FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

DEROCHE CREEK
FLOOD HAZARD MANAGEMENT STUDY

June 2000

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EXECUTIVE SUMMARY

The community of Deroche has developed on a large alluvial fan adjacent to Nicomen Slough on the Fraser River. The Lakahahmen Indian Reserve No. 11 occupies part of the alluvial fan. At present the channel of Deroche Creek runs along the west side of the upper fan and towards the centre in the lower reaches, but historically it has changed course many times. The process of sediment deposition and channel changes on the fan is continuing, posing a number of hazards including avulsion, flooding and debris floods and thereby threatening the integrity and safety of structures and infrastructure on the fan.

There have been at least ten debris flows in tributaries of the upper watershed of Deroche Creek over the past 50 years. Of these, nine debris flows were associated with logging road failures and poor drainage, and one originated from a channel sidewall failure. These numbers demonstrate the strong impact of forestry operations on mass movement activity in the Deroche Creek watershed. There is a low likelihood of debris flows reaching the Deroche Creek fan.

Debris floods have reached the creek fan several times during the past 50 years. The most notable floods occurred in 1962 or 1963 and in December of 1989. Modelling of landslide dam ruptures from debris flows in the upper watershed suggests that peak flows in excess of 300 m^3/s are conceivable and should be considered in flood mitigation measures on the creek fan.

Hydrological and hydraulic analyses have been carried out to determine flows of certain return periods and the channel capacities at different locations. In particular, there are low bank elevations along the left bank downstream from the water intake, a reach that is considered to have a high avulsion risk. Portions of the left bank downstream of the Morton Road Bridge are also at risk of avulsion should the channel aggrade. Another potential location for an avulsion is at the sharp bend at the approach to the North Nicomen Road Bridge.

A review of the land use is presented, including the historical perspective, the Official Community Plan and the current zoning. The Fraser River floodplain is designated under the Floodplain Management Bylaw, which designates the Deroche Creek fan as an alluvial and debris torrent area. Each of these designations imposes limits on development. Assessed values amount to approximately $5.6M in land and $8.0M in improvements. Development potential and four outstanding subdivision applications are discussed.

The whole Deroche Creek fan is hazardous to some extent. The fan was subdivided into zones designated as being of low, moderate or high hazard. These zones have been defined in terms of

ground slope, likely water depths and velocities, and vulnerability to avulsions and debris floods. In general terms the hazard on the fan increases towards the fan apex and with proximity to the present creek channel.

Flood protection options are discussed and compared in terms of advantages, disadvantages and costs. They are categorized as non-structural, creek management and structural actions.

The non-structural options recommended include some changes to the OCP with regard to the fan boundaries and identification of the hazard zones. Some amendments to existing land use designations and zoning are recommended.

Under creek management options, it is noted that work in the upper catchment is crucial to the flood hazard management on the fan. This work includes logging road deactivation, drainage works and monitoring. Continued clearing of gravel from the creek within the fan is endorsed as a necessary channel maintenance requirement.

Several structural options are recommended including an expensive debris basin or a less expensive debris barrier at the apex of the fan. In the event that a debris basin is not constructed, it is recommended that the North Nicomen Road Bridge be replaced with one of a longer span and that the channel be straightened at the bridge approach. All new structures should be raised, either structurally or on fill, depending on their location and consideration should be given to raising existing structures.

1 INTRODUCTION

1.1 Background

This report was commissioned by Mr. Christopher Symes, Assistant Manager for Planning and Development Services for the Fraser Valley Regional District (FVRD). It was awarded as a result of a proposal submitted by Hay & Company (Hayco) in June 1999. The study was jointly funded by the FVRD, the BC Ministry of Environment, Lands and Parks (MELP) and the Lakahahmen First Nation (LFN). The FVRD acted as study coordinator.

The community of Deroche has developed on a large alluvial fan adjacent to Nicomen Slough on the Fraser River. The fan has formed over thousands of years as a result of sediment deposition from the upper catchment of Deroche Creek being deposited on the flatter slopes of the Fraser River floodplain. The Lakahahmen Indian Reserve No. 11 occupies part of the alluvial fan. At present the channel of Deroche Creek runs through the centre of the fan, but historically it has changed course many times.

The process of sediment deposition and channel changes on the fan is continuing, creating a number of hazards including the following:

- **Avulsion** – The creek is liable to change its course during floods, despite the channelling and bank protection works that have been carried out.
- **Flooding** – The hydraulic capacity of the channel is lower in some places than others, leading to the possibility of bank overtopping.
- **Debris Flows** – Slope instability in the upper catchment can lead to debris flows in tributaries and down the creek channel for some distance.
- **Debris Floods** – These are water floods often triggered by geomorphic processes such as landslide damming and logjam outbreaks.

Any of these processes can cause flooding, erosion as well as sediment and debris deposition, thereby threatening the integrity and safety of structures and infrastructure on the fan. It is of interest to note that Deroche Creek was referred to as Crazy Creek until the mid 1980s.

The study area encompasses the watershed and alluvial fan of Deroche Creek, as shown on Figure 1.1.

1.2 Study Team

The multidisciplinary study team comprised the following individuals:

Adrian Chantler, P.Eng.	Hay & Company	Project Manager
Bob Wallwork, P.Eng.	Hay & Company	Senior Hydraulic Engineer
Ryan Mulligan, EIT	Hay & Company	Junior Engineer
Jamie Stirling, M.Sc.	Hay & Company	Geomorphologist
Tony Cerqueira, AScT	Hay & Company	Technologist
Matthias Jakob, P.Geo.	EBA Engineering Consultants	Geomorphologist
Bernard Teufele, EIT	EBA Engineering Consultants	Geotechnical Engineer
Jeff Matheson, RPBio	EBA Engineering Consultants	Ecologist
Hagen Hohndorf, RPBio	EBA Engineering Consultants	Environmental Scientist
Hamish Weatherly, M.Sc.	EBA Engineering Consultants	Fluvial Geomorphologist
Graham Farstad, MCIP	Arlington Group	Planner

As a subconsultant to Hayco, EBA Engineering Consultants Ltd. prepared the sections relating to debris flows, debris floods and landslides (Section 4 and Appendix 1) and contributed to the recommendations. EBA also carried out the environmental review (Section 7). The Arlington Group contributed Section 8 on land use.

1.3 Study Objectives

The main objective of the study is the production of a flood hazard management plan for the Deroche Creek alluvial fan, including both the reserve and non-reserve lands. This plan is to assess and describe the flood hazard and provide a set of policies, regulations and an implementation program to manage the hazard. The emphasis was to be on non-structural options, such as regulation of new developments, rather than structural options such as dyking. The scope also included the fisheries and wildlife resources and channel maintenance.

2 HISTORICAL FLOOD INFORMATION

Information on historical floods has been gathered or deduced from various sources, including air photos, BC Environment files and local residents. Unfortunately, the files of the Provincial Emergency Program (PEP), the agency that has funded much of the restoration work after recent floods, are not accessible.

Some important flood events are listed below.

1962 or 1963

A major flood occurred with debris deposited east of North Deroche Road, and on the upper fan between the bend in North Deroche Road and the apex. One avulsion channel reached Nicomen Slough.

1974

A debris slide in the upper catchment generated a debris flow down a tributary, which then descended Deroche Creek for 50-100 m.

December 1980

Photographs dated January to May, 1981 in the MELP files show restoration work being carried out, consisting of clearing and channelling upstream of the Morton Road bridge. An island was removed upstream of the bridge and channel erosion was filled in with large boulders. The channel was widened below the Morton Road Bridge. Channelling was also done downstream of the Taylor Road bridge. Damage was incurred at the Stoney and Faulkner properties.

January 1983

A driveway was eroded at Morton Road, according to MELP photographs. The cost of repairs was $783 (Bornemann, 1983).

1983

A minor flood occurred with no major avulsions, according to air photos.

January 1984

Flooding occurred from a normally dry former creek channel, causing damage at the Booth residence (11414 Brooks Road). The total cost of restoration was $4,749 (McCracken, 1984).

November 1986

A logjam occurred downstream of the water intake, causing water to flow down an old channel. Damage occurred above Morton Road, at the intake and at the driveway of 41441 Morton Road (Sokkanen property). Mr. Sokkanen's sawmill was damaged. The Morton Road Bridge was replaced by a Bailey Bridge shortly after this.

November 1989

A debris flood occurred, probably as a result of a landslide dam failure in the upper watershed. This caused an avulsion on the east bank, washing out Morton Road. Considerable amounts of gravel were deposited between the Morton Road Bridge and North Nicomen Road. The estimated costs for gravel removal and bank protection were $55,000 (Nesbitt-Porter, 1989). February 1990 MELP photographs show that bank erosion occurred just upstream of the North Nicomen Road Bridge. Restoration was carried out under PEP.

July 1990

PEP restoration work was carried out upstream of Morton Road. Gravel blocking the North Nicomen Road Bridge was removed, including a gravel bar 100 m upstream. Gravel was also removed at the Morton Road Bridge and downstream. No cost data are available.

November 1990

Extremely heavy rainfall resulted in gravel deposition and bank erosion (McMullen, 1990). No cost estimates are available.

3 SITE RECONNAISSANCE AND SURVEYS

The site was visited on October 15, 1999 by Adrian Chantler, Bob Wallwork, Graham Farstad, Matthias Jakob and Hamish Weatherly for a general reconnaissance of the fan and creek system. A helicopter reconnaissance of the entire basin was carried out on October 20 attended by Messrs. Wallwork, Farstad, Jakob and Teufele. This visit was primarily for the assessment of logging impacts, landslide activity and the potential for debris flows and debris floods. Photos were taken of conditions in the upper basin, tributaries and lower fan. A follow-up site visit was undertaken by Messrs. Wallwork and Mulligan on November 30 to confirm some details of the creek surveys as described below.

A creek survey was undertaken by Hayco from October 19 to 22, 1999. The survey data were required for input into a hydraulic model of the creek system as described in Section 6. Flow in Deroche Creek was very low during this period with dry conditions in the lower reaches below the CPR Bridge.

The survey commenced at the CPR Bridge where a benchmark on the north side of the east concrete abutment was used for elevation control. Geodetic Control Marker No. 944470 has a listed elevation of 13.175 m and consists of a tablet in concrete, 0.6 m below the bridge seat.

The survey proceeded downstream to the creek outlet into Nicomen Slough and then resumed upstream from the CPR and Nicomen Road bridges. A total of 48 creek cross sections were surveyed, nearly four times what was originally intended, due to limited sight lines between survey set-up points as well as the complex nature of the creek system. Cross sections were surveyed only across the active flow channel and included the top of banks and/or berms as the case may be. Sections were extended to include a portion of the overbank if sight lines were favourable. Some overbank details were subsequently determined by approximate survey methods during field verification of the model in crucial locations.

Cross sections were taken in close proximity to the upstream and downstream faces of all four bridges together with road/track profiles across the bridges. Lower chord information and abutment locations were surveyed in order to define the effective flow opening through the bridges.

4 DEBRIS FLOWS, DEBRIS FLOODS AND LANDSLIDES

4.1 Introduction

It is only during the last 20 years or so that the hazards due to debris flows and debris floods in B.C. have been studied systematically and considered as potential threats to public safety. Debris flows, debris floods and landslides were addressed by EBA Engineering Consultants Ltd. as sub-consultants to Hay & Company. The EBA report is reproduced as Appendix 1 and summarized in this section of the report.

4.2 Study Area Physiography, Geology and Geomorphology

The watershed is concave, having lost material to mass movement and fluvial processes. A fan occupying an area of about 130 ha has formed on the Fraser River floodplain north of Nicomen Slough. The most recent fan aggradation events occurred in 1962 or 1963 on the lower fan and in 1989, close to the fan apex. Clearcut logging has affected sediment movement in the creek and the effects of logging on geomorphic activity are continuing.

The drainage system is characterized by stream channel gradients of 14 to 18% along the lower channel and increasing rapidly to 80% in the upper watershed and along short steep tributaries of the lower channel. Landslides descending some of these tributaries are capable of temporarily damming Deroche Creek. Outbreak floods from landslide dams have been known to exceed the 200-year flood discharge and may affect development of the fan.

Descriptions of the bedrock geology, its geomorphological significance and the Quaternary geology of the area can be found in Appendix 1.

4.3 Debris Flows and Debris Floods

Debris flows are much more destructive mass movements than pure water floods. They are discrete and rare events and cannot be analyzed using standard methods of frequency analysis. Analysis has shown that if there is a chance that a debris flow may occur on a creek with a return period of 200 years or less, it is likely to be at least one order of magnitude greater than the 200-year flood discharge. Debris flows are highly fluid but can contain rocks up to several cubic metres in size. They have significant erosive power and begin to deposit their load when slopes flatten to about 18 to 21% for bouldery flows with sandy matrices.

Debris floods are water floods and are often due to geomorphic processes such as landslide damming, logjam outbreaks and beaver dam failures. In practice there is a continuum of events ranging from landslides to floods.

There have been at least ten debris flows in tributaries of the upper watershed of Deroche Creek over the past 50 years. Of these, nine debris flows were associated with logging road failures and poor drainage, and one originated from a channel sidewall failure. These numbers demonstrate the strong impact of forestry operations on mass movement activity in the Deroche Creek watershed. All ten debris flows reached the main stem of Deroche Creek. Due to the dense tree canopy it is not possible to locate the precise runout distance of the debris flows in the main channel. However, it appears that no debris flow has reached the creek fan over the past 50 years. Furthermore, old trees bordering the lower channel do not show impact scars at high levels above the present channel that would indicate debris flows in the historical period (past 150 years). The lower channel gradient of Deroche Creek ranges between 3 and 18%, which is insufficient to allow non-volcanic debris flow transport to the creek fan and causes deposition in the channel. An exception may be a very large ($> 10{,}000$ m^3) failure in the upper watershed that enters the channel at an oblique angle allowing the debris mass to continue as a debris flow. In summary, there is a low likelihood of debris flows reaching the Deroche Creek fan.

Debris floods have reached the creek fan several times during the past 50 years. The most notable floods occurred in 1962 or 1963 and in December of 1989. Neither the 1962/63 nor the 1989 flood can be matched to exceptional flood events at neighbouring Norrish Creek, which is gauged. This suggests mechanisms other than rainfall intensity and duration to explain the observed flood

magnitudes. An interview with Mr. Kauko Sokkanen, a local resident, was conducted in which Mr. Sokkanen stated that no water flow was observed in Deroche Creek during a heavy rainstorm in December 1989. After 6-10 hours a sudden floodwave descended the channel causing widespread flooding on the creek fan. Airphoto evidence suggests that a debris slide in the upper channel dammed Deroche Creek, which was followed by a collapse of the landslide dam. The back-calculated peak discharge of this event was approximately 220 m^3/s or more than three times the 200-year flood discharge.

Modelling of landslide dam ruptures from debris flows in the upper watershed suggests that peak flows in excess of 300 m^3/s are conceivable and should be considered in flood mitigation measures on the creek fan.

4.4 Logging Impacts

The Deroche Creek basin has been logged numerous times in the last 50 years, affecting approximately 40% of the watershed. This has led to an accelerated rate of mass movements, particularly due to failures of forest roads. Forest cover maps were reviewed in this study to assess the likelihood of debris slide initiations from forest roads and open slopes. Deroche Creek has been mapped as part of the Norrish Creek Integrated Watershed Management Plan. The map included as Figure 2 in Appendix 1 designates cutblocks, locations where mass movements have already occurred, and areas prone to post-logging landslides.

An interpretation of the air photos from 1963 to 1993 has shown that there have been 13 landslides associated with logging activity and three that occurred naturally. This has caused the sediment load of Deroche Creek to increase substantially over the last three decades. Much material remains to be transported to the fan area by future floods. The EBA report in Appendix 1 details the potential debris flow source areas, debris yield rates and probable landslide volumes. Debris flow runout is discussed, as are debris flow dam outbreak scenarios.

Poor logging practices and road construction in the Deroche Creek basin should be mitigated by various watershed stabilization measures. These are discussed in the Creek Management Actions section of this report.

5 HYDROLOGY

Deroche Creek has a steep, mountainous catchment with a north-south orientation, draining southward to enter the Fraser River near the community of Deroche. Elevations in the basin range from

approximately 10 m to 1280 m. The basin is roughly 5 km long and nearly 3 km in breadth at its widest point. The overall stream gradient averages about 25%.

Water Survey of Canada operated a seasonal stream gauge on Deroche Creek for five years in the early 1960s. The drainage area was not provided for this station. Hayco determined the drainage area to be 9.18 km^2 as derived from 1:50,000 NTS mapping.

The Deroche Creek flood estimates were derived from a regional analysis given that the available station records for Deroche Creek itself are very limited. A list of the available station records considered for analysis is given in Table 5.1.

TABLE 5.1
HYDROMETRIC STATIONS

Station Number	Station Name	Drainage Area (km^2)	Record
08MH070	Deroche Creek at Deroche	9.18 (Hayco)	1960-64 MS Nat
08MH058	Norrish Creek near Dewdney	117	1959-present Reg
08MH150	Norrish Creek above Rose Creek	-	1983-present Reg
08MH091	Silverdale Creek near Mission	17.1	1960-95 Reg
08MH076	Kanaka Creek near Webster Corners	47.7	1960-present Nat
08MH077	Kenworthy Creek near Hatzic	4.92	1960-64 MS Nat
08MH045	Bouchier Creek near Hatzic	1.14	1960-64 MS
08MH095	Unnamed Creek near Hatzic	-	1960-64 MS Nat

Notes: MS – Manual, seasonal gauge
Nat – Natural flow
Reg – Regulated flow

The station records for Kenworthy, Bouchier and Unnamed Creeks were too short to be useful. Records for Norrish Creek above Rose Creek were also too short to be used for frequency analysis.

Records for Norrish Creek near Dewdney, Silverdale Creek near Mission, and Kanaka Creek near Webster Corners were considered for further analysis. Daily hydrographs for these stations were plotted against concurrent records for Deroche Creek at Deroche. Kanaka Creek records were found to be poorly correlated with those for Deroche Creek and the catchment receives much more precipitation, so it was dropped from further analysis. The other two creeks appeared to be reasonably

well correlated with Deroche Creek, based on visual examination of the concurrent hydrographs. Flood frequency analysis was undertaken for these stations as described below.

Environment Canada's Consolidated Frequency Analysis software, CFA 3.1, was used in the analysis of annual floods. This program utilizes the following frequency distributions:

- Generalized Extreme Value Distribution (GEV)
- Three-Parameter Lognormal Distribution (3PLN)
- Log Pearson Type III Distribution (LPIII)
- Wakeby Distribution (Wakeby)

In addition to the above, the Weibull Distribution is occasionally implemented by the program in cases where the data display a high negative skew. This can lead to underestimation of extreme flood events by the other methods due to upper boundary restrictions.

An areal adjustment procedure was used to transfer flood estimates from the regional stations to the Deroche Creek catchment. The areal adjustment factor was determined as follows (Coulson *et al*, 1997):

$$Q_2 = Q_1 \times (A_2/A_1)^{0.785}$$

Silverdale Creek has 31 years of maximum daily flood records and 27 years of maximum instantaneous flood records. This station was discontinued after 1995. Analysis of the station records indicated relatively low flood estimates, which were negatively skewed in most cases. The resulting daily flood estimates, transferred to the Deroche Creek catchment by means of the above areal adjustment procedure, were found to be unrealistically low. For example, the record Deroche Creek flood of 14.2 m^3/s (estimated) on February 21, 1961, was found to exceed the areally adjusted maximum daily flood estimate of 13.5 m^3/s corresponding to the 500 year return period event on the Deroche Creek catchment. The February 1961 event corresponded to a 2.1-year return period event for the Silverdale Creek catchment or 2.4 years in terms of maximum instantaneous flood discharge. The catchment for Silverdale Creek has elevations of less than 500 m, which is significantly less than Deroche Creek. Accordingly, Silverdale Creek was dropped from further analysis.

Norrish Creek near Dewdney has 32 years of maximum daily flood records and 29 years of maximum instantaneous flood records. Regulation effects are not believed to be significant in terms of flood peak. The February 21, 1961 flood on Norrish Creek, 133 m^3/s maximum daily discharge, was not the annual flood in 1961, however, it ranked higher than annual floods for some other years. The

return period for this flood event was approximately 3.2 years, based on the frequency analysis described below, which seems reasonable in terms of the correlation with the maximum observed flood in four years of seasonal records on Deroche Creek.

Results of the flood frequency analysis on Norrish Creek are listed in Tables 5.2 and 5.3 for maximum daily and maximum instantaneous flood series, respectively.

