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THE USE AND PUBLICATION OF HYDRAULIC AND MORPHOLOGIC DATA FOR CANADIAN RIVERS

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THE USE AND PUBLICATION OF HYDRAULIC AND MORPHOLOGIC DATA FOR CANADIAN RIVERS

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Abstract

The files of the several thousand Water Survey of Canada hydrometric stations in Canada contain hydraulic and morphologic information that is largely unprocessed for publication. An assessment of the potential value of making this information readily available in a published form was the primary purpose of the study summarized herein.

The long development of ideas on the systematic compilation of river data has principally been for scientific purposes. Adaption of these ideas to engineering and environmental studies is outlined. Several case histories are presented in which a Water Survey of Canada gauge was located in close proximity to sites where river hydraulic and morphologic data were collected for specific engineering studies.

A review is made of what baseline data are typically available at a gauge site, and what hydraulic and morphologic information could be extracted and published after perhaps some additional field work. Recommendations are made with respect to how alternative levels of publication effort could be pursued.

Résumé

Les fichiers des milliers de stations hydrométriques de la Division des relevés hydrologiques du Canada contiennent des renseignements en matière d'hydraulique et de morphologie qui sont en grande partie non traités en vue d'une publication. L'étude résumée dans ce document avait principalement pour but d'évaluer dans quelle mesure il serait utile de faciliter l'accès à ces renseignements en les publiant.

La longue évolution des notions inhérentes à la compilation systématique des données relatives aux cours d'eau a surtout visé des buts scientifiques. On expose à grands traits l'adaptation de ces notions à des études de génie et à des études environnementales. On présente plusieurs cas de jauges de la Division des relevés hydrologiques du Canada situées à proximité d'emplacements où des données en matière d'hydraulique et de morphologie étaient collectées en vue d'études spécifiques de génie.

On examine quelles sont les données de base typiquement disponibles à un emplacement de jaugeage et quels renseignements en matière d'hydraulique et de morphologie pourraient être extraits et publiés après, peut-être, exécution de quelques travaux supplémentaires sur le terrain. On formule des recommandations sur la manière de mettre en branle d'autres formes d'activités reliées à la publication.

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1. INTRODUCTION

1.1 Background

Operation of the several thousand hydrometric stations across Canada basically involves measuring and recording stream stages (water levels) and measuring stream discharges. The derived stage-discharge relationships are then applied to stage records to produce estimates of discharge on a discrete or continuous basis, depending upon the particular type of gauge being operated. These data are then used to compute daily mean discharges for annual publication by Water Survey of Canada.

As part of the above process, some information and data that are gathered, analyzed and filed become utilized only on occasions when requests are made by government agencies or private concerns for access to specific files. The frequency of these requests has been increasing. Consequently, the Water Resources Branch of Environment Canada has instituted a Working Group which has the responsibility for assessing the character of these requests and to determine whether this information can be processed and published within Water Resources' existing program load.

The present report is concerned with hydraulic and morphologic data and information for streams. The overall objective is to outline how these data are utilized by practising engineers, environmentalists and researchers so that Water Survey of Canada personnel can better appreciate the purpose of any particular request. Ultimately, perhaps with little additional effort by these personnel, it may be possible to extend, formalize and publish hydraulic and morphologic data and information to benefit a wide range of users. For many engineering and environmental projects and studies that utilize Water Survey of Canada data, it would be useful to have easy access to a set of hydraulic and morphologic data describing the rivers in the vicinity of the gauging sites. Used in conjunction with streamflow data and aerial photography, such information would often enable the user to make a preliminary assessment of river characteristics, behaviour and response to interference at points distant from gauging stations, without the necessity of time-consuming field investigations at an early stage when many alternatives are still under consideration.

1.2 Terms of Reference

The study terms of reference, as incorporated by Environment Canada into their contract with Northwest Hydraulic Consultants Ltd., were as follows:

1. Explain and identify uses and value of hydraulic and morphologic data in engineering and environmental studies, with examples from actual cases where practicable.

2. Review briefly previous examples of hydraulic / morphologic data collection and publication.

3. Propose programs for systematizing of existing data and for its extension by additional data collection where necessary, with a view to publication for each region of a set of site descriptions with appropriate hydraulic and morphologic data. Indicate which data may require updating from time to time.

4. Indicate appropriate methods and standards for data collection, processing, analysis and publication. It is envisaged that the bulk of the information would be derived from existing files or would be collected in the normal course of visits by technical personnel to gauging sites.

5. Include consideration of integrating into the proposed data publication; information on key flow, stages, sediment transport and river ice conditions and processes.

1.3 Study Approach and Report Organization

The information and recommendations presented in this report are intended primarily for the field and district office personnel of Water Survey of Canada, presently tasked with collecting, processing and filing whatever hydraulic/morphologic data are being collected at hydrometric gauge sites. It has been normal practice to submit special requests for such information to Water Survey of Canada district offices. Frequently the requester, particularly if he is from a private concern, is reluctant to ask these personnel to search files and pull together information where it might be deemed to be a task outside their normal job descriptions. Inefficiencies arise where the information requested is poorly defined or where the requester has not fully appreciated the level of effort required to compile the information.

It seems appropriate then to attempt to formalize the processing of available hydraulic/morphologic data and information, at least at selected gauge sites, with a view to maintaining files or published summaries which can be readily accessed by district offices and/or outside users.

It should be noted that both engineering and environmental professionals have been identified as potential users of hydraulic/morphologic data. In the last decade the latter have been developing an increasing interest in these types of data, either for assessing the stability of aquatic habitats or for studying dispersion or decay of pollutants along a stream system.

Section 2 of the report outlines typical uses of these data by the engineer and environmentalist and presents examples. Section 3 provides an overview of previous examples of hydraulic/morphologic data collection and publication. Section 4 addresses the question of how existing hydrometric station data files could be utilized to provide useful and readily accessible information in a format which either discipline would find acceptable.

2. USES OF HYDRAULIC AND MORPHOLOGIC DATA

2.1 Definition

Hydraulic/morphologic data as used herein means an assemblage of numerical and descriptive items that, taken together, more or less establish the character or 'regime' of a river with respect to flow phenomena and velocities, hydraulic resistance, stability and movement of bed material, planform and cross-sectional dimensions, relationship to valley and floodplain, composition and erosion of banks, and deposition and migration of bars and like features.

Just as compiled hydrometeorologic data at discrete stations are used in hydrologic studies to make inferences about conditions at intermediate points, so can hydraulic/morphologic data be used by specialists to make reasonable inferences on channel behaviour and response at locations other than the compiled sites. It may be objected that hydraulic/morphologic characteristics do not vary in a smooth manner along rivers, which is certainly sometimes the case; nevertheless there are many rivers which retain a characteristic 'signature' over long distances, as seen for example on aerial photographs.

2.2 Engineering and Environmental uses of Hydraulic and Morphologic Data

In order to indicate the potential non-research related uses and value of hydraulic/morphologic data, we have in Figure 1 identified typical kinds of studies and projects in which these data are required. The diagram also outlines the types of data needed and the hydraulic parameters that are normally derived during the progress of a project.

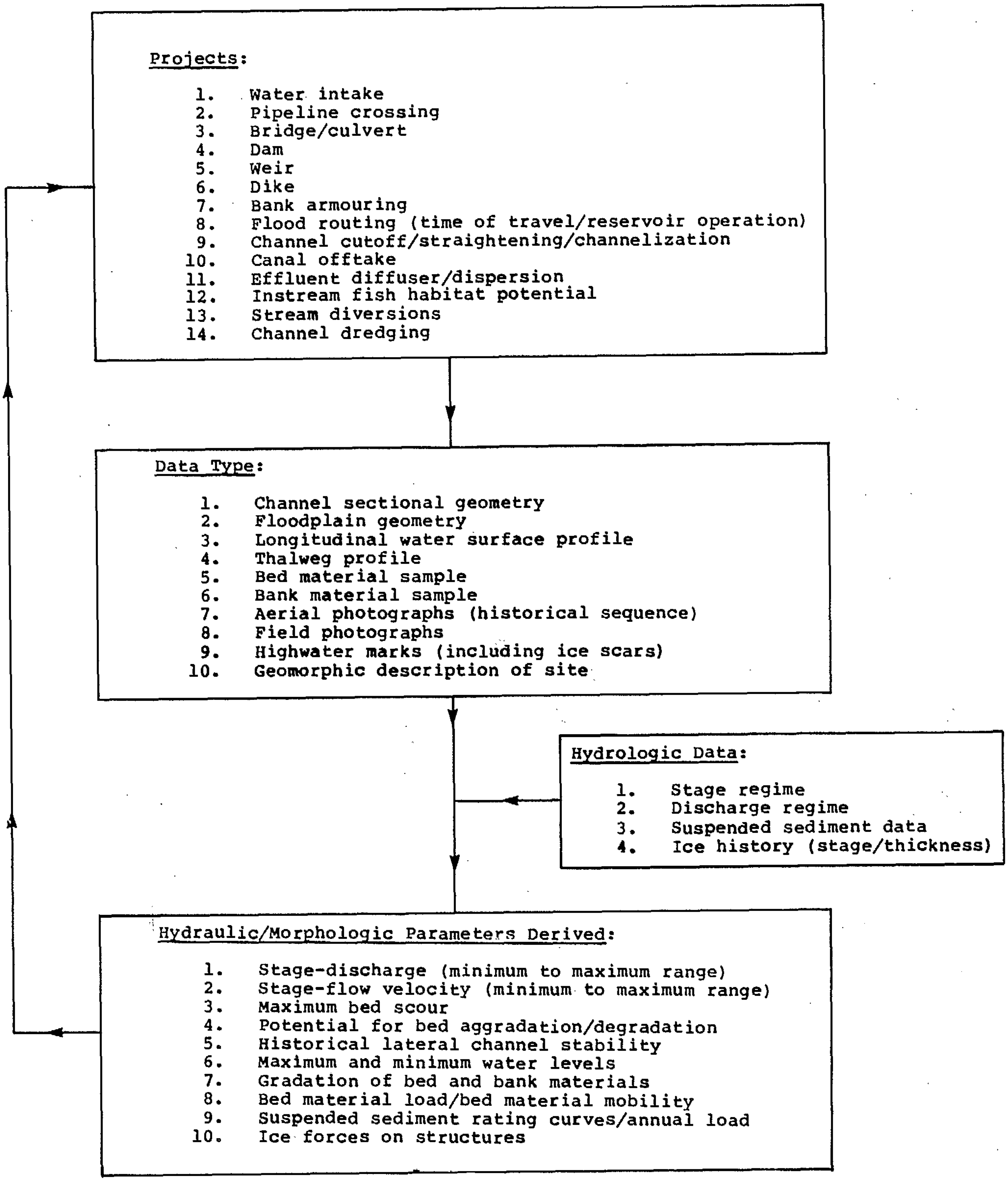


Figure 1. Uses of hydraulic and morphological data

For the purpose of illustrating ultimate end-points in the use of these data, examples are presented in Appendix A: these were taken from actual study cases. Comments pertaining to these cases are presented below.

Case 1 (Appendix A) - For the design of a proposed pipeline river crossing of the M'Clintock River at the location described, a complete data and information collection program was undertaken in 1978. The documentation presented in Appendix A includes a regime/geomorphic description of the crossing site, together with portions of the information package that was prepared for the project. The W.S.C. gauge record 6.8 km upstream of the crossing provided a readily available means of establishing a design flood discharge.

Earlier, in 1973, the Department of Indian and Northern Affairs had instituted a program of collecting a comprehensive set of hydraulic/morphologic information at selected W.S.C. gauge sites in Yukon Territory; a sample information package for the above-mentioned M'Clintock River gauge is presented in Appendix B.

A comparison of the two information packages, in relation to the question of how the upstream gauge information could be utilized to describe the hydraulic/morphologic characteristics of the M'Clintock at the downstream pipeline crossing site, suggests that the upstream site is only loosely representative of the downstream one. Flow velocities, depths and longitudinal slopes for both sites are all quite comparable, but site-specific factors predominated in the final design parameters for the pipeline site to a very significant degree. Information which was utilized from the W.S.C. gauge site included: hydraulic roughness (Manning) coefficients; bed material composition; longitudinal slope; range of water levels, velocities and depths; channel stability; and historical ice behaviour.

Case 2 (Appendix A) - A new water intake was to be constructed on the North Saskatchewan River near Lloydminister, Saskatchewan. An active W.S.C. gauge is located on the river 17 km upstream of the proposed intake site. The annual flood record available at this gauge was utilized for the prediction of a design flood discharge, while the stage-discharge data were adapted to the intake site as a check on a rating curve based on locally surveyed cross sections. The information presented in Appendix A includes cross section plots and bed topography obtained from a special river survey program.

Thus, the hydraulic information available from a nearby W.S.C. gauge was helpful in determining or confirming the hydraulics at the proposed intake site. Other kinds of information derived from the gauge site that were used in the final design calculations included: channel roughness coefficients and indications of historical ice action.

Case 3 (Appendix A) - A pipeline crossing site was investigated on a river in northwest Ontario. This case is presented as an example of a stream in a northern environment within the Canadian Shield. These streams tend to be boulder paved, rather inactive laterally (because of permafrost), entrenched, and subject to severe ice runs and jamming. The information package includes morphologic information surveyed specifically for the proposed pipeline crossing, together with derived hydraulic and hydrologic parameters. A W.S.C. gauge was located a short distance upstream of the crossing site, but the gauge information was of limited hydraulic value because there was a lake between the gauge and the pipeline site.

Case 4 (Appendix A) - This case was concerned with predicting potential degradation downstream of a proposed dam on the Oldman River in Alberta. A long term W.S.C. gauge and suspended sediment measurement station is located only 7 km downstream of the damsite. A comprehensive cross section survey program was carried out between the damsite and gauge. The close proximity of the gauge to the damsite provided a valuable source of hydraulic information that was used directly in backwater and sediment transport modelling procedures. All aspects of the gauge file were of direct applicability to the study.

Summary - In reviewing the hydraulic/morphologic aspects of the above four review cases it is apparent that:

1. The extent of required surveys for cross sections and longitudinal slope profiles are very dependent on the engineering or environmental problems at hand; cross section location and spacing requirements for pipeline crossings, bridges and water intakes, for example, might differ significantly.

2. Because of limited file information, the use of a nearby W.S.C. gauge is often limited to transferring the gauge stage-discharge relationship to the project site, or to using it to confirm a computed one at the project site.

3. Provided that the gauge is located in a reach of stream that is hydraulically and morphologically comparable with the project site, information from the gauge file which would be of interest includes: computed hydraulic roughness (Manning's 'n') and flow velocities for various stages, maximum and minimum

recorded stages, information on ice effects, bed and bank materials, and experience of channel changes in planform and cross-section over a period of time.

The typical situation, is that Water Survey of Canada hydrologic data are transposed to the project site and applied to the local hydraulic/morphologic data. If more systematic hydraulic/morphologic data were available at gauging stations, it is envisioned that they could also be transposed to some degree to a project site at some distance from the gauge, and used to supplement available site data and set it in a broader context.

3. PREVIOUS EXAMPLES OF HYDRAULIC/MORPHOLOGIC DATA COLLECTION AND PUBLICATION

3.1 Historical Review

Engineering concern with and scientific interest in the hydraulic/morphologic characteristics of rivers has a long history, but until the middle of the present century study was confined mainly to specific problem cases, for example the Mississippi River, or to limited aspects like the estimation of flow velocities or of bed-material transport. Gradually it became realized that rivers flowing in erodible materials exhibited a complex set of inter-related characteristics and processes involving hydraulics, sediment transport, erosion and deposition, channel and floodplain formation, all linked in the long term to landscape evolution and geology. It was also realized that the practical problems of predicting river behaviour and response to imposed changes, and of devising appropriate corrective measures to problems, were at least partially linked to these 'regime' characteristics. In the course of analyzing the problem of stable canal design in alluvial materials, Lacey (1929-30) examined some river data and demonstrated similarities between canal and river 'regime' dimensions. Inglis (1948) discussed various aspects of river behaviour from a similar viewpoint, and Blench (1957) further generalized the findings of canal studies as a basis for treatment of river problems.

A milestone paper on the hydraulic geometry of stream channels by Leopold and Maddock (1953), Appendix C, examined particularly the cross-sectional properties of river channels and their relationship to characteristic discharges and sediment loads, but it also touched on relationships involving slope and roughness. Probably for the first time, a substantial set of river hydraulic/morphologic data at gauging sites was tabulated and analyzed, although the parameters listed were mostly cross-sectional dimensions and mean discharges. Following this study, the U.S. Geological Survey produced a number of Professional Papers under the series subtitles of "Physiographic and Hydraulic Studies of Rivers" and "Sediment Transport in Alluvial Channels". Some of these studies were concerned with particular rivers or basins (e.g. Fahnestock, 1963) and others with general topics as analyzed from a number of cases, like the Leopold and Maddock paper. Among topics examined in later studies were the dimensions and shapes of meanders (Langbein and Leopold, 1966), the relationship of channel patterns to discharge and slope (Leopold and Wolman, 1957), the progression of bars and bedforms (Langbein and Leopold, 1968), processes of scour and fill (Colby, 1964) and floodplain formation (Wolman and Leopold, 1957). All of these studies were characterized by a broad physical view of river mechanics rather than a narrowly mathematical one. Many of the results were incorporated in the book by Leopold, Wolman and Miller (1964).

Parallel with these developments in the United States, similar investigations proceeded in other countries. Nixon (1959), Appendix C, applied a Leopold-Maddock type of analysis to a set of British rivers, tabulating and graphing bankfull cross-sectional dimensions against bankfull discharge (as opposed to the more easily definable but less logical mean discharge that had been used by Leopold and Maddock). Translations were published of various river studies in the USSR (eg. Kondratiev, 1959; Popov, 1962), but these did not include extensive data sets.

In western Canada, various studies of river characteristics were initiated in the 1960's, mainly influenced by the work of Blench and of the U.S. Geological Survey.

Neill (1964) summarized some of the findings of various investigators and suggested a list of key data required for scientific analysis of river behaviour. The concept of a comprehensive data set was further developed by Neill and Galay (1967), Appendix C, and illustrated with reference to the lower Red Deer River in eastern Alberta, of which a detailed study had been completed. Some guidance was also given on methods of collecting and compiling the suggested data set. Kellerhals (1967) examined the cross-sectional and slope characteristics of a number of B.C. rivers with gravel-paved beds, and included a limited data table. Kellerhals et al (1972), Appendix C, presented tables of hydrologic, hydraulic, and morphologic data for 110 river gauging stations in Alberta, together with detailed slope profiles of the major rivers and aerial and ground photographs of selected reaches. Bray (1972; 1975) used these data for an extensive analysis of hydraulic geometry relationships and for investigating the question of 'dominant' discharge.

Elsewhere in Canada, Jolly et al (1977) presented a data set for gauging stations in the Yukon and Northwest Territories which, listed river widths and flood discharges and was used only to develop width-discharge correlations for flood estimation purposes. In Alaska, Drage and Carlson (1977) examined hydraulic geometry relations for a set of braided rivers, on similar lines to Bray's study for Alberta. In Great Britain, Charlton et al (1978), Appendix C, tabulated and analyzed data for a set of 23 gravel rivers. Church and Rood (1983), Appendix C, further developed the concept of a standardized data set arranged and coded for computer processing.

The hydrologic/hydraulic/morphologic tables of Kellerhals et al (1972) for Alberta rivers have generally proven to be useful in situations where a quick overview of a river is required. As of 1985, an additional 15 years or so of discharge record was available for each of the 110 gauge sites utilized; as well, additional gauge sites have been installed since 1972. Alberta Research Council is conducting a field program at the new gauge sites with the objective of publishing a set of separate tables as an addendum to the 1972 publication.

Summarizing the above review, it can be said that there has been a long development of ideas on the systematic compilation of river data for scientific and engineering purposes, and that there is considerable guidance and example available on what constitutes an adequate data set and on how to acquire and compile it. In Section 4, this guidance is applied to propose a program for gauging stations across Canada.

3.2 Required Level of Hydraulic/Morphologic Information

The question of what constitutes an adequate data set in respect of the present study objectives involves at least three considerations: (1) what current standards and guidelines can be applied in planning a hydraulic/morphologic data collection program? (2) for solving everyday practical problems, do engineering/environmental requirements differ from research requirements? and (3) to what degree can existing gauging station data be adapted to the requirements of these disciplines?

As the majority of ideas and recommendations on systematic compilation of hydraulic/morphologic data have derived from research-oriented projects, a critical examination of some of the more recent references is essential. Items of particular interest include cross sections (number, spacing), longitudinal slopes (river bed, water surface) and bed material composition.

Stream Cross Sections - Neill and Galay (1967) suggest that the number and spacing at cross sections should reflect variability of channel dimensions, character, and the purpose for which the data are being collected. They also suggest that one or more of the cross sections should be extended across the floodplain to at least expected maximum flood level. In one particular example presented, cross sections were spaced at about 10 channel widths apart.

Bray (1972) recommends that cross sectioning should extend over at least one meander wave length, or at least two pool and riffle sequences, or at least 20 river widths. Within this length, he suggests that 10 cross sections be surveyed; this implies an average spacing of 2 river widths.

Church and Rood (1983) suggest that to properly define the 'averaged' channel geometry, cross sections should be surveyed in a reach having an approximate length of 10 channel widths, or one complete pool/riffle sequence, or at least one meander bend.

In each of the foregoing references, the recommendations apply principally to research-type studies where the objective was to quantify various regime parameters. A hydrometric gauge was normally located within the study reach, or at least nearby. A single cross section at the gauge is usually not considered desirable because a gauge site is often not hydraulically or morphologically representative of the stream; a gauge site is typically selected for reasons of access, low potential for being flooded out, and channel stability.

In the case of engineering or environmental project studies, the sites are usually located at some distance from a gauge, and the requirements for cross section surveys may differ significantly from those of a research-oriented study. For a floodplain zoning study, for example, sections have to be located to give due weight to changing channel geometry and roughness. Studies for bridge and pipeline crossings require several closely spaced cross sections at the crossing, plus several upstream and downstream cross sections for the assessment of flow hydraulics and surface profiles. Studies for water intakes typically require several closely spaced complete cross sections, as well as a number of partial cross sections providing good definition of the topography. For modelling of instream fish habitat, 5 to 10 closely spaced cross sections are required at each of several locations. Thus, for the solution of practical engineering and environmental problems, stream section data should at least meet the same level of quality as for a research study, but the number and spacing of cross sections varies considerably according to the nature of the problem.

In the case of gauge sites where under present arrangements only one cross section location is normally surveyed, there remains the question of how useful is this one section for practical or research studies. Since most engineering/environmental studies are at locations some distance from a gauge, a single cross section location can serve only for a generalized description of the stream at the gauge. If the single section is not truly representative of the stream, then even a generalized description may require additional cross sections. Selection of gauge sites where additional cross sections are to be surveyed should be based on a gauge by gauge review to develop priorities - this issue is discussed further at the end of this section.

Longitudinal Profiles - The longitudinal profile of a stream normally refers to a water surface profile, although a bed profile is frequently surveyed in conjunction with the surface one. No realistic quantitative guidelines will be found in the literature with respect to what minimum reach length is considered acceptable for a longitudinal profile survey. Church and Rood (1983) suggest that a representative measure of slope should extend "over a sufficiently long distance (where)...such a distance will be several repeating distances of the river planform" (taken to mean several meander wave lengths).

Survey of a water surface profile requires greater precision than cross section surveying, particularly for flat-sloped streams. As a general rule the profile reach length should extend the full distance between upstream and downstream cross sections, where a multi-section survey program is being conducted. Otherwise, the distance required depends mainly on stream character: for large streams having a uniform section throughout, profile lengths of 10 channel widths should suffice; for small to intermediate streams this profile length should be about 20 channel widths; and for small, steep streams the profile should extend through several pool and riffle sequences. Braided streams are the most difficult to profile, but there is normally a primary subchannel which should be surveyed for a distance at least equal to the active width of the braided channel system.

In all cases the longitudinal profile should be surveyed during a period of nearly constant discharge.

Topographic maps are frequently used to estimate overall stream slopes over substantial distances where a ground survey is not deemed practicable. Bray (1972) and Church and

Rood (1983) strongly recommend against basing local slopes of map interpretation because significant errors can result. Figure 2 provides a measure of the scatter that results when surveyed stream slopes are compared with estimates from topographic maps.

Bed Material Gradations - The sampling of coarse streambed materials and the derivation of size distribution curves have been the subject of much study and discussion. Lane and Carlson (1953), Wolman (1954), Mier (1969), Bray (1972), and Church and Rood (1983) outline the problems encountered in organizing a sampling program for gravel bed streams; the conclusion is that a universally acceptable, practical, sampling technique is not available for the purpose of deriving truly representative bed material sizes in coarse materials.

In engineering and environmental studies, grainsize distributions of bed material may have various applications. In relation to bulk bed-material transport and to permeability (in fisheries applications), the constitution of a volumetric sample to some depth may be most relevant. In relation to hydraulic roughness and to the stability of the bed, the areal distribution of sizes in a surface sample may be more meaningful.

