



Report

**DEWDNEY-ALOUETTE REGIONAL DISTRICT
MISSION, B.C.**

**HATZIC PRAIRIE DRAINAGE STUDY
VOLUME 2**

August 1992



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ACKNOWLEDGEMENTS
PROJECT TEAM
EXECUTIVE SUMMARY

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VOLUME 2

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PHOTO No. 2.1

Hatzic Lake at Lougheed Highway and CPR culverts.
Debris accumulation at the CPR culverts.
(November 12, 1990)
(Photo courtesy B.C. Min. of Environment)

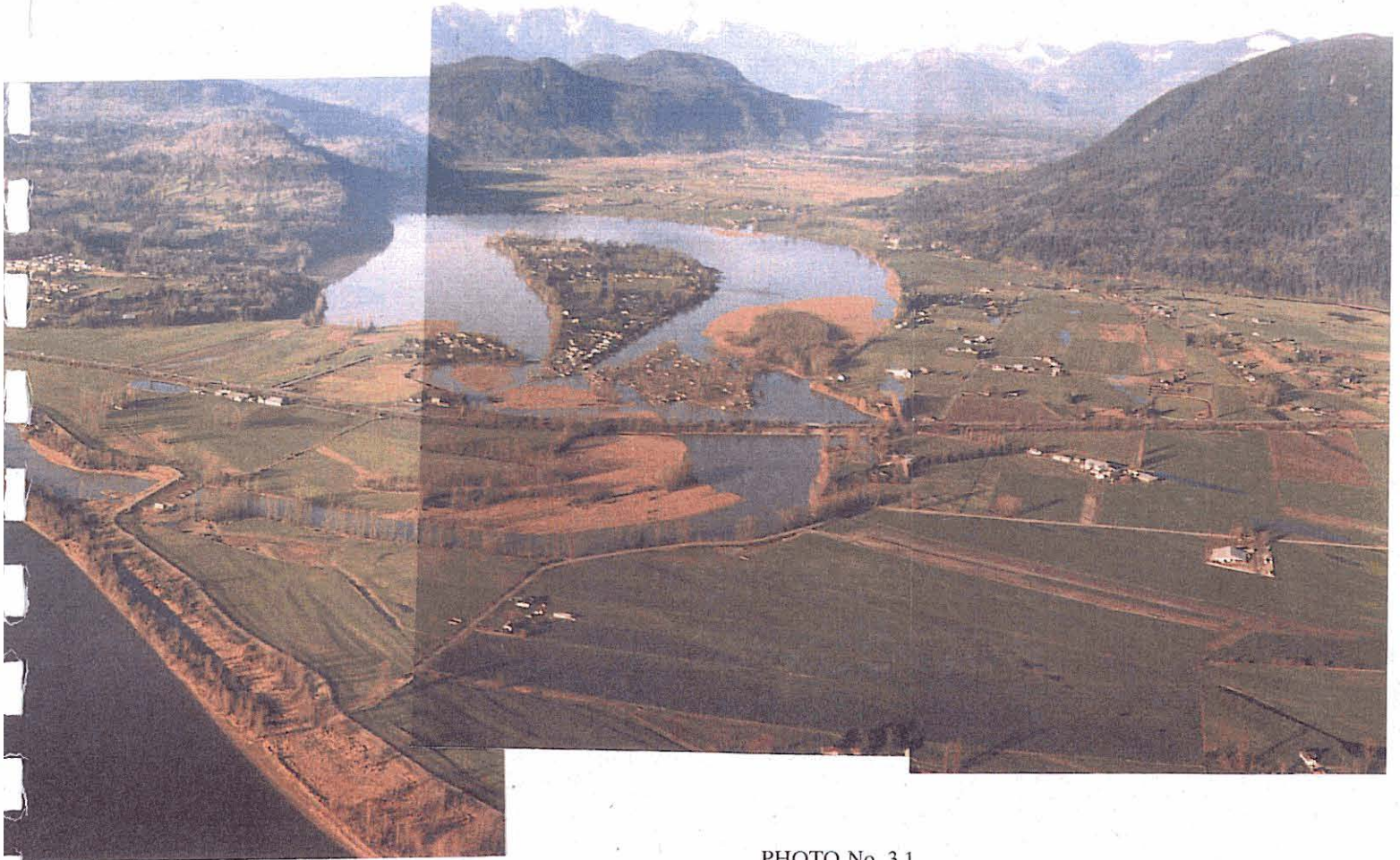


PHOTO No. 3.1

View of Hatzic Lake and Hatzic Prairie.
The floodboxes at the outlet to Fraser River are at the
left, the lake is in the middle of the photo.

(December 7, 1990)



PHOTO No. 3.2

Flooding of Hatzic Prairie.

Lagace Creek flows within the treed area in the middle of the photo and Farms road is between the two barns (red and yellow).

(November 11, 1990)
(Photo courtesy B.C. Min. of Environment)



PHOTO No. 3.3

Flooding at the south end of Hatzic Lake.
The Fraser river is flowing left to right in the background.

(November 11, 1990)
(Photo courtesy B.C. Min. of Environment)



PHOTO No. 3.4

Bank erosion upstream and downstream from Sylvester Road Bridge during November, 1990 flood. Flow is right to left. The debris flow deposit along the right bank downstream from the bridge has been eroded as well as the left bank adjacent to the highway.

(November 11, 1990)
(Photo courtesy of B.C. Min. of Environment)



PHOTO 3.5

First landslide (Slide A) in Pattison Creek Watershed.
The slide occurred in 1935 prior to any logging
and is now inactive.

(July 3,1991)



PHOTO No. 3.6

Material at the upper portion of landslide C.
The material consists of sand, gravel and cobbles.
The remnants of a logging road is evident in the middle of the photo.

(July 3, 1991)



PHOTO No. 3.7

Two landslides on Pattison Creek
The upper slide (C) completely
bypasses the much deeper
lower side (Slide B)
View is upstream to the watershed.

(July 3, 1991)



PHOTO No. 3.8

Upslope View of lower Slide (B)
showing stiff sides and trees at the base
of the eroded area.

(July 3, 1991)

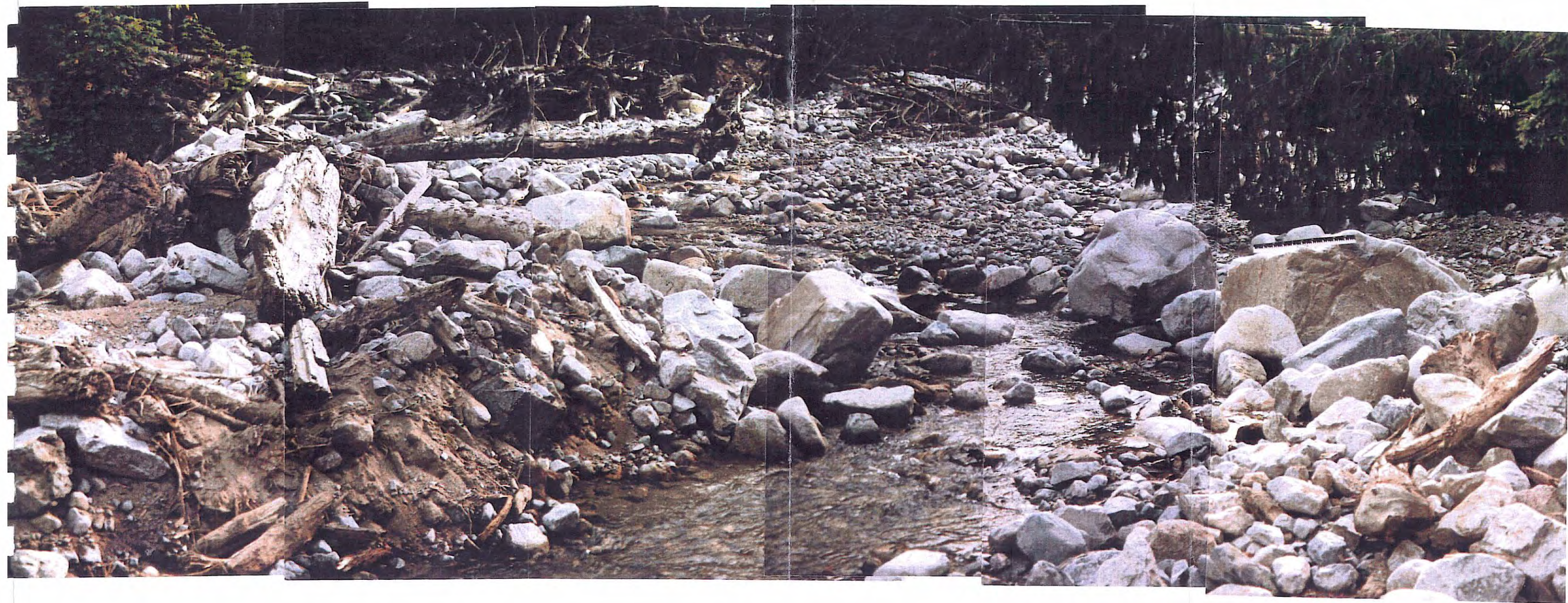


PHOTO 3.9

PATTISON CREEK

Looking upstream at alluvial fan just downstream from waterfall (approx. Sta. 6+200 m). The largest boulders are up to 2.0 m along the longest axis, and the deposited material ranges from sand to boulders. Extensive log jams have induced deposition over the confined alluvial fan. The scale on the boulder at the right side is one metre long.

(September 29, 1991)



PHOTO No. 3.10

Confluence of Pattison and Lagace Creeks.
Debris flow appears to have run out at or near confluence.
Pattison Creek enters from the right of the photo.

(August 21, 1991)



PHOTO No. 3.11

Lagace Creek - upstream view from Farms Road Bridge (Sta. 2+284)

The bed material consists of sand, gravel and some cobbles.

There is no evidence that the debris torrent took place along
this reach of the creek.

The channel is about 30 m wide through this reach.

(July 14, 1991)



PHOTO No. 3.12

Coarse sand excavated from bed of Lagace Creek at Dale Road Bridge.

(October 5, 1991)



PHOTO No. 3.13

Looking upstream to the Pattison Creek watershed on the right, showing landslides B and C, and the eastern slopes of the Lagace Creek Watershed. Allen Lake is located near the bottom of the photo.

(July 3, 1991)



PHOTO No. 3.14

Upper portion of Pattison Creek Watershed
showing potential for three landslides on the upper road
and a potential headcutting of Slide B into the
debris torrent path of Slide C.

(July 3, 1991)



PHOTO No. 3.15

Hatzic Lake - downstream view to south end of lake.
A small delta developed by Draper Creek is evident on the right
and the deposition on the left (east side) appears to be
from sediment originating in Pattison and Lagace Creeks.

(November 7, 1991)



PHOTO 3.16

Pattison Creek upstream from Sylvester Road Bridge (Upstream View)
The low flow is rapidly moving sand, gravel and silt from the creek bed.

(November 11, 1991)

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ENGINEERING



83 Marler Drive



BEFORE



AFTER

PHOTO 4.1

House raising for flood protection at Marler Drive

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91 Marler Drive



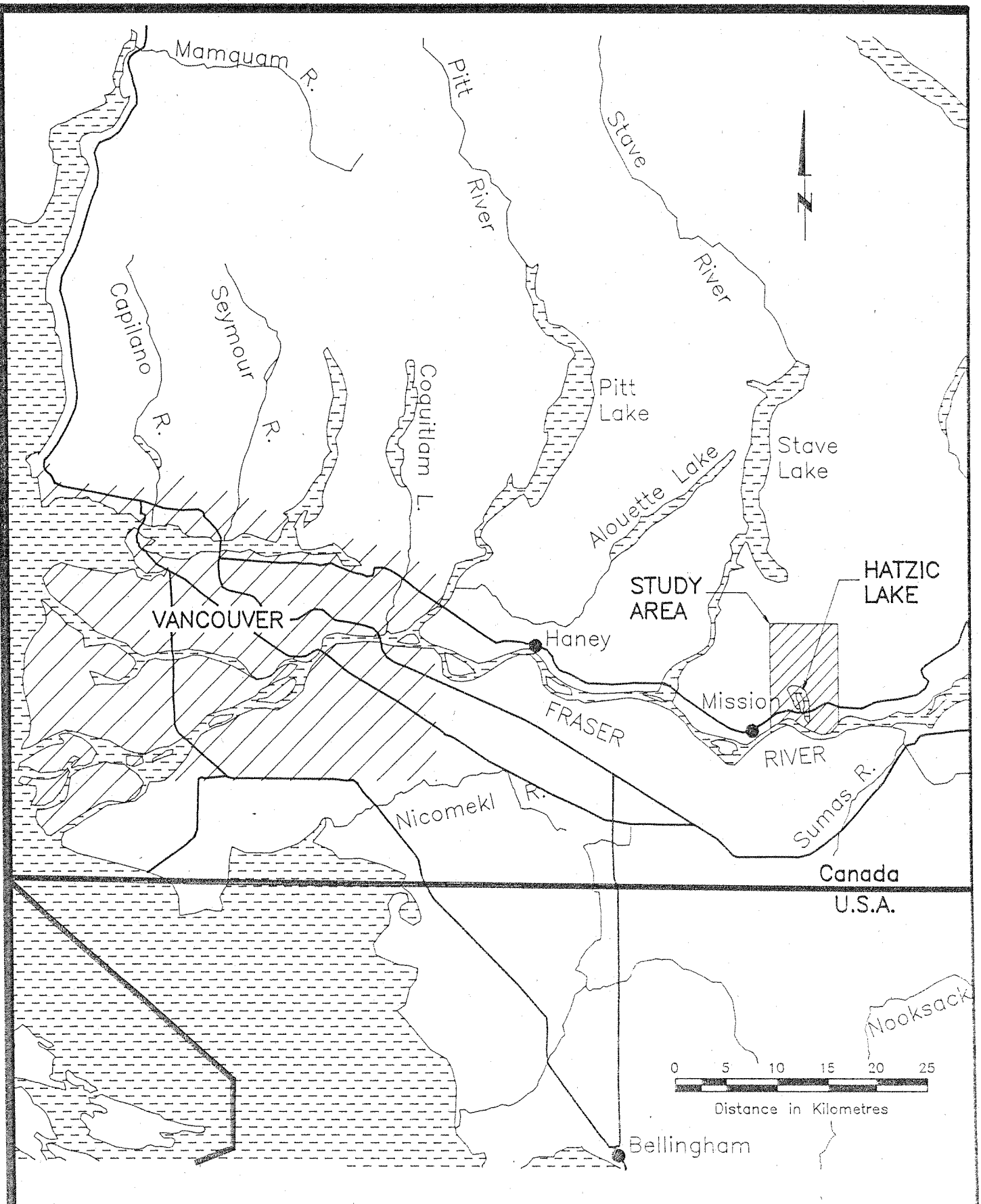
BEFORE



AFTER

PHOTO 4.2

House raising for flood protection at Marler Drive



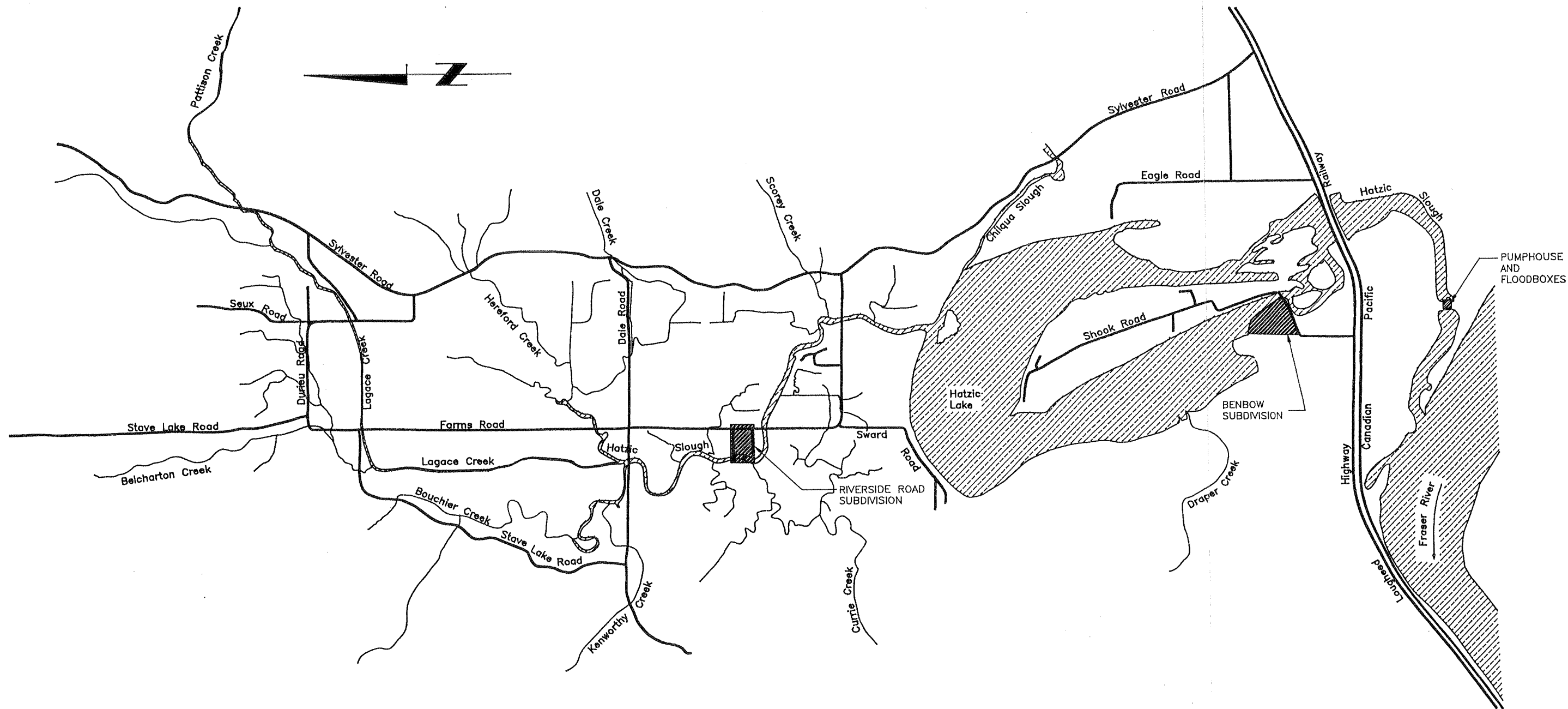
PROJECT No. VP97
 DATE OCT 29/91
 APPROVED K.R.
 SCALE 1=500000
 DWG No. 1.1

DEWDNEY-ALOUETTE REGIONAL DISTRICT
 HATZIC PRAIRIE DRAINAGE STUDY

LOCATION PLAN

ASSOCIATED
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0 400 800 1200 1600 2000

Distance in metres

DEWDNEY ALOUTTE REGIONAL DISTRICT
HATZIC PRAIRIE STUDY

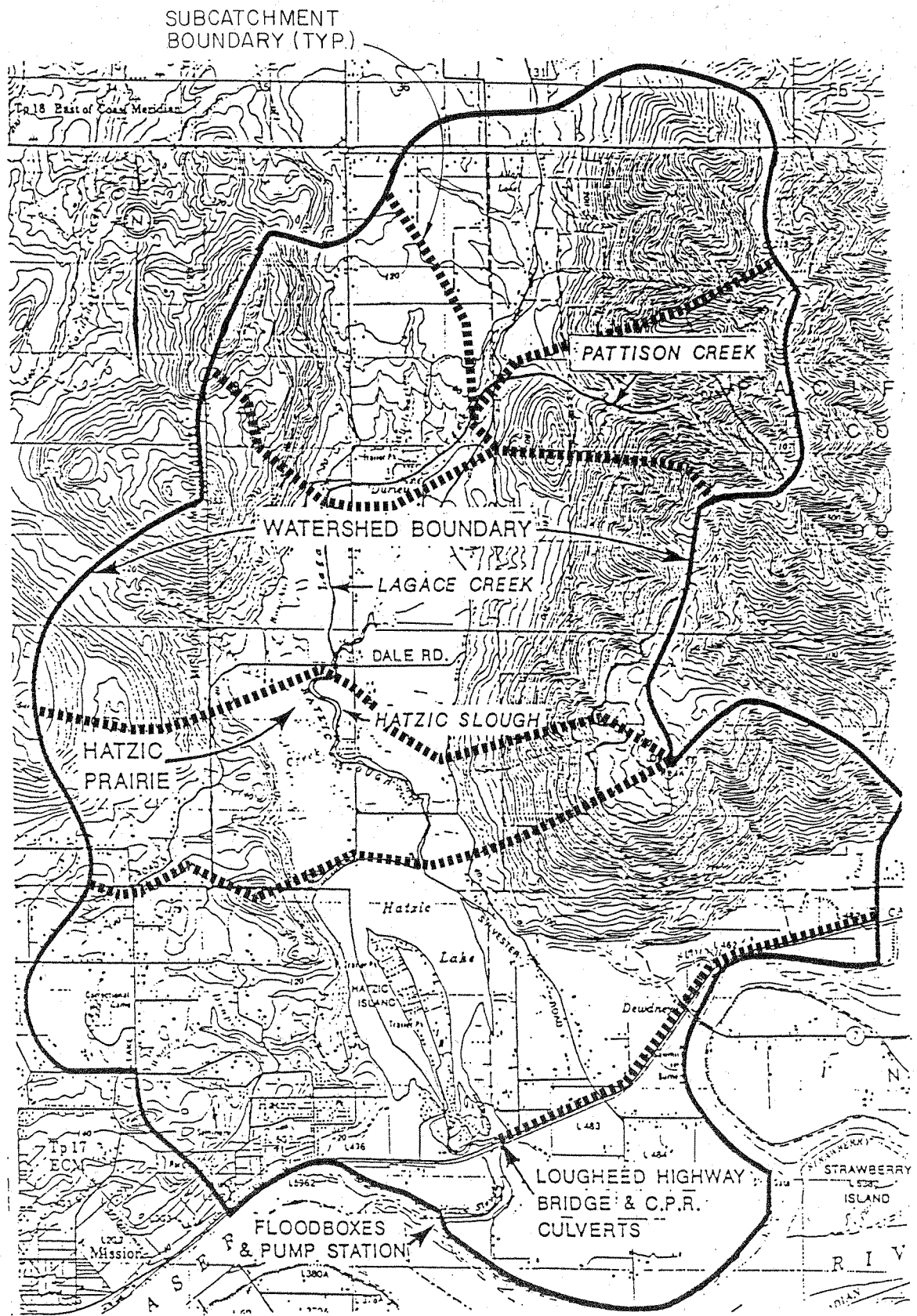
PRAIRIE KEY PLAN

PROJECT No. VP97
DATE JAN. 92
APPROVED K.R.

SCALE 1:30000
DWG No. I.2

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PROJECT No. VP97

DATE OCT. 91

APPROVED JVE

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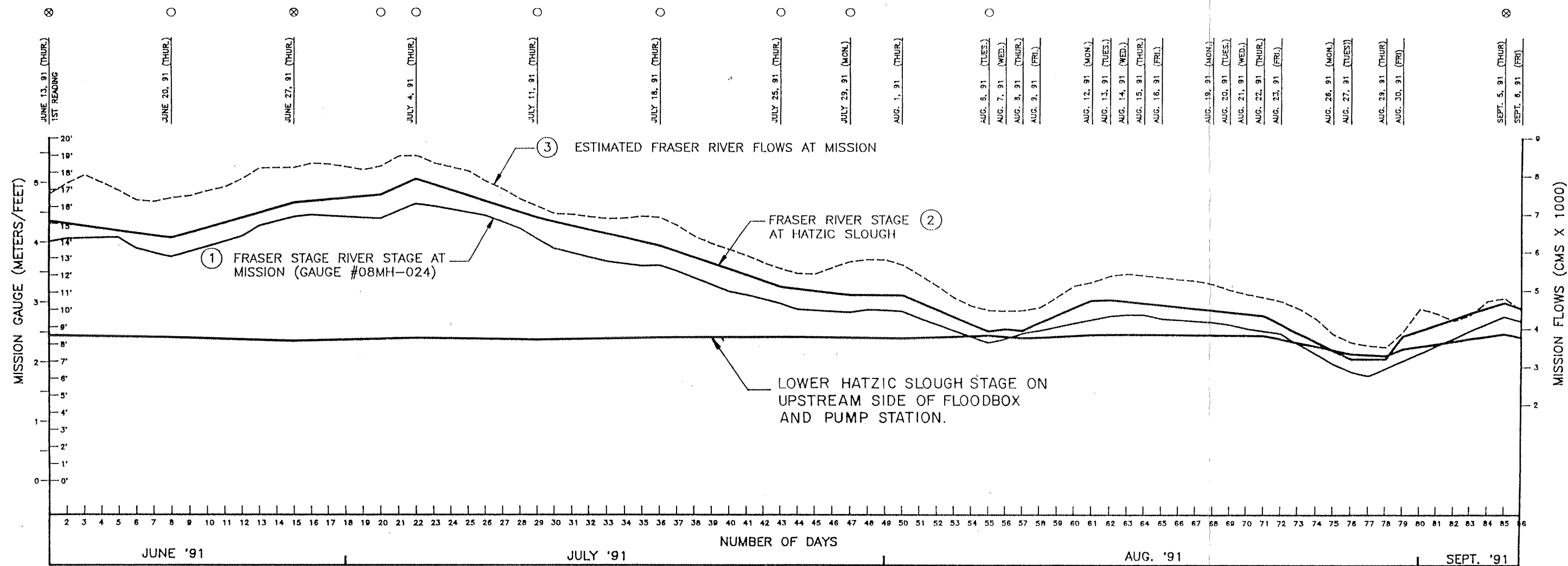
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DEWDNEY-ALOUETTE REGIONAL DISTRICT
HATZIC PRAIRIE DRAINAGE STUDY

HATZIC PRAIRIE WATERSHED
WATERSHED & SUBCATCHMENT BOUNDARIES

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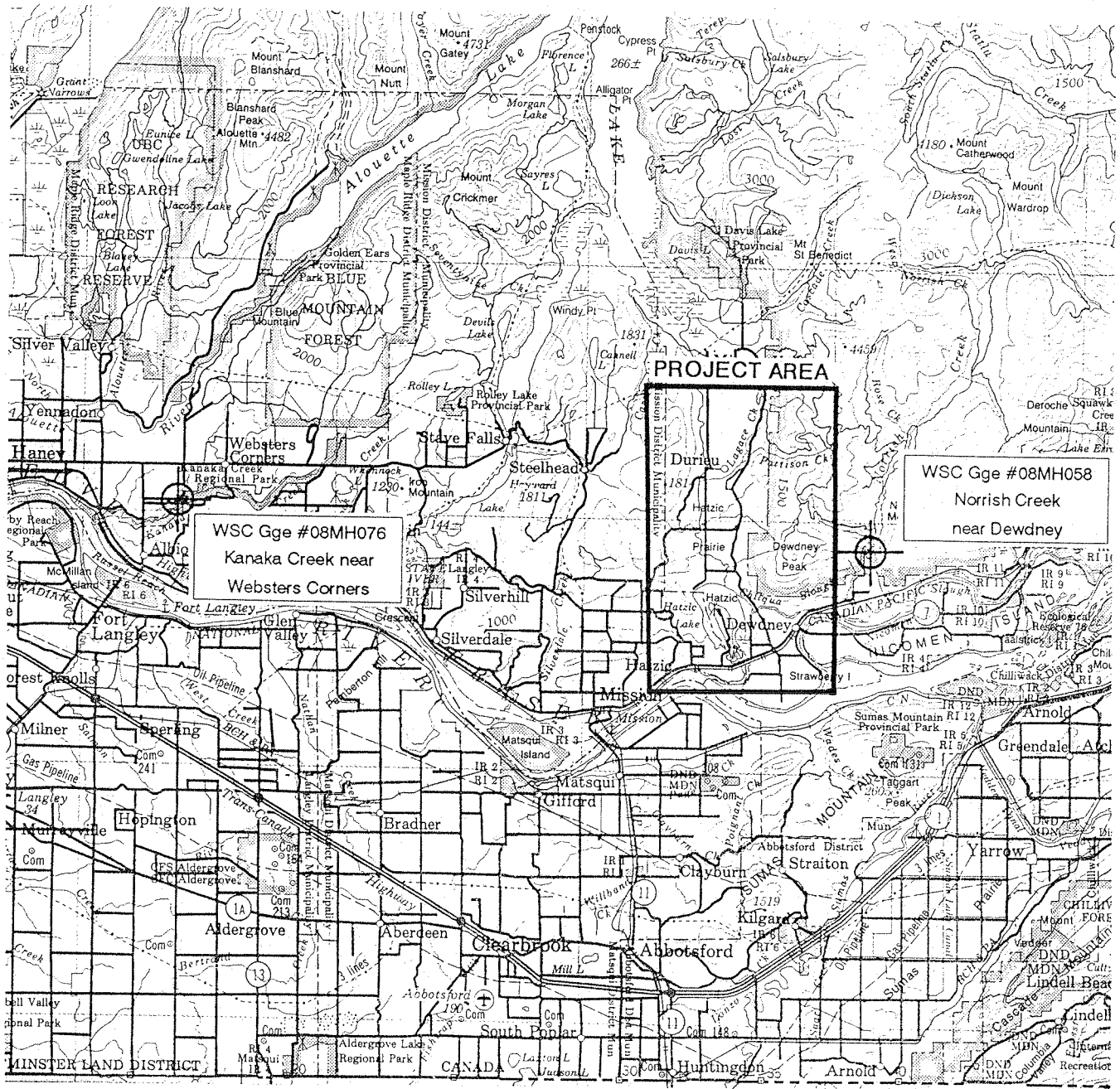


NOTES

- INDICATE PUMPS ARE RUNNING
- ⊗ INDICATE PUMPS ARE NOT RUNNING
- 1 BASED ON INFORMATION FROM W.S.C. GAUGE READINGS RECORDED AT 7:30 A.M. DAILY
- 2 BASED ON HATZIC SLOUGH OUTLET GAUGE READINGS BY A.E.(BC) LTD.
- 3 FRASER RIVER FLOWS WERE ESTIMATED USING MEAN DAILY FLOWS AT HOPE GAUGE #08MF005 FOR 1991 ADJUSTED TO MISSION VALUES BASED ON A RELATIONSHIP DERIVED BETWEEN THESE TWO STATIONS FOR FLOWS IN 1990

DEDWNEY-ALOUETTE REGIONAL DISTRICT HATZIC PRAIRIE DRAINAGE STUDY

PROJECT No. VP97	SCALE N.T.S.
DATE JAN. 92	
APPROVED S.G.	DWG No. 1.4



Legend:



Water Survey of Canada
Gauge Location

Scale 1:250 000

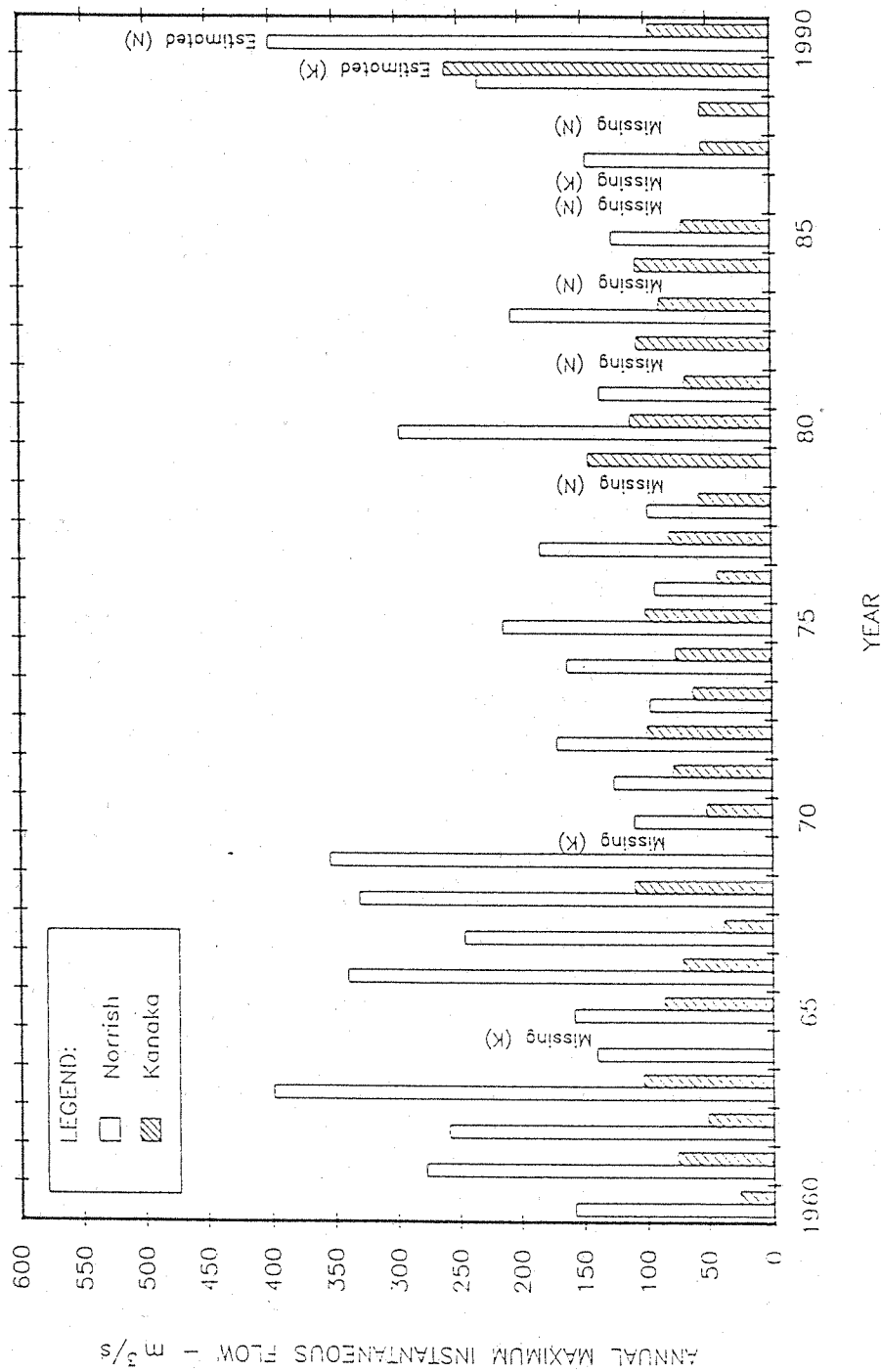


Hatzic Prairie Study

Project Area

Hatzic Prairie and Hatzic Lake

northwest hydraulic consultants

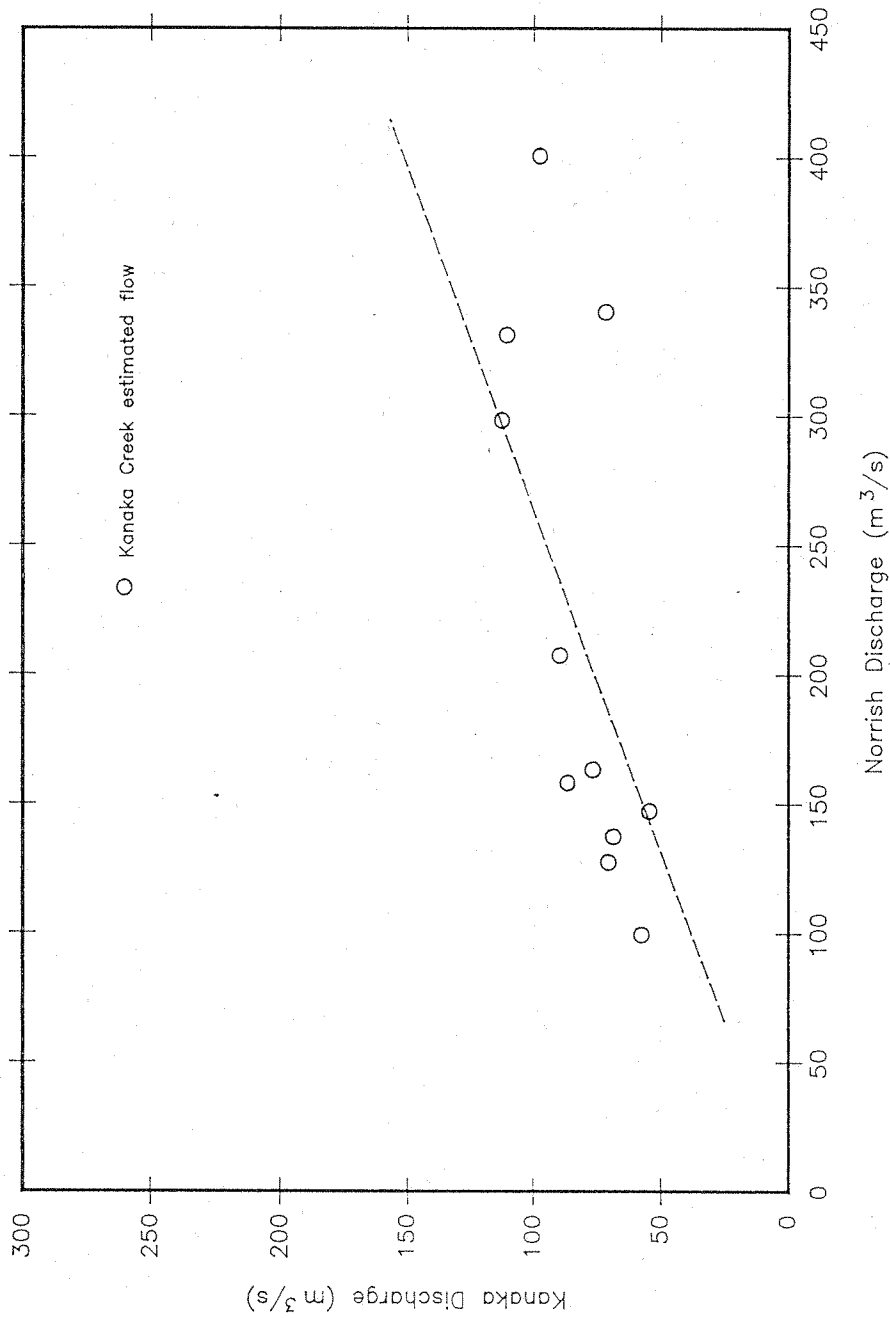


Hatzic Prairie Study

Annual Maximum Instantaneous Flows
 Norrish and Kanaka Creeks

northwest hydraulic consultants

Sequences of reported annual maximum instantaneous flows;
 Norrish and Kanaka Creeks, 1960 - 1990.

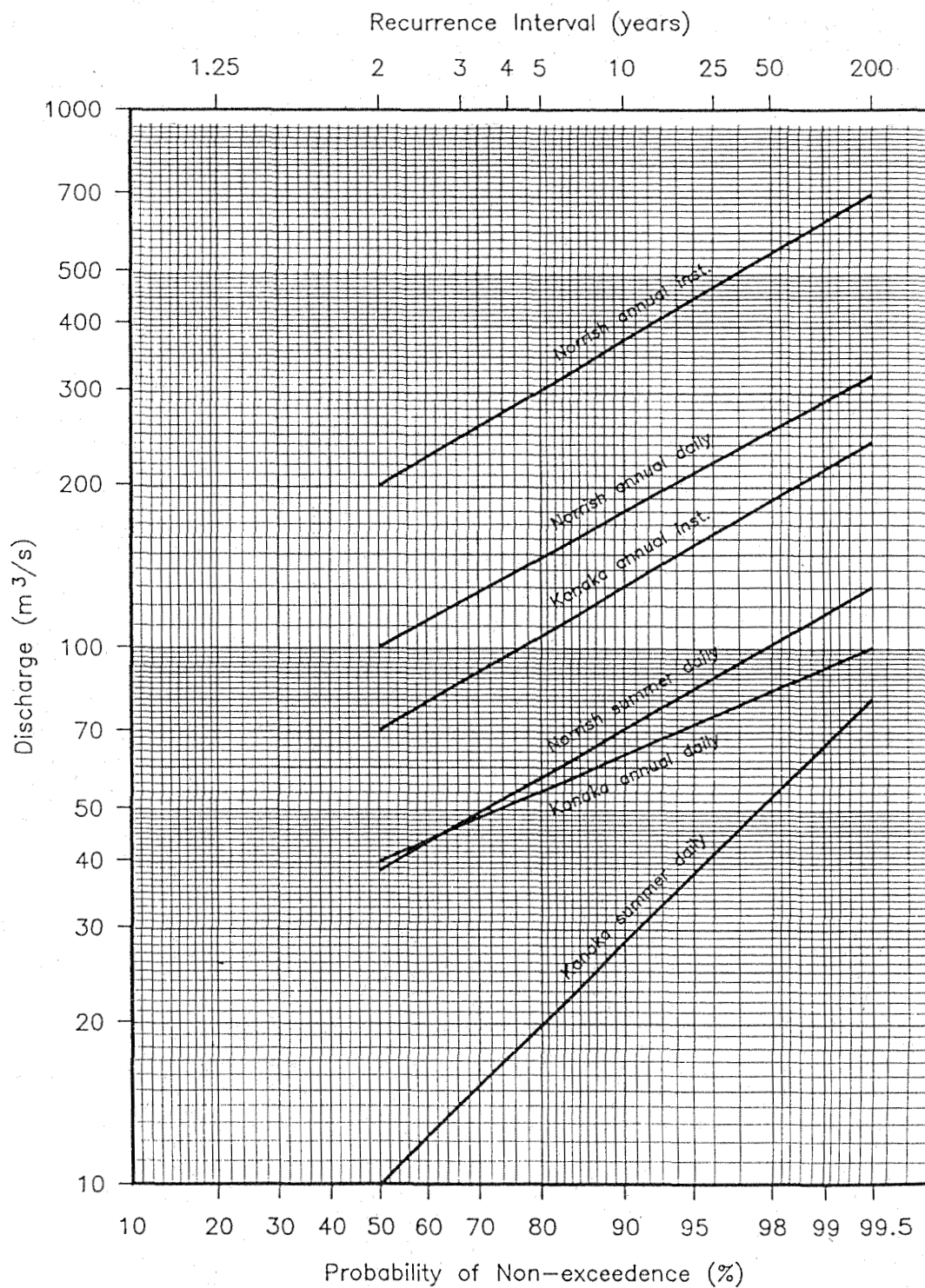


Correlation of annual maximum instantaneous flows in Kanaka and Norrish Creeks due to the same storm events.

Hatzic Prairie Study

Correlation of Annual
Maximum Instantaneous Flows
Norrish and Kanaka Creeks

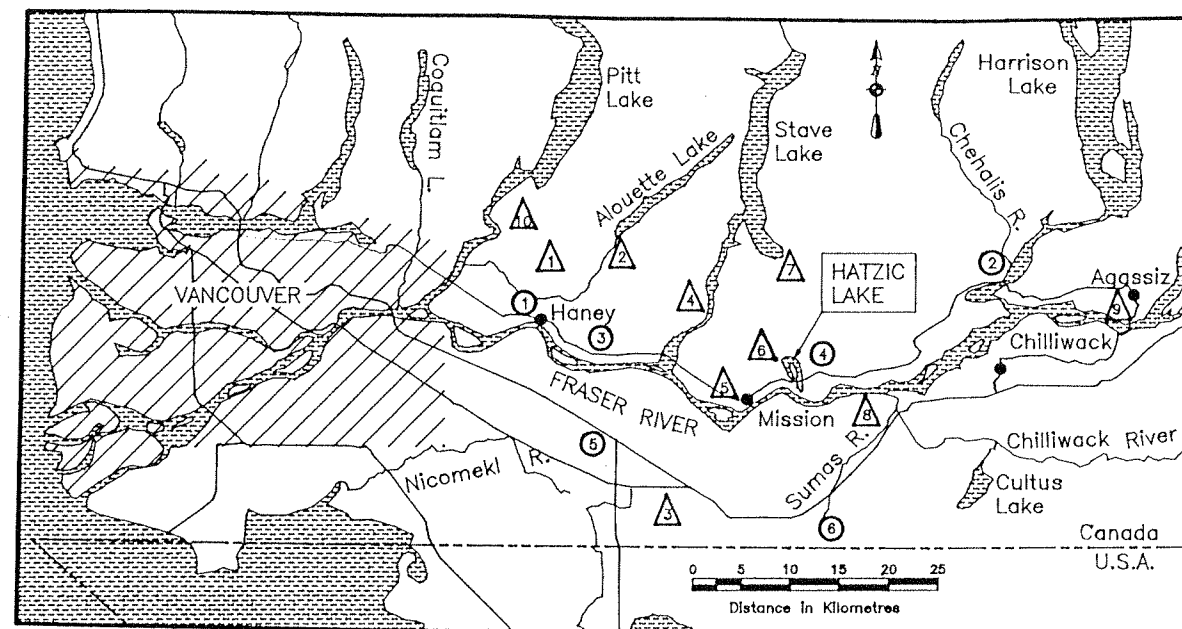
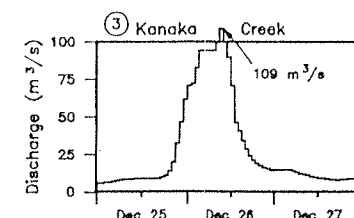
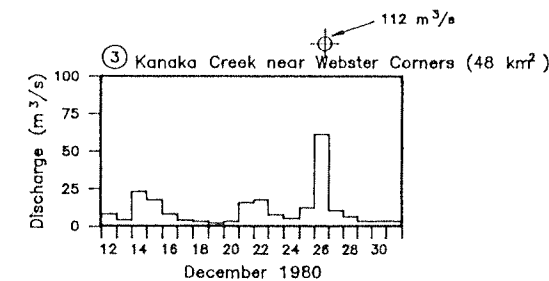
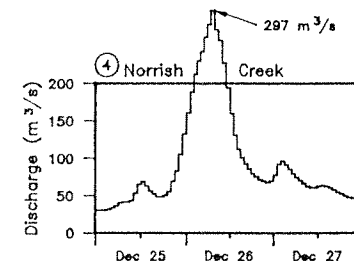
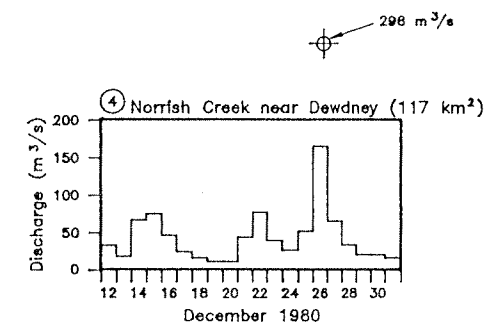
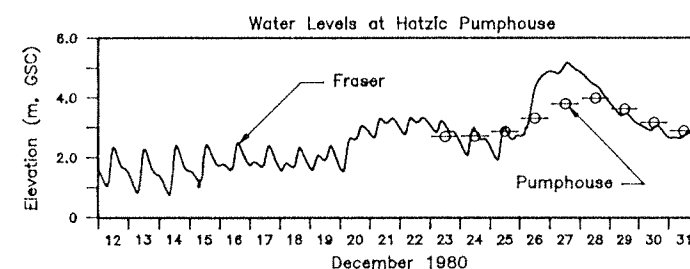
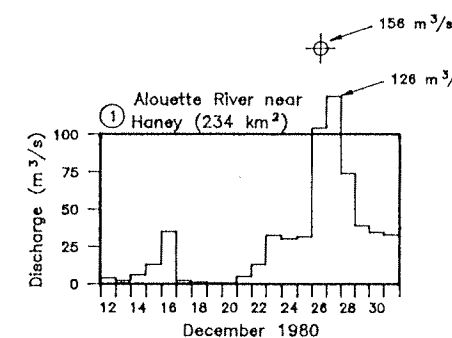
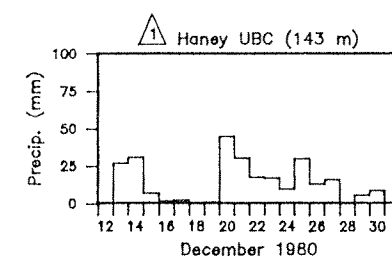
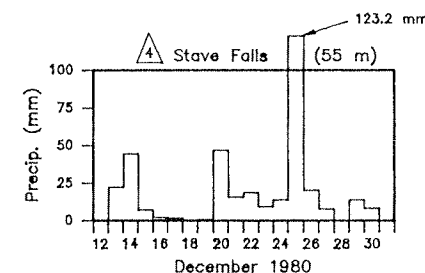
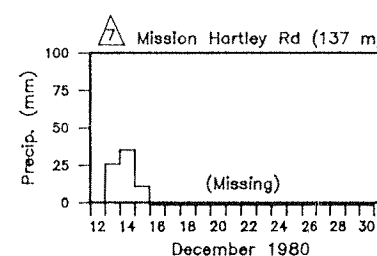
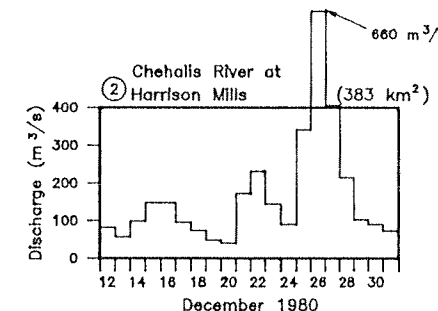
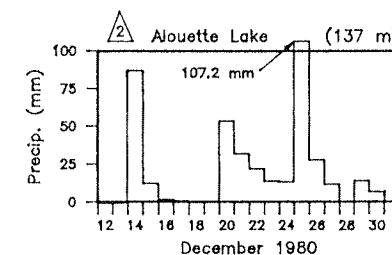
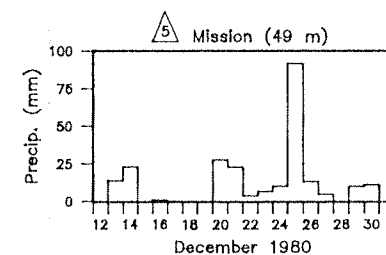
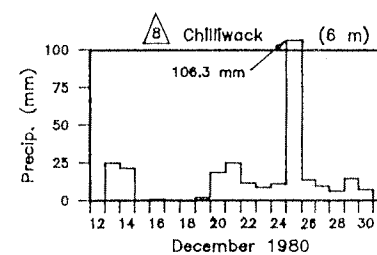
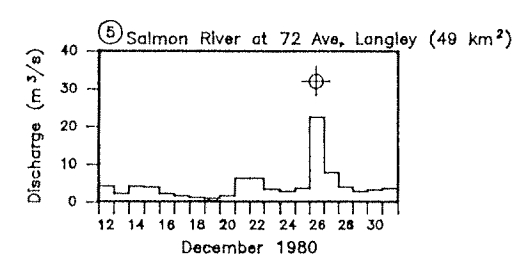
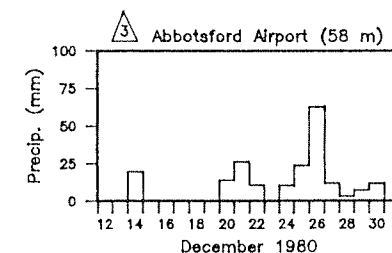
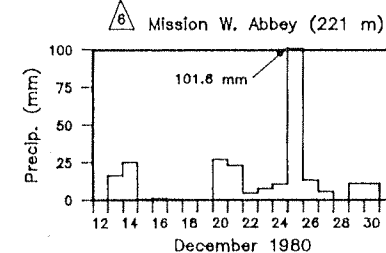
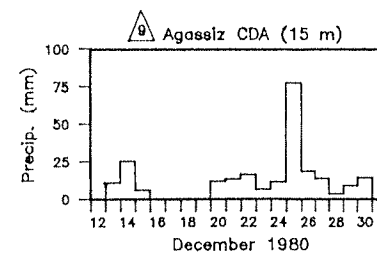
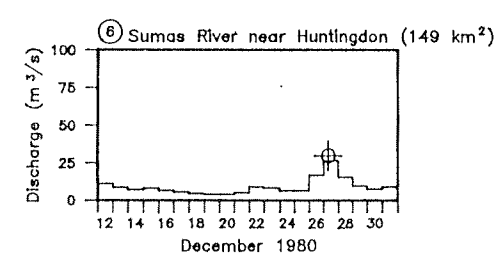
northwest hydraulic consultants



Hatzic Prairie Study

Flow Frequency Relationships
Norrish and Kanaka Creeks

northwest hydraulic consultants



Recurrence Intervals: Precipitation (Annual)
(Number in brackets represent the last day of the n-day event)

Station	Return Period *				
	1-day	2-day	3-day	4-day	5-day
③ Abbotsford Airport (58 m)	2 (26)	3 (26)	2 (27)	<2 (27)	<2 (28)
④ Stave Falls (55 m)	15 (25)	3 (26)	2 (26)	<2 (26)	<2 (26)
⑥ Mission W. Abbey (221 m)	15 (25)	5 (26)	5 (26)	<2 (26)	<2 (25)
⑩ Pitt Polder (2 m)	5 (25)	3 (26)	2 (27)	2 (27)	<2 (25)

*based upon Log-Normal Distribution (Three parameter method of maximum likelihood)

Trends

- Two storm events occurred over the period from December 13 through 27. Major precipitation occurred on 25 December with 101.6 mm falling at Mission West Abbey.
- Total precipitation was greatest in the mountains north of the Fraser River (Stave Falls) and decreased moving up the valley.
- The return period for the 25 December rainfall at Mission West Abbey and Stave Falls was 15 years.
- 2-day runoffs were comparable with 2-day precipitations. Recurrence intervals for precipitation and for maximum flows are around 5 years.

Hatzic Prairie

- Pumphouse records show water level at the pumphouse for 23-30 December only. Over 26 December the Fraser River rose 2.5 m effectively stopping discharge from the flood-boxes. The lake level at the pumphouse reached 3.99 m GSC (13.2 ft), the second highest internal flood stage recorded since the construction of the pumphouse in 1948.
- Pumps started at 3:30 pm on 26 December and were turned off at 8:00 am on 2 January.
- On 28 December, debris at the CPR culverts was removed.

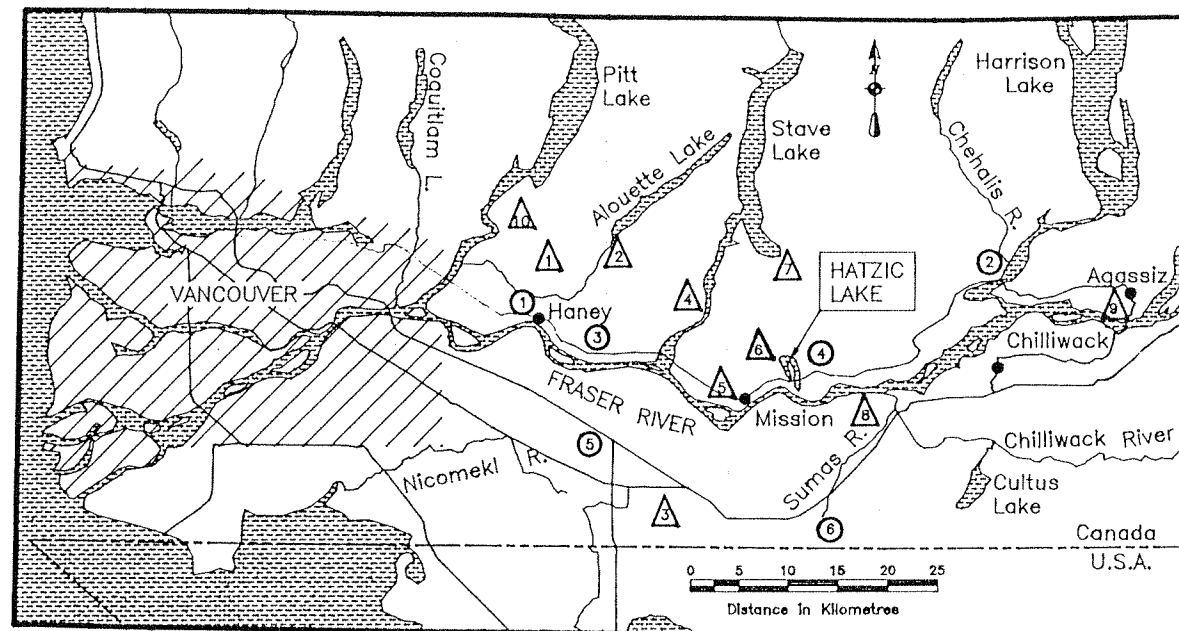
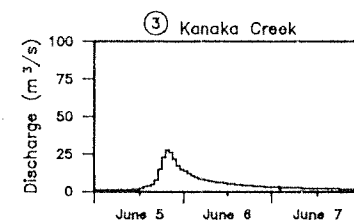
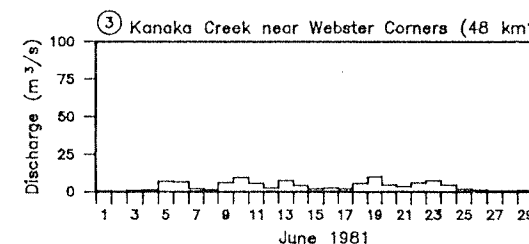
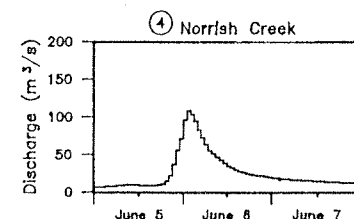
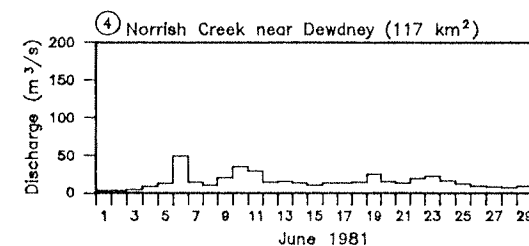
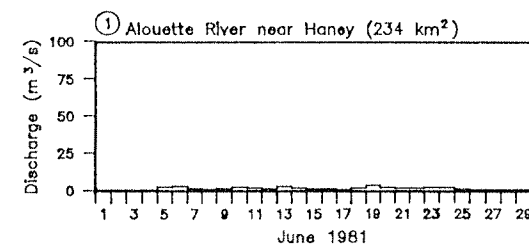
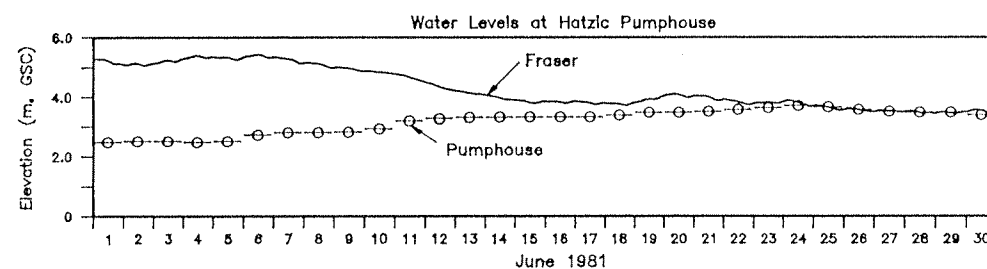
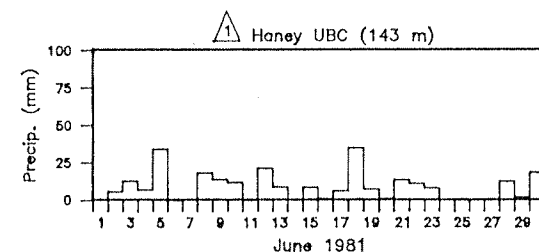
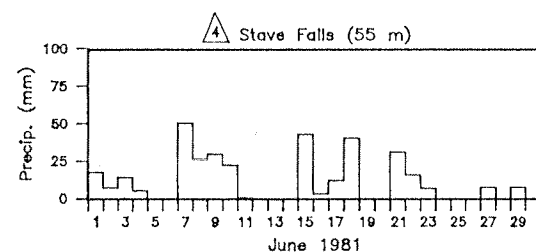
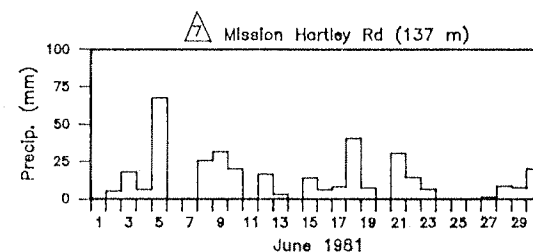
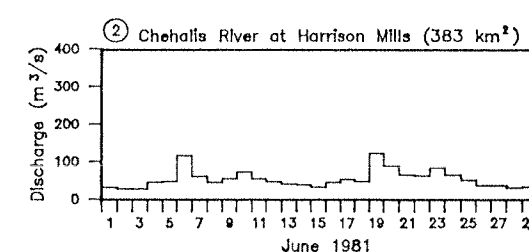
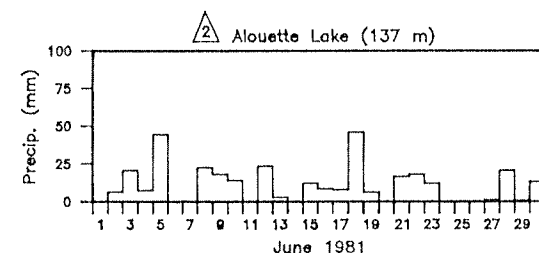
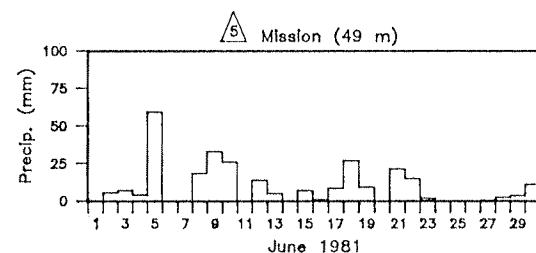
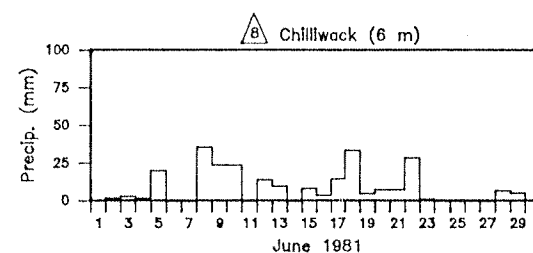
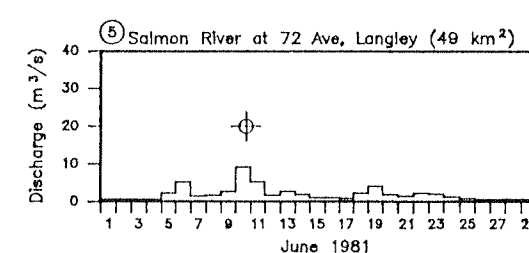
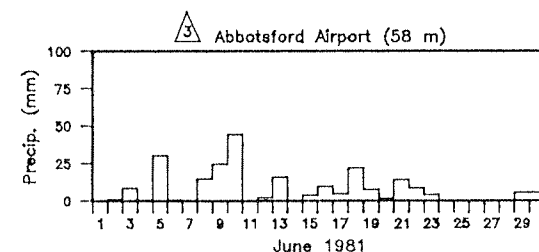
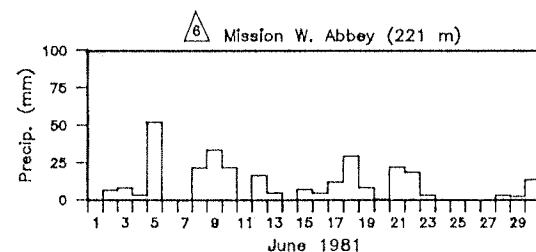
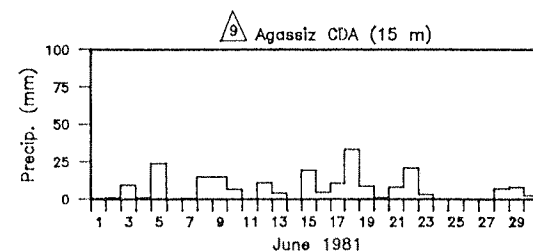
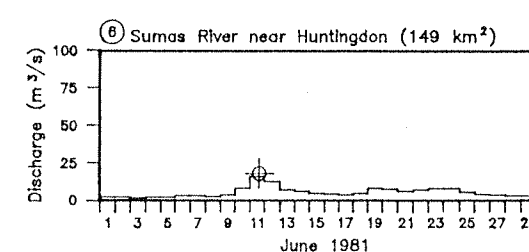
Legend:

- Fraser River level at the Hatzie Pump House. The river level at Mission was adjusted by +0.300 m to estimate the level at the pumphouse.
- Level recorded at Hatzie Pump House. Have assumed the level was recorded at noon.
- Precipitation Gauge Location (Gauge Elevation, m GSC)
- Streamflow Gauge Location (Drainage Basin Area, km²)
- Peak Instantaneous Flow, where reported

Hatzic Prairie Study

Storm Event Data
December 1980

northwest hydraulic consultants



Recurrence Intervals: Precipitation (Annual/Summer)
(Number in brackets represent the last day of the n-day event)

Station	Return Period *				
	1-day	2-day	3-day	4-day	5-day
③ Abbotsford Airport (58 m)	<2/8 (10)	<2/20 (10)	<2/20 (10)	-	-
④ Stave Falls (55 m)	<2/8 (7)	<2/10 (8)	<2/30 (9)	<2/25 (10)	<2/15 (11)
⑥ Mission W. Abbey (221 m)	<2/5 (5)	<2/3 (9)	<2/8 (10)	-	-
⑩ Pitt Polder (2 m)	<2/3 (18)	<2/2 (19)	<2/2 (19)	<2/2 (5)	<2/2 (22)

*based upon Log-Normal Distribution (Three parameter method of maximum likelihood)

Trends

- 1) A single day of moderately heavy precipitation, on 5 June, amounted to between 50 and 70 mm in the Mission area. Precipitation occurred for over two-thirds of the month. Greater total precipitation occurred in the mountains north of the Fraser at the higher elevation, but decreased up the Fraser Valley.
- 2) Total runoff in Norrish Creek for the two-day period 6-7 June amounted to about 48 mm. Maximum daily flows in both creeks had recurrence intervals of about 3 years as summer maxima.
- 3) The recurrence interval for the precipitation at all stations was less than two years.

Hatzic Prairie

- 1) Both pumps operated over the entire month of June. On 24 June and 26 June pumps were off for about 2 hours due to a blown transformer and a power outage.
- 2) On 6 June lake gained approximately 30 cm.
- 3) Towards the end of the month some floodbox relief was noted.

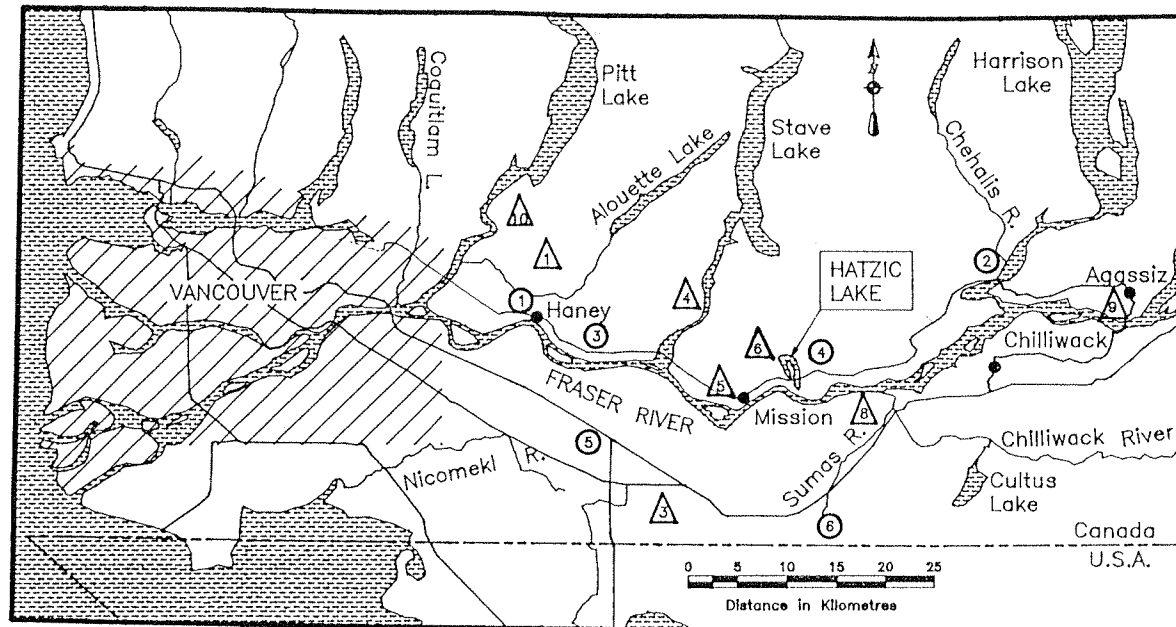
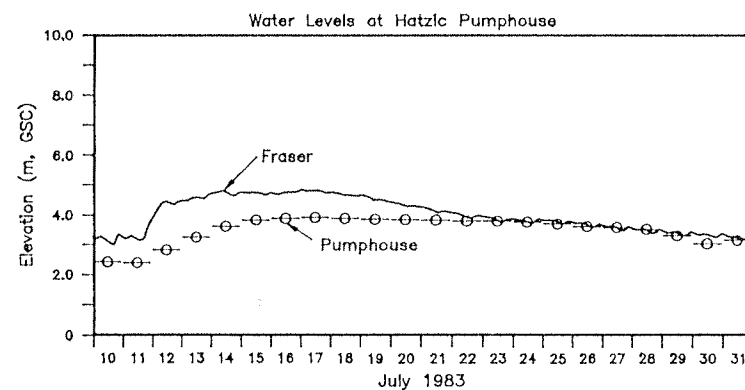
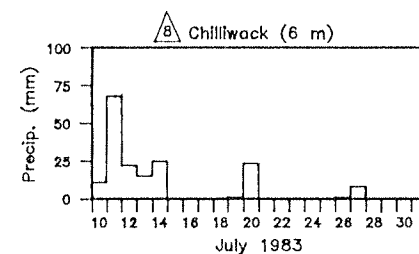
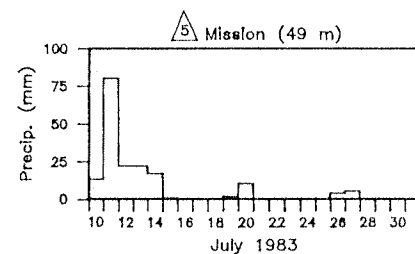
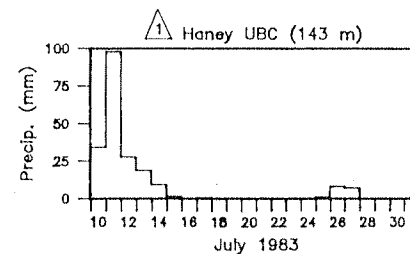
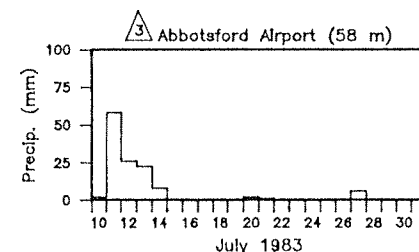
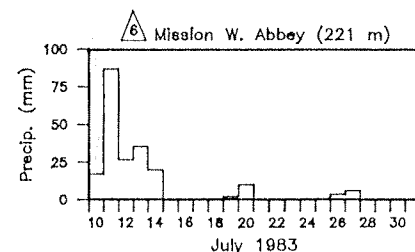
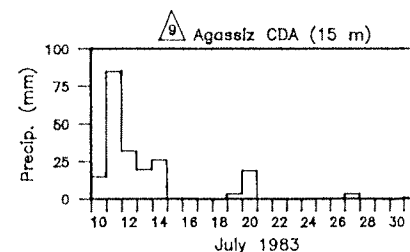
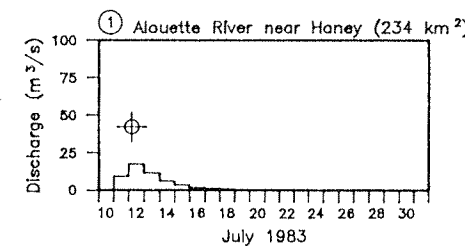
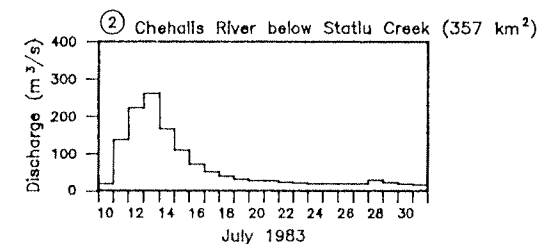
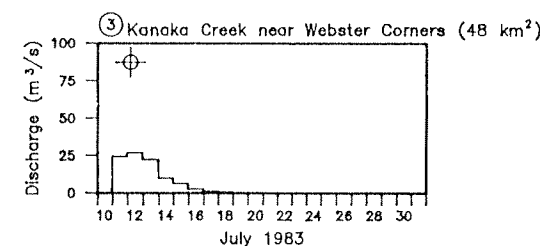
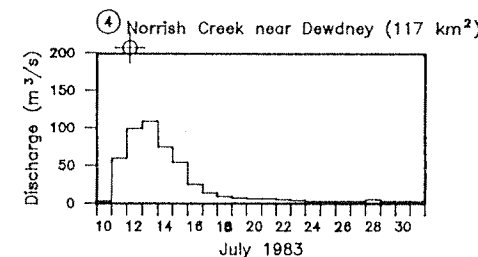
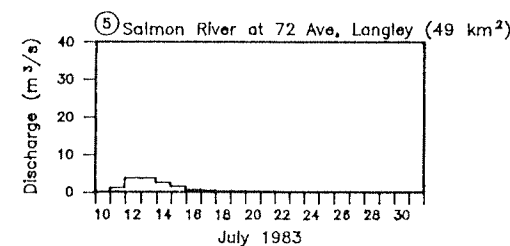
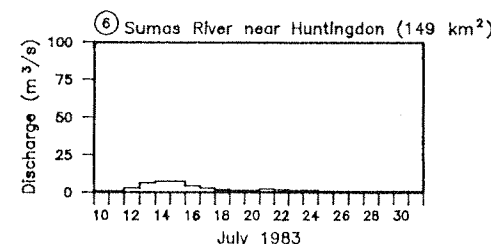
Legend:

- Fraser River level at the Hatzic Pumphouse. The river level at Mission was adjusted by +0.300 m to estimate the level at the pumphouse.
- Level recorded at Hatzic Pumphouse. Have assumed the level was recorded at noon.
- Precipitation Gauge Location (Gauge Elevation, m GSC)
- Streamflow Gauge Location (Drainage Basin Area, km²)
- Peak Instantaneous Flow, where reported

Hatzic Prairie Study

Storm Event Data
June 1981

northwest hydraulic consultants



Recurrence Intervals: Precipitation (Annual/Summer)
(Number in brackets represent the last day of the n-day event)

Station	Return Period *				
	1-day	2-day	3-day	4-day	5-day
③ Abbotsford Airport (58 m)	3/30 (11)	10/50 (12)	15/75 (13)	15/50 (14)	-
④ Stave Falls (55 m)	No Records				
⑥ Mission W. Abbey (221 m)	8/40 (11)	5/60 (12)	10/75 (13)	8/60 (14)	5/30 (14)
⑩ Pitt Polder (2 m)	8/100 (11)	5/100 (11)	5/75 (12)	5/75 (13)	3/30 (14)

*based upon Log-Normal Distribution (Three parameter method of maximum likelihood)

Trends

- Generally, the precipitation over the whole of the north side of the Fraser valley was uniform. Lower total precipitation occurred in the valley at Chilliwack and Abbotsford.
- There was a 5-day rainfall of about 190 mm at Mission, including one day of heavy rainfall on 11 July. The recurrence intervals are 8 years for a 1-day storm and 5 years for a 2-day storm. Abbotsford recorded 15 year events for 3-day and 4-day storms.
- Total runoff in Norrish Creek for 6 days was about 315 mm. Kanaka Creek had a total runoff of about 170 mm. These figures suggest that rainfall must have been much higher at the higher elevations of the Norrish Creek basin.
- Maximum daily flows had recurrence intervals in the order of 25 years as summer maxima.

Hatzic Prairie

- From 10 July to 10 August, the level at the pumphouse was above 8.0 ft (2.41m, GSC) and above the flood stage of 11.0 ft (3.32m, GSC) for 17 days. During this period both pumps were operating. On 23 July the floodboxes began operating.

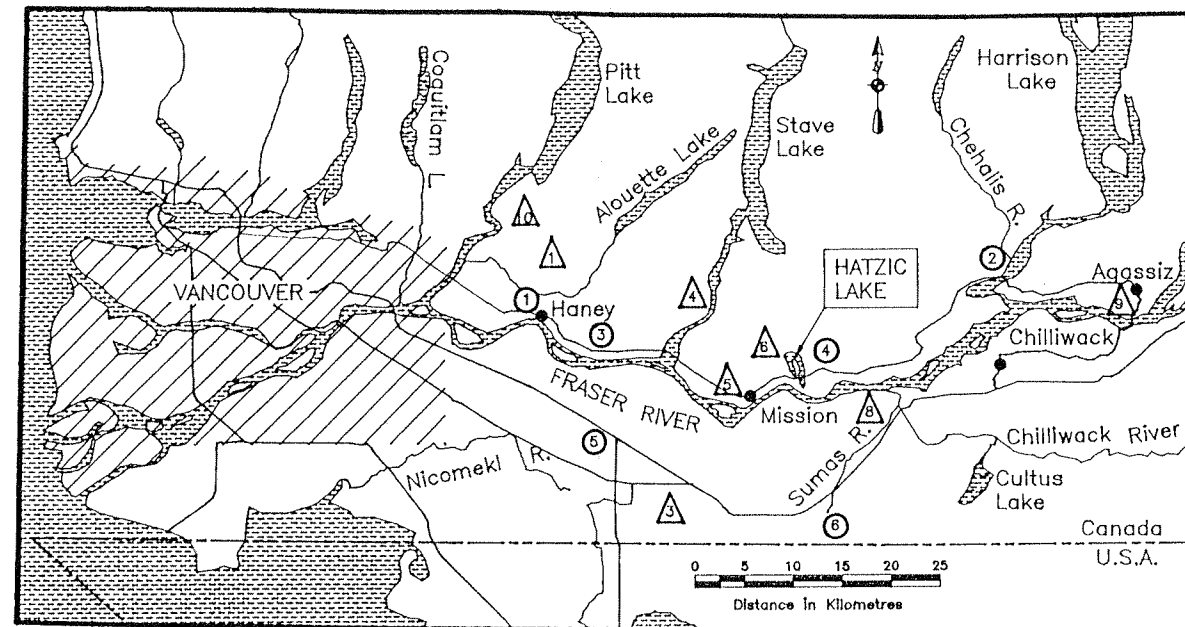
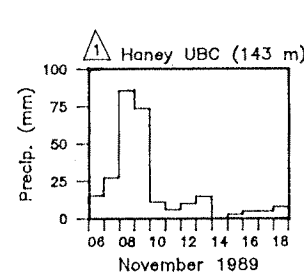
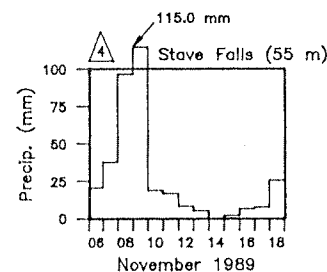
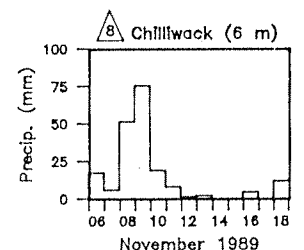
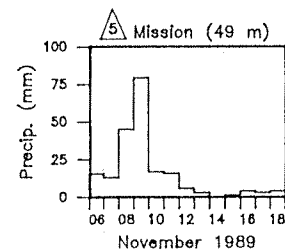
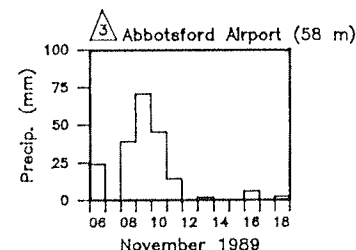
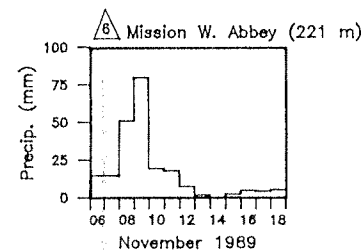
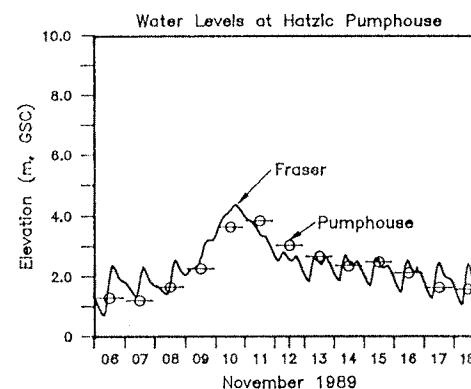
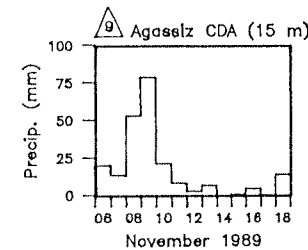
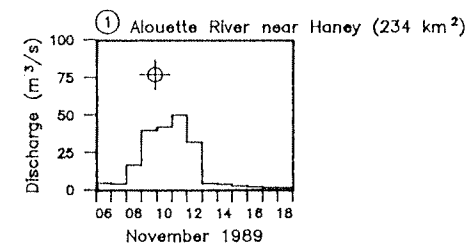
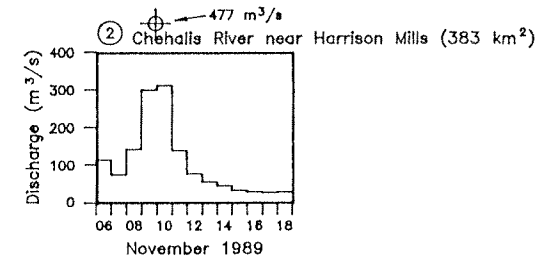
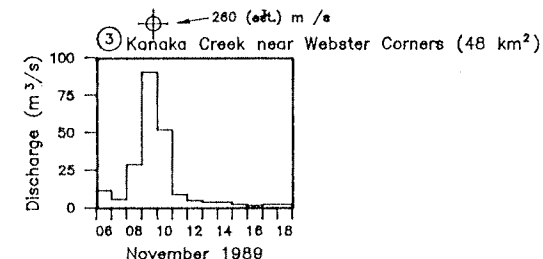
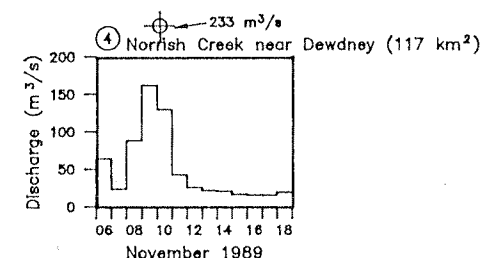
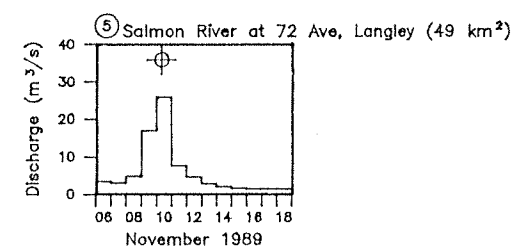
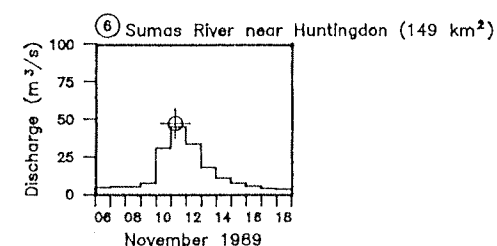
Legend:

- Fraser River level at the Hatzic Pumphouse. The river level at Mission was adjusted by +0.300 m to estimate the level at the pumphouse.
- Level recorded at Hatzic Pumphouse. Have assumed the level was recorded at noon.
- Precipitation Gauge Location (Gauge Elevation, m GSC)
- Streamflow Gauge Location (Drainage Basin Area, km²)
- Peak Instantaneous Flow, where reported

Hatzic Prairie Study

Storm Event Data
July 1983

northwest hydraulic consultants



Recurrence Intervals: Precipitation (Annual)
(Number in brackets represent the last day of the n-day event)

Station	Return Period *				
	1-day	2-day	3-day	4-day	5-day
③ Abbotsford Airport (58 m)	3 (9)	10 (10)	15 (10)	15 (11)	—
④ Stave Falls (55 m)	10 (9)	30 (9)	25 (9)	20 (9)	20 (10)
⑧ Mission W. Abbey (221 m)	5 (9)	20 (9)	10 (10)	8 (11)	5 (11)
⑩ Pitt Polder (2 m)	10 (9)	25 (9)	20-25 (9)	25 (9)	20 (9)

*based upon Log-Normal Distribution (Three parameter method of maximum likelihood)

Trends

- 1) Greater total precipitation occurred in the mountains north of the Fraser River (Haney UBC RF and Stave Lake). Over the whole of the valley the total precipitation was generally uniform.
- 2) There was a 4-day rainfall (8-9 Nov) of about 290 mm at Stave Falls and 169 mm at Mission West Abbey. These represent recurrence intervals of 20 and 8 years, respectively.
- 3) Norrish and Kanaka Creeks had 3-day runoffs (8-10 Nov) of 285 and 310 mm respectively, again suggesting considerably higher rainfall at higher elevations.
- 4) Recurrence intervals of maximum daily flows appear to be in order of 10 and 50 years for Norrish and Kanaka Creeks, respectively.

Hatzic Prairie

- 1) The mean Fraser level rose from about 1.50 m to 4.50 m GSC during 6-10 November. The levels recorded at the pumpouse followed the level of the Fraser River.
- 2) Between 9-12 November, the level at the pumpouse was above the flood stage of 11.0 ft (3.32 m GSC).
- 3) Both pumps operated from 6:00 pm 9 November to 7:00 am 14 November.
- 4) CPR culverts blocked with debris (picnic tables, freezers, etc.) between 11-14 November, which may account for the noticeable drop in the pumpouse level on 11 November.

Legend:



Fraser River level at the Hatzic Pumpouse.
The river level at Mission was adjusted by +0.300 m to estimate the level at the pumpouse.



Level recorded at Hatzic Pumpouse.
Have assumed the level was recorded at noon.



Precipitation Gauge Location (Gauge Elevation, m GSC)



Streamflow Gauge Location (Drainage Basin Area, km²)

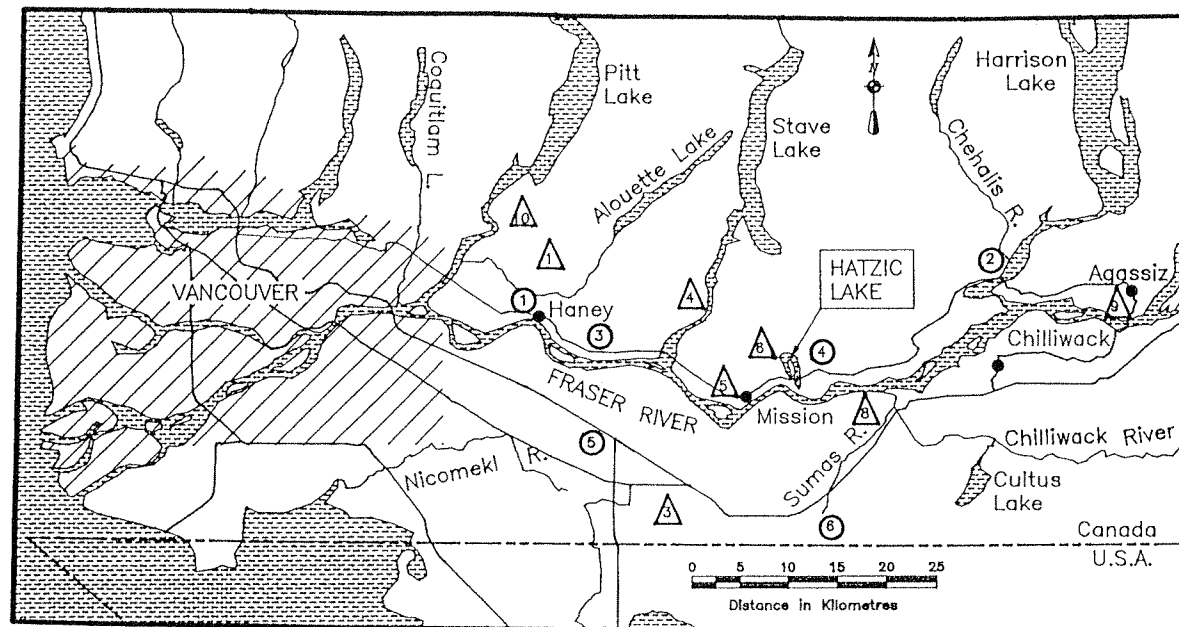
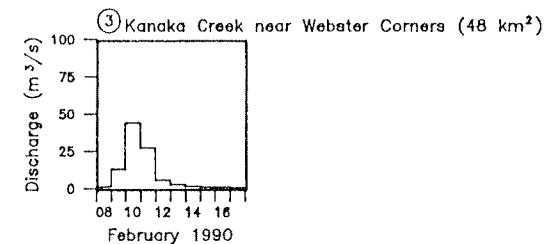
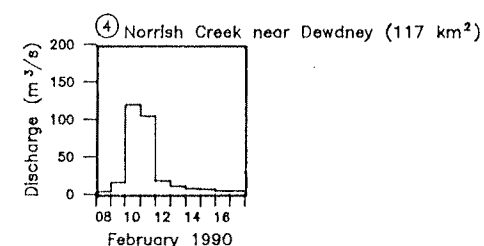


Peak Instantaneous Flow, where reported

Hatzic Prairie Study

Storm Event Data
November 1989

northwest hydraulic consultants



Recurrence Intervals: Precipitation (Annual)
(Number in brackets represent the last day of the n-day event)

Station	Return Period *				
	1-day	2-day	3-day	4-day	5-day
3 Abbotsford Airport (58 m)	<2 (10)	8 (10)	4 (11)	-	-
4 Stave Falls (55 m)	3 (9)	3 (10)	3 (10)	2 (10)	-
6 Mission W. Abbey (221 m)	2 (9)	5 (10)	8 (10)	3 (10)	-
10 Pitt Polder (2 m)	Data not available				

*based upon Log-Normal Distribution (Three parameter method of maximum likelihood)

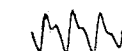
Trends

- 1) A 2-day rainfall (9-10 February) resulted in a total rainfall accumulation of between 100 and 150 mm for the given stations. Higher rainfalls occurred north of the Fraser River and further up the Fraser Valley.
- 2) The 2-day runoff (10-11 February) in Norrish and Kanaka Creeks amounted to about 170 and 130 mm respectively, possibly including some snowmelt.
- 3) Recurrence intervals are about 5 years for precipitation and about 3 years for maximum daily flows.

