Technical Memorandum

DATE: December 21, 2006

TO: Pemberton Valley Dyking District

FROM: Mike Currie and Erica Ellis

RE: **PEMBERTON CREEK**
Gravel Management Plan - Draft
Our File 713.008

1. INTRODUCTION

This technical memorandum outlines a preliminary gravel management plan for Pemberton Creek.

SITE DESCRIPTION

Pemberton Creek is tributary to the Lillooet River, and drains the mountains to the northwest of the Village of Pemberton. Where the creek exits the mountains, it deposits bed material that forms an alluvial fan. Currently, Pemberton Creek flows along the south border of the fan. The Village of Pemberton is partially situated on the fan, and as such, is potentially exposed to flooding and erosion from Pemberton Creek. Both the British Columbia Railway (BCR) and Highway 99 cross the creek on the fan. A dyke contains the creek on the left bank from the fan apex to the confluence with the Lillooet River, while the right bank is partially protected by a berm between the BCR Bridge and Highway 99.

Upstream of the fan, the creek gradient is variable. In the bedrock-controlled reach immediately upstream of the fan the average gradient is 18%. On the fan, the gradient decreases from about 5% to less than 1 % at the confluence with the Lillooet River.

Pemberton Creek transports coarse bed material (gravel, cobbles and boulders) and deposits it on the fan. Some material is derived from upstream reaches, and additional material is derived from incision into the fan. As the creek gradient lessens and stream power decreases, bed material is deposited and the channel bed is raised. Ongoing aggradation of the channel poses a threat to the adjacent dykes and creek crossings.

Some representative photos are attached for reference purposes.

HISTORICAL SEDIMENT MANAGEMENT

The Pemberton Valley Dyking District (PVDD) has periodically removed gravel from Pemberton Creek in the last decade as a means of flood mitigation. From 1980 to 1987 a total of 27,500 m^3 of gravel was removed from Pemberton Creek near the highway crossing[1]. Minor removals also occurred in 1991 (500 m^3), 1998 (800 m^3), and 2000 (900 m^3), and most recently in February 2005 (approximately 400 m^3).

A flood and geohazard study of Pemberton Creek was undertaken in 2001[2]. The study proposed target bed elevations and recommended removing a minimum volume of 2,000 m^3 every 5 years from a left bank gravel bar upstream of the Highway 99 bridge. This recommendation was based on a comparison of 1985 and 2001 cross-sections surveyed upstream of Highway 99. The study estimated that the annual influx of sediment to the reach upstream of Highway 99 was approximately 400 m^3 based on cross-sections and documented removals. In the short-term, the study also recommended annual removal of 1,000 m^3, which would exceed the estimated annual influx, in order to create a gravel storage area and lower the creek bed level.

RECENT LIAISON WITH DFO

Over the last several years, Fisheries and Oceans Canada (DFO) has become increasingly concerned about gravel removal from rivers and the potential impact on fish habitat. DFO now has a number of information requirements before an authorization for gravel removal is issued. In particular, the removal must be justified from a hydraulic perspective by demonstrating that the proposed excavation will lower the flood profile. Other information requirements include:

- survey data, both existing and historical (if available), of the proposed removal area;
- hydrological review of peak flows;
- description of the existing fish and fish habitat;
- fish habitat impact assessment;
- habitat compensation plans (if the removal is likely to negatively impact fish habitat); and
- design drawings of the proposed removal.

PVDD submitted an application for gravel removal from Miller Creek and Pemberton Creek to DFO in the spring of 2003. DFO responded with a letter informing the PVDD that the application did not meet their information requirements (i.e. the hydraulic justification of the project) and that a comprehensive management plan was necessary for both creeks. In a letter to DFO dated Septmber 15, 2003, PVDD agreed that a

[1] Sutek Services Ltd. and Kellerhals Engineering Services Ltd. March 1989. Assessing Gravel Supply and Removal in Fisheries Stream. Report prepared for Department of Fisheries and Oceans and B.C. Ministry of Environment.
[2] Northwest Hydraulic Consultants. March 2001. Pemberton Creek Fan Flood/Geohazard and Dike Study. Report prepared for the Village of Pemberton.

comprehensive management plan was necessary, and also expressed a strong desire to set up a process that would allow gravel removals to be performed expeditiously within the appropriate fish windows.

OPERATION AND MAINTENANCE MANUAL

As part of a private development on the Miller Creek fan, a gravel management plan for Miller Creek has been developed for PVDD in consultation with DFO. In order to facilitate the project approval, the project proponent retained KWL to update the PVDD Operation and Maintenance Manual (O&M Manual) that applies to all PVDD works. The site-specific gravel management requirements for Miller Creek were documented in a special appendix to the O&M Manual. At the time, PVDD agreed that any further site-specific O&M requirements would also be documented in appendices to the O&M Manual. This would facilitate development of a single O&M reference document for ease and practicality of implementation.

PVDD subsequently approached KWL to develop a gravel management plan for Pemberton Creek. The intention was that this plan could eventually become another appendix to PVDD's O&M Manual.

This technical memorandum provides a first draft gravel management plan for Pemberton Creek. Available cross-section data has been examined in order to better determine patterns of aggradation and degradation along the channel. Preliminary gravel management recommendations are made on the basis of available information, and future information requirements are outlined in order to progressively refine the plan.

2. ANALYSIS OF HISTORICAL AGGRADATION TRENDS

CROSS-SECTION DATA

The former Ministry of Environment, Land and Parks (MELP) established cross-section monuments on Pemberton Creek in 1985. A total of 24 cross-sections were surveyed between the fan apex and the confluence with the Lillooet River (about 4.4 km). In 2001, cross-sections upstream of Highway 99 (XS 13 through 24) were re-surveyed by R.B. Brown Land Surveying Ltd. (RBB) for B.C. Rail. RBB was not able to locate the 1985 MELP section markers and therefore sections were re-established based on traverse notes. A KWL survey of the Lillooet River corridor in 2000 incorporated some Pemberton Creek cross-sections (XS 1, 3-5, 13 and 14). An additional "as-built" survey in 2000 by Bunbury and Associates only captured the left bank of the creek.

There has been no cross-section data collected since 2001. Given the occurrence of a large flood in October 2003, this represents a significant data gap.

CROSS-SECTION COMPARISONS

KWL has obtained available cross-section data for Pemberton Creek and has compared the cross-section plots. Cross-section locations are indicated on the attached figures, and figures showing cross-section overlay plots have also been provided. Trends in channel bed aggradation and degradation can be discerned from the plots, and areas of net erosion and deposition are summarized in Table 1. It should be noted that not all of the 1985 cross-sections have been re-surveyed, particularly in the reach downstream of Highway 99.

Table 1: Summary of Pemberton Creek Cross-section Comparisons

1985 XS ID	Date Re-survey	Net Change (m^2)	Distance to Downstream XS (m)	Notes
XS 24	RBB 2001	**10.2**	63	
XS 23	RBB 2001	**8.2**	55	
XS 22	RBB 2001	-8.2	95	
XS 21	RBB 2001	-6.9	45	
XS 28 (20.5)	RBB 2001	-1.2	49	
XS 20	RBB 2001	-13.7	81	
XS 19	RBB 2001	-18.1	111	
XS 18	RBB 2001	**4.8**	4	*Upstream of BC Rail bridge*
XS 17	RBB 2001	-3.1	98	*Downstream of BC Rail bridge*
XS 16	RBB 2001	**15.6**	216	
XS 15	RBB 2001	**10.3**	78	
XS 14	RBB 2001	**1.4**	13	*Upstream of Highway 99 bridge*
XS 13	RBB 2001	**5.8**	n/a	*Downstream of Highway 99 bridge*
XS 12	n/a	n/a	n/a	
XS 11	n/a	n/a	n/a	
XS 10	n/a	n/a	n/a	
XS 9	n/a	n/a	n/a	
XS 8	n/a	n/a	n/a	
XS 7	n/a	n/a	n/a	
XS 6	n/a	n/a	n/a	
XS 5	KWL 2000	-8.4	305	See Note 1
XS 4	KWL 2000	**4.3**	362	See Note 1
XS 3	KWL 2000	-23.5	n/a	See Note 1
XS 2	n/a	n/a	n/a	*Upstream of Airport Road bridge*
XS 1	KWL 2000	**22**	n/a	*Downstream of Airport Road bridge* See Note 1

Note 1: 2000 survey alignment differs from 1985 alignment.
Cross-section net aggradation areas in **bold**.

The cross-section comparisons in Table 1 can be used to describe trends of aggradation and degradation in the creek. Near the fan apex, the two most upstream cross-sections indicate net deposition between 1985 and 2001. Downstream of the apex, from XS 22 to the BCR Bridge, almost all cross-sections indicate net degradation, which suggests that the creek is eroding into the fan surface. Between the BCR bridge and the Highway 99 bridge the trend switches again to net aggradation.

Remaining comparative data are located in the reach just upstream of the Lillooet River confluence (XS 1, 3, 4 and 5). The survey alignments differ between the 1985 and 2000 surveys for these cross-sections, which makes a comparison of survey data difficult to evaluate. Aside from the most downstream cross-section, the comparison suggests that the net change tends toward degradation, or no change. At cross-section 1, the comparison indicates substantial aggradation, but this may be a result of a misalignment between surveys.