Kellerhals and Bray (1971) address the problem of how various sampling techniques for coarse materials (bulk, grid and areal samples), combined with various forms of analysis to determine a size distribution, can often lead to non-equivalent results. They recommend a method of applying correction factors to gain some equivalency. Many other problems remain to be resolved, as for example:

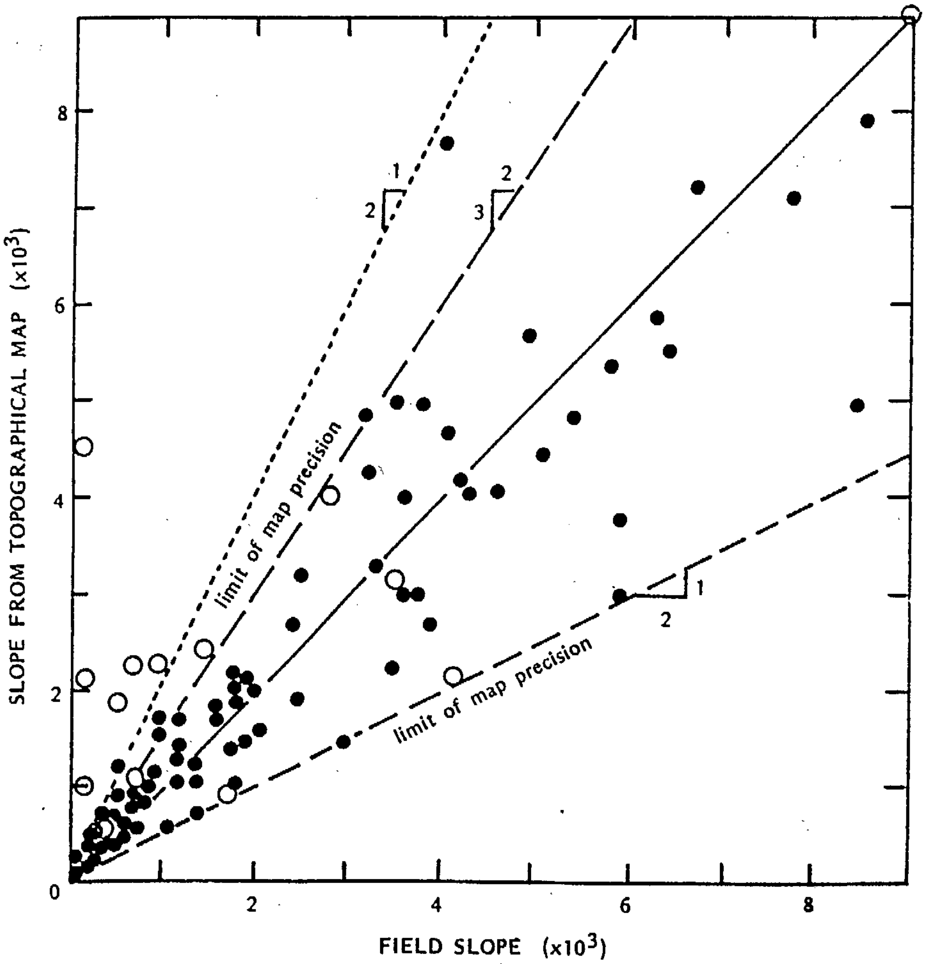


Figure 2

Relation between field slope and slope derived from 1:50,000 topographic maps for 88 river reaches in Alberta. Open circles indicate similar data from Yukon rivers compiled by McDonald and Lewis (1973)

Source: Church and Rood (1983)

1. the wide variation of size distributions even on a single gravel bar, and the question of which part of the bar should be sampled;

2. the difficulty of sampling armoured or paved beds;

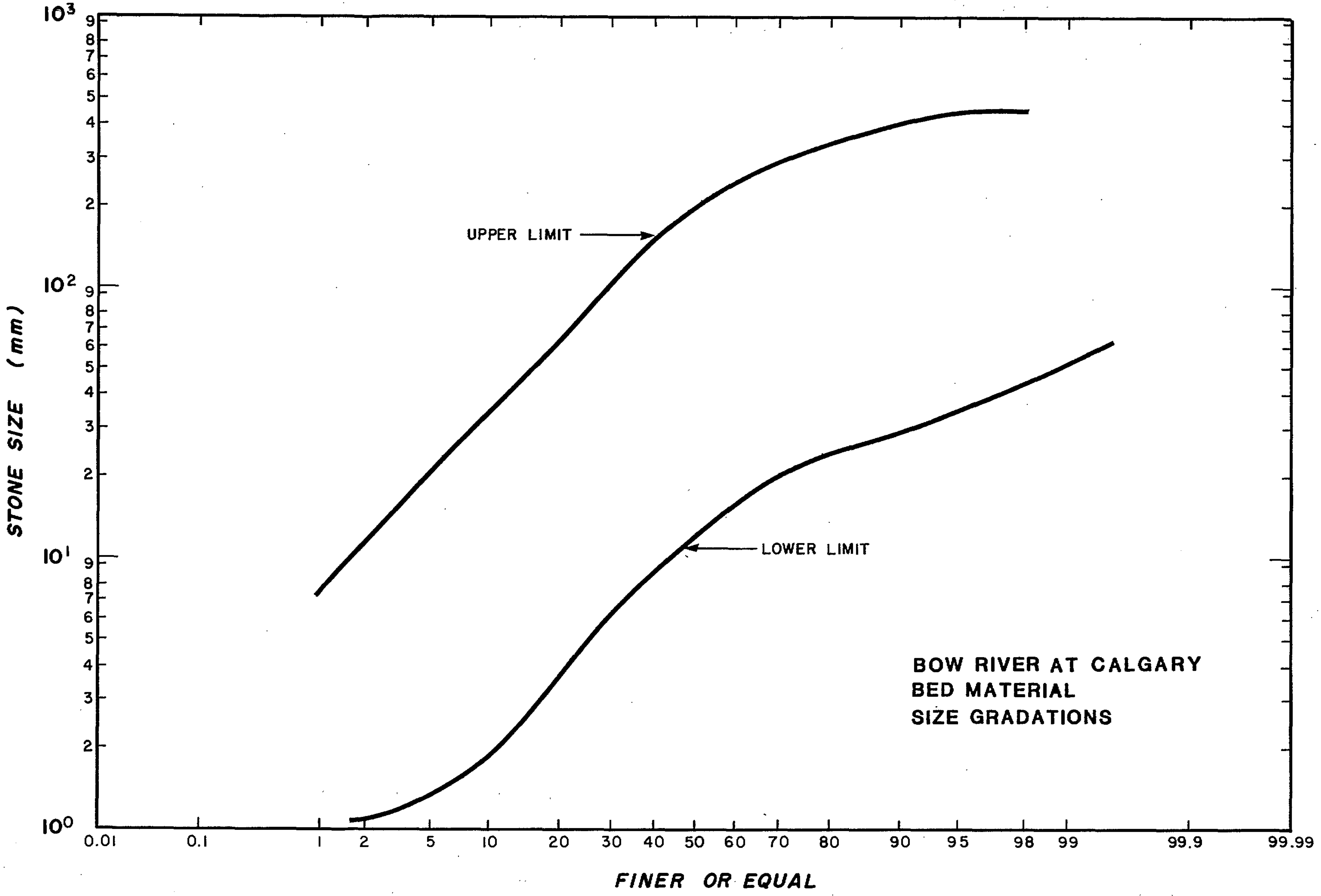
3. the difficulty of sampling bed material in flowing water;

4. the question of how bed material distributions might change at high flows, when the material is being transported, and;

5. the question of what size can be called representative; various researchers have adopted the D_{90}, D_{84}, D_{65} or D_{50} size, or combinations thereof.

Yuzyk (1985), in a recently completed study of current practices for sampling bed material in gravel-bed streams, acknowledges the inconsistencies and problems in this area of data collection. He concludes that much more research is required before definitive widely-accepted guidelines can be developed, but in the meantime he recommends a sampling program for adoption by Water Survey of Canada. Details are provided herein in Section 4.3 (Item 10); generally it would require the collection of both a bulk (volumetric) sample and a surface grid (areal) sample.

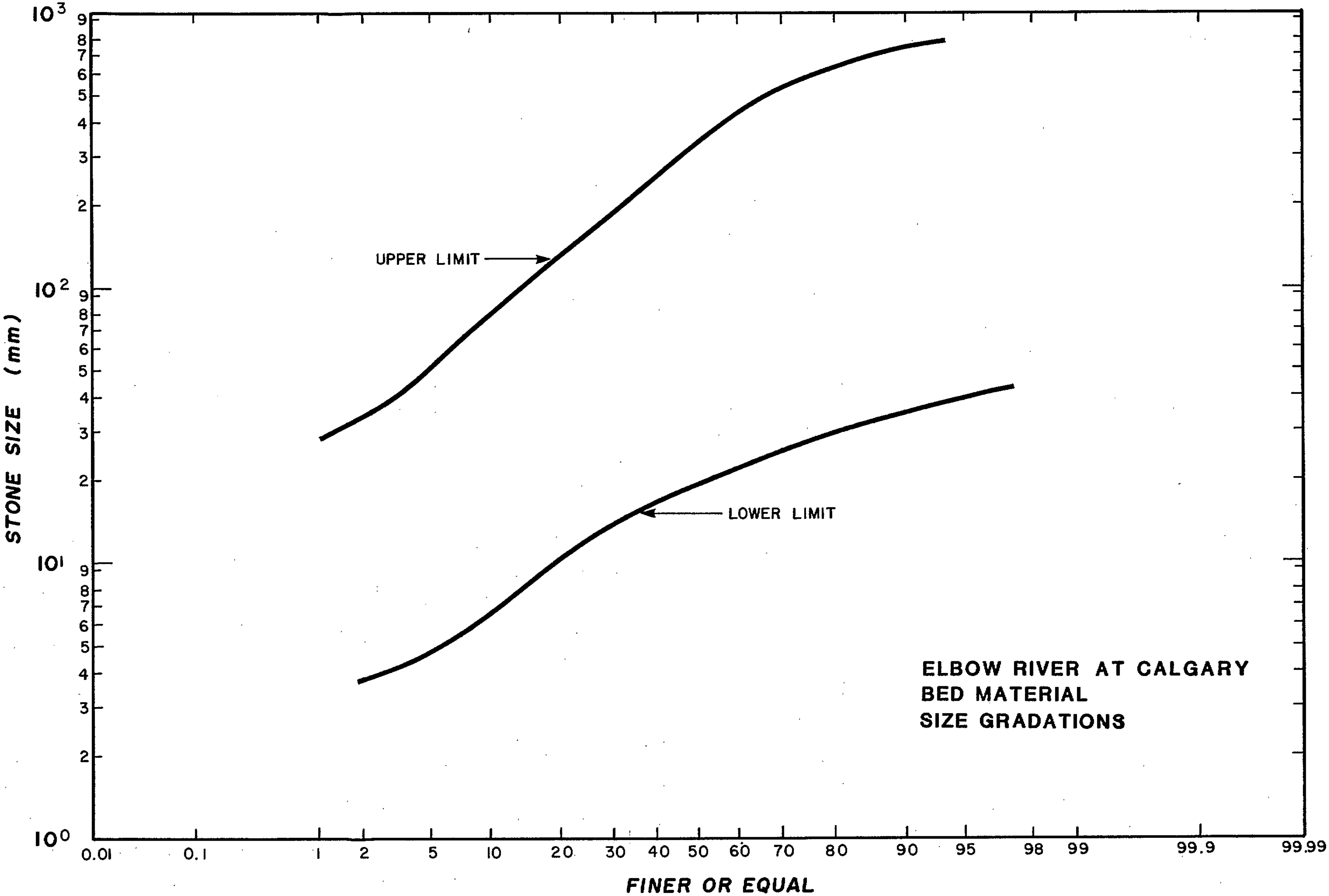
A recent example of the problems that can result from an extensive sampling program is shown by Figures 3 and 4. A total of 156 "samples", consisting of photographs taken through a surface grid, of bed material on the Bow River and the Elbow River near Calgary, Alberta were analyzed to yield size



Source: Yaremko (1986)

FIGURE 3

ENVELOPE OF SAMPLES



Source: Yaremko (1986)

FIGURE 4

ENVELOPE OF SAMPLES

distributions by number. All of the gradation curves from each river were plotted; the curves shown on these figures represent upper and lower envelope curves of all plots in each case. These samples were collected from midchannel and sidechannel gravel bars, with no special guidelines as to which part of a bar should be sampled. Parts of the beds of both rivers have undergone paving and armouring, but no attempt was made to sample beneath the top layer. To select a single gradation curve within either of these enveloped zones as truly representative of the bed material is quite impossible, because of the several possible end-uses of the gradation. A coarser gradation might be required for computation of channel roughness parameters, while a finer gradation might be more representative for estimating sediment transport rates in flood conditions. If the paved surface could be removed during some relatively infrequent flood discharge, then the analysis of channel roughness and bed material mobility may depend on size gradations different from those sampled on the surface. This points out the need to sample beneath the surface layer, although even size gradations obtained in this manner would likely fit within the envelope curves on Figures 3 and 4.

3.3 Possible Categories of Station Program

It is shown in Section 4 that the level of hydraulic/morphologic information normally available at gauge sites will fall short of what a river research study or engineering project would typically require. Notwithstanding this statement, it is our opinion that the existing data/information set should be harvested, processed and published. In addition, some gauge sites should be selected for upgrading of their data bases, with possibly two levels of upgrading: (i) a modest upgrading, following the formats presented in Section 4; and (ii) a more extensive effort that would require surveys of at least several cross sections, along with longitudinal water surface and river bed profiles.

An example of a more extensive effort, shown in Appendix B, is taken from an assignment for Department of Indian and Northern Affairs that involved river surveys at eleven gauge sites in the Yukon Territory (NHCL 1974). The objective was to present data concerning the hydraulic/morphologic characteristics of selected channel reaches at these gauge sites.

Suggested categories of station program are as follows:

1. Available existing hydraulic/morphologic data and information at active gauges would be collected, including any which might have been collected by outside government agencies and private concerns: information packages would then be prepared for publication. The information outlined in Items 1 to 9 of Section 4.1 would be included in this package; basically, this category would involve no additional field work.

2. At selected gauge sites, Water Survey of Canada would carry out a limited field program sufficient to complete the level of information outlined in Sections 4.2 and 4.3. Selection of gauge sites would be based on the criterion that a reasonable distribution of stream types throughout Canada should be represented. This might involve perhaps 20 percent of all active stations in each district.

3. A further selection of gauge sites would be made for which extensive data packages would be prepared. This would involve a complete survey of a stream, including several cross

sections and a longitudinal water surface profile. This category of program might involve perhaps 5 percent of all active stations. Selection would be based on streams of special interest, including: actively degrading or aggrading reaches in conjunction with dams; reaches that experience severe ice jamming, affecting populated areas; reaches that have been constricted, widened, diked or deepened by man; and reaches having a special environmental (fisheries) interest. A typical extensive data package as developed by Bray (1972) is presented in Appendix E.

4. SYSTEMATIZING WATER SURVEY OF CANADA DATA

4.1 Present Availability of Hydraulic/Morphologic Data

Gauging station files typically contain the following information:

1. Water level record: tabulated readings on an intermittent, daily, or several times per day basis; or continuous (chart, tape).

2. Measured flow velocities at preselected points across a channel section, as well as depth measurements at these same points - a procedure usually carried out several times a year. Information also includes a measurement of water surface width at each visit.

3. Station history, including benchmark tie-ins to recorded water levels, metering location, possibly historic extreme (maximum and minimum) water levels, and field photographs.

4. Ice thickness measurements and notes on presence of ice.

5. Longitudinal water surface profile and one or more channel sections: at some stations only, where a slope/area computation has been carried out for the purpose of extending a rating curve or estimating an extreme discharge.

6. Water temperatures.

It is from this material that any interpretation and documentation of hydraulic/morphologic parameters has to evolve. With a certain amount of processing and analysis, the following information could be generated, corresponding to category (1) of station program discussed in Section 3.3:

1. Stage-discharge/velocity/area relationships, in both graphical and tabular form.

2. Plotted metering cross-section showing key water levels (historic high and low, long-term mean) - several surveys might be superimposed where a section has exhibited a high degree of change due to scour, degradation or bank erosion.

3. Tabulation of maximum ice thicknesses, dates of freeze-up and dates of breakup.

4. "Specific gauge" plots of stage vs. year for specified discharges, that would provide an indication of the long-term stability of the bed profile.

5. Tabulation of water temperature record.

6. Profile and cross section plots where this additional information has been collected as part of a slope-area analysis.

7. Selected aerial and field photographs that might show the overall character of the stream at the gauge.

8. Tabulation of velocity measurements for selected metering times, and a graphical representation of the

velocity distribution across a channel for selected stages of flow.

9. Derivation and tabulation of hydraulic roughness coefficient at various stages of flow.

4.2 Expansion of Data Base

With some additional effort during one or more visits to a gauging station, additional data could be collected which would greatly improve the usefulness of the hydraulic/ morphologic information file and upgrade it to the category (2) of station program discussed in Section 3.3. Suggested items are as follows:

1. Bed and bank material samples could be collected and analyzed for gradation.

2. A detailed geomorphic description could be prepared, using an established system of guidelines for interpretation of a stream's geomorphic character.

3. A set of field photographs could be compiled to illustrate the stream's geomorphic characterisics.

4. Ground profiles could be surveyed to extend the metering cross-section across the floodplain or valley bottom.

5. Local evidence could be collected of highwater and ice marks in the floodplain, tied into gauge benchmarks.

6. Interviews could be conducted and recorded with gauge observers and local, longtime residents regarding historic flood and minimum flow events, ice jamming and stream channel planform stability.

The category (3) of station program discussed in Section 3.3 is referred to briefly in Section 4.4 but will not be treated in detail here.

4.3 Format for Publishing W.S.C. Data and Information

The objective is to process the data and information contained in a given file, assuming it contains as a minimum the material outlined in Section 4.1. It is expected that this lowest category of station information could be developed and published for most of the active gauges in Canada. In the second category of station program, selected gauge sites would have as a minimum the material outlined in both Sections 4.1 and 4.2; the data base would be processed to generate a number of tables and figures which would indicate more completely the hydraulic/ morphologic characteristics at a given gauging site.

Both categories of station information could then be combined for a series of gauge sites along a particular stream or within a particular basin, and published for general use. Files could be reviewed and updated, perhaps on a 10-year cycle, and the information package revised accordingly.

A suggested menu of items which might be included in an information package is outlined in Table 1. The format for presentation cannot be rigidly fixed; a review of relevant publications shows various formats. However, some guidelines

TABLE 1

Proposed Content Format
Publication of Hydraulic/Morphologic Data
Water Survey of Canada

Item	
1	Location plan
2	Airphoto mosaic of gauging site
3	Gauge description/history
4	Channel/floodplain cross-section
5	Longitudinal water surface profile (if avaiable)
6	Stage-discharge/mean velocity/area curves
7	Geomorphic description of stream at gauge
8	Selected site photographs
9	Specific gauge plot
10	Bed/bank material gradation curves
11	Table (and or graphical illustration) of measured flow velocities at selected stages
12	Table of maximum ice thickness (annual)
13	Table of water temperature for period of record
14	Table of cross-section coordinates for metering section
15	Plots of additional channel sections (if available)
16	Hydrologic information (discharge and sediment)

and suggestions can be given which should help standardize presentations. These are general guidelines - selection of items for 2 categories of program are discussed further in Section 4.4.

Item 1, Location Plan. This item should consist of 2 maps on one page. The first would be a global view showing the gauging site's location relative to larger towns, ranges, townships and major roadways. A $1{:}10^5$ or 10^6 scale map could be used for this purpose. The second would be of larger scale showing greater detail of the stream and gauge location relative to the local geography, drainage system and topography. A 1:50,000 scale N.T.S. map could be used, or a detailed sketch might be appropriate where adequate map coverage is not available.

Item 2, Airphoto Mosaic. The most recent aerial photography should be used for this item. Enlargement of a photograph is normally required in order to provide greater detail of the gauge site area. The feasible degree of enlargement is, however, limited because contrast is lost if the enlargement is too great. Typically (and depending on stream size) a 5x to 10x enlargement is acceptable.

The photo image is normally developed on the reverse side of mylar stock so that information can be drafted on the front side - this enables corrections to be made without damaging the photo image.

Information annotated on the mosaic might include the following:

- gauge and metering section locations
- location of any additional channel sections
- bed and bank material sample locations
- geomorphic features
- historic bank lines
- highwater mark locations
- historic flood boundaries
- geographic features

Item 3, Gauge Description/History. This item would consist of one or more pages describing the following:

- gauge location (by map coordinates, township/range, distance from major confluence; location relative to bridge, river bank, building or road);

- period of record and gauge type;

- benchmark location and elevation;

- zero gauge;

- comments, descriptions of extreme (maximum, minimum) flow events, based on observations made by a gauge reader or district personnel of W.S.C. (including ice jam events).

Item 4, Channel/Floodplain Cross-section. This cross-section should be plotted as viewed downstream, with stationing from left to right. If possible, the cross-section should be extended through the entire floodplain or valley bottom to above maximum flood level. It is normally necessary to exaggerate the vertical scale: distortions of 10 to 20 are typical.

Information annotated on the cross section plot can include the following:

- key water levels (minimum recorded, long term mean, mean annual flood peak, maximum recorded);

- historic sections, where there has shown to be large variations in the channel configuration because of scour and bank erosion processes;

- bedrock or borehole logs (if available, where the metered section is at a bridge);

- detailed descriptions of vertical benchmark and horizontal stationing.

If there is sufficient information, an undistorted cross-section should be drawn above the exaggerated one - this plot should be extended to the top of each valley wall.

Item 5, Longitudinal Water Surface Profile. As pointed out in Section 3.2 and shown by Figure 2, a surveyed water surface profile is strongly recommended, as opposed to one derived from topographic maps. The plotted profile would drop from left to right on the page. Annotated information would include: average slope in the reach; gauge location; discharge and date on day of survey.

Item 6, Stage/Discharge/Mean Velocity/Area Curves. These are items which are currently available in most station files. The plots should include all of the data points, curves used for various periods of record and a tabulation of stage corrections used for periods of ice cover.

Item 7, Geomorphic Description of Stream at Gauge. The geomorphic coding system outlined by Bray (1972) and presented in Appendix D is recommended as the means to articulate the geomorphic/ physiographic character of a particular stream. This system is reasonably comprehensive, and provides a standardized well-defined terminology. The system of multiple choice tables, whereby the technician or engineer merely checks off a descriptive code, is not recommended, as this tends to result in a disjointed set of information which is difficult to integrate. Rather, the technician or engineer should be prepared to write several paragraphs of descriptive text, using the coding system to guide the content and terminology. Photographs should be taken of geomorphic elements that are considered particularily important, and these could then be included as part of Item 8.

Although the geomorphic coding system presented in Appendix D was developed for alluvial streams in Western Canada, much of it could be adapted for eastern Canadian and northern streams. Codes involving those special features for streams in these areas could be developed and appended to the Bray system.

Item 8, Selected Site Photographs. These should include historic views of floods, low water views of the channel and views of geomorphic elements. Small-sized prints should be utilized so that 4 photos could be placed on a 22cm x 28cm page.

Item 9 - Specific Gauge Plot. Where the stage/discharge curve exhibits a definite trend to change over the years, there may be several reasons, including: the transitory effect of sand/gravel bars moving through the gauged reach; long term aggradation or degradation of the channel's bed due to the influence of dams, weirs, channel cutoffs constrictions or diking.

"Specific gauge" plots of gauge reading versus time, over a period of years, for a few selected discharges will provide a measure of regime stability for the gauged channel. Discharges used might include the long-term average,and floods of return period in the range of 2 to 10 years.

Item 10 - Bed Material Gradation. Because the objective is to have W.S.C. personnel sample a streambed during their normal schedule of visits, it is recommended that a relatively simple procedure be adopted. A sampling program for coarse bed streams might otherwise require considerable time, specialized equipment and effort.

This is in agreement with the recommendations by Yuzyk (1985) whereby for sampling of coarse material, collection of one bulk and one grid sample per site is recommended. The above reference provides details with respect to selection of sample sites, sizes of samples and method of analysis.

For streambeds composed of clay, silt and sand, a single sample is sufficient and it should weigh at least 3 to 5 kg.

The published material would consist of composite plots of size distribution, plus a tabulation of D_{90}, D_{65} and D_{50} sizes from each sample and a description of sample locations. Locations would be shown on the mosaic (Item 2).

Bank material samples would also have to be collected, one from each bank. Sampling procedures outlined for the bed material would apply also to bank samples.

Item 11 - Flow Velocities. This would simply consist of a tabulation of measured flow velocities across a metered channel for at least 3 stages of flow ranging from lowest to highest on the stage/discharge curve. In addition to velocities, the tabulation would include station or location of each measurement (referenced to the channel cross section) and depth of flow at each point, as well as date of measurement, total discharge and mean velocity in the section. Updated values would be provided in the publication, depending on stability of the stage/discharge curve. It would also be useful to graphically portray measured velocities on a plot of the metered channel section for each selected stage. In cases where sufficient velocity data are available, it might be possible to draw iso-velocity lines (lines of equal velocity).

Item 12 - Maximum Ice Thicknesses. For every year of record, the maximum ice thickness measured during a metering visit to the gauge would be tabulated. As well, date of breakup for each year would be provided.

Item 13 - Monthly Water Temperatures. This would consist of a tabulation of the recorded water temperature for a given date, for the period of record. It is assumed that the data are intermittent, with a measurement obtained on each metering visit. If continuous readings are available, then mean monthly values would be tabulated for each year of record.

Item 14 - Cross Section Coordinates. A tabulation of the x-y coordinates of the plotted metered cross-section (Item 4). Coordinates for additional cross sections would also be provided here.

Item 15 - Additional Cross Sections. Plots of any cross sections that might have been surveyed as part of a slope-area computation. Format of plot would be the same as for Item 4.

Item 16 - Hydrologic Information. Selected hydrologic parameters would be tabulated or plotted. The specific items to be included in this tabulation are for example:

- mean annual flow;
- flow-duration (annual) (plot);
- maximum (mean daily, instant means) recorded discharges and stages;
- minimum recorded discharge and stage;

- segmentation of above values for selected periods, where there may be man-made influences that have affected natural runoff (eg. dams);

- flood frequencies;

- mean monthly discharges;

- suspended sediment loads (annual and mean monthly).

As suggested earlier, a review of each information package would be carried out on a 10-year basis. The hydrologic information is most likely to require updating, but hydraulic/morphologic information might also require upgrading because of improved survey data or due to man-made impacts.

4.4 Publication Format Versus Level of Information

In Sections 3.3 and 4.3 we discussed two categories of station program for the assembly and publication of hydraulic/ morphologic information. Category (1) would involve no additional field work. Category (2) would involve a limited field program. It is recommended that the two categories be formatted to include the following items as described in Section 4.3:

Category 1:

Items 1 and 3

Item 4 - Single plot of gauge section, or multiple plots if section is prone to significant periods of aggradation, degradation or scour.

Items 6, 8, 9, 11, 12, 13, 14 and 16.

Category 2: All of the items described in 4.3.

A third category, discussed in Section 3.3, would involve a complete 'regime-type' study of a stream, based on special circumstances or needs, with a typical data base set (Bray, 1972) as presented in Appendix E. As suggested in Section 3.3, it is expected that this might involved 5 percent of all active stations. Presentation of the data shown in Appendix E could follow the item format (Items 1 to 16), but might involve a greater volume of material.

5. CONCLUSIONS AND RECOMMENDATIONS

1. With the historical development of an understanding of hydraulic processes and stream morphology in the last 40 years, there has evolved some formalization of what constitutes an adequate database and publication format.

2. The majority of effort related to generation of a hydraulic/morphologic database has been scientifically motivated - the need for collection and illustration of these data for engineering and environmental applications have drawn on the work of the researcher's efforts.

3. As a source of hydraulic/morphologic data, the Water Survey of Canada hydrometric gauge files could prove to be of considerable value, even where the site of interest is some distance away from a gauge site.

4. As an aid to a research type study of river regime, the amount of hydraulic/morphologic data available at most gauges in Canada would not be sufficient to meet the minimum level considered necessary - additional survey data and local information would have to be collected.

5. For engineering and environmental use, where the site of interest is some distance from a gauge, the gauge information is typically utilized in the derivation of a stage-discharge relationship, the estimate of hydraulic roughness parameters, flow velocities and depths, and ice effects.

6. Information and data typically available at hydrometric gauges is summarized and a publication format is outlined which could be generated with no additional effort by W.S.C. field personnel. It was envisaged that this would be the minimum level of effort at every active gauge in Canada.

7. An expanded data base is recommended for some selected gauge sites . This would require some additional field work, including collection of bed and bank material samples, geomorphic descriptions, field photographs, flood and low flow information, and an extension of the metered cross section through the floodplain.

8. A third level of effort is recommended in which a full-scale hydraulic/morphologic survey and sampling program would be conducted at selected sites that are of special interest.

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APPENDIX A

Case Histories, Hydraulic/Morphologic Information and Data Use

APPENDIX A

Selected cases presented in Appendix A provide examples of where hydrologic and morphologic stream data have been utilized in the analysis of engineering and environmental projects. In each case the material includes both data and all or some of the derived parameters identified in Figure 1. Specific comments pertaining to each case will be found in Section 2.2

Special attention should be given to the format used to present the data.

A1. Case 1

Project: Pipeline river crossing
Stream name: M'Clintock River
Location:: Yukon Territory

Data type collected:

- channel sectional geometry
- floodplain geometry
- longitudinal water surface profile
- thalweg profile
- aerial photographs (historical sequence)
- field photographs
- highwater marks
- geomorphic description of site

Hydraulic/Morphologic Parameters Derived:

- stage-discharge (minimum to maximum range)
- stage-flow velocity (minimum to maximum range)
- maximum bed scour
- potential for bed aggradation/degradation
- historical lateral channel stability
- maximum water level
- assumed bed and bank material gradation (based on visual observation that bed and bank material comprised of find sand)
- bed material load

Hydrology: Water Survey of Canada hydrometric station No.9AB8 - located approximately 8.4 km upstream from mouth of Marsh Lake; pipeline crossing at mouth of Marsh Lake.

M'Clintock River K.P. 466.2

Channel Regime and Design Considerations

The M'Clintock River (Figure 7-A) is a flat-sloped, tortuously meandering stream which has experienced many loop cut-offs. It is expected that these cut-offs occurred several hundred years ago. The channel, which is partially entrenched in glacial lake basin sediments, has straightened its course through the crossing reach resulting in the oxbow lake located to the left (east) of the present channel. The terrain in this vicinity (east of the main channel) is flat and wet. The right (west) bank of the river is located adjacent to the toe of the valley wall.

The proposed crossing of the M'Clintock River is located about 400 m upstream of the bridge on the Alaska Highway, and about 1 km upstream of the mouth of the river at Marsh Lake. The flows out of Marsh Lake are regulated by a control structure on the Yukon River, and therefore the lake levels are frequently higher than they would normally be under natural flow conditions. During periods of high lake level the crossing will be situated within a backwater region. This condition results in a greater zone of land adjacent to the river being flooded, but the flow velocities and scour potential are reduced. During periods of low lake level the flow velocities and scour potential are, conversely, greater. The prediction of the design high water level and the calculation of maximum scour were based on a high and low lake level, respectively.

Source: "The Alaska Highway Gas Pipeline Project (South Yukon Route)"; Foothills Pipe Lines (South Yukon) Ltd., April, 1982.

Comparison of recent (1976) and old (1946) aerial photographs (Figure 7-B) shows no significant change with the M'Clintock River over the period of record. It is expected that the stream is relatively stable laterally in the crossing reach such that placing the pipe 5 m into the banks will be adequate. However, because the banks are formed in a fine-grained material (silt, sand and clay), it is recommended that a layer of coarse material (D_{50} = 150 mm) be placed to a depth of 0.5 m over the disturbed portion of the pipeline right-of-way.

