FRASER VALLEY REGIONAL DISTRICT

FLOOD DAMAGE RECOVERY PLAN
LAGACE CREEK, HATZIC VALLEY

JUNE 2005

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FLOOD DAMAGE RECOVERY PLAN
LAGACE CREEK, HATZIC VALLEY
DRAFT REPORT

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EXECUTIVE SUMMARY

Lagace Creek is the main creek entering Hatzic Lake near Mission, BC, and has experienced chronic flooding and erosion problems since at least the mid-1930s. Recent flooding events along its main tributary, Pattison Creek, have initiated a new cycle of sediment deposition and redistribution, which has resulted in overbank flooding and bank erosion, damaging property and threatening structures. The largest of the recent events, which occurred in October 2003, resulted from a major, intense Pacific offshore storm that caused widespread damage throughout the Lower Mainland, the Sea-to-Sky corridor, and the Pemberton Valley. This event caused a debris flood in Pattison Creek, which is the main source of recent coarse sediment loads to Lagace Creek. A subsequent high-flow event in November 2004 caused further damage, compounded by the changes in the channel from the previous year's event. At present the channel is at high risk of avulsion, overbank flooding, and bank erosion.

The channel has been divided into reaches with reach breaks that correspond, for convenience, to the location of road crossings. The upper reach (Reach 6) comprises the 600 m of Pattison Creek immediately upstream of Sylvester Road Bridge. Reach 5 is between Sylvester Road and the Lagace confluence and Reach 4 extends to the Seux Road. Reach 3 (Farms Reach) is between Seux Road and Farms Road, and is the traditional location of gravel extraction operations. Reach 2, downstream of Farms Road Bridge and ending at the Dale Road crossing is the transition between fine gravel and sand, and Reach 1, from Dale Road to Hatzic Lake, is partially backwatered by Hatzic Lake during high flows.

The recovery plan for Lagace Creek, includes areas of gravel removal, channel recontouring, bank protection and sediment traps. A detailed habitat mitigation and compensation plan will be developed during Phase 2, to offset potential fish habitat impacts resulting from the instream works. We have provided the background and rationale to make an application to PEP for funding to return the channel to pre-disturbance conditions. The cost of these works has been estimated on a reach by reach basis and total approximately The cost of these works has been estimated on a reach-by-reach basis and total approximately $1,048,000 including all

engineering and supervisions costs, habitat compensation and a 20% contingency fee. The following is a brief summary of these costs:

- Reach 1 – Excavate Sand: $50,000
- Reach 2 – Excavate Sand: $70,000
- Reach 3 – Excavate Gravel: $75,000
- Reach 4 – Excavate Gravel and Channel Re-contour: $100,000
- Reach 5 – Excavate Gravel and Cobble, and protect banks: $60,000
- Reach 6 – Excavate Gravel, Cobble and Boulders: $300,000

We have also provided options for a longer-term sediment management strategy. Elements of this strategy would include installation of another sediment trap in the upper reaches of the system, regular maintenance of the sediment traps, and regular excavations of sandy sediments from Reach 2 of Lagace Creek. The annual long-term maintenance budget could be as high as $100,000 per year.

It is important to note that the majority of the issues affecting Lagace Creek do not originate locally. The majority of the sediment in the channel is derived from the chronic occurrence of high-energy debris flood or debris flow events that regularly introduce vast quantities of sediment to the channel. There is a very high likelihood that the works proposed here will be overwhelmed by another similar event at some time in the future. Addressing the problems in the upper watershed of Pattison Creek are necessary if any long-term solution to the sedimentation problems in Hatzic Valley are to be realised.

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1 INTRODUCTION

1.1 BACKGROUND

Recent flood events on Lagace Creek have initiated a proposal for works under the Provincial Emergency Program (PEP) by the Fraser Valley Regional District (FVRD). Lagace Creek is one of several flood-prone creeks that drain into Hatzic Slough, immediately east of Mission, BC. The Hatzic Valley is drained by several steep, active stream systems carrying significant bed material load that deposits in the lower valley bottom, causing avulsion and flooding hazards. Glacial history, historic land-use, settlement, and physical processes in the watershed result in sediment and debris events that are typically associated with high precipitation and runoff.

In recent years, two large precipitation events have occurred, triggering debris flows and debris floods in the tributaries draining the Hatzic Valley, particularly Pattison Creek, a tributary to Lagace Creek. These storms, which occurred in October 2003 and November 2004 were associated with intense pacific frontal systems. The resulting damage to the Lagace Creek channel and floodplain includes: 1) deposition of large amounts of sediment and organic debris, 2) bank erosion, and 3) overbank flooding. As a result of these two events, the channel is at higher risk of ongoing bank erosion and overbank flooding during normal high flows because of reduced channel capacity due to the deposition of large amounts of sediment and debris.

The nature of the existing alluvial fan topography, land-use and current channel conditions suggest that natural recovery of the channel in the short-term is unlikely. Therefore, properties in the Hatzic Valley are at risk to further damage resulting from natural channel processes and inherent hazards. This report outlines options and recommendations to be included in the recovery plan for Lagace Creek. The goal of the recovery plan is to stabilize Lagace Creek to prevent further bank erosion and loss of property, and to reduce the likelihood of overbank flooding causing damage to adjacent properties.

1.2 SCOPE

Hatzic Valley has experienced persistent flooding events that have often resulted in loss of land and damage to property, which can be attributed to two main causes as presented by **nhc** (1985):

1. flooding over the flat agricultural land by backwater from Hatzic Lake; and
2. flooding due to rising of the river bed on the Pattison-Lagace Creek alluvial fan.

The problem of aggradation has, in recent years extended beyond the Pattison-Lagace Creek alluvial fan. This has resulted in more frequent overbank flooding over the Hatzic Prairie caused by a rise in the riverbed.

Flooding due to rising of the riverbed increases progressively and becomes the dominant cause unless sand and gravel is excavated on a regular basis. The purpose of this report is to quantify the effects that the two most recent high-magnitude precipitation events have had on Lagace Creek and to develop a Flood Damage Recovery Plan and rationale in order to secure PEP funding for recovery works. In essence this will address flooding issues from cause #2, above, though these issues are no longer confined to the fan. The control of Hatzic Lake requires the construction of another pump house (**nhc**, 2001a) and is outside the scope of PEP funding, and therefore outside the scope of this report. The geographic extent of this study therefore extends from approximately 600 m upstream of Sylvester Road to several hundred metres downstream of the Dale Road crossing.

Phase II of this project will include further development and implementation of the recovery plan and will incorporate a public consultation meeting.

1.3 PROJECT TEAM

Northwest Hydraulic Consultants (**nhc**) has been contracted to develop the recovery plan with Mr. Bruce Walsh, P.Eng. acting as project manager and Mr. Derek Ray, P.Geo. as project geomorphologist. **nhc** has engaged Mr. Jim Scott of Scott Resource Service Inc., a fisheries and environmental consultant who is familiar with the environmental issues at Lagace Creek, to provide appropriate review and input with respect to environmental assessments, habitat

compensation and mitigation and regulatory permitting. Mr. Graham Daneluz is providing contract administration and information support on behalf of the FVRD.

1.4 OUTLINE

Section 2 of this report provides an overview of the study area, a review of the recent precipitation events, and a review of past studies. Section 3 gives a detailed description of the damage that has occurred as a result of the recent events as well as a brief outline of the expected damage should the ongoing processes continue unchecked. Section 4 provides a rationale for assistance for PEP funding, while Section 5 outlines various options for addressing the problems outlined in Section 4. Section 6 outlines the recovery plan including estimated costs for the various options.

2 OVERVIEW

2.1 STUDY AREA

Hatzic Valley is located on the north side of the Fraser Valley near Mission, BC (Figure 1). The south end of the valley terminates in a low-lying floodplain deposited by Fraser River and occupied by Hatzic Lake, a Fraser River oxbow lake. The valley floor to the north rises to a maximum elevation of 140 m before dropping down to the southern shore of Stave Lake. This higher ground between Hatzic Valley and Stave Lake likely represents a former moraine originating from the valley glacier that occupied the Stave Lake valley during the recent Wisconsinan Glaciation. Alluvial and colluvial deposits, originating from the steep valley side-slopes, in the form of fans overlie the glacial and floodplain deposits of the valley floor.

Hatzic Lake drains a total area of 90 km^2 of uplands and low floodplain. Lagace Creek is the main tributary to Hatzic Lake with a drainage area of approximately 54 km^2. The main source of sediment to Lagace Creek is Pattison Creek, which drains a 6 km^2 area of steep mountainside on the east side of Hatzic Valley. Since 1935, the Pattison Creek watershed has experienced numerous landslides, debris flows and debris flood events that have deposited large volumes of sediment on the Pattison Creek fan and in Lagace Creek. Upstream of Pattison Creek, Lagace Creek carries a modest sediment load, however the character of the channel changes dramatically downstream of the confluence, as a consequence of the very high sediment inputs from Pattison Creek on Lagace Creek. Sediment that is largely originating from Pattison Creek is carried downstream and preferentially deposited by clast size according to channel slope. The coarsest material is deposited immediately downstream of the confluence, while fine sand is transported all the way to Hatzic Lake. Upstream of Lagace Creek, material stored in Pattison Creek coarsens to cobbles and boulders.

For the purposes of this report and ease of discussion, Lagace and Pattison Creeks have been divided into reaches that are delineated by road crossings and their confluence:

- Reach 1 – upstream of Hatzic Lake to the Dale Road crossing
- Reach 2 – upstream of the Dale Road crossing to Farms Road
- Reach 3 – upstream of Farms Road to Seux Road (Farms Reach)
- Reach 4 – upstream of Seux Road to Pattison Confluence
- Reach 5 – Pattison confluence upstream to Sylvester Road (Pattison Creek)
- Reach 6 – upstream of Sylvester Road for approximately 600 m (Pattison Creek)

Hatzic Prairie occupies the low-lying area north of Hatzic Lake extending to near the upper limit of Reach 2. The Lagace-Pattison Creek alluvial fan extends radially south-westwards from the Lagace-Pattison confluence, occupying an area of approximately 2.1 km^2 and sloping with an average gradient of 0.0275 from its apex down to the level of the Hatzic Prairie at approximate elevation of 5 m. Hatzic Prairie is periodically flooded, due partially to backwatering from Hatzic Lake, while flooding on the Lagace-Pattison alluvial fan is due primarily to overbank flooding from Lagace Creek. Avulsions of Lagace and Pattison Creeks on the fan have occurred in the past and could occur in the future.

2.2 SEDIMENT TRANSPORT

Annual bedload transport volume estimates were reported in **nhc** (1985) using a variety of empirical formulae. The sediment transport rates calculated for the channel at the Seux Road crossing were as follows:

1. The mean annual gravel transport rate is about 7,500 m^3/year;
2. The year-to-year variation in gravel transport can be very high with annual volumes ranging from virtually zero to 30,000 m^3/year. This range occurred over a simulated 22-year period when the largest single flood had a return period of 25 years;
3. The gravel transport during a 200-year flood was estimated to be 74,000 m^3/year or about 10 times the annual average.