Hatzic Prairie

- 1) The pumps did not operate during the flooding since the level at the pumphouse was less than 8 ft (2.41 m GSC). The floodboxes operated during the storm event.
- 2) Flooding on Hatzic Prairie was caused when Lagace Creek overflowed its left bank upstream of Dale Road Bridge. The flow across the prairie was from west to east.
- 3) Lagace Creek, above Dale Road Bridge, was observed to have lost its full flow capacity, probably caused by sediment deposition during the November 1989 flood.
- 4) Backwater from Hatzic Lake was not a factor in the flooding on the prairie.

Legend:



Fraser River level at the Hatzic Pumphouse.
The river level at Mission was adjusted by +0.300 m to estimate the level at the pumphouse.



Level recorded at Hatzic Pumphouse.
Have assumed the level was recorded at noon.



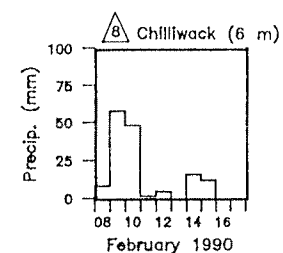
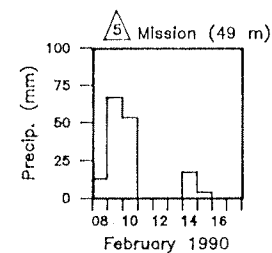
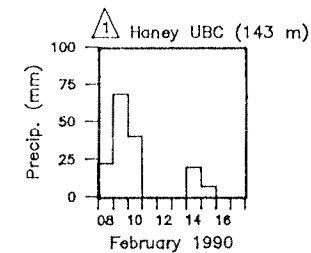
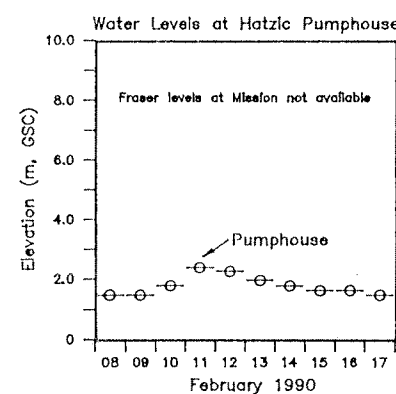
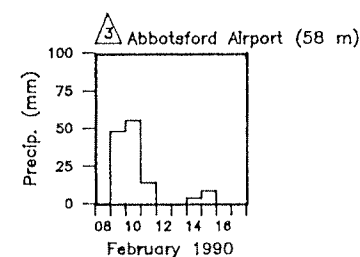
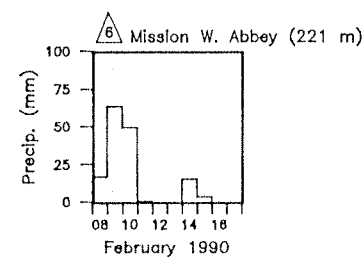
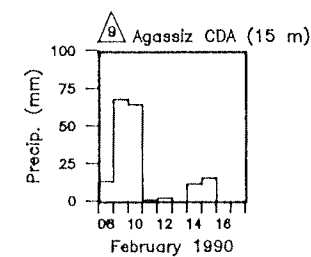
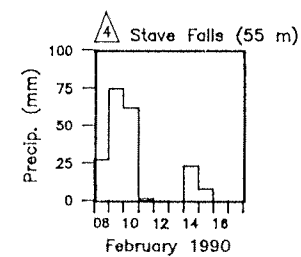
Precipitation Gauge Location (Gauge Elevation, m GSC)



Streamflow Gauge Location (Drainage Basin Area, km²)



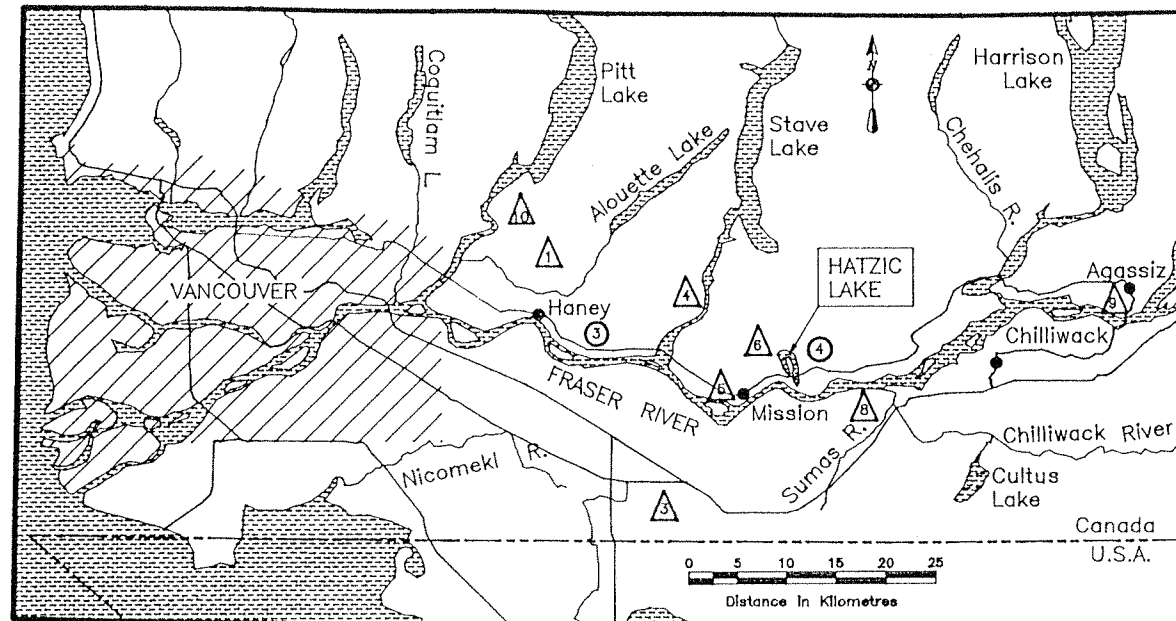
Peak Instantaneous Flow, where reported



Hatzic Prairie Study

Storm Event Data
February 1990

northwest hydraulic consultants



Recurrence Intervals: Precipitation (Annual)
(Number in brackets represent the last day of the n-day event)

Station	Return Period *				
	1-day	2-day	3-day	4-day	5-day
③ Abbotsford Airport (58 m)	10 (9)	35 (10)	20 (10)	25 (10)	9 (11)
④ Stave Falls (55 m)	25 (9)	20 (9)	30 (10)	20 (11)	20-25 (12)
⑥ Mission W. Abbey (221 m)	25 (9)	100 (9)	50 (10)	20-50 (10)	25-50 (12)
⑩ Pitt Polder (2 m)	5 (9)	5 (9)	15 (10)	10 (10)	10 (10)

*based upon Log-Normal Distribution (Three parameter method of maximum likelihood)

Trends

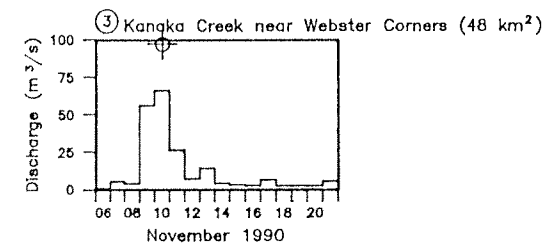
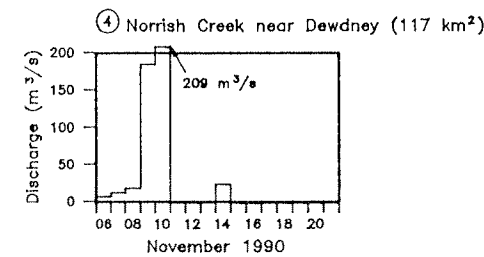
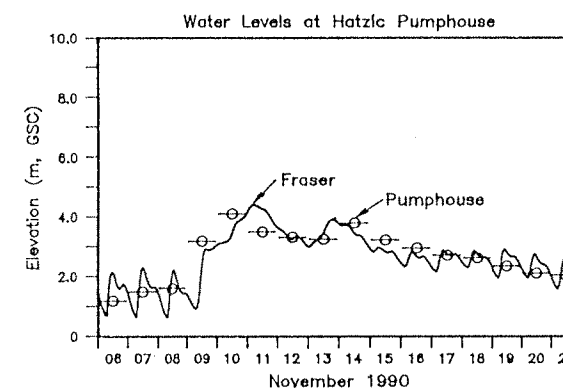
- 1) The 3-day rainfall (8-10 November) produced the highest total rainfall in the mountains north of the Fraser River. There was 260 mm of rainfall at Stave Falls, 197 mm at Mission West Abbey. These have recurrence intervals of 30 and 50 years. The 2-day recurrence interval at Mission West Abbey for 9 November was 100 years, though this value should be viewed with caution.
- 2) Maximum 2-day and 3-day rainfall at Abbotsford Airport had return periods of 35 and 20 years.
- 3) 3-day runoff in Norrish and Kanaka Creeks (8-10 November) amounted to 350 and 270 mm respectively; it is believed that runoff was augmented by snowmelt at higher levels.
- 4) Maximum daily flows in both creeks had recurrence intervals of around 15 years as annual maxima.

Hatzic Prairie

- 1) The main flooding occurred between the 9-15 November. During this period, both pumps were operating. On 10 November the level at the pumphouse reached a maximum of 13.6 ft (4.11 m GSC), the highest recorded internal flooding stage since the pumphouse was constructed in 1948. High water marks on Sward Road north of Hatzic Lake and at the Everglades were surveyed to be 4.32 m GSC and 4.26 m GSC, respectively.
- 2) Lagace Creek did not overflow its banks; however, on 10 November a debris flow from Pattison Creek broke through the right bank at the 90° bend downstream of Farms Road Bridge causing flooding west of Lagace Creek.
- 3) Heavy runoff from Dewdney peak caused flooding from east to west across Hatzic Prairie.
- 4) CPR culverts were observed to be blocked between 11-14 November, which may account for the noticeable drop in the water level at the Pumphouse on 11 November.

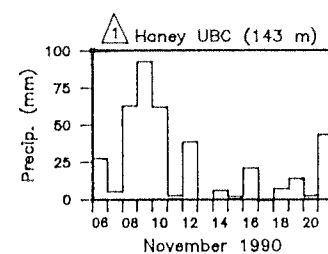
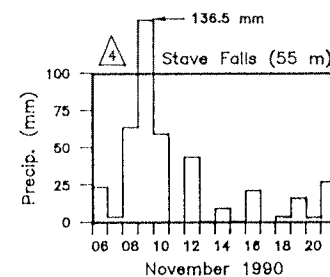
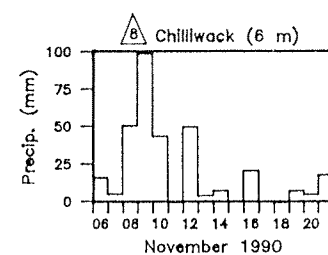
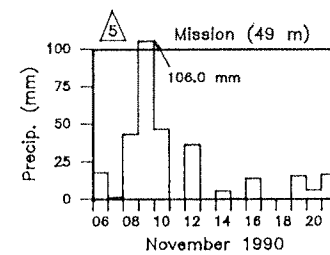
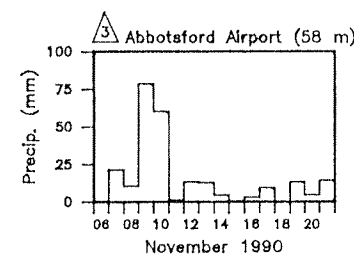
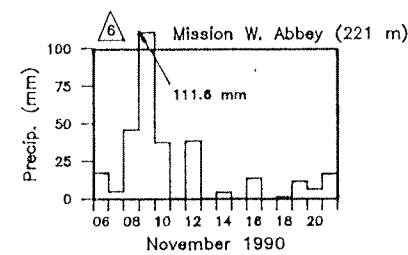
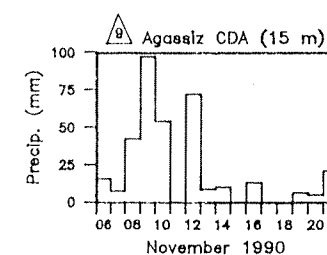
Legend:

- Fraser River level at the Hatzic Pumphouse. The river level at Mission was adjusted by +0.300 m to estimate the level at the pumphouse.
- Level recorded at Hatzic Pumphouse. Have assumed the level was recorded at noon.
- Precipitation Gauge Location (Gauge Elevation, m GSC)
- Streamflow Gauge Location (Drainage Basin Area, km²)
- Peak Instantaneous Flow, where reported



High Water Marks (surveyed)

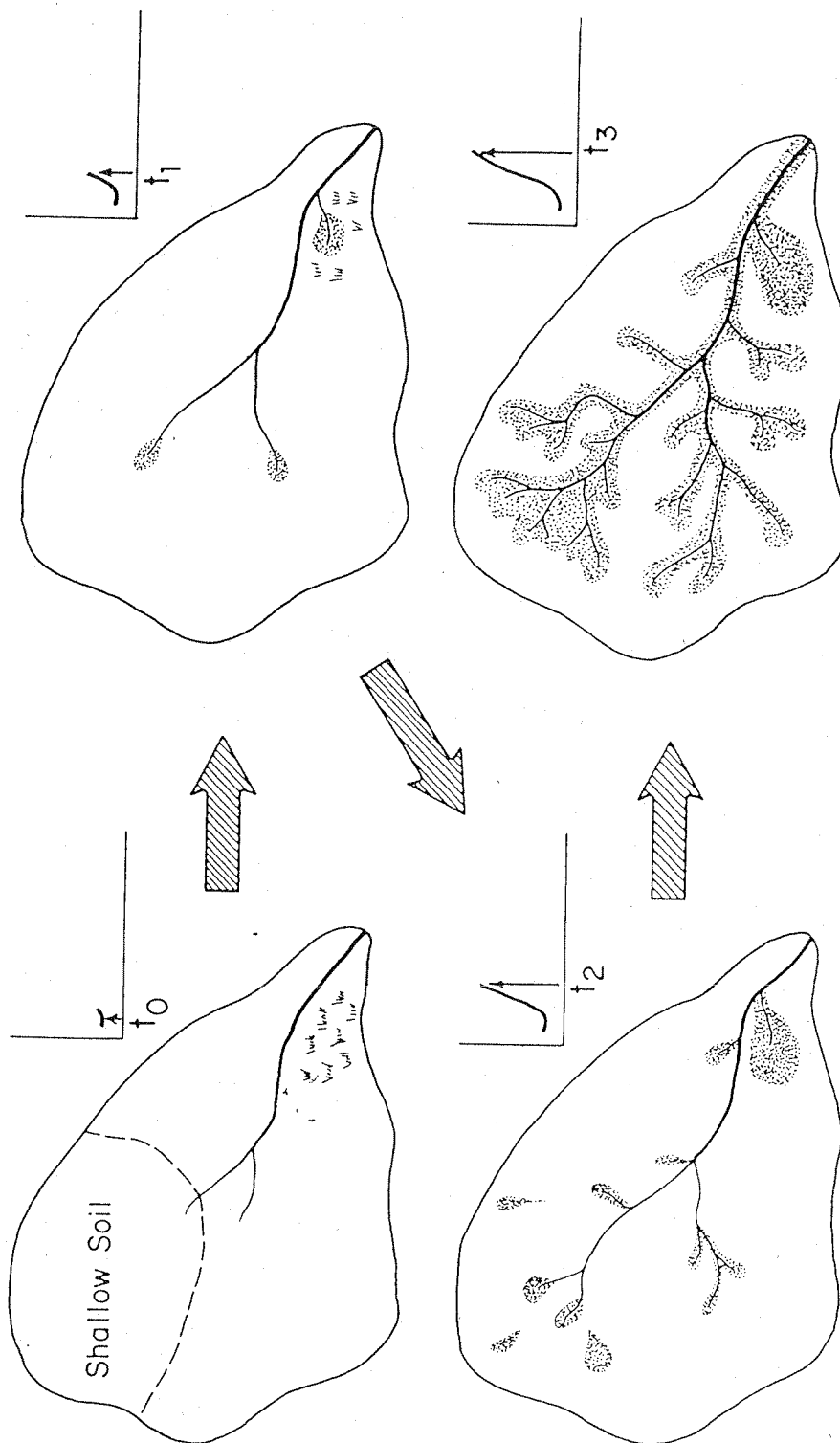
Location	Elevation (m GSC)
South tip of Hatzic Island (Everglades)	4.254 m GSC
Sward Road (North end of Hatzic Lake)	4.318 m GSC
Pumphouse gauge	4.115 m GSC
F. Leuzinger house (near 2nd Farms Road Bridge)	4.256 m GSC (house) 4.115 m GSC (fence)



Hatzic Prairie Study

Storm Event Data
November 1990

northwest hydraulic consultants



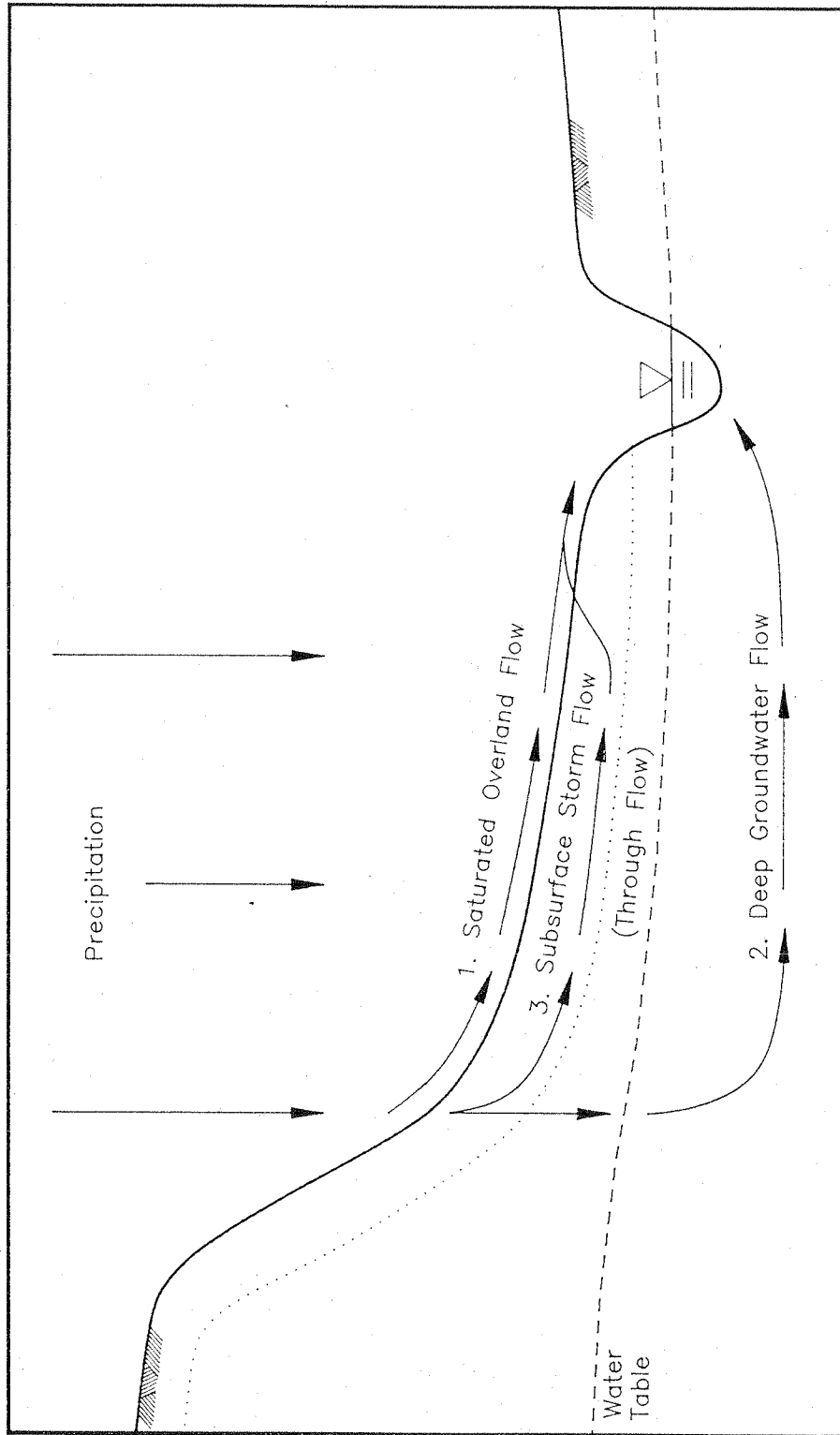
Notes:

1. The small arrows in the hydrographs show how streamflow increases as the variable source extends into swamps, shallow soils and ephemeral channels. The process reverses as streamflow declines.
2. After Hewlett, 1982.

Hatzic Prairie Study

Concept of Variable Source Area
during Storms

northwest hydraulic consultants



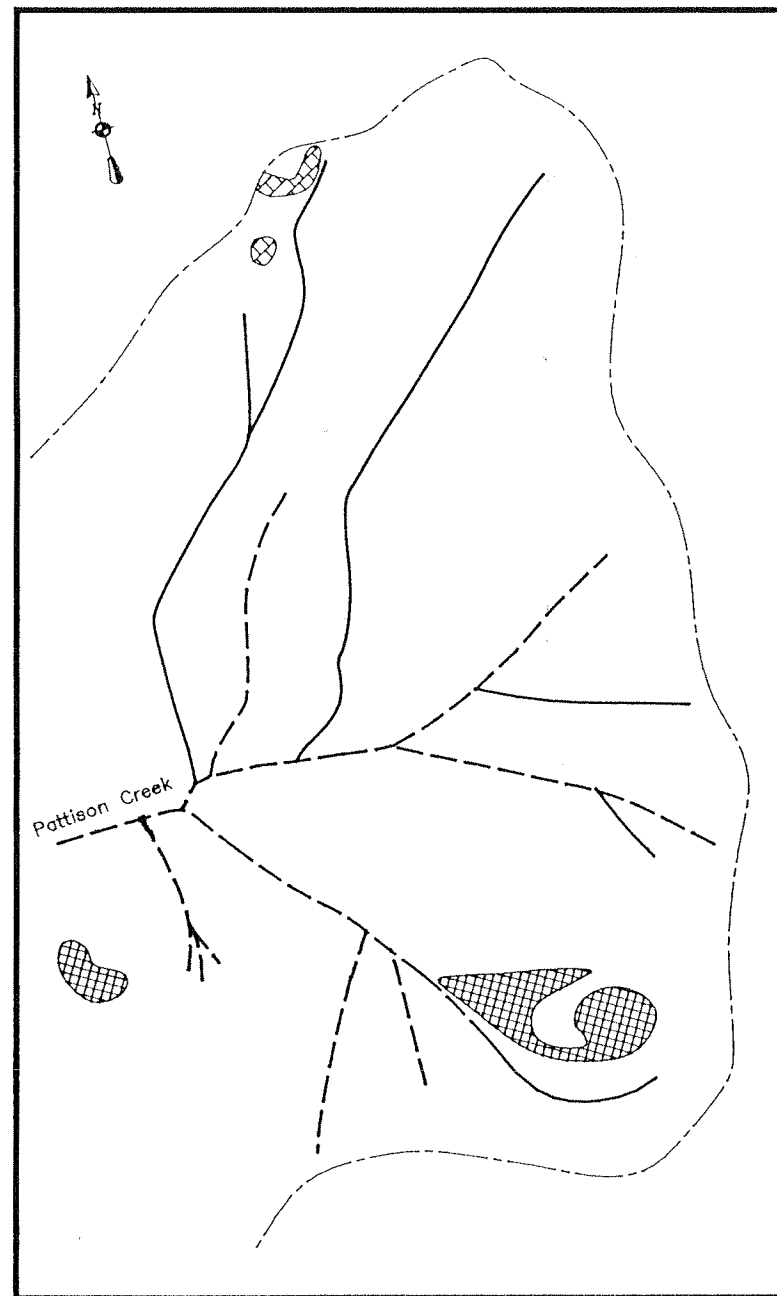
PATHS OF RUNOFF
(after Dunne, 1982)

Hatzic Prairie Study

Concepts of Runoff
during Storms

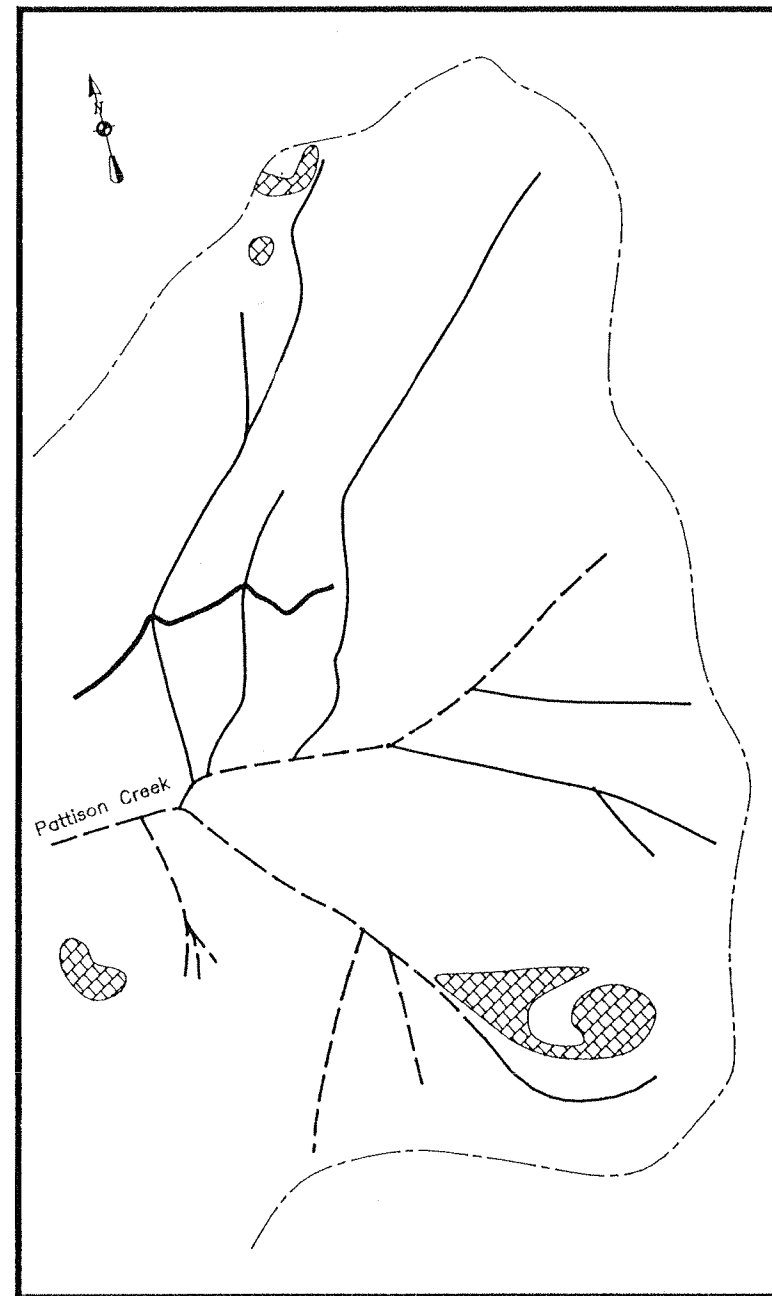
northwest hydraulic consultants

15 July, 1940



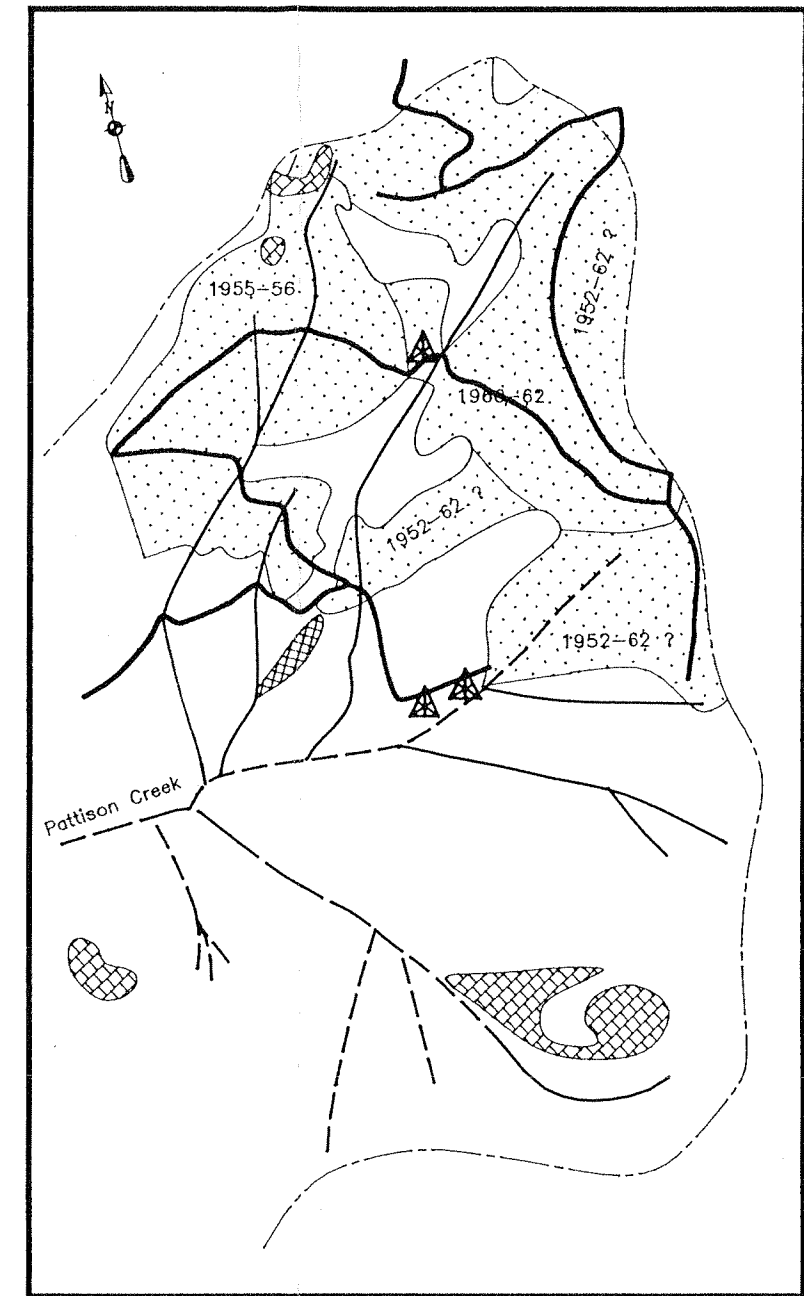
From air photos BC203 (#110-113), BC204(#5-8)

01-02 October, 1952



From air photos BC1621 (#44-45, 66-68)

21 July, 1962



From air photos BC4067 (#211-214)

Notes:

Maps are schematic..

Scale is approximately 1:17,000.

Legend:

- Stable stream
- - - - Torrented stream
- Logging road
- - - - Drainage basin boundary



Cut block with year of cutting



Active Slide



Scree slope



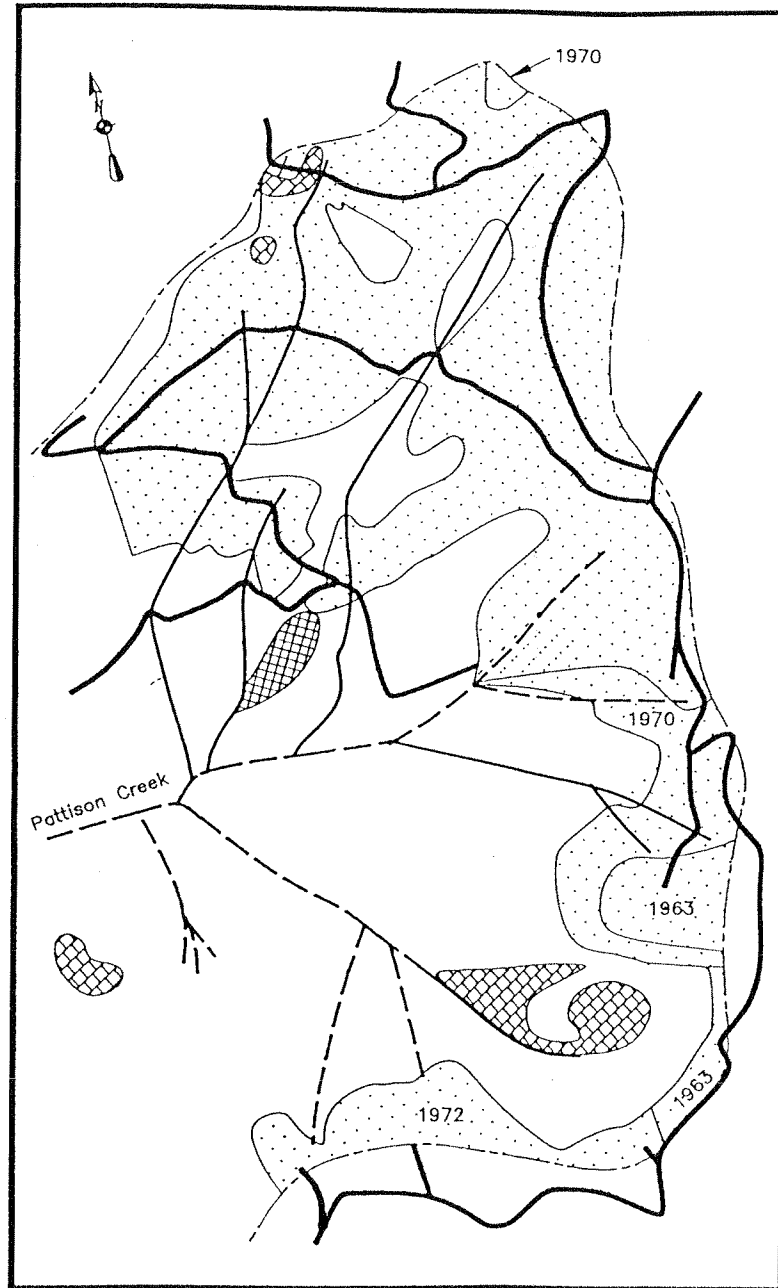
Unstable cut-bank or fill-slope

Hatzic Prairie Study

Historical Forestry, 1940-1962
Pattison Creek Basin

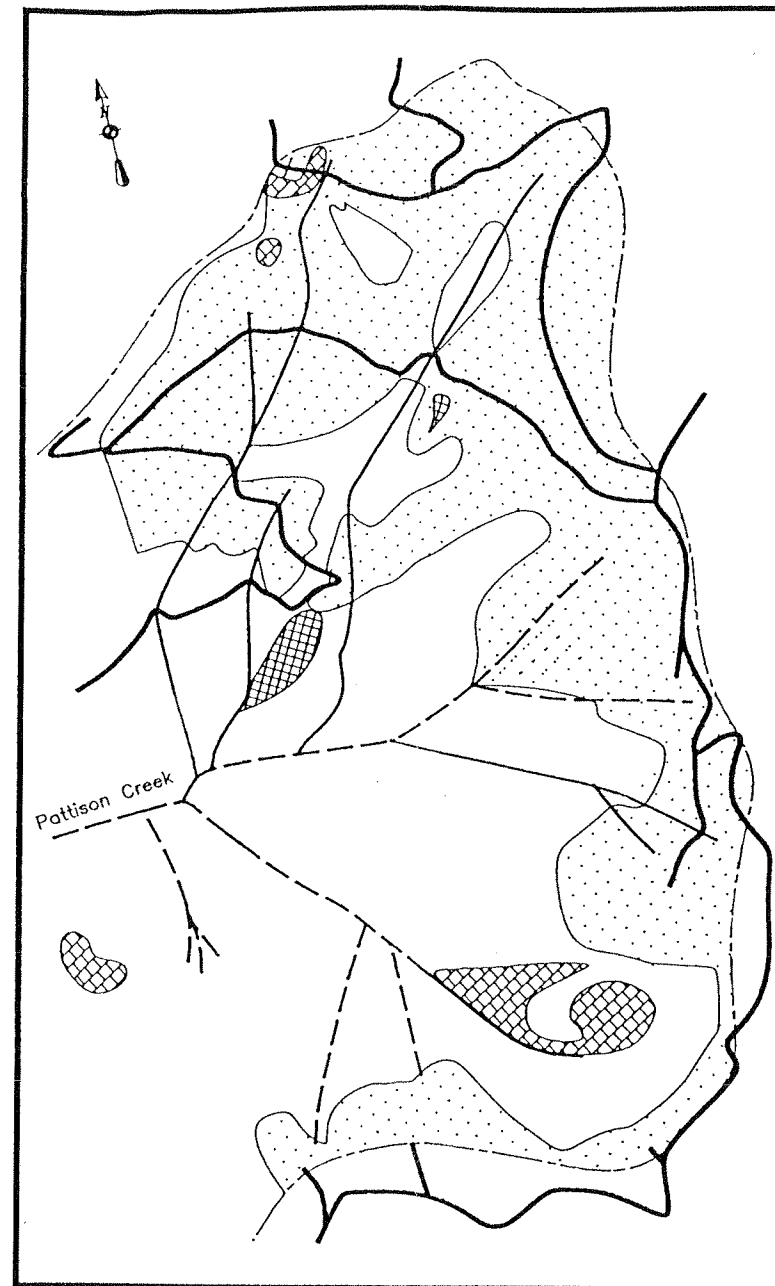
northwest hydraulic consultants

31 May, 1974



From air photos BC5580 (#42-45, 90-93)

20,28 September, 1983



From air photos BC83057 (#124-125), BC83058 (#202-203)

11 November, 1990



From NHC reconnaissance photos

Notes:

Maps are schematic..

Scale is approximately 1:17,000.

Legend:

- Stable stream
- - - Torrented stream
- Logging road
- - - Drainage basin boundary

1962 Cut block with year of cutting

Active Slide

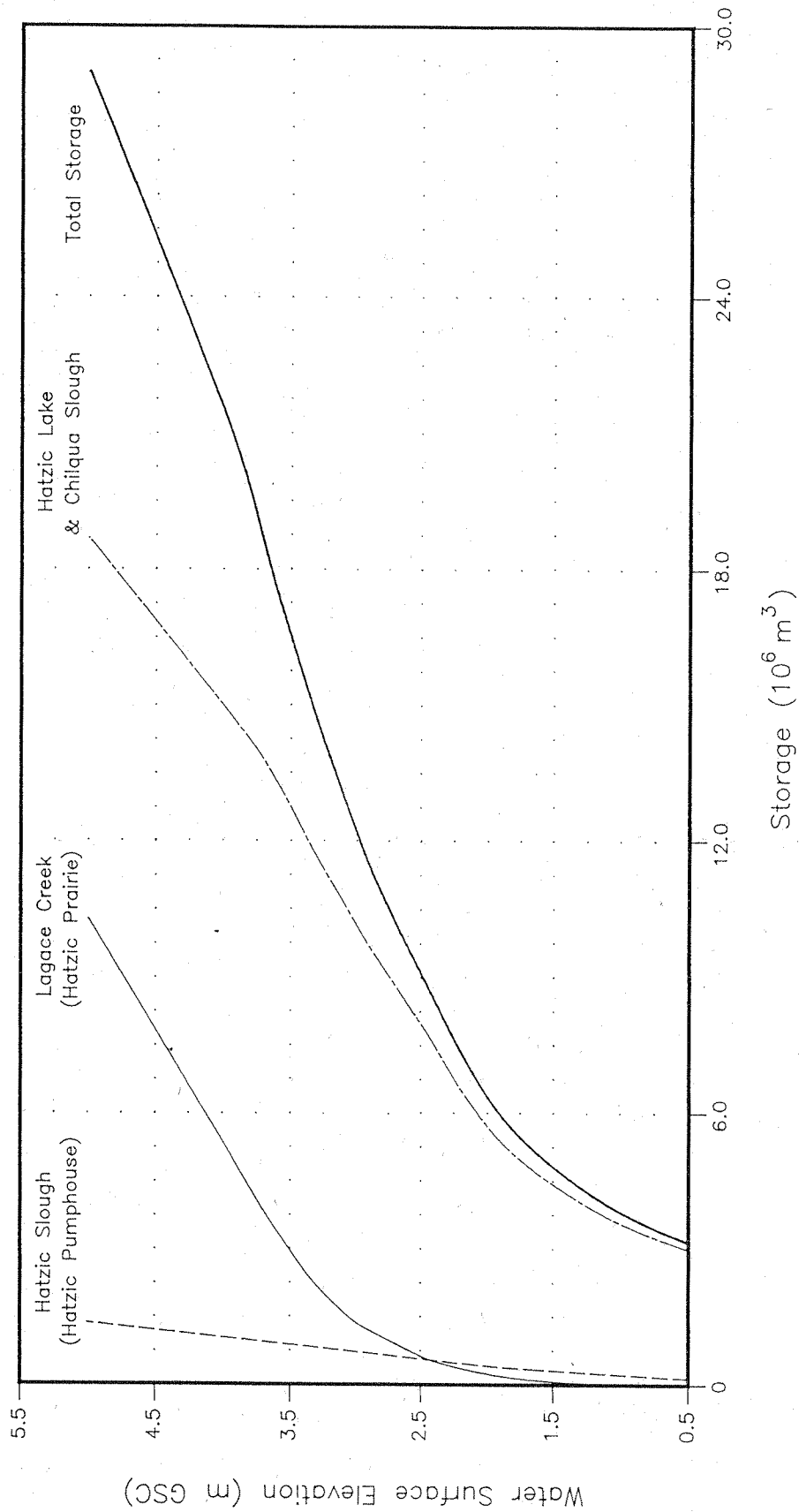
Scree slope

Unstable cut-bank or fill-slope

Hatzic Prairie Study

Historical Forestry, 1974-1991
Pattison Creek Basin

northwest hydraulic consultants



Notes:

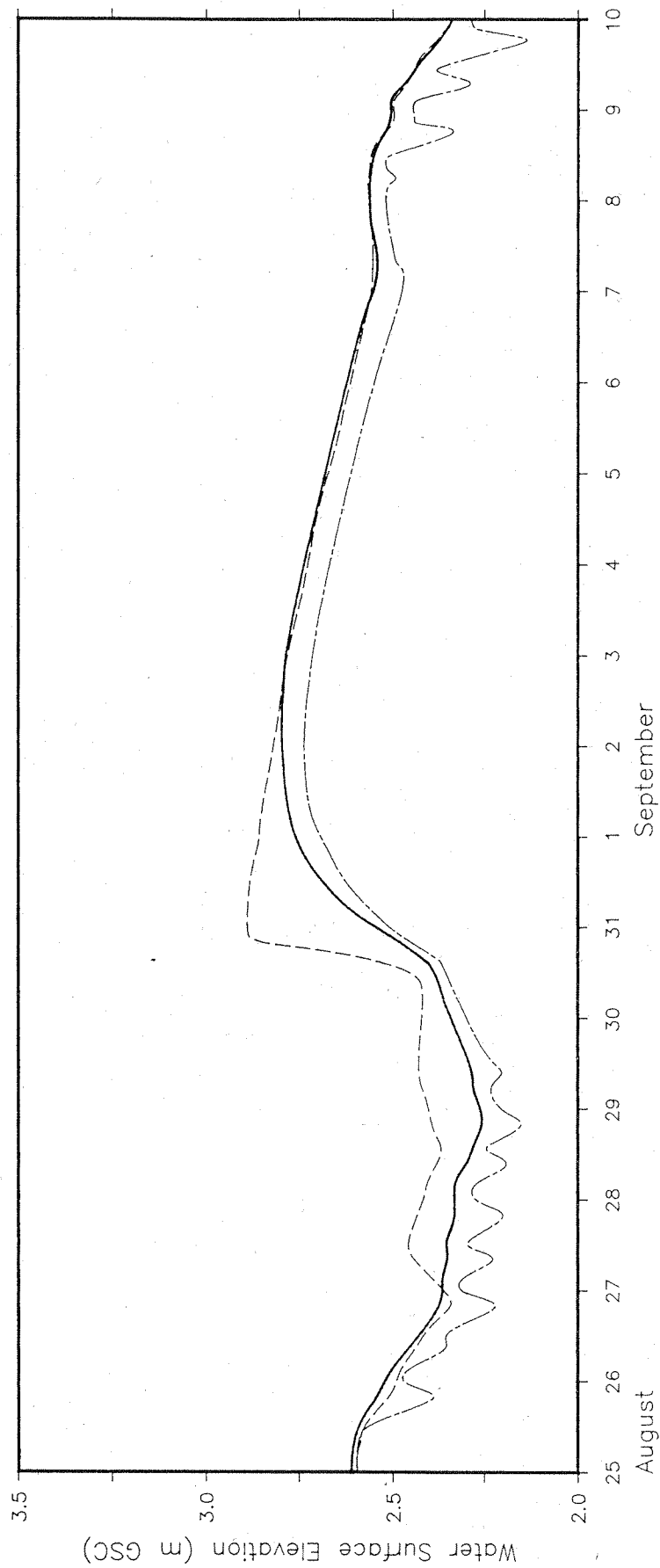
- 1) The storage curves are shown as the total volume for each region.

Hatzic Prairie Study

Storage Curves

NHCv1692-960

northwest hydraulic consultants



Legend:

- Lagace Creek at Dale Road Bridge
- Shook Road Bridge (Hatzic Lake level)
- .- Pumphouse

Notes:

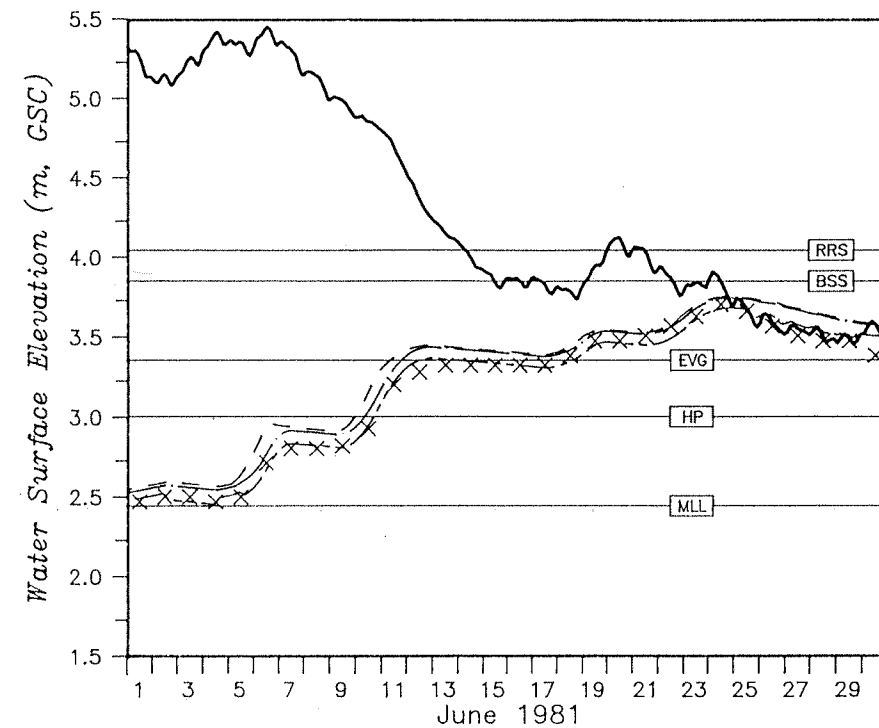
Water levels recorded using the water level recorders installed by NHC in July 1991.

Hatzic Prairie Study

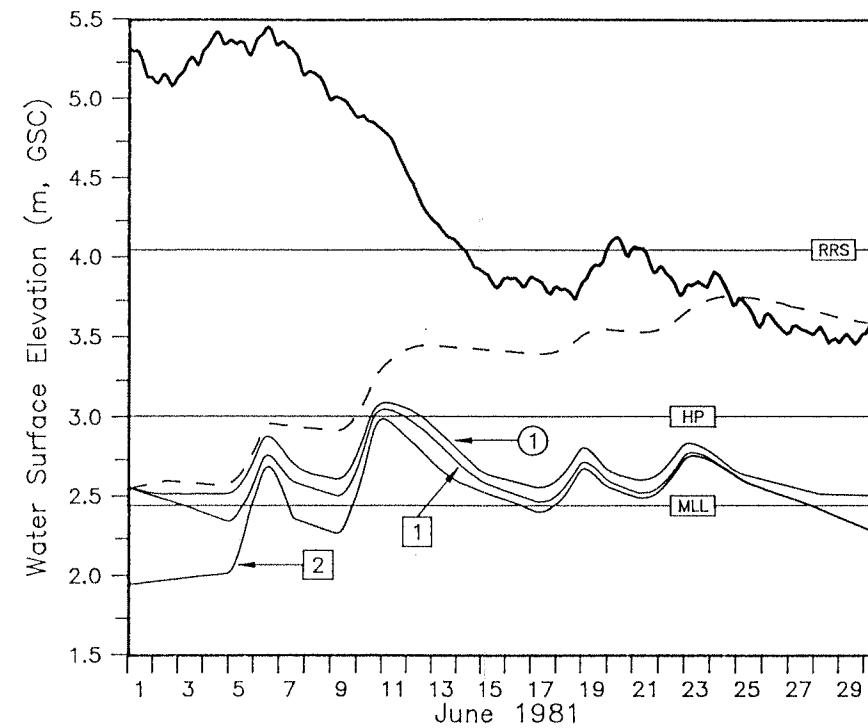
Recorded Water Levels
August/September 1991

northwest hydraulic consultants

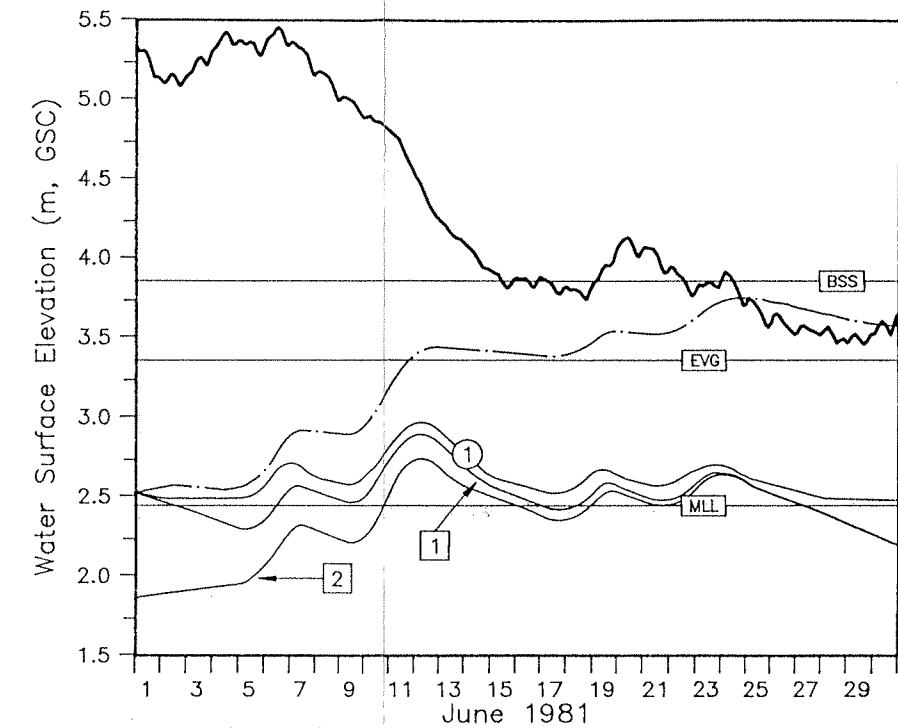
Calculated Water Surface Elevations
Existing Conditions



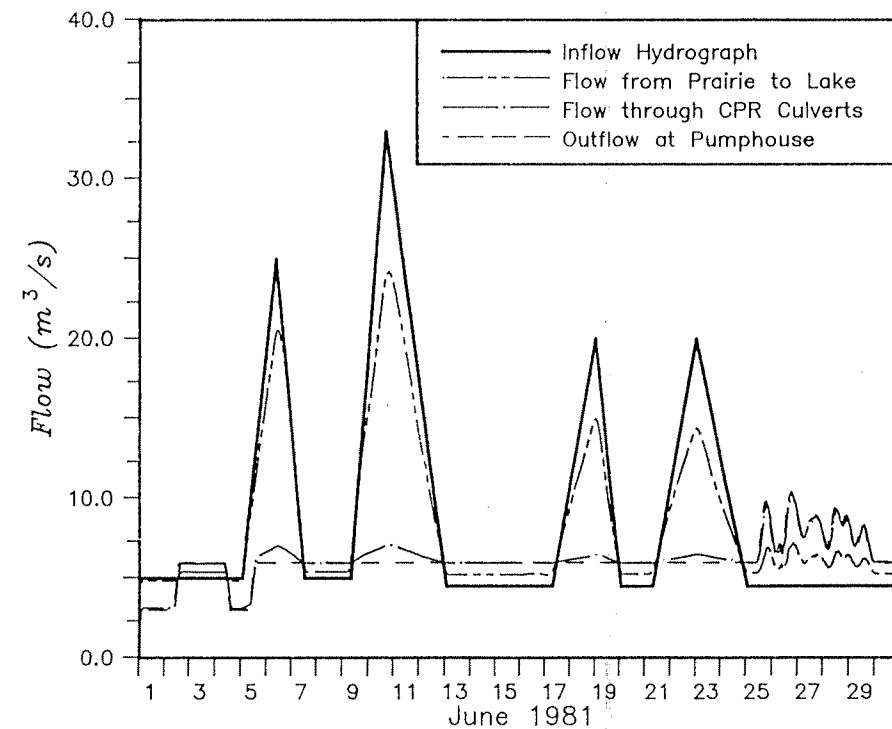
Predicted Water Surface Elevations
Lagace Creek at Dale Road Bridge



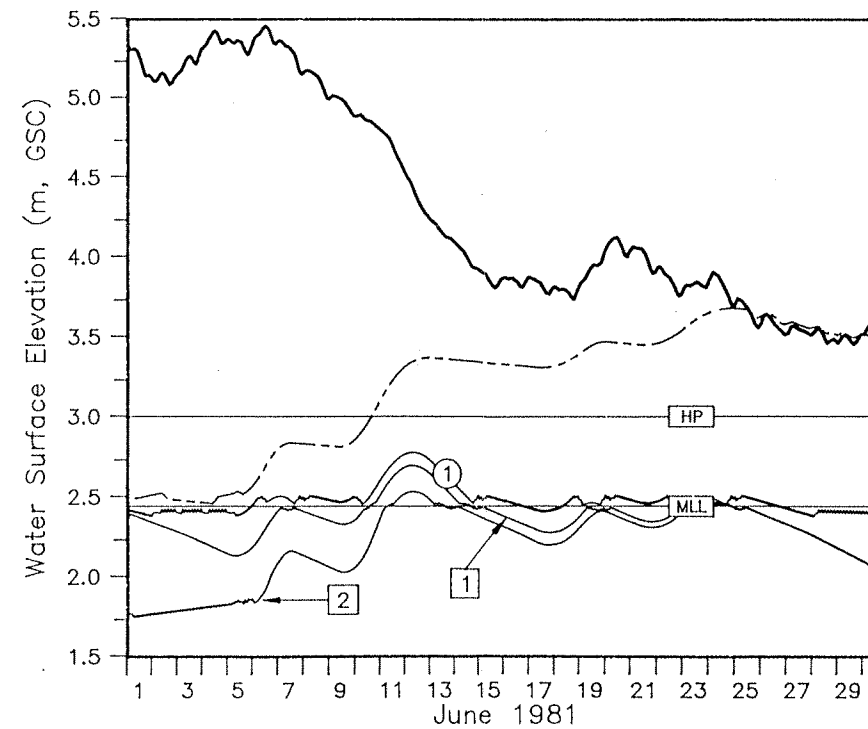
Predicted Water Surface Elevations
Hatzic Lake



Inflow Hydrograph & Flows
Existing Conditions



Predicted Water Surface Elevations
Hatzic Pumphouse



Legend:

- Estimated Fraser River level at Hatzic Pumphouse
- - - Calculated Water surface elevation of Lagace Creek at Dale Road Bridge for EXISTING CONDITIONS
- . - Calculated water surface elevation of Hatzic Lake for EXISTING CONDITIONS
- . - Calculated water surface elevation at Hatzic Pumphouse for EXISTING CONDITIONS
- x Observed water surface elevation at Hatzic Pumphouse (as recorded in the Pumplogs)
- ① Water surface elevation for EXISTING CONDITIONS with ADDITIONAL PUMPS.
- ① Water surface elevation for EXISTING CONDITIONS with ADDITIONAL PUMPS. Additional pumps operating for levels above 1.8 m GSC and existing pumps operating for levels above 2.41 m GSC. Initial level at pumphouse as recorded for the storm.
- ② Water surface elevation for EXISTING CONDITIONS with ADDITIONAL PUMPS. Additional pumps operating for levels above 1.8 m GSC and existing pumps operating for levels above 2.41 m GSC. Initial level at pumphouse set at 1.80 m GSC
- RRS Riverside Rd. Subdivision - Flooding above 4.04 m GSC
- BSS Benbow St. Subdivision - Flooding above 3.85 m GSC
- EVG Everglades - Flooding above 3.353 m GSC (Historical Flood Level)
- HP Hatzic Prairie - Flooding above 3.00 m GSC near Dale Rd. and Farms Rd.
- MLL Mean Lake Level

Notes:

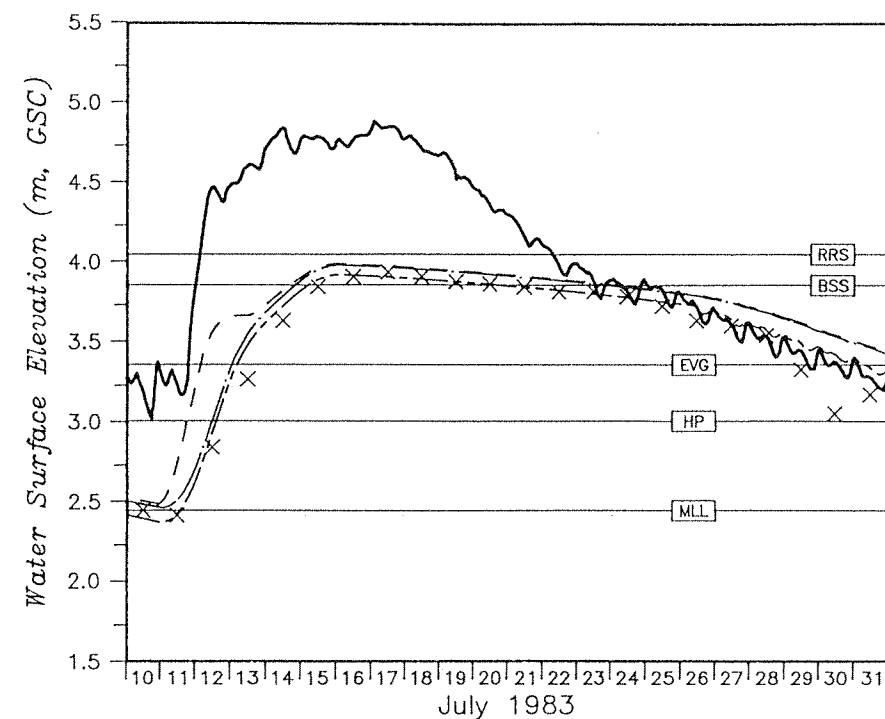
- 1) ADDITIONAL PUMPS - additional pump capacity of 8.34 m³/s.
- 2) Mean lake level - 2.438 m GSC (8 ft).
- 3) Historical flood level - 3.353 m GSC (11 ft) - Flooding of the Everglades and 270 hectares (670 acres) on Hatzic Prairie.

Hatzic Prairie Study

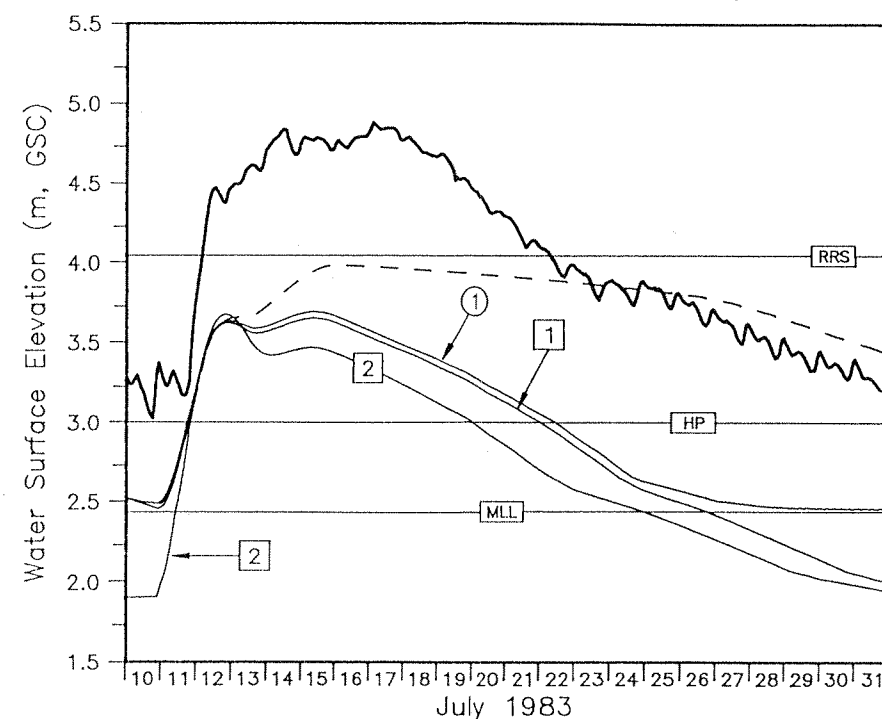
Forward Flood Routing
June 1981

northwest hydraulic consultants

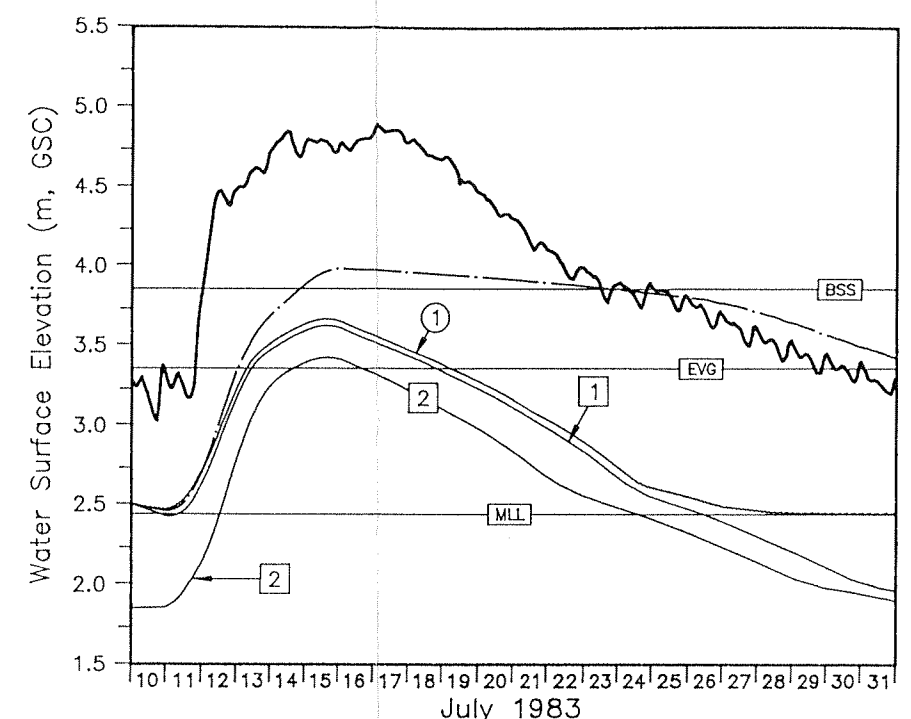
Calculated Water Surface Elevations
Existing Conditions



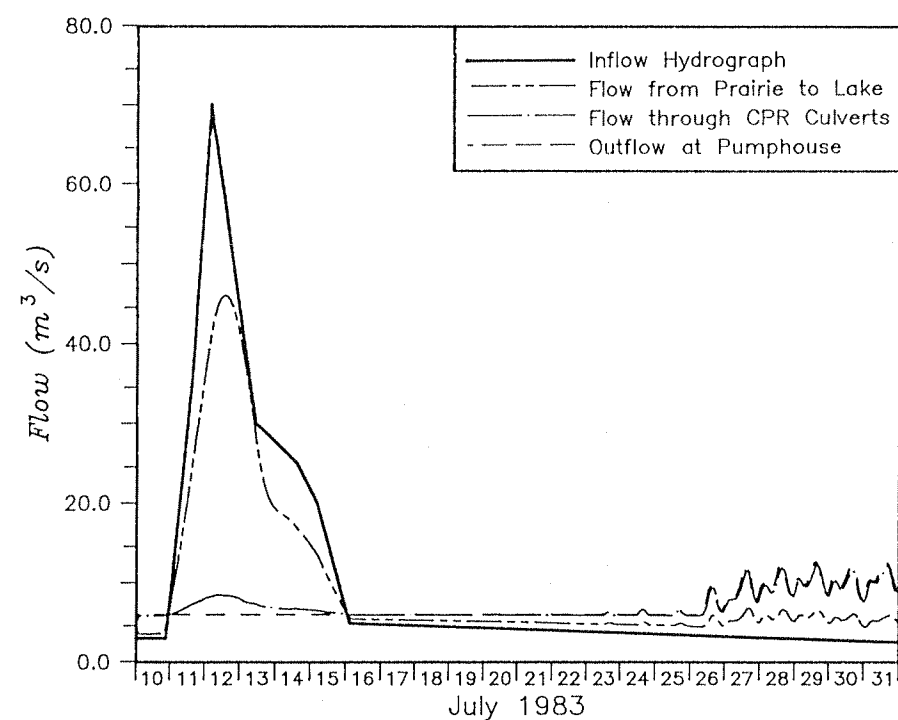
Predicted Water Surface Elevations
Lagace Creek at Dale Road Bridge



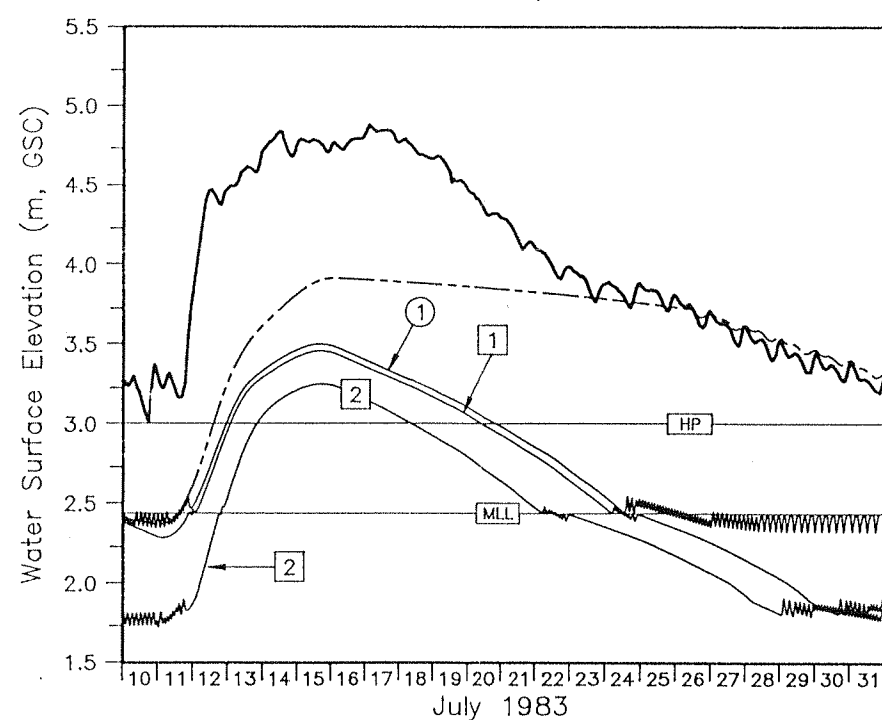
Predicted Water Surface Elevations
Hatzic Lake



Inflow Hydrograph & Flows
Existing Conditions



Predicted Water Surface Elevations
Hatzic Pumpouse



Legend:

- Estimated Fraser River level at Hatzic Pumpouse
- - - - - Calculated Water surface elevation of Lagace Creek at Dale Road Bridge for EXISTING CONDITIONS
- - - - - Calculated water surface elevation of Hatzic Lake for EXISTING CONDITIONS
- - - - - Calculated water surface elevation at Hatzic Pumpouse for EXISTING CONDITIONS
- x Observed water surface elevation at Hatzic Pumpouse (as recorded in the Pumplogs)
- ① Water surface elevation for EXISTING CONDITIONS with ADDITIONAL PUMPS. Additional pumps operating for levels above 1.8 m GSC and existing pumps operating for levels above 2.41 m GSC. Initial level at pumpouse as recorded for the storm.
- 1 Water surface elevation for EXISTING CONDITIONS with ADDITIONAL PUMPS. Additional pumps operating for levels above 1.8 m GSC and existing pumps operating for levels above 2.41 m GSC. Initial level at pumpouse set at 1.80 m GSC
- 2 Water surface elevation for EXISTING CONDITIONS with ADDITIONAL PUMPS. Additional pumps operating for levels above 1.8 m GSC and existing pumps operating for levels above 2.41 m GSC. Initial level at pumpouse set at 1.80 m GSC
- RRS Riverside Rd. Subdivision - Flooding above 4.04 m GSC
- BSS Benbow St. Subdivision - Flooding above 3.85 m GSC
- EVG Everglades - Flooding above 3.353 m GSC (Historical Flood Level)
- HP Hatzic Prairie - Flooding above 3.00 m GSC near Dale Rd. and Farms Rd.
- MLL Mean Lake Level

Notes:

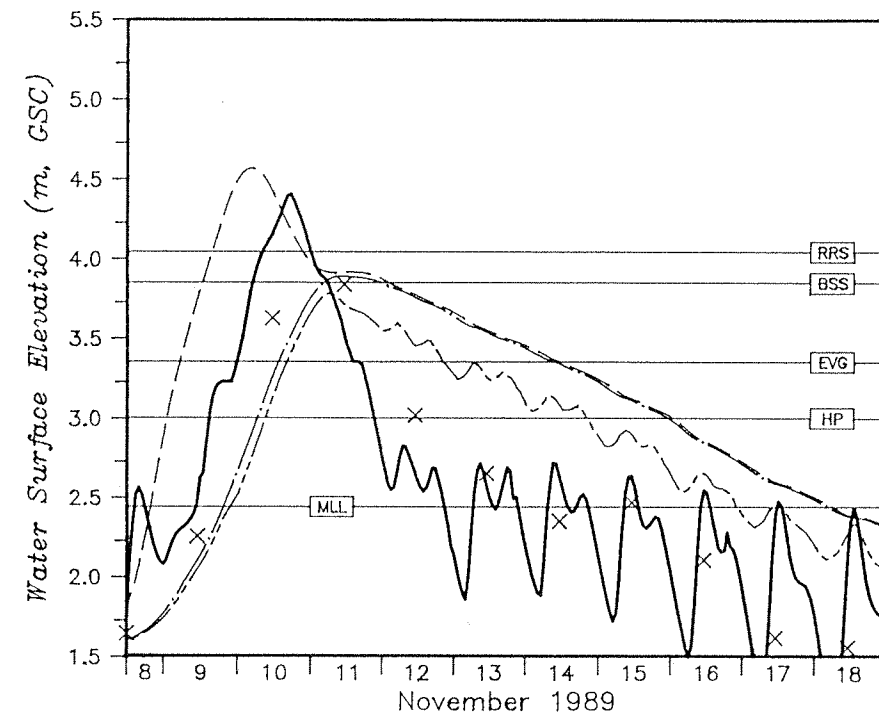
- 1) ADDITIONAL PUMPS - additional pump capacity of 8.34 m³/s.
- 2) Mean lake level - 2.438 m GSC (8 ft).
- 3) Historical flood level - 3.353 m GSC (11 ft) - Flooding of the Everglades and 270 hectares (670 acres) on Hatzic Prairie.

Hatzic Prairie Study

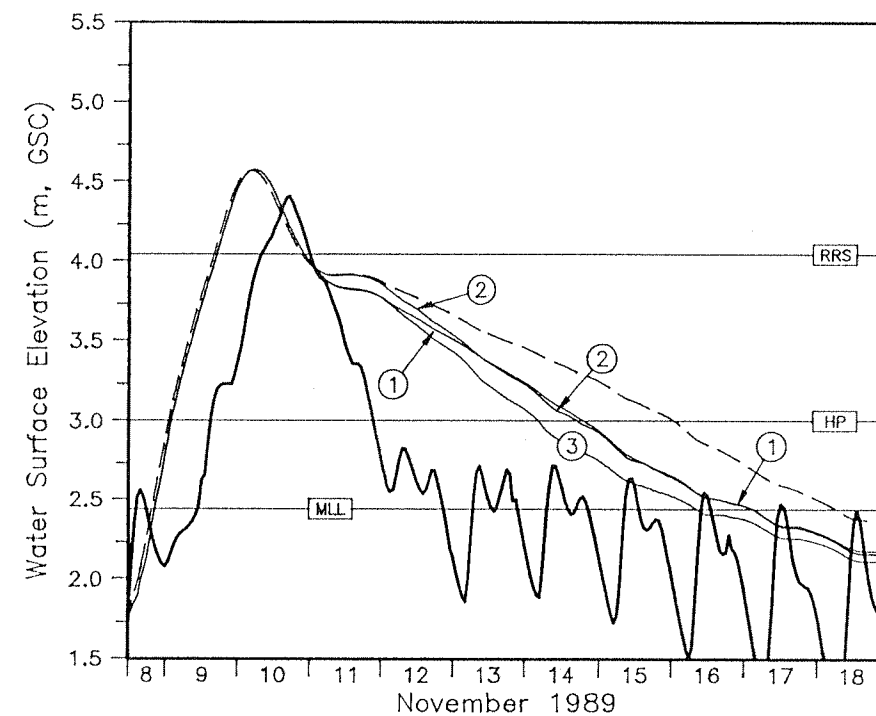
Forward Flood Routing
July 1983

northwest hydraulic consultants

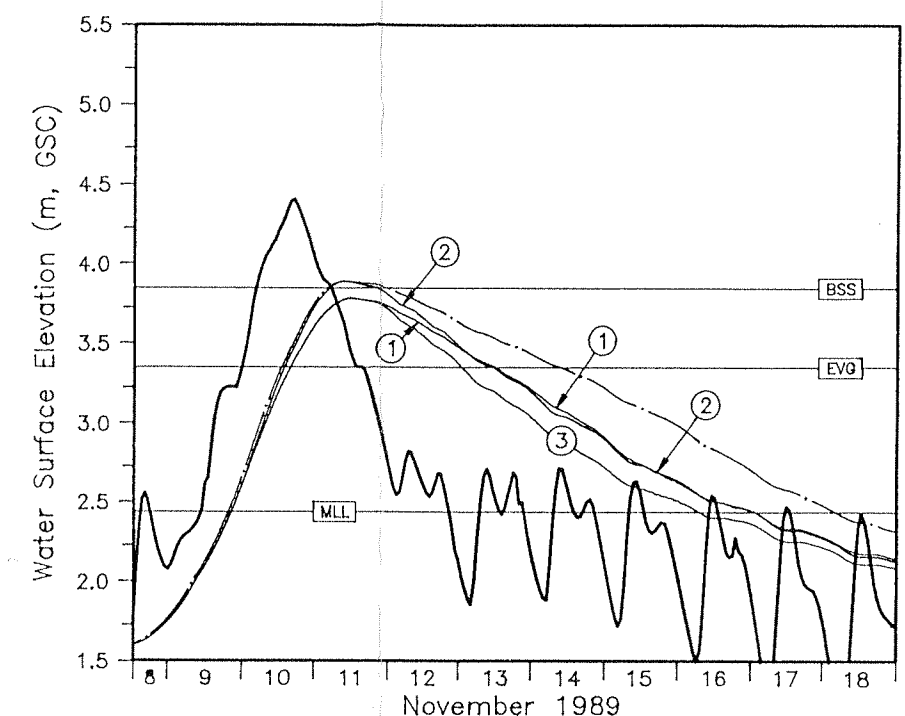
Calculated Water Surface Elevations
Existing Conditions



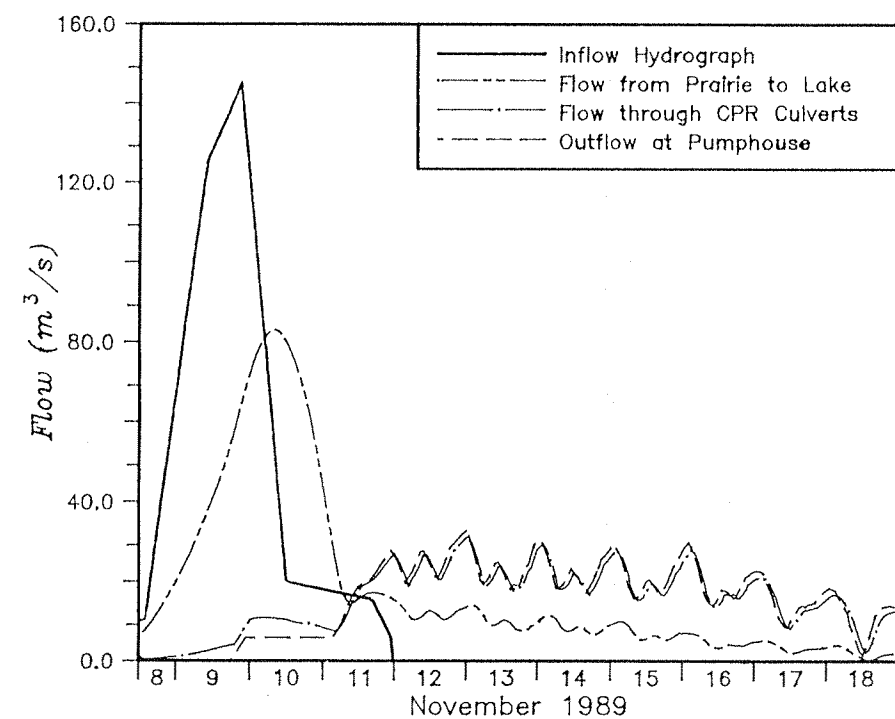
Predicted Water Surface Elevations
Lagace Creek at Dale Road Bridge



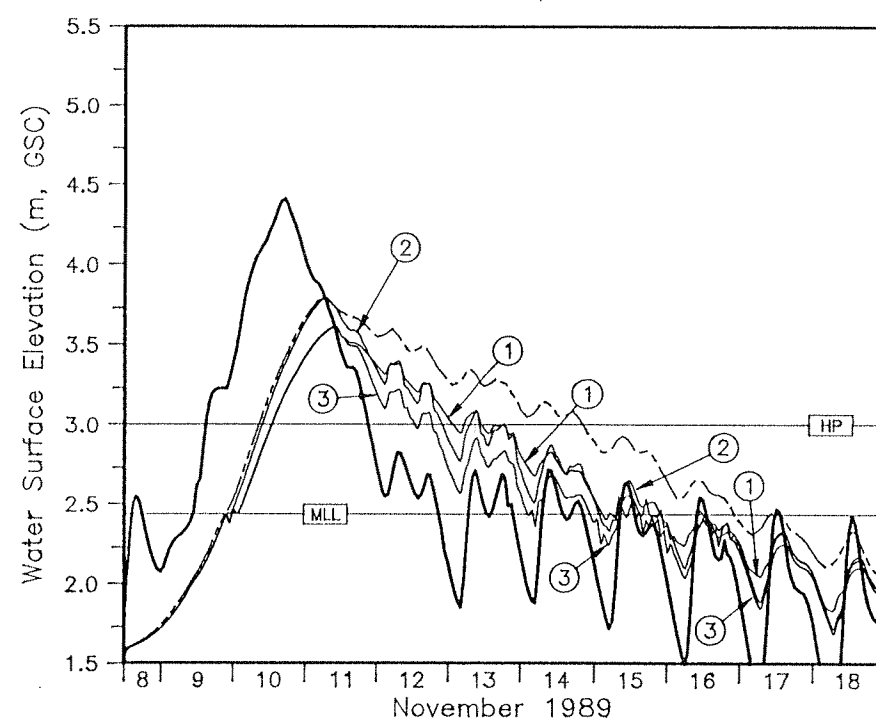
Predicted Water Surface Elevations
Hatzic Lake



Inflow Hydrograph & Flows
Existing Conditions



Predicted Water Surface Elevations
Hatzic Pumpphouse



Legend:

- Estimated Fraser River level at Hatzic Pumpphouse
- - - Calculated Water surface elevation of Lagace Creek at Dale Road Bridge for EXISTING CONDITIONS
- ... Calculated water surface elevation of Hatzic Lake for EXISTING CONDITIONS
- . - Calculated water surface elevation at Hatzic Pumpphouse for EXISTING CONDITIONS
- X Observed water surface elevation at Hatzic Pumpphouse (as recorded in the Pumplogs)
- ① Water surface elevation for EXISTING CONDITIONS with ADDITIONAL PUMPS.
- ② Water surface elevation for EXISTING CONDITIONS with ADDITIONAL FLOODBOXES and ADDITIONAL CPR CULVERTS
- ③ Water surface elevation for EXISTING CONDITIONS with ADDITIONAL FLOODBOXES, ADDITIONAL CPR CULVERTS, and ADDITIONAL PUMPS
- RRS Riverside Rd. Subdivision - Flooding above 4.04 m GSC
- BSS Benbow St. Subdivision - Flooding above 3.85 m GSC
- EVG Everglades - Flooding above 3.353 m GSC (Historical Flood Level)
- HP Hatzic Prairie - Flooding above 3.00 m GSC near Dale Rd. and Farms Rd.
- MLL Mean Lake Level

Notes:

- 1) ADDITIONAL PUMPS - additional pump capacity of 8.34 m³/s.
- 2) ADDITIONAL FLOODBOXES - four additional 1.829 m by 1.829 m (6 ft by 6 ft) floodboxes at Hatzic Pumpphouse.

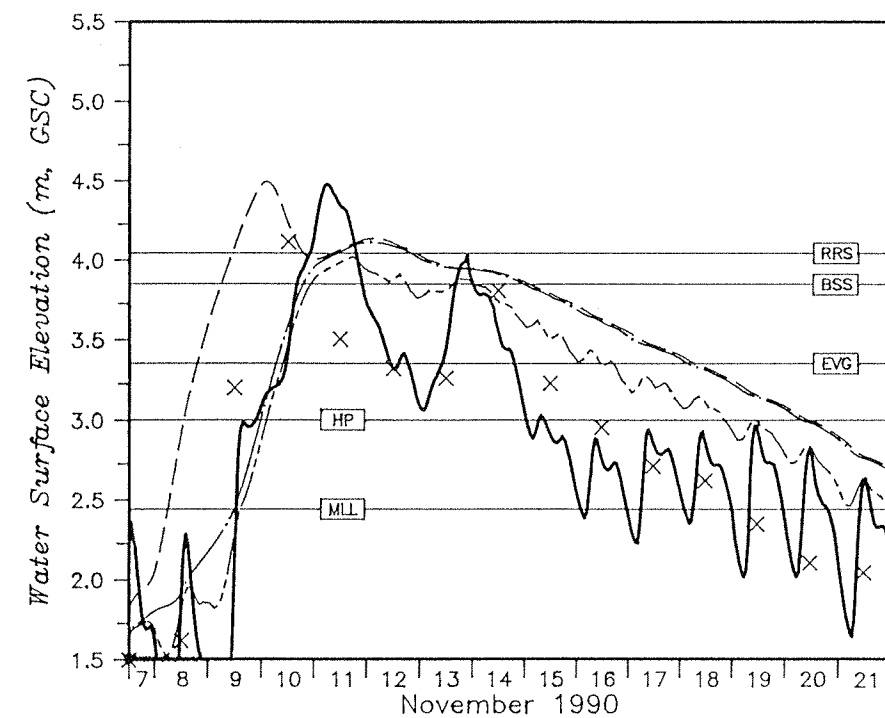
- 3) ADDITIONAL CULVERTS - two additional 3 m culverts at the CPR crossing.
- 4) Mean lake level - 2.438 m GSC (8 ft).
- 5) Historical flood level - 3.353 m GSC (11 ft) - Flooding of the Everglades and 270 hectares (670 acres) on Hatzic Prairie.