The bed of the M'Clintock River is apparently comprised of very fine sand (D_{50} = 0.1 mm) and silt material. Scour calculations were based on this material size. This material is highly susceptible to scour as shown by the scour holes on the longitudinal profile (Figure 7-C); these scour holes have formed at bends in the channel. Since the proposed crossing is located on a relatively straight reach of channel it is not anticipated that a large scour hole will form over the pipe. However, to ensure the integrity of the pipeline, it has been recommended that the top of the pipe not be placed higher than the equivalent centerline elevation of the deepest observed scour hole. An additional allowance of 0.5 m has also been included. This results in a minimum depth of cover of 2.6 m as shown in Figure 7-D.

The 1978 spring break-up study (NHCL, 1978-4) indicated that the winter ice cover on the M'Clintock River was a smooth-surfaced, solid (thermal), floating ice sheet which had formed in-situ. It was also reported that the ice thickness was nearly equal to the recorded mean value, and that the break-up date was within a couple of days of the mean date of recorded break-up. Shore ice ledges were observed, and these were noted as having occurred as a result of falling lake levels in Marsh Lake. The spring break-up was very mild, with the ice largely melting in place as advanced candling of the ice sheet occurred. Little sign of historic ice action on the trees along the banks was observed.

Although the proposed crossing is located just upstream of the bridge on the Alaska Highway, and the mouth of the river at Marsh Lake, it is not expected that severe ice jamming will occur so as to cause concern for the integrity of the pipeline. The reasons for this are: 1) little sign of historic ice action has been observed; 2) the relatively 'normal' break-up in the spring of 1978 did not indicate any cause for concern; and 3) the stream is not highly entrenched upstream of the proposed crossing such that upstream flows could be diverted onto a fossil floodplain in the event of an ice jam forming.

A comparison of the regime slope and the actual slope of the stream indicated a very low degradation potential. It was considered that there is little potential for the downstream meander loop to cut off, and that degradation of the stream bed resulting from such a cut-off would be minimal.

It is not considered likely that the stream would ever move to inhabit all or any of its former channel which is now an oxbow lake. For this reason it is recommended that only the minimum floodplain depth of burial of 1.5 m be used in this vicinity. During periods of high water level in Marsh Lake it is expected that this region will be flooded, and therefore the pipeline will have to be weighted to Sta. 466+725.

SCALE 1:10,000

LEGEND

Surveyed cross-section (see fig. 7-D for cross-section plots).............	—— U-1
Proposed pipeline centreline (see fig. 7-B for plot)....................	-------
Grid photograph bed sample location and number (see fig. 7-E)...........	5-16 ■
Volumetric bed sample location and number (see fig. 7-E)................	#17 ●
Field photograph location and number (see fig. 7-F).....................	23-7 ➤

FIGURE 7-A

M'CLINTOCK RIVER KP 466.2
LOCATION PLAN

THE ALASKA HIGHWAY GAS PIPELINE PROJECT
FOOTHILLS PIPE LINES (SOUTH YUKON) LIMITED

FILE: 81-549
northwest hydraulic consultants limited

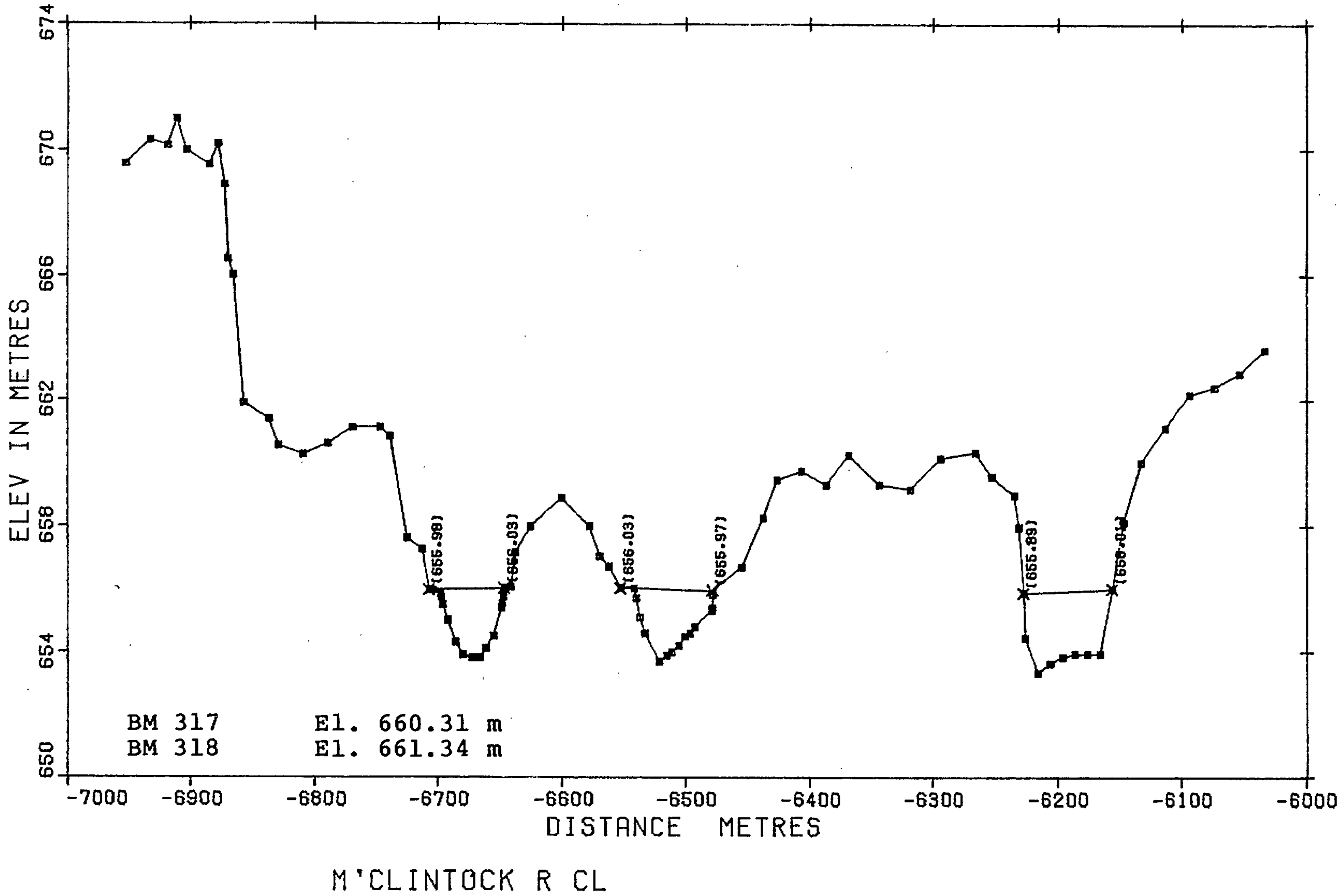


FIGURE 7-B

M'CLINTOCK RIVER KP 466.2

CENTRELINE PROFILE

THE ALASKA HIGHWAY GAS PIPELINE PROJECT

FOOTHILLS PIPE LINES (SOUTH YUKON) LIMITED

FILE: 81-549

northwest hydraulic consultants limited

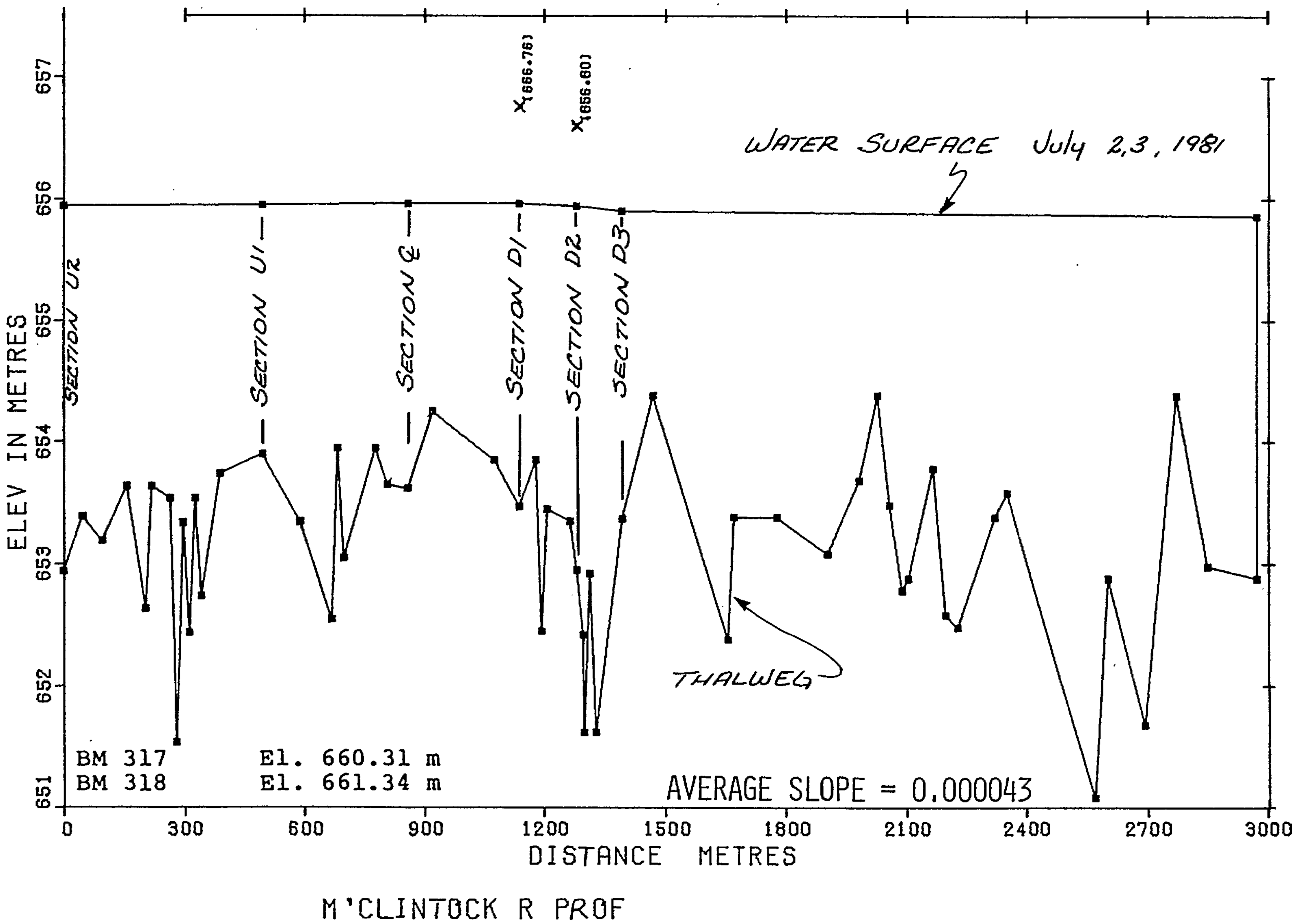
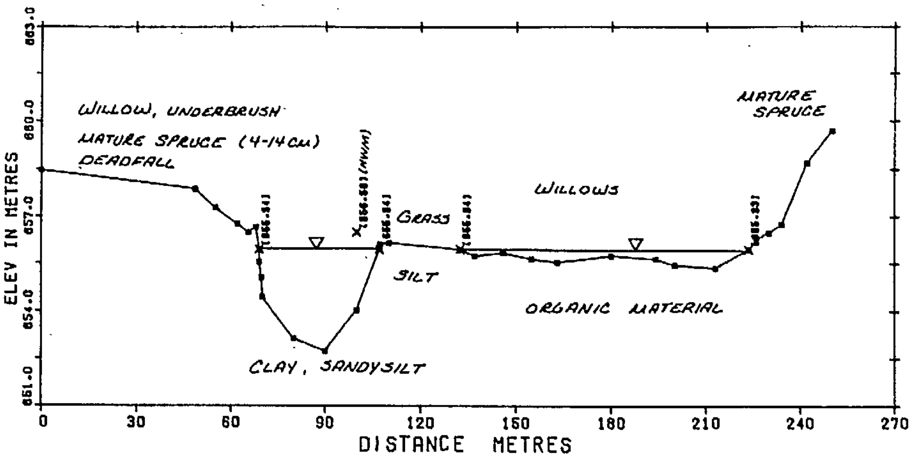


FIGURE 7-C

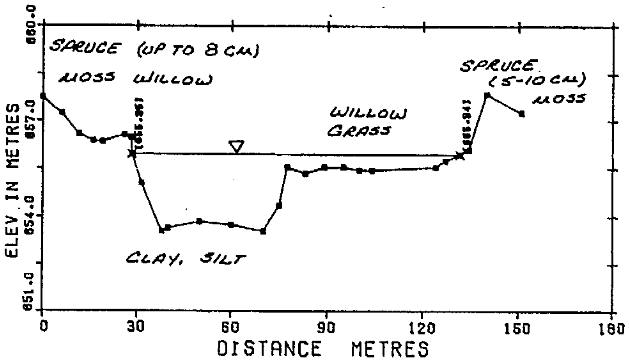
M'CLINTOCK RIVER KP 466.2
LONGITUDINAL STREAM PROFILE

THE ALASKA HIGHWAY GAS PIPELINE PROJECT
FOOTHILLS PIPE LINES (SOUTH YUKON) LIMITED

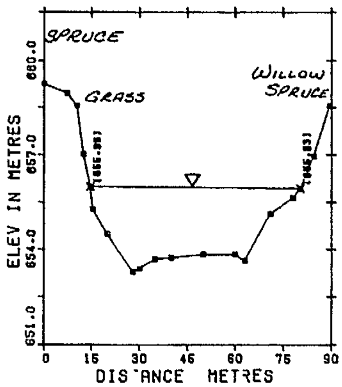
FILE: 81-549
northwest hydraulic consultants limited



M'CLINTOCK R U2



M'CLINTOCK R U1



M'CLINTOCK R HCL

Notes:

All sections plotted looking downstream
Section coordinates listed in table 7-1.
Section location shown on fig. 7-A.

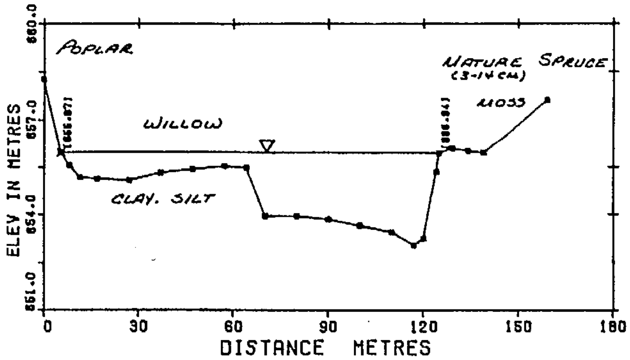
BM 317	El. 660.31 m
BM 318	El. 661.34 m

FIGURE 7-D(1)

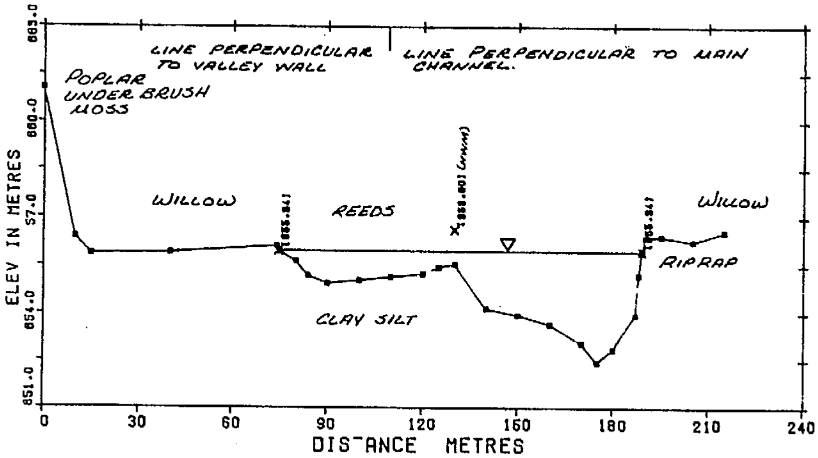
M'CLINTOCK RIVER KP 466.2
CHANNEL CROSS-SECTIONS

THE ALASKA HIGHWAY GAS PIPELINE PROJECT
FOOTHILLS PIPE LINES (SOUTH YUKON) LIMITED

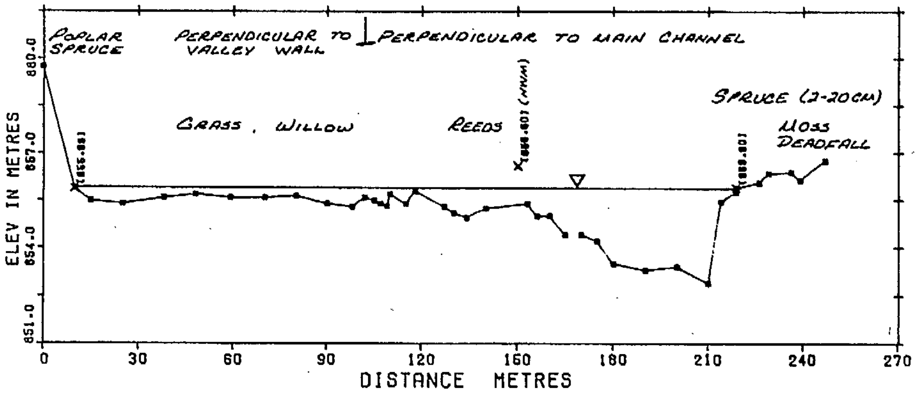
FILE: 81-549
northwest hydraulic consultants limited



M'CLINTOCK R. D1



M'CLINTOCK R D2



M'CLINTOCK R D3

Notes:

All sections plotted looking downstream
Section coordinates listed in table 7-1.
Section location shown on fig. 7-A.

BM 317 El. 660.31 m
BM 318 El. 661.34 m

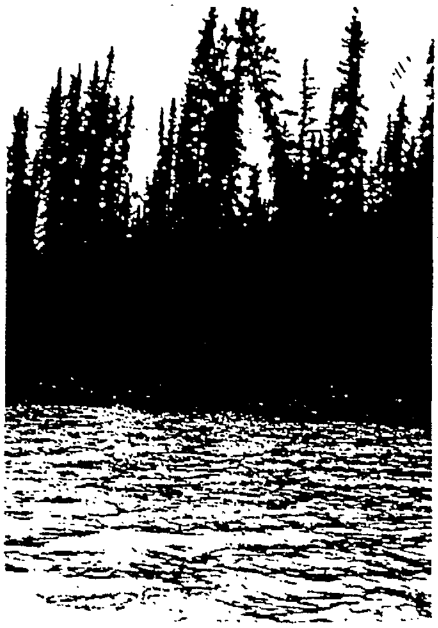
FIGURE 7-D(2)

M'CLINTOCK RIVER KP 466.2
CHANNEL CROSS-SECTIONS

THE ALASKA HIGHWAY GAS PIPELINE PROJECT
FOOTHILLS PIPE LINES (SOUTH YUKON) LIMITED

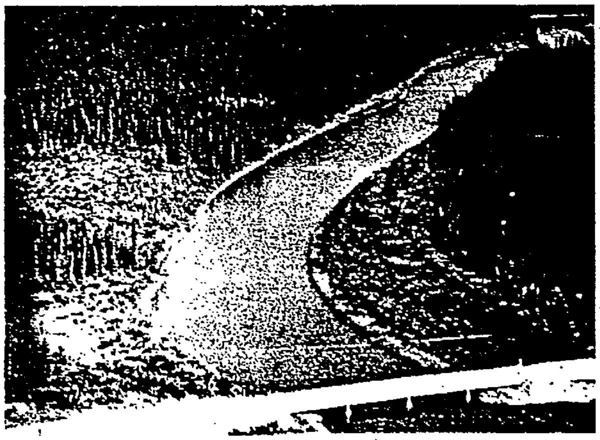
FILE: 81-549
northwest hydraulic consultants limited

View of left bank at crossing centerline (Photo 6-20A).



View of right bank at crossing centerline (Photo 6-19A).

Aerial view downstream of bridge showing flooded area (Photo 9-24A).

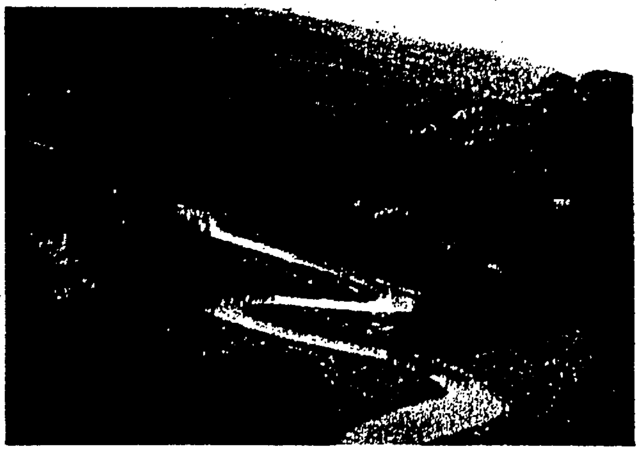


Aerial view upstream from just downstream of bridge (Photo R16-4).

M'CLINTOCK RIVER K.P. 466.2 FIELD PHOTOGRAPHS FIG. 7-F(1)

Viewing upstream toward crossing centerline (Photo 6-21A).

Aerial view in westerly direction along crossing centerline (Photo R16-1).



Aerial view downstream to centerline from just upstream of upstream bend in channel (Photo R16-5).

Aerial view looking from right bank to left bank (Photo R16-3).

M'CLINTOCK RIVER K.P. 466.2 FIELD PHOTOGRAPHS FIG. 7-F(2)

SECTION COORDINATES IN METRES

M'CLINTOCK R U2		M'CLINTOCK R U1		M'CLINTOCK R HCL		M'CLINTOCK R. 01		M'CLINTOCK R D2	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
0.0	658.47	0.0	657.75	0.0	659.26	0.0	658.28	0.0	661.05
48.50	657.90	6.00	657.24	7.50	658.96	5.50	655.97	10.00	656.38
55.00	657.29	11.50	656.58	10.50	658.56	8.00	655.57	15.00	655.86
62.00	656.77	16.00	656.36	12.50	657.01	11.50	655.17	40.00	655.90
65.50	656.50	19.00	656.34	14.70	655.98	17.00	655.12	74.00	656.10
68.00	656.66	26.00	656.56	15.50	655.28	27.00	655.07	74.80	655.94
69.00	655.94	28.00	656.47	20.00	654.48	37.00	655.32	80.00	655.64
69.00	655.54	28.50	655.95	28.00	653.28	47.00	655.42	84.00	655.19
69.70	655.04	31.50	655.05	30.00	653.38	57.00	655.52	90.00	654.94
70.00	654.44	38.00	653.55	35.00	653.68	64.00	655.47	100.00	655.04
80.00	653.14	40.00	653.65	40.00	653.73	70.00	653.94	110.00	655.14
90.00	652.74	50.00	653.85	50.00	653.83	80.00	653.94	120.00	655.24
100.00	654.04	60.00	653.75	60.00	653.83	90.00	653.84	125.00	655.44
107.20	655.94	70.00	653.55	63.00	653.63	100.00	653.64	130.00	655.54
107.30	656.11	75.00	654.35	71.00	655.13	110.00	653.44	140.00	654.14
110.00	656.15	77.40	655.54	78.00	655.63	117.00	653.04	150.00	653.94
132.50	655.94	83.00	655.34	80.30	655.93	120.00	653.24	160.00	653.64
137.00	655.74	89.00	655.54	84.50	656.94	124.00	655.34	170.00	653.04
146.00	655.84	95.00	655.54	89.50	658.56	124.80	655.94	175.00	652.44
155.00	655.64	100.00	655.45			129.00	656.09	180.00	652.84
163.00	655.54	104.00	655.45			134.00	656.01	187.00	653.94
180.00	655.74	124.00	655.55			139.00	655.96	188.00	655.20
194.00	655.64	127.00	655.75			146.00	656.48	189.00	655.94
200.00	655.44	131.60	655.94			159.00	657.62	190.00	656.37
213.00	655.34	134.40	656.10					195.00	656.41
223.50	655.93	140.00	657.86					205.00	656.25
226.00	656.18	151.00	657.26					215.00	656.55
230.00	656.46								
234.00	656.74								
242.00	658.69								
250.00	659.69								

Note:

- Section locations are shown on Figure 7-A.
- Centerline section plotted and annotated on Figure 7-B.
- Longitudinal stream profile plotted and annotated on Figure 7-C.
- Hydraulic sections plotted and annotated on Figure 7-D.
- Cross-section coordinates are listed from left to right (viewing downstream).
- Profile coordinates are listed from upstream to downstream along the thalweg, and from downstream to upstream along the water surface.
- Section CL refers to stream WX-3066 crossing surveyed by SURTECH on 1, 2 July 1981.
- Other sections surveyed by NHCL on 2 July 1981.

TABLE 7-1(1)

M'CLINTOCK RIVER KP 466.2

SECTION COORDINATES

THE ALASKA HIGHWAY GAS PIPELINE PROJECT
FOOTHILLS PIPE LINES (SOUTH YUKON) LIMITED

FILE: 81-549
northwest hydraulic consultants limited

SECTION COORDINATES IN METRES

M'CLINTOCK R D3

HORIZ	VERT
0.0	659.75
10.00	655.89
15.00	655.49
25.00	655.39
38.00	655.59
48.00	655.69
59.00	655.59
70.00	655.59
80.00	655.64
90.00	655.39
98.00	655.29
102.00	655.59
105.00	655.49
107.00	655.39
109.00	655.31
110.00	655.69
115.00	655.39
118.00	655.79
127.00	655.29
130.00	655.09
134.00	654.94
140.00	655.24
153.00	655.39
156.00	654.99
160.00	655.00
165.00	654.40
170.00	654.40
175.00	654.20
180.00	653.50
190.00	653.30
200.00	653.40
210.00	652.90
214.00	655.45
218.70	655.77
218.70	655.90
226.00	656.07
229.00	656.36
236.00	656.40
239.00	656.14
247.00	656.77

M'CLINTOCK R PROF

HORIZ	VERT
0.0	652.94
46.00	653.39
93.00	653.19
155.00	653.64
201.00	652.64
217.00	653.64
263.00	653.54
279.00	651.54
295.00	653.34
310.00	652.44
325.00	653.54
340.00	652.74
387.00	653.74
495.00	653.90
588.00	653.35
665.00	652.55
680.00	653.95
695.00	653.05
774.00	653.95
805.00	653.65
857.00	653.28
919.00	654.25
1074.00	653.85
1137.00	653.47
1179.00	653.85
1193.00	652.45
1207.00	653.45
1263.00	653.35
1279.00	652.95
1294.00	652.42
1296.00	651.62
1310.00	652.92
1325.00	651.62
1390.00	653.37
1467.00	654.38
1653.00	652.38
1668.00	653.38
1777.00	653.38
1901.00	653.08
1979.00	653.68
2025.00	654.38
2056.00	653.48
2087.00	652.78
2103.00	652.88
2165.00	653.78
2196.00	652.58
2227.00	652.48
2320.00	653.38
2351.00	653.58
2568.00	651.08
2599.00	652.88
2692.00	651.68
2769.00	654.38
2847.00	652.98
2971.00	652.88
2971.00	655.86
1390.00	655.90
1279.00	655.94
1137.00	655.96
857.00	655.96
495.00	655.95
0.0	655.94

M'CLINTOCK R CL

HORIZ	VERT
-6952.30	669.55
-6932.30	670.30
-6918.00	670.13
-6911.10	670.98
-6903.00	669.98
-6885.10	669.51
-6878.10	670.18
-6873.10	668.88
-6870.40	666.51
-6866.30	666.01
-6858.00	661.90
-6837.50	661.38
-6829.60	660.54
-6809.60	660.26
-6789.60	660.60
-6769.60	661.11
-6747.30	661.12
-6739.50	660.83
-6725.60	657.61
-6713.00	657.26
-6707.00	655.98
-6703.60	655.97
-6698.00	655.86
-6697.00	655.73
-6696.00	655.51
-6692.00	655.01
-6686.00	654.31
-6680.00	653.91
-6673.00	653.81
-6667.00	653.81
-6662.00	654.11
-6656.00	654.51
-6650.00	655.41
-6649.00	655.53
-6648.00	655.76
-6647.00	656.03
-6642.30	656.07
-6638.70	657.16
-6626.60	657.98
-6601.10	658.88
-6578.80	657.99
-6570.40	657.04
-6563.00	656.71
-6553.30	656.03
-6542.80	656.02
-6540.80	655.70
-6537.80	655.10
-6533.80	654.60
-6521.80	653.70
-6515.80	653.90
-6511.80	654.00
-6505.80	654.20
-6500.80	654.50
-6496.80	654.60
-6492.80	654.80
-6479.40	655.32
-6478.90	655.40
-6478.80	655.83
-6478.40	655.97
-6455.60	656.70
-6438.60	658.26
-6427.30	659.46
-6407.30	659.75
-6387.30	659.31
-6369.00	660.26
-6344.00	659.32
-6319.00	659.17
-6294.00	660.15
-6266.00	660.35
-6253.00	659.58
-6235.30	658.99
-6231.80	657.97
-6228.10	655.89
-6226.60	654.45
-6216.60	653.35
-6206.60	653.65
-6196.60	653.85
-6186.60	653.95
-6176.60	653.95
-6166.60	653.95
-6156.60	656.01
-6147.60	658.12
-6133.60	660.02
-6113.60	661.12
-6093.60	662.19
-6073.60	662.42
-6053.60	662.87
-6033.60	663.63

Note:

- Section locations are shown on Figure 7-A.
- Centerline section plotted and annotated on Figure 7-B.
- Longitudinal stream profile plotted and annotated on Figure 7-C.
- Hydraulic sections plotted and annotated on Figure 7-D.
- Cross-section coordinates are listed from left to right (viewing downstream).
- Profile coordinates are listed from upstream to downstream along the thalweg, and from downstream to upstream along the water surface.
- Section CL refers to stream WX-3066 crossing surveyed by SURTECH on 1, 2 July 1981.
- Other sections surveyed by NHCL on 2 July 1981.

