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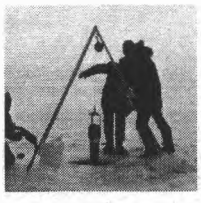
Northern River Basins Study



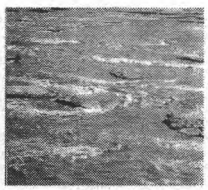







NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 77

HYDRAULIC FLOOD ROUTING MODELS OF THE PEACE AND SLAVE RIVERS, HUDSON HOPE TO GREAT SLAVE LAKE






Prepared for the
Northern River Basins Study
under Project 1154-D1

by

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

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Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

(Dr. Fred J. Wrona, Science Director) — (Date) 10 Jan 96

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
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(Dr. P. A. Larkin, Ph.D., Chair) — (Date) Jan 9/96

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

(Lucille Partington, Co-chair) — (Date) Jan. 11/96

(Robert McLeod, Co-chair) — (Date) 11/01/96

HYDRAULIC FLOOD ROUTING MODELS OF THE PEACE AND SLAVE RIVERS, HUDSON HOPE TO GREAT SLAVE LAKE

STUDY PERSPECTIVE

The filling and operation of Williston Reservoir created by the W.A.C. Bennett Dam in British Columbia in 1967, altered the natural flow patterns of the Peace River. The effects of this change are discernable most immediately downstream of the dam, but are also apparent in the Peace - Athabasca Delta, almost 2000 km downstream and in the Slave River Delta, a further 500 km downstream. People associated with these riverine environments had previously raised concerns about the effect of flow regulation on the aquatic ecosystem. The Northern River Basins Study Board identified, under its science program, flow regulation as an area requiring further investigation. A program of studies was initiated within the Hydrology component to investigate the effects of flow regulation on the Peace River. The studies included a number of impact related investigations into the effects of flow regulation on river morphology, flows, ice jamming and aquatic habitat of the Peace and Slave rivers and their associated deltas. An understanding of flow under historical and regulated conditions was an important element of the studies.

Related Study Questions

10. How does and how could river flow regulation impact the aquatic ecosystem?

13 a) What predictive tools are required to determine the cumulative effects of man-made discharges on the water and aquatic habitat?

13 b) What are the cumulative effects of man-made discharges on the water and aquatic environment?

14. What long term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems? These programs must ensure that all stakeholders have the opportunity for input.

Flow models for the Peace River were in existence but some could only generate discharges at the Water Survey of Canada (WSC) gauging sites. Water managers also had problems matching modelled flows with the WSC gauge data. An existing hydraulic model, based on physical laws and data, appeared to provide the best potential for determining flows at any location along the river. With sufficient appropriate geometric data, water levels and mean channel velocities would be provided.

A copy of the Peace/Slave River flow model is included in the report. Agencies and individuals who are pursuing investigations for the NRBS are licensed to use this model only. The model is intended for use by qualified professionals for the determination of discharge hydrographs only and the authors are not responsible for any inappropriate use of the model or any misinterpretation or inappropriate use of the results output by the model.

Users are encouraged to register with the authors in order to receive updates of the model and changes to the inputs used in the model.

This report describes a hydraulic flood routing model developed to accurately model the open water river discharge. This newer model is capable of modelling the open water discharge at intermediate sites along the Peace River where no discharge data exists. A previous report "A Hydraulic Flood Routing Model of the Peace River, Bennett Dam to Peace Point, NRBS Report Number 77," described the first stage of the model covering the Peace River from the Bennett Dam to Peace Point. This project focused on extending the model to the Slave River delta and incorporating additional cross section data on the Peace River. Although researchers were able to update the hydraulic model, absence of data downstream of Peace Point on the Peace River, particularly tributaries associated with the Peace Athabasca Delta, limits the models's usefulness for the Slave River and Delta.

Additional data will improve the model's capability to predict more accurately than presently available, discharge at various points along the Peace/Slave rivers. A user friendly PC WINDOWS program has been developed to allow routing of flows for user specified conditions. At this point, because the model only has approximate cross sections for the most part, it is only able to generate hydrographs along the river. In the future (post NRBS), the program will likely be modified by water managers to predict water level data where surveyed cross section data is available. There is also a likelihood that a freeze up component will be added.

REPORT SUMMARY

This study was conducted to service a number of impact-related studies initiated by the Northern River Basins Study to assess the effects of flow regulation by the W.A.C. Bennett Dam on the downstream aquatic ecosystems of the Peace and Slave Rivers. All require a flood routing model capable of providing comparisons between historical and naturalized flows. The primary objectives of this study were: to update the Peace River hydraulic flood routing model developed in the preliminary study; to extend this hydraulic flood routing model downstream to include the Slave River; to develop a user-friendly, graphics assisted version of the models; and to run historical versus naturalized flow for the entire period of record.

A major component of this project involved the development of the geometric model of the two study reaches using all of the available survey data, and supplementing this data with information obtained from N.T.S. maps. New data surveyed by Water Survey of Canada for the NRBS in 1994, along with data collected by the Alberta Research Council in 1982, confirmed the accuracy of the Peace River model developed in the preliminary study. Additional surveys by Water Survey of Canada on the Slave River (1994) supplemented with cross sections surveyed by UMA in 1980, facilitated the development of the Slave River model.

The only calibration parameter involved in the development of the hydraulic model was the channel resistance coefficient. Base values calibrated for this parameter provided good agreement between measured and computed hydrographs for average flood conditions. Unfortunately, little data is available at this time to facilitate a similar calibration for the Slave River model. Therefore, model users are strongly encouraged to conduct a sensitivity analyses as a part of any hydraulic analyses done using this model.

The most limiting aspect of the Slave River model is the lack of tributary data defining contributions from the Athabasca River basin through the Peace-Athabasca delta. Consequently, two hydraulic models of the Slave River had to be developed. The first is a short reach model which extends from Fitzgerald to Great Slave Lake which can model historical events based on input from the Fitzgerald gauge. The second is a full reach model which extends from Peace Point to Great Slave Lake. Of the three tributaries in this reach: Chenal des Quatre Fourches, Riviere des Rochers, and Dog River, only the Dog River is currently gauged. Therefore, a| the present time, this full reach model cannot be used. However, when data becomes available for the other two tributaries, it will only be necessary to edit the tributary data files to take advantage of the full reach model.

Based on these investigations it is concluded that the hydraulic flood routing model based on limited field data and topographic map data, can reliably predict flood hydrographs. The key advantage of this approach over traditional hydrologic flood routing methods is that output describing flood hydrographs between gauge sites is produced. Because the program developed employs hydraulic modelling techniques, water level and velocity output can be extracted from the model, as well. However, the quality of the latter two types of output is heavily dependent upon channel geometry. Therefore, it is recommended that the discharge calculated with the flood routing model be used as input to site specific hydraulic models based on *detailed* geometry to determine accurate water levels and velocities, rather than depending upon the velocity and water level output from the model.

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Special thanks are extended to Mr. Malcolm Conly, Environment Canada/NRHI, who was the technical liaison/administrator for this project. His tremendous input and efforts were essential to the successful completion of the project and were very much appreciated.

1.0 INTRODUCTION

The Northern River Basins Study (NRBS) seeks to assess the effects of flow regulation by the W.A.C. Bennett Dam on the downstream aquatic ecosystems of the Peace and Slave Rivers. A number of impact-related studies have been initiated by the NRBS. All require a flood routing model capable of providing detailed information about hydraulic flow conditions at specific locations of interest along these two rivers. In particular, it was desirable to develop flood routing models for these rivers which would enable comparisons between historical and naturalized flows.

Flood routing models are simply calculation methods (usually solved on a computer) which determine discharge hydrographs along a river, given the inflow hydrograph at the upstream end of the reach and hydrographs defining the tributary inflows in between the inflow section and the site at which the calculated discharge hydrograph is required. Although Alberta Environmental Protection (AEP) hydrologists have successfully developed a *hydrologic* flood routing model of the Peace River reach (Taggart, 1995), output from their routing model is limited to Water Survey of Canada (WSC) gauge sites because of the conceptual way in which the physics of the flow are handled in such models. In contrast, *hydraulic* flood routing models are *deterministic* rather than conceptual, as they are based on physical laws and physical data. Consequently, hydraulic models can provide discharge hydrographs at any location within the modelled reach. In fact, with appropriate geometric data, they can provide local water levels and flow velocities, as well.

To achieve this, however, hydraulic models require not only a sophisticated mathematical model of the physics of the flow, they requires adequate information describing the channel geometry and its resistance characteristics. Until recently, hydraulic models were considered unsuitable for flood routing problems because of their data intensive nature and the associated high cost of obtaining adequate geometric data over long reaches. However, in the preliminary phase of this study, NRBS Project 1154-C1 (Hicks *et al.*, 1994), it was shown that hydraulic flood routing models could be applied to determine discharge hydrographs in cases where details of channel geometry were scarce. In that project a database for the entire Peace River reach was synthesized based on limited cross section surveys, supplemented with topographic map data. The resulting model provided routed hydrographs which were shown to provide good agreement to measured data.

This study represents an extension to NRBS Project 1154-C1. Four objectives were specified in the terms of reference (Appendix D) for this new study.

1. Update the current Peace River hydraulic model (from Project 1154-C1) with additional cross section information as required so that hydrographs can be modelled at ungauged cross sections.
2. Extend the hydraulic model developed for the Peace River downstream to include the Slave River.

3. Produce a user-friendly, graphics assisted version of the model.
4. Run various flow scenarios for other projects as directed by the Component Leader.

Specifically, the major objective of the study was to adapt the computational model to both the PC WINDOWS environment in general, and to the Peace and Slave Rivers in particular. The resulting user-friendly computer program incorporates: a graphic user interface including map selection of output sites; automated incorporation of WSC and naturalized inflows; a built-in plotting package; and a direct interface of output to EXCEL spreadsheet files. Users can run any simulation for which WSC gauge records are available to define the inflows from upstream and tributary contributions, by merely selecting the dates of the desired simulation period. Combined, naturalized, and historical runs can be conducted and the results graphically compared to measured gauge data. The program is generalized so that the model can be extended directly by the user, simply by adding new ASCII data files derived from future WSC CD-ROM issues.

Chapter 2 presents the details of the development of this model including a description of the development and extension of the geometric database, as well as a summary of the WSC data incorporated into the model. In Chapter 3, the results of sample numerical simulations are presented to illustrate the appropriate use of the model and to facilitate interpretation of the output. Conclusions and recommendations are provided in Chapter 4.

A description of the numerical method used and the equations modelled are provided in Appendix A. Appendix B presents the results of the flood routing simulations required by the Component Leader, specifically comparisons between historical and available naturalized outflows for the period 1962 to 1991. Appendix C contains the users' manual for the user-friendly computer program.

2.0 DATABASE FOR THE HYDRAULIC MODELS

2.1 INTRODUCTION

Figure 1 illustrates the Peace River study reach, which extends from the Water Survey of Canada (WSC) gauge at Hudson Hope (28 km downstream of W.A.C. Bennett Dam) to Peace Point in Wood Buffalo National Park, a distance of 1107 km in terms of length measured along the channel centerline. The actual model extends downstream an additional 93 km (to station 1200 km) to minimize the influence of boundary effects on the calculations at Peace Point. This is the same reach that was modelled in the preliminary study (Project 1154-C1, Hicks *et al.*, 1994). Figure 2 presents the Slave River reach which extends from Peace Point to Great Slave Lake, a distance of 509 km.

The hydraulic flood routing model implemented for these two reaches required two types of input data: geometric data and hydrologic data. Both are discussed in this section of the report.

2.2 DEVELOPMENT OF THE GEOMETRIC DATABASE

The premise behind the application of an hydraulic model in a flood routing application is that an adequate representation of the of the salient geometry can be developed from limited survey data supplemented with topographic map data (Hicks *et al.*, 1994). Given the approximate nature of the geometric model in this approach, a rectangular channel approximation is warranted. The basic data requirements for the model then include details of the effective bed profile, channel widths, and hydraulic resistance characteristics of the river channel.

It is important to recognize that the local geometry is not significant to the model, in terms of its ability to successfully route floods over long reaches. The primary influence on the hydraulic model in the context of flood routing over long distances, is the accuracy with which the gradient of the river is represented, as this is the driving force behind flood wave propagation. This is what makes it possible to employ hydraulic modelling techniques without surveying thousands of river cross sections. However, detailed local geometry *is* required to determine local responses to the routed hydrographs, such as water levels and velocities at specific sites. This kind of microscale detail would be obtained from a small scale hydraulic model, which would consider detailed geometry available over a short reach of interest. The discharge hydrographs determined from the hydraulic flood routing model presented here would provide the essential input to facilitate such an analysis.

2.2.1 Channel Distances

River stations, or locations along the channel length, were obtained by marking out 1 km intervals on the 1:250,000 scale maps with dividers. The origin was specified as the downstream face of the W.A.C. Bennett Dam, and the stations were specified in kilometers (km) downstream of this origin. For consistency with earlier and future investigations, the stations were measured along the channel centreline, rather than along the thalweg as the latter is a more subjective criteria when limited cross section data are available. The difference between the channel stations obtained using these two criteria was marginal in this case, and the choice of channel centreline as the longitudinal axis was consistent with the assumption of a rectangular cross section shape. Each of the surveyed cross sections was referenced to this stationing system, as were all major tributaries and key sites of interest. Table 1 presents the location of these key sites along the Peace/Slave River, in terms of their distances downstream of the W.A.C. Bennett Dam.

2.2.2 Water Surface Slopes from the N.T.S. maps

Water surface slopes were obtained from 1:250,000 scale National Topographic Series (N.T.S.) maps by identifying locations where the topographic contours intersected the river channel. The corresponding stations, in terms of distance downstream of the dam, were then used to determine water surface slopes. Table 2 provides the water surface elevations obtained in this way. Table 3 presents the estimates of the water surface slope obtained from the data in Table 2.

Table 1. Location of key sites along the Peace and Slave Rivers.

Location	Station (km)
Peace River at Hudson Hope	***28***
Halfway River confluence	65
Moberly River confluence	103
Peace River at Fort St. John	110
Pine River confluence	120
Peace River at Taylor	**121**
Beaton River confluence	141
Kiskatinaw River confluence	154
British Columbia-Alberta Border	*166*
Clear River confluence	186
Peace River at Dunvegan Bridge	**295**
Smoky River confluence	388
Heart River confluence	394
Peace River at Peace River	**395**
Notikewin River confluence	558
Peace River near Carcajou	650
Peace River at Fort Vermilion	808
Boyer River confluence	819
Wabasca River confluence	865
Peace River at Peace Point	***1107***
Chenal des Quatres Fourches confluence	1199
Riviere des Rochers confluence	1216
Slave River at Fitzgerald	**1321**
Dog River confluence	1322
Slave River at Fort Smith	1345
Apex of the Slave River delta	1607
Great Slave Lake †	1616

† *measured along the main channel through the delta*

2.2.3 New Survey Data

There is a reasonable minimum to the amount of survey data required to achieve a reliable hydraulic flood routing model. Therefore, a key question arising from the original study was whether the lack of survey data in the 400 km reach between the town of Peace River and Fort Vermilion diminished the quality of the model output at Peace Point. Consequently, one key objective of this study was to assess the quality of the original Peace River model through the incorporation of new surveys at strategic locations. A second objective was to extend the model down the Slave River to Great Slave Lake. Both objectives required field surveys, particularly in the Slave River reach.

Table 2. Water surface elevations from the N.T.S. maps.

Station (km)	Contour Elevation
24	1500 ft (457.20 m)
72	1400 ft (426.72 m)
127	1300 ft (396.24 m)
221	1200 ft (365.76 m)
323	1100 ft (335.28 m)
425	1000 ft (304.80 m)
542	900 ft (274.32 m)
893	800 ft (243.84 m)
1089	220 m
1487	160 m

Table 3. Water surface slopes based on the N.T.S. map data.

Reach (km)	Water Surface Slope
24 to 72	0.000635
72 to 127	0.000554
127 to 221	0.000324
221 to 323	0.000299
323 to 425	0.000299
425 to 542	0.000261
542 to 893	0.000087
893 to 1089	0.000122
1089 to 1487	0.000151

Peace River (28 km to 1107 km downstream of W.A.C. Bennett Dam)

As discussed in the first study report, detailed survey data was available upstream of the B.C./ Alberta border. However, in Alberta, cross section surveys had been conducted at very few sites. Specifically, cross section data in Alberta was available at Dunvegan, Peace River, Fort Vermilion and Peace Point only. Virtually hundreds of kilometers of river remained unsurveyed in the intermediate reaches.

One of the first requirements of this investigation, therefore, was to determine what additional surveys would be required on the Peace River to produce an hydraulic model which could be used with confidence. Based on an assessment of the geomorphologic variances within the study reach, in conjunction with available data on river gradient from the N.T.S. maps, it was concluded that at least one, and possibly more, changes in bed slope occur between the town of Peace River and Fort Vermilion. It was considered essential to the improvement of the existing model to identify the locations of these breaks. Based on the available information, in particular the geomorphologic pattern, two locations were identified for *essential* surveys. At the time the survey recommendations were made it was stressed that the identification of changes in channel gradient was more critical to the hydraulic flood routing model than sparse details of cross section geometry. Therefore, bed and/or water surface profiles were recommended over cross section surveys. Supplemental, or *desirable*, sites for similar surveys were also recommended. Figure 3, adapted from the preliminary study report (Hicks *et al.*, 1994), illustrates the locations for the surveys which were recommended.

A total of four cross sections were surveyed on the Peace River upstream of Peace Point for the NRBS in 1994. These survey were conducted by Water Survey of Canada (WSC) staff. Three were located in the vicinity of Fort Vermilion, and one was located at Carcajou (which is within the downstream reach designated as essential for surveys in Figure 3). Only the cross section at Carcajou was tied in to Geodetic Survey of Canada (GSC) monuments. An additional six cross sections were surveyed downstream of Peace Point, all of which were tied into GSC. Although these downstream sections were primarily used to provide data to the Slave River model, they also provided information to update the Peace River model extension downstream of Peace Point (which is required to minimize the influence of boundary effects on the results at Peace Point).

Figure 4 presents the contribution these surveys provide to the existing Peace River database. As the figure illustrates, the Carcajou section amounts to a single point which does not discount or confirm the profile assumed in the original study. Fortunately, additional surveys, collected by the Alberta Research Council (ARC) in 1982, were made available to the authors by Trillium Engineering and Hydrographic Ltd. Figure 5 illustrates this additional data which is seen to confirm the channel gradient and slope breaks assumed in the original model.

Slave River (1107 km to 1616 km downstream of W.A.C. Bennett Dam)

As discussed above, six cross sections were surveyed downstream of Peace Point for the NRBS by WSC staff. These were located between stations 1184 and 1215 km. An additional cross section was surveyed on the Slave River near station 1225. WSC staff also surveyed a water surface profile between stations 1215 km and 1321 km. Figure 6 illustrates the information available from these surveys, the original study and from the N.T.S. maps. As the figure indicates, there is a significant change in slope in the vicinity of Fort Smith and Fitzgerald, which was not picked up by these surveys. Also, there was virtually no data available downstream.

A search of the AEP survey library produced cross section survey data collected by UMA Engineering Ltd. in 1980. These extended from 1224 km to 1606 km and, as illustrated in Figure 7, contributed a great deal of additional information to the model.

2.2.4 Effective Bed Profile

Peace River

In the original study (Hicks *et al.*, 1994), effective bed elevations were obtained for each of the surveyed cross sections by first determining the hydraulic mean depth (= flow area/ water surface top width) at the 1:2 year flood level. The flow area and water surface top widths were determined based on a steady, gradually varied flow analysis of each surveyed reach. These analyses were done using the U.S. Army Corps of Engineers HEC-2 model, and were based on the Mannings resistance values reported by Kellerhals, Neill and Bray (1972), as shown in Table 4. No refinement of these Mannings *n* values were considered warranted at this early stage, given the purpose of this analysis.

Table 4. Mannings *n* values used in the preliminary hydraulic analysis.
(after Kellerhals, Neill and Bray, 1972)

Location (km)	**Mannings *n***
Peace River at Hudson Hope (28 km)	0.031
Peace River at Taylor (121 km)	0.049
Peace River at Dunvegan Bridge (295 km)	0.021
Peace River at Peace River (395 km)	0.022
Peace River near Carcajou (650 km)	0.023
Peace River at Fort Vermilion (808 km)	0.017
Peace River at Peace Point (1107 km)	0.023

Effective bed elevations were defined at each surveyed cross section as: the computed (HEC-2) 1:2 year water surface elevation minus the hydraulic mean depth. To establish the effective bed profile at even 1 km increments for the hydraulic model, a best fit line was drawn through the effective bed points from the surveyed cross sections. Effective bed levels between the surveyed reaches were estimated by projecting values in the surveyed reaches using the water surface slopes obtained from the 1:250,000 N.T.S. maps. Figure 8 shows the effective bed profile obtained by this method, which has been confirmed on the basis of the additional survey data from ARC (1982) and WSC (1994), as discussed above.

Figure 8 also shows the effective bed level determined for the new cross section surveyed at Carcajou by WSC in 1994. Since only a single cross section was available, a gradually varied flow analysis could not be conducted. However, a sensitivity analysis determined that the effective bed elevation obtained was not particularly sensitive to the water level. Therefore, the effective bed was simply determined using the flow area and water surface top width on the day of survey. As Figure 8 shows, the original model is consistent with the effective bed elevation provided by the new cross section.

Slave River

The same approach was used to determine the effective bed elevations for the WSC (1994) and the UMA (1980) cross sections on the Slave River. This was an essential choice as the UMA data, although sufficient for a gradually varied flow analysis, was available in graphical form only. Figure 9 presents the effective bed profile determined for the Slave River based on the available data. Again, as in the Peace River model, the effective bed profile at even 1 km increments was obtained from a best fit line drawn through the effective bed points from the surveyed cross sections.

2.2.5 Channel Widths

Peace River

The channel widths used in the hydraulic model were obtained from the 1:250,000 scale N.T.S. maps, by measuring the channel top width with scale and dividers at one kilometer intervals along the channel centreline. Figure 10 shows the top widths obtained by this approach in comparison to the measured top widths at the surveyed cross sections. Although the computational model is robust enough to allow for the use of such varying widths, such noise in the data does dramatically increase computational effort. As it was the intention of this study to provide a version of the program capable of running on a personal computer, it was considered essential to increase computational efficiency wherever possible. Therefore, the channel top widths were smoothed, as shown in Figure 10.

As illustrated in Figure 10, the widths used in the model were different from those based on surveyed cross sections. There are two reasons for these differences. First, the top widths from the surveyed cross sections were based on the flow top width of an irregular section at the 1:2 year (naturalized) flood level. However, given the limited amount of data, the N.T.S. map values had to be used, for consistency in the model. Second, the river size on the 1:250,000 scale maps was quite small. Although more accurate results could have been obtained from larger maps (e.g. 1:50,000 scale maps), the number of maps required would have been excessive and this was not considered an economic alternative.

As a result of these differences, it was desirable to evaluate the sensitivity of the model to the width variable. This assessment was achieved by developing the simple width model illustrated in Figure 11. A simulation of the 1987 flood event using this simple width model produced

discharge hydrographs within 3% of those obtained with the smoothed widths, at Taylor, Dunvegan Bridge, Peace River and Peace Point. Output at intermediate stations were similarly close with the exception of the Fort Vermilion station, where the hydrographs obtained with the two width models were 12 hours out of phase. Nevertheless, the peak discharges were still within 4% of each other. Based on these results it is concluded that the hydraulic flood routing model is not particularly sensitive to the accuracy of the width variable. Therefore, the use of small scale maps and smoothed widths are justified.

Slave River

Figure 12 presents the top widths obtained from the 1:250,000 scale maps by the same approach, for the Slave River study reach. Again, the surveyed top widths are presented for comparison. These data are similar to those presented in Figure 10, in that the surveyed top widths and the top widths from the map are quite variable. However, in this case, the top widths from the maps are consistently larger than those obtained from the surveys. This can be attributed to the fact that the UMA surveyed cross sections were only available in graphical form. Therefore, the top widths shown are for the water level on the day of survey (at low flow). As the model is not sensitive to this parameter, the map values were taken over the surveys, to provide a consistent data base of top widths at every kilometer along the Slave River. As in the case of the Peace River model, these top widths were smoothed, as shown in the figure, to increase computational efficiency.

2.2.6 Channel Resistance

Channel resistance, specifically Mannings *n*, is the only calibration parameter required for this hydraulic flood routing model. This resistance factor must take into consideration the effects of both roughness and form drag on the flow. In the context of this limited geometry model, it must also include the effects of storage associated with floodplain inundation, if it occurs.

Channel resistance is a function of channel characteristics *and* discharge and, therefore, it varies in both time and space. Consequently, there is no single set of roughness values which would be expected to be applicable for all of the flow situations the flood routing program will be expected to model. Therefore, the approach taken was to determine a base set of Mannings *n* values (varying with location) which could be uniformly increased or decreased through an option in the user friendly program. These values were selected to produce a reasonably good fit to the measured data for average flow conditions. To obtain a better fit to lower flows, the user could increase the base values by a uniform percentage. Alternatively, to obtain a better fit at high discharges, the user could decrease the base values.

Peace River

The base values for channel resistance for the Peace River reach were estimated from the values presented by Kellerhals, Neill and Bray (1972) for 1:2 year flood events, as summarized in Table 4. Table 5, below, presents the values used in the various Peace River sub-reaches (obtained assuming the local values cited in Table 4 were valid halfway to each adjacent site).

Table 5. Mannings *n* values used in the Peace River hydraulic flood routing model.
(based on the data from Kellerhals, Neill and Bray, 1972)

Location (km)	Mannings *n*
28 to 75	0.030
75 to 210	0.045
210 to 345	0.025
345 to 1107	0.020

Slave River

Estimating the hydraulic resistance for the Slave River was considerably more difficult, because of the limited data available and the scarcity of previous hydraulic studies on this reach. Hydraulic data relating flow area, top width and discharge were available from Water Survey of Canada, however, as they operate a stream flow gauge at Fitzgerald. Based on a uniform flow approximation, the Mannings *n* for the metering site (located approximately 27 km downstream of the gauge) was found to be 0.05. This is a markedly different value than that used on the Peace River near Peace Point ($n = 0.020$). In the absence of any other data, it was assumed that the Peace Point value (0.020) applied to Fitzgerald, and the larger value (0.050) applied from Fitzgerald downstream to Great Slave Lake. ***It is recommended that data enabling a proper calibration be obtained before the model is used extensively. In the meantime, the user is strongly encouraged to conduct a sensitivity analysis as a part of any hydraulic analysis done using this model.***

2.3 AVAILABLE HYDROLOGIC DATA

The National Topographic Series 1:250,000 scale maps show a total of more than 80 tributaries for these two rivers. However, only a fraction of these streams are gauged. This means that flood routing models, both hydrologic and hydraulic are constrained by a lack of hydrologic data. Consequently, it is impossible to assess the magnitude of the error in modelling the Peace and Slave Rivers in certain reaches, because the difference between modelled and observed stream flows are comprised of both model errors and ungauged (unquantified) lateral inflows.

In this section the available data is discussed, including details of how the lateral inflows were quantified, as well as information on the sites along the Peace and Slave Rivers for which gauge data was available for comparison to the computed results.

2.3.1 Peace River

WSC Gauge Data Available on the Peace River

Data from five streamflow gauges were incorporated into the user-friendly model for graphical comparison to computed output for the Peace River, including: the Peace River at Hudson Hope (which was used as the upstream boundary condition for the flood routing computations since dam outflows are not published) at station 28 km; the Peace River near Taylor, at station 122 km; the Peace River at Dunvegan Bridge, at station 295 km; the Peace River at the town of Peace River at station 395 km; and the Peace River at Peace Point, located at station 1107 km. Data for the discontinued stations at Carcajou (650 km) and Fort Vermilion (808 km) were also included. However, the records for these two gauges are limited. Although the data at Hudson Hope was used as the inflow boundary condition to the historical runs, it was included in the user-friendly model to facilitate graphical comparisons between historical and naturalized outflows from the W.A.C. Bennett Dam.

WSC Gauge Data Available on the Peace River Tributaries

To facilitate a consistent comparison with Alberta Environmental Protection's SSARR model of the Peace River, the tributary inflows used in this *hydraulic* flood routing model were identical to those used by Alberta Environmental Protection (AEP). Table 6 presents the tributaries considered in this analysis, the numbers of the WSC gauges from which the data were obtained, and the multiplication factor used by AEP to transpose the tributary gauge data downstream to the confluence with the Peace River (Taggart, 1995). Since the gauges are located relatively close to their confluences, a simple linear adjustment was done. That is, the multiplication factor is simply the ratio of the catchment area at the confluence to the catchment area at the gauge (Taggart, 1995).

Table 6. Peace River tributaries considered in the flood routing models.

Location	WSC	Factor
Halfway River near Farrell Creek	07FA006 (1987)	1.00
Halfway River near Farrell Creek (lower)	07FA001 (1980)	1.00
Moberly River near Fort St. John	07FB008	1.40
Pine River at East Pine	07FB001	1.00
Beaton River near Fort St. John	07FC001	1.03
Kiskatinaw River near Farmington	07FD001	1.26
Clear River near Bear Canyon	07FD009	1.00
Smoky River near Watino	07GJ001	1.02
Heart River near Mampa	07HA003	1.00
Notikewin River at Manning	07HC001	1.39
Boyer River near Fort Vermilion	07JF002	1.00
Ponton River above Boyer River	07JF003	1.26
Wabasca River at Walden Lake Road	07JD002	1.10

Additional tributary inflow data were available from gauges on the Alces River (at the 22nd Baseline), the Saddle River (near Woking), and the Whitemud River (near Dixonville). However, as these data were not used in the AEP hydrologic flood routing model, no multiplication factors were provided to transpose the gauge data downstream to the confluence in a manner consistent with the data from the other tributaries. Therefore, these tributaries were not considered in the hydraulic model simulations. As these tributaries have limited flow records, and relatively small contributions, this is not considered significant to the model. Of far greater importance are the ungauged inflow from major tributaries, such as the Wabasca River, downstream of Fort Vermilion. As will be seen in the discussion of the numerical simulations, when significant, these ungauged inflows introduce significant errors in the hydrographs predicted at the Peace Point gauge.

The user-friendly PC program has been set up to run historical flows from 1961 to 1993, inclusively, based on inflow (Hudson Hope) and tributary data available from the current issue of the WSC records on the HYDAT CD-ROM. It has also been set up to simulate naturalized flows on the Peace River for 1969 to 1991, based on data provided to AEP by B.C. Hydro. It is important to note, however, that not all of the tributaries listed in Table 6 contain complete records during this extensive period. The program has been set up to advise the user when this situation arises, by providing details of the missing data. It is the responsibility of the user to recognize that this affects the reliability of the model results.

2.3.2 Slave River

WSC Gauge Data Available on the Slave River

Data from two streamflow gauges were incorporated into the user-friendly model for graphical comparison to computed output for the Slave River, including: the Peace River at Peace Point (which was used as the upstream boundary condition for the flood routing computations), located at station 1107 km; and the Slave River at Fitzgerald, located at station 1321 km.

WSC Gauge Data Available on the Slave River Tributaries

The three main tributaries to be considered in the Slave River models are: the Chenal des Quatres Fourches, located at 1199 km; the Riviere des Rochers, at 1216 km; and the Dog River, located just downstream of Fitzgerald at 1322 km. The Dog River is gauged (WSC07NB008). However, the Chenal des Quatres Fourches and the Riviere des Rochers are more significant as they contribute the inflows from the Athabasca River basin, through the Peace-Athabasca delta. Unfortunately, these two rivers are not gauged and there is currently no model available which can reliably route flows through the Peace-Athabasca delta, quantifying the flows carried by these two channels.

This lack of tributary data presented a serious problem, as the only alternative was to develop a short reach model with its upstream boundary at Fitzgerald, where there is a WSC gauge (7NB001) to define the inflow boundary condition for historical floods. However, this option

has the distinct disadvantage of eliminating the possibility of modelling naturalized flows, since the inflows to the Slave River model must be routed down the Peace and Slave Rivers to provide the necessary boundary condition, and this requires a continuous model. To accommodate naturalized runs in the future, two Slave River models have been set up in the user-friendly program. The first is a short reach model which extends from Fitzgerald to Great Slave Lake, taking as its upstream boundary condition, the Fitzgerald historical record. This short reach option can only model historical events and the only tributary data required is the Dog River gauge data. The second is a full reach model which extends from Peace Point to Great Slave Lake, taking as its upstream boundary condition the historical flow (from the gauge) or the naturalized flow (from the Peace River model).

As stated above, of the three tributaries to be considered, only the Dog River data is currently available. Zeros have been entered for the tributary data on the Chenal des Quatres Fourches and the Riviere des Rochers. *Therefore, at the present time, this full length Slave River model cannot be used.* It is known that the Peace/Slave River and the Athabasca Delta complex are intricately linked, in that these linking "tributaries" carry flow in both directions, depending upon relative water levels between the two systems. To adequately quantify historical flows in this complex system, a sophisticated hydraulic model capable of handling flow networks and transcritical flow would be required. The *cdg1-D network model*, possibly coupled with the newer *cdg2-D model* (both developed at the University of Alberta) could be used to quantify these complex flow scenarios for historical and naturalized events. Output from an analysis of this type would provide the input (tributary inflows/outflows as a function of time) to the NRBS Slave River model. When, and if, these historical simulations are conducted it will only be necessary to edit the tributary data files to take advantage of the full reach model in the user friendly program.

It is important to note that the inflows for the naturalized runs comes from the output of the Peace River model at Peace Point. Should the naturalized flows from the dam ever be updated, the Peace River model would have to be rerun to obtain naturalized flows at Peace Point to replace the current naturalized data files at Peace Point. Also, situations where it is clear that ungauged tributaries have contributed significant flow to the Peace River, the naturalized flows obtained with the model will be in error. This is discussed in more detail in the next section.

3.0 APPLICATION OF THE HYDRAULIC FLOOD ROUTING MODELS

3.1 INTRODUCTION

Appendix A provides the details of the numerical model used in the flood routing program, which is based on a finite element technique developed by the first author. As a part of the mandate of this study, a comparison of naturalized versus historical flows was required for the entire record period (1969 to 1991). The results of these runs are provided in Appendix B. In all runs the base values of the calibration parameter were used to give model users a frame of reference for modifying these values for specific applications.

In this section, the intention is to provide potential users of the model with some information regarding the reliability of the results and any limitations associated with the output provided by the model. It should be noted that the user-friendly model has been set up to limit the simulation period from May 15th to October 15th, that is, to the open water season. This is not a limitation of the computational model, but rather is due to the lack of data (in terms of varying ice conditions, both spatially and temporally).

3.2 MODELLING DISCHARGE HYDROGRAPHS: FLOOD ROUTING

3.2.1 Events Considered in the Original Study

As a part of the original study, two flood events were considered in the model evaluation. The first was the 1980 spring runoff event and the second was the 1987 summer flood. Input data for each simulation included the geometric data describing the channel as well as lateral inflow (tributary) hydrographs. In addition, two boundary conditions (discharge upstream, and stage downstream) and initial conditions at every computational node (stage and discharge) had to be specified for each event. The gauge site at Hudson Hope was taken as the upstream boundary of the computational domain, with the WSC data from the gauge providing the inflow boundary condition. The model was extended 100 km downstream of Peace Point (assuming a constant width and slope) to allow for an estimated stage as the downstream boundary condition. The numerical model was used to calculate the initial conditions for each steady flow test, by calculating a gradually varied flow profile for constant inflow and tributary discharges, based on observed flows on the day the simulation started. For each event, calculated results were output at select sites, to facilitate a comparison to WSC gauge data. These tests have been reproduced here to illustrate the analysis for naturalized flows, in which naturalized flows at Hudson Hope (provided to AEP by B.C. Hydro) are used as the inflow boundary condition rather that the historical record from the gauge.

Figure 13 illustrates the results obtained for the 1980 simulation, which extended from May 15 to October 15, a period of 5 months. Peak discharge magnitudes were smaller than 1:2 year flood flows. Therefore, this event might be described as a "small" flood event. This figure shows the discharge hydrographs obtained from the model both for historical (H) and naturalized (N) outflows, as compared to WSC gauge data. Agreement between the former and the WSC data measured at these sites was good. The timing of the flood peaks are exact, and peak magnitudes are only slightly lower than measured values from Peace River, upstream. As the figure shows, the dam captured a significant portion of the inflow to the reservoir.

Figure 14 illustrates the results obtained for the 1987 simulation which also extended from May 15 to October 15. Peak discharge magnitudes were only slightly higher than 1:2 year flood flows. Therefore, this event might be described as a "moderate" flood event. Again, general agreement between the calculated historical flood and the WSC data measured at these sites was good.

3.2.2 Historical Events

As a part of the model evaluation, historical runs were conducted for the pre-regulation period for which sufficient tributary data was available, specifically 1965 to 1968, inclusively. These tests are extremely valuable because of the fact that the gauge at Fort Vermilion was operational during this period.

The results of these runs for the Dunvegan Bridge, Peace River, Fort Vermilion, and Peace Point stations are compared to gauge records for each of these four years in Figures 15 through 18, respectively. As the figures illustrate, the model consistently provides a good match to the gauge data at Fort Vermilion, despite the fact that there is virtually no geometric data over the 400 km reach in between Peace River and Fort Vermilion. These results clearly illustrate the validity of the approximate geometry model. Also, the chosen values of Mannings n, based solely on the experience of earlier investigators, are reasonable and require no further calibration.

3.2.3 Historical versus Naturalized Flows

As required under the terms of reference for this study, every year for which data was available was simulated to provide a comparison of historical and naturalized flows. These results are presented in Appendix B.

Where possible, (1970 through 1974, 1976, and 1978) the simulation results at Fort Vermilion are presented and compared to gauge records. Comparisons are also presented for the Hudson Hope (providing a direct evaluation of the effects of regulation), Peace River and Peace Point stations. For the years in which the Fort Vermilion gauge was not operational, results at Dunvegan Bridge were compared to gauge data are provided.

An examination of these plots (in Appendix B) illustrates that, for 15 of the years of record, the Peace River model performed exceptionally well over a range of flows and, consequently, the comparisons between historical and naturalized flood hydrographs can be considered reliable. It is particularly interesting to note that in some cases a better match is achieved at Fort Vermilion that at Peace Point (e.g. in 1974 and 1978). This suggests that ungauged tributary inflows between these two stations were significant, introducing error into the model results. It is likely, therefore, that the poor agreement between the measured and simulated flows at Peace Point in 1977, 1979, 1984, 1986, and 1988 to 1992 can also attributed to ungauged tributary inflow. In these cases, the naturalized flows are also in error. That is, in years where the ungauged tributaries provided significant inflow to the system, model results must be expected to be in error.

3.3 OTHER MODEL OUTPUT

As required by the Project Leader, the user-friendly model provides details of the calculated stage changes and average channel velocities as a function of time at user-selected output stations. However, it is important for the model user to appreciate that this type of output is heavily dependent upon channel geometry and therefore, in this limited geometry model, must be considered crude estimates. Estimates of the level of accuracy which can be expected are provided in the following discussion.

3.3.1 Comparisons of Computed and Measured Water Levels

The numerical model presented here, being an hydraulic model, does calculate water levels. However, the application in this context is for flood routing over long distances with limited channel geometry, whereas *detailed channel geometry is essential to the quantification of the corresponding local flood levels*. This is illustrated in Figure 19, which presents a comparison of measured and computed water levels at Peace River, Dunvegan Bridge and Fort Vermilion, for the 1987 flood event. As the figures show, the model results appear consistent with the measured data in terms of the timing and relative stage changes observed. However, the computed values are vertically offset because of the approximate geometry used, primarily because the effective bed level in the model is different from the actual bed level. The reason for the difference is illustrated in Figure 20, which shows an expanded view of the river's bed profile in the vicinity of the town of Peace River. Natural variations in bed level are large and consequently, the effective bed used in the limited geometry model can be several metres different from the surveyed bed at a given point.

This difference is not significant in terms of the quality of the predicted discharge hydrographs, as has been shown in the comparison of computed and measured values. However, in the context of determining water levels at specific sites, these differences are important and the output water levels must be considered arbitrary. In the practical application, the flood peak (which the model predicts accurately) would provide the input to a steady gradually varied flow model based on detailed geometric data (such as the HEC-2 model) to determine flood levels at key sites of interest. The advantage offered by the hydraulic flood routing model over the hydrologic approach in this context, therefore, is discharge at intermediate sites (i.e. between gauge sites) rather than water level output.

As a result of this limitation, model output has been limited to provide only details of relative stage changes referenced against the initial water level calculated in the steady flow computation for the historical runs. In the case of combined historical vs. naturalized runs, both sets of output are referenced to the same initial water level (from the steady flow analysis done for the historical run). *Based on the results presented in Figure 19, the user could expect these computed stage changes to be in the order of a metre, or more, different from the actual values.* As discussed above, it is recommended that the output discharges from this model be used as the input to a detailed geometry hydraulic model for site specific determinations of water levels.

3.3.2 Average Channel Velocity

Average channel velocity is a *derivative* output. That is to say, it is not a direct output of the model, but rather is determined from other variables. Specifically, average channel velocity is equal to the discharge divided by the flow area. As has been discussed in detail already, the discharges computed in the model are considered to be very reliable. However, area, being a geometric variable, is not accurately reproduced in a limited geometry model. *Therefore, the velocities output by the model must be considered to be very crude estimates.* Again, it is recommended that the output discharges from this model be used as the input to a detailed geometry hydraulic model for site specific determinations of velocities.

4.0 SUMMARY AND RECOMMENDATIONS

This study was conducted to service a number of impact-related studies initiated by the Northern River Basins Study to assess the effects of flow regulation by the W.A.C. Bennett Dam on the downstream aquatic ecosystems of the Peace and Slave Rivers. All require a flood routing model capable of providing comparisons between historical and naturalized flows. The primary objectives of this study were: to update the Peace River hydraulic flood routing model developed in the preliminary study (based on new field surveys); to extend this hydraulic flood routing model downstream to include the Slave River; to develop a user-friendly, graphics assisted version of the models; and to run historical versus naturalized flow for the entire period of record.

A major component of this project involved the development of the geometric model of the two study reaches using all of the available survey data, and supplementing this data with information obtained from N.T.S. maps. New data surveyed by Water Survey of Canada for the NRBS in 1994, along with data collected by the Alberta Research Council in 1982, confirmed the accuracy of the Peace River model developed in the preliminary study. Additional surveys by Water Survey of Canada on the Slave River (1994) supplemented with cross sections surveyed by UMA in 1980, facilitated the development of the Slave River model. The final geometric models consist of more than 1600 computational nodes describing channel width, effective bed elevation and channel roughness.

A users manual for the user-friendly PC WINDOWS computer program is included in Appendix C. The software incorporates a graphic user interface, automated input of boundary and lateral flows inflows; an graphical and tabular output. Users can run any simulation for which WSC gauge records are available to define the inflows from upstream and tributary contributions, in including combined naturalized and historical runs. The user can also extend the database as more streamflow data becomes available.

The only calibration parameter involved in the development of the hydraulic model was the channel resistance coefficient, specifically Mannings *n*. It has been shown that base values for this parameter derived from the data provided by Kellerhals, Neill and Bray (1972) for 1:2 year

flood events at gauge sites provide for good agreement between measured and computed flood hydrographs on the Peace River. Unfortunately, little data is available at this time to facilitate a similar calibration for the Slave River model. Therefore, it is recommended that data enabling a proper calibration be obtained before the Slave River model is used extensively. In the meantime, the user is strongly encouraged to conduct a sensitivity analysis as a part of any hydraulic analysis done using this model.

The most limiting aspect of the Slave River model is the lack of tributary data defining contributions from the Athabasca River basin through the Peace-Athabasca delta. Consequently, two hydraulic models of the Slave River had to be developed. The first is a short reach model which extends from Fitzgerald to Great Slave Lake, taking as its upstream boundary condition, the Fitzgerald historical record. This short reach option can only model historical events and the only tributary data required is the Dog River gauge data. The second is a full reach model which extends from Peace Point to Great Slave Lake, taking as its upstream boundary condition the historical flow (from the gauge) or the naturalized flow (from the Peace River model). Of the three tributaries in this reach, only the one is currently gauged. Therefore, at the present time, this full reach model cannot be used. A separate hydraulic model linking the Peace/Slave River system to the Athabasca delta complex, is required to quantify the historical inflows/outflows between the two systems first. The user friendly model has been set up to accommodate that information, if and when it becomes available.

It is important to note that the inflows for the naturalized runs come from the output of the Peace River model at Peace Point. Should the naturalized flows from the dam ever be updated, the Peace River model would have to be rerun to obtain naturalized flows at Peace Point to replace the current naturalized data files at Peace Point. Furthermore, because of the significance of ungauged lateral inflows upstream of Peace Point in certain years (1977, 1979, 1984, 1986, and 1988 to 1992), naturalized runs on the Slave River would be based on erroneous inflows.

Based on these investigations, it is concluded that the hydraulic flood routing model based on limited field data and topographic map data can reliably predict flood hydrographs, provided that ungauged tributary inflows are not significant. This limitation is independent of the flood routing technique used. The key advantage of this *hydraulic* flood routing approach over traditional *hydrologic* flood routing methods is that output describing flood hydrographs *between* gauge sites is provided.

Because the program developed here employs hydraulic flood routing techniques, water level and velocity output can be extracted from the model, as well. However, unlike the predicted discharge hydrographs, the quality of the water level and velocity output is heavily dependent upon channel geometry. Therefore, in this limited geometry flood routing application, the predicted stage changes and velocities are crudely estimated. Consequently, it is recommended that the discharges, which are accurately calculated with the flood routing model, be used as input to site specific hydraulic models which incorporate detailed geometry to determine accurate water levels and velocities.

5.0 REFERENCES

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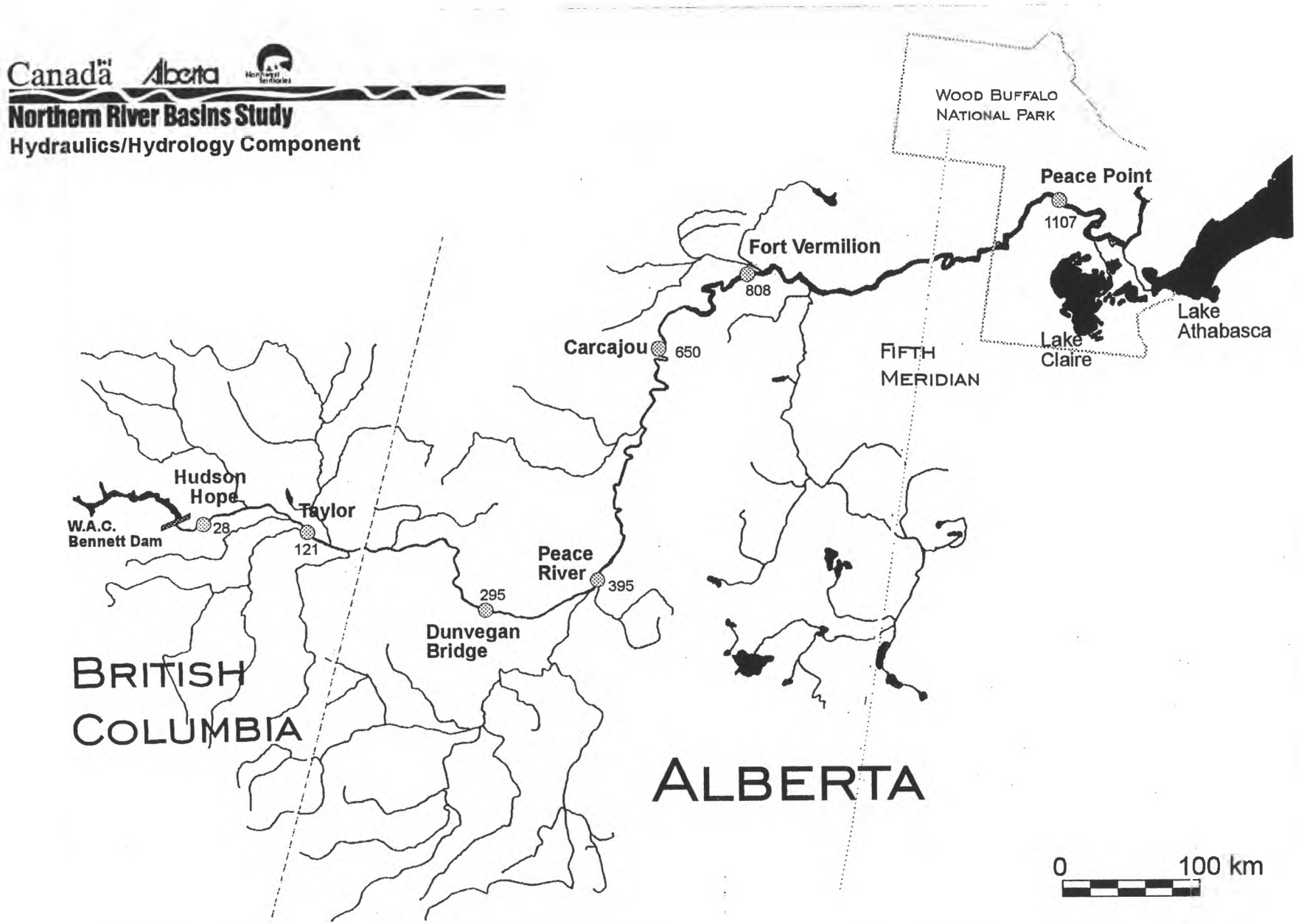


Figure 1. The Peace River study reach.

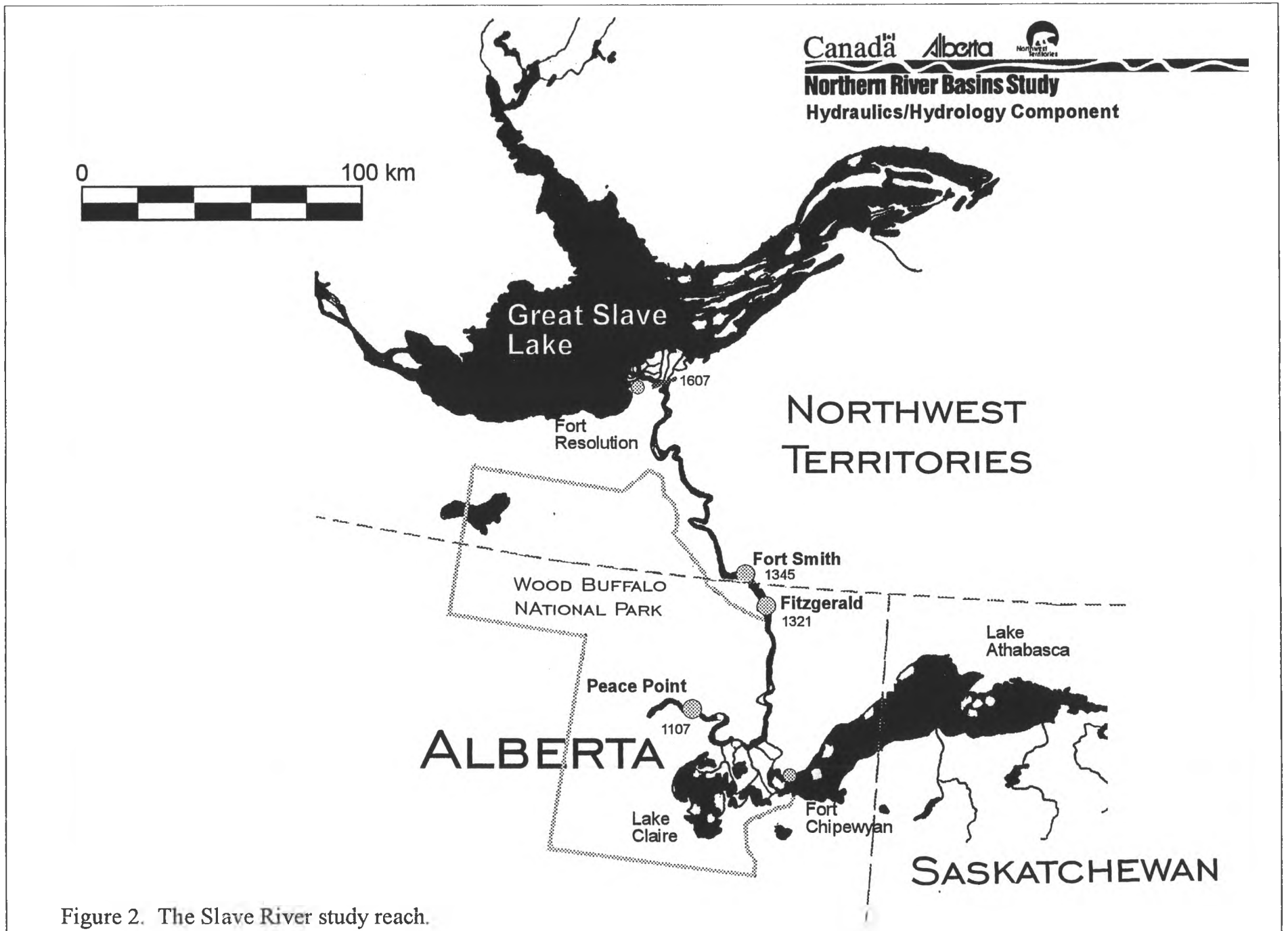


Figure 2. The Slave River study reach.

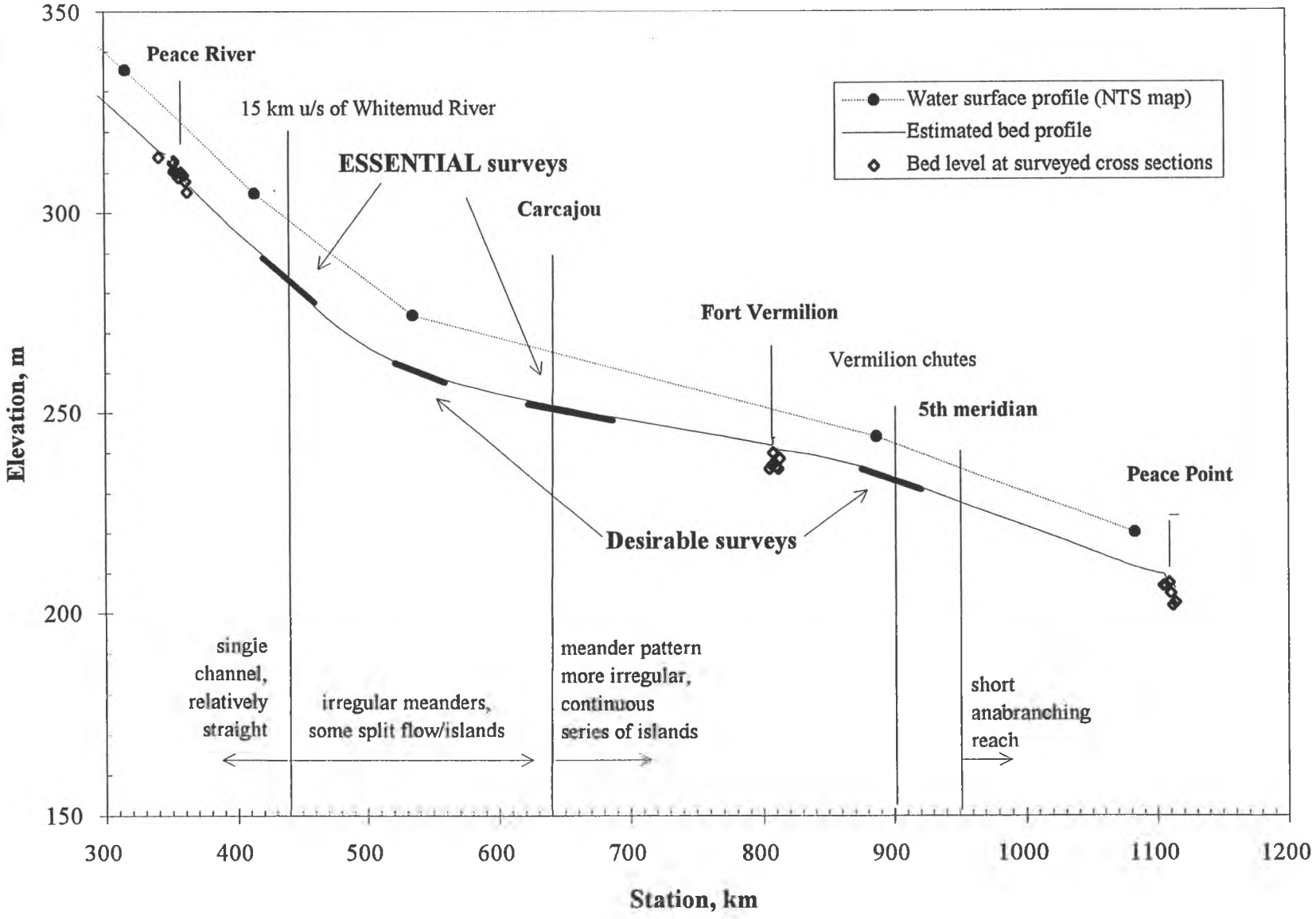


Figure 3. Surveys recommended for the Peace River reach.

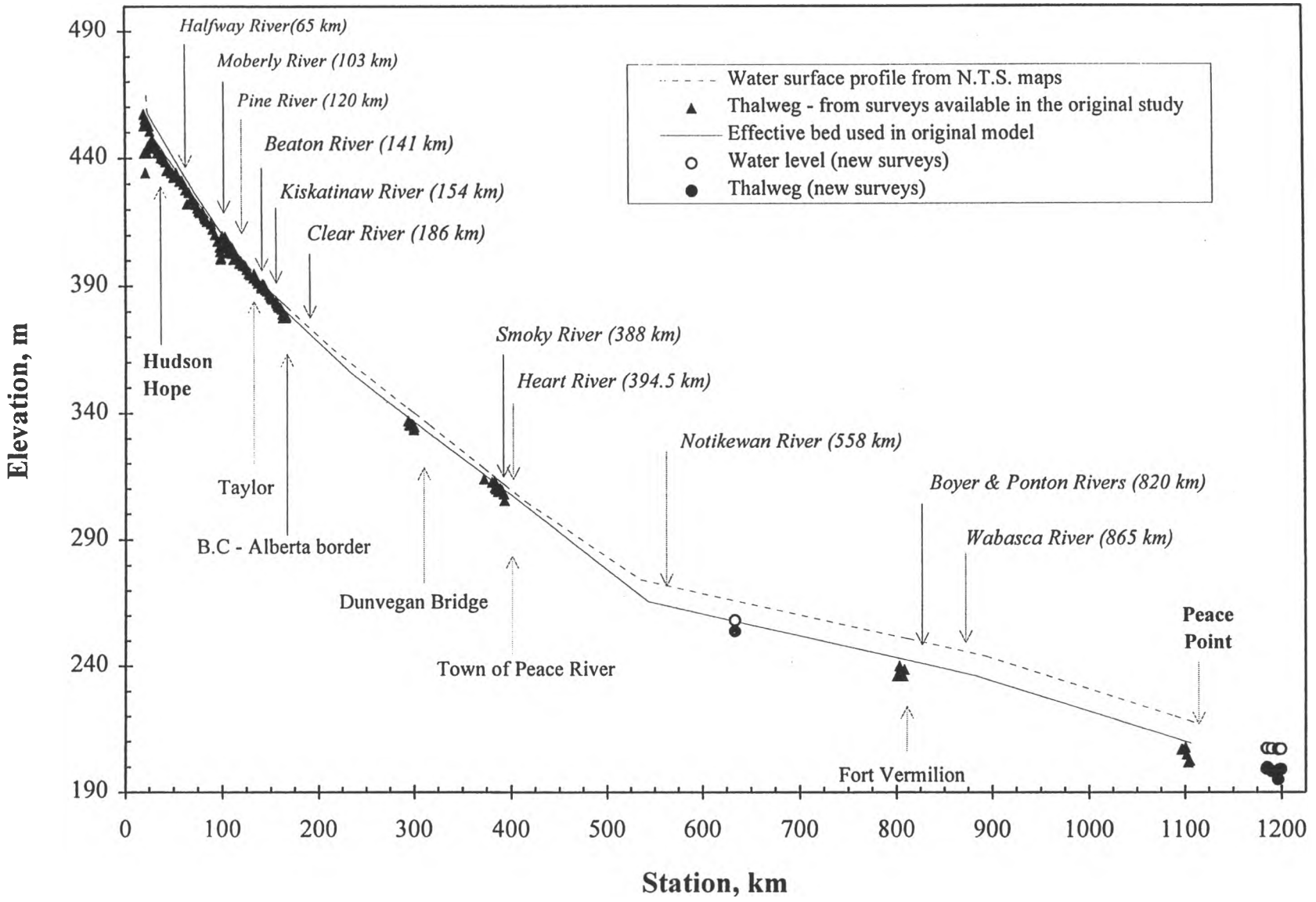


Figure 4. Additional data collected on the Peace River for the NRBS by WSC in 1994.

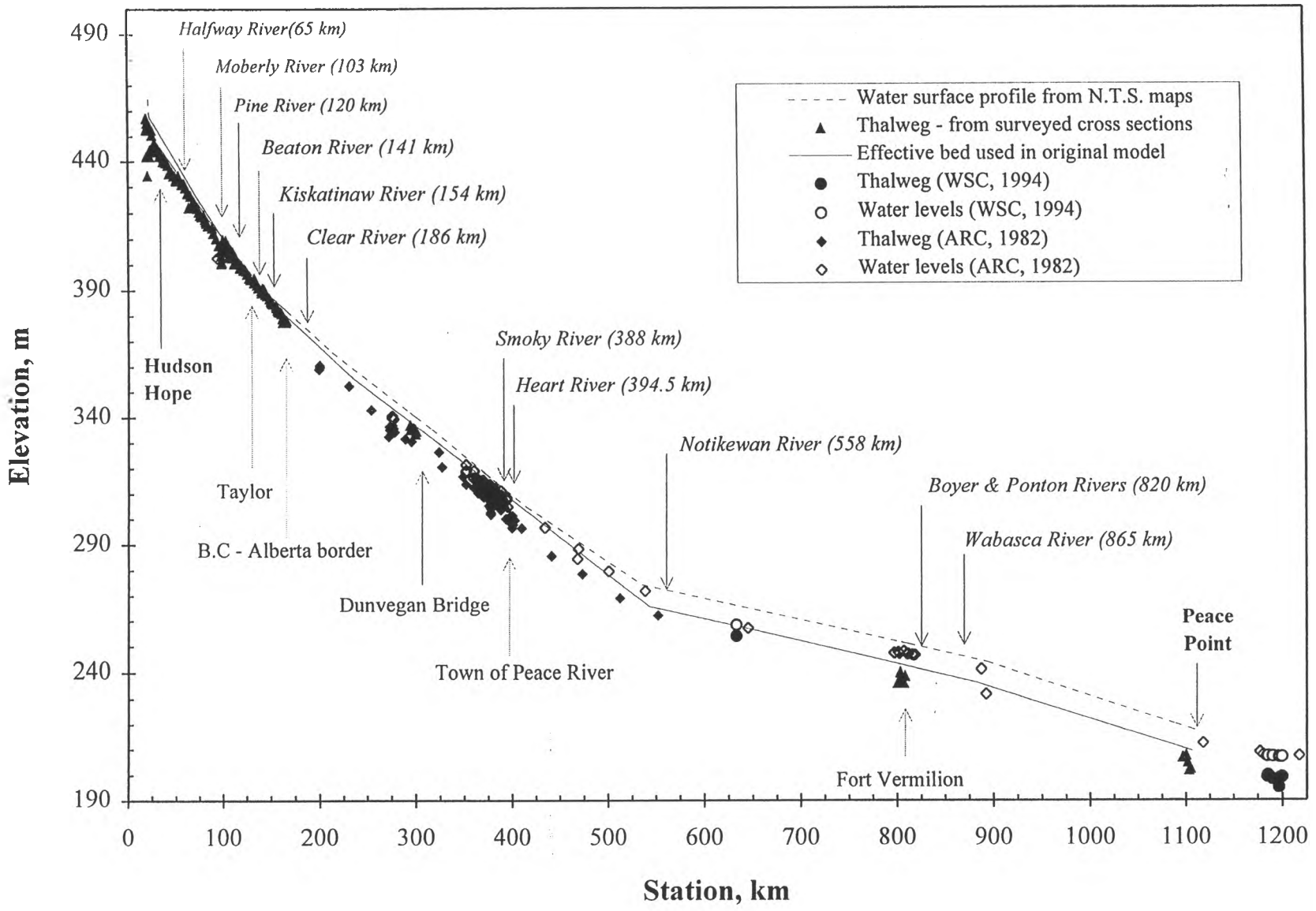


Figure 5. Available data for the Peace River reach.

