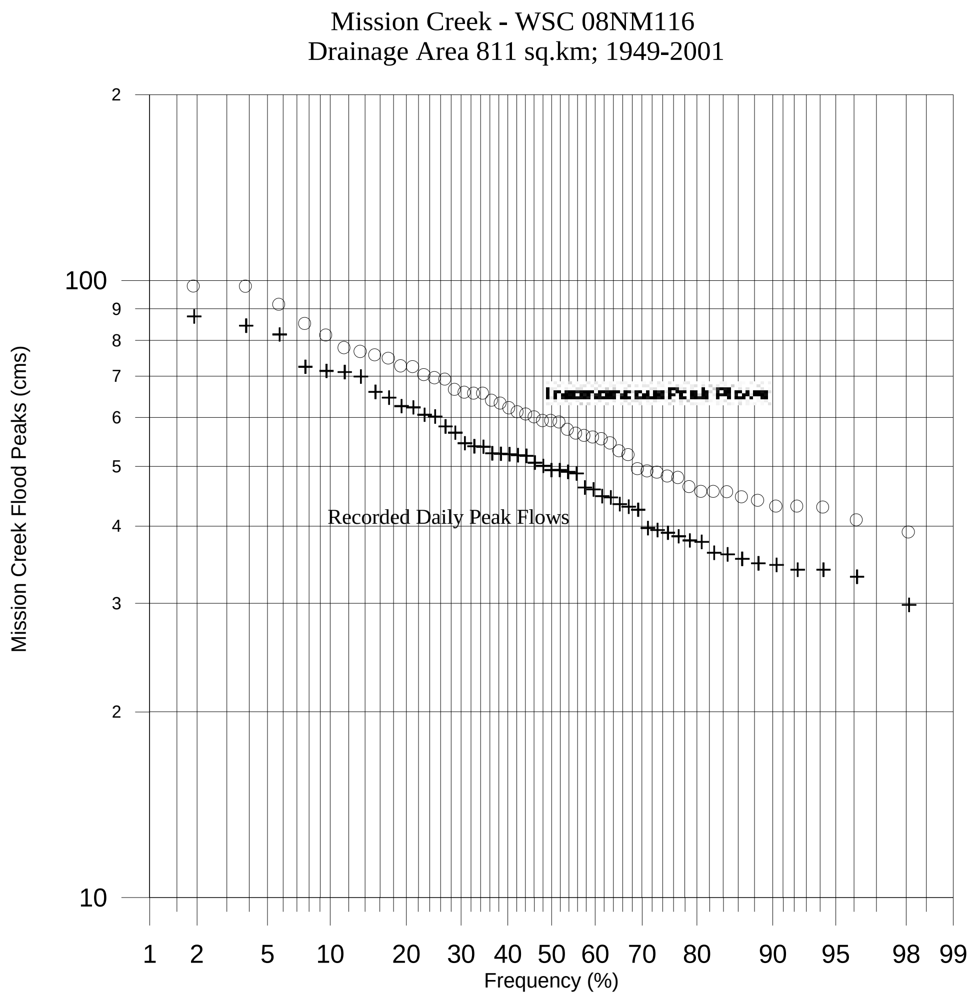


Figure 4. Flood frequency for Mission Creek.