TABLE 7-1(2)

M'CLINTOCK RIVER KP 466.2

SECTION COORDINATES

THE ALASKA HIGHWAY GAS PIPELINE PROJECT
FOOTHILLS PIPE LINES (SOUTH YUKON) LIMITED

FILE: 81-549

northwest hydraulic consultants limited

RIVER ENGINEERING DESIGN SUMMARY

M'Clintock River K.P. 466.2

Channel parameters

Mean channel slope = 0.00053

Estimated Manning's n value = 0.030

Average channel width in crossing reach (m) = 51

Hydrology

Flow stage on date of survey (m) = 655.9

Approximate discharge on date of survey (m^3/s) = 28

Average bankfull stage (m) = 656.1

Calculated bankfull discharge (m^3/s) = 153

Equivalent high water mark stage (m) = 656.8

Calculated high water mark discharge (m^3/s) = N/A(1)

Design flood discharge (m^3/s) = 150

Design flood stage (m) = 656.1

Design high water stage (m) = 657.4(2)

Scour computations(3)

Reference stage (m) = 656.1

Minimum bed elevation (m) = 653.3

Design scour discharge (m^3/s) = 150

Average flow velocity (m/s) = 1.2

Average D_{50} bed material size (mm) = 0.1(4)

Regime depth of flow (m) = 2.8

Design scour factor = 1.4

Depth of scour (m) = 3.9

Design scour elevation (m) = 652.2

Minimum cover (m) = 1.1

Notes

(1) high water marks were assumed to have been induced by high lake levels in Marsh Lake, and therefore they do not necessarily correspond to a particular discharge condition.

(2) based on assumed high lake level in Marsh Lake - an additional 0.5 m was added to the maximum instantaneous recorded lake level.

(3) based on flow conditions at sec. CL.

(4) assumed value.

Recommendations

Recommended minimum cover (m) = 2.6*

Maximum top of pipe elevation
in zone of greatest scour potential (m) = 650.7

Recommended minimum pipe setback:

Left bank (m) = 5

Right bank (m) = 5

Sagbend location at minimum pipe elevation:

Left sagbend (station) = 466+231

Right sagbend (station) = 466+157

Distance between sagbends (m) = 74

Width of floodplain (for weighting purposes):

Left edge of floodplain (station) = 466+150

Right edge of floodplain (station) = 466+725

Length of pipe in floodplain (m) = 575

Bank protection requirements

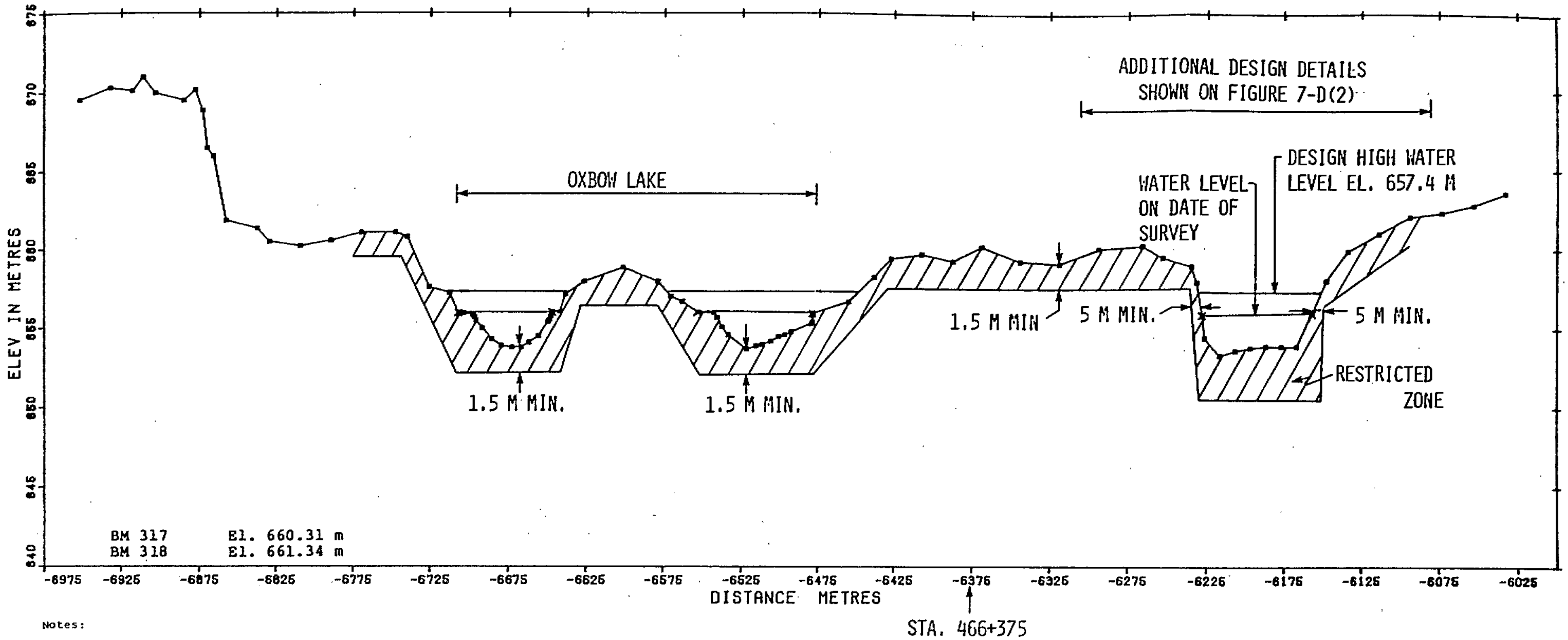
COARSE MATERIAL LAYER

1) A coarse material layer shall be placed to a depth of 0.5 m over that portion of the pipeline R.O.W. that has been disturbed by construction (clearing and excavation) activity. The coarse material layer shall be placed on a graded surface having a maximum slope of 2(H):1(V).

2) the placed coarse material layer shall have a gradation which falls within the band defined by the two gradation curves as follows:

Percent lighter by weight	Range of equivalent spherical diameter (mm)	Weight range (kg)
100	250	21.7
90	160 - 230	5.7 - 16.9
50	135 - 165	3.4 - 6.2
15	90 - 130	1.0 - 3.0

* the recommended minimum cover has been arrived at by having the pipe placed 0.5 m below the equivalent minimum stream bed elevation of the deepest scour hole observed in the crossing reach.



SCALE: 1:2500 HORIZ.
1:250 VERT.

Notes:

1. Top of pipe (or pipeline weights) to be located below restricted zone. Where bedrock is encountered within the trenching zone the top of pipe (or pipeline weights) shall be placed 1.0 m below the competent bedrock surface, or to the depth shown on Figure 7-D, whichever requires the least excavation.

2. Setback allowances to be referenced from the constructed crossing approach slopes or banks, should this differ from the existing natural slopes or banks.

3. Section surveyed by SURTECH and NHCL on 1,2 July 1981; Crossing WX-3066.

4. Section plotted viewing downstream.

5. The disturbed portion of the pipeline R.O.W. on both banks shall be protected with a 0.5 m thick layer of coarse material (D_{50} = 150 mm) extending from the toe of the bank up to the design flood level (see River Engineering Design Summary).

Foothills Pipe Lines (South Yukon) Ltd.		
M'CLINTOCK RIVER KP 466.2 DESIGN CENTRELINE SECTION		
northwest hydraulic consultants ltd.		
File. 81-547	Date. Feb. '82	Figure 7-D(1)

A2. Case 2

Project: River water intake
Stream name: North Saskatchewan River
Location: Saskatchewan

Data type collected:

- channel sectional geometry
- floodplain geometry
- longitudinal water surface profile
- thalweg profile
- bed material sample (estimate)
- aerial photogaphs (historical sequence)
- field photographs
- highwater marks
- geomorphic description of site (file notes)
- ice behaviour

Hydraulic/Morphologic Parameters Derived:

- stage-discharge (minimum to maximum range)
- stage-flow velocity
- maximum bed scour
- potential for bed aggradation/degradation
- historical lateral channel stability
- maximum water level
- gradation of bed and bank materials
- bed material load
- suspended sediment load

Hydrology: W.S.C. station-North Saskatchewan River at Deer Creek (SEF-1), located 17 km upstream of project site. Sediment station (W.S.C. Station 5GG-1) - North Saskatchewan River at Prince Albert.

2. FACILITIES DESCRIPTION

The new water intake facility is to be located in the general vicinity of an existing intake now operated by Husky on the right bank of the North Saskatchewan River, 30 km east and 11 km north of Lloydminster (see Figure 1).

The existing water supply facility (called the Tangleflags Intake Facility) was constructed in 1980 and consists of a lagoon intake, a pumphouse and a sedimentation pond. The lagoon intake was dredged into the right bank of the river; it has experienced operating problems involving siltation within the lagoon and across its mouth, and instability of the lagoon side slopes.

The new facility is to be designed for a 30-year operating life. The existing lagoon intake was to be considered along with other intake types and locations.

The intake facility is to be sized for a design flow rate of 22,000 m^3/d.

Source: "Husky Oil Operations Ltd., North Saskatchewan River, Water Supply Facility Hydraulic Investigation"; Assoc. Engineering (Sask.) Ltd.; October 1985.

4. RIVER HYDRAULICS AND HYDROLOGY

Figure 4 contains a flood frequency curve derived from Water Survey of Canada records for the North Saskatchewan River at Deer Creek (17 km upstream of the proposed intake site). A stage discharge curve applicable to the intake site is plotted in Figure 5. The stage discharge relationship was derived on the basis of hydraulic calculations using channel cross section profiles surveyed near the intake site.

For design purposes a low water level of 488.8 m is recommended corresponding to a flow of 40 m^3/s. Levels this low can occur under open water conditions in late fall while an ice cover is forming on the river. Once an ice cover forms, water levels rise substantially due to the added resistance to flow resulting from the surface cover.

Predicted water levels corresponding to various flood levels in the river are as follows:

Return Period years	Discharge m^3/s	Water Level m
2	1,200	492.9
5	1,800	493.9
10	2,300	494.9
20	3,100	496.0
50	3,900	497.2
100	4,700	498.2

For the purpose of pumphouse design, a high water level of 498.2 m corresponding to a 100-year flood is recommended.

6. SEDIMENTATION

A river water intake that draws water through ports situated above the river bed will intake sediment carried in suspension by the flow. Intake of sediment by a river water intake has a bearing on pumphouse design, pump selection, and the need for water treatment facilities.

A duration curve for suspended sediment concentration is plotted in Figure 7. This curve is based on an analysis of 10 years of suspended sediment records for the North Saskatchewan River at Prince Albert (Water Survey of Canada, Station 05GG1). It was assumed that these data would be representative of conditions at the intake site for the purpose of estimating the average annual rate of sediment withdrawal. Miscellaneous sediment observations near the intake site have been made by Saskatchewan Environment. These observations were, however, too few in number to permit conclusions to be made concerning the validity of the above assumption.

The concentration-duration curve in Figure 7 yields an average annual sediment intake rate of 490 tonnes per year for a supply rate of 13,200 m^3/day which is planned for the first ten years of project operation. It would be appropriate to use a somewhat higher design value of 700 tonnes/year in sizing treatment facilities in view of the reliability of sediment data on which the estimate is based.

7. RIVER ICE

Operating problems on river intakes in Western Canada are often related to river ice processes.

During freeze-up substantial quantities of frazil ice are generated along open reaches of river. This ice can block intake screens and interrupt the supply of water to the pumphouse until such time as a solid ice cover forms. Where fixed screens are used provision should be made to remove the screens during the freeze-up period. With travelling screens, which we understand are to be installed in this facility, ice can be washed from the screens, during the period when an ice cover is forming.

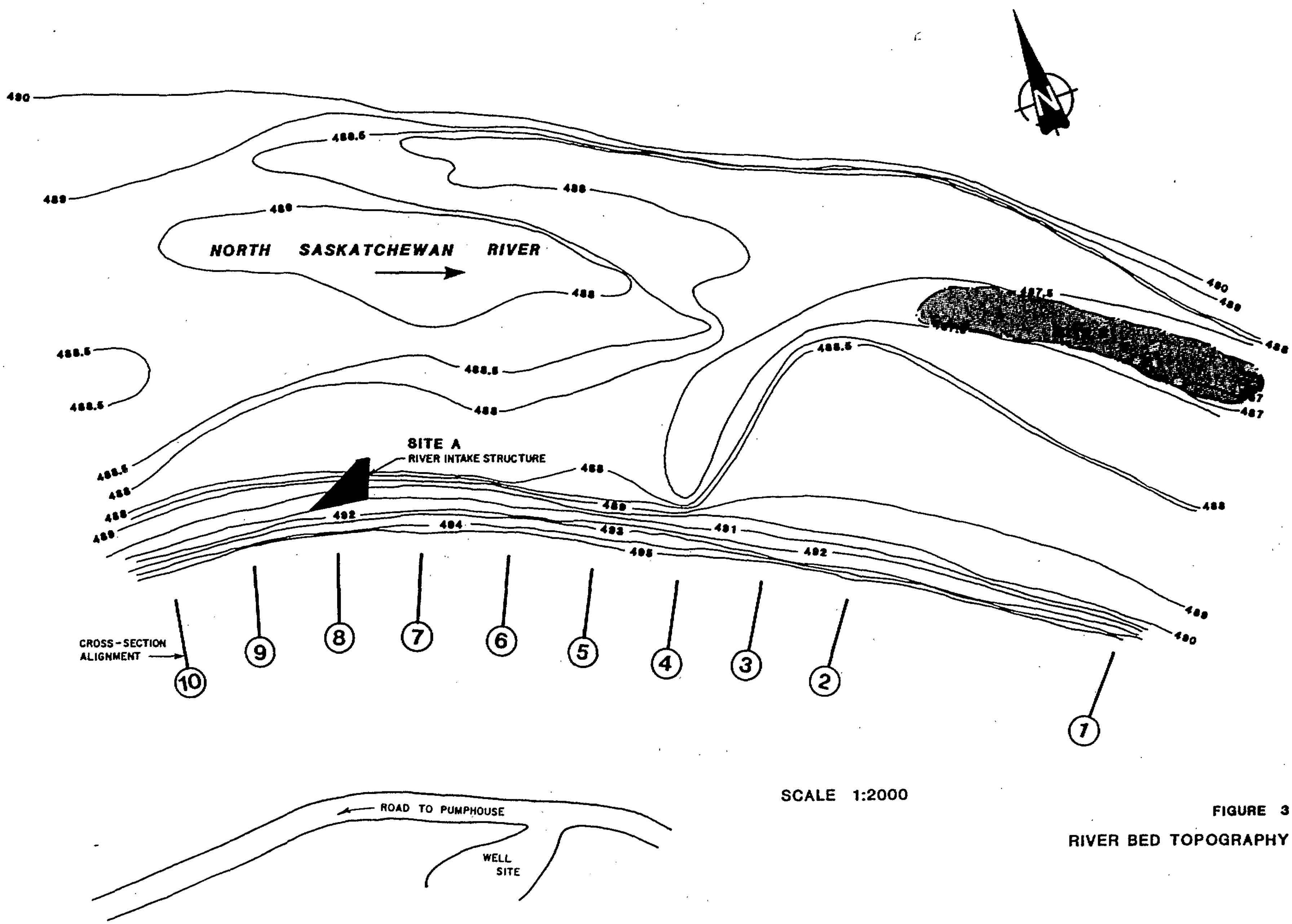
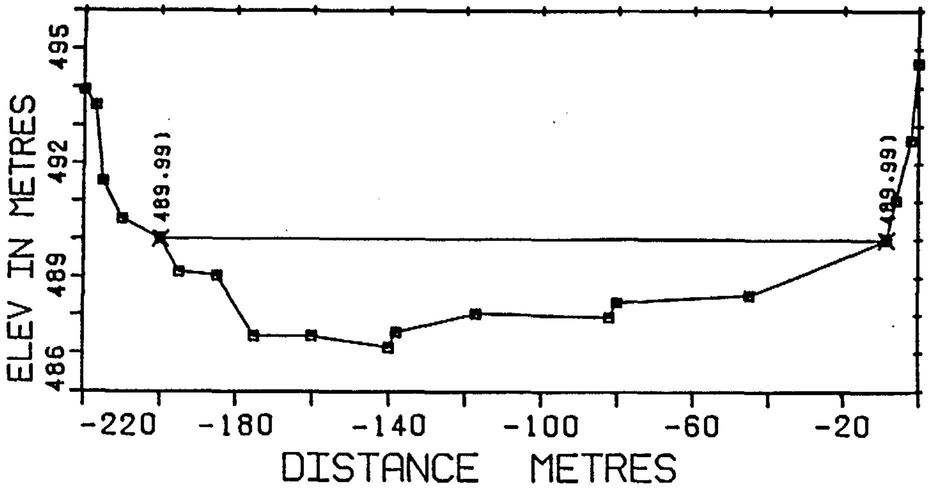
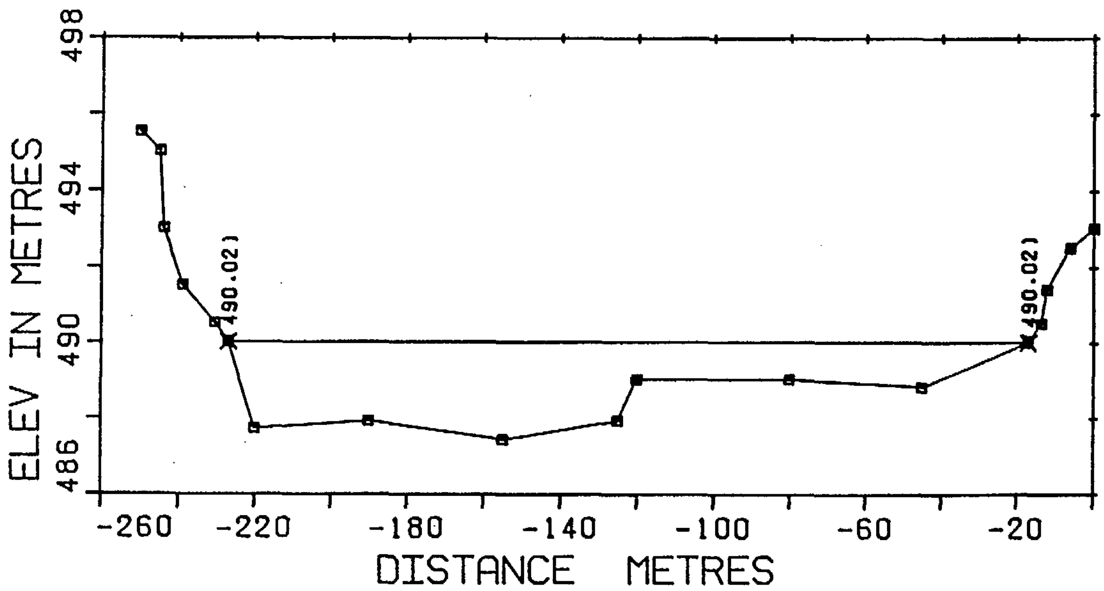