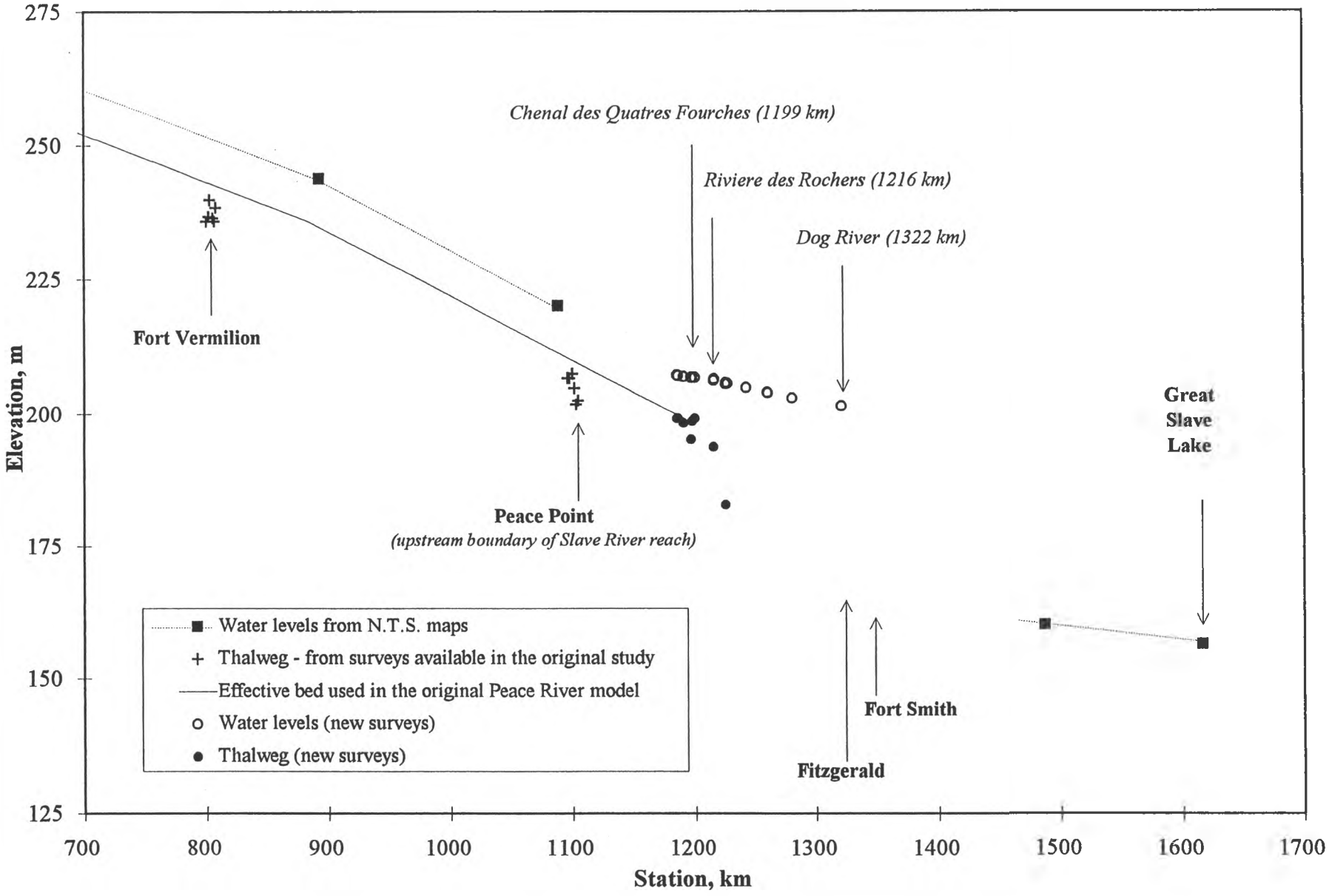


Figure 6. Data collected on the Slave River for the NRBS by WSC in 1994.

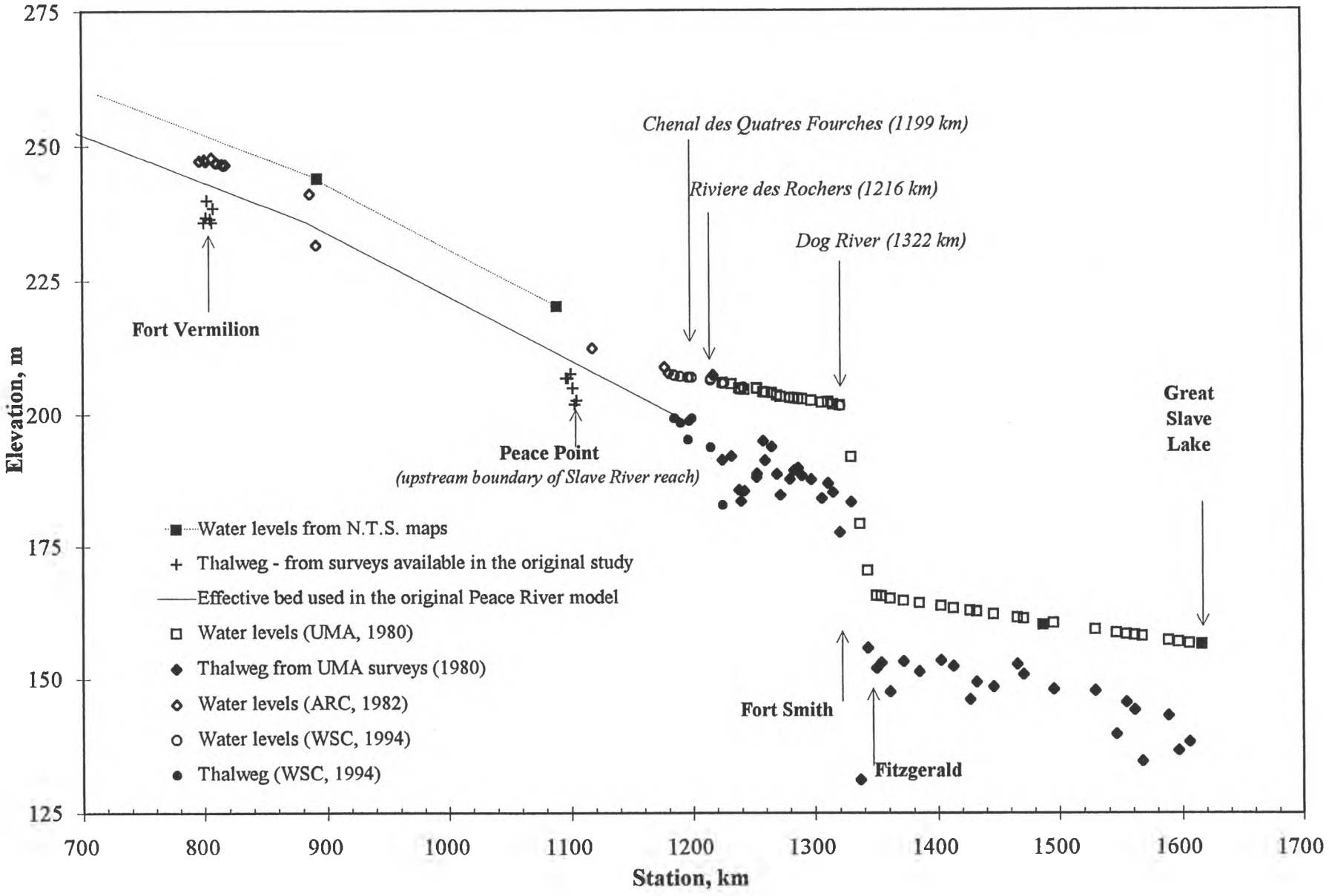


Figure 7. Available data for the Slave River reach.

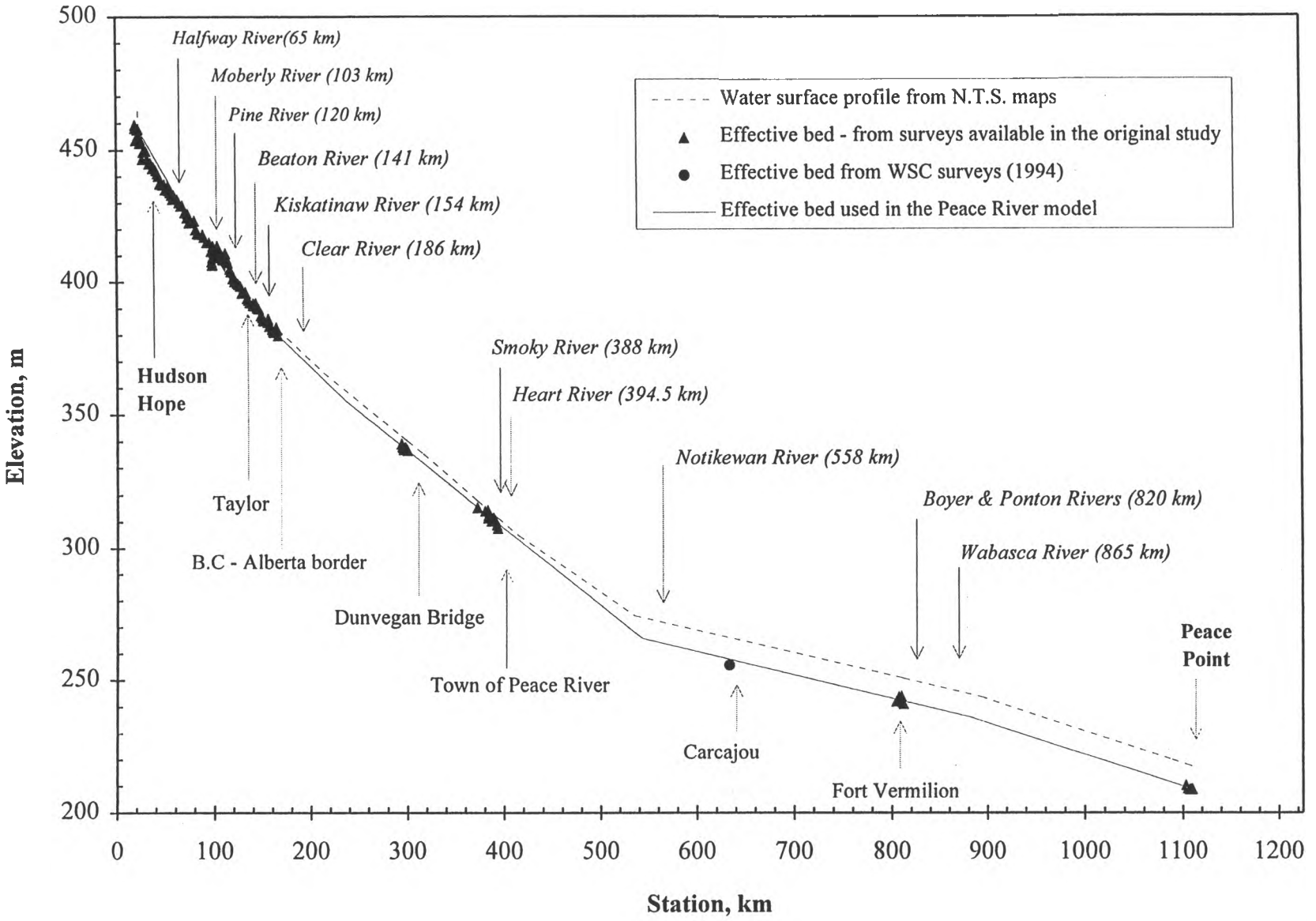


Figure 8. Effective bed profile used in the Peace River model.

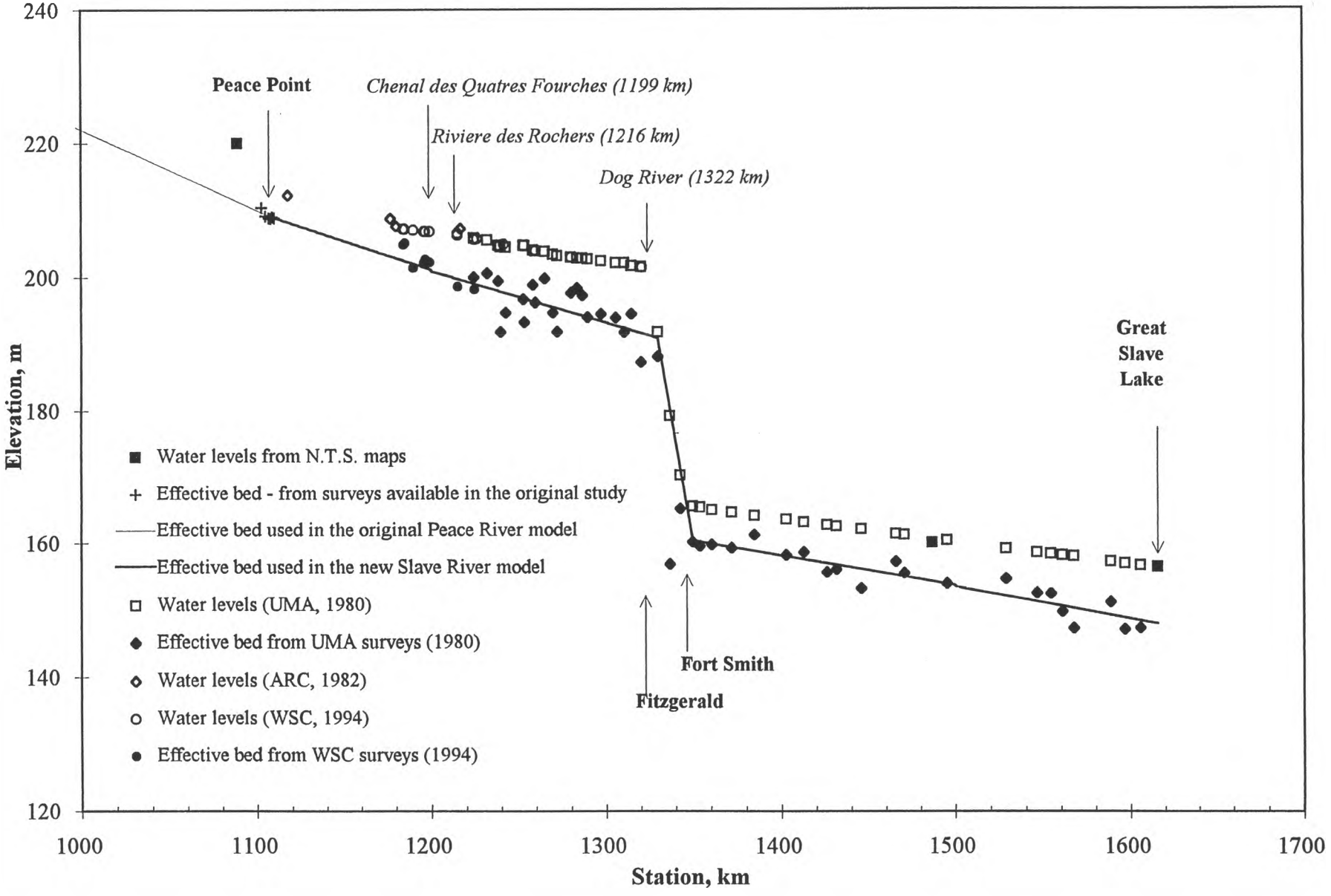


Figure 9. Effective bed profile used in the Slave River model.

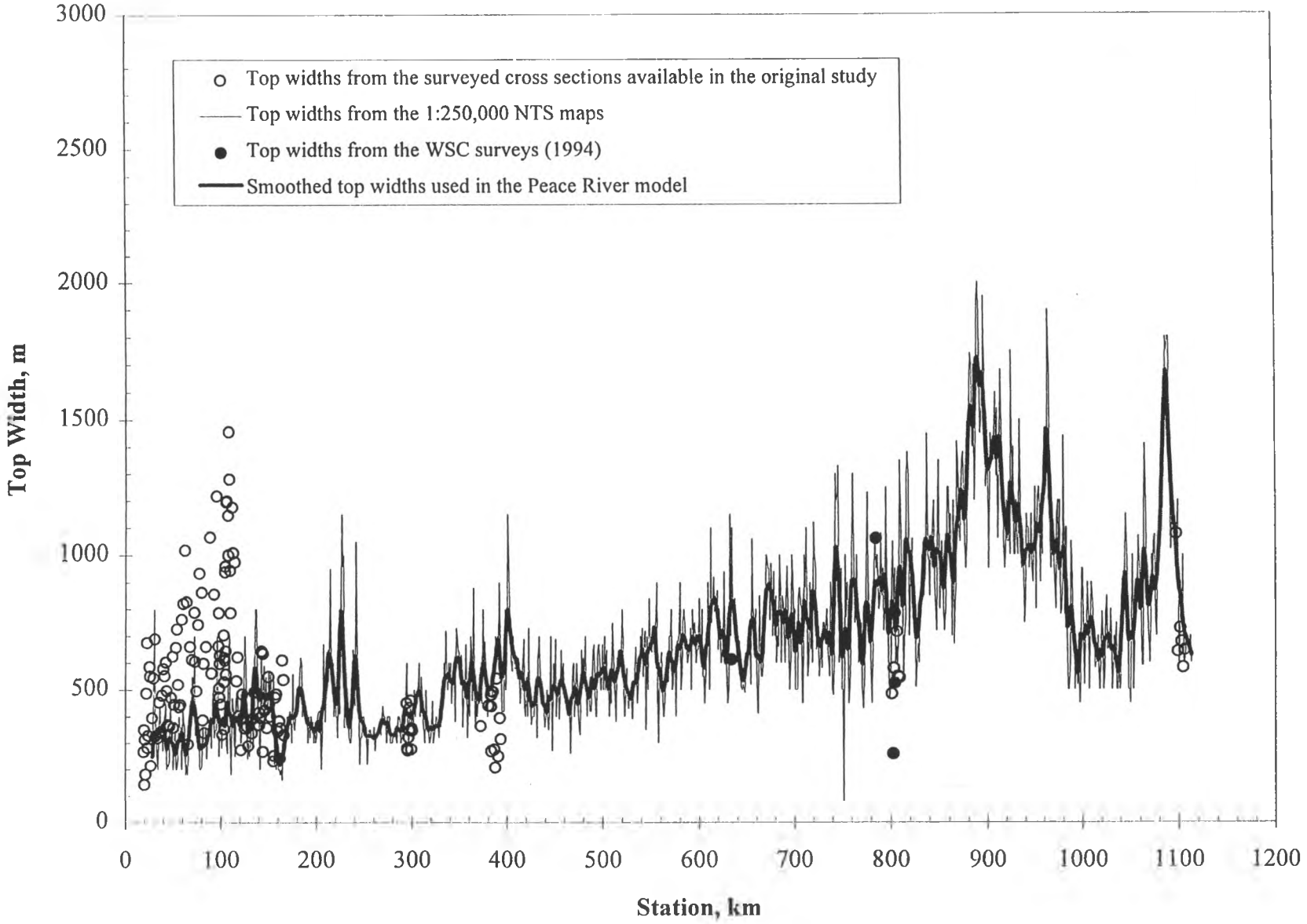


Figure 10. Top widths used in the Peace River model.

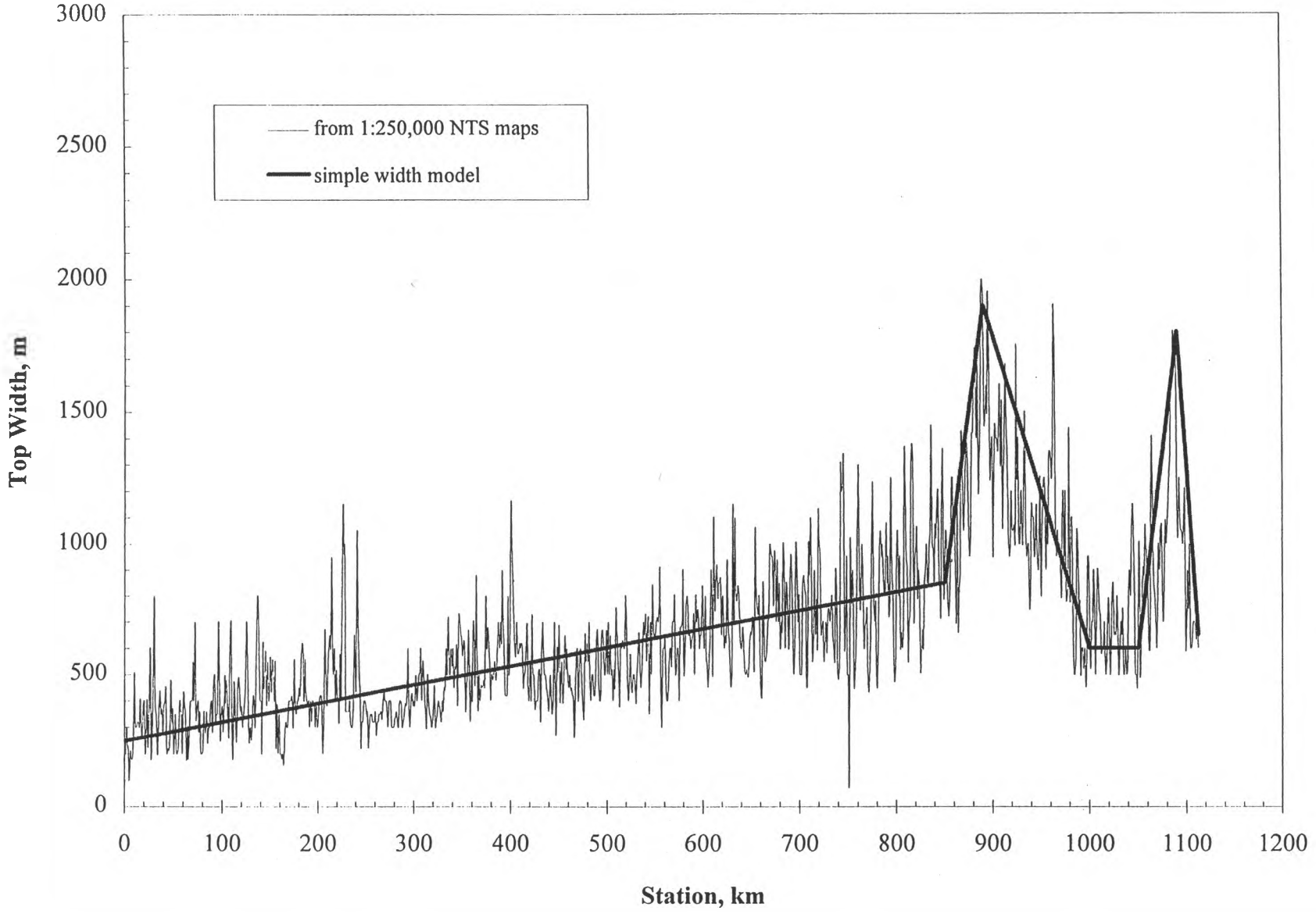


Figure 11. Top widths used to test the sensitivity of the Peace River model to the top widths used.

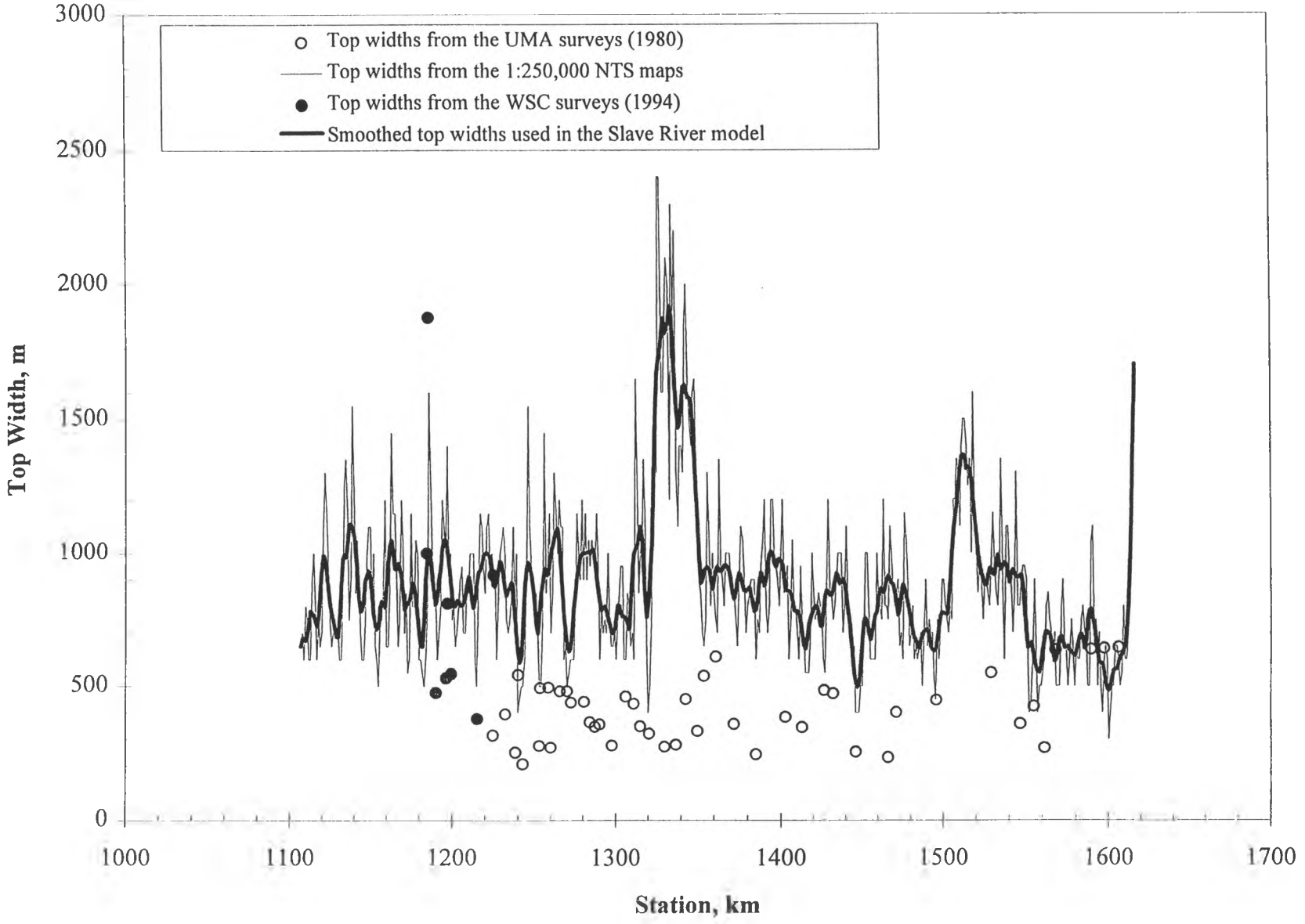
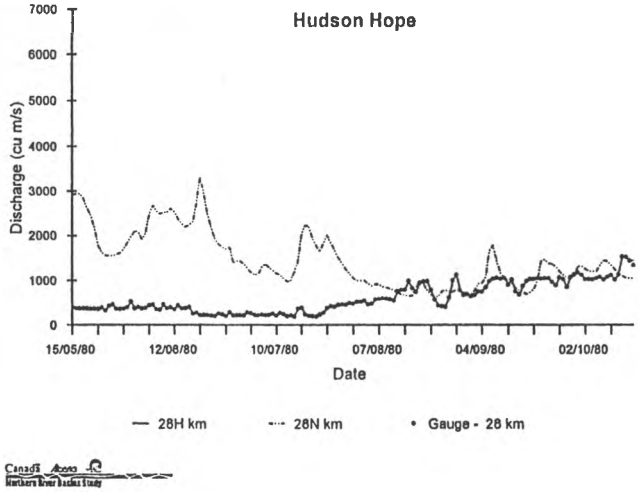
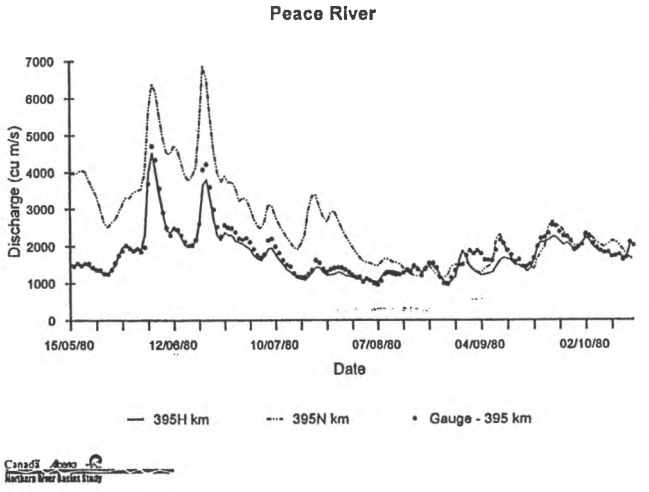
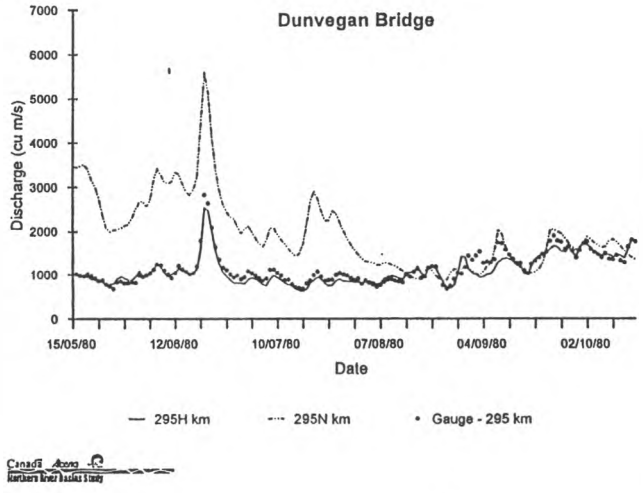


Figure 12. Top widths used in the Slave River model.







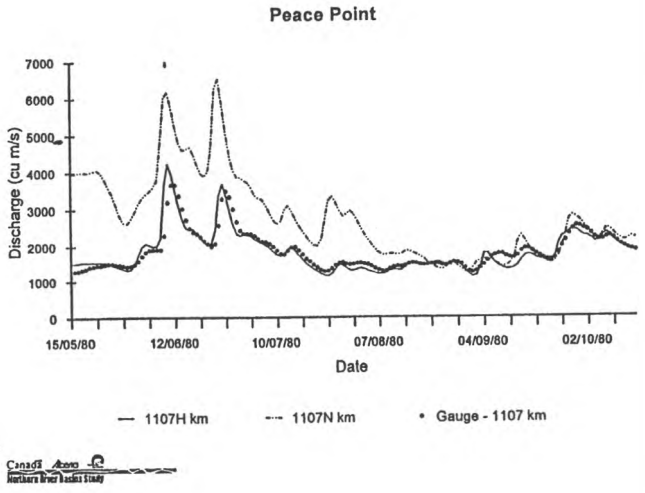
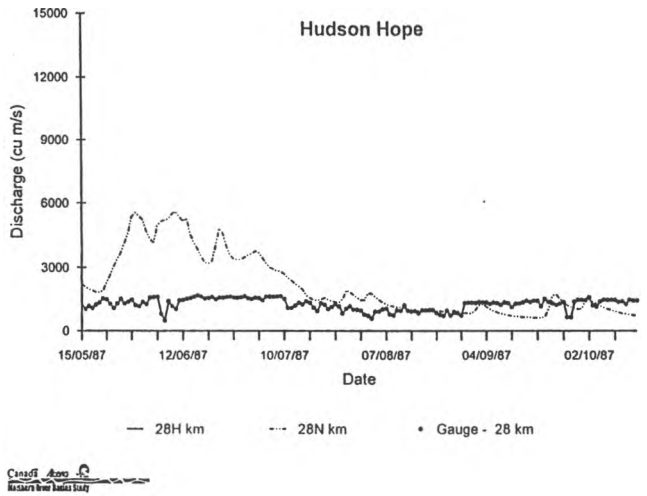
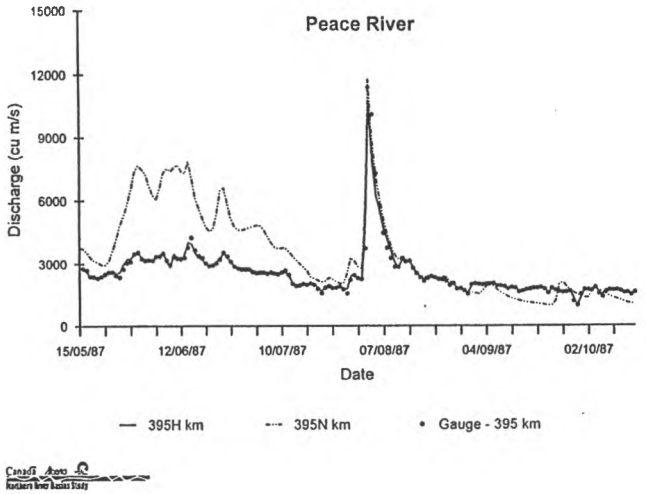
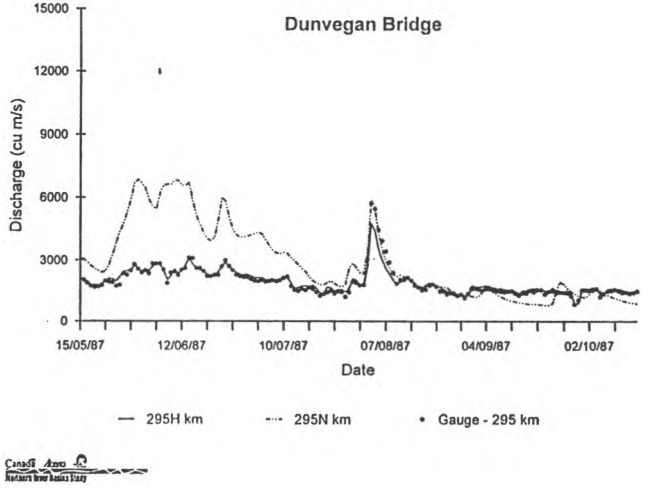


Figure 13. Simulation results for regulated and naturalized flow in the Peace River reach, 1980 event.







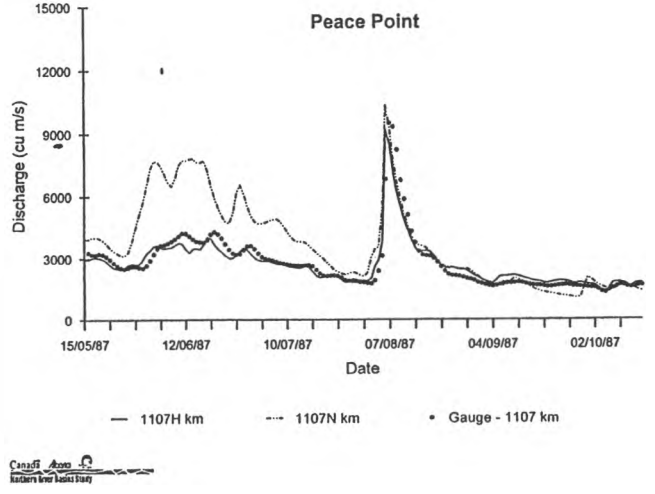
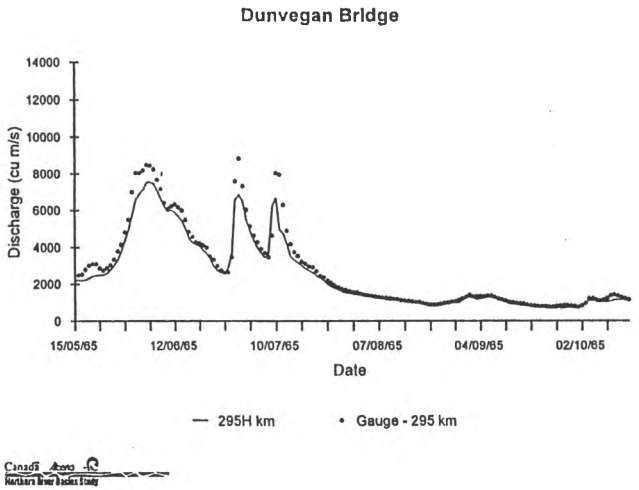
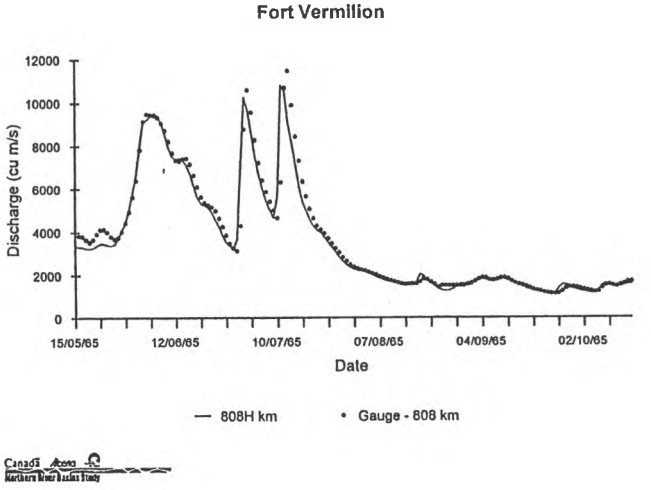
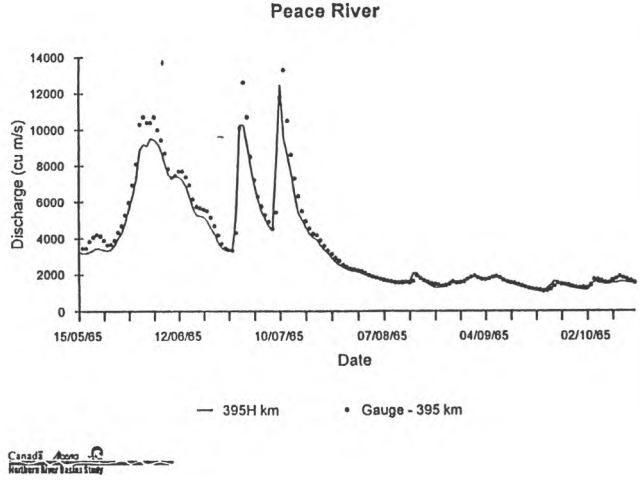


Figure 14. Simulation results for regulated and naturalized flow in the Peace River reach, 1987 event.







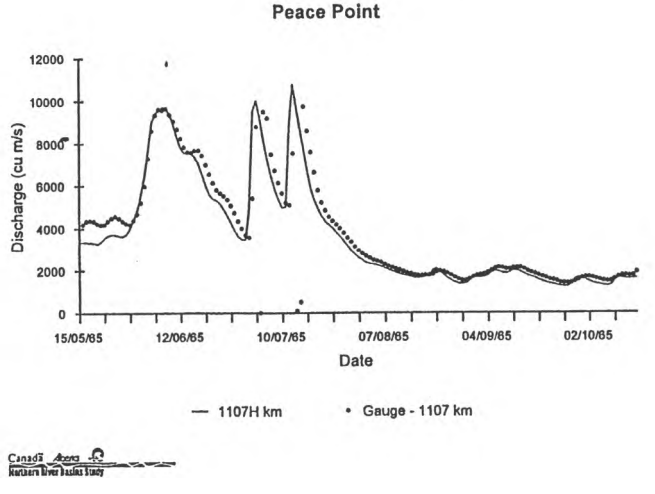
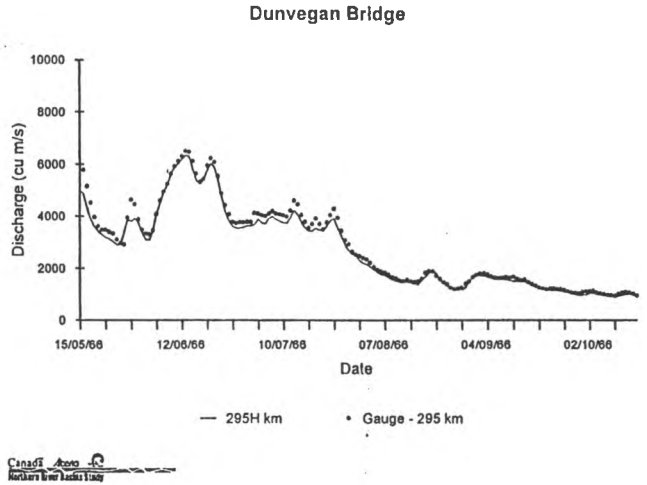
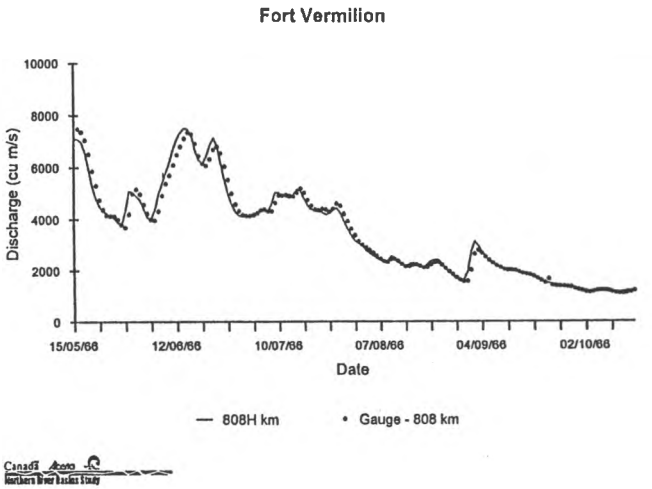
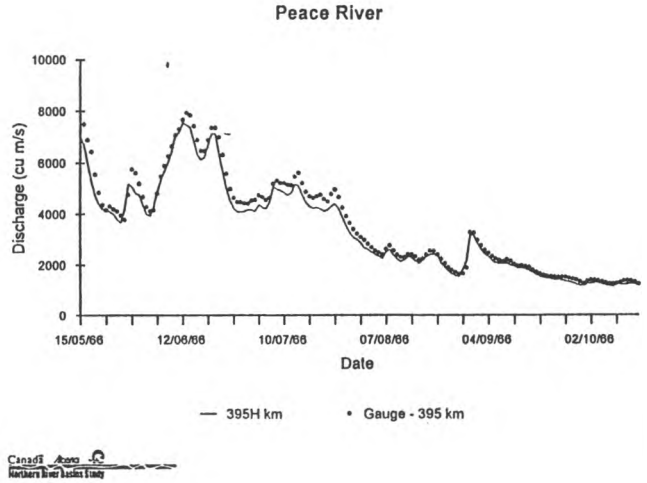


Figure 15. Simulation results for historical flows in the Peace River reach, May 15 to October 15, 1965.







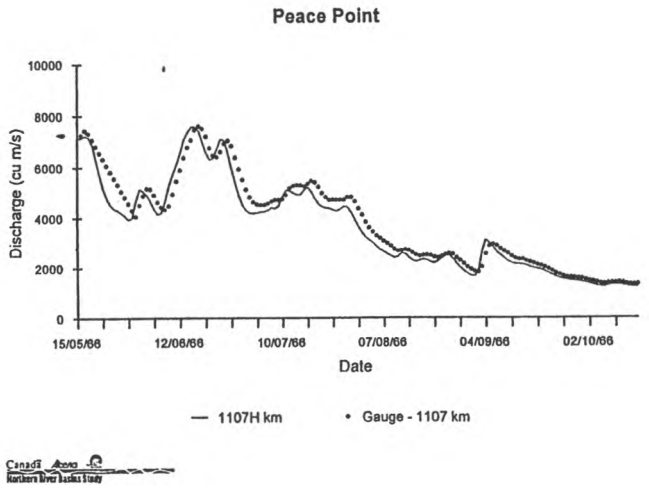
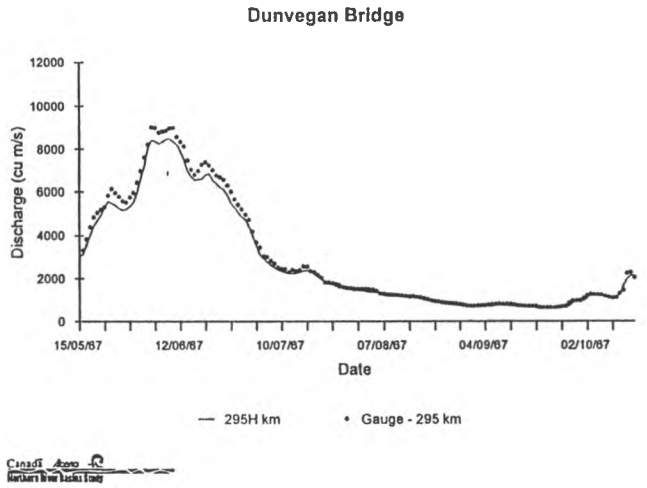
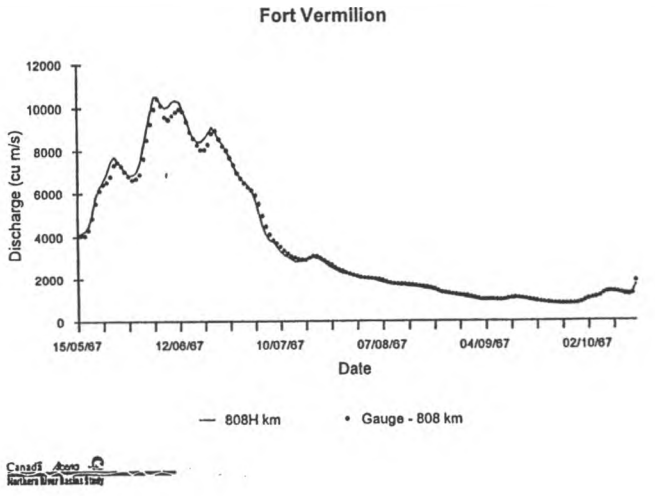
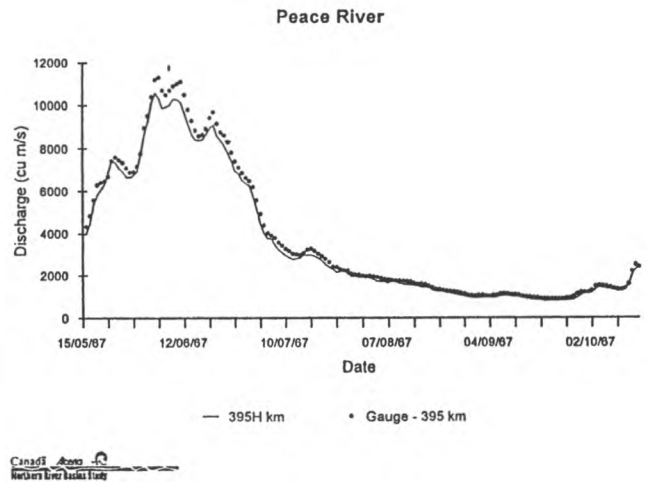


Figure 16. Simulation results for historical flows in the Peace River reach, May 15 to October 15, 1966.







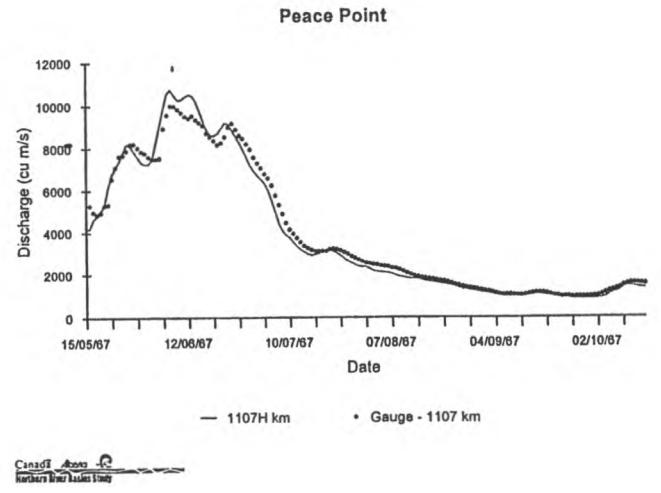
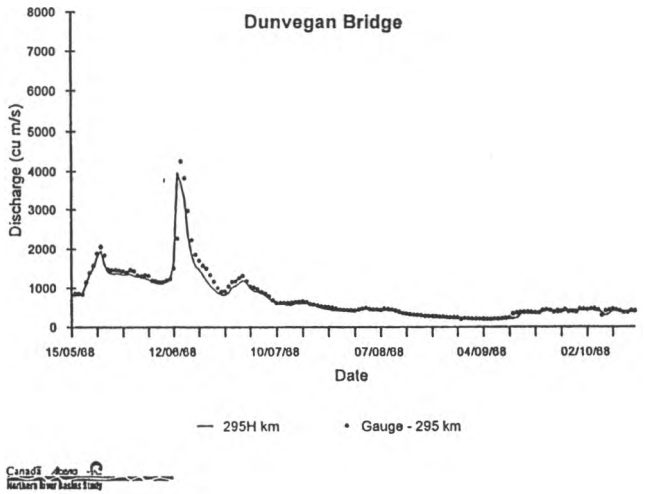
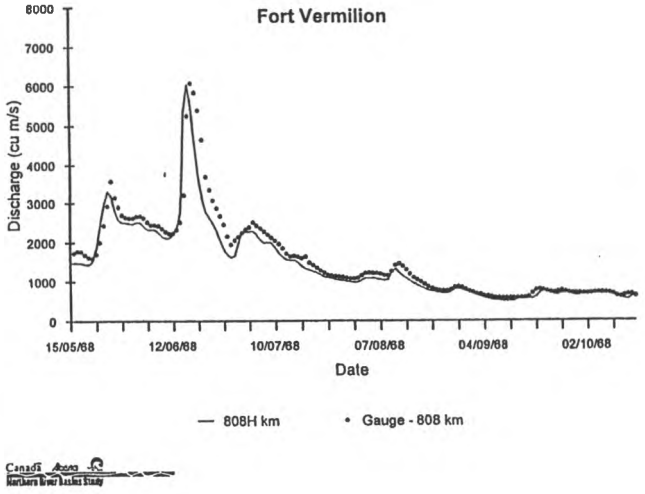
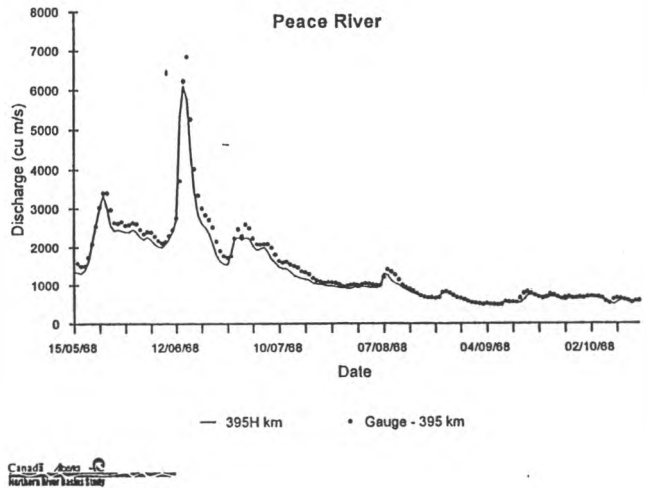


Figure 17. Simulation results for historical flows in the Peace River reach, May 15 to October 15, 1967.







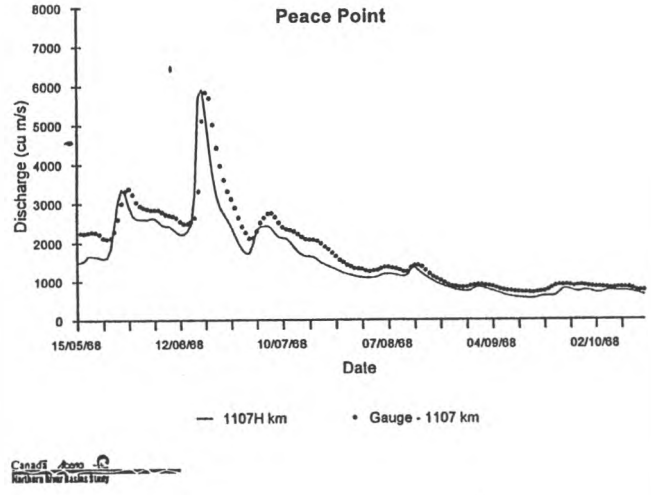


Figure 18. Simulation results for historical flows in the Peace River reach, May 15 to October 15, 1968.

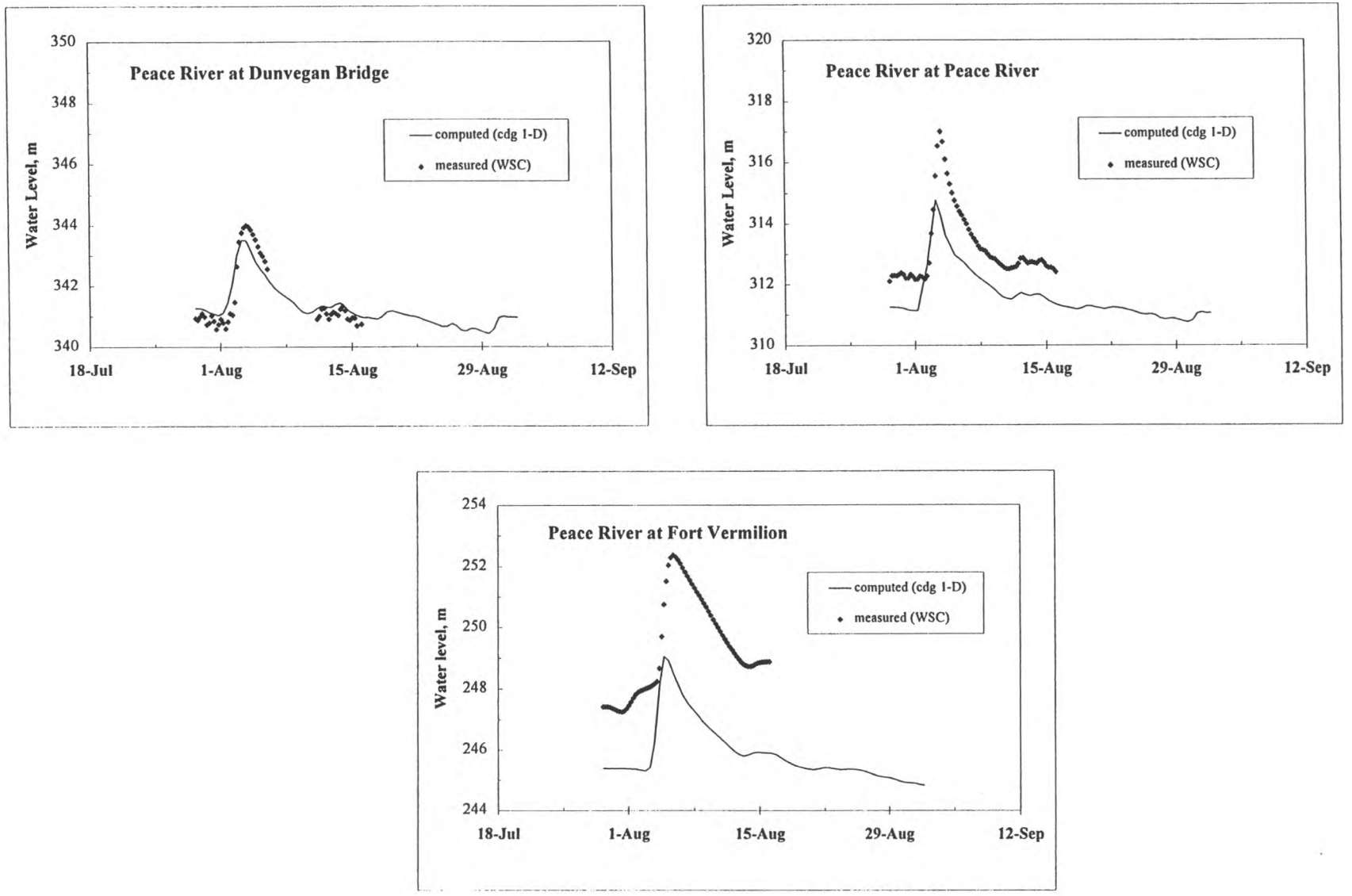


Figure 19. Comparison of measured water levels to the water levels predicted with the limited geometry model for the Peace River reach, 1987 event.

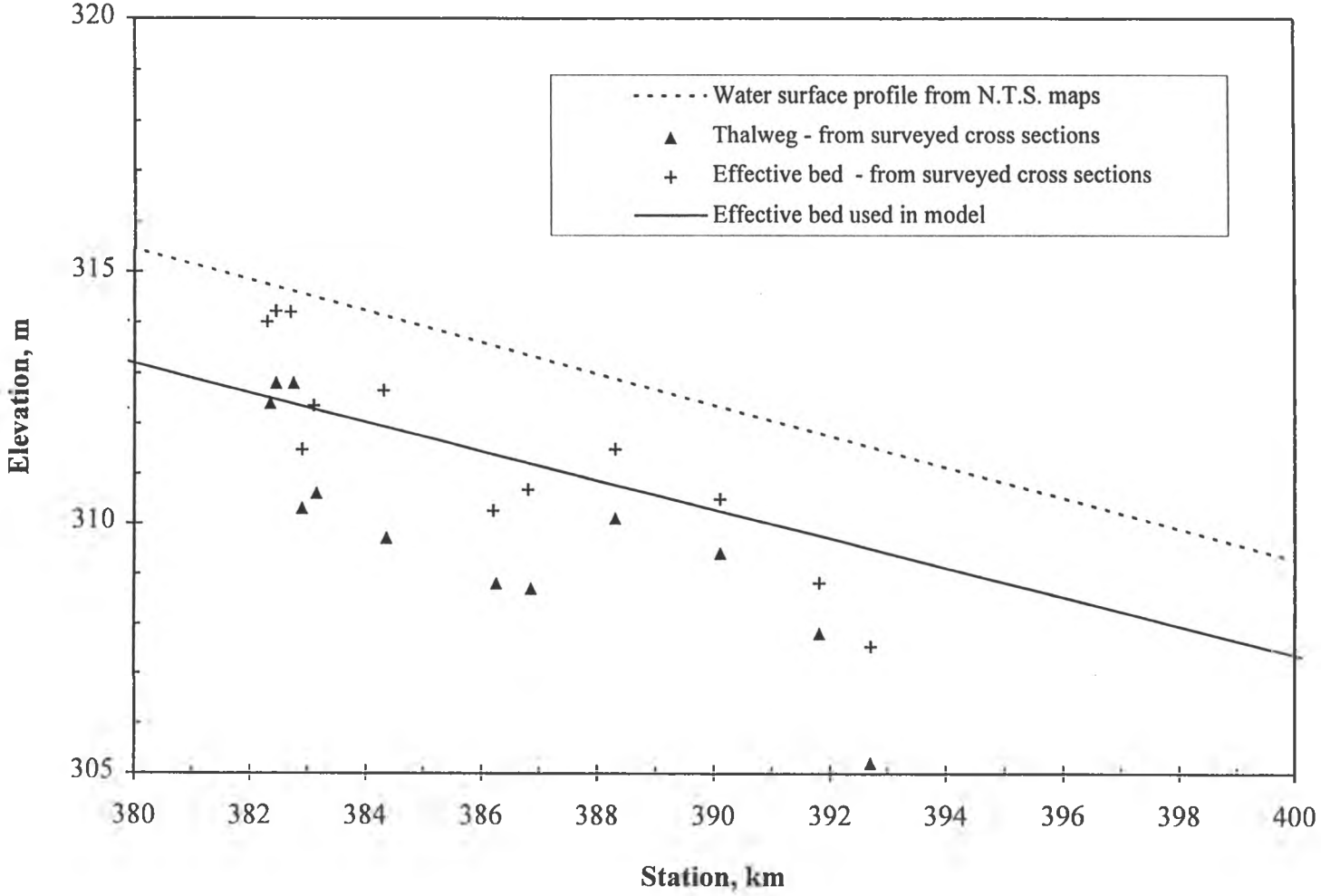


Figure 20. Comparison of measured and effective bed profiles in the vicinity of the town of Peace River.

APPENDIX A

NUMERICAL SOLUTION TECHNIQUE: cdg-1D

In this study the cdg-1D hydraulic flood routing model, developed in the Civil Engineering Department at the University of Alberta, was used to model the propagation of flood flows along the Peace River. This model employs a Petrov-Galerkin finite element method known as the characteristic-dissipative-Galerkin scheme (Hicks and Steffler, 1990, 1992) to solve the one-dimensional unsteady open channel flow equations.

Given the approximate nature of the geometric model, a rectangular channel section was assumed. The hydraulic flood routing model was based on the St. Venant equations (Henderson, 1966), which were modified to provide a conservation formulation applicable to rectangular channels of varying width (Hicks and Steffler, 1990):

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=0 \qquad [A.1]$$

$$\frac{\partial Q}{\partial t}+\frac{\partial QU}{\partial x}+\frac{\partial}{\partial x}\left(\frac{gAH}{2}\right)-\frac{gAH}{2B}\frac{dB}{dx}=gA\left(S_o-S_f\right) \qquad [A.2]$$

where:

A = cross sectional area perpendicular to flow;
Q = discharge;
U = cross sectionally averaged longitudinal velocity;
H = depth of flow;
B = width of rectangular cross section;
S_f = longitudinal boundary friction slope;
S_o = longitudinal channel bed slope;
g = acceleration due to gravity;
t = temporal coordinate; and
x = longitudinal coordinate.

This system of equations describing one-dimensional, unsteady open channel flow may also be written in matrix notation:

$$\frac{\partial\{\phi\}}{\partial t}+\frac{\partial\{F\}}{\partial x}+\{f_c\}=\{0\} \qquad [A.3]$$

where,

$$\{\phi\} \equiv \begin{Bmatrix} A \\ Q \end{Bmatrix} \quad ; \quad \{F\} \equiv \begin{Bmatrix} Q \\ \left(UQ + \dfrac{gAH}{2}\right) \end{Bmatrix} \quad ; and, \quad \{f_c\} \equiv \begin{Bmatrix} 0 \\ -gA\left(S_0 + \dfrac{H}{2B}\dfrac{dB}{dx} - S_f\right) \end{Bmatrix}$$

[A.4]

A non-conservation form of the system may also be considered:

$$\frac{\partial\{\phi\}}{\partial t} + [A]\frac{\partial\{\phi\}}{\partial x} + \{f_n\} = \{0\}$$

[A.5]

where,

$$[A] \equiv \frac{\partial\{F\}}{\partial\{\phi\}} = \begin{bmatrix} 0 & 1 \\ c^2 - U^2 & 2U \end{bmatrix}$$

[A.6]

and,

$$\{f_n\} \equiv \begin{Bmatrix} 0 \\ -gA\left(S_0 + \dfrac{H}{B}\dfrac{dB}{dx} - S_f\right) \end{Bmatrix}$$

[A.7]

The modified (conservation) formulation of the St. Venant equations has the significant advantage over more conventional (non-conservation) formulations in that it has been shown to be more effective in ensuring conservation of both mass and longitudinal momentum over a broad spectrum of complex flow scenarios (Hicks and Steffler, 1990, 1995).

In this study, the system of equations represented by equation [A.3] were solved using the finite element method. Although many successful hydraulic flood routing models have been developed based on the finite difference method, commercially available finite difference models are based on non-conservation formulations of the governing equations. Furthermore, none of the available models incorporate the effects of ice on the flow. Recent research in the Civil

Engineering Department at the University of Alberta has led to the development of a numerically robust finite element model which has already been used to assess the potential impact of ice jam release surges on the Hay River, NWT. Comparisons of this numerical scheme to more conventional, commercially available finite difference code as well as other finite element schemes (Hicks and Steffler, 1990, 1995) have confirmed the superiority of this finite element scheme in terms of both solution accuracy and numerical stability.

The finite element equations were derived using the Galerkin weighted residual method. The simplest implementation is the Bubnov-Galerkin method (analogous to centered finite differences). In this method the test functions are simply set equal to the basis functions which is analogous to centered differences, that is,

$$\frac{\partial \phi}{\partial x} = \theta \left(\frac{\Phi_{j-1}^{n+1} - \Phi_{j+1}^{n+1}}{2\Delta x} \right) + (1-\theta) \left(\frac{\Phi_{j-1}^{n} - \Phi_{j+1}^{n}}{2\Delta x} \right) \qquad [A.8]$$

where the indices n and j denote the temporal and spatial discretizations, respectively. θ represents the implicitness factor such that $\theta = 1$ represents a fully implicit formulation. Also,

$$\frac{\partial \phi}{\partial t} = \frac{\Phi^{n+1} - \Phi^{n}}{\Delta t} \qquad [A.9]$$

where,

$$\Phi = \frac{\Phi_{j-1} + 4\Phi_{j} + \Phi_{j+1}}{6} \qquad [A.10]$$

In open channel flow applications, the Bubnov-Galerkin formulation has been shown to be useful for modeling relatively flat waves but it performs poorly in the vicinity of steep gradients in the solution (Katapodes, 1984). An alternative is to use the Petrov-Galerkin method, in which upwind weighted test functions are used to introduce *selective* artificial dissipation, smoothing out spurious, short wavelength oscillations while preserving the physical wave behavior. Essentially, this is equivalent to a Bubnov-Galerkin formulation of the extended system,

$$\left(\frac{\partial \{\phi\}}{\partial t} + \frac{\partial \{F\}}{\partial x} + \{f_c\} \right) - \omega \frac{\Delta x}{2} [W] \frac{\partial}{\partial x} \left(\frac{\partial \{\phi\}}{\partial t} + [A] \frac{\partial \{\phi\}}{\partial x} + \{f_n\} \right) = \{0\}$$

$\Leftarrow$ *original system* $\Rightarrow$ $\Leftarrow$ *upwinding terms* $\Rightarrow$ [A.11]

In which ω is an 'upwinding coefficient' or diffusion parameter, while the matrix, $[W]$, controls the distribution of the upwinding. It should be noted that the upwinding terms are formed from derivatives of the non-conservation form of the original system. Artificial dissipation is

introduced through the second derivative in x, and is balanced to third order by the other upwinding terms when a semi-implicit formulation is used. This process corresponds to $\theta = 0.5$.