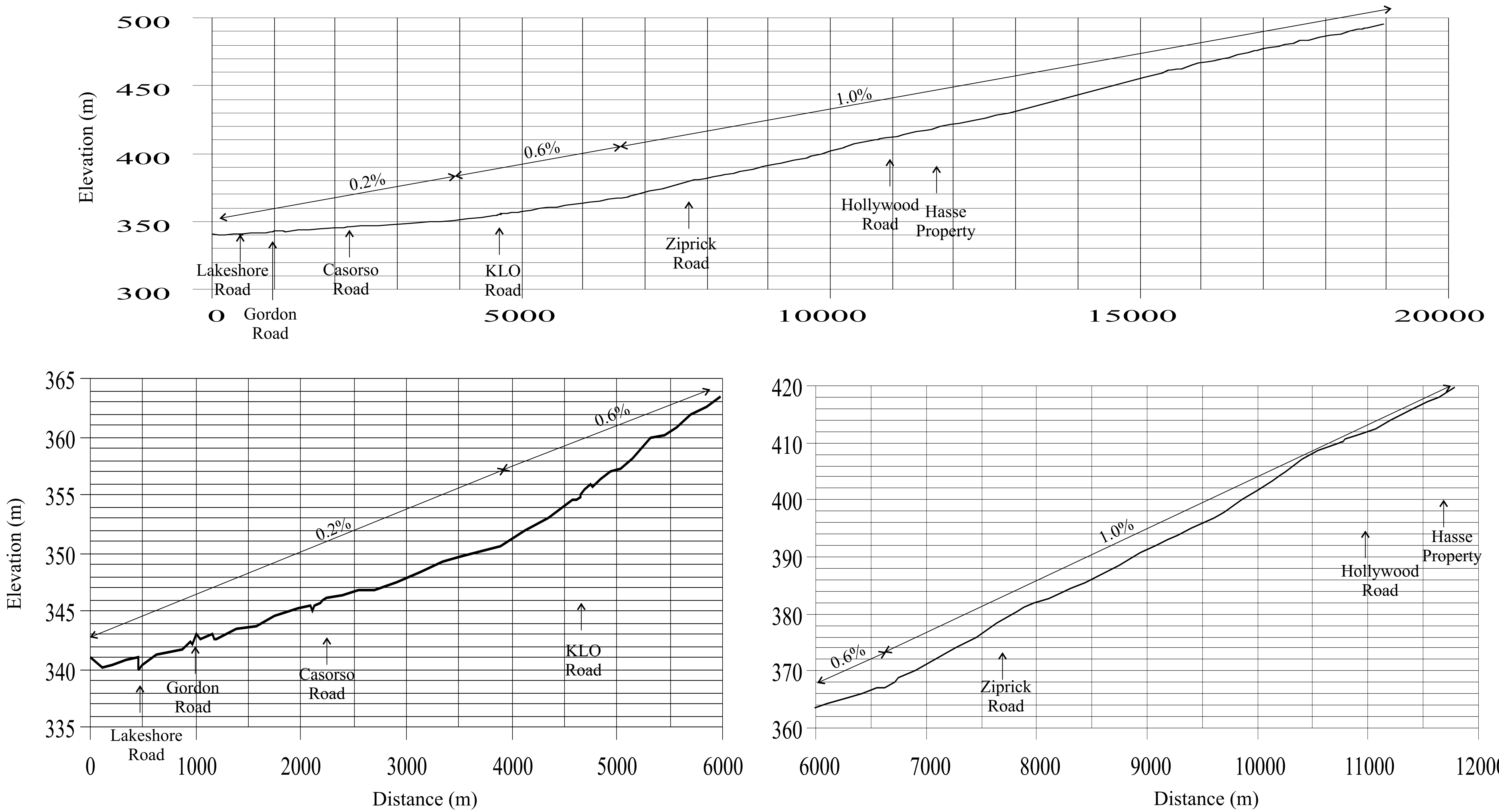


Figure 5. Streambed profile in Mission Creek based on 1980 and 1983 surveys.

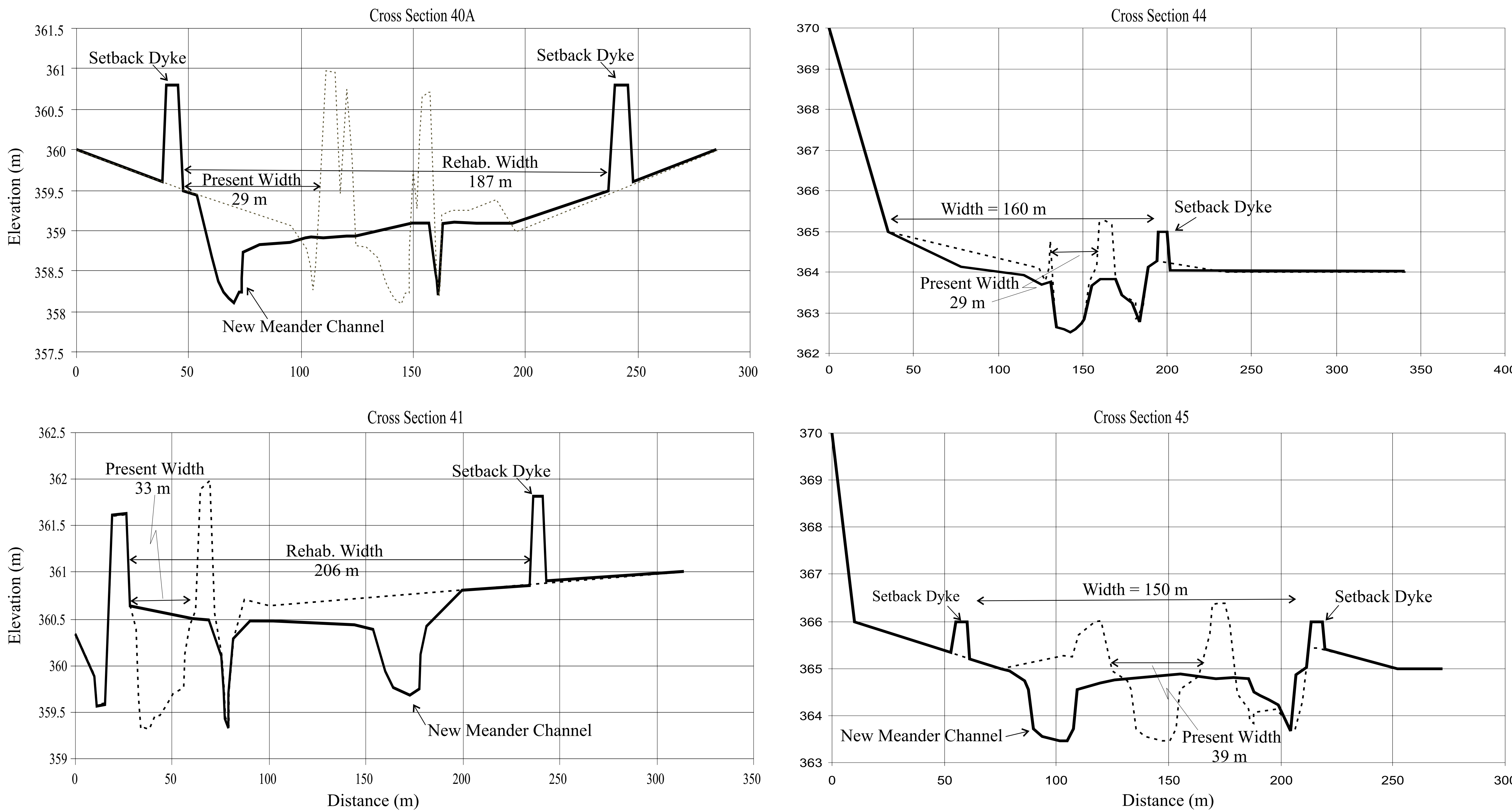


Figure 6. Representative cross sections showing existing and proposed rehabilitation measures.