TABLE 5.2
NORRISH CREEK NEAR DEWDNEY
MAXIMUM DAILY FLOOD ESTIMATES

Return Period (years)	Frequency Distribution: Discharge (m^3/s)			
	GEV	3PLN	LPIII	Wakeby
2	99	92	99	98
5	139	138	139	145
10	168	182	167	175
20	198	235	197	201
50	241	322	240	229
100	277	402	274	248
200	315	496	311	263
500	370	645	365	281

TABLE 5.3
NORRISH CREEK NEAR DEWDNEY
MAXIMUM INSTANTANEOUS FLOOD ESTIMATES

Return Period (years)	Frequency Distribution: Discharge (m^3/s)			
	GEV	3PLN	LPIII	Wakeby
2	183	180	182	180
5	260	260	257	266
10	314	318	312	323
20	368	378	368	373
50	442	462	446	431
100	501	528	509	468
200	563	599	576	502
500	648	699	672	540

In each case, the Log Pearson Type III (LPIII) estimates were found to provide the best fit to the data. These estimates are also the most consistent in terms of maximum instantaneous to daily flood ratios for each of the return periods. Frequency plots of the maximum daily and maximum instantaneous flow data are shown in Figures 5.1 and 5.2, respectively.

The areal adjustment factor for conversion of the Norrish Creek flood estimates to the Deroche Creek catchment was determined to be 0.136 based on the aforementioned formula and the drainage areas listed in Table 5.1. The resulting flood estimates are listed in Table 5.4 together with estimates derived from the Hydrologic Mapping and Datasheet Compilation Project (Coulson *et al*, 1997). The mapping encompasses all available hydrographic records and gives an indication of regional trends due to geographic features. These latter estimates (B in Table 5.4) are 0.093 and 0.090 times the Norrish Creek flood estimates.

TABLE 5.4
DEROCHE CREEK
MAXIMUM INSTANTANEOUS FLOOD ESTIMATES (PRELIMINARY)

Return Period (years)	A: Norrish Creek x 0.1356 (m^3/s)	B: Regional Mapping (m^3/s)	Ratio B/A
10	42.3	29.1	0.688
100	69.0	46.0	0.667

From the above table it is apparent that the areal adjustment of the Norrish Creek flood estimates results in substantially higher estimates than those derived from the provincial hydrologic mapping. In order to resolve this discrepancy, further analysis of Deroche Creek and Norrish Creek floods was undertaken. Each significant daily discharge from the limited Deroche Creek records was matched with the corresponding flow from Norrish Creek near Dewdney. These flood flows are listed in Table 5.5.

The average of the top four Deroche to Norrish flood ratios is 0.113 in terms of daily discharge. Considering the range and limitations of the data, this ratio can be rounded off to 0.11 for use with both daily and instantaneous discharges. This ratio is in agreement with the highest recorded flow on Deroche Creek.

TABLE 5.5

DEROCHE CREEK VS. NORRISH CREEK FLOODS (DAILY FLOW)

Year	Date	Deroche Creek (m^3/s)	Date	Norrish Creek (m^3/s)	Ratio D/N
1960	Jan 29	4.84	Jan 29	77.6	0.0624
	Feb 7	2.38	Feb 7	52.4	0.0454
	Apr 3	2.38	Apr 3	66.0	0.0361
	Nov 18	2.38	Nov 19	45.6	0.0522
	Dec 12	3.60	Dec 12	56.1	0.0642
1961	Jan 15	12.5	Jan 15	193	0.0648
	Feb 21	14.2 E	Feb 21	133	0.107*
	Oct 13	4.19	Oct 13	52.4	0.0800
	Nov 10	4.19	Nov 10	58.0	0.0722
	Dec 29	5.61	Dec 29	69.7	0.0805*
1962	Jan 7	6.60	Jan 7	50.7	0.130*
	Feb 3	5.61	Feb 2	41.9	0.134*
	Apr 7	1.98	Apr 6	36.2 E	0.0547
	Nov 25	1.55	Nov 25	49.3	0.0314
1963	Nov 26	7.93 E	Nov 26	214	0.0371
	Dec 23	2.92 E	Dec 23	163	0.0179
1964	Jan 1	4.05 E	Jan 1	66.8	0.0606
	Apr 1	1.64	Apr 1	34.0	0.0482
				Avg. top 4*	0.113

E - Estimated

The recommended Deroche Creek flood estimates are listed in Table 5.6 based on the 0.11 factor applied to the LPIII flood estimates for Norrish Creek near Dewdney, as listed above in Tables 5.2 and 5.3.

TABLE 5.6
RECOMMENDED DEROCHE CREEK FLOOD ESTIMATES

Return Period (years)	Maximum Daily Flood (m^3/s)	Maximum Instantaneous Flood (m^3/s)	Regional Mapping Instantaneous Flood (m^3/s)
2	10.9	20.0	
5	15.3	28.3	
10	18.4	34.3	29.1
20	21.7	40.5	
50	26.4	49.1	
100	30.1	56.0	46.0
200	34.2	63.4	
500	40.2	73.9	

The Regional Mapping flood estimates are included in the above table for comparison with the maximum instantaneous flood estimates. The recommended flood estimates are significantly higher than the Regional Mapping estimates and are therefore believed to be conservative.

6 HYDRAULIC ANALYSIS

The hydraulic characteristics of the present day creek channel traversing the fan were investigated by means of a hydraulic model. The purpose of this analysis was to evaluate existing channel capacity and hydraulic characteristics of the system so that likely avulsion locations could be determined. Field data was collected for input into the model as described in Section 4.

6.1 HEC-RAS Model

The river profile analysis utilized HEC-RAS Ver 2.2, River Analysis System software developed by the US Army Corps of Engineers, Hydrologic Engineering Center, Davis, California. This is a standard tool for hydraulic analysis and is used throughout North America.

River survey information was reduced and incorporated into a CADD-based digital terrain model. Cross sections and river profile station locations were then exported in a file format acceptable for input to the HEC-RAS program. This basic input data was converted into a working river model through the addition of bank station locations, road and bridge details and some adjustments for

overbank reach length. Cross sections at the Morton Road Bridge were adjusted for a skew angle of 18.5 degrees. Overbank extensions to the cross sections were derived from 1:5000 topographic mapping of the Deroche basin, as supplied by the Fraser Valley Regional District. Overbank extensions within Lakahahmen I.R. No. 11 were derived from 1:2000 Fraser River Flood Risk Mapping developed by Northwest Hydraulic Consultants (1995).

Channel roughness parameters were estimated from site observations, photos, literature, and changes in slope along the river profile. It was observed that the size of the bed material becomes larger as one proceeds upstream from the creek mouth. Transport of this material would require progressively higher velocities. Since velocity is a function of bed slope, it was concluded that channel slope would be a good indicator of both velocity and bed material size. Channel roughness is related to the size of this bed material and was adjusted in accordance with slope changes along the channel. The adopted Manning's n values ranged from 0.035 at the creek outlet to 0.075 near the apex of the fan as indicated in Table 6.1 below. The river stations are designated on the flood hazard map, Figure 6.1.

TABLE 6.1
MANNING'S N VALUES USED IN HEC-RAS MODEL

River Station (RS) (m)	Description	Manning's n
0 to 70	Mouth of Deroche Creek: Nicomen Slough to Taylor Road Bridge	0.035
79 to 147	Fraser River Floodplain: Taylor Road Bridge approx. 1/3 way to CPR Bridge	0.042
217 to 650	Lower Reach of Deroche Creek Fan: Below CPR Bridge to above North Nicomen Road Bridge	0.050
700 to 1279	Middle Reach of Deroche Creek Fan: Below Morton Road Bridge	0.060
1286 to 1632	Upper Reach of Deroche Creek Fan: Morton Road Bridge to Water Intake Structure	0.075

Each of the changes in channel roughness represents an increase of approximately 20 to 25% over the downstream value. Overbank roughness varied from 0.100 to 0.150 for forested areas, 0.060 for fields and 0.030 for paved areas. Abandoned side channels were modelled as part of the overbank and were assigned a roughness value of 0.080. These latter values were not crucial as the model was primarily developed for the purpose of predicting the channel capacity up until the point of overtopping.

Overbank flows were artificially curtailed in the model by establishing ineffective flow areas and/or dykes (levees) along the crests of berms, banks or topographic high points. This approach was necessary to avoid anomalous results due to lost flow from the channel, which in the model would be assumed to re-enter the channel further downstream, contrary to actual conditions on the fan. Also, large transfers of flow in and out of the overbank tend to cause stability problems for the model.

Side channels were modelled approximately, along with overbank extensions.

Starting water levels in the model were approximated by the slope-area method for subcritical profile analysis. The energy grade line was assigned a value of 0.0005 representing the low gradient in Nicomen Slough. For supercritical analysis, the energy grade line was assigned a value of 0.1 representing the steep reach in the vicinity of the water intake.

Preliminary model runs were executed with a single discharge pertaining to the 10-year flood event. Initial runs were conducted assuming a subcritical profile in keeping with conditions near the creek outlet into Nicomen Slough. It soon became apparent that the upper reaches would be supercritical and consequently, a mixed flow profile analysis was adopted which permitted both subcritical and supercritical flow conditions to be evaluated in a single model run. Once the model had been debugged, a multiple profile analysis was carried out.

6.2 Results

The HEC-RAS model was used to develop water surface profiles for the floods derived in the hydrology section of this report, namely for annual floods with return periods of 10, 20, 50, 100 and 200 years. In addition, debris flood discharges were input into the model to evaluate conditions for these extreme flood events. Profiles were developed for a total of nine discharges as listed in Table 6.2.

TABLE 6.2
FLOOD PROFILES ANALYZED

Flood Description	Discharge (m^3/s)
10-year return period	34.3
20-year return period	40.5
50-year return period	49.1
100-year return period	56.0
200-year return period	63.4
*(10-year) debris flood	100
*(20-year) debris flood	150
*(30-year) debris flood	220
*(50-year) debris flood	300

*Numbers in parentheses are assumed values only, not calculated.

Selected flood profiles are shown on Figure 6.2 representing 10, 50 and 200-year return period water floods as well as 150 and 220 m^3/s debris floods.

It should be noted that the return period floods are representative of flood events attributed solely to the hydrologic response of the basin to rainfall runoff and snowmelt conditions. Debris floods are triggered by landslides resulting in channel blockages and resultant outburst floods, for which frequency methods do not apply. This subject is treated in greater detail in Appendix 1, prepared by EBA Engineering Consultants Ltd.

The predicted flood levels at each cross section location were utilized in a rating curve subroutine within HEC-RAS. These rating curves represent existing conditions up to the point where banks are overtopped. At higher water levels the overbank areas were artificially excluded through the use of imaginary dykes, as described above, in order to avoid discontinuities in the rating curves at the point of overtopping. In this manner an accurate appraisal could be made of the existing channel capacity corresponding to incipient overtopping of the lower of the two channel banks. Since the lower bank was also confined in the analysis, subsequent secondary overtopping of the higher bank would be conservative, meaning the actual discharge would be higher than indicated due to flood relief over the lower bank. The flood profiles shown on Figure 6.2 represent conditions with both banks contained by dykes.

Results of the water surface profile and associated rating curve analysis, are listed in Table 6.3 below. The analysis revealed some key locations at which extreme floods would be likely to overtop the banks and escape from the channel. These locations are identified in terms of River Station (RS):

- RS 1632 – channel capacity at the site of the community water intake structure is low and floodwaters could escape over the left bank for flows in excess of 45 m^3/s, which corresponds to a flood event with a return period of just over 30 years. This is a very high risk area for avulsions.
- RS 1426 – this site is adjacent to Mr. Gruenwald's property where flow overtopped the left bank in 1989. Capacity of the existing channel is approximately 95 m^3/s. There is a high risk of an avulsion at this location.
- RS 1066 – main channel capacity is approximately 95 m^3/s along the left bank and flows could overtop a second topographic high point at a discharge of 130 m^3/s. Land slopes away from the channel at this location and also for the reach extending approximately 150 m upstream.
- RS 444 to 471 – channel capacity is limited on the approach to the Nicomen Road Bridge at RS 438. Free flow capacity of the bridge opening is only 38 m^3/s after which the inlet would begin to prime. The return period of this flood event is approximately 15 years. After priming, the approach flow depth would increase until the banks were overtopped. Overtopping of both banks of the approach channel would occur at a discharge of approximately 60 m^3/s corresponding to a flood with a return period of over 100 years providing the channel did not aggrade during the flood. In fact, the approach channel makes a sharp 90 degree turn at the bridge entrance which constitutes poor hydraulic conditions. As well, the HEC-RAS model predicts a hydraulic jump at this location, which would result in an increase in flow depth and a drop in velocity. Both of these factors would promote sedimentation just upstream of the bridge. We understand that this location is the site of regular channel maintenance involving gravel removal to maintain flow capacity at the bridge entrance. This location is therefore at high risk of an avulsion. Flow would overtop the right bank first due to superelevation effects in the bend. Some flow could cross the road and re-enter the channel just west of the bridge, however, the bulk of the overbank flow would be constrained by the CPR track embankment on the south side, sending floodwaters down North Nicomen Road.

TABLE 6.3
SUMMARY OF HYDRAULIC ANALYSIS
OF DEROCHE CREEK CHANNEL

River Station m	Avulsion Threat	Channel Capacity Left Bank		Channel Capacity Right Bank		Remarks: LB = left bank RB = right bank LC = lower chord
		Discharge m^3/s	Water level m	Discharge m^3/s	Water level m	
1632	Left bank	45	87.7			Water intake; low LB
1596	Left bank	185	85.7			Low LB
1553	Left bank	230	80.7			Low LB
1493	Left bank	250	74.5			Low LB
1462	Left bank	300	70.6			
1426	Left bank	95	66.4			Low LB; high risk
1379	Left bank	>300	62.9			Sharp bend
1348	Left bank	>300	60.6			
1304	Left bank	>300	56.3			
1286	Left bank	~270	56.5			
1283	Capacity =	~270	56.5 LC			**Morton Road Bridge**
1279	Left bank	~270	56.5			
1242	Left bank	105	50.3			High LB; RB chan
1193	Left bank	170	48.3			Low LB; gentle slope up
1147	Left bank	220	45.3			Low LB; slopes away
1066	Left bank	130/95	40.5/40.3			LB chan; slopes away
980	Left bank	230	36.5			Low LB
902	Left bank	300	31.7			LB slopes up
828	Left bank	290	28.1			Low LB; slopes away
771	Left bank	180	25.9			Low LB; new LB chan
700	Both banks	300	23.4	240	22.9	RB opens up
650	Both banks	160	21.2	125	20.9	
593	Both banks	210	19.9	285	20.5	
557	Both banks	185	18.3	200	18.4	Berms on both banks
537	Both banks	>300	18.3	150	17.3	
509	Both banks	240	17.1	90	15.8	
491	Both banks	>300	16.8	190	15.8	
481	Both banks	~300	~16	~60	~15	End of LB berm
471	Both banks	~60	15.1	~60	~15	
464	Both banks	~60	15.1	50	14.7	
454	Both banks	~60	15.1	55	14.8	Sharp bend
447	Both banks	~60	15.1	~60	15.2	Sharp bend
444	Both banks	~60	15.1	~60	~15	Sharp bend
438	Capacity =	38	14.0 LC	~60	~15.1 Road	**Nicomen Road Bridge**
431						
429	Both banks	100	13.9	110	14	
425						
420	Capacity =	88	13.85 LC	~100	~14.5 Track	**CPR Bridge**
415						
402	Both banks	150	13.8	170	~14	
387	Both banks	220	13.9	260	14.2	
332,294						Well incised
256	Left bank	270	10.4			
217	Right bank			~35	8.0	Fraser River Floodplain
147	Both banks	90	~8	90	~8	Fraser River Floodplain
123	Both banks	56	7.4	85	8	Fraser River Floodplain
79	Both banks	120	8.2	125	8.3	
75	Capacity =	106	7.6 LC	~120	8.0	**Taylor Road Bridge**
70,58						
21						Nicomen Slough

The above analysis has revealed some critical locations with respect to channel avulsions. It must be recognized, however, that the analysis has assumed a fixed channel bed. Aggradation and degradation can be expected to occur throughout the channel system during a large flood event. These channel changes may favour avulsions at other locations along the channel. In particular, it is noted that low overbank elevations exist along the left bank downstream from the water intake for a distance of over 200 m. This entire reach is considered to have a high avulsion risk associated with it. Portions of the left bank downstream of the Morton Road Bridge are also at risk of avulsion should the channel aggrade. Deroche Creek has also eroded a second channel just downstream of RS 828, close to an existing house and North Deroche Road. A rock berm has been built across the entrance to this side channel, however, it remains at risk from erosion and/or overtopping due to its location on the outside of a channel bend.

The likelihood for the channel to avulse at a particular location is predicated upon its existing capacity to convey flow and its relative proximity to the apex of the fan. A chain is as strong as its weakest link and likewise the channel's capacity to contain floodwaters is limited to the first location encountered by the flow at which the flow exceeds channel capacity. For a gradually varied flow, this will correspond with the lowest capacity reach in the system. In a rapidly advancing floodwave, such as might be expected from an outburst flood, the breach will occur as soon as the floodwave discharge exceeds bankfull capacity of the channel. Once this critical location is breached, a portion of the floodwaters will escape as overbank flow and take an alternate flow path across the fan, possibly re-entering the channel system further downstream. This flow escapement provides a form of flood relief, which may limit the magnitude of the flood discharge down the remainder of the main stem. It should be recognized, however, that the flow passing the initial breach point can exceed the channel capacity corresponding to incipient overtopping at this location due to the surcharge depth associated with overbank flow. Flow remaining in the main stem will also likely exceed the channel capacity at locations further down the fan such that multiple breach locations are possible from the same flood event. An obvious location for a secondary breach is at the sharp bend at the approach to the North Nicomen Road Bridge.

In summary, the breach location for an outburst flood is a function of flood magnitude. The higher the flood magnitude, the higher up the fan will be the point at which the floodwaters first overtop the banks of the channel. The aforementioned uncertainty in breach location means that the vast majority of the fan surface has the potential to convey flow during extreme flood events. Just because the flow overtopped the banks at a particular location in the past is no guarantee that future breaches will occur at the same location.

7 ENVIRONMENTAL REVIEW

7.1 Introduction

The Fraser Valley Regional District requested an Environmental Review of the Deroche Creek fan as part of the Hazard Assessment and Technical Analysis portion of the Scope of Work. The objectives of this assessment were to identify any fish and wildlife habitat areas on the fan adjacent to Deroche Creek, and to determine constraints to development and/or flood protection options and natural areas that may require protection, particularly with respect to Nicomen Slough.

Following a brief office review of information, the field environmental assessment of the Deroche Creek fan was conducted on November 5, 1999. This assessment consisted of an overview examination of the fish, wildlife and vegetation values adjacent to the creek channel on the fan. No major fish, wildlife or environmental issues or concerns are noted, but there are environmental recommendations for Best Management Practices (BMPs) to safeguard fish and wildlife habitat.

7.2 Environmental Assessment

The following sections summarize the results of the background review and the field assessment.

7.2.1 Background Review

Prior to engaging in the field survey, EBA Engineering Consultants Ltd. (EBA) reviewed the Fisheries Information Summary System (FISS) database for fisheries information on Deroche Creek. The information in the database indicated that both coho *(Oncorhynchus kisutch)* and chum salmon *(Oncorhynchus keta)* use this stream for spawning in the lower sections. The database also noted the presence of cutthroat trout *(Oncorhynchus clarki)*, an unidentified species of sculpin *(Cottus sp.)* and an unidentified species of stickleback *(Gasterosteus sp.)*. The FISS data indicated that the creek transports large quantities of gravel, which could cause the creek to leave its channel upstream of the Canadian Pacific Railway (CPR) bridge. The potential of complete dry-up of the channel in the lower sections was also noted.

Mr. Rick McKamey (Pers. Comm.) of the North Fraser Community Futures Development Corporation commented that 90 returning coho salmon were recorded in 1999. Mr. McKamey added that a spawning pond was constructed downstream of the lower bridge on Deroche Creek under the Salmonid Enhancement Program (SEP) of the Department of Fisheries and Oceans (DFO).

7.2.2 Field Assessment

Appendix 2 includes a detailed description of the survey results from the environmental field assessment. During the field assessment, EBA completed the MELP Stream Survey Site Card, and walked the stream from the mouth to the Morton Road crossing, a distance of approximately 1,400 m. Along the way, notes were recorded on riparian vegetation and signs of wildlife and wildlife habitat. Within this reach of the stream, two distinct sub-sections were observed, based on gradient and channel type: from the mouth to the CPR Bridge, and from the CPR Bridge to the Morton Road crossing.

7.2.3 Constraints to Development/Flood Protection

This section examines constraints to development/flood protection that were identified during the environmental review.

The lower sections of Deroche Creek are utilized by anadromous salmonids, and resident trout, sculpins and stickleback for rearing and spawning. Waterfowl were observed on the delta near the mouth. The presence of these sensitive species in this low-density residential area warrants a riparian setback zone of at least 15 m on either side of the stream channel and the delta (DFO and MELP, 1993).

New development proposals should be checked for compatibility with existing land uses and Official Community Plan (OCP) objectives and directives. In addition, compatibility of new developments with any existing groundwater licences should be investigated.