Hatzic Prairie Study

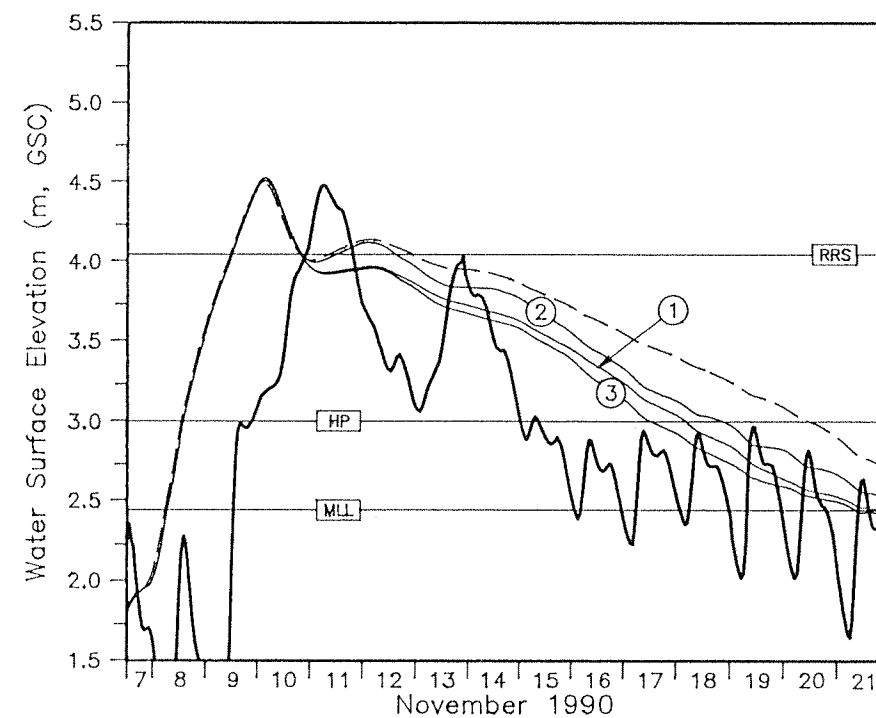
Forward Flood Routing
November 1989

northwest hydraulic consultants

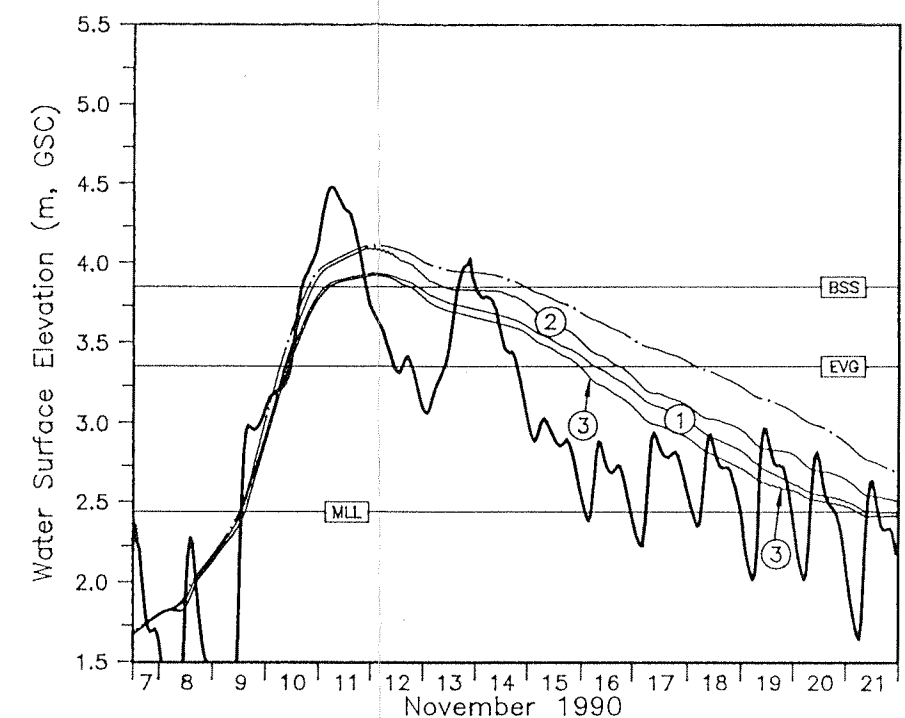
Calculated Water Surface Elevations
Existing Conditions



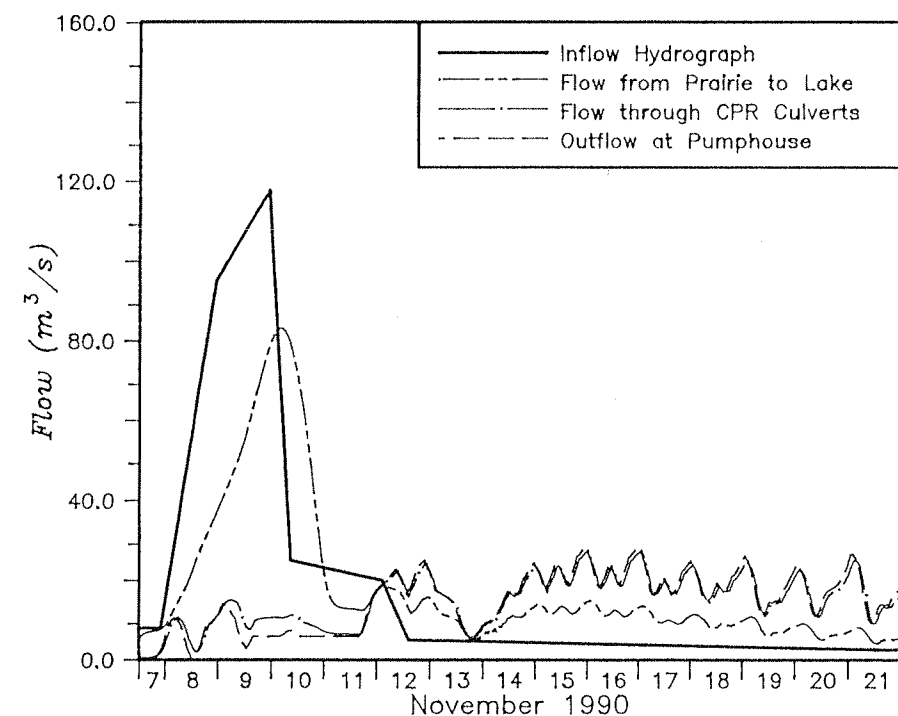
Predicted Water Surface Elevations
Lagace Creek at Dale Road Bridge



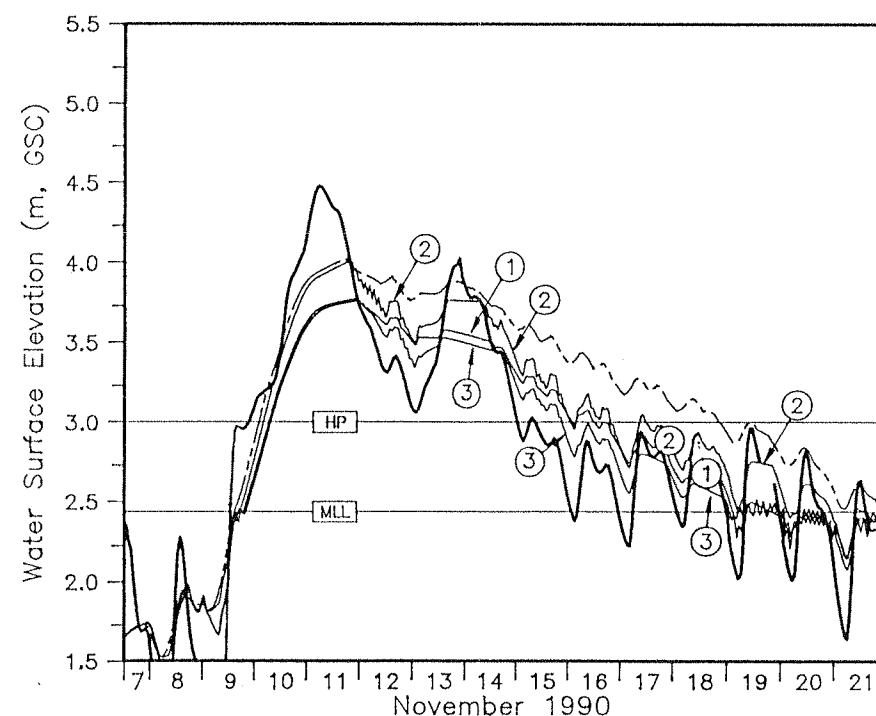
Predicted Water Surface Elevations
Hatzic Lake



Inflow Hydrograph & Flows
Existing Conditions



Predicted Water Surface Elevations
Hatzic Pumphouse



Legend:

- Estimated Fraser River level at Hatzic Pumphouse
- - - Calculated Water surface elevation of Lagace Creek at Dale Road Bridge for EXISTING CONDITIONS
- ... Calculated water surface elevation of Hatzic Lake for EXISTING CONDITIONS
- . - Calculated water surface elevation at Hatzic Pumphouse for EXISTING CONDITIONS
- X Observed water surface elevation at Hatzic Pumphouse (as recorded in the Pumplogs)
- ① Water surface elevation for EXISTING CONDITIONS with ADDITIONAL PUMPS.
- ② Water surface elevation for EXISTING CONDITIONS with ADDITIONAL FLOODBOXES and ADDITIONAL CPR CULVERTS
- ③ Water surface elevation for EXISTING CONDITIONS with ADDITIONAL FLOODBOXES, ADDITIONAL CPR CULVERTS, and ADDITIONAL PUMPS
- RRS Riverside Rd. Subdivision - Flooding above 4.04 m GSC
- BSS Benbow St. Subdivision - Flooding above 3.85 m GSC
- EVG Everglades - Flooding above 3.353 m GSC (Historical Flood Level)
- HP Hatzic Prairie - Flooding above 3.00 m GSC near Dale Rd. and Farms Rd.
- MLL Mean Lake Level

Notes:

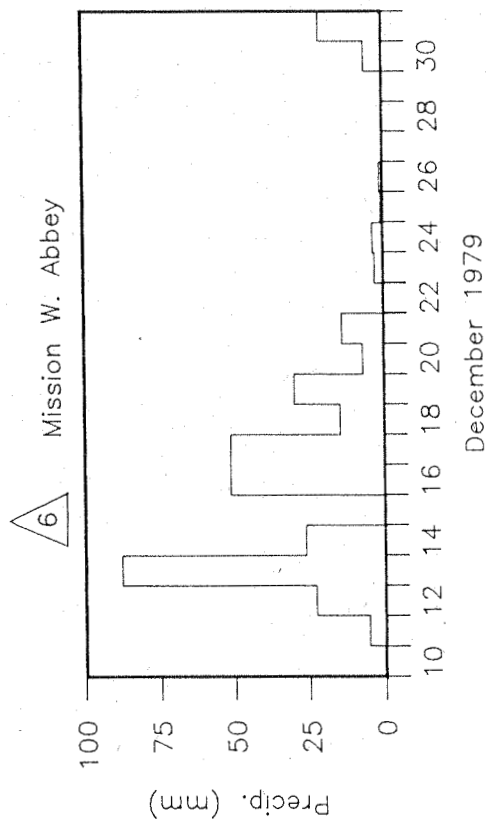
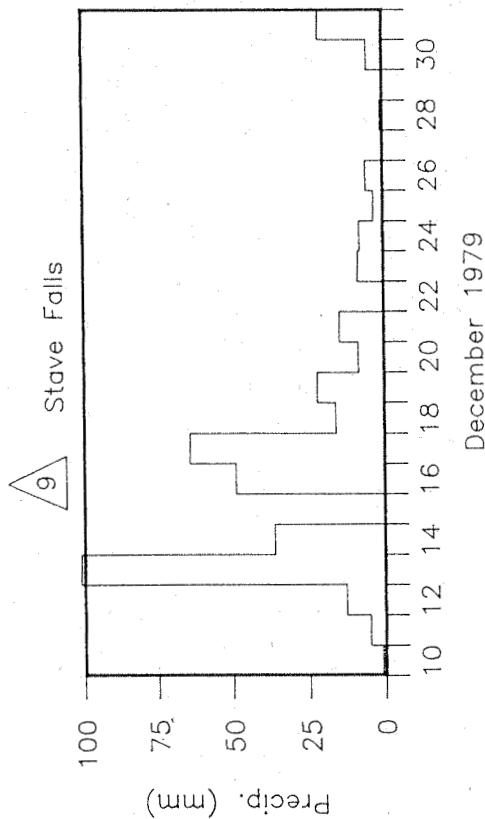
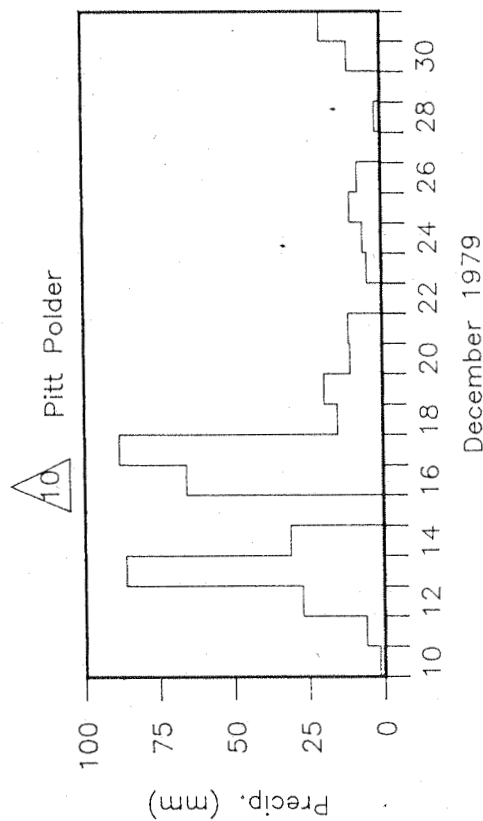
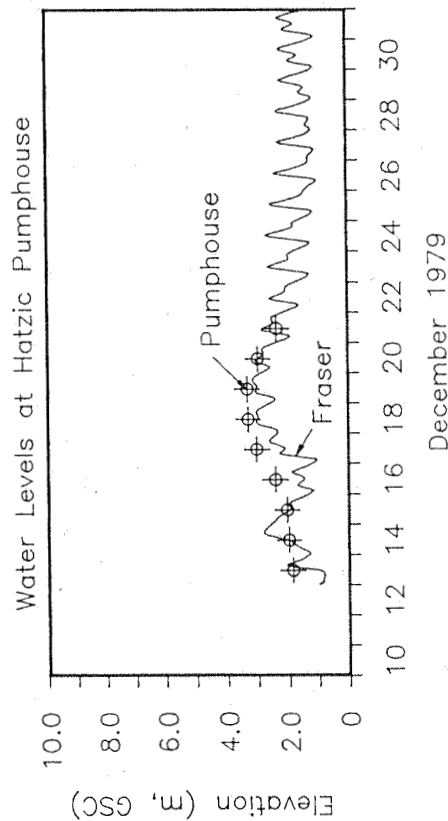
- 1) ADDITIONAL PUMPS - additional pump capacity of 8.34 m³/s.
- 2) ADDITIONAL FLOODBOXES - four additional 1.829 m by 1.829 m (6 ft by 6 ft) floodboxes at Hatzic Pumphouse.

- 3) ADDITIONAL CULVERTS - two additional 3 m culverts at the CPR crossing.
- 4) Mean lake level - 2.438 m GSC (8 ft).
- 5) Historical flood level - 3.353 m GSC (11 ft) - Flooding of the Everglades and 270 hectares (670 acres) on Hatzic Prairie.

Hatzic Prairie Study

Forward Flood Routing
November 1990

northwest hydraulic consultants



Legend:



Fraser River level at the Hatzic Pumphouse.
The river level at Mission was adjusted by
+0.300 m to estimate the level at the pumphouse.



Level recorded at Hatzic Pumphouse.
Have assumed the level was recorded at noon.



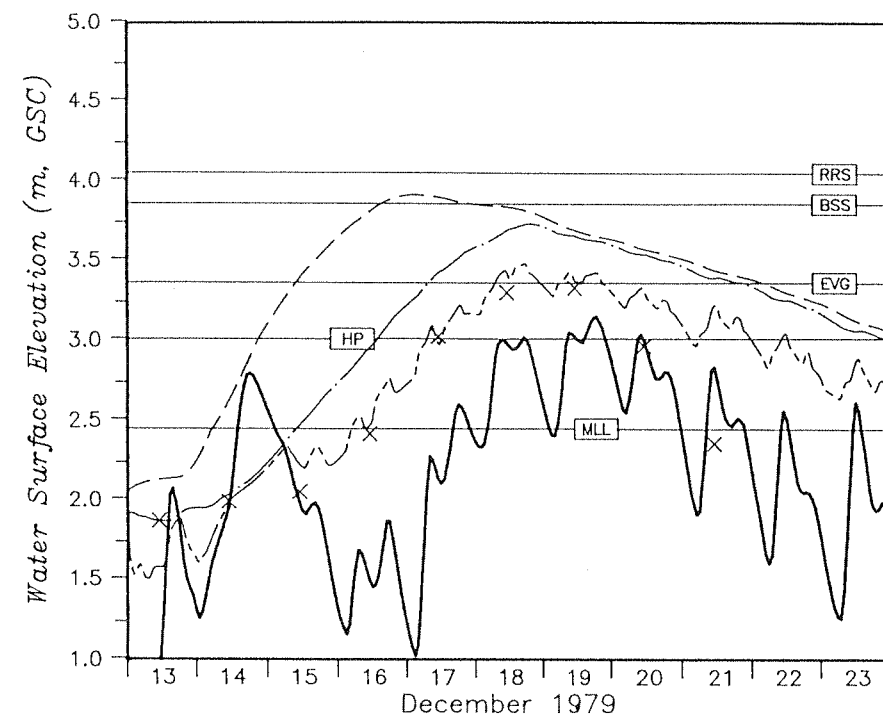
Precipitation Gauge (for location, see DWG No. 2.10)

Hatzic Prairie Study

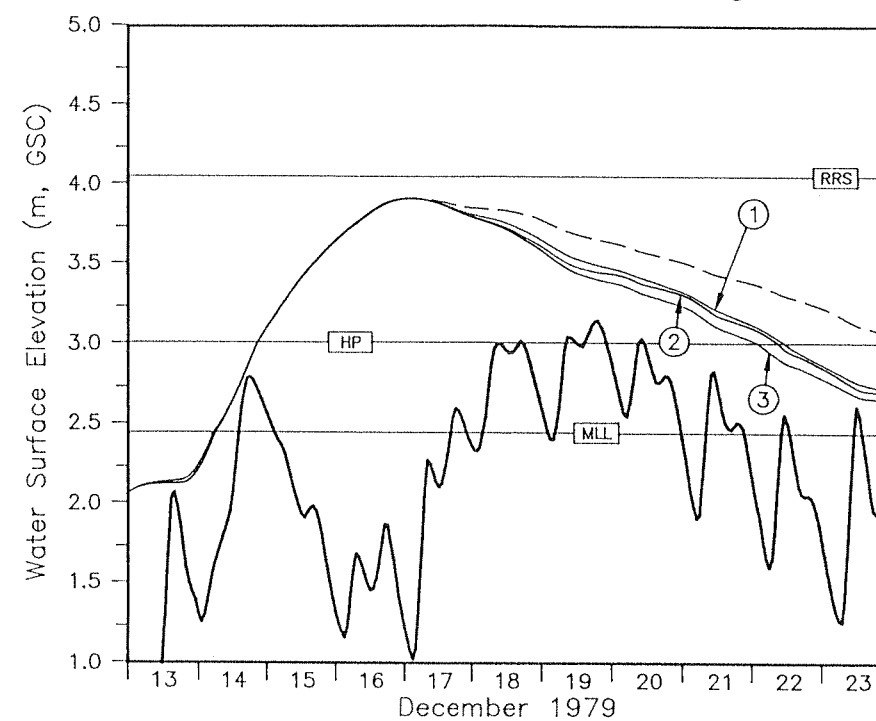
10-Year 5-Day Storm Event
December 1979

northwest hydraulic consultants

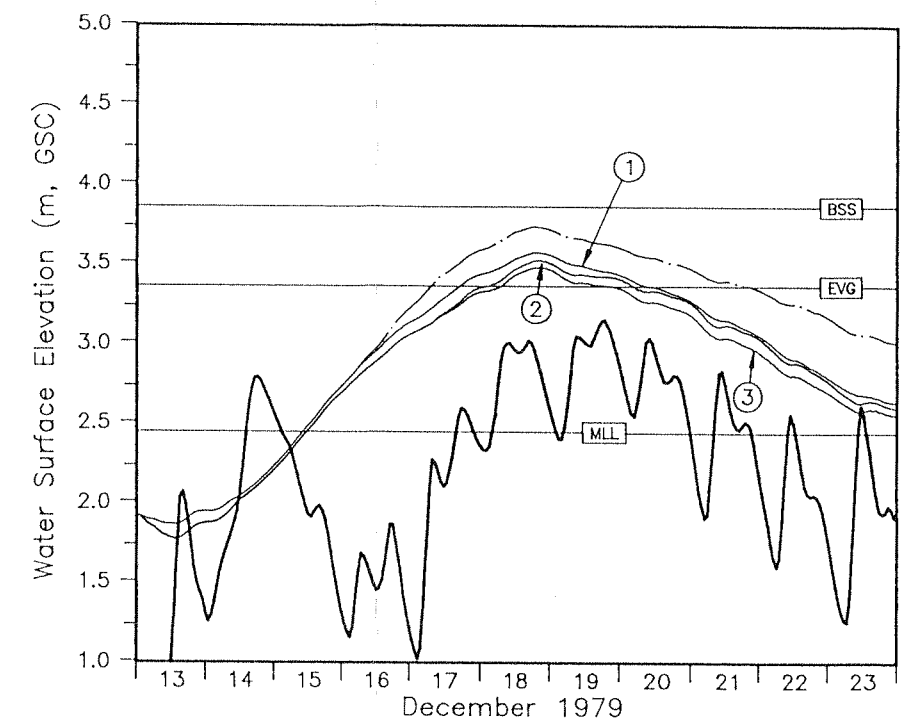
Calculated Water Surface Elevations
Existing Conditions



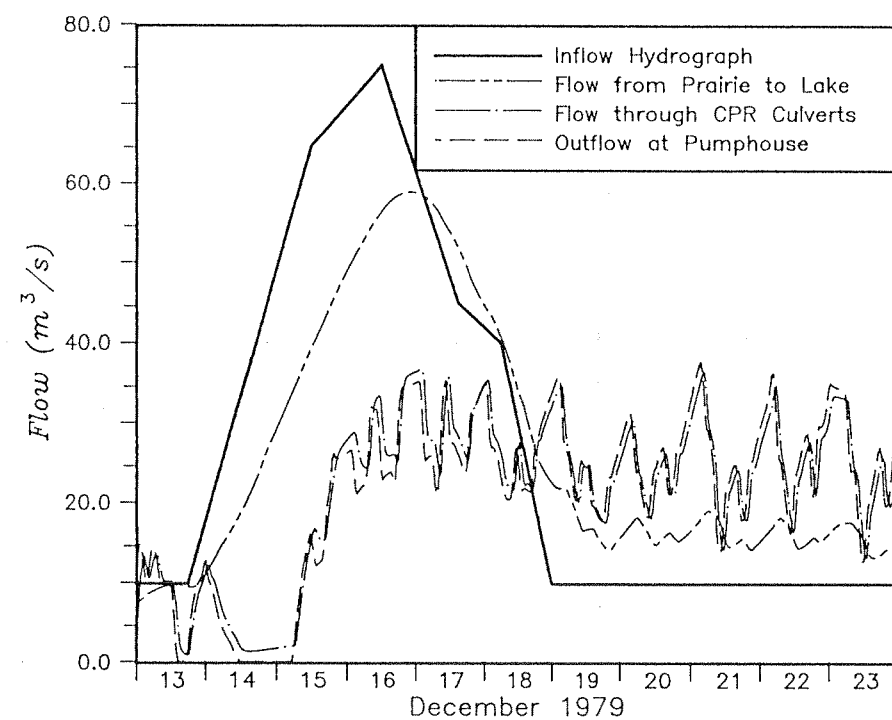
Predicted Water Surface Elevations
Lagace Creek at Dale Road Bridge



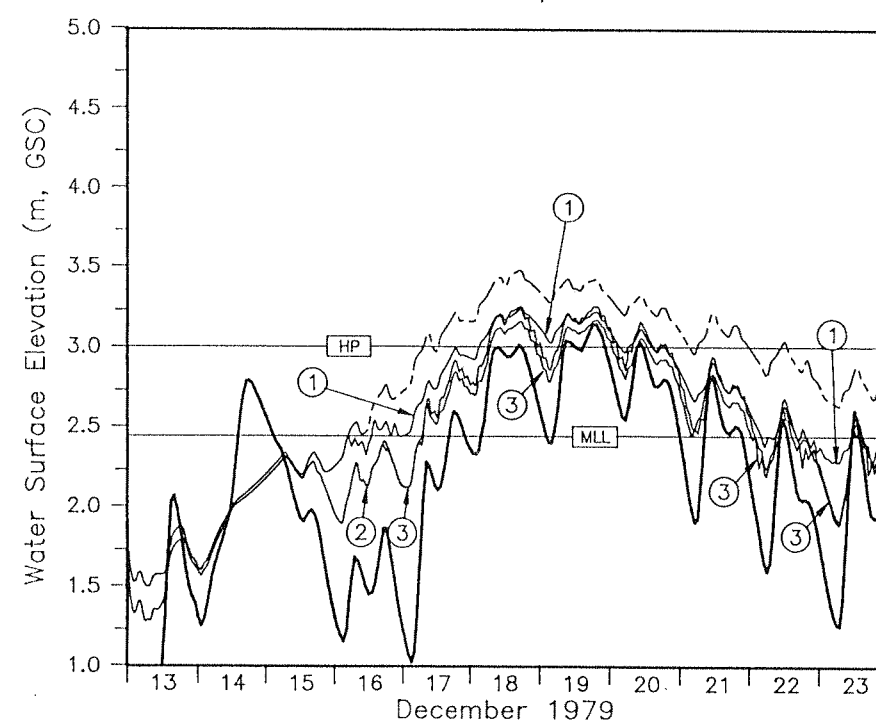
Predicted Water Surface Elevations
Hatzic Lake



Inflow Hydrograph & Flows
Existing Conditions



Predicted Water Surface Elevations
Hatzic Pumphouse



Legend:

- Estimated Fraser River level at Hatzic Pumphouse
- - - Calculated Water surface elevation of Lagace Creek at Dale Road Bridge for EXISTING CONDITIONS
- Calculated water surface elevation of Hatzic Lake for EXISTING CONDITIONS
- - - Calculated water surface elevation at Hatzic Pumphouse for EXISTING CONDITIONS
- × Observed water surface elevation at Hatzic Pumphouse (as recorded in the Pumplogs)
- ① Water surface elevation for EXISTING CONDITIONS with ADDITIONAL PUMPS.
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- ③ Water surface elevation for EXISTING CONDITIONS with ADDITIONAL FLOODBOXES, ADDITIONAL CPR CULVERTS, and ADDITIONAL PUMPS
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- EVG Everglades - Flooding above 3.353 m GSC (Historical Flood Level)
- HP Hatzic Prairie - Flooding above 3.00 m GSC near Dale Rd. and Farms Rd.
- MLL Mean Lake Level

- DECEMBER 1979 -

Hatzic Prairie Study

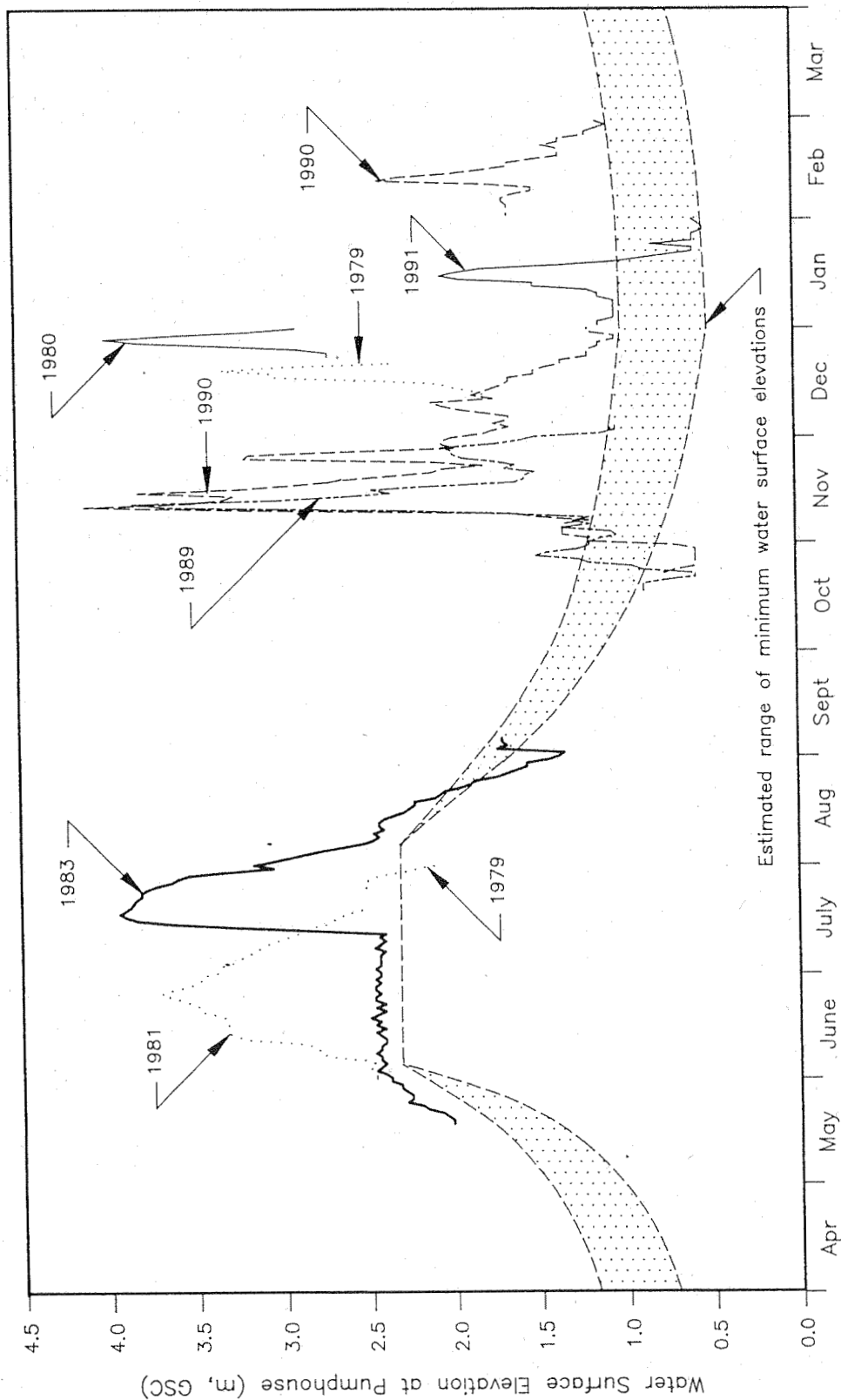
Forward Flood Routing
5-Day 10-Year Storm

northwest hydraulic consultants

Notes:

- 1) ADDITIONAL PUMPS - additional pump capacity of 8.34 m³/s.
- 2) ADDITIONAL FLOODBOXES - four additional 1.829 m by 1.829 m (6 ft by 6 ft) floodboxes at Hatzic Pumphouse.

- 3) ADDITIONAL CULVERTS - two additional 3 m culverts at the CPR crossing.
- 4) Mean lake level - 2.438 m GSC (8 ft).
- 5) Historical flood level - 3.353 m GSC (11 ft) - Flooding of the Everglades and 270 hectares (670 acres) on Hatzic Prairie.



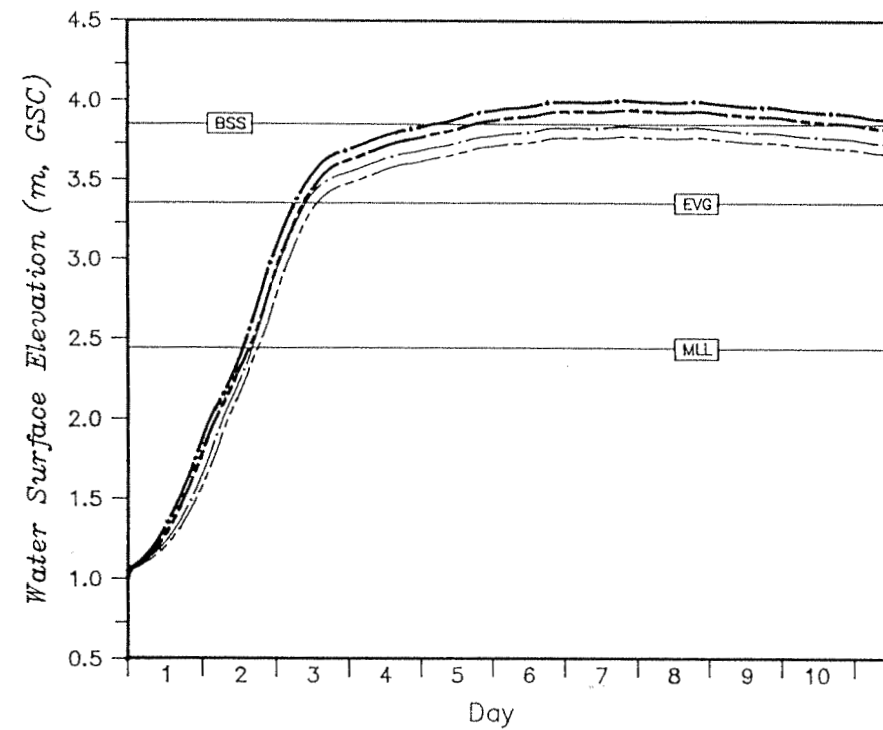
Note: Water levels taken from pumplogs.

Hatzic Prairie Study

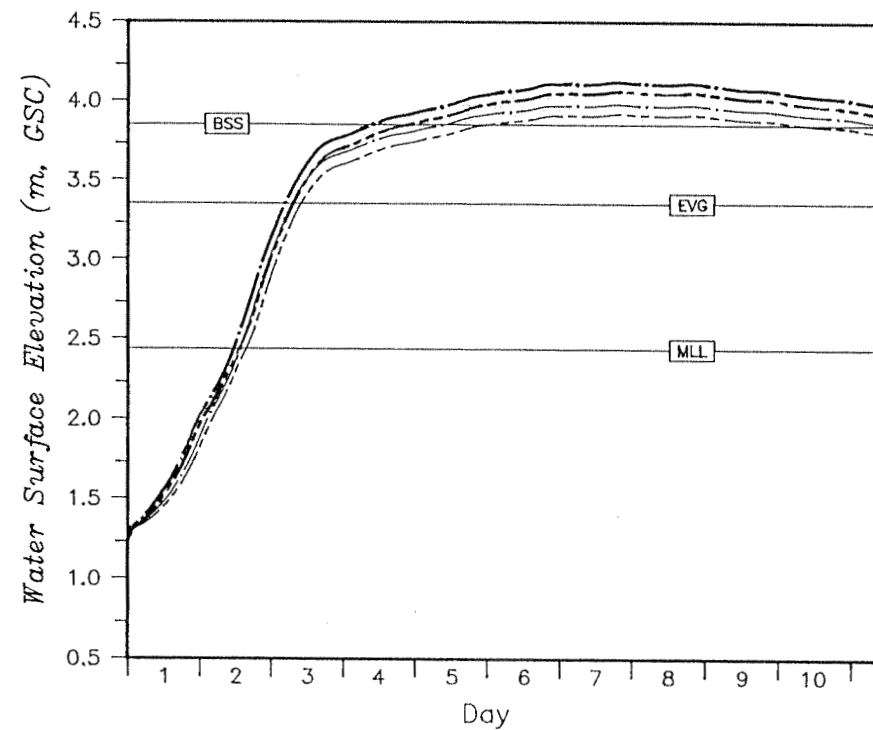
Water Level at Pumphouse
for Previous Storms

northwest hydraulic consultants

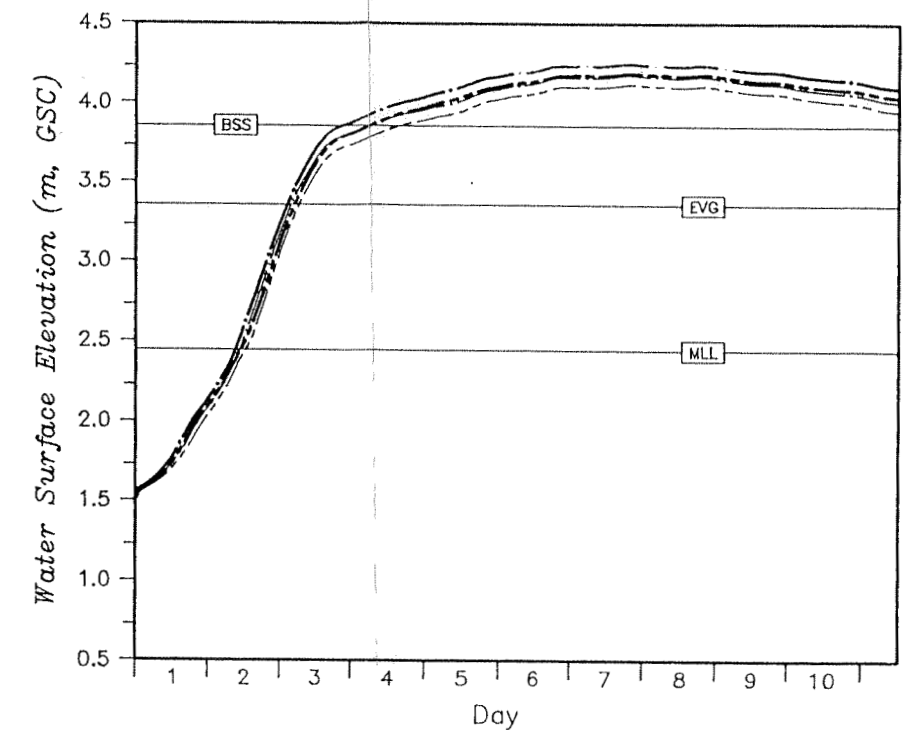
Initial Level at the Pumphouse 1.00 m



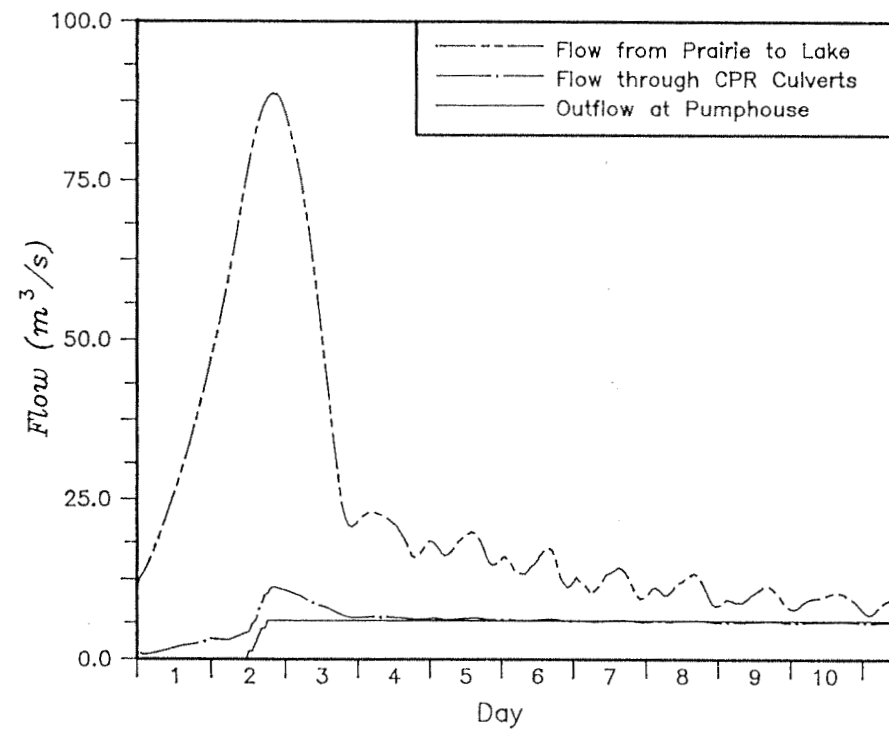
Initial Level at the Pumphouse 1.25 m



Initial Level at the Pumphouse 1.50 m



Inflow Hydrograph & Flows
Existing Conditions



Dredging Effects on Peak Water Surface Levels:
(East side of Hatzic Lake dredged to 0.5 m GSC)

Initial Levels (m GSC)		Peak Levels (m GSC)				Reduction of Peak Level (m)	
		No Dredging		Dredged			
Lake	Pumphouse	Lake	Pumphouse	Lake	Pumphouse	Lake	Pumphouse
1.05	1.00	4.005	3.945	3.838	3.766	0.167	0.179
1.30	1.25	4.125	4.064	3.982	3.921	0.143	0.143
1.55	1.50	4.249	4.189	4.176	4.116	0.073	0.073

Legend:

- — — — — Calculated water surface elevation of Hatzic Lake with NO DREDGING and EXISTING CONDITIONS
- — — — — Calculated water surface elevation of Hatzic Lake with DREDGING and EXISTING CONDITIONS
- — — — — Calculated water surface elevation at Hatzic Pumphouse with NO DREDGING and EXISTING CONDITIONS
- — — — — Calculated water surface elevation at Hatzic Pumphouse with DREDGING and EXISTING CONDITIONS
- BSS — Benbow St. Subdivision — Flooding above 3.85 m GSC
- EVG — Everglades — Flooding above 3.353 m GSC (Historical Flood Level)
- HP — Hatzic Prairie — Flooding above 3.00 m GSC near Dale Rd. and Farms Rd.
- MLL — Mean Lake Level

East Side of Hatzic Lake
Dredged to 0.5 m GSC

Notes:

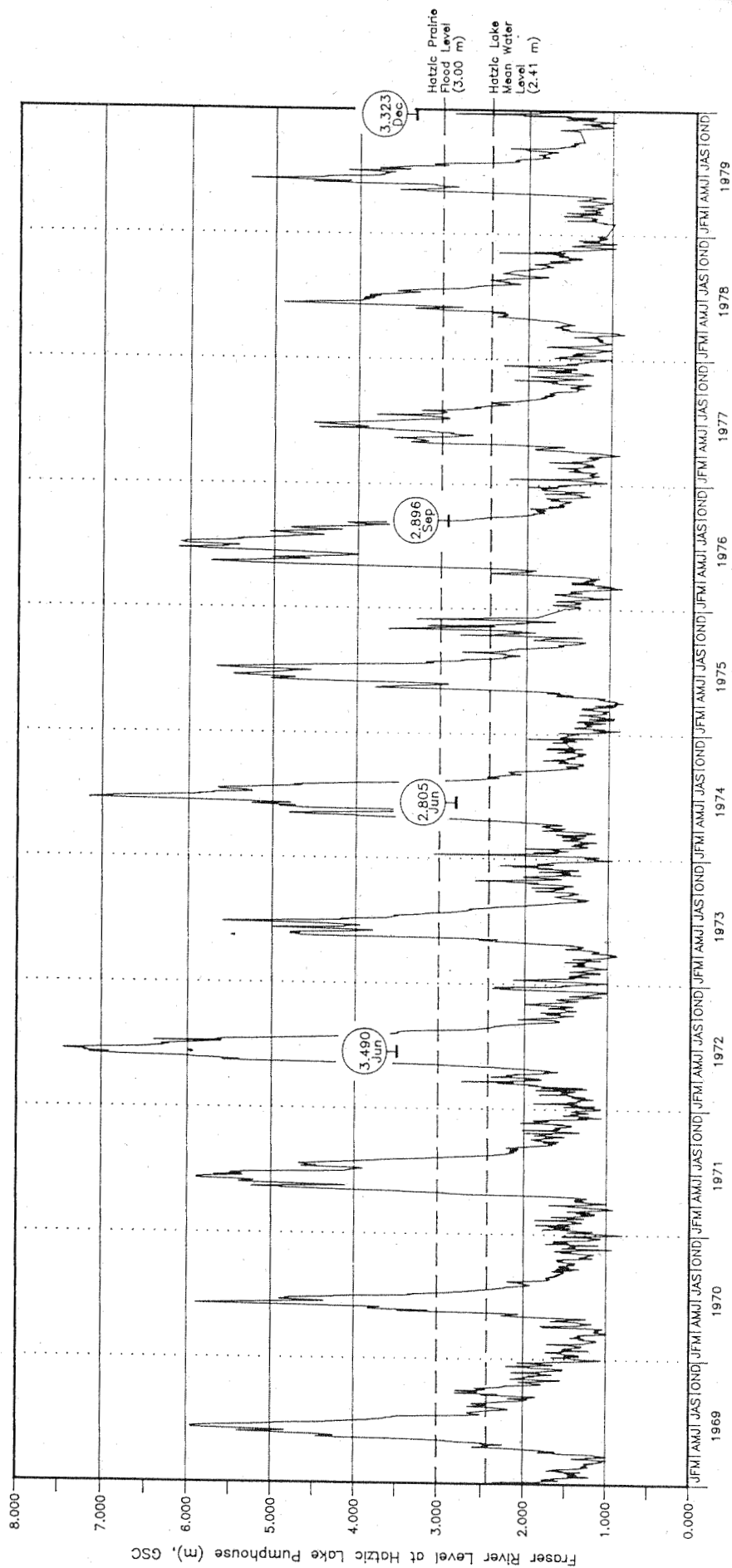
- 1) Mean lake level — 2.438 m GSC (8 ft).
- 2) Historical flood level — 3.353 m GSC (11 ft) — Flooding of the Everglades and 270 hectares (670 acres) on Hatzic Prairie.
- 3) Inflow to the lake was adapted from the November 1989 storm.

- 4) Pumps operated when level at pumphouse is above 2.41 m GSC.
- 5) Have assumed that the floodboxes provide no flood relief.
- 6) Base time scale is in days.

Hatzic Prairie Study

Forward Flood Routing
Dredging Effects on Peak Levels

northwest hydraulic consultants



1969 - 1979

Hatzic Prairie Study

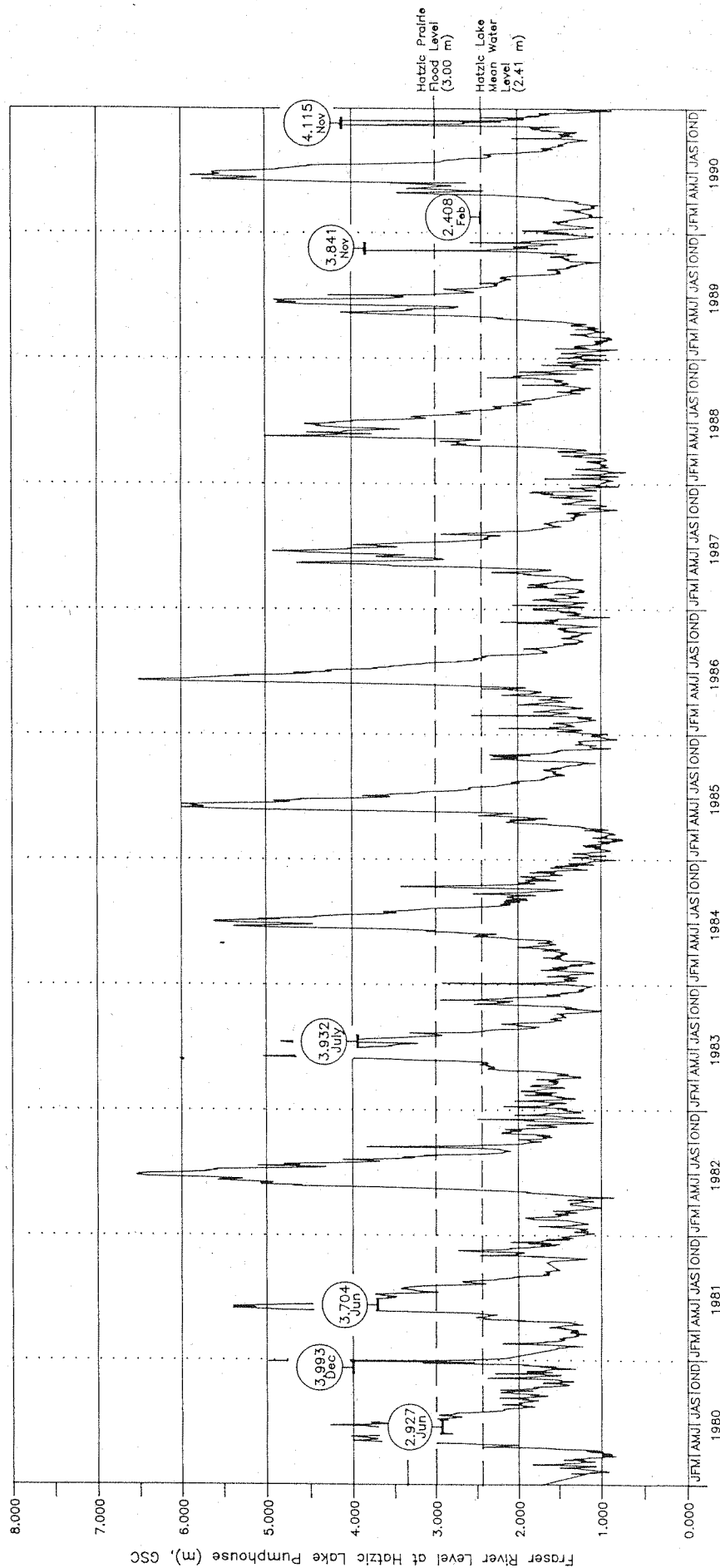
Mean Daily Fraser River Levels
at Hatzic Pumphouse

northwest hydraulic consultants

Notes:

- 1) The river level at the pumphouse was estimated by adding 0.3 m to the level recorded at the Mission. This represents the water level decrease for the 5.0 km reach given a hydraulic gradient of 0.00006 at Mission.
- 2) Maximum lake levels were obtained from Hatzic Lake pumphouse records.

NHC\1692-100



Legend:

Maximum lake level at Hatzic Lake Pumphouse for the indicated month (Elevation given as m GSC).

1980 - 1990

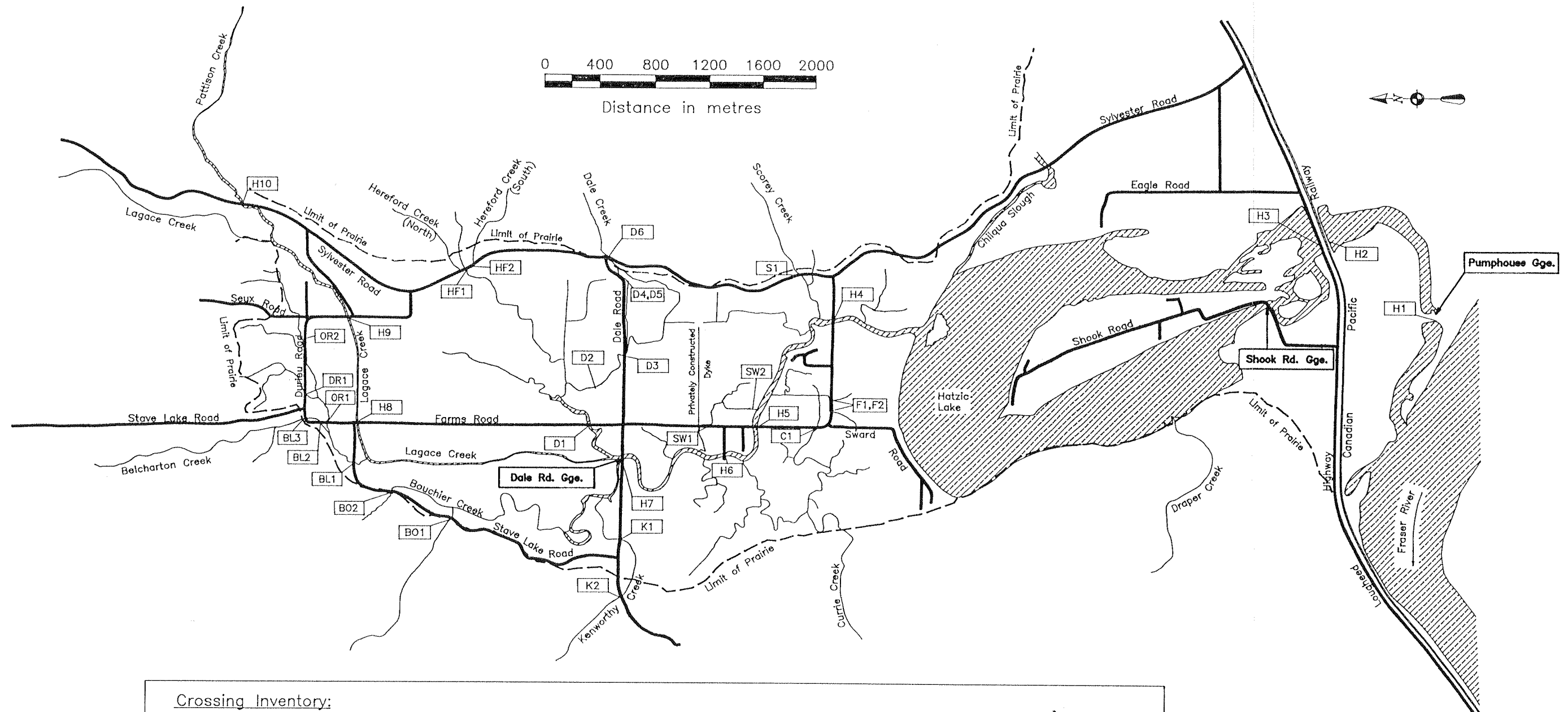
Hatzic Prairie Study

Mean Daily Fraser River Levels
at Hatzic Pumphouse

northwest hydraulic consultants

Notes:

- 1) The river level at the pumphouse was estimated by adding 0.3 m to the level recorded at the Mission. This represents the water level decrease for the 5.0 km reach given a hydraulic gradient of 0.00006 at Mission.
- 2) Maximum lake levels were obtained from Hatzic Lake pumphouse records.



Crossing Inventory:

Belcharton Creek

- BL1 10.8m, 2 span, timber bridge
- BL2 3 x 0.9m concrete culverts
- BL3 3 x 0.9m concrete culverts

Bouchier Creek

- BO1 2 x 0.4m steel culverts
- BO2 0.9m steel culvert

Currie Creek

- C1 1.1m steel culvert

Dale Creek

- D1 10.8m, clear span, timber bridge
- D2 5m, clear span, timber bridge
- D3 4.7m, clear span, timber bridge
- D4 3.3m, clear span, log bridge
- D5 1.3m steel culvert
- D6 1.5m concrete culvert

Durieu Creek

- DR1 1.2m concrete culvert

Farms Road Ditch

- F1 0.6m steel culvert
- F2 0.5m steel culvert

Hatzic Slough/Lagace Creek

- H1 2 x 1.8m x 1.8m concrete box culverts
2 x 3.0m/s capacity pumps
- H2 2 x 3m steel culverts
1 x 2.4m steel culvert
- H3 21.5m, 2 span, timber bridge
- H4 36m, 7 span, timber bridge
- H5 36m, 7 span, timber bridge
- H6 36m, 7 span, timber bridge
- H7 36m, 6 span, timber bridge
- H8 14m, clear span, timber bridge
- H9 36m, 3 span, concrete bridge
- H10 20m, 3 span, timber bridge

Hereford Creek

- HF1 2.13m, multiplate culvert
- HF2 900mm, steel culvert

Kenworthy Creek

- K1 1.5m concrete culvert
0.9m concrete culvert
- K2 1.5m concrete culvert
0.9m steel culvert

Oro Creek

- OR1 1 x 1.8m steel culvert
1 x 0.9m concrete culvert
- OR2 2 x 1.3m concrete culverts

Scorey Creek

- S1 2m, clear span, timber bridge

Leuzinger Farm Drainage

- SW1 2 x 1.1m (approx.), culverts, CLOSED
- SW2 0.9m x 60m steel culvert
50cm pump powered by 80hsp. tractor

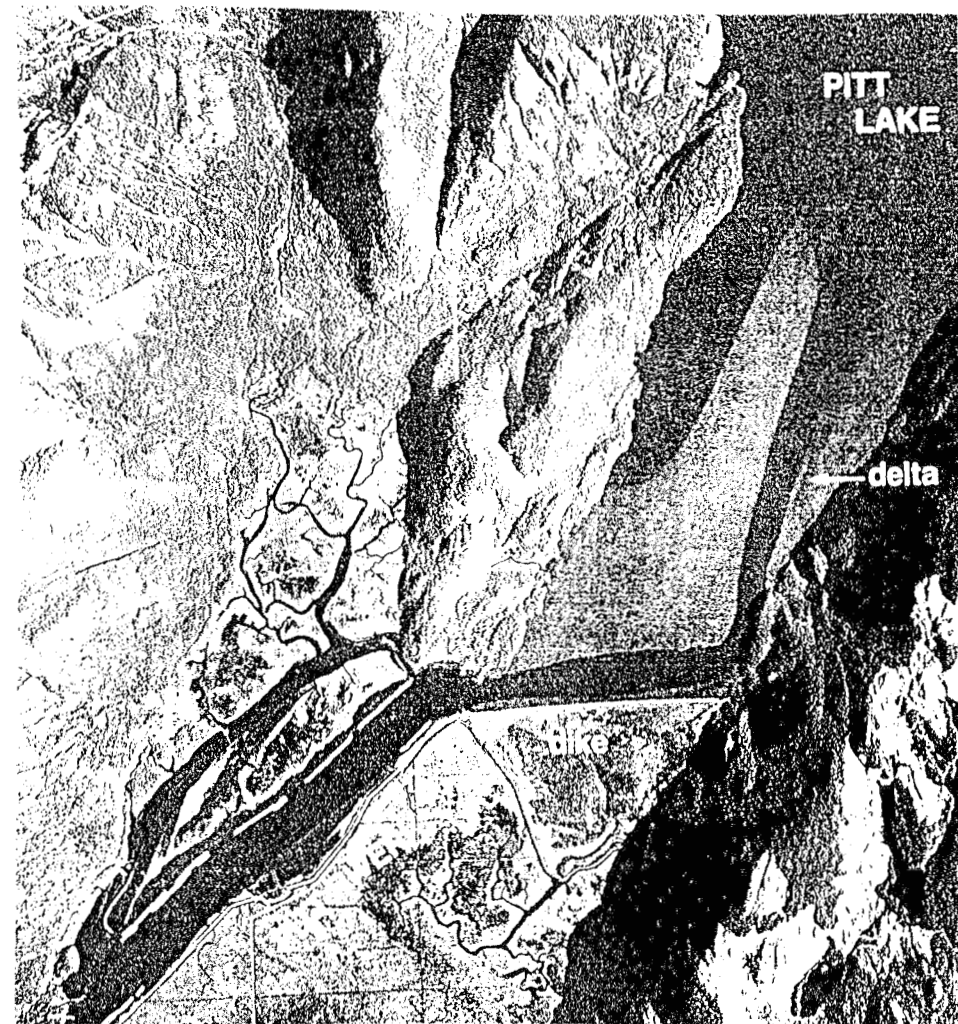
Hatzic Prairie Study

Drainage Channel Survey Crossing Inventory

northwest hydraulic consultants



Hatzic Prairie — Drainage channels on Lagace Creek near Dale Road Bridge (1984).



Pitt Lake — Lower Pitt system showing tidal influence on drainage channels (1954).

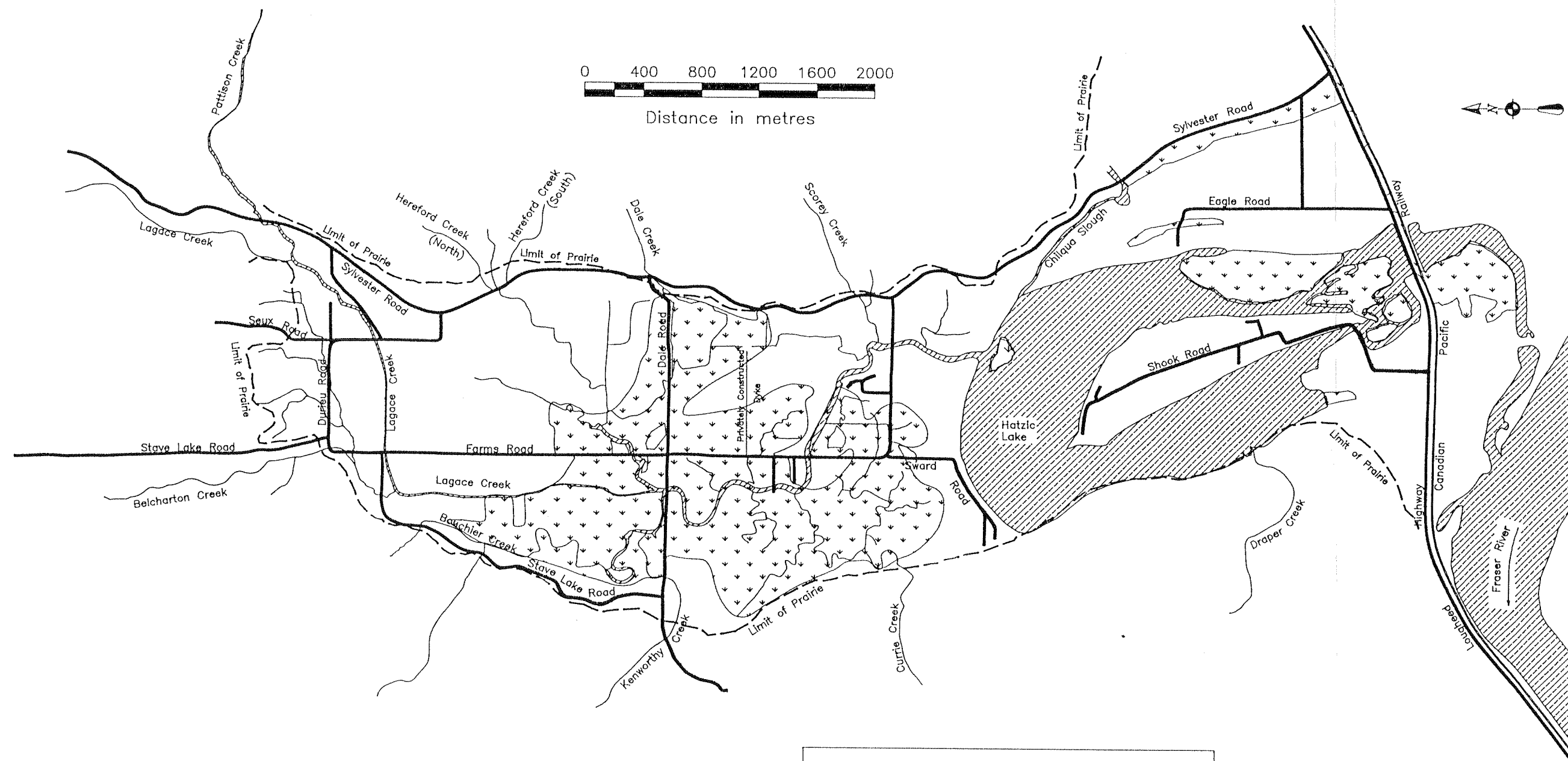


Trenchard Inlet, South Carolina — Typical tidal channel pattern (1951).

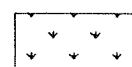
Hatzic Prairie Study

Similarities between Hatzic Prairie
Drainage Channels and Tidal Channels

northwest hydraulic consultants



Legend:



Areas below 3.6 m GSC

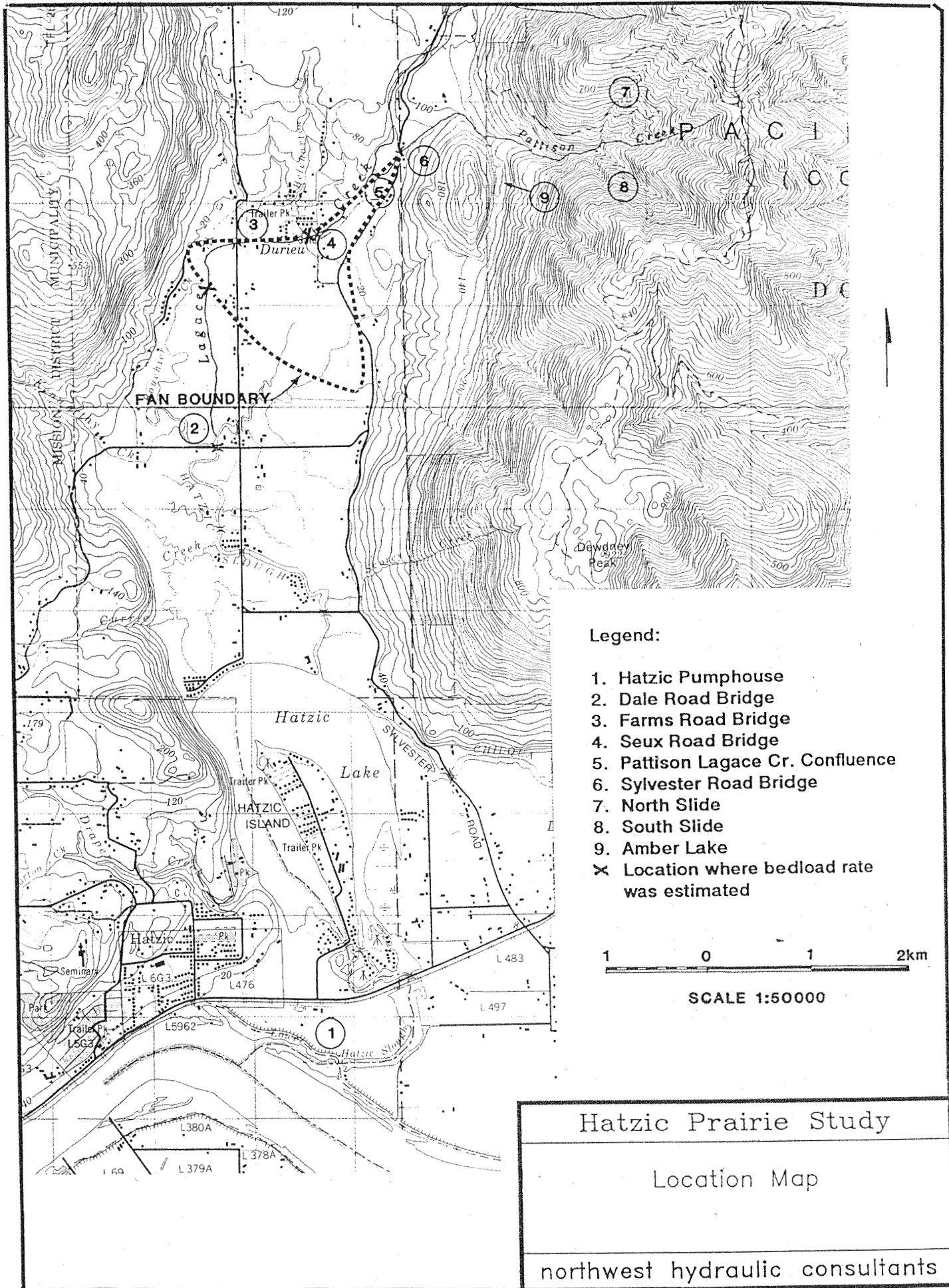
ARDSA Criteria

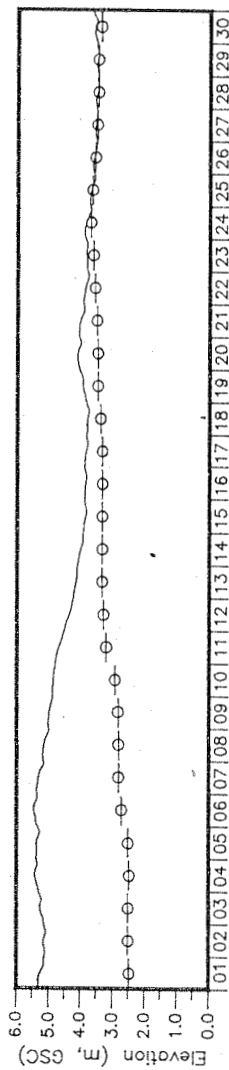
2.4 m	Average Summer Lake Level
+1.2 m	ARDSA Required Freeboard
3.6 m	Elevation below which ARDSA criteria cannot be achieved

Hatzic Prairie Study

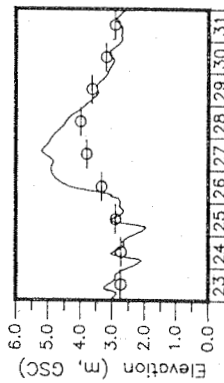
ARDSA Criteria
Areas Below 3.6 m GSC

northwest hydraulic consultants

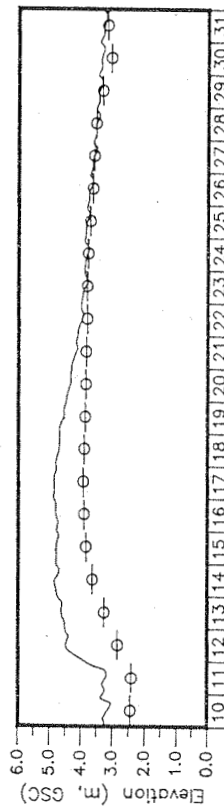




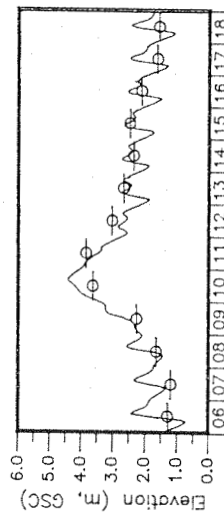
June 1981



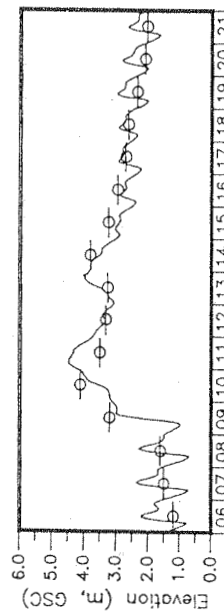
December 1980



July 1983



November 1989



November 1990

Legend



Fraser River level at the Hatzic Pumphouse.
The river level at Hatzic Pumphouse was estimated
by adding 0.300 m to the level at Mission.



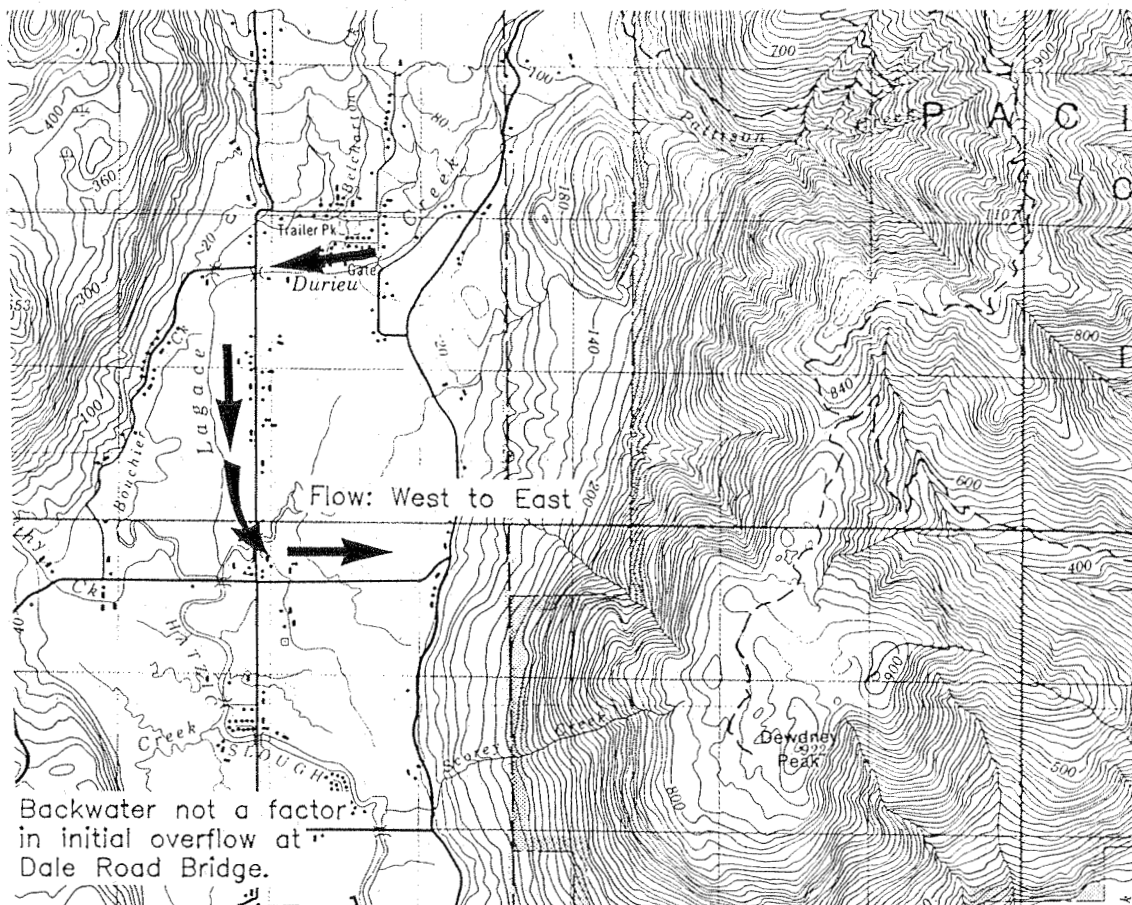
Lake level recorded at Hatzic Pumphouse.
Have assumed the level was recorded at noon.

See Figure 2-5 through 2-10 for more detailed information
on each of the storm events.

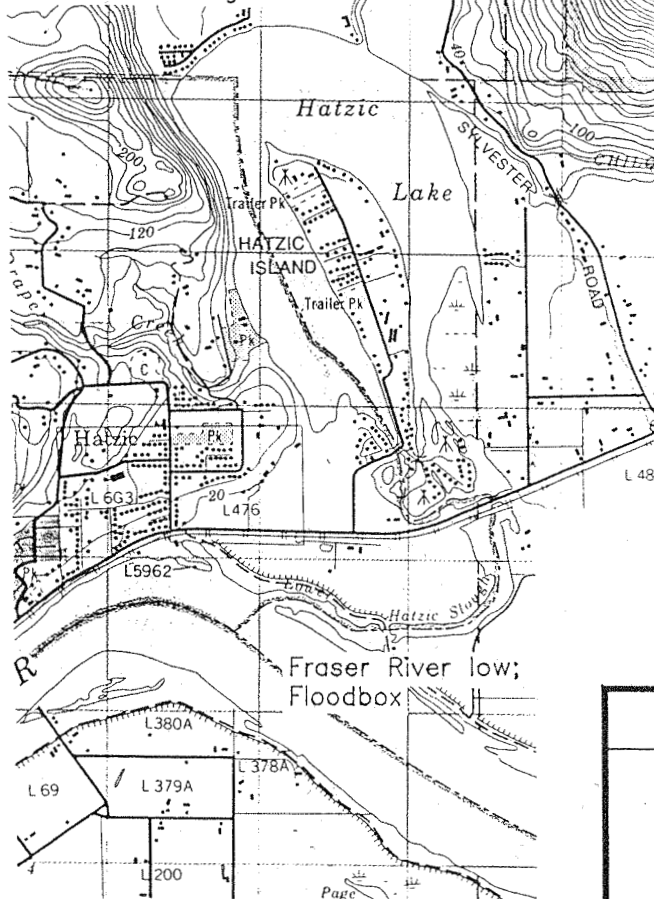
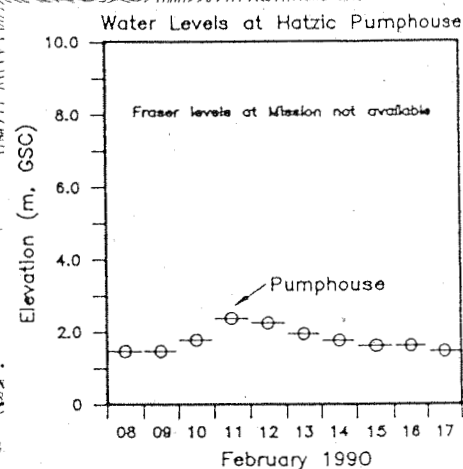
Hatzic Prairie Study

Fraser River and Hatzic Lake
Levels at Hatzic Pumphouse

northwest hydraulic consultants



Backwater not a factor in initial overflow at Dale Road Bridge.



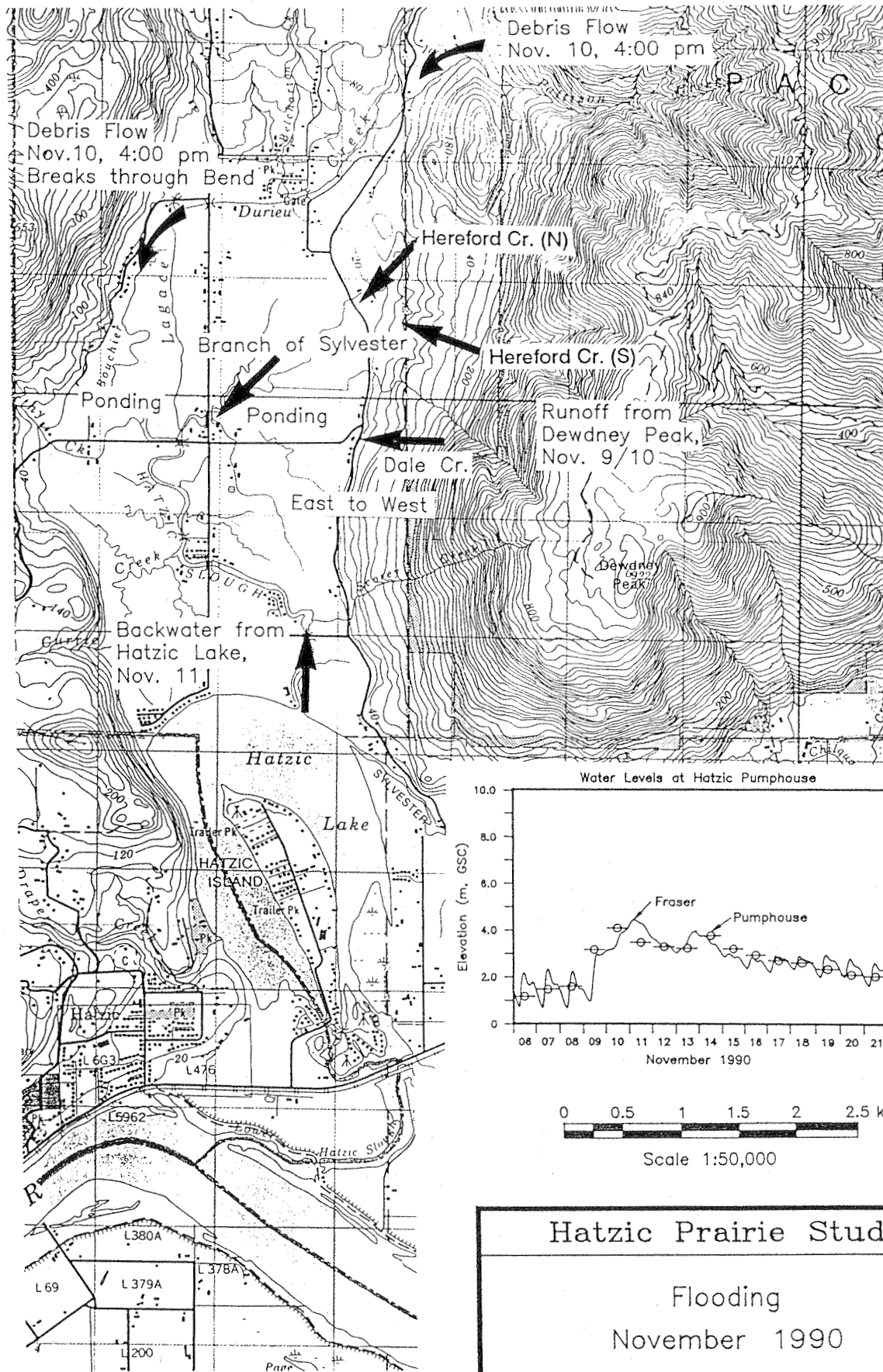
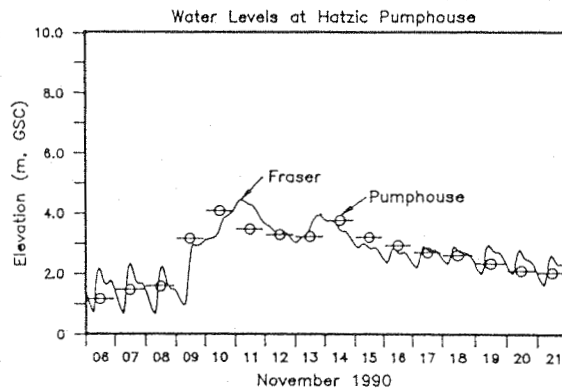
0 0.5 1 1.5 2 2.5 km

Scale 1:50,000

Hatzic Prairie Study

Flooding:
February 1990

northwest hydraulic consultants



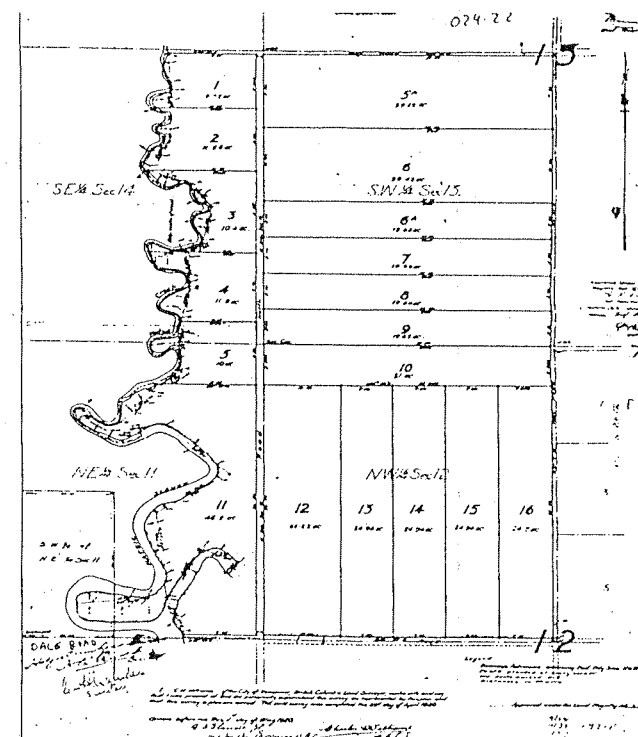
0 0.5 1 1.5 2 2.5 km

Scale 1:50,000

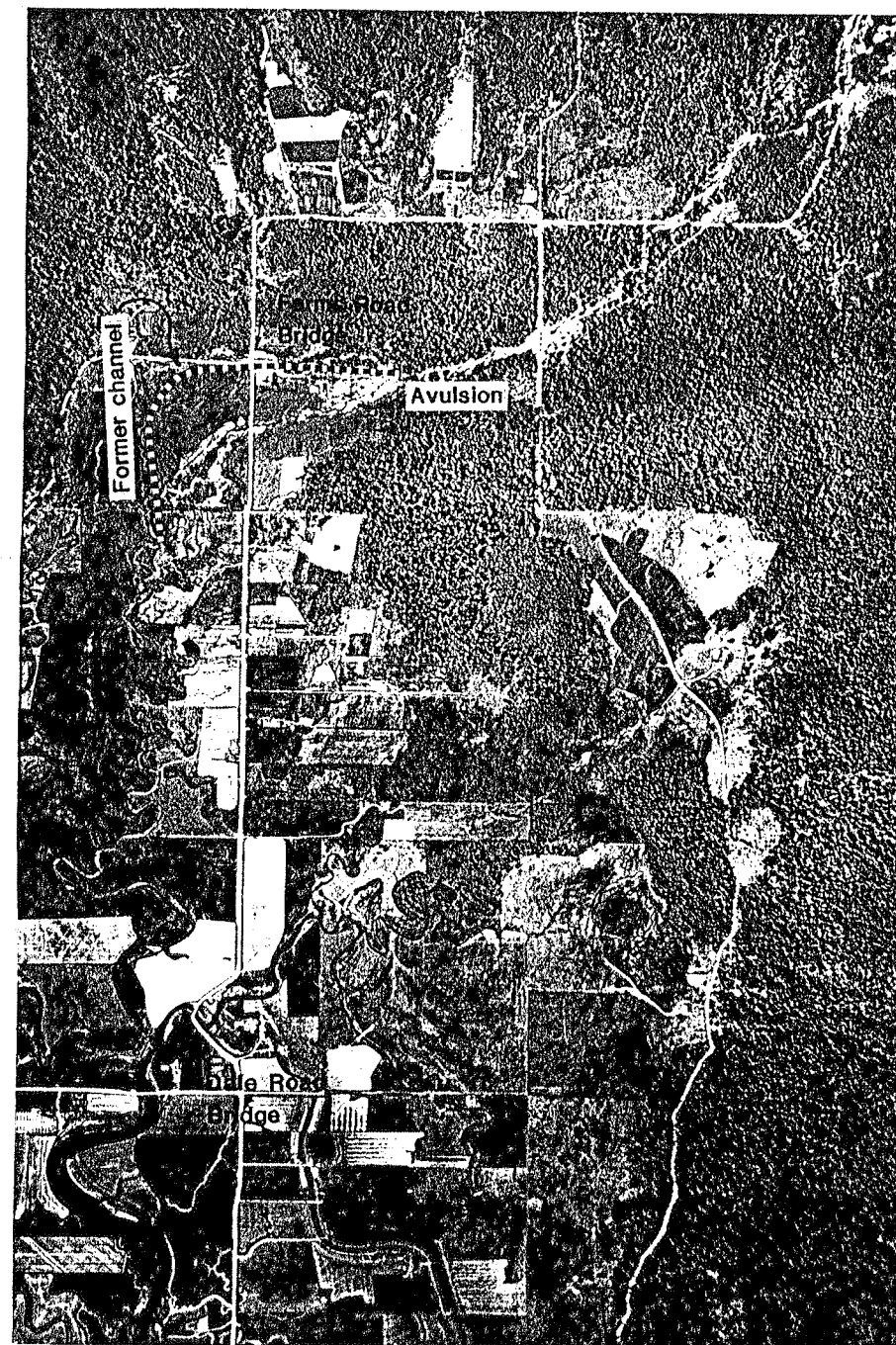
Hatzic Prairie Study

Flooding
November 1990

northwest hydraulic consultants



MAY 1, 1920



JUNE, 1940



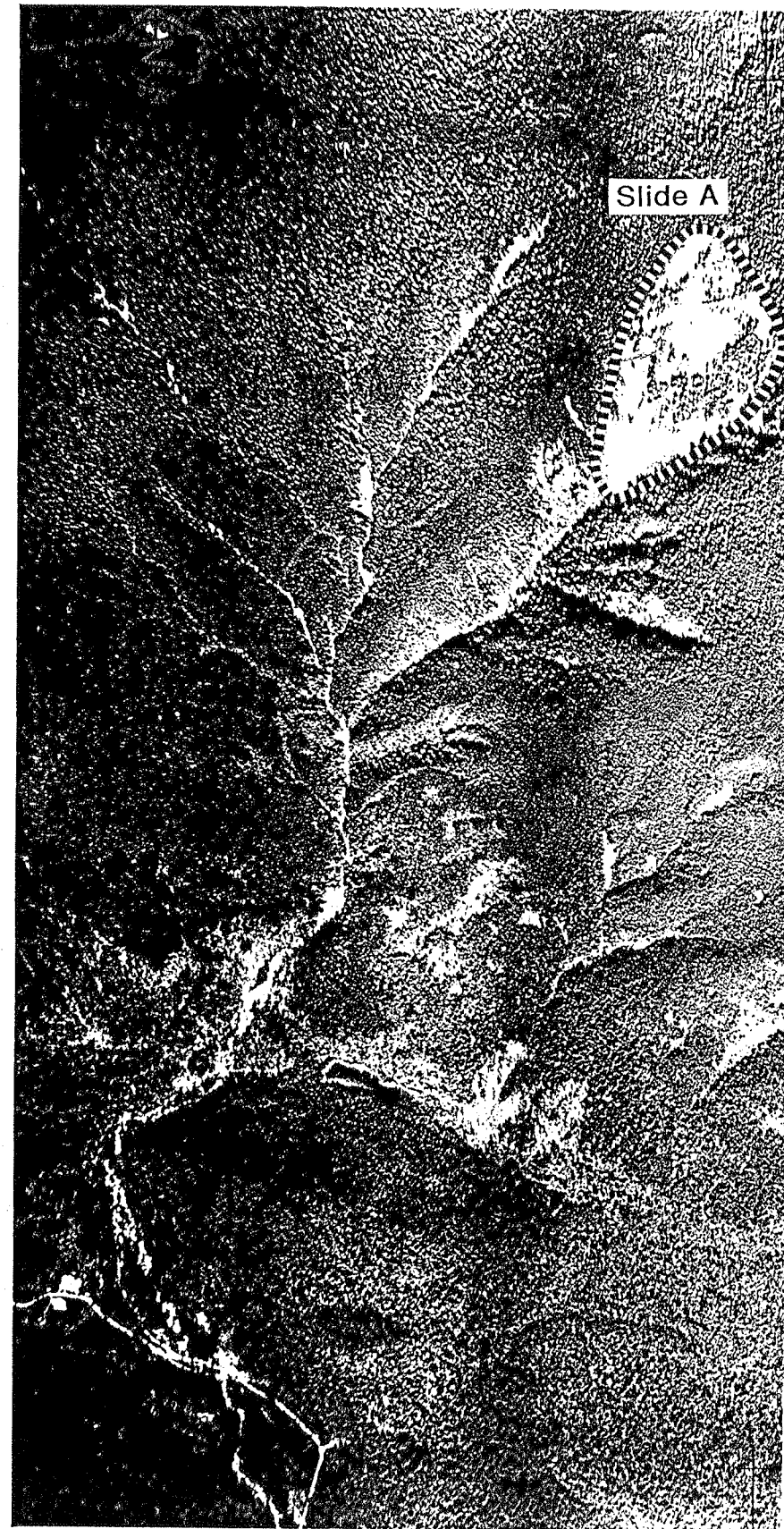
MARCH 11, 1981

Hatzic Prairie Study

Channel Changes
Along Lagace Creek

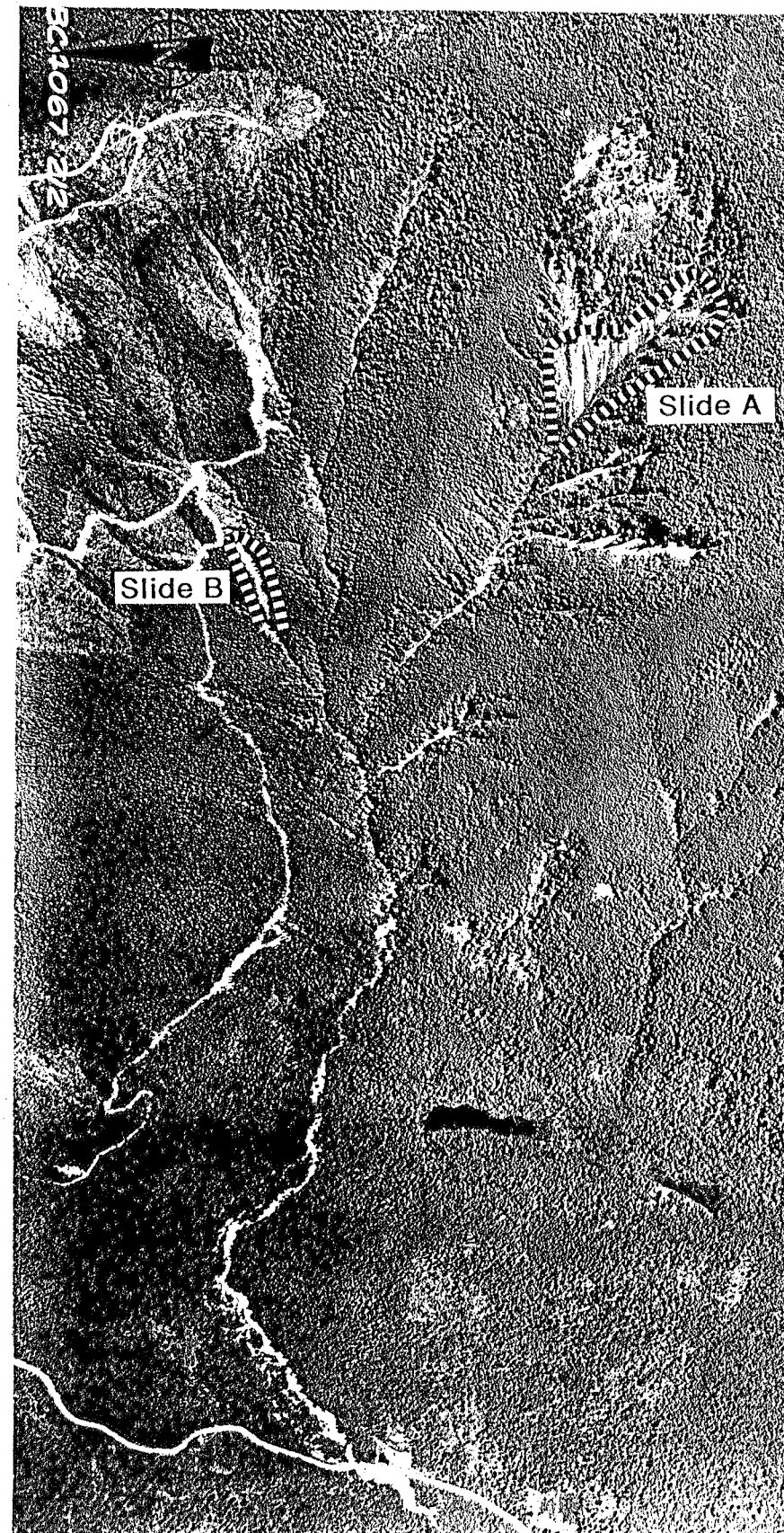
northwest hydraulic consultants

DWG No. 3.5

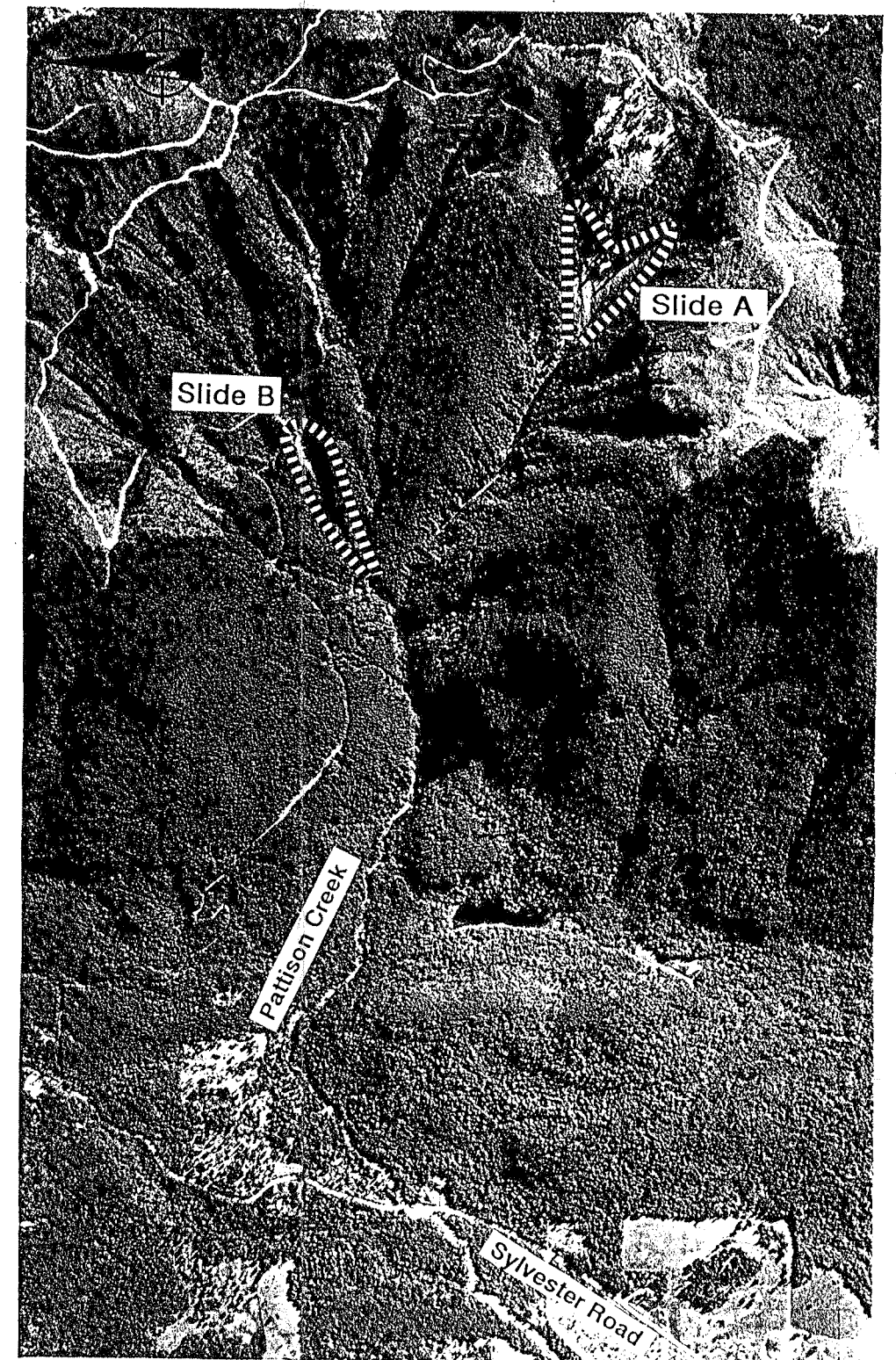


JUNE, 1940

SCALE: 0 1km (Approximate)



JULY 21, 1962



SEPTEMBER 11, 1979

Hatzic Prairie Study

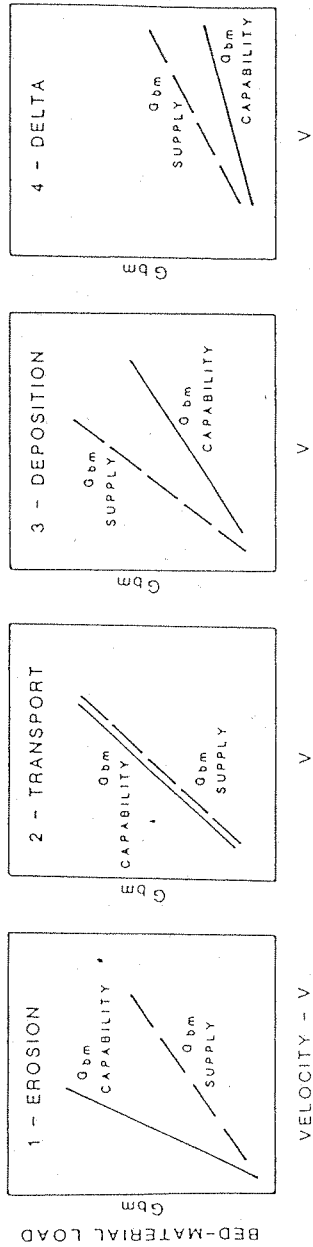
Landslide Activity in
Pattison Creek Basin

northwest hydraulic consultants

DWG No. 3.6

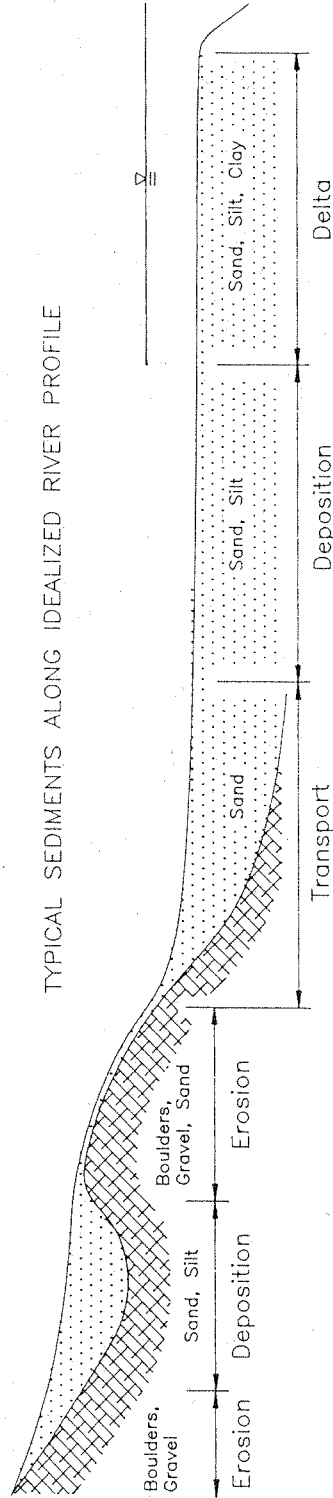
WATER/SEDIMENT PROCESSES

SEDIMENT ERODED FROM A WATERSHED IS CONVEYED ALONG RIVER CHANNELS. A SIMPLIFIED CLASSIFICATION OF WATER/SEDIMENT PROCESSES WITHIN RIVER CHANNELS CAN BE REDUCED TO FOUR DISTINCT PROCESSES DEPENDING UPON THE CAPABILITY OF THE RIVER CHANNEL TO MOVE SEDIMENT:



1. River can transport more bed-material than watershed can supply. The slope of the river is controlled by bedrock.
2. River transport capability matches supply of sediment. The river is stable.
3. River cannot transport all the bed-material supplied and forms bars and islands. The river is unstable.
4. River capability to transport bed-material is low and distributary channels develop.