These calculated rates compared favourably with estimates of sediment deposition derived from estimates of actual extracted sediment. In addition to the annual sediment bedload transport, periodic debris flood events have the potential to introduce volumes of sediment that are an order of magnitude higher. From approximate sediment budget estimates made by **nhc** (in Associated Engineering, 1992), a debris flood event in 1990 resulted in the following deposition:

- above Sylvester Road: 60,000 m^3
- Sylvester Road to confluence: 40,000 m^3
- downstream of confluence: 30,000 m^3

The total deposition of approximately 130,000 m^3 is almost twice as much as the estimated 200-year flood estimate volume. Although it is not possible to directly compare the calculations because the channel conditions are different at these two locations, the assumed sediment transport rates during a debris flood event would be significantly higher than estimated by the empirical formulae employed in **nhc**'s 1985 study.

2.3 RECENT EVENTS

Although sediment deposition and bank erosion appear to be ongoing processes at Lagace Creek, the majority of the recent changes to the channel appear to have been caused by two separate runoff events occurring since 2003. These runoff events are associated with prolonged and intense rainstorms, which occurred in October 2003 and November 2004.

The October 2003 rainstorm event, which caused widespread flooding throughout the Lower Mainland, the Sea-to-Sky corridor and the Pemberton Valley, is described in detail in Appendix II of the BGC report Preliminary Debris Flow Hazard Assessment of Field, Carratt, Eng, McNab and Dale Creeks, Hatzic Valley (February, 2004), and is summarised here. The BGC report describes the October 2003 rainstorm as an extraordinary event from a climatic perspective. A major Pacific frontal system arrived on the coast on the evening of October 15th, developing into a full "Pineapple Express" as circulation became well established and a series of moist impulses surged along the frontal stream as the system stalled over south-western BC for the next several days. New 48-hour rainfall records were established as a result of this storm, which had a calculated return period of over 100 years at some stations. Table 1 shows preliminary data from selected climate stations in the regional vicinity of Hatzic Lake, illustrating

the days of heavy rain with a lull in rainfall around October 18th followed by more heavy rain on the 20th.

Table 1 October 2003 Daily Precipitation Measurements (mm), after BGC (2003).

	Date							
Station Name	**Oct 15**	**Oct 16**	**Oct 17**	**Oct 18**	**Oct 19**	**Oct 20**	**Oct 21**	**Total**
Haney UBC Research Forest	44.2	145.8	59.5	19.0	11.0	51.8	1.2	332.5
Agassiz CDA	3.6	99.0	86.6	0.2	17.4	69.4	31.4	307.6
Pitt Meadows CS	12.2	136.6	73.8	0.4	15.2	21.6	14.8	274.6
Abbotsford Airport	12.4	93.8	73.6	0.0	11.8	50.6	25.0	267.2

Further north, where flooding was most severe in the region, estimates of the return period for the October 2003 storm made by Knight Piésold (2004) placed the storm somewhere above a 25-year return period event.

The more recent November 2004 rainstorm was of much lower magnitude. Table 2 shows preliminary data for Pitt Meadows and Abbottsford for November 22nd to 28th (data for the other stations were not available). These stations received less than half of the total 7-day rainfall than occurred during the October 2003 storm.

Table 2 November 2004 Daily Precipitation Measurements (mm).

	Date							
Station Name	**Nov 22**	**Nov 23**	**Nov 24**	**Nov 25**	**Nov 26**	**Nov 27**	**Nov 28**	**Total**
Pitt Meadows CS	2.8	8.8	65.2	1.0	16.6	2.4	0.2	97.0
Abbotsford Airport	10.4	11.8	77.8	4.2	6.4	1.8	0.0	112.4

Stream discharge response to rainfall events is complex. Antecedent conditions in the watershed, such as soil moisture levels and snowpack can have a marked effect, as well as the size and elevation range of the watershed. Therefore, a 100-year rainstorm does not necessarily result in a 100-year flow. Furthermore, as the data in Tables 1 and 2 illustrate, rainfall tends to be highly variable over fairly modest distances, being affected by such factors as elevation, local relief, and the internal makeup of the storm system. Even large storms such as the 2003 event may cause some rivers to flood while other rivers in the region will experience only normal high flows. Knight Piésold (2004) analysed the discharge at several river gauges in the Whistler-Pemberton area and found that although some of the rivers experienced flows with a return period of between 20- and 30-years, others experienced only 2-year return floods.

There are no longer any active hydrometric stations in the Hatzic Valley. However, the Water Survey of Canada maintains five gauges in the region with reasonably long flow records that can be used to perform a regional analysis. These stations are listed in Table 3 along with pertinent basin statistics and the calculated recurrence interval of the October 2003 flow.

Table 3 Regional Water Survey of Canada active hydrometric stations near Hatzic Valley.

Station No.	Station Name	Period of Continuous Record (yrs)	Watershed Area (km^2)	Recurrence Period of Oct 2003 Flow (yrs)
08MH005	Alouette River near Haney	34	234	3.1
08MH006	North Alouette River at 232nd St	44	37.3	6.6
08MH076	Kanaka Creek near Webster Corners	44	47.7	no data
08MH058	Norrish Creek near Dewdney	38	117	1.3
08MH150	Norrish Creek above Rose Creek	18	-	3.7

Table 3 shows that while drainages in the region of Lagace Creek certainly experienced high flows as a result of the October 2003 rainstorm, the magnitude of these high flows was not directly relative to the magnitude of the storm. The gauge at Norrish Creek near Dewdney experienced the lowest relative flow, while the North Alouette flow was estimated to be a 6.6-year return flow. It is plausible to assume, based on the flows in nearby watersheds, that Lagace Creek experienced a flow with a return period in the range of 2 to 7 years. The occurrence of a debris flood emanating from Pattison Creek, would have exacerbated the damage caused by high flows in Lagace Creek.

The November 2004 event that affected Hatzic Valley did not produce a yearly maximum flow in any of the gauges in the region (there was no data released for Kanaka Creek when this report was prepared). Two of the remaining four gauges that reported flows for the year showed quite high flows around November 24th (the date of peak rainfall), however, in all cases the flows generated by this storm were exceeded either by a storm in December or January of the same year. For instance, the November flow measured at Norrish Creek near Dewdney (*WSC* 08MH058) would have been rated at about a 3-year flow had it not been exceeded slightly in December. Based on this regional analysis it is possible that 2- to 3-year flow occurred around November 24th, 2005 and highly probable that a flow occurred with the capacity to transport significant amounts of bed material and erode the channel.

Conditions in the Lagace Creek channel is the main factor in determining whether a high flow event will result in flooding and erosion. Excessive sediment and debris inputs from Pattison Creek raise the general level of the bed in Lagace Creek and reduce the capacity of the channel to conduct flow. Subsequent high flows will cause greater damage than would be normally expected, such as occurred during the November 2004 event.

2.4 PAST EVENTS

There has been a persistent occurrence of debris flow or debris flood events originating from Pattison Creek since the first recorded landslide occurred in 1935. These high-energy hydrogeomorphic events are largely driven by meteorological processes such as the 2003 and 2004 storms. However, their frequency and degree of impact on the Lagace Creek channel are exacerbated by past forest harvesting and road building activities in the upper watershed (BGC, 2004). Similar events emanating from the watershed are also likely in the future.

2.5 PAST STUDIES

Numerous studies have been completed in the past to address the problems of flooding and sedimentation in the Hatzic Valley. **nhc** prepared a report in 1985 for the Ministry of Environment titled *Investigation of Sedimentation and Flood Control on Lagace Creek*. **nhc** was also one of the main contributors to the Associated Engineering studies *Hatzic Prairie Drainage Study, Volumes 1 & 2*, completed in 1992. In 2001 and 2002, **nhc** was commissioned by the FVRD to complete a series of studies to investigate the problems of sedimentation in Lagace Creek and to develop and oversee works to extract sediment from the channel.

In addition to the above-mentioned studies that specifically investigate flooding and sedimentation processes on the valley bottom, there have been a series of studies completed to investigate hillslope hazards and sediment delivery. Rather than review all of these reports first-hand, summaries provided in the recent (2004) BGC report discussed in Section 2.2 were reviewed. A full reference for all of these studies is provided at the end of this report.

3 DAMAGE ASSESSMENT

Field evidence and comparisons made with past photographs and surveys indicate that the November 2004 event caused bed aggradation and erosion that is exacerbating conditions caused by the October 2003 event. If this aggradation is not addressed, it could continue to adversely affect nearby properties and structures. To address this potential problem, an assessment of the existing conditions in the channel was completed, as well as two future conditions with and without improvements.

3.1 EXISTING CONDITIONS ASSESSMENT

In addition to the damage that occurred within the channel as a result of the 2003 and 2004 events, ongoing deposition, bank erosion and overbank flooding are of concern due to the changes to the channel. Inspection and documentation of the channel from Sylvester Road Bridge to Hatzic Lake identified locations of recent sediment aggradation, debris accumulation, erosion, and flooding. For convenience, the channel has been divided into reaches, as outlined in Section 2.1.

3.1.1 REACH 1 – UPSTREAM OF HATZIC LAKE TO THE DALE ROAD CROSSING

The lower half of Reach 1 is periodically backwatered by high water levels in Hatzic Lake. The channel has a very low gradient, and the dominant bed material is sand. Cross section surveys were completed in April 2005 for the purposes of future monitoring. Previous cross sections were surveyed in the 1980s and early 1990s, however it was not possible to make accurate comparisons due to the absence of vertical control. Transport of sand occurs on a frequent basis during moderate and higher flows.

The upper half of the reach, approximately 1500 m downstream from Dale Road Bridge, appears to be fairly heavily aggraded at present. Residents have reported more frequent flooding at successively lower flows, and comparison of the channel with older photographs appears to indicate an increase in the number of sandy bars and shoals in this portion of the reach. Photo 1 shows the extent of flooding and high sediment load.

3.1.2 REACH 2 – UPSTREAM OF THE DALE ROAD CROSSING TO FARMS ROAD

The channel has been artificially straightened for almost the entire length of this reach, with the width imposed during construction. The gradient ranges from approximately 0.017 m/m at

Farms Road Bridge to 0.001 at Dale Road Bridge. Similarly the mean sediment size decreases from gravel to fine sand. The banks consist primarily of immature alders, cottonwoods and shrubs. The major bend at approximately 300 m downstream of Farms Road Bridge marks the approximate downstream edge of the Lagace-Pattison alluvial fan. Downstream of the fan in the Hatzic Prairie, natural and man-made levees on both sides of the channel result in the top-of-bank being slightly above the surrounding floodplain. In general the channel section capacity is inadequate to pass large storm flows.

A series of five cross sections were surveyed upstream of Dale Road in 1984, partially resurveyed in 1991 and fully resurveyed in 2002 (Appendix A). A full survey was completed in April 2005 as part of the present study. These surveys (FIGURE A-1) show a complete refilling of the dredged 1991 channel. At several cross-sections, the present bed is higher than the bed prior to the 1991 dredging. We have estimated that approximately 10,000 m^3 of sandy material could be excavated from this reach.

During a site visit in April 2005 during a low to moderate flow, active sand transport was observed in the channel upstream of the Dale Road Bridge, and larger amounts of sediment may be moved during large floods. This reach potentially transports large amounts of sand during normal flows and bed elevation adjustment occurs almost continuously during normal flows. Unless upstream sources of sediment are reduced, channel excavations are likely to infill and re-adjust to existing conditions controlled largely by downstream channel grades and elevations. A multi-year program of sediment extractions would be required to have a lasting effect on this reach.