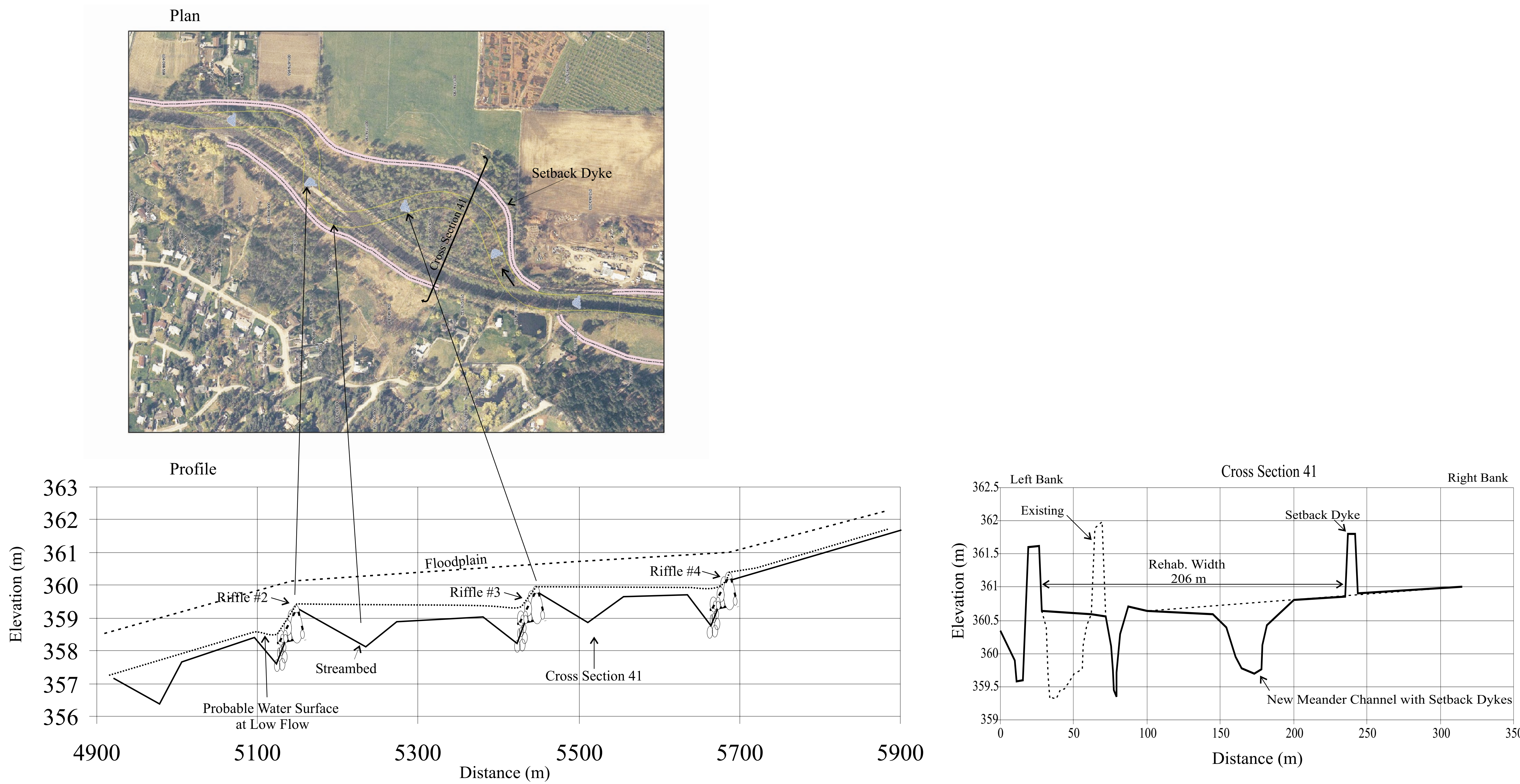


Figure 7. Plan, profile and cross section views of typical riffle-pool sequences in a proposed meander section of Mission Creek.