Mr. Rick McKamey of the LFN indicated that the LFN has no plans for further residential developments on their lands in the lower Deroche Creek fan area. He also noted that the LFN had developed objectives for fisheries enhancement in the lower Deroche Creek area, including the creation of fish habitat. Mr. McKamey mentioned that the LFN supports the installation of a debris trap on upper Deroche Creek as a measure to reduce channel aggradation.

The existing berms on lower Deroche Creek may have an influence on the effects of Deroche Creek floods. During Deroche Creek floods, the berm forces sediment and debris from the upper sections to be deposited in a single channel downstream of the CPR Bridge, leading to aggradation of the channel. A highly aggraded streambed may lead to dewatering of the channel, which represents a loss in fish habitat and a potential barrier to upstream migration of chum and coho salmon during the spawning

run. In order to ameliorate the effects of the present dyke, the channel width between the berm walls should be increased to afford the channel more lateral movement. The berms could be rebuilt to mark the outer boundary of the setback zone.

The time window for gravel removal operations should be tied to the Fisheries Sensitive Zone (FSZ) species timing window for the salmonid species present in Deroche Creek. The species and their windows (DFO and MELP, 1993) are as follows: coho salmon (June 15- September 15), chum salmon (May 15 – September 15) and cutthroat trout (August 1- September 30). To minimize harm to these species, a suggested time window for gravel removal would therefore be August 15 – September 15. In addition, any activity that may cause a disturbance to shrubs or trees should be conducted outside the spring bird nesting period.

7.3 Conclusions

No major fish, wildlife or environmental issues or concerns are noted. However, a number of environmental recommendations for BMPs are made to safeguard fish and wildlife habitat. These are:

- Implement a riparian setback zone of at least 15 m on either side of the stream channel and the delta;
- Check new development proposals for compatibility with existing land uses and OCP objectives and directives;
- Investigate the compatibility of new developments with any existing groundwater licences;
- Expand the channel width between the berm walls (downstream of the CPR bridge) to afford the channel more lateral movement; and
- Limit gravel removal activities to the period of August 15 – September 15. Limit activities that may cause a disturbance to shrubs or trees to be conducted outside of the spring bird nesting period.

8 LAND USE

8.1 History

Prior to 1800, native villages were established in Deroche and Nicomen Island. These settlements were later designated as Indian Reserves including I.R. 11 (Lakahahmen). The first European pioneers settled in the Deroche area in the 1860s. They established farms and provided services to prospectors attracted to the Cariboo gold rush. Major settlement occurred following the completion of the

Canadian Pacific Railway to the west coast in 1885. The main economic activities consisted of dairy cattle, growing of crops and logging.

Some early milestones consisted of the first Deroche school in 1893, a bridge linking Deroche with Nicomen Island in 1906, a sawmill in 1908 and a railway station in 1915. The first subdivision plan for the Deroche village was registered in 1909 followed by the first water supply system in 1913.

Flooding of the Fraser River was a perennial problem, which was addressed by the construction of a south dyke in 1923 followed by a north dyke in 1929. The Fraser River flood of 1948 had a major impact on the area. All of Nicomen Island was flooded and a portion of the CPR track was removed by floodwaters. Reconstruction of the dykes began in September of 1948. No major flooding of the Fraser River has taken place since then.

8.2 Official Community Plan

The Official Community Plan (OCP) for Deroche is part of a larger planning area of approximately 52 square km. The Deroche-Lake Errock-Nicomen OCP was adopted as Bylaw No. 436 in January 1987. Approval was by the Dewdney-Alouette Regional District, which subsequently became part of the Fraser Valley Regional District. The OCP documents the overall development strategy for Deroche as well as policies concerning land use.

Environmental hazards are identified on Schedule D-1 of Deroche-Nicomen OCP Amendment Bylaw No. 0219, 1998. Schedule D-1 maps hazards consisting of the Fraser River floodplain as established by the Ministry of Environment, potential flooding and erosion areas in the Deroche Creek fan and an overlap area subject to hazards from both sources. The OCP text indicates that the Ministry of Environment recommendation is that these areas should be critically evaluated on an individual basis for suitability for settlement or community uses.

The OCP text addresses the hazard land areas and states that development in areas susceptible to flooding, erosion, slumping or any other physical condition which could lead to the deterioration of the environment or endanger the health and safety of area residents should be limited (Objective 9). No building or structure shall be located within areas identified as subject to potential flooding or erosion unless the Building Inspector is satisfied that the development may be safely constructed (Policy 6.1). It adds that structures within the Fraser River floodplain must be located above the flood level as specified in the Zoning By-law regulations (Policy 6.2).

The OCP does not include development permit areas for the protection of the natural environment or the protection of development from hazardous conditions (authorized under Sections 879(1)(a) and (b) of the *Municipal Act*. If such designation takes place, Section 920 of the *Municipal Act* prohibits any subdivision of land or building construction unless a development permit is first obtained from the Fraser Valley Regional District. Such a development permit may specify that areas of land subject to flooding or debris flows remain free of development except in accordance with the conditions specified in the development permit. The development permit may prevent the construction of septic tank drainage and deposit fields or water systems. The development may also require that works be constructed to preserve or enhance natural water systems or specify that areas of land located above the natural boundary of streams must remain free of development, except in accordance with the conditions contained in the permit.

Key objectives of the development strategy for the Deroche-Lake Errock-Nicomen OCP as well as the preceding 1979 Official Settlement Plan are to preserve the rural character of the area and maintain a slow growth rate. The OCP also states that community services, such as fire protection, water and solid waste should only be provided within the financial ability of the Regional District and the local community.

Six land use designations apply to Deroche on Schedule F-1 of the Deroche-Nicomen OCP as amended by Bylaw No. 0219, 1998. They consist of the following (see Figure 8.1):

- **Rural Residential.** This designation applies to almost all existing development on the west side of Deroche Creek and most on the east side of Deroche Creek. This designation is intended for lands suitable for on-site servicing, with good access to public roads and with limited environmental hazards. Such lands may be used only for residential and agricultural uses. A minimum parcel size of 1.0 ha (2.47 acres) is specified, which may be reduced to 0.5 ha (1.24 acres) where a community water system is provided.

- **Rural I.** This designation applies to most properties along the northern, western and eastern edges of Deroche. It is intended only for moderate to large parcel sizes used for residential, agricultural and natural resource extraction purposes. A minimum parcel size of 2 ha (4.94 acres) is specified.

- **Rural II.** This designation applies only to one property at the top of the Deroche Creek fan. This designation applies to large parcels with steep slopes, limited road access, and environmental hazard areas. A minimum parcel size of 4.0 ha (9.88 acres) is specified.

- **Institutional.** This designation applies to existing and former Deroche Elementary School sites, the existing groundwater well site next to the former elementary school, the Community Hall, and a section of land west of Morton Road. This designation is intended for established institutional uses in a central location within an existing community and suitable for on-site servicing. A minimum parcel size of 1.0 ha (2.47 acres) is specified, which may be reduced to 0.18 ha (0.44 acres) where a community water system is provided.

- **Commercial.** This designation applies along the north side of the Lougheed Highway south of Cooper Road and south of the Deroche Elementary School. It is intended for existing commercial uses with a central location within an existing community and suitable for on-site servicing. A minimum parcel size of 1.0 ha (2.47 acres) is specified, which may be reduced to 0.18 ha (0.44 acres) where a community water system is provided.

- **Agricultural.** This designation applies to lands south of the railway that are not within I.R. 11. It includes all lands with high agricultural potential that are within the ALR. Only agricultural or residential uses are permitted. A minimum parcel size of 16 ha (39.5 acres) is specified.

- **I.R. 11.** No OCP designation applies, as the Fraser Valley Regional District has no jurisdiction over land uses within Indian Reserves. The Lakahahmen First Nation have their own Physical Development Plan, as shown in Figure 8.2.

The population of the OCP plan area has increased slowly over the past 30 years with average annual increases of less than 1%. At the 1971 census, the population in the plan area excluding Indian Reserves was 910. This increased to 1,000 in 1986. However, the population of Deroche is substantially lower. The number of dwelling units located on the Deroche Creek fan including I.R. 11 is approximately 140 with an additional 50 to 60 other dwellings in Deroche but outside the fan. This would indicate a current total population of approximately 600 in Deroche, of which approximately 420 reside on the Deroche Creek fan.

8.3 Zoning

Zoning for the Deroche area is regulated by By-law 559, adopted by the Dewdney-Alouette Regional District in July 1993. Figure 8.3 shows the zoning in Deroche. The following minimum requirements apply to zones in Deroche:

- Floodplain Agriculture (A-2) Minimum parcel size of 16.0 ha.
- Rural 1(R-1) Minimum parcel size of 2.0 ha.
- Rural 2 (R-2) Minimum parcel size of 4.0 ha.

- Rural 3 (R-3) Minimum parcel size of 8.0 ha.
- Rural Residential 1 (RS-1) Minimum parcel size of 0.5 ha and a community water system.
- Rural Residential 2 (RS-2) Minimum parcel size of 1.0 ha.
- Neighbourhood Commercial (C-1) Minimum parcel size of 0.5 ha.
- Civic Assembly (P-1) Minimum parcel size of 1.0 ha.
- Cemeteries (P-4) Minimum parcel size of 1.0 ha.

8.4 Lakahahmen First Nation Physical Development Plan

The Lakahahmen First Nation Physical Development Plan is shown on Figure 8.2. It identifies land uses within Lakahahmen I.R. No. 11. The majority of the land south of the CPR is proposed for agricultural use. The three existing trailer parks are shown on the northerly and easterly parts of I.R. No. 11. A number of single family lots are also identified, the majority of which are occupied. The existing sacred ground (cemetery) is located in the north-east corner of I.R. No. 11, adjacent to North Deroche Road. The Deroche Community Hall is identified in a different way from other uses within the reserve, as this site has been made available to the Deroche community as a whole, as long as a community use remains.

The Lakahahmen First Nation Physical Development Plan is under the control of the Lakahahmen First Nation Band Council. Its intent is to provide for the orderly management of land uses within the Lakahahmen I.R. No. 11.

8.5 Floodplain Management Bylaw

Dewdney-Nicomen Floodplain Management Bylaw No. 0056, 1996 designates those lands as a floodplain, which are identified in the OCP as subject to environmental hazards. This provides an alternate mechanism to the use of development permits for addressing hazard lands. The Floodplain Management Bylaw was enacted under Section 969 of the Municipal Act (now Section 910). Under this bylaw, the Fraser River floodplain is designated as Schedule A. Key provisions affecting development in the Fraser River floodplain are as follows:

- No building or structure may be constructed outside the area protected by dykes;
- A minimum setback of 60 m from the natural boundary of the Fraser River is required for any manufactured home or floor system for any habitable area;
- Minimum Flood Construction Levels of 10.6 to 10.9 m Geodetic, depending on site location is required for habitable areas; and

- Structural support or compacted landfill may be used to elevate the underside of the floor system to protect against scour and erosion from flood flows, wave action, ice and other debris.

The Deroche Creek fan is designated an alluvial and debris torrent area under Schedule B. Key provisions affecting development in the Deroche Creek fan are as follows:

- A minimum setback of 60 m from the natural boundary of Deroche Creek is required for any manufactured home or floor system for any habitable area;
- Minimum Flood Construction Level 3.0 m above the natural boundary of Deroche Creek;
- Minimum Flood Construction Level 1.0 m above the undisturbed ground elevation or 0.6 m above the crown of the adjacent road, whichever is higher; and
- Assessment of the suitability of development by a qualified Professional Engineer.

It should be noted that the Floodplan Management Bylaw does not apply to LFN lands.

8.6 Agricultural Land Reserve

The lower part of the Deroche Creek fan is within the Agricultural Land Reserve (ALR). This includes all lands south and east of the CP Railway to the Nicomen Slough. The majority of I.R 11 is within the ALR boundaries although the Agricultural Land Commission does not have jurisdiction over Indian Reserves. A total of six fee simple properties within the revised Deroche Creek fan boundaries are within the ALR.

8.7 Services

Water service is provided by a combination of individual wells, collective wells and Deroche Creek. A community water system serves 40-45 properties on the east side of Deroche Creek. The intake is located on the east side of the creek on private property approximately 1.2 km north of the Lougheed Highway. As documented in a report by the Fraser Valley Regional District in February 1998, the intake consists of a small concrete dam that raises the water level to just above the top of the side intake. A wire screen covers the intake, which is maintained manually. A 100 mm pipe supplies water to the residents, who pay $300 annually for this service.

The Lakahahmen I.R. No.11 is served by a well near the intersection of the Lougheed Highway and the CPR tracks as shown on Figure 8.2. There is no indication that it suffers from the water quality problems of the Deroche community water system as noted below. However, neither system includes a reservoir or fire fighting capacity.

The community water system suffers from a number of problems and deficiencies including variable water quality due to debris, which occasionally enters the intake, small diameter pipes and no reservoir. The community water system has no fire fighting capacity. The Ministry of Health has undertaken water quality tests on a regular basis since 1986. A boil water advisory has been in effect since 1987 and was reconfirmed in a letter to the Chairman of the Fraser Valley Regional District in February 1998. Six of eight water quality tests by the Ministry of Health in 1998 tested positive for fecal coliform.

The Deroche School is supplied by a well located on a small lot north of the intersection of the North Deroche Road and the Lougheed Highway. The well is 23 m deep and operates at 15 US gpm at 76 m of head. The school is connected with a 150 mm diameter line along the road and a 100 mm pipe within the school property.

Other properties including all those on the west side of Deroche Creek and I.R. 11 have on-site wells.

The 1998 Regional District study identified a water upgrading program to provide adequate fire protection to most of the community. This included replacement of most of the water lines with minimum 150 mm diameter mains, a 200,000 L storage tank and acquisition of the school well for community use. Total costs of approximately $700,000 were identified. In the fall of 1999, a grant of $132,500 for upgrading of the Deroche Water system toward a total project cost of $265,000 was announced. Proceeding with the project is subject to a community vote in favour of its 50% share of the funds.

All sewage in Deroche is disposed by septic tank fields. Fee simple properties have individual septic tanks while two mobile homes on I.R. 11 each share a septic tank field. There is no indication of unfavourable soil conditions for septic tanks.

All power is supplied by B.C. Hydro from overhead poles.

All main roads in Deroche are paved although several local roads have a gravel surface. Road standards are quite variable. They range from the Lougheed Highway, with two paved travel lanes

plus paved shoulders totaling 13 m in width, to Pullin and Morton Roads with three metres of gravel. Most local roads have pavement of five to six metres in width.

8.8 Assessed Land and Building Values

An estimate of property and building values at risk in the Deroche Creek fan was prepared using 1999 BC Assessment Authority data. All properties partly or wholly within the revised fan boundaries upstream of the Nicomen Slough were included.

Although land and improvements within I.R. 11 (Lakahahmen) are not subject to the BC Assessment Authority, the band has contracted with the BC Assessment Authority to provide this service due to the large number of non-native residents. As a result, lands and improvements on I.R. 11 have been assessed in the same way as lands outside the reserve. However, two differences should be noted. The first is that taxes on I.R. 11 are payable to the Lakahahmen Band, not the Fraser Valley Regional District. The second is that no assessed values have been prepared for status Indians living on-reserve. In the case of I.R. 11, the number of on-reserve Indians is very small, as the vast majority of residents are non-native and reside in the three mobile home parks. However, for comparative purposes, the value of land and improvements on I.R. 11 is somewhat under-represented, as only land leased to non-natives and their improvements is available. These improvements consist of the café and several residential dwellings.

Table 8.1 contains a total of 133 folios located wholly or partly within the Deroche Creek fan. It consists of 59 folios outside of I.R. 11 (all fee simple properties) plus 74 folios within I.R. 11. Almost all properties are occupied, as only six properties do not contain improvements. Most of the properties outside I.R. 11 contain conventional or wood frame, single family dwellings, while nearly all the folios inside I.R. 11 consist of mobile homes in one of three mobile home parks.

In terms of total values, 59% of all assessed values consist of buildings or other improvements while the remainder (41%) consists of land. It should be noted that not all land values are comparable as land within the Agricultural Land Reserve or with farm tax status is assessed at a lower level than other land. This primarily affects those lands south and east of the railway.

TABLE 8.1

1999 ASSESSED VALUES ON DEROCHE CREEK FAN

Location	Folios	Land	Improvements	Total
North Nicomen Road west of I.R. 11	6	$556,200	$243,500	$799,700
Parke and Fernie Roads	8	$886,000	$423,400	$1,309,400
North Deroche Road – RR to Pullin Road	9	$929,800	$2,861,100	$3,790,900
North Deroche Road – north of Pullin Road	8	$910,000	$452,100	$1,362,100
Cooper/Park Road	17	$1,030,400	$984,500	$2,014,900
Lougheed Highway/North of Cooper Rd.	5	$499,500	$191,500	$691,000
South of RR and east of I.R. 11	3	$59,200	$131,800	$191,000
Taylor Road west of I.R. 11	3	$120,200	$168,200	$288,400
I.R. 11 (Community Hall)	1	$123,000	$39,300	$162,300
I.R. 11 (Lakahahmen Mobile Home Park)	22	$99,000	$734,200	$833,200
I.R. 11 (Evergreen Estates)	20	$90,000	$935,400	$1,025,400
I.R. 11 (Kelly Estates)	26	$117,000	$679,100	$796,100
I.R. 11 (other non-native leases)	5	$167,500	$169,600	$337,100
TOTAL	133	$5,587,800	$8,013,700	$13,601,500

Source: BC Assessment Authority

Includes all properties wholly or partly within the boundaries of the Deroche Creek fan except land and improvements to band land within I.R. 11.

All land and improvements have been grouped into a number of geographical sub-areas. They consist of three sub-areas west of Deroche Creek, four east of Deroche Creek, one in the upper fan straddling Deroche Creek. Also included are those lands within I.R. 11. Although I.R. 11 is mostly west of Deroche Creek, most of the building improvements on the reserve are east of Deroche Creek.

In terms of improvements, the vast majority (80% assessed at $6,425,900) is located east of Deroche Creek. These improvements include the new elementary school, all commercial buildings and two of the three mobile home parks. The new elementary school alone represents over one third of the value ($2,574,000) of all buildings on the Deroche Creek fan.

Nearly half of the assessed value of all improvements (48%) is located in the area bounded by the Lougheed Highway, I.R. 11, Deroche Creek, Pullin and Cooper Roads. This central area contains most commercial buildings as well as the Deroche Elementary School. It includes a total of 26 properties with total assessed values of $3,665,600. Most of the remaining improvements on the Deroche Creek fan are located within I.R. 11. Over 30% of all assessed improvements valued at $2,518,300 (excluding the Community Hall) are within I.R. 11. They consist of 68 mobile homes plus two conventional single family dwellings.

A substantial part of the Deroche community is not within the boundaries of the Deroche Creek fan. These areas consist of a majority of properties along North Deroche Road, several properties on Fernie Road, North Nicomen Road, Taylor Road and along the Lougheed Highway.

8.9 Development Potential

Four subdivisions have been proposed within the Deroche community, see Figure 8.4. All have been held in abeyance pending the outcome of this Flood Hazard Management Study.

The first proposed subdivision, dated June 15, 1995, is for a change in lot lines for an existing dairy farm at 10524 North Deroche Road. The owners, Joseph and Jean Whittaker, propose to create a reduced lot area of 38 ha (95 acres) from North Deroche Road and an expanded lot area of 20 ha (50 acres) from Taylor Road. Both properties are in the ALR and no change of use is proposed. Both properties are substantially west of the revised Deroche Creek fan boundaries.

The second proposed subdivision, dated January 31, 1995, is at 10310 Fernie Road. The applicant, Fernando Cordeiro, proposes to create a second residential lot on the existing 4.656 ha (11.5 acre) property. The existing house is at the north-west corner of the property near the top of Fernie Road. The house is approximately 14 m above and 40 m west of Deroche Creek. A lot area of 2.306 ha is proposed for the existing dwelling with 2.35 ha for the second property. The building site for the second lot is approximately 90 m from Deroche Creek and 24 m lower in elevation than the existing house. Servicing of each lot is proposed to be by a well and septic tank. The existing house is outside the revised Deroche Creek fan while the second building site is within the revised boundaries of the Deroche Creek fan. Both existing properties are within the revised Deroche Creek fan boundaries.

The third proposed subdivision, dated September 19, 1997, is at 10699 North Deroche Road. The owners, Charles and Maureen Clem, propose to create a second rural residential property. The existing property has an area of 8.0 ha (19.7 acres). The proposed subdivision would result in one lot with an area of 6.2 ha and a second lot with an area of 1.8 ha. Servicing of each lot is proposed to be

by means of a well and a septic tank. The proposed subdivision is east of the revised Deroche Creek fan boundaries.