The Petrov-Galerkin formulation employed in the investigation was the characteristic-dissipative- Galerkin (CDG) scheme originally introduced by Brooks and Hughes (1982) as the Streamline Upwind Petrov-Galerkin (SU/PG). In this approach, the numerical diffusion was incorporated using an upwinding term which was determined based upon the sign of the flow direction. Adaptation of this concept to the problem of open channel flow is defined by (Hicks and Steffler, 1990, 1992):

$$[W] \equiv \frac{[A]}{[\![A]\!]} = [M]\left[\frac{\lambda_i}{|\lambda_i|}\right][M]^{-1} = \begin{bmatrix} \frac{1}{2c} & -\frac{1}{2c} \\ \frac{U+c}{2c} & \frac{-(U-c)}{2c} \end{bmatrix} \begin{bmatrix} \frac{U+c}{|U+c|} & 0 \\ 0 & \frac{U-c}{|U-c|} \end{bmatrix} \begin{bmatrix} -(U-c) & 1 \\ -(U+c) & 1 \end{bmatrix} \qquad [A.12]$$

A constant value of 0.25 for the upwinding parameter, ω, minimizes dissipation of long wavelengths while achieving good phase accuracy. Phase accuracy may be optimized by employing a value of $\omega = 0.5$, with slightly increased dissipation. As it has been shown that the effect of varying ω on phase and amplitude is only marginal (Hicks and Steffler, 1990, 1992) a constant value of 0.5 was used in this investigation.

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Brooks, A. N. and T. J. R. Hughes. 1982. Streamline Upwind/Petrov-Galerkin formulations for convection dominated flows with particular emphasis on the incompressible Navier-Stokes equations". Computer Methods in Applied Mechanics and Engineering. 32: pp. 199-259.

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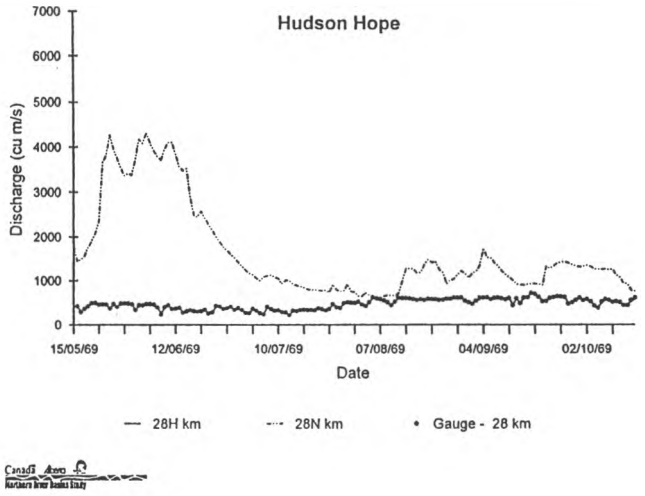
Hicks, F.E. and P.M. Steffler. 1992. A characteristic-dissipative-Galerkin Scheme for open channel flow. ASCE Journal of Hydraulic Engineering. 118(2): 337-352.

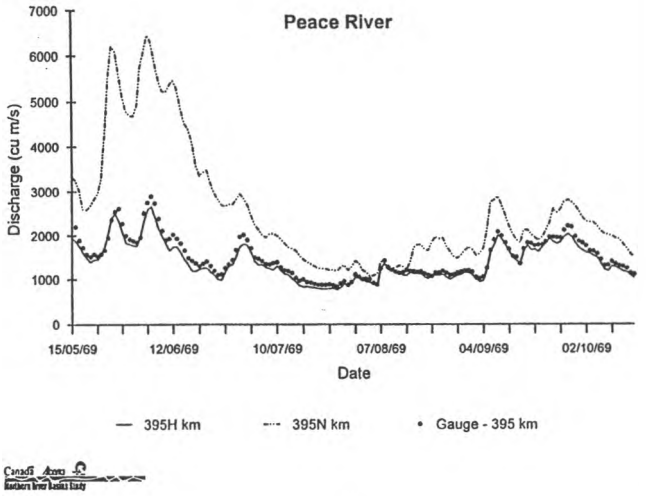
Hicks, F.E. and P.M. Steffler. 1995. Comparison of finite element method for the St. Venant equations. International Journal for Numerical Methods in Fluids. **20**: 99-113.

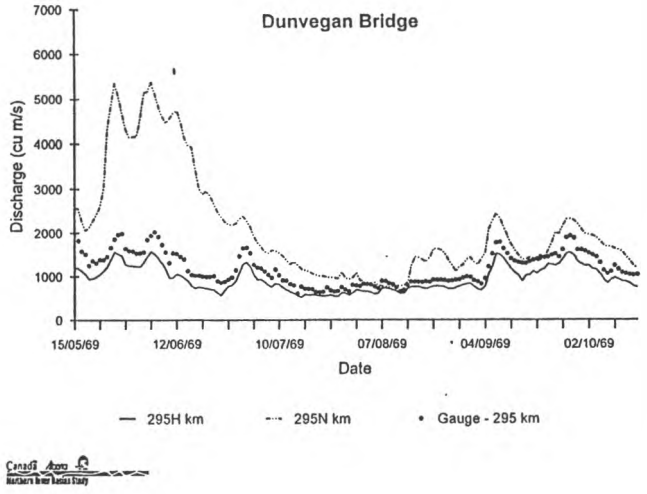
Katopodes, N. D. 1984. A dissipative Galerkin scheme for open-channel flow. ASCE Journal of Hydraulic Engineering, 110 (4): pp. 450-466.

APPENDIX B

PEACE RIVER MODELLING RESULTS - HISTORICAL vs. NATURALIZED







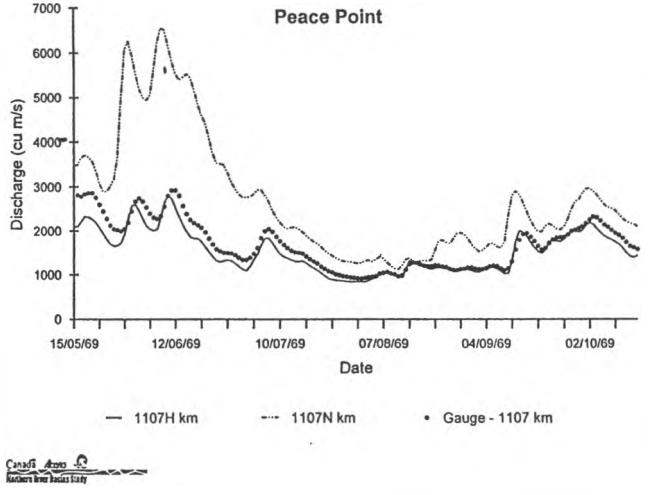
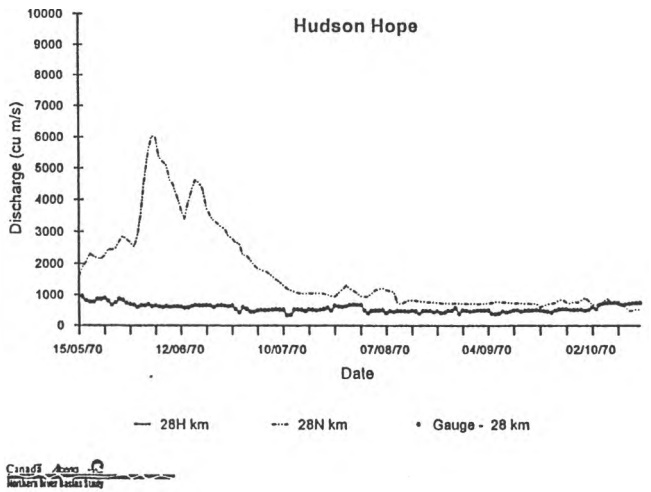
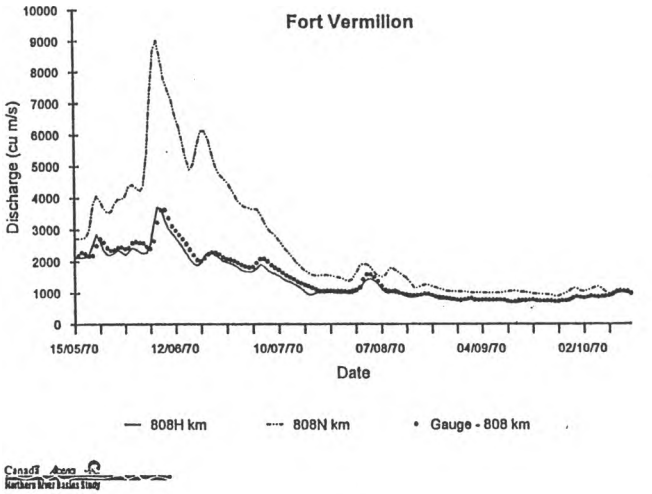
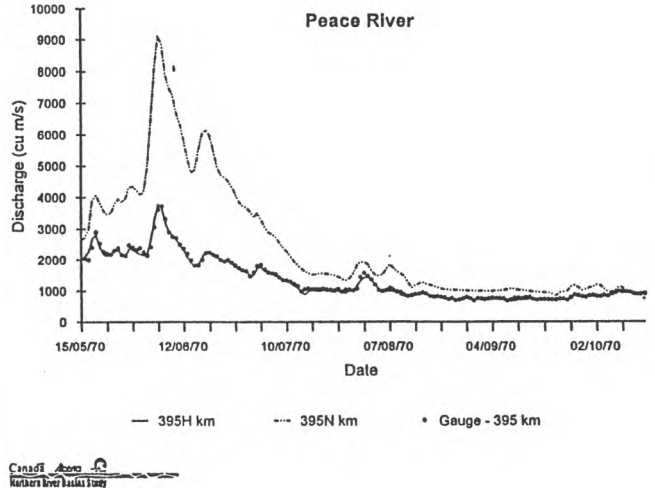


Figure B.1 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1969.







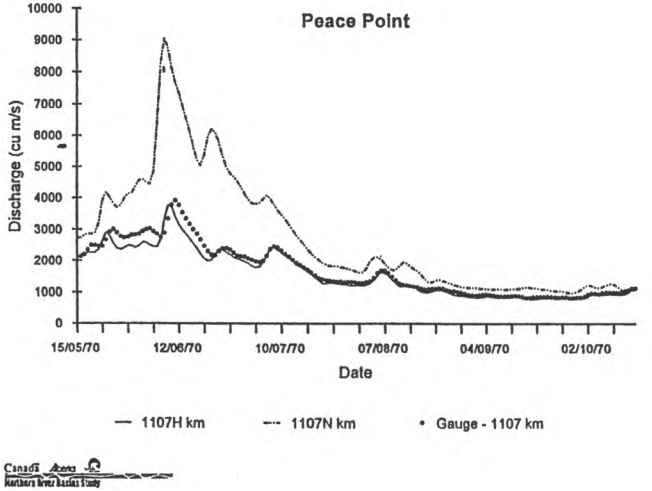
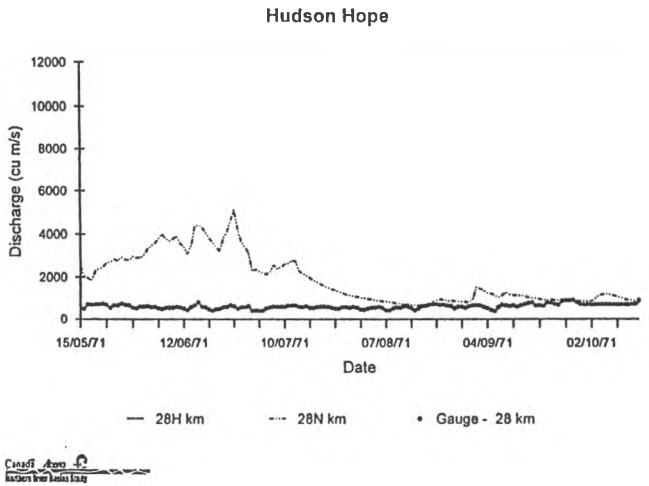
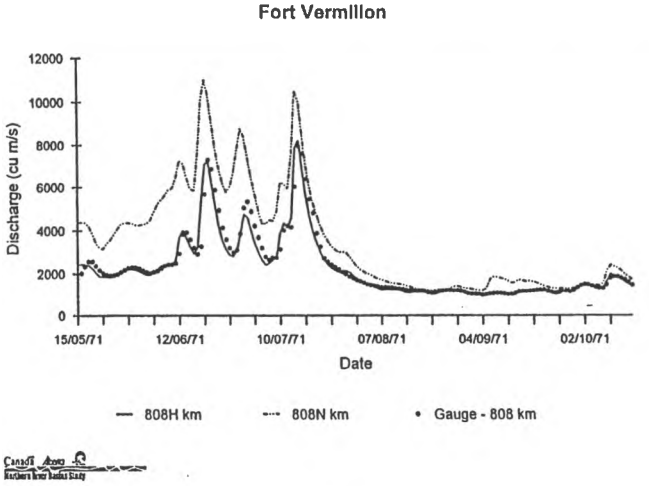
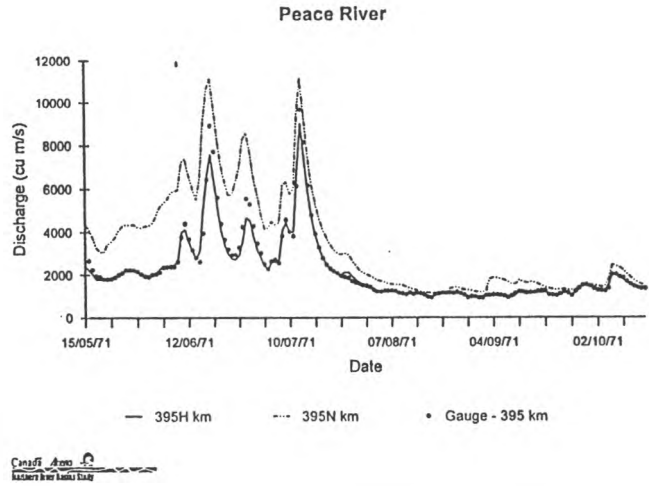


Figure B.2 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1970.







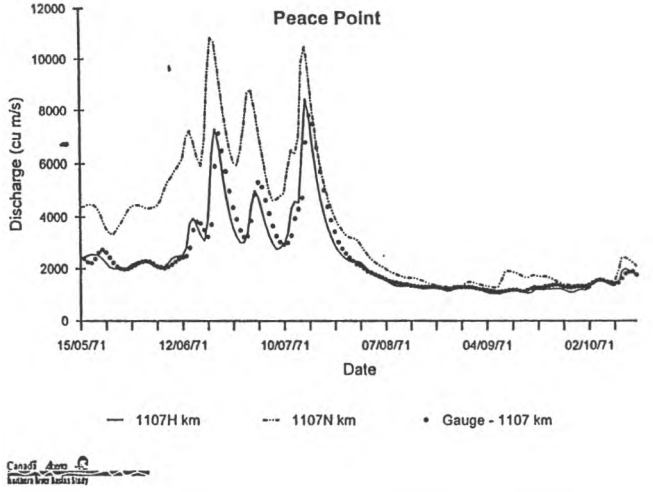
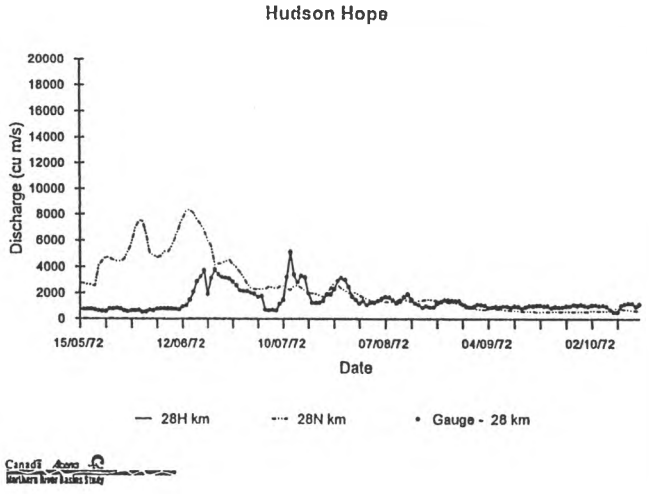
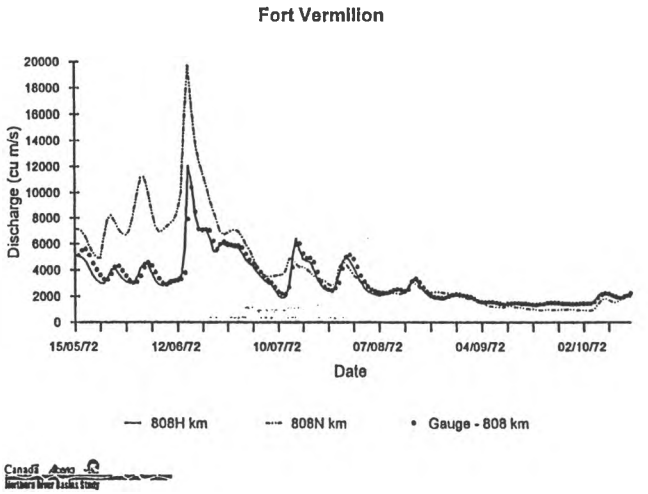
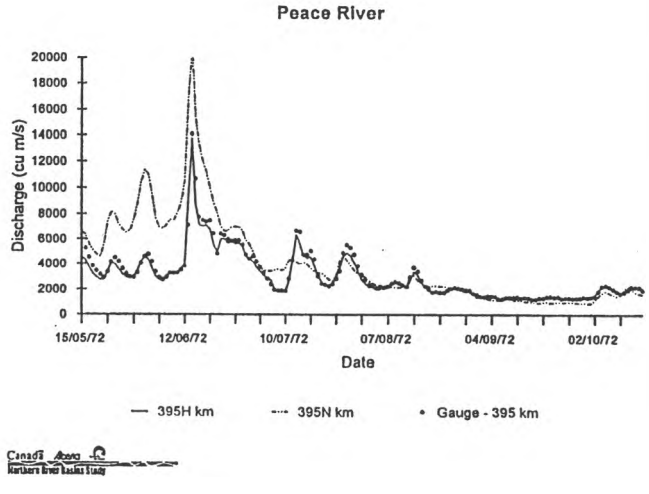


Figure B.3 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1971.







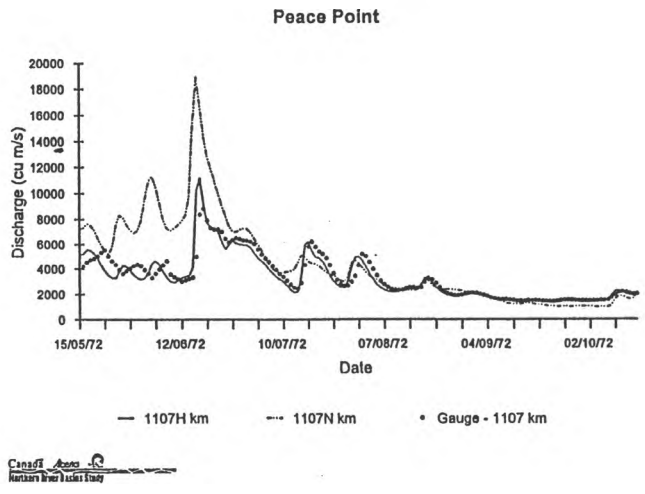
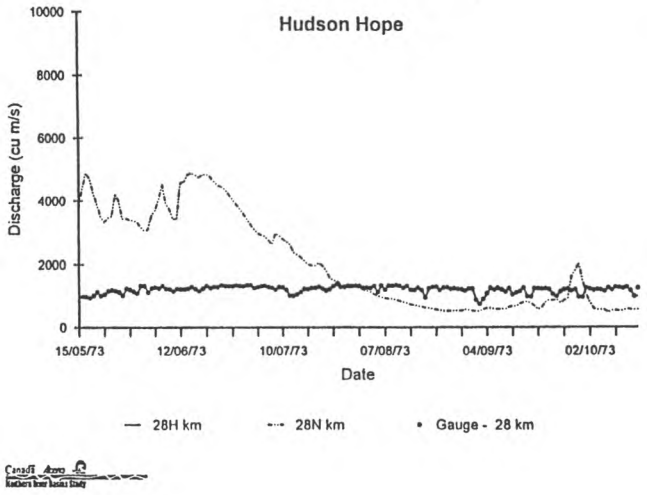
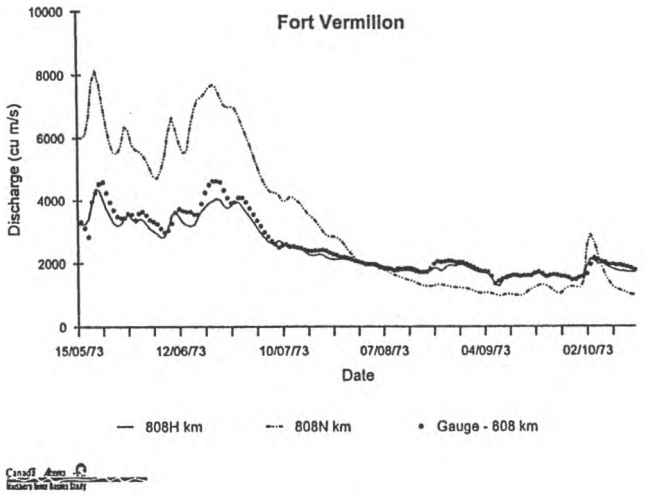
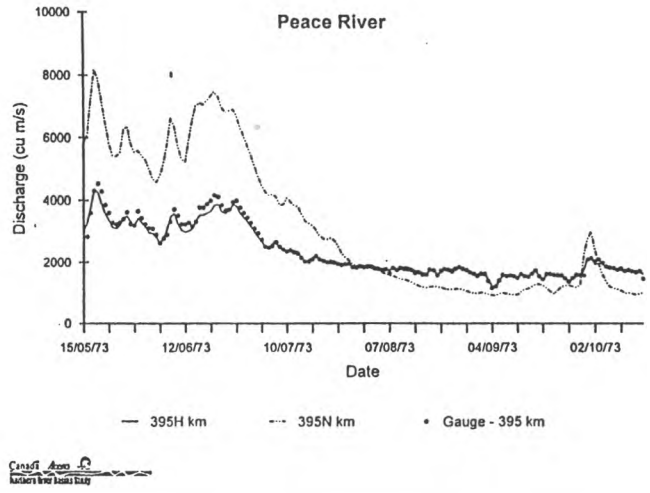


Figure B.4 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1972.







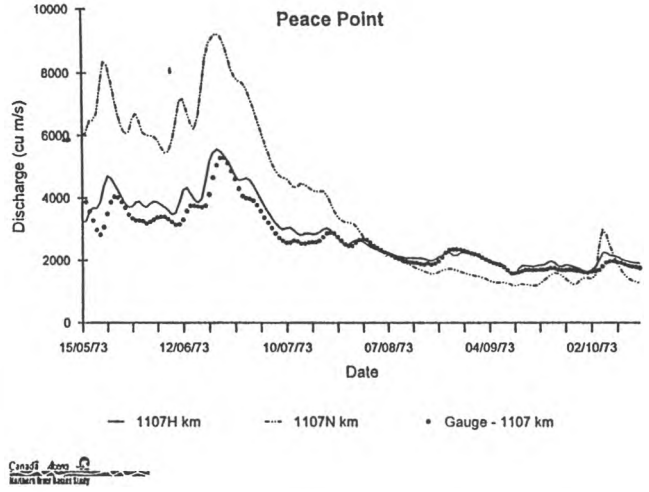
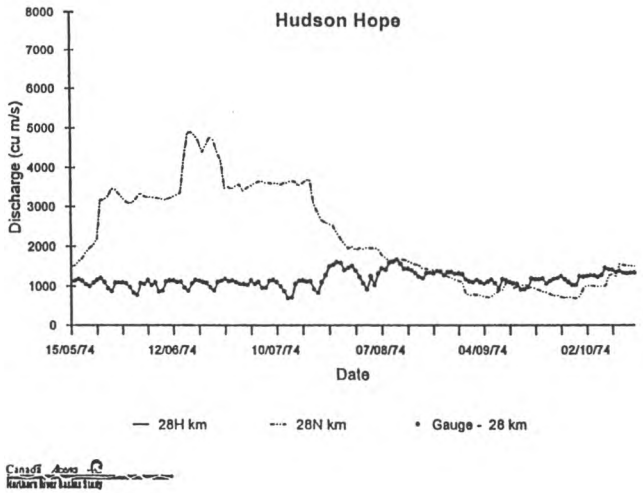
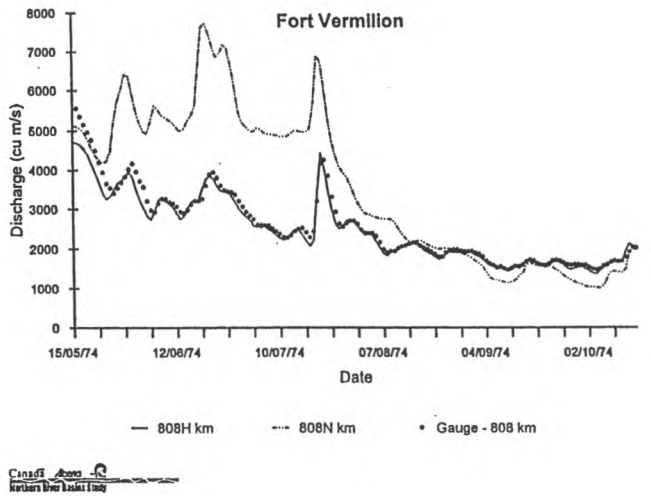
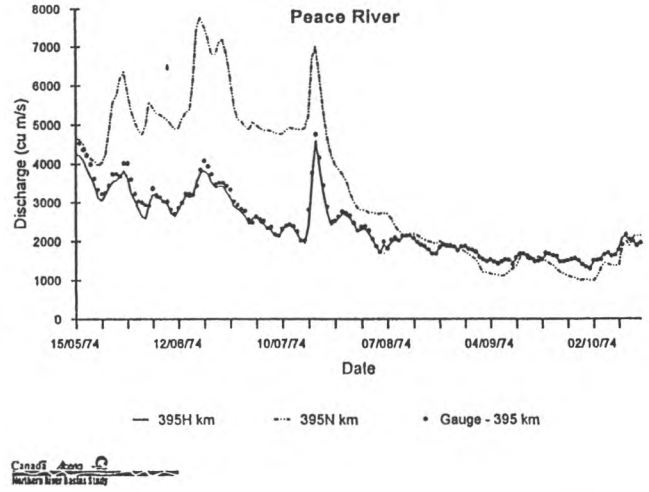


Figure B.5 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1973.







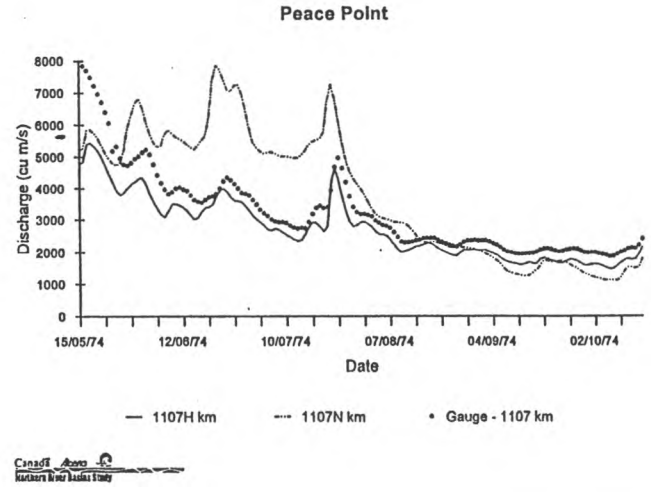
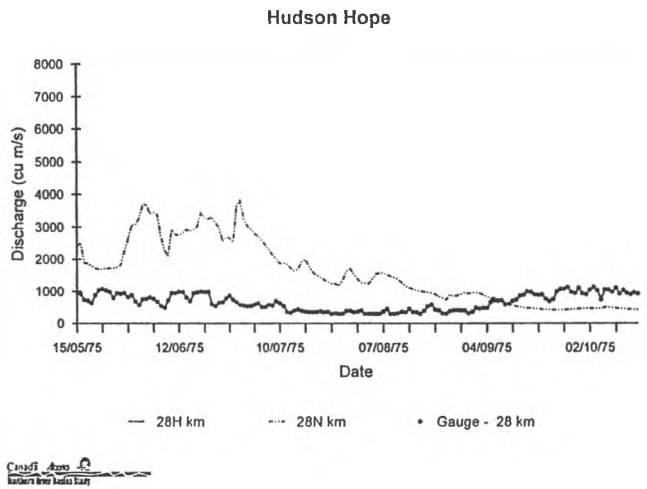
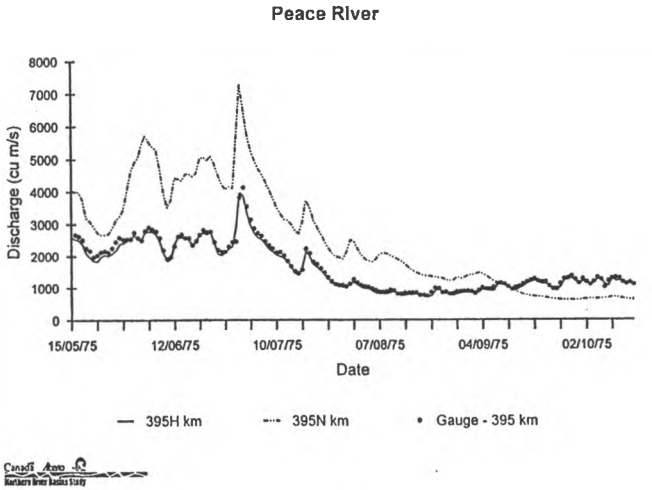
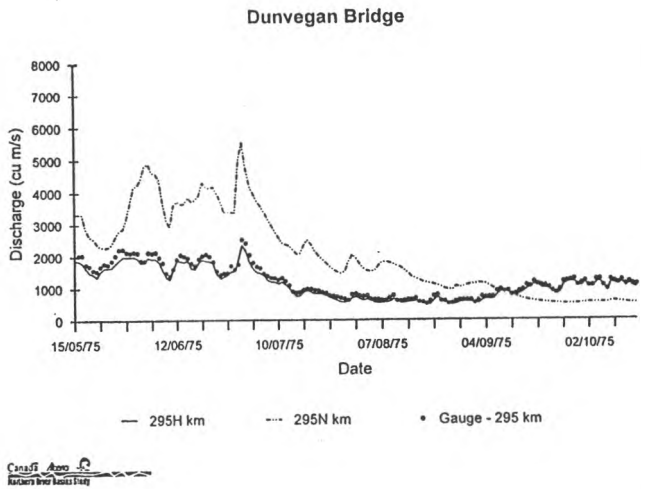


Figure B.6 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1974.







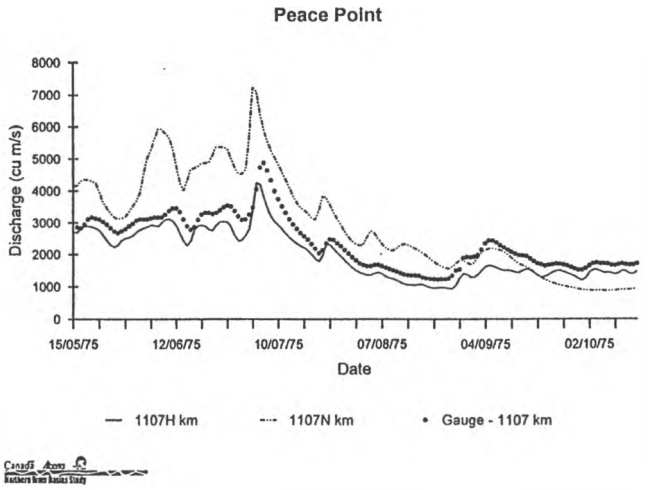
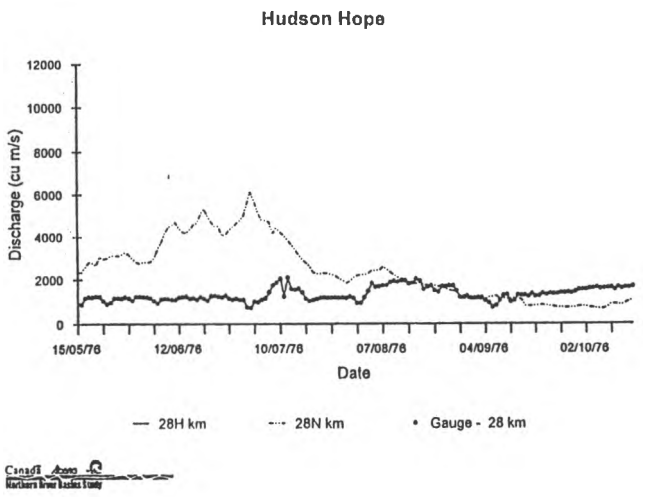
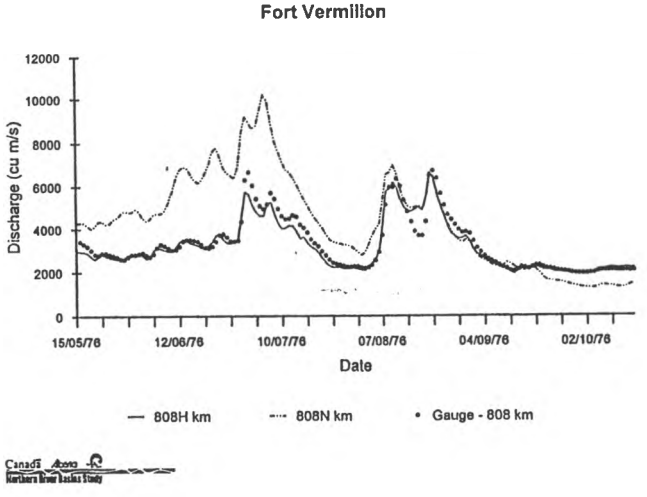
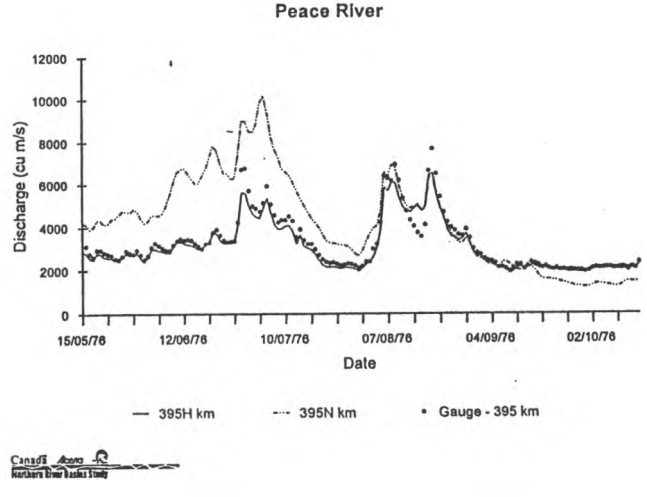


Figure B.7 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1975.







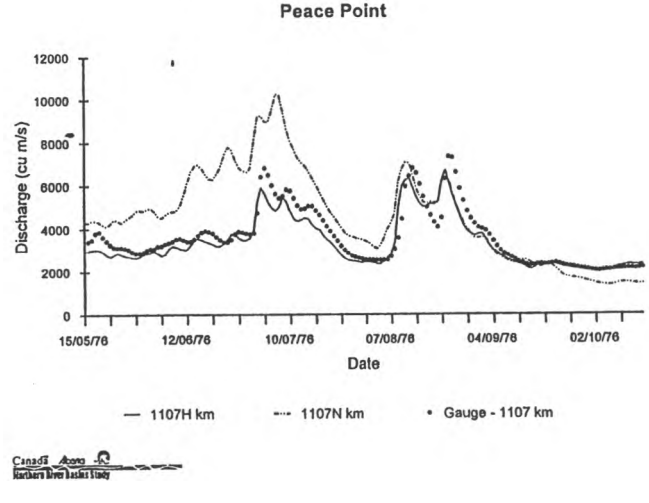
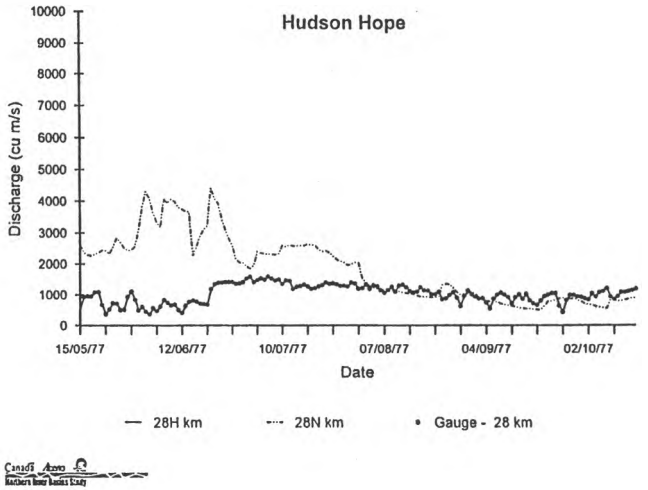
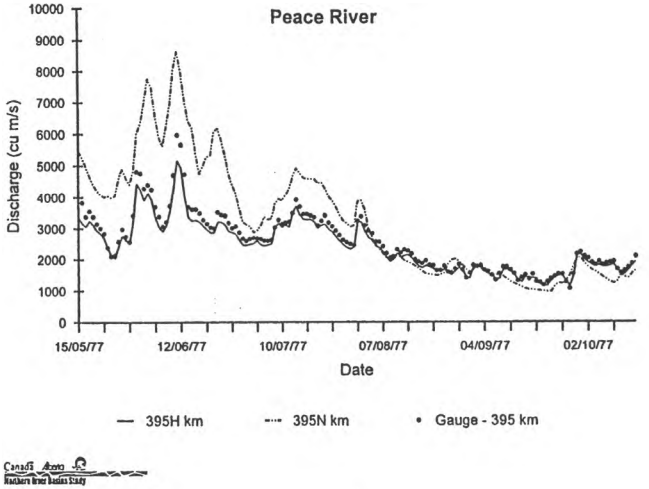
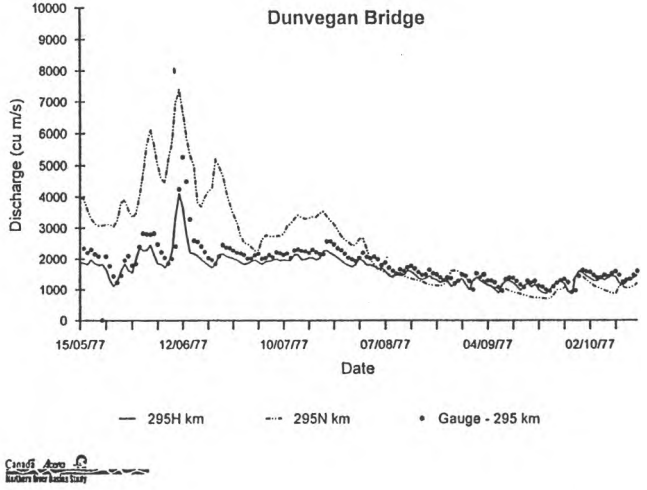


Figure B.8 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1976.







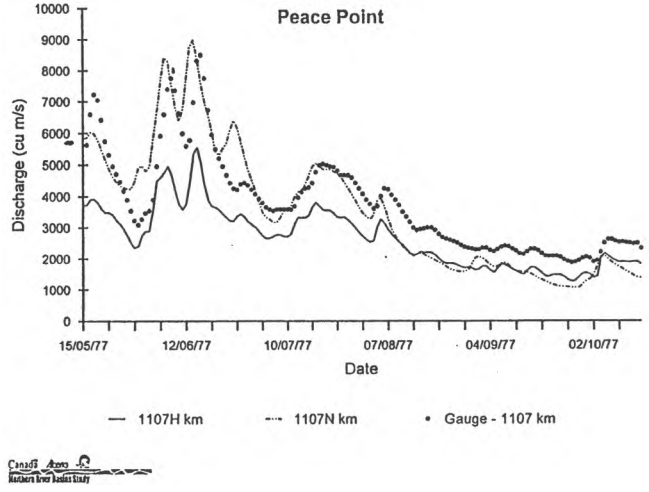
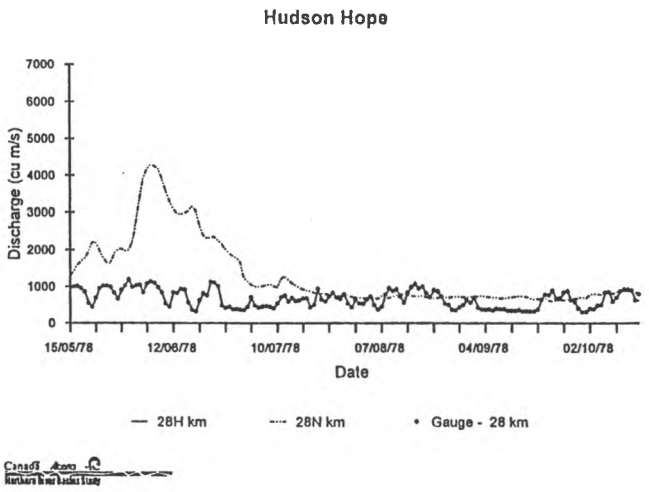
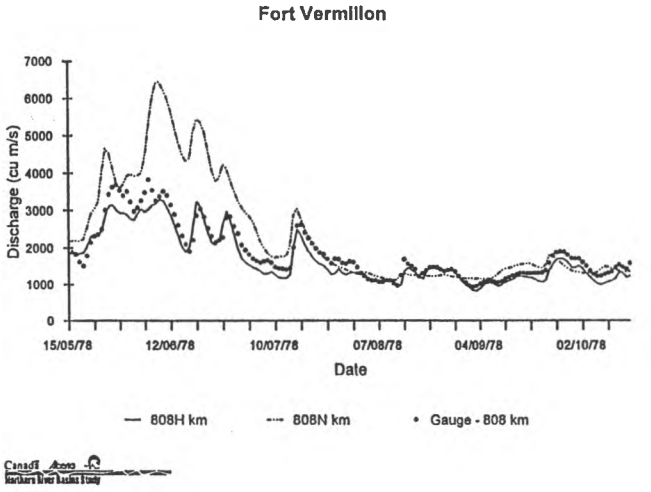
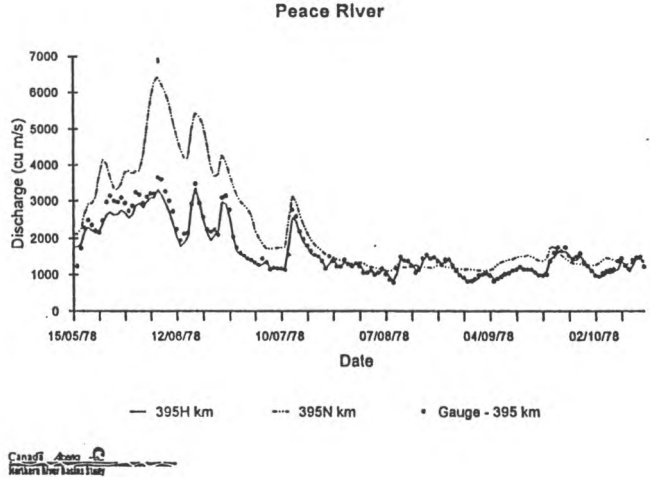


Figure B.9 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1977.







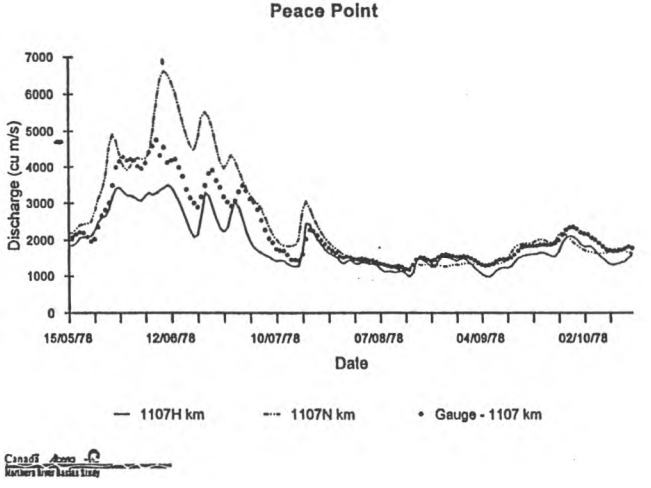
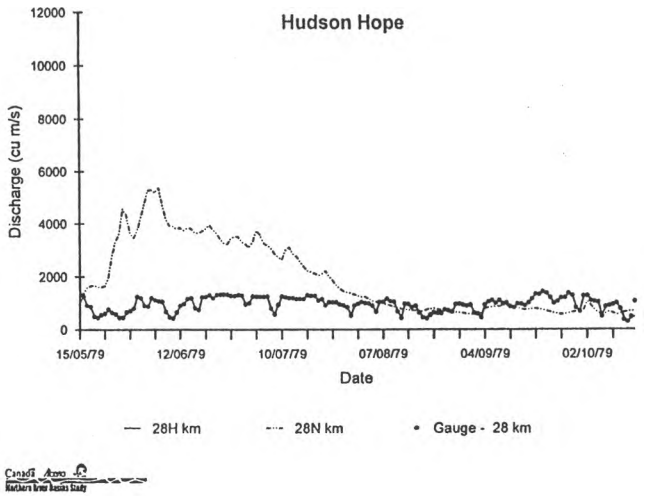
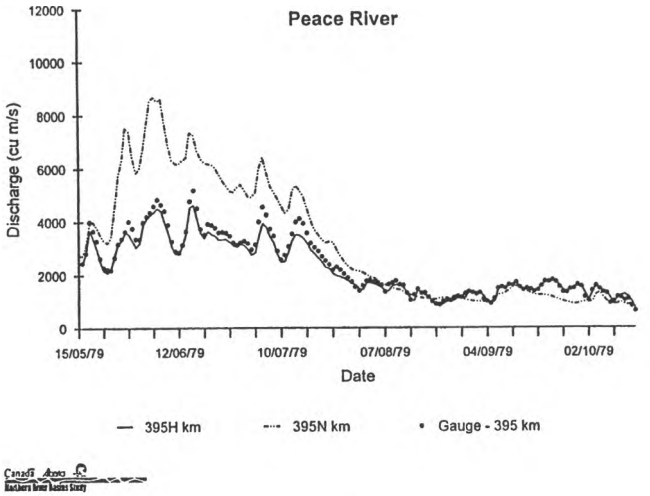
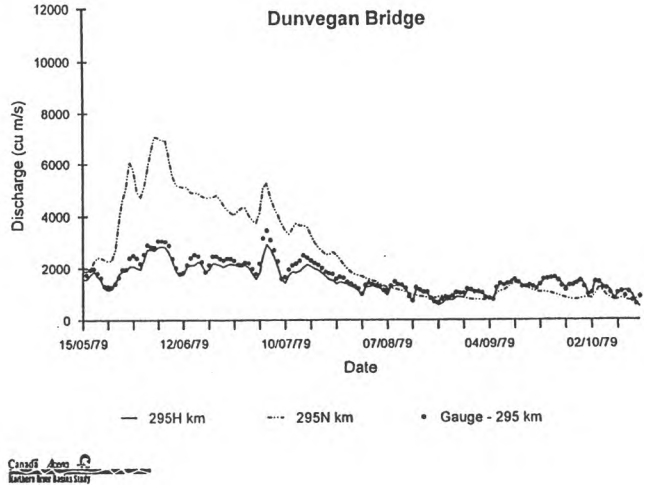


Figure B.10 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1978.







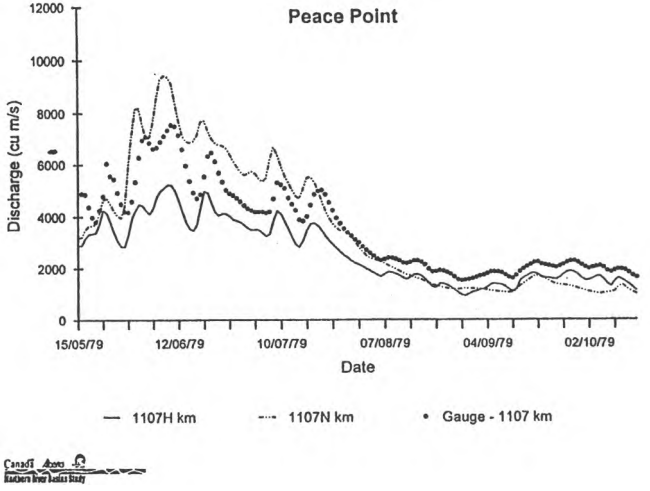
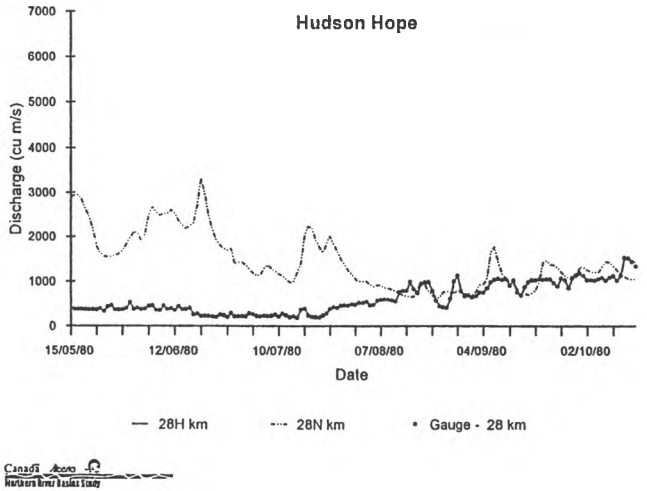
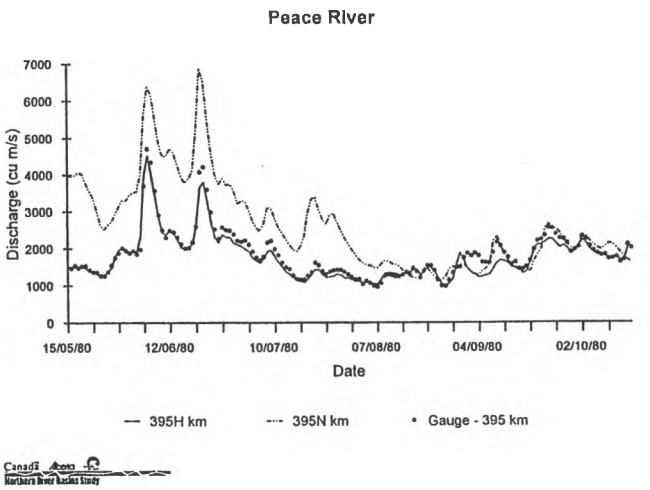
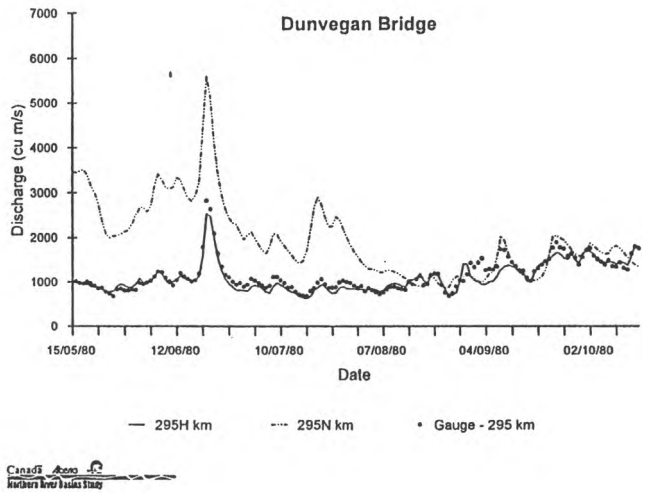


Figure B.11 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1979.







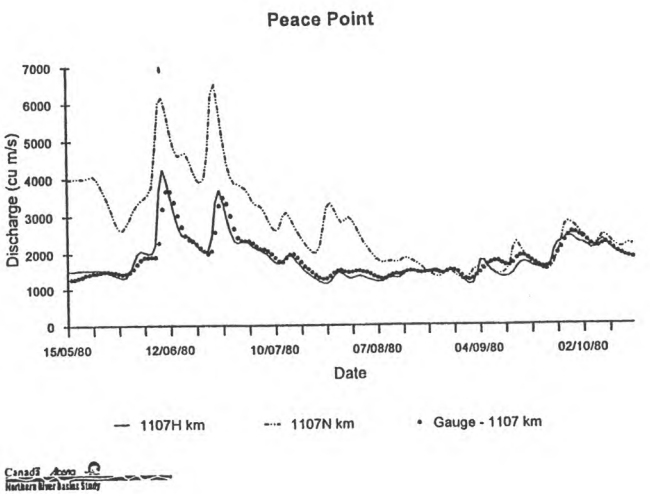
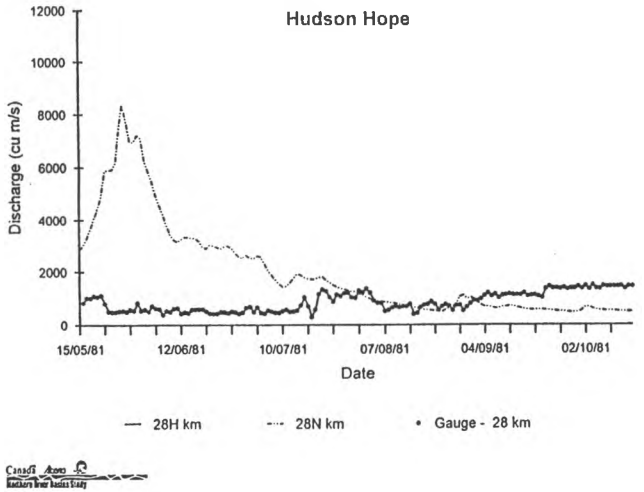
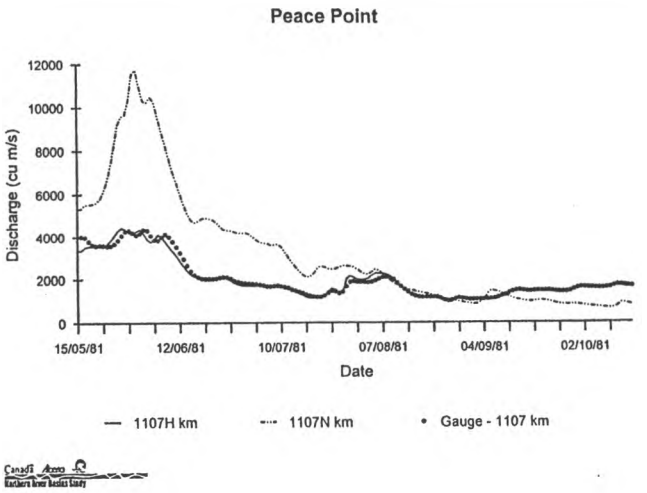
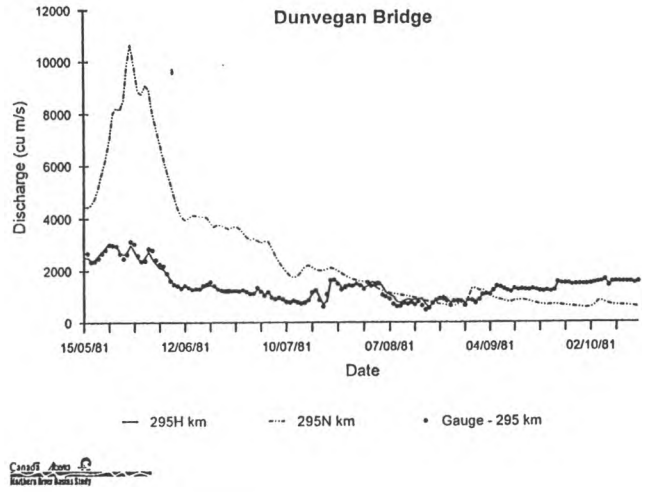


Figure B.12 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1980.







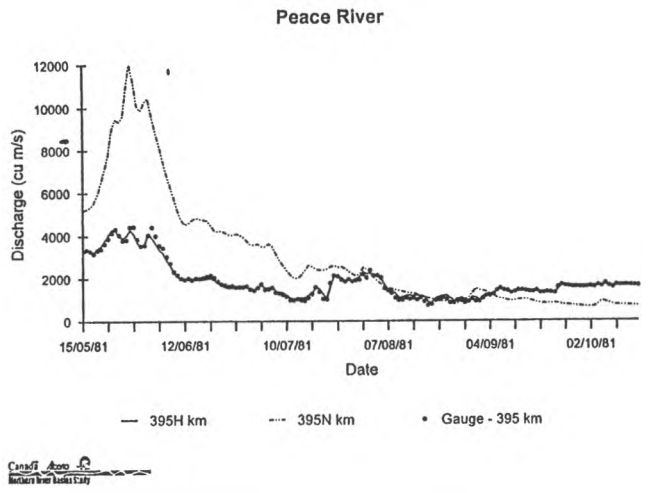
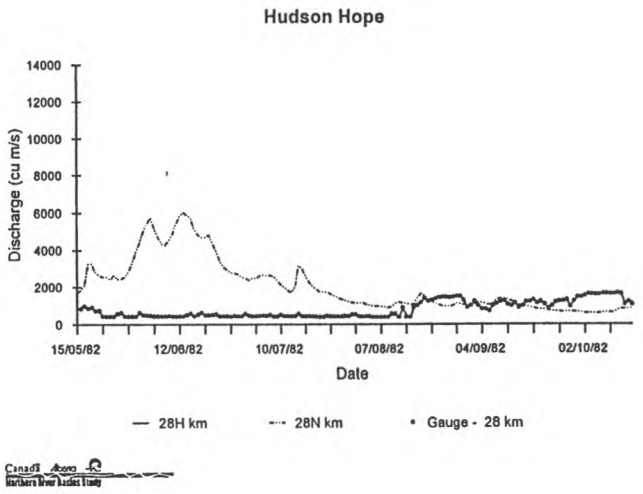
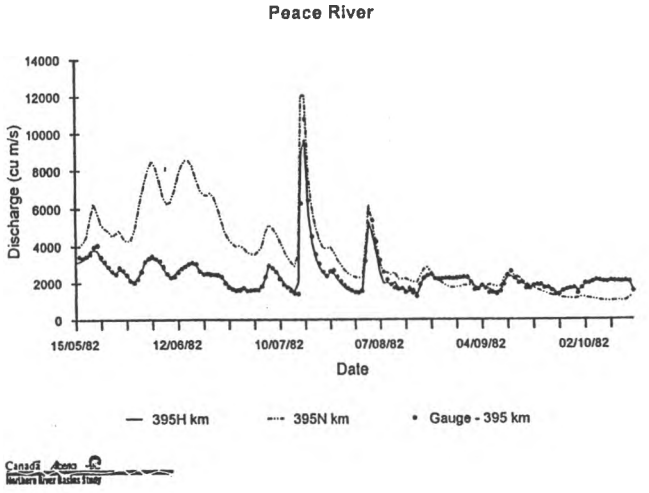
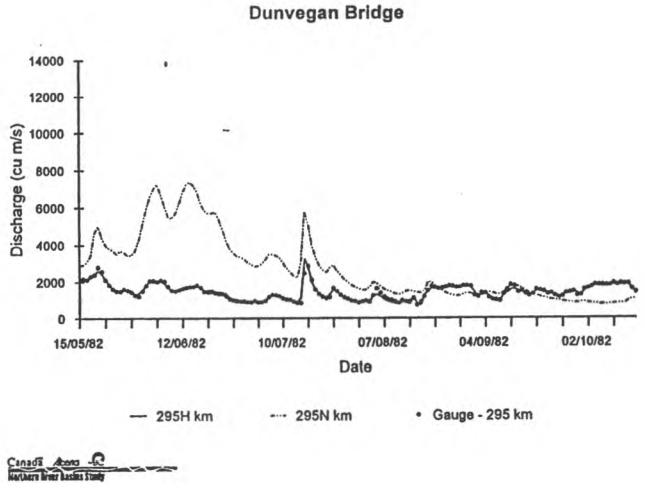


Figure B.13 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1981.







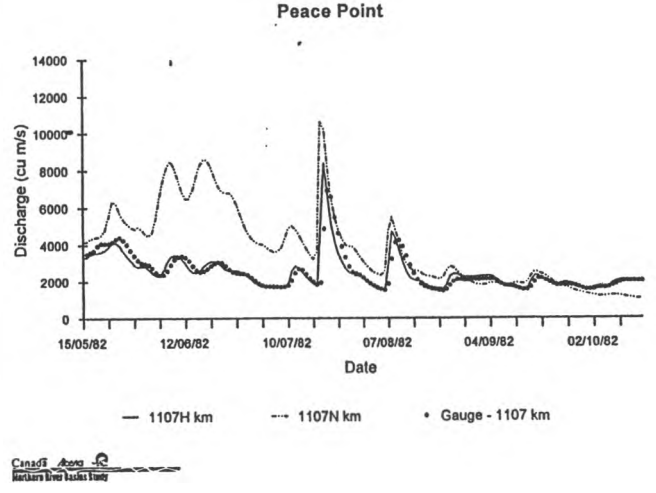
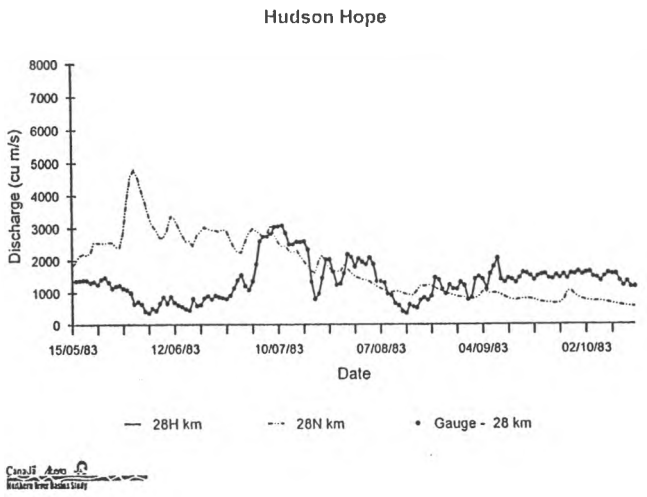
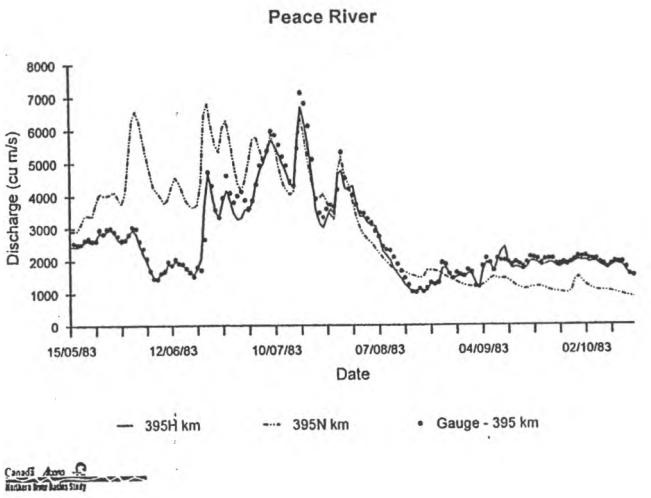
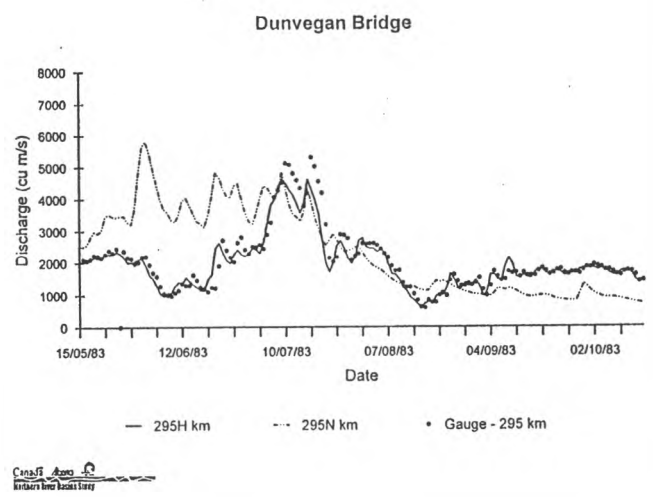


Figure B.14 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1982.