ESTIMATED SEDIMENT TRANSPORT

By applying the distance between cross-sections, net cross-section changes can be used to estimate net change in stored volumes of sediment. Based on the cross-section comparison, the net change in sediment storage between XS 24 and XS 13 (1985 to 2001) is about +1,200 m^3. After accounting for the known volume of sediment removals in the same period (at least 2,200 m^3), the total change in storage is +3,400 m^3, or about +230 m^3/year. This is likely a lower bound estimate of the annual sediment transport given that:

- compensating scour and fill between the surveys cannot be assessed;
- gravel removals between 1985 and 1987 cannot be explicitly accounted for; and
- some sediment is likely transported through the reach.

The 2001 creek study estimated an average sediment transport of about 400 m^3/year based on the same cross-section data and volumes of historical gravel removals.

For initial planning purposes, it seems reasonable to adopt a preliminary average annual sediment transport rate of 400 m^3 above Highway 99. This estimate should be periodically refined as better information comes available. Obviously it must be recognized that the actual rate of sediment transport in any year is primarily dependent on the magnitude of flood flows in that year.

3. SEDIMENT MANAGEMENT MEASURES FOR PEMBERTON CREEK

In order to manage the bed level of Pemberton Creek such that the current level of flood protection is at least maintained, this section outlines preliminary sediment management measures.

SEDIMENT REMOVAL OBJECTIVE

The upper Pemberton Creek channel (above Highway 99) is considered the priority area for sediment removal in view of documented aggradation and a high damage potential in the event of flood overflows. This area is understood to be the area of lowest fish habitat value along the Pemberton Creek fan (to be confirmed).

For the purpose of this document, the reach of Pemberton Creek between the BCR bridge and Highway 99 (about 400 m) is defined as the Creek Maintenance Zone (CMZ). A primary intention of this sediment management plan is to focus PVDD's sediment removal effort to the CMZ where more flood relief benefit will result to the adjacent community, and where there will be less disruption to fish habitat. By focusing sediment removal in this area, it is intended that the need for work in other areas will be lessened. Although the reach below Highway 99 is not included within the CMZ, it is acknowledged that sedimentation is ongoing in this area, and the need for sediment removal should be periodically reviewed in the future.

TARGET BED LEVELS

Based on the 2001 creek study, target bed elevations for Pemberton Creek within the CMZ are noted in Table 2. These elevations correspond to 2001 surveyed bed levels.

Table 2: Target Bed Elevations for Pemberton Creek CMZ

1985 XS ID	Location	Target Bed Elevation (m)
XS 13	Downstream Hwy 99 bridge	206.2 m
XS 14	Upstream Hwy 99 bridge	206.3 m
XS 15		207.1 m
XS 16		209.8 m
XS 17	Downstream BCR bridge	211.5 m
XS 18	Upstream BCR bridge	211.5 m

INSPECTION AND MONITORING

Channel conditions through the CMZ should be visually monitored by Dyking District staff on a regular basis during ongoing activities in the general area.

An annual inspection should be carried out by a qualified individual each spring. The inspection should extend from the fan apex to the Lillooet River. In addition to the general inspection considerations that apply to all PVDD works, specific inspection issues at Pemberton Creek are as follows:

- the presence of log debris or other channel obstructions that may be of concern;
- bank erosion along the creek channel; and
- the pattern and degree of bedload deposition which may have a significant effect on flood hydraulics.

Any significant channel obstructions or erosion problems should be referred to a professional engineer for investigation and appropriate action taken (with environmental approvals as required).

The District should hire a professional engineer or professional geoscientist to conduct an inspection of the creek about every five years. Such inspections should extend from the fan apex to the Lillooet River.

In addition to any maintenance items arising from the District's inspections, the Regional Water Manager may request work to be performed as a result of monitoring by provincial government staff.

CHANNEL SURVEY

The bed level of Pemberton Creek within the CMZ should be spot checked during low flow conditions every other spring (every 2 years) or immediately following a significant sediment deposition event. The spot checks could be made with a survey level referenced to the creek cross-sections. If the bed level is determined to be more than approximately 0.5 m above the target bed elevation, then a full cross-section survey should be conducted. At a minimum, this survey should cover the thalweg profile and the creek cross-sections within the CMZ. By performing the survey in the spring, it would hopefully be possible to perform any required bedload removal later that year during the fisheries window.

Every 4 years, or immediately following a major sediment deposition event, a full re-survey of the 1985 cross-sections should be conducted, from the fan apex to the Lillooet River.

PERIODIC SEDIMENT REMOVAL IN CMZ

Sediment transport in creeks and rivers is highly episodic and dependent on the flow regime: large volumes of sediment may be transported during floods while relatively little may be transported at lower flows. Therefore channel aggradation is best considered on a longer time horizon, such as every 5 years, rather than annually.

The 2001 creek study recommended an initial sediment removal rate from the CMZ of 1,000 m^3 per year, decreasing to 2,000 m^3 every five years over time.

PVDD should initiate creek bedload removal within Pemberton Creek upon a creek survey determining that the creek thalweg averages 0.5 m or more above the design creek thalweg elevation through the CMZ. This work should be performed in the summer immediately following the survey unless approvals are not forthcoming from government agencies. In the event of approval not being obtained, PVDD should pursue the bedload removal project in the following year.

Gravel removal projects should be designed by a professional engineer, and undertaken in accordance with government agency approvals.

NEED FOR DOWNSTREAM SEDIMENT REMOVAL (BELOW HIGHWAY 99)

Survey data is limited downstream of the Highway 99 bridge and it is difficult to assess trends of channel change. It is likely that sediment transport continues in this area. The Highway 99 bridge likely constricts the channel at high flow, promoting deposition of the coarsest material at or upstream of the bridge. However, finer fractions of sediment will likely remain in transport and be deposited in the reach downstream as channel slope declines. Anecdotal evidence from maintenance activities in the channel suggests that this is indeed the case.

The channel is unconfined on the right bank and, in the upper part of the reach, overbank flows spill into One-Mile Lake, thus posing relatively little flood hazard in the short term. However, in the longer term, channel aggradation may tend to lead to channel instability, which may threaten existing development on the left bank of the creek.

Aggradation downstream of Highway 99 has the potential to elevate the local water table in the vicinity of the left bank dyke on Pemberton Creek. This could cause increased seepage and potentially reduce the geotechnical stability of the dyke. Aggradation in this area also has the potential to obstruct drainage outlets and cause internal drainage problems. The need for sedimentation in this area should be monitored in the future.

As downstream cross-section data become available in the future, the data should be evaluated for trends in aggradation and/or degradation. If an aggradation trend becomes apparent to the extent that the left bank dyke capacity becomes compromised, then a sediment removal program for the lower creek should be developed in consultation with environmental agencies.

The need for sediment removal in the vicinity of the Arn Canal drainage outlet should be specifically considered from time to time to ensure that operation of the drainage works is not impaired.

SEDIMENT REMOVAL METHODS

Where possible, sediment removal should be undertaken in isolation of flowing water. This would be facilitated by diverting the flow to one side of the channel and excavating in the opposite side. Specific removal methods (and timing) may be dictated by the environmental agencies from time to time.

Large boulders excavated during the sediment removal work should be stored for fisheries complexing work. PVDD should consult with fisheries agencies or environmental and engineering professionals for appropriate fisheries complexing measures.

OTHER PERIODIC CHANNEL MAINTENANCE ACTIVITIES

In addition to periodic gravel bedload removal, some potential channel maintenance activities that may be triggered by the spring inspection include:

- removal of a channel obstruction, such as a logjam, where the adjacent channel bank or dyke slope is threatened, or where the hydraulic capacity of the channel is reduced;
- attention to bank erosion where the potential impact of the erosion is of concern; and/or
- maintenance at existing infrastructure, such as bridges, outfalls and other works.

The nature of the work required should be defined by a professional engineer. Environmental approval requirements may apply in these cases.

NEED FOR APPROVALS

Sediment removal approval requirements may include the following:

- the Section 9 regulation of the Water Act (Land and Water BC); and
- the Fisheries Act (Fisheries and Oceans Canada).

It is noted that approval agencies and legislation change from time to time.

4. EMERGENCY CONDITIONS AND POST-EVENT RESTORATION

EMERGENCY CONDITIONS

While the Pemberton Creek dyke on the fan is reportedly able to convey the design (200-year return period) flood with adequate freeboard, it is not certain that the dyking system can withstand all possible creek events, including ice flows, debris flows and sediment events. Previous hydraulic modelling by NHC suggests that the Highway 99 bridge can not pass the 200-year return period flood. Although the risk of overtopping may be low,

in view of the urban development on the fan, extreme caution should be exercised in times of extreme high flow conditions.

Emergency patrols should be undertaken during such times. Local expertise should be supplemented by expert advisors if possible.

POST-EVENT RESTORATION

Following any major sediment event, an inspection by a professional engineer should be undertaken as soon as possible. Appropriate restoration should be developed in consultation with environmental agencies. The Provincial Emergency Program is likely to be involved in such situations.

5. FUTURE WORK

This section outlines some further work that should be considered in order to refine this gravel management plan in the future.

PEAK FLOW REVIEW

Part of the information required by DFO when assessing gravel removal applications is a review of peak flow data. The Water Survey of Canada has operated a hydrometric station on Pemberton Creek since 1987. Estimates of the 200-year return period peak instantaneous flow (Qi_{200}) at the mouth of Pemberton Creek range from 64 m^3/s (KWL[3]) to 104 m^3/s (NHC). Both of these estimates were derived prior to the major flood of October 2003. A re-analysis of the Qi_{200} estimate would be appropriate in light of the peak flow recorded in 2003, and the longer available hydrometric record.