The fourth proposed subdivision, dated December 2, 1999, is at 10599 North Deroche Road and 41351 Morton Road. The applicant, Kauko Sokkanen proposes to resubdivide two existing lots and create a four lot subdivision. Both existing properties have houses. The proposed lots with existing houses would have an area of 4.87 ha west of Deroche Creek and 5.75 ha east of Deroche Creek. Two new lots with areas of 1.52 and 1.71 ha would also be created east of Deroche Creek. Servicing of each lot would be by means of a well and a septic tank. A road extension west of North Deroche Road of approximately 110 m and a new cul de sac is proposed.

Only two of the four proposed subdivisions are within the boundaries of the revised Deroche Creek fan. Apart from the above noted subdivision proposals, there are several other properties on the Deroche Creek fan with subdivision potential under existing zoning. They consist of one property bisected by Deroche Creek (zoned R-1), one property on North Nicomen Road (zoned RS-2) plus three large parcels almost entirely outside the Deroche Creek fan. In addition the Deroche school site (zoned P-1) could potentially be subdivided although this is of no relevance, given its public ownership and current use.

Development potential of the LFN land, I.R. No. 11, is discussed in the Physical Development Plan by Kerr Wood Leidal (1999).

Overall, the subdivision potential of lands on the Deroche Creek fan is considered very limited, given the current minimum parcel size requirements of the existing zoning. Even the few parcels with subdivision potential cannot proceed without first meeting the requirements of the Minister of Environment under Section 82 of the *Land Title Act* and the provisions of the Dewdney-Nicomen Floodplain Management Bylaw No.0056, 1996.

9 HAZARD ZONES

The entire Deroche Creek fan should be considered as a hazardous area to some degree. This reflects the nature of the processes that have formed the fan. The hydraulic analysis of the creek channel capacity, presented in Section 6, together with the Debris Flow and Debris Flood Study by EBA, included in Appendix 1, have identified several areas at high risk from avulsions and associated overland flows. The flow paths across the fan from these sites are more difficult to assess than are the potential avulsion sites themselves, due to limitations in the base mapping. Overland flows would likely be shallow with depths of less than a metre, except near the fan apex where higher initial flow

depths could be expected due to the confined flow. These flows would follow the fall line down the fan from the avulsion site. Numerous flow paths are possible, as there are many possible avulsion sites. A rigorous analysis to define potential flow paths would require a very detailed topographic plan of the fan surface with a contour interval of about 0.5 m or less. The available base mapping has a 2 m contour interval with portions of the lower fan, namely Lakahahmen I.R. No. 11, available at a 1 m contour interval. Neither is sufficient to accurately identify potential paths for shallow overland flows. The small creek adjacent to the school is a preferential overland flow route.

Due to the nature of alluvial fans, flow paths could occur almost anywhere across the fan surface. It is therefore difficult to accurately predict potential flow paths and specific areas that are at higher risk than others. However, in spite of these difficulties, there are two methods that can prove useful in helping to identify probable paths for overland flows. Firstly, low elevation routes such as old channels, gullies and depressions can be identified. Secondly, historical routes of slides, torrents and channel avulsions can be documented. The results of such an analysis are provided in Figure 9.1. Mapping at a contour interval of 2 m is useful in defining the main or active channel, as well as secondary and relic channels on the fan. These active channels are clearly the most probable flow paths for future floods. The current active channel is identified on Figure 9.1.

Historical air photos dating back to 1963 were evaluated to determine past flow paths and avulsion routes throughout the fan. Two significant events were noted, having occurred in 1962 or 1963 and in 1989. In 1962/63 two main avulsions occurred on the left (east) bank. The smaller, upstream one occurred just downstream from the fan apex and impacted most of the eastern half of the fan for a length of about 300 m, Figure 9.1. The second and larger avulsion occurred about mid-way down the fan. A large amount of sediment was deposited east of North Deroche Road down to the highway. The impacted area covers a total area of approximately 400 m in length and 180 m in width, Figure 9.1. The other notable avulsion occurred in 1989 and impacted a smaller area just downstream from the fan apex. The flow path of the 1989 avulsion joined the main channel approximately 200 m downstream from where it overtopped the bank. The impacted area was about 70 m wide, Figure 9.1. All of these areas, which have historically been impacted by overbank flows and debris flows, are likely candidates for future avulsion activity providing that land development has not changed the topography since historic avulsion activity took place.

Some general observations can be made with regard to hazard zones on the Deroche Creek fan:

- The degree of hazard on the fan increases in the upslope direction toward the apex, which has the highest risk for avulsions and damage to property.
- The typical shape of the fan surface results in steeper slopes and higher overland flow velocities toward the fan apex. Overland flow depths also tend to increase toward the apex where the fan width is more confined.
- Flood hazard on the fan generally decreases downslope, toward the fan boundaries, and away from the creek channel.
- Flood hazard decreases with increased elevation above the surrounding fan surface.

The following observations are more specific with respect to hazard zones on the fan:

- Deroche Creek is presently confined to the right (west) side of the alluvial fan throughout most of the upper reach above RS 902. Avulsions above this point would place nearly the entire left (east) side of the fan at risk.
- The fan is presently confined by dykes or berms below RS 700. Except near the North Nicomen Road Bridge, existing berms have been built from riverbed material consisting of rounded boulders, cobbles and gravel. These banks are not engineered, are unstable and could be eroded during major flood events. In fact, merely walking across some of these bank slopes provided sufficient force to displace bank material including sizable rounded boulders.
- Near the North Nicomen Road Bridge, the left bank berm is considerably higher than on the right bank such that overtopping would favour the right side. The higher left bank is intentional as it allows for superelevation effects in the water surface along the channel bend forming the bridge approach. This places the right side of the fan at risk downstream of RS 700 and extending to the bridge. The risk increases toward the bridge and along the right bank of the channel. An avulsion at this location would be confined by the CPR tracks to the south and would follow the road westward toward a depression north of the tracks and the Lakahahmen I.R. 11. Ponding in this area could develop to the level of the tracks, which have a local minimum elevation of 10.3 m, resulting in flooding comparable to the 200-year flood levels from the Fraser River.
- Fraser River flood construction levels vary from 10.6 m to 10.7 m across the Lakahahmen Reserve and 10.9 m on the eastern limit of the fan. Assuming freeboard of 0.6 m, this translates into Fraser River flood levels of 10.0 to 10.3 m. These flood levels apply to the lower reaches of the fan bordering on Nicomen Slough.

The hazard zones shown on Figure 6.1 are approximate only. These zones have been developed based on an overall assessment of the fan, channel capacity and past activity on the fan. There is no guarantee that the dividing lines between zones are definitive in terms of hazard changes on the fan. It must be stressed that the entire fan surface has been active in the past. In the long term, all areas of the fan could be reactivated. The hazard zones reflect relative degrees of hazard across the fan and identify areas that are more likely to experience flood related problems in the future. Everyone living on the fan shares some risk by virtue of being there.

The hazard zone categories are as follows:

Low Hazard Area

The low hazard area extends below the CPR tracks to Nicomen Slough with the exception of the floodway 60 m either side of the natural boundary of Deroche Creek. The floodway is considered a high hazard area above the CPR tracks and is downgraded to the moderate hazard category below the tracks. In addition, two zones of low hazard exist on either side of the fan above the CPR tracks. The western zone is protected by high ground in the vicinity of Fernie Road. On the eastern side of the fan, armoured fill placement for the new community school presently provides a protective shield for land and property in the south-east corner of the fan. Also, the nearby small creek represents a preferential flow path to the south of the school and residential/business area. However, based on advice from MELP, these have been ignored in developing the hazard zones as areas adjacent to the school, including the small creek, could be filled at some point in the future, either for land development or by a debris flow, rendering the school fill ineffective. A small low hazard area remains on the eastern side of the fan, however.

The overland slopes in this area vary from 2 to 3%. Overland flow velocities are expected to be in the 2 to 3 m/s range with depths of 0.4 m or less. Areas of low hazard are expected to be flooded only in the largest floods.

Moderate Hazard Area

The moderate hazard area extends north of the CPR tracks to the 35 m contour which passes through the intersection of North Deroche Road and Pullin Road. This hazard area extends laterally to the limits of the fan boundaries with the exception of the floodway 60 m either side of the natural boundary of Deroche Creek. This floodway is considered a moderate hazard area below the CPR tracks and high hazard area above the tracks.

This area represents the middle fan with overland slopes in the 3 to 6% range. Overland flow velocities of 2.5 to 4 m/s can be expected, depending on ground cover and flow depth. Flow depths are expected to be 0.6 m or less. Greater depths are possible if flows persist for long periods permitting channelling to develop.

High Hazard Area

The high hazard area extends from the 35 m contour to the apex of the fan near the community water supply intake. The high hazard area also includes the Deroche Creek floodway as described above. In addition, there is a high hazard area along the North Nicomen Road corridor on the west side of the Bridge and extending to the foot of Parke Road. Should an avulsion occur at North Nicomen Bridge, flows could travel west along the north side of the CPR embankment and enter the low lying land near the foot of Parke Road. These flows would be trapped and could impound to the level of the adjacent tracks depending on the flood volume involved. There is a culvert under the tracks, however, it would not handle the high flows associated with an avulsion. High velocities could be expected where flows drop into the depression just southeast of the foot of Parke Road.

The upper portion of the fan is highly confined with ground slopes to 10% or more. There is less room for flow to spread and consequently overland water depths to 1 m or more are possible. Overland flow velocities of 3 to 5 m/s can be expected in this area, depending on the type of ground cover and water depth. This area is subject to debris impacts, scour and erosion as well as sediment deposition.

Some approximate characteristics of the three hazard zones are given in Table 9.1 and on Figure 6.1.

TABLE 9.1
HAZARD ZONE PROPERTIES

Zone	Ground Slope (%)	Possible Velocity (m/s)	Possible Depth of Flow (m)	Typical Debris	Possible Depth of Deposition (m)	Possible Depth of Scour (m)
Low	2-3	3	0.4	Branches, gravel, sand	0.3	0.3
Moderate	3-6	4	0.6	Small logs, boulders up to 0.3 m	0.6	1
High	6-10	5	1.0	Big logs, boulders up to 0.6 m	1	2

10 STRUCTURAL FLOOD PROTECTION OPTIONS

10.1 General

There are many options available for mitigation of the flood risk on the Deroche Fan. EBA have presented some structural options in Appendix 1. A debris barrier has been proposed for the channel just above the water intake structure at an estimated cost of $0.5 to $1 million. A debris basin has also been discussed for the area just below the water intake at an estimated cost of $2 million (see Appendix 1). These mitigation measures are aimed at dealing with the hazard directly as it enters the fan near the apex, before it has a chance to spread out and cause flood, erosion and debris impact damage.

The preferred mitigation strategy for most of the high hazard areas is to relocate the structures to a safer location. An exception on LFN lands is the "tongue" of high hazard area west of the North Nicomen Road bridge. Upgrading the road bridge would reduce the hazard from high to moderate in this area.

The high costs associated with property acquisition make the relocation option expensive. Also there would be considerable public resistance. However, it provides the only long-term solution with assured success. It is recognized that the high capital costs may preclude implementation of these measures. Other mitigation measures can be considered, as discussed below.

10.2 Dykes

Dyke works can be used to contain the flood throughout the length of the creek channel. This option requires that the dykes be constructed to a uniform standard across the fan, otherwise unprotected areas can be subjected to an increased level of flood risk. Apart from the high capital cost, there are some inherent problems in the use of dykes to mitigate the flood threat across the fan. These problems are as follows:

- The use of dykes requires that a design flood event be well established. Regular flood events due to rainfall and snowmelt can be estimated with a reasonable assurance that the design event will not be exceeded within a specified time period. As discussed previously, the magnitude of debris floods is very difficult to predict accurately. Existing channel capacity may be only a fraction of the instantaneous peak flow during an outburst flood event. It therefore becomes necessary to design for a very large capacity channel, with high armoured banks. A large freeboard allowance is necessary to accommodate potential channel aggradation during the flood.

- Sediment deposited in the channel would have to be removed following each major flood event in order to maintain sufficient capacity in the channel to accommodate the next flood event. Good access is required for heavy machinery throughout the length of the channel. Gravel removal is more expensive than would be the case if it were concentrated at one collection point.
- Dyke works must be continuous which may cause problems where the channel is crossed by roads and rail lines. The North Nicomen Road Bridge has very limited capacity to pass large floods. If floodwaters were confined to the channel, this bridge would have to be replaced with a larger span, capable of passing several times its existing capacity. As well, both the CPR Bridge and the Taylor Road Bridge would require upgrades as neither would accommodate a debris flood without overtopping (see Table 6.3 for bridge flow capacities).
- The existing development on the fan leaves little room for dyke construction in some areas. The approach to the Nicomen Road Bridge is highly confined by existing houses and has a very poor channel alignment.
- No matter what standard a dyke is built to, there is always the chance of failure. Should the dyke system fail in the upper part of the fan, floodwaters would be prevented from re-entering the channel at downstream locations as they would be trapped on the outside of the lower dykes. This could exacerbate the flood damages to the lower portion of the fan over the undyked condition.

The total length of required dyke is approximately 1470 m on the left bank and 330 m on the right bank, or 1800 m in total. Left bank dyke works are required everywhere except below the Taylor Road Bridge and a short reach below the CPR Bridge. Right bank dyke works are required for a distance of approximately 330 m upstream from the CPR Bridge. Dyke works are assumed even when existing channel capacity is 300 m^3/s or higher because the stability of existing banks is poor.

The cost of bank protection generally runs about $600 to $1000 per lineal metre. Dykes represent increased cost over straight bank protection as there are additional fill and filter requirements. Dykes also require road access along the crest for emergency response and repair. Typical dyke costs are in the range of $1000 to $1500 per lineal metre. This results in a total cost for dyke works of approximately $1.8 million, not including the cost of bridge replacement and/or upgrades. The cost of dyke works is therefore roughly the same as the estimate of $2.0 million for a debris basin. Maintenance costs for a dyked channel would exceed the maintenance costs associated with a debris basin.

10.3 Raising of Structures

The alternative to channel confinement is to accept that the creek will occasionally overtop its banks and flow across the fan. Measures can be taken to provide protection to individual property on the fan. Flood proofing can be achieved by raising existing buildings above the surrounding grade allowing floodwaters to pass on either side. This approach is only feasible with relatively slow moving water and would not be suitable on the upper slopes of the fan where high overland flow velocities

could be expected. A general analysis was carried out to estimate overland flow velocities as a function of ground cover, slope and flow depth, see Table 10.1.

TABLE 10.1

OVERLAND FLOW VELOCITIES

Ground Surface	Manning's "n"	Surface Slope	Flow velocity in m/s for given water depth in m of:					
			0.3	0.4	0.5	0.6	0.8	1.0
Asphalt (rough)	0.016	0.01	2.8	3.4	3.9	4.5	5.4	6.3
	0.016	0.02	4.0	4.8	5.6	6.3	7.6	8.8
	0.016	0.03	4.9	5.9	6.8	7.7	9.3	10.8
	0.016	0.04	5.6	6.8	7.9	8.9	10.8	12.5
	0.016	0.05	6.3	7.6	8.8	9.9	12.0	14.0
	0.016	0.06	6.9	8.3	9.6	10.9	13.2	15.3
	0.016	0.08	7.9	9.6	11.1	12.6	15.2	17.7
	0.016	0.10	8.9	10.7	12.5	14.1	17.0	19.8
Short grass	0.030	0.01	1.5	1.8	2.1	2.4	2.9	3.3
	0.030	0.02	2.1	2.6	3.0	3.4	4.1	4.7
	0.030	0.03	2.6	3.1	3.6	4.1	5.0	5.8
	0.030	0.04	3.0	3.6	4.2	4.7	5.8	6.7
	0.030	0.05	3.3	4.1	4.7	5.3	6.4	7.5
	0.030	0.06	3.7	4.4	5.1	5.8	7.0	8.2
	0.030	0.08	4.2	5.1	5.9	6.7	8.1	9.4
	0.030	0.10	4.7	5.7	6.6	7.5	9.1	10.5
High grass	0.035	0.01	1.3	1.6	1.8	2.0	2.5	2.9
	0.035	0.02	1.8	2.2	2.6	2.9	3.5	4.0
	0.035	0.03	2.2	2.7	3.1	3.5	4.3	5.0
	0.035	0.04	2.6	3.1	3.6	4.1	4.9	5.7
	0.035	0.05	2.8	3.5	4.0	4.5	5.5	6.4
	0.035	0.06	3.1	3.8	4.4	5.0	6.0	7.0
	0.035	0.08	3.6	4.4	5.1	5.8	7.0	8.1
	0.035	0.10	4.1	4.9	5.7	6.4	7.8	9.0
Light brush and trees in winter	0.050	0.01	0.9	1.1	1.3	1.4	1.7	2.0
	0.050	0.02	1.3	1.5	1.8	2.0	2.4	2.8
	0.050	0.03	1.6	1.9	2.2	2.5	3.0	3.5
	0.050	0.04	1.8	2.2	2.5	2.9	3.5	4.0
	0.050	0.05	2.0	2.4	2.8	3.2	3.9	4.5
	0.050	0.06	2.2	2.7	3.1	3.5	4.2	4.9
	0.050	0.08	2.5	3.1	3.6	4.0	4.9	5.7
	0.050	0.10	2.8	3.4	4.0	4.5	5.5	6.3
Medium to dense brush in winter	0.070	0.01	0.6	0.8	0.9	1.0	1.2	1.4
	0.070	0.02	0.9	1.1	1.3	1.4	1.7	2.0
	0.070	0.03	1.1	1.3	1.6	1.8	2.1	2.5
	0.070	0.04	1.3	1.6	1.8	2.0	2.5	2.9
	0.070	0.05	1.4	1.7	2.0	2.3	2.8	3.2
	0.070	0.06	1.6	1.9	2.2	2.5	3.0	3.5
	0.070	0.08	1.8	2.2	2.6	2.9	3.5	4.0
	0.070	0.10	2.0	2.5	2.8	3.2	3.9	4.5
Heavy stand of timber, a few down trees, little undergrowth, Flood stage below Branches	0.100	0.01	0.5	0.5	0.6	0.7	0.9	1.0
	0.100	0.02	0.6	0.8	0.9	1.0	1.2	1.4
	0.100	0.03	0.8	0.9	1.1	1.2	1.5	1.7
	0.100	0.04	0.9	1.1	1.3	1.4	1.7	2.0
	0.100	0.05	1.0	1.2	1.4	1.6	1.9	2.2
	0.100	0.06	1.1	1.3	1.5	1.7	2.1	2.5
	0.100	0.08	1.3	1.5	1.8	2.0	2.4	2.8
	0.100	0.10	1.4	1.7	2.0	2.3	2.7	3.2

10.3.1 Lower Fan Below CPR Tracks

The land south of the CPR tracks, on the east side of Deroche Creek and southwest of the Lougheed Highway, has relatively low ground slopes, varying from 1.8% to 2.9%. This land is part of the Low Hazard Area and is presently occupied by a trailer court. A brief analysis of potential overland flow was carried out. It was determined that in a worst case scenario, upwards of 150 m^3/s could flow over the tracks and through the trailer court based on EBA's estimates of debris flood magnitude and assuming that 70 m^3/s remains in the main channel. If the track acted as a broad-crested weir, it would take a 200 m length of track, flowing 0.63 m deep, to convey this much flow.

An analysis of overland flow indicates that floodwaters would flow through the trailer court at an average depth of 0.3 m and with velocities of approximately 2.5 m/s, assuming flow over short grass ($n = 0.030$). The structures in this area could be protected against overland flows by elevation on fills. Water depth plus velocity head in the flow, known as the total energy grade, equals 0.62 m for the above flow condition. A fill height of 1.0 m would be required to provide some reserve freeboard (0.3 m) and to allow for flow constriction due to fill mound construction. If structures were elevated on columns instead, then a height of 0.9 m would suffice as there would be no significant constriction to overland flows, however, freeboard would still be required to provide for debris passage as well as potential sedimentation effects which can locally elevate flood levels. Costs for raising a typical house by 1 m would be on the order of $8,000.

In addition, the structures below El 10.7 m, bordering on Nicomen Slough, should be raised to provide protection against flooding from the Fraser River, as per Fraser River Flood Risk Mapping prepared by Northwest Hydraulic Consultants. It is noted that roughly half the trailer court, and most of Lakahahmen I.R. No. 11, is within the potential flood impact zone from the Fraser River with Flood Construction Levels (FCLs) in the 10.6 m to 10.9 m range across the lower edge of the Deroche Fan. Those properties lying below El 9.7 m would have to be raised more than 1.0 m to achieve protection against Fraser River flooding. Some of these properties are presently below El. 9 m and would have to be raised by about 2 m or more. Raising a house by 2 m on fill is estimated to cost in the order of $20,000. These fill heights may be impractical such that the only option would be structural elevation on piles or columns.

Consideration could also be given to raising part of Taylor Road to act as a dyke along Nicomen Slough, protecting part of I.R. No. 11 against high water levels in the Fraser River. Two options have been studied by Northwest Hydraulic Consultants Ltd. (2000). These are:

- to raise the portion of the road between Highway 7 and Deroche Creek by an average of 1.1 m and to construct a wing dyke along part of Deroche Creek; or
- to raise 950 m of Taylor Road along the reserve and a portion of the road south-west of the reserve. Wing dykes up both sides of Deroche Creek would be required.