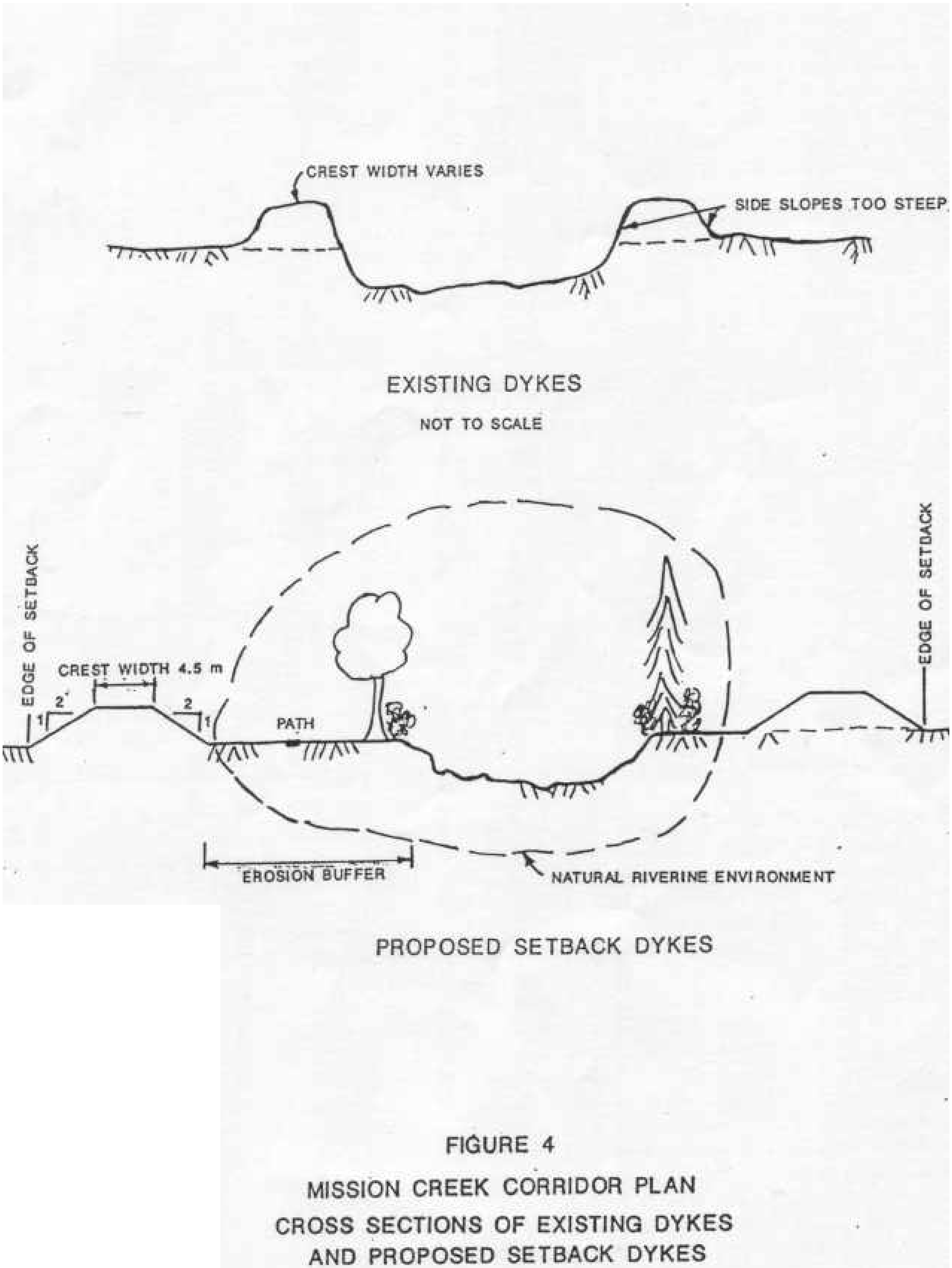


Figure 8. Setback dyke cross section for Mission Creek, as proposed by Bergman (1995).

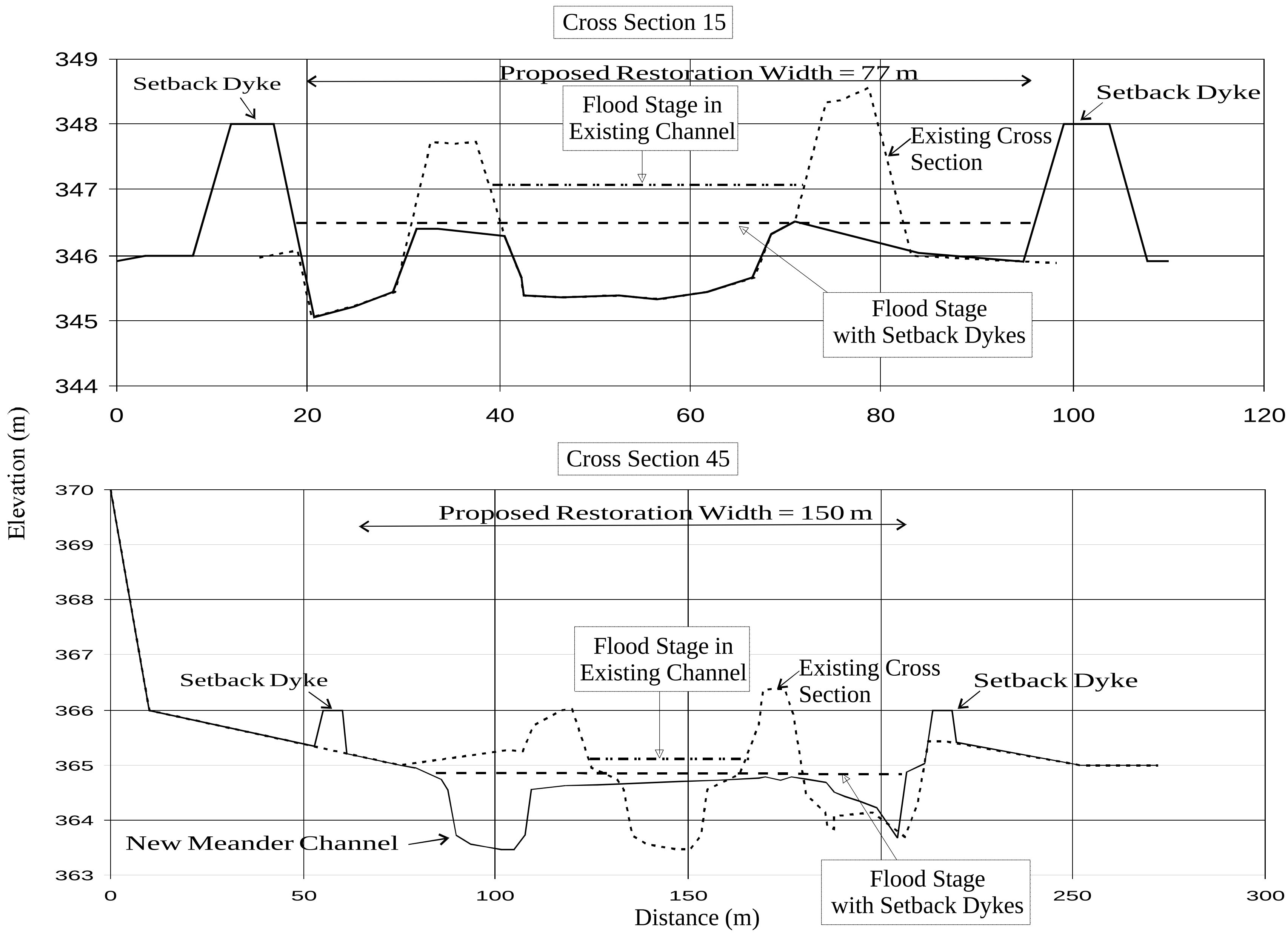
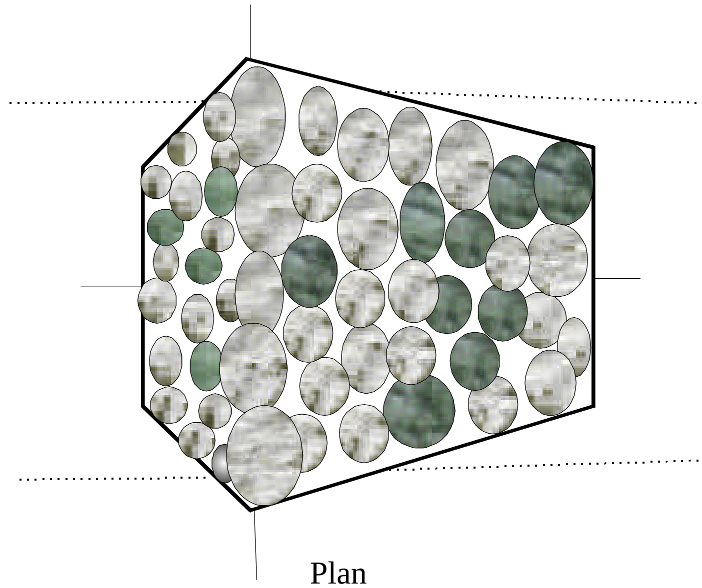


Figure 9. Comparison of estimated flood stage at 110 cms (1 in 200 yr recurrence interval) for existing, setback dyke and meander cross sections.