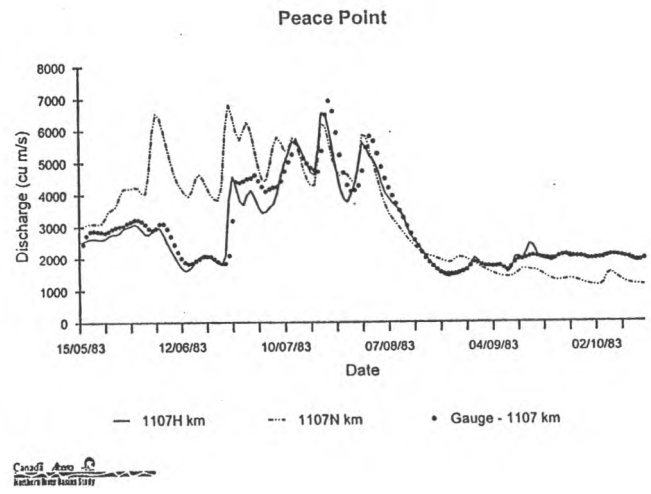
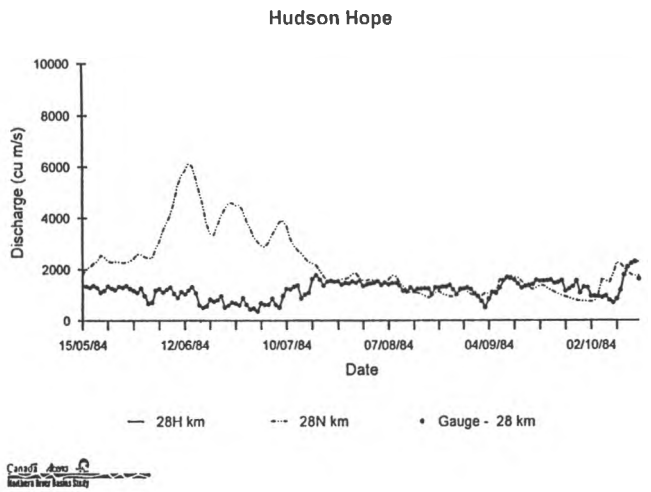
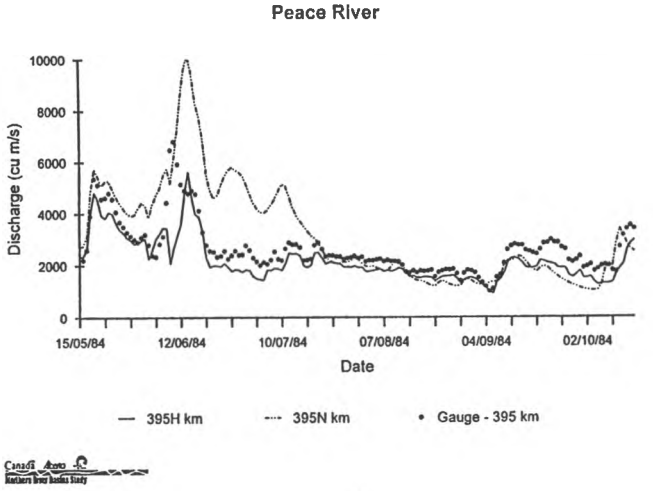
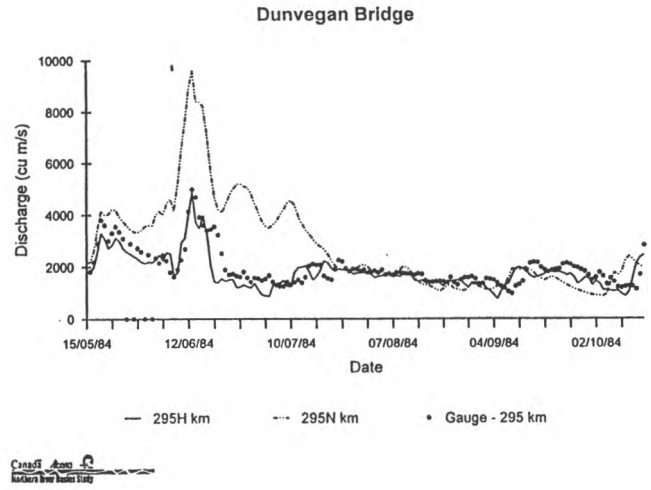


Figure B.15 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1983.







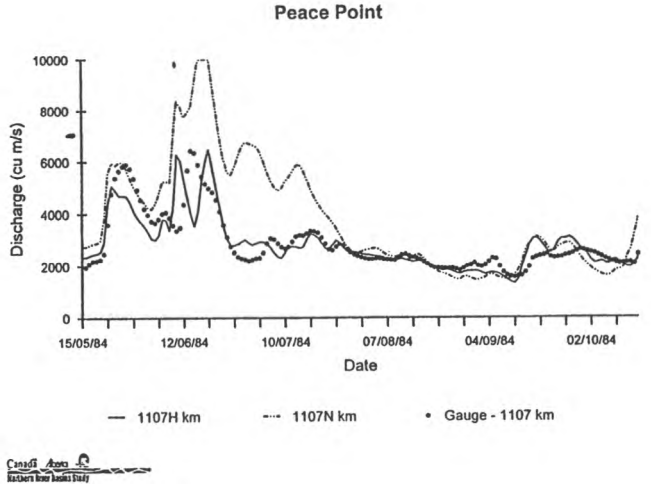
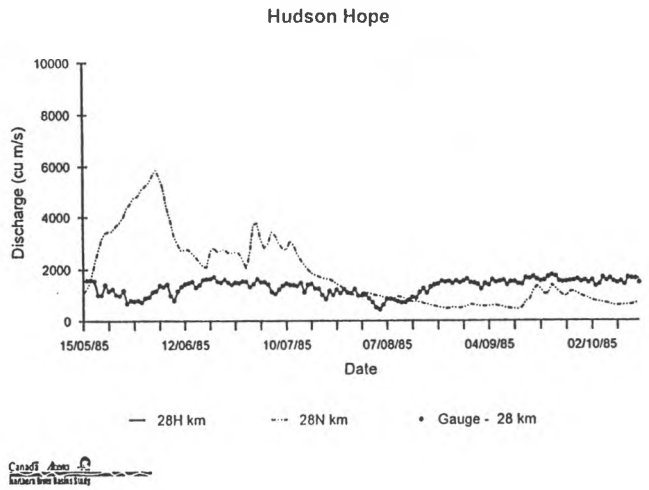
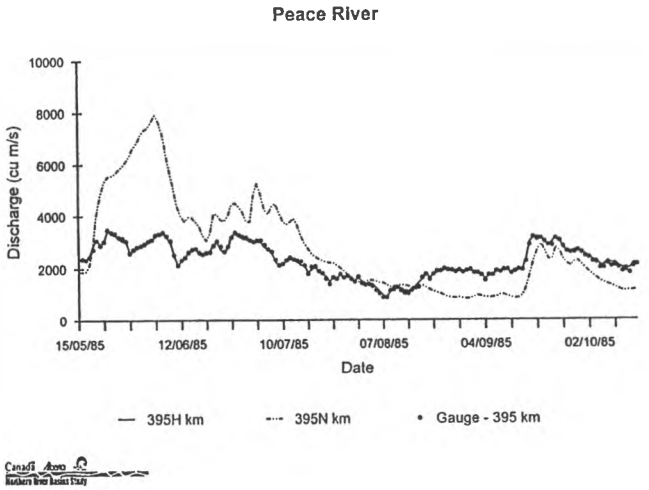
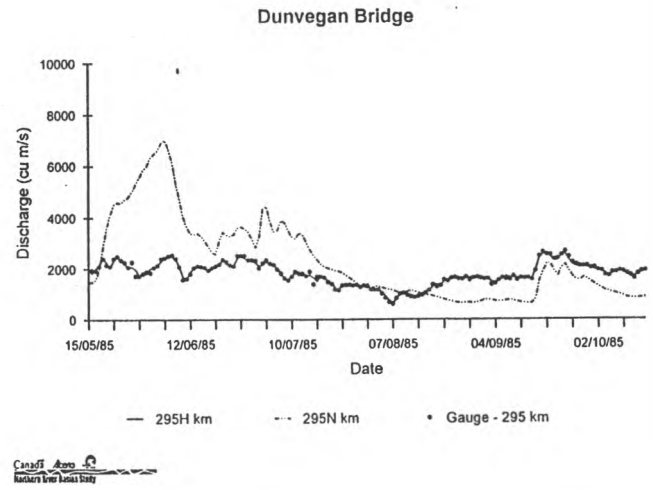


Figure B.16 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1984.







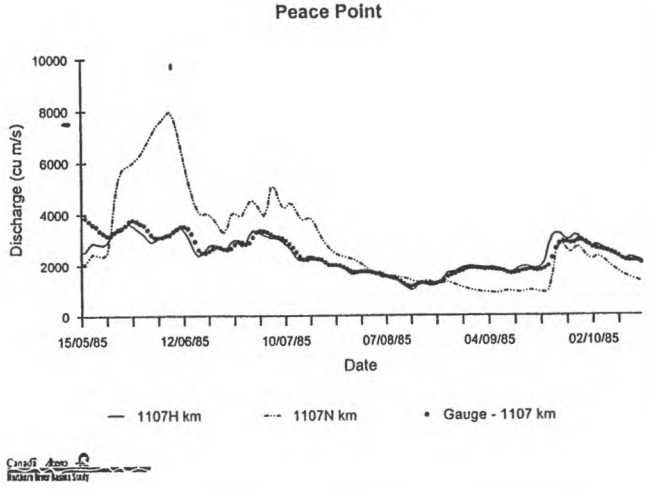
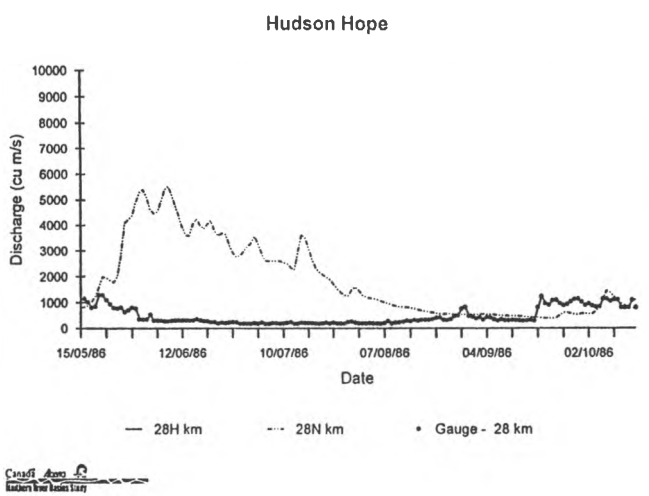
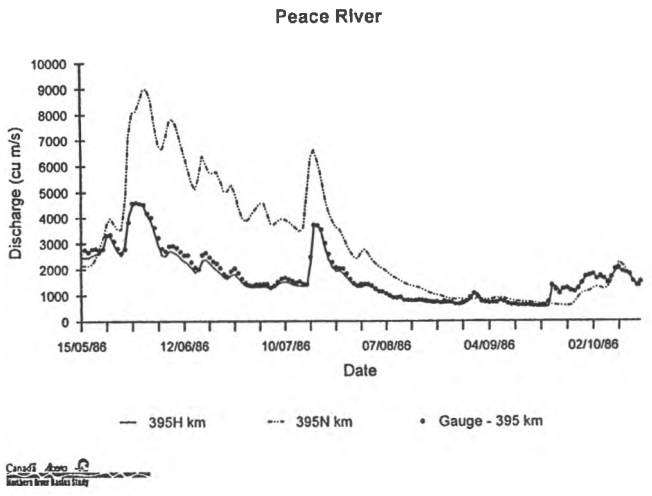
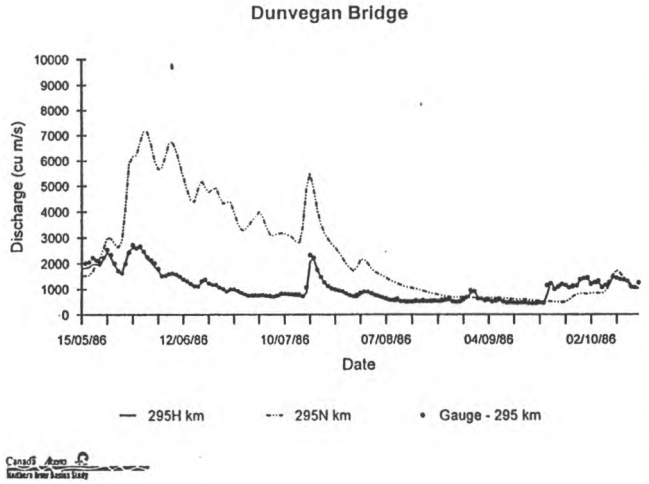


Figure B.17 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1985.







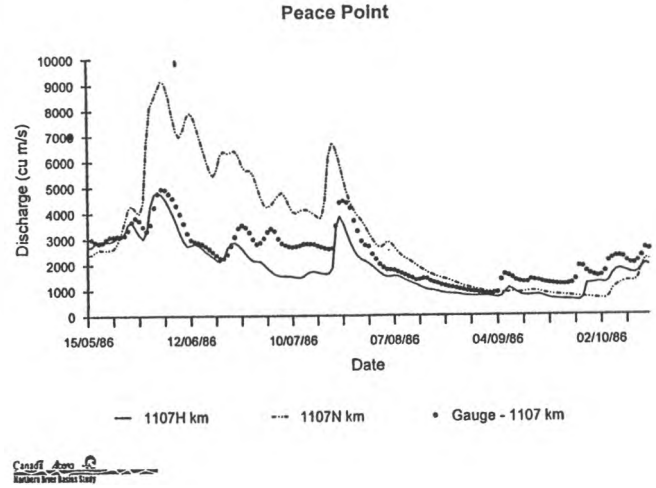
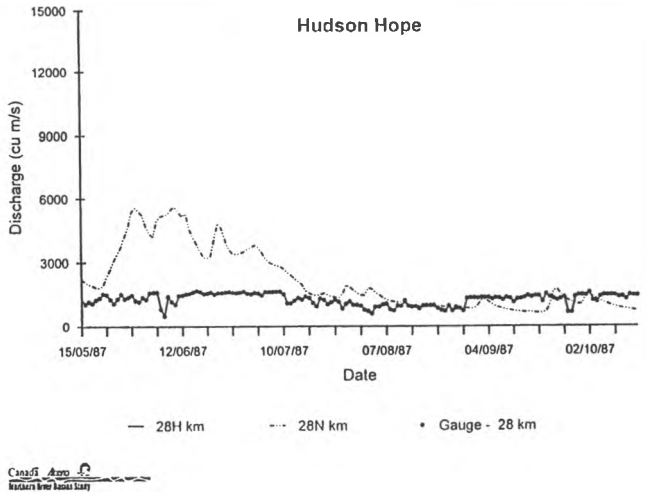
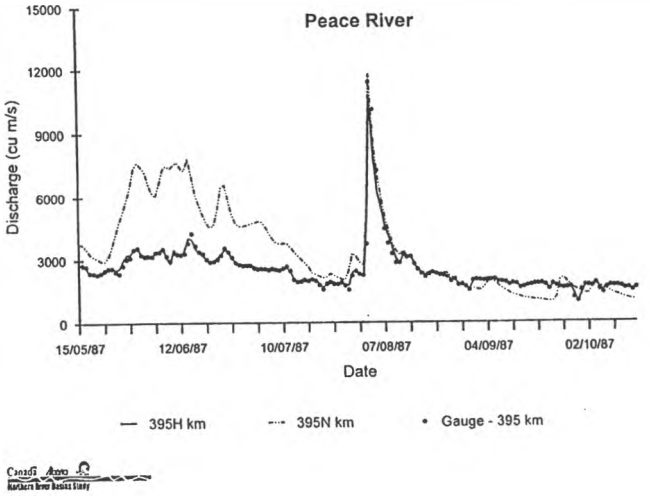
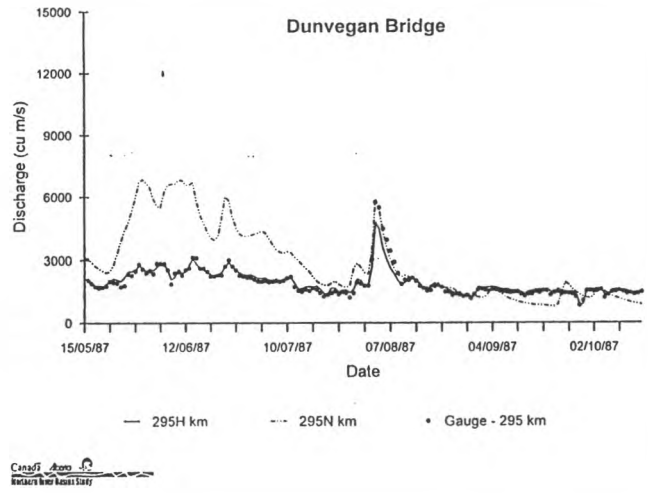


Figure B.18 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1986.







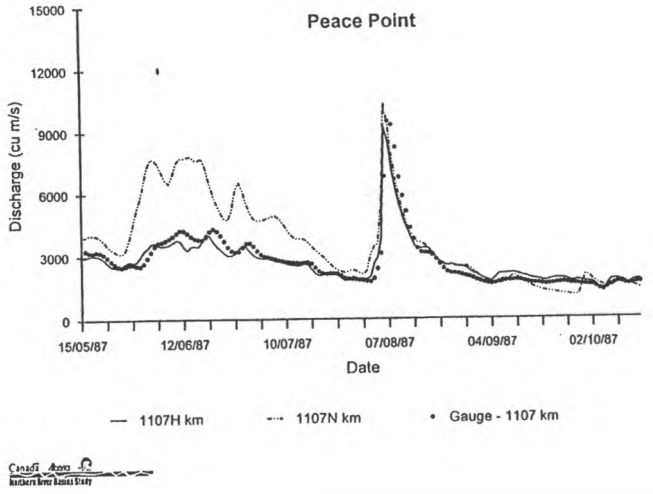
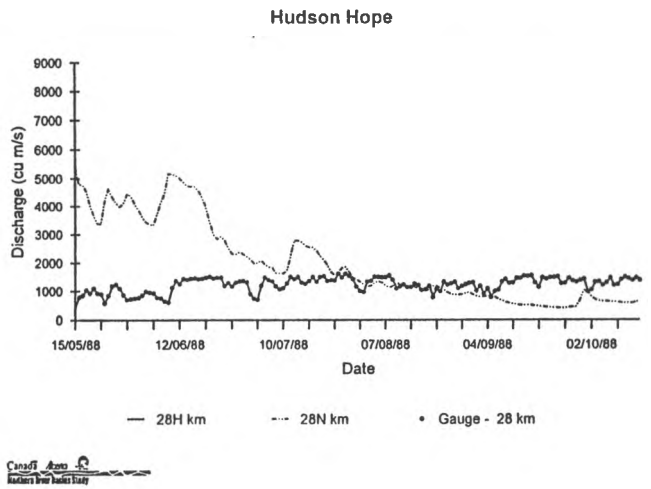
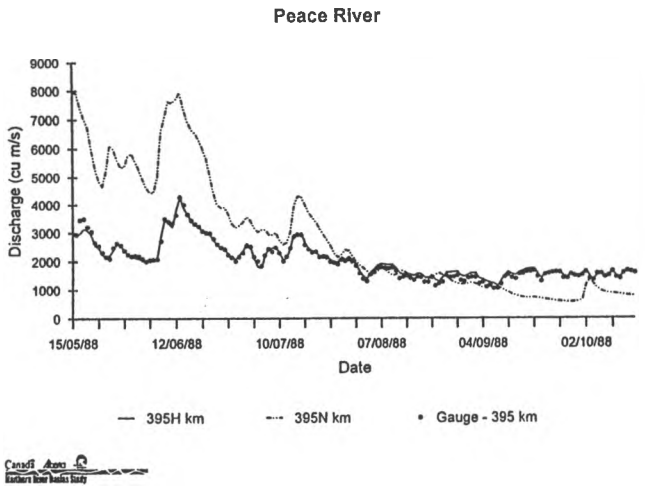
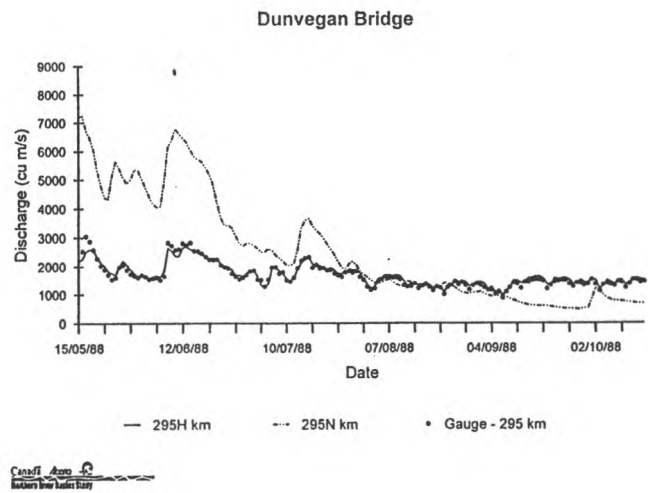


Figure B.19 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1987.







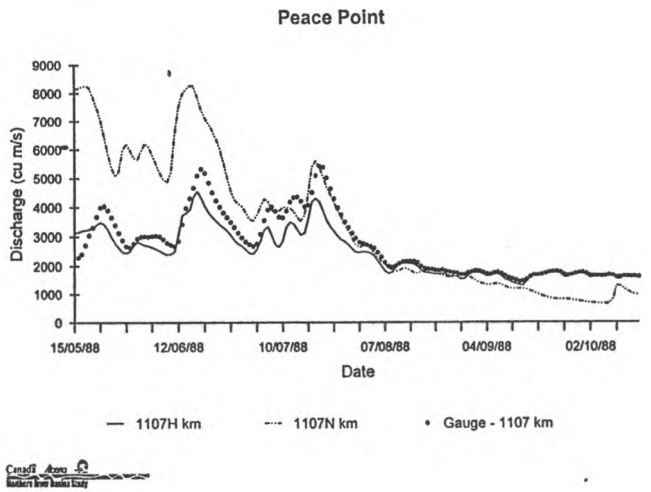
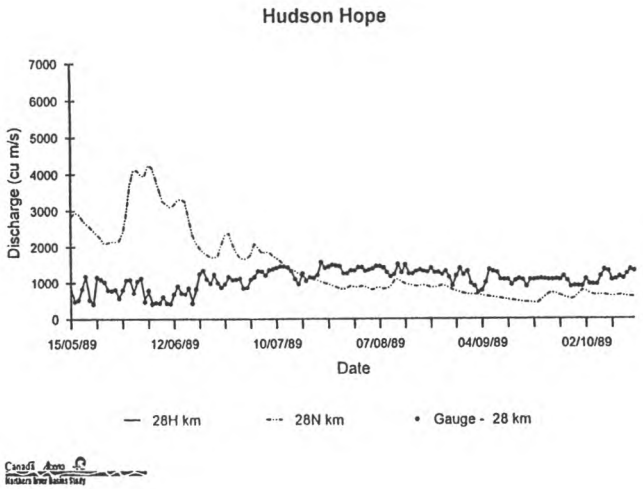
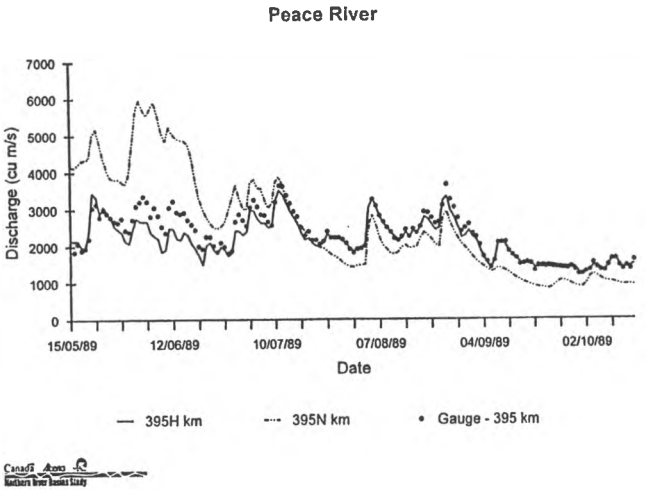
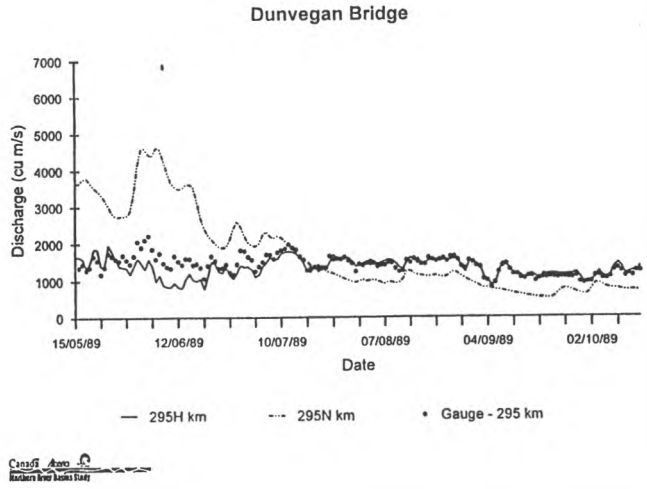


Figure B.20 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1988.







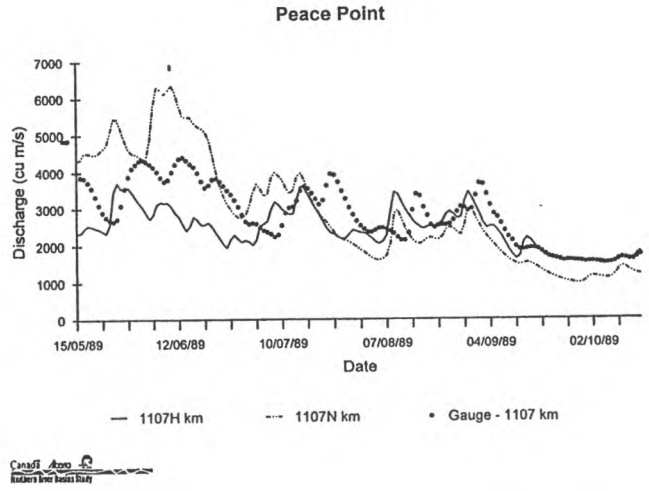
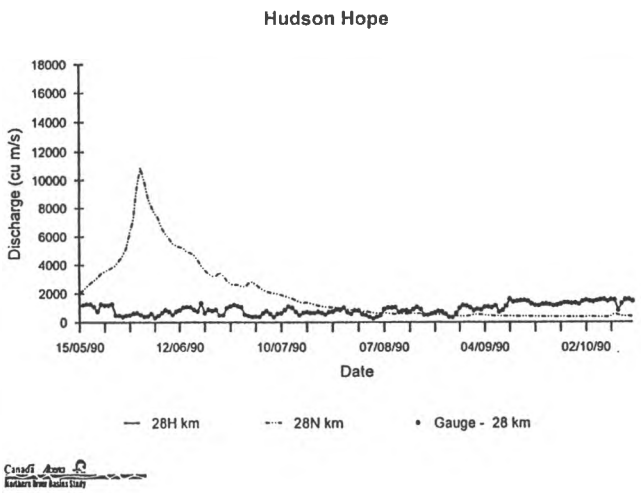
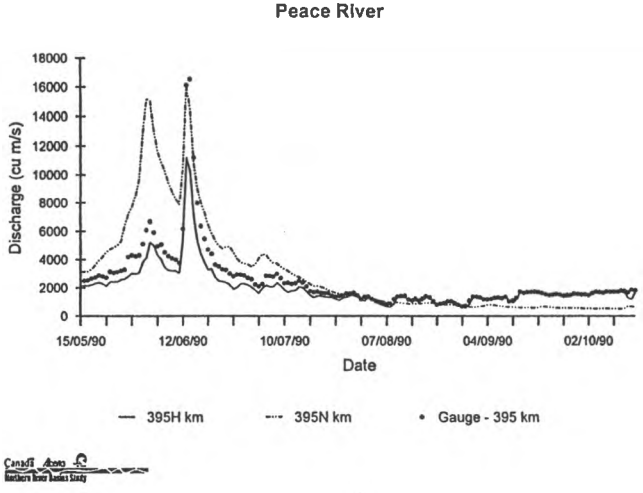
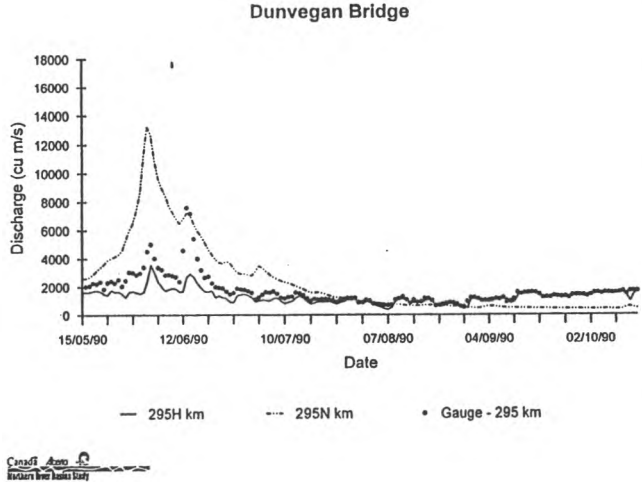


Figure B.21 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1989.







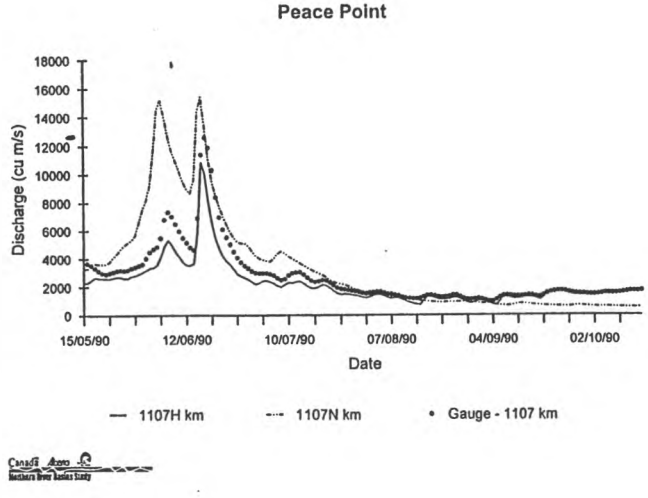
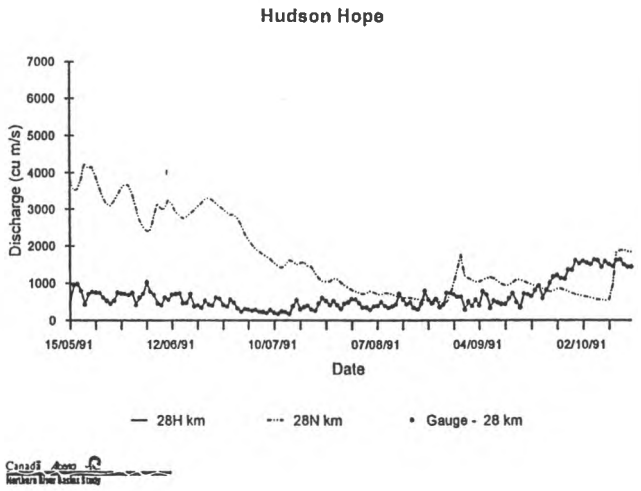
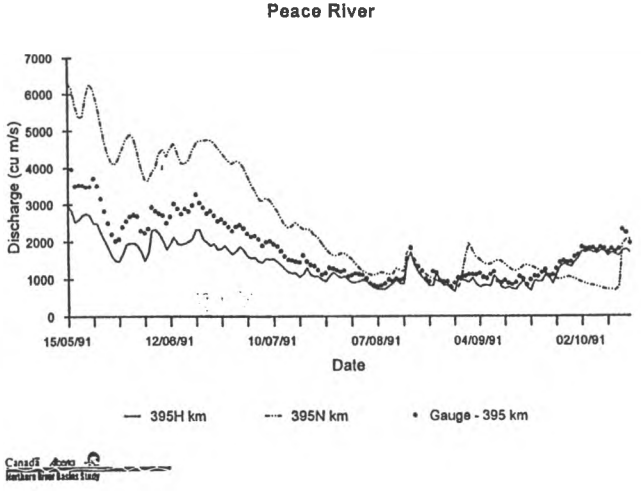
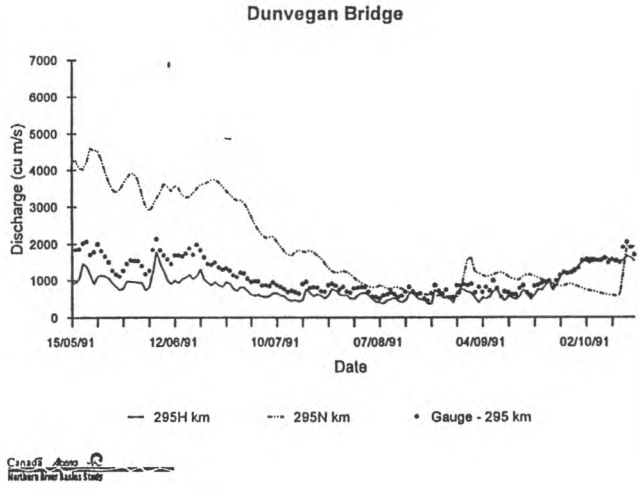


Figure B.22 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1990.







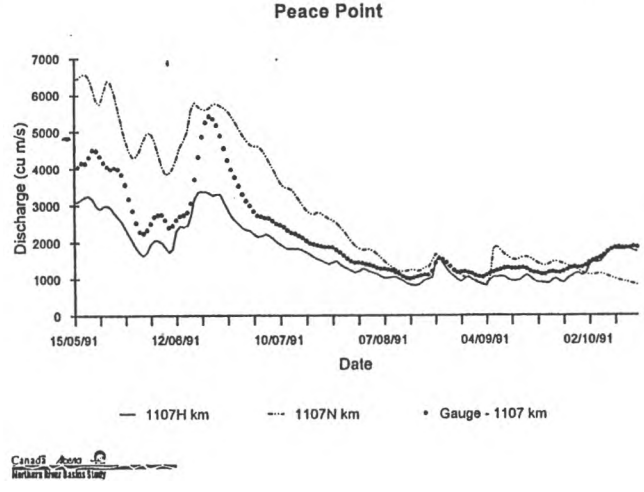
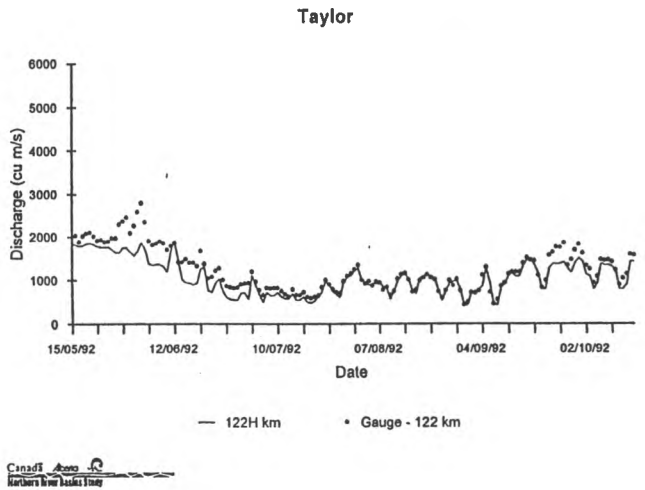
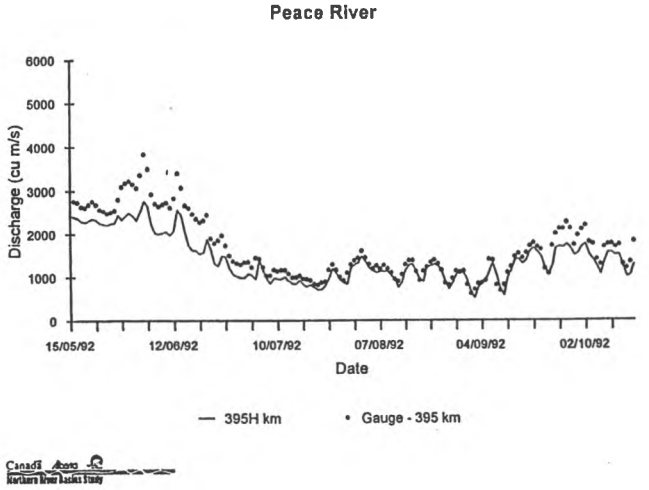
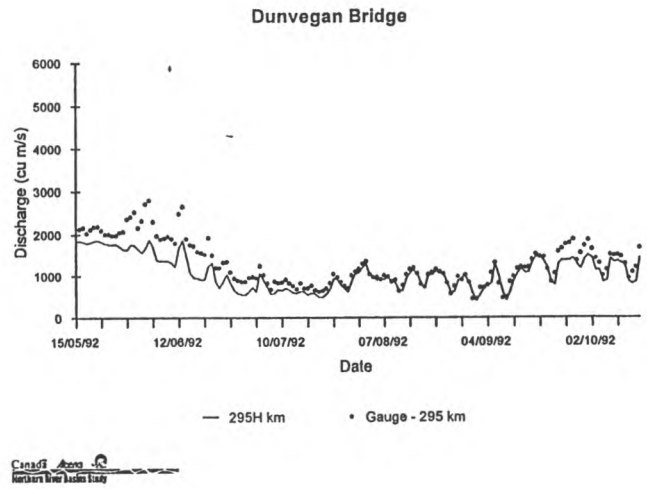


Figure B.23 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1991.







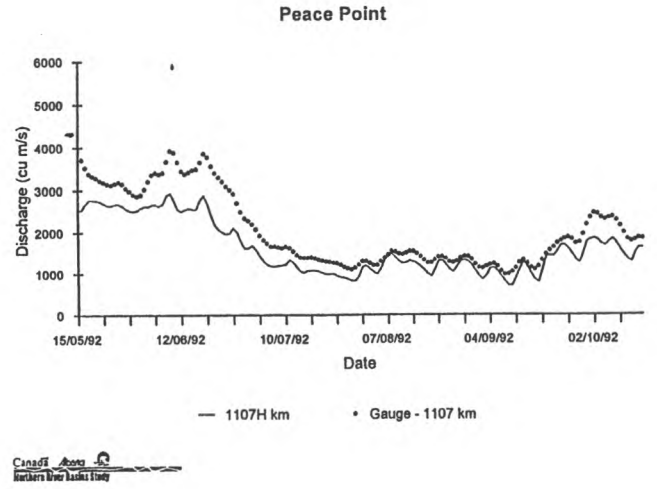
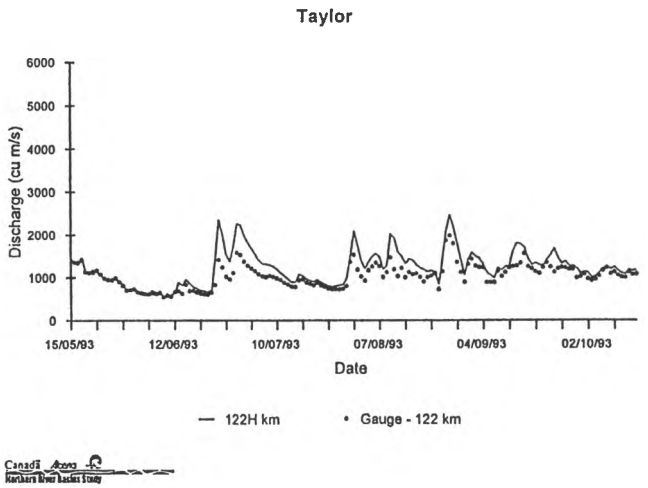
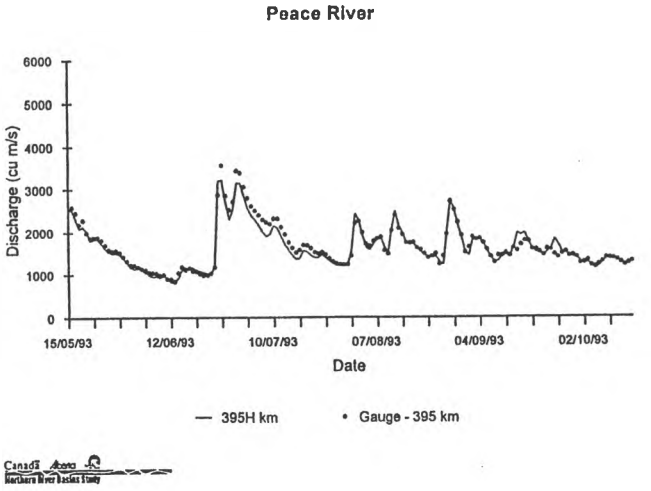
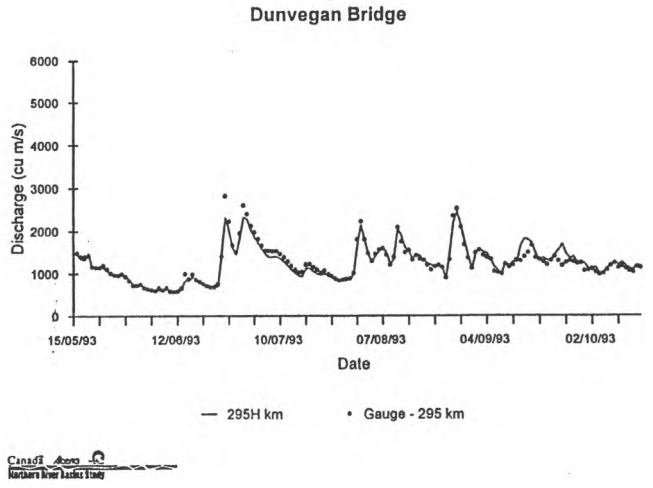


Figure B.24 Simulation results for historical (H) and naturalized (N) flows in the Peace River reach, May 15 to October 15, 1992.







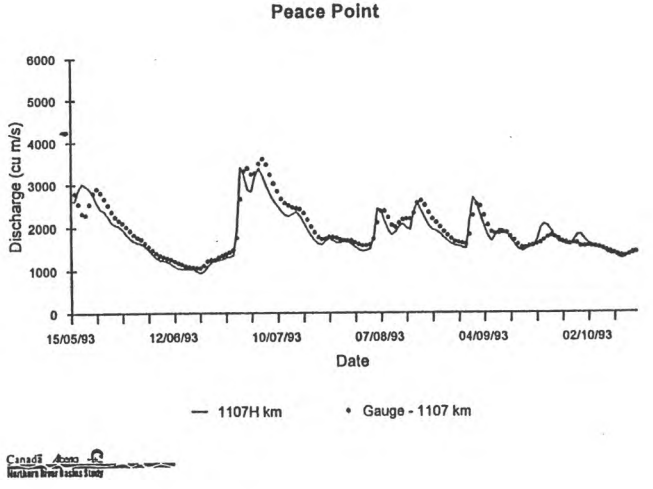


Figure B.25 Simulation results for historical flows in the Peace River reach, May 15 to October 15, 1993.

APPENDIX C

USERS' MANUAL FOR THE USER-FRIENDLY PROGRAM

C.1 INTRODUCTION

The user-friendly WINDOWS interface for the cdg-1D model of the Peace and Slave Rivers was developed by:

F. G. Yeomans
YTech Solutions
512-68 Avenue NW
Calgary, Alberta, T2K 0M9

This user-friendly version of the cdg1-D flood routing model incorporates: a graphic user interface including map selection of output sites; automated incorporation of WSC and naturalized inflows; a built-in plotting package; and a direct interface of output to EXCEL spreadsheet files. Users can run any simulation for which WSC gauge records are available to define the inflows from upstream and tributary contributions, by merely selecting the dates of the desired simulation period. Combined naturalized and historical runs can be conducted and the results graphically compared to measured gauge data. The program is generalized so that the model can be extended directly by the user, simply by adding new ASCII data files derived from future WSC CD-ROM issues.

The user-friendly PC program has been set up to run historical flows from 1960 to 1993, inclusively, based on inflow (Hudson Hope) and tributary data available from the current issue of the WSC records on the HYDAT CD-ROM. It has also been set up to simulate naturalized flows on the Peace River for 1969 to 1991, based on data provided to AEP by B.C. Hydro. It is important to note, however, that not all of the tributaries listed in Table 6 contain complete records during this extensive period. The program has been set up to advise the user when this situation arises, by providing details of the missing data. It is the responsibility of the user to recognize that this affects the reliability of the model results.

Two reaches have been set up for the Slave River because of the current lack of data regarding the relationship between the Peace-Athabasca Delta and Peace/Slave River flows. The user is referred to the main body of the report for details.

This Appendix outlines the steps involved in installing and operating this program. It is assumed throughout that the user is familiar with basic WINDOWS operations (copying files, running programs from the Program Manager, saving, printing, etc.). If this is not the case, please refer to your WINDOWS manual and familiarize yourself with these basic operations.

C.2 HARDWARE REQUIREMENTS

The program runs on IBM PC compatible personal computers and requires the following *minimum* resources:

486DX33 processor (Pentium processor recommended)
8 MB RAM
5MB free hard disk space
Windows 3.11
DOS 6.2

It may possible to run the program on older hardware (e.g. 386 processors). However, the runtime will likely be excessive.

C.3 INSTALLING THE PROGRAM

The software is provided on three 1.4MB floppy disks. The first step is to make a complete backup of these three installation disks. After making the backup, place the originals in a safe place and work with the copies.

Place the disk marked Disk 1 of 3 in your floppy drive and select **"Run"** under the **"File"** menu in the program manager. Using the Browse option, select the **install.exe** file from the floppy disk and press **"OK"**.

Follow the steps outlined in the installation program, placing the disks in the floppy drive as requested by the installation program.

Once the installation is complete, control returns to the Program Manager and a new Program Group will appear containing the NRBS program icon.

C.4 CONFIGURING YOUR WINDOWS ENVIRONMENT

In order for the NRBS program to run, your WINDOWS environment must be configured with the correct date format. To do this, go to Control Panels, select the "International" icon and set the date formats to "M/D/Y".

C.5 RUNNING THE PROGRAM

Once you have successfully installed the program and you have configured the date format properly, you can run the program by double clicking on the NRBS icon. Depending upon the speed of your computer's processor the program may take a few seconds to load. Figure C.1 illustrates the initial screen which will appear once the program initiates. The following steps outline the procedure for running the model, using the Peace River as an example:

Step 1

Select the reach you wish to model by clicking on the appropriate button in the upper right hand corner of the screen (see Figure C.1). In this example, we choose the Peace River. Figure C.2 illustrates the screen that appears after this choice.

Step 2

The next step is to select the sites along the river at which you would like to have the program provide hydrograph output after the simulation is complete. If desired, you can zoom in on either the upstream or downstream half of the reach by double clicking on the map itself. Figure C.3 illustrates the window which appears after clicking anywhere on the upstream portion of the map.

Output sites may be selected by either one of two methods, as shown in Figure C.3. One approach is to input the numbers directly into the "Output Stations" text boxes. Note that this can be done without zooming in (i.e. directly from the window depicted in Figure C.2).

The second method for selecting the output stations is to position the cursor over one of the numbered icons on the map itself (see Figure C.3) which appear as yellow on the screen, hold the mouse button down, and drag the numbered icon along the river to the desired output location. Note that the station corresponding to that numbered icon will change in the corresponding "Output Stations" text box as you drag it along the river.

Step 3

The next step is to select the start and end dates for the simulation as shown in Figure C.2. Note that this can be done with any of the maps shown in the window (i.e. you do not have to zoom out to select the dates). The dates entered must be between May 15th and October 15, as there is insufficient ice data to simulate ice affected conditions on these rivers. You will hear a beep as the model accepts your date entry.

Step 4

Next you must select the type of run to be conducted:

1. *historical* - Inflows at the most upstream section (Hudson Hope in the case of the Peace River, Peace Point for the full Slave Reach and Fitzgerald for the short Slave reach) are based on measured gauge data (regulated since 1969)

2. *naturalized* - Inflows at the most upstream section are based on naturalized flow records (beginning 1969)
    a) Peace River reach: Hudson Hope station - provided by Alberta Environmental Protection based on data from B.C. Hydro
    a) Slave River (full) reach: Peace Point station - these flows were determined using the model to route naturalized flows down the Peace River
    a) Slave River (short) reach: Fitzgerald station - naturalized flows are *unknown* at this station at this time

2. *combined* - For simulations conducted for the post-regulation situation (beginning in 1969) the user can select this option. Both simulations are conducted consecutively, and the user can then plot comparisons between historical and naturalized simulations. The output presented in Appendix B was obtained using this approach.

Options Menu

To choose between the short and full Slave reach options, toggle the **"short Slave reach"** option (under the options menu) on and off.

The values of Mannings *n* used in the model, as outlined in the main body of the report, have been selected to optimize results over a range of discharges. If you are running for a short period during particularly high or low flows, you may wish to optimize this parameter, as it tends to vary with discharge. This is done by selecting the **"Manning n"** item in the options menu. Here you can scale the values up or down with a multiplication factor, using the results in Appendix B to aid you in your decision. This scale factor returns to 1.0 each time the program is run, in order to prevent the accidental use of test values.

Step 5

Finally, to begin the simulation, click on the green light, as shown in Figure C.2. Again, this can be done with any of the various map views shown in the window, provided the previous steps have been completed.

At this time, you may get a warning from the program that tributary data is missing. As stated earlier, it is the responsibility of the user to recognize that this affects the reliability of the model results.

Program Control During the Simulation

The user has limited control over the program during the simulation. Basically, you can interrupt the program by pressing the red light, as shown in Figure C.4, or you can change the type of plot viewed during the analysis by using the buttons at the bottom of the window (also shown in Figure C.4).

Initially, the model must conduct a steady gradually varied flow analysis to determine the initial condition for the run. This can take from 2 to 10 minutes, depending upon your computer's processor, and the user *cannot* interrupt the program during this period. If you press the red light during this analysis, the simulation will be interrupted before the unsteady flow simulation begins.

Once the unsteady flow analysis begins, feedback (reported in the upper left hand corner as shown in Figure C.4) will advise of the current time step. Just to the right of this, progress is reported, along with an estimate of the time of completion for the run. Note if a combined run is being performed, which essentially involves two consecutive runs, the estimated time of completion is only for the current run. A full combined run (historical and naturalized runs, each from May 15 to Oct. 15) takes approximately 4 hours on a Pentium (90MHz) processor.

C.6 SAVING AND PLOTTING PROGRAM RESULTS

Once the simulation is successfully completed, you are advised to save your results immediately. This is done by choosing **"Save"** from the **"File"** menu. The program will suggest a filename

which you are recommended to use. Please note that it is important that you do not change the file extension. There are actually three output files associated with each run. Each has the prefix you specify when saving (the default name if you accepted it) and each has a unique extension: **.nrb**, **.vtc**, and **.xls**. You must have all three files together in the same directory to open a saved run in the NRBS program. The **.xls** file can be read directly by Microsoft EXCEL, and contains all of the tabular output from the run. This data can also be viewed from within the program by pressing the spreadsheet icon in the upper right corner, as shown in Figure C.5.

The output hydrographs (stage or discharge) can be plotted and printed directly from the NRBS program, as illustrated in Figures C.5 and C.6. Again, use the buttons at the bottom of the screen to choose the plot type. The user can change the plotted stations, or add gauge data for comparison, as shown in the figure. Items on the plot itself (such as title, symbols, line type, axes limits) can be set directly by double clicking on the item to be changed. When printing, you may wish to alter the setup. However, as shown in Figure C.6, you must come back to the "Print tab" and press the **"Print"** button to send the plot to the printer.

C.7 TROUBLE SHOOTING

Should you have any problems with the program, please read over the instructions one more time to make sure that you have not missed anything. The most common error occurs when the user does not customize the WINDOWS environment (date format) properly. Should you get an error saying **"File Not Found"** upon starting the program, this is probably the problem.

Please do not hesitate to contact us if you have any other problems with the program, including any "bugs" you may uncover:

Faye Hicks
<fhicks@maligne.civil.ualberta.ca>
Phone: 403-492-7170
Fax: 403-492-0249

Fred Yeomans
<fyeomans@agt.net>

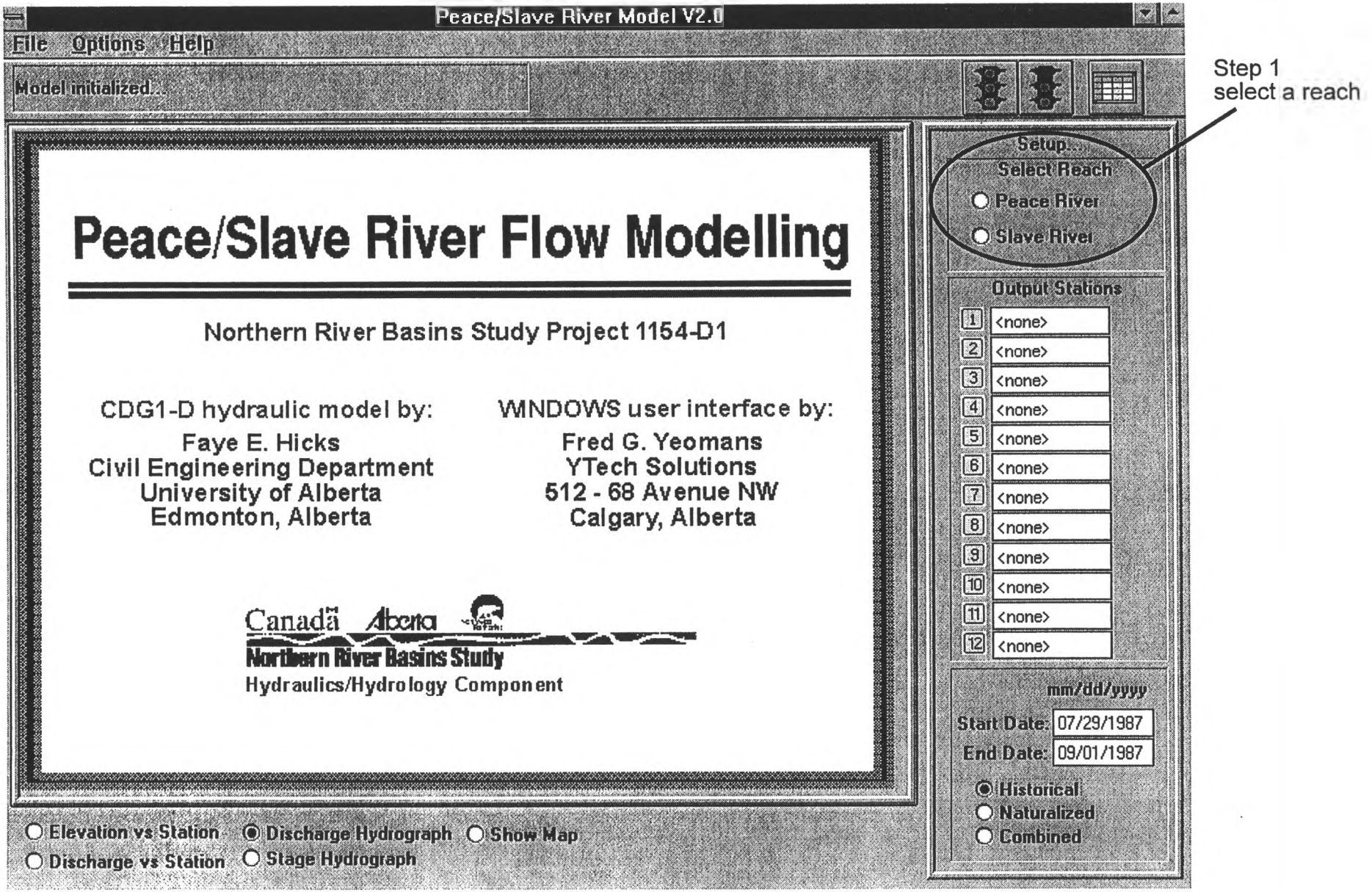


Figure C.1 Initial screen in the NRBS cdg1-D program.

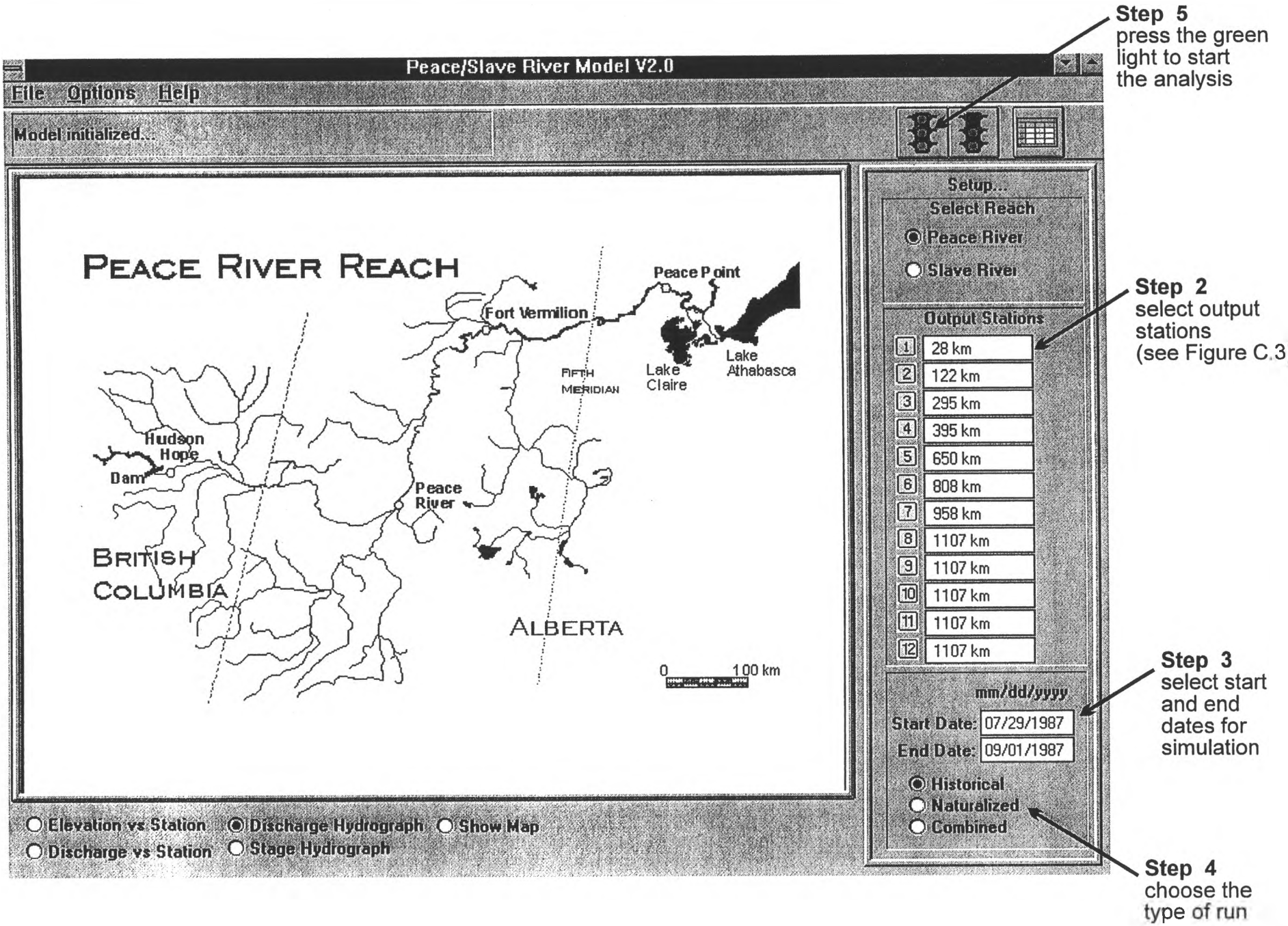


Figure C.2 Starting a routing simulation with the NRBS cdg1-D program.

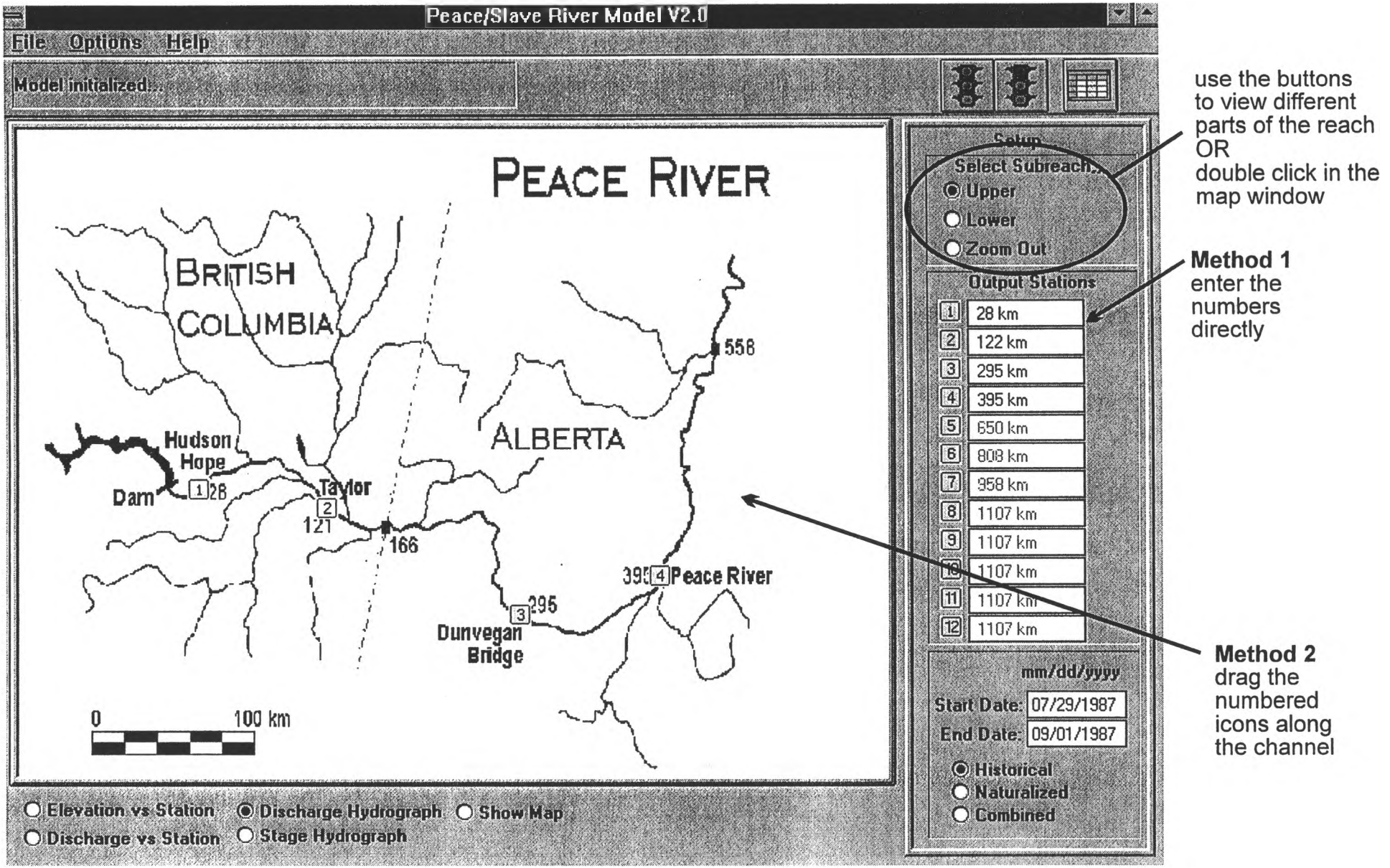


Figure C.3 Various ways to select the output stations.

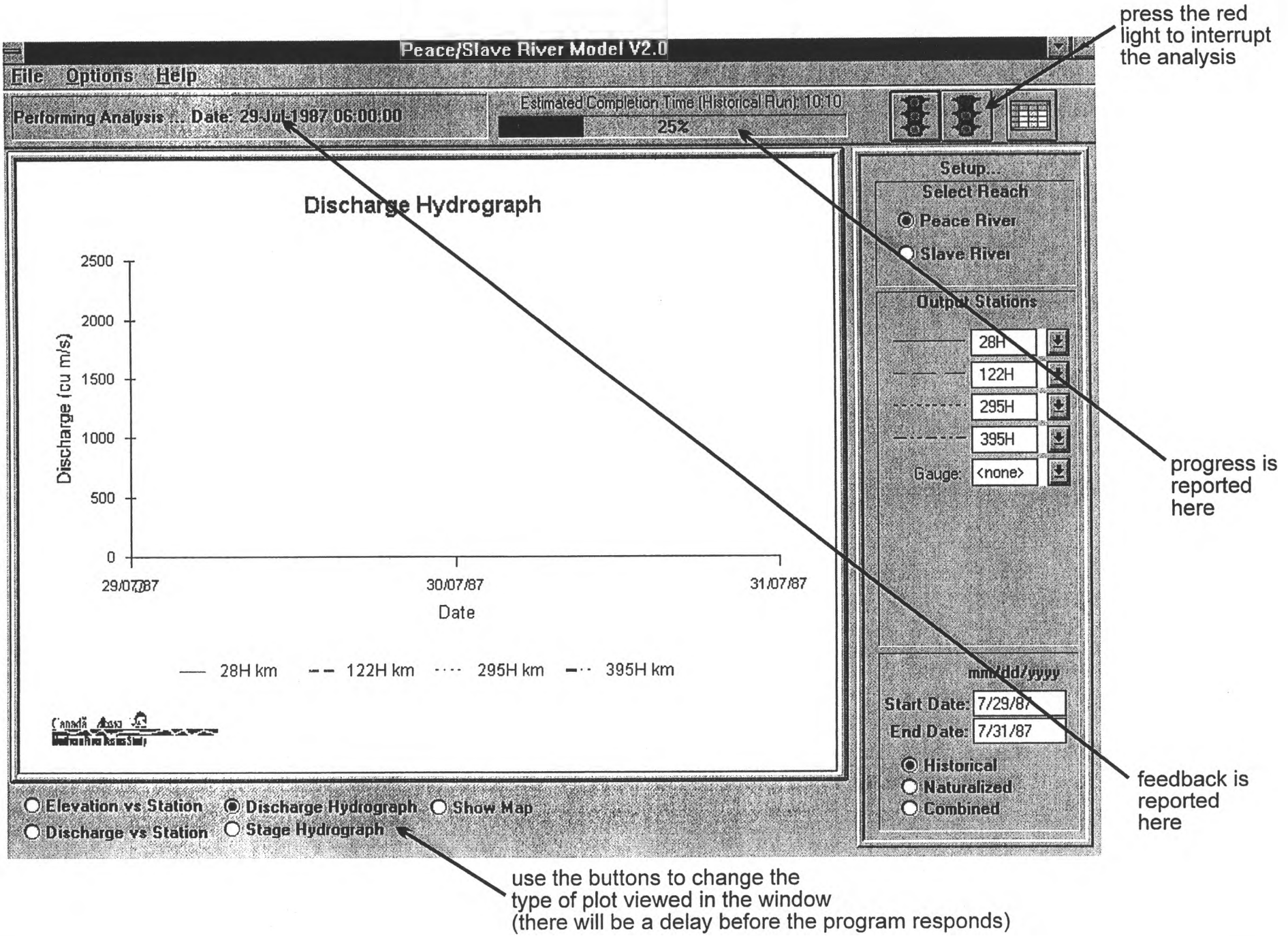


Figure C.4 Program control during the flood routing simulation.