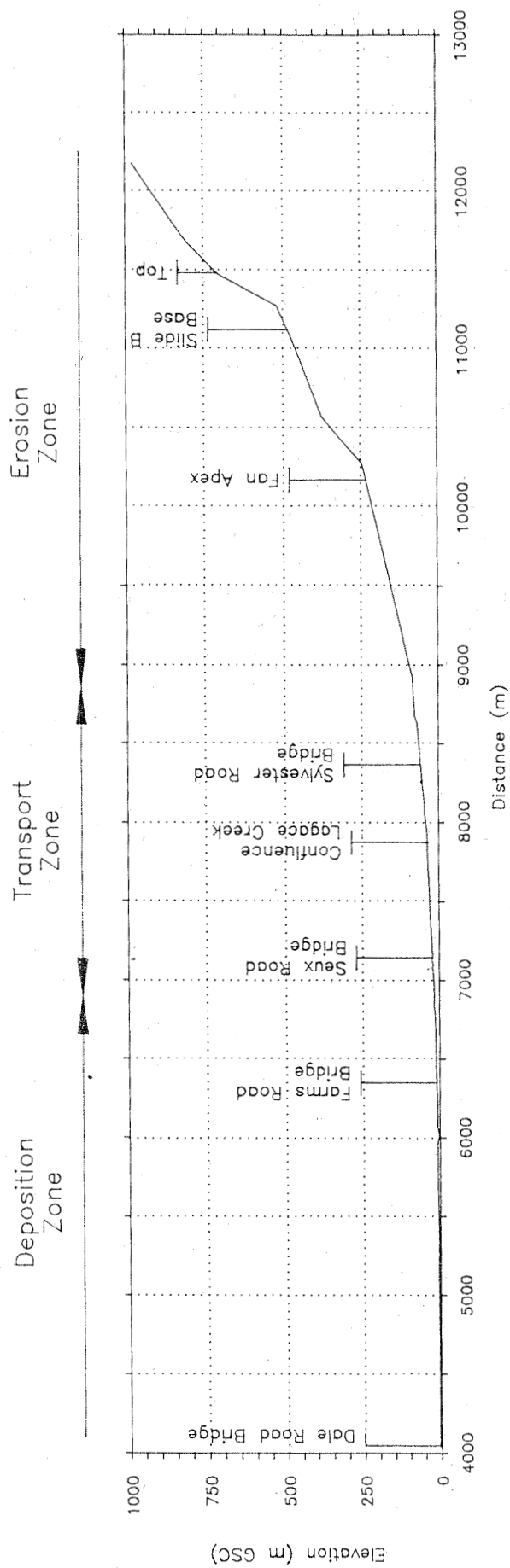
TYPICAL SEDIMENTS ALONG IDEALIZED RIVER PROFILE



Hatzic Prairie Study

Idealized River Profile

northwest hydraulic consultants

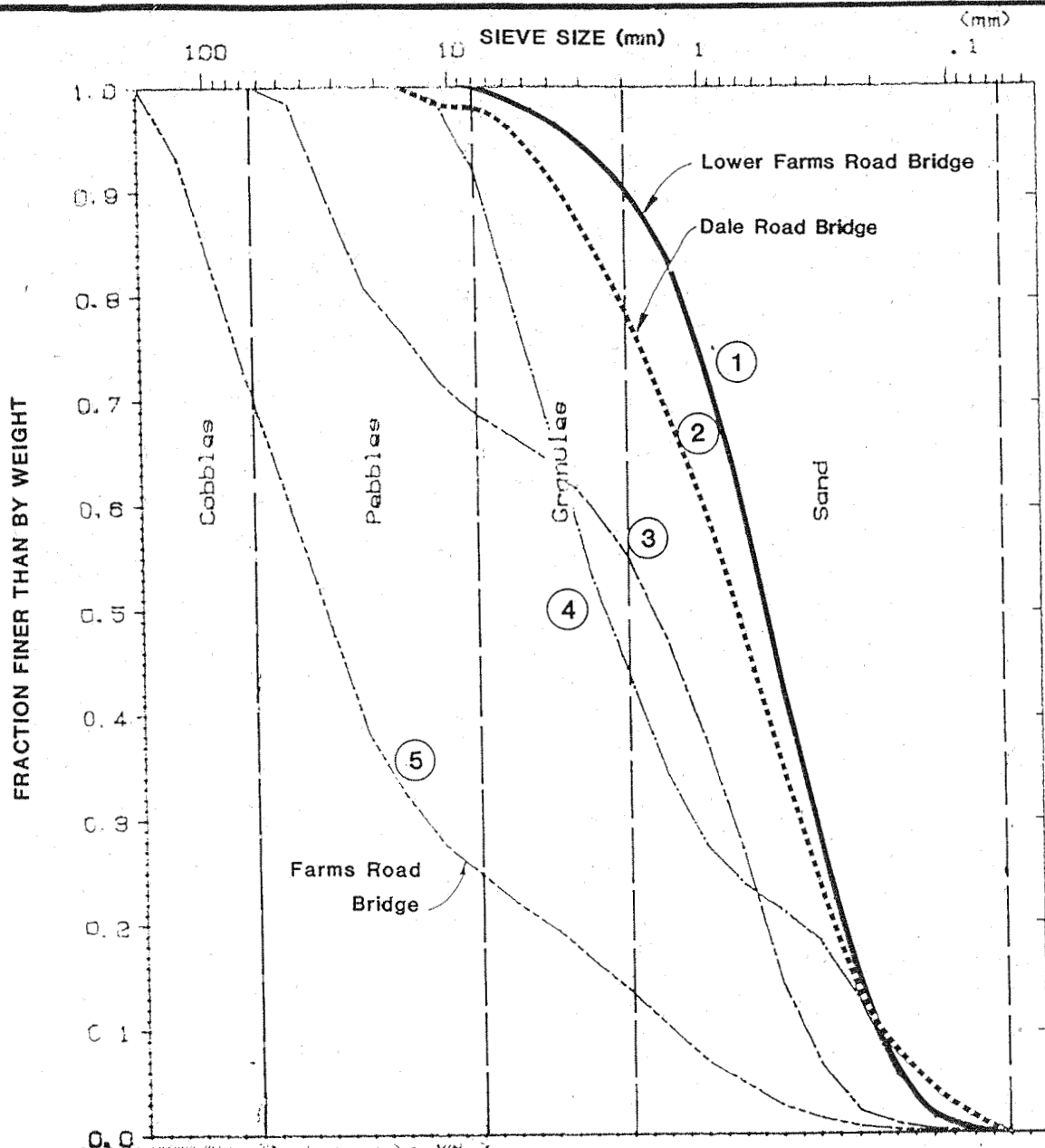
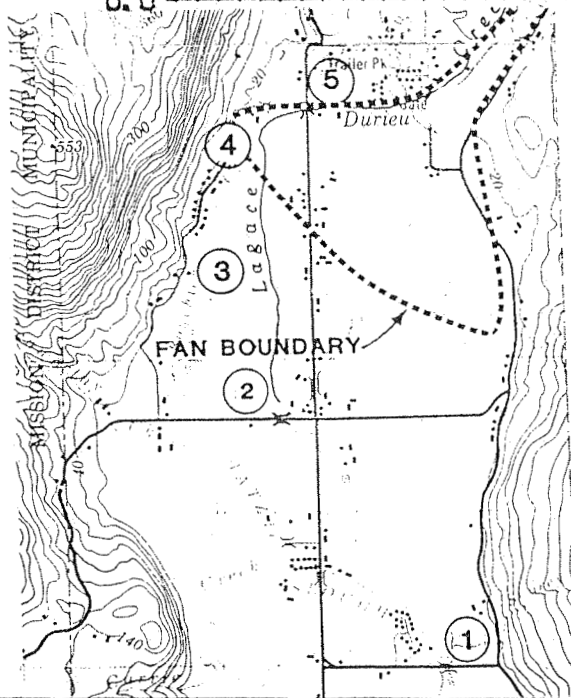


Hatzic Prairie Study

Pattison/Lagace Creek Profile

Erosion, Transport, and Deposition

northwest hydraulic consultants

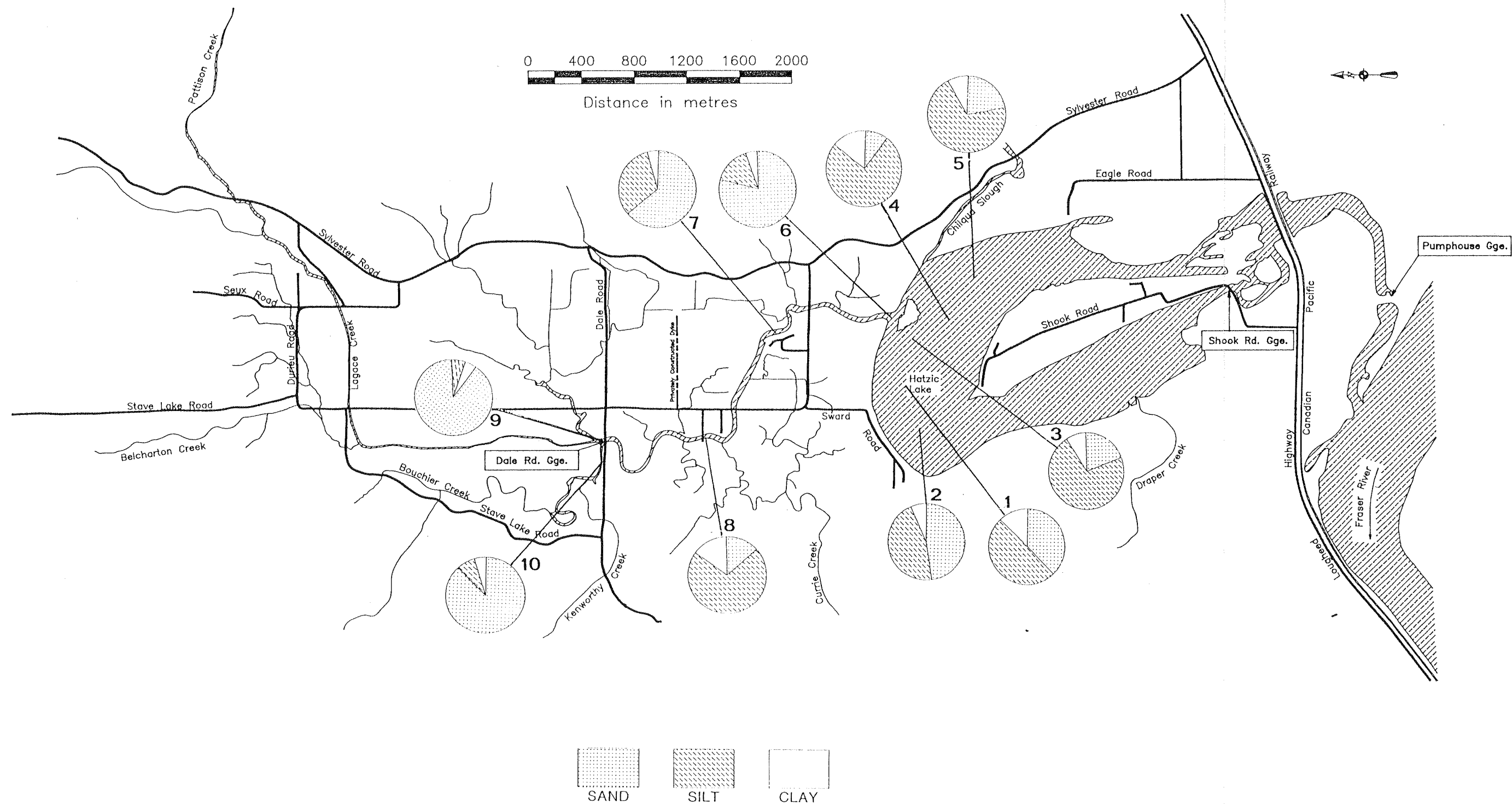


Hatzic Prairie Study

Grain Size Analyses
of Bed Material

northwest hydraulic consultants

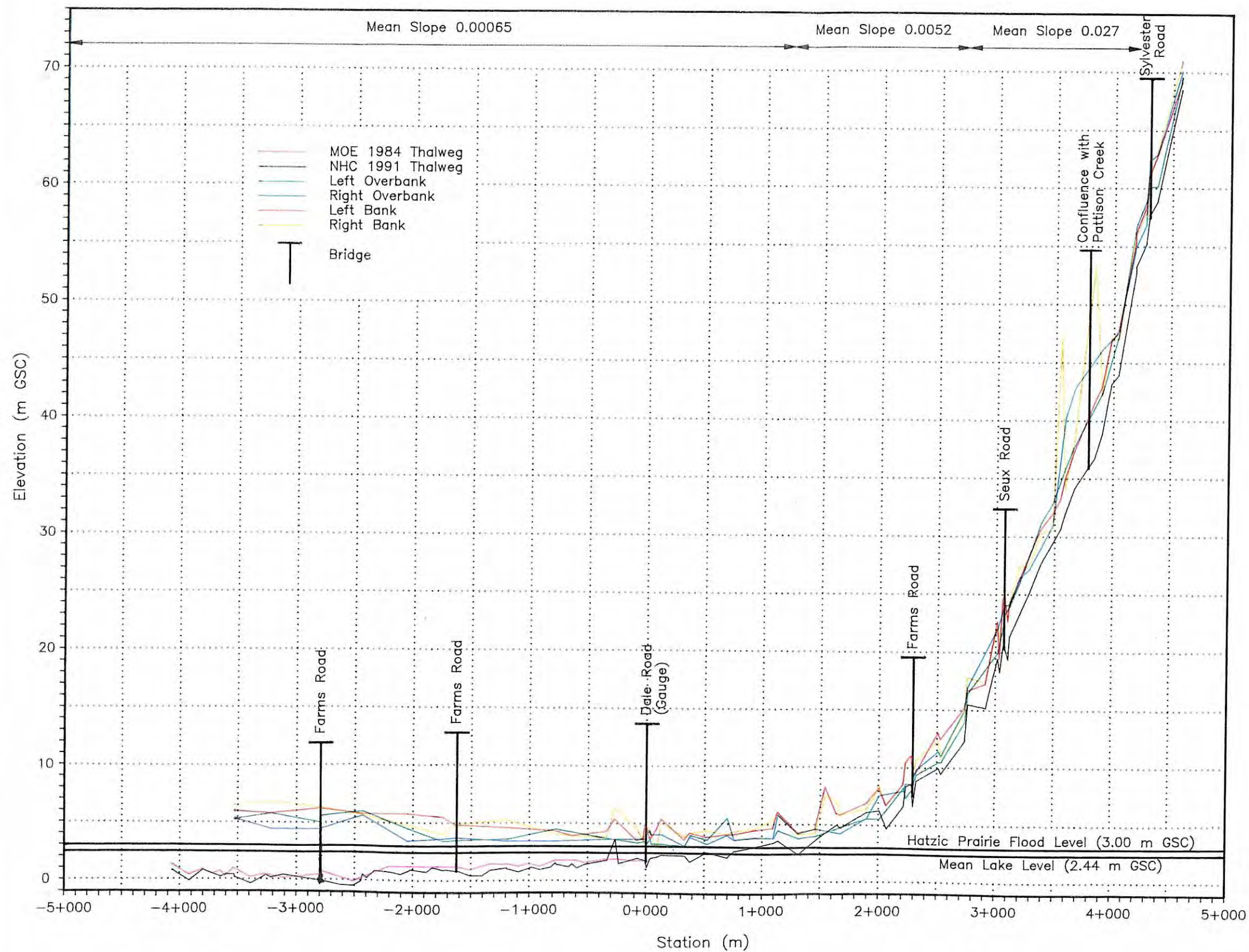
DWG No. 3.9



Hatzic Prairie Study

Sediment Sample Locations
September 1991

northwest hydraulic consultants



Hatzic Prairie Study

Lagace Creek
Thalweg and Bank Profiles

northwest hydraulic consultants

DWG No. 3.11



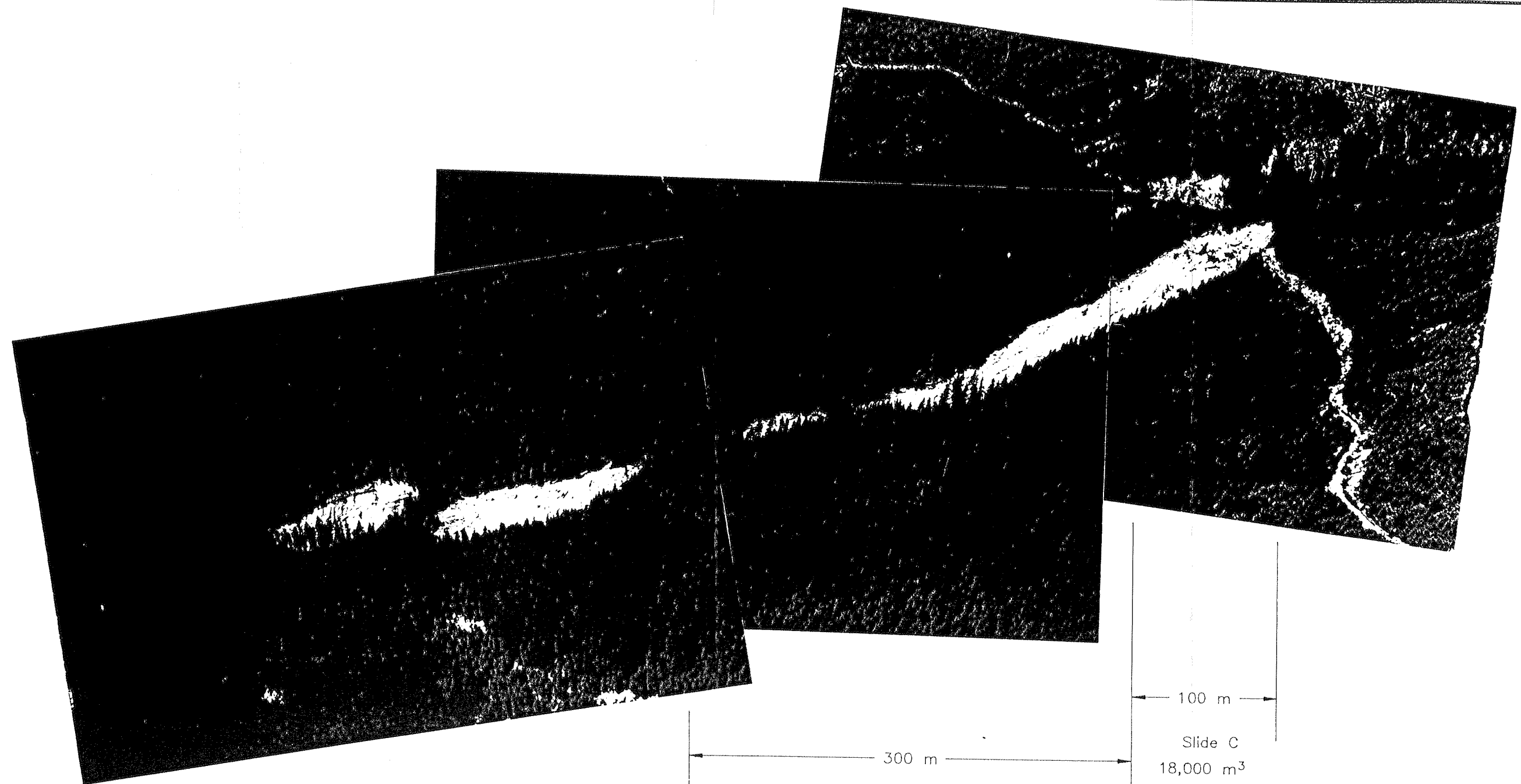
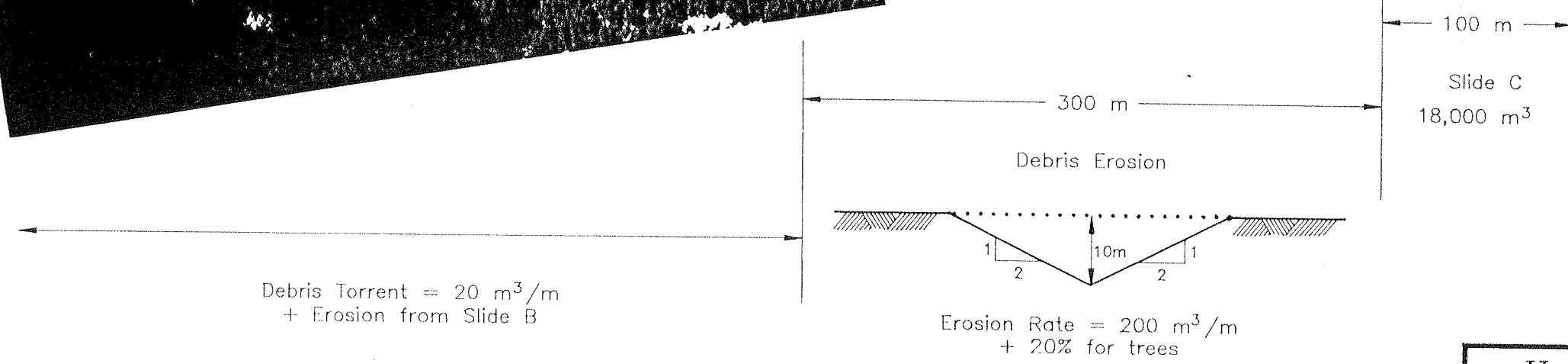
Hatzic Prairie Study

Pattison Creek Watershed
18 May 1968

northwest hydraulic consultants

NHCV1692-051

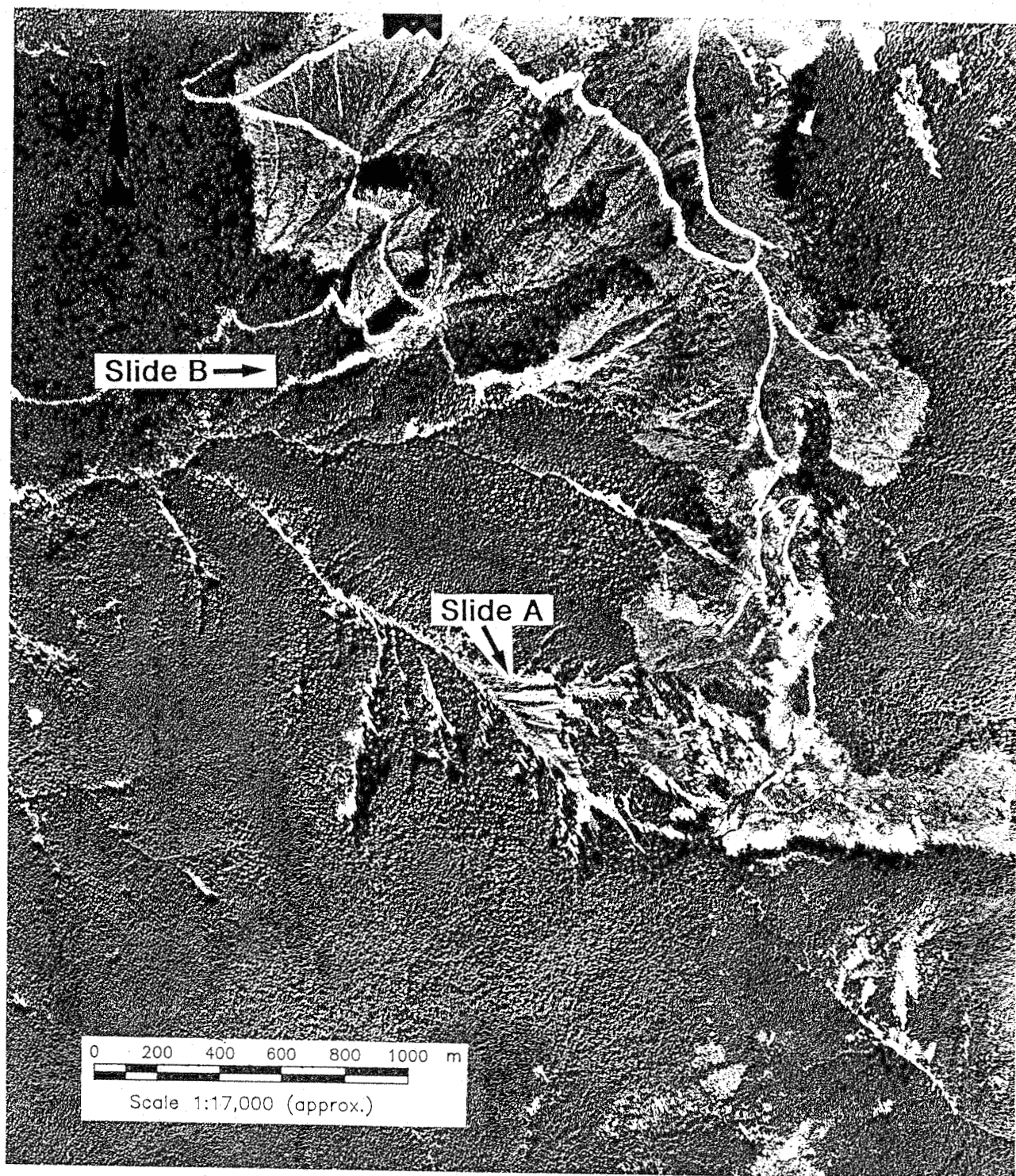
DWG No. 3.12



Hatzic Prairie Study

Debris Torrent
Sediment Budget

northwest hydraulic consultants

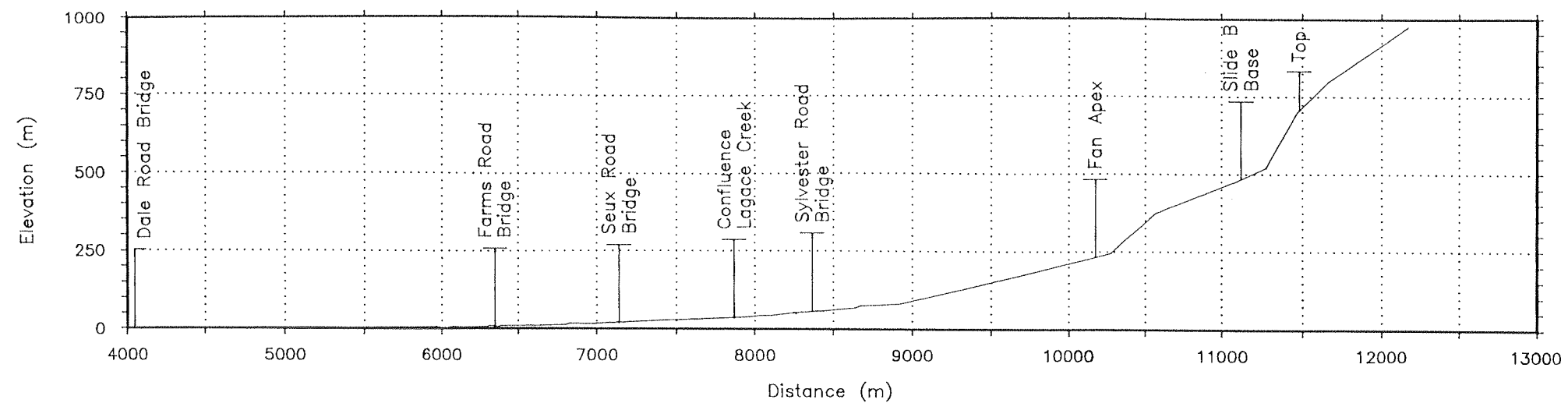


Hatzic Prairie Study

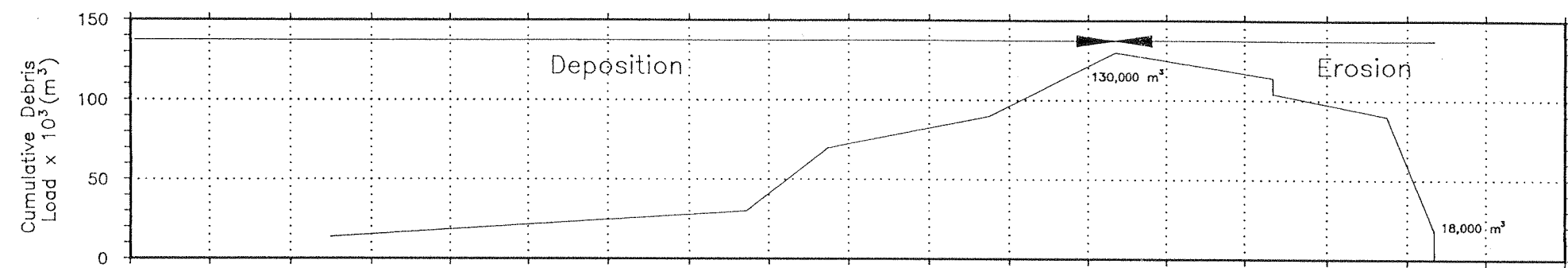
Pattison Creek Watershed

21 June 1990

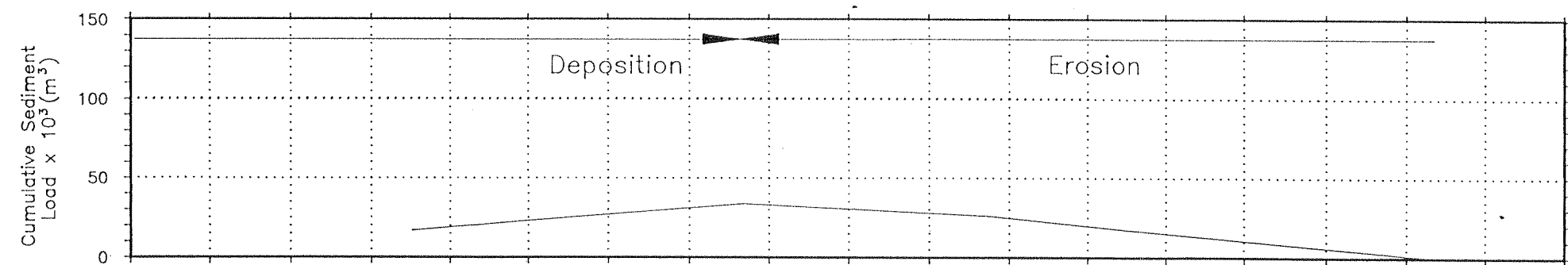
northwest hydraulic consultants



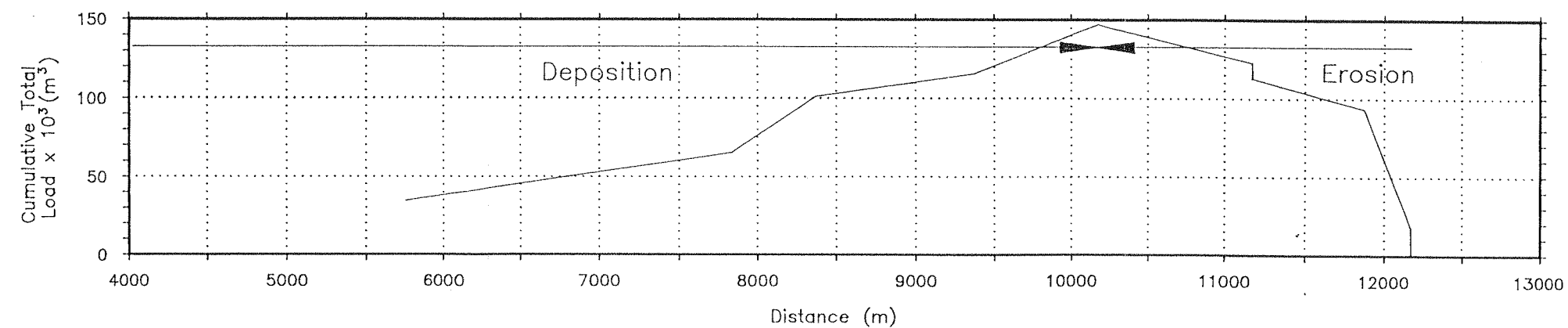
a) Profile of Pattison - Lagace Creeks.



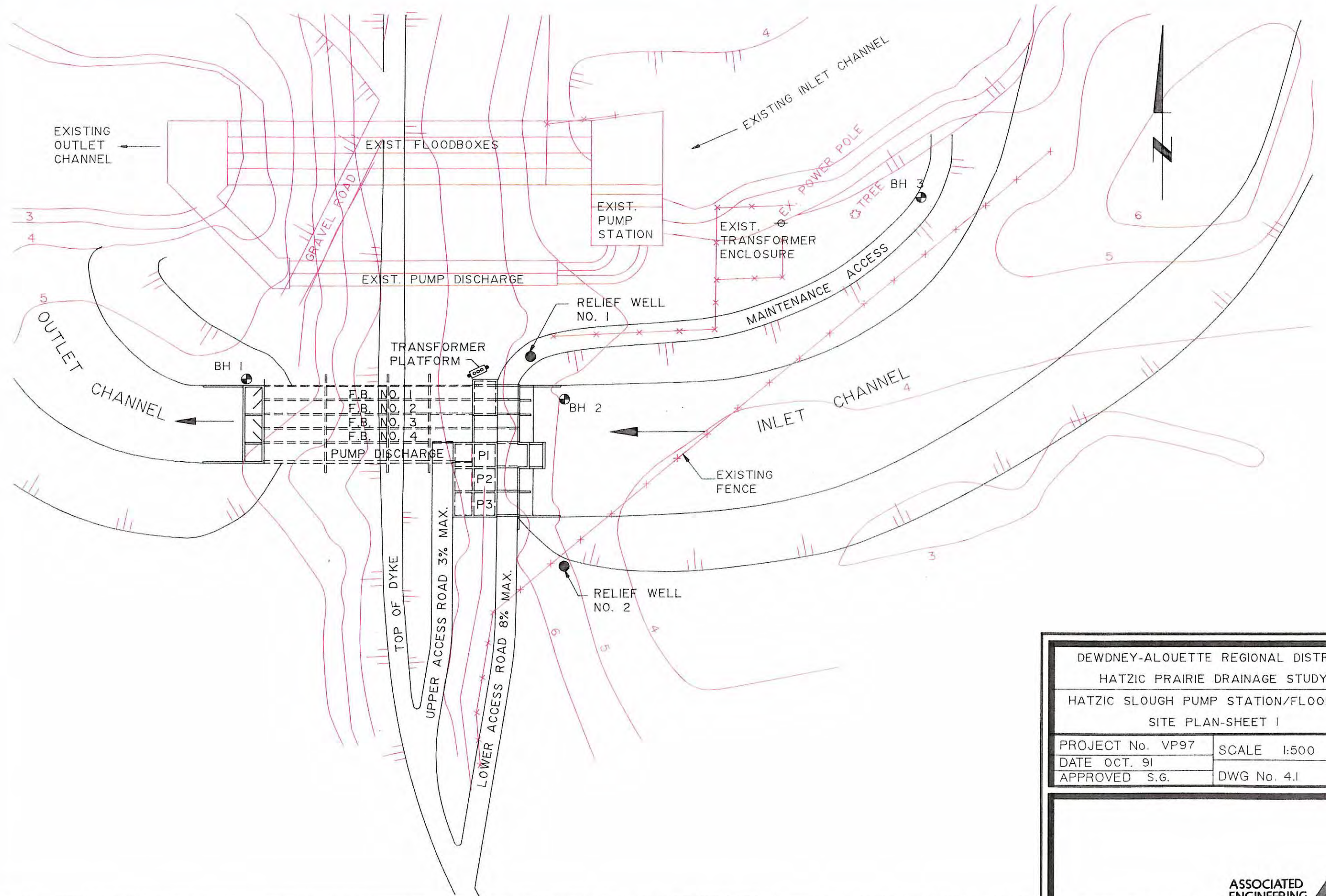
b) Sediment budget for debris flow event (about one hour).



c) Post-debris torrent sediment budget (about one day).

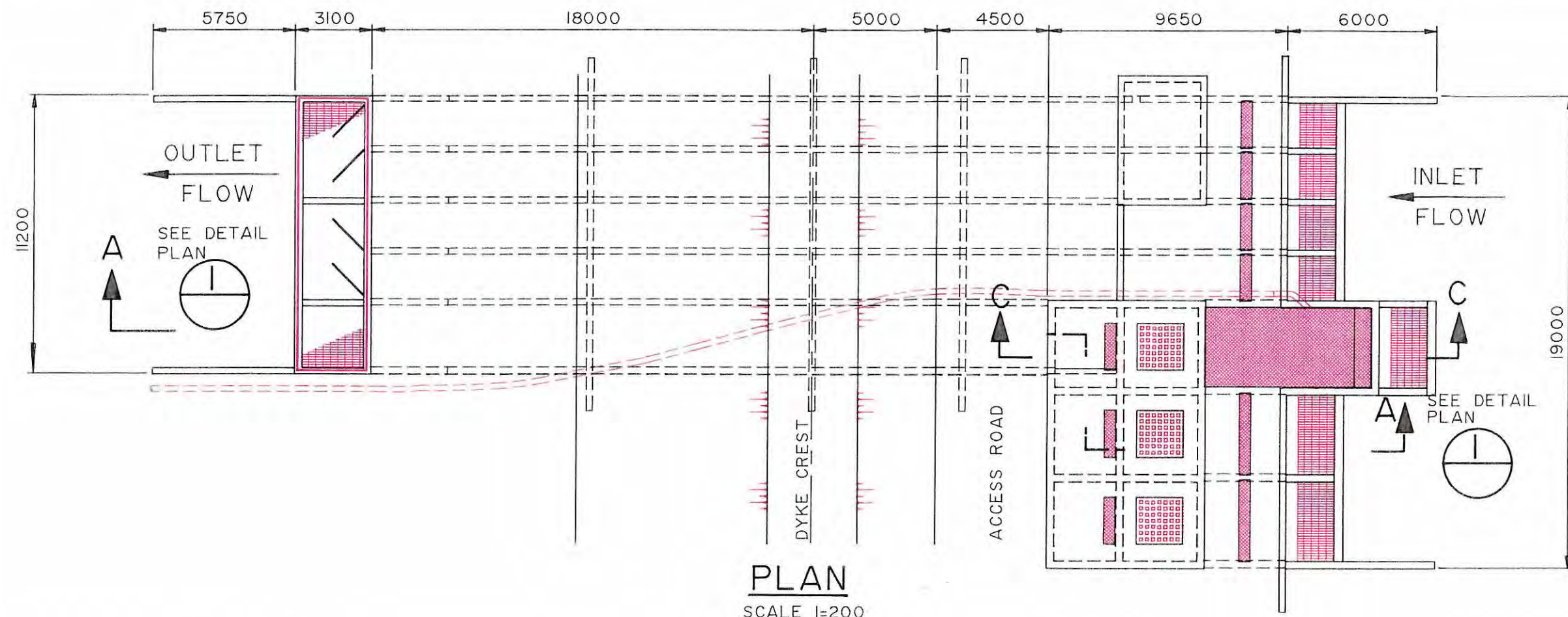
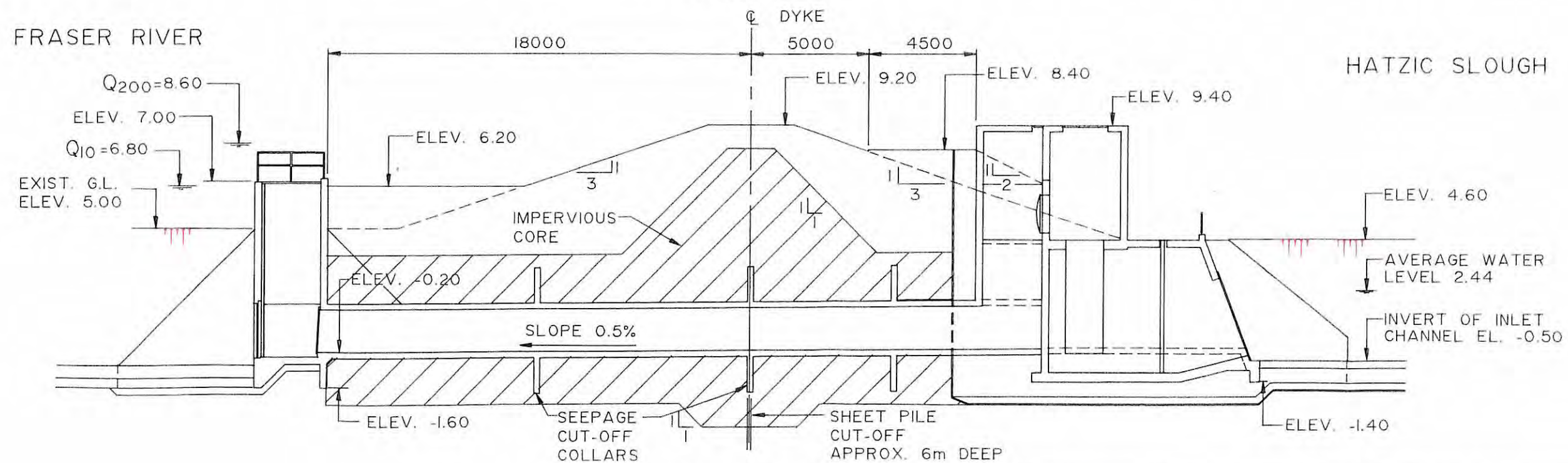


d) Total sediment budget (about one day).



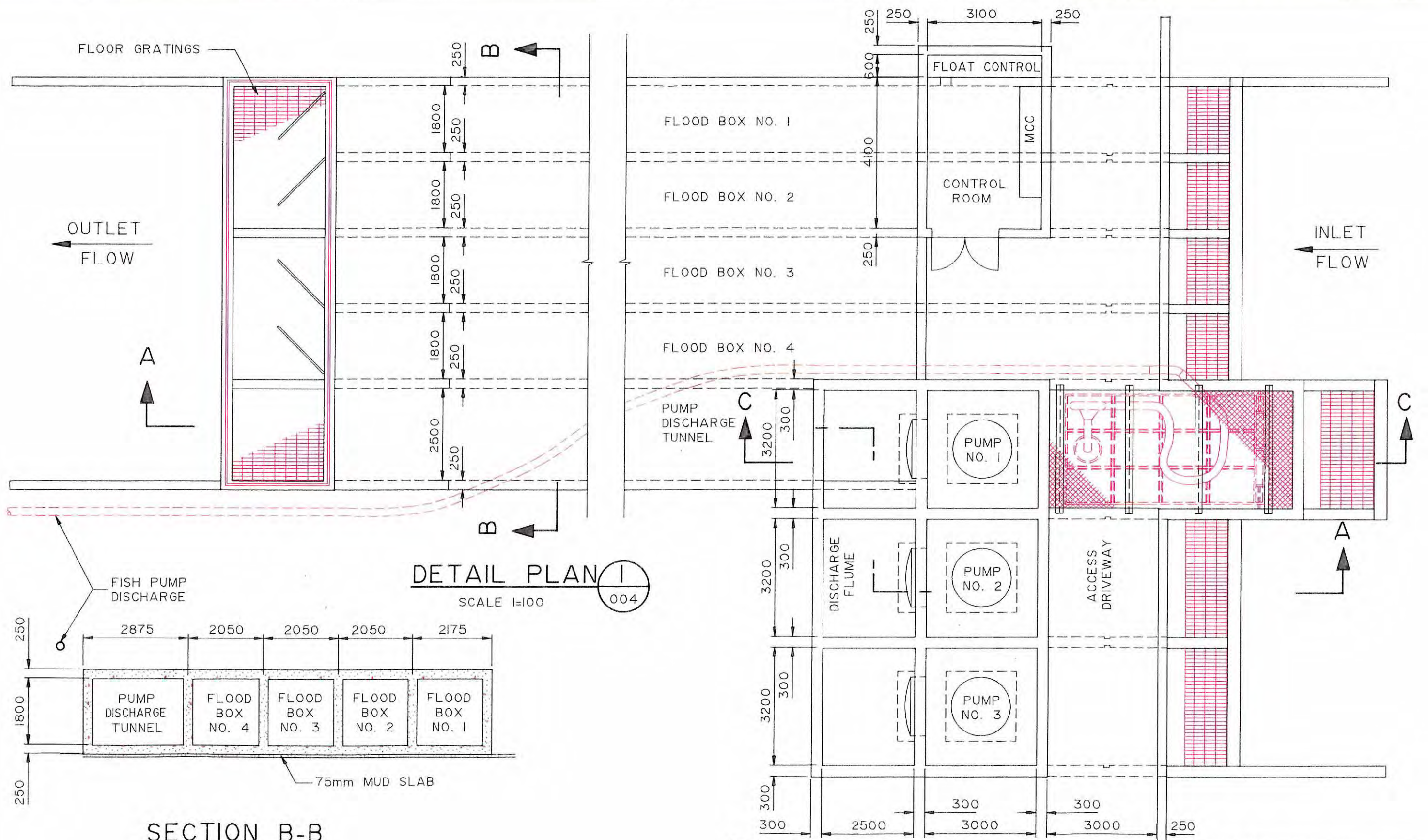
DEWDNEY-ALOUETTE REGIONAL DISTRICT
 HATZIC PRAIRIE DRAINAGE STUDY
 HATZIC SLOUGH PUMP STATION/FLOODBOX
 SITE PLAN-SHEET 1

PROJECT No. VP97	SCALE 1:500
DATE OCT. 91	
APPROVED S.G.	DWG No. 4.1



PROJECT No. VP97
 DATE OCT. 91
 APPROVED S.G.
 SCALE 1:200
 DWG No. 4.2

DEWDNEY-ALOUETTE REGIONAL DISTRICT
 HATZIC PRAIRIE DRAINAGE STUDY
 HATZIC SLOUGH PUMP STATION/FLOODBOX
 PLAN AND SECTION-SHEET 2

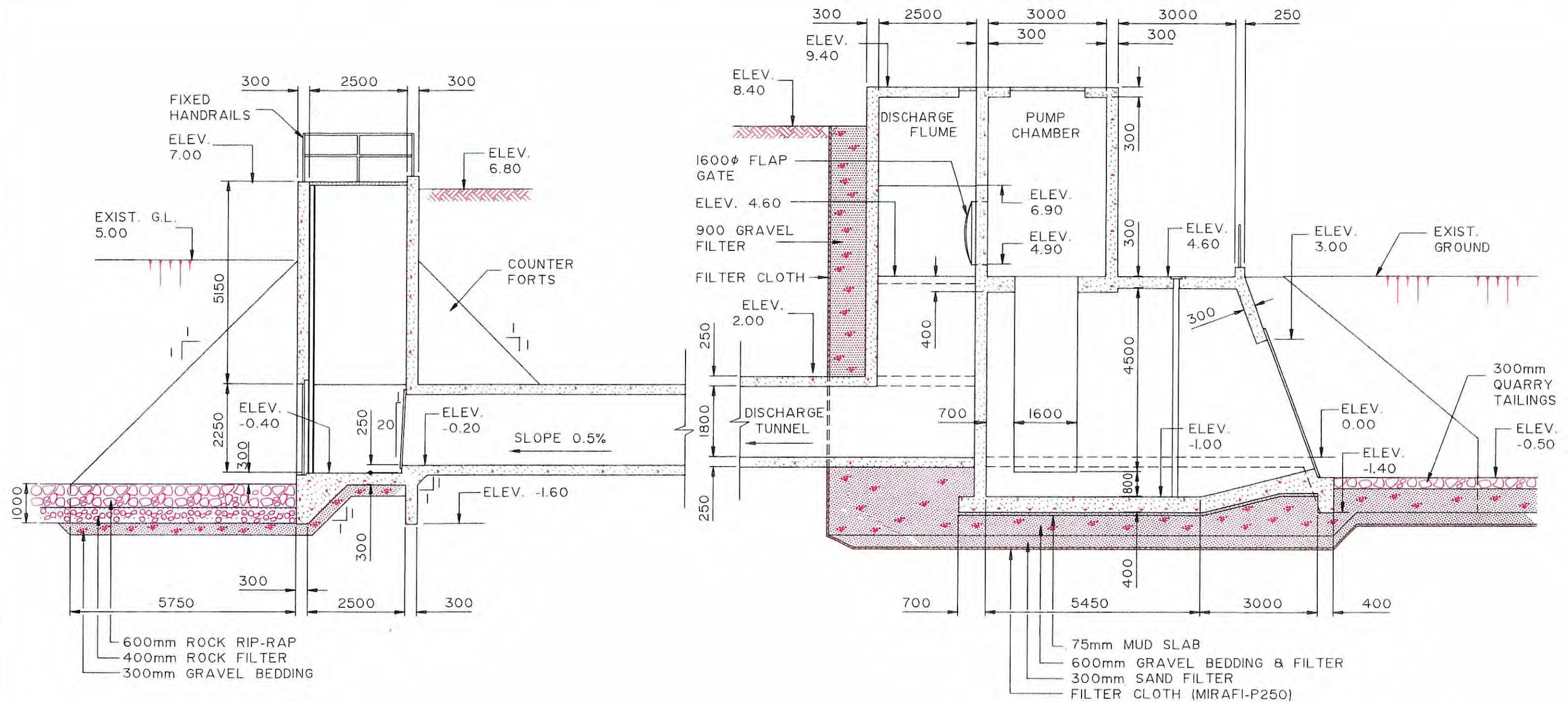


PROJECT No. VP97
 DATE OCT. 91
 APPROVED S.G.
 SCALE 1:100
 DWG No. 4.3

DEWDNEY-ALOUETTE REGIONAL DISTRICT
 HATZIC PRAIRIE DRAINAGE STUDY
 HATZIC SLOUGH PUMP STATION/FLOODBOX
 DETAIL PLAN-SHEET 3

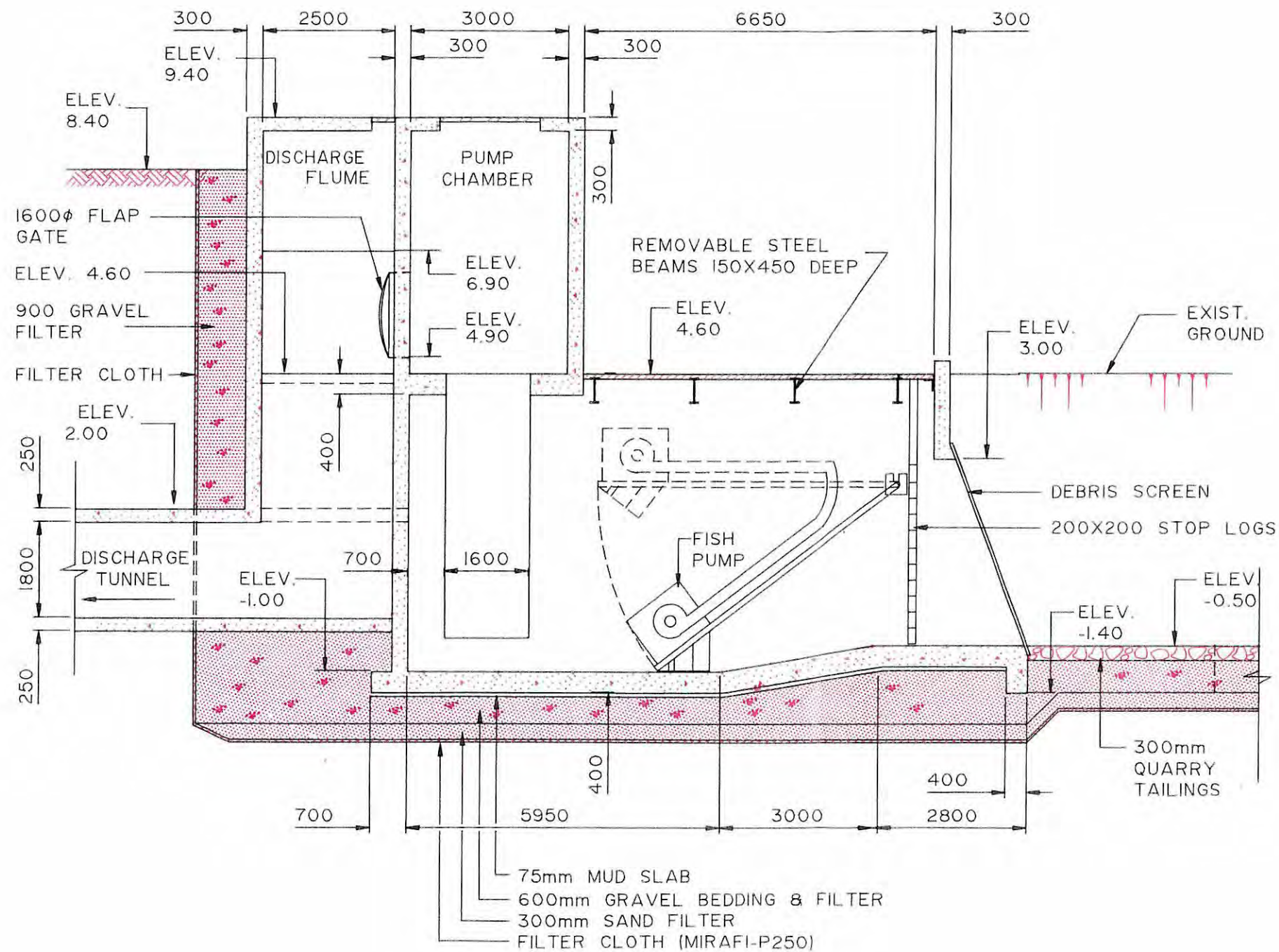
ASSOCIATED
 ENGINEERING





DETAIL SECTION A-A
(DYKE DELETED)
SCALE 1:100

DEWDNEY-ALOUETTE REGIONAL DISTRICT	
HATZIC PRAIRIE DRAINAGE STUDY	
HATZIC SLOUGH PUMP STATION/FLOODBBOX	
DETAIL SECTION-SHEET 4	
PROJECT No. VP97	SCALE 1:100
DATE OCT. 91	DWG No. 4.4
APPROVED S.G.	

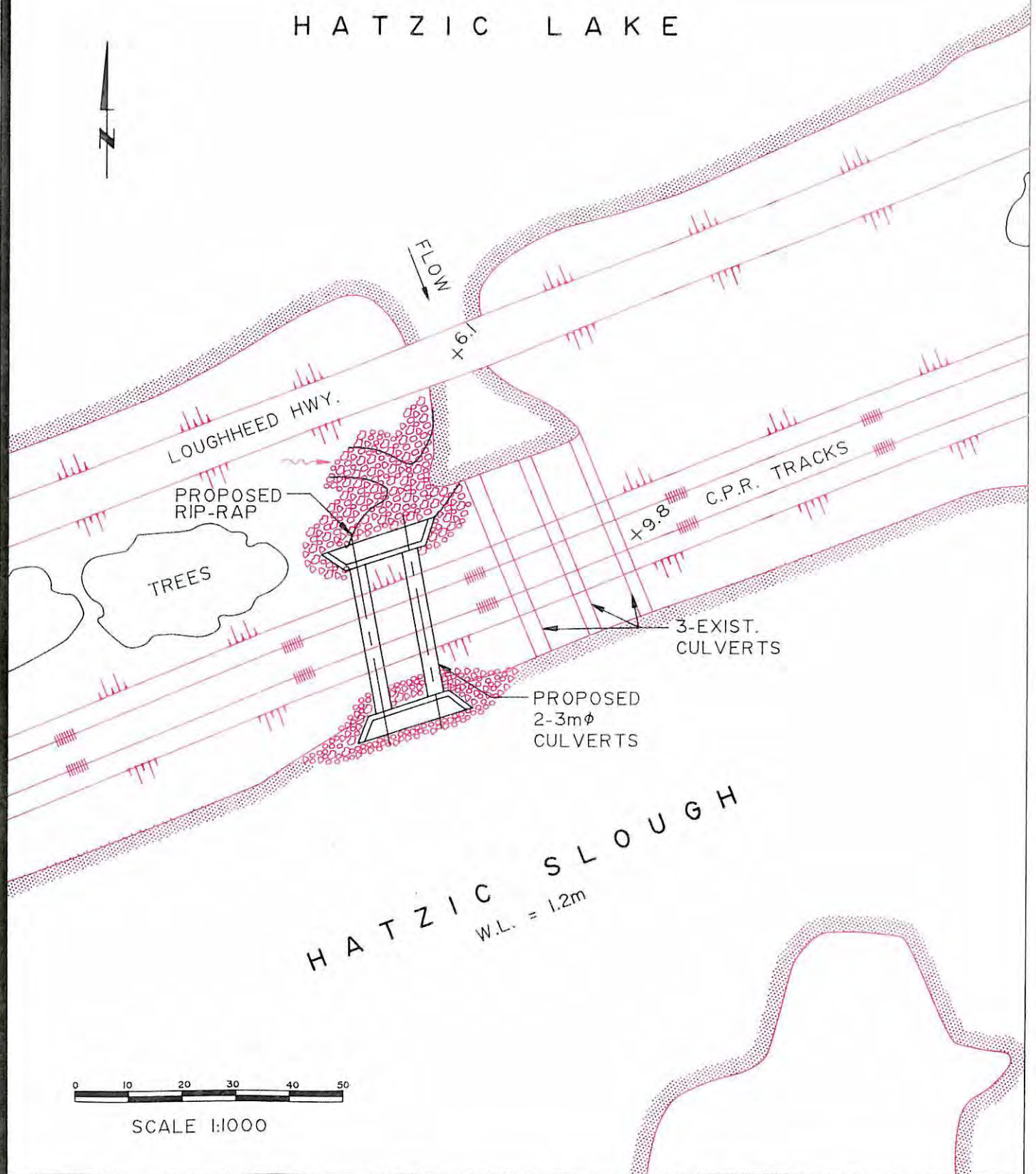


SECTION C-C
PUMP CHAMBER NO. 1
 SCALE 1:100

DEWDNEY-ALOUETTE REGIONAL DISTRICT
 HATZIC PRAIRIE DRAINAGE STUDY
 HATZIC SLOUGH PUMP STATION/FLOODBOX
 DETAIL SECTION-SHEET 5

PROJECT No. VP97	SCALE 1:100
DATE OCT. 91	
APPROVED S.G.	DWG No. 4.5

HATZIC LAKE



PROJECT No. VP97

DATE OCT/91

APPROVED LPB

SCALE 1:1000

DWG No. 4.6

DEWDNEY-ALOUETTE REGIONAL DISTRICT
HATZIC PRAIRIE DRAINAGE STUDY

LOCATION OF PROPOSED
CULVERTS AT CPR TRACKS

ASSOCIATED
ENGINEERING



HATZIC LAKE

FLOW ↓

ARTICULATED WALKWAY SECTION

1.2m WIDE FLOATING BROOM & WALKWAY

ARTICULATED WALKWAY SECTION

8.0m

2.0m

1.0m

6.0m

6.0m

6.0m

6.0m

6.0m

8.0m

1.0m

+4.0

SLOPE ±5%

PROPOSED ACCESS ROAD

+6.1

TO MISSION ←

EXIST. BRIDGE

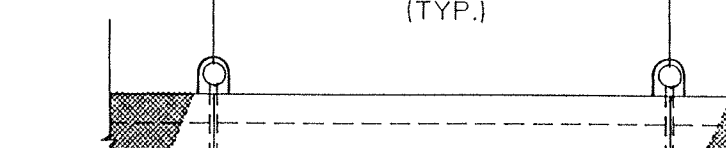
LOUGHEED HWY.

TO HARRISON →

SITE PLAN

SCALE 1=250

HANDRAIL ON DOWNSTREAM 1.6m



A plan view diagram of a bridge deck section. The deck is represented by a horizontal rectangle with a dashed centerline. At each end, there are two circular pile caps, each containing two circles representing 300mm diameter standard pipe piles. A dimension line above the deck indicates a length of 6.0m (TYP.). Hatched areas at the ends represent aluminum decking. Labels with leader lines point to the piles and the decking.

300 ϕ STD. PIPE PILES

6.0m (TYP.)

ALUMINUM DECKING

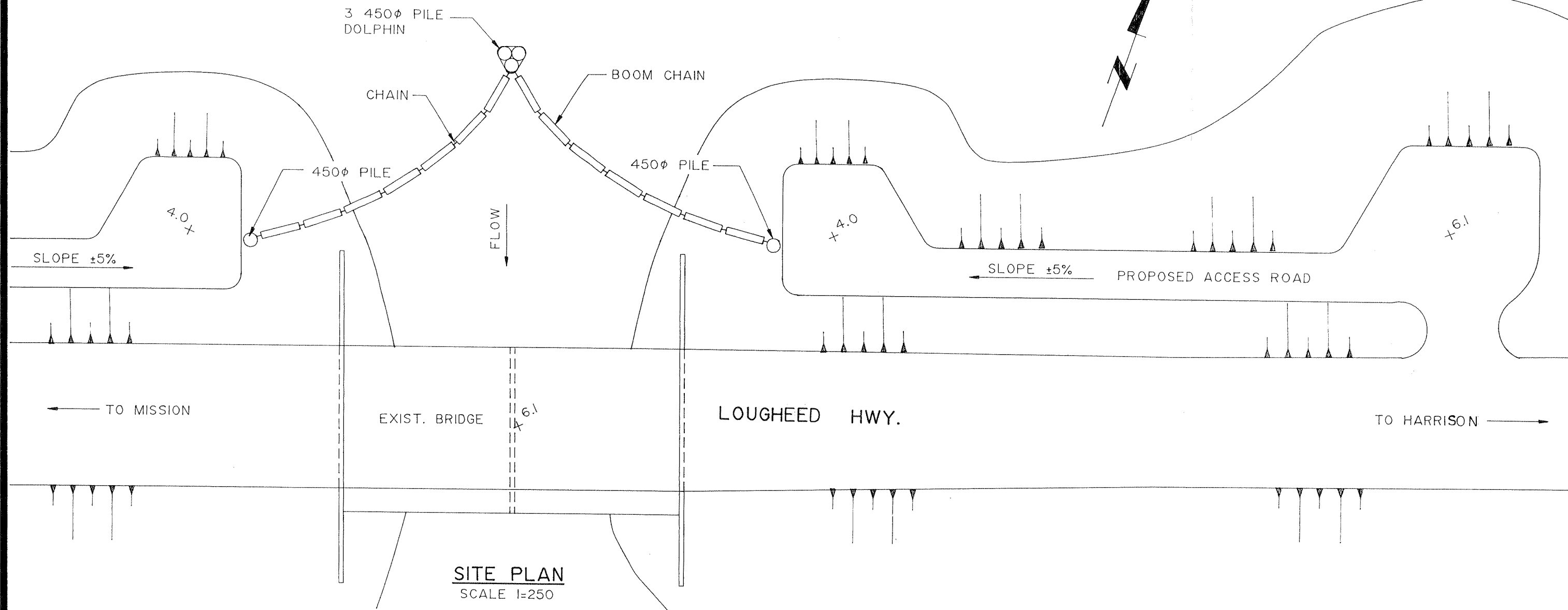
TYPICAL
PLAN DETAIL
SCALE 1:100

Diagram illustrating the cross-section of a bridge structure, showing the piles, deck, and water levels. The diagram includes the following labels and dimensions:

- HANDRAIL ON DOWNSTREAM ONLY
- TOP OF PILE ELEV. 5.0 (16.4 FT.)
- MAX. FLOOD LEVEL 4.3 (14.1 FT.)
- 400 ϕ STEEL PIPES
- LOW LEVEL 2.0 (6.6 FT.)
- 1.6m
- 1.2m
- ALUMINUM DECKING
- L 100X300 WELDED TO STEEL PILES
- 300 ϕ STD. PIPE PILES TO APPROX. -5.0 (-16.4 FT.)
- C310 STOP

**ASSOCIATED
ENGINEERING** 

HATZIC LAKE



DEWDNEY-ALOUETTE REGIONAL DISTRICT
HATZIC PRAIRIE DRAINAGE STUDY

HATZIC LAKE
DEBRIS CONTROL STRUCTURE

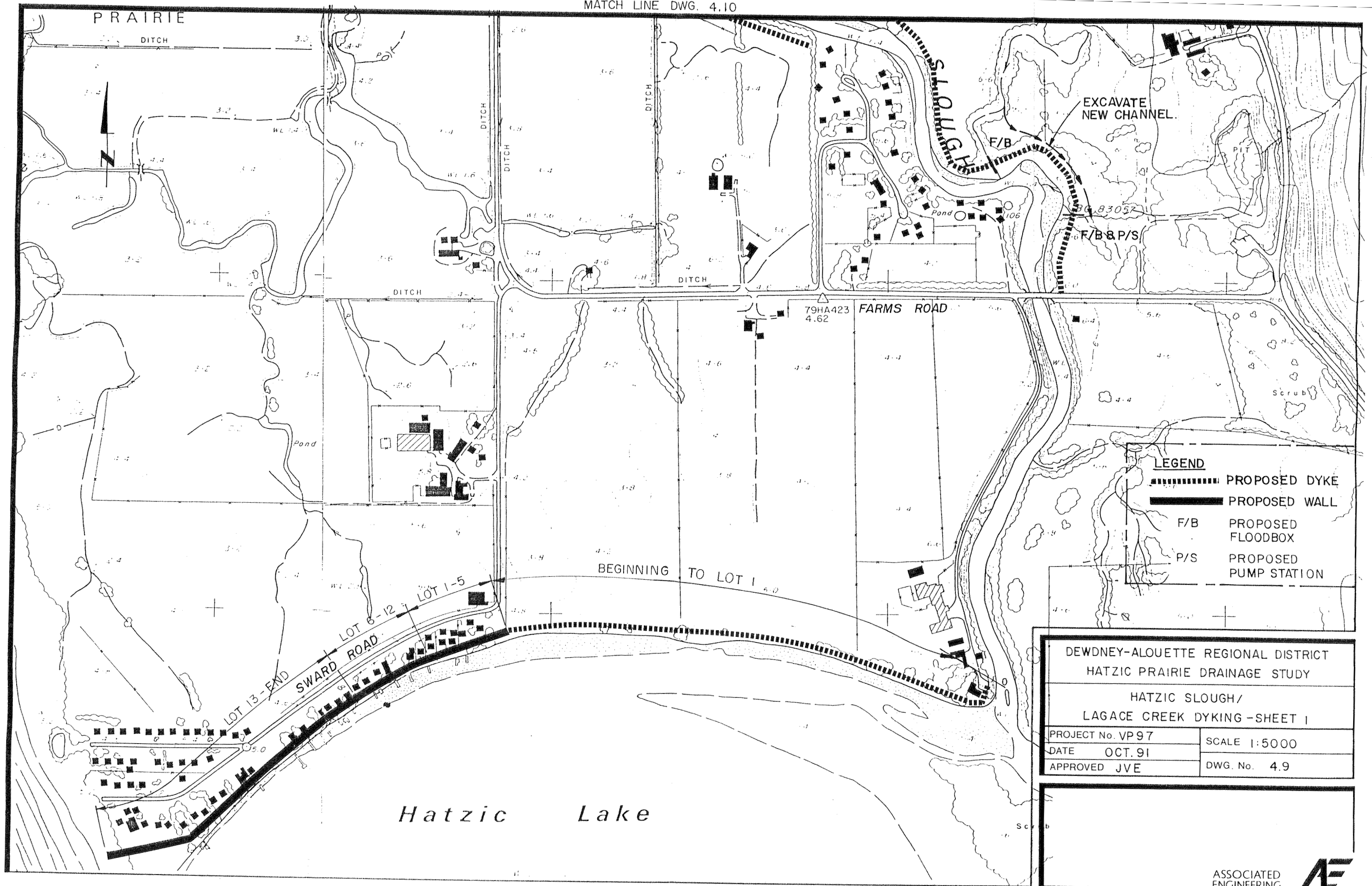
PROJECT No. VP97

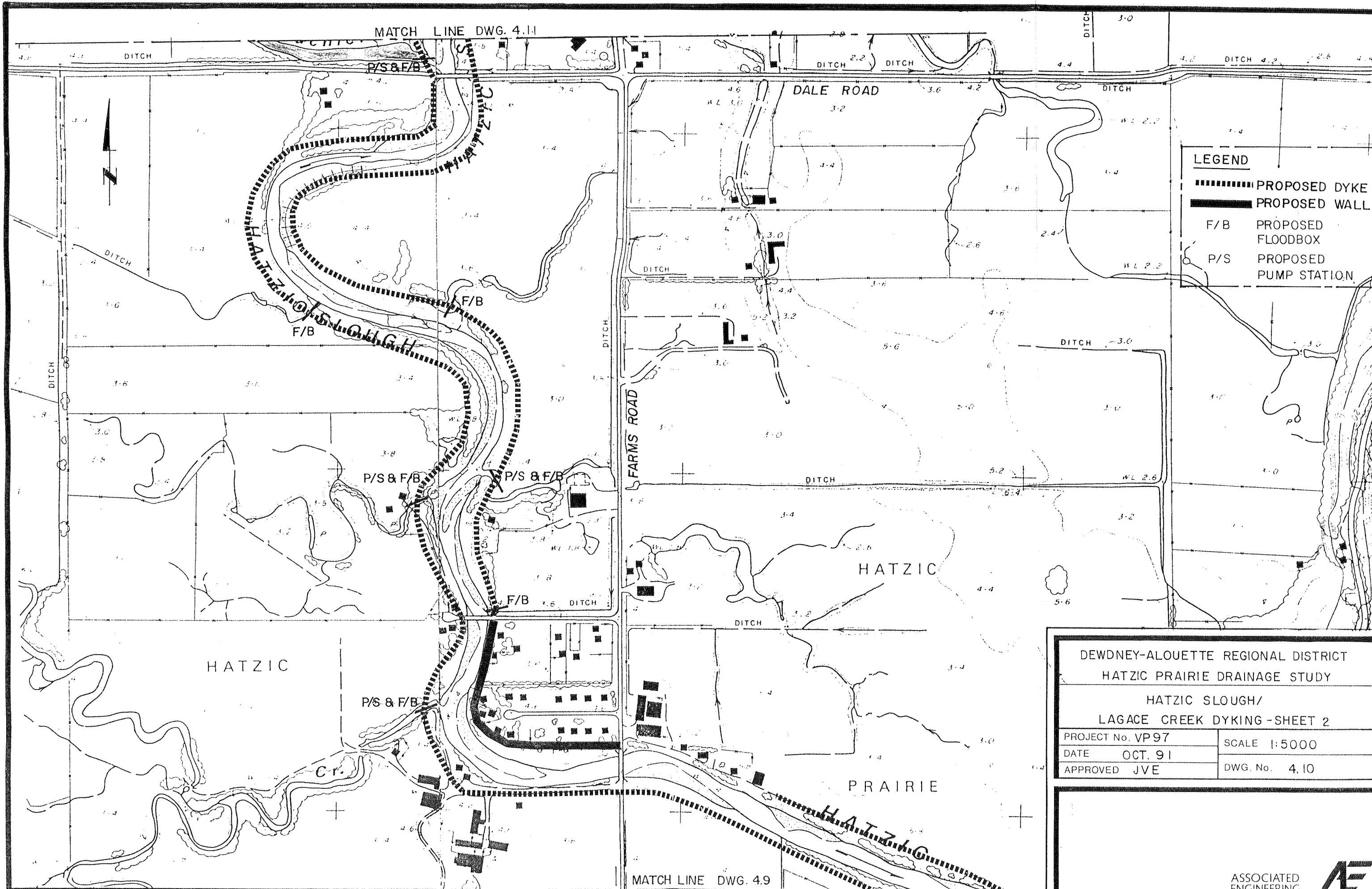
SCALE 1:250

DATE OCT. 91

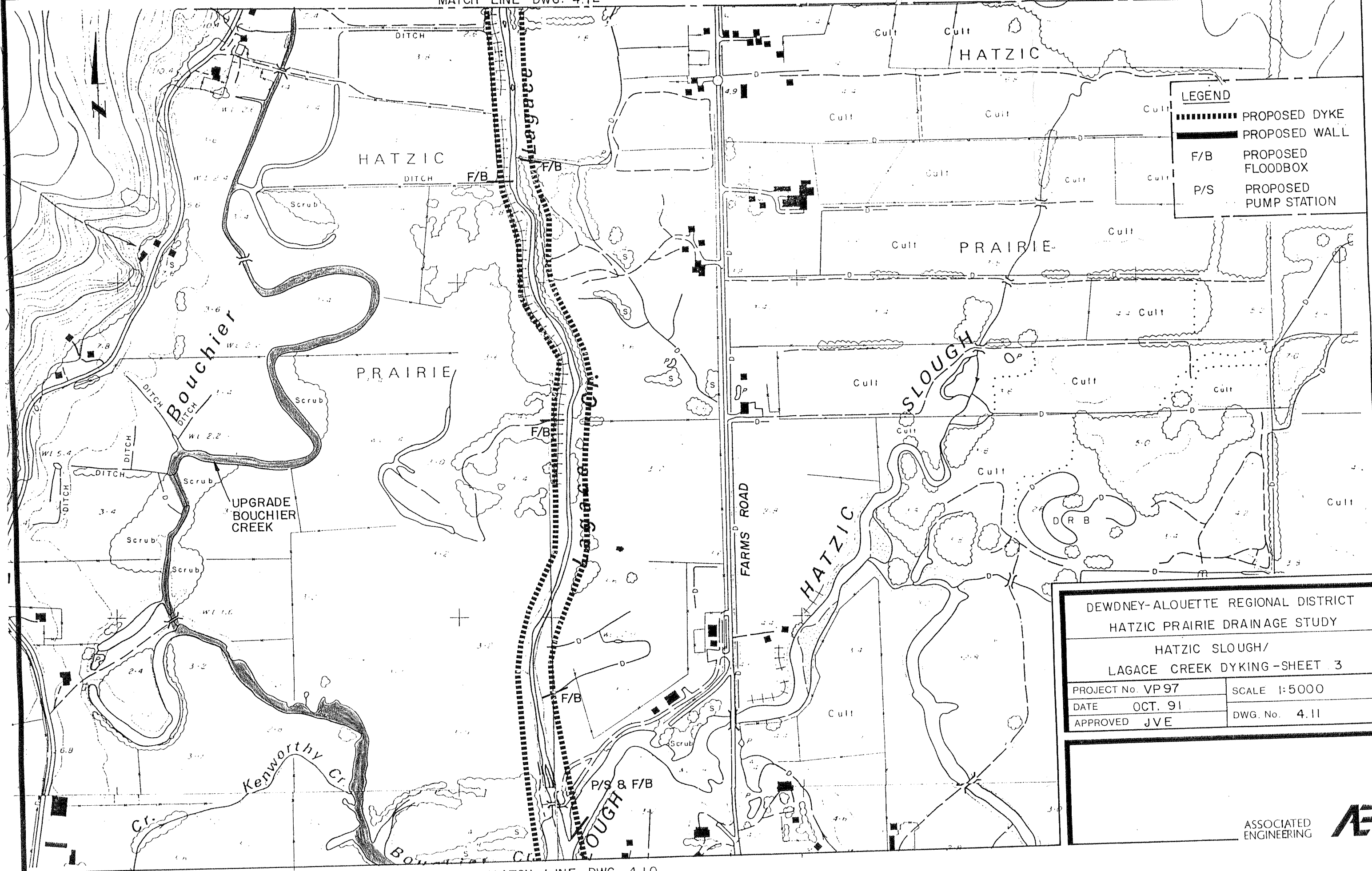
APPROVED S.G.