FIGURE 3

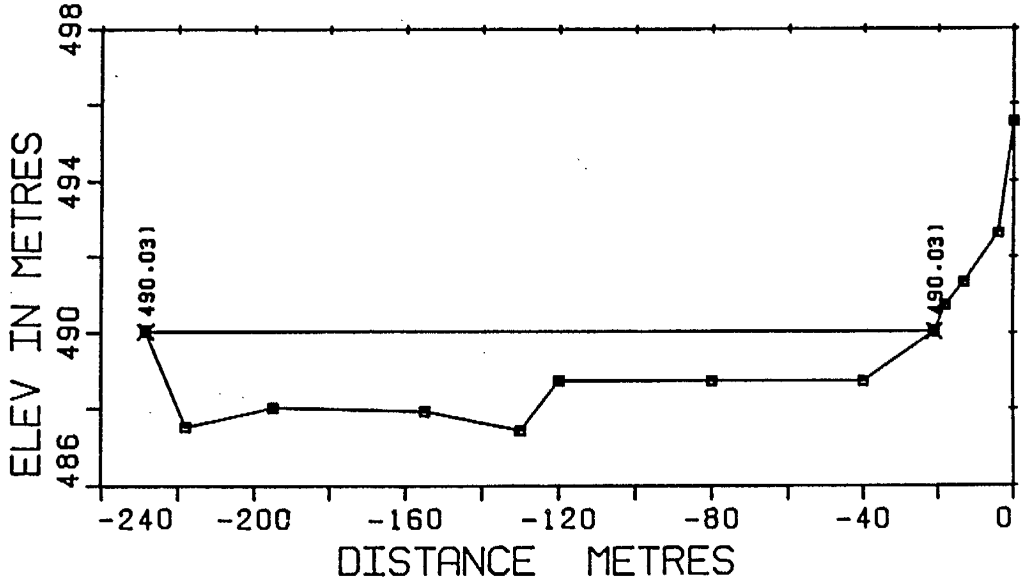
RIVER BED TOPOGRAPHY



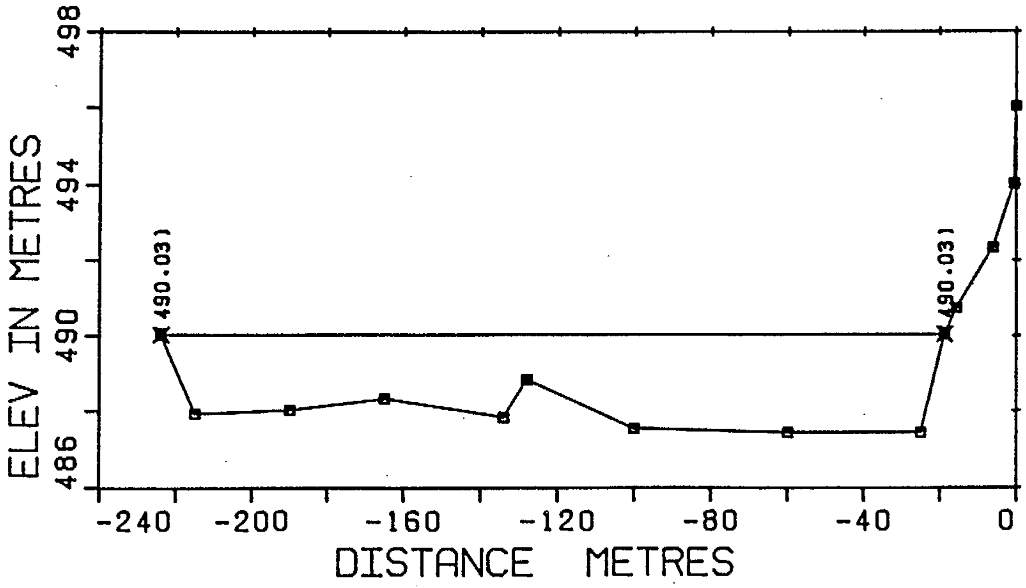
INTAKE CS 1



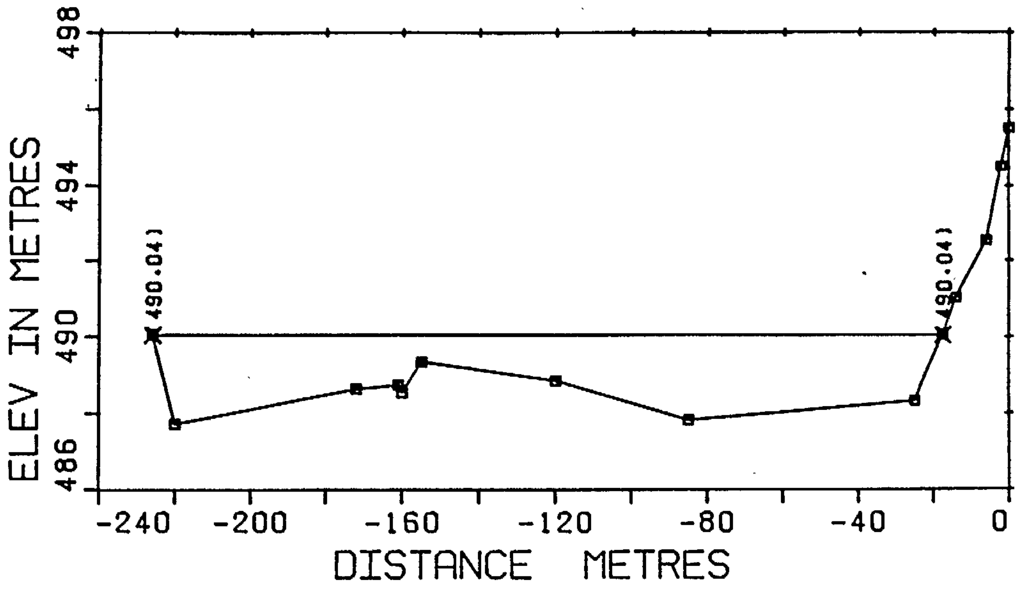
INTAKE CS 2



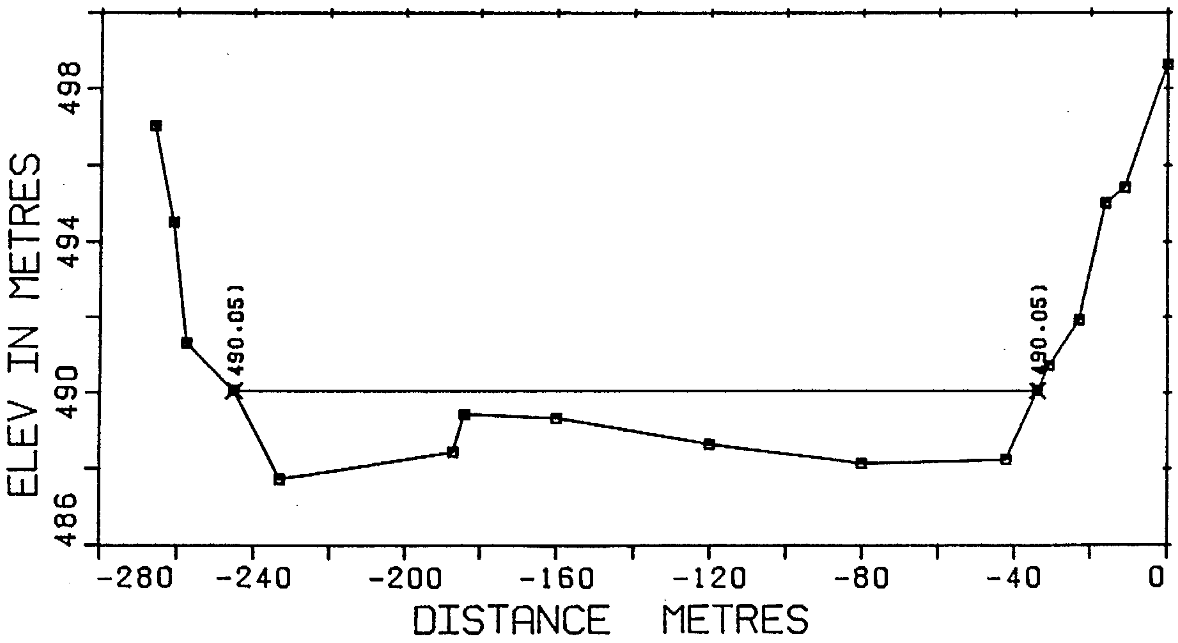
INTAKE CS 3



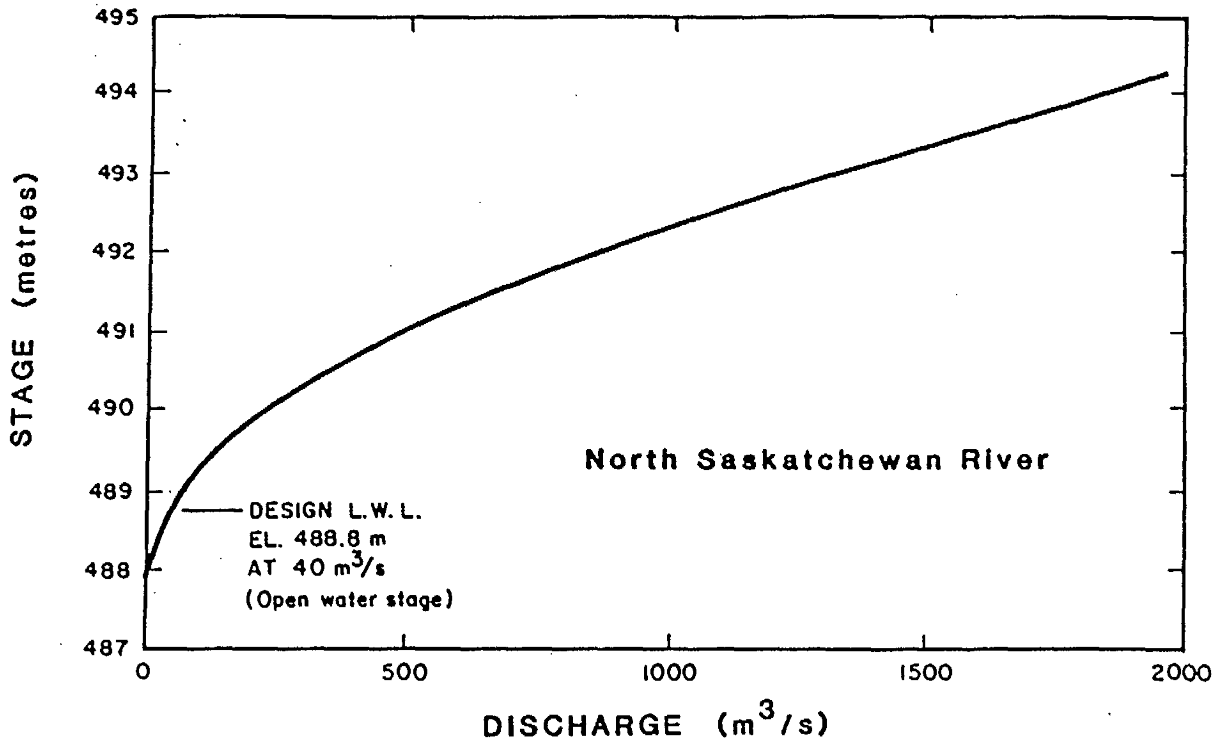
INTAKE CS 4



INTAKE CS 5



INTAKE CS 6



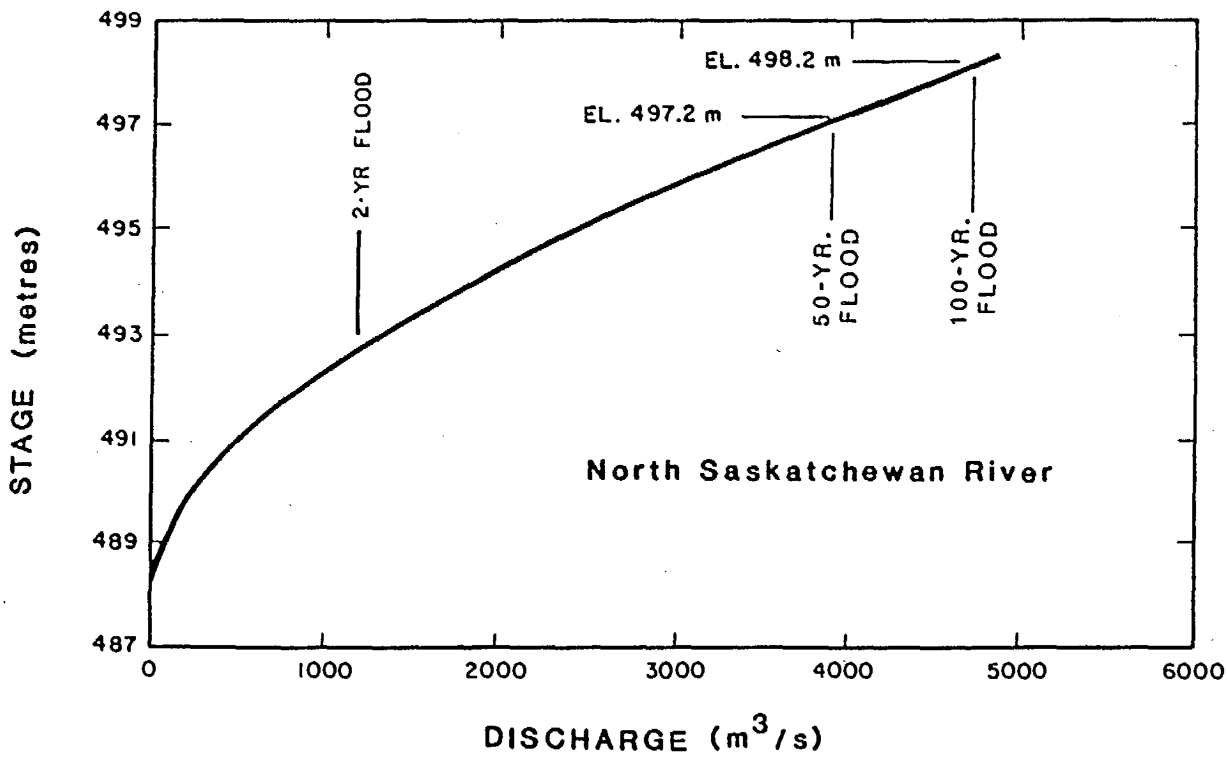


FIGURE 5

STAGE – DISCHARGE CURVE

SECTION COORDINATES IN METRES

~~HUSKY~~ INTAKE CS 1		~~HUSKY~~ INTAKE CS 2		~~HUSKY~~ INTAKE CS 3		~~HUSKY~~ INTAKE CS 4		~~HUSKY~~ INTAKE CS 5	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
-220.00	90.80	-250.00	92.40	-224.50	86.90	-224.00	86.90	-226.00	86.81
-217.00	90.40	-245.00	91.80	-218.00	84.40	-215.00	84.80	-220.00	84.60
-216.00	84.40	-244.00	89.90	-195.00	84.80	-190.00	84.90	-172.00	85.50
-210.00	87.40	-238.00	88.40	-166.00	84.60	-185.00	85.20	-161.00	85.80
-200.00	86.86	-230.50	87.40	-130.00	84.30	-134.00	84.70	-160.00	85.40
-195.00	86.00	-227.00	88.68	-120.00	85.80	-128.00	85.70	-155.00	86.20
-185.00	85.90	-220.00	84.60	-80.00	85.80	-100.00	84.40	-120.00	85.70
-175.00	84.30	-190.00	84.80	-40.00	85.60	-60.00	84.30	-85.00	84.70
-160.00	84.30	-155.00	84.30	-21.00	88.90	-25.00	84.30	-25.00	85.20
-140.00	84.00	-125.00	84.80	-18.00	87.60	-18.70	88.90	-17.50	86.91
-138.00	84.40	-120.00	85.80	-13.00	88.20	-15.50	87.60	-14.00	87.90
-117.00	84.90	-80.00	85.90	-4.00	89.50	-6.00	89.20	-5.00	89.40
-82.00	84.60	-45.00	85.70	-0.0	92.40	-0.50	90.90	-2.00	91.40
-80.00	85.20	-17.00	86.88			-0.0	92.90	-0.0	92.40
-45.00	85.40	-13.50	87.40						
-8.30	86.86	-12.00	88.30						
-6.80	87.90	-6.00	88.40						
-2.00	89.50	-0.0	89.80						
-0.0	91.50								

SECTION COORDINATES IN METRES

~~HUSKY~~ INTAKE CS 6		~~HUSKY~~ INTAKE CS 7		~~HUSKY~~ INTAKE CS 8		~~HUSKY~~ INTAKE CS 9		~~HUSKY~~ INTAKE CS 10	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
-266.00	93.90	-228.00	86.93	-243.50	86.93	-255.00	85.95	-290.00	92.90
-261.00	91.40	-212.00	84.70	-240.00	85.40	-240.00	86.40	-285.00	89.40
-257.50	88.20	-185.00	85.50	-235.00	85.70	-220.00	86.00	-279.00	88.40
-245.00	88.92	-182.00	85.10	-208.00	85.00	-207.00	85.60	-272.00	86.97
-233.00	84.80	-175.00	85.10	-176.00	86.20	-200.00	86.90	-258.00	85.90
-187.00	85.30	-170.00	86.40	-120.00	85.80	-165.00	86.20	-247.00	88.40
-184.00	86.30	-107.00	86.10	-90.00	85.70	-130.00	85.60	-235.00	86.40
-160.00	86.20	-105.00	85.70	-82.00	84.80	-100.00	85.80	-230.00	86.00
-120.00	85.50	-80.00	85.10	-60.00	84.60	-92.00	85.80	-220.00	86.30
-80.00	85.00	-55.00	84.70	-47.00	84.80	-70.00	84.70	-217.00	85.90
-42.00	85.10	-26.00	84.90	-35.00	84.70	-55.00	84.70	-157.00	85.90
-34.00	86.82	-17.00	86.83	-30.00	86.00	-47.00	85.20	-148.00	85.80
-31.00	87.60	-15.00	87.40	-23.50	86.94	-35.00	84.80	-112.00	85.20
-23.00	88.80	-5.50	89.00	-21.00	87.40	-30.00	88.20	-82.00	88.00
-16.00	91.80	-0.0	92.40	-9.00	88.20	-18.50	88.95	-60.00	86.20
-11.00	92.30			-4.00	89.90	-15.00	87.40	-43.00	84.70
-0.0	85.50			-0.0	92.10	-4.00	89.50	-35.00	86.00
						-0.0	94.00	-19.00	86.97
								-18.00	87.30
								-5.00	90.40
								-0.0	95.40

SECTION COORDINATES IN METRES

~~HUSKY~~ INTAKE CS 11		~~HUSKY~~ INTAKE CS 12		~~HUSKY'~~ INTAKE CS 13	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
-327.00	93.00	-325.00	92.00	-350.00	91.00
-325.00	91.00	-320.00	88.00	-345.00	87.30
-320.00	90.00	-315.00	87.50	-330.00	86.80
-317.00	89.00	-305.00	87.50	-320.00	86.40
-310.00	87.07	-302.00	88.70	-300.00	87.00
-295.00	85.40	-300.00	87.24	-270.00	87.50
-275.00	85.40	-280.00	86.60	-265.00	89.00
-235.00	86.20	-270.00	86.70	-223.00	84.50
-200.00	85.80	-256.00	86.30	-220.00	87.30
-185.00	86.60	-220.00	86.50	-185.00	85.20
-180.00	86.20	-190.00	86.50	-180.00	85.20
-157.00	85.60	-187.00	85.80	-144.00	84.70
-110.00	86.20	-105.00	85.10	-120.00	86.10
-105.00	86.40	-100.00	86.20	-80.00	86.10
-100.00	85.10	-80.00	86.00	-68.00	85.70
-75.00	85.10	-60.00	86.40	-60.00	85.30
-60.00	84.70	-42.00	85.80	-11.50	87.30
-30.00	86.40	-11.50	87.24	-0.0	91.00
-10.00	87.07	-0.0	91.00		
-5.00	89.00				
-0.0	92.00				

A3. Case 3

Project: Pipeline River Crossing
Stream name: Sachigo River
Location: Northwestern Ontario

Data type collected:

- channel sectional geometry
- floodplain geometry
- longitudinal water surface profile
- thalweg profile
- bed material sample
- bank material sample
- aerial photographs (historical sequence)
- field photographs
- highwater marks
- geomorphic description of site

Hydraulic/Morphologic Parameters Derived:

- stage-discharge (minimum to maximum range)
- stage-flow velocity (minimum to maximum range)
- maximum bed scour
- potential for bed aggradation/degradation
- historical lateral channel stability
- maximum water level
- gradation of bed and bank materials
- bed material load
- ice loading

Hydrology: No Water Survey of Canada hydrometric station on stream - design flow based on regional analysis.

LOCATION PLAN
SCALE 1:6,000

LEGEND:

- - - - - - APPROXIMATE LOCATION OF LONGITUDINAL SOUNDINGS (SEE DRAWING 34-E)

———— 1500 US - CROSS SECTION NUMBER AND LOCATION. (SEE DRAWING 34-D FOR SECTION PROFILES)

12.02 ➔ - FIELD PHOTOGRAPH INDEX NUMBER AND VIEWING DIRECTION (SEE DRAWING 34-F)

GENERAL NOTES

LOCATION

UTM 15U 5999000 m N 562000 m E

SURVEY CONTROL

Benchmark: Estab'd June 1976 by NHCL: spike in blazed spruce stump on south bank at station 279.2 m (916 ft) on section CL. Assigned elevation = 152.40 m (500.00 ft). Note: Cross-sections are plotted to assigned elevation.

Elevation conversion equation: Approximate geodetic elevation = assigned elevation plus 88.1 m (289.0 ft).

HORIZONTAL REFERENCE

Blazed spruce stump witness post on south bank at station 279.2 m (916 ft) on section CL.

DIRECTION CONVENTION

All river cross-sections are plotted so that the north end of the route is on the left of the plot.

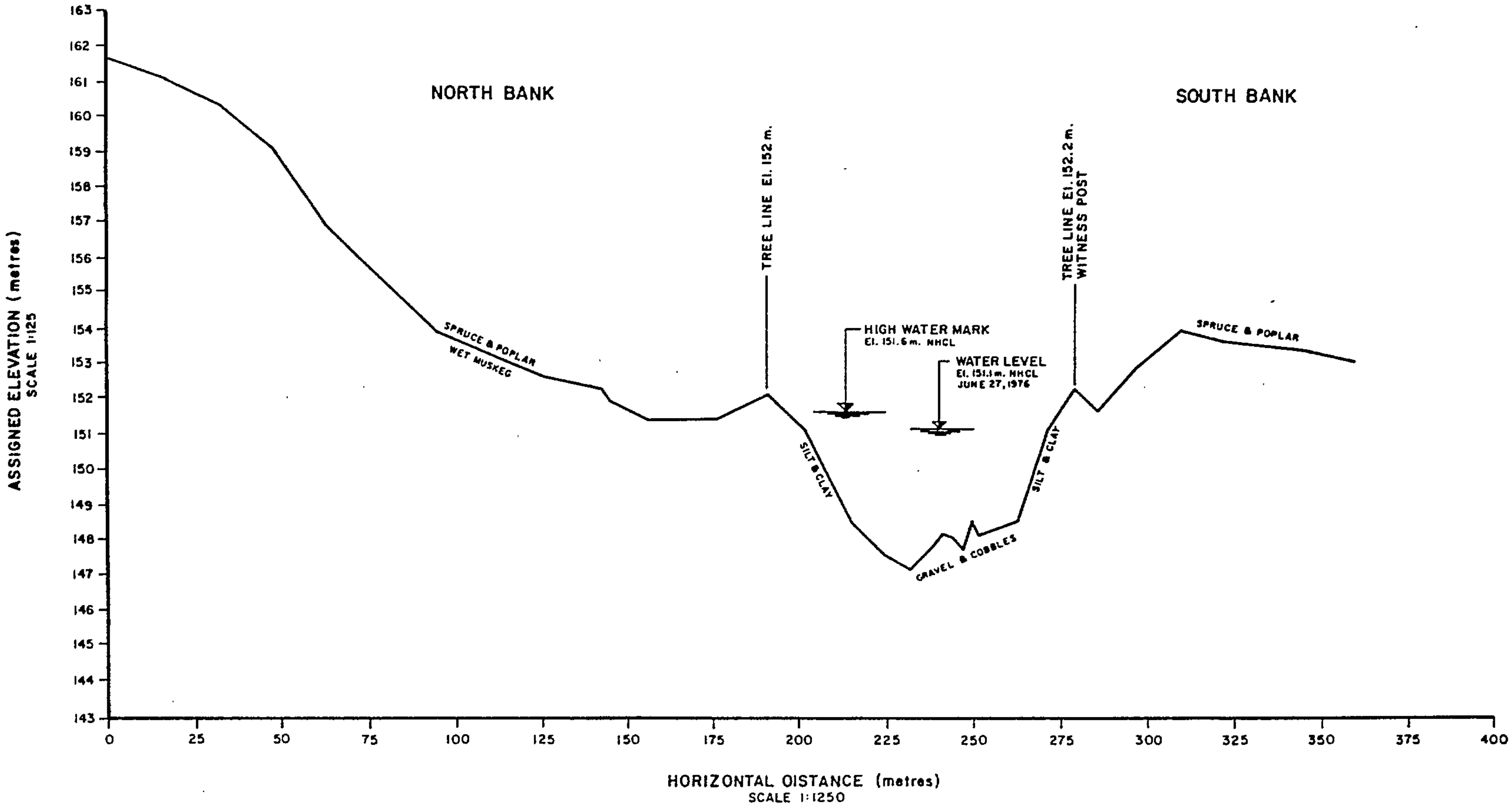
DATE OF SURVEY

24 June 1976. Water levels shown on cross-section plots correspond to this date.

RIVER CROSSING CLASSIFICATION

Minor.

POLAR GAS PROJECT		
LOCATION PLAN AND GENERAL NOTES SACHIGO RIVER		
northwest hydraulic consultants ltd. edmonton vancouver		
Drawn SD.	Date DEC., 1976	Dwg 34-A



NOTE:
FOR PROFILE LOCATION SEE
DRAWING 34-A, SECTION CENTERLINE.

POLAR GAS PROJECT

ANNOTATED CROSS-SECTIONAL PROFILE
SACHIGO RIVER

northwest hydraulic consultants ltd
edmonton vancouver

Drawn SD.	Date DEC., 1976	Dwg 34-B

SITE DESCRIPTION

<u>Physiographic Setting</u>:

Swampy lowland with organic and lacustrine deposits, heavily wooded.

<u>Channel Type</u>:

Irregular meanders; site located 2 km below Little Sachigo Lake.

<u>River Banks</u>:

Silt and clay, heavily vegetated, frozen at shallow depth, 24 June 1976.

<u>River Bed</u>:

Gravel and cobbles probably overlying till.

<u>Floodplains</u>:

No definite floodplains: low land either side.

<u>Water Levels and Velocities</u>:

Range in water levels estimated 1 to 2 m.
Measured velocity 24 June 1976, 0.3 m/s.
Estimated flood velocity 1 m/s.

<u>Ice Conditions</u>:

Not significant.

<u>Discharge Data</u>:

Water Survey gauging station upstream of Little Sachigo Lake, daily flow data since 1970.

<u>Sediment</u>:

Water generally silty.

HYDROLOGICAL ASSESSMENT

<u>Comments on Crossing Location</u>:

Exact location not critical.

<u>Bank Stability and Channel Shifting</u>:

Banks fairly stable in natural conditions; liable to instability if thawed.

<u>Bed Movement and Scour</u>:

Not expected.

<u>Ice Action</u>:

Not significant.

<u>Drainage Area</u>:

4800 km^2.

<u>Maximum Flow Conditions</u>:

Estimated 25-year maximum flow 230 m^3/s.

<u>Minimum Flow Conditions</u>:

Estimated 25-year minimum flow 8 m^3/s.

<u>Proposed Minimum Cover</u>:

1.5 m.

<u>Bank and Bed Restoration</u>:

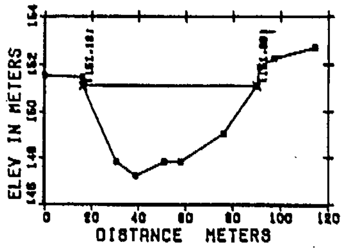
Banks may require erosion protection when thawed.

POLAR GAS PROJECT

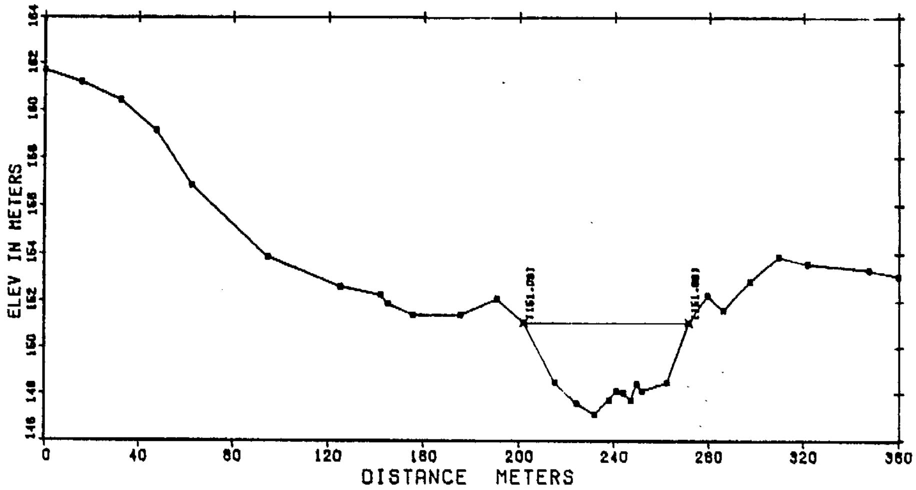
SITE DESCRIPTION AND HYDROLOGICAL ASSESSMENT
SACHIGO RIVER

northwest hydraulic consultants ltd.
edmonton vancouver

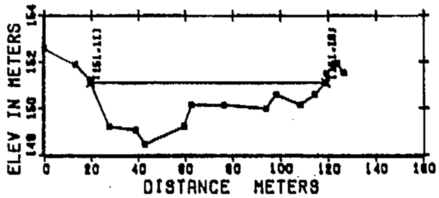
Drawn	Date DEC., 1976	Dwg 34-C



SACHIGO 1675 DS

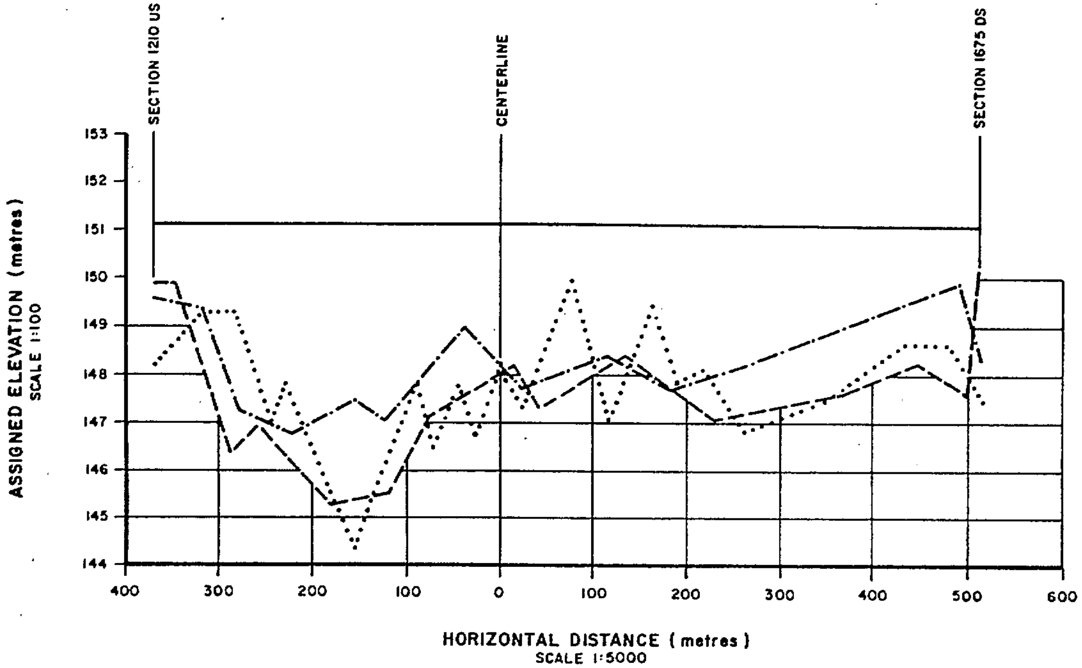


SACHIGO CL



SACHIGO 1210 US

POLAR GAS PROJECT		
CHANNEL CROSS SECTIONS SACHIGO RIVER		
northwest hydraulic consultants ltd. edmonton vancouver		
Drawn	Date DEC, 1976	Dwg 34-D



LEGEND:

- WATER SURFACE PROFILE.
- MID-CHANNEL LONGITUDINAL PROFILE.
- NORTH QUARTER-CHANNEL LONGITUDINAL PROFILE.
- SOUTH QUARTER-CHANNEL LONGITUDINAL PROFILE.

NOTES:

1. AVERAGE SURFACE VELOCITY AT CENTERLINE SECTION; JUNE 24, 1976 = 0.30 m/s.
2. AVERAGE WATER SURFACE SLOPE FROM SECTION 1210 US TO SECTION 1675 DS (DROP OF 0.03m., DISTANCE OF 879m.) = 0.00003

LONGITUDINAL RIVER SLOPE PROFILE
SACHIGO RIVER

View east to CL section on Sachigo River (Photo PG-SF1 7.12A)

View of top of one of several large erratic boulders in channel approx. 75 m downstream of CL section (Photo PG-SF1 7.3A).

View of left bank of CL section (Photo PG-SF1 7.5A).

View of right bank of CL section (Photo PG-SF1 7.4A).

POLAR GAS PROJECT

SITE PHOTOGRAPHS
SACHIGO RIVER

northwest hydraulic consultants ltd.
edmonton vancouver

Drawn	Date DEC. 1976	Dwg 34-F

A4. Case 4

Project: Dam (prediction of hydraulic and morphologic changes)
Stream name: Oldman River
Location: Southwestern Alberta, 10 km north of Pincher Creek.

Data type collected:

- channel sectional geometry
- floodplain geometry
- longitudinal water surface profile
- thalweg profile
- bed material sample
- bank material sample
- aerial photographs (historical sequence)
- field photographs
- highwater marks
- geomorphic description of site

Hydraulic/Morphologic Parameters Derived:

- stage-discharge (minimum to maximum range)
- stage-flow velocity (minimum to maximum range)
- maximum bed scour
- potential for bed aggradation/degradation
- historical lateral channel stability
- maximum water level
- gradation of bed and bank materials
- bed material load

Hydrology: Water Survey of Canada hydrometric station No. 5AA-24-Oldman River near Brocket - located 7 km downstream of damsite. Also utilized suspended sediment data.

SUMMARY

A water storage and flow regulation dam is to be constructed on the Oldman River at the Three Rivers site. Studies of the projected morphological changes to the river system resulting from the impoundment of flow by the proposed Oldman River Dam are reported herein. These include:

- reservoir sedimentation;
- river bed aggradation at the head of the reservoir; and
- river bed degradation downstream of the dam.

The 4400 km^2 catchment of the Oldman River above the damsite lies between the Continental Divide and the Porcupine Hills. Elevations range from 2800 m at the Divide to 1050 m on the river at the site. Approximately half of the catchment drains to the Upper Oldman River; the remainder of the catchment is divided approximately equally between the Crowsnest and Castle Rivers.

Erosion of fine-grained glacio-lacustrine soils provides the greater part of the sediment load in the Oldman River. These fine-grained soils lie mainly along the lower 15 km or so of the Upper Oldman, Crowsnest and Castle Rivers. About half of these reach lengths will be drowned by the reservoir. Stream bank erosion and landsliding are the main processes supplying sediment to the rivers.

Suspended sediment data have been collected by Water Survey of Canada at the Brocket gauging station about 7 km downstream of the proposed damsite since 1966. Reported

Source: "Oldman River Dam, Assessment of Reservoir Sedimentation and Impacts on River Morphology"; Alberta Environment; December, 1985.

annual loads range widely from 7.0 kt in 1977 to 1108 kt in 1975 - the mean value is 266 kt. On average 91% of the annual load occurs during May and June. A value of 320 kt/a has been adopted herein as the long-term mean sediment inflow to the reservoir, including bedload. This does not include an allowance for material slumping from the reservoir banks. Silt and clay make up about 70% of the suspended sediments.