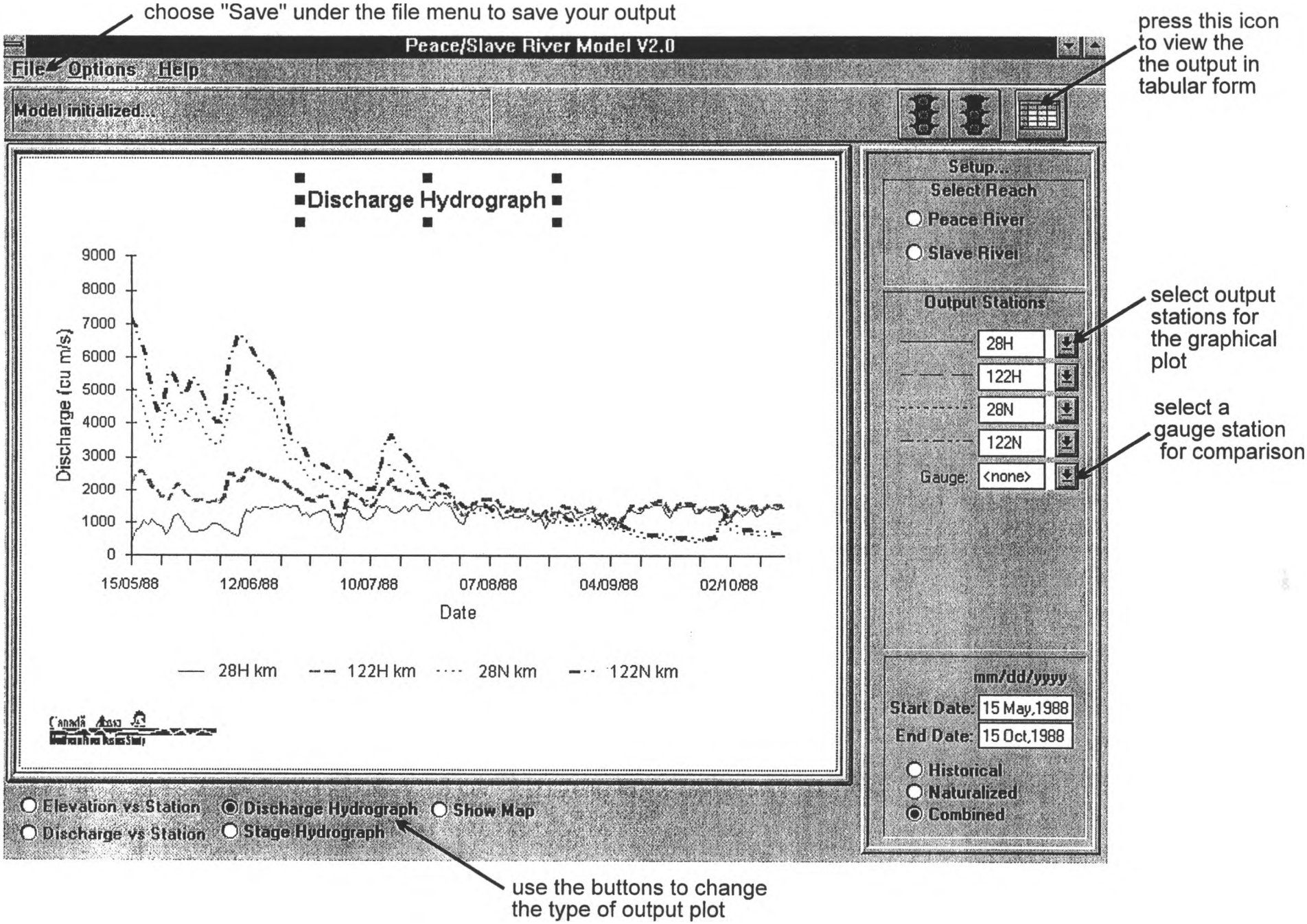


Figure C.5 Viewing the output once the simulation is complete.

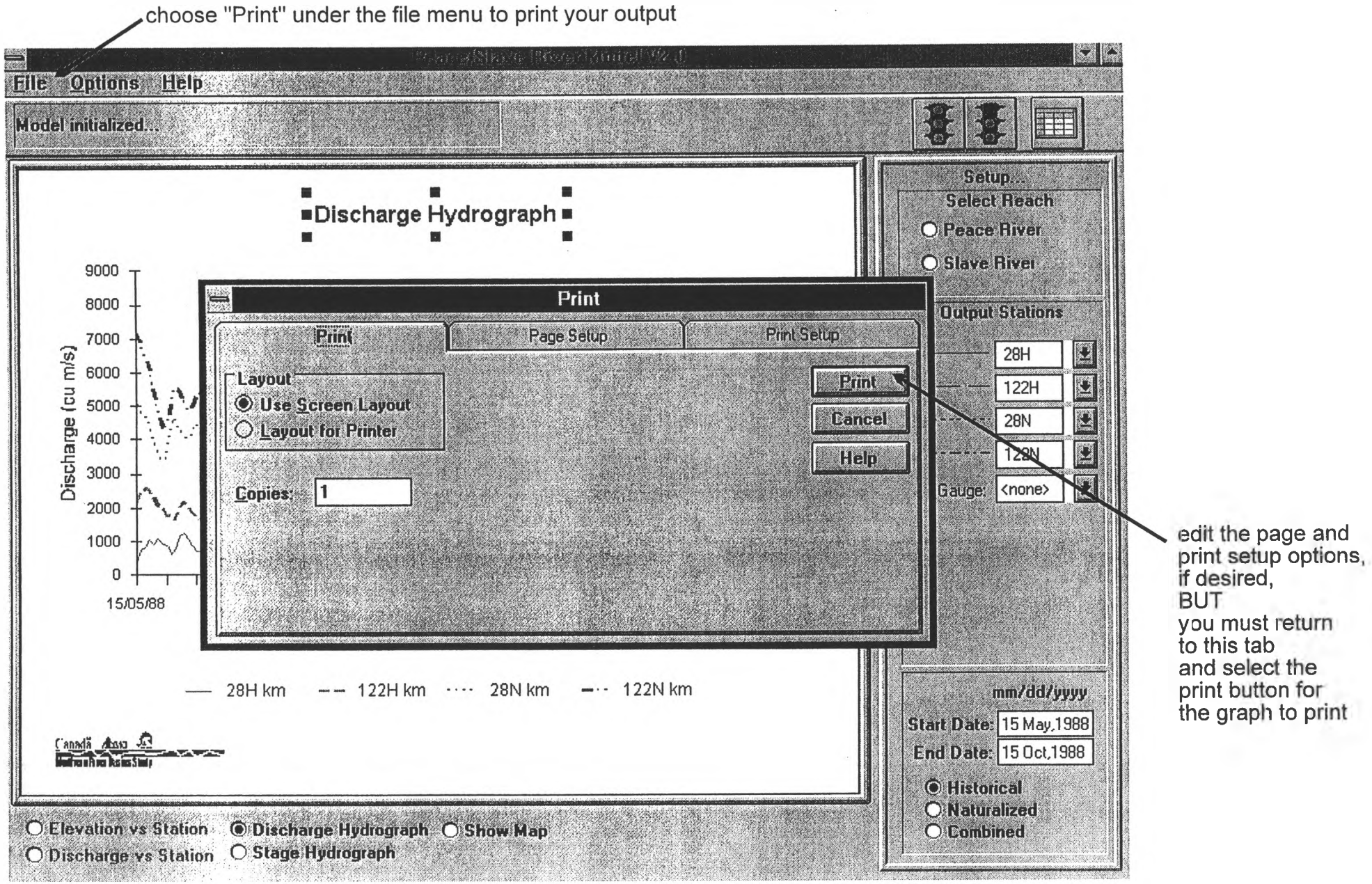


Figure C.6 Printing your graphs.

APPENDIX D

TERMS OF REFERENCE

Project 1154-D1 - Peace/Slave River Flow Modelling

I. BACKGROUND & OBJECTIVES

The Northern River Basins Study seeks to assess the effects of flow regulation of the Peace River on the downstream aquatic ecosystem. Although a number of impact-related studies have been initiated by the NRBS, all require detailed information about hydraulic flow conditions at specific locations along the river. Studies proposed for the 1994/95 fiscal year include:

(a) Project 1422-C1 - Hydrometeorlogical Conditions Controlling Ice-Jam Floods on the Peace River

(b) Project 1321-C2 - Temporal Evolution of Channel Morphology and Riparian Vegetation on the Peace River

(c) Project 1521-D1 - Regulation Effects on the Slave River Delta: Landform and Distributary Sensitivities to Changes in River Regime

(d) Project 4131-D1 - Aquatic Habitat Mapping for Instream Flow Needs

An assessment of the effects of regulation has been conducted by Alberta Environment using hydrologic flood routing techniques and calibrated at the existing hydrometric stations. To improve modelling of flow along the river and to create the ability to model cross-sectional velocities at sections of particular interest to the impact-related studies, the NRBS initiated the development of a hydraulic flow model in 1993/94, Project 1154-C1. This work has benefited from recent research conducted in the Civil Engineering Department at the University of Alberta to develop a numerically robust, unsteady hydraulic flow model. This model employs a Petrov-Galerkin finite element method known as the Characteristic-Dissipative-Galerkin (CDG) scheme. Comparisons of this numerical scheme to more conventional, commercially available code have been conducted, confirming the superiority of the CDG scheme in terms of both solution accuracy and numerical stability. Because of the apparent significance of river-ice to the morphology and ecology of the Peace River, a long term objective in assessing overall impacts of flow regulation will be to model changes in the river-ice regime. Notably, the U of A model has already been used for a related purpose on the Hay River, NWT. Specifically, it has proven useful in modelling the potential impact of ice jam release surges. More generally, development of such a hydraulic model will provide the essential foundation for the eventual incorporation of a comprehensive river-ice model (RIVICE) currently being developed through Environment Canada, and for state of the art IFN (Instream Flow Needs) two-dimensional hydraulic flow models.

This project is an extension of NRBS project number 1154-C1. The first version of the model will be upgraded with the input of additional cross-section information to be collected during 1994/95. The locations of cross-sections are those specified as being important for: improved hydraulic modelling (Project 1154-C1); understanding the formation of ice jams (Project 1422-C1); evaluation the effects of regulation on the temporal evolution of channel morphology and riparian vegetation on the Peace River (Project 1321-C2) and in the Slave River Delta (Project 1521-D1), and in evaluating changes in aquatic habitat (Project 4131-D1).

Selection of cross-sections is currently being coordinated through the NRBS Hydrology/Hydraulics/Sediment Component of which Dr. Hicks, the project leader (1154-C1) is a member. The final outcome of the project will be a user-friendly model for assessing natural and regulated flow scenarios at selected sites along the Peace and Slave River system.

Objectives

1. Update the current Peace River hydraulic model (from Project 1154-C1) with additional cross section information as required so that hygrographs can be modelled at ungauged cross-sections.

2. Extend the hydraulic model developed for the Peace River downstream to include the Slave River.

3. Produce a user-friendly, graphics-assisted version of the model.

4. Run various flow scenarios for other projects (1422-C1, 1321-C2, 1521-D1, and 4131-D1) as directed by the Component Leader

II. REQUIREMENTS

1. Determine the additional cross sections that must be surveyed to produce a hydraulic model that can be used with confidence and notify the Component Leader/Study Office what is required.

2. Using the existing and newly surveyed cross sections, update the hydraulic model developed under project 1154-C1 to include the Slave River to Slave Lake.

3. Run the model for several flow scenarios to provide relevant input to companion studies:

    a) Project 14221-C1 - Hydrometeorlogical Conditions Controlling Ice-Jam Floods on the Peace River

    b) Project 1321-C2 - Temporal Evolution of Channel morphology and Riparian Vegetation on the Peace River

c) Project 1521-D1 - Regulation Effects on the Slave River Delta: Landform and Distributary Sensitivities to Changes in River Regime

d) 4131-D1 - Aquatic Habitat Mapping for Instream Flow Needs (Peace River)

Final selection of flow scenarios will be directed by the Component Leader.

III. DELIVERABLES

1. User friendly hydraulic dynamic model of the Peace/Slave system due March 1, 1995

2. User's manual for model due March 1, 1995

3. Report of results from flow scenarios due March 1, 1995

4. Six to ten 35 mm slides that can be used at public meetings to summarize the results and main points and any pertinent photographs due March 1, 1995

IV. REPORTING REQUIREMENTS

1. The Contractor is to provide draft and final reports in the style and format outlined in the NRBS Style Manual. A copy of the Style Manual entitled "A Guide for the Preparation of Reports" will be supplied to the contractor by the NRBS.

2. Ten copies of the Draft Report along with an electronic disk copy are to be submitted to the Project Liaison Officer by March 1, 1995.

   Three weeks after the receipt of review comments on the draft report, the Contractor is to provide the Project Liaison Officer with two unbound, camera ready copies and ten cerlox bound copies of the final report along with an electronic version.

3. The final report is to include the following: an acknowledgement section that indicates any local involvement in the project, Project Summary, Table of Contents, List of Tables, List of Figures and an Appendix with the Terms of Reference for this project.

   Text for the report should be set up in the following format:

   a) Times Roman 12 point (Pro) or Times New Roman (WPWIN60) font.
   b) Margins; are 1" at top and bottom, 7/8" on left and right.
   c) Headings; in the report body are labelled with hierarchical decimal Arabic numbers.

d) Text; is presented with full justification; that is, the text aligns on both left and right margins.
e) Page numbers; are Arabic numerals for the body of the report, centred at the bottom of each page and bold.

- If photographs are to be included in the report text they should be high contrast black and white.
- All tables and figures in the report should be clearly reproducible by a black and white photocopier.
- Along with copies of the final report, the Contractor is to supply an electronic version of the report in Word Perfect 5.1 or Word Perfect for Windows Version 6.0 format.
- Electronic copies of tables, figures and data appendices in the report are also to be submitted to the Project Liaison Officer along with the final report. These should be submitted in a spreadsheet (Quattro Pro preferred, but also Excel or Lotus) or database (dBase IV) format. Where appropriate, data in tables, figures and appendices should be geo-referenced.

4. All figures and maps are to be delivered in both hard copy (paper) and digital formats. Acceptable formats include: DXF, uncompressed E00, VEC/VEH, Atlas and ISIF. All digital maps must be properly geo-referenced.

5. All sampling locations presented in report and electronic format should be geo-referenced. This is to include decimal latitudes and longitudes (to six decimal places) and UTM coordinates. The first field for decimal latitudes / longitudes should be latitudes (10 spaces wide). The second field should be longitude (11 spaces wide).

V. CONTRACT ADMINISTRATION

The Project Liaison Officer (Component Coordinator) for this project is:

Firstly;
Dr. Terry Prowse
NHRI
11 Innovation Blvd.
Saskatoon, Saskatchewan
Bus. Phone: (306) 975-5737
Fax: (306) 975-5143

OR

James Choles P. Eng.
Component Coordinator
Northern River Basins Study
690 Standard Life Centre
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Edmonton, Alberta
T5J 3N4
Home Phone: (403) 455-4812
Bus. Phone: (403) 427-1742
Fax: (403) 422-3055

APPENDIX E

BENCH MARK DESCRIPTIONS AND CROSS SECTION DATA

Appendix E: Bench Mark Descriptions and Cross Section Data

This Appendix is provided on the disk bound as the last page of this report; it contains data files for cross sections surveyed on the Peace and Slave Rivers and the location information is described in the Bench Mark Descriptions.

The disk comprising this Appendix contains three files, using 594,058 bytes.

1. INSTALL.BAT; being 72 bytes in size.
2. PR77.EXE; being 593,600 bytes in size.
3. DISCLAIM.TXT; being 486 bytes in size.

To install the database, copy the three files on this disk to a directory on your hard drive and type install.bat. The result will be 21 files totaling 1,747,430 bytes. To use the files with extension .XLS requires Microsoft Excel.

There is no warranty expressed or implied for the use of this database; the Northern River Basins Study does not guarantee the accuracy of the data. The NRBS does not assume any liability for actions or consequences resulting from the use of the data; individuals using this data do so entirely at their own risk. The NRBS will not update the data except as deemed necessary for its own purpose.

BENCH MARK DESCRIPTIONS

In 1981 Water Survey of Canada (WSC) installed bench marks on a reach of the Peace River from Peace Point downstream to the confluence of the Peace and Slave Rivers. In 1982 McElhanney Surveying and Engineering Ltd. surveyed elevations for these bench marks and prepared a report of bench mark descriptions (their file: 163214).

In 1994 bench marks were installed on the Peace and Slave Rivers as reference points for cross-sections to be completed in support of the Northern River Basins Study. Some of the bench marks surveyed in 1982 were located and utilized for this survey.

Reconnaissance:

1993 - On Jun. 28-30 WSC survey party Glen R. Carpenter and Doug A. Robertson completed a reconnaissance in support of the Peace Athabasca Delta Technical Studies. The survey included a reach of the Peace River from Peace Point downstream to the confluence of the Peace and Slave Rivers. The purpose was to locate bench marks surveyed in 1982 and determin if the sites were accessible by GSC for a survey in Aug. 1993. Location of bench marks proved difficult. Most of the markers were missing, bench marks were destroyed due to bank slumping, and vegetation at the sites was very thick. (5) original bench marks were located and GSC were able to determin elevations for all (5).

1994 - On May 31-Jun. 1 a survey party consisting of Malcolm Conly (NHRI), Doug A. Robertson and Murray K. Jones (WSC) completed a reconnaissance in support of Northern River Basins Study. The survey involved the reach of the Peace River from Peace Point downstream to the confluence of the Peace and Slave Rivers. The purpose of the survey was to identify cross-section sites and bench mark locations.

Installation:

Bench marks were installed by Doug A. Robertson and Murray K. Jones during two field trips Jul. 11-15 and Jul. 25-29, 1994. (2) types of bench marks were installed; 3/8" ground rods or brass caps set in bedrock. The ground rods were driven to a depth that the electric hammer had difficulty with or could no longer drive rods deeper.

Bench marks were installed far enough inland from the river bank in anticipation of any bank erosion. An exception is bench mark PR94-161 which is installed on a low bank

and is vulnerable to effects of an ice push. All bench marks except PR94-161 are considered stable and long term installations.

Identification:

All ground rod bench marks are marked with a red 1m. high steel post supporting a small galvanized bench mark identification plate and is set 0.3m. inland from the bench mark. Examples of identification plate:

WSC PR94-41 — WSC - Water Survey of Canada
PR - Peace River
94 - 1994 (year installed)
41 - bench mark number

WSC SR94-04 — WSC - Water Survey of Canada
SR - Slave River
94 - 1994 (year installed)
04 - bench mark number

The identification is stamped on the brass cap bench marks.

The bench marks are numbered in goups of 10 from km 0.0 of the Peace River progressing upstream to Boyer Rapids. Each group corresponds with the numbering of the cross-sections allowing for 10 bench mark installations for each area of cross-section. For example PR94-**01**, PR94-**02** and PR94-**03** are the first group and PR94-**11** and PR94-**12** are the second group continuing to PR94-221. In the event that bench marks used for a particular cross-section are destroyed and more are to be installed they can be added to the system in logical sequence. For example if in 1997 bench mark PR94-12 was found destroyed and new one could be installed and named PR97-13.

No original bench marks were located at the cross-sections above Ft. Vermilion and only temporary ones were installed. The naming of these bench marks was according to the location and type.
Example of naming:

WS-410RC — WS - wooden stake
410 - km 410.78 on the Peace River
RC - right channel

Cross Sections

Eighteen cross sections were also surveyed during the installation of the benchmarks and their locations are shown in the following pages. Cross section information is summarized in Table 1. Electronic copies of the cross sections are in Excel files in the accompanying disks.

Table 1: Summary of Cross Sections and Associated Benchmarks

Cross Section Number	River	Associated Benchmarks
PR94X001	Peace River	PR94-01, PR94-02, PR94-03,
PR94X032	Peace River	PR94-31, PR94-32, PR94-33, TBM90-1,
PRX033A	Peace River	PR94-31, PR94-32, PR94-33, TBM90-1,
PRX0421C	Peace River	PR94-41, PR-42, PR94-43, PR-44, PR-45
PRX042RC	Peace River	PR94-41, PR-42, PR94-43, PR-44, PR-45
PRX061LC	Peace River	PR94-61, PR94-62, PR94-63
PRX061RC	Peace River	PR94-61, PR94-62, PR94-63
PRX071LC	Peace River	PR94-71, PR94-72, PR94-73
PRX071MC	Peace River	PR94-71, PR94-72, PR94-73
PRX071RC	Peace River	PR94-71, PR94-72, PR94-73
PRX408RC	Peace River	WS-408, IP-408 LB
PRX408LC	Peace River	WS-408, IP-408LB
PRX410RC	Peace River	WS-410RC, WS-410LC, IB-410LCRB, IB-410LCLB
PRX410LC	Peace River	WS-410RC, WS-410LC, IB-410LCRB, IB-410LCLB
SRX004	Slave River	SR94-04, GSC 1720-D
PRXCARCJ	Peace River	ASCM378430,
PRX430	Peace River	TBM#1, TBM#2

BENCH MARK PROFILE

BENCH MARK NO: **PR94-01** ELEV. Geodetic: 212.609 m
March 1968 (Rev. No.1)

INSTALLED: AUG. 11-81 UPDATED: JUL. 12-94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of three 6-foot lengths of 3/8" diameter rod, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 0 (Mile 0) at the confluence of the Peace and Slave rivers, in a 2m wide cut-line just downstream of red Coast Guard navigation buoy marking a gravel bar (exposed at low water levels). Benchmark is located 9.75m inland from BM WSC PR94-02, 17.5m inland from top of 2nd cutbank and 28.5m inland from top of 2.3m high cutbank. Ground at top of 2nd cutbank is level covered by mature spruce and aspen.

HISTORICAL/other marker names, etc.

Benchmark was established by Water Survey of Canada (WSC) in 1981 for cross-sections on the Peace River, and tied by McElhanney Surveying & Engineering Ltd. in 1982 (their file #163214), as Point 1, Cross-Section #1. Renamed and marked July 12, 1994 by WSC for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) Study.

UTM and **LAT/LONG** coordinates derived by GPS with differential.

CO-ORDINATES: **NAD83** (see Historical)

Latitude: 58° 59' 33" UTM Northing: 6539292.809
Longitude: 111° 25' 13" Easting: 475848.922

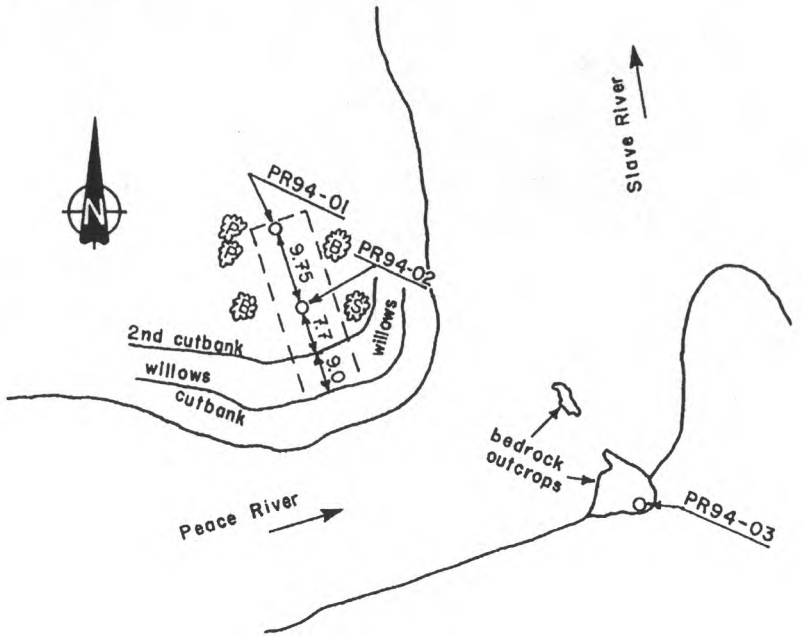
CROSS-SECTION

Number: PR94X001 Azimuth:
Number: Azimuth:
Number: Azimuth:

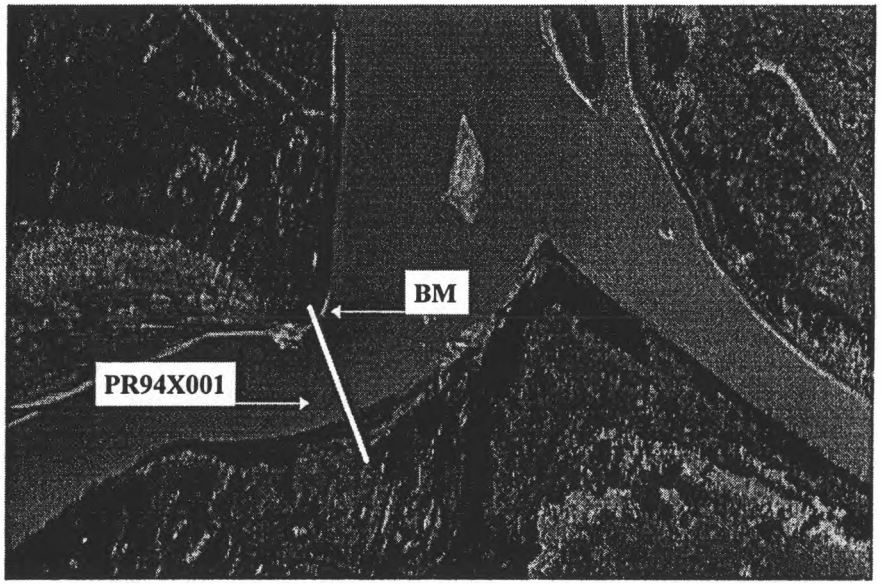
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 47-NE
Roll: AS4475 Photo: 342

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-02** ELEV. Geodetic: 212.343 m

March 1968 (Rev. No.1)

INSTALLED: JUL. 12-94 UPDATED: SEP. 20-94 CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 0 (Mile 0) at the confluence of the Peace and Slave rivers, in a 2m wide cut-line just downstream of red Coast Guard navigation buoy marking a gravel bar (exposed at low water levels). Benchmark is located 9.75m toward river from BM WSC PR94-01, 7.7m inland from top of 2nd cutbank and 16.7m inland from top of 2.3m high cutbank. Ground at top of 2nd cutbank is level covered by mature spruce and aspen.

HISTORICAL/other marker names, etc.

Benchmark was established by Water Survey of Canada (WSC) on July 12, 1994 for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) Study. Benchmark was tied to BM PR94-01 on Sept. 20, 1994.

UTM and LAT/LONG coordinates derived by GPS with differential.

CO-ORDINATES: **NAD83** (see Historical)

Latitude: N 58° 59' 33" UTM Northing: 6539291.279

Longitude: W111° 25' 13" Easting: 475762.279

CROSS-SECTION

Number: PR94X001 Azimuth:

Number: Azimuth:

Number: Azimuth:

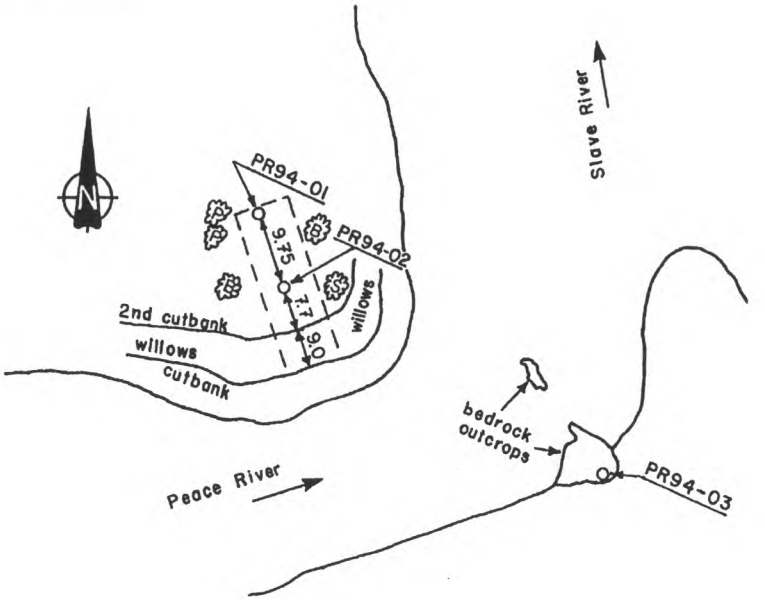
AIR PHOTO INFORMATION

Name: PEACE RIVER

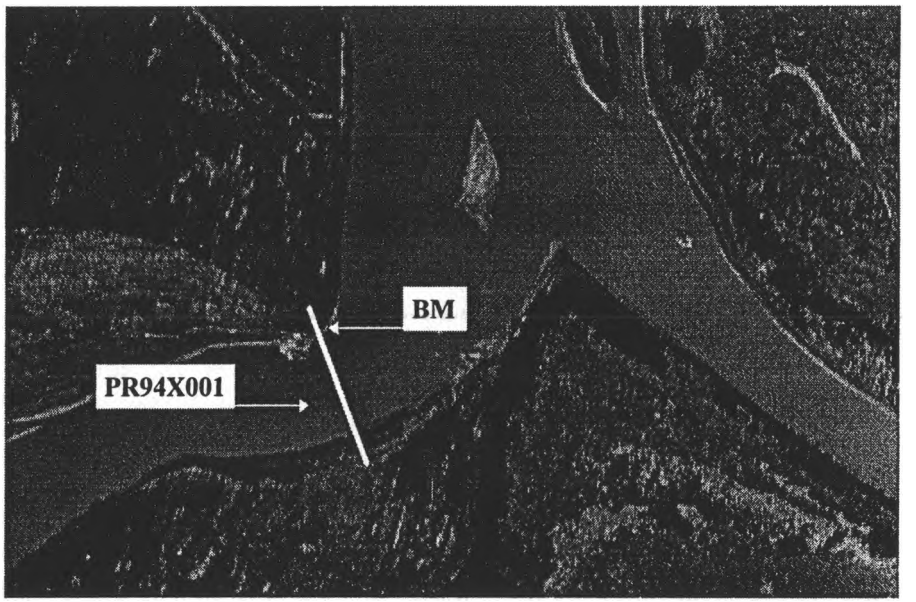
Date: OCT. 08-93 Line: 47-NE

Roll: AS4475 Photo: 342

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-03** ELEV. Geodetic: 210.984 m

March 1968 (Rev. No.1)

INSTALLED: JUL. 12-94 UPDATED: SEP. 20-94 CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a WSC brass cap set in bedrock. Benchmark is located on the right bank of the Peace River at Km. 0 (Mile 0) at the confluence of the Peace and Slave rivers, on a bedrock outcrop just downstream of red Coast Guard navigation buoy marking a gravel bar (exposed at low water levels).

HISTORICAL/other marker names, etc.

Benchmark was established by Water Survey of Canada (WSC) on July 12, 1994 for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) Study. Benchmark was tied into BM PR94-01 on Sept. 20, 1994.

UTM and LAT/LONG coordinates derived by GPS with differential.

CO-ORDINATES: **NAD83 (see Historical)**

Latitude: N 58° 59' 26" UTM Northing: 6539203.461

Longitude: W 111° 24' 44" Easting: 476372.908

CROSS-SECTION

Number: PR94X001 Azimuth:

Number: Azimuth:

Number: Azimuth:

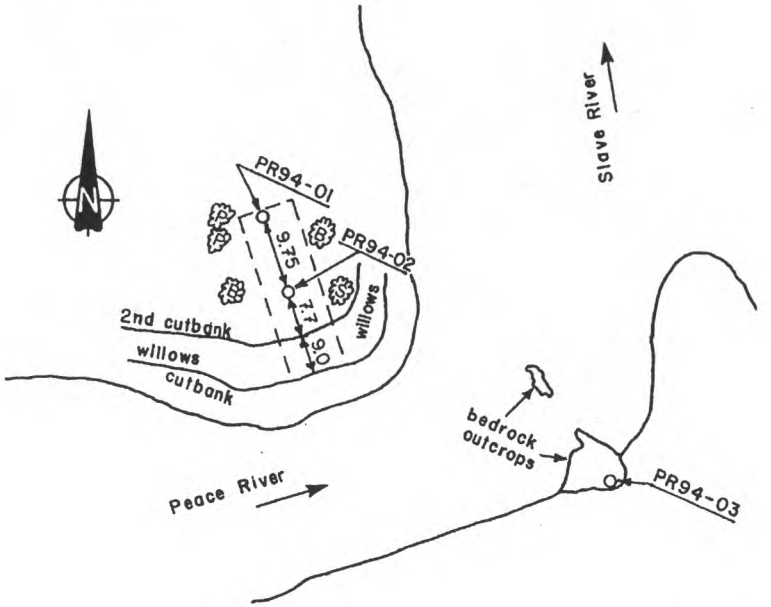
AIR PHOTO INFORMATION

Name: PEACE RIVER

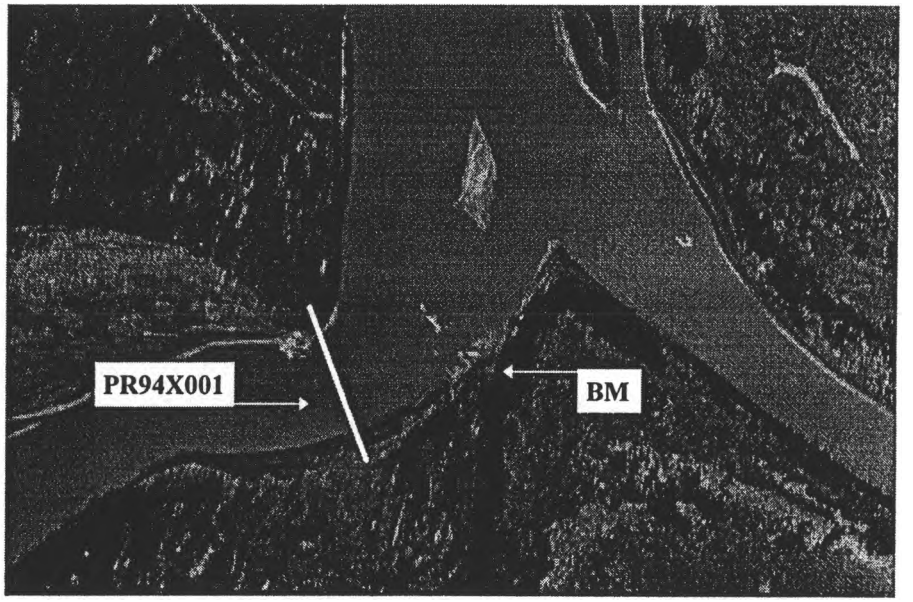
Date: OCT. 08-93 Line: 47-NE

Roll: AS4475 Photo: 342

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-11**

ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 12, 94 UPDATED:

CONDITION:
NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of five 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River, upstream of a small island, at Km. 5.6 (Mile 3.5), in a 2m wide cut-line. Benchmark is 17.4m inland from BM WSC PR94-12, and 49.4m inland from the top of cutbank, in an area of mature poplars.

HISTORICAL/other marker names, etc.

Benchmark was established July 12, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: 58° 58' 42" UTM Northing: 6537743.825
Longitude: 111° 29' 34" Easting: 471671.158

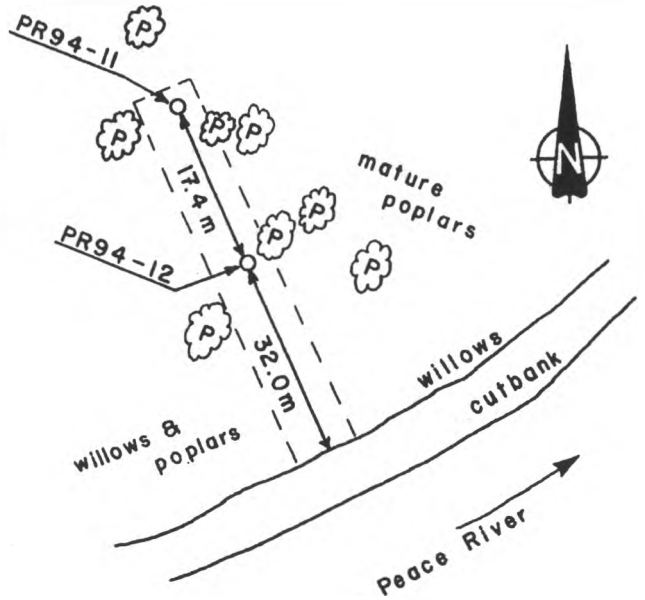
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

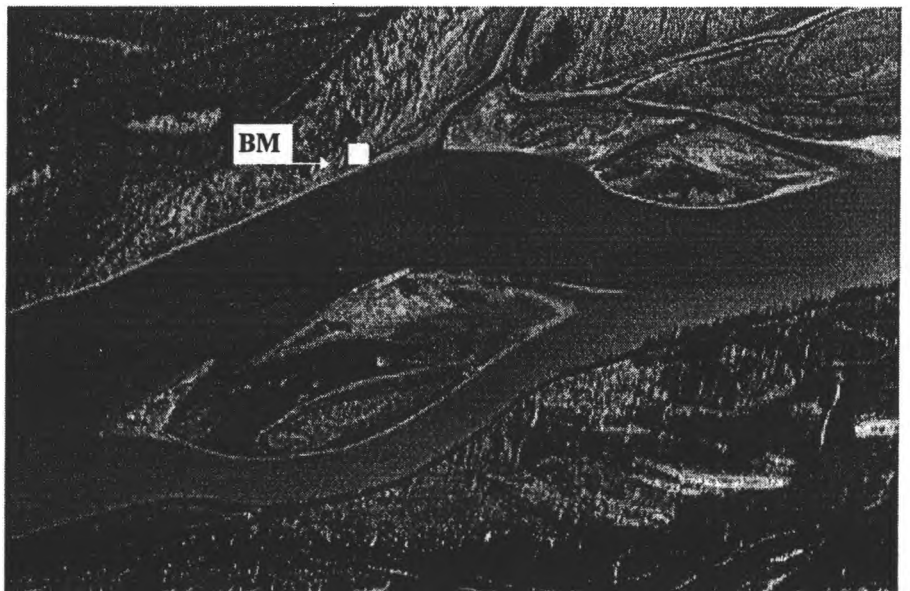
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 47-NE
Roll: AS4475 Photo: 340

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-12** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 12, 94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of five 5-foot lengths of 1/2" dia. rod., extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River, upstream of a small channel, at Km. 5.6 (Mile 3.5), in a 2m wide cut-line. Benchmark is 17.4m towards river from BM WSC PR94-11, and 32.0m inland from the top of cutbank, on the edge of an area of mature poplars.

HISTORICAL/other marker names, etc.

Benchmark was established July 12, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: 58° 58' 42" UTM Northing: 6537743.825
Longitude: 111° 29' 34" Easting: 471671.158

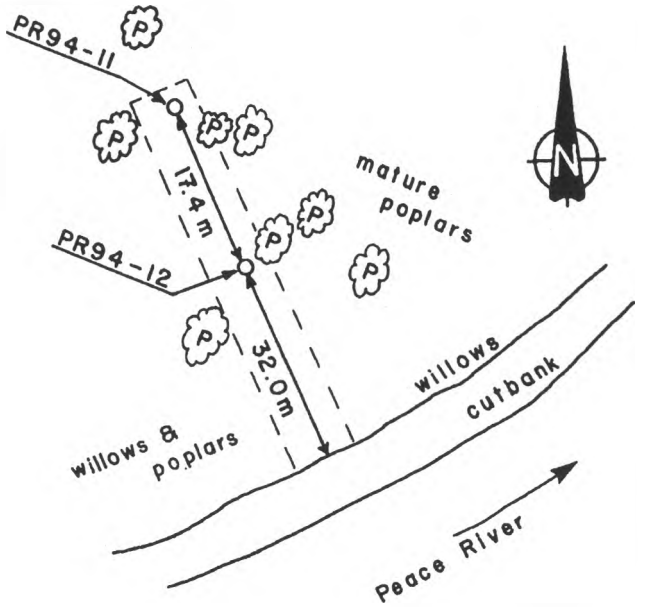
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

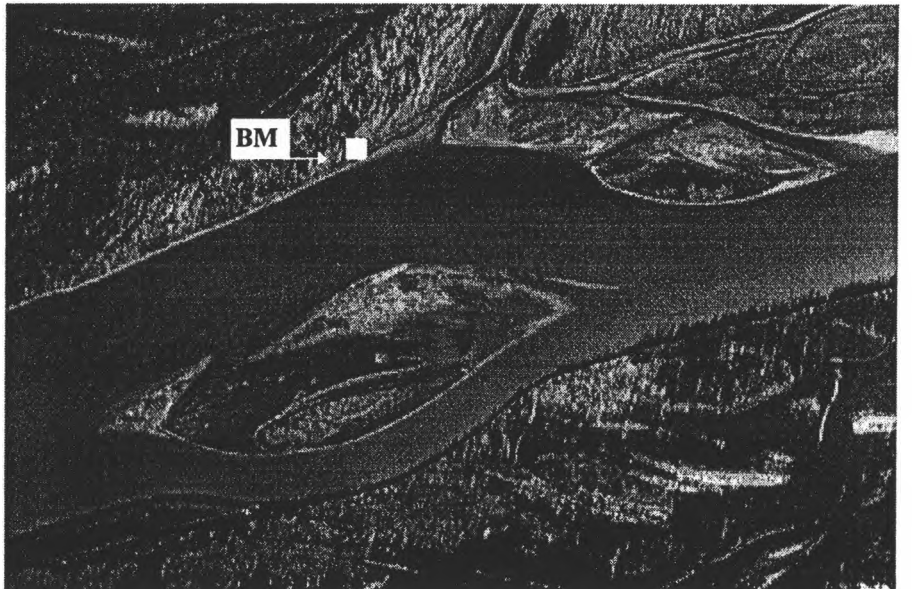
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 47-NE
Roll: AS4475 Photo: 340

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-21**

ELEV. Geodetic:

Assumed:

INSTALLED: JUL. 12-94 UPDATED:

CONDITION: NEW

BENCH MARK DESCRIPTION

1. Benchmark is a ground rod made of five 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River, upstream of Scow Channel, at Km. 9.6 (Mile 6), in a 2m wide cut-line. Benchmark is set 4m towards river from large poplar at back of cut-line, 15.8m inland from BM WSC PR94-022, and 35.8m inland from top of cutbank., in a mixed stand of poplar and alder.

HISTORICAL/other marker names, etc.

Benchmark was established July 12, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: 58° 57' 31" UTM Northing: 6535575.701

Longitude: 111° 33' 17" Easting: 468091.922

CROSS-SECTION

Number: Azimuth:

Number: Azimuth:

Number: Azimuth:

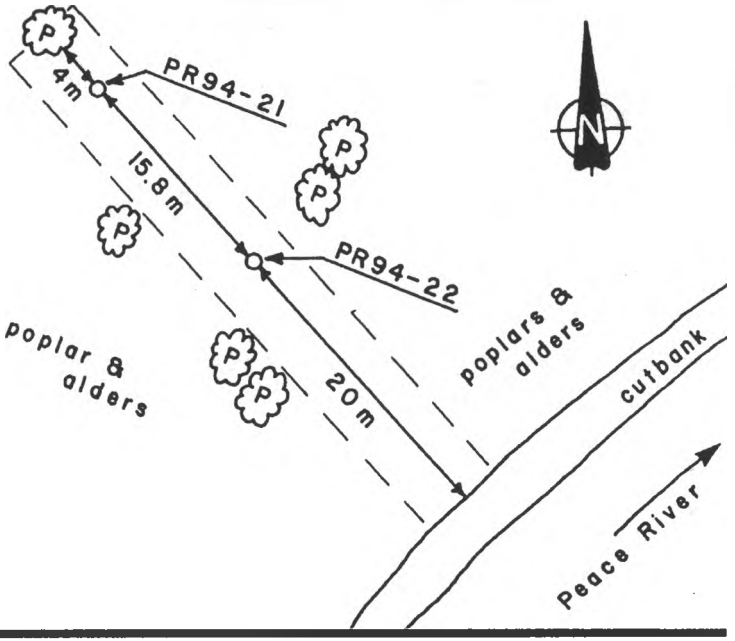
AIR PHOTO INFORMATION

Name: PEACE RIVER

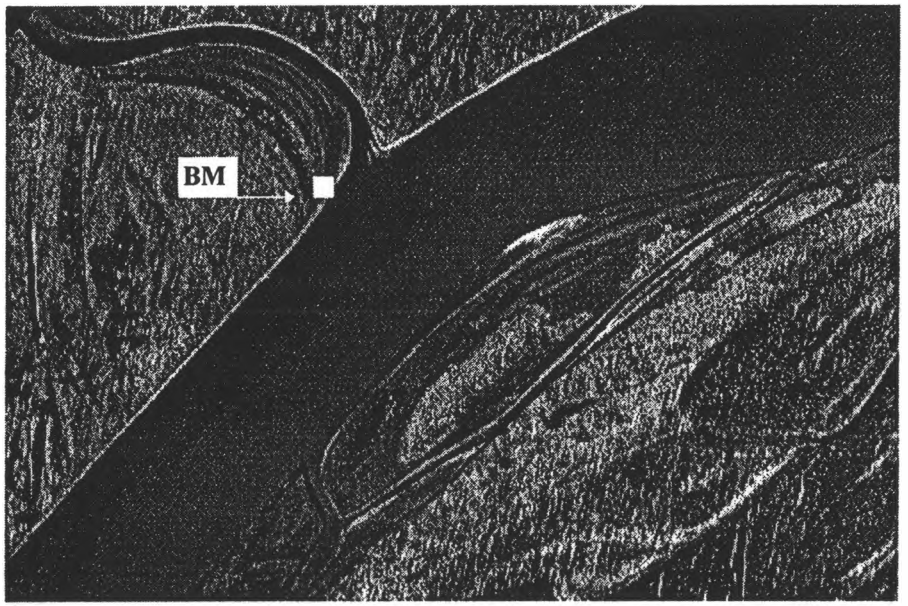
Date: OCT. 08-93 Line: 47-NE

Roll: AS4475 Photo: 338

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-22** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 12-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

1. Benchmark is a ground rod made of five 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River , upstream of Scow Channel, at Km. 9.6 (Mile 6), in a 2m wide cut-line. Benchmark is set 15.8m towards river from BM WSC PR94-021, and 20m inland from top of cutbank., in a mixed stand of poplar and alder.

HISTORICAL/other marker names, etc.

Benchmark was established July 12, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: 58° 57' 31" UTM Northing: 6535575.701
Longitude: 111° 33' 17" Easting: 468091.922

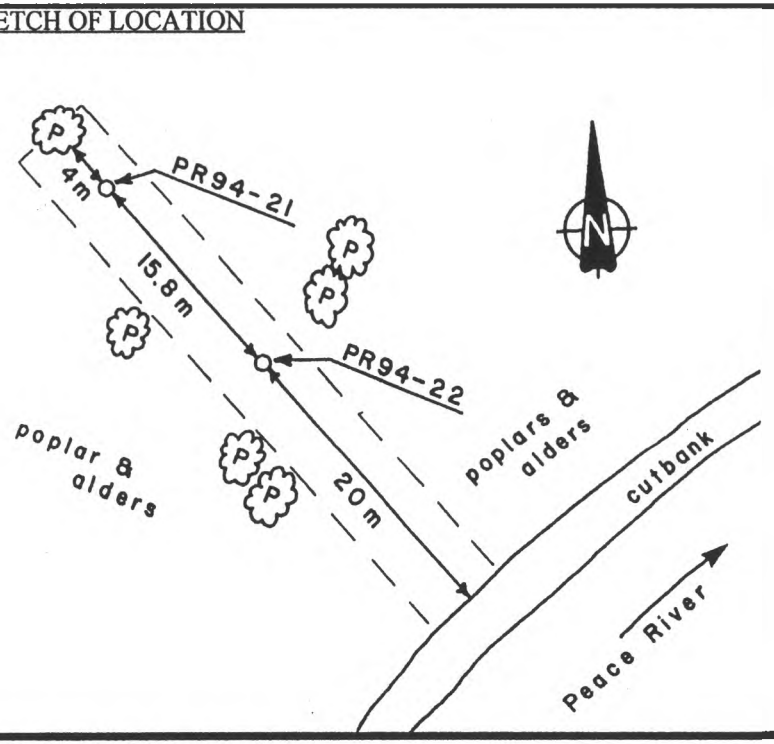
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

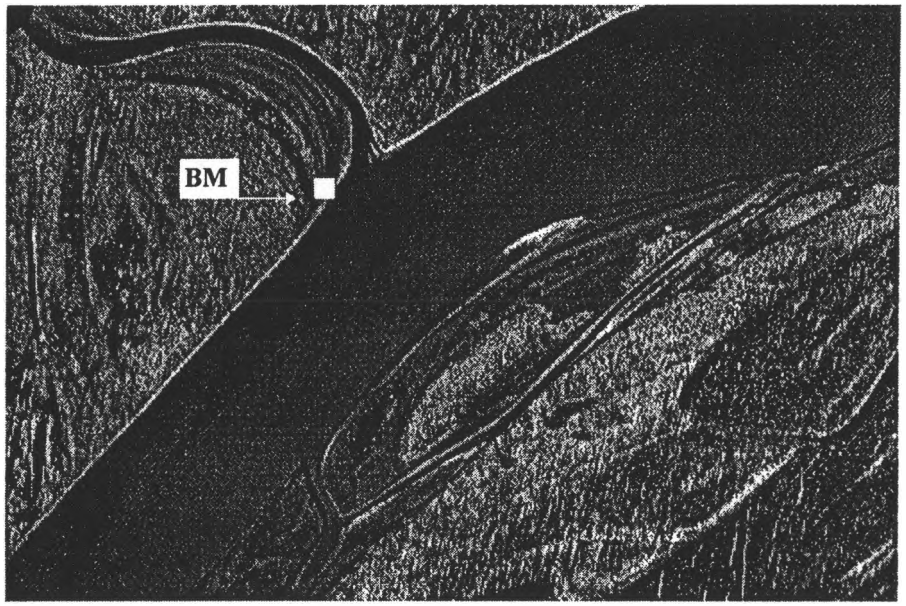
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 47-NE
Roll: AS4475 Photo: 338

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **TBM93-1**

ELEV. Geodetic: 215.182 m
Assumed:

INSTALLED: OCT. 26-93 UPDATED:

CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is an WSC Brass Cap located on the left bank of the Peace River below Rocky Point, in a cleared area with several cabins, Km 14.8 (Mile 9.2), at Alberta Environmental Protection station 07KC005. Benchmark is set in a bedrock outcrop 3.1m SW of SW corner of cabin, 23.4m inland from TBM93-2.

HISTORICAL/other marker names, etc.

Benchmark was set for use by Alberta Environmental Protection station 07KC005. See this station description for details.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: 58° 55' 00.2" UTM Northing: 6530930.803
Longitude: 111° 35' 37.6" Easting: 465804.044

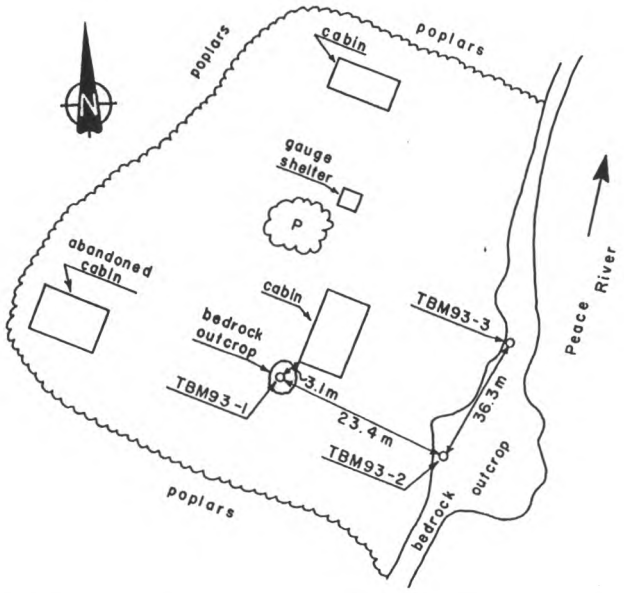
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

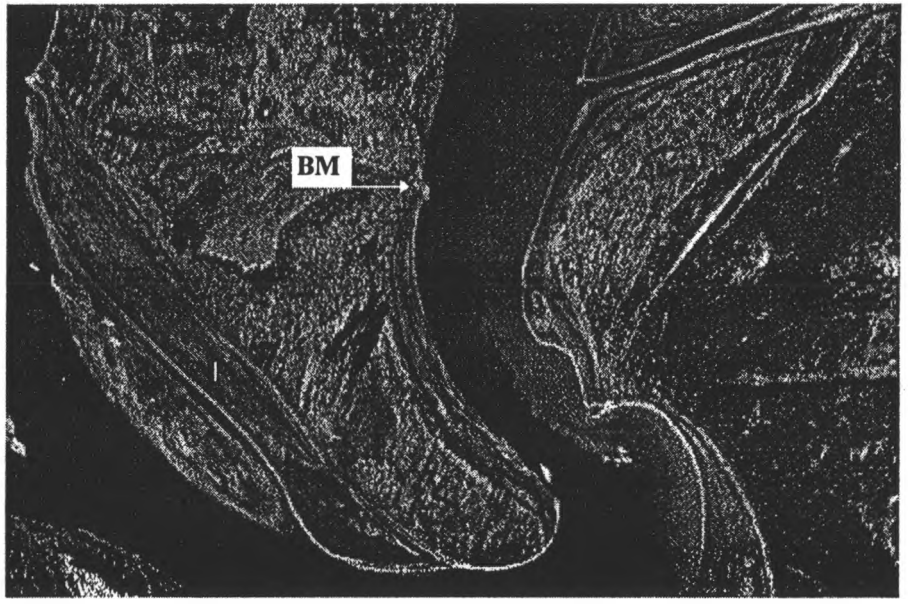
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **TBM93-2** ELEV. Geodetic: 213.839 m
Assumed:

INSTALLED: OCT. 26-93 UPDATED: SEP. 16-94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is an WSC Brass Cap located on the left bank of the Peace River below Rocky Point, in front of a cleared area with cabins, Km 14.8 (Mile 9.2), at Alberta Environmental Protection station 07KC005. Benchmark is set in a bedrock outcrop on rivers edge just below the top of the bank, 23.4m towards river from TBM93-1, and 36.3m upstream of TBM93-3 on the same rock outcrop.

HISTORICAL/other marker names, etc.

Benchmark was established for use by Alberta Environmental Protection station 07KC005 (see the station description for more details). Benchmark was tied Sept. 16, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study, to a GSC stake (PR4 ECC) set Aug. 10, 1993.

CO-ORDINATES **NAD83** (see Historical, above)

Latitude: 58° 54' 58.9" N UTM Northing: 6530866.164
Longitude: 111° 32' 31.8" W Easting: 468776.561

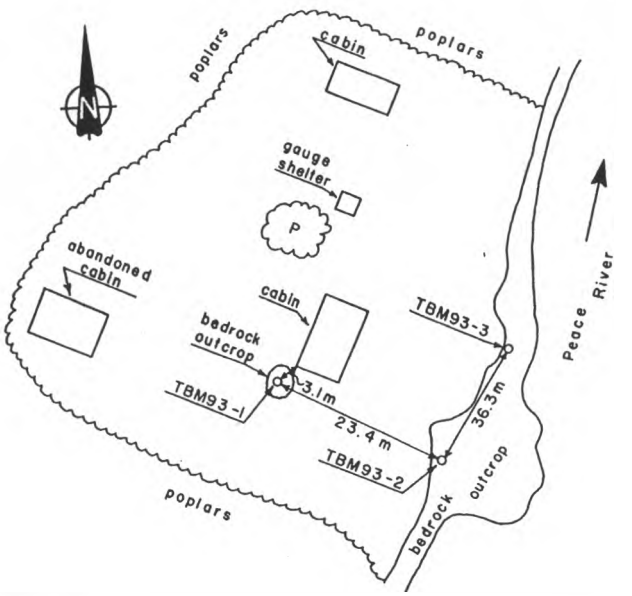
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

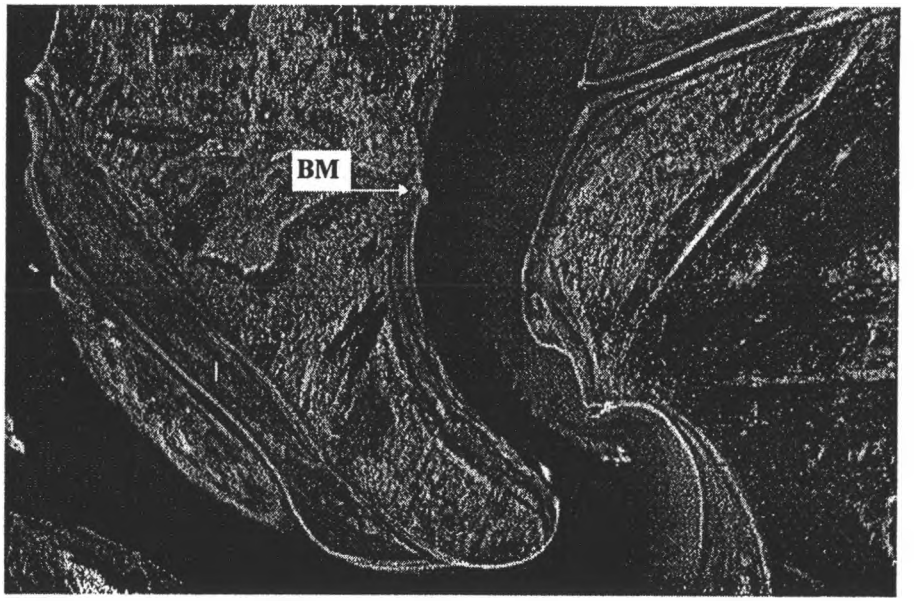
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **TBM93-3**

ELEV. Geodetic: 210.522 m
Assumed:

INSTALLED: OCT. 26-93 UPDATED:

CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is an WSC Brass Cap located on the left bank of the Peace River below Rocky Point, in front of a cleared area with cabins, Km 14.8 (Mile 9.2), at Alberta Environmental Protection station 07KC005. Benchmark is set in a bedrock outcrop on rivers edge just below the top of the bank, 36.3m downstream of TBM93-2 on the same rock outcrop.

HISTORICAL/other marker names, etc.

Benchmark was set for use by Alberta Environmental Protection station 07KC005. See this station description for details.

UTM and LAT/LONG coordinates derived by GPS with differential.

CO-ORDINATES: NAD83 (see Historical)

Latitude: 58° 55' 00.2" UTM Northing: 6530930.803
Longitude: 111° 35' 37.6" Easting: 465804.044

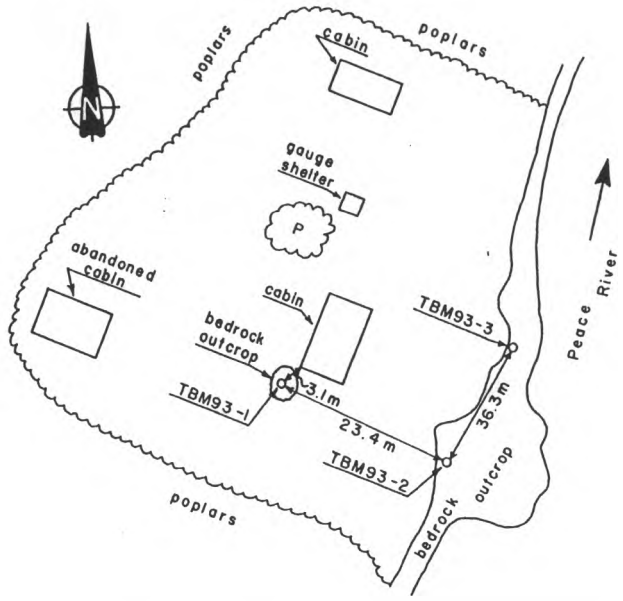
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO

BENCH MARK PROFILE

BENCH MARK NO: **PR94-31** ELEV. Geodetic: 214.760 m
Assumed:

INSTALLED: UPDATED: JUL. 12-94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is a WSC brass cap set in bedrock. Benchmark is located on the right bank of the Peace River at Rocky Point, Km. 16 (Mile 10). Benchmark is set at the top of the rock outcrop, 3m from the bush line, 1.4m inland from BM WSC PR94-032.

HISTORICAL/other marker names, etc.

The past history of this benchmark is unknown.

Benchmark was renamed WSC PR94-031 on July 12, 1994 for the Northern River basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by land survey and referenced to known GSC point determined by GPS with differential.

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°54'35.007" UTM Northing: 6530146.844
Longitude: W111°34'48.241" Easting: 466586.915

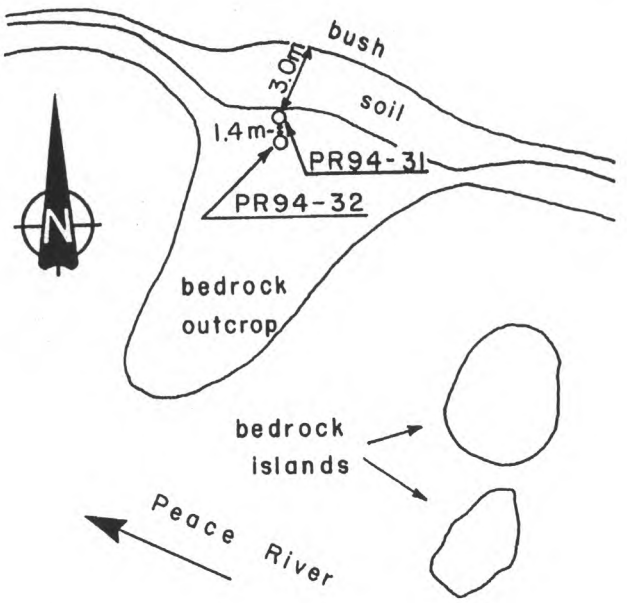
CROSS-SECTION

Number: PRX032 Azimuth:
Number: PRX033A Azimuth:
Number: Azimuth:

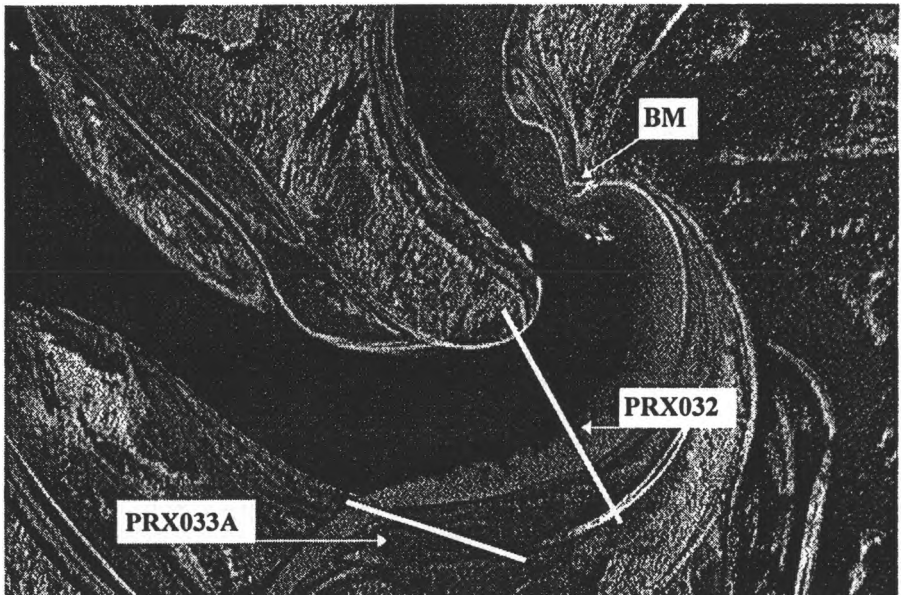
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-32** ELEV. Geodetic: 214.698 m
Assumed:

INSTALLED: unknown UPDATED: JUL. 12-94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is an iron pin set in bedrock. Benchmark is located on the right bank of the Peace River at Rocky Point, Km. 16 (Mile 10). Benchmark is set at the top of the rock outcrop, 1.4m towards river from BM WSC PR94-031.

HISTORICAL/other marker names, etc.

Reason for the establishment and the past history of this benchmark is unknown.

Benchmark was renamed WSC PR94-032 on July 12, 1994 for the Northern River basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by land survey and referenced to known GSC point determined by GPS with differential.