3.1.3 REACH 3 – UPSTREAM OF FARMS ROAD TO SEUX ROAD (FARMS REACH)

The lower portion of Farms Reach is a primary area of deposition in Lagace Creek, and has traditionally been used for sediment traps and sediment extraction. Significant deposition of coarse sediment (coarse gravel to cobbles) has occurred along the Anderson gravel trap since the 1991 dredging. Also, recent excavations were of the following amounts: in 2001 about 12,000 m^3 and in 2002 about 10,000 m^3. The channel widths are much greater (almost twice as wide) in this section compared to the upstream portion of the reach. The upper portion of the reach has also experienced areas of significant bank erosion. The average gradient in this

reach is approximately 0.014, which includes a slight flattening in the profile immediately upstream of Farms Road Bridge, which appears to be caused by a channel constriction at the road crossing.

A total of 13 cross sections were surveyed in this reach in 2001 and five of them were resurveyed in 2002 (Appendix A). A full resurvey was completed in April 2005 with additional cross sections added to facilitate monitoring of the channel in future. A comparison of these surveys indicates that there was an accumulation of sediment in the main deposition section after each of the 2001 and 2002 excavations. Extensive bar deposits topped by accumulations of organic debris (logs) are obviously recent and in areas of bank erosion, the banks are nearly vertical.

In general the channel appears to be overwhelmed by recent sediment deposition. The typical channel cross section is convex or elevated in the middle of the channel, which results in the concentration of flow against the base of the banks during high flow stages, accelerating bank erosion. There is generally a poorly defined thalweg with frequent flow splits, and high rates of sediment transport would be expected during high flows as well as remobilization of the existing bed material.

Based on a comparison of the 2002 and 2005 cross sections, a total of approximately 13,000 m^3 of sediment should now be removed from the Anderson gravel trap. (see Photo 2). Also, some excavation up to Seux Road bridge is necessary to reduce bank erosion.

3.1.4 REACH 4 – UPSTREAM OF SEUX ROAD TO PATTISON CONFLUENCE

The channel steepens upstream of Seux Road Bridge, to an average gradient of 0.026, ranging from 0.015 to 0.045. Bed material is much coarser than downstream reaches and is dominated by cobbles and small boulders. The channel width in this reach varies considerably, ranging from 22 to 52 m, in areas of transport and deposition respectively. Total reach length is approximately 1200 m.

Cross section surveys were completed in April 2005 for the purposes of quantifying the channel dimensions and providing future monitoring sites (Appendix A). There were no previous

surveys so a direct comparison is not possible. However, based on the sections and channel inspections, about10,000 m^3 of material was deposited in the channel as a result of the 2003 and 2004 events. Unlike the reach upstream of Sylvester Road, the areas of sediment deposition are not continuous. In addition to the large volume of sediment that was deposited, there has been significant bank erosion along portions of the channel, especially along the south (left) bank immediately upstream of the Seux Road bridge. The riprap has been damaged and the bank has experienced erosion immediately upstream of the left bank bridge abutments. A detailed inspection of this site is recommended for Phase II of this study, and a preliminary estimate is included for bank protection in Phase 1.

3.1.5 REACH 5 – PATTISON CONFLUENCE UPSTREAM TO SYLVESTER ROAD (PATTISON CREEK)

The channel from the confluence upstream to Sylvester Road represents an area of significant sediment deposition. Reach 5 is short in relation to the other reaches (375 m) with an almost uniform channel width of 35 m and a slope of 4 to 5%. Approximately 10,000 m^3 of material was deposited in this reach as a result of the 2003 and 2004 events. Portions of the bank have experienced erosion, particularly immediately downstream of the bridge and also to the south along Sylvester Road.

3.1.6 REACH 6 – UPSTREAM OF SYLVESTER ROAD (PATTISON CREEK)

Though originally outside the scope of the proposal for this study, it was necessary to inspect the channel upstream of Sylvester Road Bridge in order to assess the potential for sediment deposited upstream of the channel to be transported to the downstream reaches. Therefore the channel was inspected upstream of Sylvester Road for a distance of approximately 650 m in May 2005.

The channel gradient upstream of Sylvester Road Bridge is nearly uniform at 0.07 with a nearly constant channel bottom width of 40 m. The material deposited in the channel ranges from coarse sand to very large boulders, with the dominant clast size is in the small boulder to very large cobble range. The effects of the 2003 event are still freshly evident and include deposition of a large amount of coarse sediment and erosion of the right bank for approximately 90% of the inspected reach length.

Surveys of the channel were not completed in this reach, however, reasonably accurate estimates of the volume of sediment deposited in the channel were made during the site visit. With the exception of two conspicuous sediment wedges, there appears to be a nearly uniform thickness of sediment in the channel for the majority of the reach on the order of 1.5 to 2.0 m. The thickness of sediment on the two wedges is approximately 1.5 to 2.0 m greater than the general reach aggradation. One exception is the riprapped section of channel immediately upstream of the Sylvester Road Bridge, which appears to have been degraded by approximately 0.7 m. There is an estimated 41,000 m^3 of material deposited in the 600 m of channel upstream of Sylvester Road Bridge.

At several sites, the possibility of channel avulsion is very real because the deposited sediment has raised the profile of the bed to near the elevation of the top of bank. Avulsion is defined as a change in the course of the channel through abandonment of one channel and formation of a new channel.

3.2 FUTURE CONDITIONS ASSESSMENT

Based on our assessment of the Lagace Creek channel, it is possible to make general predictions about the ongoing stability of the channel and risk of future flooding. It is clear that the flood conveyance of the channel has been reduced by the large amount of sediment that was introduced as a result of the recent high flow events, and that natural recovery may not occur. The presence of significant amounts of sediment in the channel upstream of Sylvester Road represents a significant source area for continued downstream transport. The fact that the channel pattern is irregular and aggraded indicates that ongoing sediment transport into the lower reaches will remain quite high in the immediate future.

Of prime concern is the convex cross section shape that is typical of many mountain streams in BC that experience very high rates of sediment transport. This condition typically results in an increase in bank erosion, as high flows are more likely to be concentrated along the edges of the channel. This leads to increased bank erosion that further destabilizes the channel, introduces more sediment and increases the width of the channel. Increased channel width results in additional expansion area for sediment deposition. Aggradation of the bed also has the effect of reducing the effective flood conveyance of the channel, and increasing the frequency that high flows go overbank. Excessive aggradation also increases the potential for

channel avulsion, and risk of damage to bridge crossings when accumulations of organic debris partially block the channel and cause local scour.

Based on our assessments of the existing conditions, there is a high probability that bank erosion and overbank flooding will continue to damage existing property and structures on the Lagace-Pattison alluvial fan for a considerable period of time. There is a considerable risk that even greater flood damage could occur from future events initiated by channel impacts caused by the October 2003 flow event. Overbank flooding is a major concern on the Hatzic Prairie, where recent flooding almost resulted in the deaths of two motorists. Also, frequent inundation is impeding the ability of farmers to work their land.

4 ASSISTANCE RATIONALE

There is a history of geomorphic events occurring in the Pattison Creek watershed that have directly impacted Lagace Creek. Large debris flood events have occurred most recently in the early 1980s and early 1990s, as well as in 2003, and typically result in the deposition of large amounts of sediment in the channel. Following these events, the channel is much more susceptible to damage from normal high flows, which can include accelerated bank erosion and overbank flooding. In addition, the risk of channel avulsion is much higher due to near-complete filling of the channel by sediment and organic debris. Properties directly adjacent to the channel are most at risk, but any property on the Lagace-Pattison Fan is theoretically exposed to an avulsion hazard.

Based on our field investigations, photographs and comparison of channel surveys, we have quantified the direct impact of the most recent flooding events that occurred in 2003 and 2004. As well, we have outlined the increased likelihood for further and ongoing damage from subsequent normal high flow events. The rationale for assistance from PEP is based on the fresh evidence of damage from the most recent flooding events and the potential for future and ongoing flooding and channel erosion resulting from the altered channel conditions. Implementation of the Recovery Plan outlined below will reduce the frequency of overbank flooding and slow or arrest channel bank erosion from normal flood events.

5 RECOVERY OPTIONS

The recovery plan outlined below has been developed to address the processes outlined in the channel assessments, included above. These processes include:

- sedimentation,
- potential channel avulsion,
- channel erosion, and
- overbank flooding.

Although most of these problems are chronic and ongoing, the recent debris flood event in October 2003, and subsequent high flow events (ie. November 2004) have initiated a fresh cycle of channel adjustment and have resulted in adverse channel conditions that are threatening adjacent properties.

There are a variety of techniques that can be applied to the problems of flooding and bank erosion at Lagace Creek. They fall into two main categories: 1) techniques to reduce the amount of sediment in the channel, and 2) techniques to prevent overbank flooding by diking.

Many of these techniques have been investigated in previous studies and are outlined below, along with a summary of the relative merits of implementing each one. Isolating the channel from the fan and floodplain would be achieved through the construction of offset dykes. This option is very costly and will not be investigated further in this study. We have instead focused on the various techniques to remove in-channel sediment.

5.1 TECHNIQUES TO REDUCE IN-CHANNEL SEDIMENT

The root cause of channel aggradation is an excess of sediment supply from upstream compared to the stream's capacity to transport sediment through the system. The following options are presented as potential strategies to address the issue of excess sediment.

5.1.1 WATERSHED RESTORATION

Periodic large debris flood events originating in the Pattison Creek watershed have been an ongoing occurrence since at least the mid-1930s. These events introduce very large quantities of sediment to the channel while causing significant damage to the channel banks and often result in damage to adjacent properties. It is likely that the watershed processes in Pattison Creek have been impacted by past forest harvesting practices, and thus there is a high likelihood of future occurrence of these events. Any works carried out in the lower reaches of Lagace Creek are at risk to impact from future high-energy events and therefore cannot be considered a long-term solution until issues of instability in the upper watershed of Pattison Creek are addressed.

BGC (2004) noted that natural instabilities and past forest harvesting activities have severely destabilized many of the watersheds draining the eastern slopes of Hatzic Valley. The following is a partial list of recommendations made in their report that pertain to the present study:

1. The discontinued Level 1 Watershed Study should be completed and reviewed by an expert on forestry-related landslides and debris flows.
2. A detailed forest road stability assessment should be initiated in which all forest roads in the upper watersheds of the above creeks are visited by qualified personnel and prescriptions are made to deactivate those road portions that pose the highest risk for failure.
3. A Coastal Watershed Assessment Procedure (CWAP) should be conducted and peer reviewed for all study watersheds and adjacent smaller drainages with downstream resources.
4. Slope stability experts should scrutinize all future logging plans in the study area watersheds and nearby creeks.
5. The bedrock failure in the upper watershed of Pattison Creek should be investigated by a bedrock landslide specialist with reference to potential catastrophic failure and transformation into a rock avalanche, which could destroy development downstream.
6. A long-term management plan should be compiled on how to address recurrent debris flows and continuous streambed aggradation.

With the exception of point number 6, it is beyond the scope of the present study to investigate these issues. There is a very strong likelihood that debris flood events will occur in the future and these will have a serious impact on the channel. These issues must be addressed as part of a long-term management solution for Hatzic Valley.