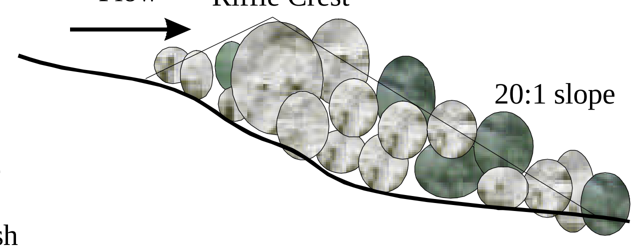
1. PLAN: build riffle crest across the stream with large diameter boulders; back up with next largest stone downstream



Plan

2. PROFILE: construct downstream face of riffle at a shallow re-entry slope that mimics local natural riffles

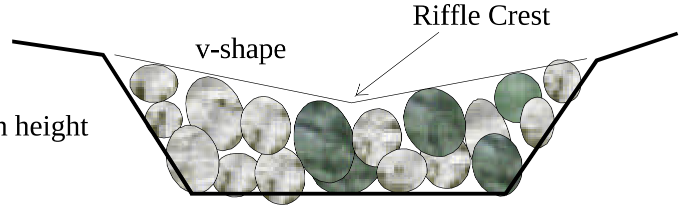
3. SURFACE: place large rocks randomly on the downstream face, 20 to 30 cm apart to dissipate energy and create low flow fish passage channels and back eddies



Profile

4. CROSS SECTION: V-shape the crest and face downwards to the centre of the riffle. Centre should be 0.3 to 0.6 m lower than height at the banks

5. BANKS: rip-rap both banks with embedded boulders and cobbles to the floodplain level

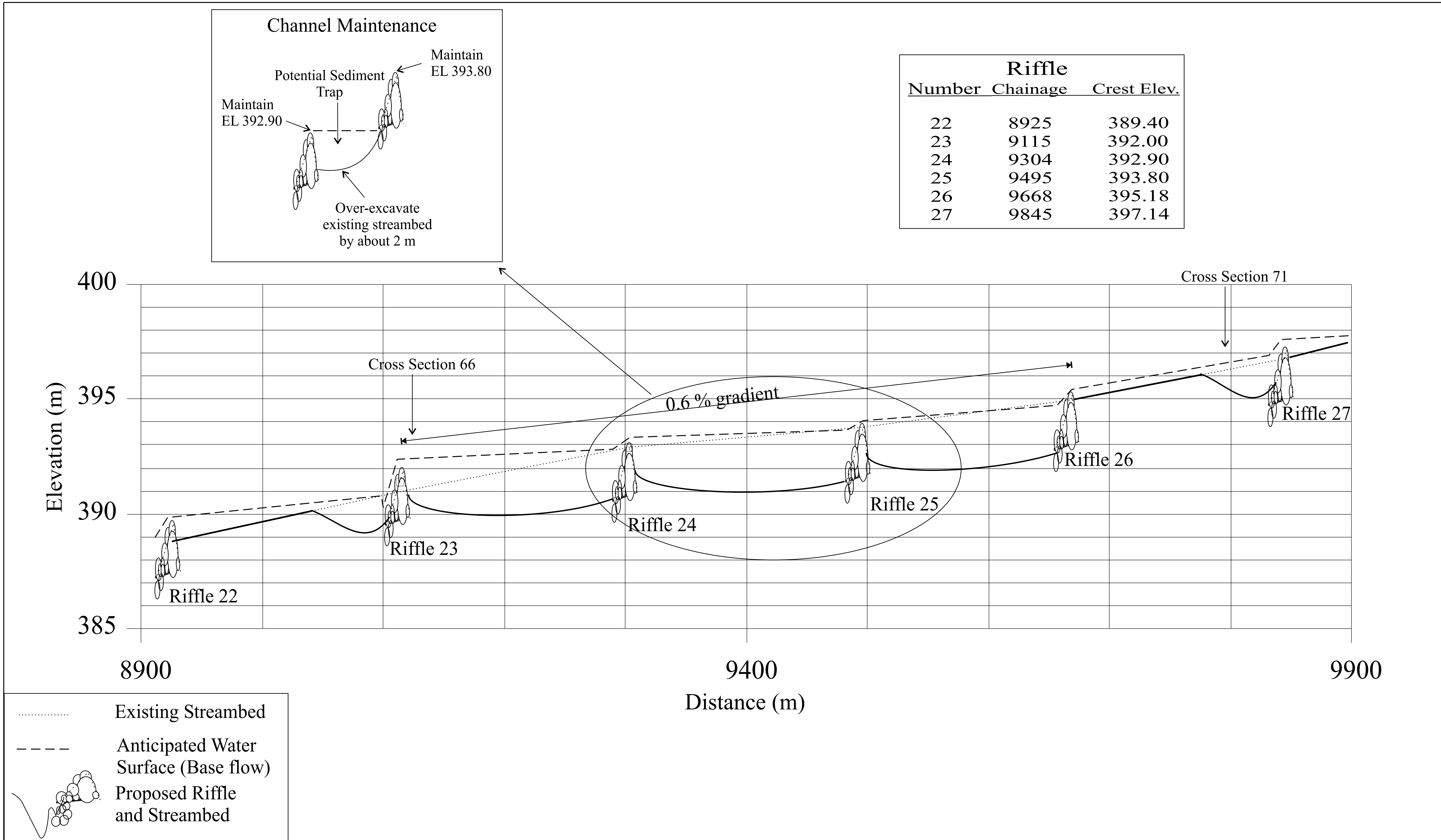


Cross Section

This drawing may be augmented for machine operators or hand labour crews with notes on the placement of construction stakes and photographs of natural and well-constructed riffles (after Newbury et al. 1997).