CO-ORDINATES: **NAD83** (see Historical)

Latitude: N 58°54'35.037" UTM Northing: 6530145.602
Longitude: W111°34'48.251" Easting: 466586.739

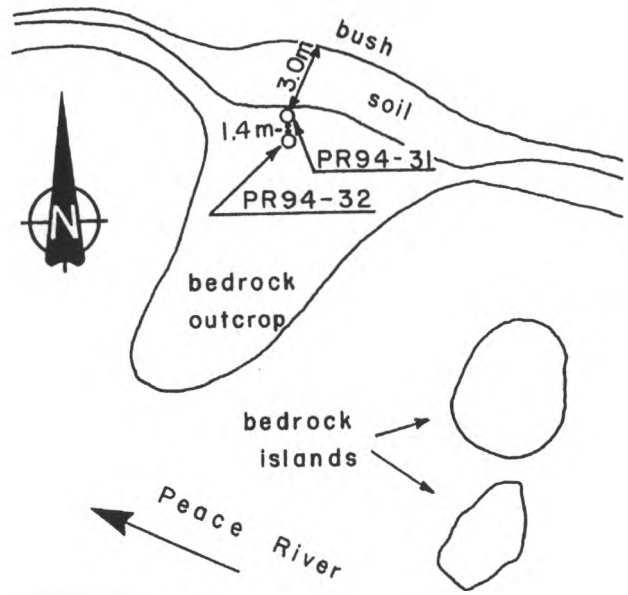
CROSS-SECTION

Number: PRX032 Azimuth:
Number: PRX033A Azimuth:
Number: Azimuth:

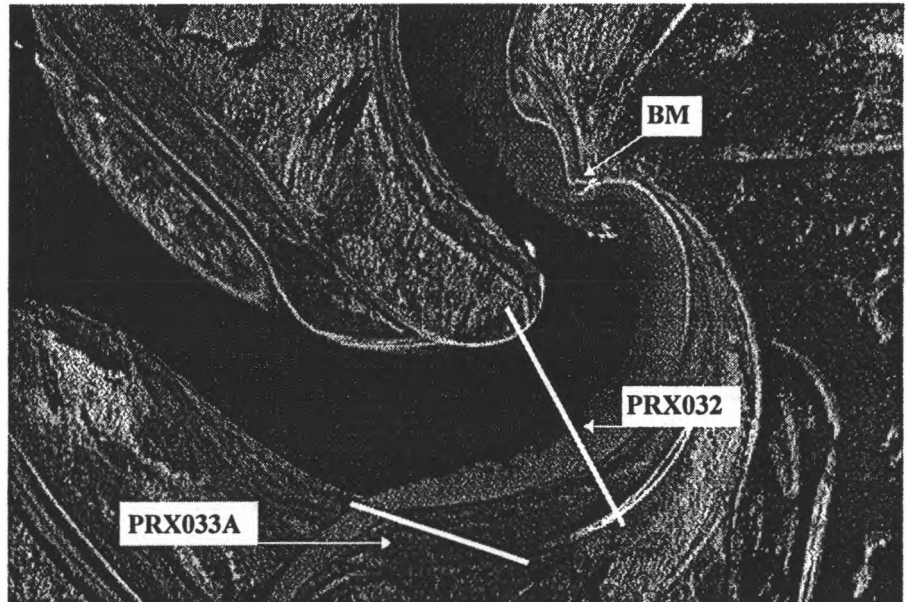
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-33** ELEV. Geodetic: 213.243 m
Assumed:

INSTALLED: Jul. 12-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of five 5-foot lengths of 1/2" dia. rod, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River upstream of rock outcrop at Rocky Point, at Km. 16.6 (Mile 10.3), in a 2m wide cut-line, within a group of 3 large spruce trees. Benchmark is set 48m inland from top of cutbank, 41m inland from BM TBM 90-1, in an area of level ground of very tall and large mature spruce.

HISTORICAL/other marker names, etc.

Benchmark was established July 12, 1994 by Water Survey of Canada (WSC) for the Northern River basin Study (NRBS) Peace Athabasca Delta (PAD) study. Benchmark was tied into TBM90-1 on Sept. 17, 1994, by WSC.

UTM and LAT/LONG coordinates approximate, used TBM90-1 values.

CO-ORDINATES: **NAD83** (see Historical)

Latitude: N 58° 54' 12.6" UTM Northing: 6529456.746
Longitude: W111° 35' 24.8" Easting: 465995.819

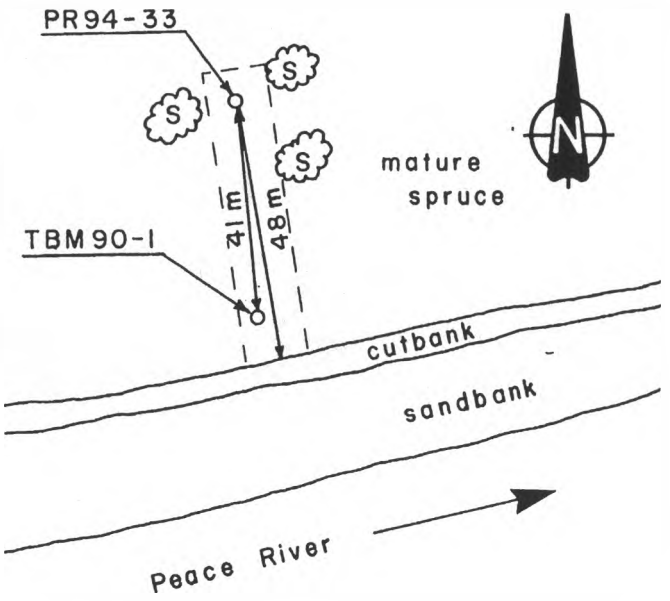
CROSS-SECTION

Number: PRX032 Azimuth:
Number: PRX033A Azimuth:
Number: Azimuth:

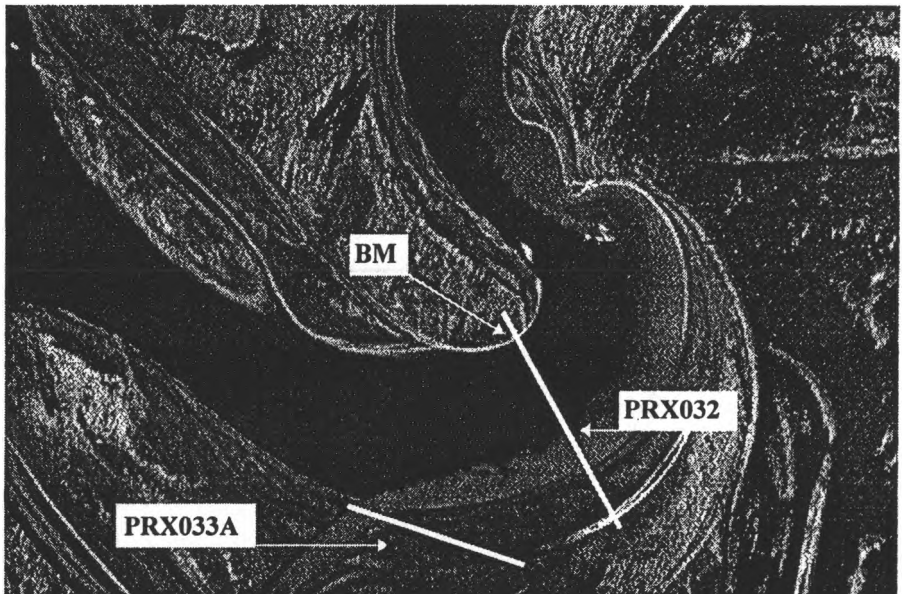
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **TBM90-1** ELEV. Geodetic: 213.850 m
Assumed:

INSTALLED: 1990 UPDATED: AUG. 1993 CONDITION: FAIR

BENCH MARK DESCRIPTION

Benchmark is spike driven into 15.2cm poplar tree. Benchmark is located on the left bank of the Peace River upstream of rock outcrop at Rocky Point, at Km. 16.6 (Mile 10.3), offset slightly upstream near the mouth of a 2m wide cut-line. Benchmark is set approx. 7m inland from top of steep cutbank, 41m toward river from BM WSC PR94-033, in an area of level ground of very tall and large mature spruce.

HISTORICAL/other marker names, etc.

Benchmark was established in 1990 by Alberta Environmental Protection for a hydrometric station, since moved. Benchmark was updated by GSC in Aug., 1993, for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and **Lat./Long.** coordinates derived by GPS with differential.

CO-ORDINATES: NAD83 (see Historical)

Latitude: 58° 54' 12.6" UTM Northing: 6529456.746
Longitude: 111° 35' 24.8" Easting: 465995.819

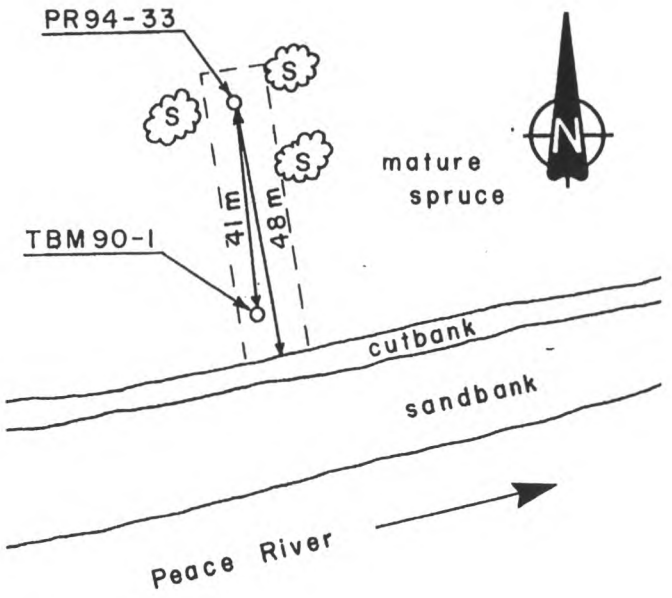
CROSS-SECTION

Number: PRX032 Azimuth:
Number: PRX033A Azimuth:
Number: Azimuth:

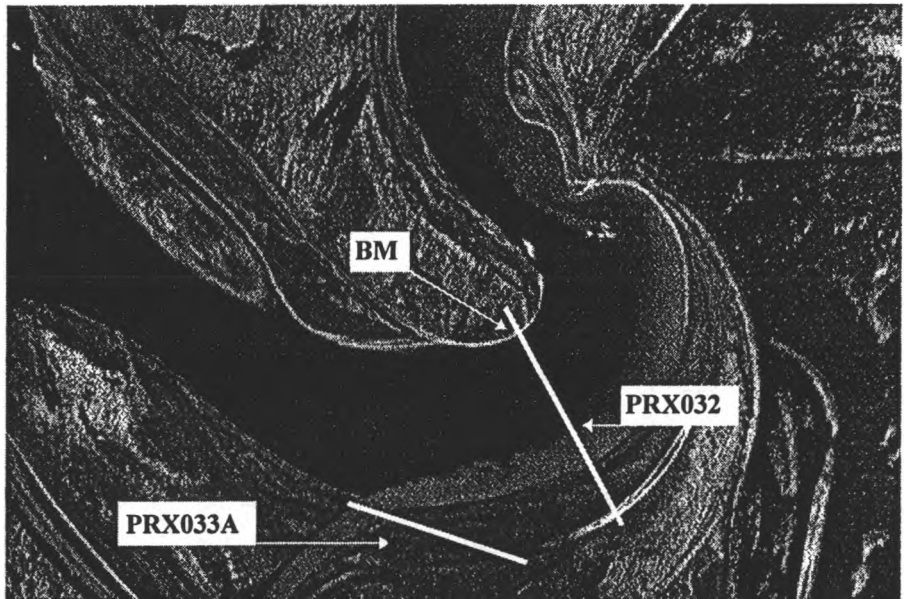
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-41** ELEV. Geodetic: 214.376 m
Assumed:

INSTALLED: AUG. 31-81 UPDATED: JUL. 15-94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of two 6-foot lengths of 3/8" dia. rod, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the right bank of the Peace River across from the downstream tip of Sawmill Island and just upstream from the mouth of a small channel, at Km. 19.7 (Mile 12.3), in a 2m wide cut-line. Benchmark is set 1m from a large poplar at back of cut-line, 12.6m inland from top of cutbank.

HISTORICAL/other marker names, etc.

Benchmark was established by Water Survey of Canada (WSC) in 1981 for cross-sections of the Peace River, and tied by McElhanney Surveying & Engineering Ltd. in 1982 (their file #163214), as Point 1, Cross-Section #6. Renamed and marked as PR94-41 by WSC on July 15, 1994, for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and **LAT/LONG** coordinates derived by GPS with differential.

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°55'38" UTM Northing: 6524390
Longitude: W 111°37'32" Easting: 463952

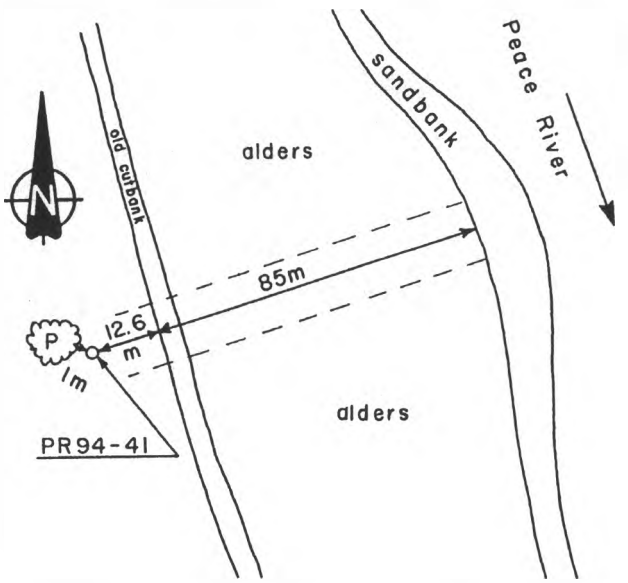
CROSS-SECTION

Number: PRX041 Azimuth:
Number: PRX042LC Azimuth:
Number: PRX042RC Azimuth:

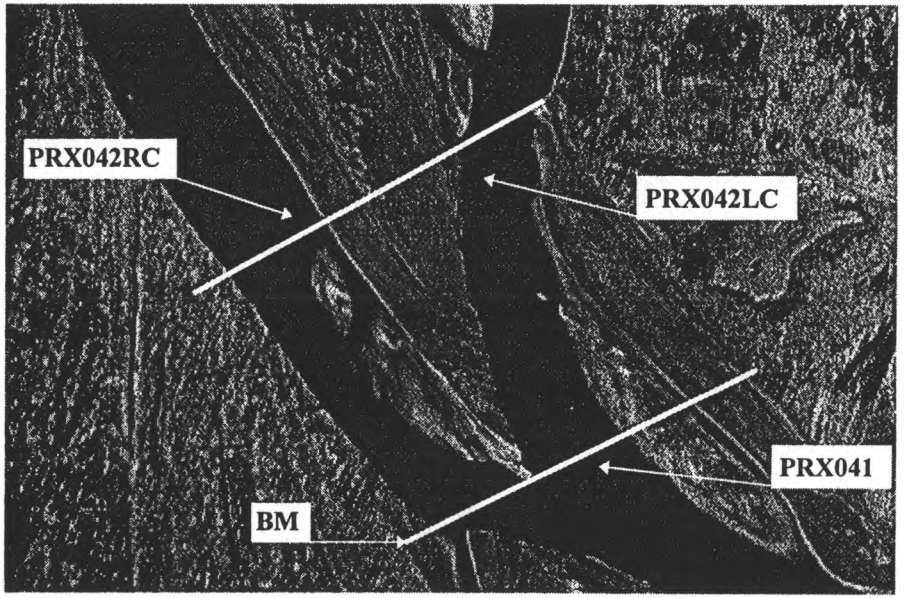
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-42** ELEV. Geodetic: 215.520 m
Assumed:

INSTALLED: AUG. 13-81 UPDATED: JUL. 15, 94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is the SE corner of concrete foundation, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m from concrete foundation. Benchmark is located on the left bank of the left channel of the Peace River across from Sawmill Island, at Km. 20.2 (Mile 12.6), in a clearing about 10m inland from the top of the cutbank and just inland from BM WSC PR94-43.

Note that a trapper is planning to build a cabin at this site.

HISTORICAL/other marker names, etc.

Benchmark was established by Water Survey of Canada (WSC) in 1981 for cross-sections of the Peace River, and tied by McElhanney Surveying & Engineering Ltd. in 1982 (their file #163214), as BM "S.E. Corner", Cross-Section #8. Benchmark was updated by GSC for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study. on Aug. 10, 1993. Benchmark was renamed and marked as PR94-42 on July 15, 1994 by WSC.

UTM and **LAT/LONG** coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°55'05" UTM Northing: 6531100
Longitude: W 111°37'12" Easting: 464294

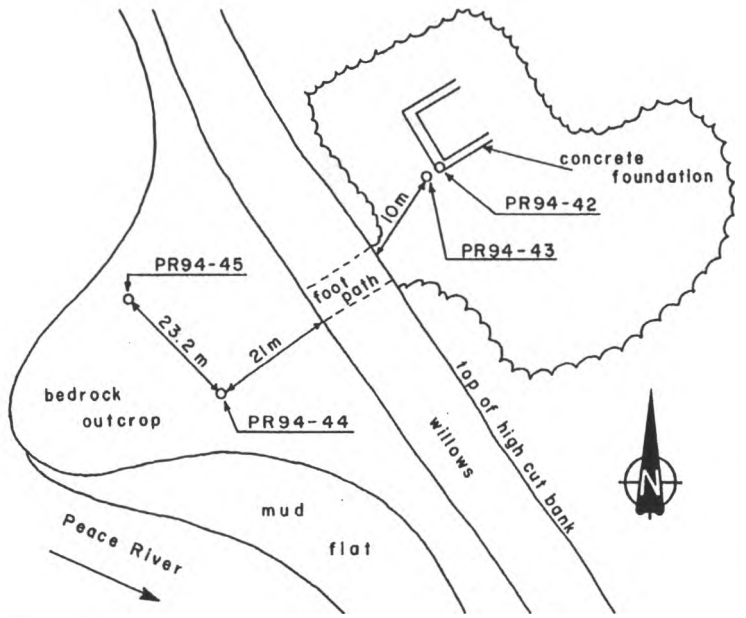
CROSS-SECTION

Number: PRX042LC Azimuth:
Number: PRX042RC Azimuth:
Number: Azimuth:

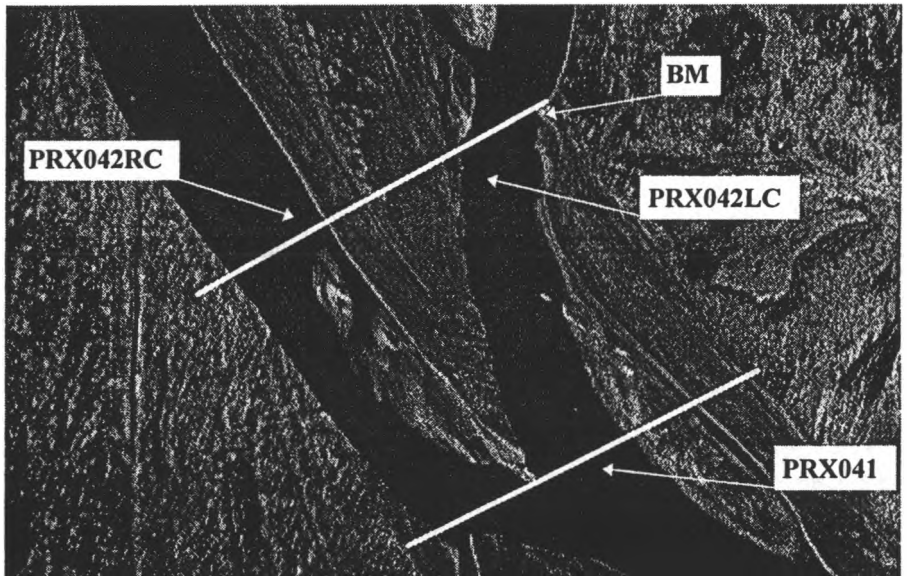
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-94 Line: 45-ESE
Roll: AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH M. .K PROFILE

BENCH MARK NO: **PR94-43** ELEV. Geodetic: 215.566 m
Assumed:

INSTALLED: JUL. 15, 94 UPDATED: SEP. 18-94 CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of three 5-foot lengths of 1/2" dia. rod, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the left channel of the Peace River across from Sawmill Island, at Km. 20.2 (Mile 12.6), in a clearing. Benchmark is set 10m NNE from the top of a high cut bank at the head of a footpath, and very near BM WSC PR94-041, which is set on the SE corner of a concrete foundation.

Note that a trapper is planning to build a cabin at this site.

HISTORICAL/other marker names, etc.

Benchmark was established July 15, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study. Benchmark was tied to BM PR94-42 by WSC on Sept. 18, 1994.

UTM and LAT/LONG coordinates derived by GPS with differential.

CO-ORDINATES: **NAD83** (see Historical)

Latitude: N 58°55'05" UTM Northing: 6531099.792
Longitude: W 111°37'12" Easting: 464292.994

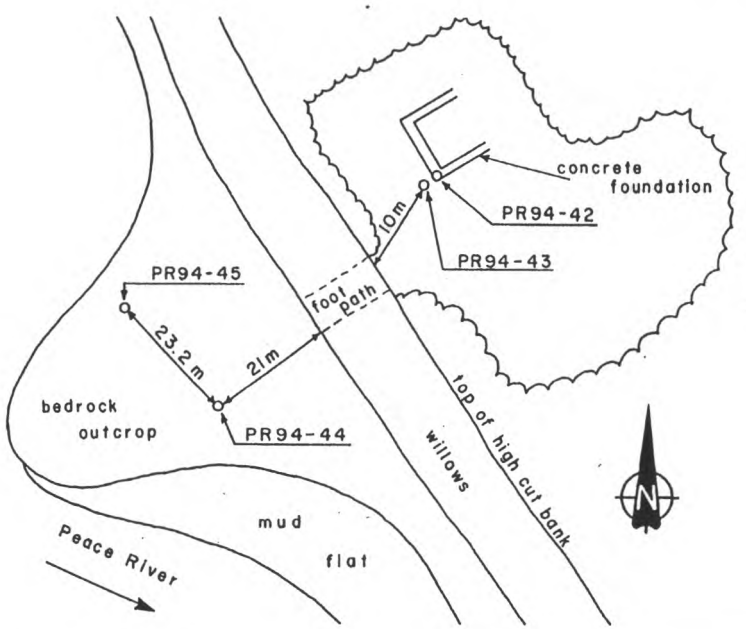
CROSS-SECTION

Number: PRX042LC Azimuth:
Number: PRX042RC Azimuth:
Number: Azimuth:

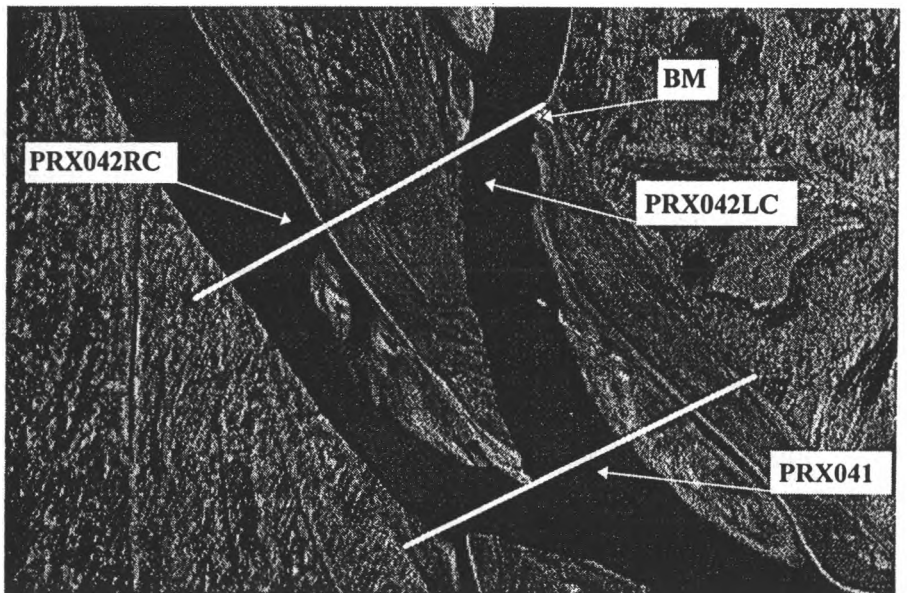
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-94 Line: 45-ESE
Roll: AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-44** ELEV. Geodetic: 211.394 m
Assumed:

INSTALLED: JUL. 15, 94 UPDATED: SEP. 18-94 CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a WSC brass cap set in bedrock. Benchmark is located on an rock outcrop on the left bank of the left channel of the Peace River across from Sawmill Island, at Km. 20.2 (Mile 12.6). Benchmark is set 21m SW from the bottom of a footpath at the base of a high cut bank, and 23.2m downstream from BM WSC PR94-045.

Note that benchmark can be covered with mud or debris following high water.

HISTORICAL/other marker names, etc.

Benchmark was established July 15, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study. Benchmark was tied to BM PR94-42 by WSC on Sept. 18, 1994.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: **NAD83** (see Historical)

Latitude: N 58° 55' 06" UTM Northing: 6531123.449
Longitude: W111° 37' 09" Easting: 464343.571

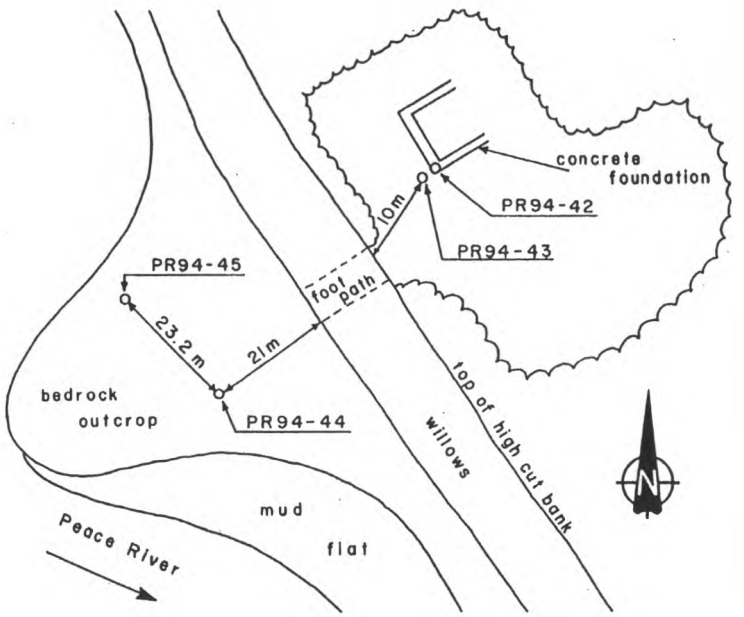
CROSS-SECTION

Number: PRX042LC Azimuth:
Number: PRX042RC Azimuth:
Number: Azimuth:

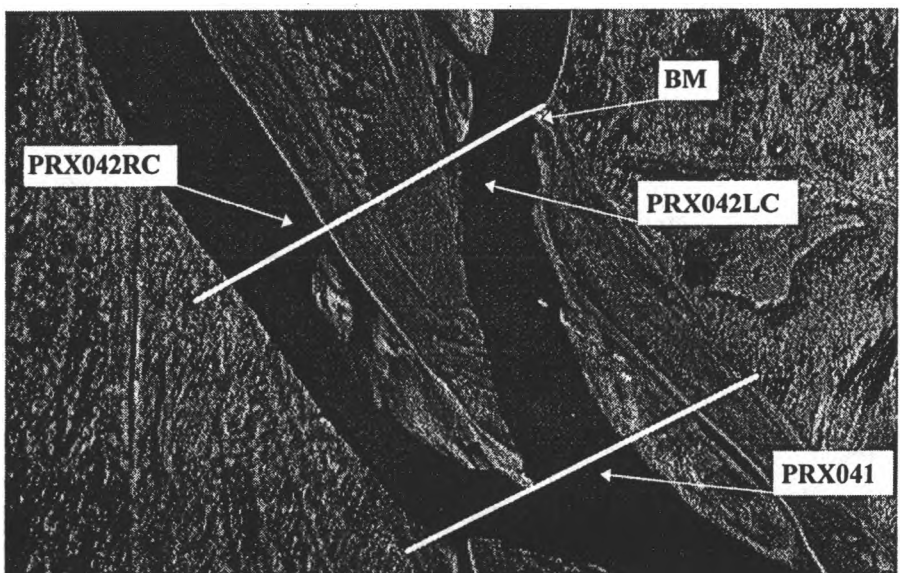
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-94 Line: 45-ESE
Roll: AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MA K PROFILE

BENCH MARK NO: **PR94-45** ELEV. Geodetic: 210.900 m
Assumed:

INSTALLED: JUL. 15, 94 UPDATED: SEP. 18-94 CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a WSC brass cap set in bedrock. Benchmark is located on a rock outcrop on the left bank of the left channel of the Peace River across from Sawmill Island, at Km. 20.2 (Mile 12.6). Benchmark is set 23.2m upstream from BM WSC PR94-44.

Note that benchmark can be covered with mud or debris following high water.

HISTORICAL/other marker names, etc.

Benchmark was established July 15, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study. Benchmark was tied to BM PR94-42 by WSC on Sept. 18, 1994.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 55' 06" UTM Northing: 6531123.449
Longitude: W111° 37' 09" Easting: 464343.571

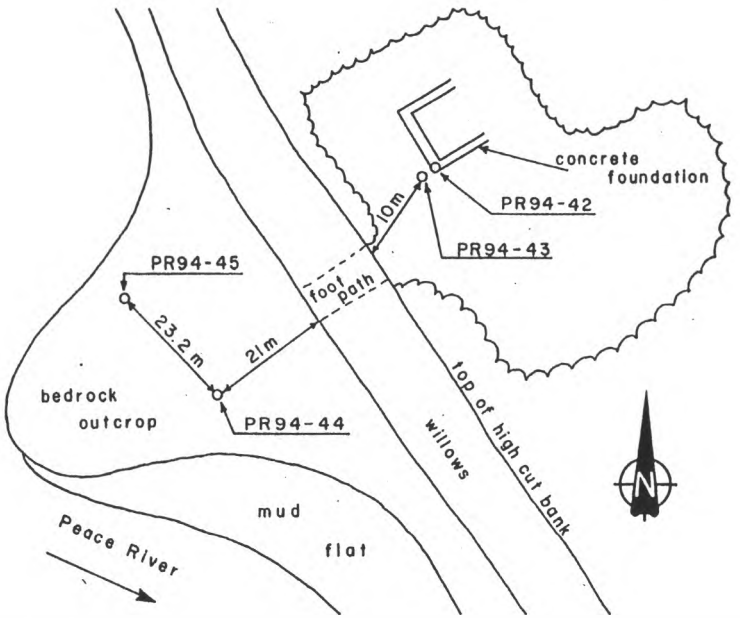
CROSS-SECTION

Number: PRX042LC Azimuth:
Number: PRX042RC Azimuth:
Number: Azimuth:

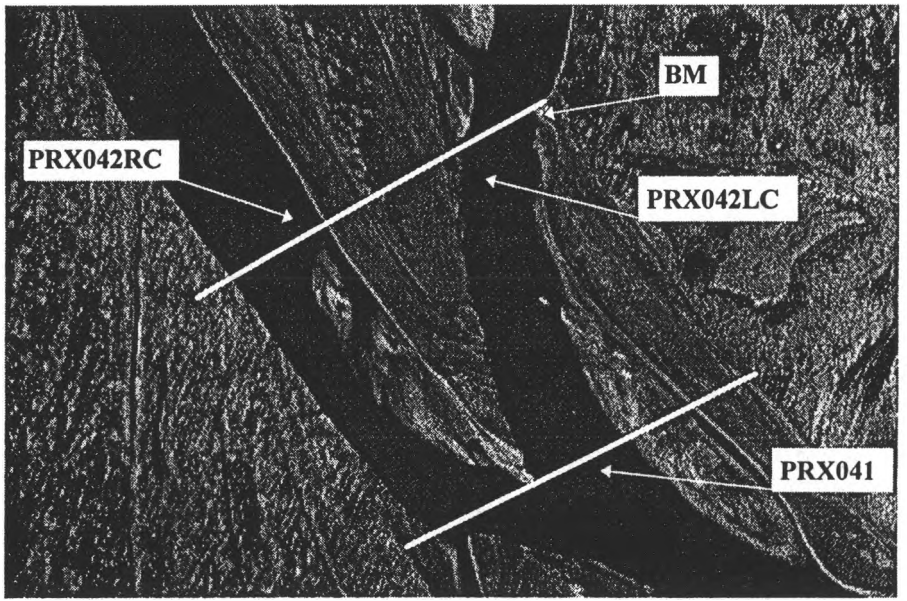
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-94 Line: 45-ESE
Roll: AS4475 Photo: 320

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-51**

ELEV. Geodetic:

Assumed:

INSTALLED: Jul. 13-94 UPDATED:

CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of three 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River on the upstream side of an old logging road located at Km. 24 (Mile 15). Benchmark is set 32.5m inland from top of steep cutbank, 11m inland from BM WSC PR94-52, in a level area of mature spruce.

HISTORICAL/other marker names, etc.

Benchmark was established July 12, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 56' 41" UTM Northing: 6534091.070

Longitude: W111° 40' 19" Easting: 461333.797

CROSS-SECTION

Number: Azimuth:

Number: Azimuth:

Number: Azimuth:

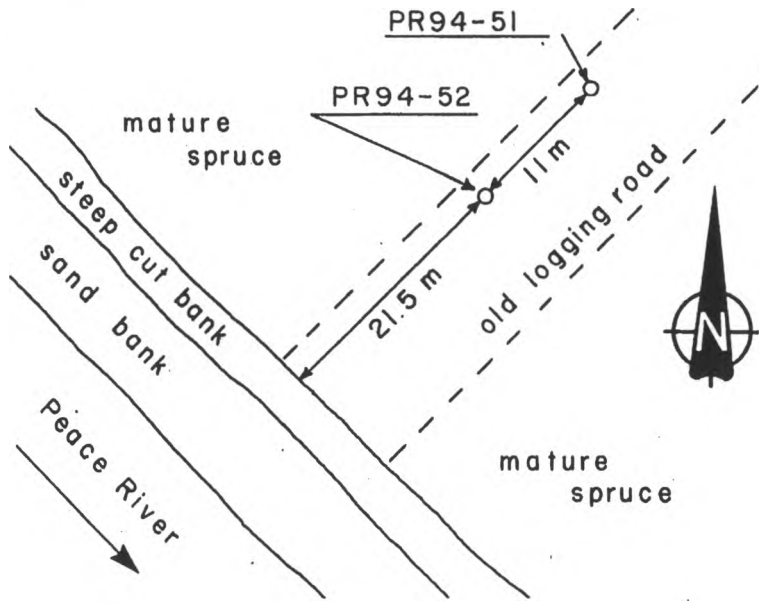
AIR PHOTO INFORMATION

Name: PEACE RIVER

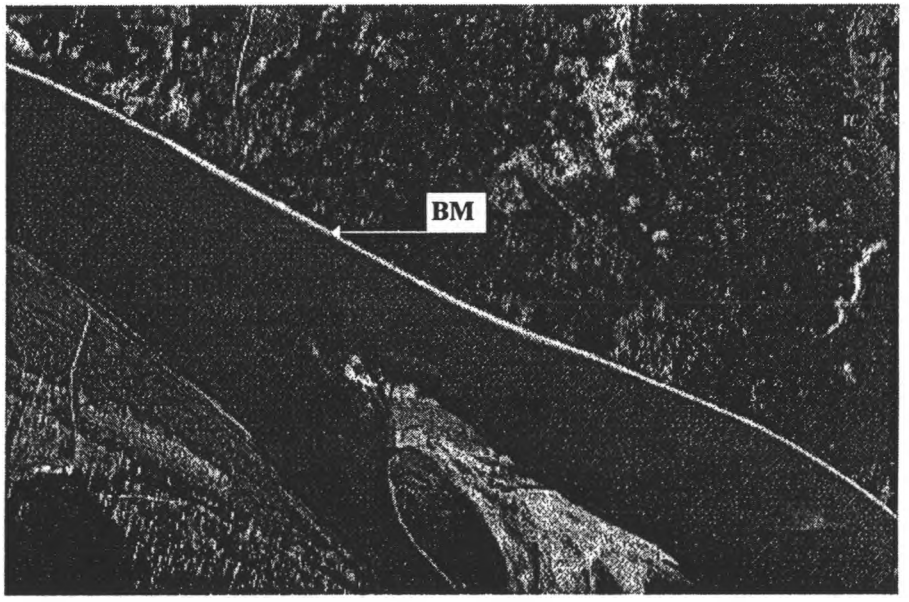
Date: OCT. 08-93 Line: 46-WNW

Roll: AS4475 Photo: 329

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-52**

ELEV. Geodetic:
Assumed:

INSTALLED: Jul. 13-94 UPDATED:

CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of three 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River on the upstream side of an old logging road located at Km. 24 (Mile 15). Benchmark is set 21.5m inland from top of steep cutbank, 11m towards river from BM WSC PR94-51, in a level area of mature spruce.

HISTORICAL/other marker names, etc.

Benchmark was established July 12, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 56' 41" UTM Northing: 6534091.070
Longitude: W111° 40' 19" Easting: 461333.797

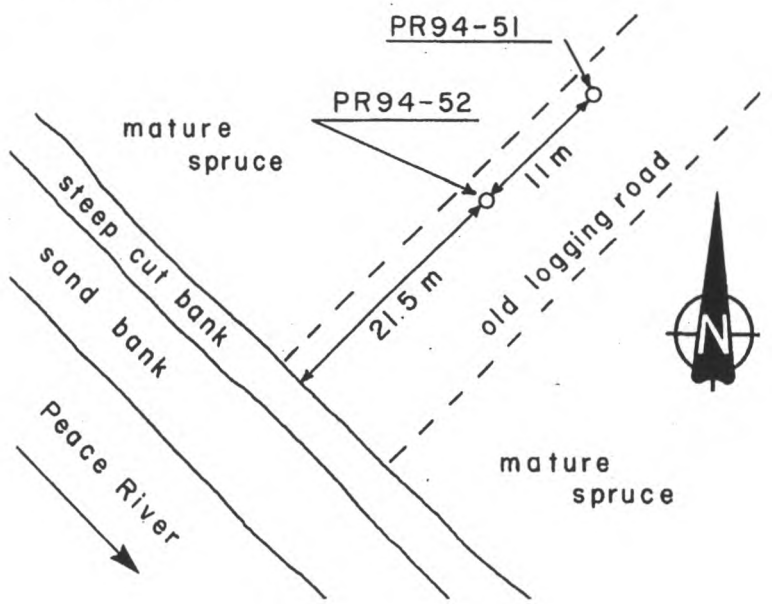
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

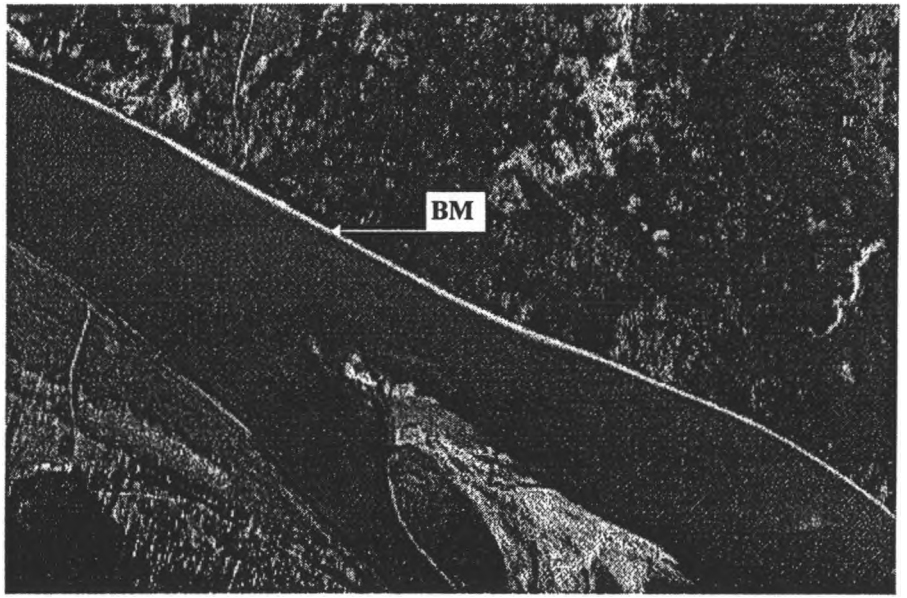
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 46-WNW
Roll: AS4475 Photo: 329

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-61** ELEV. Geodetic: 218.478 m
Assumed:

INSTALLED: JUL. 13-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River, upstream of a winter road crossing known as Moose Island Crossing, at Km. 26.7 (Mile 16.7), in a clearing. Benchmark is set 26m inland from top of sand bank., between two poplar trees.

HISTORICAL/other marker names, etc.

Benchmark was established July 13, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

Benchmark was tied in to BM WSC PR94-63 on Sept. 19, 1994.

UTM and LAT/LONG coordinates derived by GPS with differential.

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°57'04.350" UTM Northing: 6534836.173
Longitude: W111°42'37.595" Easting: 459126.172

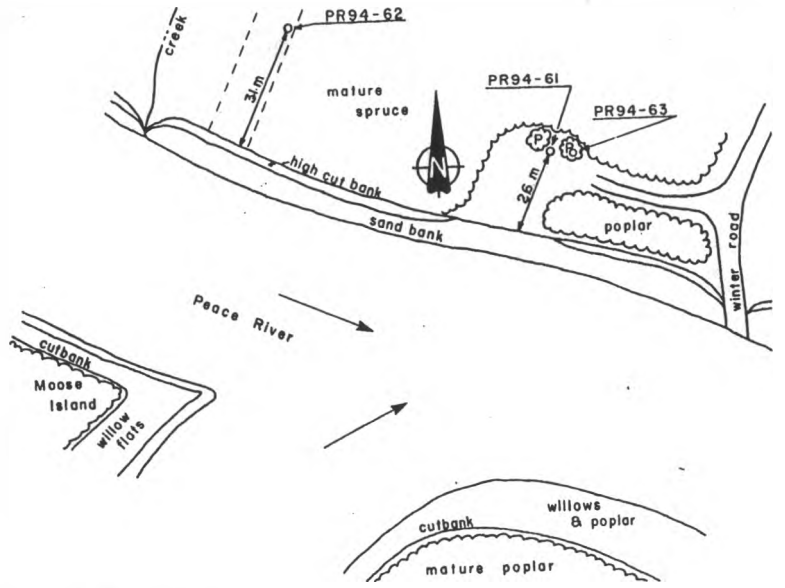
CROSS-SECTION

Number: PRX061LC Azimuth:
Number: PRX062RC Azimuth:
Number: Azimuth:

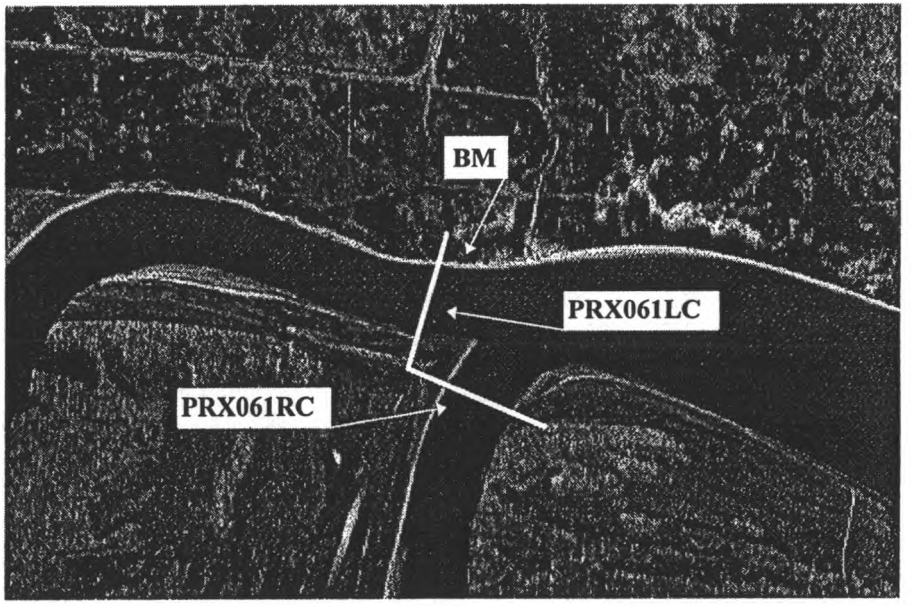
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 46-WNW
Roll: AS4475 Photo: 328

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-62**

ELEV. Geodetic: 218.135 m
Assumed:

INSTALLED: JUL. 13-94 UPDATED:

CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River, upstream of a winter road crossing known as Moose Island Crossing, at Km. 26.9 (Mile 16.8), in a cut-line. Benchmark is set 31m inland from top of high cutbank., upstream of BM WSC PR94-61 and BM WSC PR94-63, downstream of a small creek, in a level area of mature spruce.

HISTORICAL/other marker names, etc.

Benchmark was established July 13, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

Benchmark was tied in to BM WSC PR94-63 on Sept. 19, 1994.

UTM and LAT/LONG coordinates derived by GPS with differential.

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°57'05.936" UTM Northing: 6534887.399
Longitude: W 111°42'50.458" Easting: 458921.124

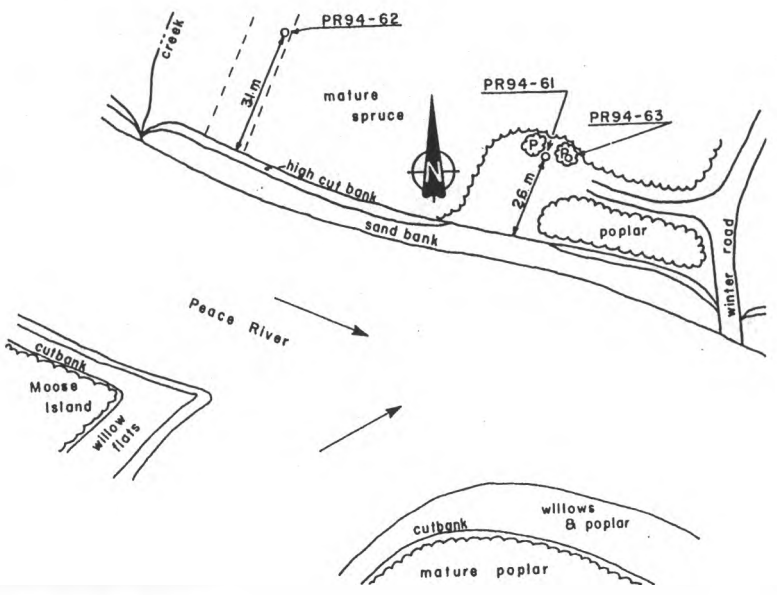
CROSS-SECTION

Number: PRX061LC Azimuth:
Number: PRX061RC Azimuth:
Number: Azimuth:

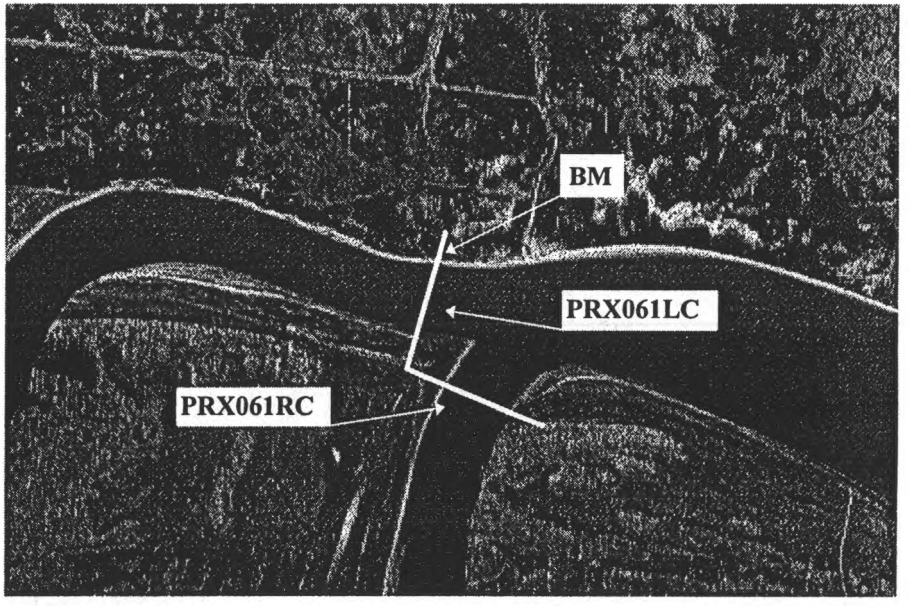
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 46-WNW
Roll: AS4475 Photo: 328

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-63** ELEV. Geodetic: 218.700 m
Assumed:

INSTALLED: AUG. 10-93 UPDATED: JUL. 13-94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is 4 nails in a tree, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River, upstream of a winter road crossing known as Moose Island Crossing, at Km. 26.7 (Mile 16.7), in a clearing. Benchmark is set approx. 26m inland from top of sand bank., in downstream of two large poplar trees; between the trees is located WSC BM PR94-61.

HISTORICAL/other marker names, etc.

Benchmark was established by Geological Survey of Canada (GSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD)study, as "nail in tree", Aug. 10, 1993. Renamed and marked as PR94-63 by WSC, July 13, 1994.

UTM and LAT/LONG coordinates derived by land survey and referenced to known GSC point determined by GPS with differential.

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°57'04.387" UTM Northing: 6534837.313
Longitude: W111°42'37.583" Easting: 459126.376

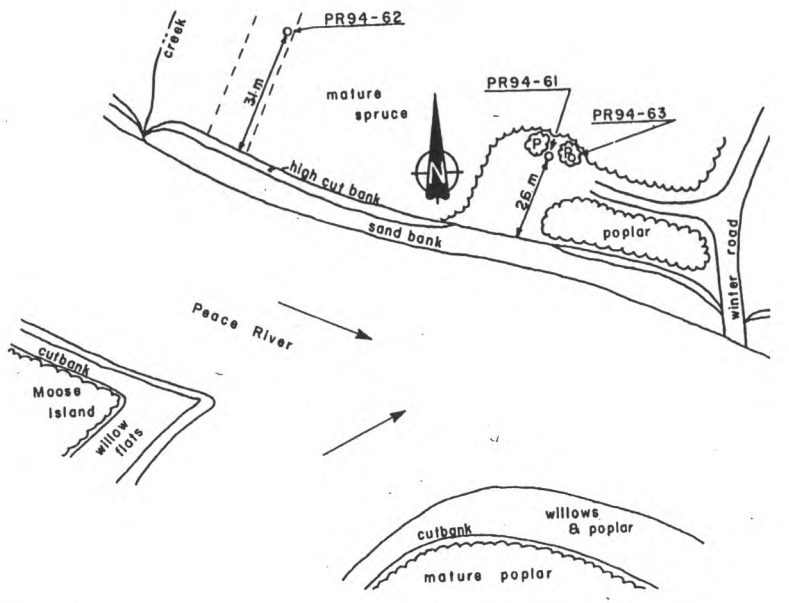
CROSS-SECTION

Number: PRX061LC Azimuth:
Number: PRX062RC Azimuth:
Number: Azimuth:

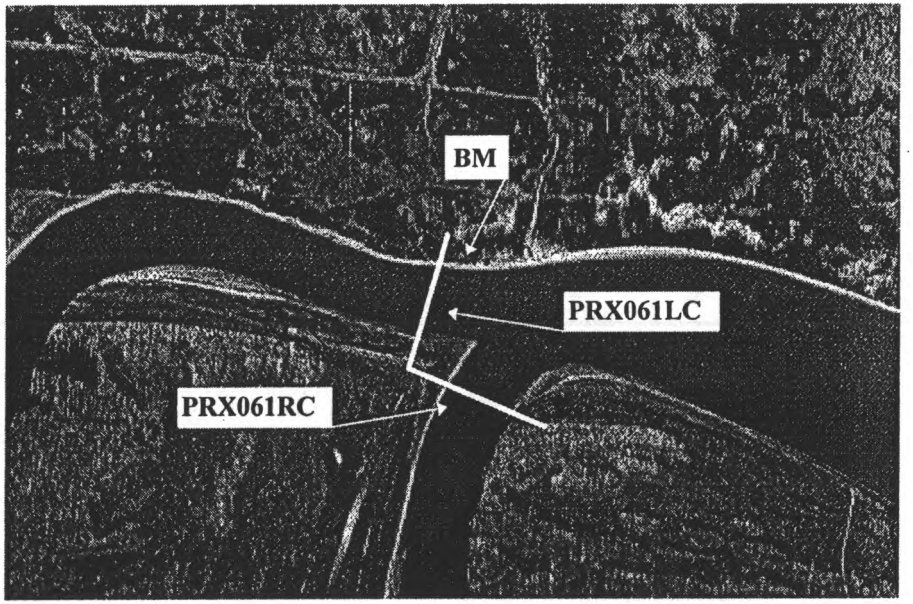
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 46-WNW
Roll: AS4475 Photo: 328

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-71** ELEV. Geodetic: 214.300 m
Assumed:

INSTALLED: 1981 UPDATED: JUL. 13-94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of three 6-foot lengths of 3/8" dia. rod, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 32.2 (Mile 20.1), at the mouth of and downstream edge of a 2m wide cut-line, near a grouping of 3 poplar trees. Benchmark is set approx. 4.5m inland from top of cutbank, 22.6m toward river from BM WSC PR94-72. Just downstream of the BM the cutbank changes to a willow covered bank.

The BM will be destroyed as the river continues to cut away at the bank.

HISTORICAL/other marker names, etc.

Benchmark was established by Water Survey of Canada (WSC) in 1981 for cross-sections of the Peace River, and tied by McElhanney Surveying & Engineering Ltd. in 1982 (their file #163214), as Point 1, Cross-Section #13 & #15.

Benchmark was tied in by GSC for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD)study, Aug.10, 1993. Renamed and marked as PR94-71 by WSC for NRBS, PAD study, Jul. 13, 1994.

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°56'56" UTM Northing: 6534628.141
Longitude: W 111°47'21" Easting: 454593.670

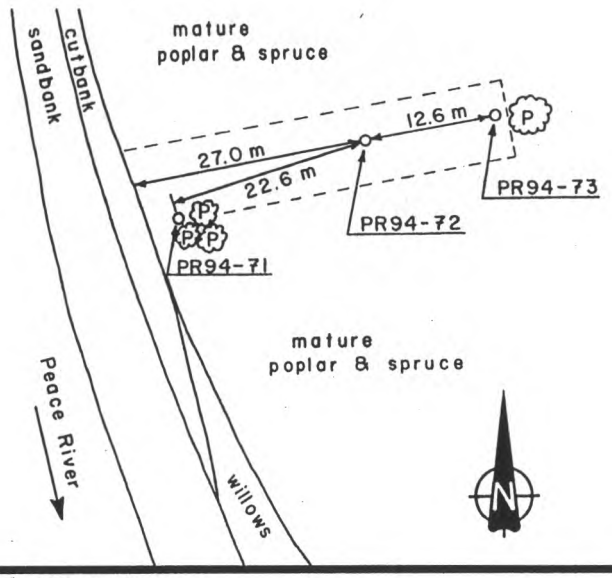
CROSS-SECTION

Number: PRX071MC Azimuth:
Number: PRX071RC Azimuth:
Number: PRX071LC Azimuth:

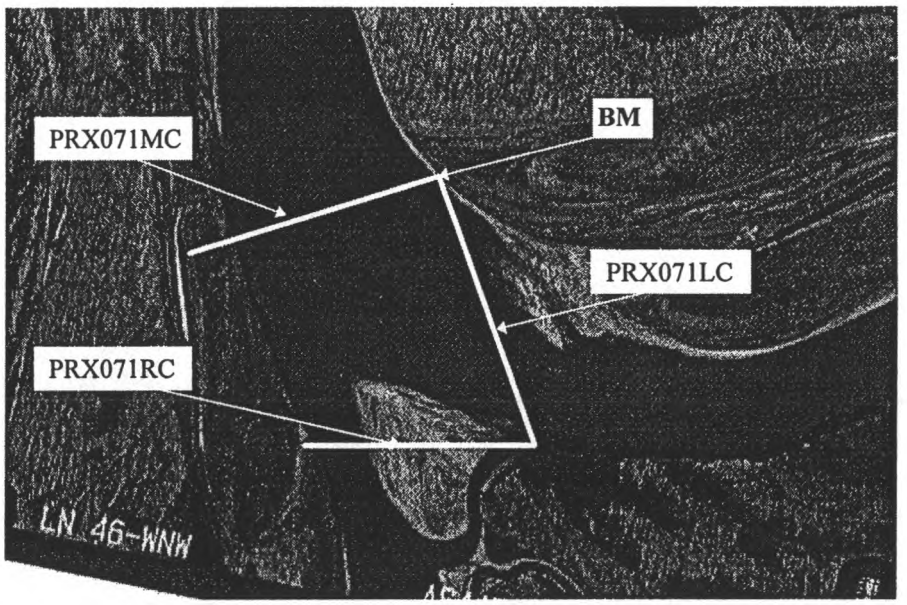
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT, 08-93 Line: 46-WNW
Roll: AS4475 Photo: 326

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-72** ELEV. Geodetic: 214.360 m

Assumed:

INSTALLED:JUL. 13-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 32.2 (Mile 20.1), in a 2m wide cut-line. Benchmark is set 27m inland from top of cutbank, 22.6m inland from BM WSC PR94-71 and 12.6m toward river from BM WSC PR94-73, in a level area of mature poplar and spruce. Just downstream of the BM the cutbank changes to a willow covered bank.

HISTORICAL/other marker names, etc.

Benchmark was established July 13, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study. Benchmark was tied in to BM WSC PR94-71 on Sept. 19/94.

UTM and LAT/LONG coordinates derived by GPS with differential.

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°56'56" UTM Northing: 6534640.103

Longitude:W 111°47'20" Easting: 454612.840

CROSS-SECTION

Number: PRX071MC Azimuth:

Number: PRX071RC Azimuth:

Number: PRX071LC Azimuth:

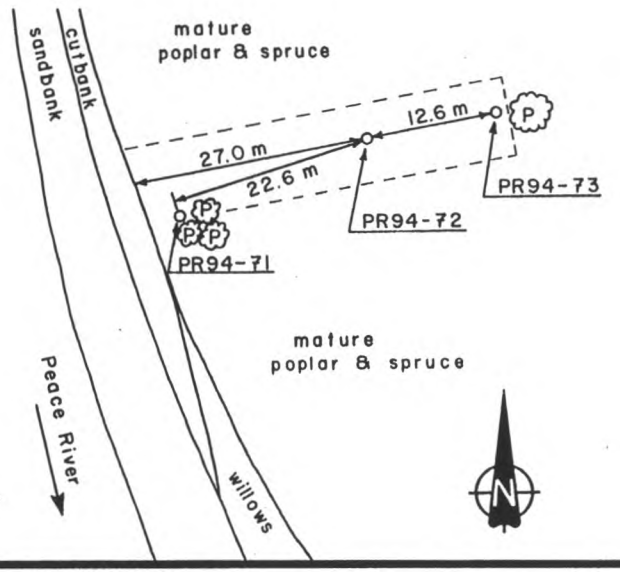
AIR PHOTO INFORMATION

Name: PEACE RIVER

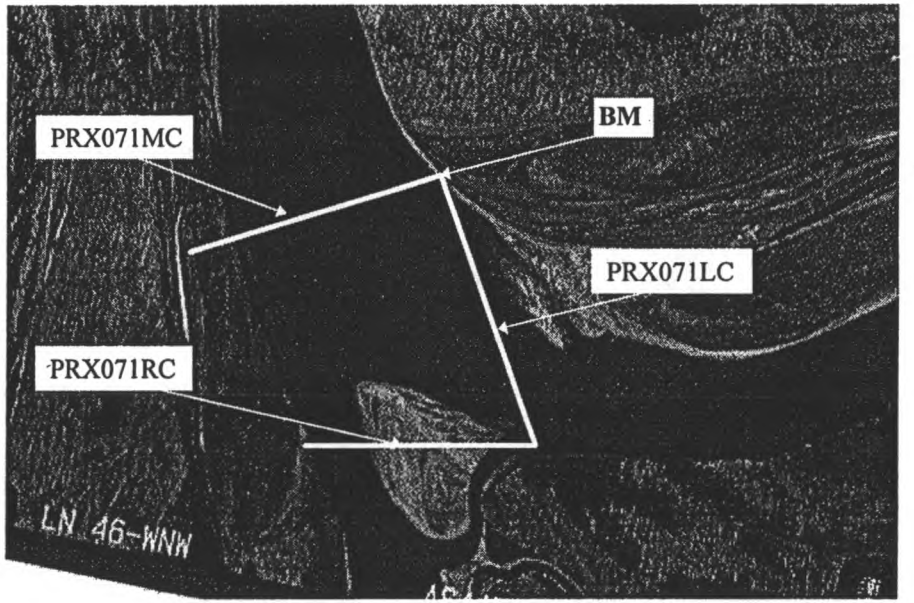
Date: OCT, 08-93 Line: 46-WNW

Roll: AS4475 Photo: 326

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-73**

ELEV. Geodetic: 214.078 m
Assumed:

INSTALLED: JUL. 13-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 32.2 (Mile 20.1), in a 2m wide cut-line. Benchmark is set 39.6m inland from top of cutbank, 12.6m inland from BM WSC PR94-72, in a level area of mature poplar and spruce. Just downstream of the BM the cutbank changes to a willow covered bank.

HISTORICAL/other marker names, etc.

Benchmark was established July 13, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study. Benchmark was tied in to BM WSC PR94-71 on Sept. 19/94.

UTM and LAT/LONG coordinates derived by GPS with differential.

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°56'57" UTM Northing: 6534646.882
Longitude: W 111°47'19" Easting: 454624.641

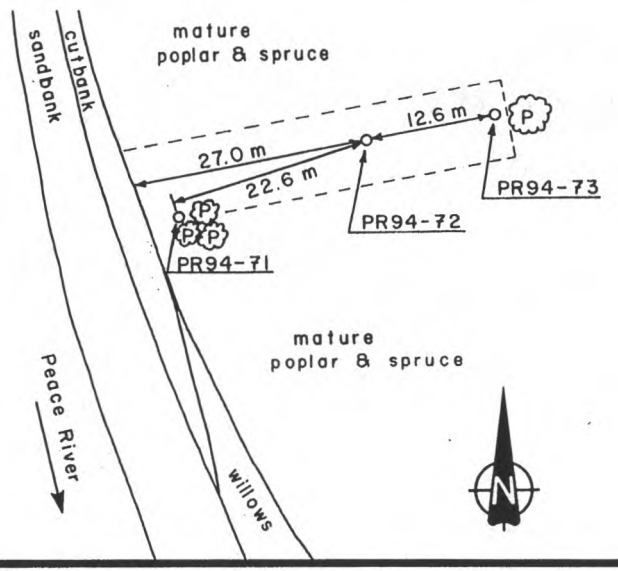
CROSS-SECTION

Number: PRX071MC Azimuth:
Number: PRX071RC Azimuth:
Number: PRX071LC Azimuth:

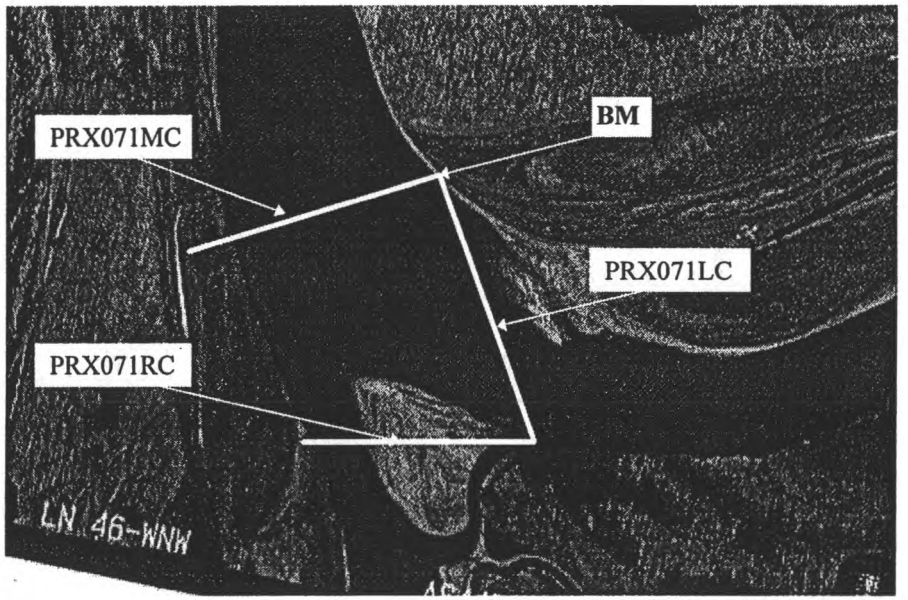
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT, 08-93 Line: 46-WNW
Roll: AS4475 Photo: 326

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-81**

ELEV. Geodetic:

Assumed:

INSTALLED: JUL. 14-94 UPDATED:

CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of three 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 35.2 (Mile 22), in a 2m wide cut-line. Benchmark is set 34.7m inland from top of high cutbank just downstream of a slumping bank, 14.7m inland from BM WSC PR94-082, in a level area of mature spruce and poplar.

A firetower is located about 1 km upstream of BM.

HISTORICAL/other marker names, etc.