5.1.2 CHANNEL EXCAVATION

There has been a significant amount of sediment deposited in the channel following the October 2003 debris flood event. At present the channel is overloaded with sediment, particularly in the reach upstream of Sylvester Road. Excavation of the channel will provide a short- to medium-term solution to the problem of overbank flooding, will generally slow the rate of bank erosion, and will reduce the risk of channel avulsion.

We have estimated the amount of sediment that has been deposited in the channel as a result of the October 2003 and November 2004 events. Much of this sediment, which should be considered to be in temporary storage at present, will eventually be transported through the system and will continue to impact downstream reaches for many years to come. Removal of a portion of the in-channel sediment would reduce the available supply and result in lowered rates of sediment delivery through the system. As a one-time effort, this strategy should have a beneficial effect. A longer-term maintenance program would be necessary to maintain the channel.

Excavation of sediment should be approached strategically, especially if budgetary restraints prevent the full implementation of the proposed recovery plan (as would seem likely given the magnitude of the problem). In a paper titled *Interference with Braided Gravel Rivers*, Galay, *et al*. (1995) made the following recommendations with regards to excavations from braided gravel rivers:

1. Excavations in wide, braided reaches should be located through the middle of high channel bars, which are generally located in the centre of the cross-section. This would reduce flood levels and flows along the outside boundaries.

2. Excavations should be restricted to the upstream half of the braided reach. The excavations would then trap some of the material coming from upstream and control any tendency for rising bed levels farther downstream.

These recommendations have direct applicability to Lagace Creek. Excess sediment in the channel is causing ongoing bank erosion. Removing gravel from the upstream portion of the system will benefit a greater length of channel than simply removing sediment from the lower end. This applies also to the location of sediment traps, as discussed below.

5.1.3 BANK PROTECTION

Channel widening is a common response of rivers to adjust to a high sediment load. A significant portion of the banks along Reaches 4, 5, and 6 are undergoing active erosion, which further exacerbates the problem of the high sediment load that is supplied from upstream. In addition, at many sites bank erosion is directly threatening private property.

A variety of treatments can be applied to protect eroding banks from further retreat. These techniques include:

- Bio-engineering
- Riprap
- Log structures

At the reach scale in Lagace/Pattison Creek, widespread application of these types of treatments would be very costly. For instance, a rough estimate for installing riprap is about $\$50/m^3$. A typical 10 m length of 1.5 m high eroding bank in Lagace Creek would cost in the range of $1100 to protect. We do not recommend the widespread use of bank protection. However, the bulldozing of boulders and cobbles from the centre of the channel to the banks could reduce the rate of bank erosion. This measure was implemented in 1991 along short reaches of the south bank in Reach #4, but some of the boulders are being undermined.

5.1.4 CHANNEL CROSS SECTION RECONTOURING

As discussed in Section 3.2, the ongoing processes of bank erosion and aggradation are acting in a positive feedback loop. Channel cross section recontouring is proposed as a lower-cost alternative to bank protection techniques, with the added benefit of isolating a portion of the excess sediment from the flow.

Figure 2 illustrates graphically the benefit that cross section recontouring would have for the long-term stability of the channel. The convex-up cross section would be partially excavated to create a 15 to 20 m wide channel, nominally capable of carrying the 1- to 2-year flow. Approximately 50% of the excavated material in the cross section would be removed from the channel while the rest would be spread over the remaining portion of the cross section to form bars. Material would be piled along the edges of the channel to lower the depth of flow against the banks. In select locations, larger material could be sorted from the excavated sediment and used to help armour the toe of the bank. This winnowed material could not be thought of as riprap but would be more resistant to flow than the majority of the bed material.

5.1.5 SEDIMENT TRAPS

Sediment traps are excavated depressions in the channel that trap a portion of the bedload and prevent it moving from upstream to downstream reaches. They provide a means to manage high bedload by interception and periodic removal of material. As outlined in Section 5.1.2 above, the most effective location for a sediment trap, in terms of benefit to the channel, is in the upper portion of the system. However, due to higher channel slopes in the upper portion of the system, trap efficiency is expected to be lower.

nhc (1985) investigated various options for installing sediment traps in Pattison and Lagace Creeks. Four areas were identified as potential sites for installation of sediment traps:

- downstream of Sylvester Road bridge (Pattison Creek);
- upstream of Seux Road bridge;
- between Farms Road and Seux Road bridges; and

- downstream of Farms Road bridge.

The site downstream of Farms Road bridge would be effective for trapping sand and a long reach would have to be executed. The site immediately downstream of Sylvester Road Bridge (Pattison Creek) was considered as a potential site. The site upstream of Seux Road bridge and the site between Farms Road and Seux Road were deemed to have the best potential for managing sediment, and in fact the latter of the two has been an active sediment trap for some time, and because of its relative low cost, should be maintained.

6 RECOVERY PLAN

The recovery plan for Lagace Creek includes proposed works to address the most recent damage caused by the October 2003 and November 2004 events as well as works to address the ongoing issue of high bedload transport into the affected reaches. We would expect the works addressing recent damage to be funded by PEP, while alternate sources of funding would be required to address ongoing sedimentation issues.

6.1 SHORT-TERM WORKS

Works that would have immediate short-term benefits include;

- excavation of sandy material from the upper portion of Reach 1,
- excavation of sandy material from Reach 2 above Dale Road up to the big bend,
- excavation of sediment from Reach 3, including removal of sediment from the Reach 3 sediment trap,
- excavation and recontouring of the channel in reach 4,
- excavation and recontouring of the channel in reach and construction of a trap, and
- excavation of sediment from Reach 6.

These works are warranted given the amount of sediment that has recently been deposited and the potential for channel avulsion, and the increased risk of ongoing bank erosion and overbank flooding. A range of estimated costs is included below. The layouts for these works will be developed in Phase 2.

Due to the high costs for these works, Fraser Valley Regional District may be in the position of having to choose from amongst the various options. We anticipate that these decisions will be made in the political arena with significant public input. We have made recommendations, from the physical standpoint, regarding priorities for these works, which may be useful for informing the public debate.

6.2 MAINTENANCE

The works that would be of benefit to the long-term recovery of the channel include:

- installation of additional sediment traps,
- ongoing sediment removal from the traps, and
- ongoing sediment removal from Reaches 1 and 2.

These maintenance works represent important components in the long-term management of the sedimentation issues in Lagace Creek. It is important to note that these works will address only the average sediment inputs from upstream portions of the channel. Large events, such as that which occurred in October 2003, have the potential to completely overwhelm the sediment traps as well as the channel, particularly on the upper portions of Lagace-Pattison fan. In order to have a significant effect, extraction from Reaches 1 and 2 should be a planned, yearly operation for the next several years. Extraction from the sediment traps should also be carried out frequently. Depending on monitoring, this could prove to be necessary on a yearly or twice-yearly basis.

6.3 HABITAT MITIGATION AND ENVIRONMENTAL CONCERNS

A comprehensive environmental and habitat mitigation plan will be developed during Phase 2 and will be included in the final construction plan. This plan will be based on current best management practices (BMPs) to mitigate potential damage during instream works and will focus on habitat compensation where environmental damage is unavoidable.

6.4 ESTIMATED COSTS

Table 4 shows the estimated construction costs for each reach. The estimates are based on our prior experience in Hatzic Valley, government of British Columbia machine rates, or prior

experience elsewhere, and do not include construction supervision or environmental monitoring. The possibility of onsite sediment disposal has been indicated by several local residents and could save considerable trucking costs. All values should be viewed as estimates for planning purposes only.

Additional costs such as Engineering Design and Environmental Study for Phase 2, Construction Supervision, Environmental Monitoring, and Project Administration have been estimated on a percentage basis. We have estimated an additional 10% for Habitat Compensation works and have included a 20% Contingency to allow for unforeseen costs.

Table 4 Cost Estimates for Various Short-Term Lagace Creek Treatments.

Stream Reach	Problem	Hazard	Treatment	Volume (m^3)	Cost Estimate
1 - 1500 m downstream of Dale Road	Sand deposition	Flooding	Excavate sand	10,000	$50,000
2 - Dale Road to Farms Road	Sand deposition	Flooding	Excavate sand	10,000	$70,000
3 - Farms Road to Seux Road	Gravel deposition	Flooding	Excavate gravel	25,000	$75,000
4 - Seux Road to Confluence	Gravel deposition and bank erosion	Bank erosion	Excavate gravel and channel recontour	12,000	$100,000
5 - Confluence to Sylvester Road	Gravel/cobble deposition and bank erosion	Bank erosion	Excavate gravel and cobble and contour channel	10,000	$60,000
6 - Upstream of Sylvester Road	Gravel/cobble/boulder deposition and bank erosion	Avulsion and bank erosion	Excavate gravel, cobble and boulders	40,000	$300,000
			Sub-total		$655,000
			Engineering Design – 10%		$65,500
			Environmental Study – 5%		$32,750
			Construction Supervision – 5%		$32,750
			Environmental Monitoring – 5%		$32,750
			Project Administration – 5%		$32,750
			Habitat Compensation – 10%		$65,500
			Contingency – 20%		$131,000
			Total		$1,048,000

6.4.1 MAINTENANCE

The long-term maintenance cost is estimated to be $100,000 per year and will be based upon an annual monitoring program.

6.4.2 REACH 1 – DALE ROAD AND DOWNSTREAM

The upper 1500 m of Reach 1 have the potential for overbank flooding during high flows in the fall and winter when Hatzic Lake levels are lower. A full reach excavation along the 1500 m length of channel would remove on average 1 m depth of sand, totalling approximately 22,000 m^3. This preferred option is not likely to be feasible due to access issues along the banks. Therefore, we recommend that selected sections, with better access, could be excavated to a greater depth totalling approximately 10,000 m^3. These selected sites would be chosen to have the maximum benefit for drainage of upstream reaches, specifically the low areas upstream of Dale road to the east and west of Lagace Creek.

A number of options have been proposed in the past for installation of sand sediment traps in this portion of the reach. These options include temporary diversion of the channel and excavation of sand and will be revisited in Phase II.

6.4.3 REACH 2 – DALE ROAD TO FARMS ROAD

We have estimate that approximately 10,000 m^3 of aggraded sands could be removed from the downstream portion of this reach (1120 m of channel length). Excavation would lower the bed of the channel by an average of 0.75 m over a width of 12 m. This volume of sediment removal would be the smallest of the treatments proposed but not the cheapest to construct because of the remoteness of the reach from spoil sites and the road network. However, substantial savings could result if sand removed from the channel is stockpiled as a berm beside the channel. Stockpiling would eliminate the need for trucks on the project and limit excavation time to the speed of the excavator instead of the turn-around time of the trucks. If material removed from the channel is stockpiled on-site we estimate that the project could cost $50,000 and take 20 days to complete.

These estimates do not include any value that the excavated sand may have. It may be possible to obtain bids from local contractors for less than the estimates provided if rights are granted to sell the material. Establishing rights to this material is complicated by the fact that the straightened channel crosses several property boundaries and is therefore located on private as well as crown lands. Sand could be worth between $3 and $5 per cubic metre for local use. Local contractors with a stockpile area and a demand for the material may be encouraged to tender bids that reflect the value of the material to be removed.