DWG No. 4.8





MATCH LINE DWG. 4.12



MATCH LINE DWG. 4.10

LEGEND

- PROPOSED DYKE
- PROPOSED WALL
- F/B PROPOSED FLOODBOX
- P/S PROPOSED PUMP STATION

DEWDNEY-ALOUETTE REGIONAL DISTRICT
HATZIC PRAIRIE DRAINAGE STUDY

HATZIC SLOUGH/
LAGACE CREEK DYKING-SHEET 3

PROJECT No. VP 97

SCALE 1:5000

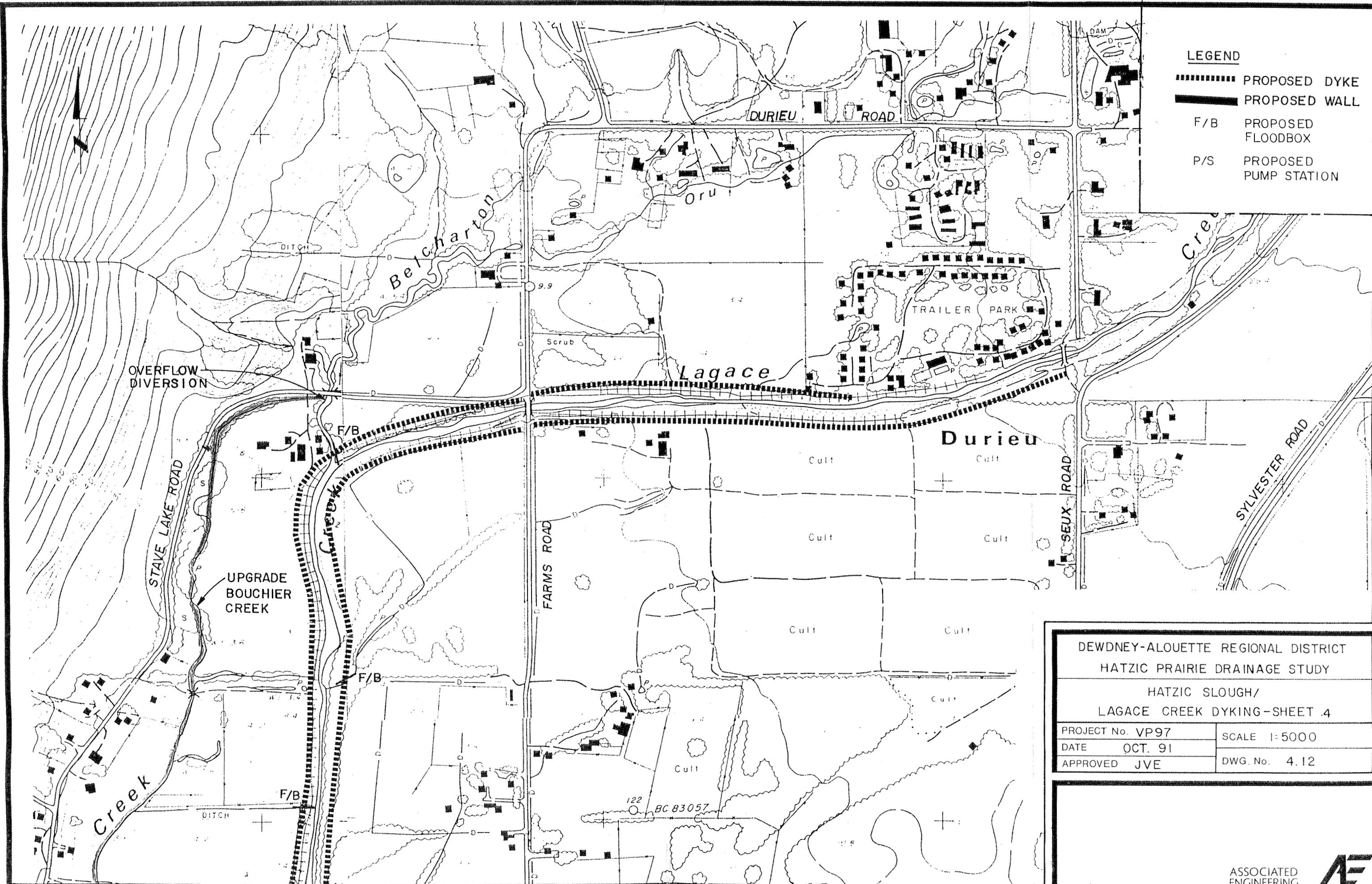
DATE OCT. 91

APPROVED JVE

DWG. No. 4.11

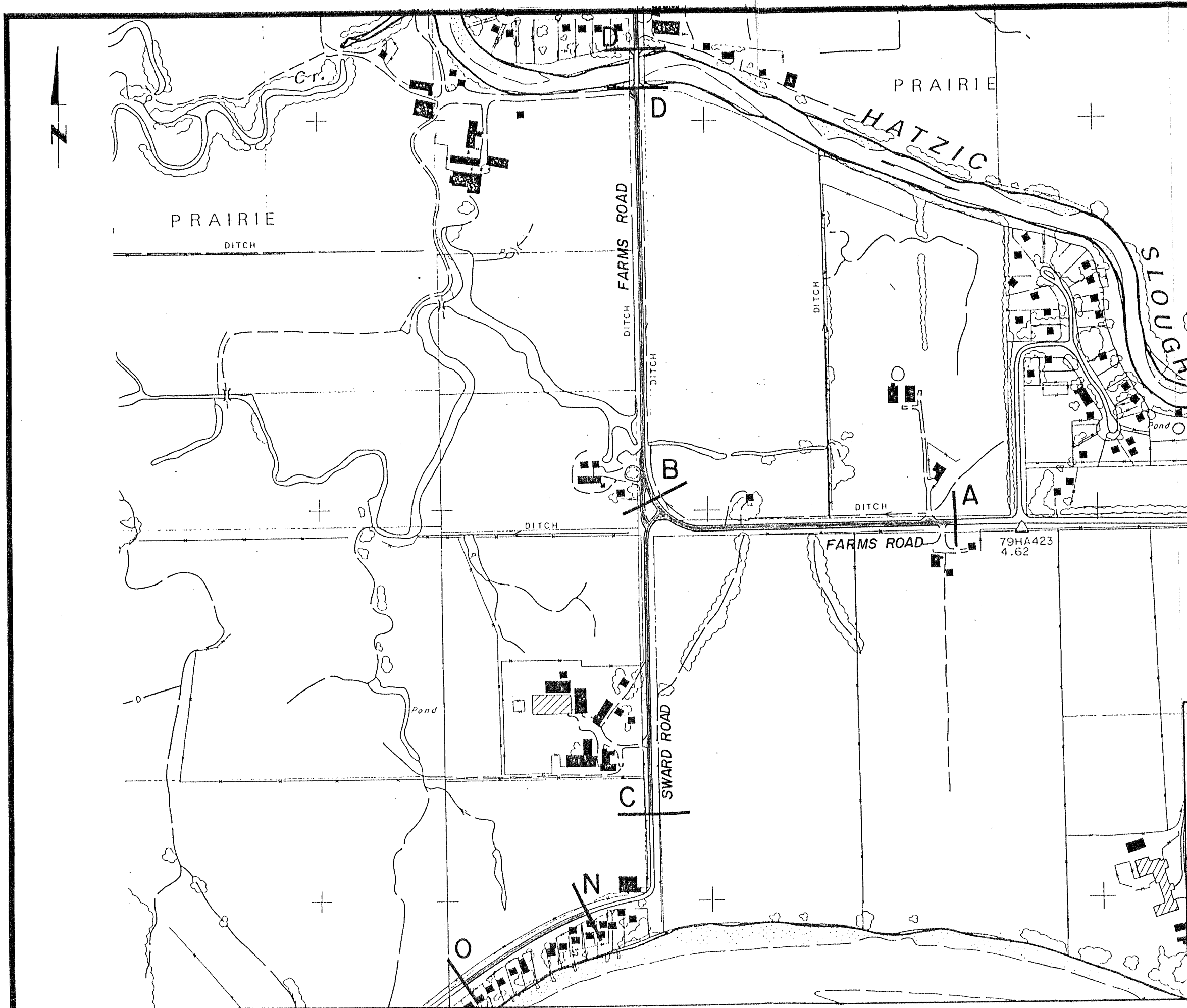
ASSOCIATED
ENGINEERING





- LEGEND**
- PROPOSED DYKE
 - PROPOSED WALL
 - F/B PROPOSED FLOODBOX
 - P/S PROPOSED PUMP STATION

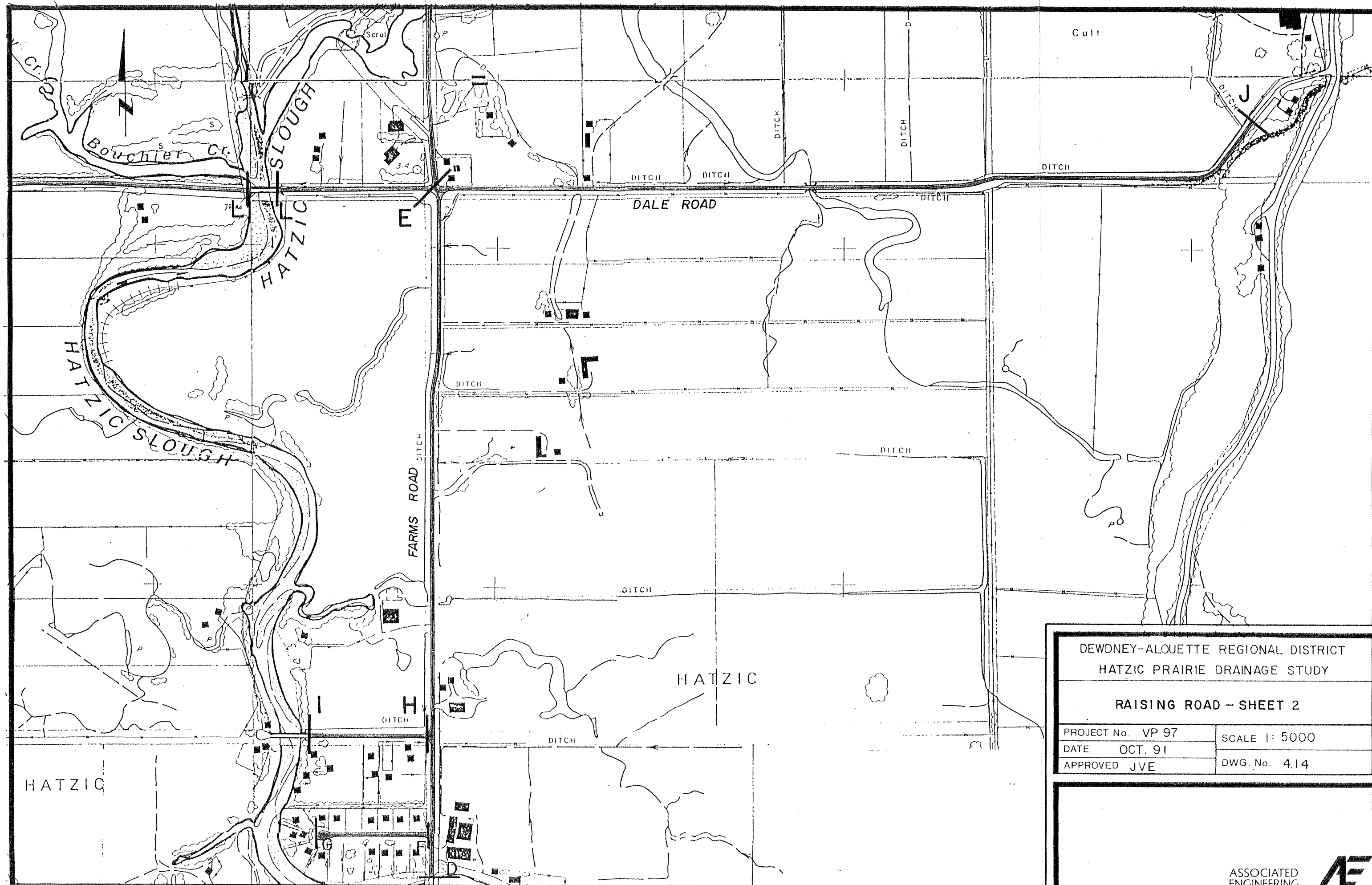
DEWDNEY-ALOUETTE REGIONAL DISTRICT	
HATZIC PRAIRIE DRAINAGE STUDY	
HATZIC SLOUGH/ LAGACE CREEK DYKING-SHEET .4	
PROJECT No. VP97	SCALE 1:5000
DATE OCT. 91	DWG. No. 4.12
APPROVED JVE	



DEWDNEY-ALOUETTE REGIONAL DISTRICT HATZIC PRAIRIE DRAINAGE STUDY	
RAISING ROAD - SHEET 1	
PROJECT No. VP 97	SCALE 1: 5000
DATE OCT. 91	DWG. No. 4.13
APPROVED JVE	



ASSOCIATED
ENGINEERING



DEWDNEY-ALOUETTE REGIONAL DISTRICT
HATZIC PRAIRIE DRAINAGE STUDY

RAISING ROAD - SHEET 2

PROJECT No. VP 97

DATE OCT. 91

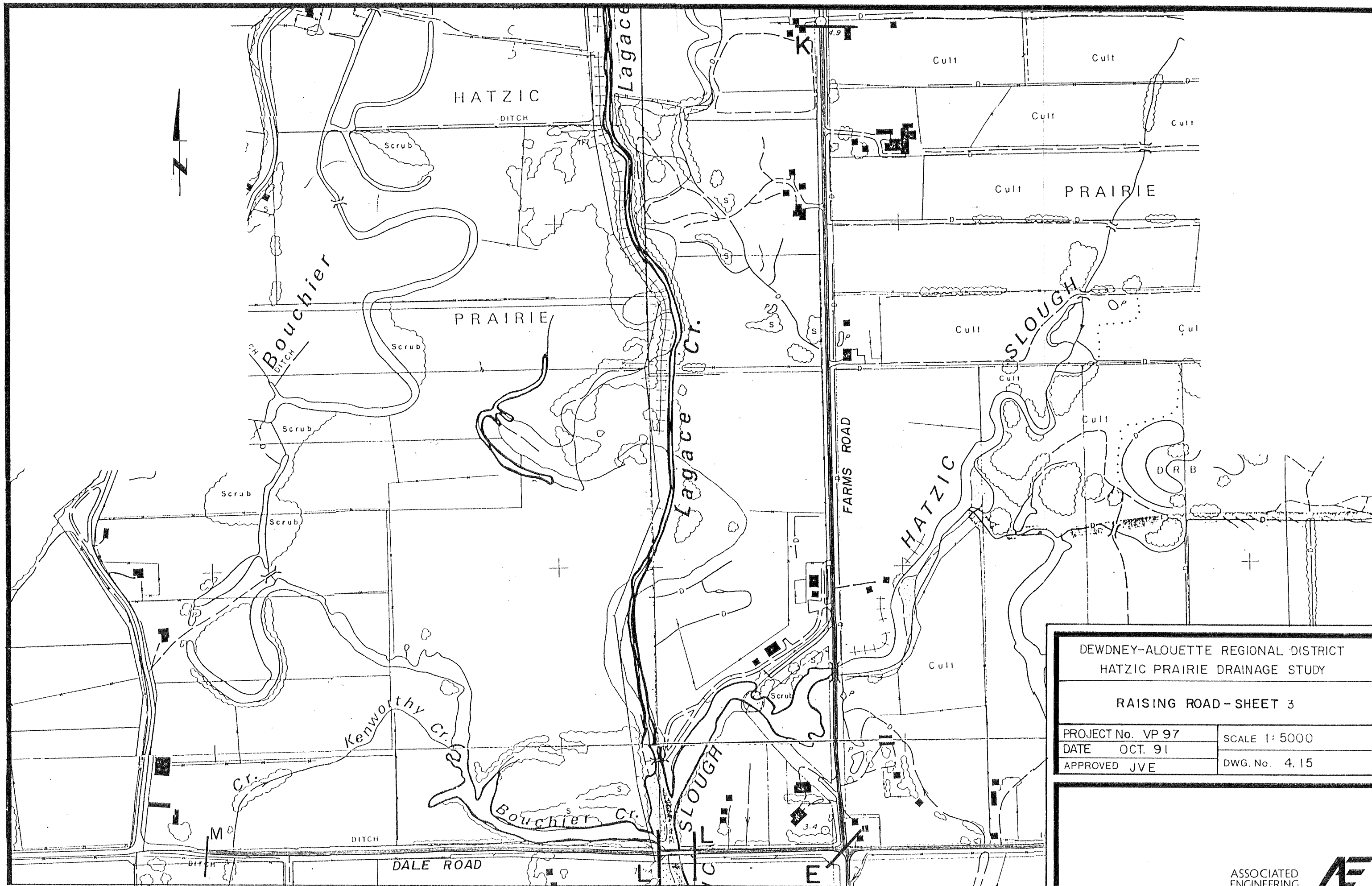
APPROVED JVE

SCALE 1: 5000

DWG. No. 4.14

ASSOCIATED
ENGINEERING





DEWDNEY-ALOUETTE REGIONAL DISTRICT
HATZIC PRAIRIE DRAINAGE STUDY

RAISING ROAD - SHEET 3

PROJECT No. VP 97

DATE OCT. 91

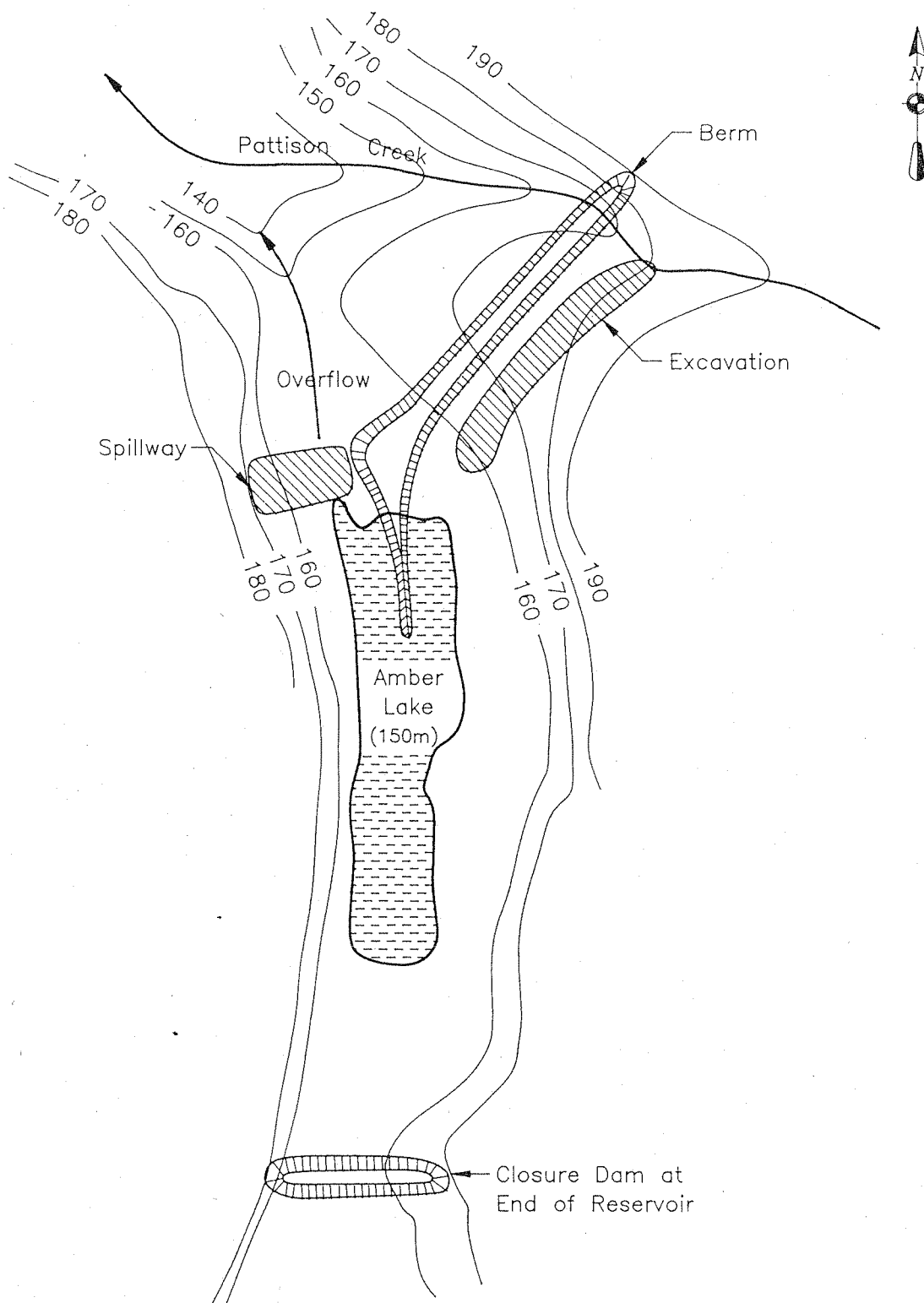
APPROVED JVE

SCALE 1: 5000

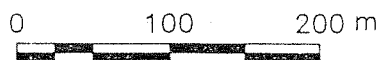
DWG. No. 4.15

ASSOCIATED
ENGINEERING





Note: Contour interval = 10 m.



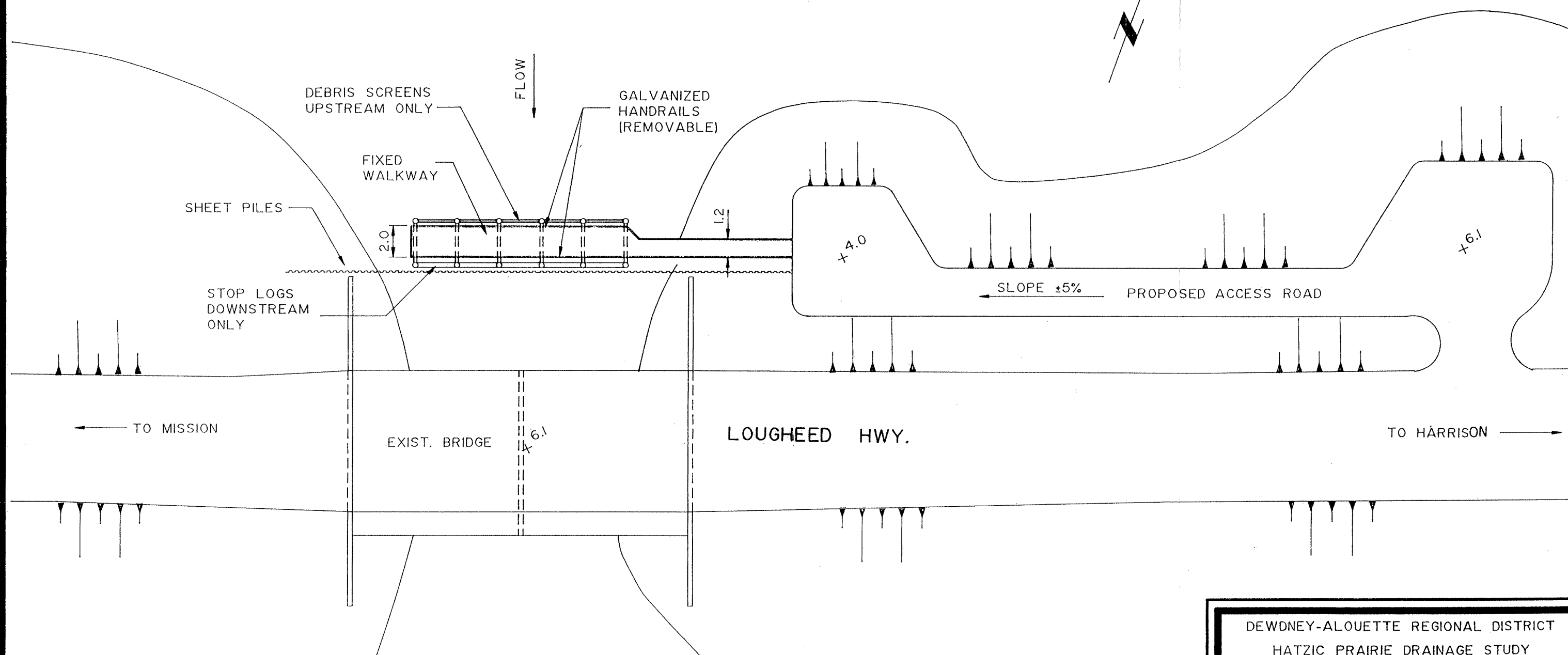
Scale 1:5000

Hatzic Prairie Study

Diversion of
Pattison Creek

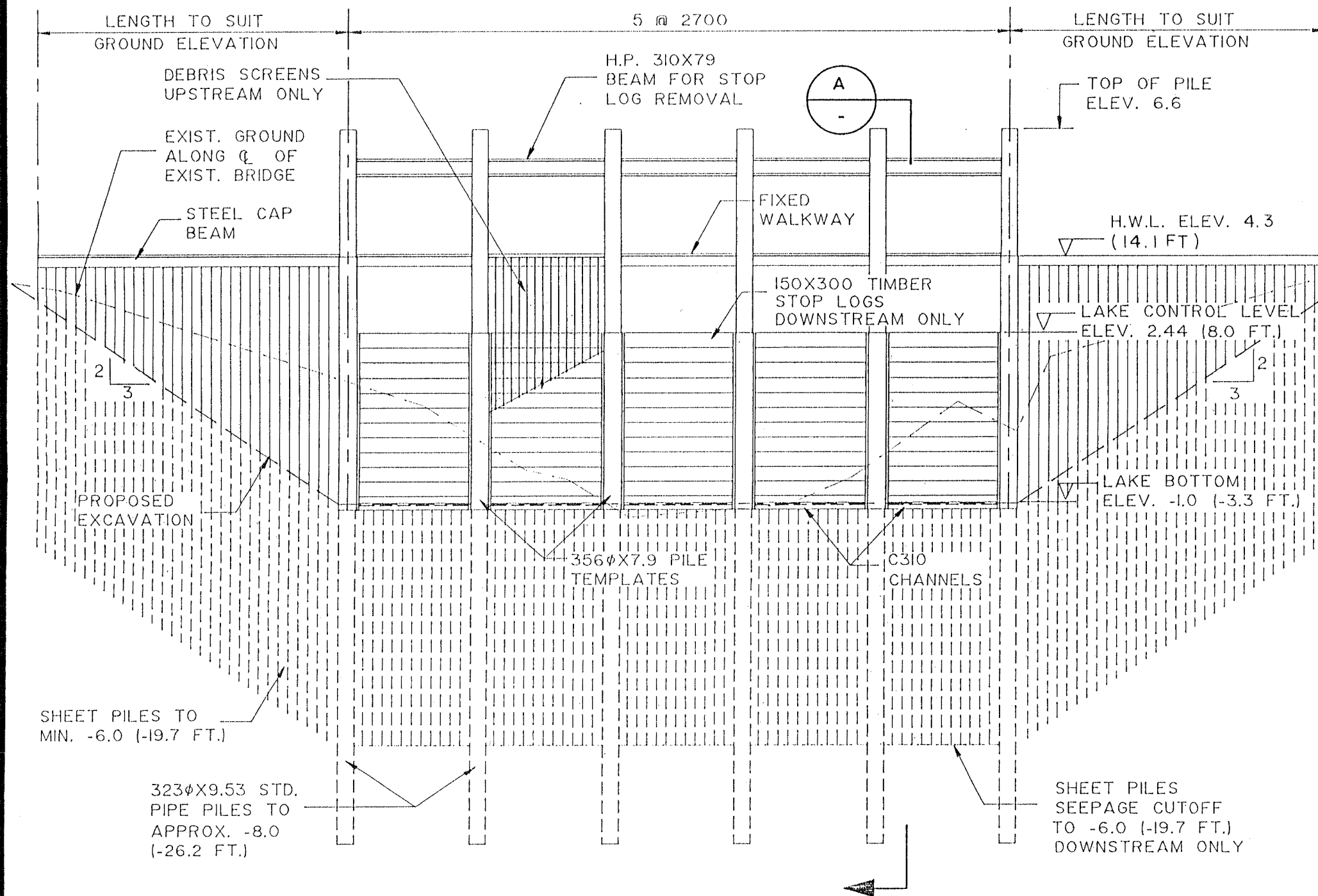
northwest hydraulic consultants

HATZIC LAKE

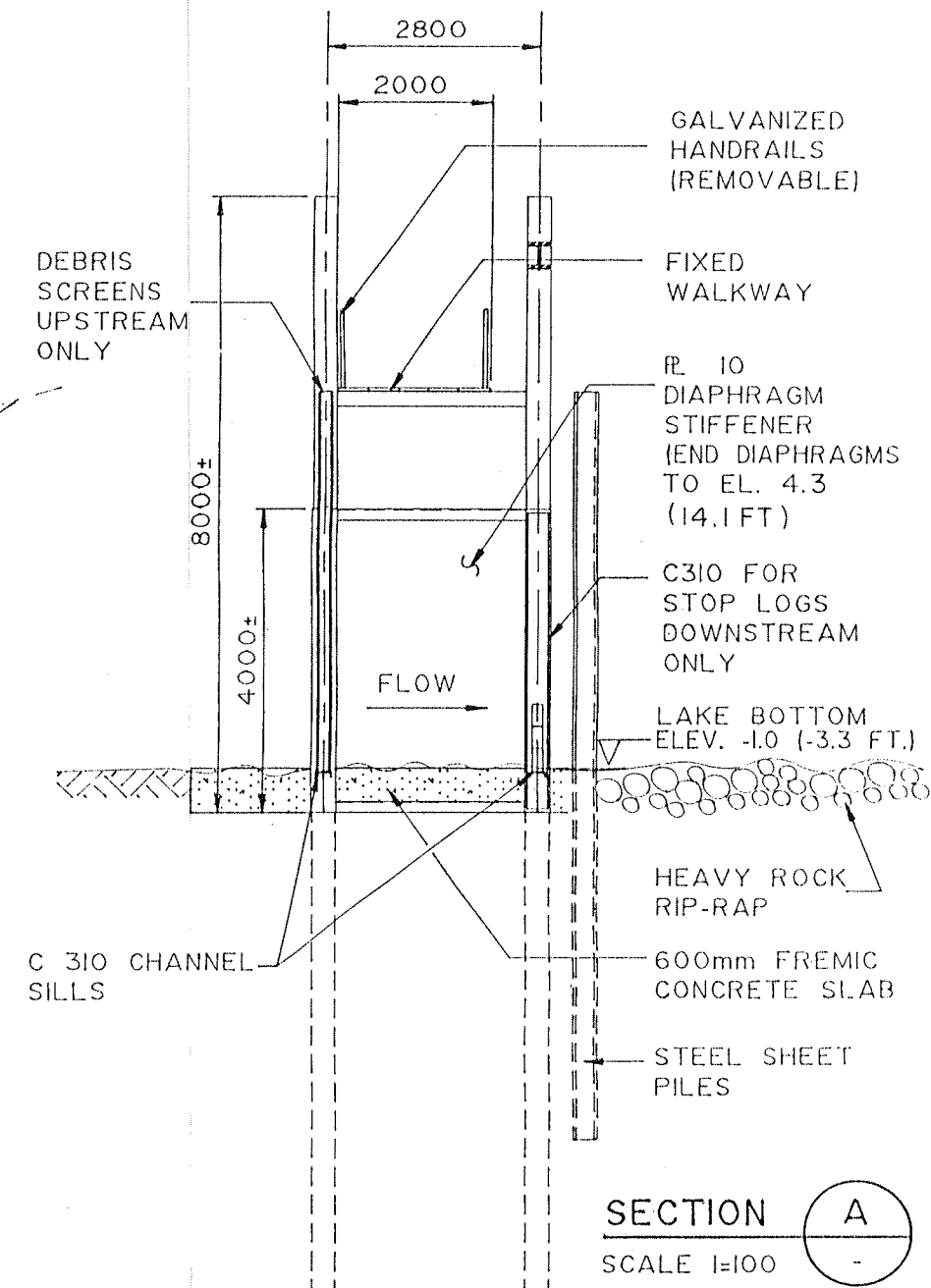


SITE PLAN
SCALE 1:250

DEWDNEY-ALOUETTE REGIONAL DISTRICT	
HATZIC PRAIRIE DRAINAGE STUDY	
HATZIC LAKE LEVEL CONTROL AND	
DEBRIS CONTROL STRUCTURE-SHEET 1	
PROJECT No. VP97	SCALE 1:250
DATE OCT. 91	DWG No. 4.17
APPROVED S.G.	

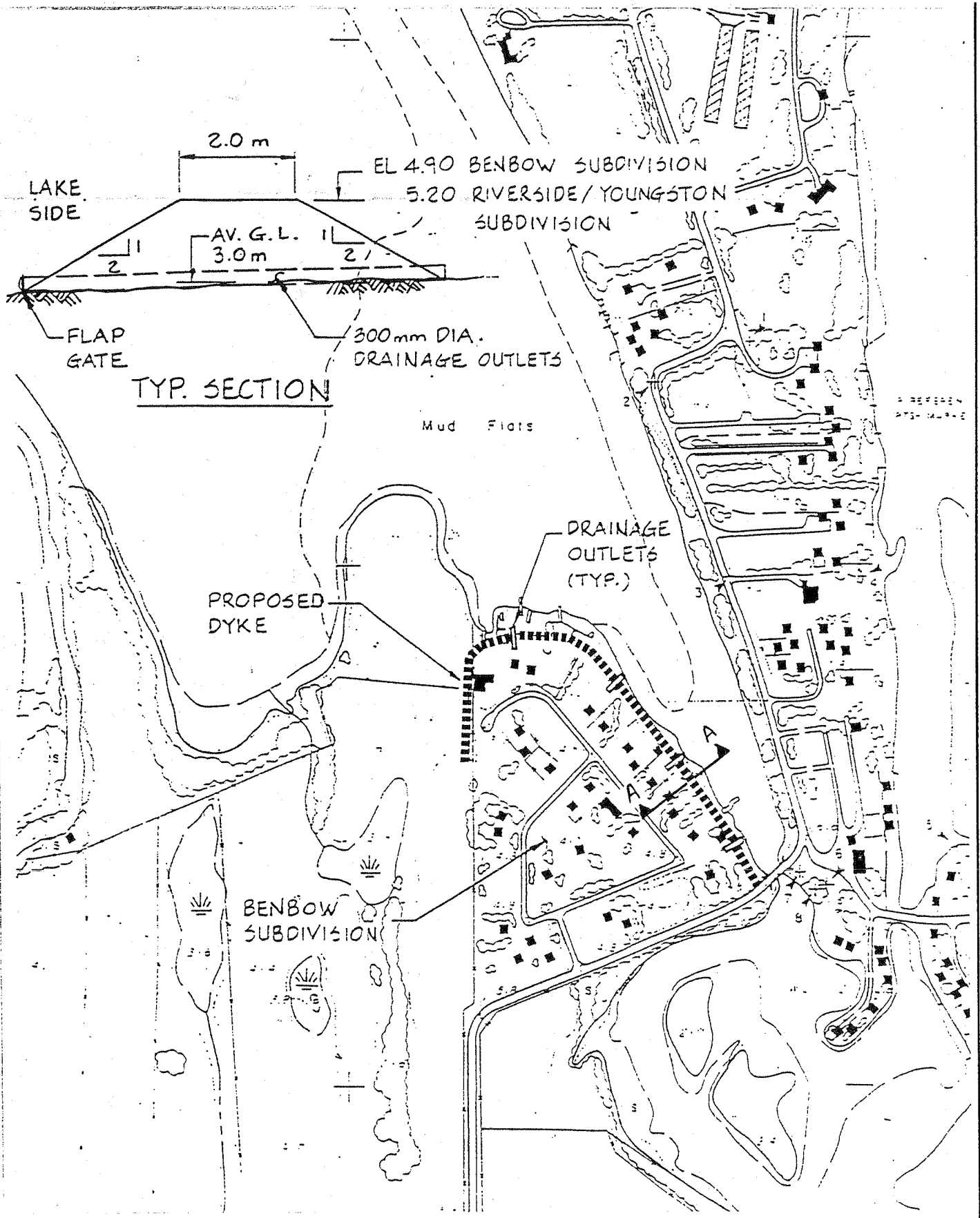


UPSTREAM ELEVATION
SCALE 1:100



SECTION A
SCALE 1:100

DEWDNEY-ALOUETTE REGIONAL DISTRICT	
HATZIC PRAIRIE DRAINAGE STUDY	
HATZIC LAKE LEVEL CONTROL AND	
DEBRIS CONTROL STRUCTURE-SHEET 2	
PROJECT No. VP97	SCALE 1:100
DATE OCT. 91	DWG No. 4.18
APPROVED S.G.	



PROJECT No. VP97

DATE OCT. 91

APPROVED JVE

SCALE N.T.S.

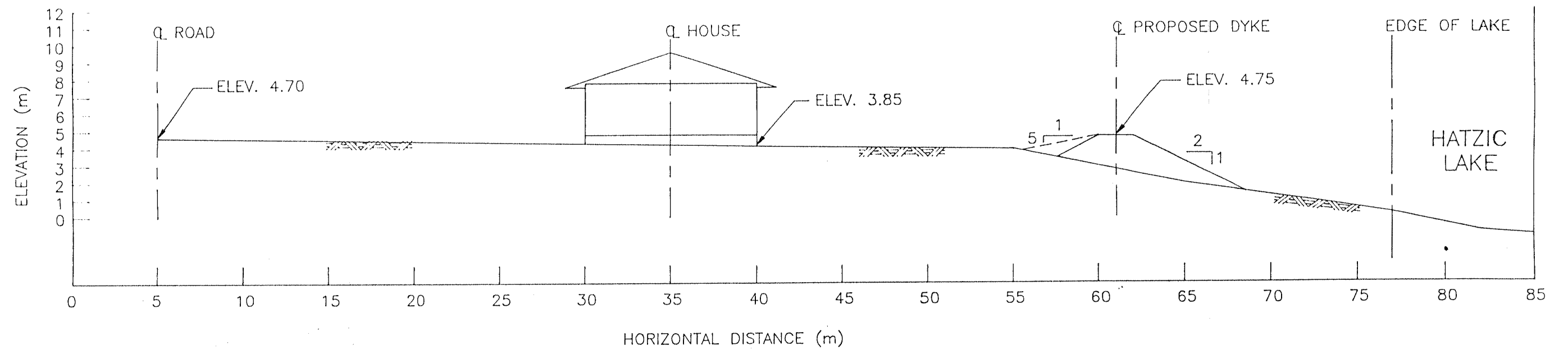
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DEWDNEY-ALOUETTE REGIONAL DISTRICT
HATZIC PRAIRIE DRAINAGE STUDY

BENBOW SUBDIVISION DYKING WORKS

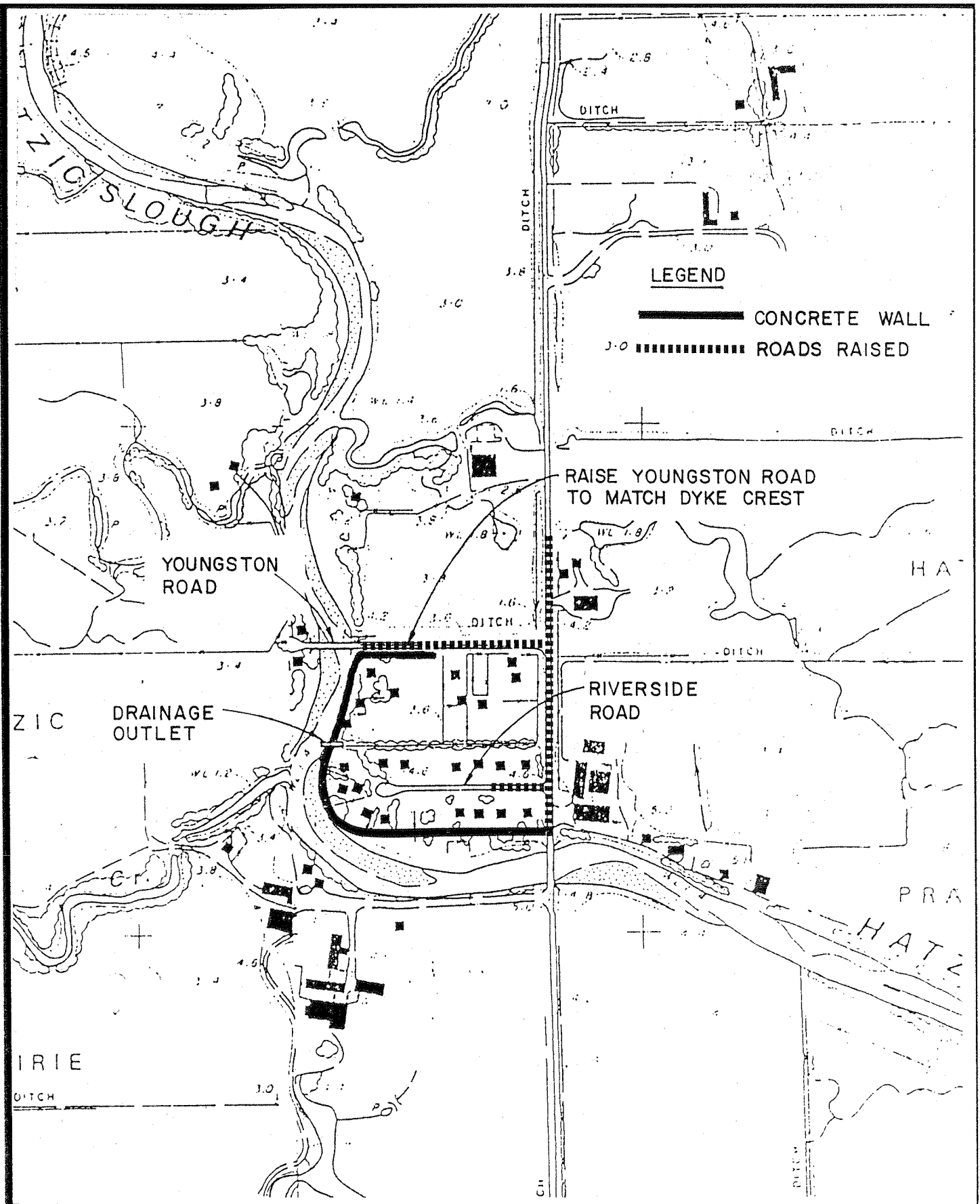
ASSOCIATED
ENGINEERING





SECTION A-A
SCALE 1:250

DEWDNEY-ALOUETTE REGIONAL DISTRICT	
HATZIC PRAIRIE DRAINAGE STUDY	
TYPICAL DYKE CROSS SECTION	
BENBOW SUBDIVISION	
PROJECT No. VP97	SCALE 1:250
DATE OCT. 91	DWG No. 4.20
APPROVED S.G.	



PROJECT No. VP97

DATE OCT. 91

APPROVED JVE

SCALE 1:5000

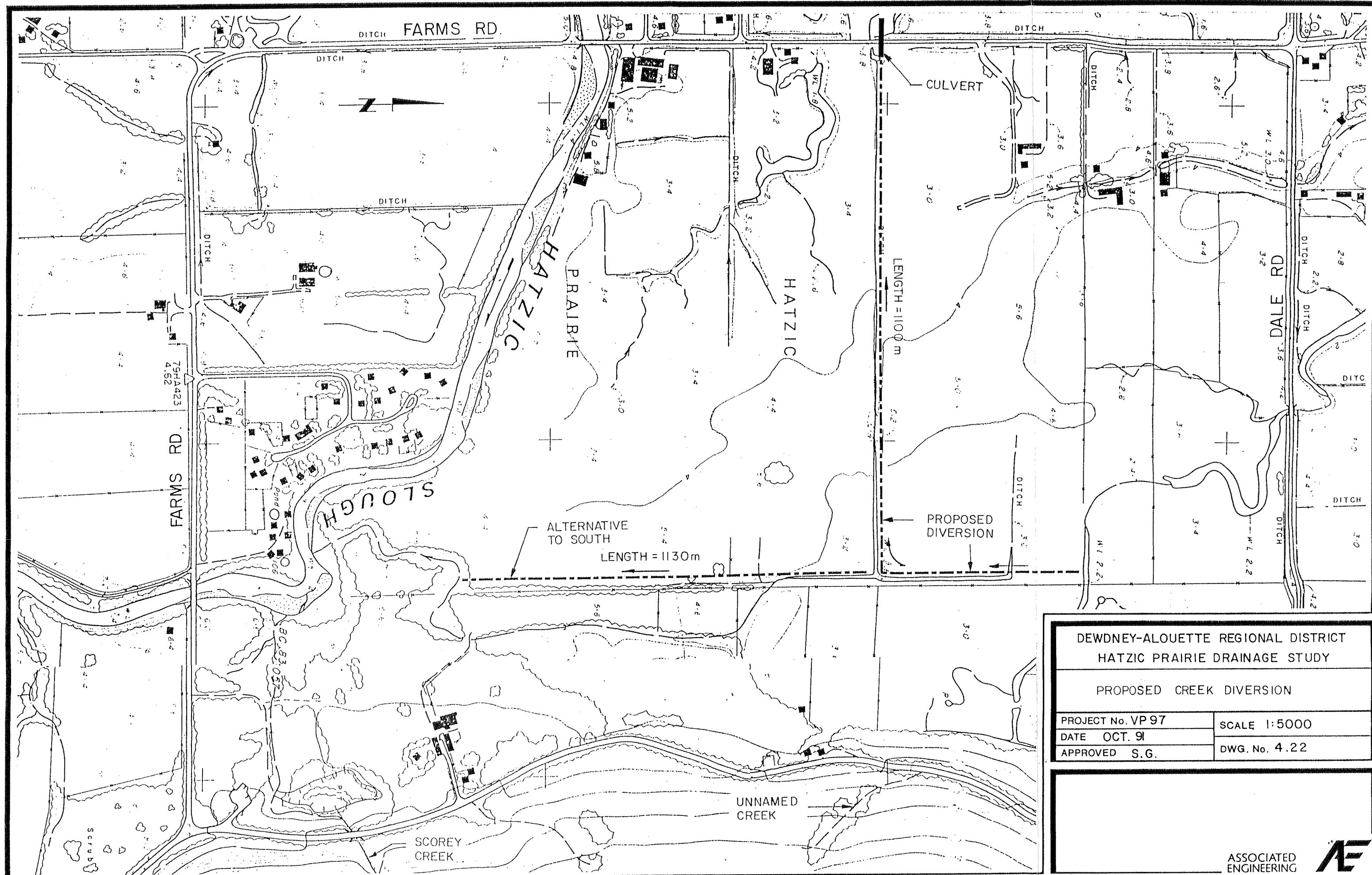
DWG. No. 4.21

DEWDNEY-ALOUETTE REGIONAL DISTRICT
HATZIC PRAIRIE DRAINAGE STUDY

RIVERSIDE / YOUNGSTON ROADS
SUBDIVISION DYKING WORKS

ASSOCIATED
ENGINEERING





DEWDNEY-ALOUETTE REGIONAL DISTRICT
HATZIC PRAIRIE DRAINAGE STUDY

PROPOSED CREEK DIVERSION

PROJECT No. VP 97

DATE OCT. 91

APPROVED S.G.

SCALE 1:5000

DWG. No. 4.22

ASSOCIATED
ENGINEERING



TABLE 1.1
COMPARISON OF ELEVATIONS OBTAINED BY FIELD SURVEY AND
AVAILABLE MAPPING

Location	Elevation Shown On Mapping	Elevation Obtained By Field Survey
Intersection of Sylvester Road and Farms Road	8.6	8.42
Bridge over Hatzic Slough on Farms Road	6.0	6.29
Intersection Farms Road and Mountain View Road	5.8	5.95
Intersection Farms Road and Sward Road	4.4	4.72
Intersection South of Farms Road Bridge over Hatzic Slough	5.0	4.83
Centreline of Farms Road Bridge over Hatzic Slough	4.8	4.92
Intersection Riverside Road, Farms Road	4.6	4.61
Centre of Cul-de-sac Riverside Road	4.6	4.79
Intersection Youngston Road, Farms Road	4.2	4.15
Intersection Farms Road and Track to East	3.8	4.0
Intersection Farms Road and Dale Road	3.6	4.01
Hatzic Slough Bridge at Dale Road	4.4	4.87
Centreline Dale Road Bridge Over Unnamed Creek	4.2	4.09
Dale Road at Fence Line to South	4.2	3.79

TABLE 1.2

SUMMARY OF DRAINAGE AND FLOOD PROOFING REVENUES AND EXPENDITURES

Year	Revenue - Drainage Improvement District Only	Expenditure					
		DAID	MOTH	CPR	BCE/PEP	Mission	DARD
1966	\$33,402	\$33,090	N/A	N/A		N/A	
1967	51,784	45,566					0
1968	26,097	21,065			10,000		0
1969	20,476	12,304			10,000		0
1970	21,021	17,290					0
1971	21,205	28,666			10,000		0
1972	31,276	40,991					0
1973	17,165 ¹	17,055 ¹			20,000		0
1974	19,975 ¹	29,800 ¹					0
1975	20,858	21,639					0
1976	32,173	25,444					0
1977	N/A	N/A					0
1978	32,823	18,811					0
1979	33,298	17,718			100,000		0
1980	73,735	73,526					0
1981	44,776	43,092			60,000		0
1982	52,467	40,824	N/A				0
1983	50,568	32,303	208,000		21,840*		0
1984	49,965	49,496	N/A		41,617*		0
1985	49,712	22,032			107,150		0
1986	51,291	45,818			0*		0
1987	53,701	32,928			22,443*		0
1988	54,342	34,789			0*	N/A	0
1989	62,330	42,621			141,515*	54,287	0
1990	60,394	45,844			15,993	52,318	0
1991	N/A	N/A	N/A		633,893	N/A	0
Totals	\$964,834	\$792,712	\$208,000	N/A	\$1,194,451*	\$106,605	0

¹ Not calendar year values.

* Does not include a total of \$6,978,568 for dyke reconstruction including engineering

DAID - Dewdney Area Improvement District

MOTH - Ministry of Transportation and Highways

CPR - Canadian Pacific Railway

BCE - BC Environment (previously Ministry of Environment)

PEP - Provincial Emergency Program

DARD - Dewdney-Alouette Regional District

Table 2.1

HATZIC PRAIRIE STUDY

Annual Maximum Peak Instantaneous Flows
in Norrish and Kanaka Creeks

Year	Norrish		Kanaka		Coincident Event
	<i>m³/s</i>	<i>Date</i>	<i>m³/s</i>	<i>Date</i>	
1960	158	6 Feb	27	24 Oct	—
1961	278	15 Jan	76	10 Oct	—
1962	259	19 Nov	51	3 Jan	—
1963	399	26 Nov	104	23 Dec	—
1964	140	30 Nov	missing	missing	—
1965	158	4 Feb	86	4 Feb	yes
1966	340	13 Dec	71	13 Dec	yes
1967	246	10 Dec	38	3 Apr	—
1968	331	20 Jan	110	20 Jan	yes
1969	354	5 Jan	missing	missing	—
1970	110	9 Apr	51	6 Dec	—
1971	126	19 Jan	78	26 Jan	—
1972	171	5 Mar	100	12 Jul	—
1973	97	13 Oct	62	28 Oct	—
1974	163	21 Dec	76	21 Dec	yes
1975	214	2 Dec	101	8 Dec	—
1976	93	26 Dec	42	15 Jan	—
1977	184	1 Nov	81	12 Jul	—
1978	99	7 Nov	57	28 Oct	yes
1979	missing	missing	146	21 Dec	—
1980	298	26 Dec	112	26 Dec	yes
1981	137	1 Oct	68	1 Oct	yes
1982	missing	missing	107	3 Dec	—
1983	207	12 Jul	89	12 Jul	yes
1984	missing	missing	108	4 Jan	—
1985	127	1 Nov	70	1 Nov	yes
1986	missing	missing	missing	missing	—
1987	147	3 Mar	54	3 Mar	yes
1988	missing	missing	55	12 Dec	—
1989	233	10 Nov	260 est. *	9 Nov	yes
1990	400 est. *	10 Nov	97	10 Nov	yes

* Maximum of record.

1692-400.wk1

Table 2.2

HATZIC PRAIRIE STUDY

Annual Maximum Instantaneous Flow Frequency Estimates
for Upland Tributaries to Lagace Creek

Tributary	Drainage area to edge of flood plain (km ²)*	Annual maximum instantaneous flow (m ³ /s)					
		Recurrence interval (years)					
		200	50	25	10	5	Mean Ann.
<u>East Side</u>							
Scorey Creek	2.0	31	24	21	17	14	10.3
Dale Creek	3.3	48	37	32	27	22	16
Hereford Creek (North & South)	3.6	52	40	35	29	24	17
Pattison Creek	6.0	80	62	54	44	36	27
Unnamed creek**	1.4	22	17	15	12	10	7.4
MacNab Creek into Allen Lake	3.7	53	41	36	29	24	18
<u>West Side</u>							
Currie Creek	2.5	38	29	25	21	17	13
Kenworthy Creek	4.5	63	48	42	35	28	21
Bouchier Creek	1.0	16	12	11	8.8	7.2	5.3
Belcharton Creek	4.8	67	51	45	37	30	22

* The area used in this analysis totals 33km². The total mountainous area to the edge of the floodplain is 39 km². Because the flows are calculated at the point at which the creeks enter the floodplain, 6 km² of mountainous region is unaccounted for in the tributary flow, but will eventually end up in Lagace Creek.

** Located midway between Pattison Creek and MacNab Creek.

Table 2.3

HATZIC PRAIRIE STUDY

Summary of Analysis from Seven Storm Events

Date	Norrish Creek (117 km ²)			Kanaka Creek (48 km ²)			Nearest Comparable Rainfalls			
	Flood Runoff (mm)	Reported Maximum Flow (m ³ /s)	Recurrence Interval of Maximum* (years)	Flood Runoff (mm)	Reported Maximum Flow (m ³ /s)	Recurrence Interval of Maximum* (years)	Duration	Gauge**	Depth (mm)	Recurrence Interval (years)
Jan 1968	210 (2 days)	331 inst.	8	240 (2 days)	110 inst.	8	2 days	A.L. S.F.	240 223	— 40
Dec 1980	120 (2 days)	298 inst.	5	110 (2 days)	112 inst.	8	2 days	S.F. M.W.A.	145 115	3 5
June 1981	48 (2 days)	50 daily	3 summer	30 (2 days)	10.3 daily	3 summer	1 day	Mission M.W.A. M.H.R.	60 52 65	— 5 summer
July 1983	315 (6 days)	110 daily	25 to 50 summer	170 (6 days)	27.5 daily	15 to 25 summer	5 days	M.W.A.	190	30 summer
Nov 1989	285 (3 days)	160 daily	10	310 (3 days)	90 daily	50	4 days	S.F.	270	20
Feb 1990	170 (2 days)	122 daily	3	130 (2 days)	45 daily	3	2 days	S.F. M.W.A.	137 115	3 5
Nov 1990	350 (3 days)	209 daily	15	270 (3 days)	97 inst. 67 daily	5 15	3 days	S.F. M.W.A.	260 195	30 50

1692 - 402.wk1

* Recurrence intervals are for the maximum instantaneous or maximum daily flow, depending on how the maximum flow was recorded. Summer recurrence intervals are for flows between May and August.

**See Figures 2.5 to 2.10 for locations of gauge stations.

A.L. : Alouette Lake

S.F. : Stave falls

M.W.A. : Mission West Abbey

M.H.R. : Mission Hartley Road

Table 2.4

HATZIC PRAIRIE STUDY

Flow Frequency Estimates for Four Points
along Lagace Creek System

<i>Location</i>	<i>Effective Drainage Area (km²)</i>	<i>200-Year</i>		<i>50-Year</i>		<i>25-Year</i>	
		<i>Instantaneous (m³/s)</i>	<i>Daily (m³/s)</i>	<i>Instantaneous (m³/s)</i>	<i>Daily (m³/s)</i>	<i>Instantaneous (m³/s)</i>	<i>Daily (m³/s)</i>
Sylvester Road (Pattsion Cr.)	6	80	—	59	—	53	—
Seux Road (Lagace Cr.)	16	180	45	140	33	120	30
Farms Road (Lagace Cr.)	21	210	70	160	52	140	47
Dale Road (Lagace Cr.)	38	320	160	240	120	210	105

Table 2.5
HATZIC PRAIRIE STUDY
Flood Record Summary
of Hatzic Lake at the Pumphouse

<i>Year</i>	<i>Days Pumping</i>	<i>Pumphouse Records</i>		
		<i>Days over 3.323 m GSC (11 ft)</i>	<i>Maximum Level at Pumphouse</i>	
			<i>Gauge (ft)</i>	<i>Geodetic (m GSC)*</i>
Dec 1980	10	5	13.2	3.993
June 1981	20	12	12.25	3.704
July 1983	25	16	13.0	3.932
Nov 1989	6	2	12.7	3.841
Feb 1990	0	—	8.0	2.408
Nov 1990	10	4	13.6	4.115

1692-404.wk1

* To convert the gauge reading from Imperial to Geodetic,
convert the gauge reading to metric and subtract 0.030 m.

Table 2.6
HATZIC PRAIRIE STUDY

Backward Routing Results
(based on 24-hour time increment)

<i>Year</i>	<i>Conditions</i>	<i>Computed Maximum Daily Inflow (m³/s)</i>	<i>Computed Total Inflow (10⁶ m³)</i>	<i>Flood Runoff * (mm)</i>
Dec 1980	–floodboxes operated –pumps on for 7 days	55	14.7	163 (5 days)
June 1981	–floodboxes did not operate –pumps on for 20 days	23	10.1	112 (11 days)
July 1983	–floodboxes did not operate –pumps on for 25 days	47	15.3	168 (8 days)
Nov 1989	–floodboxes operated –pumps on for 6 days	110	20.3	224 (4 days)
Feb 1990	–floodboxes operated –pumps were not used	130	32.0	355 ** (5 days)
Nov 1990	–floodboxes operated –pumps on for 10 days	220	29.7	328 (4 days)

1692 – 405.wk1

* Based upon a drainage area of 90 km².

** The water level gauge at Mission was inoperative during the February, 1990 storm; instead, the Fraser River level recorded at the pumphouse was used in the analysis, which is not necessarily equal to the mean daily Fraser River level.

Table 2.7

HATZIC PRAIRIE STUDY

Forward Routing Results
(based upon hourly time increment)

<i>Year</i>	<i>Conditions</i>	<i>Computed Maximum Instantaneous Inflow (m³/s)</i>	<i>Computed Total Inflow (10⁶ m³)</i>	<i>Flood Runoff * (mm)</i>	<i>Flood Runoff Ratio Kanaka Creek (from Table 2-3)</i>	<i>Flood Runoff Ratio Norrish Creek (from Table 2-3)</i>
June 1981	– floodboxes did not operate – pumps on for 20 days	23	2.2	24 (2 days)	0.80	0.50
July 1983	– floodboxes did not operate – pumps on for 25 days	70	12.2	135 (5 days)	0.79	0.42
Nov 1989	– floodboxes operated – pumps on for 6 days	145	14.4	160 (4 days)	0.52	0.56
Nov 1990	– floodboxes operated – pumps on for 10 days	120	17.8	198 (5 days)	0.70	0.56

1692-406.wk1

* Based upon a drainage area of 90 km².

Table 2.8

HATZIC PRAIRIE STUDY

**Number of Days of Flooding
Based upon Forward Routing Analysis**

Conditions *	Number of Days of Flooding			
	Riverside Rd. Subdivision (El. 4.04 m GSC)	Benbow St. Subdivision (El. 3.85 m GSC)	Everglades (El. 3.323 m GSC)	Hatzic Prairie (El. 3.00 m GSC)
June 1981				
Existing Conditions	0	0	>20	>20
Scenario 1	0	0	2	0
1.8 m GSC – A	0	0	1	0
1.8 m GSC – B	0	0	0	0
July 1983				
Existing Conditions	0	10	20	>20
Scenario 1	0	0	6	10.5
1.8 m GSC – A	0	0	5	10
1.8 m GSC – B	0	0	2	8
November 1989				
Existing Conditions	1.5	1	4	7.0
Scenario 1	1.5	0	3	5.5
Scenario 2	1.5	1	3	5.5
Scenario 3	1.5	0	2.5	5
November 1990				
Existing Conditions	3.5	4	8	12
Scenario 1	1.5	2	6	9.5
Scenario 2	2.5	2.5	6.5	10.5
Scenario 3	1.5	1.5	5.5	9

1692-413.wk1

* Scenario 1: Existing conditions with additional pumps.

Scenario 2: Existing conditions with additional floodboxes and additional CPR culverts.

Scenario 3: Existing conditions with additional floodboxes, additional CPR culverts, and additional pumps.

1.8 m GSC – A: Existing conditions with additional pumps. Initial water level at pumphouse as recorded for the storm. Additional pumps operate for water levels above 1.8 m GSC.

1.8 m GSC – B: Existing conditions with additional pumps. Initial water level at pumphouse set at 1.8 m GSC. Additional pumps operate for water levels above 1.8 m GSC.

Table 2.9

HATZIC PRAIRIE STUDY

**Total Precipitation for a 10-Year 5-Day Storm
at Three Gauge Stations**

<i>Station</i>	<i>Total 5-Day Precipitation (mm)</i>
Mission West Abbey	195
Pitt Polder	260
Stave Falls	255
Average	237

1692-414.wk1

Table 2.10

HATZIC PRAIRIE STUDY

**Total Precipitation for a 5-Day Storm
during December 1979**

<i>Station</i>	<i>Total 5-Day Precipitation (mm) (recurrence interval in brackets)</i>	
	<i>Dec. 12-16</i>	<i>Dec. 13-17</i>
Mission West Abbey	189 (8-10)	217 (20)
Pitt Polder	209 (5)	271 (8-10)
Stave Falls	199 (5)	250 (10)

1692-414.wk1

Table 2.11

HATZIC PRAIRIE STUDY

Lake Volumes at Increasing Water Levels for Various Dredging Scenarios
on the East Side of Hatzic Lake *

Lake Level (m, GSC)	Elevation to which East Side of Hatzic Lake is Dredged (m, GSC)				
	No Dredging (1991 Survey)	1.5	1.0	0.5	0.0
	Lake Volume (10^6 m^3)				
0.5	3.0	3.0	3.0	3.0	3.9
1.0	3.5	3.5	3.5	4.3	5.2
1.5	4.4	4.4	5.0	5.7	6.5
2.0	5.5	5.8	6.4	7.1	8.0
2.438	7.7	8.1	8.6	9.4	10.2

1692-407.wk1

* The east side of Hatzic Lake extends from the mouth of Hatzic Slough
to the Everglades (sectors E1, E2, E3 – see Appendix G).

Table 2.12

HATZIC PRAIRIE STUDY

Volume of Dredged Material

Elevation to which East Side of Hatzic Lake is Dredged (m, GSC)				
No Dredging (1991 Survey)	1.5	1.0	0.5	0.0
	Lake Volume (10^6 m^3)			
0.0	0.3	0.9	1.7	2.6

1692-407.wk1

Table 2.13

HATZIC PRAIRIE STUDY

Average Summer Lake Depth – East Side of Hatzic Lake (May to August)

Sector *	Elevation to which East Side of Hatzic Lake is Dredged (m, GSC)				
	No Dredging (1991 Survey)	1.5	1.0	0.5	0.0
	Average Lake Depth (m GSC)				
E2	1.10	1.20	1.45	1.95	2.45
E3	0.75	0.80	1.45	1.95	2.45
E4	1.45	1.50	1.70	1.95	2.45

* For location of sectors E1, E2, and E3 see Appendix G.

1692-409.wk1

Table 2.14

HATZIC PRAIRIE STUDY

Additional Live Storage – Winter Storm (September to April)

Assumes that the lake level rises to above 2.41 m GSC

Lake Level at Start of Flood (m, GSC)	Elevation to which East Side of Hatzic Lake is Dredged (m, GSC)			
	1.5	1.0	0.5	0.0
	Additional Live Storage (10^6 m^3)			
0.5	0.3	0.9	1.7	1.7
1.0	0.3	0.9	0.9	0.9

1692-408.wk1

Table 2.15
HATZIC PRAIRIE STUDY

**Fraser River Levels and Total Precipitation
for Typical Winter Storms**

Date	Total Precipitation (mm) *		Approximate Recurrence Interval		Fraser River Level at Hatzic Pumphouse (m GSC)		
	(number in parenthesis represents the last day of the n-day event)				(date and time in parenthesis represents the time the level was recorded)		
	2-day	5-day	2-day	5-day	Lowest Level at Beginning of Storm	Highest Level During Storm	5-day Mean Level upto Beginning of Storm
October 1975	103.7 (17 Oct)	152.0 (18 Oct)	4	5	0.880 (14 Oct 1200hrs)	3.022 (18 Oct 1800hrs)	1.631
December 1979	114.6 (14 Dec)	217.0 (17 Dec)	8	20	1.025 (17 Dec 900hrs)	3.023 (18 Dec 1800hrs)	1.500
January 1983	65.8 (7 Jan)	133.4 (10 Jan)	<2	2	0.935 (7 Jan 900hrs)	2.654 (11 Jan 1600hrs)	1.430
February 1982	127.6 (14 Feb)	198.8 (16 Feb)	10	10	0.712 (13 Feb 800hrs)	1.710 (15 Feb 800hrs)	1.321

* Total precipitation is taken at Mission West Abbey gauging station.

Table 3.1

HATZIC PRAIRIE STUDY

Flood Record Summary
of Hatzic Lake at the Pumphouse

<i>Existing Pumphouse Records:</i>						
Item	Year	Month	Days Pumping	Days Over 3.323 m GSC (11 ft)	Maximum Level	
					Gauge (ft)	Geodetic (m GSC)*
1	1949	Nov/Dec	4	1	11.2	3.383
2	1950	June	6	—	9.2	2.774
3	1951	Feb	4	3	13	3.932
4	1955	May/June	7	—	9.2	2.774
5	1955	Nov	3	2	12	3.628
6	1956	June	6	—	9.15	2.758
7	1959	Apr/May	4	2	11.9	3.597
8	1959	Sept	6	—	9.7	2.926
9	1960	May/June	23	—	9.95	3.002
10	1964	June/July	21	—	10.5	3.170
11	1966	Dec	3	3	12.4	3.749
12	1968	Jan	3	—	11	3.322
13	1972	June	22	8	11.5	3.475
14	1974	June	8	—	9.3	2.804
15	1976	Sept	8	—	9.6	2.896
16	1979	Dec	3	—	11	3.323
17	1980	June	8	—	9.7	2.926
18	1980	Dec	10	5	13.2	3.993
19	1981	June	20	12	12.25	3.704
20	1983	July	25	16	13	3.932
21	1989	Nov	6	2	12.7	3.840
22	1990	Feb	0	—	8	2.408
23	1990	Nov	10	4	13.6	4.115

* To convert the gauge reading from Imperial to Geodetic,
convert the gauge reading to metric and subtract 0.030 m.

1692-030.wk1

Table 3.2

HATZIC PRAIRIE STUDY

Time Sequence – November 1990

Legend:

D/S – Downstream
 U/S – Upstream
 MOTHS – Ministry of Transportation and Highways
 Cat – Caterpillar (bulldozer)

Date	Location	Time*	Observation
Nov 9	<u>Pattison Creek:</u>		
	U/S of Sylvester Rd. Bridge	pm	–light erosion on left and right bank U/S of riprap protection near bridge
	<u>Lagace Creek:</u>		
	Between Dale Rd. and Farms Rd. Bridges	pm	–erosion of existing spoil piles –0.3 m freeboard
	<u>Hereford Creek North:</u>		
Nov 10	At Sylvester Rd.	pm	–2.4 m multiplate culvert filled to capacity –water not yet flowing over the road
	<u>Hereford Creek South:</u>		
	At Sylvester Rd.	pm	–U/S of culvert, channel filled with gravel and 900 mm culvert nearly plugged –creek flow over road –excess flow from north creek flowing down ditch to south culvert
	<u>Hatzic Island/Prairie:</u>		
	Farms Rd.	pm	–flooded between L. Clarke property and Dale Rd. –Gas Station at intersection of Farms Rd. and Dale Rd. flooded approximately 0.15–0.30 m
	<u>Pattison Creek:</u>		
	Sylvester Rd. 1km north of Pattison Creek	2:00 pm	–road flooded by approximately 0.15–0.30 m
	D/S of Sylvester Rd. Bridge	2:00 pm	–right bank erosion

* Time of observation, not necessarily time of described event.

Table 3.2 (cont'd)

Nov 10 con't	Sylvester Rd. Bridge	4:00 pm	<ul style="list-style-type: none"> – debris flow down Pattison Creek – channel filled with gravel, boulders, and debris (primarily logs and stumps) – scoured right bank immediately D/S of bridge and left bank further D/S of bridge – scoured left bank immediately U/S of bridge
	<u>Lagace Creek:</u>		
	U/S of Farms Rd. Bridge	2:00 pm	– erosion of left and right banks
	Between Seux Rd. Bridge and Farms Rd. Bridge		– D-9 Cat repairing bank erosion, pushing bed material up both banks
		4:00 pm	– debris flow littering Legace Creek with gravel boulders and debris (primarily logs)
	At 90° bend D/S of Farms Rd. Bridge	4:00 pm	– debris broke through right bank dyke, 45° SW from main channel, and flooded onto C. Schroots property
	Dale Rd. Bridge		– wood debris accumulated for approximately 60 m U/S of bridge
	<u>Hereford Creek North:</u>		
	At Sylvester Rd.	am	– 2.4 m multiplate culvert completely submerged
Nov 11	<u>Hereford Creek South:</u>		
		am	<ul style="list-style-type: none"> – south channel overflowing road – highway crews cleaning D/S end of culvert – channel completely filled with gravel
	<u>Hatzic Island/Prairie:</u>		
	Everglades	1:30 pm	– completely flooded
	Hatzic Bridge U/S of CPR culverts	1:30 pm	<ul style="list-style-type: none"> – lake level approximately 1 ft below main bridge beam – no debris has collected
	Hatzic Lake	1:30 pm	– lake backing up to J. Kokoska property
	Dale Rd. west of Dale Rd. Bridge	3:10 pm	– low section of road flooded

Table 3.2 (cont'd)

Nov 11 con't	South bend on Farms Rd.	3:30 pm	– road north of bend flooded by up to 0.60–0.75 m of water
	Farms Rd. at L. Clarke property	3:30 pm	– lake backing up causing 0.60–0.75 m of flooding
	Chilqua Slough	pm	– area appears to remain unflooded
	<u>Pattison Creek:</u>		
	Sylvester Rd. Bridge		– MOTH removing logs piled against bridge – channel 650 ft U/S of bridge cleared with a D–7 Cat
	<u>Lagace Creek:</u>		
	U/S of Farms Rd. Bridge		– creek meandering between new bars, attacking left and right banks
	Between Farms Rd. Bridge and Seux Rd. Bridge		– TD–25 Cats cleaning channel and repairing left and right banks
Nov 12	<u>Hatzic Island/Prairie:</u>		
	Hatzic Bridge U/S of CPR culverts	11:30 am	– MOTH repairing east abutment washout – debris that had collected at bridge and culverts, since Nov 11, removed – debris primarily from the Everglades and included tables, trelises, freezers, etc.
	Everglades	11:30 am	– low areas completely submerged (cars covered by flood waters)
	<u>Lagace Creek:</u>		
	D/S of Seux Rd. Bridge	3:00 pm	– TD–25 Cat continues to repair left bank
Nov 13	<u>Lagace Creek:</u>		
	Seux Rd. Bridge		– D–9 and TD–25 Cats cleaning channel and repairing banks U/S and D/S of bridge

Table 3.2 (cont'd)

Nov 14	<p><u>Hatzic Island/Prairie:</u></p> <p>Farms Rd.</p> <p>– A. Neufeld house surrounded by water from early Nov 9 to Nov 14</p> <p><u>Lagace Creek:</u></p> <p>Dale Rd. Bridge</p> <p>– debris jam extends 60 m U/S of bridge and continues to disrupt flow</p> <p>– debris jam extends 120 m U/S of wooden bridge, located just U/S of Dale Rd. Bridge</p>
Nov 15	<p><u>Hatzic Island/Prairie:</u></p> <p>Everglades</p> <p>– continues to be flooded, all roads are still under water</p> <p>Hatzic Prairie</p> <p>– areas east of Farms Rd. Bridge and south/north of Dale Rd. Bridge still flooded</p> <p>– large fields north of Dale Rd. and east of Farms Rd. still flooded to Sylvester Rd.</p> <p><u>Lagace Creek:</u></p> <p>U/S and D/S Dale Rd. Bridge</p> <p>– creek is within its banks but adjacent fields still flooded</p> <p>– MOTH removing debris jam at bridge</p> <p>U/S of Farms Rd. Bridge</p> <p>– all Cat work completed and all debris removed from channel</p> <p>– creek water levels significantly down</p>
Nov 19	<p><u>Hatzic Island/Prairie:</u></p> <p>Everglades</p> <p>– water level has receded to allow dry road access</p>

1592 – 034, wk 1

TABLE 4.1
FLOOD RECORD SUMMARY AND PROJECTED POWER CONSUMPTION COSTS

Page 1 of 2

			EXISTING PUMP STATION RECORDS DECEMBER 1980 - JULY 1991 CAPACITY 6.06 m ³ /s				COMBINED PUMPING EFFECT OF EXISTING 6.06 m ³ /s PUMPS AND PROPOSED 8.34 m ³ /s PUMPS TOTAL CAPACITY 14.4 m ³ /s			
Item	Year	Month	Total Hours Pumping ¹	Days Over 3.35 m	Max. Level	Annual Pump Operating Cost 1991 \$	Total Pump Hours	Days Over 3.35 m	Max. Level	Annual Pump Operating Cost 1991 \$
1.	1980	Dec 12 - 21	95	-	3.35	5,084 ²	96	-	2.96	9,724 ²
2.	1981	May-July	1,164 ³	15	3.73	49,142	456	-	2.56	73,185
3.	1982	May-Aug	808	-	2.53	27,419	360	-	2.44	38,689
4.	1983	June-Aug	838.5	15	3.96	30,763	432	-	3.35	46,374
5.	1983	Nov	51	-	2.90		48	-	2.56	
6.	1984	Jan	36.5 ⁵	-	3.17	44,262	72	-	2.95	77,242
7.	1984	June-Aug	627.5	-	2.53		264	-	2.44	
8.	1984	Oct	72.5	-	2.47		48	-	2.44	
9.	1985	May-July	511	-	2.51	33,002	216	-	2.44	52,042
10.	1986	Feb	26.5 ⁵	-	2.99	39,952	72	-	2.45	72,083
11.	1986	May-Aug	664	-	2.48		288	-	2.44	
12.	1987	May-July	767.5	-	2.83	23,235	336	-	2.44	35,631
13.	1988	April-July	1176	-	2.87	33,066	528	-	2.44	43,741
14.	1989	May-July	670.5	-	2.80	29,648	336	-	2.44	45,652
15.	1989	Nov	112.5	2	3.87		96	2	3.58	

TABLE 4.1
FLOOD RECORD SUMMARY AND PROJECTED POWER CONSUMPTION COSTS

Page 2 of 2

			EXISTING PUMP STATION RECORDS DECEMBER 1980 - JULY 1991 CAPACITY 6.06 m ³ /s				COMBINED PUMPING EFFECT OF EXISTING 6.06 m ³ /s PUMPS AND PROPOSED 8.34 m ³ /s PUMPS TOTAL CAPACITY 14.4 m ³ /s			
Item	Year	Month	Total Hours Pumping ¹	Days Over 3.35 m	Max. Level	Annual Pump Operating Cost 1991 \$	Total Pump Hours	Days Over 3.35 m	Max. Level	Annual Pump Operating Cost 1991 \$
16.	1990	April	48	-	2.50	53,944	24	-	2.44	88,554
17.	1990	May-Aug	1129.5	-	3.11		504	-	2.44	
18.	1990	Nov	312	3	4.15		240	1	3.97	
19.	1991	May-July	864	-	2.59	46,333 ⁴	408	-	2.44	81,971 ⁴
Power Cost - 10 Yr. Annual Average (1981 - 1990)						36,443				57,319

- Assumptions:
- (i) Pumps on elevation is 2.44 m.
 - (ii) Operating costs calculated using secondary metering and include minimum monthly and demand charges.
 - (iii) Pumping during Nov-March periods results in a minimum charge of 50% of the max monthly charge for the Nov-March period, applied over the following 11 months.
 - (iv) Minimum monthly charge without pumps running assumed @ 1000 kW - hrs = \$64.29, from power consumption records.
 - (v) Assumed average power consumption for existing pump = 274 kW/hr/pump from power consumption records.

¹ Total pumped hours taken from pump logs unless noted otherwise.

² 1980 annual cost based on December 12th - 21st only.

³ Assumed pumping hrs/day = 90% of 24 hrs = 21.5 hrs (based on typical hours/day pumped obtained from pump logs)

⁴ Cost projections for 10 months, based on available records from Jan-July 1991. No pumping assumed for Aug-Oct but minimum charges apply due to pumping previous November.

⁵ Clock hours appear too low and are inconsistent with number of days pumps were operating.

TABLE 4.2

**PATTISON CREEK DIVERSION TO AMBER LAKE
APPROXIMATE DIMENSIONS AND QUANTITIES**

- | | | |
|----|---------------------------------|--|
| 1) | Diversion Berm | - 400 m long
- starts at elevation 190 m ends at elevation 160 m
- approximate volume: 80,000 m ³ |
| 2) | Diversion Canal | - volume = 30,000 m ³ excavation
- storage volume = 600,000 m ³ and more with maintenance |
| 3) | Earth Dam | - about 120 m long with a maximum height of 10 m to elevation 163 m
- volume = 24,000 m ³ |
| 4) | Spillway | - rock control structure set at elevation 158 m
- length = 75 m
- height = 8 m
- volume = 17,000 m ³ |
| 5) | Clearing Trees | - 16 hectares |
| 6) | Access Road within Project Area | - length = 1000 m |

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TABLE 4.3 SUMMARY OF CONSTRUCTION COST ESTIMATES

	<u>Item</u>	<u>Estimated Cost</u>
.1	Pump Station/Floodbox Structure	
.1	Triplex Pump Station (Built Separately)	\$ 1,908,300
.2	4 - 1.83 m x 1.83 m Floodboxes (Built Separately)	\$ 1,105,000
.3	Combined Triplex Pump Station and Floodbox Structure	\$ 2,723,800
.2	Crossing CP Rail Embankment	
.1	Bridge Crossing at CPR Embankment	\$ 1,105,000
.2	2 - 3.05 m Culverts without Ground Stabilization	\$ 1,000,000
.3	2 - 3.05 m Culverts with Ground Stabilization	\$ 1,750,000
.3	Debris Control Structure	
.1	Floating Walkway at Lougheed Highway	\$ 116,500
.2	Boom Chain at Lougheed Highway	\$ 93,000
.3	Boom Chain at Pump Station	\$ 27,000
.4	Lake Dredging	
.1	Lake Side Disposal	\$12,000,000
.2	Offsite Disposal	\$21,000,000
.5	Dyking Lagace Creek and Hatzic Slough	\$ 9,862,000
.6	Raising Roads Above Flood Levels	
.1	Using Local Granular Fills	\$ 2,360,000
.2	Using Imported Granular Fills	\$ 3,694,000
.7	Construct Water Bars in Pattison Creek Catchment	\$ 55,000
.8	Pattison Creek Diversion into Amber Lake	\$ 2,350,000
.9	Sediment Excavation from Lagace and Pattison Creek (10 Year Period)	\$ 2,025,000
.10	Sediment Excavation from Sediment Trap (10 Year Period)	\$ 2,390,000
.11	Lengthen Sylvester Road Bridge over Pattison Creek	\$ 1,157,000
.12	Lake Level Control Structure	
.1	At Lougheed Highway (including Debris Control Structure)	\$ 228,600
.2	At pump Station Including Boom Chain	\$ 92,000
.13	Bank Protection Downstream of CPR Culverts	\$ 16,000
.14	Local Drainage Problems	\$ 308,000
.15	Local Dyking	
.1	Benbow Subdivision: Earthfill Dyke	\$ 147,000
.2	Benbow Subdivision: Concrete Wall Alternative	\$ 312,000
.3	Riverside Road Subdivision	\$ 368,000
.4	Isolated Properties	\$ 513,000
.16	Raising Homes	
.1	Most Probate Cost Per Home	\$ 40,000
.2	Raising Homes in Benbow Subdivision (9 Home which Submitted Damage Claims)	\$ 360,000
.3	Raising Homes in Benbow Subdivision (19 homes below Floodproofing Elevation)	\$ 760,000
.4	Raising Homes in Riverside Road Subdivision (24 Homes below Floodproofing Elevation)	\$ 960,000
.17	Improvements to Existing Pump Station	\$ 85,000
.18	Diversion of Local Creek, 800 m North of Scorey Creek	\$ 81,500

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—
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— **APPENDIX A**

TERMS OF REFERENCE

PROVINCE OF BRITISH COLUMBIA

MINISTRY OF ENVIRONMENT

HATZIC PRAIRIE STUDY

TERMS OF REFERENCE

Water Management Division

March 28, 1991

HATZIC PRAIRIE STUDY

TERMS OF REFERENCE

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HATZIC PRAIRIE STUDY

TERMS OF REFERENCE

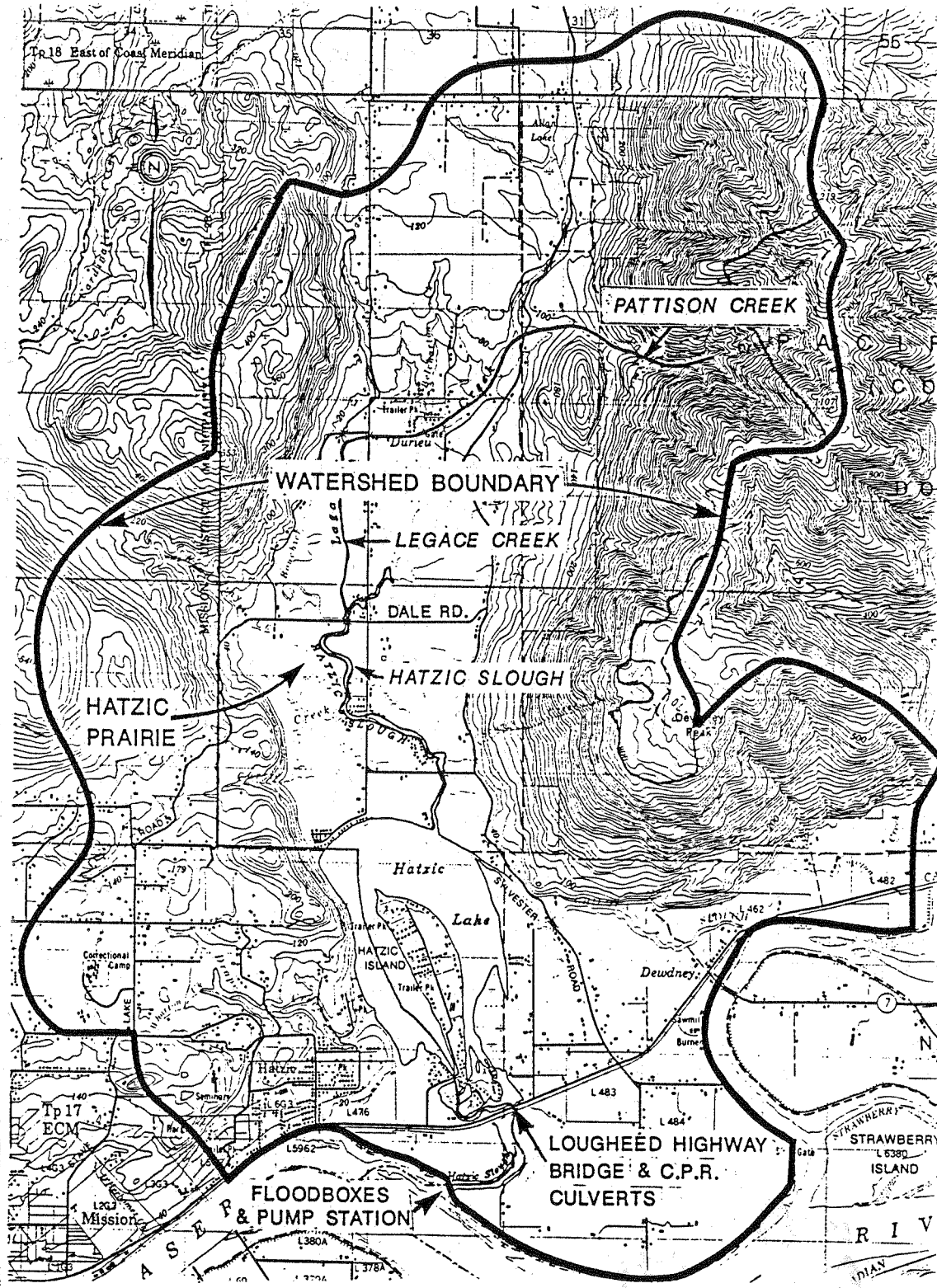
1. Introduction

The Hatzic Lake watershed lies east of Mission on the north side of the Fraser River, see Figure 1. The total watershed is about 8900 ha. The lake covers an area of 337 ha, and around the lake and to the north of the lake is about 2531 ha of level, arable lowland. About half of the watershed is steeply sloping mountain-side, some of which has been logged. The floodplain is predominantly agricultural land, with scattered small holdings, small subdivisions, and recreational property. The lake is a popular area for swimming and boating in the summer.

The watershed lies in the Dewdney-Alouette Regional District (DARD), with the southwest portion of the watershed being in the District of Mission, the north and northeast portion of the watershed being in Electoral Area "E," and the southeast portion being in Electoral Area "B." The Hatzic Island Ratepayers' Association, the Dewdney Ratepayers' Association, the Hatzic Prairie-McConnell Creek Ratepayers' Association, and the Sheltered Cove Improvement District represent specific interests in the floodplain. Dyke maintenance and the operation and maintenance of the pump station and floodboxes are the responsibilities of the Dewdney Area Improvement District (DAID). In the unorganized areas, road maintenance is under the jurisdiction of the Ministry of Transportation and Highways (MTH). In the past, both MTH, the Ministry of Environment (MOE), and the Provincial Emergency Program (PEP) have contributed to the cleaning out of Legace Creek and Pattison Creek.

Several landslides have occurred in the Pattison Creek watershed. In large storms, heavy sediment loads are transported downstream, with heavy deposition occurring in the transition zone between lower Pattison Creek near Sylvester Road, and the downstream end of Legace Creek near Dale Road. Along with substantial aggradation in the channel, new areas of aggressive bank erosion have occurred, threatening adjacent buildings. Occasionally, the creek has broken out of its established channel, spreading gravel over the adjacent fields and flooding nearby buildings. On several occasions remedial work has had to be carried out by the Province on an emergency basis. There is a clear need to stabilize the creek, provide for its regular maintenance, and reduce the threat to adjacent properties.

In large regional storms and during the Fraser River freshet, the floodboxes are closed and the lowlands are completely dependent on



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Ministry of Environment
WATER MANAGEMENT BRANCH

TO ACCOMPANY REPORT ON

HATZIC PRAIRIE WATERSHED

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DATE

MARCH 1991

K. WILSON

ENGINEER

FILE No.

DWG. No.

FIGURE 1

pumping for flood protection. The existing pumps which have a combined capacity of 5.6 mm/day from the watershed area are quite inadequate to the task, and widespread flooding occurs. The flooding of houses and barns is most severe in the intense winter storms when the maximum flood stages are usually reached. However, the floodboxes will usually open after one to three days of high river levels, greatly increasing the outflow and providing flood relief. According to questionnaires that have been returned by landowners, the houses that are most affected by flooding appear to be in the Benbow Street subdivision in Hatzic Estates and in the Riverside Road subdivision off Farms Roads where the houses were built before floodplain regulations came into effect. The Everglades recreational property at the south end of Hatzic Island and the trailer park at the north end of the island are also areas that are heavily impacted. The most damaging storms for agriculture have occurred in the summer when crops are most sensitive to damage due to prolonged inundation. The agricultural area that is most affected by flooding problems is a large depression of about 500 ha in Hatzic Prairie, lying about 2 km north of the lake and centered on the Farms Road and Dale Road area. Because of the low elevation of this land and its location on the far side of the lake from the pump station and floodboxes, it appears from the reports we have received that the land can be flooding when there is barely enough water at the pump station to run the pumps. The farming areas to the east and south of the lake are generally at a higher elevation and have only fairly minor flooding problems that are localized in the bottom of swales.

An entirely different water problem occurs in many years toward the end of summer when the Fraser River begins to recede, causing the lake level to fall as well. The shallow areas of the lake become exposed mud banks and the recreational values of the lake are substantially diminished. Recreational users of the lake have called in the past for stoplogs or gates to be installed on the upstream end of the floodboxes, but cost considerations and concerns about potential flooding damages have prevented any action from being taken so far.

Many efforts have been made to deal with these problems over the years, and a list of past studies is contained in the Reference section. The basic underlying problems are that the runoff and sediment transport from a large upland watershed impact heavily on only some parts of the floodplain and that there has been no overall authority and only a limited tax base available to deal with the problems.

2. Purpose of the Study

The purpose of the study is to develop a comprehensive plan to reduce flood damages and channel instability.

The report will update and expand on previous reports. It will also examine several concerns raised by representatives of major ratepayer groups and by individual landowners through their questionnaires. The emphasis in the final report will be on the identification of practical options and realistic cost estimates. The report should provide landowners and the different levels of government with a technical and cost basis for deciding on future actions.

3. Study Tasks

The listing of study tasks begins with general issues that the consultant will deal with and then proceeds to specific tasks. Several constraints and guidelines on how the consultant will deal with these tasks are outlined in the sections on Technical Criteria, Environmental Considerations, and Cost Estimates.

Task No. 1

The consultant will prepare a comprehensive historical review of major flooding events, channel instability problems, and the construction of flood protection works in the area.

Task No. 2

The consultant will describe existing institutional arrangements and responsibilities for flood protection and internal drainage and how these responsibilities have evolved over time. The consultant will identify capital works expenditures, emergency works expenditures, regular operation and maintenance expenditures, and local taxation revenues for flood protection purposes over the past 25 years. If the existing institutional arrangements appear inadequate for dealing with the flooding and channel problems and with the improvements that are being proposed, then the consultant shall recommend alternative arrangements and responsibilities that could be adopted.

Task No. 3

The consultant will compile information on the nature and value of the flood damages from past reports, damage claims, questionnaires, and selected interviews with landowners. The consultant will also identify the approximate value of property in the affected areas.

Task No. 4

The consultant will define the watershed and major sub-watershed boundaries. The consultant will check whether any storm drainage measures in the District of Mission have altered the watershed boundaries.

Task No. 5

The peak flow estimates for Legace Creek in the report "Investigation of Sedimentation and Flood Control on Legace Creek" by Northwest Hydraulics Ltd., are about twice as high as the estimates in the report "Peak Flow Estimates for Small Streams in the Lower Fraser Valley," by J. Cheng, Ministry of Environment. The consultant will review the runoff estimates and methodology and recommend values to be used in this study for the average peak daily discharge and the instantaneous peak discharge for the mean annual flow and the 5, 10, 25, 50 and 200-year storm events. The consultant will provide peak flow estimates for all the major upland tributaries where they enter the floodplain. Where possible, the peak flow estimates will be cross checked with any available field information that can be gathered on the behaviour of the creeks at key points such as the Sylvester Road bridge on Pattison Creek.

The consultant will estimate the recurrence interval for several storms in recent years that have caused extensive flooding in the Hatzic Prairie. The storms of interest occurred in December 1980, June 1981, July 1983, November 1989, February 1990 and November 1990. The summer storms should be related to a frequency curve for summer storm events.

The consultant will examine plans and possibilities for upland development that could affect future upland runoff. The consultant will assess whether future change in the character of the upland is likely to produce significant changes in either the peak flow estimates or the time-averaged flow estimates contained in the report "Review of Outlet Conditions at Hatzic Lake," by J. Wigmore, Ministry of Environment. If it appears desirable that some form of stormwater management measures should be implemented as part of the development process on the upland, the consultant will make general recommendations on the nature of the controls that should be considered.

Task No. 6

The consultant will prepare a history of logging activities in the watershed and estimate the contribution that logging may have made toward the flooding problems, slide problems, and sediment transport problems in the area. The consultant will determine what logging is planned for the future.

If the consultant considers that future logging activities may significantly affect future runoff, slide, or sediment transport problems, he will recommend policies, practices and procedures that will minimize these problems.

Task No. 7

The report "Hatzic pump station" by Crippen Consultants, tabulated the occasions and extent to which the water level at the pump station exceeded the Hatzic Lake flood stage of 3.35 m (11.0 ft.). The consultant will update these records from the pump station logs through to the present. The consultant will try to determine if the stage readings have been on geodetic datum since 1949.

The consultant will review the pump logs, previous reports, and will contact the offices of the Water Survey of Canada (WSC) and the Inspector of Dykes for any records giving the relationship between the water level on the downstream side of the floodboxes and the WSC gauge at Mission. The consultant will arrange for manual readings to be taken on the staff gauge on the downstream side of the floodboxes during the study in order to further define the relationship for various stages and flows in the Fraser River.

Task No. 8

The consultant will install a low level staff gauge on the downstream side of the floodboxes. The consultant will install automatic water level recorders on the upstream side of the floodboxes in the vicinity of the pump station, in Hatzic Lake upstream of the highway bridge, and at the Dale Road bridge. The sites selected and the arrangement of the installation should be capable of recording the full range of stage to be expected at each location. The consultant will provide vandal-resistant stilling wells and recorder boxes similar to those used by MOE. Drawings of the stilling well and instrument shelter designs are available from MOE. The Ministry will provide three Stevens water level recorders for

the study. The consultant will service the water level recorders on a weekly basis during the study and prepare a combined record of all the stage data collected to show the dynamic behaviour of the system. All the stage records and the stilling wells will be turned over to the Regional District at the end of the study.

Task No. 9

The consultant will report on the condition of the existing pumps and their prospects for an extended operating life into the future.