Figure 10. Schematic riffle construction drawing.

Scale: Not to scale



Riffle Number	Chainage	Crest Elev.
22	8925	389.40
23	9115	392.00
24	9304	392.90
25	9495	393.80
26	9668	395.18
27	9845	397.14

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Figure 11. Streambed profile in Mission Creek showing potential sediment traps using constructed riffle-pool sequences.

Looking downstream at an eroding left bank on Mission Creek

Looking upstream at an eroding left bank on Mission Creek

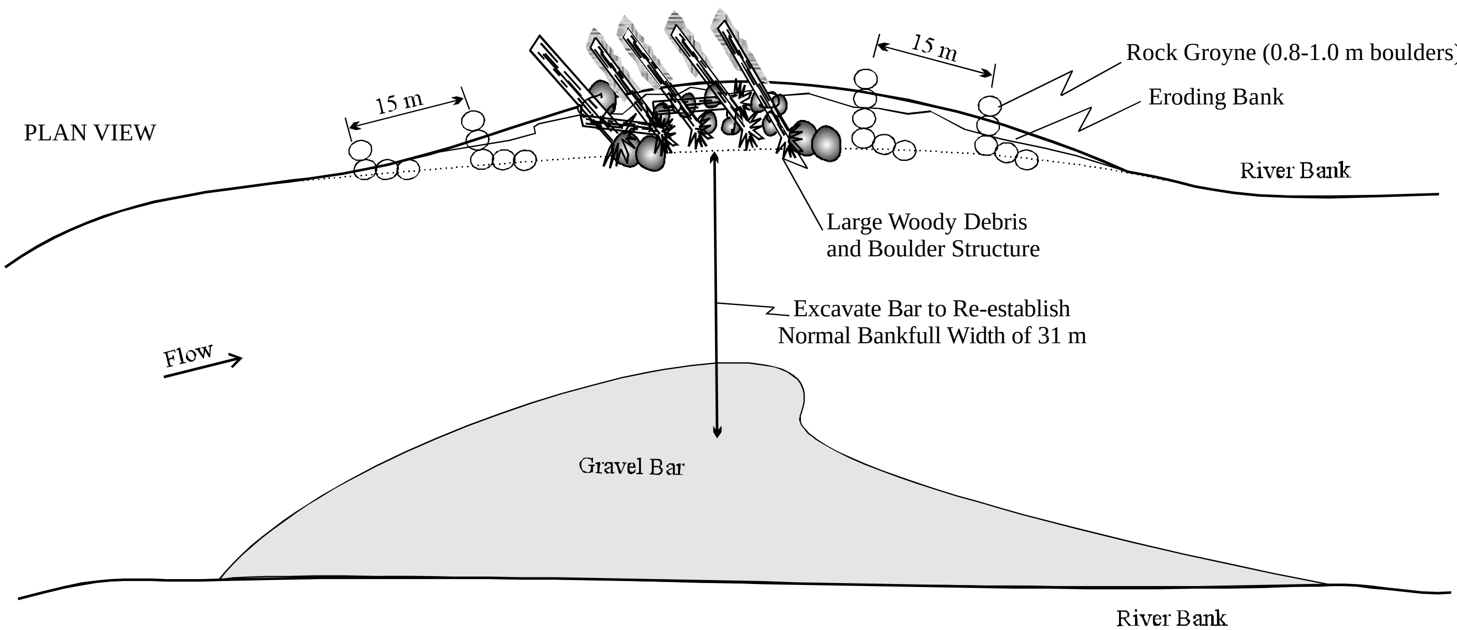


Figure 12. A maintenance option to stabilize eroding banks along Mission Creek.	Not to Scale

MAPS

MAP 1


Mission Creek overflow channels
Riprap Dyke
- constructed to contain floodwaters
Active Channel
- typically 60m - 80m wide
Abandoned Mission Creek mainstem
Mission Creek mainstem in 1938
Mosaic of 1938 Air Photos showing historic Mission Creek channel
1:7500
0 100 200 300 400 500 600 700 800 900 1000
Metres
Universal Transverse Mercator
Zone 11 (CM 117° W)
North American Datum 1983
LGL Limited, December 2002

MAP 1

MAP 2

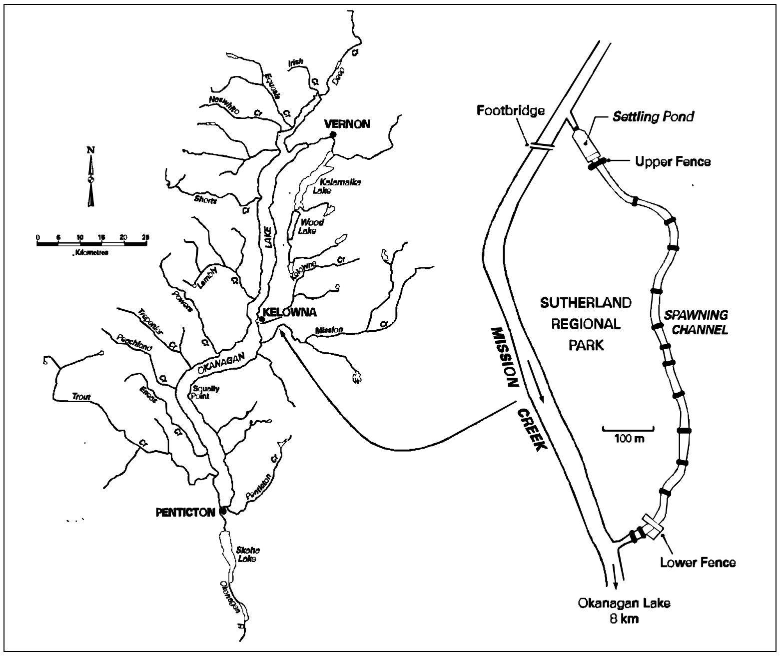
Contemporary orthophoto plan view of Mission Creek showing proposed restoration options.