6.4.4 REACH 3 – FARMS ROAD TO SEUX ROAD

Upstream of Farms Road, Lagace Creek is aggraded by gravel and sand. This reach has been the site of past excavations and the channel is wide and flat. We estimate that 12,000 m^3 of material has recently filled the sediment trap and about the same amount could also be excavated upstream to the Seux Road bridge. This would be quite a simple excavation to perform due to the proximity of good spoil sites beside the channel and existing access. We estimate that excavation could be completed for about $75,000 depending upon the contractor's bid.

6.4.5 REACH 4 – SEUX ROAD TO CONFLUENCE

Aggradation of Reach 4 is less severe but has occurred over a high proportion of the channel length. Therefore excavation is expensive due to the longer distances over which the sediment must be moved. The primary treatment for Reach 4 would be channel recontouring and protection of the banks using boulders found in the bed. Approximately 12,000 m^3 of material would be removed from this reach, while a further 12,000 m^3 would be moved to the channel margins. We have assumed that sediment could be stockpiled nearby to minimise the cost of trucking. We have estimated that treatment of Reach 4 would cost approximately $100,000.

6.4.6 REACH 5 – CONFLUENCE TO SYLVESTER ROAD (PATTISON CREEK)

Upstream of the Lagace-Pattison Creek confluence, the bed of Pattison Creek channel is aggraded with a volume of approximately 10,000 m^3 of cobbles and boulders for the 375 m long

reach. This has lead to a general bed rise of 0.75 m over the entire 35 m width. However distribution of the sediment across the channel has not been uniform and selective deposition in the centre of the channel has lead to a convex up cross section shape that forces flow against the toe of the eroding banks.

Assuming a unit cost of $5/m^3 for removal of the accumulated sediment and an additional $10,000 for sorting the largest material and pushing it against the banks, the total cost for this reach would be $60,000. This type of bank protection would not be adequate for very high flows but, in combination with the channel excavation, would significantly reduce the rate of bank retreat.

This site may be suitable for installation of a long-term gravel trap. Although the channel gradient is high compared to downstream reaches, the greater channel width, and the fact that the site is above the Lagace Creek confluence warrant further investigation as a long-term extraction site.

6.4.7 REACH 6 – UPSTREAM OF SYLVESTER ROAD

Boulders, cobbles and gravel from the upper watershed have nearly filled the channel of Pattison Creek above Sylvester Road. We estimate that 40,000 m^3 of sediment has been deposited as a result of the 2003 event and should be excavated from the lower 600 m of this reach to lower the avulsion and bank erosion hazards. This volume estimate corresponds to a 1.5 m depth of sediment across the entire 42 m channel width for a length of 530 m. In addition two distinct sediment wedges have formed in the reach, raising the bed locally an additional 2 m. The volume of sediment to be removed from the channel is the largest of any reach in the study and as a result the cost estimate for this work is the highest. It is unlikely that the poorly sorted material would have any commercial value (Emil Anderson Maintenance Co. Ltd., pers. com.) and therefore all of the material removed would have to be stockpiled.

We have assumed that the unit cost of excavation will be higher because access to the site will be more difficult. We therefore estimate that the project would cost in the range of $300,000 to complete.

6.4.8 HABITAT MITIGATION

We have estimated the costs for habitat mitigation at approximately 10% of the construction budget, or $65,000. As a mitigation/compensation package will only be determined following discussions with the various agencies and the fisheries consultant, Scott Resources Ltd., this figure provides only a very rough estimate for budgeting purposes. Previously approved habitat mitigation in the vicinity of the Dale Road Bridge will comprise part of the proposed plan, however a detailed environmental and habitat compensation/mitigation plan will be developed during Phase 2, detailed design.

7 CONCLUSIONS AND RECOMMENDATIONS

Lagace Creek has been adversely impacted by a large debris flood or debris flow event originating in Pattison Creek that occurred in October 2003. Subsequent high flow events, such as occurred in November 2004 have caused further damage to the channel, compounded by the damage incurred from the 2003 event. At present, in-channel sediment deposition has resulted in an unstable channel that is at a high risk of avulsion upstream of Sylvester Road, has ongoing bank erosion for much of its length across the Lagace-Pattison alluvial fan, and that is subject to higher flood levels.

We have provided the background and rationale to make an application to PEP for funding to return the channel to pre-disturbance conditions. These proposed works include significant excavation of sediment and channel recontouring, as well as some localized bank protection to address specific sites of concern such as the damaged riprap immediately upstream of the Seux Road bridge. The cost of these works has been estimated on a reach-by-reach basis and total approximately $1,048,000 including all engineering and supervisions costs, habitat compensation and a 20% contingency fee. The following is a brief summary of these costs:

- Reach 1 – Excavate Sand: $50,000
- Reach 2 – Excavate Sand: $70,000
- Reach 3 – Excavate Gravel: $75,000
- Reach 4 – Excavate Gravel and Channel Re-contour: $100,000
- Reach 5 – Excavate Gravel and Cobble, and protect banks: $60,000
- Reach 6 – Excavate Gravel, Cobble and Boulders: $300,000

7.1 TIMING

The instream construction window for Lagace Creek runs between August 15th and September 15th. We anticipate that the Pattison Creek channel upstream of Sylvester Road will be dry by mid-summer and therefore it may be possible for some of the works to begin as early as the first

week of August. The month of September is statistically fairly dry and it may be possible apply for an extension to allow instream construction beyond September 15th if necessary.

Phase 2, Detailed Engineering Design, should be completed by mid-July to allow for input and permitting from DFO and other environmental agencies, preparation of a tender package to solicit bids from suitable contractors, and administration of contracts.

The recommended works outlined in this report represent a significant undertaking. Depending on such factors as budgets, permitting and contractor response, it is possible that not all works can be completed during a single construction season. The following represents the order of priority that should be assigned to the recommended works based on their effects on reducing flood frequency, bank erosion, and reduction of avulsion hazard. Other considerations may arise during public input to this process.

Highest Priority	Reach 1 – Excavate Sand Reach 2 – Excavate Sand Reach 6 – Excavate Gravel, Cobble and Boulders
High Priority	Reach 3 – Excavate Gravel Reach 4 – Excavate Gravel and Channel Re-contour Reach 5 – Excavate Gravel and Cobble, and protect banks

7.2 LONG-TERM PLANNING

We have also outlined options for a longer-term sediment management strategy. Elements of this strategy would include installation sediment traps elsewhere in the system, regular maintenance of the sediment traps, and regular excavations of sandy sediments from Reach 2 of Lagace Creek. The annual long-term maintenance budget could be as high as $100,000 per year.

It is important to note that the issues affecting Lagace Creek do not originate locally. The majority of the sediment in the channel is derived from the chronic occurrence of high-energy debris flood or debris flow events that regularly introduce vast quantities of sediment to the channel. There is a very high likelihood that the works proposed here will be overwhelmed by another similar event at some time in the future. Addressing the problems in the upper watershed of Pattison Creek are necessary if any long-term solution to the sedimentation problems in Hatzic Valley are to be realised.

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FIGURES

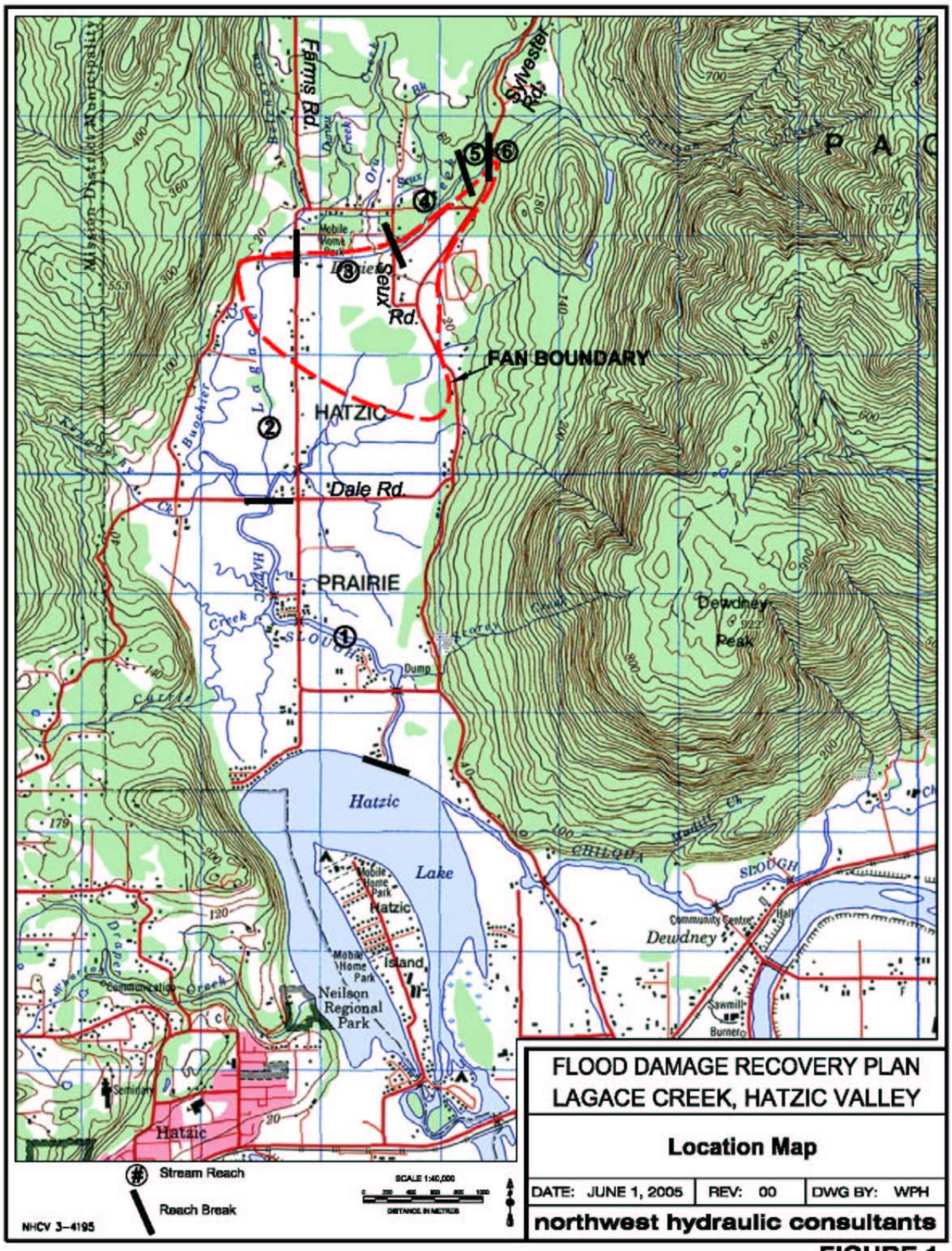


FIGURE 1

Figure 1. Study area location map of Hatzic Valley.