NHC conducted hydraulic modeling for Pemberton Creek using Qi_{200} = 104 m^3/s. The results of the modeling were used to assess the existing condition of the dyke. If the peak flow were subsequently revised, the hydraulic modeling results should potentially be revised as well.

TARGET BED ELEVATION

The target bed elevation should be revisited and possible refined if the hydraulic modeling is revised, in order to better define the link between bed elevation and estimated flood profile. This information is often requested by DFO in support of proposed sediment management activities.

[3] Kerr Wood Leidal Associates Limited. December 2002. Engineering Study for Lillooet River Corridor. Report prepared for Pemberton Valley Dyking District, Mount Currie Band, BC Ministry of Water, Land and Air Protection, and India and Northern Affairs Canada.

CROSS-SECTION MONUMENTS

In order to easily reference cross-section locations in the field, it may be worth installing cross-section monuments in the field, most importantly in the CMZ.

HIGHWAY 99 BRIDGE DESIGN

The Highway 99 bridge is undersized for the Qi_{200}, pending a hydrologic review. Over the long term, raising the Highway 99 bridge should be considered, as a means to provide greater flow conveyance and minimize in-channel sediment management activities. PVDD should raise this issue with the Ministry of Transportation.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

Reviewed by:

For Erica Ellis, M.Sc.
Fluvial Geomorphologist

Mike V. Currie, M.Eng., P.Eng.
Project Manager

EE/
Encls.

LIST OF ATTACHMENTS
Photo Appendix
Cross-section location maps (3)
Cross-section overlay figures (17)

Photo 1
Pemberton Creek above fan apex (July 29, 2005).

Photo 2
Pemberton Creek, downstream of fan apex. Large gravel bar/island (July 29, 2005).

Photo 3
Pemberton Creek above BCR bridge, looking downstream. Note gravel bar on right bank.

Photo 4
Looking upstream at same gravel bar. Note large woody debris in channel (July 29, 2005).

Photo 5
Pemberton Creek immediately upstream of BCR bridge (July 29, 2005).

Photo 6
Looking upstream from BCR bridge at large gravel bar (July 29, 2005).

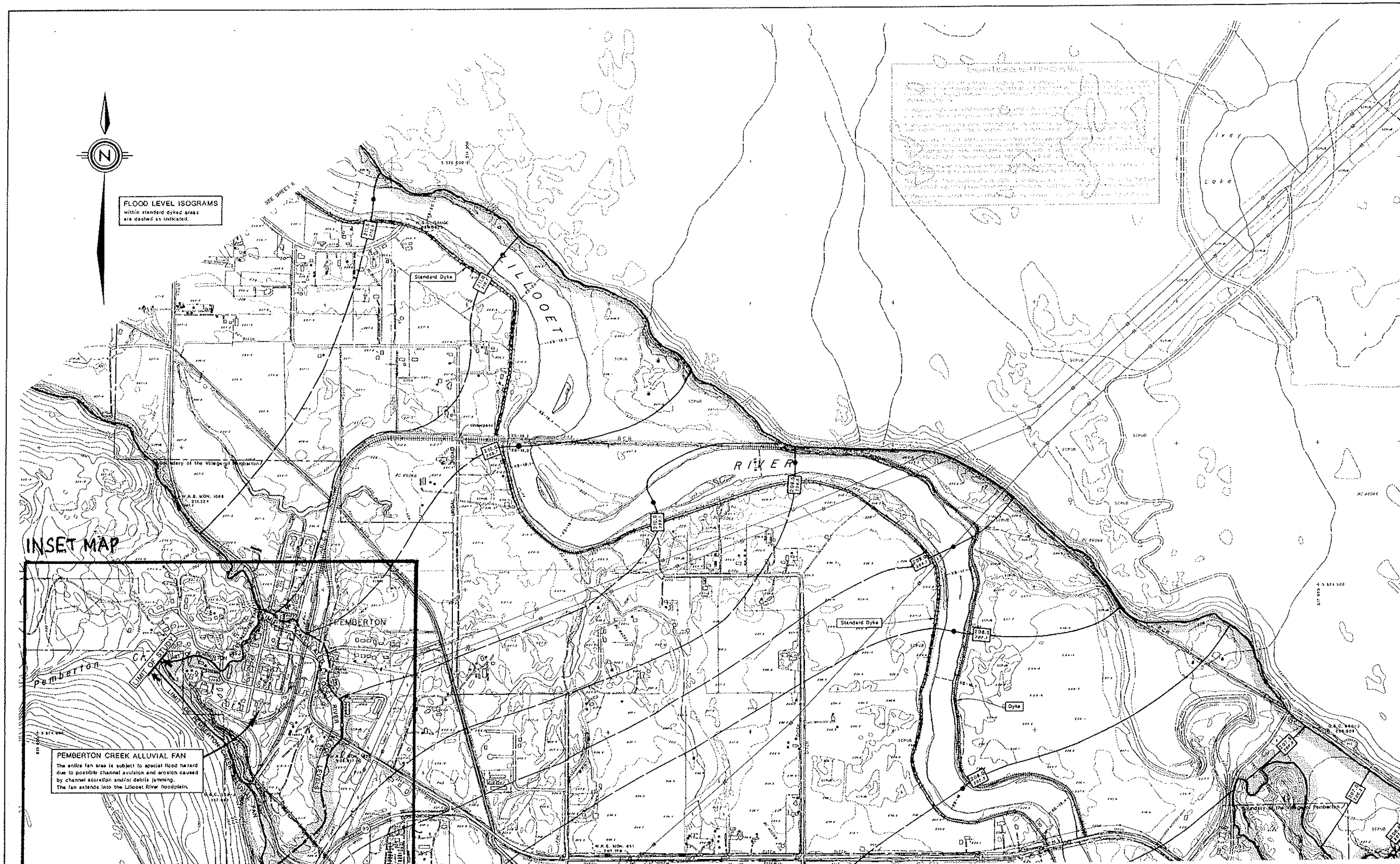
Photo 7
Pemberton Creek immediately downstream of BCR bridge (July 29, 2005).

Photo 8
Looking downstream at large gravel deposit upstream of Hwy 99 bridge, post-removal (July 29, 2005).

Photo 9
Looking upstream from Hwy 99 bridge at gravel deposit post-removal (June 7, 2005).

Photo 10
Downstream side of Hwy 99 bridge, Q = 2.4 m^3/s (July 29, 2005).

Photo 11
Channel downstream of Hwy 99 (July 29, 2005).



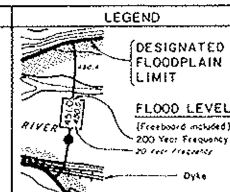
NOTES	
Produced by:	British Columbia Water Management Branch, Special Projects Section, Floodplain Mapping Program.
Survey:	River survey done by Surveys Section, Water Management Branch, Project 85 RFP-5 (1985). a) Horizontal control based on provincial network. c) Elevations are in metres and are referred to Geodetic Survey of Canada datum. (⊕ indicates Survey Monuments).
Mapping:	Base mapping done by Map Production Division, Surveys and Resource Mapping Branch, Project 88-028 (1988). a) Contour interval 1 metre and greater, spot elevations shown to 0.1 metres, with accuracy to ± 0.3 metres, except where noted. b) Grid origin referred to U.T.M. Projection Zone 10.

FLOODPLAIN DATA

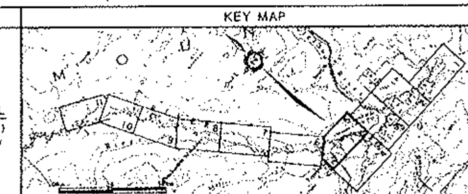
1. The floodplain areas as depicted on this map have been designated pursuant to the Canada/British Columbia Floodplain Mapping Agreement (1988) by the Minister of the Environment for Canada and the Minister of Environment for British Columbia.

   Flooding may still occur outside of the designated floodplain areas. The Ministers do not assume any liability by reason of the designation or failure to designate areas on this map.
2. The Designated Flood has a statistical frequency of occurrence of once every 200 years.
3. The flood levels were computed using a standard step method modelling technique, assuming open water flow conditions.
4. The floodplain limits assume the absence of all dykes.
5. The floodplain limits and flood levels include an allowance for freeboard.
6. The floodplain limits are not established on the ground by legal survey.
7. The floodplain limits are not estimated for side streams and tributaries, except as noted.
8. The required setback of buildings from the natural boundaries of lakes and watercourses to allow for the passage of floodwaters and possible bank erosion is not shown. This information is available either through local municipalities or the Ministry of Environment.
9. MAPS AVAILABLE FROM THE MINISTRY OF CROWN LANDS, SURVEYS AND RESOURCE MAPPING BRANCH, MAPS B.C. MAP AND AIR PHOTO SALES, VICTORIA, B.C.

LEGEND



KEY MAP



REVISIONS

No.	DESCRIPTION	DATE
	REPLACES DWG. NO. 5022, SHEETS 1 TO 10, DATED DEC. 1973 AND REVISED JAN. 1980.	

ISSUE OF MAPPING
DATE SEPTEMBER 30, 1990

ENVIRONMENT CANADA INLAND WATERS / ENVIRONNEMENT CANADA EAUX INTÉRIEURES
BRITISH COLUMBIA MINISTRY OF ENVIRONMENT / COLOMBIE-BRITANNIQUE MINISTÈRE DE L'ENVIRONNEMENT
CANADA BRITISH COLUMBIA FLOODPLAIN MAPPING AGREEMENT / L'ACCORD CANADA COLOMBIE-BRITANNIQUE SUR LA CARTOGRAPHIE DES PLAINES D'INONDATION

DRAWN B. V. W., T. C. E.
CHECKED P. T. D.
RIVER SURVEY M.P.
DESIGNED S.C.