The existing pump capacity is $6.06 \text{ m}^3/\text{s}$. The Wigmore report determined that a pump capacity of $14.4 \text{ m}^3/\text{s}$ would be sufficient to control the runoff from a 10 year-2 day summer storm between May and August, when the Fraser River is in freshet and the floodboxes are closed. The consultant will identify a suitable location for a new pump station having a capacity of $14.4 - 6.06 = 8.34 \text{ m}^3/\text{s}$. The consultant will provide preliminary drawings for a new pump station and will determine all costs associated with constructing a new pump station and outlet works. Several different options of twin pumps and single pumps, with electrical drive and non-electrical drive should be investigated.

At the one end of the spectrum would be a two-pump, electrical, fully automatic pump station with a hinged fish screen in front of one of the pumps. The fish screen would be similar to the one that has just been installed on the Matsqui Slough pump station. The details and cost of the fish screen would be provided to the consultant by MOE. The new pump station would become the lead pump station, with the existing pump station becoming the back-up. At the other end of the spectrum would be a single large motor-driven pump with manual or rudimentary semi-automatic controls which would only be operated in large storms. A tentative minimum operating level for the pumps would be 1.8 m (6.0 ft.), but the consultant will investigate whether a lower level would be necessary in order to achieve a desirable drainage effect in the Hatzic Prairie area around Dale Road.

In the long term, the operating procedures and operating costs of the pump stations will be of great importance to the local community. With the growing concern over flooding, it is possible that the pumps will be used more than they have been in the past. The consultant will review the current operating procedures and determine whether any changes in the operating procedures could result in reduced flooding upstream. The consultant will clearly identify the increase

that will occur in annual operating and maintenance costs if pumping capacity is increased and operating procedures changed. The consultant should illustrate the effect of increased pumping capacity or changes in operating procedure by preparing a table similar in concept to Table 2 in the Crippen report. The table should distinguish between the power costs as the station is presently being run and the power costs with enlarged pumping capacity and any changes in operating procedures. All comparisons should be made in terms of 1991 dollars.

Task No. 10

The Wigmore report investigated the effect of doubling the existing floodbox capacity. The consultant will identify a suitable location for a new floodbox outlet and will prepare a cost estimate for new floodboxes having a total end area of 13.4 m². The consultant will carry out a geotechnical investigation of the foundation conditions at the proposed site of the new floodboxes and the new pump station.

Task No. 11

In August, the Fraser River and Hatzic Lake usually begin to drop, exposing mud flats in the lake. Recreational users want the lake held at 2.44 m (8.0 ft.) through to the Labour Day weekend. The farming community, on the other hand, is concerned that any attempt to block the floodboxes or use stoplogs will increase the risk of flooding in the event of a storm.

The consultant will review the possibilities for installing some form of stoplogs or control gates at the floodboxes. The consultant will review the storm potential in the month of August, and assess the increased flooding risk if some forms of gate were installed and additional pumping capacity were provided. The consultant will identify any additional operating procedures that would have to be in place for dealing with a storm event if the gates were in place. The cost estimate should cover the stoplog or gate requirements for the existing floodboxes as well as for the new floodboxes.

Task No. 12

A local erosion problem exists on the property downstream of the CPR culverts. The consultant will review the problem and the MOE file on the issue and report on the solution and costs of dealing with the problem.

Task No. 13

The Wigmore report investigated the hydraulic effect of installing two additional 3 m diameter culverts under the CPR. The consultant will discuss with the CPR how this could be done and will provide a cost estimate for doing the work. If the costs are in the same range as that of providing a bridge, then it would be much preferable to have a bridge.

Task No. 14

In large storms a great deal of debris including picnic tables will lodge in front of the CPR culverts partially blocking the waterway. The consultant will investigate the installation of a diverter boom upstream of the highway bridge. If access ramps from the highway are required for the periodic removal of debris, then the cost of the ramps should be included in the cost estimate. The consultant will identify who should be responsible for this maintenance.

Task No. 15

Soundings were made of Hatzic Lake in 1951. MOE is trying to establish the datum of the soundings. The consultant will carry out a bathymetric survey of the lake. The consultant will use the 1951 sounding map, old air photos, and any anecdotal information he can gather to try to determine the location and magnitude of the accretion and sedimentation that has occurred in the lake since 1951. Particular attention should be paid to any areas where the buildup of sediment could be affecting flood discharges. The consultant will report on any conclusions that can be drawn from the data about long-term sedimentation trends in the lake.

Task No. 16

Calls have been made to dredge the lake to increase its flood storage capacity and enhance its recreational potential. The consultant will estimate the increase in live storage that would be available if extensive dredging were undertaken, and he will estimate the significance of this increase in live storage volume relative to the volume of storm runoff that can be expected in major storms. The consultant will also review the pump station stage records for several large storms in the past to see whether the additional live storage volume would have been available at the start of the storm.

The consultant will analyse some samples of the sediment to determine the suitability of the material for spreading on

farmland or as a commercial topsoil. The consultant will check on whether there are any potential cost recovery opportunities from the sale of the dredged material. The consultant will estimate the cost of extensive dredging. If it appears that this might be a viable option, the consultant will identify how the material could be disposed of. The consultant should also consider whether some small-scale, localized dredging would be desirable to improve the drainage hydraulics of the lake.

Task No. 17

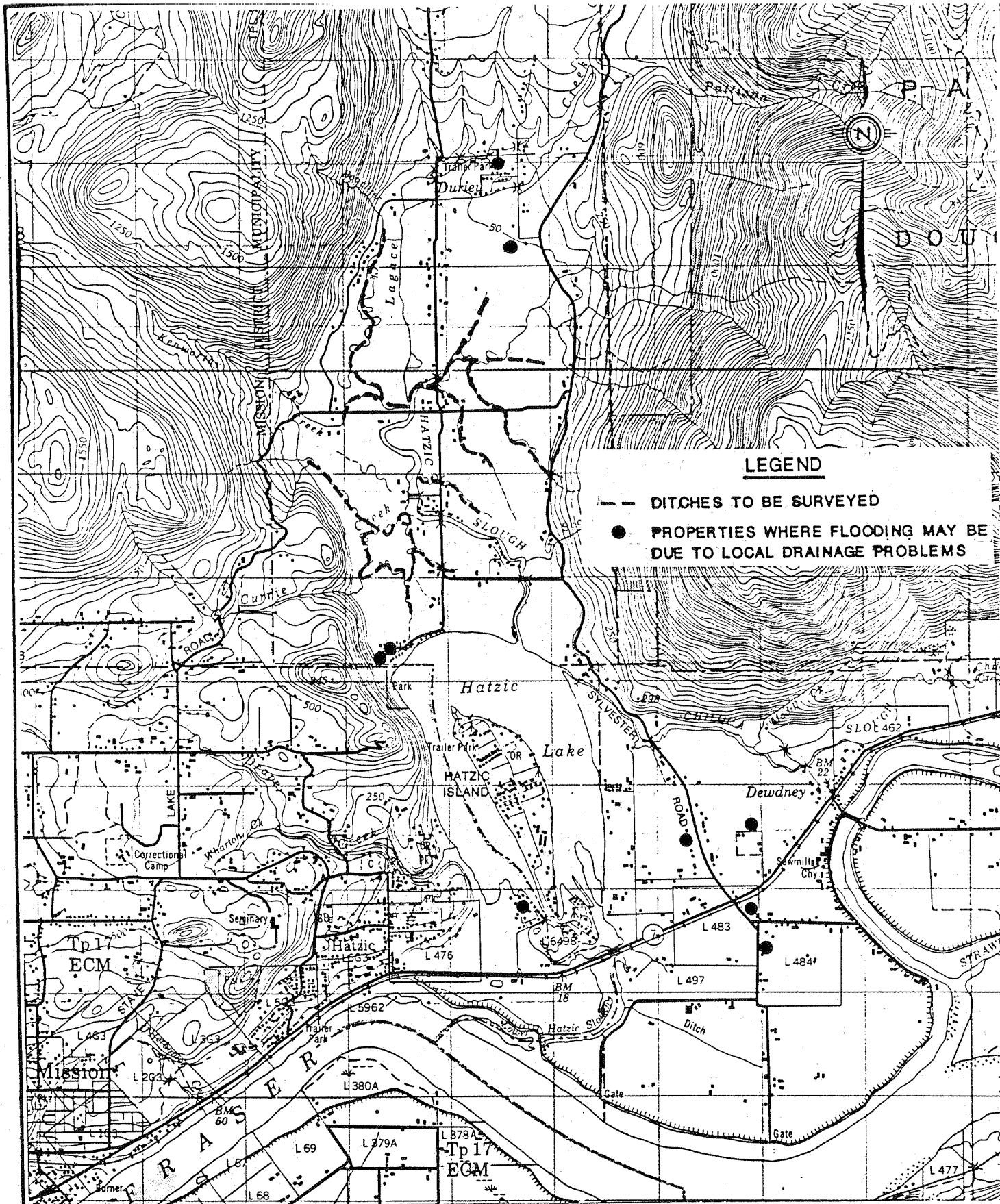
A suggestion has been made that Chilqua Slough might a better outlet to the Fraser River rather than improving the existing outlet works. The consultant will investigate this possibility before undertaking a detailed analysis of the cost of upgrading the existing outlet works. The old floodbox through the CPR washed out in the 1948 flood. The consultant should consider whether a floodbox in close proximity to the railway at the proposed outlet of Chilqua Slough would pose any threat either to the railway or the dyke due to the vibration caused by the passage of heavy trains at the design flood stage on the Fraser River.

Task No. 18

According to the questionnaires, nine landowners described flooding problems that may be related more to inadequate ditches or culverts, or poor maintenance rather than to the flooding problems of the main channels or the lake. The location of these landowners is shown on Figure 2. The consultant will review the questionnaires and problems and recommend improvements.

Task No. 19

Suggestions have been made in earlier reports and by landowners that Hatzic Slough is silting up. Given the aggradation occurring on Legace Creek this would be a reasonable thing to expect. However, a comparison of cross sections surveyed at the three bridges between Dale Road and Hatzic Lake show little difference in cross section between surveys carried out by MOE in July 1984 and March 1991. This is quite surprising. The consultant will pick up the thalweg of the channel between Dale Road and Hatzic Lake and compare it with the thalweg surveyed in 1984. The consultant will also survey cross sections at approximately 500 m intervals and at any obvious constrictions or shallower points. If the channel appears to have been stable over time, the consultant



Province of British Columbia
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WATER MANAGEMENT BRANCH

TO ACCOMPANY REPORT ON
**LOCATION OF DITCH SURVEYS AND
POSSIBLE DRAINAGE PROBLEMS**

K. WILSON

ENGINEER

SCALE: 1:50 000

DATE
MARCH 1991

FILE No. DWG No. **FIGURE 2**

will determine what is happening to the fines that come downstream from Legace Creek.

The consultant will carry out a backwater analysis to determine whether Hatzic Slough should be deepened or widened to provide a better outlet during flooding conditions or to reach the ARDSA base flow freeboard criteria (see Section 4) for the lowlands in Hatzic Prairie. The consultant should identify any long-term maintenance problems that might result from deepening the channel. The consultant should also recommend a maintenance cycle and describe how the maintenance would be carried out.

Task No. 20

The consultant will survey the main drainage channels on Hatzic Prairie up to the 4 m contour. The location of the main drainage channels is shown on Figure 2. The survey will pick up cross sections at about 300 m intervals, at major changes in cross section, and will pick up culverts and bridges. The consultant will carry out backwater analysis on these ditches for base flow conditions to determine what improvements would be required to meet ARDSA drainage criteria. The winter base flow value will be taken as 10 mm/day as shown in the Wigmore report.

A creek starting about 800 m north of Scorey Creek on Sylvester Road runs northwest to Hatzic Slough. A suggestion has been made that this flow should be directed to the southwest to lower Hatzic Slough in order to minimize flooding in the area north of Dale Road. The consultant will assess the merit and cost of this proposal.

Task No. 21

The consultant will carry out a flood-routing analysis to determine the effectiveness of the proposed improvements in reducing the magnitude and duration of flooding in the Hatzic Prairie area. The consultant should carry out the analysis for the July 1983 storm, the November 1989 storm and the November 1990 storm and a 10 year-5 day storm. The analysis should carry out runs with the existing outlet works and pump station, with the existing outlet works plus the new pump station, with the new outlet works and the existing pump station, and with the new outlet works plus the new pump station. This should provide a picture of the relative effectiveness of the various options that are being considered. The consultant should be able to calibrate the flood-routing runs for the existing system to anecdotal information that

the consultant can gather from the questionnaires and interviews with selected landowners.

Task No. 22

According to the questionnaires, 12 houses and 6 barns or outbuildings have experienced major flooding. Most of the houses were in the Benbow Street subdivision off Shook Road and in the Riverside Road subdivision off Dale Road. Several complaints were also made about the inconvenience that occurs due to the flooding of the roads. The consultant will check with neighbours of the landowners we have received questionnaires from to determine whether the questionnaires we have received so far represent the full extent of the flood damages that are being experienced with respect to buildings. The consultant will estimate the cost of floodproofing the houses and of providing flood protection to barns. The consultant will estimate the cost of raising roads above the flooding levels. The consultant will discuss the practicality and effectiveness of these measures.

Task No. 23

At present the peak discharges coming down Legace Creek contribute to widespread flooding on Hatzic Prairie. The consultant will examine whether these flows could be contained by dykes through the lowlands around Dale Road and passed directly through to Hatzic Lake. This may be difficult to implement because of houses and buildings. It may require the raising of some bridges. It would require the installation of floodboxes on most of the tributaries to Hatzic Slough, and it would require local pump stations at the major tributaries. The pump station would be sized to deal with the ARDSA criteria. This proposal would decrease the detention effect of the flood storage that is presently occurring on Hatzic Prairie and would likely result in a more rapid rise in lake levels. The consultant will examine whether this might cause any problems. The consultant will discuss the merit and costs of this proposal compared to improving the main outlet works.

Task No. 24

In determining what approach should be taken to deal with Pattison Creek and Legace Creek, a fundamental question is what sediment volume can be expected from the Pattison Creek watershed in future years. Obviously, if the availability of

easily transported material is nearing an end, then the solutions that would be considered for Legace Creek and the costs of dealing with the problem may be quite different from the measures that will be required if the slide problem is still in its early stages. The consultant will review the reports "Investigation of Sedimentation and Flood Control on Legace Creek" by Northwest Hydraulics and "Pattison Creek Risk Assessment" by Thurber Engineering Ltd. The consultant will supplement these reviews by site reconnaissance and air photo interpretation, if necessary, to provide a clearer picture, if possible, of the volumes of sediment and the character of sediment that will likely have to be dealt with in future years.

Task No. 25

The consultant will assess whether any measures could be taken in the upper Pattison Creek watershed to reduce the generation and transport of sediment from the existing slides and whether any measures or practices could be implemented to reduce the likelihood of activating new slides in the future.

Task No. 26

About 1 km upstream of Sylvester Road there are two small lakes lying in a saddle to the south of Pattison Creek. A suggestion has been made that Pattison Creek could be diverted into the saddle and the northern lake used as a major long-term sediment basin. The consultant will investigate the feasibility of this proposal.

Task No. 27

The Thurber report observed that major deposition was occurring in the section of Pattison Creek upstream of Sylvester Road. A suggestion has been made that rather than maintain this section of channel, that it be left as a major natural deposition zone for the future. The consultant will assess the feasibility of this proposal. The consultant will determine the effect of this proposal on adjacent private property and whether it might be desirable to relocate Sylvester Road in the vicinity of Pattison Creek.

Task No. 28

The "McConnell Creek - Hatzic Prairie Official Community Plan" by DARD, shows land zoned as Rural Residential on Legace Creek downstream of the junction with Pattison Creek.

MOE is currently withholding approval of development on this land because of the natural hazard risk. The Northwest Hydraulics report focused on the problems of dealing with the sediment load from a 25-year event. The consultant will examine the possible consequences of a 200-year event on the existing houses adjacent to Pattison Creek and on the land that is zoned Rural Residential. The consultant will discuss the advisability of instituting protective measures or zoning changes in high risk areas.

Task No. 29

Plans are being developed to carry out an extensive cleanout of Pattison creek and Legace Creek this summer, with funding being provided by PEP. Bank protection will be undertaken in some areas and two small sediment traps are being contemplated in the channel upstream of Seux Road. Once the work is completed, the consultant will resurvey the channel from Pattison Creek at Sylvester Road downstream to Legace Creek at Dale Road, repeating the cross sections that were picked up in the 1984 survey. While waiting for the results of the new survey the consultant will use the 1984 survey data for preliminary planning purposes. The consultant will provide an opinion on the effectiveness of the proposed sediment traps upstream of Seux Road.

Task No. 30

The section of channel between Pattison Creek at Sylvester Road and Legace Creek at Dale Road is a zone of heavy deposition of sediment, ranging in size from cobbles at the upstream end to fine sand at the downstream end. Bank erosion, aggradation, and avulsion have been characteristics of this zone. Landowners fear the sudden loss of buildings or of having major new channels suddenly running across their property. Fisheries object to the frequent and extensive disruption of habitat that accompanies present maintenance activities. Suggestions have been made to concentrate maintenance at selected sediment traps. Mr. Anderson, upstream of the Farms Road bridge on Legace Creek, has made some attempt at removing sand and gravel in the past. Another suggestion has been to use setback dykes to reduce the risk of avulsion as well as the need to heavily riprap extended lengths of channel.

The consultant will carry out a thorough review of the options for dealing with the problems in this section of the channel. The goal is to determine whether there is a better

way of dealing with the problems than the present method. Thus the options can range from minor modifications of the existing system, through the buy-out of properties and leaving nature to take its own course, to the implementation of well defined structural measures to confine and control the channel. The consultant will discuss the relative merits and costs of the different options. The consultant will also clearly describe the effect of the different options on the properties adjacent to the creek.

The consultant will also determine what will be the likely behaviour of the system in extreme events, in particular the behaviour to be expected at the road crossings and the nature of any breakout of the creek from its defined channel.

For each option the consultant will describe both the annual maintenance requirements and the maintenance that will be required in the longer term. For example, if sediment ponds were used and cleaned annually, what additional maintenance would still be required upstream and downstream over time? The consultant will describe any changes that can be expected in the appearance of the channel over time for each of the options. The consultant will investigate whether any commercial sand and gravel removal operation could be implemented to reduce or eliminate maintenance costs. If this is not a realistic option, then the consultant will identify how the volumes of sand and gravel that he estimates will have to be removed from Pattison Creek and Legace Creek will be disposed of in the long term.

With regard to long-term maintenance, if there are any maintenance requirements for Pattison Creek above Sylvester Road or Hatzic Slough below Dale Road that have not already been fully addressed under other tasks, then these additional requirements will be dealt with as part of this section.

Task No. 31

The consultant will prepare a comprehensive summary of the results of all investigations, describing the different actions that could be taken and the different flood protection benefits that would be received. The summary will detail clearly the costs and operation and maintenance requirements of the different options.

The consultant will prepare the required copies of the report and present the findings of the report at a public meeting.

Task No. 32

If the consultant thinks of other investigations that should be carried out as part of the study, he shall describe the nature of the proposed investigations and the costs of carrying them out. The decision on whether to include any of these additional investigations would be settled at the time the contract for the study is signed.

4. Technical Criteria

The construction of pump station and floodbox improvements through the river dyke will be to the standards of the Fraser River Flood Control Program. The consultant will obtain the approval of the Inspector of Dykes for the proposed designs.

The 200-year Fraser River floodplain elevation is 9.3 m in the Hatzic Prairie area. Aside from some minor exemptions to 7.6 m that were permitted for some mobile home installations on Hatzic Island, all new construction and any floodproofing of existing buildings would be to the 9.3 m elevation.

In accordance with the Flood Protection Program Guidelines any dyking along Legace Creek would be for the 50-year flood. In the lower agricultural lands, where widespread ponding occurs and economic considerations govern rather than safety considerations, the design would be based, if possible, on the ARDSA design criteria. The criteria requires the removal of the estimated total runoff from the 10 year-5 day storm within 5 days in the dormant period between November 1 and February 28, and for the removal of the estimated total runoff from the 10 year-2 day storm within 2 days in the growing period between March 1 and October 31. The estimated total runoff consists of the direct storm runoff and the base flow. Base flow is treated as being proportional to the upstream catchment area. The design base flow values used in the Wigmore study were 10 mm/day in winter, 5 mm/day in spring and fall, and 2.5 mm/day in summer. These values represent the base flow values that can usually be expected in the channel and ditches at the end of a major storm, or when periods of mild to moderate precipitation are occurring on a daily basis. In seasons of the year when drainage is still the primary need, the ARDSA criteria call for the design base flow water surface elevation in ditches to be held at least 1.2 m below the surface of the adjacent land to provide a good outlet for tile drains. Experience has shown that lowland channels that are sized to meet the base flow criteria, usually have sufficient capacity for the storm flow.

In backwater calculations in the lowland channels, the consultant should use the Manning "n" values defined in the memorandum "Design Criteria for the Farm Drainage Outlet Assistance Program," by K. Wilson, unless strong field evidence suggests that other values should be used. When channel improvements are proposed and any storm flow calculations are to be made, a new practice is being adopted of assuming that one bank above the base flow elevation will be maintained regularly by machine and will be primarily grassed, and the other bank will be left to develop heavy brush to provide enhanced fish habitat values. For modelling purposes this means that the one bank above the base flow level is treated as a wall. The design memorandum also provides a basis for sizing culverts on the floodplain.

There is some evidence that a number of benchmarks in the Hatzic Prairie area may be in error by as much as 0.3 m. This error may also affect the spot heights shown on the topographic mapping. This issue is currently being investigated by MOE. The Ministry will provide the consultant with an updated list of benchmark elevations to be used in the study. In the course of the survey, the consultant will pick up a number of field elevations in the low areas to compare with the spot elevations shown on the mapping. The consultant will report on his findings.

In surveying the cross sections, the surveys will extend far enough into the fields to provide representative field elevations beyond any berm effects caused by past flooding or cleaning. All ditch crossings, bridges and culverts shall be surveyed, complete with cross sections upstream and downstream, and under bridges. Silt depths, the condition of the structure, and observations on hydraulic improvements that could be made to the structure shall be noted at the time of survey. Photographs shall be taken of all cross sections and structures.

In addition to the specified channel and ditch surveys, the consultant will carry out all additional site and topographic surveys that are necessary to produce reliable cost estimates for the study tasks.

As part of the study returns, the consultant will provide a disk containing all the survey data in a format that is suitable for use on DARD's equipment. In addition, the consultant shall provide two complete copies of all of the new survey data that is collected, including plans showing the location of all cross sections, bridges, culverts, and benchmarks picked up in the survey, plots of the cross sections and ditch profiles, all the bridge and culvert data and associated notes, site surveys and other topographic and bathymetric surveys, and copies of all photographs

taken during the survey. The cross section data shall be presented in a manner similar to the 1984 MOE survey. The cross section plots shall have the same vertical and horizontal scales. The consultant shall also provide two copies of the summary output of all the final backwater runs and flood-routing runs.

5. Environmental Considerations

The study has been discussed with representatives of the Federal and Provincial Fisheries. A brief summary of their comments is as follows:

- (1) The fisheries officers recognize that there are both sediment problems and flooding problems in the area, and they do not see any major conflicts beyond the normal concerns of fisheries. They favour a comprehensive plan that would stabilize the problems and would avoid the need to have annual channel cleanout.
- (2) For most channel work, the construction would have to occur between July 15 and September 15, with minor variations in a given year.
- (3) There are coho, chum and trout in the system. The trout spawn upstream of the salmon. The major spawning area starts at Farms Road and goes upstream on Legace Creek to the lake. They do not think there is any fisheries resource upstream of Sylvester Road on Pattison Creek. They say that most of the secondary tributaries have important spawning areas, in some cases of greater value than on Legace Creek.
- (4) They were receptive to the idea of a sediment pond upstream of Farms Road, even if it is in a spawning area. Their desire is to minimize the frequency of channel cleanout.
- (5) They are open to the idea of setback dykes. When it was suggested that the setback might be about 6 m, a strong desire was expressed for a much greater setback. It was thought that the 6 m width would not leave the channel with enough room to meander and that it would only be a short period of time before erosion would be occurring and requests would be made for bank protection measures to be undertaken.
- (6) They are also concerned about riparian vegetation. They would favour measures that would permit shade vegetation to grow along the banks of the channel.

- (7) In Hatzic Lake they said that there are marsh areas that are available to fisheries and wildfowl and that any attempt to dredge the lake would have to compensate for any loss of habitat.
- (8) They did not have a strong opinion on dredging at this time. If the dredging diminished fisheries values, they would seek compensation or mitigation, but they were not clear on whether any damage would occur. They did not favour the idea of creating an island.
- (9) With regard to the tributary that runs northwest into Hatzic Prairie and which the landowners have suggested should run southwest, the only observation was that if changes occurred that would result in loss of habitat, then mitigation or compensation would be required.
- (10) On increasing culvert or floodbox capacity, they had no objection.
- (11) On increasing pumping capacity, they said that measures such as a fish screen would be required to reduce mortality on any new pump.

The consultant must develop the proposed improvements in the light of the broad general concerns that have been expressed by the fisheries representative. The consultant will provide an environmental assessment of the key improvements that are recommended in the report and on the maintenance procedures that will be required. The consultant will identify any conditions that might occur during construction, or changes that will result from the project that might have significant environmental impact.

6. Cost Estimates

A preliminary screening should be made of the technical feasibility and order of magnitude of costs of the different tasks. Any tasks that are judged to be impractical, undesirable, or excessively costly for the benefits that would be obtained shall be identified. The consultant will be given direction on whether to remove these tasks from further consideration.

It is expected that the majority of tasks will represent options that should be costed out in detail. The consultant will prepare comprehensive cost estimates that give the assumptions on which the cost estimates are based. For example: How will the spoil material be disposed of? How much fencing or landscaping or utilities relocation will be required? In what seasons of the

year will the various construction activities occur? Which parts of the project would be built under contract and which parts on a day-labour basis?

The unit costs and quantities used in the estimate shall be identified; and the cost estimate shall be broken down in such a way that priorities can be established between sub-projects. The cost estimate shall include estimates of the cost of final design, supervision of construction, the preparation of as-built drawings, the preparation of operation and maintenance manuals, general administrative charges and contingencies. The cost estimate shall include estimates of land acquisition costs, and right-of-way costs including survey costs. Where the proposed activities are of a magnitude that would have a significant adverse effect on the viability of a parcel of land, the land acquisition cost should assume that the whole parcel will be purchased. The capital costs shall be expressed in 1991 dollars.

With regard to maintenance costs, the consultant shall recommend operation and maintenance procedures for the project that consider to the extent possible both the Fisheries' concern about protection of the fisheries resource, and the landowners' need to have an effective flood protection system. The recommendations should include a description of the nature and frequency of maintenance activities, and should identify all the measures that go beyond the existing practices. The consultant shall estimate the additional annual operation and maintenance costs that would be associated with the project, including the power costs for the pump stations.

7. Reference Material

The following material will be available for inspection by consultants at DARD's office. Copies or loans of the material will be made available to the successful consultant as required.

Air Photographs

Oblique air photos taken of the November 1990 storm, showing flooding on Hatzic Prairie.

Surveys

- (1) "Hatzic Lake Outlet Channel Survey," MOE, May, 1982
- (2) "Legace Creek," MOE, July 1984
- (3) "Hatzic Slough Bridge Sections," MOE, March 1990

Mapping

- (1) 1:5000 Contour Planimetric, 1983
- (2) 1:5000 Roll Nos. and Parcel Size
- (3) 1:5000 Contour Line Base
- (4) 1:10,000 Lot Plan

Reports

- (1) "A Look at the History and Problem," DAID, 1981
- (2) "Dewdney-Hatzic Lake Official Community Plan," DARD, 1988
- (3) "McConnell Creek-Hatzic Prairie Official Community Plan," DARD, 1988
- (4) "Dewdney-South Dewdney Dyking District - All Information Available to Jan. 10, 1974"
- (5) "Dewdney Area Improvement District, Dyke Rehabilitation Program, Stage 1 Report," Klohn Leonoff, 1983
- (6) "Dewdney Area Improvement District, Contract No. 4, Rehabilitation of Hatzic Slough Dam and Floodbox," Klohn Leonoff, 1987
- (7) "Performance Test on Hatzic Pump Station," J.V. Eby and J.P. Riley, 1963
- (8) "Review of Outlet Conditions at Hatzic Lake," J. Wigmore, MOE, 1983
- (9) "Hatzic Pump Station, Report on Additional Pumping Capacity," Crippen Consultants, 1984
- (10) "Physical Characteristics and Water Quality of Hatzic Lake," DARD, 1976
- (11) "Hatzic Prairie Land Use and Drainage Study," Ministry of Agriculture, 1980
- (12) "Peak Flow Estimates for Small Streams in the Lower Fraser Valley," J.D. Cheng, MOE, 1980
- (13) "Hatzic Prairie Debris Flow Landslide Identification Study," P.J. Woods, MOE, 1983
- (14) "Dewdney Area Improvement District, Legace Creek Flooding, December 1979," A.A. McPherson, MOE, 1980
- (15) "Investigation of Sedimentation and Flood Control on Legace Creek," Northwest Hydraulic Consultants, 1985
- (16) "Pattison Creek Risk Assessment," Thurber Engineering Ltd, 1990

8. Coordination

The study is being funded by a grant to the Dewdney Alouette Regional District from the Ministry of Environment's Sustainable Environment Fund. A contract for the study will be signed between the consultant and DARD. The Ministry has agreed to provide technical support for the study and direction to the consultant will

be given by Mr. K. Wilson of MOE. An Advisory Committee has been established representing all the major interests in the study area. The Advisory Committee will meet with the consultant on a monthly basis at the DARD office in Mission to monitor the progress of the study and give guidance on problems that arise during the study. Three meetings will also be held at intervals with representatives of the Federal and Provincial Fisheries Branches so that the consultant can outline the measures that are being proposed, and efforts can be made to minimize environmental impacts. The meetings will be held at the Fisheries Office in Mission or in the field.

9. Study Report

The study report shall describe clearly the investigations that have been carried out of the specified tasks and the improvements that are proposed. In cases where any investigations have been curtailed, the reasons for cutting short the investigation shall be clearly outlined. Plans, profiles, and cross sections will be provided for all the proposed channel and dyke improvements. Tables will be prepared identifying the effects of construction on individual properties. Conceptual site plans will be prepared for the pump station, floodboxes, and CPR culvert improvements. Conceptual site plans will also be prepared for any sediment basins or other control structures proposed on Legace Creek or Pattison Creek.

Completion of the report shall not exceed 6 months from the consultant receiving notice to proceed with the study. The report shall be presented in metric units; but imperial units may be shown in parentheses to aid in public awareness of important quantities. Twenty-five copies of the report shall be submitted. The consultant shall give presentations of the findings of the study report to the Advisory Committee and to a public meeting. This type of presentation usually requires the preparation of special materials, such as plans, slides for an overhead projector, and a 4- to 6-page summary of the report. DARD will arrange for the printing of any copies of the summary report required for distribution at a public meeting.

10. Consultant's Proposal

The nature of the study lends itself to the employment of staff with broad experience and sound engineering judgement in hydrology, hydraulics, construction, costing and geotechnical investigations. Expert advice will be required on forestry practices and environmental assessment. The study also lends itself to a Project Manager who can pull together all the different aspects of the study, ensure quality control in the work, and discuss all aspects of the study authoritatively at the Advisory Committee meetings and at the public meeting.

The consultant's proposal shall include the following:

- (1) a list of staff to be employed in the study, together with a description of their relevant experience;
- (2) details of the firm's experience with similar projects;
- (3) details of sub-consultants, if required;
- (4) a schedule of rates for personnel and estimated disbursements;
- (5) a description of the effort that would be put into each task, including where appropriate the method of analysis, the models used, and the output that would be produced;
- (6) a schedule listing the staff hours, staff costs, and disbursements for each task.
- (7) a 10% contingency for any new tasks that are identified as being necessary during the study;
- (8) a schedule for completion of the report identifying the principal activities and time to complete each activity.

Any expenditure from the contingency fund will only be on the written authorization of DARD. The sum of the study costs listed in Item 6. will represent an upset price for the study, providing all the tasks are fully completed. If some tasks are shortened during the study, payment to the consultant will be made on the basis of the fraction of the task complete. Subject to this qualification, four equal progress payments will be made to the consultant. The first three payments will be made when the consultant submits a claim showing that 25%, 50% and 75% of the work identified in Item 6. has been completed. The final payment to the consultant will be made upon completion of a satisfactory final report, the return of all study materials to the Regional District, and the presentation of the report to a public meeting.

Kenneth W. Wilson.

Kenneth W. Wilson, P.Eng.
Senior Hydraulic Engineer
Water Supply and
Drainage Section
Water Management Division

KWW:khh

APPENDIX B

GEOTECHNICAL REPORTS



Golder Associates Ltd.

CONSULTING ENGINEERS

REPORT ON

**HATZIC PRAIRIE STUDY
PATTISON CREEK CATCHMENT
TASKS 24 AND 25**

Submitted to:

Associated Engineering (B. C.) Ltd.
#300 - 4940 Canada Way
Burnaby, B. C.
V5G 4M5

DISTRIBUTION:

3 copies - Associated Engineering (B. C.) Ltd.
Burnaby, B.C.

2 copies - Golder Associates Ltd.
Vancouver, B.C.

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HATZIC PRAIRIE STUDY - PATTISON CREEK CATCHMENT

1.0 INTRODUCTION

Tasks 24 and 25 relate to the existing and potential problems of the sediment generated within the Pattison Creek catchment. Previous studies have shown the existence of debris sources within the basin and the periodic mobilization of the material as debris flows and floods towards Hatzic Prairie. The TOR calls for an evaluation of the volume and character of the sediment available, and to assess whether measures can be taken to reduce the generation and transport of material. It is also required to consider whether any measures or practices can be implemented to reduce the likelihood of activities of new slides.

2.0 PREVIOUS STUDIES

Two reports have been produced by Northwest Hydraulics Consultants (NHC) in 1982 and 1985, both consider the slides on Pattison Creek and the historic activity in the basin. Thurber Engineering Ltd. (TEL) produced a risk assessment of Pattison Creek in November, 1990, in response to a debris flow event earlier that month. Several generations of airphotos have been available both to this study and the previous NHC's work.

The chronology shown on Table 1 may be deduced from the airphotos and the reports of previous studies.

3.0 DESCRIPTION OF THE CATCHMENT

Pattison Creek is a small west-facing catchment of some 6 km² which drains towards the flat floodplain of Hatzic Prairie on the north side of the Fraser River. The elevation of the watershed ranges from EL. 1,200 m down to approximately EL. 20 m on the floodplain. The creek has formed a large fan below EL. 260 m which has spilled out across the floodplain and disrupted the local drainage which flows predominantly southwards towards Hatzic Lake and the Fraser River (Figure 1). The fan is estimated to have a surface area of 2.1 km² (TEL, 1990).

The Pattison Creek catchment is formed on granodioritic rocks of the Coast Batholith, although sheared and low grade chloritized metamorphic rocks are also seen in outcrop in the upper part of the fan. Within the catchment, the rock is mostly obscured by surficial deposits comprising a variable thickness of coarse colluvium and glacio-fluvial sands and gravels, probably of ice-contact origin and till. Very coarse colluvial deposits form aprons below rock outcrops on the south side of the valley.

Tree cover obscures much of the ground within the catchment. The catchment has been partially clearcut at several periods in the past. It appears that an access road was driven into the basin on the north slopes in the 1950's, and clearcutting of that area followed over the period into the 1960's. This road was subsequently driven around the perimeter of the catchment to permit logging of the crest of the southern slopes. Only limited logging has been carried out on the steeper slopes of the catchment. The clearcut areas have since been replanted. Selective logging has been carried out in the upper part of the fan.

There appear to be several sources for the coarse fraction of the deposited materials; they do not all come from the part of the basin above the fan:

The sources include:

- colluvium and reworked glacial deposits within the basin;
- coarse colluvium from the rock slopes downstream of the waterfall;
- reworking of the glacial deposits present below El. 120 m on the north side of the creek.

The finer fraction, predominantly medium and fine sand, which causes much of the problem beyond the fan, originates from the glacial deposits within the basin and is able to wash through the coarser materials which are widely gap-graded.

4.0 DRAINAGE SYSTEM

The tributary creeks which coalesce to form Pattison Creek drain at slopes between 22° and 25°. The creek gradient at the apex of the fan lies at 9° and falls to 5° in the wider

part of the fan above the Sylvester Road Bridge and to 3 - 4° downstream. The main branch of the creek is incised into bedrock from El. 600 m down to a waterfall at El. 260 m at the apex of the fan (see Plate 1). Elsewhere, creek channels are developed in colluvial and glacial soils.

The Pattison Creek fan is predominantly a coarse bouldery deposit with material up to 1.5 m diameter near the apex fining down to a maximum size of 0.5 m diameter at Seux Road Bridge. Finer gravel and sand sizes are carried down to Hatzic Prairie where they create aggradation of the channel, periodic avulsions, flooding and deposition of sediment over the fields. A moderate proportion of organic debris is contained in the deposits throughout the upper part of the fan and is estimated to range up to 20%.

The active channel is 20 m wide for 600 m from the apex widening to some 50 m at Sylvester Road. The upper part of the fan partially spreads to cover a saddle holding two lakes to the south of Pattison Creek at El. 150 m (Figure 2, Plates 2 and 3). The fan has been deposited onto this saddle and may have been instrumental in the formation of the northern of the two lakes (termed Amber Lake). Drainage from the lake has been deflected to the west of the fan and joins Pattison Creek at El. 130 m. Below this point, and down to some 350 m above Sylvester Road Bridge, the creek is incised into glacial deposits on the north side and into colluvium or rock on the south. Beyond Sylvester Road, development of the fan is constrained by the steeper slopes formed in glacial deposits to the north; it spills out onto the floodplain deposits of the prairie to the south.

An avulsion appears to have occurred prior to the 1940 airphotos some 250 m upstream of the Sylvester Road Bridge on the north side.

5.0 PAST INSTABILITY

Slide and avulsion events as deduced from the airphotos are itemized on Table 1.

A major slide is deduced to have occurred from the south side of the catchment in 1935 (NHC, 1985) probably in the coarse colluvium, and is said to have generated a large debris flow (terminology is defined in Table 2). Lesser debris flow activity is considered to be ongoing and characteristic of most of the gullies, but events are of generally small

magnitude (say $<500 \text{ m}^3$). Continued ravelling of the thick colluvial aprons does not generally appear to trigger events precipitating large debris flows, although it is possible that the 1935 event may have occurred in this way. There does not appear to have been any increase in activity on the south side as the result of logging in the past 30-40 years.

By contrast, there is a progressively increasing level of activity from the north side of the catchment where failures in largely glacio-fluvial materials (possibly with some tills) have precipitated debris flows (Plate 4). The event of November, 1990 has been described in detail by TEL. Initial activity at Point A (Figure 2) prior to 1962 was followed by a progressively deteriorating situation at Point B over the subsequent period, and latterly the failure at Point C in 1990. Recent advice from NHC shows that $300,000 \text{ m}^3$ of material has been removed below point B and that up to $130,000 \text{ m}^3$ has been removed below point C over a 30-year period. Other incipient failures have been recognized. Most existing failures are intimately related to the presence of the Forest Access Road where the sidecast material below the road, or steep unprotected cuts in soil, have caused triggering events precipitating debris flows. The failures are seen to be initiated at the access road, but to fail retrogressively to affect the slopes above the road and to create debris flows with significant destructive power downstream.

6.0 POTENTIAL FUTURE INSTABILITY

The soil failures on, or due to, the Forest Access Road construction on the north side of the catchment have not stabilized. The exposed materials are highly erodible and further extensive sources of the same materials appear to be available. Small failure scars on the road indicate that other large failures could develop.

There does not generally appear to be any likelihood of increased activity on the south side where the availability of materials is related to channels and is released as small debris flows from colluvial sources which will continue to occur. However, a large magnitude, low probability event (such as apparently occurred in 1935) should be considered a possibility.

The potential debris flows on the north side are strongly related to the availability of water, i.e. periods of higher than average antecedent precipitation, storm cells or rain-on-snow events. Low frequency/large magnitude precipitation could generate large

pulses of material which would be transported to the fan below. Equally, higher frequency/lower magnitude precipitation could result in smaller debris flows, but with considerable accumulation of sediment downstream. This concurs with NHC's previous conclusions. However, further failures on the road could trigger substantial debris flows without extreme precipitation events if new sources of glaciofluvial materials are exposed. Such a situation has been identified at Point D (Plate 4). Further large debris flows are likely to be generated as the headscarp at Point B recedes and captures the flows from the channel below Point C.

It would be prudent to assume that the level of activity in the Pattison/Lagace Creek system will be at least as great as that in the last 30 years. TEL describe the channel of the November, 1990 event as being scoured to bedrock along part of its length but it is likely that this occurs periodically after each main event. Larger events could be experienced due to more extreme precipitation events than occurred during this antecedent period.

In recent studies involving natural hazards, it has been found to be helpful to express quantitatively the likelihood of the magnitude of future events. Obviously in this case the application of standard statistical analyses does not apply, but the concept of probability can also be used subjectively. The reliability of probabilities selected subjectively improves as our knowledge of the history of past events increases. Probabilities derived in this way are referred to as "allocated" to avoid any misunderstanding as to their origin (Morgan, 1990). Allocated probabilities of future occurrence of debris flows in the Pattison Creek Basin (above the fan) are given in Table 3. The values in this table may be used for planning and risk assessment purposes, but the notes attached to the table are important and qualify the application of the results.

The following probabilities express the anticipated productivity scenario for the next 30 year period and are compatible with Table 3.

- a) 75 percent chance of 250,000 m³ or greater
- b) 50 percent chance of 625,000 m³ or greater

In addition to these debris flow quantities, it is estimated by NHC (personal communication) that further accumulations will result from debris flood and flood events

and could total some 300,000 m³ over a 30-year period. Thus it is concluded that there is a 75% chance of a total sediment load of 550,000 m³ being accumulated over 30 years and a 50% chance of 925,000 m³ being accumulated.

7.0 SEDIMENT TRANSPORTATION MECHANISMS ON THE FAN

As the sediment content in stream flow increases, the onset of yield (shear) strength has significant implications for stream hydraulics. The flow ceases to act as a Newtonian fluid. For example, Figure 4 of Hungr et al (1984) shows that for a given discharge, the velocity of a debris flow (torrent) can readily be 2 to 5 times slower than the velocity of cleaner water under turbulent flow. However, it has been shown (Pierson et al, 1987) that water flows can carry a significant volume of coarser particles (as high as 50%) and still retain Newtonian behaviour with all the characteristics of normal stream flows. Thus as the sediment transportation mechanism on alluvial fans in mountainous areas changes from a debris torrent, or flow, to a debris flood (less bulking but still non - Newtonian behaviour) to sediment laden water, to "clean" water, then the hydraulic performance changes accordingly. In other words, surges of bulked debris with discharges, and potential for channel erosion well in excess of normal flood flows can and commonly do occur at the apex of any alluvial fan. By contrast the outstanding characteristics of debris floods further downstream are reworking of sediments, deposition (aggradation), and channel blockage (avulsion). The two most important parameters which govern the downstream limit of the highly destructive debris flow phase are the degree of channel confinement and the slope of the fan. However, it is also important to keep in mind that a spectrum of high to low energy events can occur on debris flow prone creeks, and that even within the same event, channel erosion at a given location can be rapidly replaced by deposition.

The field evidence indicates that debris flows do not proceed further than some 300 - 400 m downstream of the waterfall. TEL estimate that debris surges in the range 200 - 400 m³/sec. developed in this zone during the November, 1990 event, transporting an estimated volume of 54,000 m³. Debris in this zone consists of 20-40% sand and gravel with the remainder being cobbles, boulders and organic material. Maximum boulder size is 1.5 m and organic content may range up to 20%. This debris flow deposition has since been partially reworked by the creek.

Between the end of the tongue of debris flow deposited material and Sylvester Road Bridge, the deposits are typical of debris flood deposition. The material becomes clast-supported, rather than matrix-supported, with much evidence of fluvial sorting. The maximum grain size reduces from 1.5 m to 0.5 m, although the organic content in the uppermost sediments continues to be high. Downstream of the bridge, fluvial transportation mechanisms predominate and the approaches used by NHC (1985) for estimating bedload transport are valid.

8.0 MITIGATIVE MEASURES

8.1 Source of Supply

The chronology of events since the availability of airphotos and after the development of the main settlements in Hatzic Prairie, indicates that deposition of sediment due to hazards in the Pattison Creek catchment has been a persistent problem since at least 1935. No life-threatening events have apparently occurred, but economic hardship has resulted from flooding from these causes.

As the prime source of supply within the basin is related to forest access road construction, some rehabilitation can be undertaken to reduce the possibility of further failures and generation of sediment. These works relate primarily to control of water and include the construction, or improvement, of water bars (to prevent the concentration of flow down the roads) and the installation of culverts. However, the existing slide scars are now so large, and the exposure of erodible materials so great, that sediment will continue to be generated. There is no economic means of mitigating this situation. As the trees on the upper reforested slopes grow, the severity of the runoff will be decreased with some marginal benefit to basin stability.

Future logging practices must avoid creating slope instability which results in long-term problems for neighbouring areas.

8.2 Material Transport

The slope of the fan (6° - 9°) indicates that debris flows will begin to deposit immediately below the waterfall and will runout in the upper part of the fan. Highly destructive

events therefore do not endanger roads or habitation. There is no indication that finer debris flows have continued far into the fan. Thus any scheme for capture or diversion must deal with debris floods during which material is brought from within the basin, the upper part of the fan is reworked, and material is transported downstream.

8.3 Diversion Structures

The topography and volumes of material being considered in the vicinity upstream and downstream of Sylvester Road Bridge do not allow serious consideration of a debris catch basin in that area. However, the area between Pattison Creek and Amber Lake merits further investigation as a depositional basin.

As described earlier, an existing fan spills over into the saddle towards Amber Lake. The creek is incised into the north flank of this fan. With the construction of a diversion embankment, and excavation of a channel, the creek and hence debris floods could be routed towards the saddle. Because deposition would occur within this channel with each event, continual maintenance would be required. However, there is available space for storage of material which could be bulldozed to provide a higher berm and hence additional protection on the north side. It would be essential to ensure that avulsions were not able to occur allowing the creek to regain its existing channel. Flows could be routed either through Amber Lake, or back through the existing Amber Creek to Pattison Creek. A control structure (weir) could be further considered at the existing confluence of the two creeks where bedrock outcrops.

The effect of routing flows southwards through the saddle towards other properties would need to be carefully considered. Capturing material at this location would not preclude reworking of the existing material in the channel which would reduce in severity with time. Moreover flood flows could be minimized if the saddle routing was selected.

8.4 Protective Structures

Some properties marginal to the creek could be at risk due to avulsions, especially on the north side upstream of Sylvester Road Bridge. Protective berms might be necessary to reduce the risk from the higher magnitude events.

The Sylvester Road bridge is thus located in a marginal location with regard to the application of stream hydraulics with respect to capacity etc.

8.5 Creation of Depositional Zone Upstream of Sylvester Road

Where bridge crossings are concerned, it is important to maintain control over the upstream sections of the creek that are vulnerable to avulsion. Thurber (1990) has correctly pointed out that the creek for a distance of some 800 m upstream of the bridge location can overflow onto private property on both the left and right banks. Deposition and termination of maintenance would encourage this potential for avulsion.

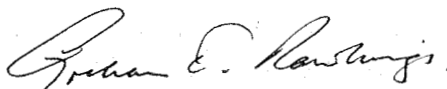
There is some merit to relocating the bridge away from the area of uncertain hydraulic performance (e.g. to a location below the confluence with Lagace Creek). However, as discussed above, the creek channel upstream would have to be maintained to avoid an avulsion.

There does not appear to be a viable opportunity for relocating the bridge upstream.

This report on Tasks 24 and 25 is provided as input to the final report for the Hatzic Prairie Study.

Yours truly,

GOLDER ASSOCIATES LTD.



Graham E. Rawlings, P. Eng.
Principal

GER/kc
912-1453

2/GR-1453

REFERENCES

NORTHWEST HYDRAULIC CONSULTANTS, 1985. Investigation of Sedimentation and Flood Control on Lagace Creek, Final Report. Prepared for B.C. Min. of Environment.

THURBER ENGINEERING LTD., 1990. Pattison Creek Risk Assessment. Prepared for B.C. Min. of Environment.

PIERSON, T.C. and COSTA, J.E., 1987. A Rheological Classification of Subaerial Sediment - Water Flows. Geological Soc. of America, Review in Engineering Geology, Volume VII, p. 1 - 12.

HUNGR, O., MORGAN, G.C. and KELLERHALS, R., 1984. Quantitative Analysis of Debris Torrent Hazards for Design of Remedial Measures. Can. Geot. Journal, Vol. 21, p. 663-77.

MORGAN, G.C., 1990. Quantification of Risks from Slope Hazards. Preprint to be published in GAC Symposium proceedings on Landslide Hazard in Canadian Cordillera.

TABLE 1
SLIDE AND AVULSION EVENTS ON PATTISON CREEK

EVENT	DATE	COMMENTS
1. Landslide, south side Pattison Creek Basin.	January 1935	Deduced from 1930 and 1940 airphotos and records of most severe winter storm of century (Won, 1971).
2. Avulsion in channel between Seux Road and Farms Road Bridges.	January 1935	Deduced from 1930 and 1940 airphotos and records of most severe winter storm of century (Won, 1971).
3. Rapid sedimentation in Pattison Creek Channel.	1951	MOE records.
4. Major slide, north side Pattison Creek Basin.	Between 1952 and 1962	NHC, 1982.
5. North side of basin clearcut by this date with access road to limit of watershed. Instability from road excavation at eastern limit of lower access road. Small slide developed in tributary below lower hairpin on access road, north side.	1962	Airphoto BC 4067:211, July 1962.
6. Creek channel aggraded 1.5 m between Seux Road and Farms Road Bridges.	1968	MOE Records.
7. Access road continued around eastern limit of basin; south side not visible, possibly clearcut. Slide scar below lower hairpin substantially larger.	1968	Airphoto BC 7058-033
8. Avulsion at Farms Road Bridge, flow directed into Bouchier Creek. Slide below lower hairpin almost up to road.	December 1979	MOE Records. Airphoto BC 79193-005
9. No apparent changes from 1979.	1981	Airphoto BC 81005 L15, N1
10. Debris flow from failure on Upper Access Road, north side of basin.	November 10, 1990	TEL, 1990

TABLE 2
CLASSIFICATION OF DEBRIS MASS MOVEMENTS

(After O. Hungr, 1988)

Debris Flow/Debris Torrent*:	<ul style="list-style-type: none"> • low fines content (<10% silt and clay) • high organic content, often 60% timber, mulch • high velocities * a synonym for debris flow applied in the Pacific Northwest
Debris Flood:	<ul style="list-style-type: none"> • transitional between flood and debris flow • small debris surges dragged by flowing water • magnitude may compare to that of a debris flow • low discharges, moderate velocities
Debris Slide:	<ul style="list-style-type: none"> • shallow failure of the colluvial veneer • common over resistant and impervious substratum • occurs on open slopes and in gullies • associated with heavy rain
Debris Avalanche:	<ul style="list-style-type: none"> • unchannelled debris flow • a debris slide with long displacement • flow-like motion, high velocities
Mudflow:	<ul style="list-style-type: none"> • fine-grained debris flow (>30% silt and clay)
Slow Earth Flow:	<ul style="list-style-type: none"> • slow, plastic displacement of cohesive soil • no dilution, low water content • low slope angle
Rapid Earth Flow:	<ul style="list-style-type: none"> • rapid flow of material liquefied at its natural water content - no dilution • source material is not colluvium • quick clay flow, sand liquefaction flow
Rockslide:	<ul style="list-style-type: none"> • dry rock debris, limited reach
Snow Avalanche:	<ul style="list-style-type: none"> • snow or slush and debris

TABLE 3
ALLOCATED PROBABILITY OF OCCURRENCE OF DEBRIS
FLows ON PATTISON CREEK

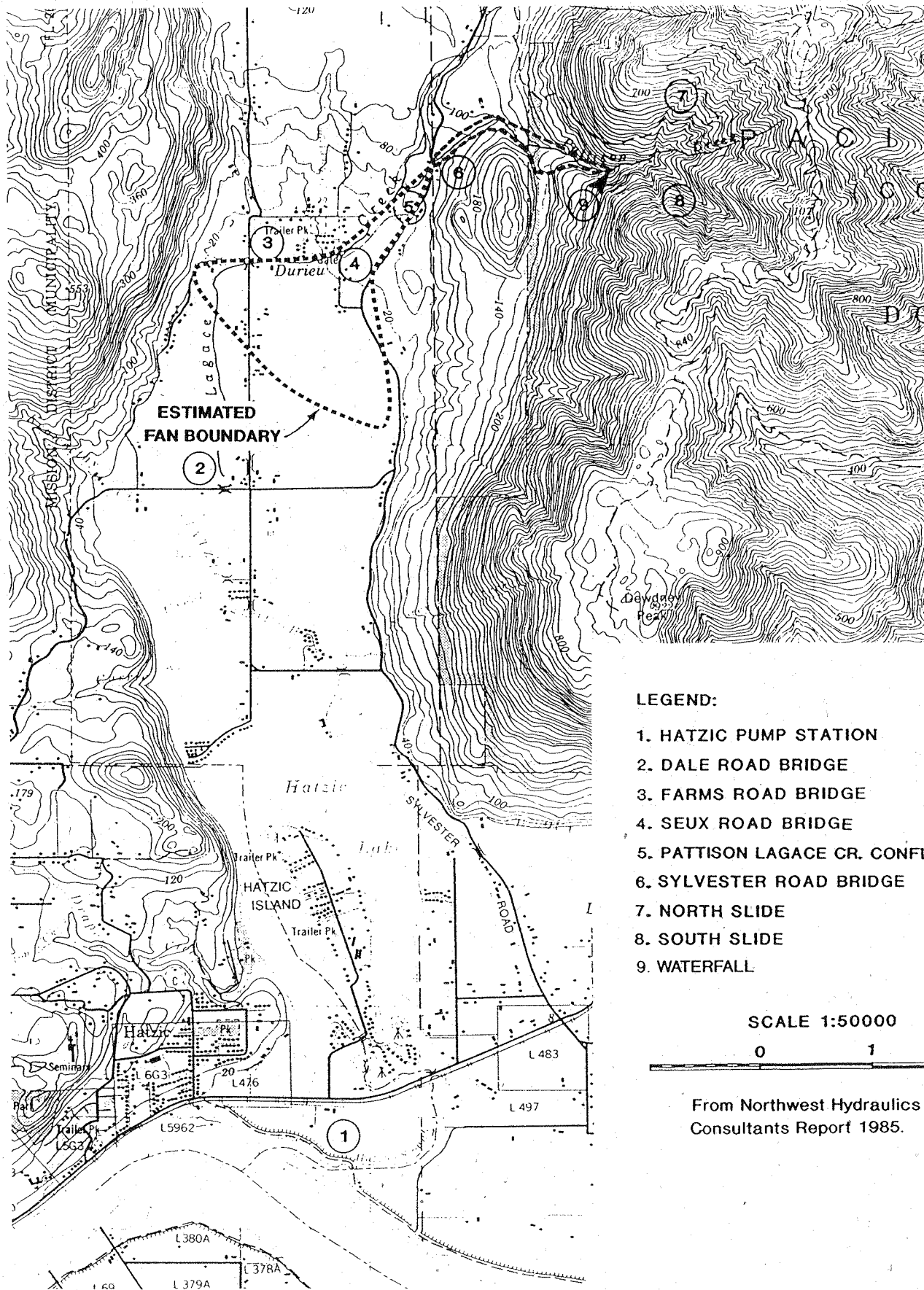
Annual Probability Range	Debris Flow Magnitude (m ³)
1:5 to 1:10	25,000
1:10 to 1:50	100,000
< 1:50	250,000

Notes:

1. Applicable time period, 30 years.
2. Our present understanding and records of the occurrence of debris flows do not permit a rigorous estimate of probabilities. The above values represent a quantitative consensus which is compatible with the history of debris torrent occurrence during the last 30 years and the potential for future activity reported by NHC (1985, 1991), Thurber (1990) and as indicated by the recent (July 1991) helicopter inspection of the basin. The magnitudes are believed to be a reasonable estimate, but both these and the quoted annual probabilities should be reviewed and are subject to change as further data and information become available. The figures do not include the transportation of material from the basin by normal flood events.

LOCATION PLAN

Figure 1



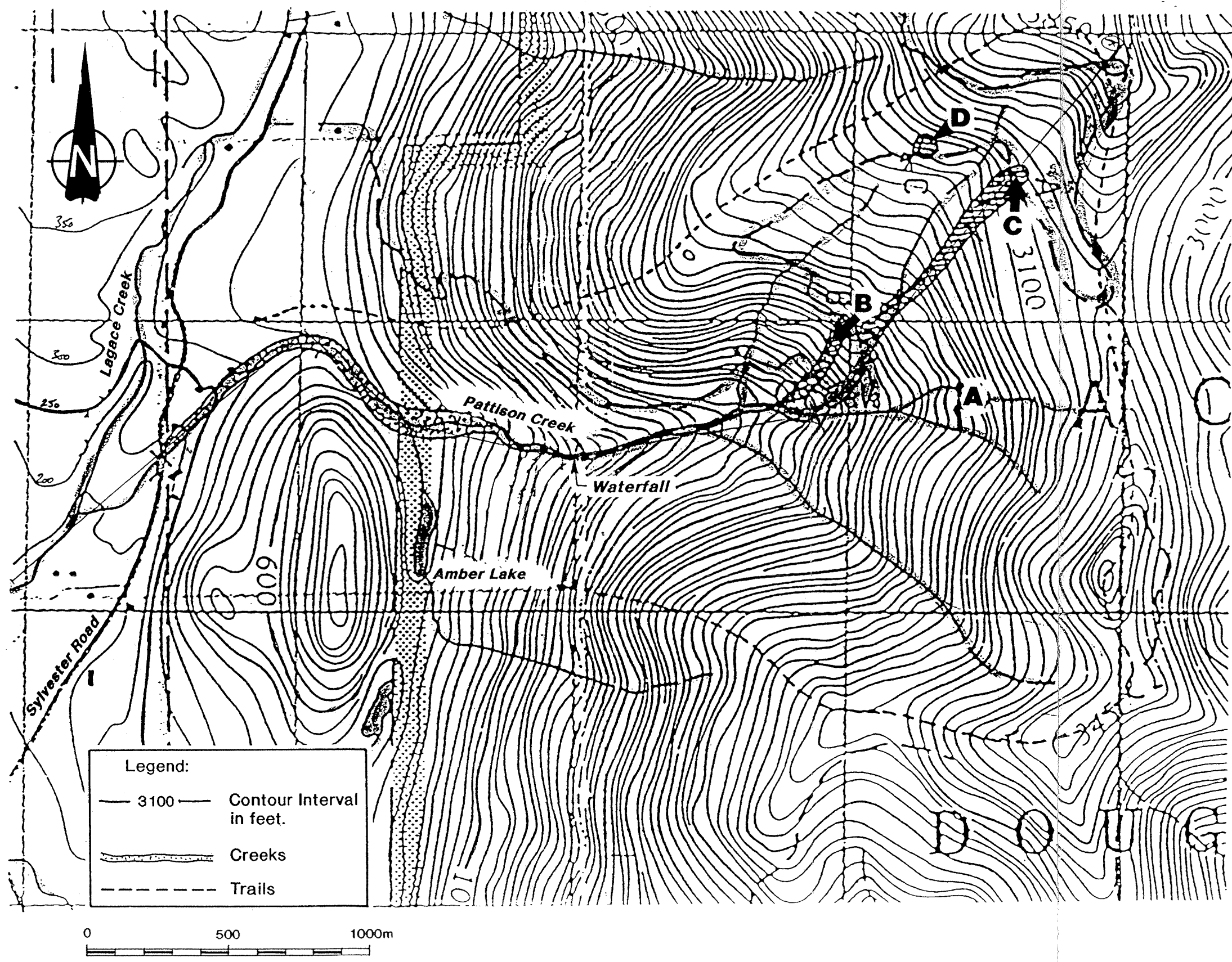
LEGEND:

1. HATZIC PUMP STATION
2. DALE ROAD BRIDGE
3. FARMS ROAD BRIDGE
4. SEUX ROAD BRIDGE
5. PATTISON LAGACE CR. CONFLUENCE
6. SYLVESTER ROAD BRIDGE
7. NORTH SLIDE
8. SOUTH SLIDE
9. WATERFALL

SCALE 1:50000



From Northwest Hydraulics
Consultants Report 1985.

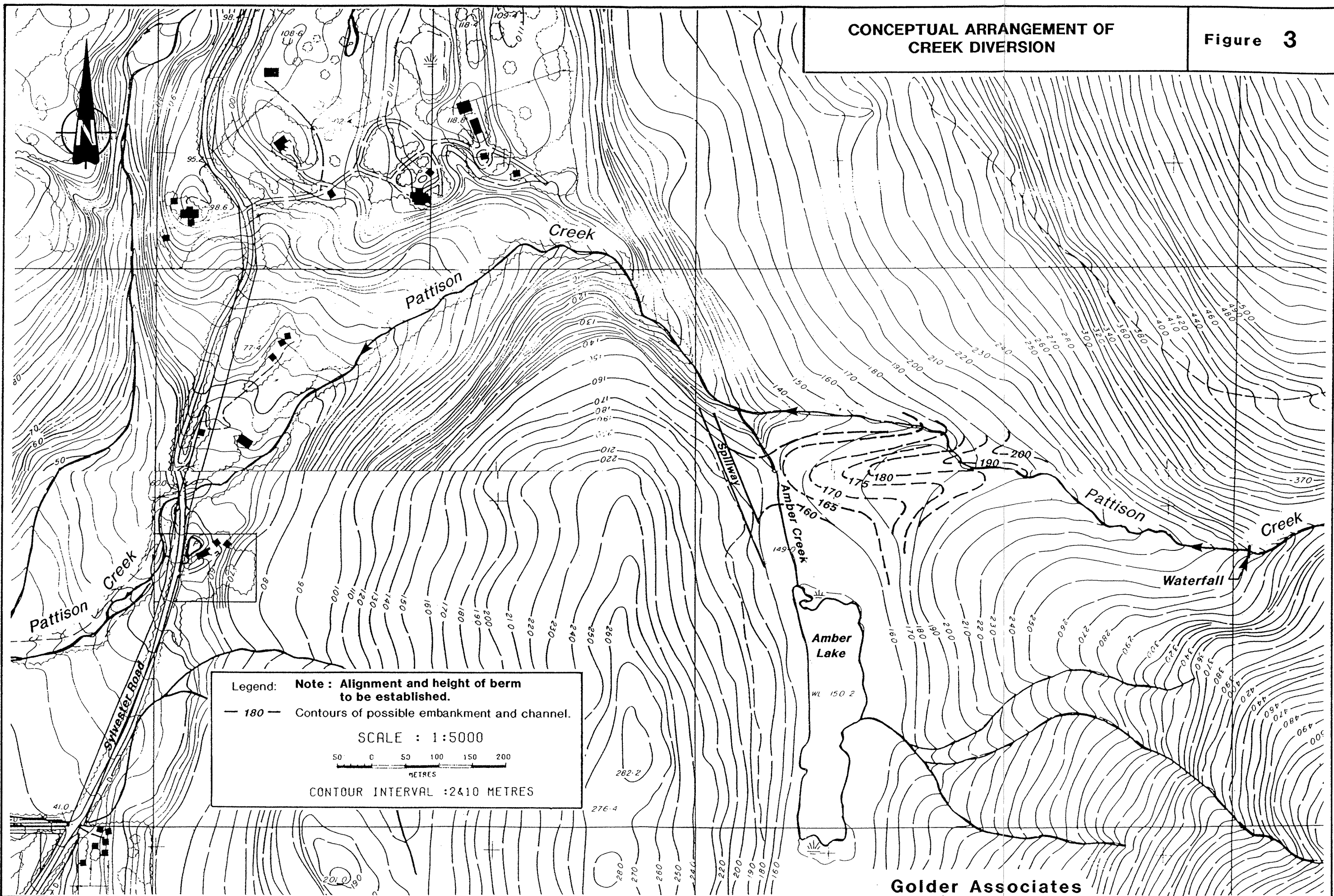


PROJECT NO. 912.1453 DRAWN REVIEWED DATE Aug. 91

CONCEPTUAL ARRANGEMENT OF
CREEK DIVERSION

Figure 3

PROJECT NO. 917-1453 DRAWN REVIEWED DATE Nov '91



Golder Associates



Plate 1 – Waterfall at apex of fan



**Plate 2 – Relationship of Pattison Creek
and Amber Lake**



Note: Existing channel at left.

Plate 3 – Extension of fan towards Amber Lake

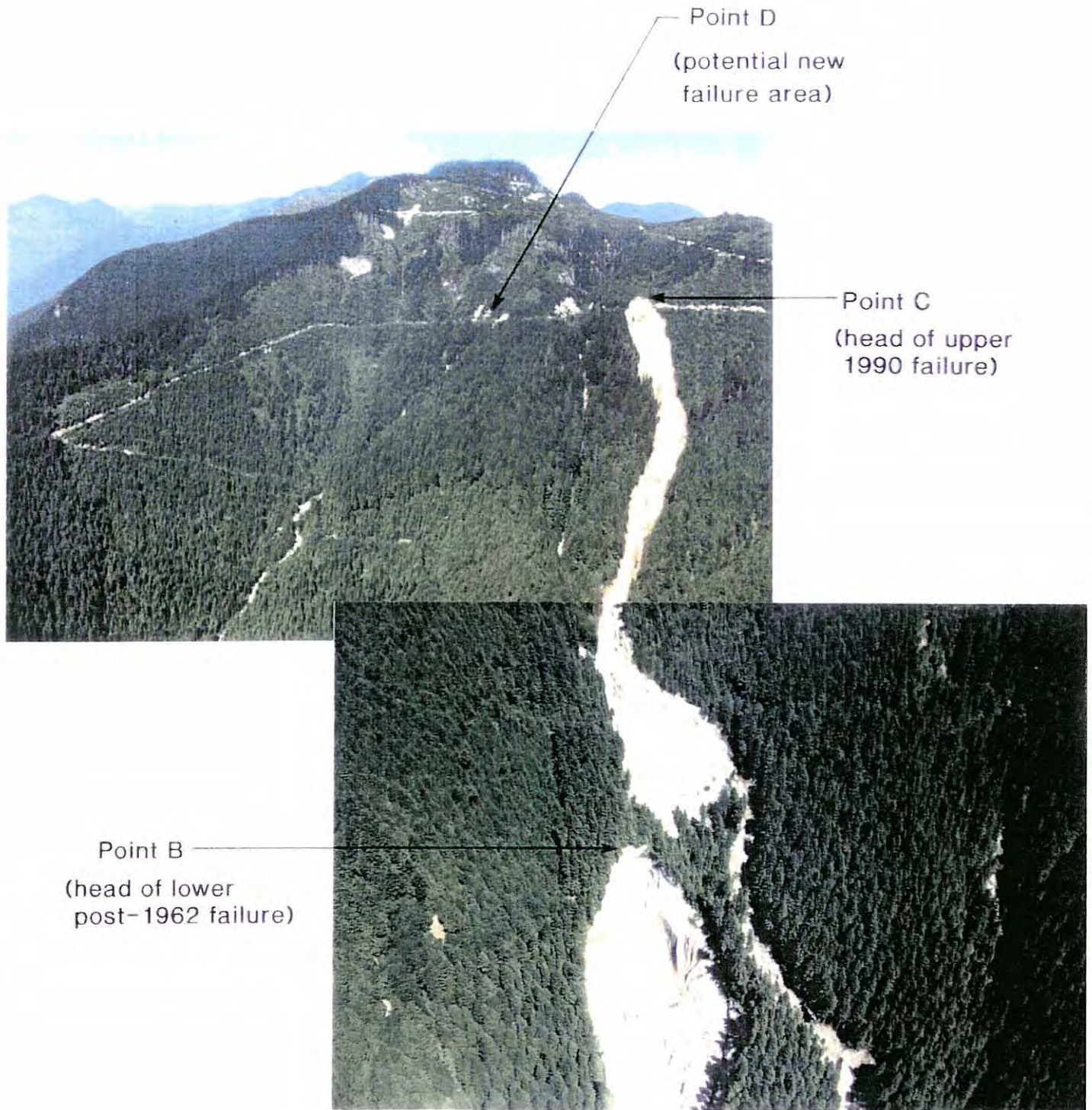
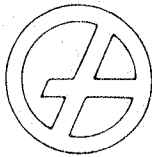


Plate 4 – Debris failures on North side of catchment



Golder Associates Ltd.
CONSULTING ENGINEERS

REPORT ON

**GEOTECHNICAL INVESTIGATION
HATZIC PRAIRIE DRAINAGE STUDY
HATZIC SLOUGH DAM PUMP STATION
HATZIC, B.C.**

Submitted to:

Associated Engineering (B.C.) Ltd.
4940 Canada Way
Burnaby, B.C.
V5G 4M5

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November, 1991

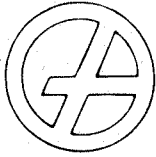
912-1966

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Golder Associates Ltd.
CONSULTING ENGINEERS

November 12, 1991

912-1966

Associated Engineering (B.C.) Ltd.
4940 Canada Way
Burnaby, British Columbia
V5G 4M5

ATTENTION: Mr. Kerry Rudd, P.Eng.

**RE: GEOTECHNICAL INVESTIGATION AND ASSESSMENT
HATZIC PRAIRIE DRAINAGE STUDY
PROPOSED HATZIC SLOUGH PUMP STATION
AND FLOODBOX INSTALLATION
HATZIC, B.C.**

Dear Sir:

Golder Associates has carried out a geotechnical investigation at the site of the proposed pump station and floodbox structures to be constructed at the Hatzic Slough dam near Hatzic Lake, B.C. The purpose of this investigation was to provide supplementary information on the soil and groundwater conditions at the proposed pump station and floodbox site.

The following report presents a summary of the factual results of our drilling investigation and provides our comments, recommendations and design parameters for the geotechnical aspects of the pump station and floodbox design and construction.

This study was carried out within the Hatzic Prairie Drainage Study, specifically Task No. 10 as identified in the Terms of Reference for this study, undertaken on behalf of the Dewdney-Alouette Regional District.

The scope of this report is limited to the determination of the foundation engineering properties of the site and does not include the investigation, chemical testing or assessment of potential soil or groundwater contamination of the site.

1.0 EXISTING SITE CONDITIONS

The Hatzic Slough dam and pump station site is located approximately 800 m upstream and to the east of the confluence of the Hatzic Slough channel and the Fraser River near Hatzic, B.C, as shown in Figures 1 and 2 within Appendix I following the text of this report. The "dam" structure actually forms a segment of the Fraser River flood control dykes on the north side of the river floodplain within the Dewdney Area Improvement District.

The Hatzic Slough dam measures approximately 150 m in length and provides a closure structure across the Hatzic Slough channel, which is the main outlet channel for Hatzic Lake. The slough channel is oriented in an east-west direction at the dam location, with the dam structure oriented perpendicular to the channel in the north-south direction.

A dual-unit pump station and a four-bay gravity floodbox structure are located adjacent to the southern bank of the slough channel. Water is supplied to the pump station and floodbox forebay area by means of an inlet channel incised into the southern bank of the slough channel. A concrete outfall structure is situated on the downstream (western) toe of the dam, where the accumulated discharge from the pump station and the floodboxes is discharged to the slough channel via a short outlet channel.

The land adjacent to the Hatzic Slough channel is currently used for farming and animal grazing and generally consists of cultivated fields and open pastures with isolated stands of mature trees.

The Hatzic Slough dam is located within the floodplain of the Fraser River and is underlain by river floodplain sediments. The surficial geology in the dam area can generally be characterized as comprising a surficial layer of silty sand to sandy silt with trace amounts of clay and organic material. The surficial silt stratum is variable in

thickness and composition and is underlain by, and grades into, a relatively clean sand stratum which extends to depths of up to 20 m and greater below the ground surface.

It is understood that a recent upgrading and rehabilitation program was carried out on the Dewdney area dykes in 1987 to improve the stability and integrity of the dykes and pump station facilities. Details of the rehabilitation program are described in detail in the report prepared by Klohn Leonoff Ltd. dated December 12, 1983 and titled "Fraser River Flood Control Program, Dewdney Area Improvement District Dyke Rehabilitation Program, Stage I" prepared for the B.C. Ministry of Environment, Water Management Branch. The rehabilitation program is understood to have included the installation of toe drains and seepage weighting berms on the land side of the dykes. In addition, work carried out at the Hatzic Slough dam included repairs to the concrete components of the pump station and floodbox, installation of a land side toe drain adjacent to the floodbox and installation of seven water pressure relief wells on the land side toe of the dam.

2.0 PROPOSED SITE DEVELOPMENT

It is understood that it is proposed to increase the discharge capacity of the flood control facilities on Hatzic Slough by constructing a new pump station and floodbox to supplement the existing facilities at the Hatzic Slough dam site.

We understand that the pump station and floodbox design details have yet to be finalized. However, it is understood that a multi-bay concrete floodbox structure equipped with flapgates is proposed, having an invert level at approximately elevation -0.5 m relative to Geodetic datum. The proposed pump station is understood to have a design invert level at approximately elevation -1.0 m and pump station output is planned to be discharged through an enclosed bay constructed integral with the concrete floodbox structure.

We understand that two possible locations have been considered for the pump station/floodbox facilities, including alignments located on the northern and southern banks of the slough channel, as shown schematically in Figure 2. However, based on hydrological concerns, geotechnical criteria and logistical considerations, it is understood

that the southern location is currently considered to be more favorable, as discussed in more detail in Section 5.2 below.

3.0 FIELD INVESTIGATION

3.1 Previous Investigations

The Klohn Leonoff report described above contains a summary of the available geotechnical information at the Hatzic Slough dam, including test hole logs from previous geotechnical investigations carried out at the site. These investigations include: boreholes and test pits put down at the site by Klohn Leonoff Ltd. in 1983 as part of the rehabilitation program; boreholes put down by the Department of Highways for the Water Resources Branch in 1963; and boreholes put down by the Prairie Farm Rehabilitation Association (P.F.R.A.) during the original dyking investigation in 1948. Although not reproduced within this report, this information has been used to supplement the soil and groundwater information obtained within the present study.

3.2 Drilling Investigation

The current field investigation consisted of putting down a total of eight rotary boreholes, designated as BH1 through BH8, using a track-mounted auger drill rig on September 9 and 10, 1991. The boreholes were put down to depths which varied from 0.5 to 15.2 m below the ground surface at the approximate locations shown in Figure 2. Boreholes BH1 through BH3 were put down along the proposed southern alignment, and boreholes BH4 through BH8 were put down on the proposed northern alignment.

Dynamic Penetration Tests (DPT's) were carried out adjacent to boreholes BH1 through BH7 to obtain a profile of penetration resistance with depth from which the density or consistency of the subsurface soils can be inferred. The DPT's were put down to depths which varied between 10.4 to 16.8 m below the ground surface, and penetration resistance profiles are reported on the borehole logs.

The customized SDS Drilling dynamic penetration probe was employed in carrying out the DPT's. This probe has a non-standard 60 mm diameter tip and is equipped with a 150 mm sleeve behind the probe tip to reduce drilling rod friction.

All of the field work was carried out under the full-time supervision of a member of our engineering staff who located the test holes approximately in the field and logged in detail the soil and groundwater conditions encountered. During the drilling of the test holes, representative soil samples were taken from the flights of the solid stem augers for detailed examination and subsequent identification testing in our soils laboratory. Relatively undisturbed piston tube samples were also obtained at boreholes BH1 and BH2. On completion of the logging and soil sample collection, the test holes were backfilled to ground surface with a mixture of the native soil and bentonite pellets installed as seals within the impervious subsurface soils.

Following completion of the drilling investigation, our site inspector conducted a brief visual and photographic reconnaissance of the dykes and existing facilities in the vicinity of the proposed pump station site.

Borehole locations and ground surface elevations were determined for boreholes BH1 through BH7 by survey carried out by Associated Engineering (BC) survey crews on September 24, 1991, as shown in AE(BC) drawing VP97-24-001 dated October 1991.

4.0 SUBSURFACE CONDITIONS

Detailed descriptions of the soils encountered in the boreholes are presented in the Record of Boreholes in Appendix II. Inferred soil profiles are shown in cross-sections plotted along the proposed southern and northern alignments shown in Figures 3 and 4, respectively.

The following is a summary of the inferred subsurface conditions encountered at the site based on the results of the current drilling investigation, previous geotechnical studies and published geological information.

It should be noted that considerable variation in the soil and groundwater conditions was observed between the test holes put down during the previous and current investigations. Similar, and possibly greater, variations in subsurface conditions may be encountered across the site.

4.1 Fill

A surficial layer of granular fill material was encountered at boreholes BH1, BH3, BH4 and BH8. The fill material was variable in composition but generally consisted of gravelly sand, sand and gravel and sand with trace amounts of silt and cobbles. The thickness of this stratum was observed to vary from 0.9 to 3.4 m at the boreholes put down during this investigation. Thicker or deeper sequences of granular fill were encountered during the previous investigations carried out at the site.

It is inferred that the dyke cross-section was originally constructed of a layered sequence of sand and gravelly sand fill materials. Additional layers of similar granular materials were subsequently placed on the dam crest and sloping sides during rehabilitation and improvement programs.

Borehole BH8 was put down at the crest of the dyke in the vicinity of the proposed northern alignment. Coarse cobbly and bouldery granular fill was encountered to a depth of approximately 0.5 m below dyke crest, the maximum depth of penetration where effective refusal was encountered. Several attempts were made to put the borehole down to greater depth by relocating the borehole within a 3 m radius on the dyke crest. Similar coarse granular material, and effective refusal to penetration, was met. This material was not encountered in any of the other test holes put down during the current investigation, however, cobbly and bouldery layers were encountered in test pits put down at the site during the previous investigations and may be present within the dyke fill materials at other locations.

Based on the DPT penetration resistance profiles, the granular dyke fill materials are inferred to be in a loose to compact state of relative density.

4.2 Topsoil and Organics

A layer of topsoil was encountered at the ground surface at boreholes BH2, BH5, BH6 and BH7. This layer was measured to vary in thickness from approximately 0.3 to 0.6 m at the borehole locations and generally comprises silty sand to sandy silt with roots and decomposing organic material.

Based on the observed ease of penetration of the drill string and the DPT penetration resistances, this material is inferred to be very loose or soft.

A thin layer of grey and brown silt with decomposed fibrous and amorphous organic material was encountered in borehole BH2 at a depth of 8.1 m below the existing ground surface. This material is inferred to be compressed native topsoil or peat. The moisture content of this material was measured in our soils laboratory to be 53 per cent, indicating that it is not highly organic. Although this layer was not encountered at the other test hole sites, it is anticipated that isolated layers or lenses of organic material exist within the natural foundation soils on other portion of the site.

4.3 Silt and Sandy Silt

A thick sequence of layered silt and sandy silt was encountered beneath the surficial fill and topsoil layers in all of the test holes put down at the site. This sequence was found to be highly variable in thickness and composition, both with depth and across the site, and was observed to vary from silt with traces of fine sand, clay and organics to interlayered silty fine sand and fine sand.

Although considerable variability was noted in the layering and composition of the various layers that comprise this sequence, a general trend of decreasing plasticity and increasing sand content was observed with increased depth below the original ground surface. In several boreholes, the interlayered silt and sand sequence grades into the underlying sand sequence, described below.

The thickness of the silt stratum is inferred to be somewhat greater, and consequently extends to a lower elevation, on the south side of the slough channel compared to the

north side. The thickness of this sequence was measured to vary from approximately 6 to 10 m below the natural grade on the southern alignment, compared to an average thickness of approximately 4 to 6 m on the northern alignment. The silt stratum also appears to be more frequently and extensively interlayered with clean sand layers on the northern alignment compared to the southern alignment.

Moisture contents within this sequence were measured to vary between 25 to 44 per cent, with most values in the range between approximately 33 to 37 per cent. Higher moisture contents were generally found to be associated with the layers containing higher quantities of clay and organics, while the lower range of moisture content values generally correspond to non-plastic silt and silty sand layers.

The grain size distribution of a sample obtained from a silt layer within this stratum is shown in Figure 5. It should be noted, however, that significant variation in grain size distribution was encountered within individual boreholes and between adjacent boreholes.

Based on the observed resistance to drill string penetration and DPT profiles, the consistency/density of these materials was generally inferred to vary from very loose or soft to compact.

4.4 Sand

The surficial silt and sandy silt stratum overlies, and generally grades into, an extensive stratum of relatively clean sand which is inferred to extend to a significant depth below the existing river and floodplain level. All of the boreholes put down at the site during the present investigation were terminated within this stratum at maximum depths of up to some 15 m below the natural grade. Previous investigations at the site indicate that this stratum extends to depths of up to 20 m, and likely greater, below the ground surface.

The grain size distribution of a sample of the sand stratum is shown in Figure 5.

The sand stratum was encountered at depths which varied from approximately 7 to 11 m below natural grade along the proposed southern alignment and 3 to 6 m below natural grade along the northern alignment, respectively.

Based on the DPT penetration resistance profiles obtained at the boreholes, these materials are generally inferred to be loose to compact.

4.5 Groundwater Conditions

Water was observed in borehole BH1 at a depth of 2.4 m below the existing ground surface during drilling. Although water was not observed in any of the remaining boreholes put down at the site, many of the samples recovered from the augers were observed to be very moist or wet. It is anticipated that the groundwater levels at the site will vary directly with the relative water levels maintained in the adjacent Fraser River and Hatzic Slough.

"Perched" water levels are anticipated to be present within and above the relatively impervious silt layers within the stratigraphy. During and following periods of sustained precipitation, the groundwater level is expected to be perched at or near the ground surface on the interior portions of the property where silty strata are present at the ground surface. Marshy or swampy terrain was observed in low-lying areas adjacent to the dykes at the time of the field investigation.

5.0 GEOTECHNICAL ENGINEERING COMMENTS AND RECOMMENDATIONS

5.1 General

The results of the current investigation and the previous field investigations indicate that the natural subsurface soil conditions generally consist of a surficial layered sequence comprising silt, sandy silt and silty sand with trace amounts of clay and organic matter, which is underlain by, and generally grades into, a significant thickness of relatively

clean sand. The thickness of the surficial silt stratum varies widely across the project area, ranging from a few meters to in excess of 8 m.

The thickness of the surficial silt stratum is somewhat greater, and extends to a lower elevation, on the south side of the slough channel compared to the north side. The surficial silt stratum also appears to be more frequently and extensively interlayered with clean sand layers on the northern pump station/floodbox alignment compared to the southern alignment, although considerable heterogeneity and interlayering appears to be present throughout this stratum.

Based on the results of the current and previous investigations, the dyke fill materials at the site appear to comprise a layered sequence of relatively permeable sand and sand and gravel deposits with variable quantities of silt, cobble and boulder-sized particles. No evidence of dyke zoning or the presence of an impermeable dyke core has been identified within the dyke in the vicinity of Hatzic Slough, although it is understood from the Klohn Leonoff report that the portion of the dykes located to the east of Hatzic Slough are constructed primarily of silt.

Previous reports of high seepage flows through the dykes, particularly adjacent to the existing floodbox and pump station, support the conclusion that the existing dyke fill materials are relatively permeable.

The previous dyke rehabilitation and upgrading program dealt with high seepage gradients through and beneath the dykes by installing water pressure relief wells and seepage weighting berms and filter layers on the downstream (eastern) toe of the dykes to control groundwater discharge and reduce the potential for internal erosion and piping of the dyke fill materials and natural foundation soils.

Construction of the proposed pump station and outlet facilities will involve significant temporary excavations below the existing ground surface. These excavations will be carried out both within the dyke fill materials and to significant depth into the natural foundation soils. In addition, permanent excavations will be required within the banks of the slough channel for construction of the inlet and outlet channels to the new facilities.

These excavations will modify the drainage path beneath and through the dykes and may influence the existing structures.

The following issues are anticipated to have geotechnical implications during the design and construction of the proposed pump station and outlet works:

- siting of the proposed facilities, and assessment of the impact of the construction of the proposed structures on the existing pump station and floodbox;
- excavation, temporary shoring and dewatering during construction of the pump station and floodbox structures;
- excavation and subsequent backfilling and reconstruction of the dyke cross-section;
- foundation preparation for the pump station and floodbox structures;
- excavation and long-term operation of the new approach and outlet channels, including the installation of rip rap erosion protection and the requirements for graded filter layers to prevent piping; and
- mitigation of the effects of potentially high groundwater flow gradients which are anticipated during extreme flooding events on the Fraser River.

These issues are addressed separately below.

5.2 Siting of Proposed Structures

It is understood that the geometry and configuration of the existing pump station and floodbox facilities precludes, or considerably complicates, the possibility of increasing the capacity of the flood control facilities through construction of adjoining structures. Previous evidence of piping and erosion immediately adjacent to these facilities prior to the rehabilitation program carried out in 1987 also makes construction in close proximity to these structures unattractive.

The two alternative alignments, shown approximately in Figure 2, have been evaluated on the basis of geotechnical criteria. In general terms, the greater the depth to which the

relatively impermeable silt stratum extends below the ground surface and the less permeable it is, the more favorable the conditions are for development of the pump station and floodbox facilities from a geotechnical perspective. This is attributable to the reduced potential for groundwater seepage, piping, base heave, base softening and slope instability at the pump station, approach channel and forebay areas caused by high differential water pressures which can exist across the dyke (and thus across the relatively impermeable silt stratum) during freshet flood conditions in the Fraser River.

In addition, the control of groundwater flow, foundation preparation and backfilling operations may also be less difficult during construction of the pump station facilities if a significant thickness of relatively impervious silt exists below the level of the required excavations.

As discussed above, the natural silt sequence appears to be present in greater thickness, and extends to greater depth below the required level of temporary and permanent excavations, along the proposed southern alignment and is therefore considered to be a more suitable site for the proposed structures than the northern alignment.

It is recommended that the proposed structures be set back from the existing facilities a minimum distance of at least twice the depth of the required excavations at the pump station site, or approximately 15 m, to minimize the impact of construction and long-term operation of these facilities on the existing structures.

5.3 Excavation and Temporary Shoring

5.3.1 Pump Station

The proposed pump station floor slab level is understood to be approximately elevation - 1.0 m, which is approximately 6 m below the level of the existing ground surface adjacent to the pump station site. It is therefore anticipated that the pump station will be founded within the layered silt and silty sand stratum. Excavation to the proposed foundation level, including over-excavation to permit placement of the subslab structural fill layer described below, will result in a total excavation depth of up to 7 m below the surrounding ground surface.

The timing of construction of the pump station will be critical due to the influence of the ground and surface water levels on excavation shoring and dewatering procedures. Installation of a braced sheet pile cutoff wall or cofferdam system, likely in combination with well points or pressure relief wells, may be required to:

- provide temporary excavation support;
- control construction seepage flows, particularly if construction is carried out during periods of extended wet weather and/or during high water levels in the adjacent channels;
- prevent excavation base heave or disturbance of the foundation soils under high seepage gradients; and
- to permit preparation of the foundation soils and the placement and compaction of structural fill and granular backfill materials.

If a braced sheet pile system is employed, it is recommended that sufficient allowance be made within the sheet pile walls to permit construction of the station and backfilling around the perimeter walls using free-draining, select granular fill materials as described below.

The use of well points or relief wells installed within the relatively permeable sand stratum underlying the site is expected to be required to control groundwater flow volumes and/or excessive groundwater flow gradients during construction. The design of this system will depend on the relative water levels in the slough channel on either side of the dam/dyke and the excavation shoring methods employed.

It should be noted that, although the subgrade soils are generally characterized as having low plasticity, these materials contain minor amounts of clay-sized particles and organic material and may undergo immediate compression and continuing long-term consolidation settlements when subject to increased effective loading resulting from the placement of surficial fill materials, structural loads or lowering of the groundwater table. Suitable precautions should be taken by the contractors during construction to ensure that disturbance and/or settlement of the existing pump station and floodbox is minimized.

5.3.2 Floodbox and Pump Station Outlet Works

It is anticipated that construction of the concrete floodbox and integral pump station discharge outlet will require excavations to depths of up to approximately 10 m below the dyke crest level and 5 m below the surrounding natural grade. It is anticipated that the floodbox structure will be founded within the layered silt and silty sand stratum.

Temporary excavation procedures required for construction of the floodbox will be strongly influenced by the water levels in the adjacent slough and river channels. Installation of a suitable well point or water pressure relief well system will likely be required to control seepage gradients and safeguard against excavation instability, piping, base heave or softening of the silty subgrade soils.

Excavation through the dyke cross-section above the ground and surface water levels may be carried out in open cut. Temporary excavations should be developed at side slopes of 1.25 horizontal to 1 vertical (1.25H:1V), or flatter. Excavations carried down below the groundwater level will likely require the use of suitably braced or tied-back sheet pile shoring.

Alternative excavation and shoring systems could include the following:

- the use of temporary cofferdams constructed using fine-grained fill materials or partial sheet pile cutoff walls tied into the existing dyke, combined with dewatering wells or well points; or
- staged excavation procedures to maintain the integrity of the existing dyke over a portion of its cross-section while a portion of the dyke is subexcavated and replaced and floodbox facilities are constructed in segments.