The first option would protect the mobile homes at the east end of Taylor Road, the second option would also protect the agricultural land.

10.3.2 Lower Fan Above CPR Tracks

The land immediately to the north of the CPR tracks has gradually increasing ground slope. The land between the tracks and the 24 m contour has slopes that vary between 3 and 4%. This is part of the Moderate Hazard Area. The 24 m contour corresponds roughly with the north end of the cemetery and ties into the southeast quadrant of Fernie Road to the west and to the northwest corner of the new school on the east. Overland velocities in this area are expected to be on the order of 3 m/s for shallow flow depths to 0.4 m and ground cover equivalent to high grass (n = 0.035). The effective flow width would be approximately 130 m to pass 150 m^3/s overland flow. The total energy grade would be approximately 0.8 m with an assumed flow depth of 0.4 m, requiring a fill height of 1.2 m after adding an allowance for freeboard. A light riprap would be required to protect the exposed faces of the fill. Rock required would have a nominal size of 300 mm (D_{50}) and a maximum size of 450 mm. This armour rock should be trenched in to at least 0.6 m below the natural grade to protect against scour induced toe failure. Floodproofing on fills mounds would cost on the order of $10,000 for a typical house raised 1.2 m, not including the cost of armour protection.

The area described above, between the tracks and the 24 m contour, is considered the limit for the application of floodproofing fills. The assumptions made regarding overland flow depths are considered optimistic. If overland flows persist for a prolonged period, then erosion and scour can result in trenching and channelization of the flow such that substantially higher overland flow depths and velocities are possible.

It should be noted that there is a low lying area on the north side of the tracks, near the western limit of the fan, which is susceptible to ponding from overland flows. This area would be particularly at risk should an avulsion develop over the right bank at the approach to the North Nicomen Road Bridge. Floodwaters could travel alongside the track embankment and pond in this low lying area until the low point in the track grade was reached, as discussed earlier. Fill heights to El. 10.6 m would be required in this area, in keeping with the Flood Construction Level (FCL) pertaining to Fraser River flooding. Elevation on columns or piles may be preferable to avoid excessive fill heights in some

areas. The hazard could also be mitigated by improvements to the North Nicomen Road bridge as discussed in Section 10.6.

10.3.3 Middle Fan Between 24 m Contour and 35 m Contour

The middle fan extends from the north end of the cemetery to the intersection of Pullin Road and North Deroche Road. This area of the fan is part of the Moderate Hazard Area. The intersection corresponds with the beginning of the highly confined portion of the fan. Ground slopes vary from 4 to 6% in this portion of the fan and can result in substantial overland velocities as indicted in Table 10.1. Assuming high grass, velocities of 3.8 m/s would result from flow depths of 0.4 m and velocities of 4.4 m/s would occur at flow depths of 0.5 m. If overland flows to 150 m^3/s were spread out over 123 m, then the mean depth of 0.35 m would translate into velocities of 3.5 m/s. It would be unduly optimistic to suggest this latter scenario is valid.

Velocities of 3.8 m/s, corresponding to an average flow depth of 0.4 m, would translate into a required fill height of 1.5 m. Likewise, velocities to 4.4 m/s and a flow depth of 0.5 m would require a fill height of 1.8 m. Armour rock to protect the fill against velocities of 3.8 m/s would have a D_{50} of about 500 mm and would have to be trenched in 1.0 m below the natural grade to protect against a scour induced toe failure. The practicality of this approach is highly questionable.

Elevation on piles or columns would be preferable, however, there is considerable potential for scour and undermining of structures as well. If flows persisted for some time, trenching and channelization could be expected with the potential for impact damage from flood borne debris. Alternatively, structures could be elevated on foundation walls aligned with the flow and extending well below natural grade to provide scour protection.

10.3.4 Upper Fan – Above 35 m Contour

The upper fan area, above the intersection of Pullin Road and North Deroche Road, extends all the way to the apex of the fan at the water intake structure. This region is highly confined and has slopes which begin at 6% and quickly rise to 10% in the vicinity of Morton Road Bridge and northward. These are considered steep slopes and can result in very high overland velocities. This is part of the High Hazard Area. A flow depth of 0.4 m in high grass can result in velocities of 4.9 m/s while a flow depth of 0.5 m corresponds to velocities to 5.7 m/s. It is impractical to try to protect these structures with fill, however other structural means may be appropriate, such as a concrete flow-through foundation. New structures in this area would be subject to Section 699 of the *Municipal Act*, which states:

"If a building inspector considers that construction would be on land that is subject to or is likely to be subject to flooding, mud flows, debris flows, debris torrents, erosion, land slip, rockfalls, subsidence or avalanche, the building inspector may require the owner of land to provide the building inspector with a report certified by a professional engineer with experience in geotechnical engineering that the land may be used safely for the use intended."

10.4 Flow Deflectors

The high velocities described in the upper fan area are such that elevation on armour protected fills is not feasible, due to the excessive fill height and large rock required for protection.

An alternative to armoured fills would be the construction of flow deflectors just upstream of existing structures. These structures would be built in a V-shaped configuration, just upstream of existing houses and buildings, in high velocity areas. The height of flow deflectors would likely be less than for berm construction since they would be oriented at an angle to the flow and consequently would not be subject to full velocity head recovery except at the nose. Very large rock would be used for construction with graded rock behind. Any seepage could be conveyed to the sides through rock filled trenches. Alternatively, concrete flood walls could be used for the same purpose. This approach could be used in the high hazard areas north of the Pullin/North Deroche Road intersection. It would be particularly useful above the Morton Road Bridge. Single sided flow deflectors could also be used in conjunction with armoured fill on the fan margins, where they could be tied in to high ground.

The above flow deflectors are considered to be high risk mitigation measures as they could re-direct high velocity flow onto neighbouring property. A detailed study would be required to establish the feasibility of this approach.

The potential for impact damage, channelization and sedimentation is such that regardless of mitigation measures adopted, there will still be considerable residual risk to buildings and property. Relocation is the only means of eliminating the flood risk in the upper fan area.

10.5 Detention Structures

In addition to the debris basins proposed by EBA for near the fan apex, there is another site further down the fan where debris floods could be directed to trap sediment and attenuate flood peaks. The site under consideration is the field area, which was excavated for the new school. While detailed

topography is not readily available, it would appear that considerable detention volume could be achieved through the construction of berms along the low sides of the field. An armoured overflow weir section could be used to discharge from the detention pond with a stepped sill configuration. A small watercourse presently drains the area west of the school and would form part of the resulting floodway. A consensus would have to be reached with the school board regarding maintenance and/or restoration of the field following flood events. In this regard, it should be noted that the field already lies in a potential overland flow path and consequently would suffer damage during such flood events in any case. In fact, by forcing ponding to develop in this area, severe erosion damage to the field might be precluded.

The proposed detention structure would only benefit development on the lower portion of the fan in the lee of the developed pond area. Consideration could be given to training berms to encourage overland flow to enter the detention structure.

10.6 Improvements to North Nicomen Road Bridge

The discharge capacity of this bridge and the approach flow alignment are unsatisfactory. Consideration should be given to replacing the existing road bridge with a larger span to match the flow capacity of the CPR Bridge immediately downstream. As well, the approach flow to the bridge is very poor, which reduces flow capacity, promotes sedimentation and increases the potential for debris plugging. Options to improve the flow alignment include shifting the bridge opening to the northeast and re-aligning the approach channel. It appears that one or more houses on the right bank would have to be relocated. These houses are presently in a high risk area and relocation would greatly improve their safety.

10.7 Measures That LFN Could Implement on Their Own

The above discussion has dealt with a unified approach to providing flood protection to the fan as a whole. There are some measures that LFN could implement on their own. These include:

- initiating a study in conjunction with MOTH regarding improvements to the North Nicomen Road Bridge;
- channel maintenance including gravel removal;
- floodproofing buildings (structural raising on concrete foundation walls is preferred in high density areas); and
- relocation of buildings away from the most high risk areas such as near the North Nicomen Road Bridge.

11 NON-STRUCTURAL FLOOD MANAGEMENT OPTIONS

This section applies primarily to FVRD lands, though the recommended measures could be adopted, where appropriate, by the LFN through a modification to the PDP to reflect flood hazard issues.

11.1 Regulatory Framework

The existing land use regulatory framework outside I.R. 11 consists of the following four elements:

- Dewdney-Alouette Regional District Deroche-Lake Errock-Nicomen Official Community Plan Bylaw No. 436-1986 as amended;
- Dewdney-Alouette Regional District Land Use and Subdivision Regulation Bylaw No. 559-1992 as amended;
- Dewdney-Nicomen Floodplain Management Bylaw No. 0056, 1996; and
- Section 82 of the *Land Title Act*.

Regulatory control of the first two elements rests with the Fraser Valley Regional District. The third is enacted under the authority of both the Fraser Valley Regional District and the Provincial Minister of Environment. The fourth gives the Minister of Environment authority over any subdivision in an area subject to flooding.

In addition, forestry activities upstream of the Deroche fan play a very significant role as noted in Sections 4.3 and 4.4. The Agricultural Land Commission plays an indirect regulatory role in restricting land use south of the Canadian Pacific Railway.

Within I.R. 11, the Lakahahamen First Nation has regulatory authority over land use.

Non-structural flood management options for the Deroche fan range from prevention of all future development to allowing any development at the risk of the applicant. Neither extreme is considered appropriate. Rather, a measured management response to the varied risks in different parts of the Deroche fan is recommended. In general this will involve modifications to the existing regulatory framework.

11.2 Official Community Plan (OCP)

The OCP identifies environmental hazards both in map form (Schedule D-1) and in the plan text. Schedule D-1 should be revised to reflect the revised boundaries of the Deroche fan. These occur primarily in the lower fan at its outer fringes. This affects several properties east of the new Deroche School on Cooper Road and the Lougheed Highway and to the west of Deroche Creek between North Nicomen and Taylor Roads.

The identification of high, moderate and low hazard areas within the Deroche fan should also occur as the relative hazard is quite variable in different parts of the fan. Additional policies to address flood hazard management beyond the limited references in Policies 6.1 and 6.2 would be helpful.

Land use designations on Schedule F-1 in the OCP are shown on Figure 8.1. The Rural II designation is intended for parcels with steep slopes and for environmental hazard areas. Currently only one property in the Deroche fan is designated Rural II. This property is at the top of the Deroche fan and clearly contains environmental hazards. Other nearby properties are also in a high hazard area as shown on Figure 6.1.

One approach would be to designate all properties in high hazard areas as Rural II. This would heighten community awareness and serve notice that these properties need to be given particular attention with respect to any development proposal. On the other hand, the increased parcel size called for in the Rural II designation is a very blunt instrument. Most of the parcels in the high hazard area would not be affected if the minimum parcel size were to increase from 2.0 to 4.0 hectares.

An alternate approach would be for the OCP to be amended and the Deroche fan to be designated a Development Permit area under Section 879 (1)(b) of the *Municipal Act*. The purpose of such a designation would be to protect development from hazardous conditions. The advantage of this approach is that development constraints would be clearly identified in the OCP. Remedial conditions could also be specified, at least in general terms. A development permit approach would enable the Fraser Valley Regional District to control the siting of habitable dwellings. For example, there are several properties that include high hazard areas as well as potential building sites outside the Deroche fan. A development permit would enable the fine-tuning of subdivisions by allowing limited development but ensuring that habitable buildings are not constructed in high hazard areas. The four-lot subdivision application by Kauko Sokkanen is a case in point. Although the two existing properties are partially within the Deroche fan, the proposed subdivision recognizes geographical and flood hazard constraints and identifies building sites that are outside the Deroche fan.

Schedule F-1, as shown on Figure 8.1, also includes commercial and institutional designations on moderate hazard areas of the Deroche fan which do not currently have such uses.* It may be appropriate to reassess whether such designations are appropriate in these locations.

Schedule C-1 in the OCP identifies future park locations. Depending on its intended function, it may be appropriate to reconsider the potential park location on North Deroche Road. This site is in a moderate hazard area very close to Deroche Creek.

11.3 Zoning Bylaw

There are several parcels in high and moderate hazard areas with subdivision potential, subject to meeting the requirements of the Floodplain Management Bylaw and the Minister of Environment under the *Land Title Act*. Although the number of such parcels is quite limited, one property zoned R-1 is in a high hazard area and another zoned RS-2 is in a moderate hazard area. Deroche Creek runs through both properties. Rezoning such parcels, particularly in high hazard areas, to preclude further subdivision, would avert additional future risk. There are also two properties in public ownership zoned P-1, which could potentially be subdivided, although there appears no practical likelihood of this occurring.

11.4 Floodplain Management Bylaw

The Floodplain Management Bylaw identifies lands within the Fraser River floodplain (Schedule A) and the Deroche Creek fan (Schedule B). Schedule B should be amended to reflect the revised boundaries of the Deroche fan. In addition, the high, moderate and low hazard areas within the Deroche fan should also be identified by map.

No regulatory changes affecting land within the Fraser River floodplain appear warranted. Within the Deroche fan above the Fraser River floodplain, some minor additions should be considered. Several parcels with high or moderate hazards also contain building sites outside the Deroche fan. On such parcels, a requirement for structures to be built outside hazard areas would be appropriate. A requirement for scour protection to be provided in moderate hazard areas should also be considered.

11.5 High Hazard Areas

High hazard areas are located close to Deroche Creek north of the CPR tracks and west to Parke Road, as shown on Figure 6.1. The part of the Deroche fan above the 35 m contour level is of greatest concern, due to the velocity of potential floods or debris floods.

The preferred management strategy in high hazard areas is to avoid habitable development and relocate existing structures to safer locations. In some instances, this can be achieved without difficulty while in others, this objective poses a major challenge. Where an existing parcel does not have a building site outside a high hazard area, Section 699 of the *Municipal Act* should be used. This enables a building inspector to require a site specific report from a Professional Engineer. If a Professional Engineer cannot address how the hazards identified in this report can be satisfactorily mitigated, the development should not be allowed to proceed. No new subdivision should be allowed which would require the siting of habitable dwellings in high hazard areas.

A save harmless covenant should be required for any development in a high hazard area, so that the applicant assumes responsibility for damage in the event of a flood.

11.6 Moderate Hazard Areas

Moderate hazard areas are located close to Deroche Creek south of the CPR tracks and outside the high hazard areas north of the CPR tracks, as shown on Figure 6.1.

The preferred mitigation strategy is to reduce future risk by restricting further subdivision and by minimizing existing risk through a combination of setbacks, floodproofing fill or structural elevation, and scour protection. Care should be taken not to protect selective properties through setback dykes, training berms and structural fill by simply transferring risk to other sites.

The requirement of a site specific report by a Professional Engineer through Section 699 of the *Municipal Act* is also advisable. If a Professional Engineer cannot address how the hazards identified in this report can be satisfactorily mitigated, the development should not be allowed to proceed.

A save harmless covenant should be required for any development in a moderate hazard area so that the applicant assumes responsibility for damage in the event of a flood.

11.7 Low Hazard Areas

Low hazard areas are located away from Deroche Creek south of the CPR tracks and on the fringes of the Deroche fan north of the CPR tracks, as shown on Figure 6.1.

The preferred mitigation strategy is to reduce future risk by minimizing existing risk through a combination of setbacks, floodproofing fill or structural elevation and scour protection.

A save harmless covenant should be required for any development in a low hazard area so that the applicant assumes responsibility for damage in the event of a flood.

It is understood that the Ministry of Environment, Lands and Parks will continue to discourage development and withhold consent for subdivision proposals on the fan, until such time as the flooding and erosion hazard from Deroche Creek has been adequately addressed by a comprehensive community based flood damage reduction plan. This plan should include the following:

- A suitable engineering study must be prepared to the satisfaction of the Regional Lands and Water Manager
- Flood mitigation works must be constructed on lands owned by, or within statutory rights of way acquired by, the Fraser Valley Regional District and/or the Lakahahmen First Nation to provide access for channel and dyke maintenance.
- Flood mitigation works such as setback dykes, training berms and debris traps shall minimize any increase in flood hazard to other lands on the fan.
- The FVRD and or the LFN must assume all responsibility for the maintenance, repair and restoration of these works and the floodway channel up to the design flood event in accordance with an Operation and Maintenance Manual approved by the Ministry.

11.8 Generic Floodproofing Designs for Moderate and Low Hazard Areas

Floodproofing for the low hazard areas can be achieved through the use of armoured fills as described in Section 10.3. These fills would be constructed to a nominal height of 1.0 m above the surrounding grade and/or to the Fraser River FCL, whichever is higher. Fills require more land area as the height increases, Figure 11.1, which places limits on the maximum height that buildings can be raised using this method. Fills would be provided with erosion resistant slopes at the sides and upstream faces of the mound. Erosion resistance could be achieved through light riprap, say 300 mm minus, pavement or plantings. A typical layout for floodproofing with fill is also shown in Figure 11.1. Fill mounds could be provided with access ramps for vehicle parking as shown in Figure 11.1.

Fill mounds should be oriented with the direction of the floodwaters so as to minimize resistance to flow and reduce funnelling effects between adjacent mounds, as this can lead to increased flow velocity and the potential for erosion, see Figure 11.2. If several properties are to be floodproofed in one area, it may be preferable to construct a common mound as shown in Figure 11.2. This would definitely be the case with new subdivision development.

As mentioned above, fill mounds occupy a progressively larger portion of the building lot as the fill height is increased. This increased "footprint" limits the practicality of this floodproofing approach and it is also detrimental in terms of increased scour potential. Construction of fill mounds can also transfer flood risk to adjacent properties by redirecting floodwaters. Structural floodproofing options are therefore preferable in the moderate hazard areas where higher flow depths and velocities can be expected.

It is proposed that closed concrete foundations be used to floodproof the properties north of the CPR tracks and below the 24 m contour. Concrete foundation walls would be founded on footings placed below the expected scour depth, estimated at approximately 0.8 m below existing grade. A small riprap would be placed around the base of the footings to guard against potential scour. This rock would have a nominal size of approximately 300 mm (450 mm minus). Buildings should be elevated 1.2 m above the surrounding grade.

For the upper portion of the moderate hazard areas, above the 24 m contour, the preferred approach would be structural raising on open foundations with concrete walls aligned with the flow to reduce the impact from floodwaters. The flow would be allowed to pass beneath the structure. This last case is shown in Figure 11.3. The underside of the building floor system would have to be placed a reasonable distance above the predicted flood level to minimize the potential for floating debris to strike the structure. Freeboard of 0.6 m or greater should be provided for this purpose. Structures in this area should be raised 1.5 m above the surrounding grade. Foundations should also extend 1.0 m below existing grade and be provided with scour protection.

11.9 Flood Emergency Plan

It is recommended that consideration be given to development of some strategies to provide some warning of impending hazards. This aspect requires further study but possible approaches are:

- Establishing a threshold discharge and corresponding water level in the creek at a gauged location, at which bank overtopping is imminent. The upstream side of the North Nicomen Road bridge would be a suitable location, as this is a critical section with regard to channel hydraulic capacity.

- Watching for periods of unusually low flow during heavy rainfall, which could be indicative of a debris dam upstream and an imminent debris flood;

- Inspection of the creek channel from the apex of the fan to the North Nicomen Road bridge during heavy runoff;

- Regular monitoring of the upper watershed for signs of potential slope failures, which could give rise to debris flows or debris floods;

It is further recommended that residents of the high hazard zones indicated in Figure 6.1 be evacuated if the warning signs suggest that the situation is critical.

12 CREEK MANAGEMENT ACTIONS

12.1 Watershed Management

Watershed management initiatives that should be implemented are discussed in detail in Appendix 1. They are crucial, since they decrease the probability of failures and hence lower the chance of outburst floods that may affect the fan. The most important measures are:

- Logging road deactivation prescriptions;
- Keeping natural drainage paths clear and ensuring that there will be no diversions into the Deroche Creek catchment;
- Review of any further logging or road construction plans by a suitably qualified geotechnical engineer or geoscientist; and
- Monitoring the upper catchment after heavy rainfall events to assess slope stability.

12.2 Channel Works

Channel works can be carried out as part of an overall creek management plan. These include:

- Monitoring the amount of aggradation after significant high flows in the creek;

- Removing material deposited in the creek bed after significant high flows; and,
- Excavating material from the creek bed in aggradation areas or areas of low channel capacity, in anticipation of deposition during high flow periods.

The Lakahahmen First Nation currently carries out some channel maintenance on an annual basis, to remove material deposited after typical annual events. This practice should be continued.

It is proposed that several monitoring sites be established, where regular surveys of the creek cross section would be taken and inspections would be carried out to ensure that a minimum design capacity for sediment and water flows was maintained. Suitable monitoring sites are at the Morton Road Bridge, the North Nicomen Road Bridge, below the intake, at the bend below the intake, the bend below the Morton Road Bridge and at Section 1426 (a potential avulsion site). These locations are indicated on Figure 6.1.