Benchmark was established July 14, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 58' 13" UTM Northing: 6537015.537

Longitude: W 111° 47' 49" Easting: 454174.940

CROSS-SECTION

Number: Azimuth:

Number: Azimuth:

Number: Azimuth:

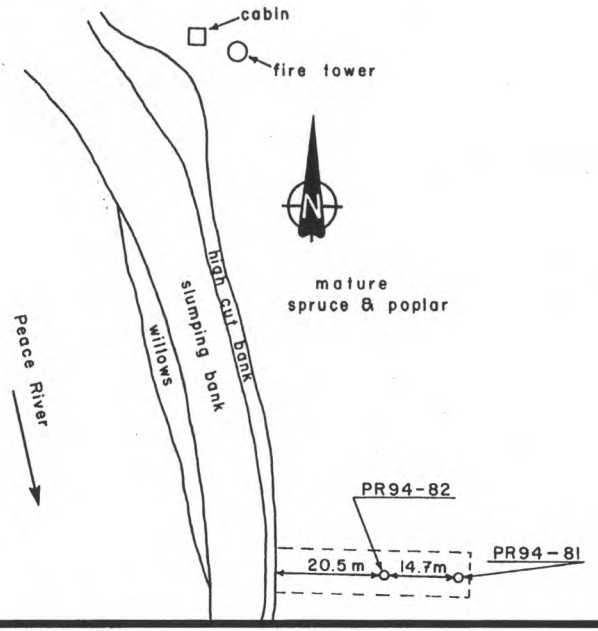
AIR PHOTO INFORMATION

Name: PEACE RIVER

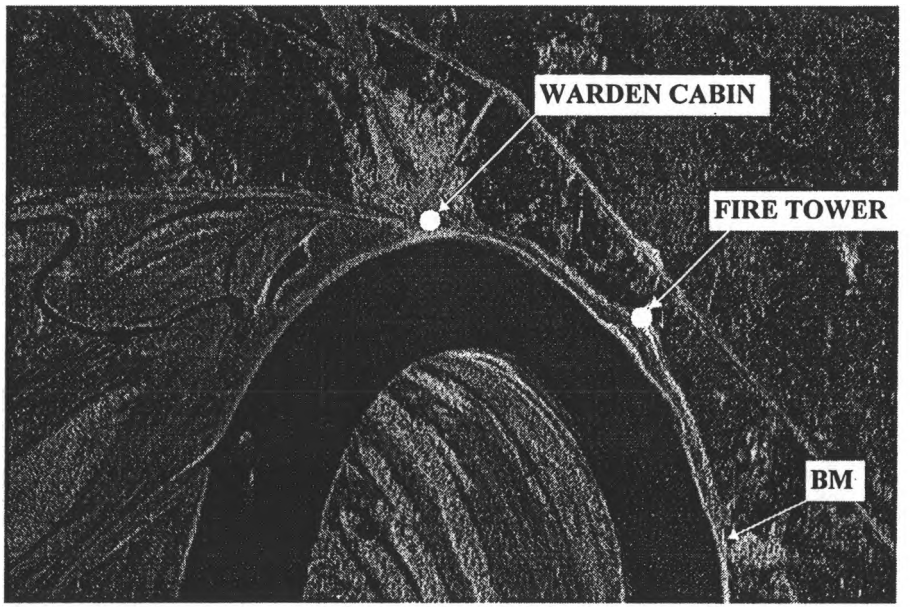
Date: OCT. 08-93 Line: 46-WNW

Roll: AS4475 Photo: 326

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-82** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 14-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of three 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 35.2 (Mile 22), in a 2m wide cut-line. Benchmark is set 20.5m inland from top of high cutbank just downstream of a slumping bank, 14.7m toward river from BM WSC PR94-081, in a level area of mature spruce and poplar.

A fire tower is located about 1 km upstream of BM.

HISTORICAL/other marker names, etc.

Benchmark was established July 14, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 58' 13" UTM Northing: 6537015.537
Longitude: W 111° 47' 49" Easting: 454174.940

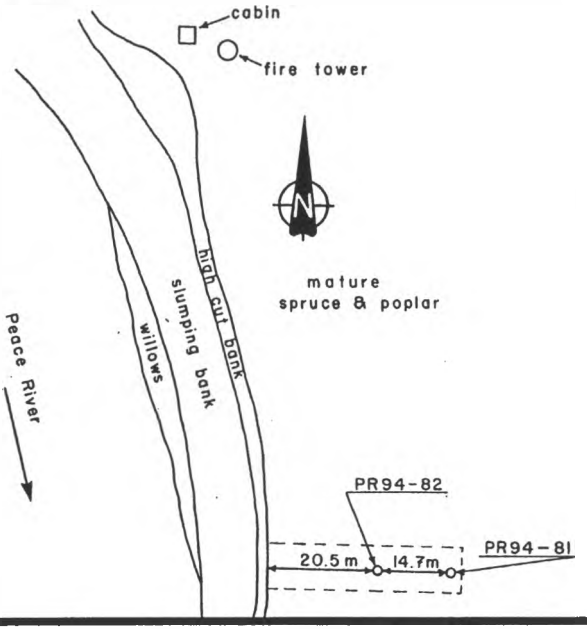
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

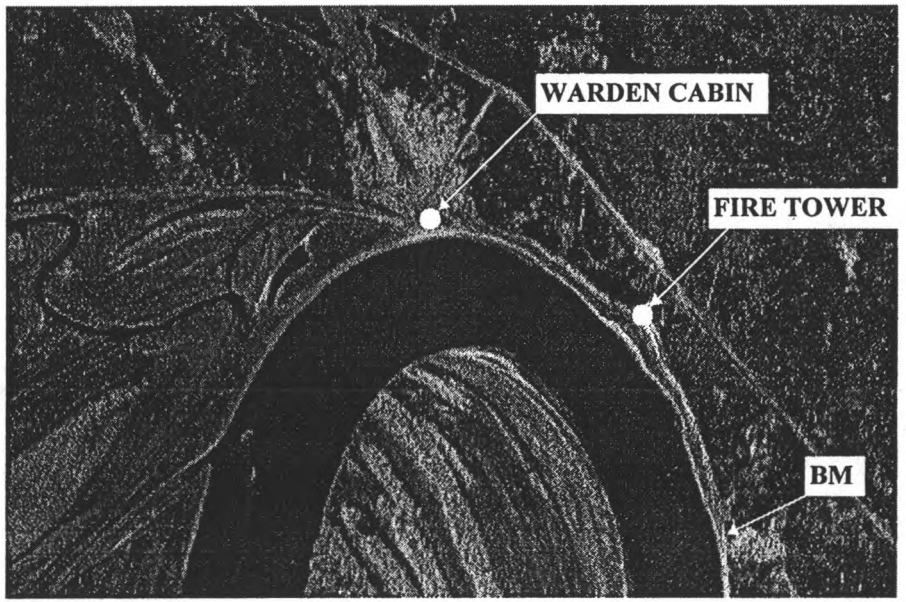
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 46-WNW
Roll: AS4475 Photo: 326

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-91** ELEV. Geodetic: 224.338 m
Assumed:

INSTALLED: JUL. 14-94 UPDATED: SEP. 21-94 CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River, at a point known as Carlson Landing, at Km. 36.3 (Mile 22.7), on level, cleared area, at the top of a very high steep bank, behind a Wood Buffalo National Park warden's cabin, near a grouping of 3 spruce trees. Benchmark is set 8.7m NE of NE corner of cabin, and 18.3m E of BM WSC PR94-092.

A fire tower is located about 1 km downstream.

HISTORICAL/other marker names, etc.

Benchmark was established July 14, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

Benchmark was tied into BM GSC 1705D on Sept. 21, 1994.

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 58' 49" UTM Northing: 6538143.256
Longitude: W111° 49' 03" Easting: 453006.628

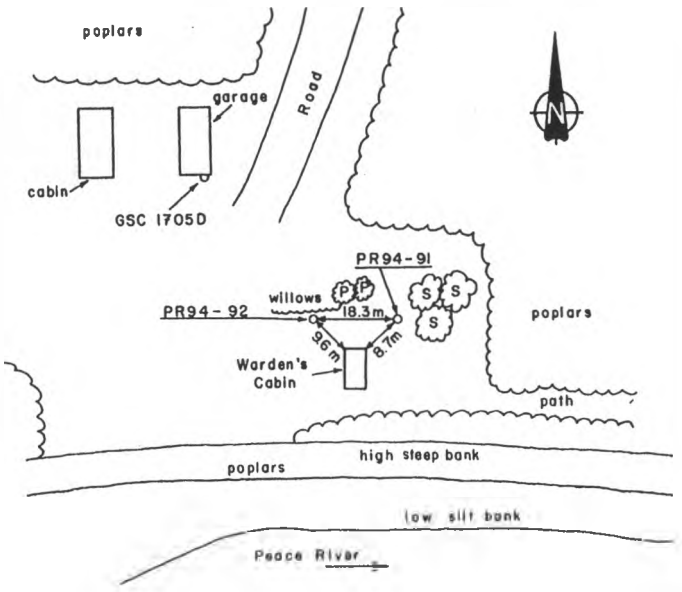
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

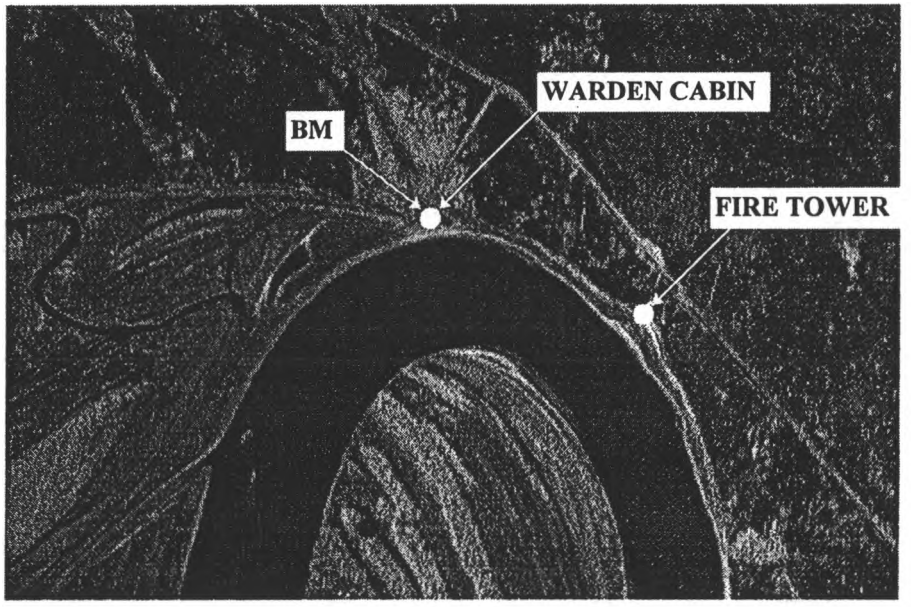
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 46-WNW
Roll: AS4475 Photo: 326

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-91** ELEV. Geodetic: 224.338 m
Assumed:

INSTALLED: JUL. 14-94 UPDATED: SEP. 21-94 CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River, at a point known as Carlson Landing, at Km. 36.3 (Mile 22.7), on level, cleared area, at the top of a very high steep bank, behind a Wood Buffalo National Park warden's cabin, near a grouping of 3 spruce trees. Benchmark is set 8.7m NE of NE corner of cabin, and 18.3m E of BM WSC PR94-092.

A fire tower is located about 1 km downstream.

HISTORICAL/other marker names, etc.

Benchmark was established July 14, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

Benchmark was tied into BM GSC 1705D on Sept. 21, 1994.

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 58' 49" UTM Northing: 6538143.256
Longitude: W111° 49' 03" Easting: 453006.628

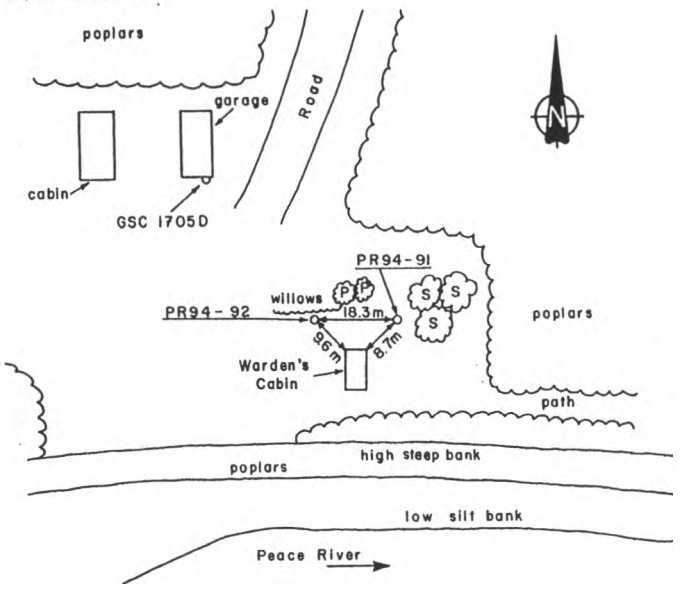
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

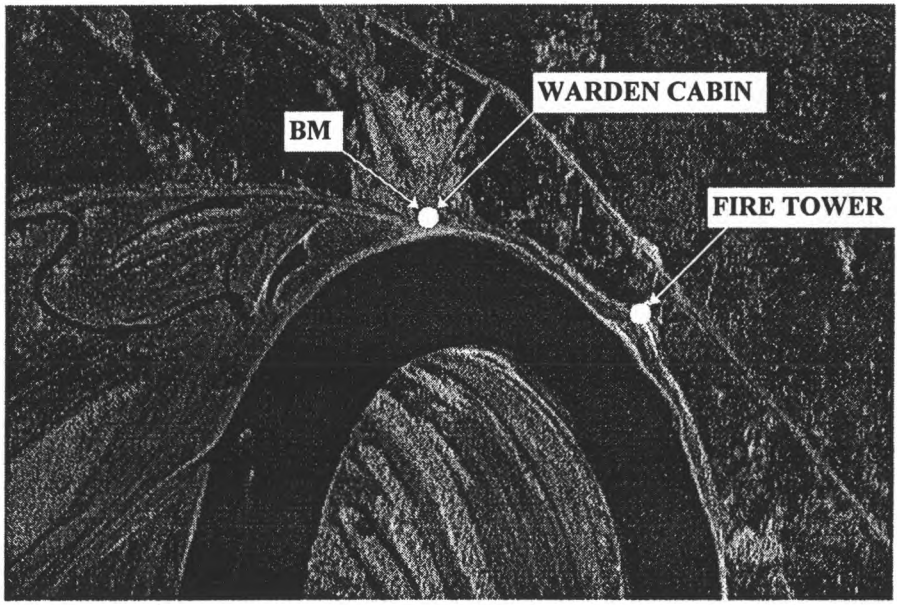
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 46-WNW
Roll: AS4475 Photo: 326

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-92** ELEV. Geodetic: 224.587 m
Assumed:

INSTALLED: JUL. 14-94 UPDATED: SEP. 21-94 CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of three 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River, at a point known as Carlson Landing, at Km. 36.3 (Mile 22.7), on level, cleared area, at the top of a very high steep bank, behind a Wood Buffalo National Park warden's cabin. Benchmark is set 9.6m NW of NW corner of cabin, and 18.3m W of BM WSC PR94-091.

HISTORICAL/other marker names, etc.

Benchmark was established July 14, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

Benchmark was tied into BM GSC 1705D on Sept. 21, 1994.

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 58' 49" UTM Northing: 6538143.256
Longitude: W111° 49' 03" Easting: 453006.628

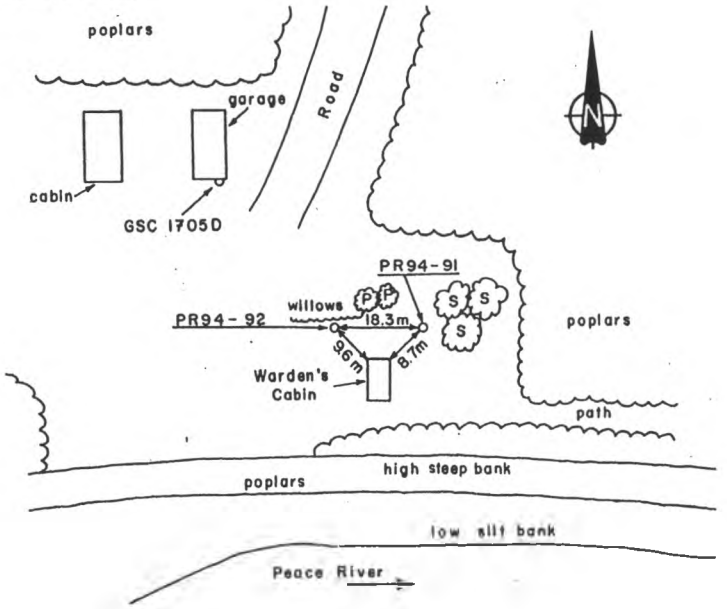
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

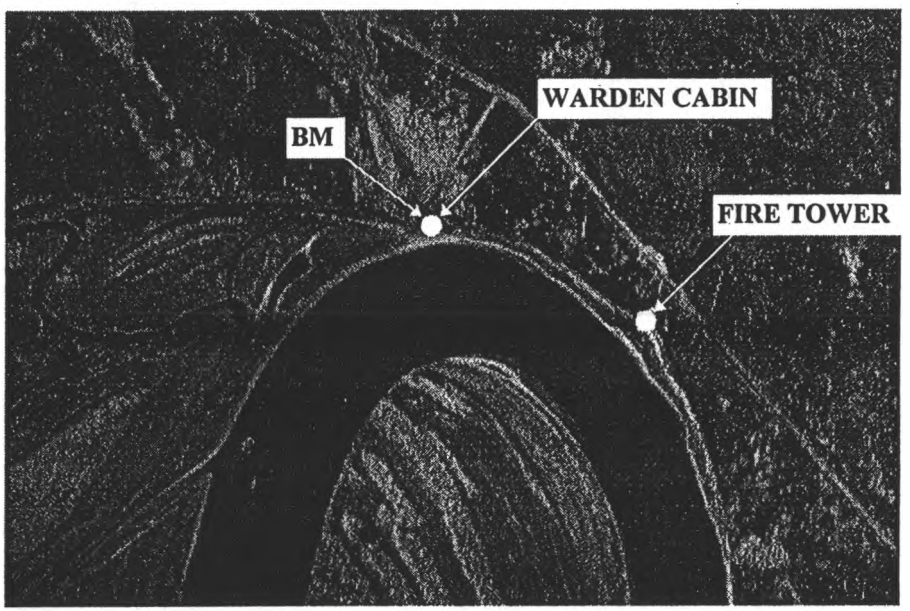
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 46-WNW
Roll: AS4475 Photo: 326

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-101** ELEV. Geodetic: 215.594 m
Assumed:

INSTALLED: AUG. 14-81 UPDATED: JUL. 14-94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of three 6-foot lengths of 3/8" dia. rod, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the right bank of the Peace River at a landing site known as Sweetgrass Landing, at Km. 45.1 (Mile 28.2), in an old cleared area adjacent to and downstream of a bison track. Benchmark is on the top of a cutbank, 6" from cutbank edge.

It is expected that the next high water event on the river will destroy this BM.

HISTORICAL/other marker names, etc.

Benchmark was established by Water Survey of Canada (WSC) in 1981 for cross-sections of the Peace River, and tied by McElhanney Surveying & Engineering Ltd. in 1982 (their file #163214), as Point 1, Cross-Section #18. Updated by GSC for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD)study, Aug. 9, 1983. Renamed and marked as PR94-101 by WSC, July 14, 1994.
UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 55' 40" UTM Northing: 6532378.724
Longitude: W111° 55' 32" Easting: 446714.466

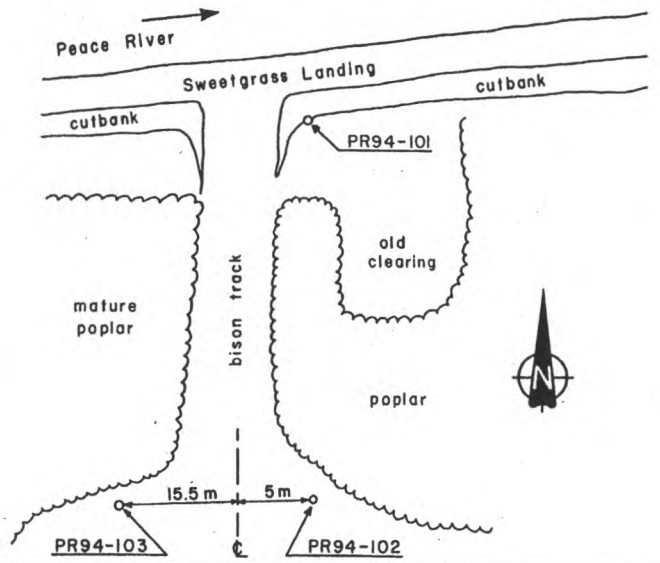
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

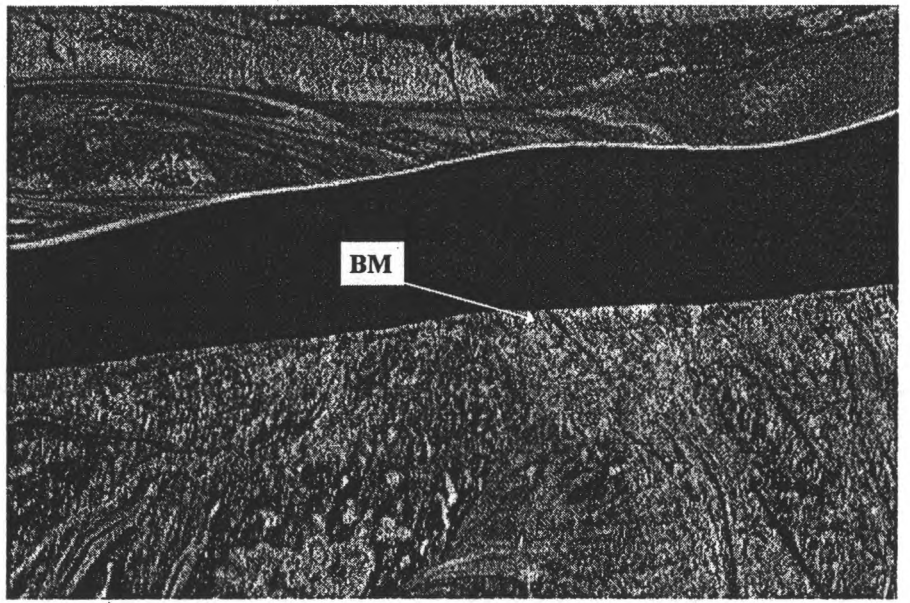
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 312

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-102** ELEV. Geodetic: 215.846 m
Assumed:

INSTALLED: JUL. 14-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the right bank of the Peace River at a landing site known as Sweetgrass Landing, at Km. 45.1 (Mile 28.2), inland, at the top of the incline of a bison trail, along the sides of a cleared area. Benchmark is set 5m E of centreline of the bison trail, and 20.5m E of BM WSC PR94-103.

HISTORICAL/other marker names, etc.

Benchmark was established July 14, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study. Benchmark was tied in to BM PR94-101, Sept. 21, 1994.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 55' 40" UTM Northing: 6532378.724
Longitude: W111° 55' 32" Easting: 446714.466

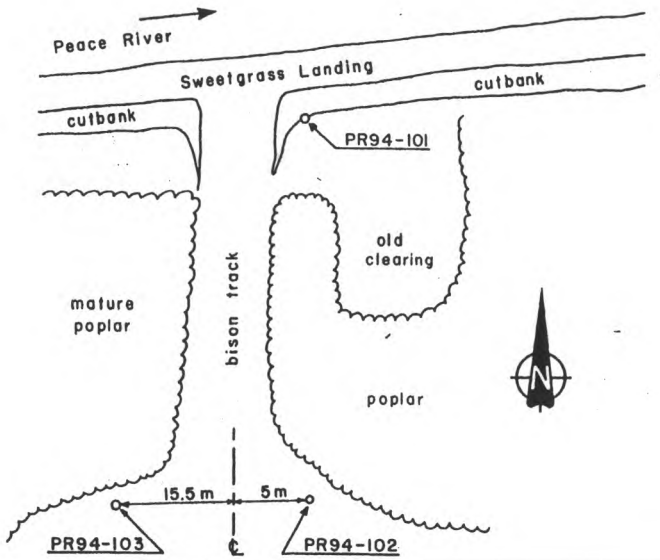
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

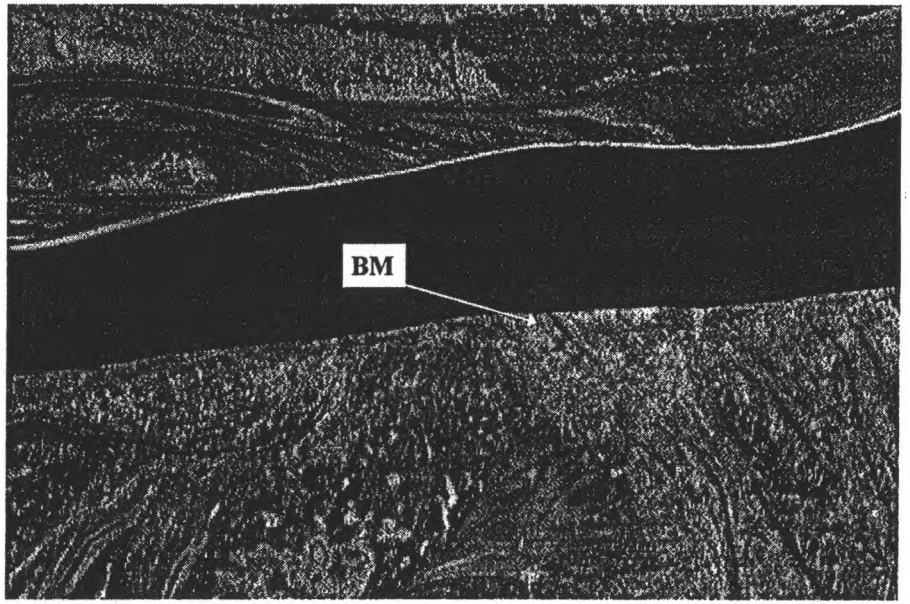
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 312

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-103**

ELEV. Geodetic: 215.974 m
Assumed:

INSTALLED: JUL. 14-94 UPDATED:

CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the right bank of the Peace River at a landing site known as Sweetgrass Landing, at Km. 45.1 (Mile 28.2), inland, at the top of the incline of a bison trail, along the sides of a cleared area. Benchmark is set 15.5m W of centreline of the bison track, and 20.5m W of BM WSC PR94-102.

HISTORICAL/other marker names, etc.

Benchmark was established July 14, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study. Benchmark was tied in to BM PR94-101, Sept. 21, 1994

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 55' 40" UTM Northing: 6532378.724
Longitude: W111° 55' 32" Easting: 446714.466

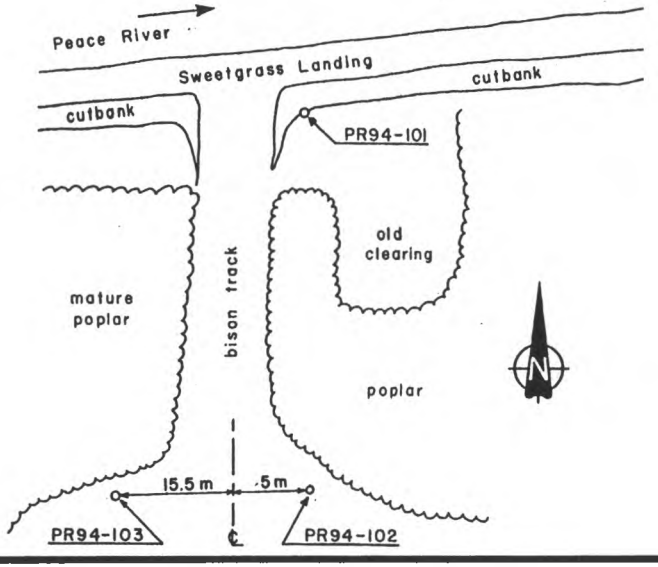
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

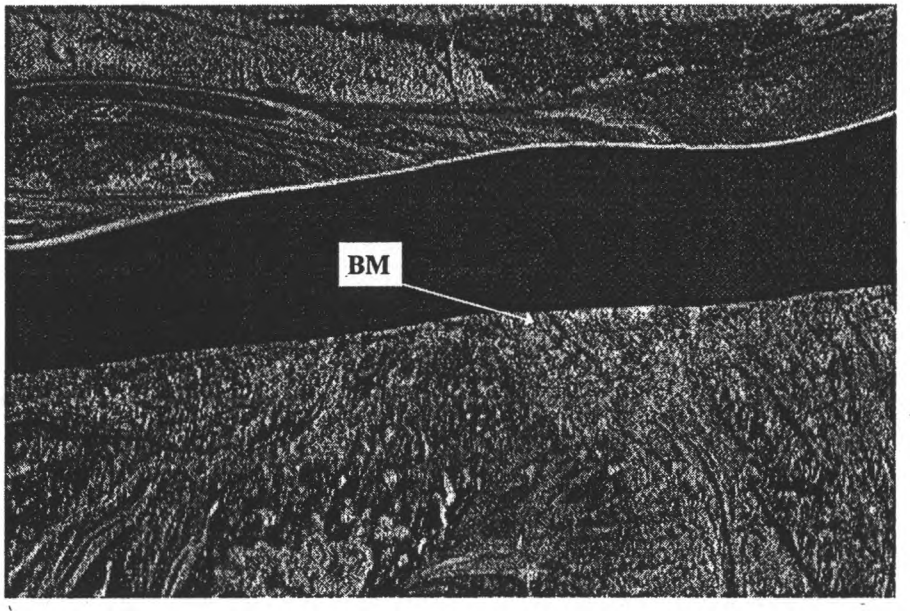
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 312

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-111** ELEV. Geodetic: 216.668
Assumed:

INSTALLED: 1981 UPDATED: JUL. 14-94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is a 3/8" dia. rod ground rod projecting 3' above the ground, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the right bank of the Peace River at Km. 49.3 (Mile 30.8), in a 2m wide cut-line, in front of a large spruce tree. Benchmark is set 7.6m inland from top of a cutbank, 12.3m toward river from BM WSC PR94-112.

HISTORICAL/other marker names, etc.

Benchmark was established by Water Survey of Canada (WSC) in 1981 for cross-sections of the Peace River, and tied by McElhanney Surveying & Engineering Ltd. in 1982 (their file #163214), as Point 1, Cross-Section #19. Updated by GSC for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD)study, Aug. 12, 1993. Renamed and marked as PR94-111 by WSC, July 14, 1994.
UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 55' 34" UTM Northing: 6532236.864
Longitude: W111° 58' 44" Easting: 443641.411

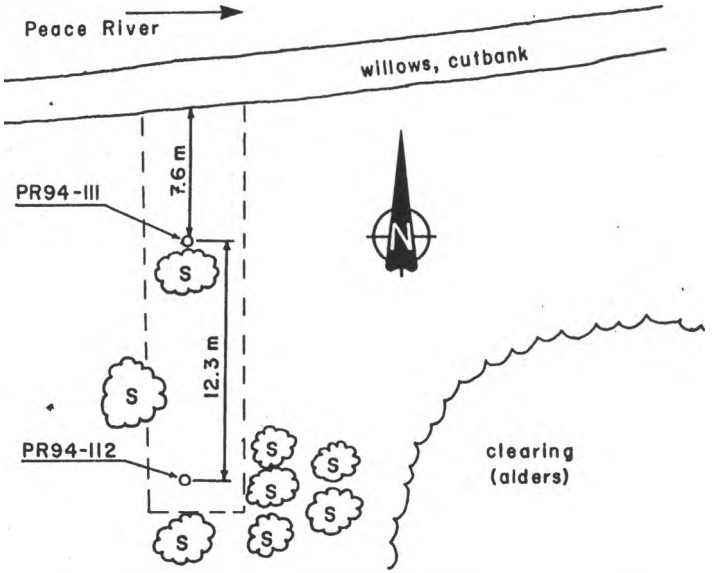
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

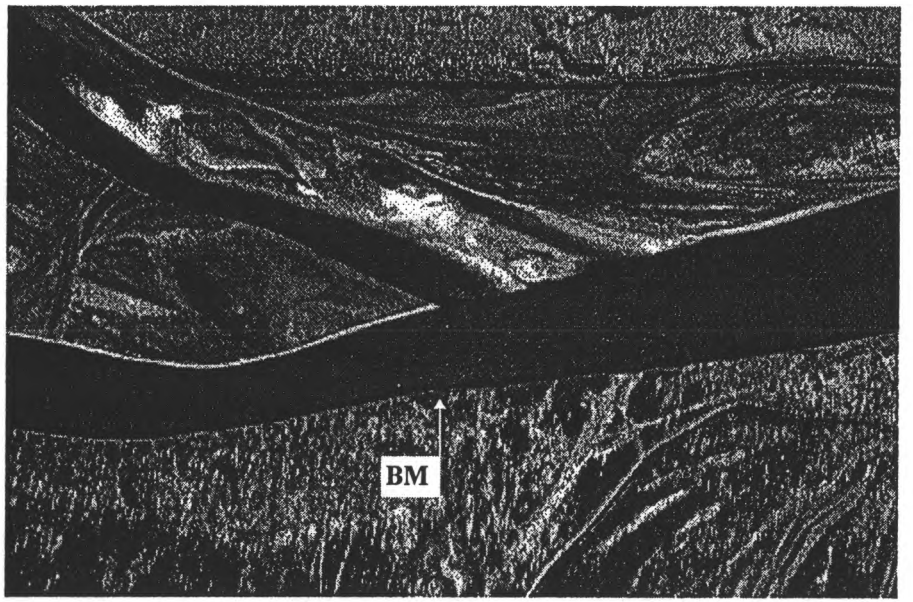
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 311

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-112** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 14-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the right bank of the Peace River at Km. 49.3 (Mile 30.8), in a 2m wide cut-line. Benchmark is set 19.9m inland from top of a cutbank, 12.3m inland from BM WSC PR94-111, between two large spruce trees, and just west of a group of five spruce trees.

HISTORICAL/other marker names, etc.

Benchmark was established July 14, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 55' 34" UTM Northing: 6532236.864
Longitude: W 111° 58' 44" Easting: 443641.411

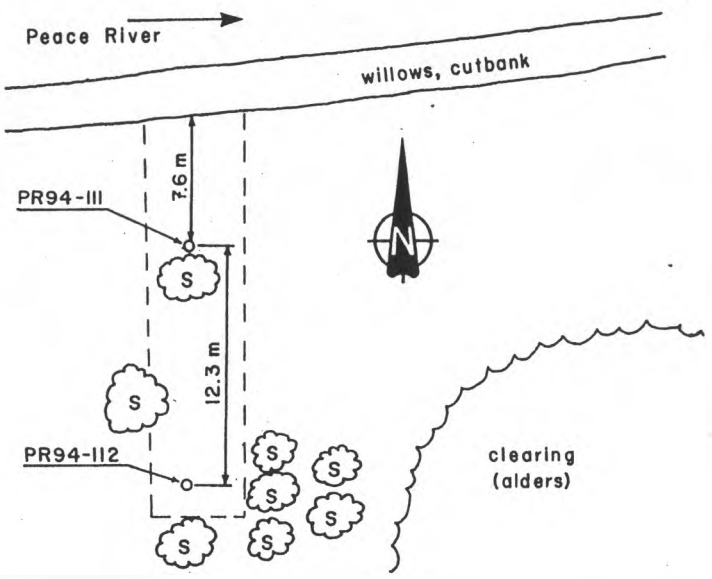
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

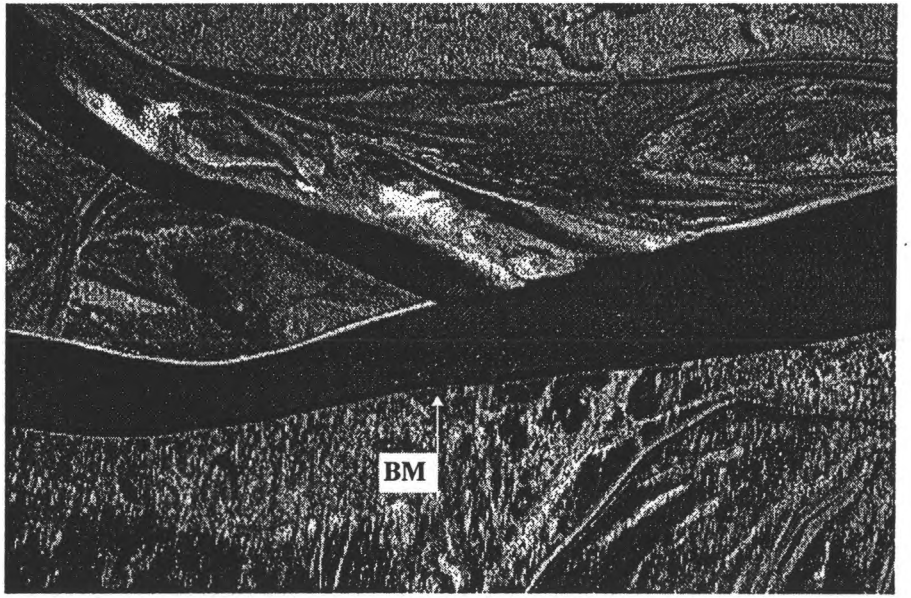
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 45-ESE
Roll: AS4475 Photo: 311

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-121** ELEV. Geodetic:
Assumed:

INSTALLED: Jul. 14, 1994 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of five 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Providence Point, Km. 56 (Mile 35), in a 2m wide cut-line. Benchmark is set 19.1m inland from top of a sandbank, 6.8m inland from BM WSC PR94-122, in a level area of mixed alders and willows.

HISTORICAL/other marker names, etc.

Benchmark was established July 14, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 57' 54" UTM Northing: 6536649.158
Longitude: W112° 04' 20" Easting: 438337.538

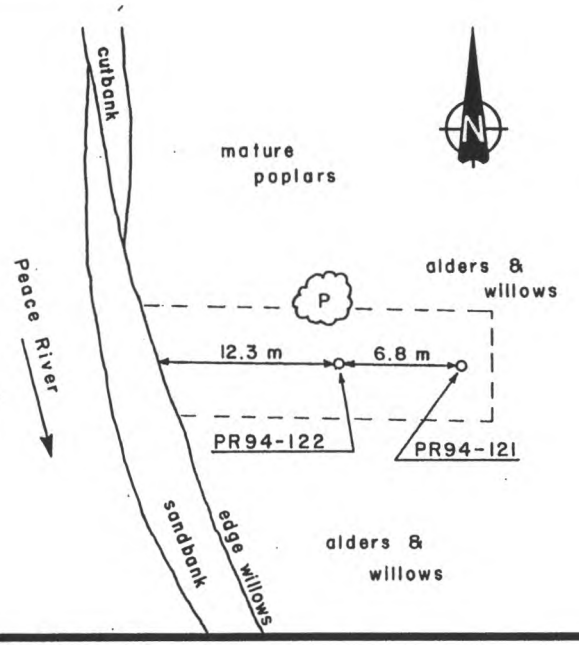
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

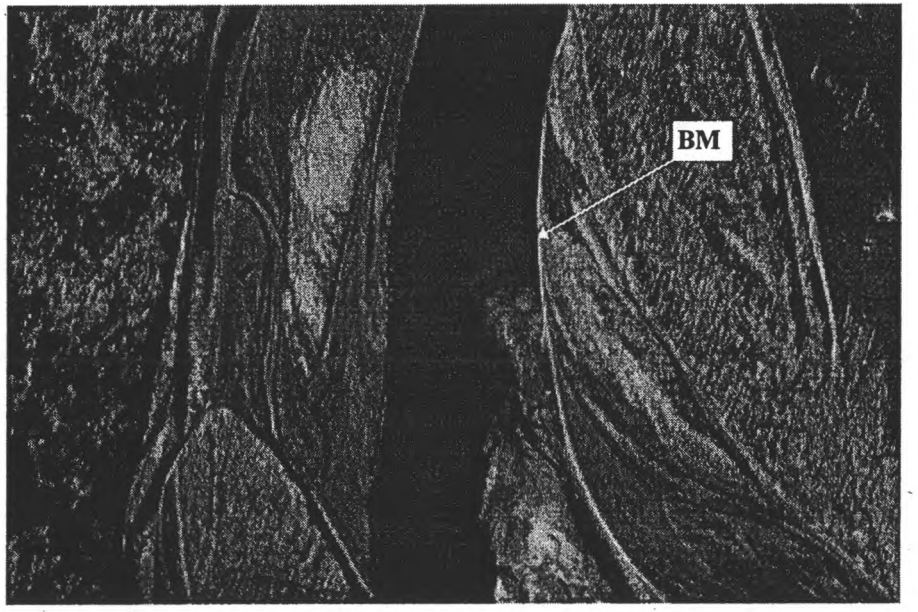
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 43-NNE
Roll: AS4475 Photo: 289

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-122** ELEV. Geodetic:
Assumed:

INSTALLED: Jul. 14, 1994 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of five 5-foot lengths of 1/2" dia. rod, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Providence Point, Km. 56 (Mile 35), in a 2m wide cut-line. Benchmark is set 12.3m inland from top of a sandbank, 6.8m towards river from BM WSC PR94-121, just south of a large poplar tree in a level area of mixed alders and willows.

HISTORICAL/other marker names, etc.

Benchmark was established July 14, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58° 57' 54" UTM Northing: 6536649.158
Longitude: W112° 04' 20" Easting: 438337.538

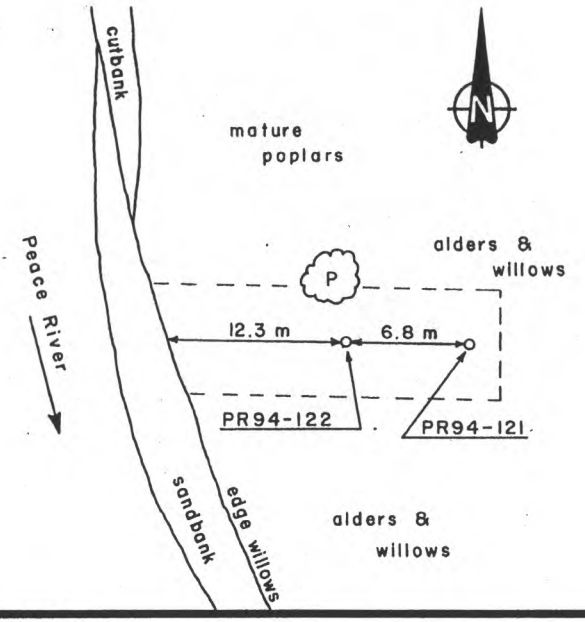
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

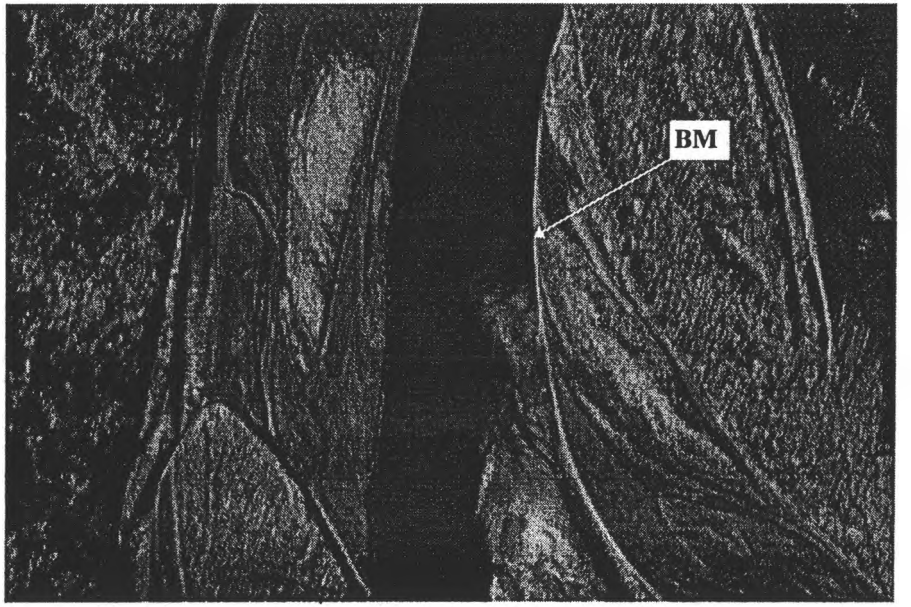
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 43-NNE
Roll: AS4475 Photo: 289

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-131** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 26-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of five 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 60.8 (Mile 38), in a 2m wide cut-line. Benchmark is set towards river from large poplar at back of cut-line, between two large spruce trees, 42.8m inland from the top of the first cut bank, 12.5m from the top of a second cutbank (1.5m high), and 10.8m inland from BM WSC PR94-132.

HISTORICAL/other marker names, etc.

Benchmark was established July 26, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 00' 21" UTM Northing: 6541176.578
Longitude: W112° 03' 05" Easting: 439607.088

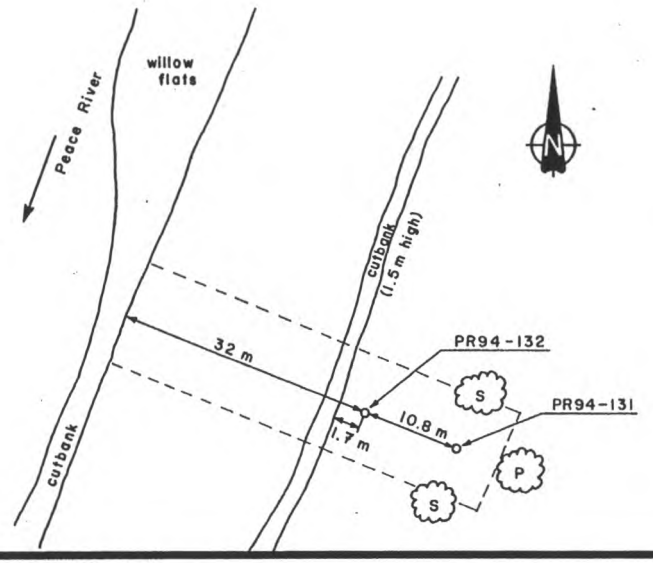
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

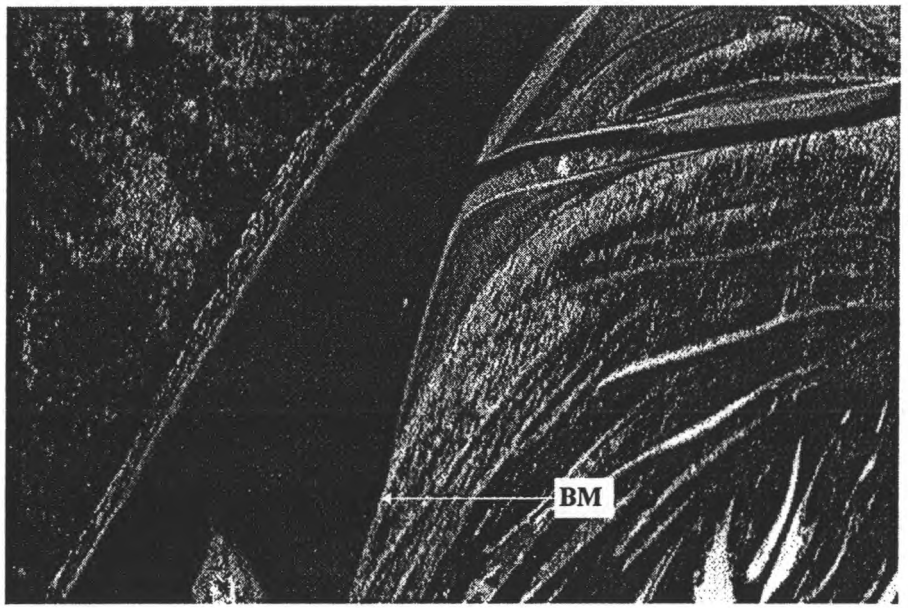
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 43-NNE
Roll: AS4475 Photo: 291

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-132**

EI EV. Geodetic:

Assumed:

INSTALLED: JUL. 26-94 UPDATED:

CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of five 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 60.8 (Mile 38), in a 2m wide cut-line. Benchmark is set 32m inland from the top of the first cut bank, 1.7m from the top of a second cutbank (1.5m high), and 10.8m towards river from BM WSC PR94-131.

HISTORICAL/other marker names, etc.

Benchmark was established July 26, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 00' 21" UTM Northing: 6541176.578

Longitude: W112° 03' 05" Easting: 439607.088

CROSS-SECTION

Number: Azimuth:

Number: Azimuth:

Number: Azimuth:

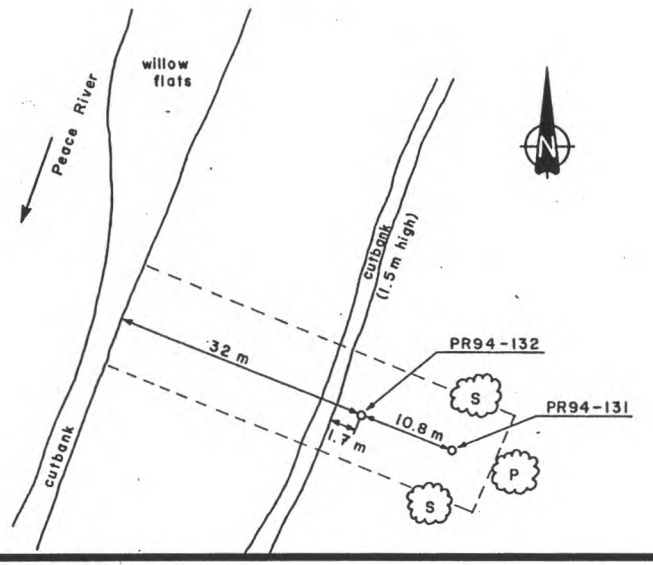
AIR PHOTO INFORMATION

Name: PEACE RIVER

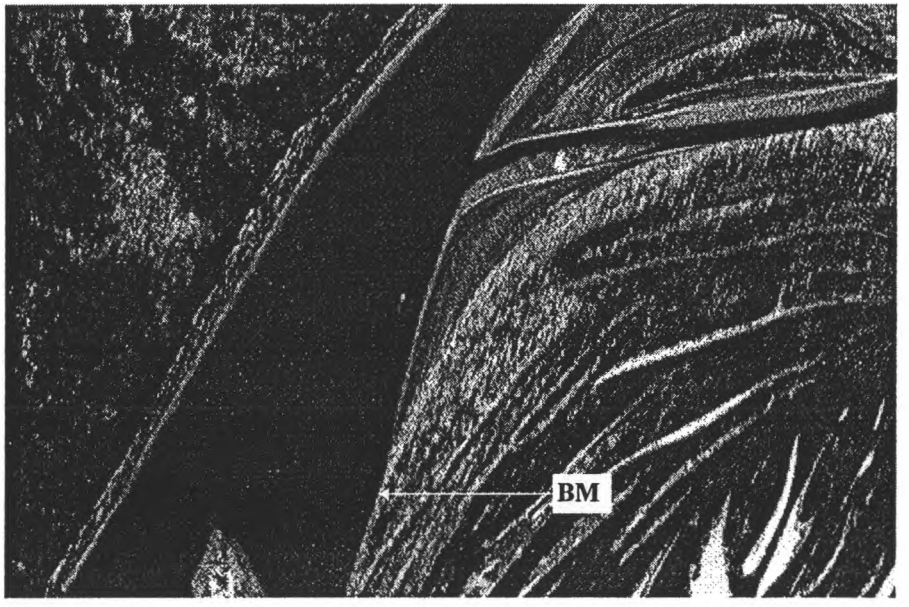
Date: OCT. 08-93 Line: 43-NNE

Roll: AS4475 Photo: 291

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

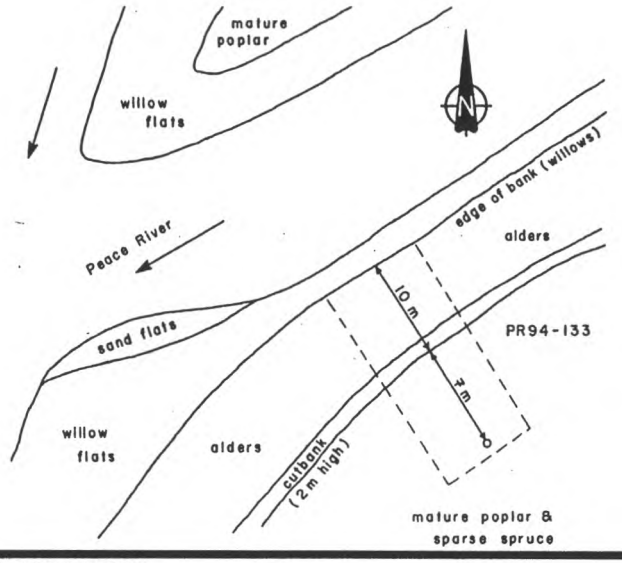
BENCH MARK NO: **PR94-133** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 26-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of a snye on the Peace River at Km. 62.4 (Mile 39), in a 2m wide cut-line. Benchmark is set 17m inland from the edge of a bank of willows and 7m inland from a 2m high cutbank.

SKETCH OF LOCATION



HISTORICAL/other marker names, etc.

Benchmark was established July 26, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

LOCATION ON AIR PHOTO

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 01' 01" UTM Northing: 6542397.786
Longitude: W112° 02' 01" Easting: 440647.345

CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 43-NNE
Roll: AS4475 Photo: 291

BENCH MARK PROFILE

BENCH MARK NO: **PR94-141** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 26-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 70.4 (Mile 44), in a 2m wide cut-line. Benchmark is set 28.5m inland from top of a high cutbank., 10.5m inland from BM WSC PR94-142, in a level area of mature spruce.

HISTORICAL/other marker names, etc.

Benchmark was established July 26, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: **NAD83** (see Historical)

Latitude: N 59° 03' 16" UTM Northing: 6546473.906
Longitude: W111° 54' 54" Easting: 447515.198

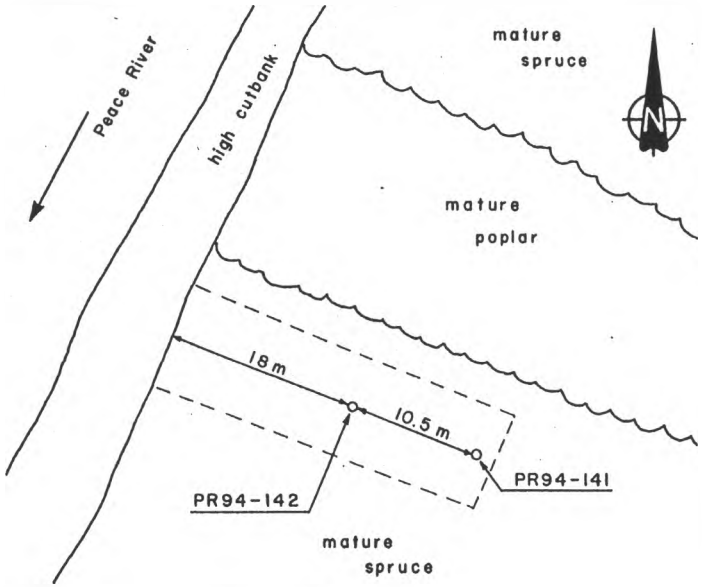
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

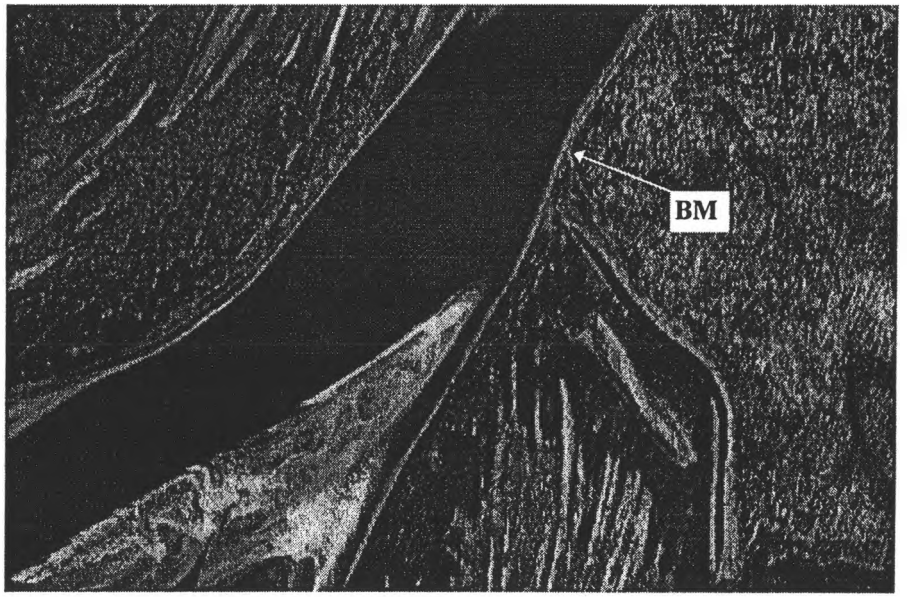
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 44-SSW
Roll: AS4475 Photo: 304

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-142** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 26-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 70.4 (Mile 44), in a 2m wide cut-line. Benchmark is set 18m inland from top of a high cutbank., 10.5m towards river from BM WSC PR94-141, in a level area of mature spruce.

HISTORICAL/other marker names, etc.

Benchmark was established July 26, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 03' 16" UTM Northing: 6546473.906
Longitude: W111° 54' 54" Easting: 447515.198

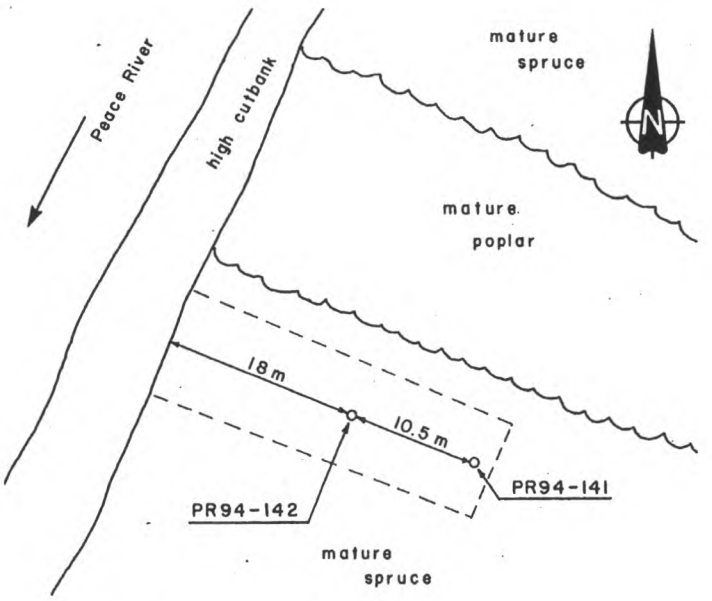
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

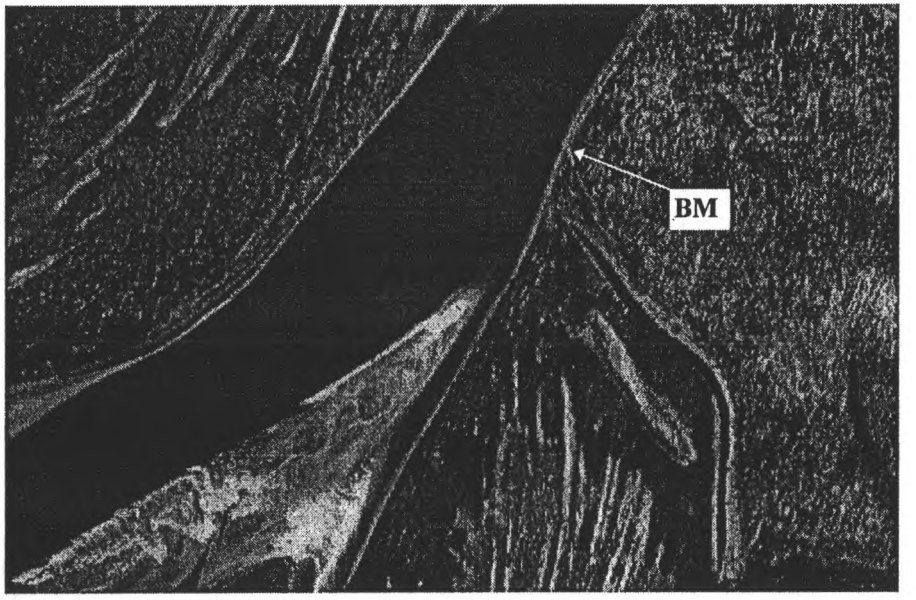
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 44-SSW
Roll: AS4475 Photo: 304

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-151** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 28-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of six 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 75.2 (Mile 47), in a 2m wide cut-line. Benchmark is 125m inland from rivers edge of slumping bank, 25m inland from top of 2nd cutbank., in a level area of mature poplar and spruce, approx. 30m above the river.

HISTORICAL/other marker names, etc.

Benchmark was established July 28, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 04' 53" UTM Northing: 6549455.734
Longitude: W111° 53' 29" Easting: 448909.530

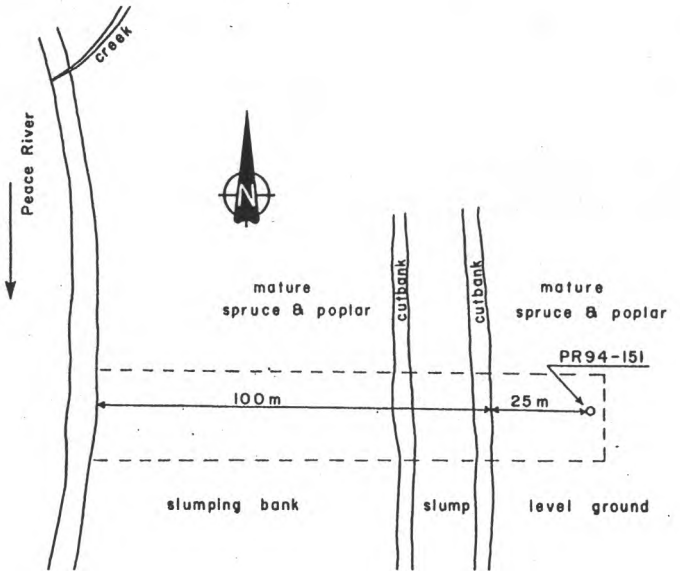
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

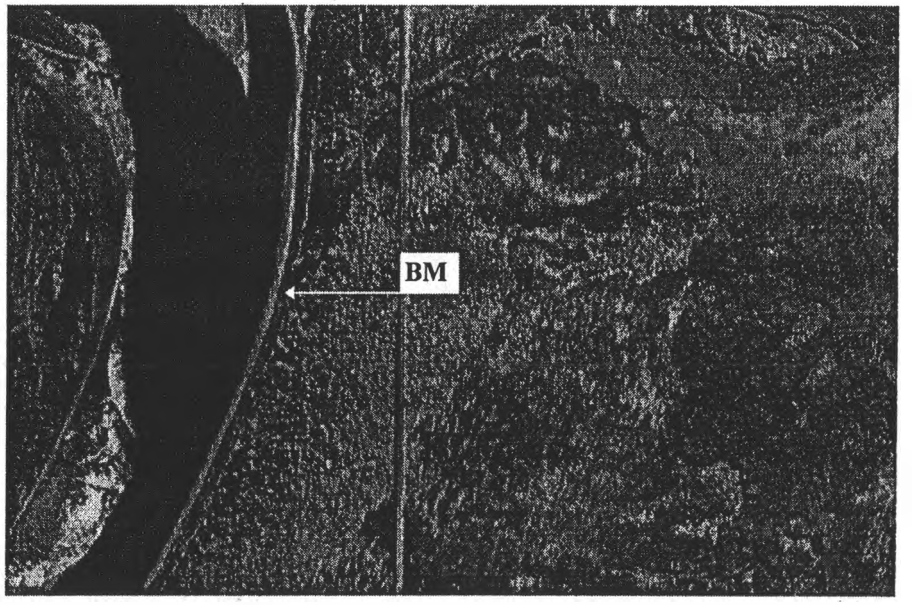
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 44-SSW
Roll: AS4475 Photo: 305

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-161** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 26-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of four 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 84.8 (Mile 53), in a 2m wide cut-line. Benchmark is set 30m inland from the first cutbank, 2m inland from top of a second, 1m high cutbank..

Benchmark location is low and may be subject to flooding & ice push during high water.

HISTORICAL/other marker names, etc.