MAP 2

APPENDICES

Appendix 1. Annual kokanee spawner counts for Mission Creek. Data provided by D. Cassidy and Ministry of Water, Land and Air Protection.

Reach Name	Year													
	2002	**2001**	**2000**	**1999**	**1998**	**1997**	**1996**	**1995**	**1994**	**1993**	**1992**	**1991**	**1990**	**1989**
Lakeshore to Gordon	0	760	680	0	0	155	744	75	294	760	2439	1680	610	2500
Gordon to Casorso	2450	3070	2670	26	0	840	8720	2071	3450	5420	4210	23540	8170	2300
Casorso to KLO	5980	10940	3390	710	241	2375	3200	2411	3079	7550	17330	13280	2490	2900
KLO to Footbridge	94	580	192	11	48	388	79	83	38	126	2441	2209	508	2670
Footbridge to Diversion	15	207	222	6	2	82	4	35	0		1024			
Div. to E. Kelowna Rd.	405	1364	716	94	161	469								
Spawning Channel	1415	4175	5220	228	685	2455	2335	1406	2505	50	15641	6064	2653	3130
Total	**10359**	**21096**	**13090**	**1075**	**1137**	**6764**	**15082**	**6081**	**9366**	**13906**	**43085**	**46773**	**14431**	**13500**
Day of Peak Spawn	24-Sep	14-Sep	13-Sep	18-Sep	24-Sep	24-Sep	29-Sep	29-Sep	9-Oct	29-Sep	28-Sep	21-Sep	4-Oct	21-Sep

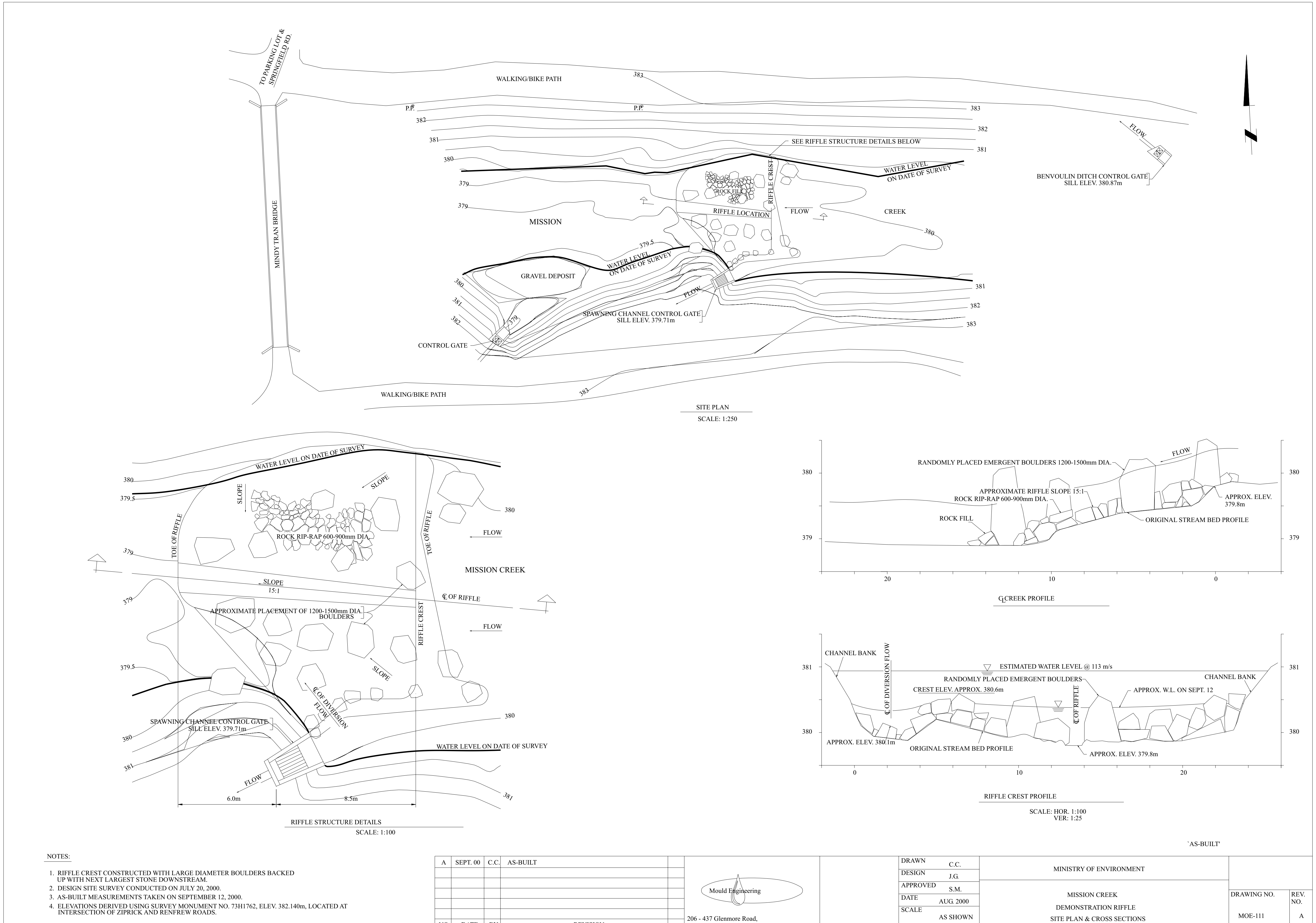


Appendix 2. Index map showing Mission Creek and the kokanee spawning channel located at km 8 (top), and photo of spawning platforms in the channel (from Andrusak 2001).