The reservoir will consist of a narrow 15 km long reach adjoined by three arms formed by the Upper Oldman, Crowsnest and Castle Rivers. At the full supply level of el. 1118.6 m the reservoir has a volume of 500 hm^3 and a surface area 24.4 km^2. It is projected that on average 0.06% of the original capacity will be lost annually due to sedimentation. At this initial rate of loss the reservoir would have a half-life of 800 years.

It is considered that three-quarters of the sediment will deposit in the Oldman River arm downstream of the present Crowsnest River confluence. Approximate sediment deposition volumes in reaches of the reservoir after 100 years of operation are summarized below:

Reservoir Reach	100-year Sediment Deposition	
	Volume hm^3	Fraction of Total %
Upper Oldman	3.9	12
Crowsnest	0.6	2
Castle	3.4	11
Oldman	24.0	75
Totals	32.0	100

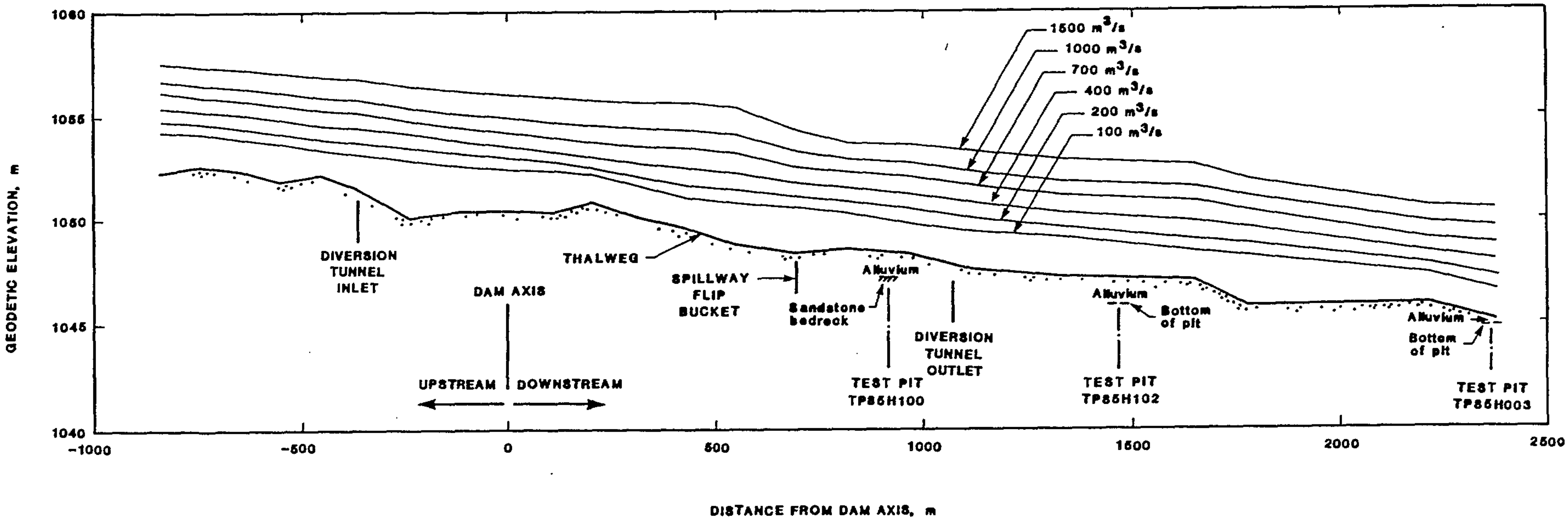
The effect of proposed reservoir crossings on the distribution of sediment in the reservoir is not allowed for in these figures.

The effect of reservoir bank slumping on sediment inputs and of proposed reservoir crossings on the distribution of deposits will be covered in an addendum when the necessary information becomes available.

Aggradation at the upstream end of the reservoir where the rivers merge into the reservoir will be minimal because of the low bedload transport of the tributary streams. It is estimated that after 100 years, bed levels in the Upper Oldman River will have increased by a maximum of 2 m and water levels by a maximum of 1 m at extreme flood flows. In the Castle River the corresponding increases would be 1.7 m and 1 m. Aggradation will be insigificant in the Crowsnest River because its bedload transport is negligible.

The bed material of the Oldman River in the reach below the damsite consists of coarse gravel and cobbles. The bed is paved, the surface material being coarser than the sub-surface material. Analysis of the mobility potential of the surface stones show that the surface layer would remain stable except during rare floods. Based on existing conditions the mean annual bed load of the surficial layer is 2.0 kt/a.

It is considered that degradation of the river bed immediately below the dam will be very small, because the bed contains a significant proportion of cobbles that only move during rare floods. An ultimate degradation of 0.5 m after 25 years is predicted. This would reduce water levels just below the dam by approximately 0.2 m.



NOTE:
- WATER LEVELS ARE CALCULATED

FIGURE 3

OLDMAN RIVER PROFILE
AT DAMSITE

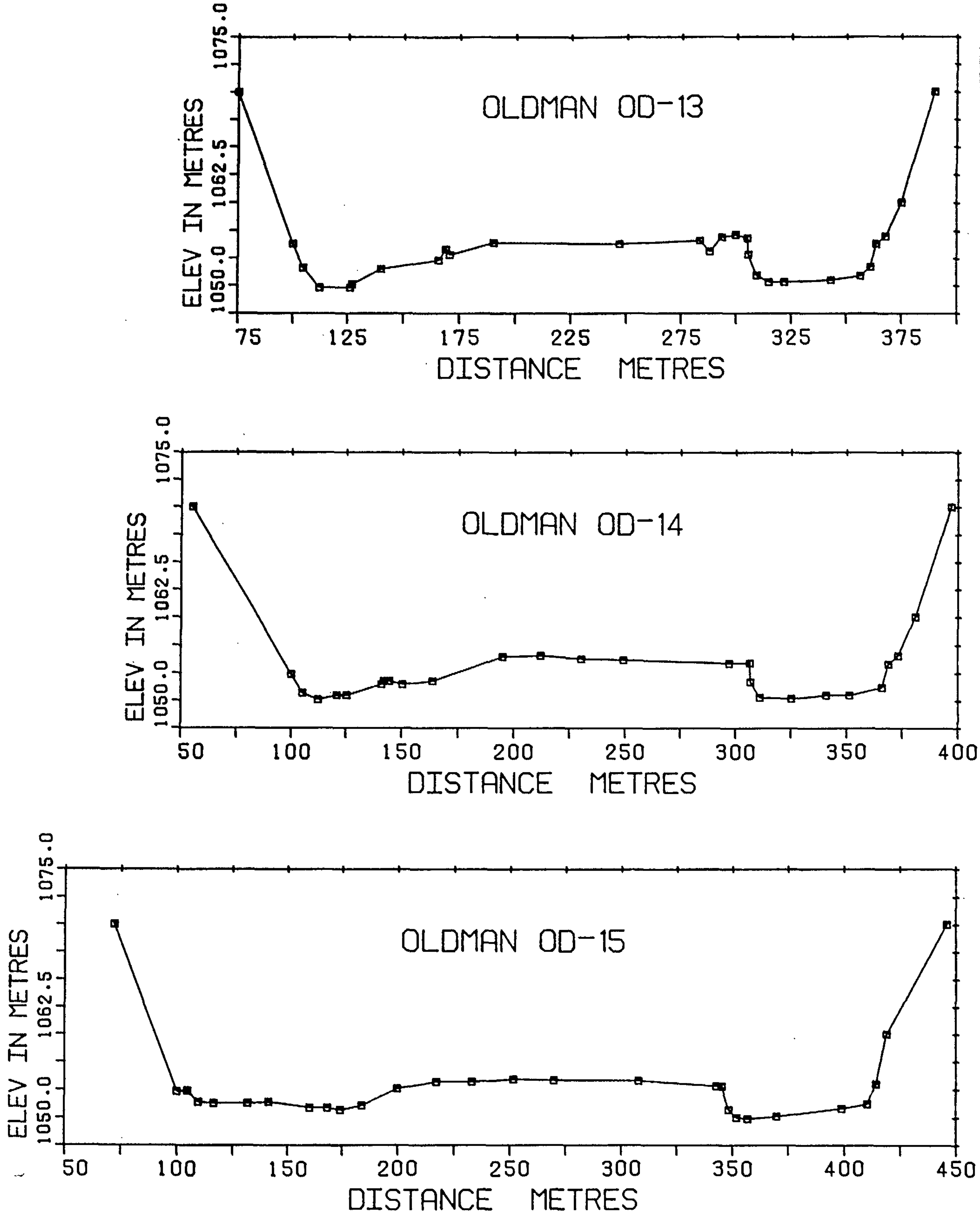
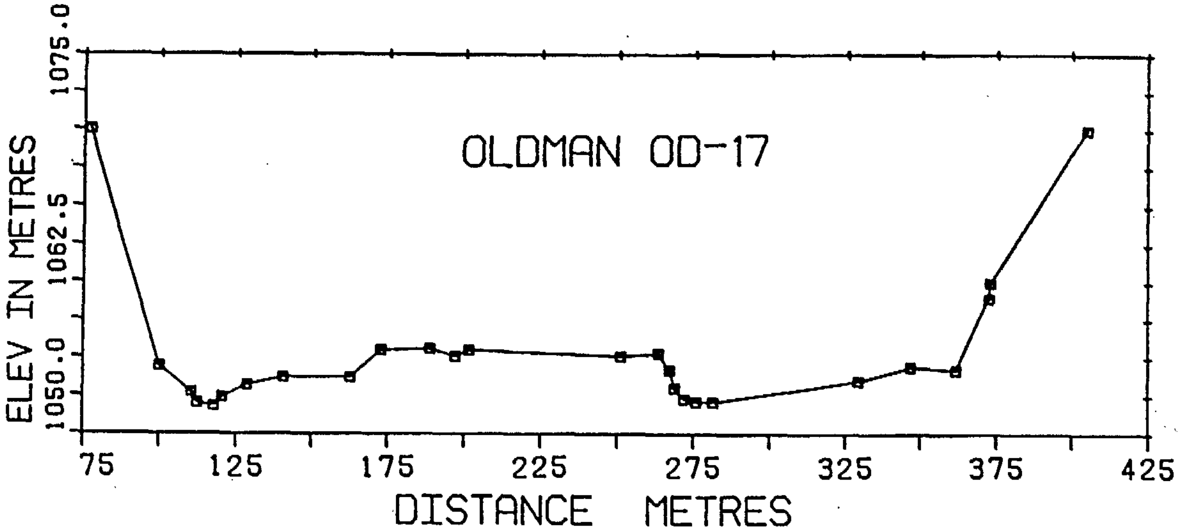
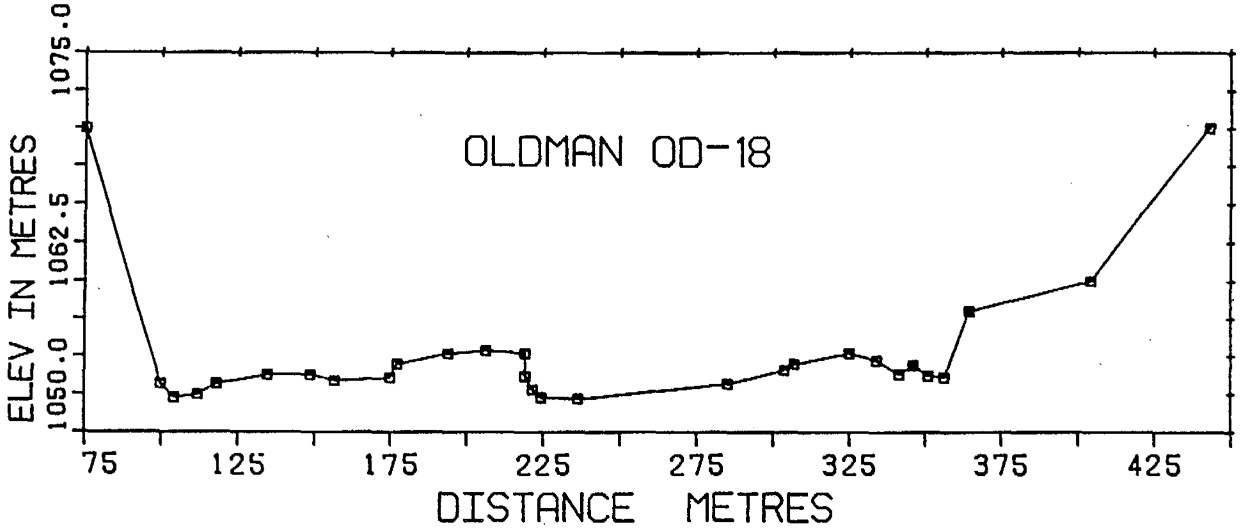

OLDMAN OD-13
OLDMAN OD-14
OLDMAN OD-15
ELEV IN METRES
DISTANCE METRES

FIGURE A.2


OLDMAN OD-17
ELEV IN METRES
1075.0
1062.5
1050.0
75
125
175
225
275
325
375
425
DISTANCE METRES


OLDMAN OD-18
ELEV IN METRES
1075.0
1062.5
1050.0
75
125
175
225
275
325
375
425
DISTANCE METRES

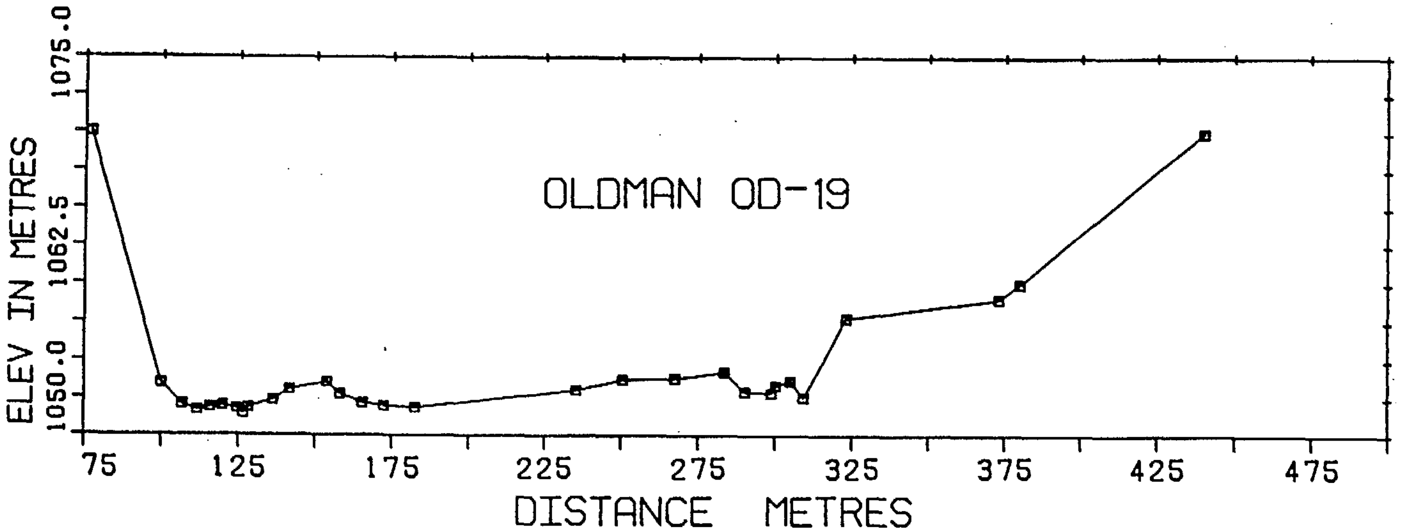
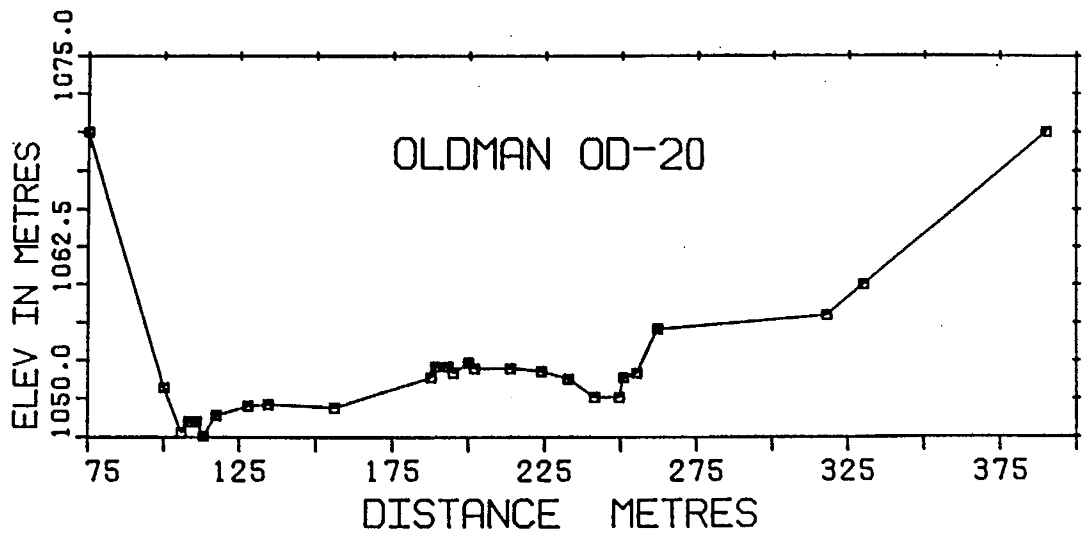
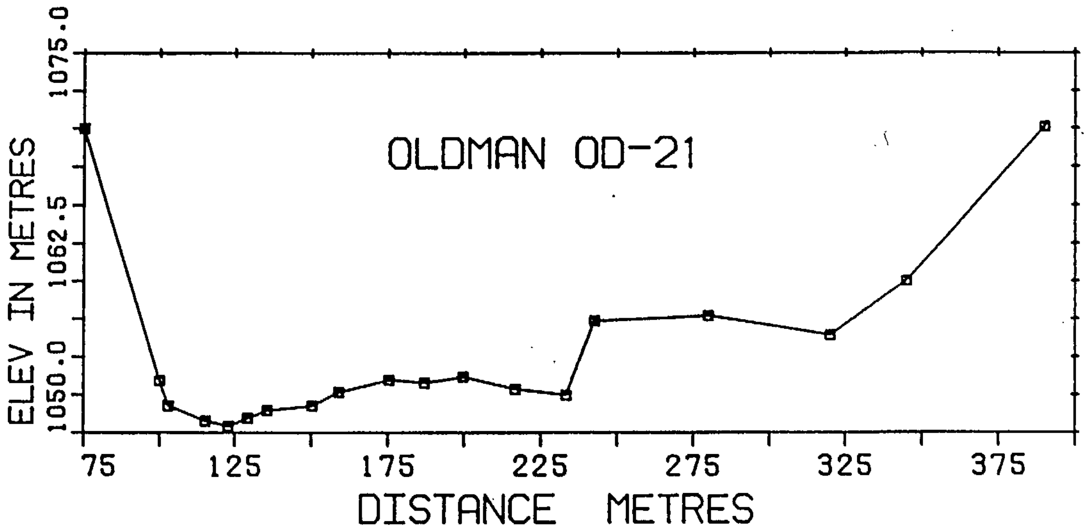

OLDMAN OD-19
ELEV IN METRES
1075.0
1062.5
1050.0
75
125
175
225
275
325
375
425
475
DISTANCE METRES

FIGURE A.3


OLDMAN OD-20
ELEV IN METRES
1050.0
1062.5
1075.0
75
125
175
225
275
325
375
DISTANCE METRES


OLDMAN OD-21
ELEV IN METRES
1050.0
1062.5
1075.0
75
125
175
225
275
325
375
DISTANCE METRES

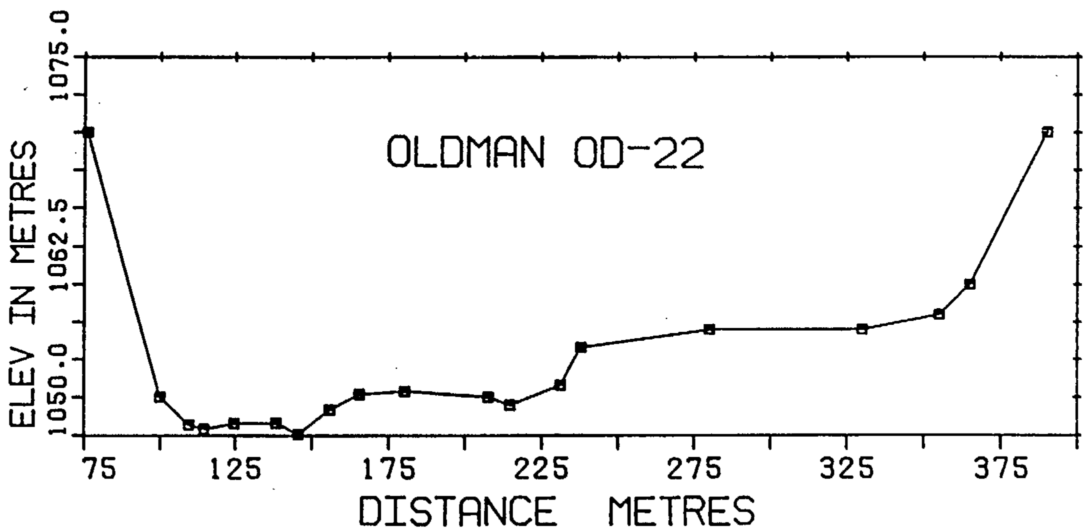
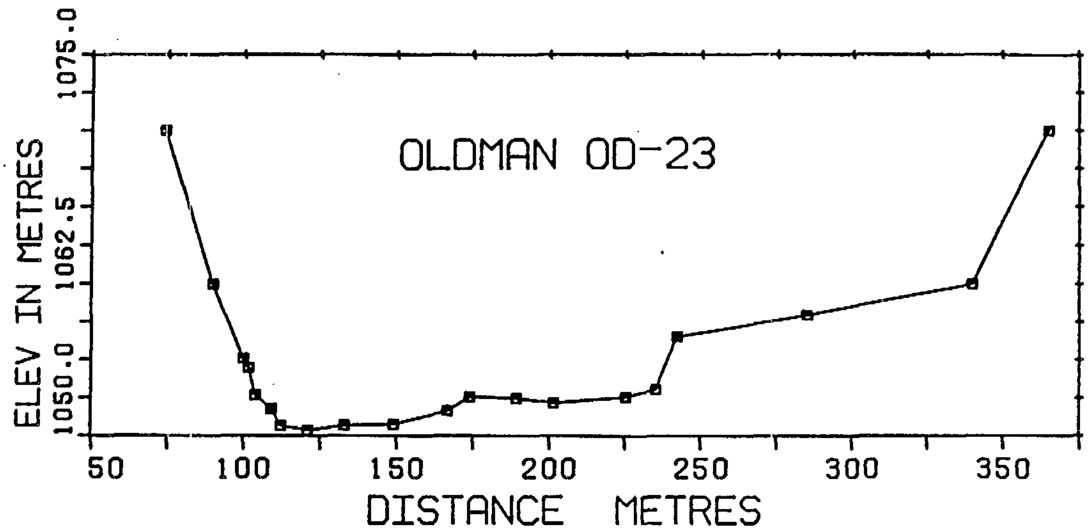
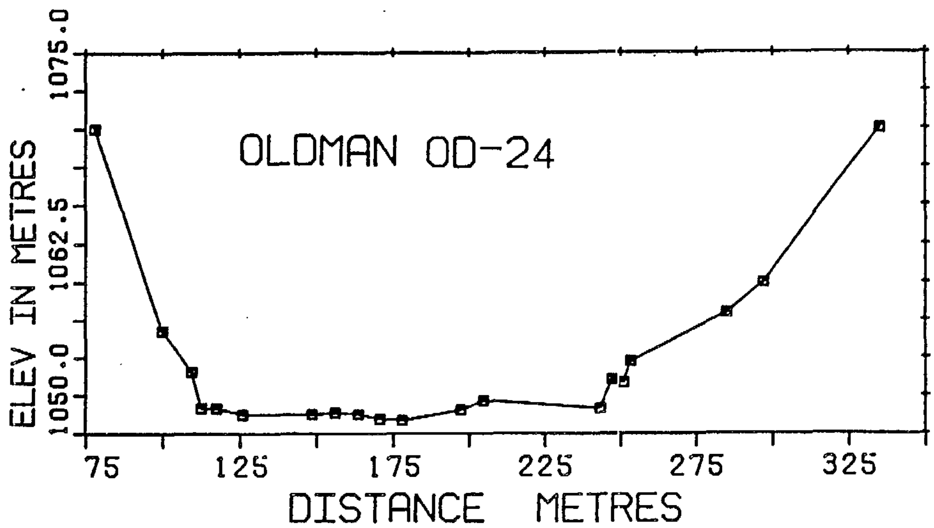

OLDMAN OD-22
ELEV IN METRES
1050.0
1062.5
1075.0
75
125
175
225
275
325
375
DISTANCE METRES

FIGURE A.4


OLDMAN OD-23
ELEV IN METRES
1050.0
1062.5
1075.0
50
100
150
200
250
300
350
DISTANCE METRES


OLDMAN OD-24
ELEV IN METRES
1050.0
1062.5
1075.0
75
125
175
225
275
325
DISTANCE METRES

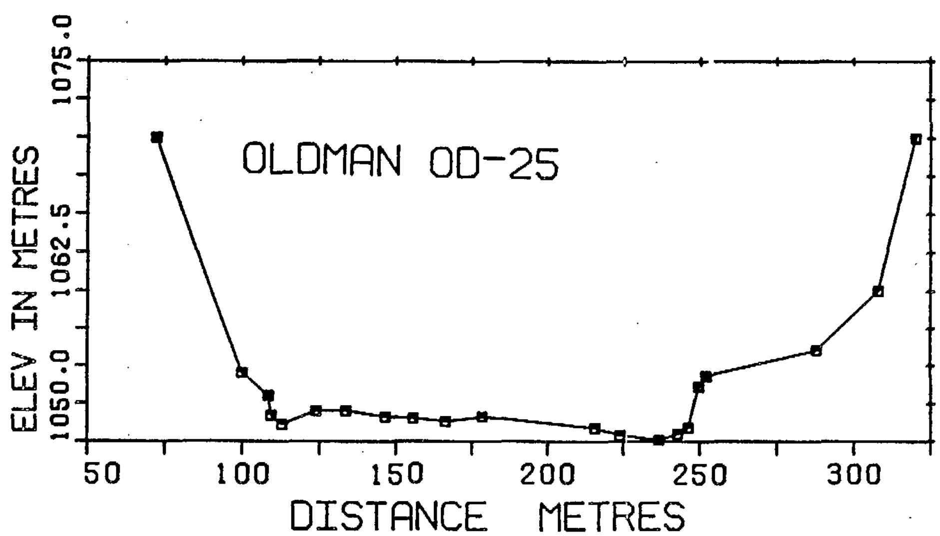

OLDMAN OD-25
ELEV IN METRES
1050.0
1062.5
1075.0
50
100
150
200
250
300
DISTANCE METRES

FIGURE A.5

SECTION COORDINATES IN METRES

OLDMAN 00-12

HORIZ	VERT
10.00	1050.01
29.99	1047.99
48.99	1046.01
85.01	1045.01
300.01	1044.00
304.60	1043.22
312.01	1042.63
324.15	1044.02
334.94	1035.42
336.75	1036.02
347.14	1035.57
356.43	1036.01
374.64	1036.62
379.51	1036.72
414.09	1036.42
435.99	1037.02
436.00	1038.22
440.16	1038.56
445.10	1040.72
452.20	1042.52
455.01	1044.00
485.00	1045.01
605.00	1046.01
705.00	1050.01

OLDMAN 00-11.8

HORIZ	VERT
0.0	1052.99
40.05	1039.00
114.01	1039.00
149.86	1040.01
230.12	1040.01
255.12	1039.00
262.13	1035.71
308.94	1035.49
330.10	1036.00
359.87	1028.39
405.06	1036.59
415.14	1039.00
460.06	1040.01
665.07	1040.01
690.07	1050.01

OLDMAN 00-11

HORIZ	VERT
0.0	1054.17
5.00	1056.99
9.30	1056.01
16.99	1050.01
27.01	1045.01
30.46	1043.54
39.99	1041.74
44.87	1043.14
57.67	1042.14
64.94	1042.44
71.34	1039.73
79.49	1042.84
89.09	1041.74
137.26	1042.64
161.69	1042.34
226.09	1042.23
294.56	1041.10
295.47	1040.70
307.76	1040.50
343.06	1040.70
361.86	1041.11
390.64	1041.20
404.07	1040.90
420.81	1040.23
430.61	1039.13
447.30	1036.54
467.41	1036.53
462.50	1042.07
480.21	1042.03
516.01	1042.99
537.00	1045.01
549.01	1050.01
566.01	1055.00