The Lakahahmen First Nation should be consulted with respect to upstream channel work. There is the potential for upstream channel works to transfer flood risk to points downstream due to a reduced likelihood of avulsions.

13 DISCUSSION ON HAZARD MANAGEMENT OPTIONS

The foregoing sections have explored various types of hazard management option, namely structural, non structural and creek management options. The non structural options, which were requested to be the focus of this study, are discussed in Section 11 and recommendations are made in Section 14. Creek management actions have been discussed in Section 12 and recommendations are made in Section 14. For structural options, several approaches have been discussed in Section 10, which are applicable to different areas of the fan or which have different benefits, costs and impacts. To assist in comparing these options it is helpful to tabulate them, as in Table 13.1.

TABLE 13.1

COMPARISON OF STRUCTURAL FLOOD HAZARD MANAGEMENT OPTIONS

OPTION	PROS	CONS	APPROX. COST
Debris basin	Protects entire fan Retains majority of debris Maintains channel morphology d/s Reduces flood peaks Reduces channel maintenance costs	Very high cost Land expropriation Post-event maintenance required	$2M
Debris barrier	Retains logs and large boulders Maintains channel morphology Protects entire fan from debris floods	Little flood peak reduction High cost Difficult access for maintenance	$0.5M
Off-channel detention area at school field	Easily implemented	Provides only partial protection Poor public perception Reduces surrounding floodproofing	$0.1-$0.2M
Dykes	Protect entire fan	Very high costs Land expropriation Serious failure consequences Increase scour and deposition Bridge upgrades required Protection to design level only	$2.0 - $2.5M
Floodproofing with fill	Easily implemented Cost effective for new construction	May increase flood hazard elsewhere	$8-20K per house
Floodproofing with enclosed concrete foundations	Smaller footprint than with fill Less impact on surrounding land than fill	May increase flood hazard elsewhere	$8-20K per house
Floodproofing with open concrete foundations	Minimal effect on surrounding land	Risk of impact damage Poor public acceptance	$8-20K per house
Flow deflectors on upper fan	Protection against impact damage	Promote local scour Increase hazard elsewhere Partial flood protection	$5-10K per house
N. Nicomen Rd. Bridge upgrade and channel realignment	Reduction of avulsion hazard Reduction of 200-year flood hazard	Benefits limited area High costs Expropriation of homes	$0.2-0.3M
Channel improvement	Low costs Reduces flood hazard Reduces avulsion hazard	Possible channel destabilization Ongoing maintenance required	
Zero solution (do nothing)	No cost Natural development of creek & fan	Continued high hazards High maintenance costs Frequent inconvenience	$0

14 CONCLUSIONS AND RECOMMENDATIONS

14.1 Conclusions

a) Deroche Creek has a history of flooding. Known significant events occurred on the Deroche Creek fan in 1962 or 1963, 1974, 1980, 1984, 1986, 1989 and 1990. The entire Deroche Creek fan should be considered hazardous to a variable degree. A flood hazard map has been prepared designating areas of the fan as having high, moderate or low hazard potential. In essence the hazard increases towards the apex of the fan and towards the present creek alignment.

b) Debris flows have occurred at least ten times in the upper watershed over the past 50 years. Of these, nine were associated with logging road failures and poor drainage control. It appears that none reached the Deroche Creek fan.

c) The lower channel slopes are insufficient to allow debris flow transport to the creek fan, except during an extremely large event. There is therefore a low probability of a debris flow reaching the fan.

d) Debris floods have reached the fan several times in the last 50 years, notably in 1962 or 1963 and 1989. The 1989 event was probably caused by landslide damming of the upper creek and a subsequent failure of the landslide dam. The discharge is estimated to have been approximately 220 m^3/s.

e) About 40% of the upper catchment has been logged, which has led to an accelerated rate of mass movements and sedimentation in the upper channel of Deroche Creek.

f) The lower part of the Deroche fan is vulnerable to flooding from the Fraser River.

g) A hydrological analysis, based on records for the neighbouring Norrish Creek, has shown that the 200-year maximum instantaneous flood flow in Deroche Creek is about 63 m^3/s.

h) An analysis of water surface profiles has identified reaches of the creek that have inadequate hydraulic capacity to convey flood discharges. Overtopping of the banks may occur at these locations in extreme floods. The locations include RS 1632 (the community water intake structure), RS 1426 (the site of the 1989 avulsion near the Gruenwald property), RS 1066, and RS 444 to 471 (the approach to the North Nicomen Road Bridge). The analysis was based on the assumption that the creek bed was fixed. Aggradation of the channel will affect avulsion and channel overtopping locations.

i) No major fish, wildlife or environmental issues or concerns were identified.

j) The OCP identifies the Deroche fan as vulnerable to flooding and erosion hazards from the creek and part of the fan as vulnerable to Fraser River flooding.

k) Present land use designations on the fan include Rural Residential, Rural I, Rural II, Institutional, Commercial, Agricultural and Lakahahmen Indian Reserve No. 11. The present population of the fan is about 420.

l) Dewdney-Nicomen Floodplain Management Bylaw No. 0056, 1996 designates the Fraser River floodplain as Schedule A and gives provisions for regulating development on the floodplain. Schedule B designates the Deroche fan as an alluvial and debris torrent area and makes provisions for development on the fan.

m) The total assessed value of land on Deroche fan is $5.6M and of improvements is $8.0M.

n) There are two current subdivision proposals involving land on the fan and several other properties with subdivision potential under existing zoning. The subdivision potential of lands on the Deroche Creek fan is considered very limited.

o) Structural and non-structural flood protection and management options have been discussed and recommendations have been developed. Creek management actions have also been reviewed.

14.2 Recommendations

14.2.1 Non-Structural Options

Non-structural options were to be given high priority, according to the Terms of Reference. Non-structural flood management options for the Deroche fan range from prevention of all future development to allowing any development at the risk of the applicant. Neither extreme is considered appropriate. Rather, a measured management response to the varied risks in different parts of the Deroche fan is recommended. In general this will involve modifications to the existing regulatory framework. Our recommendations are as follows:

- Schedule D-1 of the Deroche-Lake Errock-Nicomen Official Regional Plan should be revised to reflect the revised boundaries of the Deroche fan, as shown on the Flood Hazard Map.
- The identification of high, moderate and low hazard areas within the Deroche fan should also occur in the OCP. Additional policies to address flood hazard management beyond the limited references in Policies 6.1 and 6.2 would be helpful.
- The Rural II designation would be more appropriate than the Rural I designation for properties in high hazard areas of the Deroche fan.
- Schedule F-1 of the OCP includes commercial and institutional designations on moderate hazard areas of the Deroche fan which do not currently have such uses. It may be appropriate to reassess whether such designations are appropriate in these locations.
- Depending on its intended function, it may be appropriate to reconsider the potential park location on North Deroche Road. This site is in a moderate hazard area very close to Deroche Creek.

- Rezoning such parcels, particularly in high hazard areas, to preclude further subdivision, would avert additional future risk.
- Schedule B of the Floodplain Management Bylaw (0056-1996) should be amended to reflect the revised boundaries of the Deroche fan. In addition, the high, moderate and low hazard areas within the Deroche fan should also be identified by map.
- A requirement for scour protection to be provided in moderate hazard areas should also be considered for the Floodplain Management Bylaw.
- The Lakahahmen First Nation Physical Development Plan should be updated to incorporate flood hazard considerations.
- Consideration should be given to development of a Flood Emergency Plan, involving monitoring of the creek and upper catchment and evacuation of some residents, if necessary.

14.2.2 Creek Management Options

Watershed management actions in the upper catchment are considered crucial to the flood hazard management on Deroche Creek.

- Logging road deactivation prescriptions should be prepared and implemented as soon as possible.
- Natural drainage paths should remain clear and there should be no diversions into the Deroche Creek catchment.
- Any further logging or road construction plans should be reviewed by a suitably qualified geotechnical engineer or geoscientist.
- The upper catchment should be monitored after heavy rainfall events to assess slope stability.

Some creek management activities are being carried out already by the Lakahahmen First Nation. It is understood that gravel is removed on a regular basis from the lower reaches of the creek. This is endorsed in this study with the following recommendations.

- Operations to remove gravel from the creek should continue and should be centred on depositional reaches of the creek and areas where avulsions could potentially occur; and
- The Lakahahmen First Nation should be consulted prior to undertaking any upstream channel work due to concerns regarding transfer of flood risk to downstream locations on the fan.

14.2.3 Structural Options

The structural recommendations outlined below are intended to supplement the non-structural and creek management options described above. Some of the structural options would require a large

capital investment and it is appreciated that this may preclude them. Several options are therefore presented, in order of preference.

- A debris basin should be constructed at the apex of the fan on the left bank of Deroche Creek below the water intake structure.
- In the event that a debris basin is not constructed, a debris barrier should be constructed above the water intake structure.
- The existing North Nicomen Road Bridge should be replaced with one of a longer span to improve the hydraulic capacity of the road crossing. In addition, the alignment of the approach flow to the bridge should be improved. Options to improve the creek/bridge alignment include moving the bridge location, angling the bridge and realigning the approach channel, or combinations of all three. This may involve relocation of one or more houses. A feasibility study is recommended to review these options and it should include CPR participation due to the close proximity of the two bridges.
- All new construction within the Fraser River floodplain should be elevated on fill or by structural means to the specified flood construction level. Consideration should also be given to raising existing structures in this area. Structural raising of buildings may be preferable in the vicinity of Nicomen Slough to avoid excessive fill height.
- The houses located in the depression to the north of the CPR tracks on the west side of the fan are at risk from an avulsion of Deroche Creek at the North Nicomen Road Bridge and should be raised to a level comparable to the Fraser River flood construction level.

The following recommendations apply in the event that a debris basin is not constructed.

- All new construction within the Low Hazard Area should be elevated by structural means or on fill to 1 m above the surrounding grade. Light riprap should be used to protect exposed faces of the fill from erosion.
- All new construction in the Moderate Hazard Area should be elevated, on concrete foundations to minimize the footprint, or on armoured fills, to a height of 1.2 m. Riprap protection for fill mounds would incorporate rock with a nominal size (D_{50}) of 300 mm and a maximum size of 450 mm, keyed in below the natural grade. The use of fill would likely be restricted to properties below the 24 m contour elevation. Consideration should be given to raising the existing structures in the moderate zone also.
- All new construction within the Moderate Hazard Area and above El. 24 m should be elevated by structural means to a height of 1.5 m above grade. Piles or columns could be used with an open foundation, allowing floodwaters to pass underneath. Concrete foundation walls could also be

used, aligned in the anticipated direction of overland flows. These piles, columns and walls would be founded well below existing grade, say to a depth of 1 m, to guard against undermining.

- New construction is not recommended in the High Hazard Area, except under the terms of Section 699 of the Municipal Act.
- Consideration should be given to the use of flow deflectors to direct overland flows away from existing buildings in this area.
- Consideration should be given to relocating structures away from the High Hazard Area. Some degree of safety could be achieved by relocating to the fan boundary and tying into high ground with heavy armour protection.

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This report is submitted by:

HAY & COMPANY CONSULTANTS INC.

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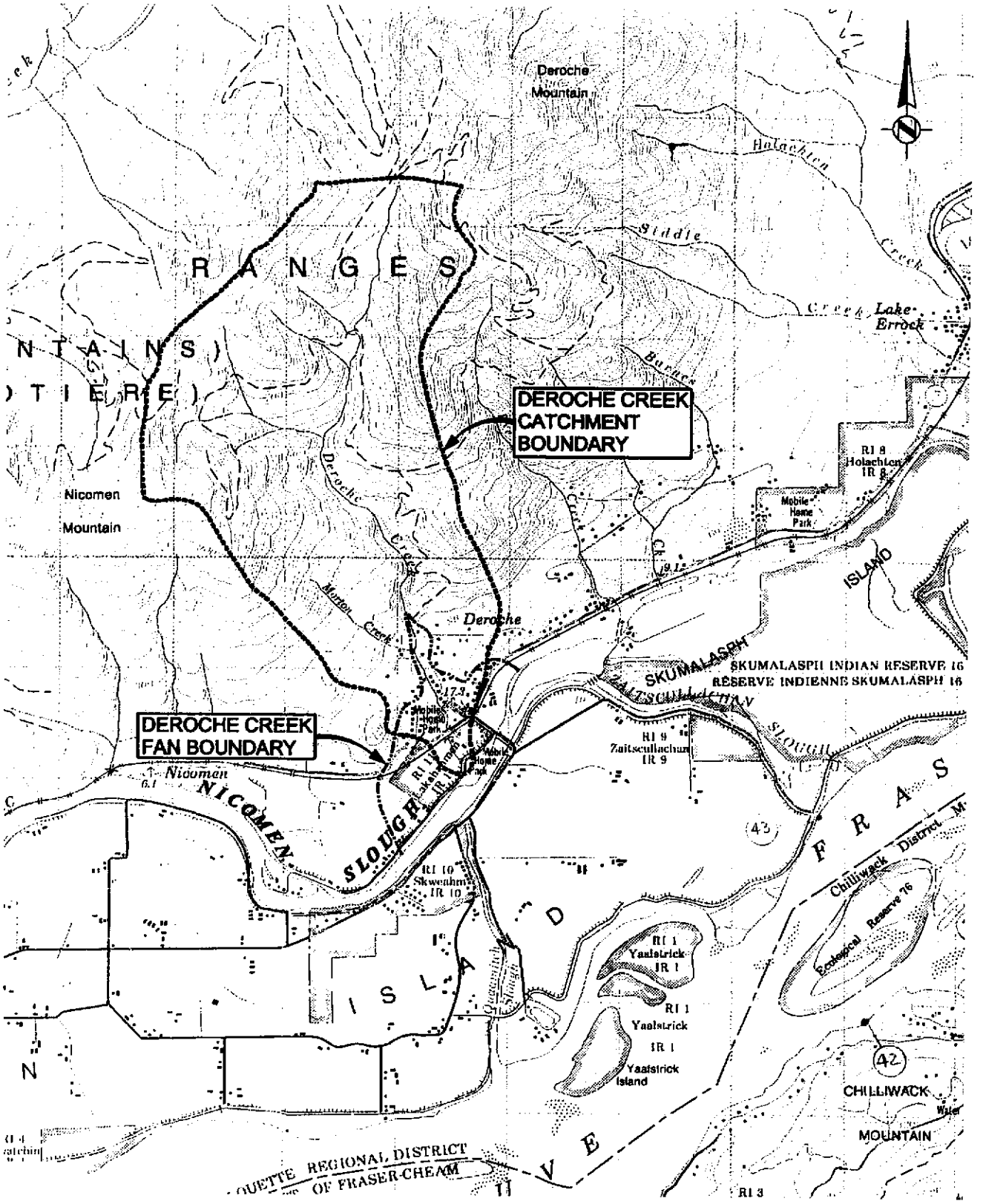
Dr. A.G. Chantler, P.Eng.
Principal

FIGURES



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FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

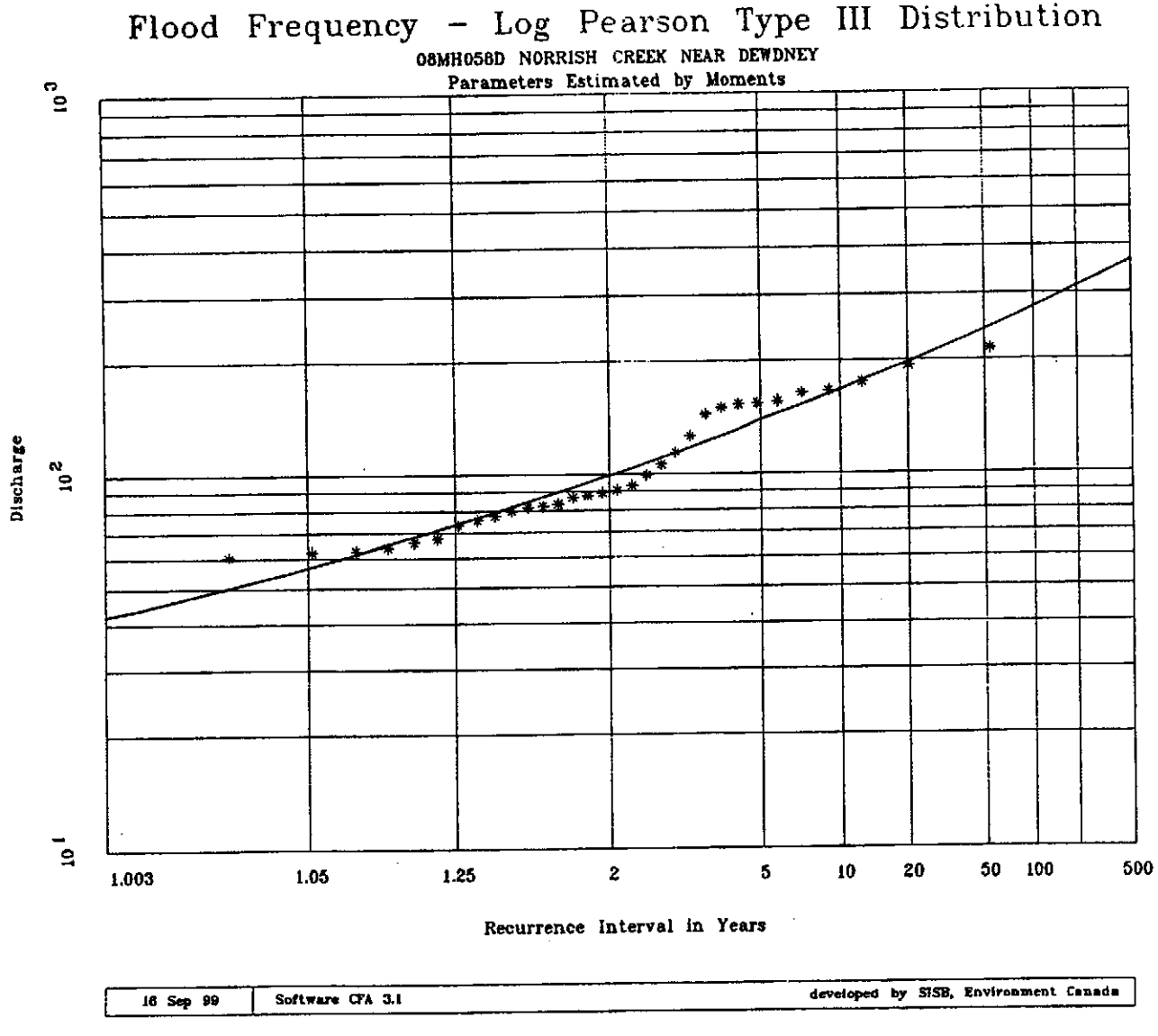
DEROCHE CREEK FLOOD HAZARD MANAGEMENT STUDY

STUDY AREA

FIG. 1.1

CAD FILE : FVRD-003 / CADD / LOCPLAN.DWG

JAN. 5, 2000



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FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