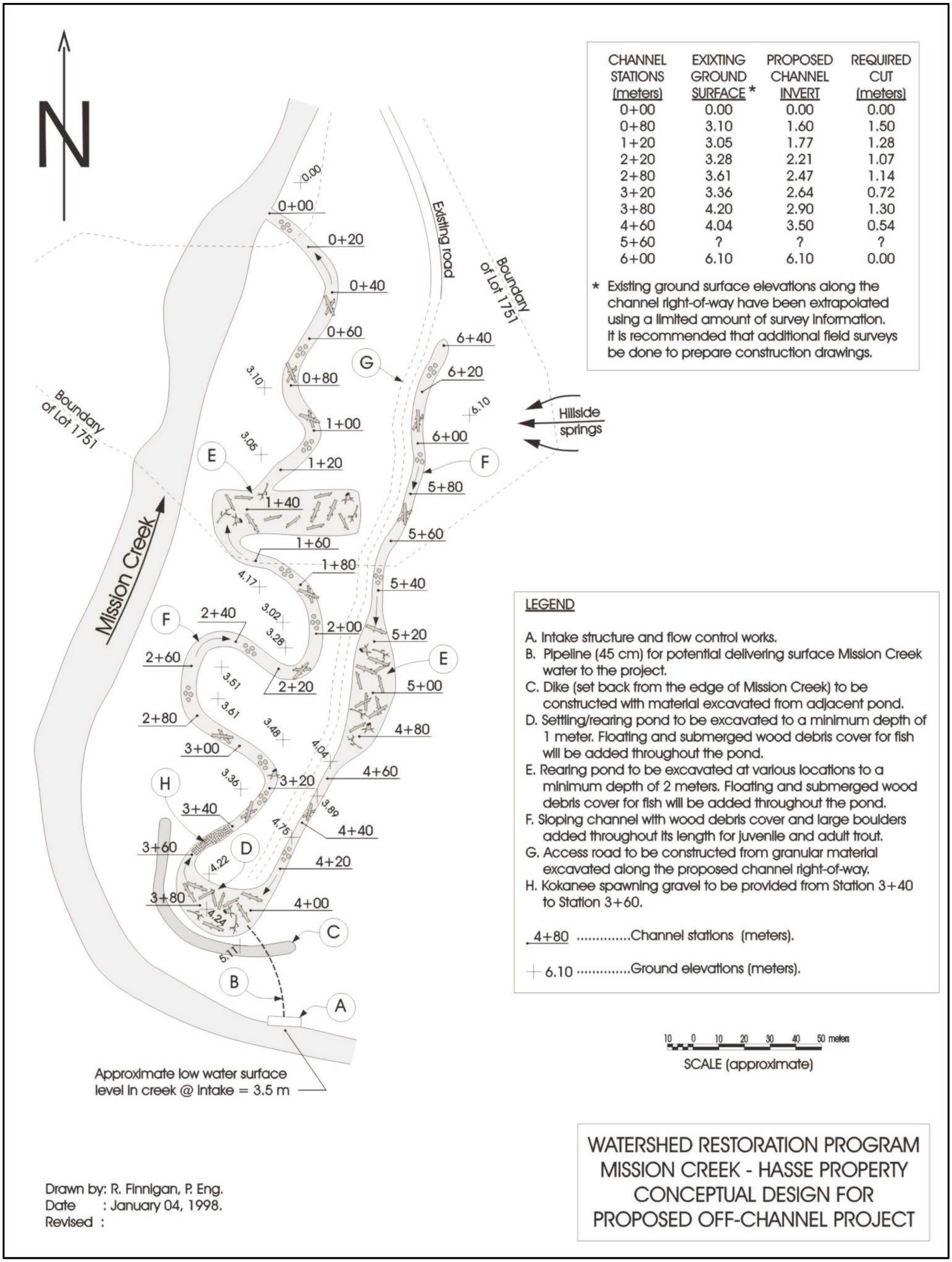
Appendix 3. Landownership, zoning and area affected by proposed restoration options for lots adjacent to Mission Creek.

PID Number (on Map)	Zoning	Landownership	Land Area (ha)
001-714-791	A1	Private	2.89
003-979-440	A1	Private	1.77
006-909-213	A1	Private	0.18
006-909-221	A1	Private	0.25
007-885-482	A1	Private	0.31
007-938-675	A1	Private	0.81
008-504-130	A1	Private	2.53
009-417-770	A1	Private	0.37
011-074-132	A1	Private	0.64
011-074-167	A1	Private	0.35
011-074-281	A1	Private	0.26
011-074-311	A1	Private	3.15
011-099-895	A1	Private	1.38
014-767-538	P1	City of Kelowna	1.00
017-816-874	P3	Regional District of Central Okanagan	2.08
024-008-168	A1	Private	0.13
024-008-184	A1	City of Kelowna	0.56
024-208-124	A1	Regional District of Central Okanagan	0.90
-	A1	Westbank First Nation	0.75
Totals		**17 Landowners**	**20.31**

Zoning codes:
A1 Agriculture 1
P1 Public and Institutional Zones (Major Institutional)
P3 Parks and Open Space



Appendix 4. As-built drawing of demonstration riffle constructed in Mission Creek on August 29, 2000 (prepared by Mould Engineering).



Appendix 5. Conceptual design for off-channel project on Hasse property (prepared by R. Finnigan 1998).

PHOTO PLATES

Photo 1. Looking upstream at a continuous riffle section in Mission Creek adjacent to the Regional Park.

Photo 2. Looking upstream at a riffle-pool section in Mission Creek adjacent to Casorso Marsh. The Mission Creek Greenway Project trail in evident on the left side of the photo.


Photo 3.   Kokanee spawning in Mission Creek adjacent to Casorso Marsh.


Photo 4. Kokanee spawning in Benvoulin Ditch, upstream of Regional Park, Sept. 24, 2002.


Photo 5. An example of channel instability from Joe Rich, showing poor riparian condition and an 800 m section of eroding streambank.


Photo 6. Looking upstream at demonstration riffle constructed in Mission Creek on August 29, 2000.

Photo 7. Looking upstream at an enhanced riffle in Little Qualicum River where pocket-pool habitat was created.