FLOODPLAIN MAPPING
LILLOOET RIVER

100m 0 100 200 300 400 500m
Scale in metres

ENGINEER RW N... RECOMMENDED [signature] APPROVED [signature]

FILE No. 01-0000-S.1
N.T.S. MAP No. 92J
SCALE 1:5 000
NEGATIVE No.
DRAWING No. 88-44-5 REV.
SHEET 5 of 11

DDfimg

PEMBERTON CREEK ALLUVIAL FAN

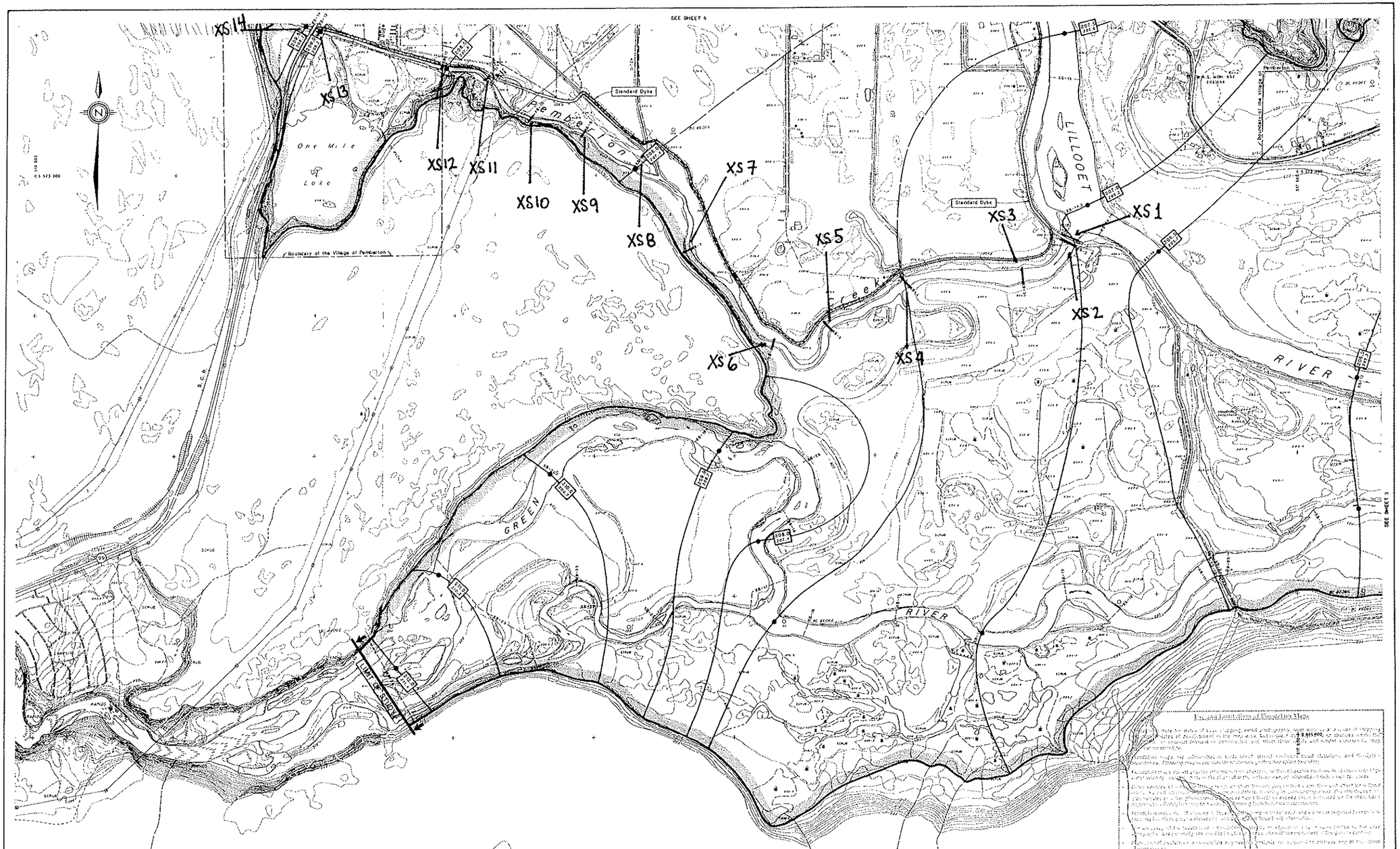
The entire fan area is subject to special flood hazard due to possible channel avulsion and erosion caused by channel accretion and/or debris jamming.
The fan extends into the Lillooet River floodplain.

NOTES

Produced by: British Columbia Water Management Branch,

FLOODPLAIN DATA

1. The floodplain areas as depicted on this map have been designated pursuant to the Canada/British Columbia Floodplain Mapping Agreement



NOTES

Produced by: British Columbia Water Management Branch, Special Projects Section, Floodplain Mapping Program.

Surveys: River survey done by Surbeck Section, Water Management Branch, August 25 to 29, 1980.
a) Horizontal control based on provincial network.
b) Elevations are to metres and are referred to Geodetic Survey of Canada datum. (@ Tidelands Survey Monuments).

Mapping: Base mapping done by Mac Production Services Surveying and Photogrammetric Mapping Branch, August 25 to 28, 1980.
a) Contour interval - 1 metre and greater; spot elevations shown to 0.1 metres, with accuracy to 0.03 metres, except where noted.
b) All points referred to U.T.M. Projection Zone 10 .

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   Flooding may occur outside of the designated floodplain areas. The ministers do not assume any liability by reason of the designation of flood plain limits shown on this map.
2. The Designated Flood has a statistical frequency of occurrence of once every 200 years.
3. The flood levels were computed using a standard step method modelling technique, assuming open water flow conditions.
4. The floodplain limits assume the absence of ice jams.
5. The floodplain limits and flood levels include an allowance for freeboard.
6. The floodplain limits are not established on the ground by recent survey.
7. The floodplain limits are not delineated for side streams and tributaries except as noted.
8. The combined setback of protection from the natural boundaries of lakes and watercourses to allow for the passage of floodwaters and possible bank erosion is 60 metres. This information is available either through local municipalities or the ministry of Environment.
9. MAPS AVAILABLE FROM THE MINISTRY OF CROWN LANDS, SURVEYS AND RESOURCE MAPPING BRANCH, ANNEX B.C. MAP AND AIR PHOTO SALES, VICTORIA, B.C.

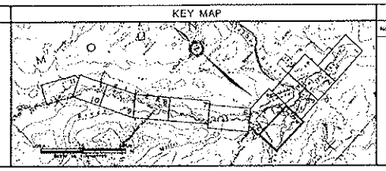
LEGEND

DESIGNATED FLOODPLAIN LIMIT

FLOOD LEVEL (Freeboard included)
200 Year Frequency
20 Year Frequency
Dyke

(METRIC, C.G.S.C. DATUM)

KEY MAP



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DRAWN B.W.W., T.C.C.
CHECKED P.T.D.
RIVER SURVEY M.P.
DESIGNED S.C.
ENGINEER R.W. Nichols

ENVIRONMENT CANADA INLAND WATERS / ENVIRONNEMENT CANADA EAUX INTERIEURES
BRITISH COLUMBIA MINISTRY OF ENVIRONMENT / COLOMBIE-BRITANNIQUE MINISTÈRE DE L'ENVIRONNEMENT
CANADA-BRITISH COLUMBIA FLOODPLAIN MAPPING AGREEMENT / L'ACCORD CANADA-COLOMBIE-BRITANNIQUE SUR LA CARTOGRAPHIE DES PLAINES D'INONDATION

FLOODPLAIN MAPPING

LILLOOET RIVER

100m 0 100 200 300 400 500m
Scale in metres

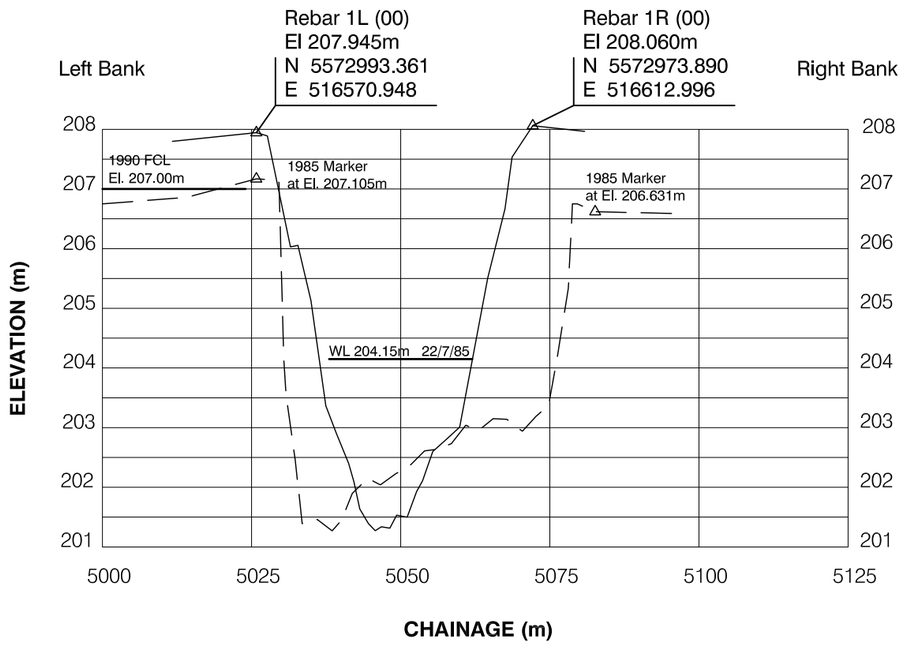
RECOMMENDED [signature]
APPROVED [signature]

FILE No. 01-0000-5.1
N.T.S. MAP No. 92J
SCALE 1:5,000
NEGATIVE No.
DRAWING No. 88-44-4
REV.
SHEET 4 of 11

DD(img

PEMBERTON CREEK

Downstream of Bridge



Flood Level Data from Floodplain Map 88-44-4

Pemberton Valley Dyking District
Pemberton Creek
Gravel Management Plan

Legend

KWL 2000

WMB Victoria 1985

Notes:

1. Data source for all but 2000 survey, MoELP.
2. Horizontal coordinate grid to NAD 83.
3. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J and 601J.
4. 2000 Survey alignment for this cross section could vary from previous surveys and may not be directly comparable.