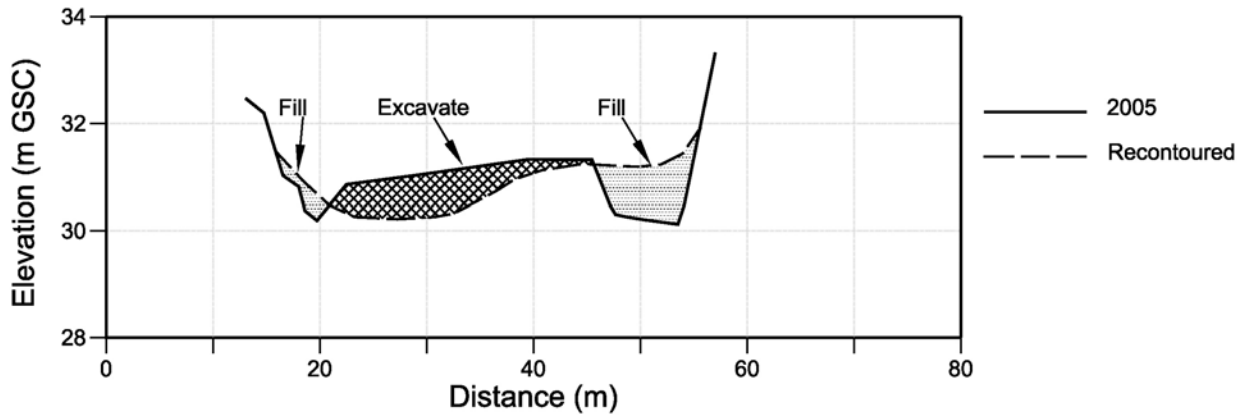


Figure 2. Graphical representation of cross section recontouring.

PHOTOGRAPHS

PHOTO NO. 1

Lagace Creek

**Flooding over the floodplain
on October 23, 2003.
The sediment-laden Lagace Creek
is in the middle of the photo and
the South Farms Road Bridge is
down from the bend.**

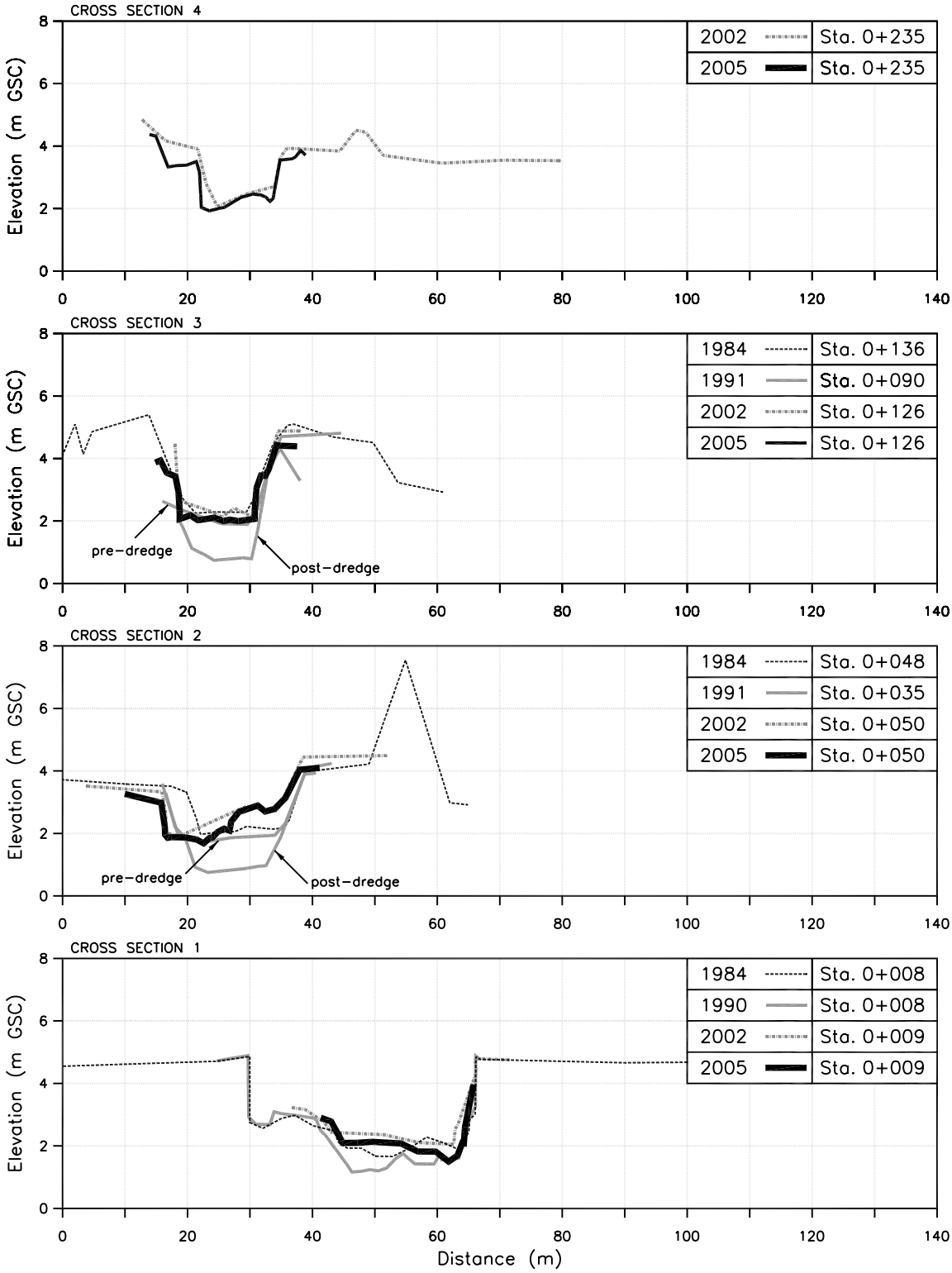
Flow is left to right

PHOTO NO. 2

Downstream view to Reach #3 (Anderson's Gravel Trap) which is almost completely filled with gravel. The creek bank on the right is the same elevation as the bed in the middle of the creek. (June, 2005)

APPENDIX A

CHANNEL SURVEYS



LAGACE REEK EMERGENCY WORKS

Lagace Creek

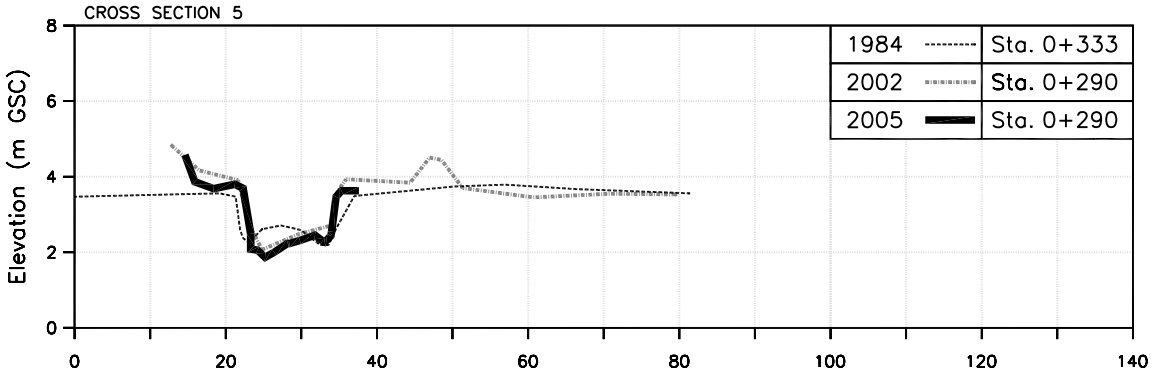
Dale Road Reach Cross Sections

Sections1 to 4

northwest hydraulic consultants

NHCV 4195 – Dale Road Reach

APPENDIX A-1



LAGACE REEK EMERGENCY WORKS

Lagace Creek

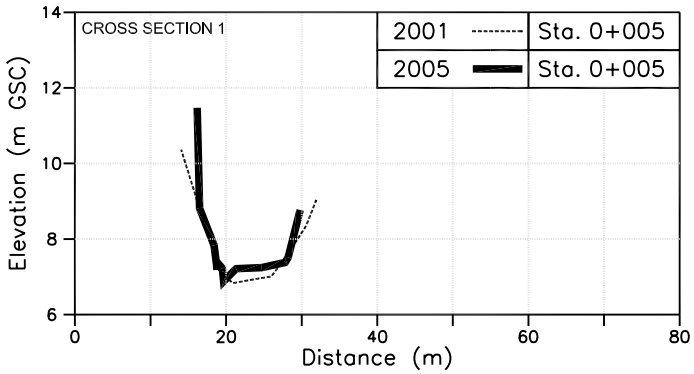
Dale Road Reach Cross Sections

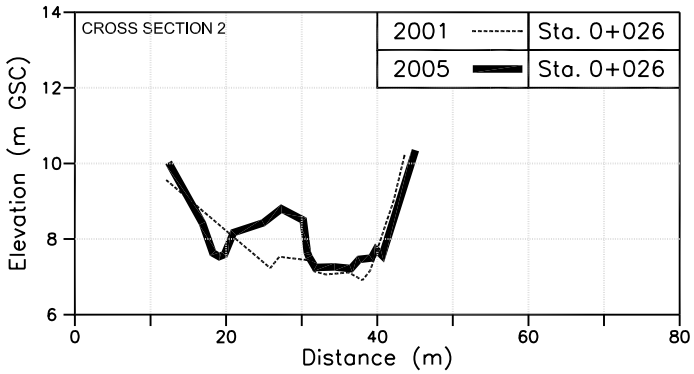
Section 5

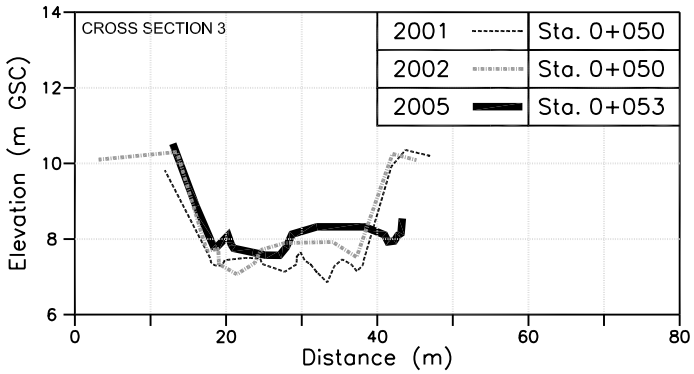
northwest hydraulic consultants

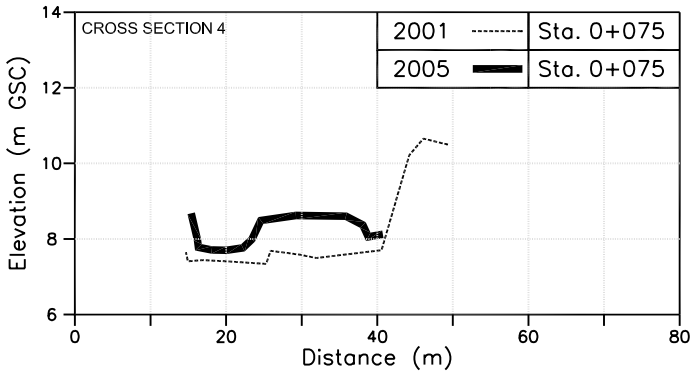
NHCV 4195 – Dale Road Reach

APPENDIX A-2









Notes:
1) Station 0+000 located at the centerline of Dale Road Bridge. Positive change is in the upstream direction.
2) Cross section numbers refer to survey completed July 12, 2001.
3) Vertical exaggeration is 5H:1V