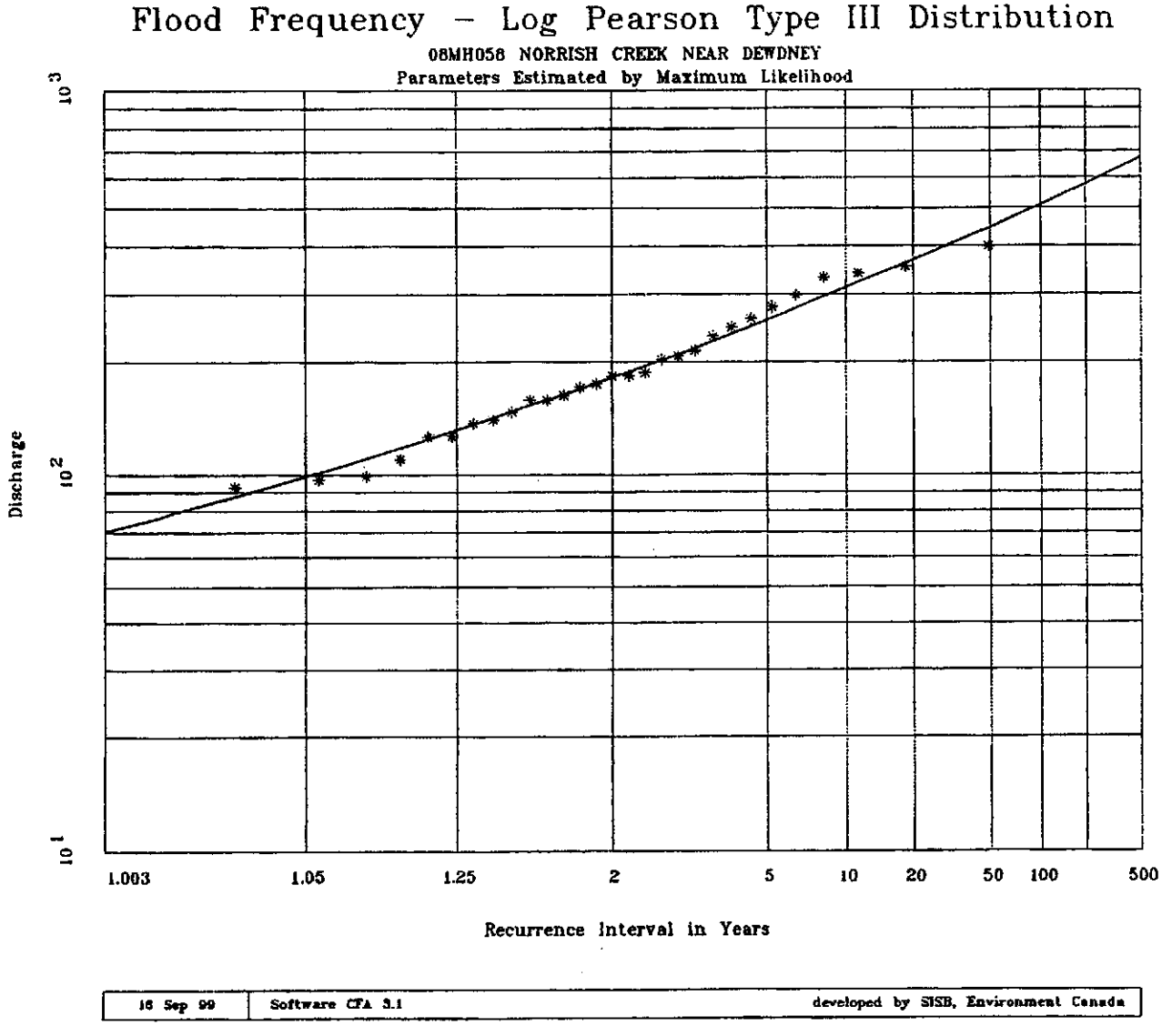
DEROCHE CREEK FLOOD HAZARD MANAGEMENT STUDY

FREQUENCY ANALYSIS MAXIMUM DAILY FLOWS

FIG. 5.1

CAD FILE : FVRD-003 / CADD / FIG5.1.DWG

JAN. 4, 2000



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FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

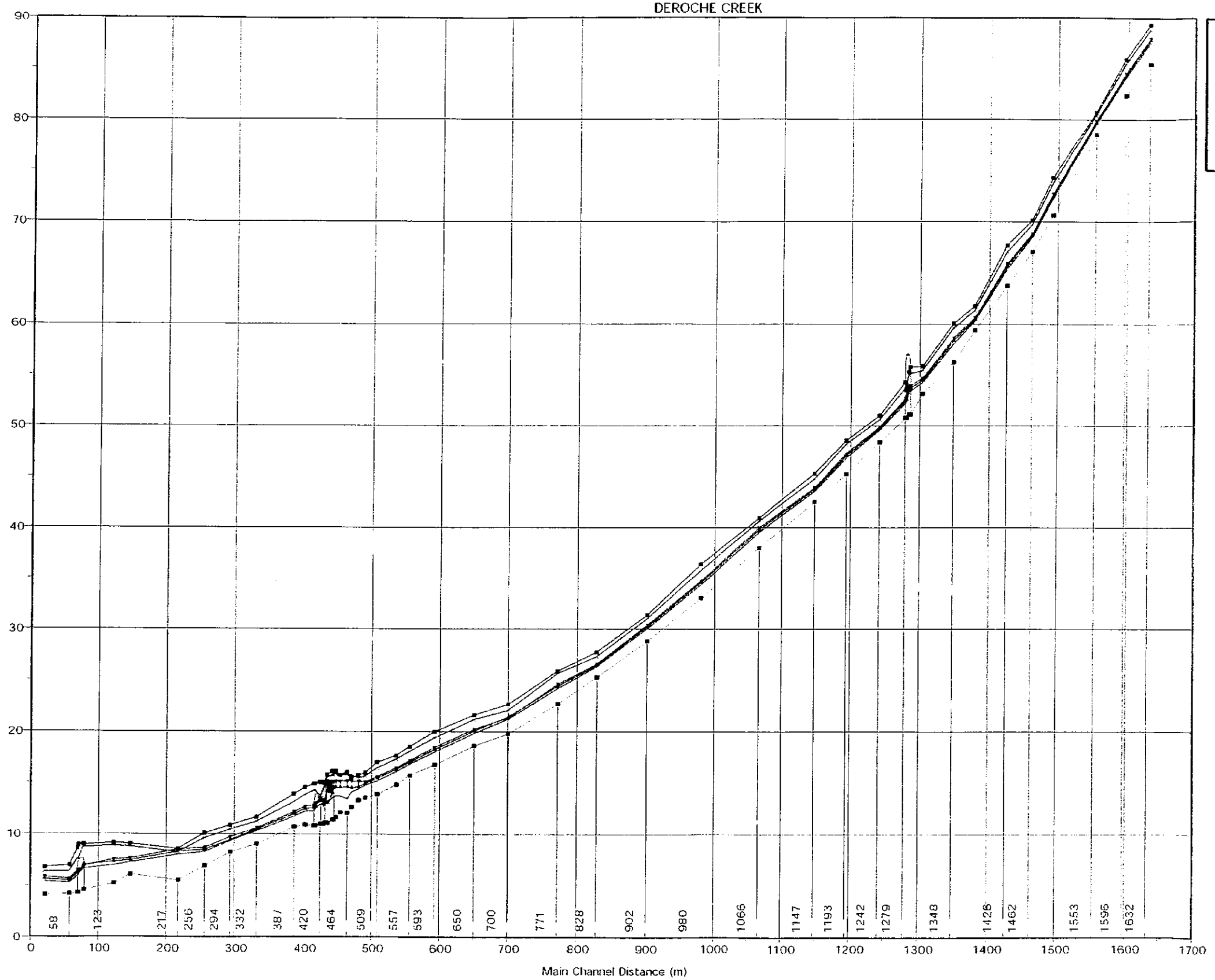
DEROCHE CREEK FLOOD HAZARD MANAGEMENT STUDY

FREQUENCY ANALYSIS MAXIMUM INSTANTANEOUS FLOWS

FIG. 5.2

CAD FILE ; FVRD-003 / CADD / FIG5.1.DWG JAN. 4, 2000

DEROCHE CREEK



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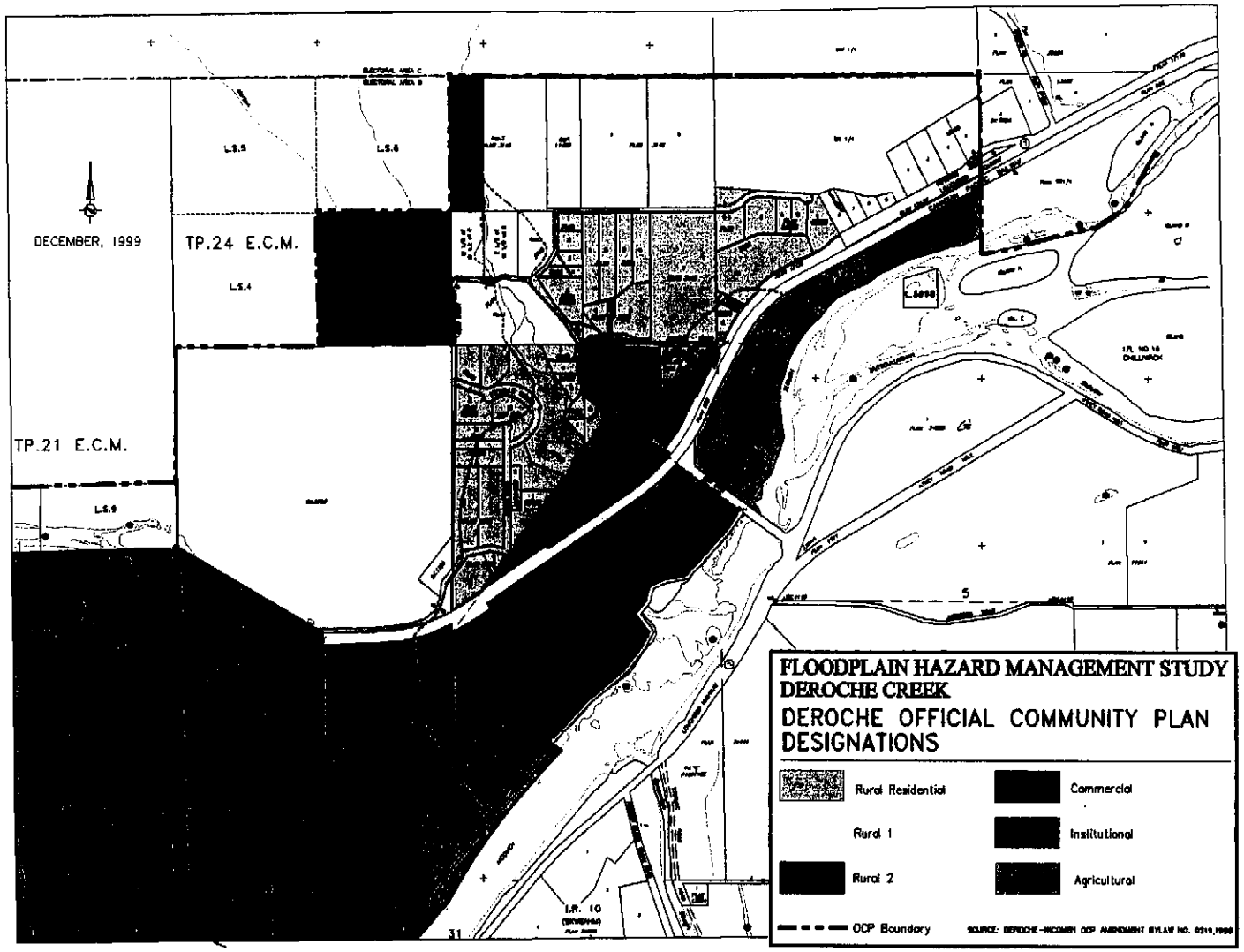
FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

DEROCHE CREEK
FLOOD HAZARD MANAGEMENT STUDY

FLOOD PROFILES

FIG. 6.2

CAD FILE ; FVRD-003 / CADD / PROFILE.DWG JAN. 5, 2000



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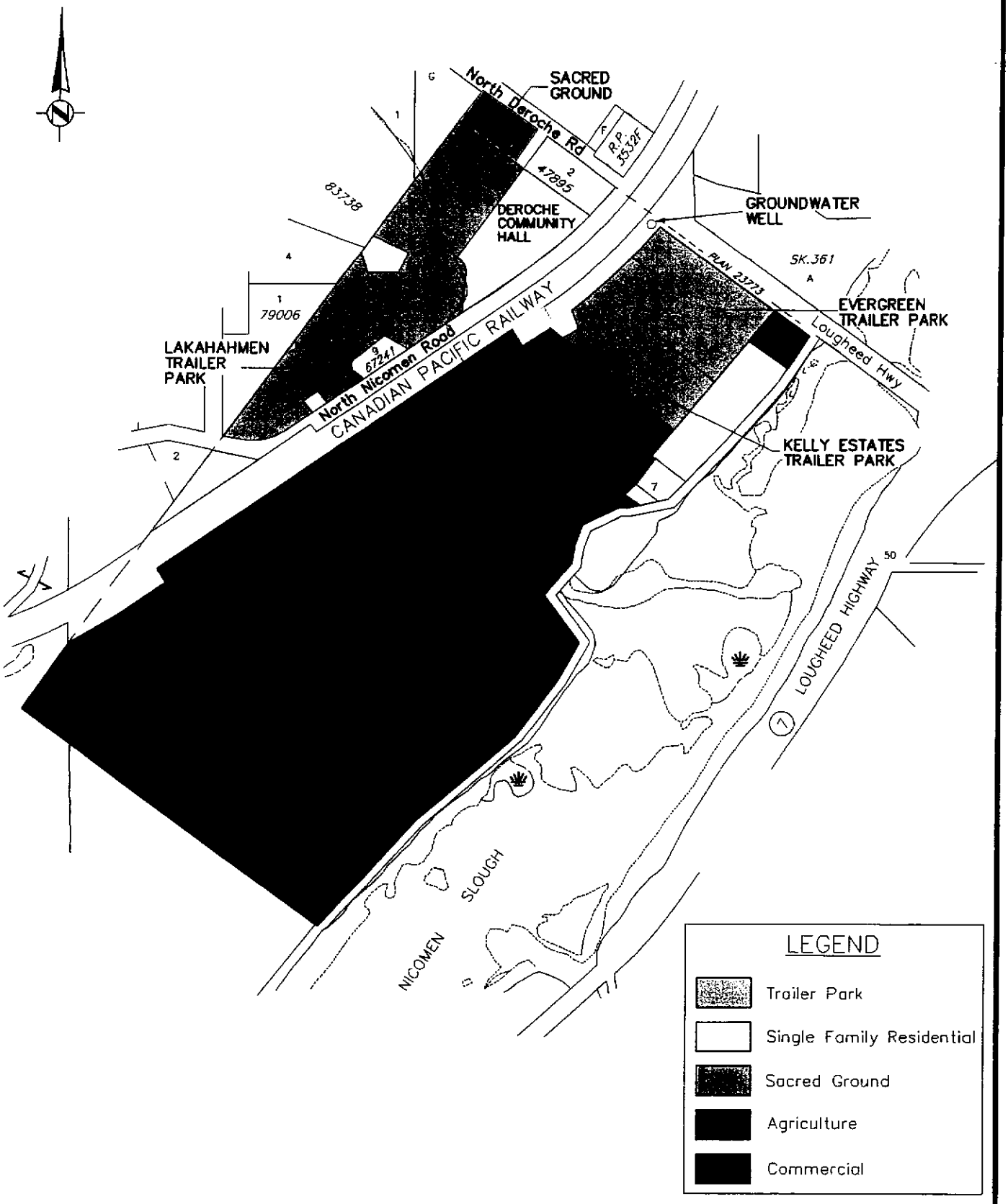
FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

DEROCHE CREEK FLOOD HAZARD MANAGEMENT STUDY

DEROCHE OFFICIAL COMMUNITY PLAN LAND USE DESIGNATIONS

FIG. 8.1

CAD FILE ; FVRD-003 / CADD / DEROCHE1.DWG JAN. 4, 2000



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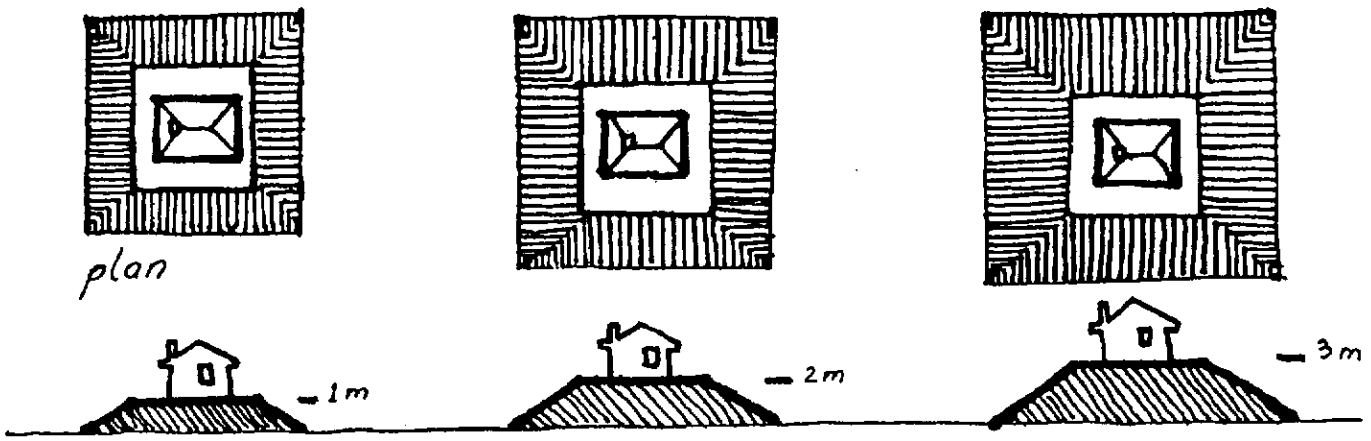
FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

DEROCHE CREEK FAN FLOOD HAZARD MANAGEMENT STUDY

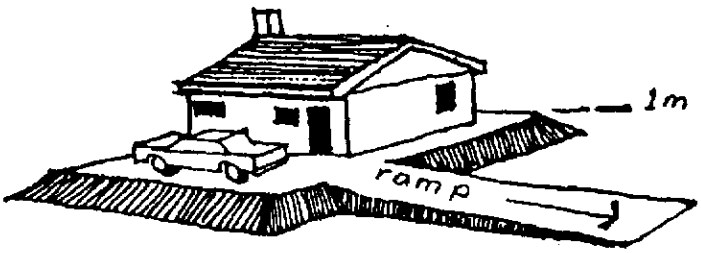
LAKAHAHMEN FIRST NATION PHYSICAL DEVELOPMENT PLAN

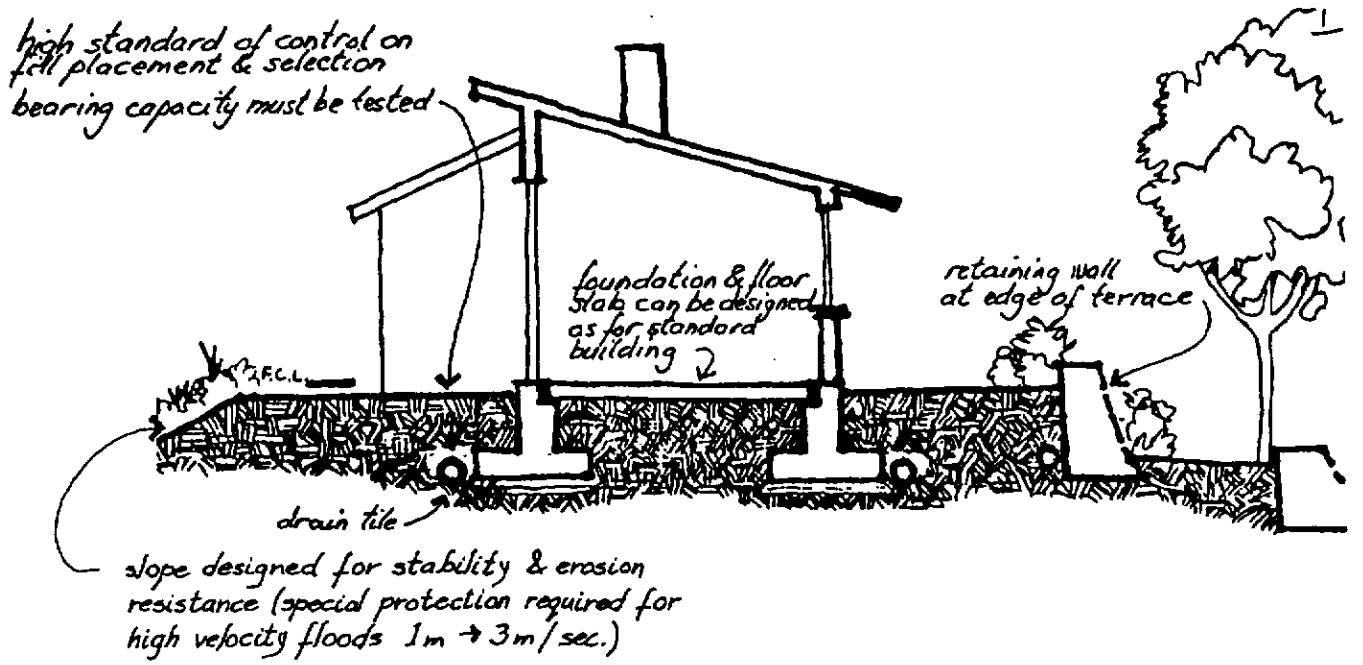
FIG. 8.2

CAD FILE ; FVRD-003 \ WORKING \ EB \ FIG8.2.DWG



Note that ramps require considerable area: a 4 metre wide ramp covers 40 square metres of land for every 1 metre rise at 10% gradient.