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 1

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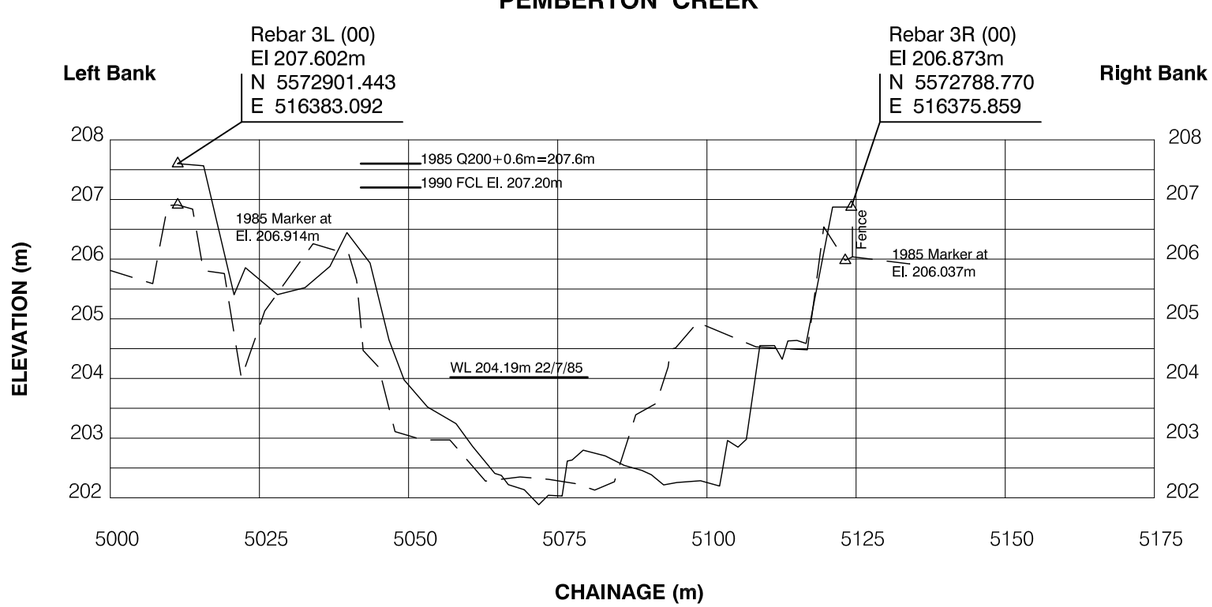
"Pemberton Creek Dyke"
Rebuilt by RPAP in 1987
to 1985 Q200 + 0.6m freeboard

PEMBERTON CREEK



Flood Level Data from Floodplain Map 88-44-4

Pemberton Valley Dyking District
Pemberton Creek
Gravel Management Plan

Legend

KWL 2000

WMB Victoria 1985

Notes:

1. Data source for all but 2000 survey, MoELP.
2. Horizontal coordinate grid to NAD 83.
3. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J and 601J.
4. 2000 Survey alignment for this cross section could vary from previous surveys and may not be directly comparable.

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 3

Dec. 15/06 11:00AM
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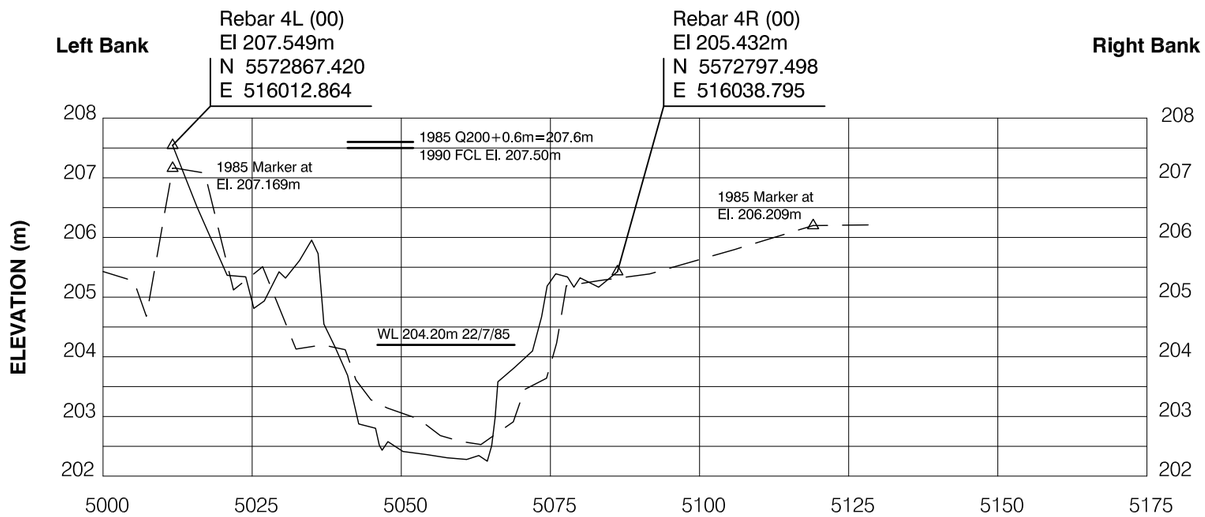
"Pemberton Creek Dyke"
Rebuilt by RPAP in 1987
to 1985 Q200 + 0.6m freeboard

PEMBERTON CREEK



Flood Level Data from Floodplain Map 88-44-4

Pemberton Valley Dyking District
Pemberton Creek
Gravel Management Plan

Legend

KWL 2000

WMB Victoria 1985

Notes:

1. Data source for all but 2000 survey, MoELP.
2. Horizontal coordinate grid to NAD 83.
3. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J and 601J.
4. 2000 Survey alignment for this cross section could vary from previous surveys and may not be directly comparable.

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 4

Dec.15/06 11:00 AM

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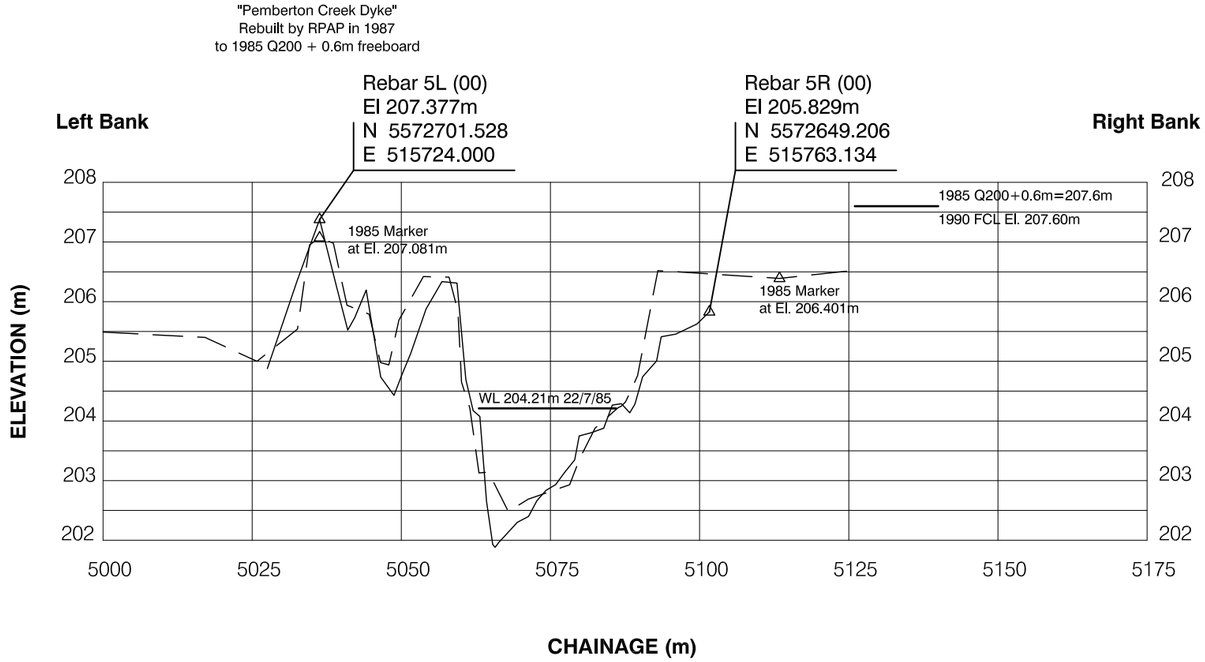
PEMBERTON CREEK



Flood Level Data from Floodplain Map 88-44-4

Pemberton Valley Dyking District
Pemberton Creek
Gravel Management Plan

Legend

——— KWL 2000

— — — WMB Victoria 1985

Notes:

1. Data source for all but 2000 survey, MoELP.
2. Horizontal coordinate grid to NAD 83.
3. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J and 601J.
4. 2000 Survey alignment for this cross section could vary from previous surveys and may not be directly comparable.