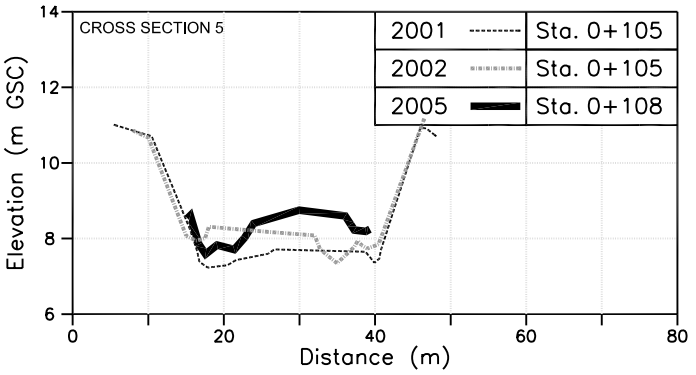
LAGACE CREEK EMERGENCY WORKS

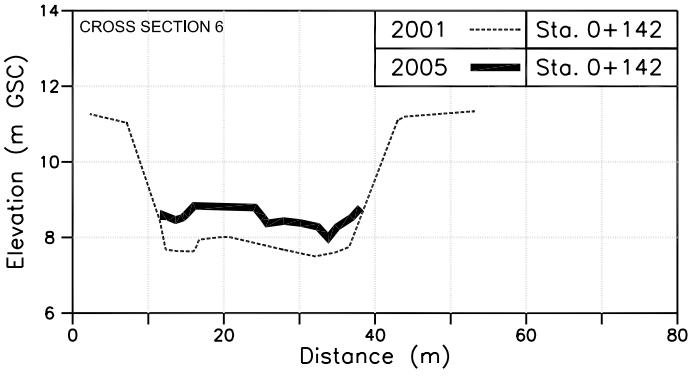
Lagace Creek
Farms Reach Cross Sections
Sections 1 to 4

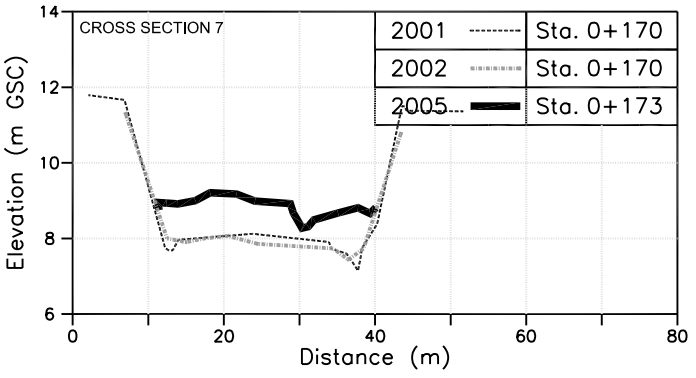
northwest hydraulic consultants

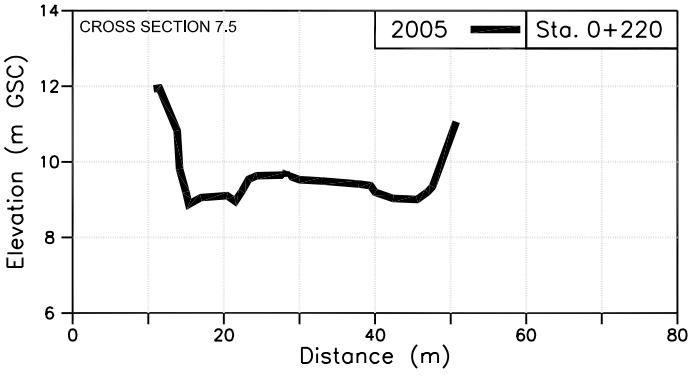
NHCV 4195 – Farms Reach XS

APPENDIX A-3









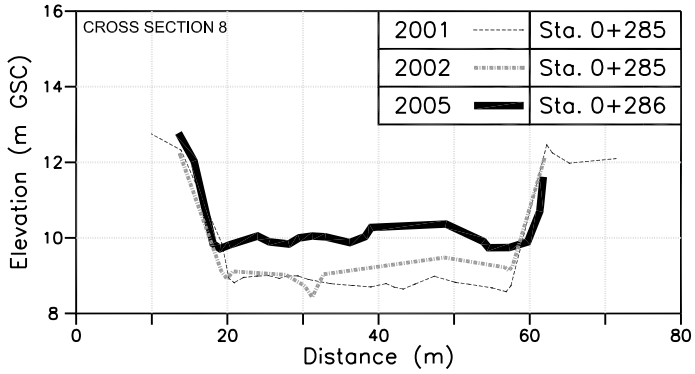
LAGACE CREEK EMERGENCY WORKS

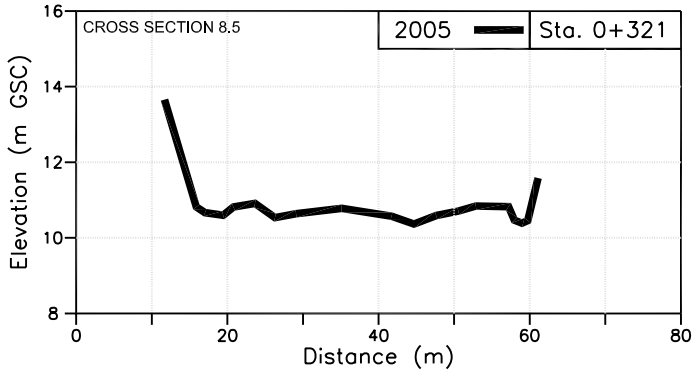
Lagace Creek
Farms Reach Cross Sections
Sections 5 to 7.5

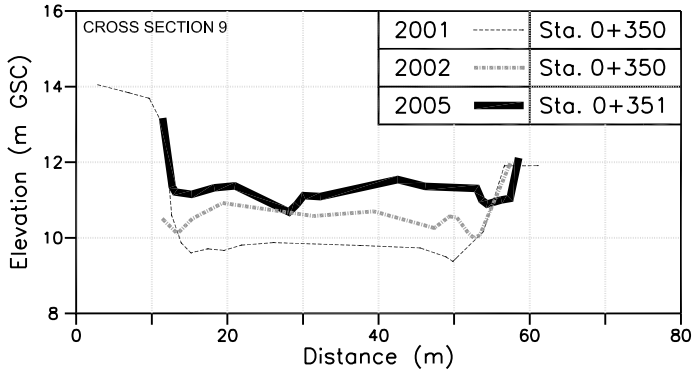
northwest hydraulic consultants

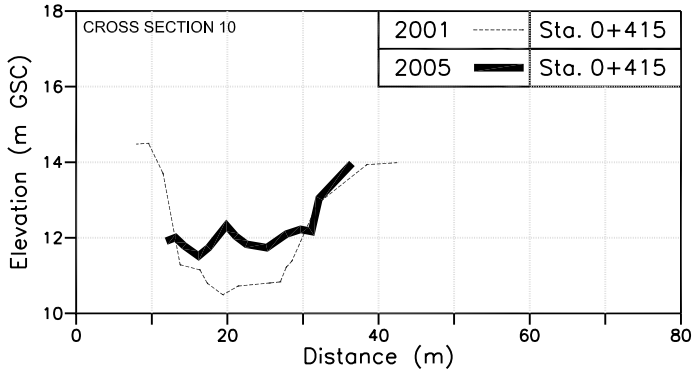
NHCV 4195 – Farms Reach XS

APPENDIX A-4









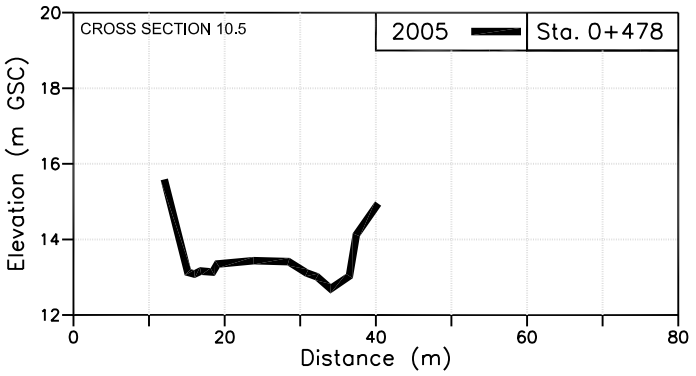
LAGACE CREEK EMERGENCY WORKS

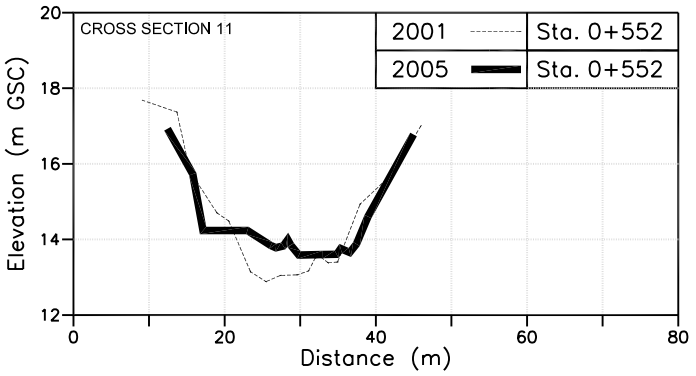
Lagace Creek
Farms Reach Cross Sections
Sections 8 to 10