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FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

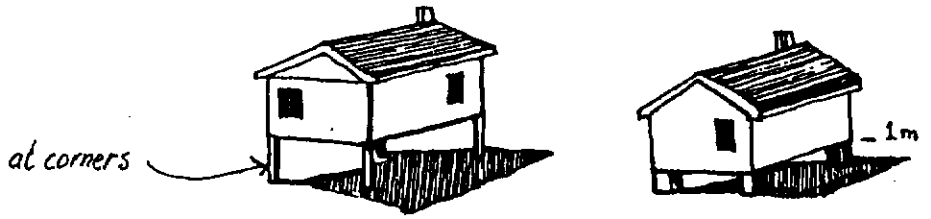
DEROCHE CREEK FAN FLOOD HAZARD MANAGEMENT STUDY

FLOODPROOFING IN LOW HAZARD AREAS USING FILL

FIG. 11.1

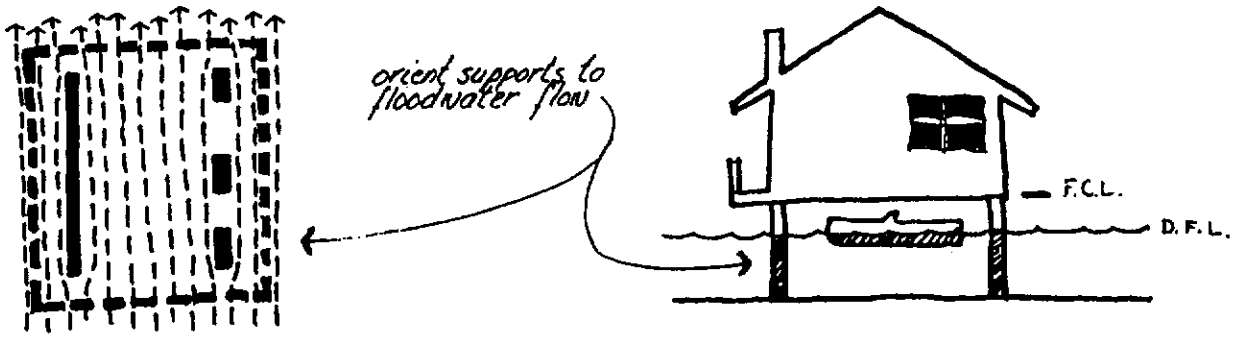
CAD FILE : FVRD-003 \ WORKING \ EB \ FIG11.1.DWG

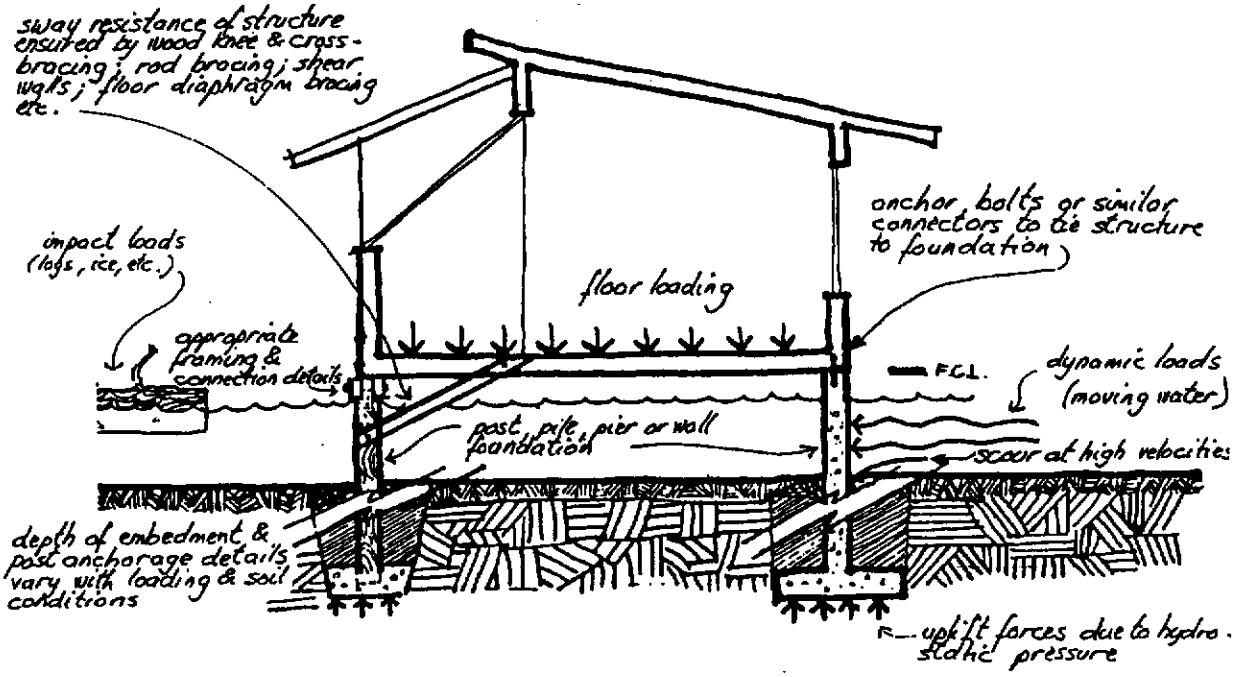
WALLS: MASONRY, CONCRETE
OR PRESERVED WOOD



POST, POLES OR PILES

PIERS: MASONRY
OR CONCRETE





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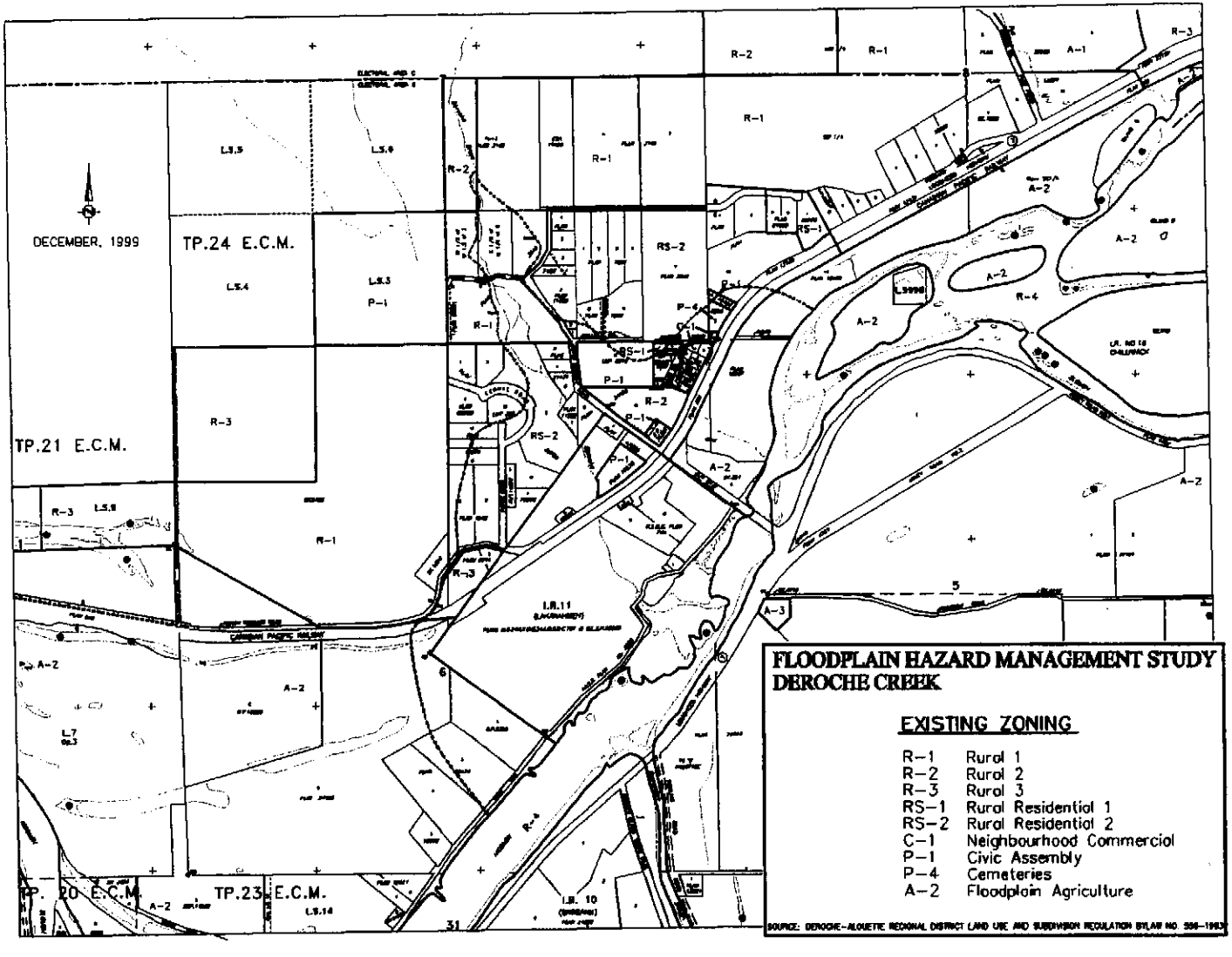
FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

DEROCHE CREEK FAN FLOOD HAZARD MANAGEMENT STUDY

STRUCTURAL FLOODPROOFING OPTIONS IN MODERATE HAZARD AREAS

FIG. 11.3

CAD FILE ; FVRD-003 \ WORKING \ EB \ FIG11.3.DWG



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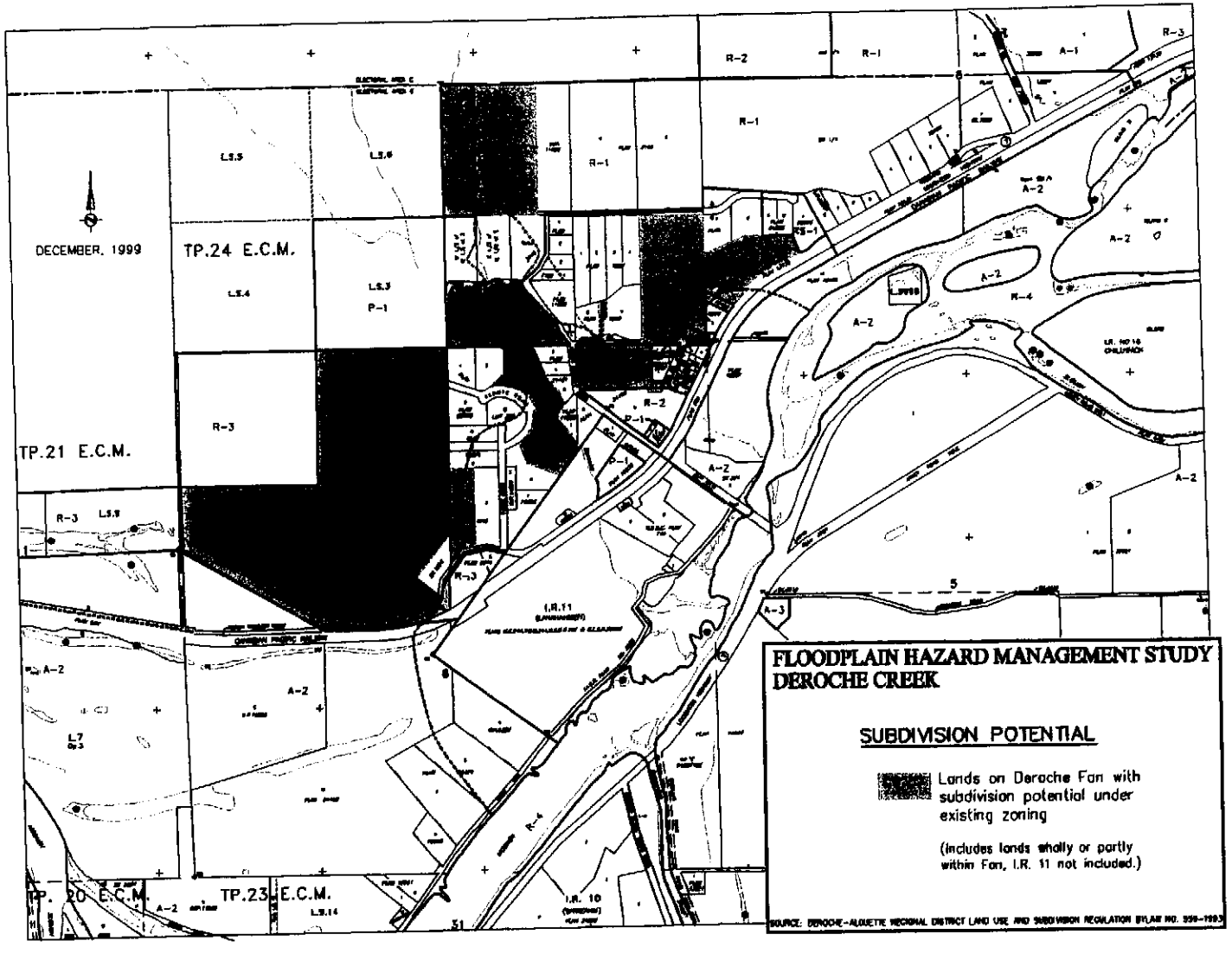
DEROCHE CREEK FLOOD HAZARD MANAGEMENT STUDY

EXISTING ZONING FOR DEROCHE CREEK

FIG. 8.3

CAD FILE : FVRD-003 / CADD / DEROCHE1.DWG

JAN. 4, 2000



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FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

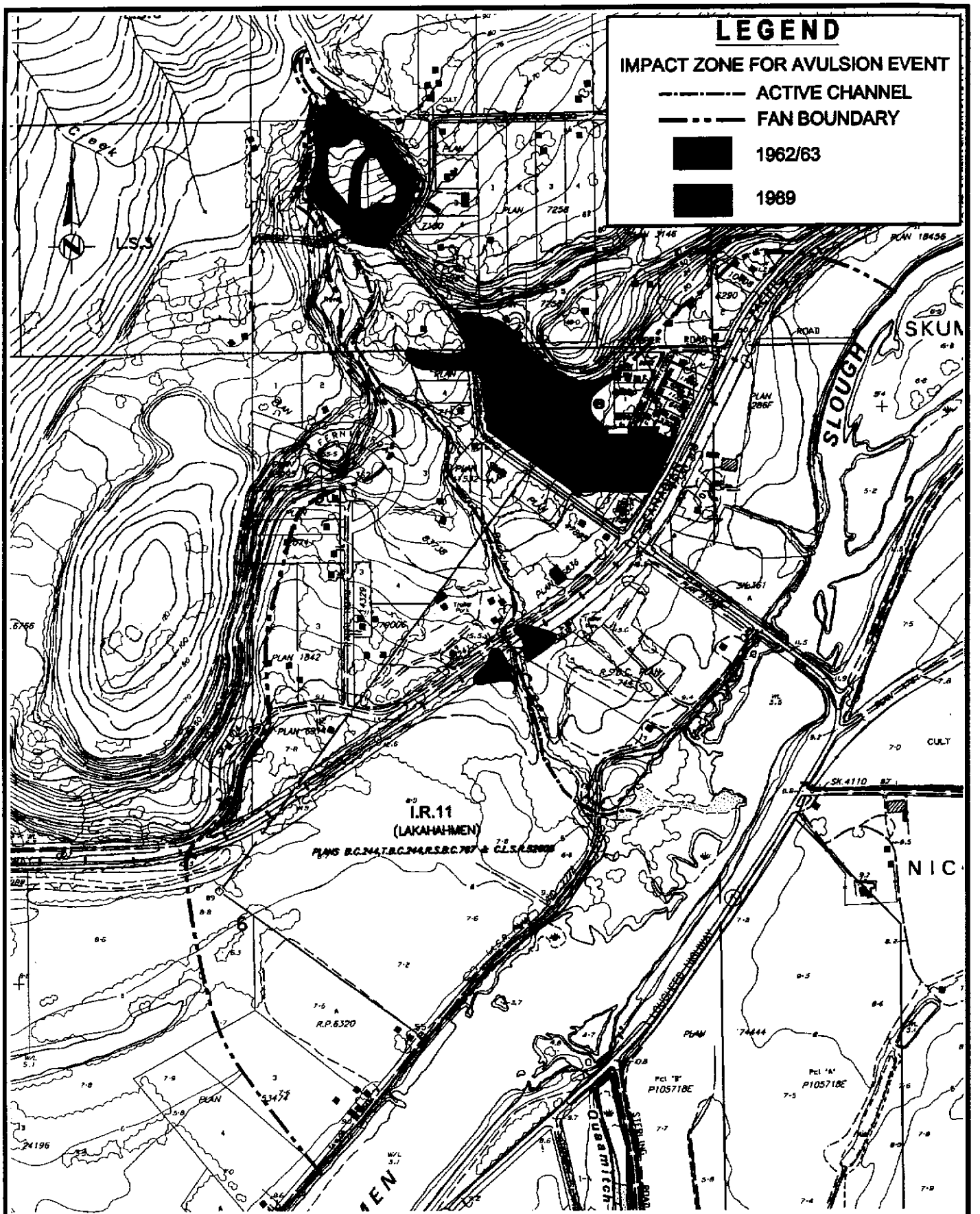
DEROCHE CREEK FLOOD HAZARD MANAGEMENT STUDY

SUBDIVISION POTENTIAL UNDER EXISTING ZONING

FIG. 8.4

CAD FILE : FVRD-003 / CADD / DEROCHE1.DWG

JAN. 4, 2000



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FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

DEROCHE CREEK FLOOD HAZARD MANAGEMENT STUDY

HISTORIC AVULSION ACTIVITY

FIG. 9.1

CAD FILE ; FVDR-003/WORKING/EB/BOB/FAN.DWG

JAN. 5, 2000

PHOTO 1 : OVERVIEW OF LOWER DEROCHE FAN AND NICOMEN SLOUGH – LOOKING EAST

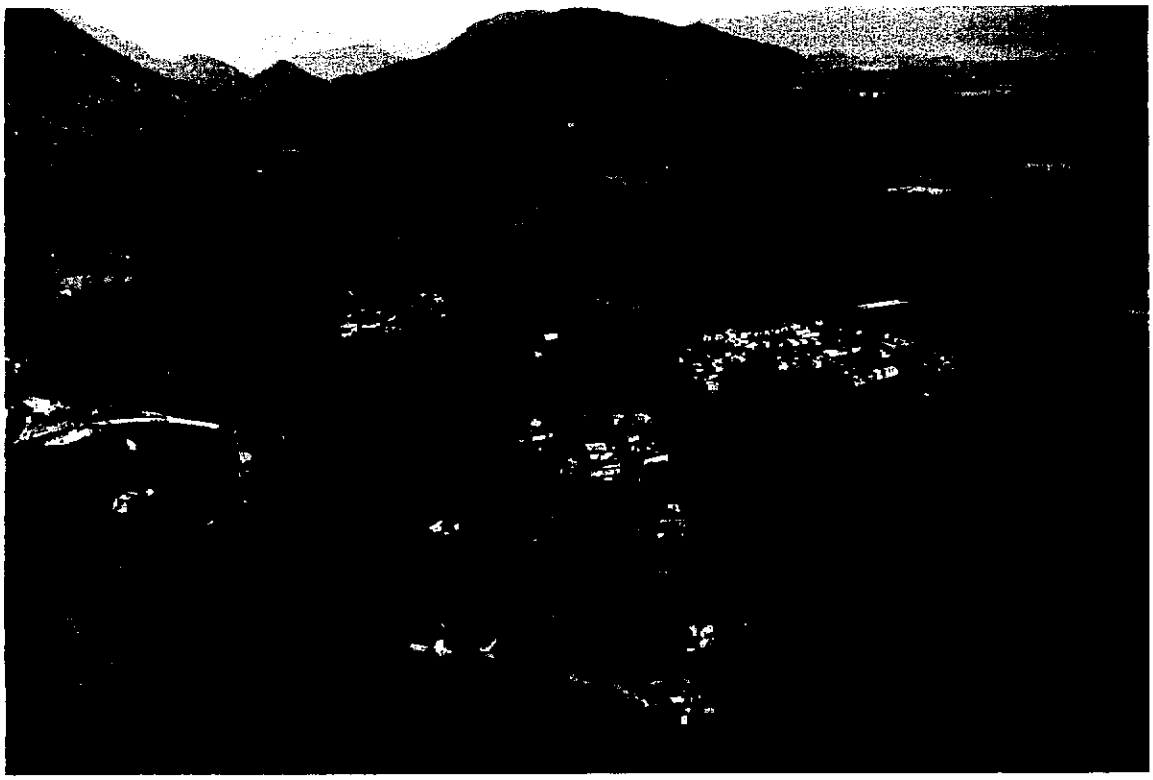

PHOTO 2 : OVERVIEW OF DEROCHE FAN AND NICOMEN SLOUGH – LOOKING EAST

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FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

DEROCHE CREEK FLOOD HAZARD MANAGEMENT STUDY

PHOTOS 1 AND 2

CAD FILE : FVRD-003 / CADD / PHOTOS.DWG JAN. 4, 2000

PHOTO 3 : DEROCHE FAN – LOOKING NORTHEAST

PHOTO 4 : DEROCHE FAN – LOOKING NORTH

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FRASER VALLEY REGIONAL DISTRICT AND LAKAHAHMEN FIRST NATION

DEROCHE CREEK FLOOD HAZARD MANAGEMENT STUDY

PHOTOS 3 & 4

CAD FILE : FVRD-003 / CADD / PHOTOS.DWG JAN. 4, 2000

PHOTO 5 : LOWER DEROCHE FAN - LOOKING SOUTH

PHOTO 6 : DEROCHE FAN - LOOKING NORTHWEST

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DEROCHE CREEK FLOOD HAZARD MANAGEMENT STUDY

PHOTOS 5 & 6

CAD FILE : FVRD-003 / CADD / PHOTOS.DWG

JAN. 4, 2000