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 5

Dec. 15/06 11:00 AM

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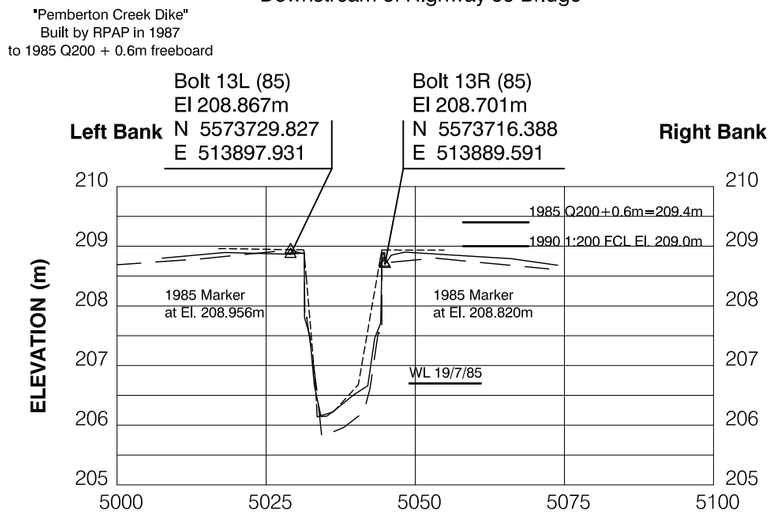
PEMBERTON CREEK

Downstream of Highway 99 Bridge



Flood Level Data from Floodplain Map 88-44-5

Dec.15/06 11:00 AM

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Pemberton Valley Dyking District
Pemberton Creek
Gravel Management Plan

Legend

- KWL 2000
- R.B. Brown 2000-01
- WMB Victoria 1985

Notes:

1. Data source for all but 2000 survey, MoELP.
2. Horizontal coordinate grid to NAD 83.
3. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J and 601J.

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

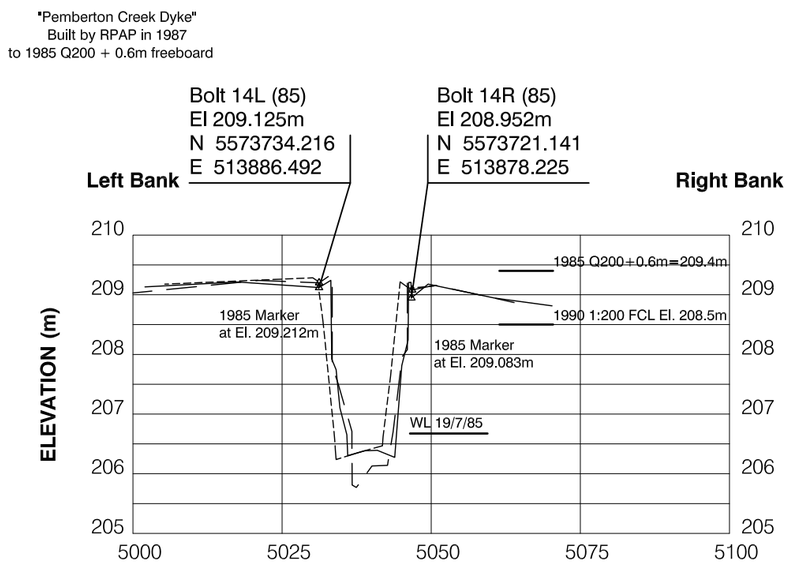
1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-2008	December 2006

Pemberton Creek
Cross-Section
XS 13

PEMBERTON CREEK

Upstream of Highway 99 Bridge



Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Management Plan

Legend

- KWL 2000
- R.B. Brown 2000-01
- WMB Victoria 1985

Notes:

1. Data source for all but 2000 survey, MoELP.
2. Horizontal coordinate grid to NAD 83.
3. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J and 601J.

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 14

Dec.15/06 11:00 AM

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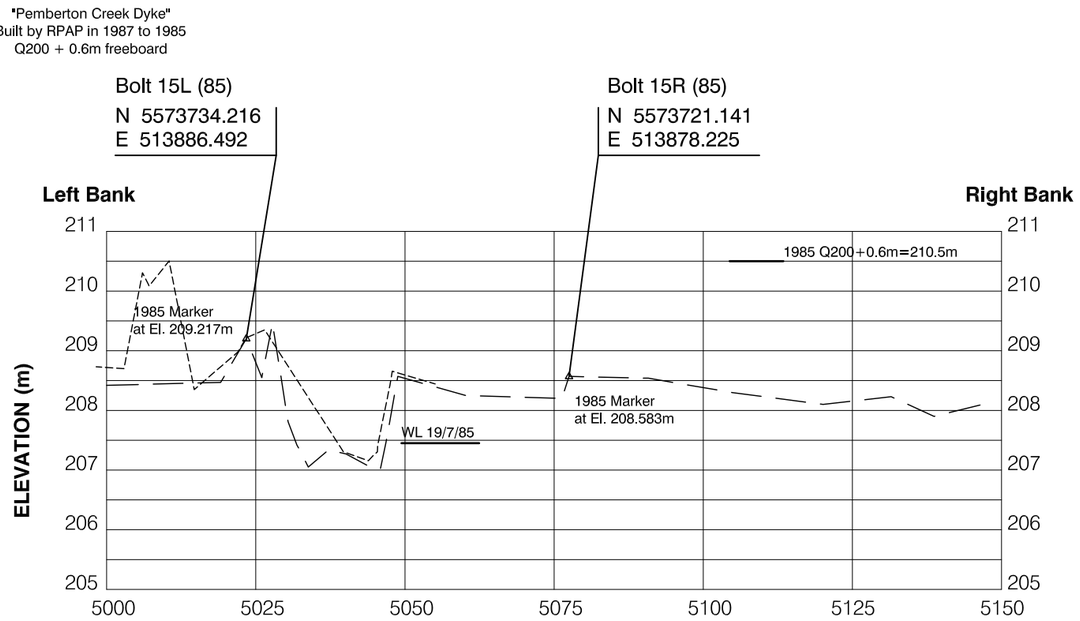
PEMBERTON CREEK

Upstream of Highway 99 Bridge



Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Management Plan

Legend

---------- R.B. Brown 2000-01

— — — WMB Victoria 1985

Notes:

1. Data source for all but 2000 survey, MoELP.
2. Horizontal coordinate grid to NAD 27.
3. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J and 601J.

KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 15

Dec. 15/06 11:00 AM

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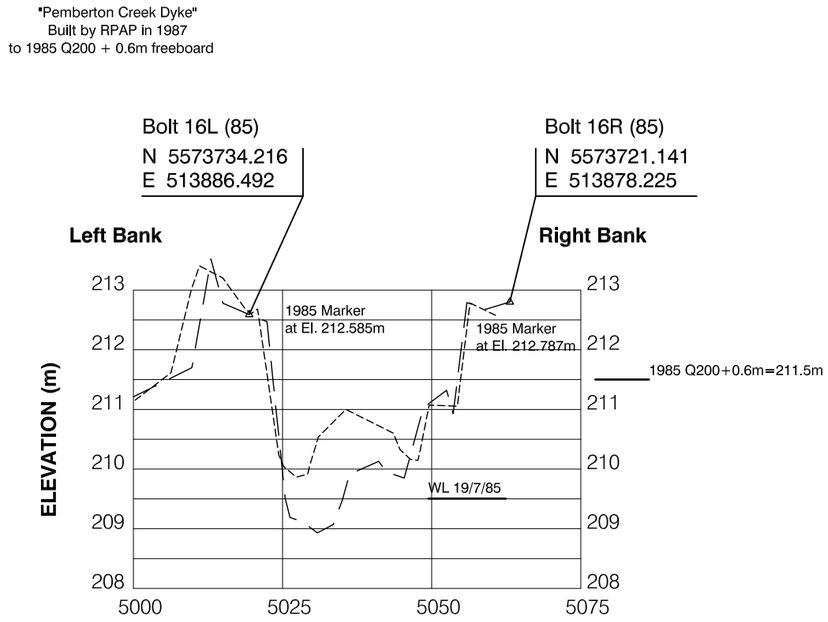
PEMBERTON CREEK

Upstream of Highway 99 Bridge



Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Mangement Plan

Legend

---------- R.B. Brown 2000-01

— — — WMB Victoria 1985

Notes:

1. Data source for all but 2000 survey, MoELP.
2. Horizontal coordinate grid to NAD 27.
3. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J and 601J.