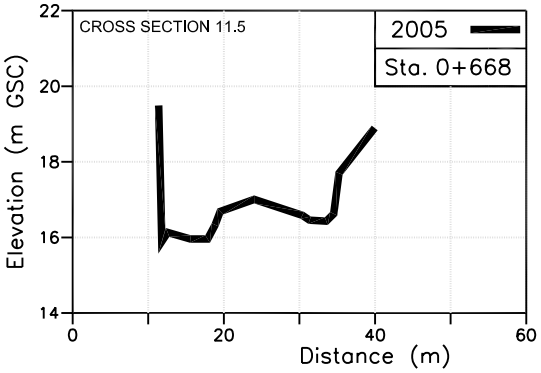
northwest hydraulic consultants

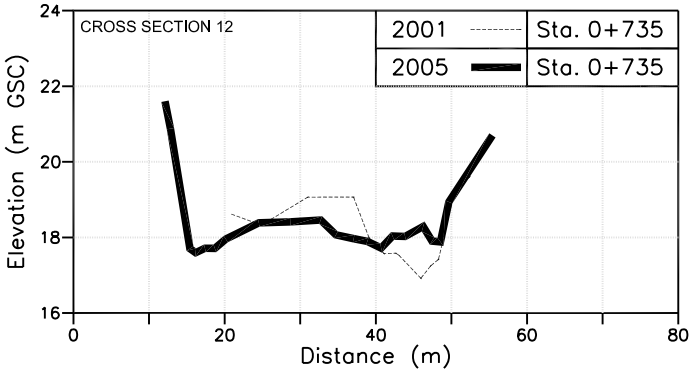
NHCV 4195 – Farms Reach XS

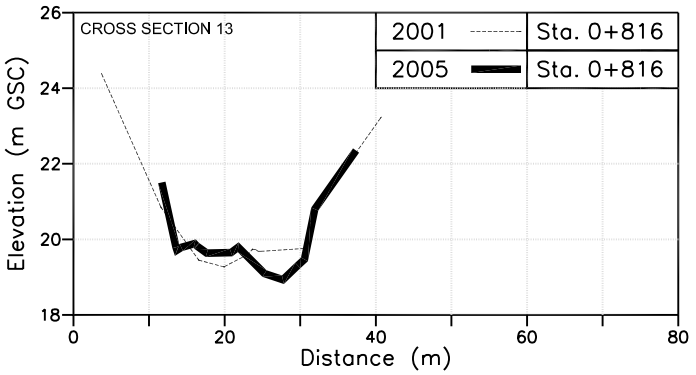
APPENDIX A-5











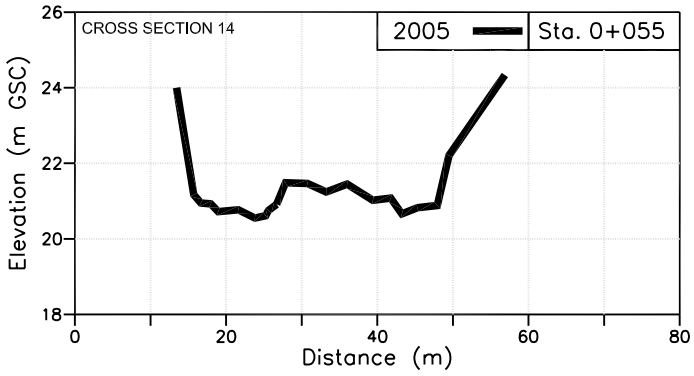
LAGACE CREEK EMERGENCY WORKS

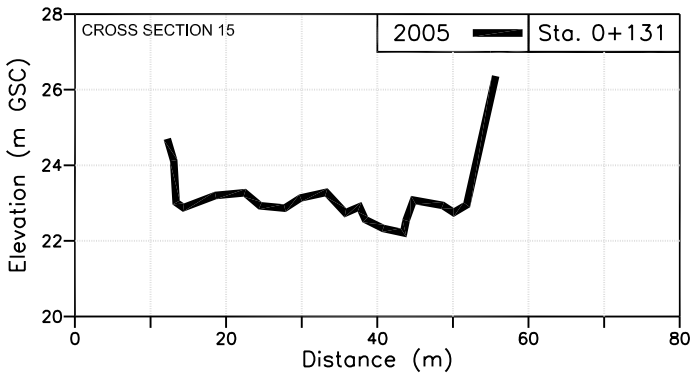
Lagace Creek
Farms Reach Cross Sections
Sections 10.5 to 13

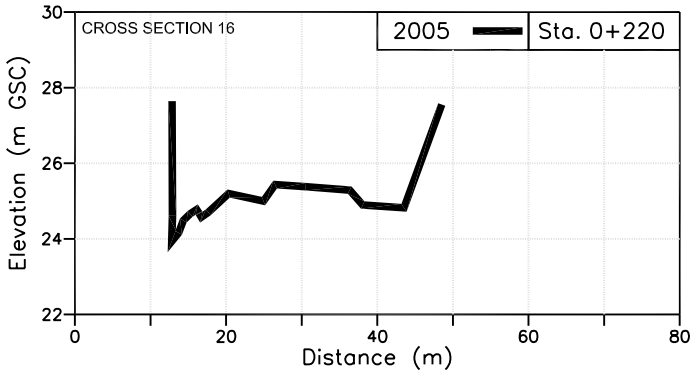
northwest hydraulic consultants

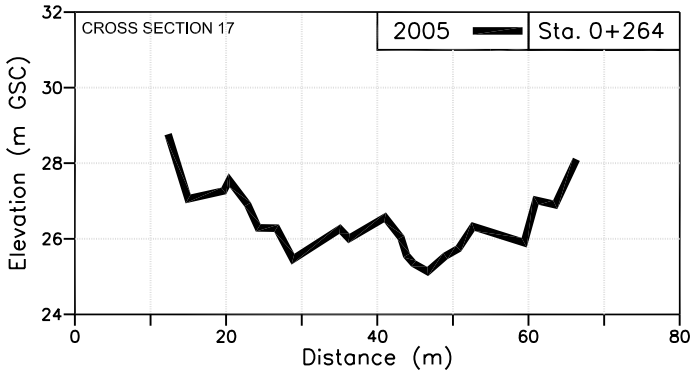
NHCV 4195 – Farms Reach XS

FIGURE A-6









Notes:
1) Station 0+000 located at the centerline of Seux Road Bridge. Positive change is in the upstream direction.
2) Cross section numbers refer to survey completed April 28, 2005.
3) Vertical exaggeration is 5H:1V

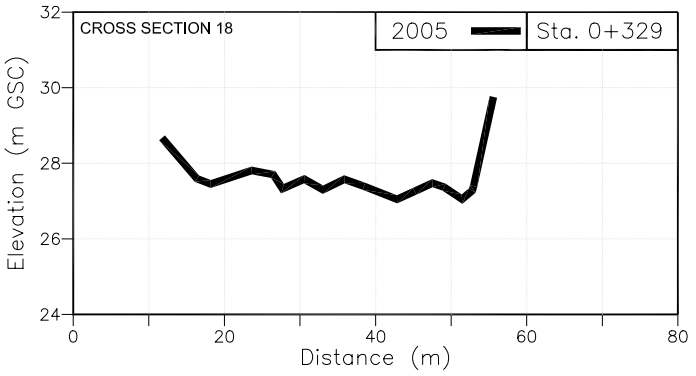
NHCV 4195 – Farms Reach XS

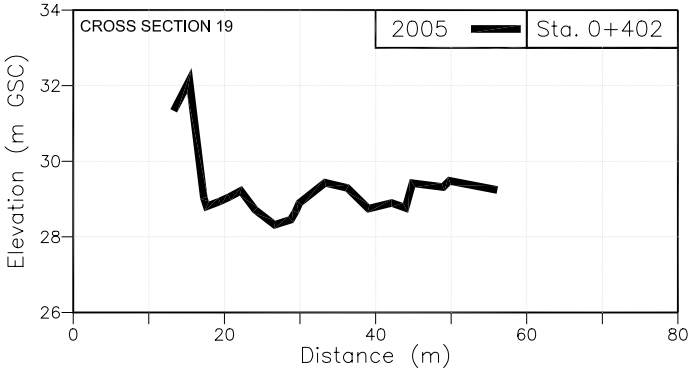
LAGACE CREEK EMERGENCY WORKS

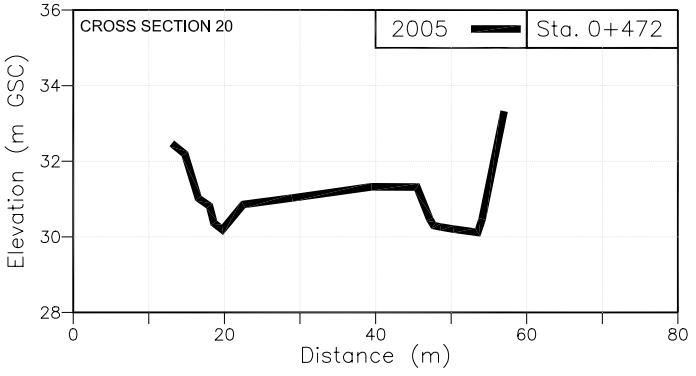
Lagace Creek
Seux Reach Cross Sections
Sections 13 to 17

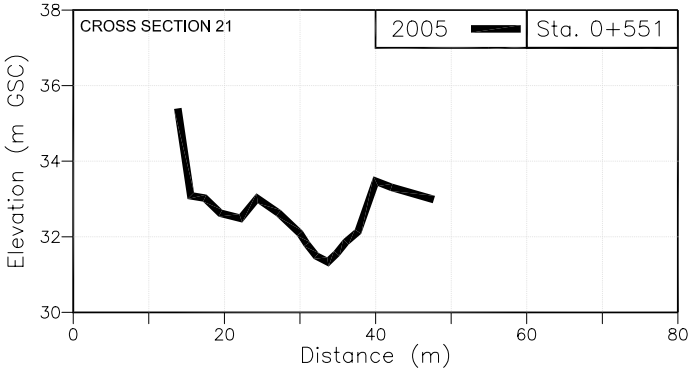
northwest hydraulic consultants

APPENDIX A-7









Notes:
1) Station 0+000 located at the centerline of Seux Road Bridge. Positive change is in the upstream direction.
2) Cross section numbers refer to survey completed April 28, 2005.
3) Vertical exaggeration is 5H:1V

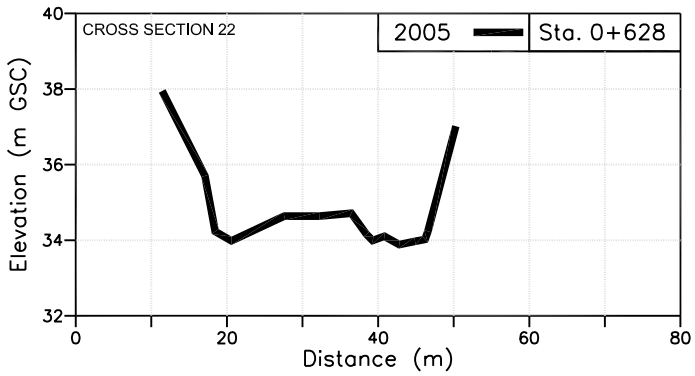
LAGACE CREEK EMERGENCY WORKS

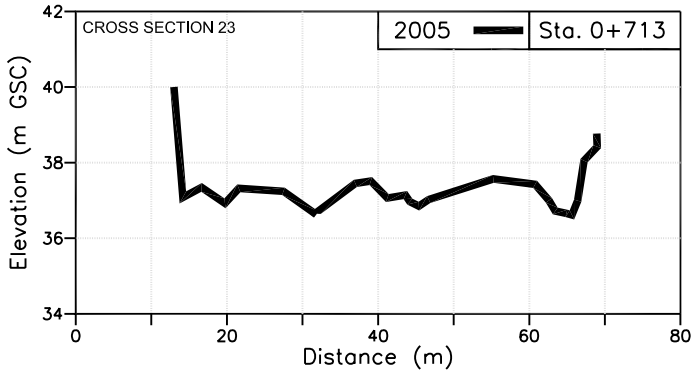
Lagace Creek
Seux Reach Cross Sections
Sections 18 to 21

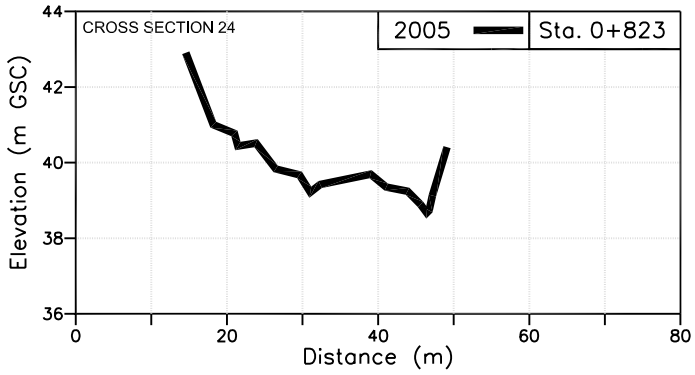
northwest hydraulic consultants

NHCV 4195 – Farms Reach XS

APPENDIX A-8







Notes:
1) Station 0+000 located at the centerline of Seux Road Bridge. Positive change is in the upstream direction.
2) Cross section numbers refer to survey completed April 28, 2005.
3) Vertical exaggeration is 5H:1V

LAGACE CREEK EMERGENCY WORKS

Lagace Creek
Seux Reach Cross Sections
Sections 22 to 24

northwest hydraulic consultants

NHCV 4195 – Farms Reach XS

APPENDIX A-9