OLDMAN 00-10

HORIZ	VERT
0.0	1055.99
5.00	1055.00
6.00	1050.01
10.00	1046.99
86.00	1049.01
91.00	1044.46
97.70	1042.46
106.00	1042.74
115.60	1042.36
146.70	1041.66
153.90	1041.26
164.60	1041.26
169.06	1041.66
184.60	1042.06
197.00	1044.46
202.69	1049.06
210.01	1055.00

OLDMAN 00-9

HORIZ	VERT
12.01	1060.00
34.01	1055.00
54.99	1051.99
60.82	1050.01
80.53	1046.01
91.44	1044.79
96.44	1044.16
102.23	1044.06
110.55	1043.35
115.95	1043.36
127.94	1042.57
146.65	1042.96
176.26	1043.36
181.64	1044.86
206.53	1047.04
213.63	1046.97
225.26	1042.76
228.73	1042.66
249.75	1046.34
259.06	1047.86
274.99	1050.01
320.01	1055.00
330.01	1060.00

SECTION COORDINATES IN METRES

OLDMAN 00-8

HORIZ	VERT
0.0	1062.01
5.00	1060.00
8.99	1056.99
15.87	1055.00
23.99	1052.99
30.46	1050.16
34.29	1049.05
35.39	1044.75
48.64	1043.45
63.66	1043.75
69.67	1043.34
76.67	1043.35
90.37	1044.35
100.77	1047.35
108.48	1047.55
174.77	1047.45
224.16	1046.65
246.89	1046.95
266.57	1048.16
301.87	1046.36
315.29	1047.45
336.77	1049.45
354.09	1047.56
376.66	1046.75
386.40	1046.86
414.99	1060.00

OLDMAN 00-7

HORIZ	VERT
15.00	1060.00
22.49	1056.99
29.99	1055.00
39.01	1051.01
58.00	1050.01
91.44	1049.21
101.25	1049.10
106.74	1046.40
110.34	1045.20
115.73	1045.10
126.75	1045.71
127.63	1045.10
137.63	1045.40
149.63	1045.60
165.05	1046.70
203.03	1047.20
220.74	1047.20
241.04	1047.80
244.46	1047.80
246.33	1046.80
256.15	1047.11
263.93	1046.40
279.96	1051.01
305.01	1060.00

OLDMAN 00-6

HORIZ	VERT
5.48	1065.00
30.46	1061.01
68.49	1055.00
74.49	1052.99
75.47	1051.96
86.47	1050.01
187.67	1049.30
149.96	1047.89
185.77	1046.99
204.67	1044.59
210.77	1046.59
217.47	1047.20
224.49	1047.29
231.47	1046.49
243.78	1044.59
266.27	1046.50
273.59	1046.29
274.96	1045.96
282.86	1046.19
287.56	1047.89
300.47	1060.00
305.47	1065.00

OLDMAN 00-5.1

HORIZ	VERT
5.46	1065.00
30.46	1062.01
65.47	1060.00
85.47	1057.00
115.46	1052.00
140.46	1061.01
160.47	1050.00
230.47	1051.18
232.47	1051.16
236.16	1050.46
242.47	1049.45
244.97	1046.36
249.70	1047.66
256.56	1047.06
262.37	1046.76
274.67	1046.56
285.57	1046.56
291.87	1046.66
296.66	1045.16
301.67	1045.76
307.76	1047.16
311.69	1046.86
321.47	1055.00
330.49	1060.00
335.46	1070.00

OLDMAN 00-5

HORIZ	VERT
19.99	1070.00
45.01	1060.00
85.01	1058.00
120.00	1055.00
130.00	1052.00
148.99	1051.01
200.01	1051.26
202.51	1051.29
206.21	1046.79
216.21	1047.79
225.69	1047.29
231.10	1047.20
251.60	1047.69
265.39	1047.69
278.41	1047.89
286.66	1046.46
296.61	1046.09
300.41	1049.09
306.40	1049.69
312.79	1047.99
319.19	1046.09
321.59	1047.20
334.01	1047.08
347.60	1052.49
355.00	1060.00
366.00	1070.00

TABLE A.1

OLDMAN RIVER
CROSS-SECTION COORDINATES

SECTION COORDINATES IN METRES

OLDMAN 00-22

HORIZ	VERT
75.99	1070.00
100.00	1052.50
105.70	1050.69
114.76	1050.42
124.79	1050.79
134.59	1050.60
145.79	1050.09
156.09	1051.68
165.61	1052.69
180.41	1052.69
207.66	1052.50
214.75	1051.69
231.10	1053.28
237.60	1055.79
270.86	1057.00
330.01	1056.89
355.00	1058.00
365.00	1060.00
388.99	1070.00

OLDMAN 00-21

HORIZ	VERT
75.01	1070.00
100.00	1053.42
103.89	1051.76
115.40	1050.76
122.98	1050.41
129.39	1050.85
135.78	1051.45
150.34	1051.76
158.20	1052.46
175.50	1053.46
187.09	1053.27
199.48	1053.86
216.60	1052.49
233.28	1052.48
242.58	1057.26
270.88	1057.88
320.01	1056.40
365.00	1060.00
388.98	1070.00

OLDMAN 00-20

HORIZ	VERT
75.01	1070.00
104.00	1053.16
105.48	1050.26
108.30	1050.86
110.89	1050.94
113.28	1050.07
117.40	1051.38
127.08	1051.86
134.60	1052.08
150.20	1051.66
167.78	1053.66
180.31	1054.58
193.30	1054.56
195.10	1054.14
200.10	1054.64
202.11	1054.69
213.70	1056.46
220.00	1054.28
228.71	1053.78
241.40	1052.56
240.61	1052.57
260.01	1053.68
266.21	1054.18
282.10	1057.04
316.00	1056.00
330.01	1060.00
348.89	1070.00

OLDMAN 00-19

HORIZ	VERT
76.99	1070.00
100.00	1053.44
106.96	1052.06
111.40	1051.68
116.01	1051.44
120.00	1051.99
124.70	1051.76
126.40	1051.44
128.41	1051.88
136.68	1052.38
141.79	1053.06
163.64	1053.56
166.31	1052.76
168.68	1052.16
172.70	1051.96
182.70	1051.46
235.21	1053.06
250.62	1053.76
267.40	1053.86
283.49	1054.36
290.20	1052.96
298.60	1052.86
300.20	1053.38
305.01	1053.88
308.40	1052.56
323.21	1057.76
373.01	1058.00
378.69	1060.00
640.00	1070.00

OLDMAN 00-18

HORIZ	VERT
75.01	1070.00
100.00	1053.17
104.39	1052.27
112.11	1052.47
118.29	1052.17
134.81	1053.76
144.60	1053.77
156.79	1053.37
175.11	1053.57
177.30	1056.47
193.91	1055.16
206.29	1055.37
216.91	1055.17
218.21	1053.67
221.71	1052.77
224.49	1052.24
236.40	1052.17
265.20	1053.17
302.78	1054.07
306.90	1054.47
324.68	1055.19
333.78	1054.70
341.41	1053.80
346.40	1054.60
351.01	1053.70
356.19	1053.60
364.28	1058.00
404.01	1060.00
643.00	1070.00

SECTION COORDINATES IN METRES

OLDMAN 00-17

HORIZ	VERT
76.88	1070.00
100.00	1054.42
110.61	1052.72
112.50	1052.02
117.80	1051.82
120.61	1052.41
128.61	1053.22
140.70	1053.72
162.79	1053.72
173.00	1055.52
184.83	1056.61
197.11	1056.12
201.66	1056.62
261.19	1055.12
263.41	1056.31
267.10	1054.21
268.88	1053.01
272.08	1052.31
276.08	1052.11
281.80	1052.11
328.40	1053.61
346.80	1054.41
361.80	1054.21
372.59	1054.58
373.01	1060.00
404.88	1070.00

OLDMAN 00-16

HORIZ	VERT
71.88	1070.00
100.00	1054.66
104.70	1054.81
109.79	1053.91
116.71	1053.41
131.88	1053.61
141.40	1053.81
180.11	1053.41
188.31	1053.41
174.19	1053.21
183.89	1053.61
189.61	1056.10
216.99	1055.71
232.61	1056.71
261.48	1055.81
288.68	1056.61
307.70	1056.80
342.64	1056.32
345.08	1056.32
348.29	1053.22
351.68	1052.52
356.80	1052.42
369.61	1052.62
380.40	1053.22
384.68	1053.32
410.28	1053.72
414.10	1056.46
418.01	1060.00
445.88	1070.00

OLDMAN 00-14

HORIZ	VERT
84.68	1070.00
100.00	1054.68
105.10	1053.19
112.11	1052.69
120.78	1052.88
126.21	1052.89
140.81	1054.00
141.91	1056.30
144.41	1054.29
160.30	1053.99
163.61	1054.30
184.69	1056.49
211.81	1054.59
230.19	1056.29
249.11	1056.19
287.08	1056.49
305.29	1055.90
306.50	1054.20
310.60	1052.40
325.10	1052.70
340.80	1052.88
351.10	1052.00
365.78	1052.70
368.61	1055.60
373.20	1056.63
381.00	1060.00
387.00	1070.00

OLDMAN 00-13

HORIZ	VERT
75.01	1070.00
100.00	1055.30
104.78	1054.16
112.29	1052.30
126.31	1052.30
127.18	1052.50
160.06	1054.00
165.61	1054.40
168.89	1055.60
170.69	1055.30
190.20	1056.41
246.71	1056.30
263.31	1056.60
287.78	1056.60
293.40	1056.80
298.60	1057.11
304.60	1056.60
305.29	1056.30
308.31	1053.40
314.60	1052.60
321.61	1052.61
343.11	1053.00
366.49	1053.40
381.10	1054.20
383.50	1056.30
387.60	1056.99
375.00	1060.00
388.88	1070.00

TABLE A.1 (Cont.)

SECTION COORDINATES IN METRES

OLDMAN 00-4

HORIZ	VERT
44.98	1070.00
70.01	1060.00
86.01	1055.00
100.00	1052.20
106.23	1048.55
112.23	1046.97
132.52	1047.35
165.44	1047.26
158.85	1047.46
169.44	1050.20
178.85	1050.37
183.34	1049.67
189.04	1049.36
201.53	1044.36
207.05	1050.46
212.62	1050.65
232.75	1050.07
235.43	1050.36
247.63	1049.84
261.73	1051.16
260.14	1050.66
265.14	1048.87
283.03	1049.06
300.65	1046.74
306.24	1048.06
308.43	1049.46
320.01	1040.00
331.49	1070.00

OLDMAN 00-3

HORIZ	VERT
64.84	1070.00
100.00	1056.14
104.66	1050.24
120.37	1049.44
126.16	1048.34
132.17	1047.57
154.17	1047.76
160.66	1047.94
166.66	1049.30
168.65	1061.14
184.85	1051.77
187.36	1050.46
211.17	1051.28
224.17	1051.66
233.67	1051.86
254.17	1051.88
274.47	1050.88
276.45	1049.86
301.67	1048.68
315.26	1050.28
320.01	1060.00
345.00	1070.00

OLDMAN 00-2

HORIZ	VERT
5.00	1070.00
42.00	1060.00
100.00	1054.36
102.34	1054.26
103.65	1052.16
109.30	1051.66
113.39	1049.67
126.10	1048.46
158.60	1048.36
169.16	1048.36
186.36	1050.69
187.60	1051.25
204.18	1051.36
214.00	1051.76
216.60	1051.84
220.24	1051.65
235.16	1051.77
252.69	1050.85
264.20	1048.56
274.06	1048.66
282.16	1051.16
284.86	1051.36
285.46	1050.86
300.01	1060.00
316.01	1070.00

OLDMAN 00-1

HORIZ	VERT
5.49	1070.00
30.44	1060.00
40.44	1056.00
66.49	1054.00
135.49	1055.00
130.46	1053.21
134.39	1052.72
141.27	1049.44
149.11	1048.72
154.41	1048.62
173.80	1049.12
200.41	1050.43
205.82	1050.72
216.31	1050.52
220.10	1049.63
227.61	1048.61
231.71	1049.03
236.52	1051.32
248.47	1060.00
258.47	1070.00

OLDMAN 00-28

HORIZ	VERT
64.01	1070.00
63.00	1060.00
147.01	1055.00
200.01	1052.69
202.69	1051.19
206.61	1049.54
216.80	1048.69
227.49	1049.69
233.51	1049.79
244.76	1048.29
246.60	1048.60
255.51	1044.30
258.61	1044.38
260.81	1049.79
262.60	1051.68
264.61	1052.41
269.99	1060.00
283.63	1070.00

SECTION COORDINATES IN METRES

OLDMAN 00-27

HORIZ	VERT
0.0	1070.00
16.00	1060.00
54.89	1055.00
100.00	1053.09
106.11	1052.49
117.20	1049.70
123.99	1049.49
130.21	1049.69
143.41	1050.59
147.71	1060.39
180.81	1051.19
170.60	1049.97
179.19	1049.29
192.39	1049.19
187.61	1048.79
205.49	1049.87
211.41	1053.64
217.99	1060.00
227.89	1070.00

OLDMAN 00-26

HORIZ	VERT
44.99	1068.84
70.01	1060.00
85.01	1056.00
100.00	1053.95
103.61	1053.75
106.91	1052.26
114.51	1051.44
116.88	1050.75
123.60	1050.35
126.18	1051.15
147.19	1051.86
166.01	1051.74
207.39	1050.25
214.30	1049.65
223.90	1050.86
235.00	1050.74
244.39	1046.69
254.01	1046.66
263.71	1049.65
265.70	1050.45
266.80	1051.32
279.01	1060.00
283.00	1070.00

OLDMAN 00-25

HORIZ	VERT
71.68	1070.00
100.00	1054.61
106.31	1053.01
109.39	1061.71
112.80	1051.11
123.80	1062.02
133.58	1062.01
146.40	1051.61
156.69	1051.51
166.30	1051.30
178.60	1051.62
218.71	1050.80
224.00	1050.41
230.69	1050.11
242.71	1050.61
246.19	1050.82
249.60	1053.61
262.10	1054.31
266.01	1056.00
306.00	1060.00
320.04	1070.00

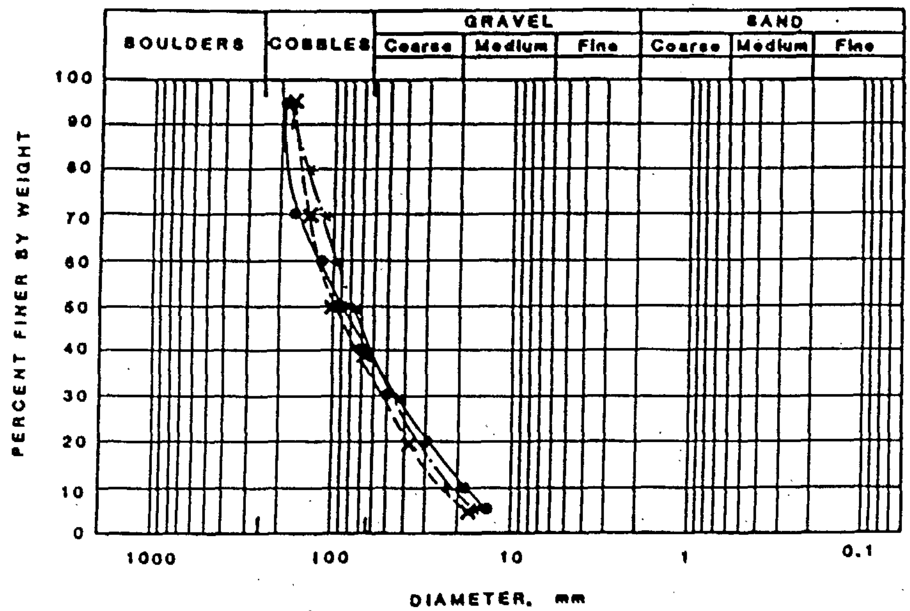
OLDMAN 00-24

HORIZ	VERT
74.00	1070.00
100.00	1066.78
109.39	1064.06
112.54	1051.65
117.59	1051.66
126.00	1051.26
144.80	1051.26
156.21	1061.36
153.50	1051.26
170.61	1050.86
176.19	1050.46
187.39	1051.56
204.60	1052.16
243.41	1051.86
247.19	1053.58
261.00	1053.39
253.20	1054.78
264.89	1056.00
287.00	1060.00
338.01	1070.00

OLDMAN 00-23

HORIZ	VERT
74.01	1070.00
80.01	1060.00
100.00	1065.06
101.60	1064.46
104.00	1052.66
109.21	1051.77
112.41	1050.68
121.19	1050.36
133.20	1050.64
149.29	1050.76
166.91	1051.95
174.16	1052.57
199.40	1052.44
201.56	1052.16
225.40	1052.56
235.31	1053.05
242.20	1056.56
284.99	1056.00
340.00	1060.00
385.00	1070.00

TABLE A.1 (Cont.)



LEGEND:

●———●———● SAMPLE S.1

×— — —×— — —× SAMPLE S.2

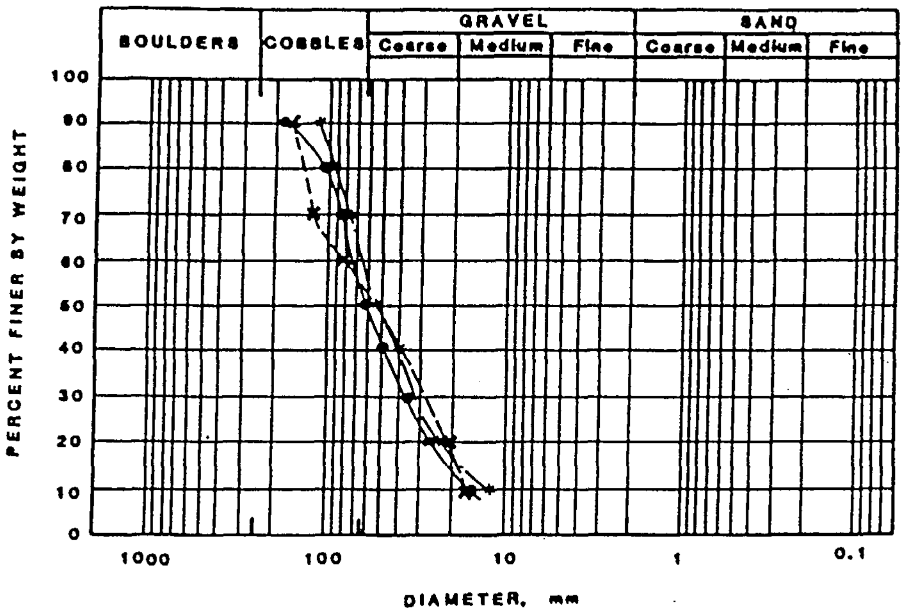
+—·—+—·—+ SAMPLE S.3

NOTES:

- SEE FIGURE II.1 FOR LOCATION OF SAMPLES
- GRAIN SIZE DISTRIBUTION BY GRID-BY-NUMBER FROM PHOTOGRAPH OF SAMPLE.

FIGURE C.2

OLDMAN RIVER
SURFACE BED MATERIAL



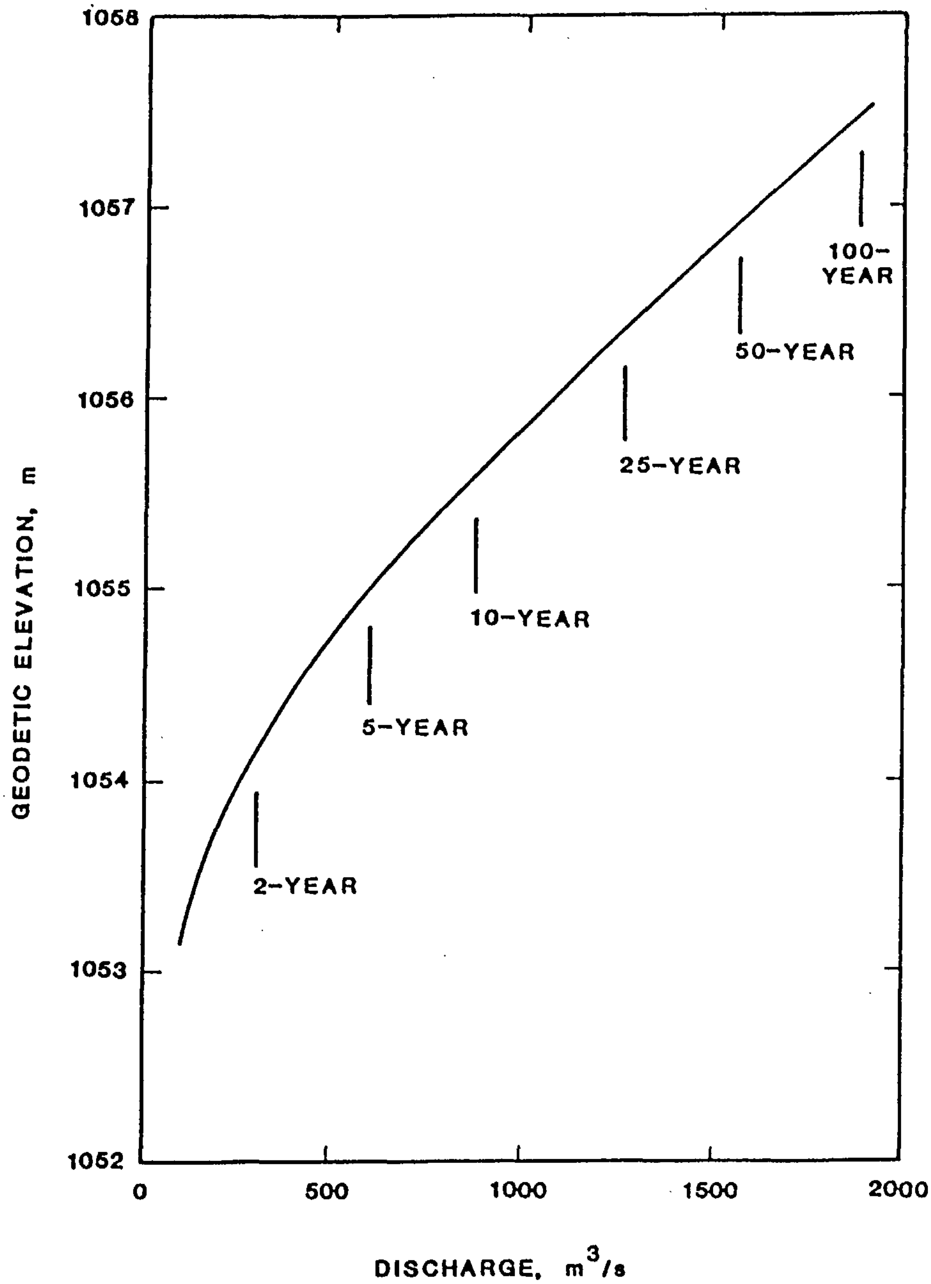
LEGEND:	DEPTH BELOW SURFACE, m	ELEVATION OF SAMPLE, m
•———•———•	0.5	1048.9
×– – –×– – –×	1.0	1048.4
+—·—+—·—+	2.0	1047.5

NOTES:

- SEE FIGURE II.1 FOR LOCATION OF TEST PIT.
- GRAIN SIZE DISTRIBUTION OBTAINED BY GRID-BY-NUMBER FROM PHOTOGRAPH OF SAMPLE.
- BEDROCK (SANDSTONE) AT EL. 1047.2m.

FIGURE C.3

OLDMAN RIVER
SUB-SURFACE BED MATERIAL
TEST PIT TP85H100

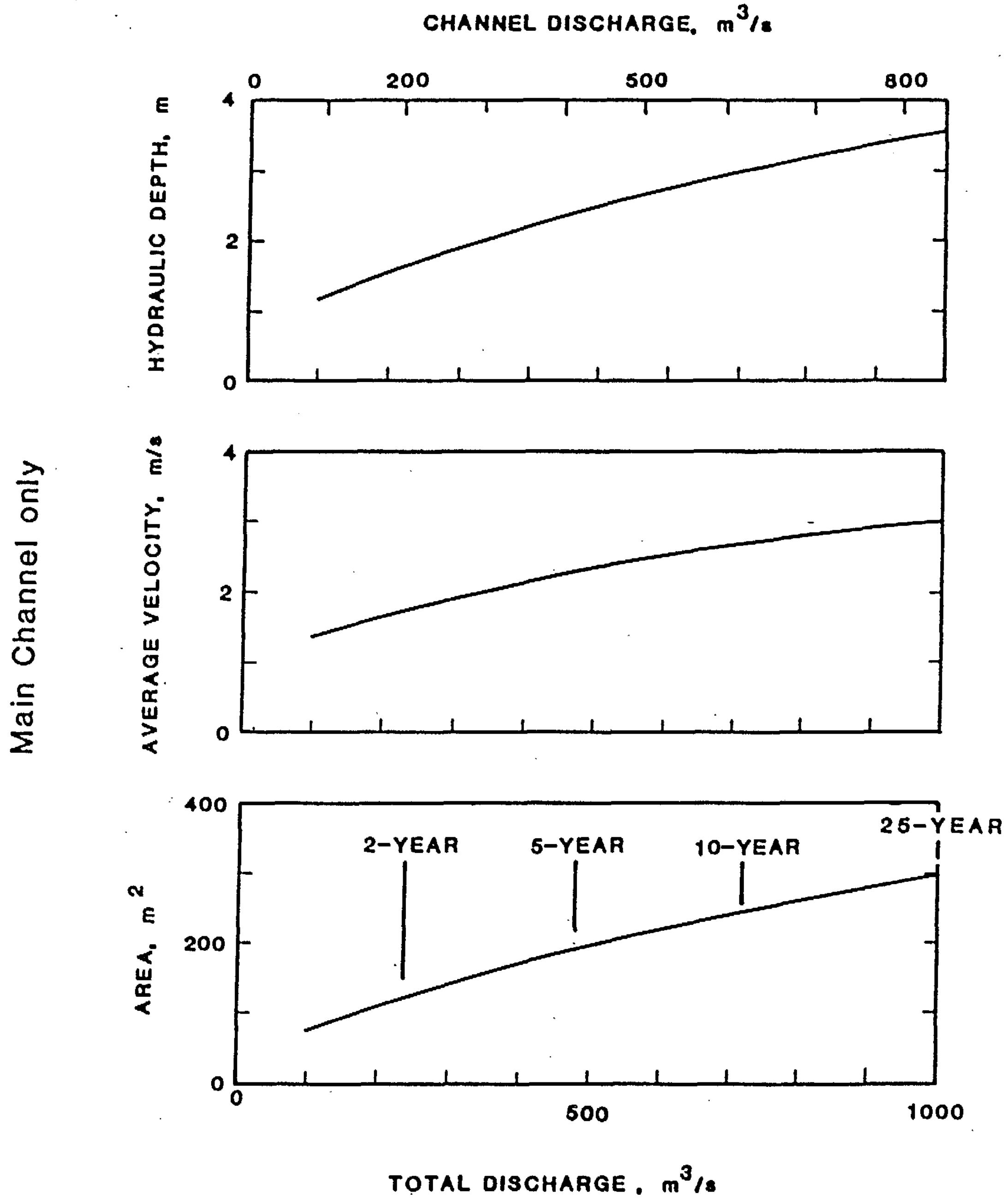


NOTES:

- SEE FIGURE 2 FOR LOCATION
- FLOOD DISCHARGES ARE INSTANTANEOUS VALUES

FIGURE 4

DISCHARGE RATING CURVE
AT DIVERSION TUNNEL INLET



NOTES:

- FLOOD FLOWS ARE MAXIMUM DAILY.
- PROPERTIES ARE FOR A 1 km REACH OF THE CHANNEL BETWEEN 400 m AND 1400 m DOWNSTREAM OF THE DAM SITE.