5.4 Foundation Preparation

The natural silty foundation soils are generally soft or loose, of low-plasticity and are highly susceptible to disturbance when exposed and subject to construction traffic, ponded water or excessive groundwater flow gradients. These materials are also weak

and will provide minimal passive soil resistance to resist lateral loads imposed on below-grade structures, particularly when subject to upward flow gradients resulting from differential water levels across the dykes.

Although the subgrade soils are generally characterized as having low plasticity, these materials contain minor amounts of clay-sized particles and organic material and may undergo limited immediate compression and continuing long-term consolidation settlements when subject to increased effective loading resulting from the placement of surficial fill materials, structural loads or permanent lowering of the groundwater table. The magnitude of the post-construction settlement of grade-supported facilities will depend largely on the construction schedule and the care with which excavation and foundation preparation is carried out.

The allowable bearing capacity of the silty subgrade soils in their undisturbed state is relatively low and will not be suitable for the subgrade support of even lightly-loaded structures due to the potential for punching failure of these foundations and the likelihood of significant post-construction settlements, particularly if these materials are disturbed during construction.

Although no details regarding foundation loads or the dimensions of the proposed structures were available at the time of preparation of this report, it is anticipated that the weight of the pump station and floodbox facilities will be less than or equal to the weight of the existing soils, possibly resulting in a slight "net unloading" of the subgrade soils when compared to the existing in situ stress conditions.

It is recommended that all grade-supported facilities, such as the pump station and floodbox structure, be founded on a minimum 600 mm thick layer of structural fill, placed and compacted on the prepared subgrade surface following subexcavation and removal of all loosened, softened or disturbed materials or soils with a high organic content.

Placement and compaction of structural fills should be carried out as described in Section 5.5 below.

A representative sample of the proposed fill material(s) should be obtained and tested for moisture content, gradation and moisture-density (Proctor compaction) characteristics prior to use on site.

Foundation preparation should be carried out over the entire plan area of the proposed structures and, where possible, should extend beyond the perimeter of these structures a distance at least equal to the depth from the underside of the foundations to the natural foundation soils.

Following excavation to grade, it is recommended that a layer of woven filter fabric, such as Mirafi P-250 or equivalent, be placed on the prepared subgrade surface prior to placement of the granular fill.

In order to provide a seepage cutoff through the granular bedding zone, it is recommended that slots or small trenches be cut completely through the completed granular bedding layer to expose the underlying filter fabric. These slots should be aligned with the longitudinal axis of the dyke and spaced at about 5 m horizontal intervals along the length of the floodbox or to correspond to the locations of seepage collars, if installed. The slots should be backfilled with an impervious fill material such as silty glacial till or a bentonite/non-shrink concrete mixture.

5.5 Backfill Materials and Procedures

5.5.1 General

It is recommended that fill placement and compaction operations should be carried out according to the following criteria:

- fill materials should be placed in horizontal lifts not exceeding 0.3 m in loose thickness, and compacted to a minimum of 90 per cent of modified Proctor maximum dry density;
- care should be taken during placement and compaction to ensure that no segregation of materials occurs, particularly at the edges of the areas being

compacted, and that all clumps or intact pieces should be broken up to ensure that uniform compaction is achieved;

- all oversized materials, and deleterious substances such as wood or organics, should be removed, by hand if necessary, during fill placement;
- the initial lift of fill placed in contact with the subgrade soils should be placed using static compaction only, with special care taken to avoid disturbance of the subgrade, followed by placement and compaction of subsequent lifts using vibratory compaction equipment; and
- fill placement and compaction adjacent to or within 0.6 m of existing structures, walls, services and utilities should be carried out using light, hand operated equipment, such as jumping jacks, to ensure adequate compaction is achieved without overstressing the adjacent facilities.

All structural fills or backfill behind below-grade walls or other ancillary facilities not requiring an impervious cutoff should consist of clean, well-graded, 75 mm minus sand and gravel having less than 5 per cent passing the 0.075 mm (U.S.S. No. 200) sieve.

Suitably graded filter cloth, such as Mirafi P-250 or equivalent, should be employed at the boundaries between all granular fill and/or native soil materials of sharply contrasting grain size distributions to prevent migration of fines. Alternatively, the use of graded granular filters, designed to permit sufficient groundwater flow while preventing migration of soil particles, is recommended to form a transition zone between contrasting materials.

5.5.2 Pump Station Backfill

It is recommended that a zone of free-draining granular backfill, such as clean well-graded sand and gravel, be placed and compacted adjacent to the walls of the pump station, particularly at the rear (west side) of the station where backfill loads and water pressures are expected to be a maximum. The backfill zone at the rear of the pump station can be triangular in cross-section, varying from a minimum of approximately 0.6 m width at base slab level, to a minimum width at least equal to 1/2 the embedded wall height at ground surface level.

5.5.3 Dyke Backfill

Although the existing dyke does not appear to be constructed with an impervious central core zone at the pump station and floodbox location, it is recommended that the dyke backfill zone be constructed using relatively impervious fill to provide improved performance and to ensure that no adverse seepage occurs through the backfill zone, between the backfill and the floodbox structure or between the new fills and the natural subgrade soils or existing dyke fill materials. Backfilling of the temporary excavation through the dyke will require strict attention to backfill material placement and compaction procedures, to avoid the possibility of creating a preferential seepage or internal erosion and piping path through the dyke.

Backfilling through the dyke should be carried out using silty, relatively impervious granular fill, such as silty glacial till or other materials having low permeability characteristics similar to the silty subgrade soils. The silty materials excavated from the pump station and floodbox excavations may be suitable for backfilling provided that they have an appropriate water content for compaction and care is taken to separate and remove all organic zones, coarse granular materials or pervious sandy layers. These materials will likely be difficult to handle and compact if they become wet and should be protected against absorption of moisture from rainfall or surface water flows.

The surface of the excavation should be cleaned of any loose or softened material prior to initiating backfilling operations. The surface of the relatively impervious silty subgrade soils should be scarified and conditioned to the appropriate water content immediately prior to placement of the fill material to assist in forming a tight seal between the subgrade soils and the impervious backfill. The water content of the backfill during placement should be at or slightly below the optimum water content for compaction, as determined by laboratory compaction analyses, and should be conditioned by the addition of water in the field during placement, if necessary, to ensure proper compaction and to bring the in-place water content to 1 to 2 per cent above the optimum water content for compaction.

If seepage collars are used around the floodbox, careful attention should be given to ensuring adequate compaction of fills in the vicinity of the seepage collars.

It is recommended that consideration be given to incorporating a free-draining granular filter zone to be placed and compacted in the dyke backfill zone on the east side of the dyke. This zone should extend from the landside face of the dyke approximately one third of the length along the buried floodbox, and should be connected to the granular backfill zone at the rear of the pump station.

5.6 Filter Layers

In areas where rip rap or quarry tailings is to be applied as a surfacing layer on the banks and bed of the drainage channels, such as adjacent to the pump station intake floodbox structures, it is recommended that filter layers be provided at the interface between these materials and the natural subgrade soils or fill materials to prevent piping and migration of fine-grained soil particles:

Filter layers can consist of either suitably graded, free-draining granular fill materials or a continuous geotextile filter fabric lining.

The granular filter layer must be sufficiently permeable to permit the passage of water while having a broad range of particle sizes to restrict the movement or migration of fine-grained soil particles from either the natural subgrade soils or the filter layer itself when exposed to high groundwater flow gradients.

While both the granular fill and geotextile fabric filters can be designed to restrict the migration of fine-grained soil particles, use of a granular filter has the following advantages:

- the additional thickness of granular material, when applied to sloping ground, improves the stability of the soil slopes, particularly when exposed to fluctuating water levels and frost action;
- placement of clean granular fill can be carried out under wet conditions where dewatering is not practical or completely effective;
- channel maintenance operations can be carried out in the future without concern for ripping or interrupting the integrity of the filter layer;

- granular filters are generally less prone to blockage or clogging due to accumulations of impervious materials and biological growth; and
- granular filters are not susceptible to decomposition with time if constructed with appropriately graded materials free from organics.

Filter fabrics are often more attractive in areas where space limitations or restrictions are present or at the interface between rigid structures and backfill materials, such as retaining walls.

The following grain size criteria are generally applied to determine the appropriate gradation of filter materials for a given subgrade soil:

Criteria	Required Ratio
1)	$4 < \frac{D_{15} \text{ filter}}{D_{15} \text{ subgrade}} < 20$
2)	$\frac{D_{15} \text{ filter}}{D_{85} \text{ subgrade}} < 6$ (for uniformly graded subgrade soils)
3)	$\frac{D_{50} \text{ filter}}{D_{50} \text{ subgrade}} < 25$
4)	$D_5 > 0.075 \text{ mm}$ (ie. less than 5% fines)

where D_X represents the particle diameter where X per cent of the soil particles are smaller than this diameter when measured as a fraction by weight.

It is anticipated that free-draining, well-graded pit run sand and gravel will be an appropriate filter material for "quarry tailings" type channel lining where the maximum particle diameter is approximately 150 mm. Coarser "rip rap" type channel lining will likely require the use of a dual filter layer, comprising both well-graded pit run sand and gravel and quarry tailings applied either as two separate layers or as a thoroughly mixed

composite layer. Examination and laboratory grain size testing of representative samples of the proposed materials is recommended to confirm the suitability of these materials.

A minimum thickness of 600 mm of granular filter material is generally considered to be appropriate to ensure that adequate coverage is achieved during construction. The required thickness will also depend on the gradation of the natural subgrade soils and the rip rap or quarry tailings layers.

If a geotextile filter fabric is considered to be more desirable, a non-woven fabric such as Mirafi P-250 or equivalent should provide suitable filter protection and puncture resistance. Suitable precautions should be taken to avoid ripping or punching of coarse angular rock through the fabrics, and all fabric joints should be overlapped according to the manufacturer's recommendation to ensure uniform coverage and protection.

5.7 Lateral Soil Pressures on Below-Grade Facilities

Backfill placed immediately adjacent to walls or underground services or utilities where an impervious cutoff is not required should consist of clean, granular fill and should be carried out using light compaction equipment to minimize the risk of excessive loading or damage. No on-site materials are expected to be suitable for use as backfill where drainage or limited post-construction settlement is required.

A coefficient of lateral earth pressure at rest of 0.45 should be used in the design of below-grade walls unless the wall is free to rotate at least 12 mm for each 3 m of height. If rotation is permitted, a lesser coefficient of active earth pressure of 0.3 may be used. In either case, it is recommended that the unit weight of the backfill should be considered to be a minimum of 20 kN per cu.m and all surcharge loads should be included. It is recommended that the resulting triangular earth pressure distribution be re-distributed in equivalent rectangular form over the entire embedded wall height. Hydrostatic and/or possible differential water pressures should be considered unless positive control of water pressures is provided on both sides of the walls.

5.8 Immediate and Long-Term Settlement

The natural subgrade soils and dyke fill materials are considered to be somewhat compressible under increased effective loading resulting from the placement of granular fill materials, increased structural loads or permanent lowering of the groundwater level. Settlement of grade-supported facilities will occur due to the immediate compression and continuing long-term consolidation of the fill materials and/or foundation soils.

To minimize the effects of post-construction settlement on the pump station and associated facilities, the following procedures are recommended:

- minimize the thickness and lateral extent of surface fill zones, particularly adjacent to grade-supported facilities;
- remove all organic materials from beneath structural fill areas and foundations;
- minimize the disturbance of the subgrade soils due to construction equipment and activities;
- schedule the construction of permanent, settlement-sensitive facilities as long as possible after the placement of fill materials to allow compression and time-dependent consolidation of the foundation soils to take place;
- delay the interconnection of the various rigid pump station and floodbox components to permit each component to settle independently prior to connection;
- make use of "flexible", settlement-tolerant connections between the pump station and the floodbox/outlet structure; or
- a combination of the above procedures.

The magnitude of post-construction differential settlement of the various pump station components will depend on the weight of these components, construction sequencing and the care with which foundation and subgrade surfaces are prepared. If the above procedures are employed, the magnitude of the total and differential settlements can be significantly reduced or can be made to occur prior to pump station completion.

5.9 Inlet and Outlet Channels

It is anticipated that the inlet and outlet channels will be constructed having invert elevations at approximately -0.5 m relative to Geodetic datum, consistent with the preliminary estimates of the proposed floodbox invert level. This will result in permanent channel banks measuring approximately 4 to 6 m in height.

It is recommended that the inlet and outlet channels be constructed having side slopes not steeper than 3H:1V to safeguard against slope instability and reduce the potential for shallow sloughing of the channel banks due to fluctuating water levels and frost action. It is also recommended that surcharge loads, resulting from the placement of additional fill materials or structures, be set back a distance equal to at least one channel depth from the crest of the channel banks to avoid overstressing the channel slopes.

The use of steeper channel side slopes (as steep as 2H:1V) can be considered if the slopes are lined with a sufficient thickness of suitably graded, free-draining granular material. The gradation of this material should either satisfy the filter criteria provided in Section 5.6 above, or a layer of filter fabric should be provided at the interface between the granular fill and the natural subgrade soils to prevent migration of fines.

6.0 WATER PRESSURE RELIEF WELLS

The relatively clean, highly permeable sand stratum which underlies the site is inferred to be in direct hydraulic connection with the Fraser River and the Hatzic Slough channel. During periods when high differential water levels exist across the dam, the most severe case occurring during the passage of the spring freshet flood, high groundwater pressures would be expected within the sandy stratum which underlies the dyke. This would result in high hydraulic gradients within and across the silty stratum which overlies the sand stratum, with the highest gradients, and the corresponding highest risk of piping and erosion, expected to occur in areas where the silt stratum thickness is a minimum.

Construction of the pump station and floodbox structures, and the associated inlet and outlet channels, will result in a reduction of the thickness of the silt stratum and drainage path length and an increase in the risk of the piping and related problems. The thickness of the relatively impermeable silt stratum at the eastern end of the proposed floodbox and in the bed and banks of the inlet channel is judged to be insufficient to permit an acceptable factor of safety against piping of the fine-grained materials under the influence of the expected high hydraulic exit gradients.

To reduce the risk of piping and internal erosion at these locations, the following measures are recommended:

- a minimum thickness of 1 m of suitably graded granular filter material, or combined filter material and coarse granular channel lining, should be placed in the bed and banks of the inlet channel to provide additional protection against the migration of fine-grained soil particles under the high hydraulic gradients; and
- gravity-flow water pressure relief wells should be installed adjacent to the eastern end of the floodbox to control differential hydraulic head and exit gradients across the relatively impervious silt stratum.

The design and location of the relief wells should be determined during final design and layout of the pump station and floodbox structures. It is anticipated that two large diameter relief wells, located adjacent to the inlet channel a short distance east of the eastern end of the floodbox in a similar layout to the relief wells at the existing floodbox, will be sufficient to reduce the risk of piping to acceptable levels.

7.0 SEISMIC LOADING EFFECTS

The Hatzic Slough dam and pump station site is located within Seismic Zone 4 of the current (1985) National and British Columbia Building Code, which is one of the higher risk seismic categories.

As described in some detail in Klohn Leonoff Ltd's. earlier dyke rehabilitation investigation report, the extensive loose to compact sand sequence which underlies the site poses a significant liquefaction risk during a major seismic event.

Liquefaction of the foundation soils will likely result in widespread subsidence of the subsurface soils and deformation of the flood control dykes and other grade-supported facilities. These deformations will also likely induce damage in the pump station and floodbox facilities that will require repair.

We concur with the conclusions of the Klohn report, namely, that the probability of an earthquake occurring with sufficient magnitude to induce foundation liquefaction at the same time that the Fraser River is in flood stage is likely less than the probability of flooding due to overtopping of the dykes by a flood of greater magnitude than the 200 year design flood. Thus, the risk of widespread flooding caused by liquefaction failure of the dykes is considered to be less than the risk level associated with the design flood.

8.0 CONSTRUCTION INSPECTION AND DESIGN REVIEW

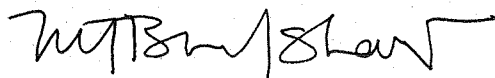
The performance of the completed pump station and floodbox will depend to a large extent on the care with which the construction is performed. It is strongly recommended that detailed construction inspection be carried out by experienced geotechnical personnel during temporary excavation, foundation preparation, backfill placement and compaction and relief well installation to ensure good quality control of the construction operations.

We also recommend that a geotechnical review be carried out of the pump station and floodbox construction drawings and specifications to verify the assumptions made regarding pump station configuration and geometry.

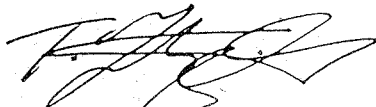
We trust that the above report satisfies the study objectives. If you have any questions regarding this report, or wish to discuss its contents, please do not hesitate to contact the undersigned.

Yours very truly,

GOLDER ASSOCIATES LTD.



M.T. Bradshaw, P.Eng.



T.P. Fitzell, P. Eng.
Associate

MTB/TPF:gmt
912-1966

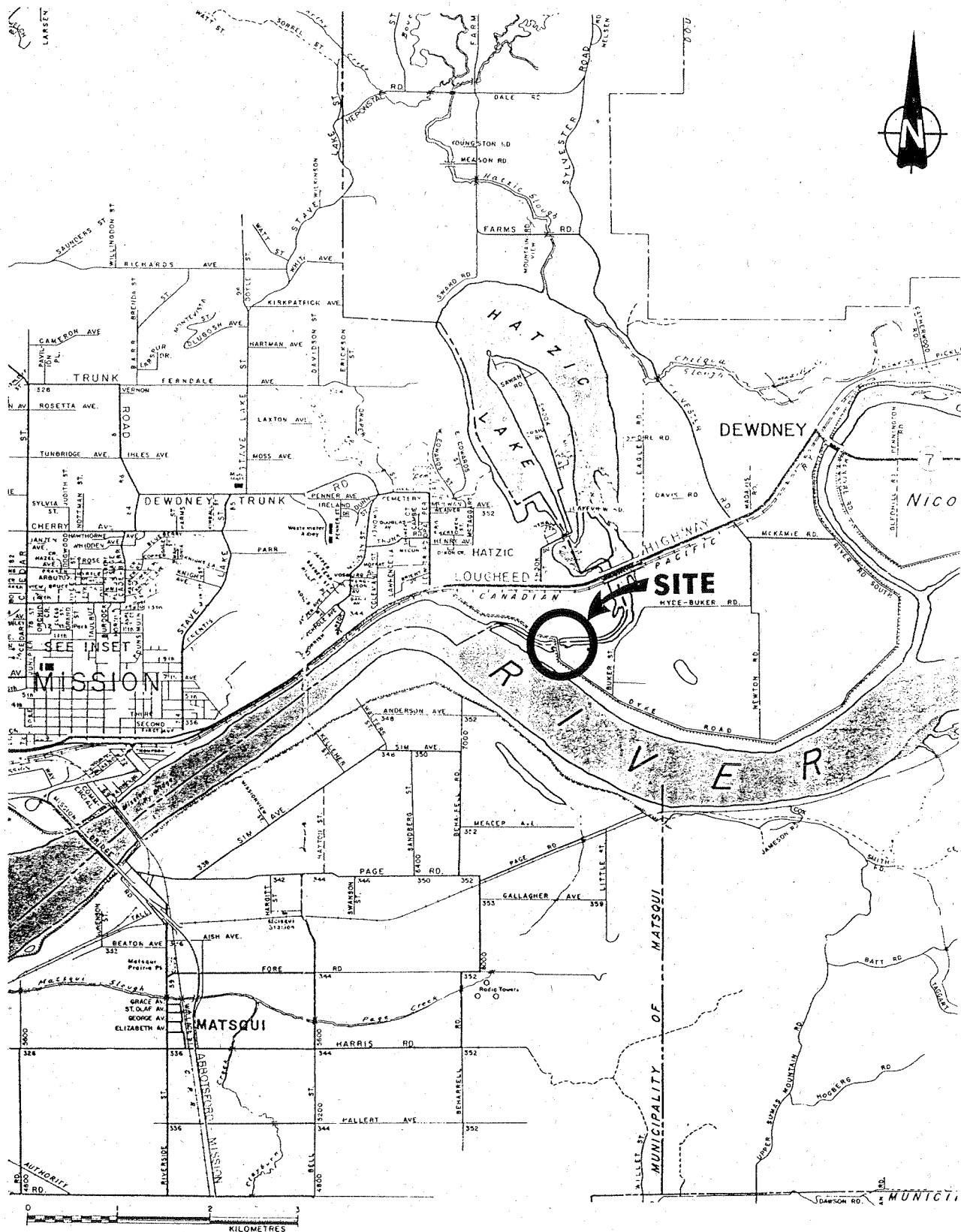
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APPENDIX I

FIGURES

KEY PLAN

Figure 1



PROJECT NO. 9121966 DRAWN dgp. DATE Oct 1991

SITE PLAN

Figure 2

Approximate Centerline of
Proposed Pumpstation and
Floodbox Structures

Legend

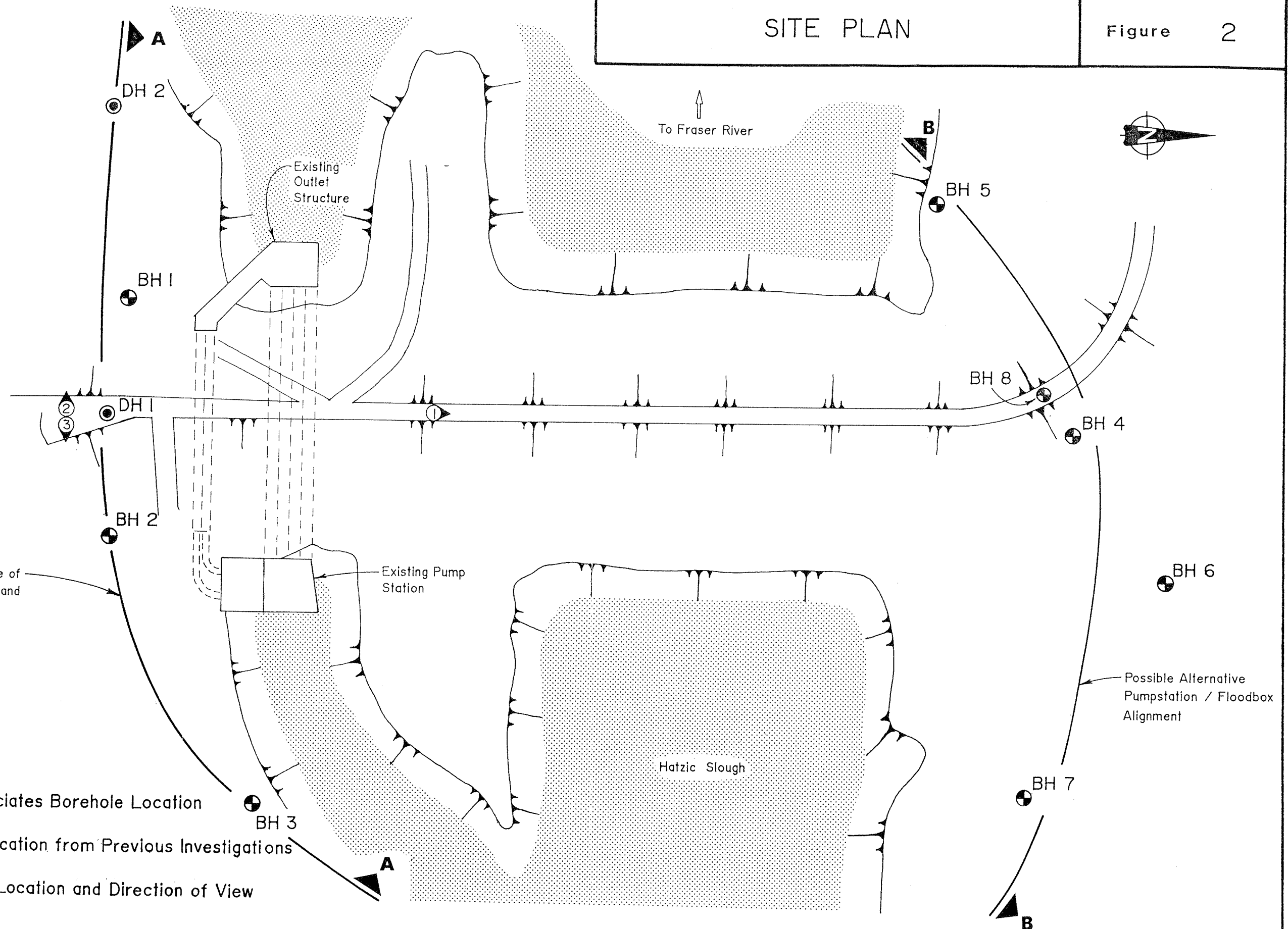
- BH 1 Golder Associates Borehole Location
- DH 2 Borehole Location from Previous Investigations
- ② Photograph Location and Direction of View

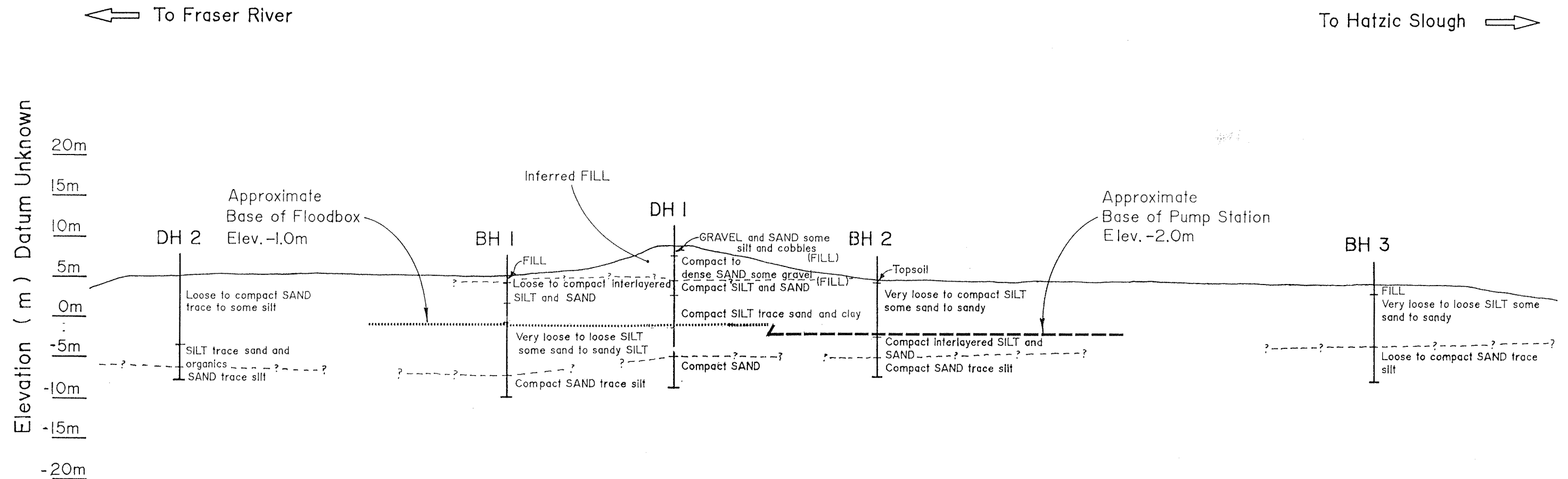
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Note; DH 1 and DH 2 drilled by Dept. of Highways for the
Water Resources Branch, M.O.E.

Golder Associates

Reference drawing ; Associated Engineering drawing
number VP97 24 001 dated Oct. 1991

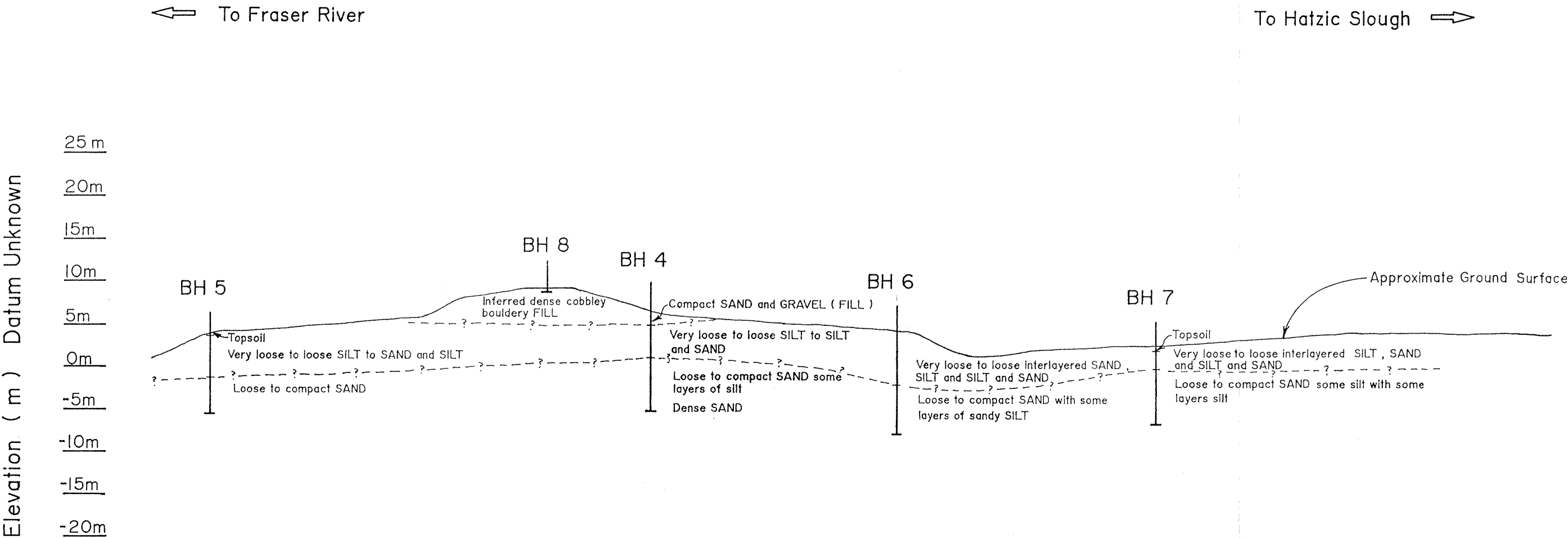




Note: DH 1 and 2 drilled in 1963 by Dept. of Highways for the Water Resources Branch

Reference Drawing ; Associated Engineering drawing number VP97 24 001 titled, Hatzic Slough Pump Station and Floodboxes

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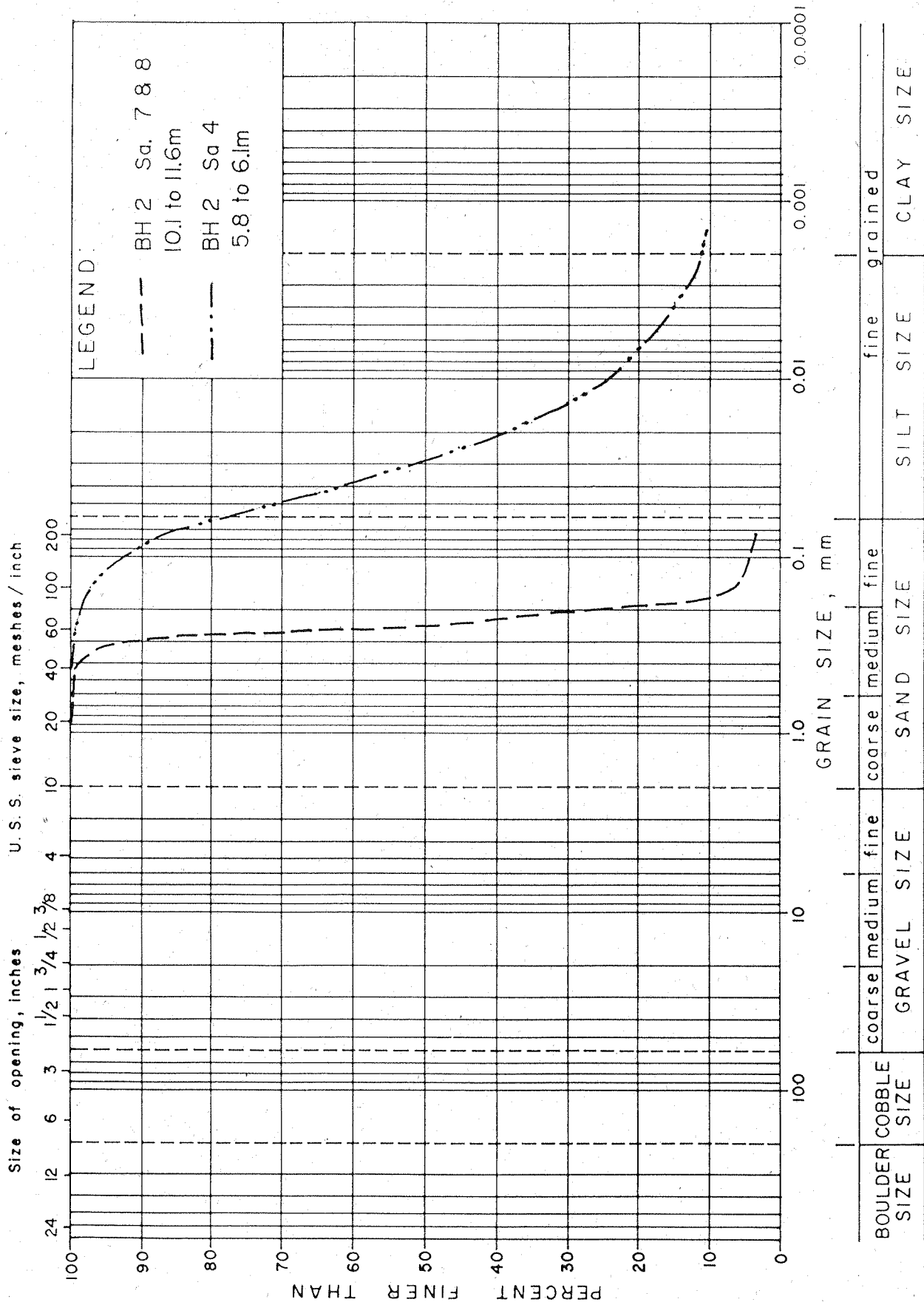
Reference Drawing ; Associated Engineering drawing numbr VP97 24 001
titled, Hatic Slough Pump Station and Floodboxes

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GRAIN SIZE DISTRIBUTION

Figure 5

M.I.T. GRAIN SIZE SCALE



APPENDIX II

RECORD OF BOREHOLE LOGS

Approximate borehole locations shown in Figure 2.

LIST OF ABBREVIATIONS

The abbreviation commonly employed on each "Record of Borehole," on the figures and in the text of the report, are as follows:

I. SAMPLE TYPES

AS auger sample
CS chunk sample
DO drive open
DS Denison type sample
FS foil sample
RC rock core
ST slotted tube
TO thin-walled, open
TP thin-walled, piston
WS wash sample

II. PENETRATION RESISTANCES

Dynamic Penetration Resistance:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 0.3 m (12 in.).

Standard Penetration Resistance, *N*:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 0.3 m (12 in.).

WH sampler advanced by static weight—weight, hammer

PH sampler advanced by pressure—pressure, hydraulic

PM sampler advanced by pressure—pressure, manual

III. SOIL DESCRIPTION

(a) <i>Cohesionless Soils</i>	
	<i>'N'</i> Blows/0.30m or Blows/ft.
Relative Density	
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) *Cohesive Soils*

Consistency	<i>'Cu'</i> kPa	psf.
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1000
Stiff	50 to 100	1000 to 2000
Very stiff	100 to 200	2000 to 4000
Hard	over 200	over 4000

IV. SOIL TESTS

C consolidation test
H hydrometer analysis
M sieve analysis
MH combined analysis, sieve and hydrometer¹
Q undrained triaxial²
R consolidated undrained triaxial²
S drained triaxial
U unconfined compression
V field vane test

NOTES:

¹Combined analyses when 5 to 95 per cent of the material passes the No. 200 sieve.

²Undrained triaxial tests in which pore pressures are measured are shown as $\bar{Q}$ or $\bar{R}$.

PROJECT: 912-1966

RECORD OF BOREHOLE BH 1

SHEET 1 OF 1

LOCATION: See Figure 2

BORING DATE: September 9/91

DATUM:

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	20	40	60	80	20	40	60	80		
0		GROUND SURFACE		5.20												
		Loose to compact, brown, gravelly SAND, some silt (FILL).		0.00												
				4.30												
		Loose, dark, grey SILT, some fine sand, trace organics.		0.90	1	AS										
2				3.40												
		Loose, brown, some orange mottling, fine to medium SAND, some silt.		1.80	2	AS										
				1.80												
4		Very loose, dark grey SILT, some fine sand, trace thin sand layers.		3.40	3	AS										
				0.60												
		Very loose to loose, dark grey, sandy SILT, trace clay.		4.60	10	TP										
					4	AS										
6				-1.50												
				6.70	5	AS										
		Loose, dark grey, fine sandy SILT, trace thin sand layers.														
				-3.90												
		Compact, grey, fine to medium SAND.		9.10												
				-4.40												
10		Loose, grey, sandy SILT, some thin layers fine to medium sand.		9.60												
				-5.20												
				10.40	7	AS										
		Loose to compact, grey SILT, some fine sand.														
				-7.00												
12				12.20	8	AS										
		Compact, grey, fine to medium SAND, trace silt.														
				14.90	9	AS										
14																
		END OF BOREHOLE.		15.20												
16																
18																
20																

15 5 PERCENT AXIAL STRAIN AT FAILURE

DEPTH SCALE

1 to 100

Golder Associates

LOGGED: DEN

CHECKED: MTB

SAMPLER HAMMER, 63.5kg; DROP, 760mm

BORING DATE: September 9/91

DATUM:

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

[illegible]

DATA INPUT: GNS

DEPTH SCALE

1 to 100

Golder Associates

LOGGED: DEN

CHECKED: MTB

SAMPLER HAMMER, 63.5kg; DROP, 760mm

BORING DATE: September 9/91

DATUM:

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

[illegible]

1 to 100

CHECKED: MTB

Golder Associates

SAMPLER HAMMER, 63.5kg; DROP, 760mm

BORING DATE: September 10/91

DATUM:

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

[illegible]

1 to 100

LOGGED: DEN

CHECKED: MTB

Golder Associates

SAMPLER HAMMER, 63.5kg; DROP, 760mm

BORING DATE: September 10/91

DATUM:

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m				HYDRAULIC CONDUCTIVITY, k, cm/s				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m										
				DEPTH (m)				SHEAR STRENGTH				WATER CONTENT, PERCENT					
								20	40	60	80	nat V - + Q - ● rem. V - ⊕ U - ○	20	40			60
0	SDS Tracked Auger, Solid Stem DPT Cone: 60mm dia., 150mm sleeve	GROUND SURFACE		3.50													
		TOPSOIL		0.00													
		Very loose, brown, fine to medium SAND, trace silt and organics.		0.30													
				0.60													
		Very loose, grey SILT, some fine sand.			1	AS											
				1.70													
2			Very loose, grey SILT, some fine sand, some layers sandy silt.			2	AS										
				0.50													
				3.00													
4			Very loose to loose, grey, fine to medium SAND and SILT.			3	AS										
			-1.40														
		Loose to compact, grey, fine to medium SAND, trace silt.			4	AS											
			4.90														
6			-3.10														
		Compact, grey, fine to medium SAND, trace silt, with a few layers of silt, some sand.			5	AS											
			6.60														
8			-4.10														
		Compact, grey, fine to medium SAND.			6	AS											
			7.60														
		END OF BOREHOLE.															
			-5.60														
10			9.10														
			-6.90														
			10.40														
12																	
14																	
16																	
18																	
20																	

DATA INPUT: GNS

DEPTH SCALE

1 to 100

Golder Associates

LOGGED: DEN

CHECKED: MTB

LOCATION: See Figure 2

BORING DATE: September 10/91

DATUM:

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

[illegible]

DATA INPUT: GNS

DEPTH SCALE

1 to 100

Golder Associates

LOGGED: DEN

CHECKED: MTB

PROJECT: 912-1966

RECORD OF BOREHOLE BH 7

SHEET 1 OF 1

LOCATION: See Figure 2

BORING DATE: September 10/91

DATUM:

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, k, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER TYPE	20 40 60 80	20 40 60 80	20 40 60 80	20 40 60 80		
0		GROUND SURFACE		0.00							
		Loose, brown SILT, trace organics (TOPSOIL).		0.60	1 AS						
2		Very loose to loose, mottled brown and orange, interlayered SILT, some fine sand and SAND, some silt.		1.80	2 AS						
		Very loose, brown, fine SAND and SILT.		2.70							
4					3 AS						
6		Loose to compact, grey, fine to medium SAND, some silt, some layers silt, some fine sand.			4 AS						
8											
10		END OF BOREHOLE.		9.10							
12											
14		END OF PENETRATION TEST.		13.40							
16											
18											
20											

DEPTH SCALE

1 to 100

0
15 5 PERCENT AXIAL STRAIN AT FAILURE
10

Golder Associates

LOGGED: DEN

CHECKED: MTB

PROJECT: 912-1966

RECORD OF BOREHOLE BH 8

SHEET 1 OF 1

LOCATION: See Figure 2

BORING DATE: September 10/91

DATUM:

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, k, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER TYPE	BLOWS/0.3m	SHEAR STRENGTH		WATER CONTENT, PERCENT			
							20	40	60			80
0		GROUND SURFACE										
		Dense, brown, cobbly SAND and GRAVEL	0.00	0.00								
		END OF BOREHOLE.		0.50								
2												
4												
6												
8												
10												
12												
14												
16												
18												
20												

DATA INPUT: GNS

SDS Tracked Auger, Solid Stem
DPT Cone, 60mm dia., 150mm sleeve

Note: Auger met refusal at 0.5 m on coarse, cobbly, bouldery FILL. Several locations attempted in a 3 m diameter, but unable to penetrate into stratum.

0
15
10
5 PERCENT AXIAL STRAIN AT FAILURE

DEPTH SCALE

1 to 100

Golder Associates

LOGGED: DEN

CHECKED: MTB

APPENDIX III

SITE PHOTOGRAPHS

Approximate photograph locations shown in Figure 2.



PHOTOGRAPH 1

Photo-mosaic looking northward along the centerline of the Hatzic Slough dam.



PHOTOGRAPH 2

Photograph looking eastward from the edge of the dyke towards the existing pump station. Hatzic Slough Channel appears in the upper left-hand side of the photograph.



PHOTOGRAPH 3

Photograph looking westward from the edge of the dyke in the downstream flow direction of Hatzic Slough. The outfall structure for the existing pump station appears at the right-hand side of the photograph.

APPENDIX C

ENVIRONMENTAL REPORTS

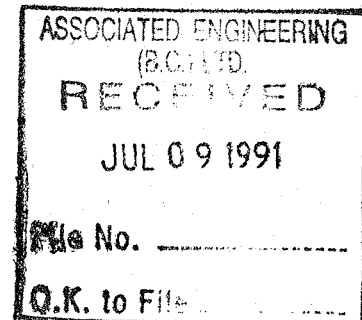


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ENVIRONMENTAL CONSULTANTS

July 8, 1991

Associated Engineering (B.C.) Ltd.
#300 - 4940 Canada Way
Burnaby, British Columbia
V5G 4M5



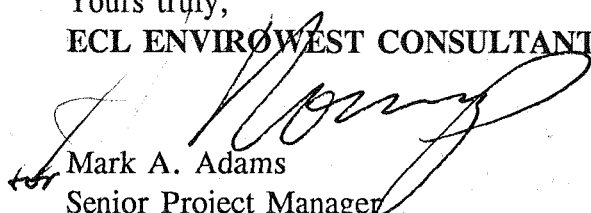
Attention: Mr. Kerry Rudd

Dear Mr. Rudd:

Re: Fish Species List for the Hatzic Prairie Watershed

Please find attached a species list to help clarify any questions which may arise regarding other fishes within the watershed. Many of the listed species are suspected to occur in the watershed according to Freshwater Fishes of Canada (Scott and Crossman 1979) but have not been recorded by DFO Stream Information Summaries.

Yours truly,
ECL ENVIROWEST CONSULTANTS LIMITED


Mark A. Adams
Senior Project Manager

MAA/sn

Common Name	Scientific Name	Occurrence
Coho Salmon	<i>Oncorhynchus kisutch</i>	r
Chum Salmon	<i>O. keta</i>	r
Pink Salmon	<i>O. gorbuscha</i>	r (1947 only)
Cutthroat Trout	<i>O. clarki</i>	r (Draper Creek)
Rainbow Trout	<i>O. mykiss</i>	r (Lagace Creek)
Mountain Whitefish	<i>Prosopium williamsoni</i>	s
Carp	<i>Cyprinus carpio</i>	s
Brassy Minnow	<i>Hybognathus hankinsoni</i>	s
Peamouth Chub	<i>Mylocheilus caurinus</i>	s
Northern Squawfish	<i>Ptychocheilus oregonensis</i>	s
Longnose Dace	<i>Rhinichthys cataractae</i>	s
Redside Shiner	<i>Richardsonius balteatus</i>	s
Leopard Dace	<i>Rhinichthys falcatus</i>	s
Longnose Sucker	<i>Catostomus catostomus</i>	s
Largescale Sucker	<i>C. macrocheilus</i>	s
Brown Bullhead	<i>Ictalurus nebulosus</i>	s
Threespine Stickleback	<i>Gasterosteus aculeatus</i>	s
Black Crappie	<i>Pomoxis nigromaculatus</i>	s
Prickly Sculpin	<i>Cottus asper</i>	r (Lagace Creek)

r = recorded occurrence (DFO: Stream Information Summary)

s = suspected occurrence (Freshwater Fishes of Canada (Scott and Crossman 1979))



envirowest

ENVIRONMENTAL CONSULTANTS

August 20, 1991

Associated Engineering (B.C.) Ltd.
#300 - 4940 Canada Way
Burnaby, BC
V5G 4M5

Attention: Mr. Kerry Rudd

Dear Mr. Rudd,

Re: Hatzic Lake Summer Water Level Controls

The following are a few concerns that should be considered before a proposed water level barrier is designed.

1. Milfoil
Yearly drops in water levels which expose mudflats in Hatzic Lake serve as a natural control for submerged vegetation, such as milfoil (*Myriophyllum* spp.), that would otherwise inhabit nearshore areas. Mudflat exposure deters the proliferation of submerged vegetation in the lake. If water levels are controlled in late summer, submerged vegetation will colonize these nearshore areas and decrease the recreational value of the lake for boaters in the future.
2. Water level
Water below the proposed barrier would remain at Fraser River levels during this period. Holding the lake at a defined level may help to alleviate any high temperature problems that the lake undergoes as a result of shallow water in the summer. The only concern, albeit a minor one, would be to ensure that a contingency plan for summer floods be formulated in case of heavy rains in August.

3. Fish passage

A. Coho Salmon - Adults migrate late in the season and over a prolonged period, often moving upstream when the first rains increase river flow in the fall. Spawning takes place from October to March. Hatching occurs in early spring. Fry emerge from early March to late July. In late March or April of the year following their emergence most fry migrate to the sea (ref. Scott, W.B. and E.J. Crossman. 1979. Freshwater Fishes of Canada. Fisheries Research Board of Canada. Ottawa. 966p.).

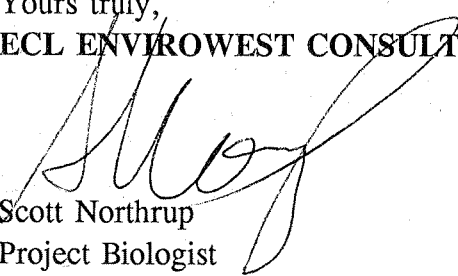
B. Chum Salmon - Chum salmon begin to arrive at the mouth of some streams in September, and arrival on the spawning grounds varies from September to early January. Hatching occurs from late December to February. Emergence occurs in late April to early May. The fry move immediately downstream to estuarine waters (Scott and Crossman 1979).

The proposed barrier should have little effect on the downstream or upstream migration of salmonid species during the proposed detention period.

If you have any questions please contact me at 521-6500.

Yours truly,

ECL ENVIROWEST CONSULTANTS LIMITED



Scott Northrup
Project Biologist

EDSN

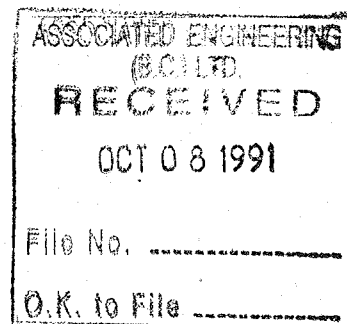


envirowest

ENVIRONMENTAL CONSULTANTS

October 4, 1991

Associated Engineering (B.C.) Ltd.
#300 - 4940 Canada Way
Burnaby, British Columbia
V5G 4M5



Attention: Mr. Kerry Rudd

Dear Mr. Rudd:

Re: Proposed Flood Control Works at Hatzic Prairie: Your File No. VP97-5-7.

The following is a list of preliminary list of comments in response to your facsimile dated September 25, 1991:

1. Pattison Creek Diversion: The infilling of Amber Lake represents a proposed impact which is not likely to receive regulatory agency approval. Marshes at the north and south ends of the lake are likely highly productive areas that may be utilized by local and migrating waterfowl as well as resident fish stocks. Additional biophysical information is required to generate a more detailed assessment.
2. Re-routing Lagace Creek: This proposal is not feasible as it stands. Alternate re-routing of Lagace Creek would require yearly fry salvages. The proposal represents a continual disturbance of fish habitat which increase the mortality of juvenile salmonids. The yearly re-routing of the creek would reduce its productive capacity for fish and wildlife. This proposal is unlikely to receive regulatory agency approval. An instream sediment trap would represent a more viable solution.
3. Lagace Creek Deposition Zone: This proposal is likely to receive approval from regulatory agencies.
4. Re-routing Unnamed Creek: Any comment pertaining to this proposal would be premature due to a lack of information. There is a need to identify fish and wildlife values for the area.

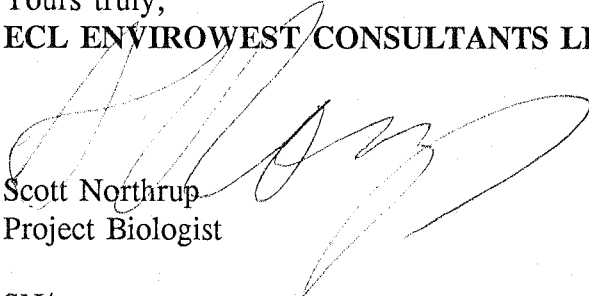
The distinct lack of available information for the area as a whole presents a problem when formulating comments on proposed works. Correspondence with Mr. Konrad Johansen of the

Mr. Kerry Rudd
October 4, 1991
Page 2

Department of Fisheries and Oceans Habitat Branch on September 27, 1991 confirmed this conclusion. It is proposed that **ENVIROWEST** perform a preliminary biophysical survey of the areas considered in the proposed works the week of October 7, 1991. This will allow **ENVIROWEST** to comment with confidence regarding the proposed works. A report on the preliminary biophysical survey and further recommendations pertaining to the proposed works would be available October 11, 1991.

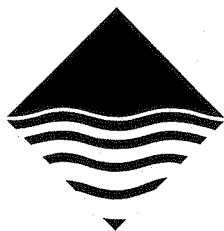
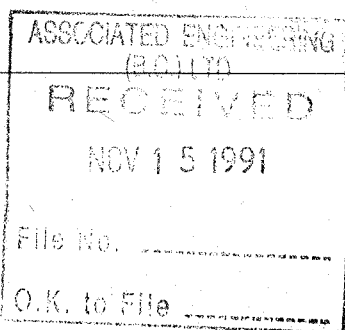
Should you have any questions please contact me at 521-6500.

Yours truly,
ECL ENVIROWEST CONSULTANTS LIMITED



Scott Northrup
Project Biologist

SN/st



envirowest
ENVIRONMENTAL CONSULTANTS

November 7, 1991

Associated Engineering (B.C.) Ltd.
#300 - 4940 Canada Way
Burnaby, BC
V5G 4M5

Attention: Mr. Kerry Rudd

Dear Mr. Rudd:

Re: Proposed Dredging of Hatzic Lake

Listed below are a number of concerns which may be raised by environmental agencies about the proposed dredging of Hatzic Lake:

Dredging Guidelines for Lakes - There exists a lack of guidelines for lake dredging. Guidelines for marine and instream dredging exist and may be utilized by Department of Fisheries and Oceans (DFO) personnel to assess a dredging proposal for Hatzic Lake.

Salmon Spawning and Rearing - The removal of 1.7 million m³ of dredgate would take approximately six (6) months (Kerry Rudd pers. comm.). The permitted work window in freshwater habitats is typically from July through September (Ref. Envirowest letter dated August 20, 1991). The length of time required to dredge would require dredging take place over two or more seasons.

Of considerable uncertainty is the value of the lake as a rearing area for juvenile coho salmon. Young coho salmon emerge in the spring and spend one (1) year rearing in freshwater streams and lakes. Since coho salmon spawn in local streams it is conceivable that fry would rear in Hatzic Lake. No data exists concerning coho salmon rearing in Hatzic Lake.

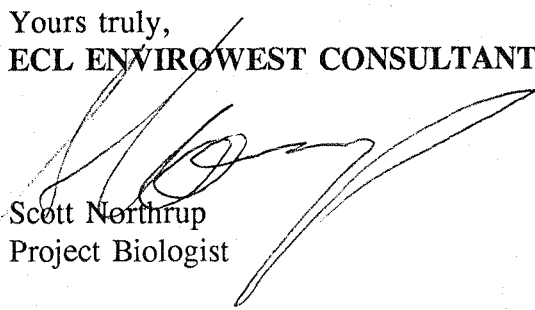
Areas of the lake proposed to be dredged are utilized by chum salmon (*Oncorhynchus keta*) for spawning. Dredging would increase siltation of and/or remove spawning gravels. Dredging would likely not be permitted in known spawning areas (e.g. mouth of Draper Creek).

Mr. Kerry Rudd
Associated Engineering
November 7, 1991
Page 2

Contaminant Analysis - An analysis program must be fulfilled to ascertain the concentration of contaminants (heavy metals, organics, etc.) within sediment to be dredged. The analysis program would determine the means and mode of dredgate disposal (landfill, ocean dumping etc.).

If you have any questions please contact me at 521-6500.

Yours truly,
ECL ENVIROWEST CONSULTANTS LIMITED



Scott Northrup
Project Biologist

SN/st

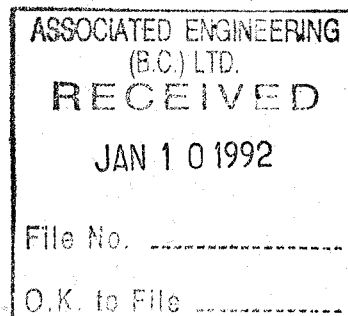


envirowest

ENVIRONMENTAL CONSULTANTS

December 16, 1991

Mr. Kerry Rudd, P.Eng.
Associated Engineering (B.C.) Ltd.
Suite 300 - 4940 Canada Way
Burnaby, B.C.
V5G 4M5



Dear Mr. Rudd:

Re: Hatzic Prairie Drainage Study

Please refer to your facsimile of December 05, 1991. As per your request, please find below our review of environmental concerns regarding conceptual projects for the Hatzic Prairie study area.

1. Construct new triplex pump station with a total capacity of $8.34\text{m}^3/\text{s}$ at Fraser River dyke; a fish pump and screen is included for one pump only, the remaining two pumps have no fish pump.

It is assumed that the remaining two pumps would be secondary to the pump that possesses the fish pump: the second two pumps would commence operating once the pumping requirements exceed the capacity of the first pump. This concept would probably be approved by the Department of Fisheries and Oceans (Department).

2. Construct a four-bay floodbox (4 @ $1.8\text{m} \times 1.8\text{m}$) at Fraser River dyke on east side of existing pump station.

The Department would likely approve the floodbox on the condition that operating guidelines are in place to ensure that migrating fish are not significantly impeded during peak downstream (juveniles) and upstream (adults) migration periods.

Mr. Kerry Rudd
Associated Engineering
Hatzic Prairie
December 16, 1991
Page 2 of 3

3. Construct dykes, set back where possible 15m from the top of banks, along both sides of Lagace Creek/Hatzic Slough between Sylvester Road and Hatzic Lake. Floodboxes would be built at tributaries and pump stations at major tributaries.

As per item 2, operating guidelines that provide fish passage would be required by the Department. It is likely that fish screens and fish pumps would be required for intakes at each prospective pump station location.

It may be necessary to compensate for impacts on riparian vegetation (shrubs and trees).

4. Gravel extraction operation from Lagace Creek or between Suex Road Bridge and Farms Road bridge (length 800-1000m of creek). Gravel processing may include washing and crushing on bank area.

See below.

5. As item 4, but at Amber Lake.

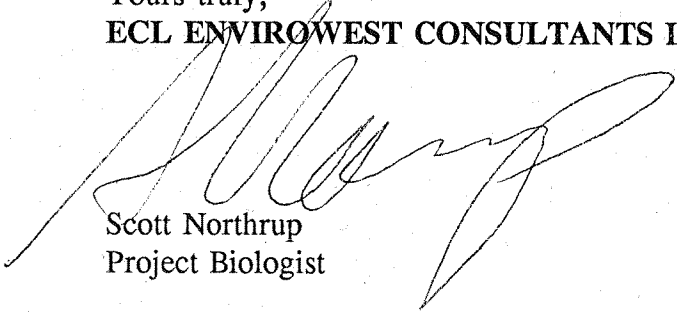
An application for gravel extraction as described in items 4 and 5 would only be considered by the Department if it were for the sole purpose of increasing the drainage capacity of affected waterways. An application to process gravel within the riparian corridor would likely not achieve approval from environmental agencies. If gravel processing is a critical component of the economical feasibility of the proposed gravel extraction, off-site processing in an upland area equipped with a series of sedimentation ponds to remove suspended solids from discharge waters would have to be considered.

If approved by the Department, gravel extraction would have to occur between July 01 and September 30 of any calendar year. Gravel extraction would have to take place in the dry: a diversion channel would have to be constructed to pass water around the active extraction area.

Mr. Kerry Rudd
Associated Engineering
Hatzic Prairie
December 16, 1991
Page 3 of 3

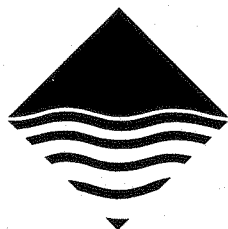
Should you have any questions regarding the above, please contact me at 521-6500.

Yours truly,
ECL ENVIROWEST CONSULTANTS LIMITED



Scott Northrup
Project Biologist

SN



envirowest

ENVIRONMENTAL CONSULTANTS

December 19, 1991

Mr. Kerry Rudd, P. Eng.
Associated Engineering (B.C.) Limited
300 - 4940 Canada Way
Burnaby, B.C.
V5G 4M5

Dear Mr. Rudd:

Re: Hatzic Prairie Drainage Study

Your facsimile dated December 16, 1991 regarding a proposed floodbox and overflow creek at the confluence of Belcharton and Bouchier creeks raises the same concerns indicated in item 2 of my letter dated December 16, 1991 (attached). The proposal is acceptable provided that operating guidelines for fish passage are in place.

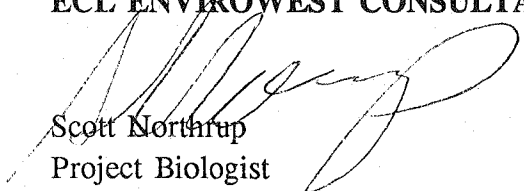
Another option would be to divert Belcharton Creek west into an improved Bouchier Creek. This would create improved compensation habitat opportunities in Bouchier Creek without detracting from habitats in Lagace Creek. This option would only be feasible if Bouchier Creek could handle flows from Belcharton Creek.

In regards to item 1 of my December 16, 1991 letter (attached) concerning a fish pump for the proposed triplex pump station, a fish pump and fish screen would be required only on the primary pump. However, the primary pump must have the capacity to discharge the majority of peak summer flows. The secondary pumps should operate only in the event of extreme flood events during the Fraser River freshet period, as this period coincides with the period of peak downstream migration of juvenile salmonids. This scenario should meet with the approval of the Department of Fisheries and Oceans and the Fish and Wildlife Branch of the Ministry of Environment, Lands and Parks.

Mr. Kerry Rudd
Associated Engineering
Hatzic Prairie
December 19, 1991
Page 2

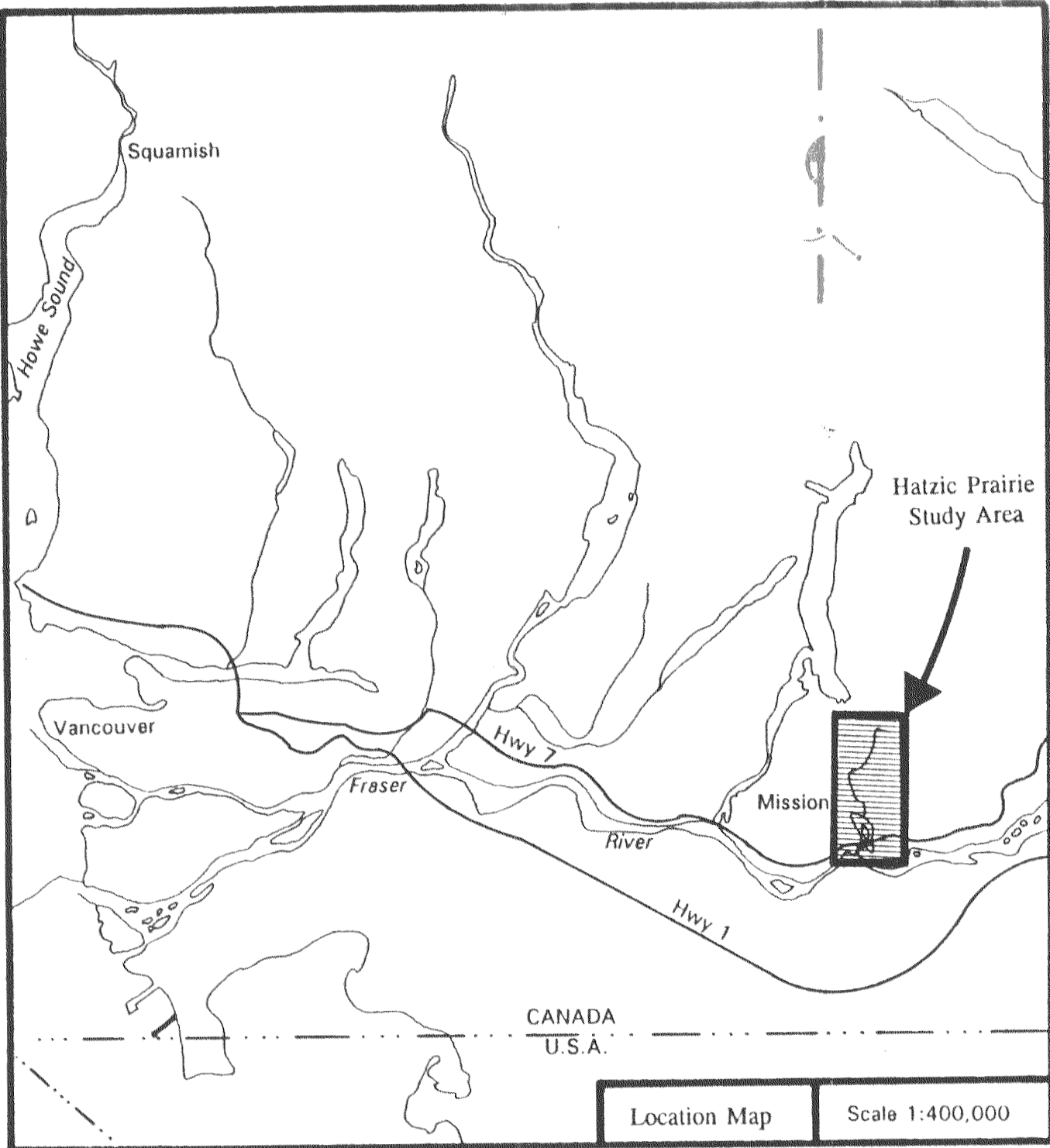
Should you have any questions about the aforementioned, please contact me at 521-6500.

Yours truly,
ECL ENVIROWEST CONSULTANTS LIMITED



Scott Northrup
Project Biologist

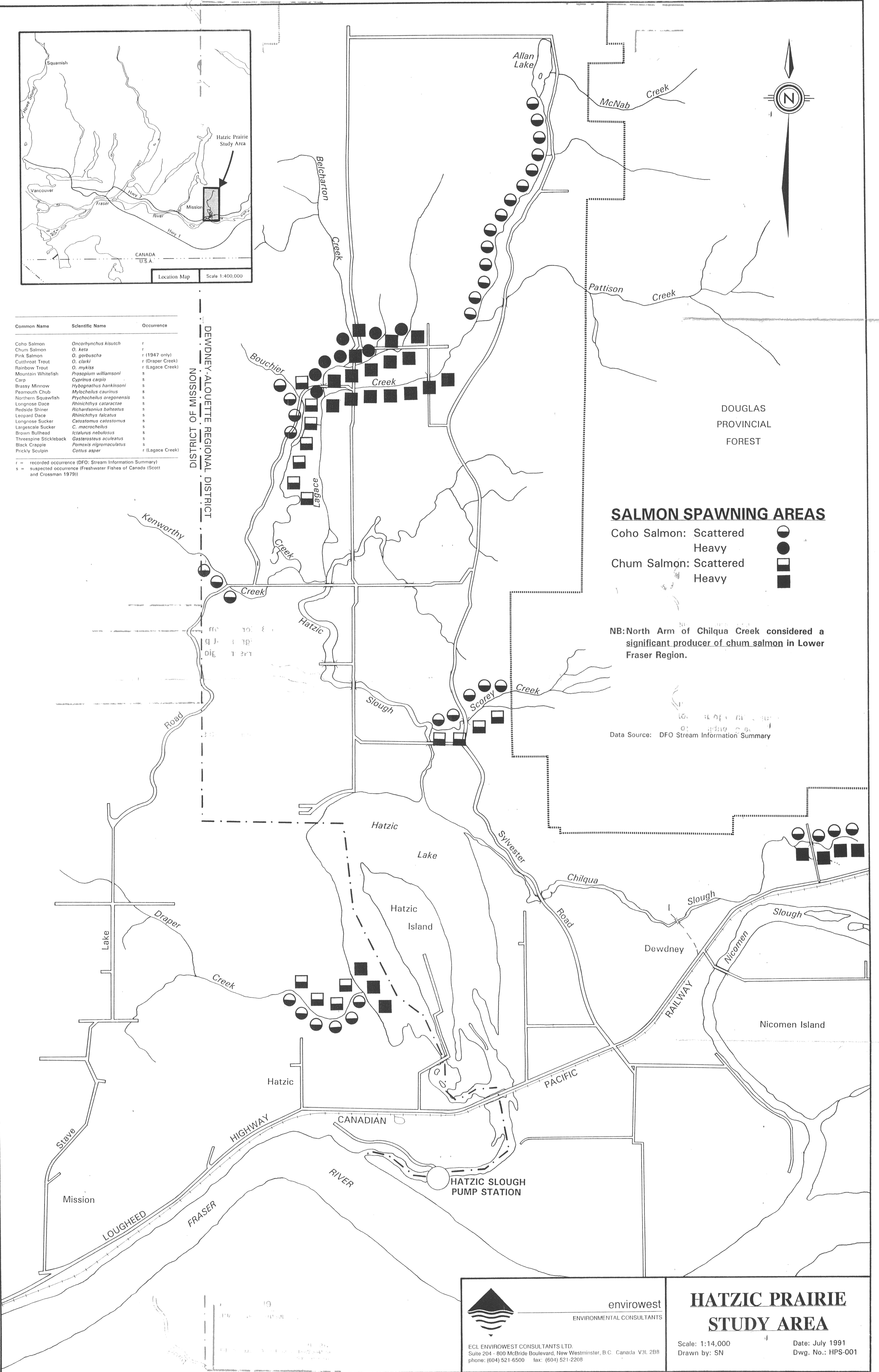
SN



Common Name	Scientific Name	Occurrence
Coho Salmon	<i>Oncorhynchus kisutch</i>	r
Chum Salmon	<i>O. keta</i>	r
Pink Salmon	<i>O. gorbuscha</i>	r (1947 only)
Cutthroat Trout	<i>O. clarki</i>	r (Draper Creek)
Rainbow Trout	<i>O. mykiss</i>	r (Lagace Creek)
Mountain Whitefish	<i>Prosopium williamsoni</i>	s
Carp	<i>Cyprinus carpio</i>	s
Brassy Minnow	<i>Hybognathus hankinsoni</i>	s
Pearmouth Chub	<i>Mylocheilus caurinus</i>	s
Northern Squawfish	<i>Psychocheilus oregonensis</i>	s
Longnose Dace	<i>Rhinichthys cataractae</i>	s
Redside Shiner	<i>Richardsonius balteatus</i>	s
Leopard Dace	<i>Rhinichthys falcatus</i>	s
Longnose Sucker	<i>Catostomus catostomus</i>	s
Largescale Sucker	<i>C. macrocheilus</i>	s
Brown Bullhead	<i>Ictalurus nebulosus</i>	s
Threespine Stickleback	<i>Gasterosteus aculeatus</i>	s
Black Crappie	<i>Pomoxis nigromaculatus</i>	s
Prickly Sculpin	<i>Cottus asper</i>	r (Lagace Creek)

r = recorded occurrence (DFO: Stream Information Summary)
s = suspected occurrence (Freshwater Fishes of Canada (Scott and Crossman 1979))

DEWDNEY-ALOUETTE REGIONAL DISTRICT
NOISSIM FO LTRISID



SALMON SPAWNING AREAS

Coho Salmon: Scattered
Heavy
Chum Salmon: Scattered
Heavy

NB: North Arm of Chilqua Creek considered a significant producer of chum salmon in Lower Fraser Region.

Data Source: DFO Stream Information Summary



envirowest
ENVIRONMENTAL CONSULTANTS

ECL ENVIROWEST CONSULTANTS LTD.
Suite 204 - 800 McBride Boulevard, New Westminster, B.C. Canada V3L 2B8
phone: (604) 521-6500 fax: (604) 521-2208

HATZIC PRAIRIE STUDY AREA

Scale: 1:14,000
Drawn by: SN

Date: July 1991
Dwg. No.: HPS-001

APPENDIX D

COST ESTIMATES

INTRODUCTION

Included within this appendix are detailed construction cost estimates for the capital works identified within Section 4 of the report.

These cost estimates have been developed based on the understanding that projects would be publically tendered and competitive bids would be received. Prices have been developed utilizing tendered unit prices received on similar publically tendered work and quotations from suppliers and contractors. Land acquisition costs where applicable have been derived from the taxation assessment role for the study area.

In addition, where applicable, an allowance has been included for engineering, design and inspection services, and for a contingency allowance. All of the cost estimates include the applicable taxes including 7% GST and are expressed in 1991 dollars.

**ESTIMATED COSTS OF
HATZIC SLOUGH PUMP STATION/FLOODBOX**

Page 1 of 2

Item	Description	Unit	Unit Price	Pump Station Structure Built Separately		Floodbox Structure Built Separately		Combined Pump Station/Floodbox	
				Quantity	Extension	Quantity	Extension	Quantity	Extension
1	Mobilization and demobilization		LS		40,000		40,000		80,000
2	Site clearing and removal of topsoil		LS		6,000		6,000		10,000
3	Excavation for structures	m ³	7.00	7,050	49,350	4,100	28,700	9,150	64,050
4	Excavation of inlet and outlet channels	m ³	6.00	12,600	75,600	17,860	107,160	24,850	149,100
5	Cofferdams and dewatering		LS		60,000		60,000		80,000
6	Gravel bedding and filter	m ³	20.00	1,780	35,600	2,780	55,600	3,800	76,000
7	Sand filter	m ³	16.00	95	1,520	85	1,360	150	2,400
8	Filter cloth	m ²	4.00	230	920	230	920	385	1,540
9	Rock filter and tailings	m ³	25.00	2,200	55,000	2,200	55,000	3,660	91,500
10	Rock riprap	m ³	50.00	420	21,000	630	31,500	880	44,000
11	Dyke backfill	m ³	15.00	1,280	19,200	3,800	57,000	4,280	64,200
12	Impervious core	m ³	20.00	170	3,400	520	10,400	580	11,600
13	Mudslab concrete	m ³	240.00	22	5,280	33	7,920	45	10,800
14	Structural Concrete	m ³	600.00	330	198,000	345	207,000	635	381,000
15	Sheet pile cut off	m ²	220.00	35	7,700	100	22,000	120	26,400
16	Miscellaneous metalwork		LS		30,000		30,000		60,000
17	Waterproofing and testing		LS		6,000				6,000
18	Doors and ventilation equipment		LS		6,000				6,000
19	Curb rings and discharge columns	ea	16,000.00	3	48,000	3		3	48,000
20	Supply 300 hp x 2.8 m ³ /s pumps	ea	115,000.00	3	345,000	3		3	345,000
21	Floodgates 1.9 m x 1.9 m	ea	10,000.00			4	40,000	4	40,000
22	1600 dia flapgates	ea	8,000.00	3	24,000	3		3	24,000

**ESTIMATED COSTS OF
HATZIC SLOUGH PUMP STATION/FLOODBOX**

Page 2 of 2

Item	Description	Unit	Unit Price	Pump Station Structure Built Separately		Floodbox Structure Built Separately		Combined Pump Station/Floodbox	
				Quantity	Extension	Quantity	Extension	Quantity	Extension
23	Motor control centre		LS		62,000				62,000
24	Transformer substation for new station		LS		36,700				36,700
25	Upgrade hydro service to 25 kV		LS		12,100				12,100
26	Electrical installation		LS		38,600				38,600
27	Upgrade existing pump station to new voltage		LS		36,400				36,400
28	Site grading and finishing		LS		6,200		4,000		6,200
29	Log boom chain		LS		10,000		10,000		10,000
30	Stop-log lifting frame		LS				20,000		20,000
31	Installation of relief walls	ea	12,000.00	2	24,000	2	24,000		24,000
32	Fish screen system and fish pump		LS		150,000				150,000
Subtotal					1,413,570		818,560		2,017,590
Engineering 25%					353,390		204,640		504,440
Contingencies 10%					141,340		81,800		201,770
TOTAL					1,908,300		1,105,000		2,723,800

NOTES:

1. Estimated costs of building the two structures separately = \$3,013,300
2. Potential savings on floodbox by combining the two structures = \$ 289,500
3. Item 25 is a BC Hydro requirement for the new services
4. Item 27 is necessary to maintain the existing pump station

ESTIMATED COST FOR PUMPING STATION ALTERNATIVES

Page 1 of 2

	Single Diesel Engine Pump	Duplex Long Column	Duplex ² Submersible	Triplex Submersible
<u>CIVIL AND STRUCTURAL</u>				
Site preparation, excavation, cofferdams, dewatering and flood protection	80,000	151,500	151,500	187,000
Backfills, including bank protection works. Topsoil and seeding, and log boom chain	20,000	127,600	127,600	138,000
Concrete, including formwork and reinforcement	20,000	307,400	182,400	204,000
Miscellaneous metalwork, including doors, ventilation equipment, and flap gates	80,000	146,000	71,000	60,000
Waterproofing and hydrostatic testing	-	6,000	6,000	6,000
Access Bridge	80,000	-	-	-
Timber Pile Structure & Housing	100,000	-	-	-
<u>ELECTRICAL</u>				
Upgrade O/H line to 25 kV	12,100 ¹	12,100	12,100	12,100
Upgrade existing pump station for the new voltage	36,400 ¹	36,400	36,400	36,400
Power supply at new pump station Including transformers	4,000	36,700	36,700	36,700
M.C.C.'s for new pump station	-	48,000	48,000	62,000
Float switches	2,500	3,000	3,000	4,000
Wiring	-	6,400	6,400	9,600
Interior and Exterior Lighting and Receptacles	25,000	25,000	25,000	25,000
Engine controls and wiring	4,000	-	-	-
<u>MECHANICAL</u>				
Supply and install pump frames	20,000	20,000	1,300	1,900
Supply and install of discharge columns and support brackets	40,000	80,000	46,400	48,000
Supply of pumping units	530,000 ³	260,000 ⁴	290,000 ⁴	345,000 ⁴
Installation of pumping units	44,800	33,600	1,000	1,500
Painting and finishing	2,000	2,000	2,000	2,000



ESTIMATED COST FOR PUMPING STATION ALTERNATIVES

Page 2 of 2

	Single Diesel Engine Pump	Duplex Long Column	Duplex ² Submersible	Triplex Submersible
Fuel Tanks	40,000	-	-	-
Testing and commissioning	3,000	3,800	3,800	4,370
Mobilization/Demobilization	50,000	80,000	80,000	80,000
Bonding/Insurance	0 ⁸	225,000 ⁶	225,000 ⁶	150,000 ⁶
Fish screen system and fish pump				
SUBTOTAL	1,193,800	1,610,500	1,335,600	1,413,570
Engineering @ 25%	298,500	402,600	338,900	353,390
Contingency @ 10%	119,400	161,000	135,500	141,340
GRAND TOTAL	\$1,611,700	\$2,174,100	\$1,830,000	\$1,908,300
Average Operating and Maintenance Costs per Year	\$36,400 ⁷	\$44,500 ⁵	\$44,500 ⁵	\$44,100 ⁵

- 1 Optional on this alternative
- 2 Has limited pump market due to pump size
- 3 Includes pump and diesel engine drive unit
- 4 Includes pump and electric motor
- 5 Based on pumping 390 hours for summer and 112 hours for winter for the year for each pump taken from pumping records over the last 11 years. Power costs include demand charge for winter pumping. Records show winter pumping for 6 years out of the past 11 years. Operating costs include \$3000 maintenance and servicing of pumps.
- 6 Based on recent costs for Matsqui pump station for the single pump, the screening costs could be very much higher as a large screen area is required.
- 7 Fuel costs \$35,400 and \$1,000 annual maintenance servicing costs of the engine.
- 8 In order to accommodate a fish pump the diesel motor would need to be multiple speed. The reliability of this type of installation is questionable and it would require a higher level of maintenance. It is therefore not recommended. The cost of converting the single speed operation to a multi-speed system would be considerable.

ESTIMATED COST OF BRIDGE OVER HATZIC SLOUGH FOR DOUBLE TRACK CPR CROSSING

Item	Quantity	Unit	Unit Price	Extension
Mobilization and Demobilization		LS		\$ 25,000
Temporary Works - Install and Remove Sheet Piles (9 m x 30 m)	270	m ²	400.00	108,000
610 mm Diameter Piles (8)	160	m	315.00	50,400
Excavation	5,000	m ³	20.00	100,000
Riprap	1,000	t	20.00	20,000
Pile Caps	4	ea	5,000.00	20,000
Steel Girders (4 - 32 m lg)	128	m	2,150.00	275,200
Precast Deck		LS		110,000
Grout Deck		LS		15,000
Subtotal				\$ 723,600
25% Engineering				180,900
10% Contingencies				72,360
Railway Charges - Install two No. 8 Turnouts (Temporary)				100,000
- Flagging - 1 month				10,000
- Remove and Reinstall Ballast				15,000
TOTAL				\$1,101,860
SAY				\$1,105,000

Based on two single span bridges, 32 m long
Track possession of 7 - 14 days required, one track remains in operation at all times.

KRR/amw/VP97.65

**ESTIMATED COST OF TWO 3.05 m CULVERTS
THROUGH CPR EMBANKMENT**

Item	Quantity	Unit	Unit Rate	Extension
3.05 m Tunnel Liner	74	m	7,200.00	\$532,800
Excavation of Inlet and Outlet Channels	2,500	m ³	7.00	17,500
Filter Layer 300 mm Thick	160	m ³	25.00	4,000
Riprap	620	t	25.00	15,500
Concrete Headwalls				
Inlet		LS		23,000
Outlet		LS		21,000
Railway Charges		LS		50,000
Subtotal				\$663,000
25% Engineering				\$165,950
25% Contingencies				\$165,950
TOTAL				\$995,700
SAY				\$1,000,000

POTENTIAL ADDITIONAL COST OF GROUND STABILIZATION

Item	Quantity	Unit	Unit Rate	Extension
Probes	222	m	300.00	\$ 66,000
Grout	625	m ³	785.00	490,625
Subtotal				\$556,625
Engineering and Contingencies (35%)				\$194,819
TOTAL				\$751,444
SAY				\$750,000

**ESTIMATED COST OF FLOATING DEBRIS CONTROL WALKWAY
STRUCTURE UPSTREAM OF LOUGHEED HIGHWAY**

Item	Quantity	Unit	Unit Rate	Extension
Mobilization and Demobilization		LS		\$ 10,000
400 mm dia Pipe Boom	64	m	200.00	12,800
356 mm dia Pipe Piles	120	m	225.00	27,000
Aluminum Decking Walkway		LS		16,000
Miscellaneous Metalwork		LS		2,000
Approach Ramp	2,000	m ³	8.00	16,000
Rock Riprap	100	t	25.00	2,500
Subtotal				\$ 86,300
Engineering and Contingencies (35%)				\$ 30,200
TOTAL				\$116,500

KRR/lp/VP97.57

**ESTIMATED COST OF LOG BOOM CHAIN DEBRIS CONTROL
STRUCTURE UPSTREAM OF LOUGHEED HIGHWAY**

Item	Quantity	Unit	Unit Price	Extension
Mobilization and Demobilization		LS		\$ 6,000
3 Pile Dolphin and 2 Anchor Piles	5	ea	4,000.00	20,000
Boom Logs and Chain		LS		6,000
Two Access Ramps	4,000	m ³	8.00	32,000
Rock Riprap	200	t	25.00	5,000
Subtotal				\$ 69,000
Engineering and Contingencies (35%)				\$ 24,150
TOTAL				\$93,150
SAY				\$93,000

ESTIMATED COST OF LAKE DREDGING

Item	Quantity	Unit	Unit Rate	Extension
Mobilization and Demobilization	2	ea	650,000	\$1,300,000
Dredge to Lake Side	1,700,000	m ³	5.50	9,350,000
*Royalties	1,700,000	m ³	0 assumed	0.00
Subtotal				\$10,650,000
Contingencies (10%)				\$ 1,065,000
Engineering				\$ 200,000
TOTAL				\$11,915,000
SAY				\$12,000,000
Additional Trucking for Disposal	1,700,000	m ³	4.80	\$8,160,000
10% Contingencies				\$ 816,000
TOTAL				\$8,976,000
SAY				\$9,000,000

* Based on discussions with BC Lands.