Benchmark was established July 26, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 05' 43" UTM Northing: 6551141.338
Longitude: W112° 03' 28" Easting: 439397.822

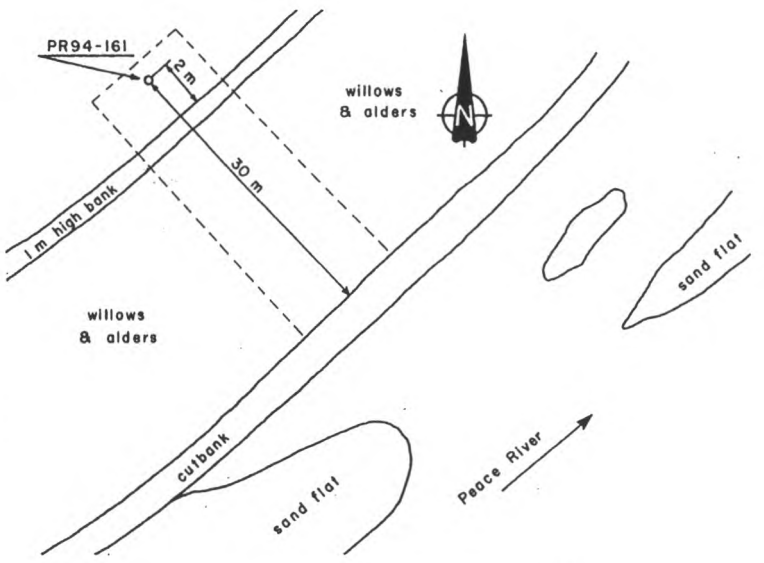
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

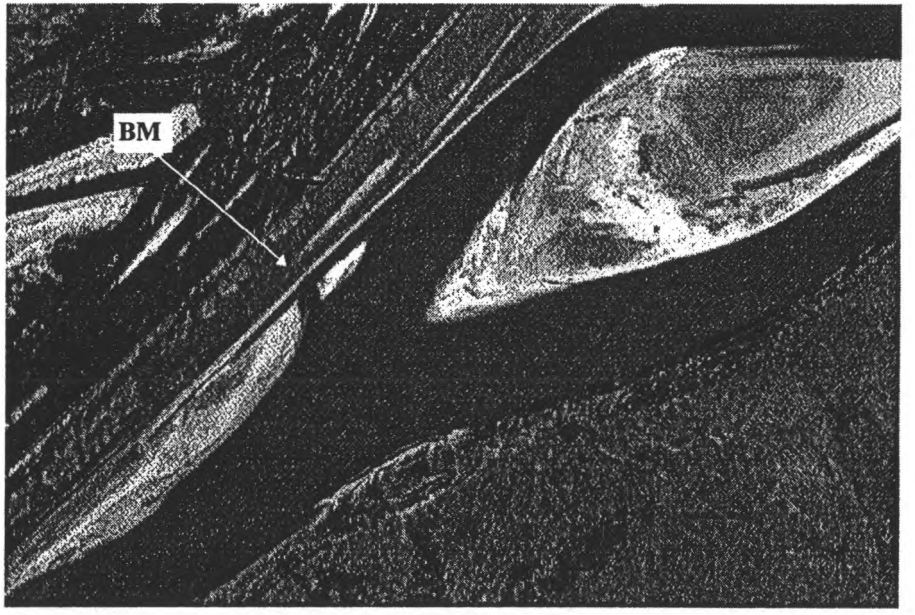
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 42-WSW
Roll: AS4475 Photo: 282

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-171** ELEV. Geodetic:

Assumed:

INSTALLED: JUL. 27-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of five 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 91.2 (Mile 57), in a 2m wide cut-line. Benchmark is set 30m inland from top of cutbank, 11m inland from BM WSC PR94-172, in a level area of sparse mature poplar.

HISTORICAL/other marker names, etc.

Benchmark was established July 27, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 04' 15" UTM Northing: 6548445.974

Longitude: W112° 09' 03" Easting: 434018.839

CROSS-SECTION

Number: Azimuth:

Number: Azimuth:

Number: Azimuth:

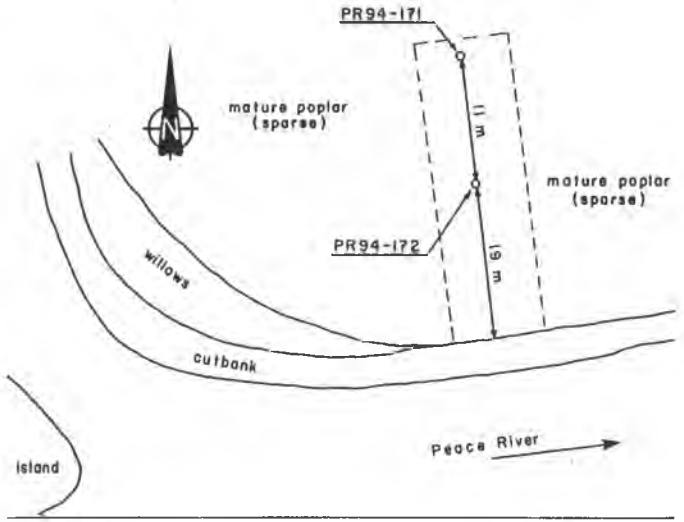
AIR PHOTO INFORMATION

Name: PEACE RIVER

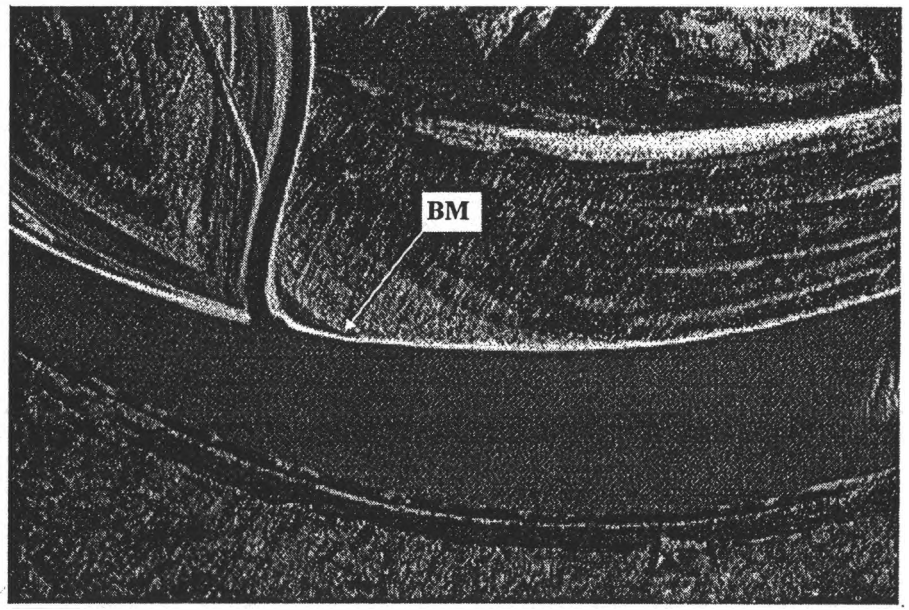
Date: OCT. 08-93 Line: 41-WNW

Roll: AS4475 Photo: 274

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

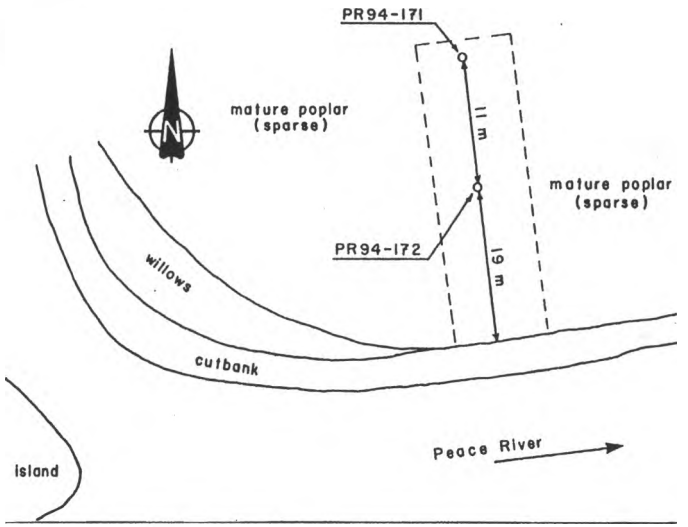
BENCH MARK NO: **PR94-172** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 27-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of five 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 91.2 (Mile 57), in a 2m wide cut-line. Benchmark is set 19m inland from top of cutbank, 11m toward river from BM WSC PR94-171, in a level area of sparse mature poplar.

SKETCH OF LOCATION

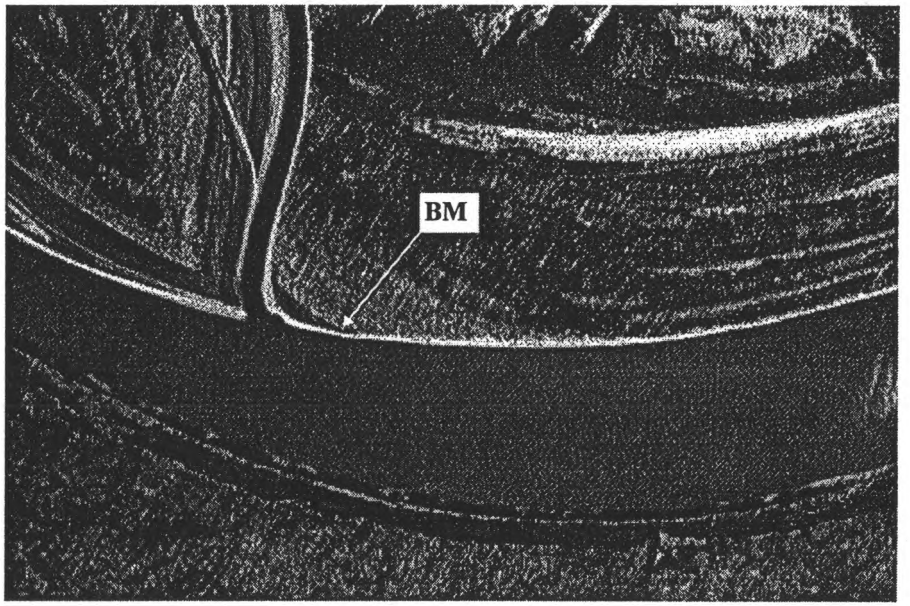


HISTORICAL/other marker names, etc.

Benchmark was established July 27, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

LOCATION ON AIR PHOTO



CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 04' 13" UTM Northing: 6548445.974
Longitude: W112° 09' 03" Easting: 434018.839

CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 41-WNW
Roll: AS4475 Photo: 274

BENCH MARK PROFILE

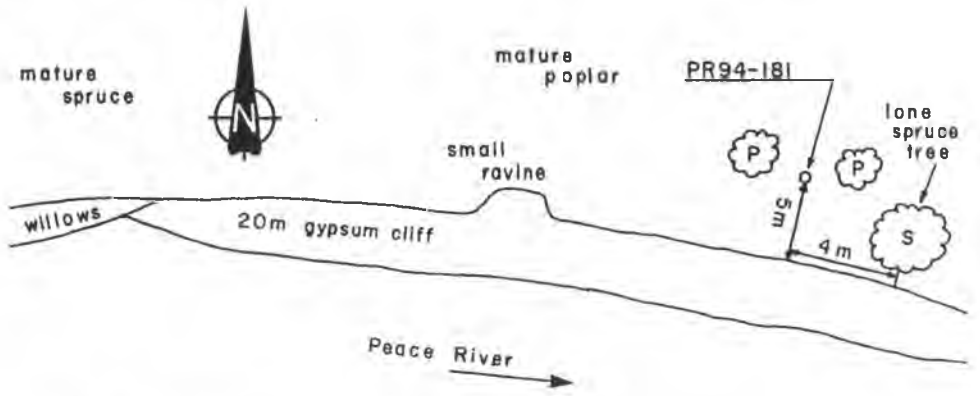
BENCH MARK NO: **PR94-181** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 27-94 UPDATED: CONDITION: NEW

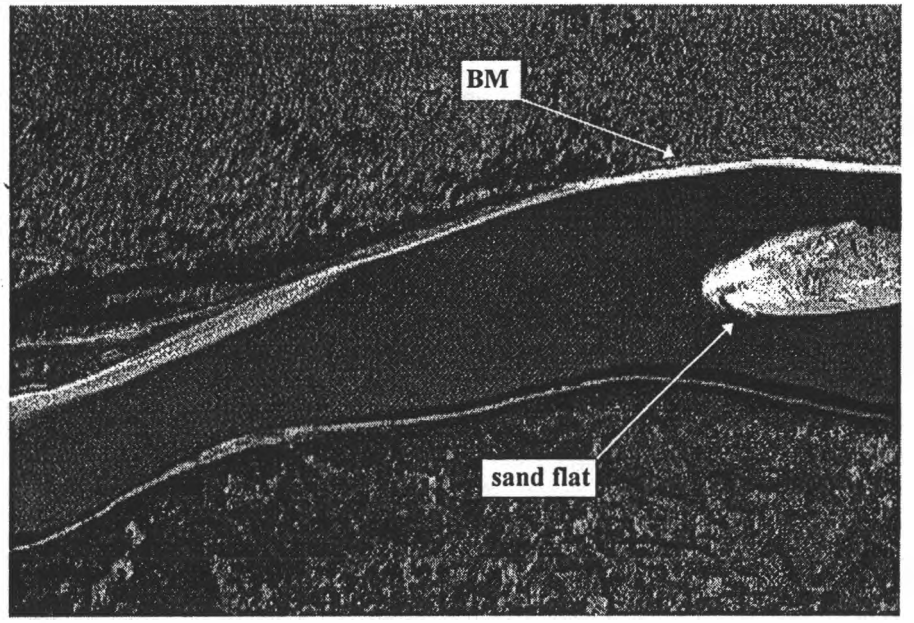
BENCH MARK DESCRIPTION

Benchmark is a ground rod made of one 5-foot length of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 105.6 (Mile 66). Benchmark is set at the top of a 20m high gypsum cliff between two poplar trees 5m inland from the edge of the cliff, 4m upstream from a large, lone spruce tree.

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



HISTORICAL/other marker names, etc.

Benchmark was established July 27, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 07' 33" UTM Northing: 6554839.087
Longitude: W112° 20' 41" Easting: 423028.013

CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 41-WNW
Roll: AS4475 Photo: 268

BENCH MARK PROFILE

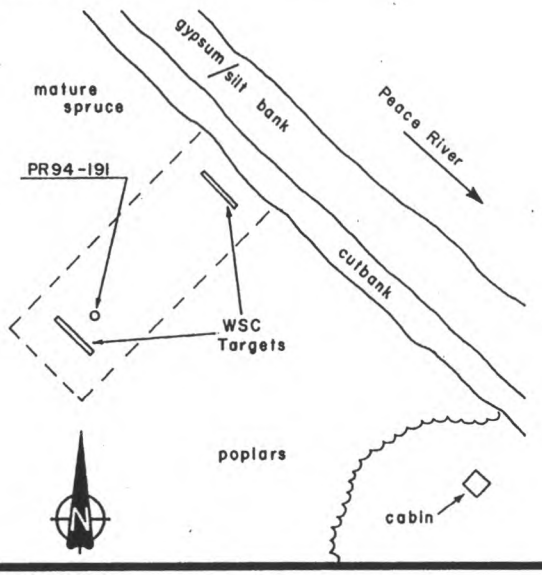
BENCH MARK NO: **PR94-191** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 28-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of one 5-foot and one 4-foot length of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the right bank of the Peace River at WSC Stn. 07KC001 summer measurement section near Km. 113.6 (Mile 71), 1.2 km upstream of Peace Point. Benchmark is set in a cut-line in front of furthest inland of 2 targets marking the measurement section.

SKETCH OF LOCATION

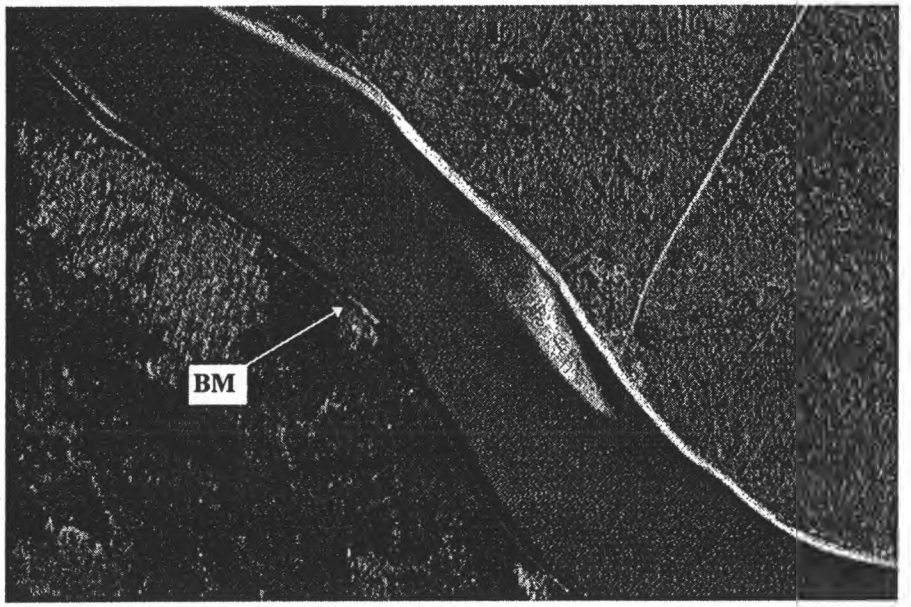


HISTORICAL/other marker names, etc.

Benchmark was established July 28, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

LOCATION ON AIR PHOTO



CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 07' 35" UTM Northing: 6555045.843
Longitude: W112° 27' 54" Easting: 416145.344

CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 41-WNW
Roll: AS4475 Photo: 266

BENCH MARK PROFILE

BENCH MARK NO: **PR94-201** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 28-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of two and a half 5-foot lengths of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at WSC station 07KC001 winter measurement section near Km. 115.2 (Mile 72), 3.8km upstream from Peace Point. Benchmark is set at the top of a 30m high cliff, 2m back from the edge of the cliff. Benchmark is placed above red paint mark on cliff marking the winter measurement section.

HISTORICAL/other marker names, etc.

Benchmark was established July 28, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 08' 28" UTM Northing: 6556708.474
Longitude: W112° 29' 01" Easting: 415116.620

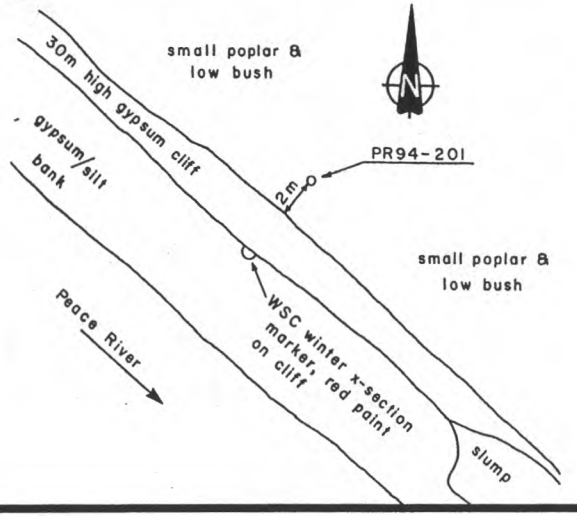
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

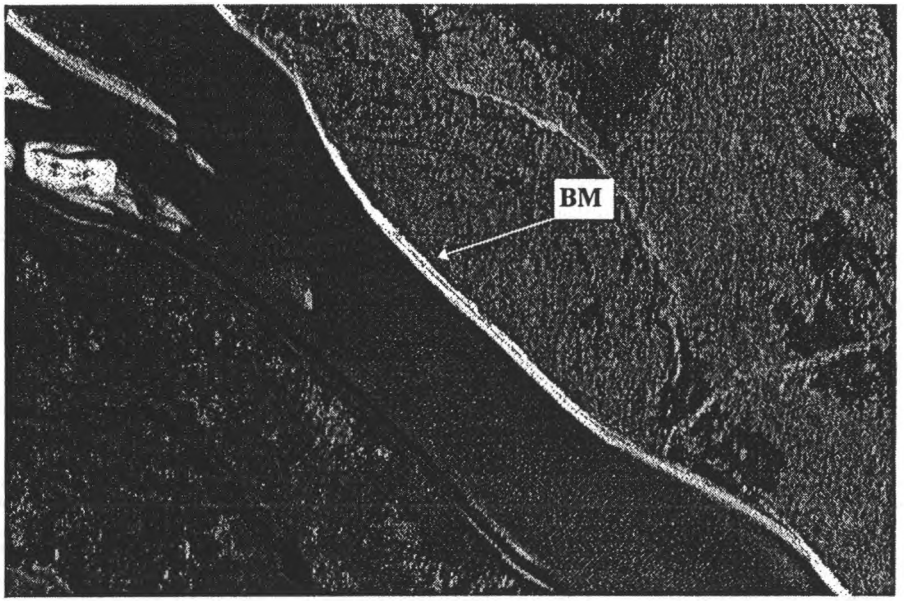
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 41-WNW
Roll: AS4475 Photo: 266

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-211** ELEV. Geodetic:
Assumed:

INSTALLED: JUL. 27-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of one and one third 5-foot lengths of 1/2" dia. rod, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 120 (Mile 75), on the top of a 30m high gypsum cliff above a slumping section. Benchmark is set 4m inland from the edge of the slump zone, in a level area of poplar and low bush.

HISTORICAL/other marker names, etc.

Benchmark was established July 27, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 10' 38" UTM Northing: 6560832.610
Longitude: W112° 33' 47" Easting: 410665.995

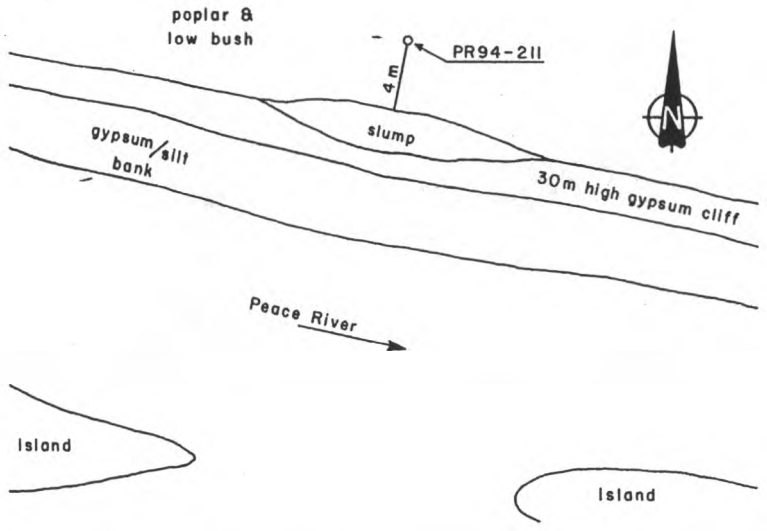
CROSS-SECTION

Number: Azimuth:
Number: Azimuth:
Number: Azimuth:

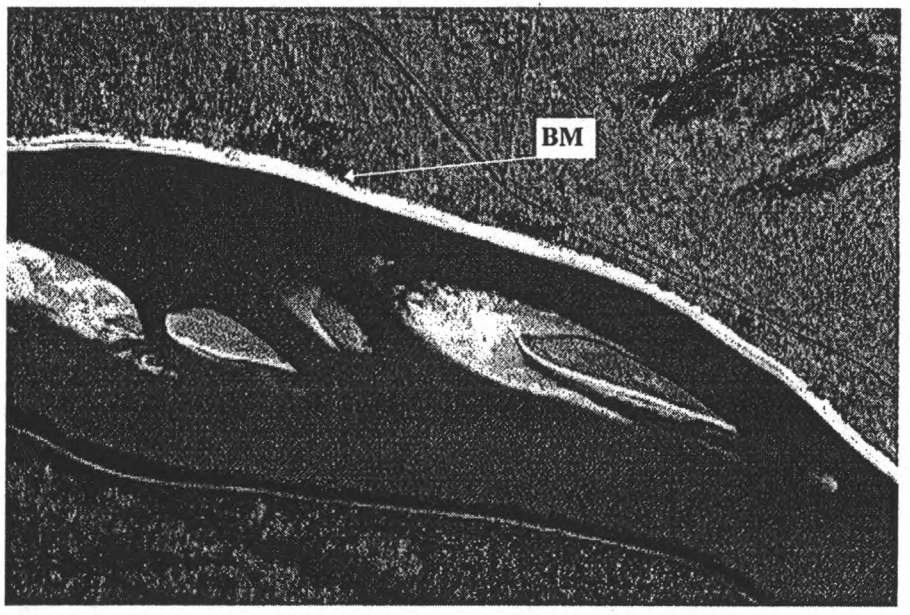
AIR PHOTO INFORMATION

Name: PEACE RIVER
Date: OCT. 08-93 Line: 41-WNW
Roll: AS4475 Photo: 263

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **PR94-221**

ELEV. Geodetic:

Assumed:

INSTALLED: JUL. 27-94 UPDATED:

CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a ground rod made of one 3.5 foot length of 1/2" dia. rod, extending 6" above ground level, marked with a 1m high red steel post supporting a small galvanized BM ID plate placed 0.3m inland from BM. Benchmark is located on the left bank of the Peace River at Km. 126.4 (Mile 79), at the top of a 30m high gypsum cliff. Benchmark is set 5m inland from the cliff edge near a large spruce tree.

HISTORICAL/other marker names, etc.

Benchmark was established July 27, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 59° 11' 06" UTM Northing: 6561835.531

Longitude: W112° 39' 44" Easting: 405020.591

CROSS-SECTION

Number: Azimuth:

Number: Azimuth:

Number: Azimuth:

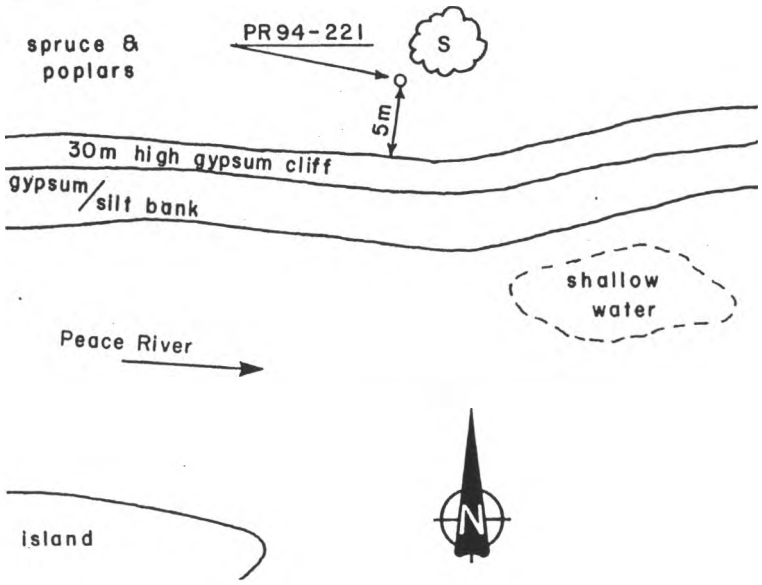
AIR PHOTO INFORMATION

Name: PEACE RIVER

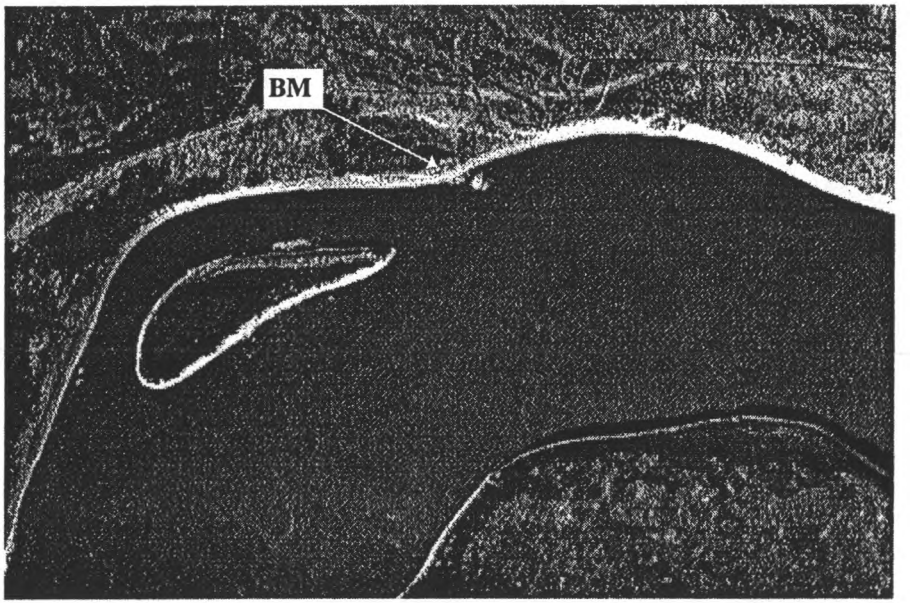
Date: OCT. 08-93 Line: 40-NNE

Roll: AS4475 Photo: 256

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **WS-408**

ELEV. Geodetic: Assumed: 100.000 m

INSTALLED: SEP. 28-94 UPDATED:

CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a 2' long 2"x2" wooden stake marked with flagging. Benchmark is located on the downstream point of a large island in the Peace River at Km. 408.78, upstream of the Fort Vermilion Bridge. Benchmark is set 2m back from 3m high cutbank, at extreme tail of island.

HISTORICAL/other marker names, etc.

Benchmark was established Sept. 28, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

Benchmark is temporary.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: **NAD83** (see Historical)

Latitude: N 58°24'13" UTM Northing: 6473973.000 assumed

Longitude: W 116°09'01" Easting: 549656.000 assumed

CROSS-SECTION

Number: PRX408LC Azimuth:

Number: PRX408RC Azimuth:

Number: Azimuth:

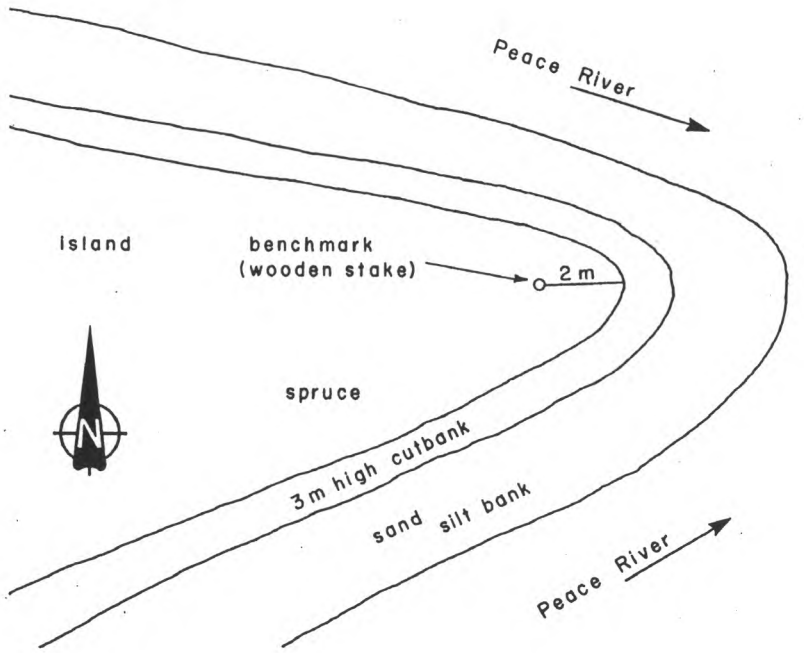
AIR PHOTO INFORMATION

Name: none

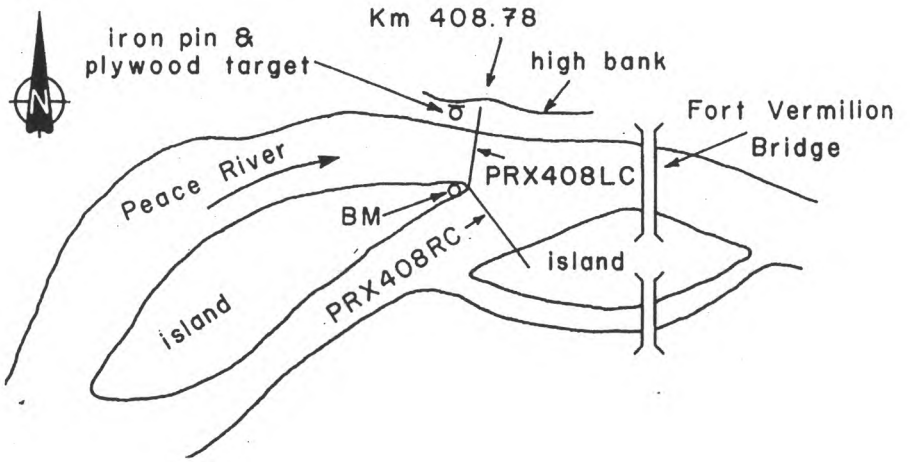
Date: Line:

Roll: Photo:

SKETCH OF LOCATION



LOCATION



BENCH MARK PROFILE

BENCH MARK NO: **IP-408 LB**

ELEV. Geodetic: Assumed: 103.476 m

INSTALLED: unknown

UPDATED: SEP. 28-94

CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is an iron pin located on the left bank of the Peace River across from the end of an island, at Km. 408.78. Iron pin is located at the base of a high bank, in front of a 2'x1' red target on a tree

SKETCH OF LOCATION

sketch not available

HISTORICAL/other marker names, etc.

History and reason for establishment of this iron pin are unknown. Point was used in 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°24'25.886" UTM Northing: 6474359.632 (ref to WS-408)

Longitude: W116°08'58.099" Easting: 549701.231 (" ")

CROSS-SECTION

Number: PRX408LC Azimuth:

Number: PRX408RC Azimuth:

Number: Azimuth:

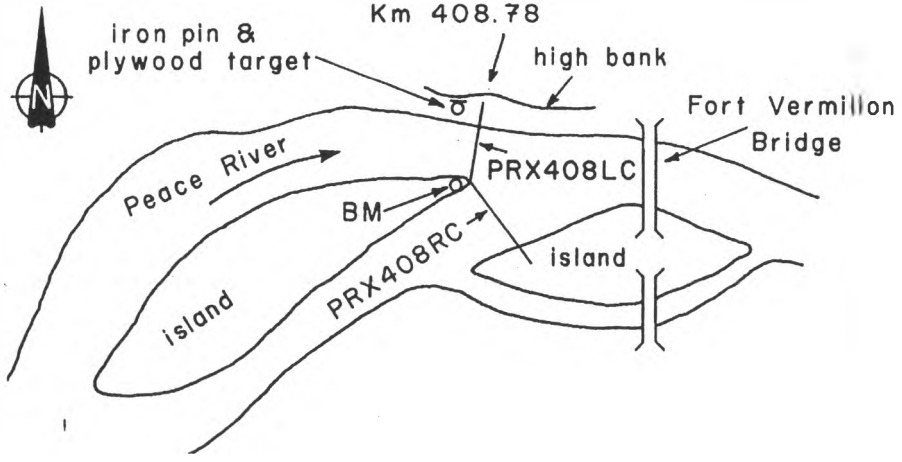
AIR PHOTO INFORMATION

Name: none

Date: Line:

Roll: Photo:

LOCATION



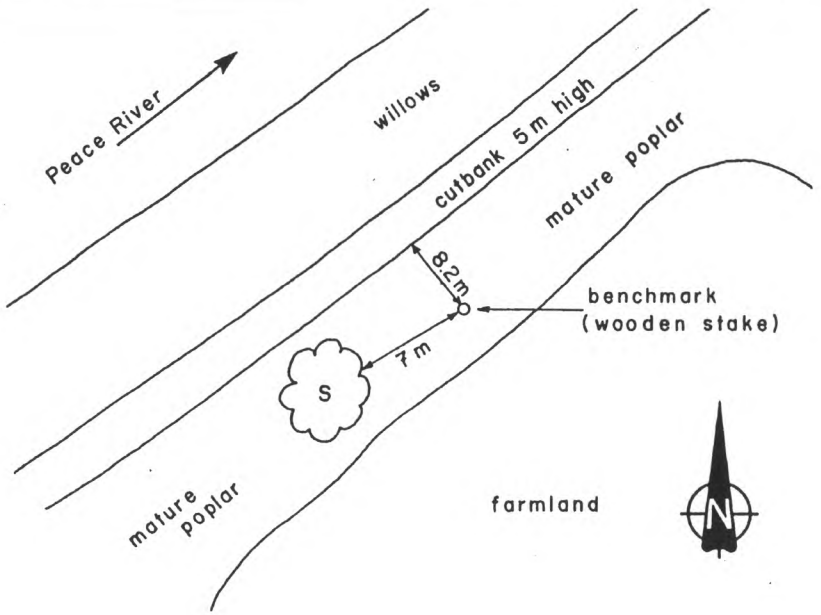
BENCH MARK PROFILE

BENCH MARK NO: **WS-410RC** ELEV. Geodetic: Assumed: 101.796 m

INSTALLED: SEP.28-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a 2' long 2"x2" wooden stake marked with flagging. Benchmark is located on the right bank of the Peace River at Km. 410.78, across from an island located upstream of the Fort Vermilion Bridge. Benchmark is set 8.2m inland from a 5m high cutbank, 7m downstream of a large spruce tree in a belt of mature poplar between the cutbank and a cultivated field.



HISTORICAL/other marker names, etc.

Benchmark was established Sept. 28, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.
Benchmark is temporary.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: **NAD83** (see Historical)

Latitude: 58°23'36.898"N UTM Northing: 6472829.501 (ref. to WS410LC)
Longitude: 116°10'12.594"W Easting: 548510.752 (" ")

CROSS-SECTION

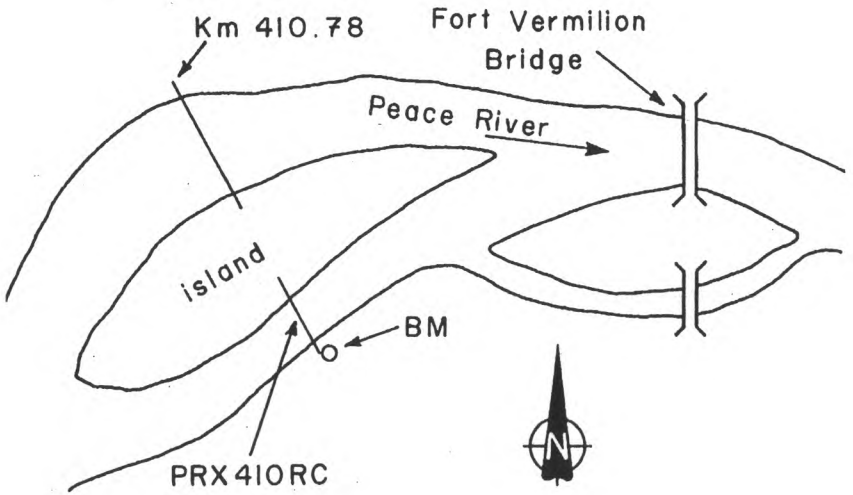
Number: PRX410RC Azimuth:
Number: Azimuth:
Number: Azimuth:

AIR PHOTO INFORMATION

Name: none
Date: Line:
Roll: Photo:

SKETCH OF LOCATION

LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **WS-410LC**

ELEV. Geodetic: Assumed: 100.000 m

INSTALLED: SEP.28-94 UPDATED:

CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a 2' long 2"x2" wooden stake marked with flagging. Benchmark is located on the left bank of the Peace River at Km. 410.78, across from an island located upstream of the Fort Vermilion Bridge. Benchmark is set 0.8m toward river from a large poplar tree marked with a 2'x1' red target, 4.7m inland from top of a cutbank, 10.4m inland from an iron bar.

HISTORICAL/other marker names, etc.

Benchmark was established Sept. 28, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

Benchmark is temporary.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES

Latitude: N 58° 24' 21" UTM Northing: 6474212.000 assumed

Longitude: W116° 10' 25" Easting: 548292.000 assumed

CROSS-SECTION

Number: PRX410LC Azimuth:

Number: Azimuth:

Number: Azimuth:

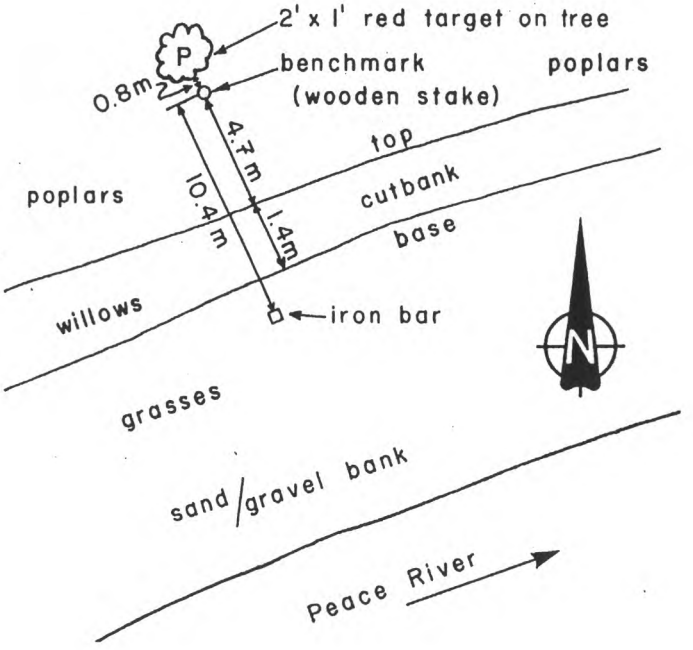
AIR PHOTO INFORMATION

Name: none

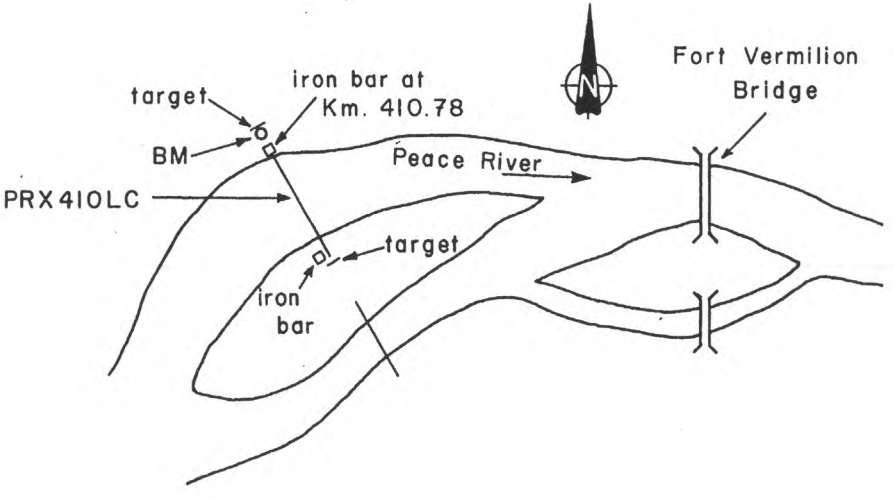
Date: Line:

Roll: Photo:

SKETCH OF LOCATION



LOCATION ON AIR PHOTO



BENCH MARK PROFILE

BENCH MARK NO: **IB-410LC RB** ELEV. Geodetic: Assumed: 97.045 m

INSTALLED: unknown UPDATED: SEP. 28-94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is a iron pin, located on the right bank of an island in the Peace River at Km. 410.78, located upstream of the Fort Vermilion Bridge.

UTM location is referenced to wooden stake 410LC.

SKETCH OF LOCATION

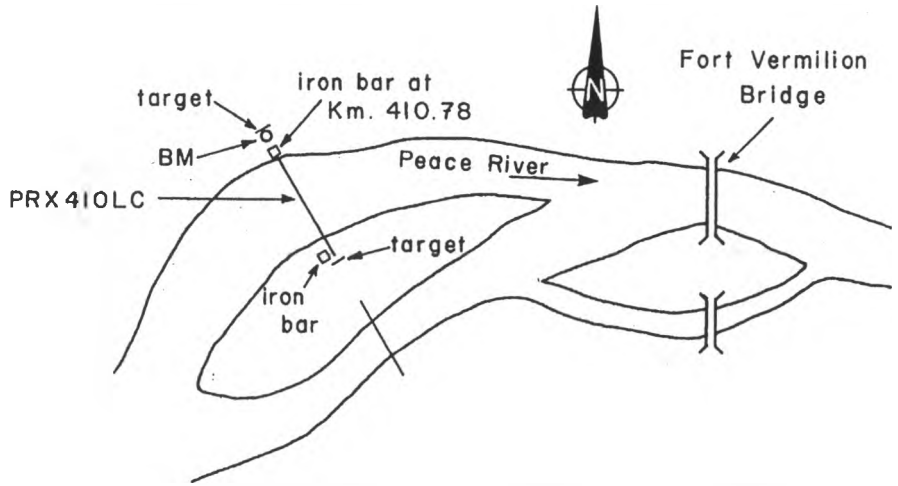
no sketch available

HISTORICAL/other marker names, etc.

History and reason for establishment of this iron bar are unknown. Point was used by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

LOCATION



CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°24'08" UTM Northing: 6473793.792 (ref. to WS-410LC)

Longitude: W 116°10'22" Easting: 548351.652 (" ")

CROSS-SECTION

Number: PRX410LC Azimuth:

Number: Azimuth:

Number: Azimuth:

AIR PHOTO INFORMATION

Name: none

Date: Line:

Roll: Photo:

BENCH MARK PROFILE

BENCH MARK NO: **IB-410LC LB** ELEV. Geodetic: Assumed: 96.299 m

INSTALLED: unknown UPDATED: SEP. 28-94 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is a iron pin, located on the left bank of the Peace River at Km. 410.78, across from an island located upstream of the Fort Vermilion Bridge. Benchmark is set 11.2m toward river from a large poplar tree marked with a 2'x1' red target, 10.4m towards river from wooden stake 410LC.

UTM location is referenced to wooden stake 410LC.

HISTORICAL/other marker names, etc.

History and reason for establishment of this iron bar are unknown. Point was used by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

CO-ORDINATES: **NAD83** (see Historical)

Latitude: N 58°24'21" UTM Northing: 6474201.618 (ref. to WS410LC)

Longitude: W 116°10'25" Easting: 548292.396 (" ")

CROSS-SECTION

Number: PRX410LC Azimuth:

Number: Azimuth:

Number: Azimuth:

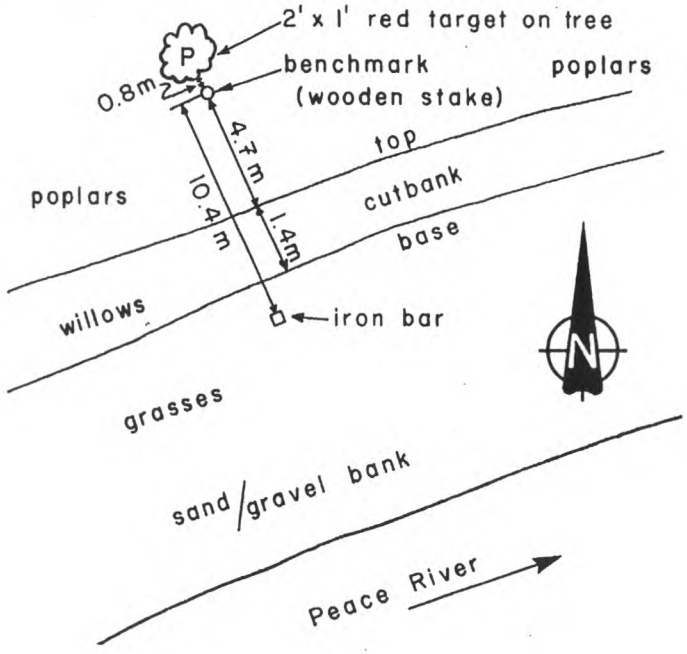
AIR PHOTO INFORMATION

Name: none

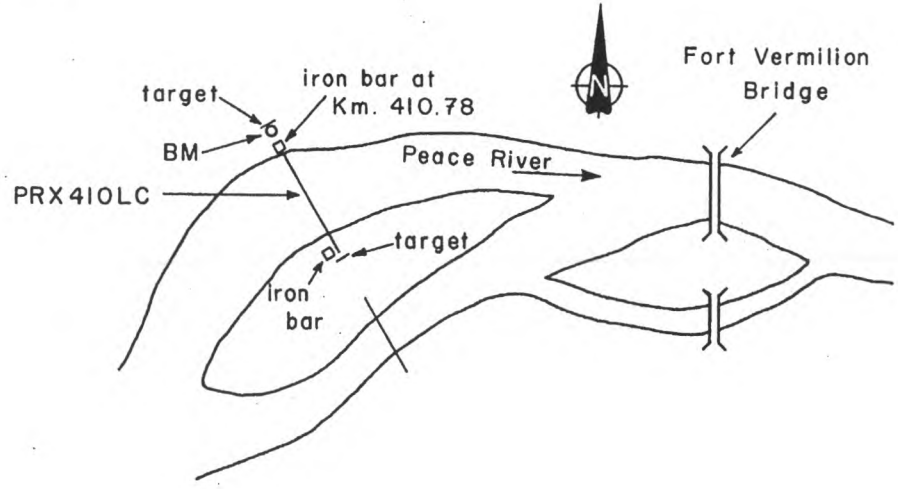
Date: Line:

Roll: Photo:

SKETCH OF LOCATION



LOCATION



BENCH M. K PROFILE

BENCH MARK NO: **TBM #1**

ELEV. Geodetic: Assumed: 100.000 m

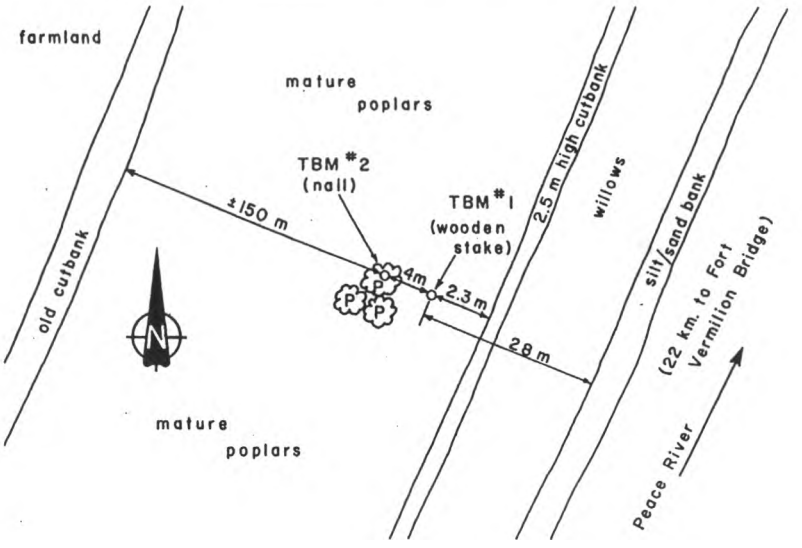
INSTALLED: SEP. 29-94 UPDATED:

CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is 2' long 2"x2" wooden stake marked with flagging. Benchmark is located on the left bank of the Peace River at Km. 430.87, 22km upstream of the Fort Vermilion Bridge. Benchmark is set 2.3m inland from the edge of a 2.5m high cutbank, 28m inland from the start of a belt of willows along the river shore, 4m towards river from TBM #2, and approx. 150m from the base of an old cutbank which has a cultivated field at it's crest.

SKETCH OF LOCATION



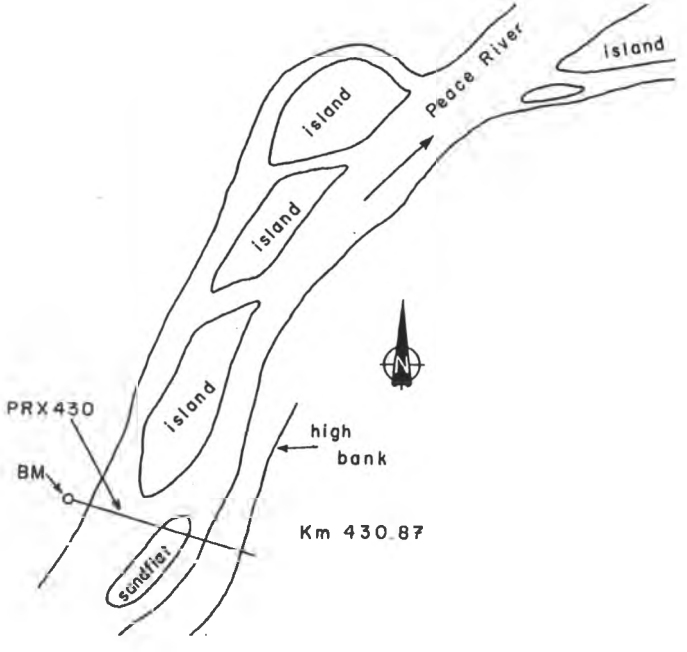
HISTORICAL/other marker names, etc.

Benchmark was established 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

Benchmark is temporary.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

LOCATION



CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°17'08" UTM Northing: 6460651.000 approx.

Longitude: W 116°23'46" Easting: 535415.000 approx.

CROSS-SECTION

Number: PRX430 Azimuth:

Number: Azimuth:

Number: Azimuth:

AIR PHOTO INFORMATION

Name: none

Date: Line:

Roll: Photo:

BENCH MARK PROFILE

BENCH MARK NO: **TBM #2**

ELEV. Geodetic: Assumed: 100.608 m

INSTALLED: SEP. 29-94 UPDATED:

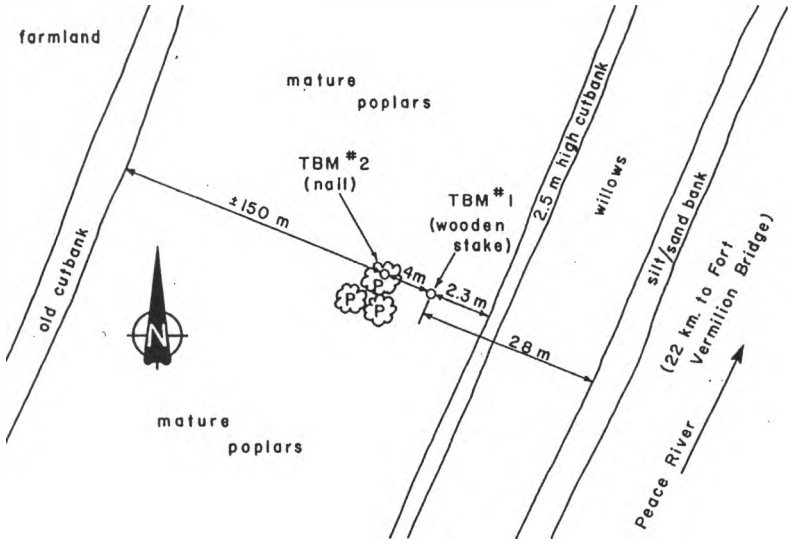
CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is nail in a poplar tree marked with flagging. Benchmark is located on the left bank of the Peace River at Km. 430.87, 22km upstream of the Fort Vermilion Bridge. Benchmark is set 6.3m inland from the edge of a 2.5m high cutbank, 32m inland from the start of a belt of willows along the river shore, 4m inland from TBM #1, and approx. 150m from the base of an old cutbank which has a cultivated field at it's crest.

BM UTM location is referenced to TBM #1.

SKETCH OF LOCATION



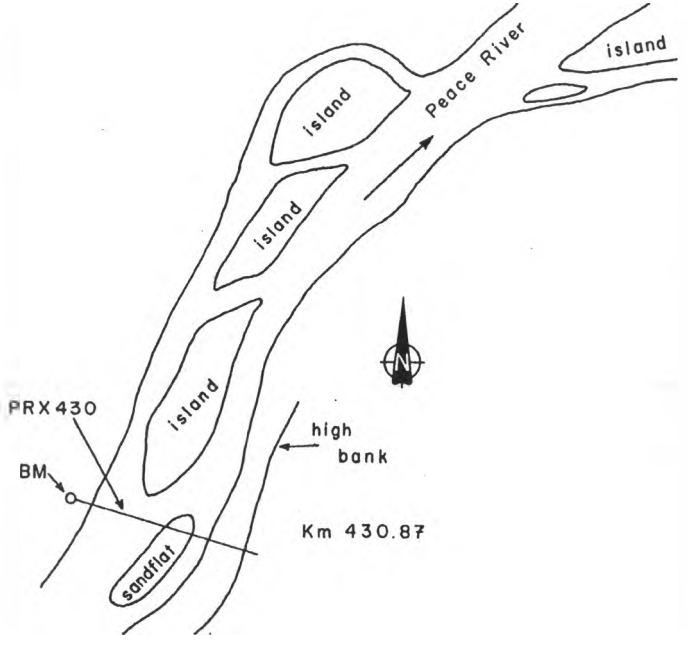
HISTORICAL/other marker names, etc.

Benchmark was established Sep. 29, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study.

Benchmark is temporary.

UTM and LAT/LONG coordinates derived by handheld GPS (accuracy ±100 m)

LOCATION



CO-ORDINATES: NAD83 (see Historical)

Latitude: N 58°17'08" UTM Northing: 6460651.653 (ref. to TBM#1)

Longitude: W 116°23'46" Easting: 535411.008 (ref. to TBM #1)

CROSS-SECTION

Number: PRX430 Azimuth:

Number: Azimuth:

Number: Azimuth:

AIR PHOTO INFORMATION

Name: none

Date: Line:

Roll: Photo:

BENCH MARK PROFILE

BENCH MARK NO: **ASCM 378430** ELEV. Geodetic: 268.592 m
Assumed:

INSTALLED: DEC. 24-85 UPDATED: JAN. 23-87 CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is an Alberta Survey Control Marker (ASCM), an Aluminum Cap on a 6cm steel pipe 2.44m long with a helix base. Benchmark is located on the right bank of the Peace River upstream of Carcajou Point, in a cutline on the north limit of NE 1/4-36-100-20-5, 8m inland of the top of a cutbank.

HISTORICAL/other marker names, etc.

See ASCM Land Information Services Division description for details.

CO-ORDINATES: NAD83

Latitude: 57° 43' 47.91424" UTM Northing: 6398654.746
Longitude: 117° 07' 18.94490" Easting: 492738.695

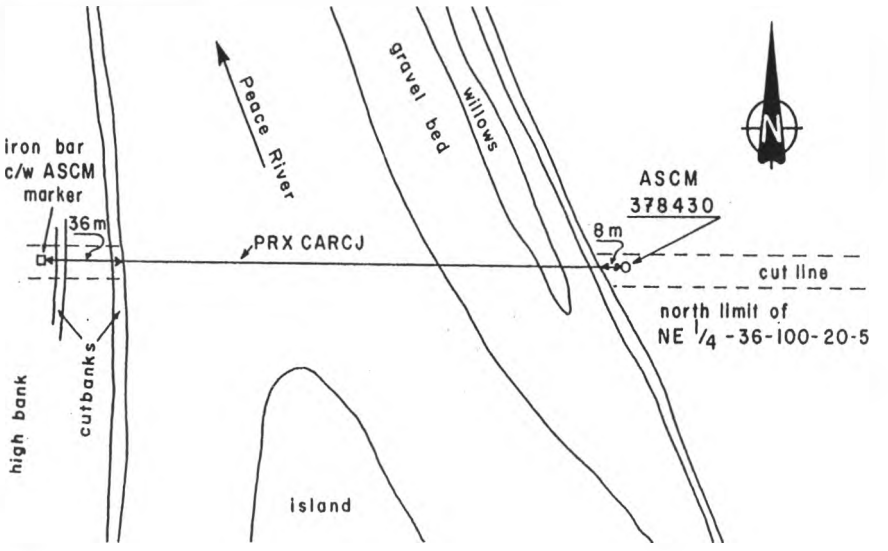
CROSS-SECTION

Number: PRX CARCJ Azimuth:
Number: Azimuth:
Number: Azimuth:

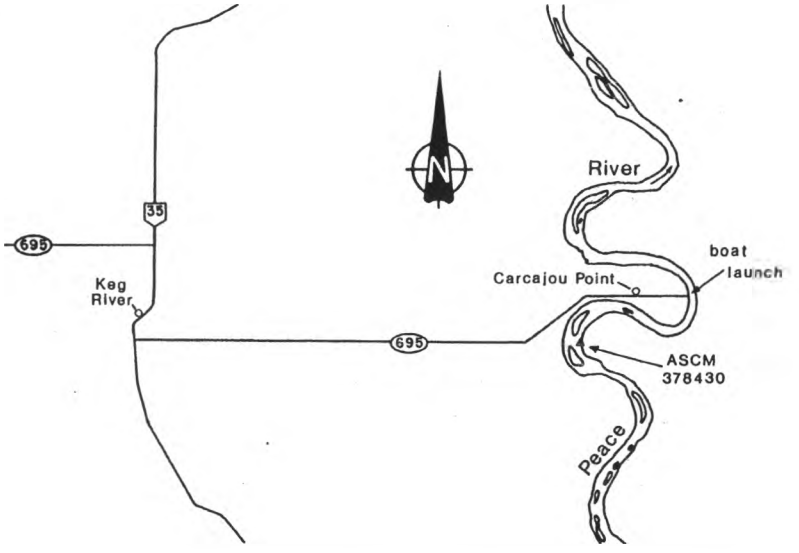
AIR PHOTO INFORMATION

Name: none
Date: Line:
Roll: Photo:

SKETCH OF LOCATION



LOCATION



BENCH MARK PROFILE

BENCH MARK NO: **SR94-04** ELEV. Geodetic: 209.745 m

Assumed:

INSTALLED: JUL. 15-94 UPDATED: CONDITION: NEW

BENCH MARK DESCRIPTION

Benchmark is a WSC Brass Cap installed at the top of a small rock island in a set of rapids in the Slave River at KM. 407.0 (Mile 254.4) (ref. Hydrographic Service chart #6301, Fort Mcmurray to Fort Smith). Benchmark was not marked with a post or sign due to ice scour.

HISTORICAL/other marker names, etc.

Benchmark was established July 15, 1994 by Water Survey of Canada (WSC) for the Northern River Basin Study (NRBS) Peace Athabasca Delta (PAD) study. Benchmark was tied to BM GSC 1720-D on Sept. 20, 1994, by WSC staff.

UTM and **LAT/LONG** coordinated derived by handheld GPS (accuracy ± 100m)

CO-ORDINATES: **NAD83** (see Historical)

Latitude: N 59°04'21" UTM Northing: 6548220.000

Longitude: W 111°24'41" Easting: 476409.000

CROSS-SECTION

Number: SR94X004 Azimuth:

Number: Azimuth:

Number: Azimuth:

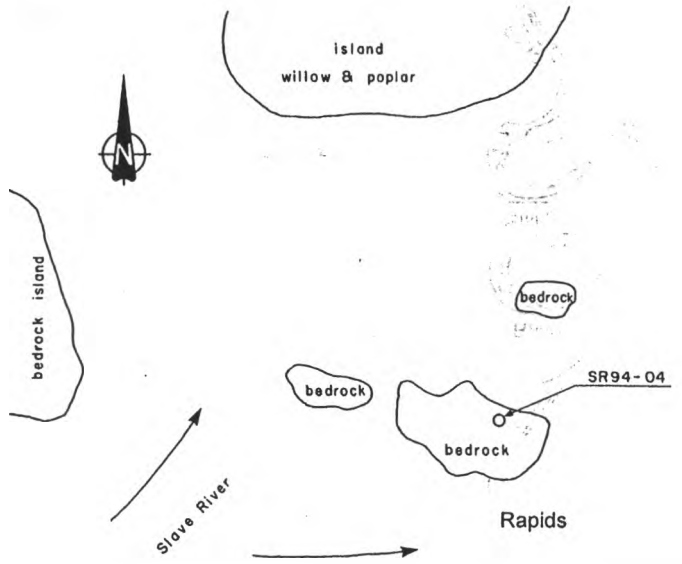
AIR PHOTO INFORMATION

Name: none

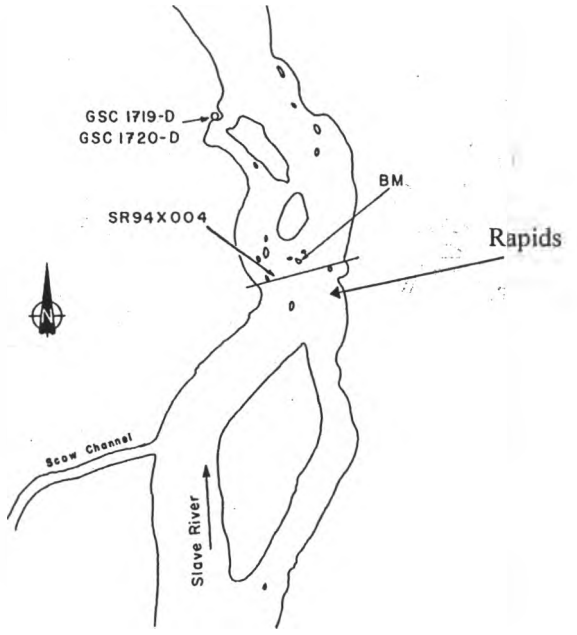
Date: Line:

Roll: Photo:

SKETCH OF LOCATION



LOCATION



BENCH MARK PROFILE

BENCH MARK NO: **GSC 1720-D** ELEV. Geodetic: 211.322 m

INSTALLED: UPDATED: March 1968 (REV. No. 1) CONDITION: GOOD

BENCH MARK DESCRIPTION

Benchmark is a Geological Survey of Canada Brass Cap located on the west side of the Slave River, at Mile244.6 (Km. 391. 4) from Fort McMurray (Waterways), Alberta, 7 miles (11.2 km) north of confluence with Peace River, just north of an island. BM is in top of rock outcrop 42 ft. (12.8 m) east of river bank.

(above adapted from GSC 1963 desc.)

HISTORICAL/other marker names, etc.

Benchmark was established by Geological Survey of Canada (GSC). Please refer to GSC for historical and current data.

UTM and **LAT/LONG** coordinated derived by handheld GPS (accuracy ± 100m)

CO-ORDINATES: NAD83 (see Historical)

Latitude: 59° 05' 12.1" UTM Northing: 6549783

Longitude: 111° 25' 29.2" Easting: 475658

CROSS-SECTION

Number: SR94X004 Azimuth:

Number: Azimuth:

Number: Azimuth:

AIR PHOTO INFORMATION

Name: none

Date: Line:

Roll: Photo:

SKETCH OF LOCATION

no sketch available

3 1510 00168 6691

LOCATION