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 16

Dec.15/06 11:00 AM

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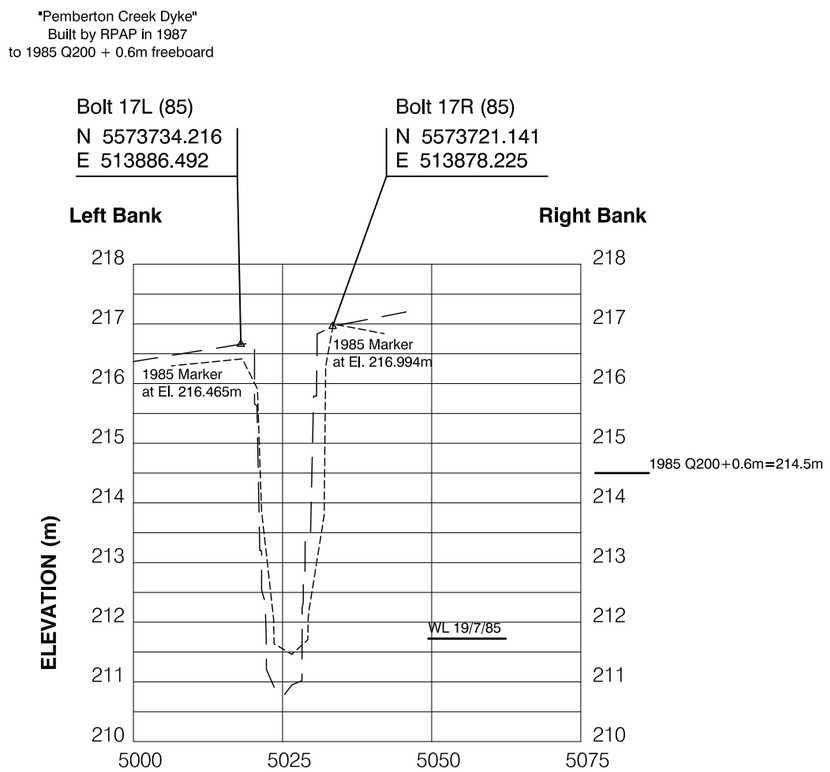
PEMBERTON CREEK

Upstream of Highway 99 Bridge



Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Mangement Plan

Legend

---------- R.B. Brown 2000-01

— — — WMB Victoria 1985

Notes:

1. Data source for all but 2000 survey, MoELP.
2. Horizontal coordinate grid to NAD 27.
3. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J and 601J.

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 17

Dec.15/06 11:00 AM

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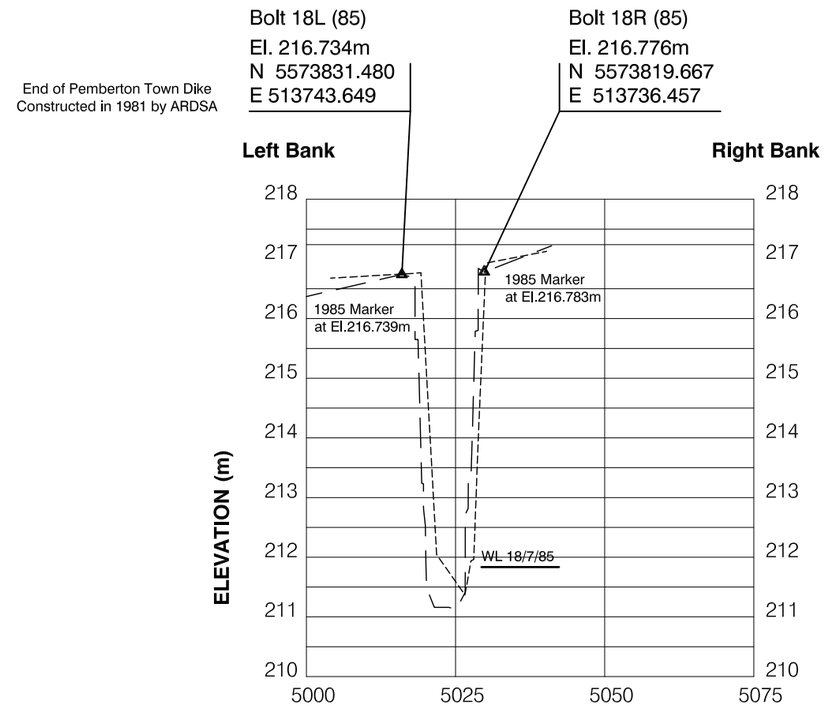
PEMBERTON CREEK

At Upstream Side of BC Rail Bridge



Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Mangement Plan

Legend

---------- R.B. Brown 2000-01

— — — WMB Victoria 1985

Notes:

1. **Horizontal coordinate grid to NAD 27.**
2. **Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J.**

KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 18

Dec. 15/06 11:00 AM

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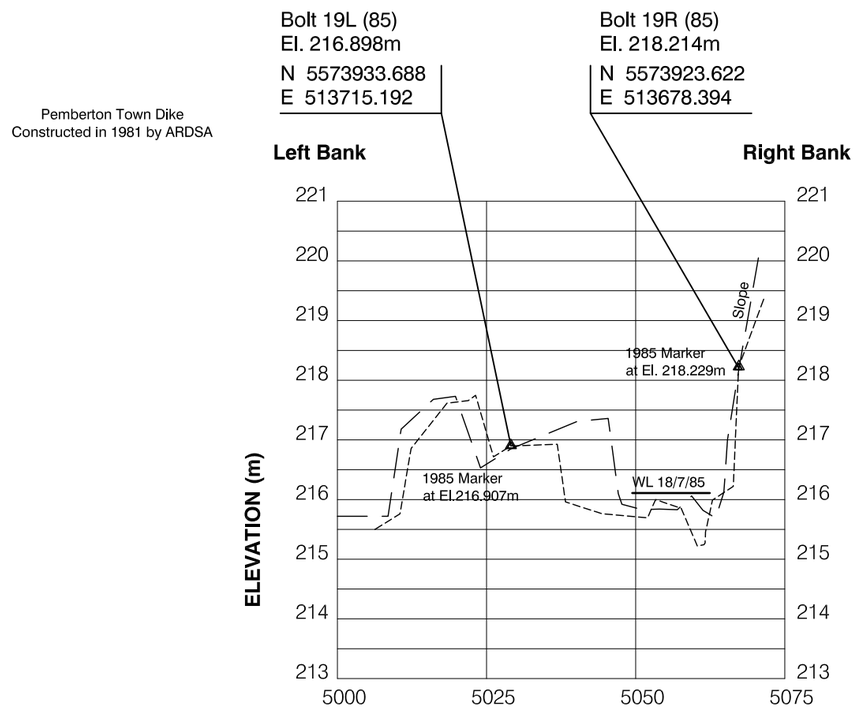
PEMBERTON CREEK

Upstream of Highway 99 Bridge



Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Mangement Plan

Legend

---------- R.B. Brown 2000-01

— — — WMB Victoria 1985

Notes:

1. Horizontal coordinate grid to NAD 27.
2. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J.

KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

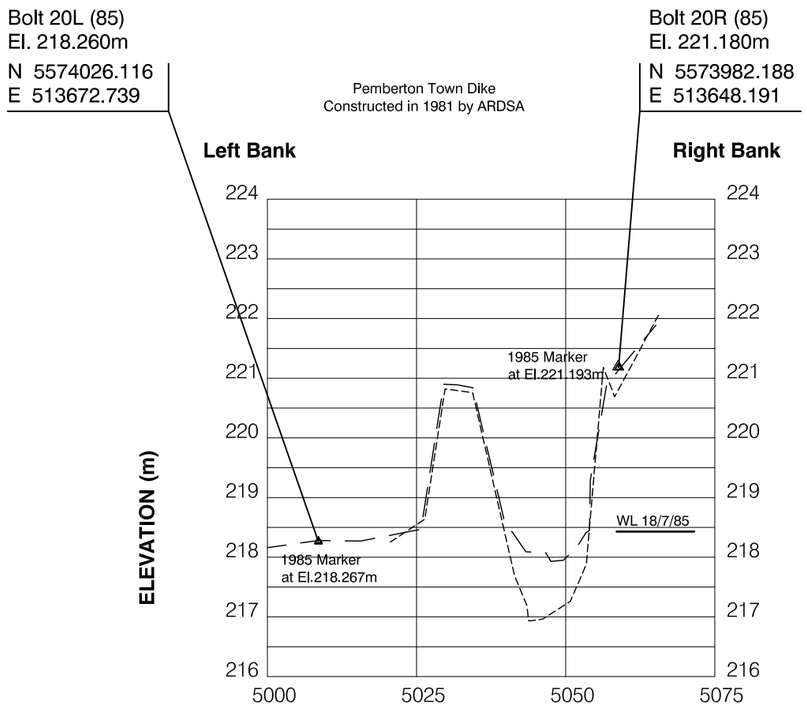
1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2005

Pemberton Creek
Cross-Section
XS 19

PEMBERTON CREEK

Upstream of Highway 99 Bridge



Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Mangement Plan

Legend

---------- R.B. Brown 2000-01

— — — WMB Victoria 1985

Notes:

1. **Horizontal coordinate grid to NAD 27.**
2. **Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J.**

KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 20

Dec.15/06 11:00 AM

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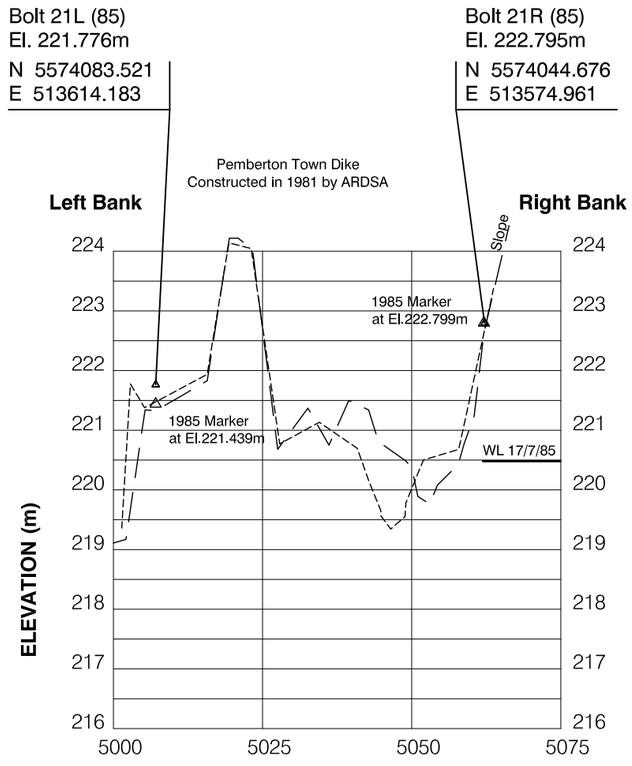
PEMBERTON CREEK