KRR/rb/VP97.59

**ESTIMATED COST FOR DYKING HATZIC SLOUGH,
LAGACE CREEK AND RELATED WORKS**

Page 1 of 2

	Quantity	Unit	Unit Cost	Extension
<u>LEFT BANK (LAGACE AND HATZIC)</u>				
Stripping	73,598	m ³	\$2.25	\$ 165,596
Bulk Fill	133,255	m ³	4.82	641,710
Topsoil/Seeding	52,350	m ²	2.30	120,406
Concrete Wall		LS		257,580
Property Acquisition	83,627	m ²	0.53	44,227
SUBTOTAL				\$1,229,519
<u>RIGHT BANK (LAGACE AND HATZIC)</u>				
Stripping	72,568	m ³	2.25	\$ 163,277
Bulk Fill	132,668	m ³	4.87	646,664
Topsoil/Seeding	53,353	m ²	2.30	122,712
Property Acquisition	80,738	m ²	0.48	38,468
SUBTOTAL				\$ 971,121
<u>PUMP STATIONS AND FLOODBOXES</u>				
A6 Scorey Creek		LS		\$ 222,222
A5 Currie Creek		LS		370,370
A4		LS		100,000
A3		LS		80,000
A2		LS		592,593
A1 Bouchier Creek		LS		1,051,852
Belcharton F/B		LS		80,000
Floodboxes (10)		LS		120,000
Fish Ladders (6)		LS		666,667
SUBTOTAL				\$3,283,704
<u>UPGRADE ROADS AND BRIDGES</u>				
Farms Road at Riverside		LS		\$ 487,000
Dale Road		LS		512,000
Farms Road at Stave Lake Road		LS		344,000
SUBTOTAL				\$1,343,000

**ESTIMATED COST FOR DYKING HATZIC SLOUGH,
LAGACE CREEK AND RELATED WORKS**

Page 2 of 2

	Quantity	Unit	Unit Cost	Extension
<u>CHANNEL IMPROVEMENTS</u>				
Bouchier Creek		LS		\$ 127,000
SUBTOTAL				\$ 127,000
<u>HATZIC LAKE (SWARD ROAD AREA)</u>				
Bulk Fill	3,161	m ³	5.00	\$ 15,806
Stripping	5,378	m ³	2.25	12,099
Topsoil/Seeding	1,677	m ³	4.60	7,714
Property Acquisition	10,145	m ²	17.57	178,248
Concrete Wall	190	m ³	600.00	114,000
Restorations		LS		23,000
SUBTOTAL				\$ 350,867
SUBTOTAL				\$7,305,211
Engineering and Contingencies - 35%				2,556,824
TOTAL				\$9,862,035
SAY				\$9,862,000

ESTIMATED COSTS FOR RAISING VARIOUS ROAD SEGMENTS (LOCAL SUBBASE)

Page 1 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Section A-B (Farms Road)				
Asphalt 50 mm	3126	m ²	6.65	\$ 20,789
Base Course	1192	m ³	27.20	32,434
Subbase	3323	m ³	5.00	16,614
Remove Exist. Pavement	2948	m ²	2.20	6,485
Tack Coat/Primer	3126	m ²	1.15	3,595
Stripping	616	m ³	2.25	1,387
Topsoil/Seeding	3007	m ²	2.30	6,916
Fencing	275	m	4.00	1,100
Culvert Extension	2	ea	990.00	1,980
Driveway Restoration	2	ea	440.00	880
Subtotal				\$92,179
Subtotal Incl. Eng. & Contingency (35%)				\$124,000
Section B-C (Sward Road)				
Asphalt 50 mm	3119	m ²	6.65	\$ 20,738
Base Course	1189	m ³	27.20	32,354
Subbase	4952	m ³	5.00	24,759
Remove Exist. Pavement	2940	m ²	2.20	6,469
Tack Coat/Primer	3119	m ²	1.15	3,586
Stripping	748	m ³	2.25	1,684
Topsoil/Seeding	3562	m ²	2.30	8,192
Fencing	550	m	4.00	2,200
Driveway Restoration	1	ea	610.00	610
Subtotal				\$100,592
Subtotal Incl. Eng. & Contingency (35%)				\$136,000
Section B-D (Farms Road)				
Asphalt 50 mm	4235	m ²	6.65	\$ 28,163
Base Course	1615	m ³	27.20	43,938
Subbase	8131	m ³	5.00	40,656

**ESTIMATED COSTS FOR RAISING
VARIOUS ROAD SEGMENTS (LOCAL SUBBASE)**

Page 2 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Remove Exist. Pavement	4417	m ²	2.20	9,716
Tack Coat/Primer	4235	m ²	1.15	4,870
Stripping	1125	m ³	2.25	2,532
Topsoil/Seeding	5276	m ²	2.30	12,134
Fencing	1100	m	4.00	4,400
Culvert Extension	1	ea	1,350.00	1,350
Driveway Restoration	1	ea	730.00	730
Subtotal				\$148,489
Subtotal Incl. Eng. & Contingency (35%)				\$200,000
Section D-E (Farms Road)				
Asphalt 50 mm	7700	m ²	6.65	\$ 51,205
Base Course	2937	m ³	27.20	79,886
Subbase	13068	m ³	5.00	65,340
Remove Exist. Pavement	8030	m ²	2.20	17,666
Tack Coat/Primer	7700	m ²	1.15	8,855
Stripping	1914	m ³	2.25	4,307
Topsoil/Seeding	9063	m ²	2.30	20,844
Fencing	1980	m	4.00	7,920
Culvert Extension	5	ea	1,260.00	6,300
Driveway Restoration	4	ea	650.00	2,600
Subtotal				\$264,923
Subtotal Incl. Eng. & Contingency (35%)				\$358,000
Section F-G				
Asphalt 50 mm	1309	m ²	6.65	\$ 8,705
Base Course	499	m ³	27.20	13,581
Subbase	875	m ³	5.00	4,376
Remove Exist. Pavement	1122	m ²	2.20	2,468
Tack Coat/Primer	1309	m ²	1.15	1,505
Stripping	213	m ³	2.25	480

**ESTIMATED COSTS FOR RAISING
VARIOUS ROAD SEGMENTS (LOCAL SUBBASE)**

Page 3 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Topsoil/Seeding	1047	m ²	2.30	2,407
Driveway Restoration	14	ea	330.00	4,620
Subtotal				\$ 38,142
Subtotal Incl. Eng. & Contingency (35%)				\$ 51,000
Section H-I				
Asphalt 50 mm	1463	m ²	6.65	\$ 9,729
Base Course	558	m ³	27.20	15,178
Subbase	2165	m ³	5.00	10,826
Remove Exist. Pavement	1254	m ²	2.20	2,759
Tack Coat/Primer	1463	m ²	1.15	1,682
Stripping	339	m ³	2.25	762
Topsoil/Seeding	1620	m ²	2.30	3,725
Driveway Restoration	6	ea	575.00	3,450
Subtotal				\$ 48,112
Subtotal Incl. Eng. & Contingency (35%)				\$ 65,000
Section E-J (Dale Road)				
Asphalt 50 mm	9571	m ²	6.65	\$ 63,648
Base Course	3651	m ³	27.20	99,299
Subbase	20564	m ³	5.00	102,821
Remove Exist. Pavement	9161	m ²	2.20	20,154
Tack Coat/Primer	9571	m ²	1.15	11,007
Stripping	2707	m ³	2.25	6,091
Topsoil/Seeding	12573	m ²	2.30	28,918
Fencing	2420	m	4.00	9,680
Bridge Upgrading		LS		60,000
Culvert Extension	2	ea	1,440.00	2,880

**ESTIMATED COSTS FOR RAISING
VARIOUS ROAD SEGMENTS (LOCAL SUBBASE)**

Page 4 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Driveway Restoration	3	ea	820.00	2,460
Subtotal				\$406,957
Subtotal Incl. Eng. & Contingency (35%)				\$549,000
Section E-K (Farms Road)				
Asphalt 50 mm	9240	m ²	6.65	\$ 61,446
Base Course	3524	m ³	27.20	95,864
Subbase	8890	m ³	5.00	44,451
Remove Exist. Pavement	9636	m ²	2.20	21,199
Tack Coat/Primer	9240	m ²	1.15	10,626
Stripping	1742	m ³	2.25	3,920
Topsoil/Seeding	8535	m ²	2.30	19,630
Fencing	1980	m	4.00	7,920
Bridge Upgrading		LS		130,000
Culvert Extension	2	ea	945.00	1,890
Driveway Restoration	8	ea	410.00	3,280
Subtotal				\$400,227
Subtotal Incl. Eng. & Contingency (35%)				\$540,000
Section E-L (Dale Road)				
Asphalt 50 mm	1733	m ²	6.65	\$ 11,521
Base Course	661	m ³	27.20	17,974
Subbase	3722	m ³	5.00	18,612
Remove Exist. Pavement	1658	m ²	2.20	3,648
Tack Coat/Primer	1733	m ²	1.15	1,992
Stripping	490	m ³	2.25	1,103
Topsoil/Seeding	2276	m ²	2.30	5,235
Fencing	495	m	4.00	1,980

ESTIMATED COSTS FOR RAISING VARIOUS ROAD SEGMENTS (LOCAL SUBBASE)

Page 5 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Driveway Restoration	1	ea	820.00	820
Subtotal				\$ 62,885
Subtotal Incl. Eng. & Contingency (35%)				\$ 85,000
Section L-M (Dale Road)				
Asphalt 50 mm	5005	m ²	6.65	33,283
Base Course	1909	m ³	27.20	51,926
Subbase	5320	m ³	5.00	26,598
Remove Exist. Pavement	4791	m ²	2.20	10,539
Tack Coat/Primer	5005	m ²	1.15	5,756
Stripping	987	m ³	2.25	2,220
Topsoil/Seeding	4814	m ²	2.30	11,073
Fencing	1430	m	4.00	5,720
Culvert Extension	1	ea	990.00	990
Driveway Restoration	1	ea	440.00	440
Subtotal				\$148,545
Subtotal Incl. Eng. & Contingency (35%)				\$201,000
Section N-O (Sward Road)				
Asphalt 50 mm	1463	m ²	6.65	9,729
Base Course	466	m ³	27.20	12,677
Subbase	839	m ³	5.00	4,196
Remove Exist. Pavement	1379	m ²	2.20	3,035
Tack Coat/Primer	1463	m ²	1.15	1,682
Stripping	226	m ³	2.25	508
Topsoil/Seeding	1100	m ²	2.30	2,531
Culvert Extension	1	ea	765.00	765

**ESTIMATED COSTS FOR RAISING
VARIOUS ROAD SEGMENTS (LOCAL SUBBASE)**

Page 6 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Driveway Restoration	7	ea	310.00	2,170
Subtotal				\$ 37,293
Subtotal Incl. Eng. & Contingency (35%)				\$ 50,000
TOTAL				\$1,748,000
TOTAL INCL. ENGINEERING & CONTINGENCY (35%)				\$2,360,000

JV/1p.4

**ESTIMATED COSTS FOR RAISING
VARIOUS ROAD SEGMENTS (IMPORTED SUBBASE)**

Page 1 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Section A-B (Farms Road)				
Asphalt 50 mm	3126	m ²	6.65	\$ 20,789
Base Course	1192	m ³	27.20	32,434
Subbase	3323	m ³	18.75	62,301
Remove Exist. Pavement	2948	m ²	2.20	6,485
Tack Coat/Primer	3126	m ²	1.15	3,595
Stripping	616	m ³	2.25	1,387
Topsoil/Seeding	3007	m ²	2.30	6,916
Fencing	275	m	4.00	1,100
Culvert Extension	2	ea	990.00	1,980
Driveway Restoration	2	ea	440.00	880
Subtotal				\$137,866
Subtotal Incl. Eng. & Contingency (35%)				\$186,000
Section B-C (Sward Road)				
Asphalt 50 mm	3119	m ²	6.65	\$ 20,738
Base Course	1189	m ³	27.20	32,354
Subbase	4952	m ³	18.75	92,845
Remove Exist. Pavement	2940	m ²	2.20	6,469
Tack Coat/Primer	3119	m ²	1.15	3,586
Stripping	748	m ³	2.25	1,684
Topsoil/Seeding	3562	m ²	2.30	8,192
Fencing	550	m	4.00	2,200
Driveway Restoration	1	ea	610.00	610
Subtotal				\$168,678
Subtotal Incl. Eng. & Contingency (35%)				\$228,000
Section B-D (Farms Road)				
Asphalt 50 mm	4235	m ²	6.65	\$ 28,163
Base Course	1615	m ³	27.20	43,938
Subbase	8131	m ³	18.75	152,460

**ESTIMATED COSTS FOR RAISING
VARIOUS ROAD SEGMENTS (IMPORTED SUBBASE)**

Page 2 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Remove Exist. Pavement	4417	m ²	2.20	9,716
Tack Coat/Primer	4235	m ²	1.15	4,870
Stripping	1125	m ³	2.25	2,532
Topsoil/Seeding	5276	m ²	2.30	12,134
Fencing	1100	m	4.00	4,400
Culvert Extension	1	ea	1,350.00	1,350
Driveway Restoration	1	ea	730.00	730
Subtotal				\$260,293
Subtotal Incl. Eng. & Contingency (35%)				\$351,000
Section D-E (Farms Road)				
Asphalt 50 mm	7700	m ²	6.65	\$ 51,205
Base Course	2937	m ³	27.20	79,886
Subbase	13068	m ³	18.75	245,025
Remove Exist. Pavement	8030	m ²	2.20	17,666
Tack Coat/Primer	7700	m ²	1.15	8,855
Stripping	1914	m ³	2.25	4,307
Topsoil/Seeding	9063	m ²	2.30	20,844
Fencing	1980	m	4.00	7,920
Culvert Extension	5	ea	1,260.00	6,300
Driveway Restoration	4	ea	650.00	2,600
Subtotal				\$444,608
Subtotal Incl. Eng. & Contingency (35%)				\$600,000
Section F-G				
Asphalt 50 mm	1309	m ²	6.65	\$ 8,705
Base Course	499	m ³	27.20	13,581
Subbase	875	m ³	18.75	16,409
Remove Exist. Pavement	1122	m ²	2.20	2,468
Tack Coat/Primer	1309	m ²	1.15	1,505
Stripping	213	m ³	2.25	480

**ESTIMATED COSTS FOR RAISING
VARIOUS ROAD SEGMENTS (IMPORTED SUBBASE)**

Page 3 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Topsoil/Seeding	1047	m ²	2.30	2,407
Driveway Restoration	14	ea	330.00	4,620
Subtotal				\$ 50,176
Subtotal Incl. Eng. & Contingency (35%)				\$ 68,000
Section H-I				
Asphalt 50 mm	1463	m ²	6.65	\$ 9,729
Base Course	558	m ³	27.20	15,178
Subbase	2165	m ³	18.75	40,598
Remove Exist. Pavement	1254	m ²	2.20	2,759
Tack Coat/Primer	1463	m ²	1.15	1,682
Stripping	339	m ³	2.25	762
Topsoil/Seeding	1620	m ²	2.30	3,725
Driveway Restoration	6	ea	575.00	3,450
Subtotal				\$ 77,884
Subtotal Incl. Eng. & Contingency (35%)				\$105,000
Section E-J (Dale Road)				
Asphalt 50 mm	9571	m ²	6.65	\$ 63,648
Base Course	3651	m ³	27.20	99,299
Subbase	20564	m ³	18.75	385,579
Remove Exist. Pavement	9161	m ²	2.20	20,154
Tack Coat/Primer	9571	m ²	1.15	11,007
Stripping	2707	m ³	2.25	6,091
Topsoil/Seeding	12573	m ²	2.30	28,918
Fencing	2420	m	4.00	9,680
Bridge Upgrading		LS		60,000
Culvert Extension	2	ea	1,440.00	2,880

**ESTIMATED COSTS FOR RAISING
VARIOUS ROAD SEGMENTS (IMPORTED SUBBASE)**

Page 4 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Driveway Restoration	3	ea	820.00	2,460
Subtotal				\$689,715
Subtotal Incl. Eng. & Contingency (35%)				\$931,000
Section E-K (Farms Road)				
Asphalt 50 mm	9240	m ²	6.65	\$ 61,446
Base Course	3524	m ³	27.20	95,864
Subbase	8890	m ³	18.75	166,691
Remove Exist. Pavement	9636	m ²	2.20	21,199
Tack Coat/Primer	9240	m ²	1.15	10,626
Stripping	1742	m ³	2.25	3,920
Topsoil/Seeding	8535	m ²	2.30	19,630
Fencing	1980	m	4.00	7,920
Bridge Upgrading		LS		130,000
Culvert Extension	2	ea	945.00	1,890
Driveway Restoration	8	ea	410.00	3,280
Subtotal				\$522,467
Subtotal Incl. Eng. & Contingency (35%)				\$705,000
Section E-L (Dale Road)				
Asphalt 50 mm	1733	m ²	6.65	\$ 11,521
Base Course	661	m ³	27.20	17,974
Subbase	3722	m ³	18.75	69,795
Remove Exist. Pavement	1658	m ²	2.20	3,648
Tack Coat/Primer	1733	m ²	1.15	1,992
Stripping	490	m ³	2.25	1,103
Topsoil/Seeding	2276	m ²	2.30	5,235
Fencing	495	m	4.00	1,980

**ESTIMATED COSTS FOR RAISING
VARIOUS ROAD SEGMENTS (IMPORTED SUBBASE)**

Page 5 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Driveway Restoration	1	ea	820.00	820
Subtotal				\$114,068
Subtotal Incl. Eng. & Contingency (35%)				\$154,000
Section L-M (Dale Road)				
Asphalt 50 mm	5005	m ²	6.65	33,283
Base Course	1909	m ³	27.20	51,926
Subbase	5320	m ³	18.75	99,743
Remove Exist. Pavement	4791	m ²	2.20	10,539
Tack Coat/Primer	5005	m ²	1.15	5,756
Stripping	987	m ³	2.25	2,220
Topsoil/Seeding	4814	m ²	2.30	11,073
Fencing	1430	m	4.00	5,720
Culvert Extension	1	ea	990.00	990
Driveway Restoration	1	ea	440.00	440
Subtotal				\$221,690
Subtotal Incl. Eng. & Contingency (35%)				\$299,000
Section N-O (Sward Road)				
Asphalt 50 mm	1463	m ²	6.65	9,729
Base Course	466	m ³	27.20	12,677
Subbase	839	m ³	18.75	15,734
Remove Exist. Pavement	1379	m ²	2.20	3,035
Tack Coat/Primer	1463	m ²	1.15	1,682
Stripping	226	m ³	2.25	508
Topsoil/Seeding	1100	m ²	2.30	2,531
Culvert Extension	1	ea	765.00	765

**ESTIMATED COSTS FOR RAISING
VARIOUS ROAD SEGMENTS (IMPORTED SUBBASE)**

Page 6 of 6

	Quantity	Unit	Unit Price (\$)	Extension
Driveway Restoration	7	ea	310.00	2,170
Subtotal				\$ 48,831
Subtotal Incl. Eng. & Contingency (35%)				\$ 66,000
TOTAL				\$2,736,000
TOTAL INCL. ENGINEERING & CONTINGENCY (35%)				\$3,694,000

JV/lp.3

ESTIMATED COST OF INSTALLING WATER BARS IN PATTISON CREEK CATCHMENT

Item	Quantity	Unit	Unit Price	Extension
Foreman	96	hours	34.20	\$3,283.20
Labourers	192	hours	27.00	5,184.00
Small Tools	---	LS	---	850.00
Helicopter	48	hours	660.00	31,680.00
Subtotal				\$40,997.20
Engineering (25%)				\$10,249.30
Contingencies (10%)				\$4,099.72
TOTAL				\$55,346.22
SAY				\$55,000.00

Based on installing twelve water bars and road crossings.

Labour rates include 20% mark-up for Contractor's overhead and profit.

Helicopter rental includes 10% mark-up for Contractor's overhead and profit.

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ESTIMATED COST OF PATTISON CREEK DIVERSION TO AMBER LAKE

Item	Quantity	Unit	Unit Price	Extension
Diversion Berm	80,000	m ³	10.00	\$800,000
Channel	30,000	m ³	10.00	300,000
End Dam	24,000	m ³	10.00	240,000
Spillway	17,000	m ³	10.00	170,000
Clearing Trees	16	ha	10,000.00	160,000
Access Road	1,000	m	75.00	75,000
Subtotal				\$1,745,000
Engineering and Contingencies (35%)				\$610,750
10-Year Maintenance*				\$300,000
TOTAL				\$2,655,750
SAY				\$2,650,000

*10-Year Maintenance = \$25,000/year for moving sediment by equipment except at the end of year 5 when a debris torrent is assumed and the added cost becomes \$50,000 for movement of torrent deposit.

**ESTIMATED COST OF SEDIMENT EXCAVATION
FROM LAGACE AND PATTISON CREEKS
BASED ON A 10 YEAR PERIOD**

Item	Quantity	Unit	Unit Price	Extension
Gravel Excavation	300,000	m ³	3.33	\$1,000,000
Debris Torrent Cleanup	100,000	m ³	5.00	500,000
Subtotal				\$1,500,000
Engineering and Contingencies (35%)				\$525,000
TOTAL				\$2,025,000

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**ESTIMATED COST OF
EXCAVATION FROM SEDIMENT TRAP
BASED ON A 10 YEAR PERIOD**

Item	Quantity	Unit	Unit Price	Extension
Excavation of Trap	50,000	m ³	5.00	\$250,000
Annual Excavation	300,000	m ³	3.33	1,000,000
Debris Torrent Cleanup	100,000	m ³	5.00	500,000
Subtotal				\$1,750,000
Engineering and Contingencies (35%)				\$612,500
Land Acquisition				\$28,800
TOTAL				\$2,391,300
SAY				\$2,390,000

**ESTIMATED COST TO LENGTHEN
SYLVESTER ROAD BRIDGE OVER
PATTISON CREEK**

Item	Quantity	Unit	Unit Price	Extension
Bridge	---	LS	750,000	\$750,000
Raise Road	---	LS	75,600	75,600
Excavation	2,250	m ³	7.00	15,750
Riprap	800	tonne	20.00	16,000
Subtotal				\$857,350
Engineering and Contingencies (35%)				\$300,000
TOTAL				\$1,157,350
SAY				\$1,157,000

KRR/rb/VP97/report/rep.4

**ESTIMATED COST OF COMBINED LAKE LEVEL CONTROL AND
DEBRIS CONTROL STRUCTURE AT LOUGHEED HIGHWAY**

Item	Quantity	Unit	Unit Price	Extension
Mobilization and Demobilization		LS		\$ 10,000
B7-17 Sheet Piles	190	m ²	220.00	41,800
356 mm dia Pipe Piles	180	m	225.00	40,500
Debris Screen		LS		20,000
Stop Logs		LS		6,000
Aluminum Decking Walkway		LS		16,000
Lifting Beam and Miscellaneous Metalwork		LS		10,000
Approach Ramp	2,000	m ³	8.00	16,000
Rock Riprap	360	t	25.00	9,000
Subtotal				\$169,300
Engineering and Contingencies (35%)				\$59,300
TOTAL				\$228,600

**ESTIMATED COST OF STOP LOGS AT EXISTING AND
NEW FLOODBOX STRUCTURE INCLUDING LOG BOOM AT INTAKE CHANNEL**

Item	Quantity	Unit	Unit Price	Extension
Two Piles and Log Boom Chain		LS		\$20,000
'A' Frame Structure, Lifting Beam and Pulley Block	2	ea	20,000	40,000
Stop Logs for Floodboxes	2	ea	4,000	8,000
Subtotal				\$68,000
Engineering and Contingenciesd (35%)				\$24,000
TOTAL				\$92,000

KRR/rb/VP97.62

**ESTIMATED COST OF BANK PROTECTION WORK FOR HATZIC SLOUGH
SOUTH OF CPR CULVERTS**

Item	Quantity	Unit	Unit Price	Extension
Bank Excavation	200	m ³	6.00	\$ 1,200
300 mm Thick Filter Layer	84	m ³	25.00	2,100
600 mm Thick Rock Riprap	336	t	25.00	8,400
Subtotal				\$11,700
Engineering and Contingencies (35%)				\$ 4,095
TOTAL				\$15,795
SAY				\$16,000

**COST ESTIMATES
FOR LOCAL DRAINAGE PROBLEMS**

Page 1 of 4

CULVERT AT SYLVESTER/SEUX ROAD

Item	Quantity	Unit	Unit Price	Extension
Pipe	20	m	200.00	\$4,000
Pavement Restoration		LS		1,000
Subtotal				\$5,000
Contingencies (35%)				1,750
TOTAL				\$6,750
SAY				\$7,000

CULVERT WEST OF 35584 DURIEU ROAD

Item	Quantity	Unit	Unit Price	Extension
Concrete Sandbag wall upstream		LS		\$4,400
Contingency (35%)				1,540
TOTAL				\$5,940
SAY				\$6,000

DRAINAGE OF ROBSON PROPERTY

Item	Quantity	Unit	Unit Price	Extension
ALTERNATIVE 1				
Ditch along east side of Madaris Road to Chilqua Slough	1400	m ³	9.00	\$12,600
Culverts	2	ea	2,000.00	4,000
Subtotal - Alternative 1				\$16,600
Contingency (35%)				5,810
TOTAL				\$22,410
SAY				\$22,500
ALTERNATIVE 2				
Drainage Tile: Excavation and Backfill	260	m ³	8.00	\$2,080
Backfill Drain Rock	22	m ³	30.00	660

**COST ESTIMATES
FOR LOCAL DRAINAGE PROBLEMS**

Page 2 of 4

Item	Quantity	Unit	Unit Price	Extension
Supply and Install Big "O" Drainage Tile (300 mm dia)	235	m	37.20	8,742
Subtotal - Alternative 2				\$11,482
Contingencies (35%)				4,020
TOTAL				\$15,502
SAY				\$15,500

SWARD ROAD SUBDIVISION

Item	Quantity	Unit	Unit Price	Extension
ALTERNATIVE 1 - DRAINAGE SYSTEM				
450 mm dia	180	m	240.00	\$43,500
525 mm dia	170	m	273.00	46,410
750 mm dia	60	m	336.00	20,160
Lawn Basins	22	ea	250.00	5,500
Leads to Lawn Basins	330	m	100.00	33,000
Manholes	5	ea	3,000.00	15,000
Conc. Outlet		LS		6,000
Subtotal - Alternative 1				\$169,570
Contingency (35%)				59,350
TOTAL				\$228,920
SAY				\$230,000
ALTERNATIVE 2 - DRAINAGE TILE SYSTEM				
Excavation	980	m ³	6.00	\$ 5,868
Drain Rock Backfill	980	m ³	30.00	29,400
Supply and Install Big "O" Drainage Tile - 300 mm dia	560	m	37.20	20,832
- 450 mm dia	100	m	63.15	6,315
Restoration of Asphalt Driveways		LS		10,000
Restoration of Road Crossing		LS		1,500

**COST ESTIMATES
FOR LOCAL DRAINAGE PROBLEMS**

Page 3 of 4

Item	Quantity	Unit	Unit Price	Extension
Manholes	1	ea	2,000.00	2,000
Rock Protection at Outlet	50	t	30.00	1,500
Subtotal - Alternative 2				\$ 77,415
Contingencies (35%)				27,095
TOTAL				\$104,510
SAY				\$105,000

LEISHMAN PROPERTY - 8689 SYLVESTER ROAD

Item	Quantity	Unit	Unit Price	Extension
900 mm dia Culvert	10	m	200.00	2,000
Fill for Driveway	600	m ³	10.00	6,000
Clean Out Ditch		LS		2,000
Subtotal				\$10,000
Contingency (35%)				3,500
TOTAL				\$13,500
SAY				\$13,500

SOUTH OF CPR - McKAMIE ROAD AND NEWTON ROAD

Item	Quantity	Unit	Unit Price	Extension
WORK ON ROAD RIGHT-OF-WAY				
Replace Culvert crossing Newton Road with 900 mm dia pipe	20	m	200.00	\$ 4,000
Pavement Restoration		LS		1,000
Clean out Culvert at McKamie Road and CPR Tracks		LS		3,000
Clean Ditches along road ROW's	130	m	7.00	910

COST ESTIMATES FOR LOCAL DRAINAGE PROBLEMS

Page 4 of 4

Item	Quantity	Unit	Unit Price	Extension
Subtotal on Road Right-of-Way				\$ 8,910
Contingency (35%)				3,120
TOTAL				\$12,030
SAY				\$12,000
WORK ON CPR RIGHT-OF-WAY				
Clean out CPR Culvert (0.6 m x 0.9 m x 35 m)		LS		\$ 3,000
Clean Ditches along CPR Tracks	270	m	7.00	1,890
Subtotal Work on CPR Right-of-Way				\$ 4,890
Contingencies (35%)				1,711
TOTAL				\$6,602
SAY				\$6,600
WORK ON PRIVATE PROPERTY				
Clean Ditches	940	m	7.00	\$ 6,580
Subtotal Work on Private Property				\$ 6,580
Contingencies (35%)				2,303
TOTAL				\$8,883
SAY				\$9,000

H. WHITE - 8413 MCKENZIE STREET - BENBOW SUBDIVISION

Item	Quantity	Unit	Unit Price	Extension
Excavation	100	m ³	10.00	\$1,000
Subtotal				\$1,000
Contingencies (35%)				350
TOTAL				\$1,350
SAY				\$1,400

**ESTIMATED COST OF
LOCAL DYKING AND RELATED ROAD IMPROVEMENTS**

BENBOW SUBDIVISION DYKING COSTS

Item	Quantity	Unit	Unit Price (\$)	Extension
Stripping	1245	m ³	3.00	\$ 3,395
Composite Fill	8178	m ³	10.00	74,343
Topsoil and Seeding	5679	m ²	3.00	15,488
Culvert c/w Flapgate	4	ea	2,500.00	10,000
Land Acquisition	1417	m ²	0.60	773
Legal Survey		LS	5,000.00	5,000
Subtotal				\$108,999
Engineering Design and Contingency (35%)				38,150
Benbow Dyke Total				\$147,000

RIVERSIDE ROAD/YOUNGSTON ROAD SUBDIVISION DYKING COSTS

Item	Quantity	Unit	Unit Price (\$)	Extension
Concrete Wall	132	m ³	600.00	\$150,600
Stripping	1029	m ³	3.00	3,087
Culverts c/w Flapgate	3	ea	2,500.00	7,500
Land Acquisition	1575	m ²	0.60	945
Legal Survey		LS	5,000.00	5,000
Asphalt	3,465	m ²	6.65	23,042
Base Course	1,322	m ³	27.20	35,958
Subbase	5,515	m ³	5.00	27,575
Remove Asphalt	2,970	m ²	2.20	6,534
Tack Coat	3,465	m ²	1.15	3,985
Topsoil and Seeding	3,496	m ²	2.30	8,041
Subtotal				\$272,267
Engineering Design and Contingency (35%)				95,293
Riverside Dyke Total				\$368,000

LENGTHEN SYLVESTER ROAD BRIDGE

Item	Quantity	Unit	Unit Price	Extension
Bridge		LS		\$750,000
Stripping	673	m ³	2.25	1,514
Subbase	6,981	m ³	5.00	34,905
Topsoil/Seeding	2,946	m ²	2.30	6,776
Asphalt	1,617	m ²	6.65	10,753
Base Course	617	m ³	27.20	16,782
Remove Pavement	1,386	m ²	2.20	3,049
Tack Coat	1,617	m ²	1.15	1,860
Channel Excavation	2,250	m ³	7.00	15,750
Riprap	800	t	20.00	16,000
Subtotal				\$ 857,389
Engineering and Contingencies (35%)				300,086
TOTAL				\$1,157,475
SAY				\$1,157,000

ESTIMATED COST TO REPLACE EXISTING PUMP STATION IMPELLER

Item	Quantity	Unit	Unit Price	Extension
New Pattern	1	ea	10,000	\$10,000
New Impeller	2	ea	20,000	40,000
Labour to Remove and Replace Pump Including Transportation to Shop	2	ea	6,000	12,000
Subtotal				\$62,000
Engineering and Contingenciesd (35%)				\$21,700
TOTAL				\$83,700
SAY				\$85,000

KRR/rb/VP97.64

**ESTIMATED COST OF DIVERSION OF UNNAMED CREEK
800 m NORTH OF SCOREY CREEK**

Item	Quantity	Unit	Unit Price	Extension
Ditch Excavation - Side Cast and Spread Spoil Material	8,000	m ³	6.00	\$48,000
Culvert 900 mm dia	11	m	450.00	4,950
Subtotal				\$52,950
Engineering and Contingencies (35%)				\$18,550
Land Acquisition Costs				\$10,000
TOTAL				\$81,500

APPENDIX E

CREAGER FLOOD ENVELOPE CURVES

APPENDIX E

BACKGROUND ON CREAGER FLOOD ENVELOPE CURVES AND FORMULA

The Creager diagram, covering a large number of "unusual" flood peak discharges from the USA and some other countries, received wide circulation through a publication by Creager et al (1945). It was modified by Neill (1986) to include some data on unusual floods in Canada. With additional Canadian data, the modified diagram was included in the NRC publication "Hydrology of Floods in Canada" (Watt et al 1989). It was further modified by Neill (1991) to include a few additional data, as well as recent PMF estimates for projects in western Alberta. The 1991 version is shown in Drawing No. A2-1.

The diagram plots peak instantaneous unit discharge ($q = Q/A$) against drainage area (A), over a range of 1 to more than 1,000,000 square miles. The data are enveloped by a set of curves that follow a complex formula devised by Creager, each curve for a different value of the Creager coefficient C . In terms of total discharge Q in m^3/s and drainage area A in km^2 , the formula can be written as:

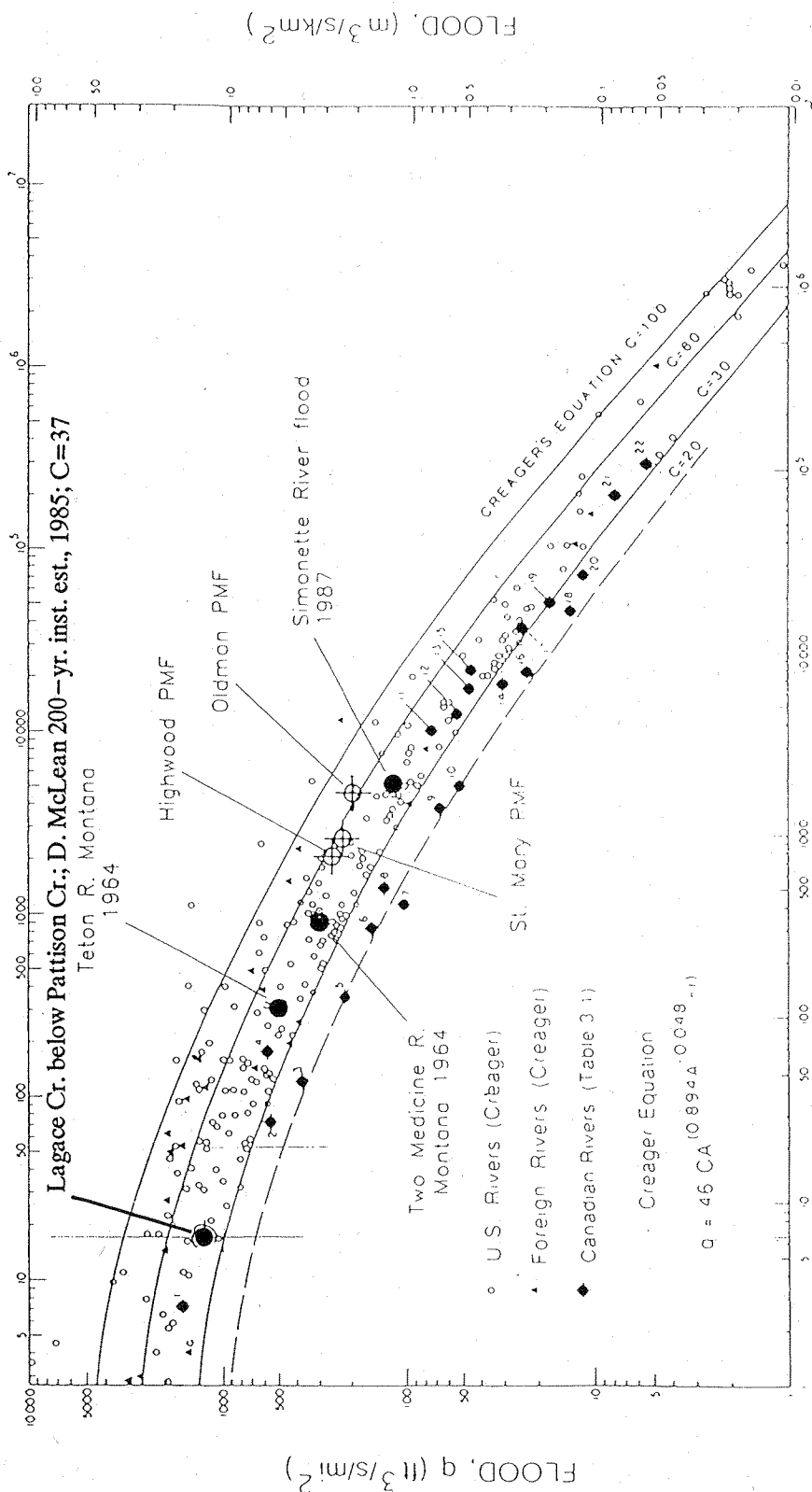
$$Q = 1.303 * C * (A/2.59)^{0.936/A^{0.048}}$$

For very small areas, the unit discharge q for a given C is virtually independent of area, that is, peak discharge increases almost proportionally to area: this reflects the physical condition that small basins are blanketed by the critical storms. For very large areas, the unit discharge for a given C is almost inversely proportional to area, that is, the peak discharge is almost constant: this reflects the physical condition that the areal coverage of a single storm is limited.

The value of C for a given basin accounts implicitly for climatic, abstraction-from-rainfall and routing factors. It should be higher for regions of higher storm rainfall intensities, and for basins of lower infiltration capacities and steeper slopes.

The limited plotting of unusual Canadian flood data (which were drawn from most provinces and territories) indicates that the highest gauged events in Canada generally have C values in the range of 20 to 40, with an upper limit of about 45 to date. In contrast, many of Creager's data from USA and elsewhere reached C values of 100 or more. Recent PMF determinations in western Alberta correspond to C values in the range of 55 to 70.

DRAINAGE AREA (km²)



Creager's diagram with added Canadian and Montana flood data and recent PMF estimates for western Alberta.

Adapted from Watt et al (1989)

Hatzic Prairie Study

Creager's Diagram

northwest hydraulic consultants

APPENDIX F

VARIABILITY OF INSTANTANEOUS TO DAILY MAXIMUM FLOW RATIO

APPENDIX F

VARIABILITY OF INSTANTANEOUS TO DAILY MAXIMUM FLOW RATIO

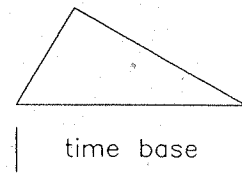
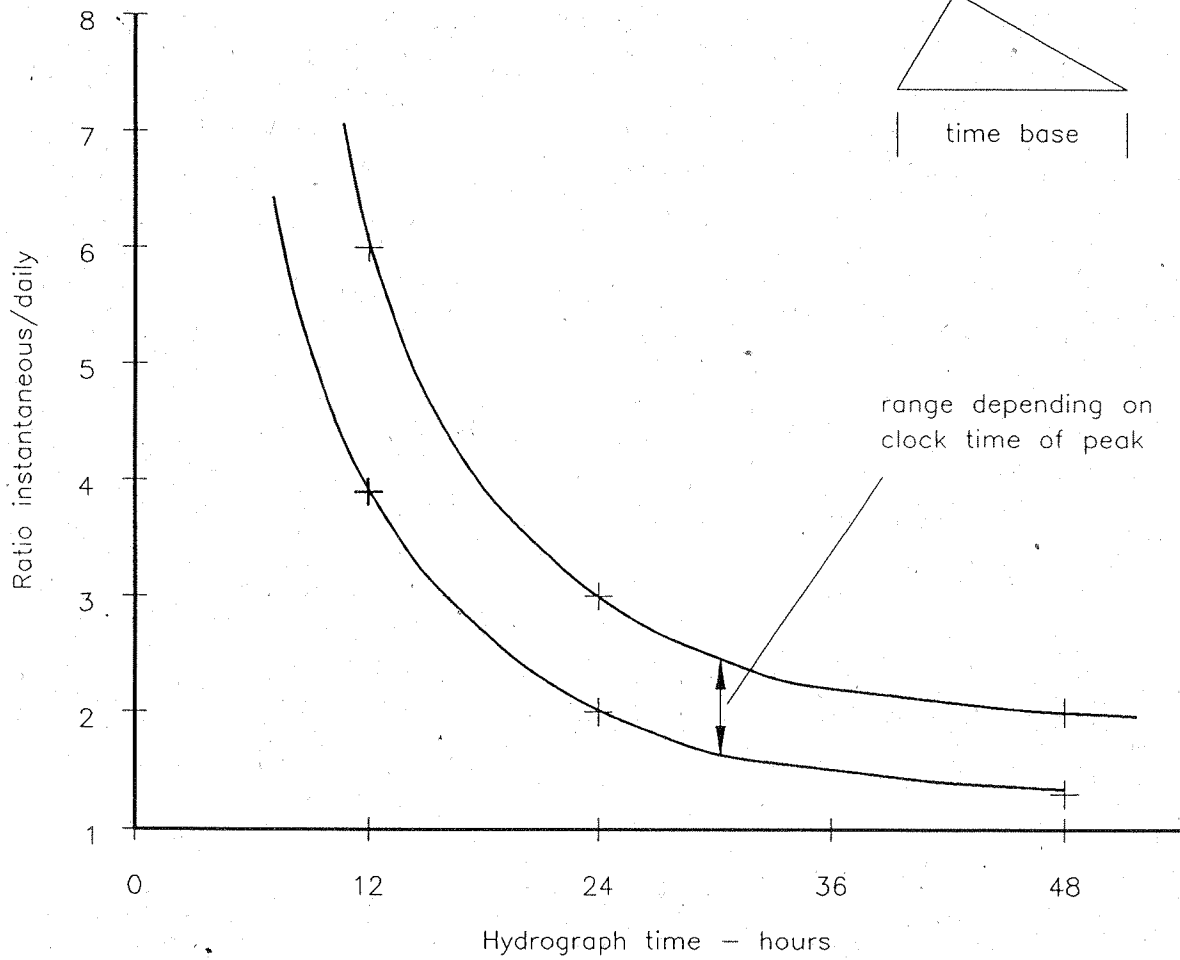
Unit hydrograph theory postulates that the time base of the direct runoff hydrograph for a given basin is more or less independent of the rainfall, but that the ordinates are proportional to the effective rainfall. It can therefore be reasoned that the peak-to-daily ratio for a given basin should not depend significantly on the frequency of the event. If the reported instantaneous and daily annual maxima for a given station are examined, the ratios usually found to vary more or less randomly and not to depend on the size of the event.

On the other hand, the ratio is very dependent on the size of the basin, small basins tending to have larger ratios. It also depends on the time of day at which the instantaneous peak occurs.

To examine these effects, numerical experiments were done assuming a simple triangular hydrograph with different time bases and different positioning of the peak within the day. Results are indicated in Drawing No. A2-2. These indicate that if the hydrograph base is 2 days or more, the ratio can vary from about 1.3 to 2 depending on the time of day. For a time base of 1 day, the ratio can vary from 2 to 3. For a time bases of 12 hours, the ratio can vary from 4 to 6. For shorter time bases, the ratio and its range of variation rise steeply.

It follows that for small basins with hydrograph time bases of one day or less, flood frequency analyses based on daily maxima are not of much value for inferring instantaneous maxima, and that the application of a constant multiplying factor to daily data is difficult to justify.

Assumed hydrograph :



Hatzic Prairie Study

Variability of Inst./Daily
Maximum Flow Ratios

northwest hydraulic consultants

XXXXXXXXXX

XXXXXXXXXX

XXXXXXXXXX

XXXXXXXXXX

APPENDIX G

LAKE SURVEY



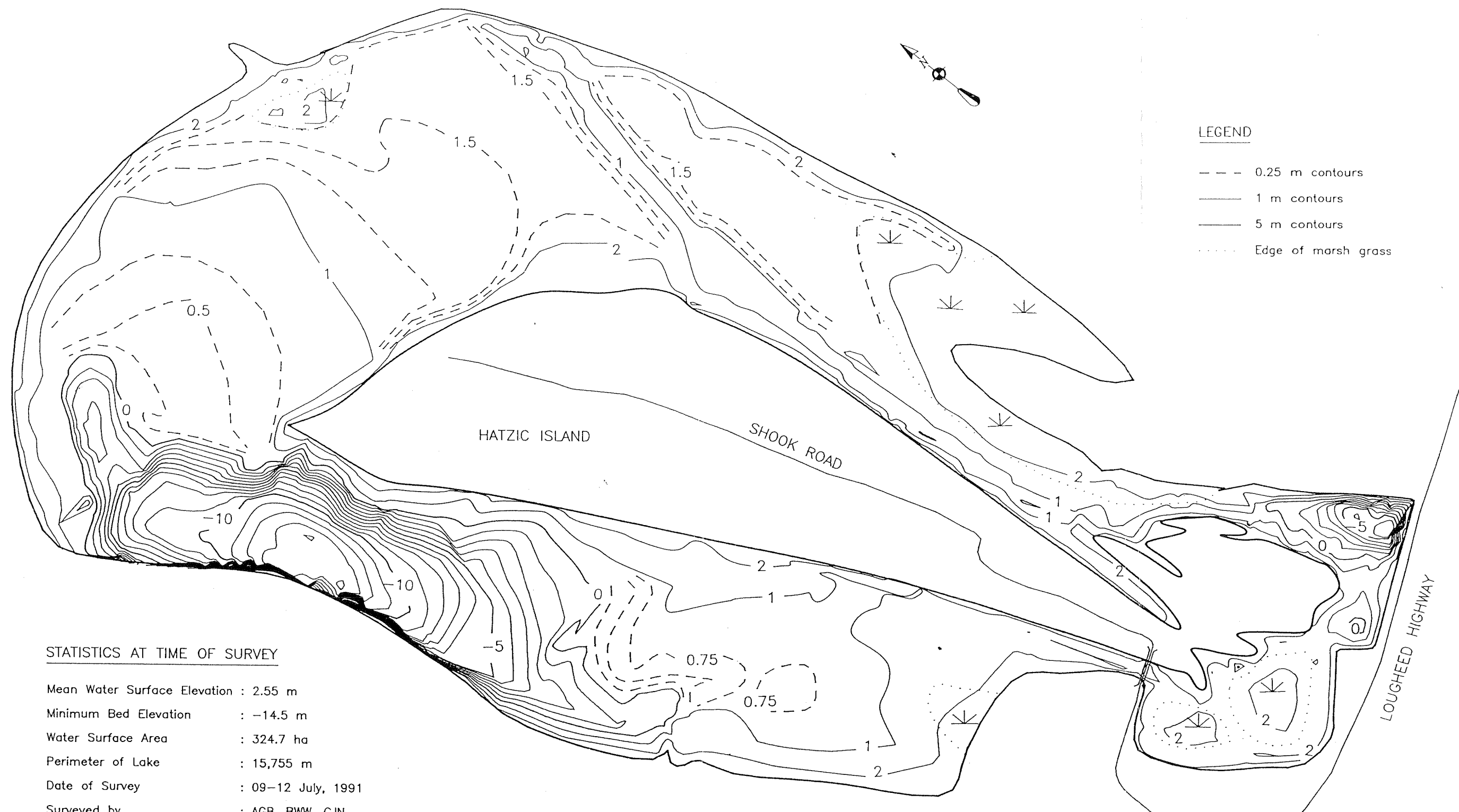
STATISTICS AT TIME OF SURVEY

Mean Water Surface Elevation	: 2.16 m
Minimum Bed Elevation	: -14.6 m
Water Surface Area	: 336.3 ha
Perimeter of Lake	: 15,144 m
Date of Survey	: 30 June, 1951
Surveyed by	: TGN, GES
Contour Interval	: 1 m
All elevations are in geodetic metres.	
Lake outline obtained from old survey map.	

NOTES

- 1) The mean water surface elevation of 2.16 m is the mean lake level for the period 23 June to 7 July, over which time the lake level varied no more than 4 cm.
- 2) The original contours were given as depth below the water surface, as given above.

Hatzic Prairie Study
Hatzic Lake Bathymetry June 1951
northwest hydraulic consultants



STATISTICS AT TIME OF SURVEY

Mean Water Surface Elevation : 2.55 m
 Minimum Bed Elevation : -14.5 m
 Water Surface Area : 324.7 ha
 Perimeter of Lake : 15,755 m
 Date of Survey : 09-12 July, 1991
 Surveyed by : AGB, BWW, CJN
 Contour Interval : 1 m

All elevations are in geodetic metres.

Lake outline digitized from airphoto SRS 4335-135 (21 June, 1990).

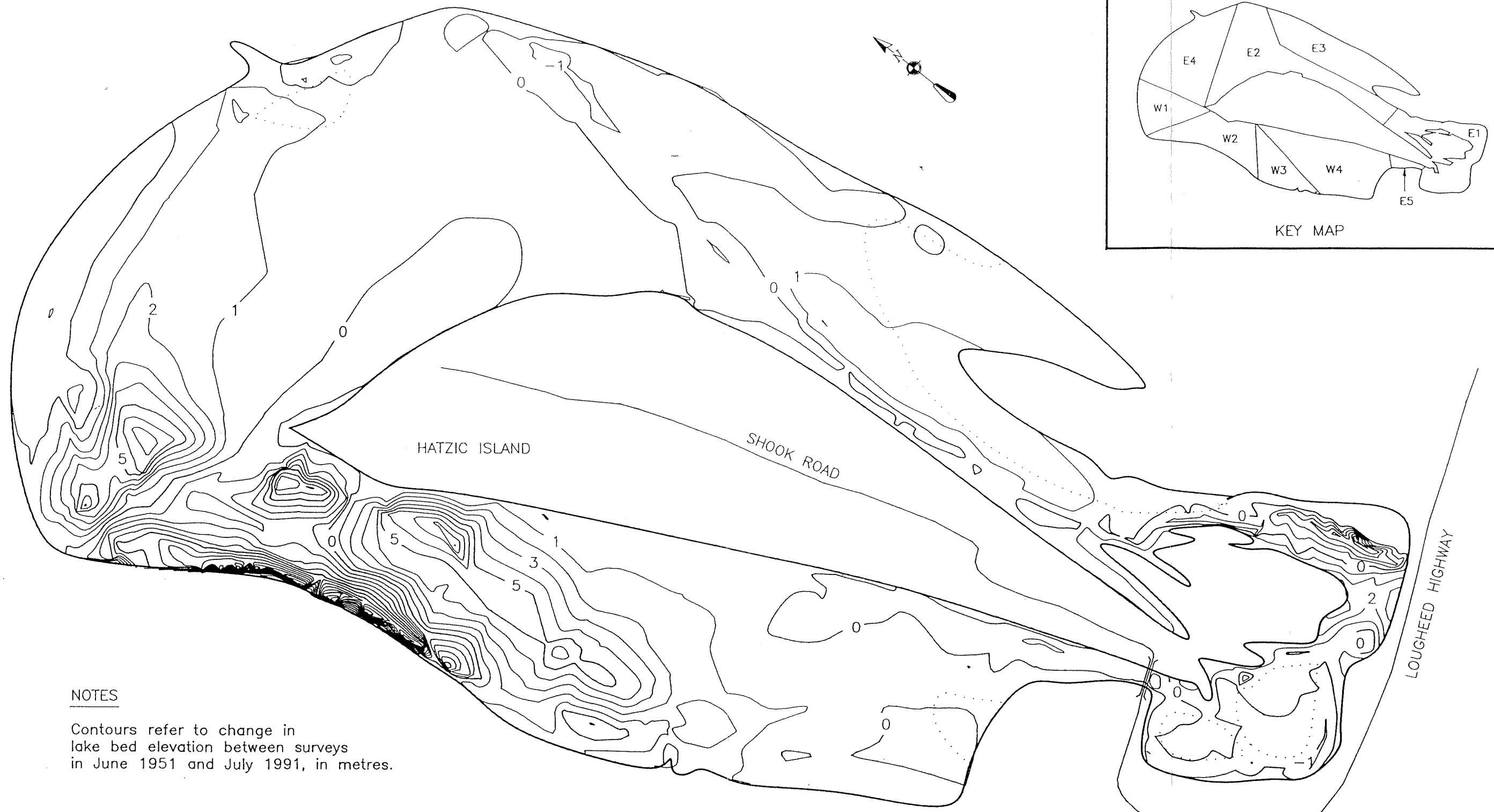
0 500 m

Scale 1:10,000

Hatzic Prairie Study

Hatzic Lake Bathymetry
July 1991

northwest hydraulic consultants



NOTES

Contours refer to change in lake bed elevation between surveys in June 1951 and July 1991, in metres.



Scale 1:10,000

Hatzic Prairie Study

Change in Bed Elevation
Hatzic Lake, 1951-1991

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APPENDIX H

SEDIMENT ANALYSIS



NORWEST LABS

"Keeping B.C. Growing"

TELEPHONE (604) 530-4344
FACSIMILE (604) 534-9996

W.O. #3812

October 15, 1991

Northwest Hydraulic Consultants
#2 - 40 Gostick Place
North Vancouver, B.C. V6M 3G2

Attention: Alan Bates

COMMENTS RE: HATZIC LAKE DREDGE SAMPLES

Physical analysis of the samples indicates that most have a reasonably good proportion of sand, silt, and clay. The exceptions are Dredge samples #9 and #10 which are high in sand (over 80%), and samples #3, #4 and #8 which are somewhat high in silt. The high sand soils will not retain water or nutrients well, while soils high in silt may not drain properly.

The principal limiting factor in all the soils is organic matter. It is low (below 3%) in all samples, and very low (below 1%) in samples #1, 2, 5, 7, 9 and 10. Organic matter is important in supplying certain nutrients (principally Nitrogen and Sulfur), as well as helping to retain moisture and nutrients in the soil. Supplemental organic matter such as peat or manure would be useful to mix with these soils.

Chemical analysis of the soils does not show any particular problems. Sodium and sodium absorption ratio levels are all low. None of the materials tested are at toxic levels. Most of the nutrients tested are at normal levels for surface soils. Salinity levels are low, which is good, and pH levels are within normal levels (5.5 to 7.0), although they are on the acid side. Phosphorus and Boron are quite low in all the samples.

In summary, these soils would all be suitable as fill on agricultural land, although some are more suitable than others. Mixing of these soils with existing surface soils by rototilling them would be preferential to simply spreading them on top. Addition of lime and fertilizer would be necessary, particularly Boron and Phosphorus. Incorporation of additional organic matter would be helpful unless the dredged soil is mixed with a higher organic matter surface soil.

Sincerely,

Dr. Thomas F. Guthrie, P.Ag.
Laboratory Manager

TFG/me

Norwest Labs



"We Solve Problems"

203 - 20771 Langley Bypass
Langley, B.C. V3A 5E8
(604) 530-4344
FAX 534-9996

Norwest Labs

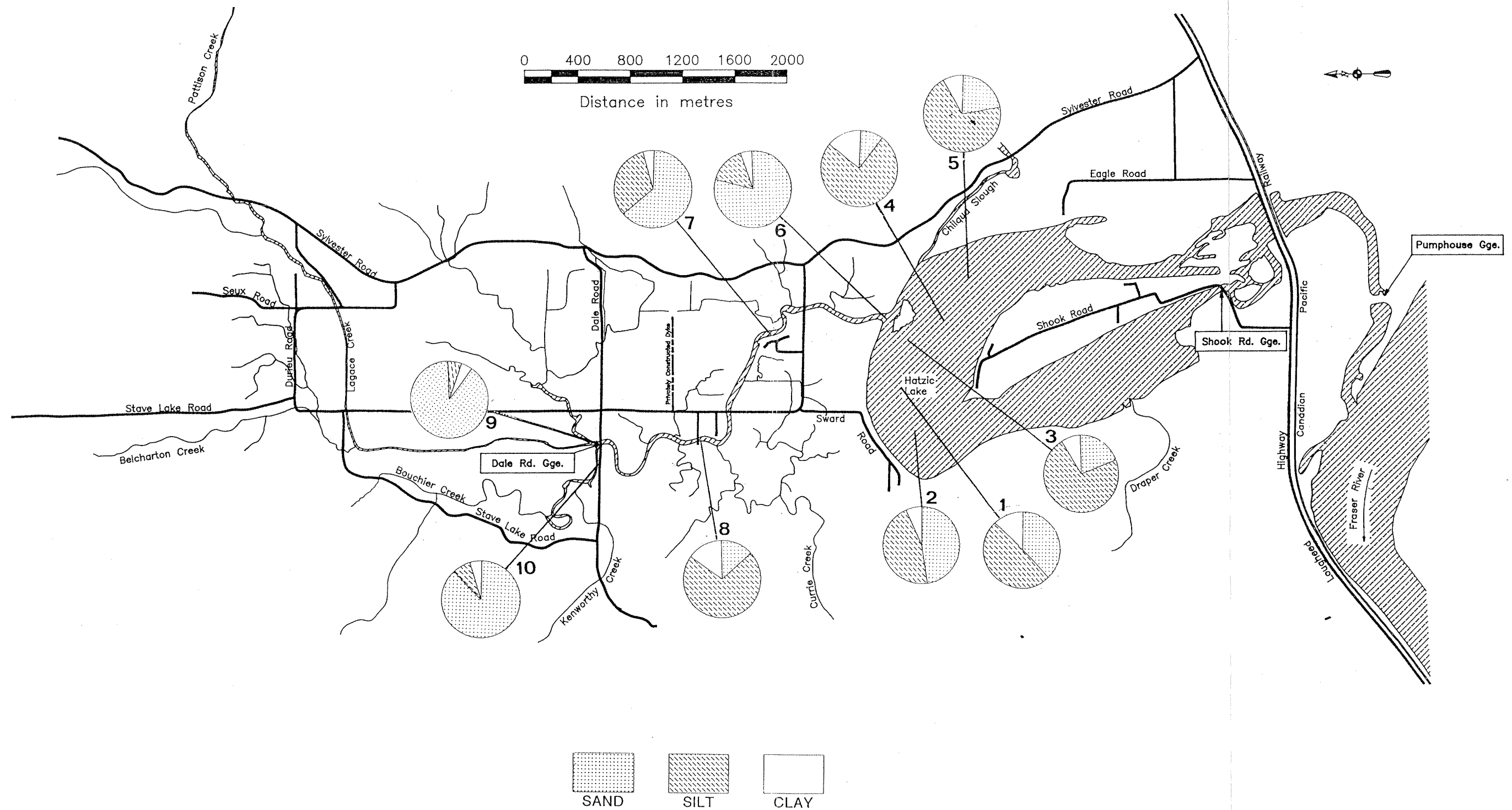
NORTHWEST HYDRAULIC CONSULTANTS
#2 - 40 Gostick Place
North Vancouver, B.C. V7M 3G2

W.O. 3812

September 26, 1991

HATZIC LAKE DREDGE SOIL ANALYSIS

LAB #	SAMPLE ID	PARTICLE SIZE ANALYSIS			CALCIUM	MAGNESIUM	SODIUM	SODIUM ABSORPTION	CHLORIDE
		SAND	SILT	CLAY				RATIO	
		----- % -----			----- me/100g-----				ppm
91-5689	Dredge #1	37.6	49.6	12.8	19.1	5.7	1.6	0.45	14
91-5690	2	47.6	45.6	6.8	20.9	6.2	3.9	1.06	114
91-5691	3	19.6	71.6	8.8	29.4	8.1	3.2	0.74	18
91-5692	4	9.6	75.6	14.8	37.4	21.2	2.2	0.41	16
91-5693	5	21.6	69.6	8.8	28.0	14.4	1.6	0.35	21
91-5694	6	79.6	15.6	4.8	9.2	2.8	0.86	0.35	12
91-5695	7	63.6	31.6	4.8	8.3	2.2	2.4	1.05	14
91-5696	8	13.6	71.6	14.8	32.4	13.6	3.6	0.75	205
91-5697	9	89.6	5.6	4.8	8.7	2.5	1.1	0.46	17
91-5698	10	87.6	7.6	4.8	8.2	3.0	1.1	0.46	12



Hatzic Prairie Study

Sediment Sample Locations
September 1991

northwest hydraulic consultants



NORWEST SOIL RESEARCH INC.,
203 20771 LANGLEY BYPASS,
LANGLEY, B.C., V3A 5E8

W.O. NUMBER: 3812
PAGE:
LAB NUMBER: 915689

SAMPLE SUBMITTED BY:
NORTHWEST HYDRAULIC CONSULTANTS

1 - 40 BOSTICK PLACE GROWER
N. VANCOUVER, B.C. V6M 3G2
Attention of: ALAN BATES

SAMPLE RECEIVED: 09-13-1991
ANALYSIS COMPLETED: 09-23-1991
SAMPLE RETAINED UNTIL FOR 60 days
FOR INFORMATION CALL Dr. T. Guthrie
AT: 530-4344

Sample description: LEGAL LOCATION
HATZIC LAKE DREDGE #1 SOIL

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)														
	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATE	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	MOLYBDENUM	CHLORIDE
	26	3	7	92	4.0	766	38	138	310	1.5	36.0	0.4	60		
TOTAL SS./ACRE	63	8	18	224	9.7	1861	92	335	753	3.6	87.5	1.0	146		
EXCESS											###		###		
OPTIMUM	###					###		###	###		###		###		
MARGINAL	###			###	###	###		###	###	###	###		###		
EFFICIENT	###		###	###	###	###		###	###	###	###	###	###		
	N		P	K	S	Ca	Na	Mg	Fe	Cu	Zn	B	Mn	Mo	Cl

SAMPLE DEPTH	SOIL QUALITY			
	PH (ACIDITY)	E.C. (SALINITY)	ORGANIC MATTER %	TEXTURE
	5.90	0.14	0.61	Min

COMMENTS

RECOMMENDATIONS

SOIL:		LAST CROP:		CROPPING PRACTICE:				
TARGET	CROP CHOICE	EXPECTED YIELDS	N	P ₂ O ₅		K ₂ O	S	LIME AND MICRONUTRIENTS Total N 0.033 % C/N Ratio - 10.4 Aluminum - 0.1 ppm
				PLACED	or BROADCAST			
HIGH								
MODERATE								
YOUR GOAL								



NORWEST SOIL RESEARCH INC.
203 20771 LANGLEY BYPASS,
LANGLEY, B.C., V3A 5E6

W.O. NUMBER: 3812
PAGE:
LAB NUMBER: 915670

SAMPLE SUBMITTED BY:
NORTHWEST HYDRAULIC CONSULTANTS

- 40 GOSTICK PLACE
VANCOUVER, B.C. V6M 3G2
Attention of: ALAN BATES

SAMPLE RECEIVED: 09-13-1991
ANALYSIS COMPLETED: 09-23-1991
SAMPLE RETAINED UNTIL: For 60 days
FOR INFORMATION CALL: Dr. T. Guthrie
AT: 530-4344

LEGAL LOCATION
Sample description: HATZOC LAKE DREDGE #2 SOIL

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)														
	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATE	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	MOLYBDENUM	CHLORIDE
	10	21	7	91	5.6	840	90	151	300	2.1	11.0	0.5	37		
TOTAL S./ACRE	23	49	17	211	13.0	1950	209	351	696	4.9	25.5	1.2	86		
EXCESS													###		
OPTIMUM					###	###		###	###		###		###		
ORIGINAL	###	###		###	###	###		###	###	###	###		###		
	###	###		###	###	###		###	###	###	###		###		
	###	###	###	###	###	###		###	###	###	###	###	###		
DEFICIENT	###	###	###	###	###	###		###	###	###	###	###	###		
	N	P	K	S	Ca	Na	Mg	Fe	Cu	Zn	B	Mn	Mo	Cl	

SAMPLE DEPTH	SOIL QUALITY			
	PH (ACIDITY)	E.C. (SALINITY)	ORGANIC MATTER %	TEXTURE
	5.57	0.54	0.8	Min

COMMENTS:

RECOMMENDATIONS

SOIL:		LAST CROP:		CROPPING PRACTICE:		
TARGET	CROP CHOICE	EXPECTED YIELDS	N	P ₂ O ₅		S
				PLACED	or BROADCAST	
HIGH						
MODERATE						
YOUR GOAL						

LIME AND MICRONUTRIENTS

Total N - 0.046% C/N ratio - 9.5
Aluminum - 0.1 ppm

NORWEST SOIL RESEARCH INC.
203 20771 LANGLEY BYPASS,
LANGLEY, B.C., V3A 5E8

W.O. NUMBER: 3812
PAGE:
LAB NUMBER: 915691

SAMPLE SUBMITTED BY:
NORTHWEST HYDRAULIC CONSULTANTS

- 40 GOSTICK PLACE
VANCOUVER, B.C. V6M 3G2
Attention of: ALAN BATES

SAMPLE RECEIVED: 09-13-1991
ANALYSIS COMPLETED: 09-23-1991
SAMPLE RETAINED UNTIL: For 60 days
FOR INFORMATION CALL: Dr. T. Guthrie
AT: 530-4344

Sample description: LEGAL LOCATION
HATZIC LAKE DREDGE #3 SOIL

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)													
	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATE	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	MOSEBYDENUM
	11	17	7	92	8.0	1180	75	197	310	3.9	3.0	0.4	56	
TOTAL SS./ACRE	21	33	13	180	15.6	2305	147	385	606	7.6	5.9	0.8	109	
EXCESS													###	
OPTIMUM						###		###	###	###			###	
MARGINAL	###	###		###	###	###		###	###	###	###		###	
DEFICIENT	###	###	###	###	###	###		###	###	###	###	###	###	
	N		P	K	S	Ca	Na	Mg	Fe	Cu	Zn	B	Mn	Mo

SAMPLE DEPTH	SOIL QUALITY			
	PH (ACIDITY)	E.C. (SALINITY)	ORGANIC MATTER %	TEXTURE
	6.15	0.15	1.8	Min

COMMENTS:

RECOMMENDATIONS							
SOIL:		LAST CROP:		CROPPING PRACTICE:			
TARGET	CROP CHOICE	EXPECTED YIELDS	N	P ₂ O ₅		K ₂ O	S
				PLACED	or BROADCAST		
HIGH							
MODERATE							
YOUR GOAL							

LIME AND MICRONUTRIENTS
Total N - 0.077% C/N Ratio - 13.1
Aluminum - 0.1 ppm



NORWEST SOIL RESEARCH INC.
203 20771 LANGLEY BYPASS,
LANGLEY, B.C., V3A 5E8

W.O. NUMBER: 3812
PAGE :
LAB NUMBER : 915692

SAMPLE SUBMITTED BY:
NORTHWEST HYDRAULIC CONSUL
42 - 40 GOSTICK PLACE
N. VANCOUVER, B.C. V6M 3G2
Attention of: ALAN BATES

GROWER

SAMPLE RECEIVED: 09-13-1991
ANALYSIS COMPLETED: 09-26-1991
SAMPLE RETAINED UNTIL: For 60 days
FOR INFORMATION CALL: Dr. T. Guthrie
AT: 530-4344

Sample description: LEGAL LOCATION
HATZIC LAKE DREDGE #4 SOIL

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)														
	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATE	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	MOLYBDENUM	CHLORIDE
	16	26	6	107	6.4	1500	50	516	80	6.2	60.0	0.4	27		
TOTAL S./ACRE	31	50	12	206	12.3	2894	96	996	154	12.0	115.8	0.8	52		
EXCESS											###		###		
OPTIMUM						###		###	###	###	###		###		
MARGINAL	###			###	###	###		###	###	###	###		###		
DEFICIENT	###	###		###	###	###		###	###	###	###		###		
	N	P	K	S	Ca	Na	Mg	Fe	Cu	Zn	B	Mn	Mo	Cl	

SAMPLE DEPTH	SOIL QUALITY			
	PH (ACIDITY)	E.C. (SALINITY)	ORGANIC MATTER %	TEXTURE
	6.35	0.11	1.9	Min

COMMENTS:

RECOMMENDATIONS

SOIL:		LAST CROP:		CROPPING PRACTICE:					
ARGET	CROP CHOICE	EXPECTED YIELDS	N	P ₂ O ₅		K ₂ O	S	LIME AND MICRONUTRIENTS	
				PLACED	or BROADCAST				
									TOTAL N 0.099 %
HIGH									C/N Ratio 10.8
									Aluminum 0.1 ppm
MODERATE									
YOUR GOAL									



Norwest Labs

SOIL TEST REPORT

NORWEST SOIL RESEARCH INC.
203 20771 LANGLEY BYPASS,
LANGLEY, B.C., V3A 5E8

W.O. NUMBER: 3812
PAGE:
LAB NUMBER: 915693

SAMPLE SUBMITTED BY:
NORTHWEST HYDRAULIC CONSULTANTS
2 - 40 BOSTICK PLACE GROWER
N. VANCOUVER, B.C. V6M 3G2
Attention of: ALAN BATES

SAMPLE RECEIVED: 09-13-1991
ANALYSIS COMPLETED: 09-23-1991
SAMPLE RETAINED UNTIL: For 60 days
FOR INFORMATION CALL: Dr. T. Guthrie
AT: 530-4344

Sample description: LEGAL LOCATION
HATZIC LAKE DREDGE #5 SOIL

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)														
	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATE	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	MOLYBDENUM	CHLORIDE
	8	26	3	114	6.4	1126	38	350	150	3.6	33.5	0.4	37		
TOTAL SS/ACRE	19	64	8	281	15.8	2778	94	863	370	8.9	82.6	1.0	90		
EXCESS											###		###		
OPTIMUM				###	###	###		###	###		###		###		
MARGINAL		###		###	###	###		###	###	###	###		###		
EFFICIENT	###	###		###	###	###		###	###	###	###		###		
	N		P	K	S	Ca	Na	Mg	Fe	Cu	Zn	B	Mn	Mo	Cl

SAMPLE DEPTH	SOIL QUALITY			
	PH (ACIDITY)	E.C. (SALINITY)	ORGANIC MATTER %	TEXTURE
	6.25	0.11	0.6	Min.

COMMENTS:

RECOMMENDATIONS

SOIL: LAST CROP: CROPPING PRACTICE:

TARGET	CROP CHOICE	EXPECTED YIELDS	N	P ₂ O ₅		K ₂ O	S	LIME AND MICRONUTRIENTS
				PLACED	BROADCAST			
HIGH								Total N - 0.020% C/N Ratio - 15.7 Aluminum - 0.1 ppm
MODERATE								
YOUR GOAL								



NORWEST SOIL RESEARCH INC.
203 20771 LANGLEY BYPASS,
LANGLEY, B.C., V3A 5E8

W.O. NUMBER: 3812
PAGE:
LAB NUMBER: 915694

SAMPLE SUBMITTED BY:
NORTHWEST HYDRAULIC CONSULTANTS

- 40 GOSTICK PLACE
VANCOUVER, B.C. V6M 3G2
Attention of: ALAN BATES

SAMPLE RECEIVED: 09-13-1991
ANALYSIS COMPLETED: 09-23-1991
SAMPLE RETAINED UNTIL: For 60 days
FOR INFORMATION CALL: Dr. T. Guthrie
AT: 530-4344

LEGAL LOCATION
Sample description: HATZIC LAKE DREDGE #6 SOIL

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)														
	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATE	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	MOLYBDENUM	CHLORIDE
	8	8	16	67	6.8	368	20	67	130	0.4	26.0	0.5	16		
TOTAL S/ACRE	16	18	35	145	14.8	799	43	145	282	0.9	56.4	1.1	35		
EXCESS											###				
OPTIMUM					###				###		###		###		
					###				###		###		###		
MARGINAL					###	###		###	###		###		###		
	###		###	###	###	###		###	###		###		###		
	###	###	###	###	###	###		###	###	###	###	###	###	###	
DEFICIENT	###	###	###	###	###	###		###	###	###	###	###	###	###	
	N	P	K	S	Ca	Na	Mg	Fe	Cu	Zn	B	Mn	Mo	Cl	

SAMPLE DEPTH	SOIL QUALITY			
	PH (ACIDITY)	E.C. (SALINITY)	ORGANIC MATTER %	TEXTURE
	5.47	0.08	1.1	Min

COMMENTS:

RECOMMENDATIONS

SOIL: LAST CROP: CROPPING PRACTICE:

TARGET	CROP CHOICE	EXPECTED YIELDS	N	P ₂ O ₅		K ₂ O	S	LIME AND MICRONUTRIENTS
				PLACED	BROADCAST			
HIGH								Total N - 0.034% C/N Ratio - 18.2 Aluminum - 0.1 ppm
MODERATE								
YOUR GOAL								



NORWEST SOIL RESEARCH INC.
203 20771 LANGLEY BYPASS,
LANGLEY, B.C., V3A 5E8

W.O. NUMBER: 3812
PAGE:
LAB NUMBER: 915695

SAMPLE SUBMITTED BY:
NORTHWEST HYDRAULIC CONSULTANTS

2 - 40 BOSTICK PLACE GROWER
VANCOUVER, B.C. V6N 3G2
Attention of: ALAN BATES

SAMPLE RECEIVED: 09-13-1991
ANALYSIS COMPLETED: 09-23-1991
SAMPLE RETAINED UNTIL 60 days
FOR INFORMATION CALL Dr. T. Guthrie
AT: 530-4344

Sample description: LEGAL LOCATION
HATZIC LAKE DREDGE #7 SOIL

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)														
	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATE	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	MOLYBDENUM	CHLORIDE
	63	3	16	70	4.8	333	55	53	130	1.2	4.9	0.3	19		
TOTAL SS/ACRE	156	8	40	173	11.9	824	136	131	322	3.0	12.1	0.7	46		
EXCESS															
OPTIMUM	###				###				###		###		###		
	###				###				###		###		###		
ARGINAL	###			###	###	###			###	###	###		###		
	###		###	###	###	###		###	###	###	###		###		
DEFICIENT	###	###	###	###	###	###		###	###	###	###	###	###	###	
	N		P	K	S	Ca	Na	Mg	Fe	Cu	Zn	B	Mn	Mo	Cl

SAMPLE DEPTH	SOIL QUALITY			
	PH (ACIDITY)	E.C. (SALINITY)	ORGANIC MATTER %	TEXTURE
	5.79	0.09	0.6	Min

COMMENTS

RECOMMENDATIONS

SOIL: LAST CROP: CROPPING PRACTICE:

ARGET	CROP CHOICE	EXPECTED YIELDS	N	P ₂ O ₅		K ₂ O	S	LIME AND MICRONUTRIENTS
				PLACED	or BROADCAST			
HIGH								Total N - 0.030% C/N Ratio - 10.3 Aluminum - 0.1 ppm
MODERATE								
YOUR GOAL								



NORWEST SOIL RESEARCH INC.,
203 20771 LANGLEY BYPASS,
LANGLEY, B.C., V3A 5E8

W.O. NUMBER: 3812
PAGE:
LAB NUMBER: 915696

SAMPLE SUBMITTED BY:
NORTHWEST HYDRAULIC CONSULTANTS
1 - 40 GOSTICK PLACE GROWER
N. VANCOUVER, B.C. V6M 3G2
Attention of: ALAN BATES

SAMPLE RECEIVED: 09-13-1991
ANALYSIS COMPLETED: 09-23-1991
SAMPLE RETAINED UNTIL: For 60 days
FOR INFORMATION CALL Dr. T. Guthrie
AT: 530-4344

Sample description: LEGAL LOCATION
HATZIC LAKE DREDGE #8 SOIL

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)														
	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATE	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	MOLYBDENUM	CHLORIDE
	69	3	4	104	8.8	1302	83	330	300	2.9	11.9	0.4	49		
TOTAL 15/ACRE	129	5	7	194	16.4	2428	155	615	560	5.4	22.2	0.7	90		
EXCESS													###		
OPTIMUM	###					###		###	###		###		###		
	###				###	###		###	###	###	###		###		
MARGINAL	###			###	###	###		###	###	###	###		###		
	###			###	###	###		###	###	###	###		###		
DEFICIENT	###			###	###	###		###	###	###	###	###	###		
	###	###	###	###	###	###		###	###	###	###	###	###		
	N		P	K	S	Ca	Na	Mg	Fe	Cu	Zn	B	Mn	Mo	Cl

SAMPLE DEPTH	SOIL QUALITY			
	PH (ACIDITY)	E.C. (SALINITY)	ORGANIC MATTER %	TEXTURE
	6.09	0.21	2.2	Min

COMMENTS:

RECOMMENDATIONS

SOIL: LAST CROP: CROPPING PRACTICE:

TARGET	CROP CHOICE	EXPECTED YIELDS	N	P ₂ O ₅		K ₂ O	S	LIME AND MICRONUTRIENTS
				PLACED	or BROADCAST			
HIGH								Total N - 0.059% C/N Ratio - 20.9 Aluminum - 0.1 ppm
MODERATE								
YOUR GOAL								



NORWEST SOIL RESEARCH INC.
203 20771 LANGLEY BYPASS,
LANGLEY, B.C., V3A 5E8

W.O. NUMBER: 3812
PAGE:
LAB NUMBER: 915697

SAMPLE SUBMITTED BY:
NORTHWEST HYDRAULIC CONSULTANTS

2 - 40 GOSTICK PLACE GROWER
1. VANCOUVER, B.C. V6M 3G2
Attention of: ALAN BATES

SAMPLE RECEIVED: 09-13-1991
ANALYSIS COMPLETED: 09-23-1991
SAMPLE RETAINED UNTIL: For 60 days
FOR INFORMATION CALL: Dr. T. Guthrie
AT: 530-4344

Sample description: LEGAL LOCATION
HATZIC LAKE DREDGE #9 SOIL

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)															
	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATE	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	MOLYBDENUM	CHLORIDE	
	15	3	8	59	3.2	349	26	61	24	1.3	27.5	0.4	13			
TOTAL 5S./ACRE	53	10	28	208	11.3	1232	92	215	85	4.6	97.1	1.4	47			
EXCESS											###					
OPTIMUM	###								###	###	###		###			
	###			###	###	###		###	###	###	###		###			
ARGINAL	###			###	###	###		###	###	###	###		###			
	###		###	###	###	###		###	###	###	###		###			
	###	###	###	###	###	###		###	###	###	###	###	###			
DEFICIENT	###	###	###	###	###	###		###	###	###	###	###	###			
	N		P	K	S	Ca	Na	Mg	Fe	Cu	Zn	B	Mn	Mo	Cl	
SAMPLE DEPTH	SOIL QUALITY							COMMENTS:								
	PH (ACIDITY)		E.C. (SALINITY)		ORGANIC MATTER %		TEXTURE									
	6.55		0.12		0.1		Min									

RECOMMENDATIONS									
SOIL:		LAST CROP:			CROPPING PRACTICE:				
TARGET	CROP CHOICE	EXPECTED YIELDS	N	P ₂ O ₅		K ₂ O	S	LIME AND MICRONUTRIENTS	
				PLACED	or BROADCAST				
HIGH								Total N - Below 0.005% C/N Ratio - / Aluminum - 0.1 ppm	
MODERATE									
YOUR GOAL									



NORWEST SOIL RESEARCH INC.
203 20771 LANGLEY BYPASS,
LANGLEY, B.C., V3A 5E8

W.O. NUMBER: 3812
PAGE:
LAB NUMBER: 915698

SAMPLE SUBMITTED BY:
NORTHWEST HYDRAULIC CONSULTANTS

1. - 40 BOSTICK PLACE GROWER
1. VANCOUVER, B.C. V6M 3G2
Attention of: ALAN BATES

SAMPLE RECEIVED: 09-13-1991
ANALYSIS COMPLETED: 09-23-1991
SAMPLE RETAINED UNTIL: 60 days
FOR INFORMATION CALL: Dr. T. Guthrie
AT: 530-4344

2. Sample description: LEGAL LOCATION
HATZIC LAKE DREDGE #10 SOIL

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)														
	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATE	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	MOLYBDENUM	CHLORIDE
	15	3	18	56	8.8	329	25	74	105	0.7	32.5	0.4	5		
TOTAL / ACRE	37	6	45	139	21.8	814	62	183	260	1.7	80.4	1.0	13		
EXCESS											###				
DEFICIENCY									###		###				
OPTIMUM	###			###					###		###		###		
MIGINAL	###		###	###	###	###	###	###	###	###	###		###		
DEFICIENT	###	###	###	###	###	###	###	###	###	###	###	###	###	###	###
	N	P	K	S	Ca	Na	Mg	Fe	Cu	Zn	B	Mn	Mo	Cl	

SAMPLE DEPTH	SOIL QUALITY			
	PH (ACIDITY)	E.C. (SALINITY)	ORGANIC MATTER %	TEXTURE
	5.79	0.11	0.6	Min

COMMENTS:

RECOMMENDATIONS

OIL: LAST CROP: CROPPING PRACTICE:

TARGET	CROP CHOICE	EXPECTED YIELDS	N	P ₂ O ₅		K ₂ O	S	LIME AND MICRONUTRIENTS
				PLACED	or BROADCAST			
								Total N - 0.014% C/N Ratio - 22.1 Aluminum - 0.1 ppm
IGH								
MODERATE								
YOUR GOAL								

APPENDIX I

HATZIC/LAGACE CREEK FLOOD LEVELS

ASSUMPTIONS

- .1 The MOE 1984 cross-sections are very similar to those surveyed by CBA-(pre-PEP), and were used for the computations. The high bed levels were assumed to be representative of post debris torrent events and the dykes would be designed to hold back water under this condition.
- .2 The dykes on each side of the creek were set back 15 m (bank edge to toe).
- .3 For supercritical flows, mostly near and upstream from the Sylvester Road bridge, the flow depths were assumed to be close to critical depth.
- .4 The dykes are to be designed for the 50-year peak discharges.

Thalweg and Overbank Profiles for Pattison – Lagace Creek.

Notes: 1) Stations are measured from centreline of Dale Road bridge (Sta 0+000) and positive chainage is in the upstream direction.

2) 50-year levels shown for instantaneous flows and assuming the tributary inflows downstream of Seur Road bridge are pumped 5-day 10-year discharges. 200-year levels are shown for instantaneous flows and assume natural tributary inflows below Seur Road bridge (see Table 2.4).

3) HEC-2 used MOE 1984 cross-sections to generate the water surface elevations for the 50-year and 200-year instantaneous flows. These sections were very similar to the CBA 1991 sections.

Have assumed dykes with 2H:1V side slopes set back 15 m from bank points.

4) Future design elevations are to be to post-PEP thalweg elevations (CBA 1991).

5) Bolded cross-sections are located immediately downstream and upstream of a bridge.

X-Section Reference	Surveyed by	Station (m)	Elevations (m GSC)				Water Surface Elevations (m GSC)		
			Thalweg				Left Bank	Right Bank	
			MOE 1984	CBA 1991 Pre-PEP	CBA 1991 Post-PEP	NHC 1991	MOE 1984	NHC	
TH 38	MOE,NHC	-4065	1.22			0.75			
TH 37	MOE,NHC	-3918	0.32			-0.15			
TH 36	MOE,NHC	-3800	0.82			0.80			
TH 35	MOE,NHC	-3713	0.42			0.45			
TH 34	MOE,NHC	-3646	0.67			0.20			
TH 33	MOE,NHC	-3602	0.22			0.40			
TH 32	MOE,NHC	-3531	0.92			0.40			
XS 47	NHC	-3525				0.17	5.98	6.53	
TH 31	MOE,NHC	-3388	0.12			-0.40			
TH 32	MOE,NHC	-3260	0.42			0.35			
XS 46	NHC	-3215				0.15	5.79	6.83	
TH 29	MOE,NHC	-3113	0.07			0.40			
TH 28	MOE	-2912	0.32						
XS 45	MOE,NHC	-2798	0.42			-0.09	6.22	6.28	5.00
XS 44	MOE,NHC	-2789	0.72			-0.09	6.17	6.29	5.72
TH 27	MOE,NHC	-2617	0.23			-0.47			
TH 26	MOE,NHC	-2515	-0.17			-0.52			
TH 25	MOE,NHC	-2446	0.18			-0.12			
XS 43.3	NHC	-2430				0.49	5.74	5.64	
TH 24	MOE,NHC	-2395	0.43			0.21			
TH 23	MOE,NHC	-2325				0.84			
TH 22	MOE,NHC	-2199	1.18			0.74			
TH 21	MOE,NHC	-2103	1.18			0.54			
XS 43.2	NHC	-2045				0.78	5.78	4.78	
TH 20	MOE,NHC	-2016	1.18			0.94			
TH 19	MOE,NHC	-1862	1.23			0.74			
TH 18	MOE,NHC	-1831	1.23			1.14			
XS 43.1	NHC	-1740				0.89	5.49	4.01	
TH 17	MOE,NHC	-1716	1.23			0.94			
XS 43	MOE	-1631	1.18	0.83			4.83	4.89	6.03
XS 42	MOE	-1623	1.18	0.86			4.86	4.92	6.76
TH 16	MOE,NHC	-1507	0.93			0.44			
TH 15	MOE,NHC	-1404	1.23			0.44			
TH 14	MOE,NHC	-1332	1.43			0.90			
XS 41	MOE	-1194	1.38	1.10		4.58	5.27	6.85	7.65
XS 40	MOE	-1188	1.43	1.01		4.59	5.26	7.58	8.37
TH 13	MOE,NHC	-1091	1.22			0.75			
TH 12	MOE,NHC	-1003	1.44			1.05			
TH 11	MOE,NHC	-980	1.39			1.15			
TH 10	MOE,NHC	-909	1.19			0.95			
TH 9	MOE,NHC	-820	1.54			1.15			
XS 39.2	NHC	-775				1.52	4.32	4.05	
TH 8	MOE,NHC	-766	1.74			1.39			
TH 7	MOE,NHC	-697	1.69			1.26			
TH 6	MOE,NHC	-663	1.74			1.19			
XS 0	CBA	-470		1.34	1.39		3.90	3.90	
TH 5	MOE,NHC	-591	1.74			1.10			
TH 4	MOE,NHC	-520	1.54			1.42			
TH 3	MOE,NHC	-350	1.84			1.76			
XS 39.1	NHC	-335				1.76	4.32	3.80	
XS 1	CBA	-190		1.36	0.79		5.40	6.40	
TH 2	MOE,NHC	-234	1.84			1.47			
TH 1	MOE	-93	1.69						
XS 2	CBA	-50		1.81	0.68		3.50	4.50	
XS 39	MOE	-20	1.74				3.70	3.44	7.84
XS 38	MOE	-5	1.72			4.86	4.85	8.55	9.56
XS 37	MOE	5	1.16			4.86	4.85	8.58	9.57
XS 3	CBA	35		1.71	0.75		3.77	4.27	
XS 36	MOE	45	1.97			3.72	3.97	8.53	9.49
XS 4	CBA	90		1.89	0.74		4.47	2.77	
XS 35	MOE	133	2.25				5.40	5.10	8.47
XS 34	MOE	330	2.19				3.56	3.79	8.81
XS 5	CBA	375		1.61	0.90		4.17	4.17	
XS 33	MOE	522	2.50				3.83	4.38	8.89
									10.02

DALE ROAD

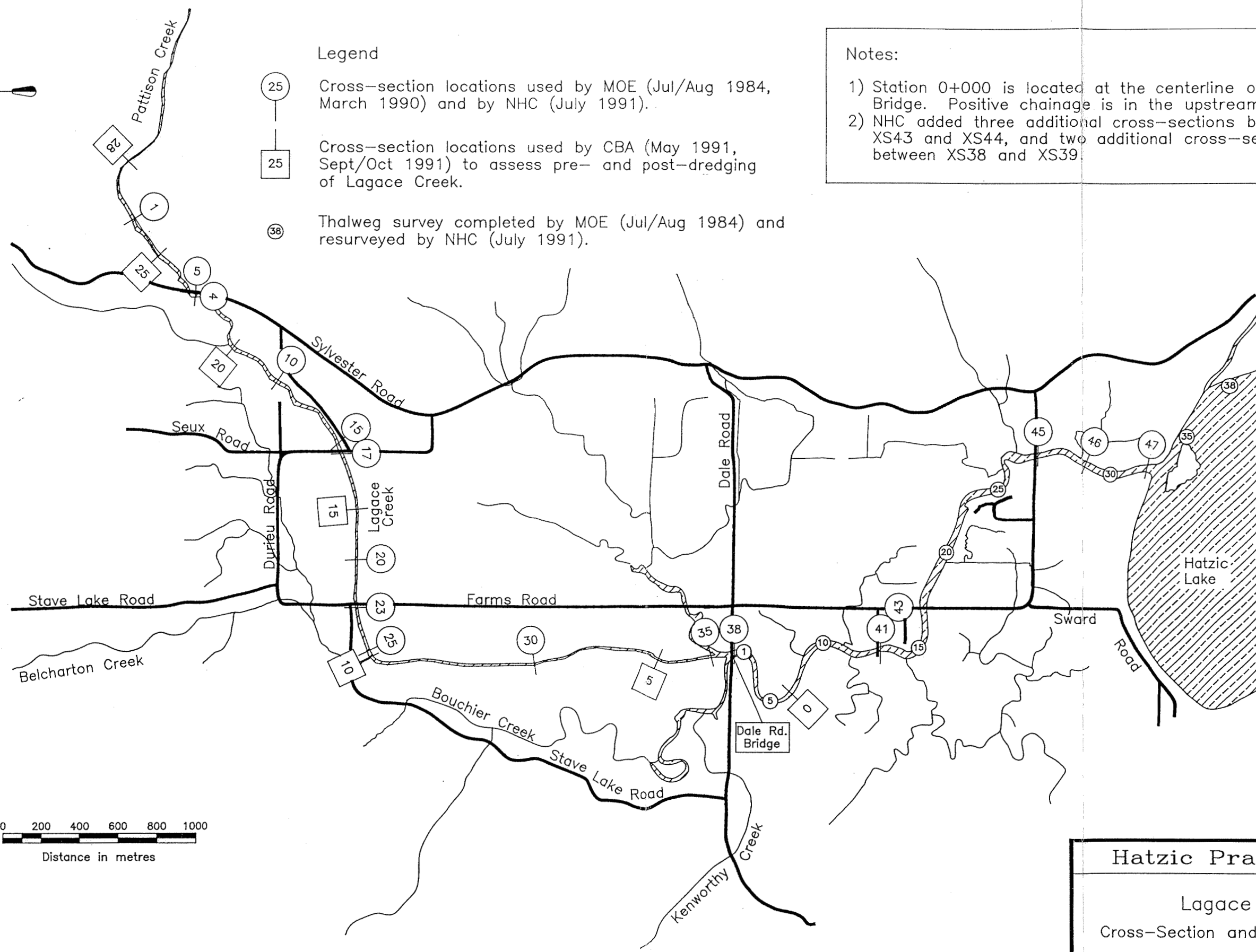
YOUNGSTON ROAD

FAHMS ROAD

Thalweg and Overbank Profiles for Pattison – Lagace Creek.

- Notes: 1) Stations are measured from centreline of Dale Road bridge (Sta 0+000) and positive change is in the upstream direction.
2) 50-year levels shown for instantaneous flows and assuming the tributary inflows downstream of Seux Road bridge are pumped 5-day 10-year discharges. 200-year levels are shown for instantaneous flows and assume natural tributary inflows below Seux Road bridge (see Table 2.4).
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4) Future design elevations are to be to post-PEP thalweg elevations (CBA 1991).
5) Bolded cross-sections are located immediately downstream and upstream of a bridge.

X-Section Reference	Surveyed by	Station (m)	Elevations (m GSC)				Water Surface Elevations (m GSC)	
			Thalweg				Left Bank	Right Bank
			MOE 1984	CBA 1991 Pre-PEP	CBA 1991 Post-PEP	NHC 1991	MOE 1984	MOE 1984
							Flow (Inst.)	Flow (Inst.)
XS 6	CBA	695		2.13	1.29		4.07	4.07
XS 32	MOE	757	2.63				4.09	4.35
XS 31	MOE	932	2.99				4.44	4.55
XS 30	MOE	1095	3.38				4.66	5.42
XS 7	CBA	1135		2.87	2.10		6.07	5.87
XS 29	MOE	1310	2.37				4.28	4.15
XS 28	MOE	1458	3.61				4.59	4.25
XS 8	CBA	1545			3.27		8.27	7.57
XS 9	CBA	1645			3.80		5.97	7.07
XS 27	MOE	1675	4.71				5.86	5.86
XS 26	MOE	1900	6.14				6.93	6.45
XS 10	CBA	1955		6.89	5.02		8.70	7.20
XS 25	MOE	2008	6.30				8.22	8.38
XS 11	CBA	2070		7.29	5.93		6.77	6.87
XS 12	CBA	2215		10.09	7.23		8.57	8.67
XS 24	MOE	2235	8.37				10.44	10.56
XS 23	MOE	2272	8.57				10.96	10.93
XS 22	MOE	2284	8.49				11.06	10.94
XS 13	CBA	2285		7.76	7.29		9.37	9.17
XS 21	MOE	2321	8.86				9.57	10.70
XS 20	MOE	2513	9.96				13.03	12.31
XS 14	CBA	2505		10.49	9.89		12.47	10.87
XS 15	CBA	2705		13.33	13.02		15.17	14.87
XS 19	MOE	2761	15.47				16.71	17.87
XS 16	CBA	2885		16.93	16.70		17.27	17.37
XS 18	MOE	3016	19.43				22.65	22.44
XS 17	CBA	3035		19.94	19.42		19.47	20.57
XS 17	MOE	3061	20.46				24.67	24.68
XS 16	MOE	3076	20.32				24.67	24.66
XS 19	CBA	3105		21.09	21.06		22.67	22.67
XS 15	MOE	3116	21.34				24.14	24.22
XS 14	MOE	3198	23.20				26.16	27.42
XS 13	MOE	3283	25.12				28.35	27.50
XS 12	MOE	3381	27.63				30.63	30.34
XS 11	MOE	3486	29.49				31.98	30.60
XS 19	CBA	3550			31.51		33.17	47.27
XS 10	MOE	3588	31.95				34.92	34.04
XS 9	MOE	3668	34.16				37.36	38.40
XS 20	CBA	3840			38.53		41.57	53.27
XS 8	MOE	3903	38.86				42.92	42.21
XS 21	CBA	3980			44.20		46.87	47.17
XS 7	MOE	4043	43.91				47.72	47.01
XS 22	CBA	4190			53.25		55.27	56.07
XS 6	MOE	4190	53.27				56.20	56.05
XS 23	CBA	4260		58.84	56.91		63.30	63.20
XS 5	MOE	4273	56.18				58.38	57.89
XS 4	MOE	4298	57.25				61.11	60.28
XS 3	MOE	4310	57.82				61.13	61.22
XS 24	CBA	4360		63.51	62.47		67.00	66.50
XS 2	MOE	4366	58.86				62.81	63.15
XS 25	CBA	4475		69.76	69.60		72.50	70.90
XS 1	MOE	4571	68.50				69.17	70.95
XS 26	CBA	4630		79.81	78.80		81.30	81.70
XS 27	CBA	4750		88.74	87.55		91.80	91.00
XS 28	CBA	5030			109.90		110.20	112.10

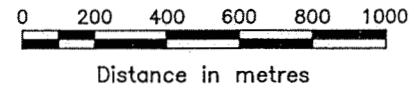


Legend

- Cross-section locations used by MOE (Jul/Aug 1984, March 1990) and by NHC (July 1991).
- Cross-section locations used by CBA (May 1991, Sept/Oct 1991) to assess pre- and post-dredging of Lagace Creek.
- Thalweg survey completed by MOE (Jul/Aug 1984) and resurveyed by NHC (July 1991).

Notes:

- 1) Station 0+000 is located at the centerline of Dale Road Bridge. Positive chainage is in the upstream direction.
- 2) NHC added three additional cross-sections between XS43 and XS44, and two additional cross-sections between XS38 and XS39.



Hatzic Prairie Study

Lagace Creek

Cross-Section and Thalweg Surveys

northwest hydraulic consultants