Upstream of Highway 99 Bridge



Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Mangement Plan

Legend

---------- R.B. Brown 2000-01

— — — WMB Victoria 1985

Notes:

1. Horizontal coordinate grid to NAD 27.
2. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J.

KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 21

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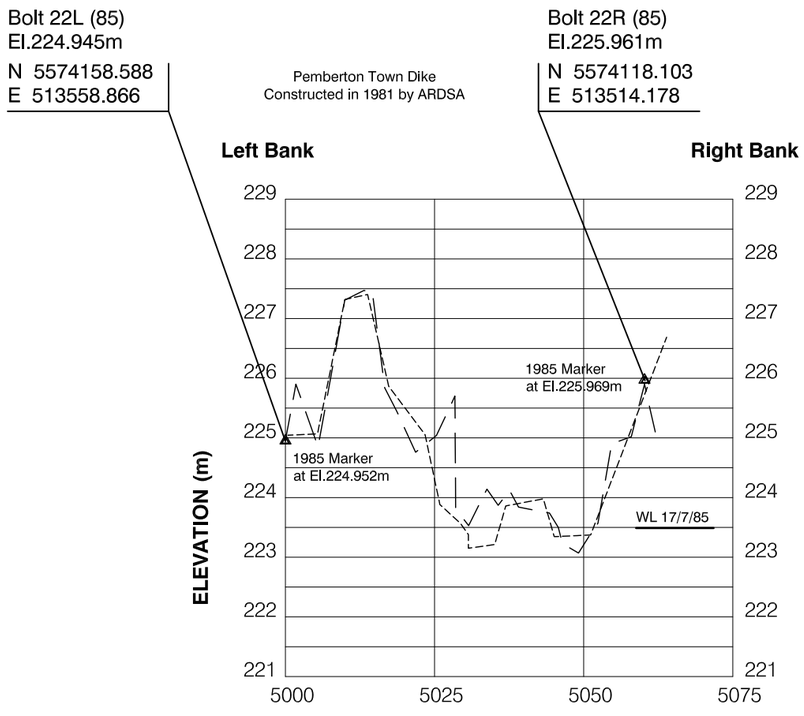
PEMBERTON CREEK

Upstream of Highway 99 Bridge



Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Management Plan

Legend

---------- R.B. Brown 2000-01

— — — WMB Victoria 1985

Notes:

1. **Horizontal coordinate grid to NAD 27.**
2. **Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J.**

KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 22

Dec.15/06 11:00 AM

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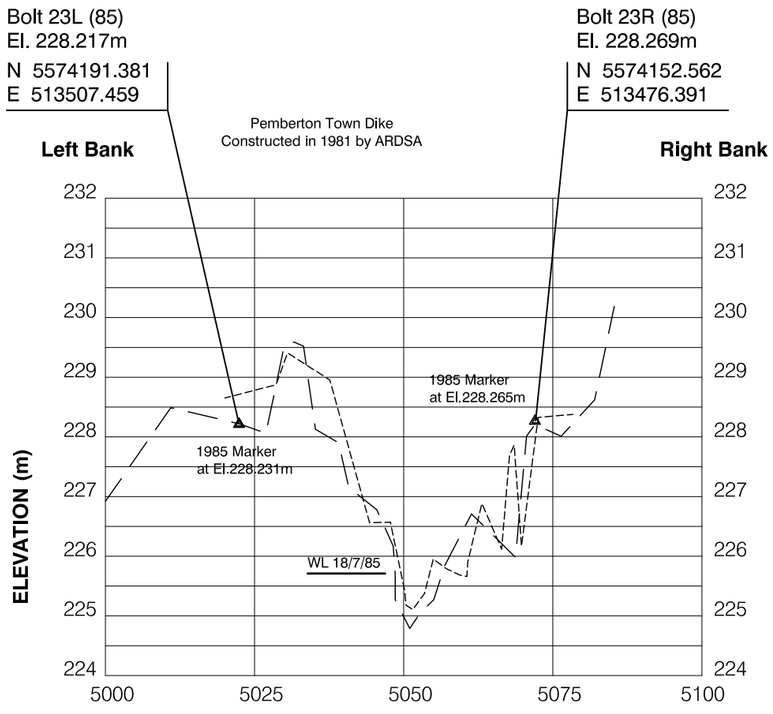
PEMBERTON CREEK

Upstream of Highway 99 Bridge



Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Management Plan

Legend

---------- R.B. Brown 2000-01

— — — WMB Victoria 1985

Notes:

1. Horizontal coordinate grid to NAD 27.
2. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J.

KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 23

Dec.15/06 11:00 AM

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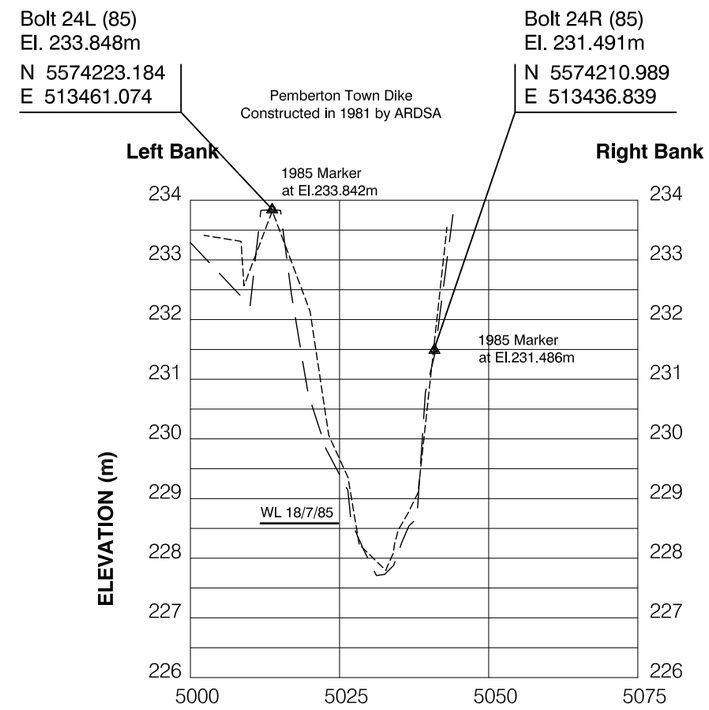
PEMBERTON CREEK

Upstream of Highway 99 Bridge



CHAINAGE (m)

Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Mangement Plan

Legend

---------- R.B. Brown 2000-01

— — — WMB Victoria 1985

Notes:

1. Horizontal coordinate grid to NAD 27.
2. Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J.

KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 24

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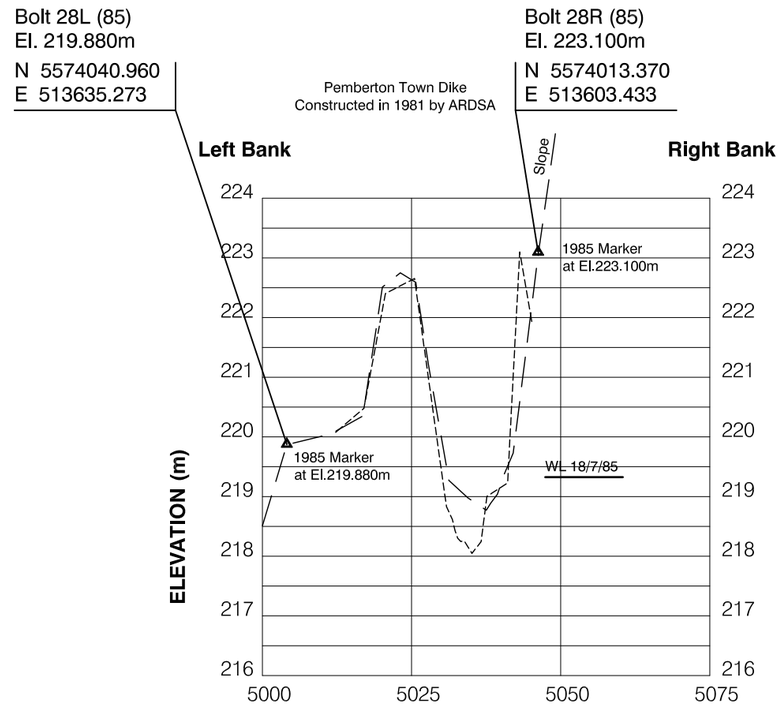
PEMBERTON CREEK

Upstream of Highway 99 Bridge



Flood Level Data from Floodplain Maps 5022-5 & 88-44-5

Pemberton Valley Dyking District
Pemberton Creek
Gravel Mangement Plan

Legend

---------- R.B. Brown 2000-01

— — — WMB Victoria 1985

Notes:

1. **Horizontal coordinate grid to NAD 27.**
2. **Elevations are to GSC CVD 28, referred to Geodetic Benchmarks 599J.**

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

1:1000 Horizontal, 1:100 Vertical

Project No.	Date
713-008	December 2006

Pemberton Creek
Cross-Section
XS 28 (20.5)

Dec.15/06 11:00 AM

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