FIGURE 5

HYDRAULIC GEOMETRY OF OLDMAN RIVER CHANNEL BELOW DAMSITE

APPENDIX B

Example of Hydraulic/Morphologic Information and Data Collection Program at Gauging Site

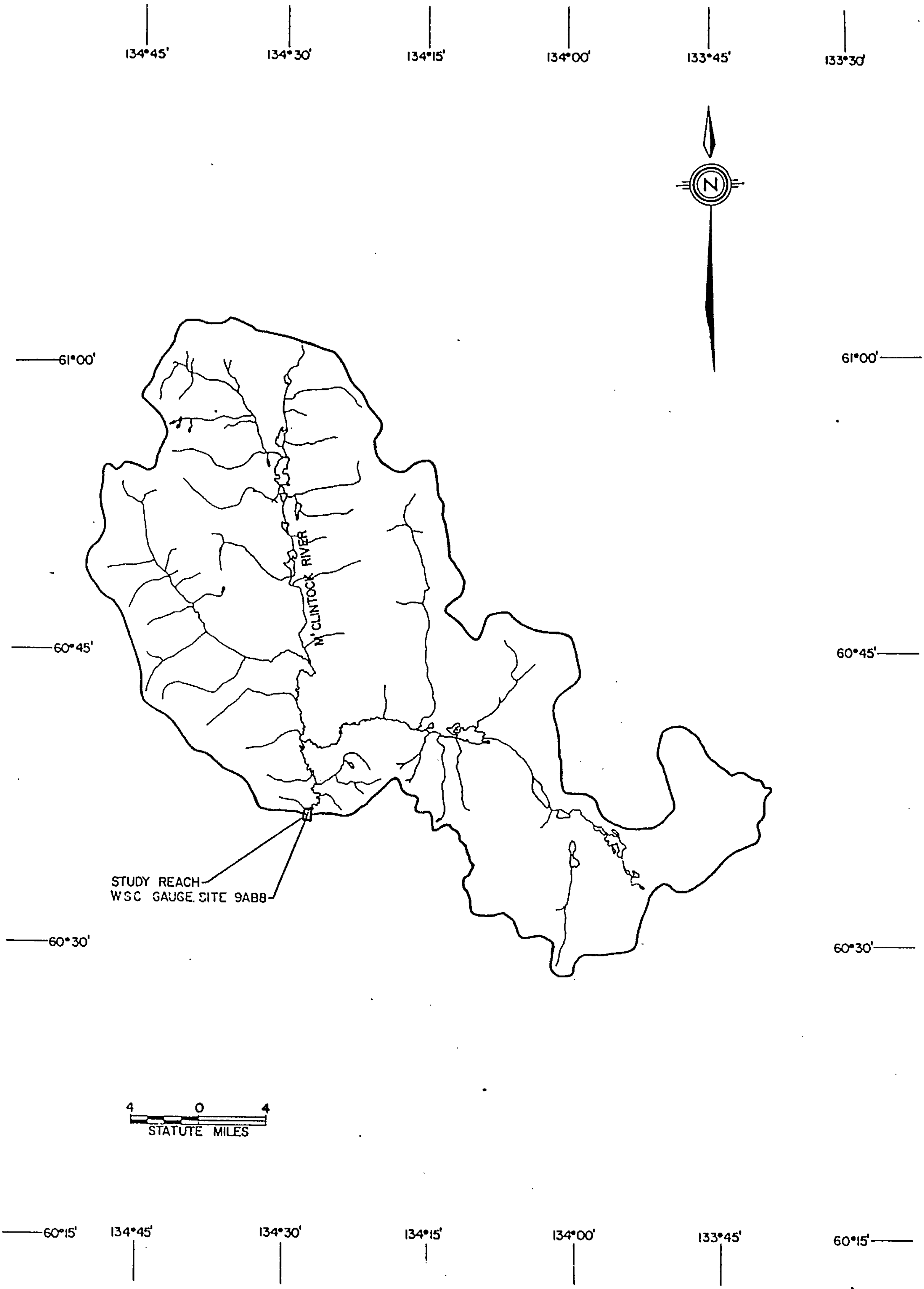
APPENDIX B

Source: "Hydrologic and Geomorphic Characteristics of Rivers and Drainage Basins in the Yukon Territory"; Department of Indian and Northern Affairs, Government of Canada; March, 1974.

SUMMARY: M'Clintock River near Whitehorse

DRAINAGE BASIN DESCRIPTION: M'Clintock River Near Whitehorse

- The basin has a drainage area of 597 square miles located approximately 20 miles east of Whitehorse.
- The basin is crescentic in shape, with the main drainage arm, the M'Clintock River, draining the high upland regions north of Marsh Lake; a principal tributary, Michie Creek, drains the low lying area in the western arm of the basin.
- The WSC gauge site is located on the M'Clintock River approximately 4 miles upstream from the mouth at Marsh Lake.



BASIN OUTLINE - M'Clintock River near Whitehorse

STATION 9AB8 PLATE 2

DRAINAGE BASIN CHARACTERISTICS: M'Clintock River near Whitehorse

Topographic Drainage Area	597 sq mi
Area of Lakes	<2 %
Area of Forest	80 %
Basin Length	31 mi
Basin Shape Factor	1.61
Basin Aspect	SE
Stream Gauge Elevation	2155.3 ft
Divide Elevation	3300 ft
Maximum Elevation	6830 ft (Mt Byng)
Basin Elevation	2345 ft
Basin Relief	4675 ft
Main Valley Slope	14.3 ft/mi
Gauge Location	60° 36' 45" N 134° 27' 27" W

DESCRIPTION OF GAUGING STATION - M'Clintock River near Whitehorse

Location: 60° 36' 45" N, 134° 27' 27" W

Gauge: A-35 Recorder in walk-in shelter on LB 300 yds above landing

Discharge Measurements: From cableway 20 ft upstream of gauge

Elevation of Gauge Zero: 2155.30 ft

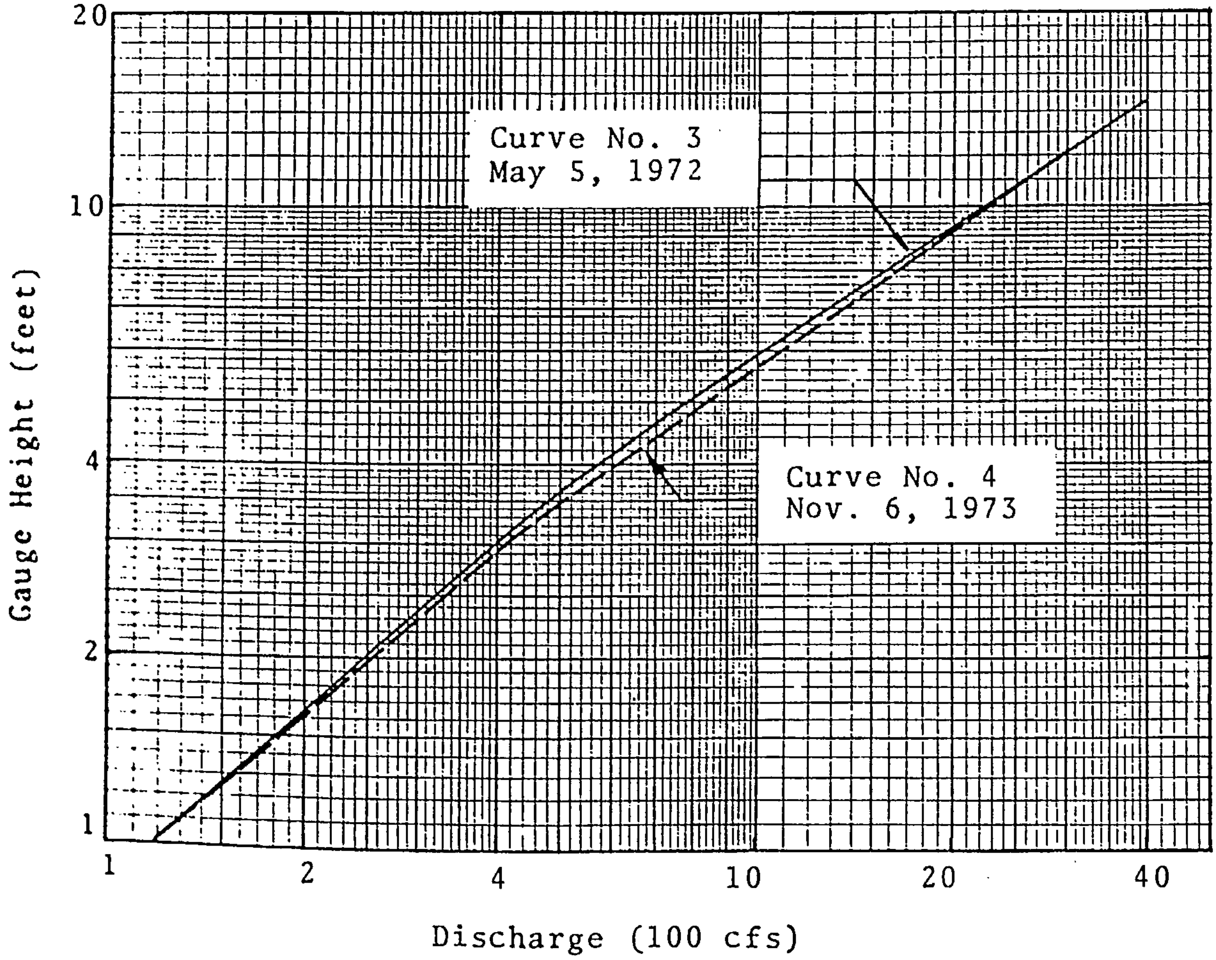
Period of Record: 55-73 (R,C)

Comments: One channel at all stages; meandering stream; Backwater near RB and current angles at low stages; Bed is coarse sand

BM Descriptions:

BM-2 - Head of horizontal lag screw in 9" blazed spruce about 100' inshore and 25' upstream of recorder; local elev 13.48', geodetic elev 2168.78'

BM-4 - Control BM, brass cap on pipe 90' inshore on line with recorder; local elev 11.98' geodetic elev 2167.28'



STAGE DISCHARGE RELATIONSHIP

GENERAL HYDROLOGY: M'Clintock River near Whitehorse

BASED ON PERIOD OF RECORD: 1955-72 (R,C)

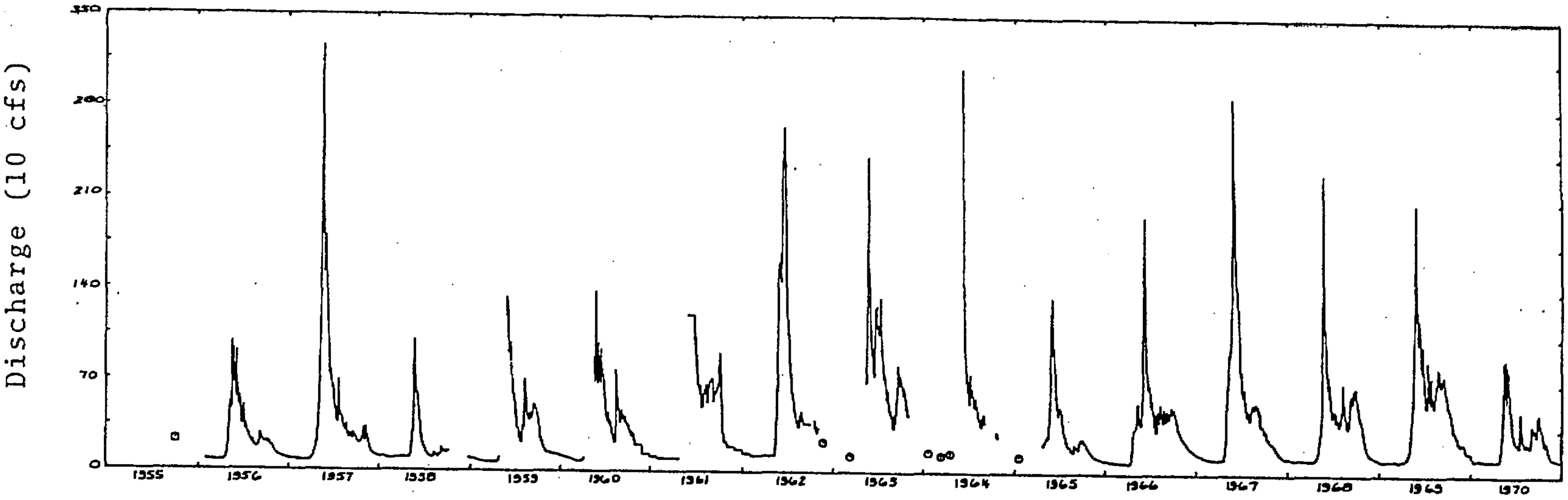
STAGE	DISCHARGE (cfs)	GAUGE HT.[1] (ft)	DATE	cfs/mi[2]
Surveyed	994	5.93	June 20/73	1.66
Long Term Mean Daily	364	2.8	-	0.61
Recorded Min. Daily	60	-	Mar. 29/59	0.11
Recorded Max. Daily	3,680	13.98	June 1/72	6.17
Recorded Max. Inst.	3,980	14.63	June 1/72	6.67

RIVER ICE SUMMARY[2]

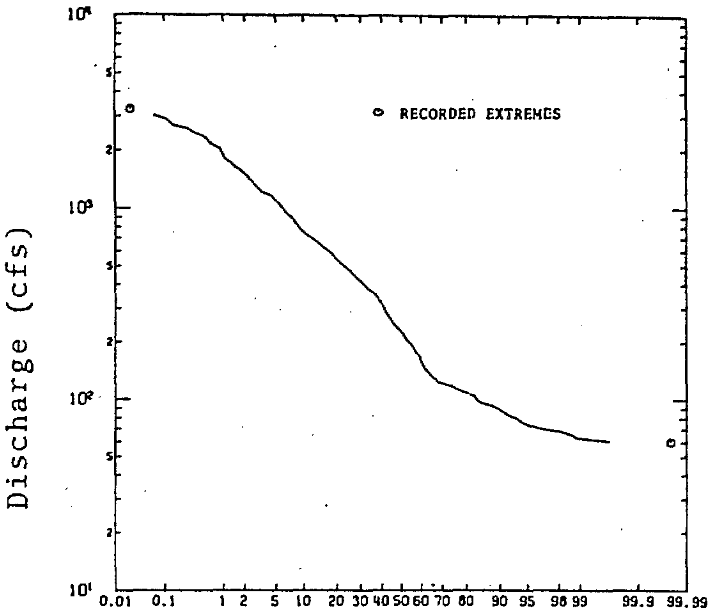
	EARLIEST	AVERAGE	LATEST	NO. OF EVENTS
FREEZE-UP	Oct. 8	Oct. 26	Nov. 17	8
BREAK-UP	Apr. 16	May 7	May 15	7
YRS: 1956-1969	MEAN ICE THICKNESS (FEET)			
DATE	MINIMUM	AVERAGE	MAXIMUM	NO. OF EVENTS
Nov. 15	0.60	0.81	1.00	5
Dec. 15	0.90	1.17	1.53	8
Jan. 15	1.20	1.44	2.03	10
Feb. 15	1.57	1.80	2.12	9
Mar. 15	1.60	1.90	2.10	10
Apr. 15	1.75	2.02	2.17	6

1 Supplied by WSC for recorded extremes or estimated from Stage Discharge Curve on Plate 4

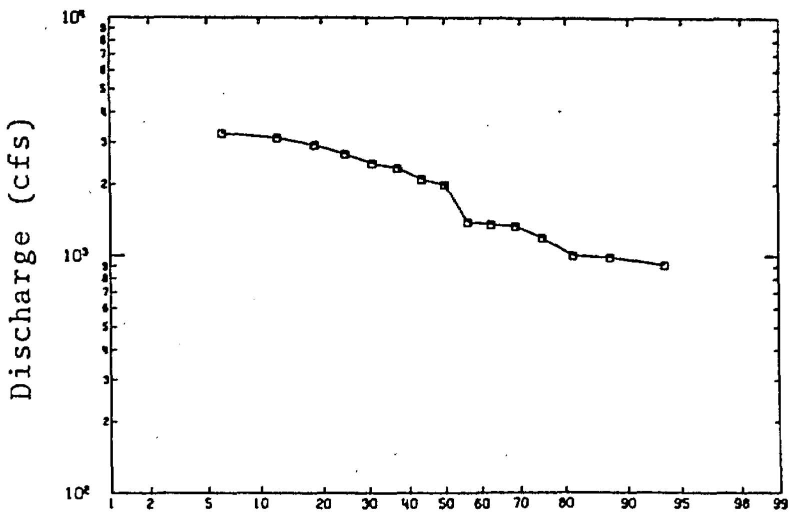
2 From River Ice in Northwest Canada - Verschuren & Nuttall



Hydrograph of Mean Daily Discharge



Frequency of Exceedence (percent)
Flow-Duration Curve



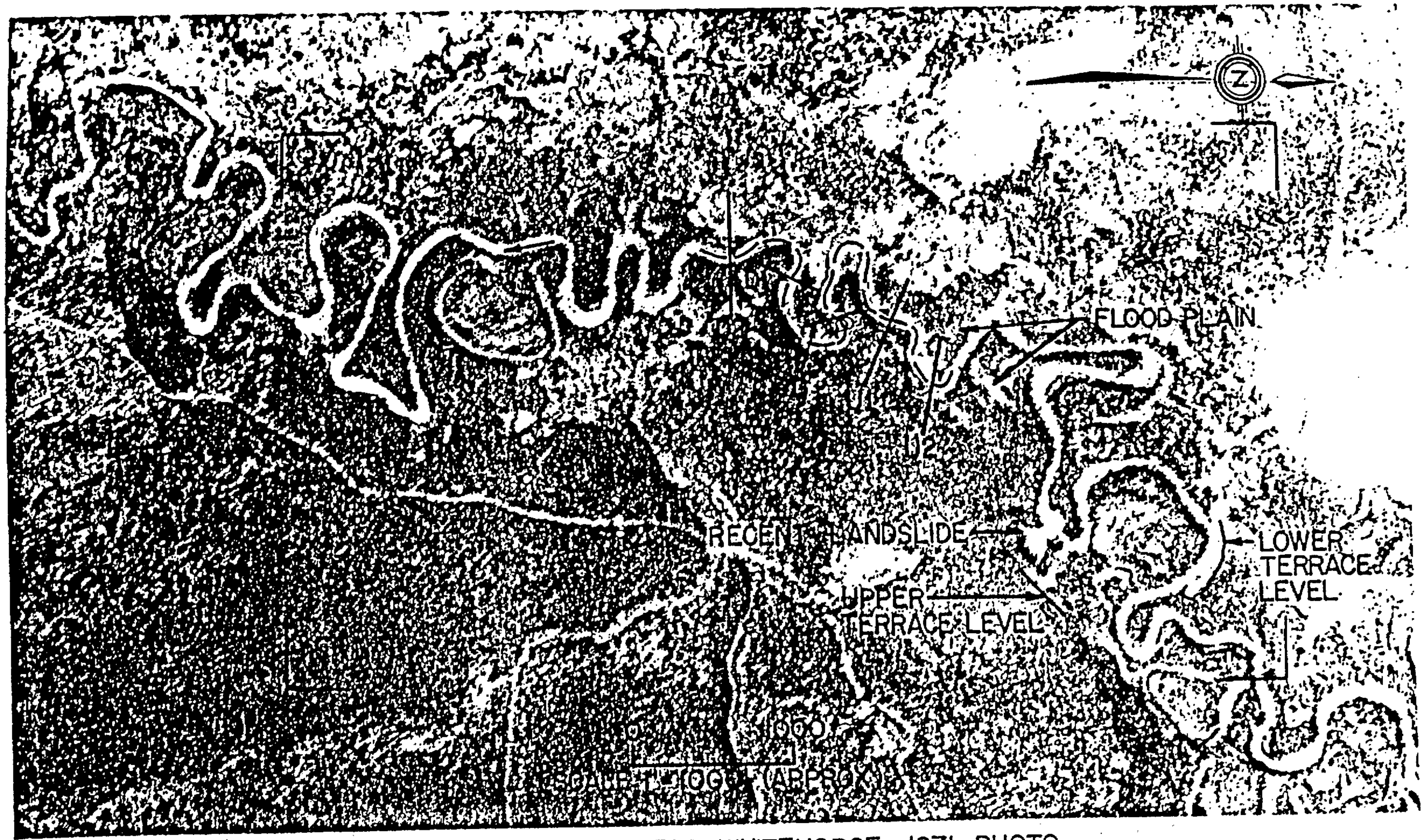
Frequency of Exceedence (percent)
Flood Frequency Curve

STREAMFLOW CHARACTERISTICS: M'Clintock River near Whitehorse

STATION 9AB8 - PLATE 6

INDEX PHOTO OF STUDY REACH: M'Clintock River near Whitehorse

STATION 9AB8 - PLATE 7



M' CLINTOCK RIVER NEAR WHITEHORSE - 1971 PHOTO

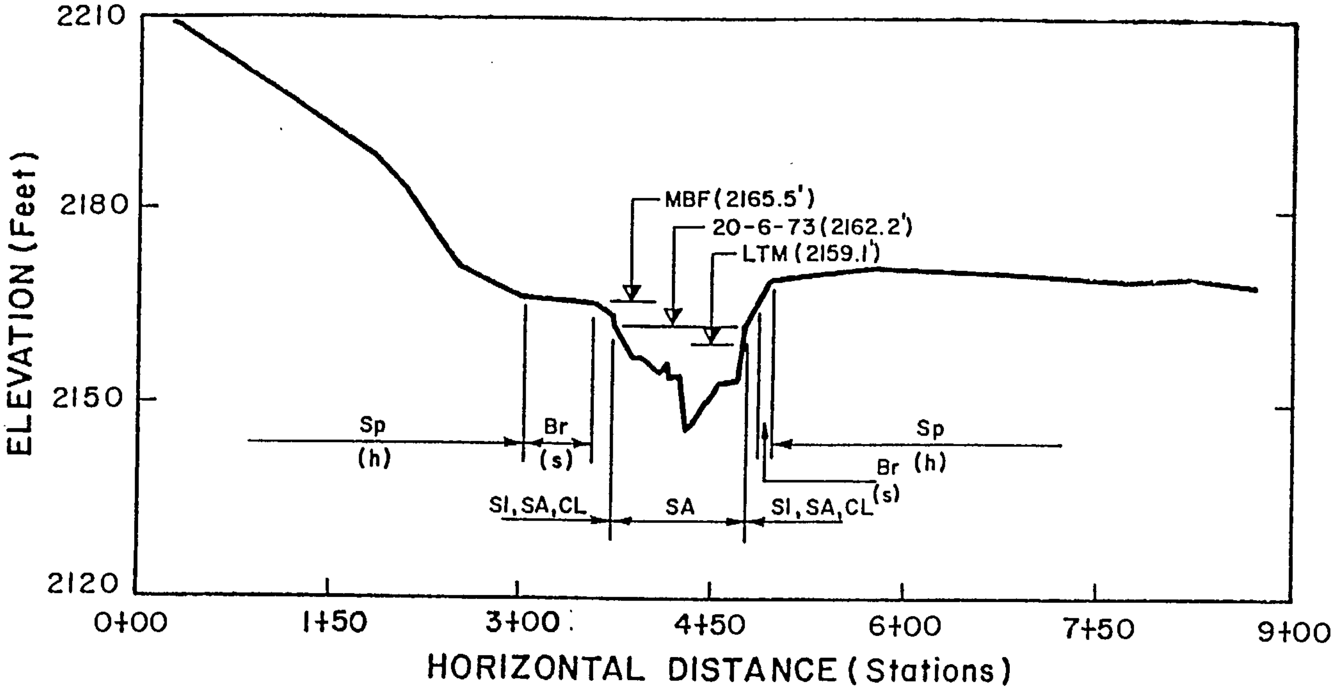
► PHOTOGRAPH LOCATION
□ BED SAMPLE GRID PHOTO
○ BED SAMPLE

——— DIRECTION OF FLOW
—U2 CROSS-SECTION LOCATION
- - - - CHANNEL BASE LINE

⌜ ⌝ AREA COVERED BY COMPARATIVE
⌞ ⌟ PHOTOGRAPHS

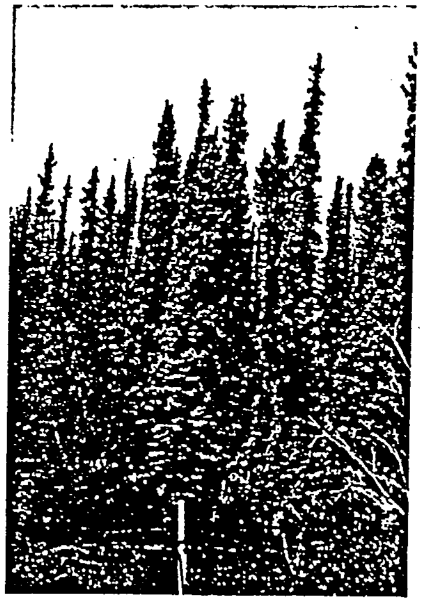
RIVER MORPHOLOGY: M'Clintock River Near Whitehorse

- The study reach, which extends 1650 feet upstream and 1350 feet downstream of the gauge site, is representative of the river in the general vicinity of the gauge.
- Within the study reach, the river flows in a tortuous meander pattern, which has become entrenched into glacio-lacustrine material.
- The flood plain is bordered by steep terrace walls throughout the study reach; upstream, the flood plain widens and eventually the terraces become fragmentary and merge with the valley flat. The valley flat is wide, with heavy coniferous forest cover on both the terraces and the flood plain.
- Channel banks are composed of glacio-lacustrine material, clayey-silty-sand, and are stabilized by a well-vegetated layer of organic soil. Aerial photos taken in 1946 and 1971 indicate relatively little channel migration in recent years.
- Since the channel bed consists of sand, rapid head-cutting could be expected following the occurrence of a meander cutoff.



NOTES:

- Elevations are relative to geodetic datum.
- Cross-section viewed looking downstream.

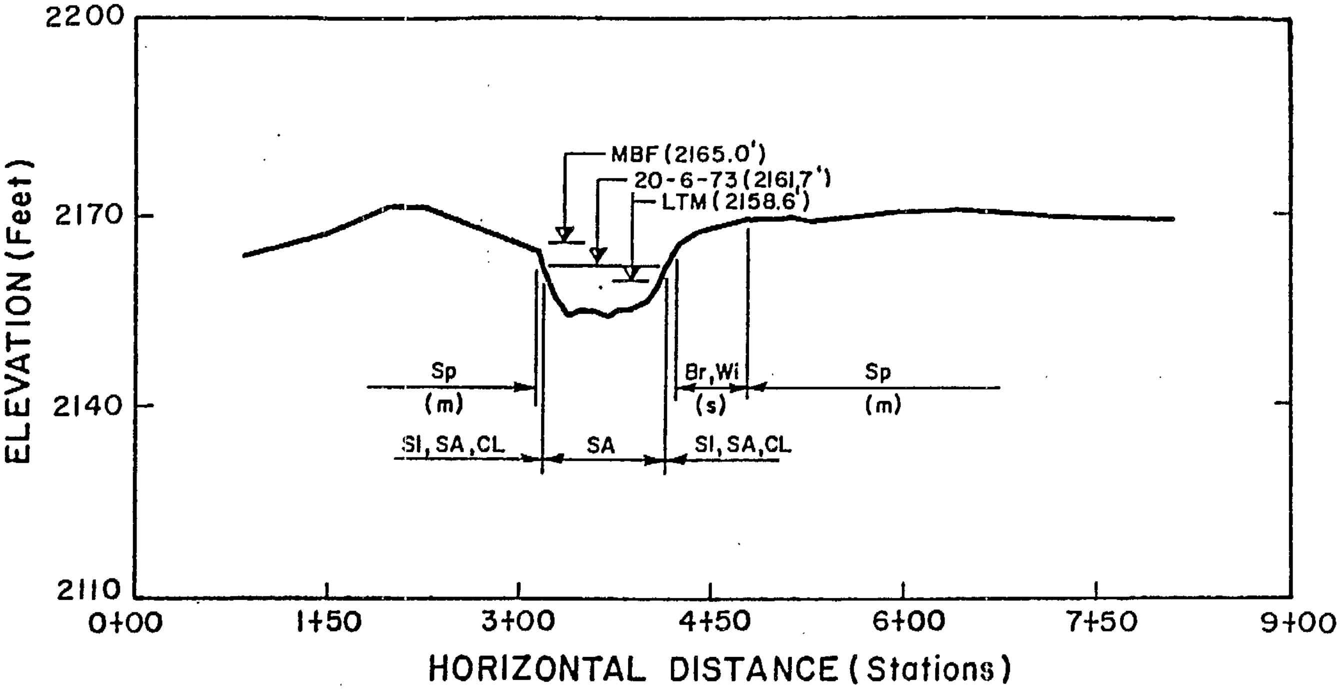


Viewing right bank

CROSS-SECTION COORDINATES

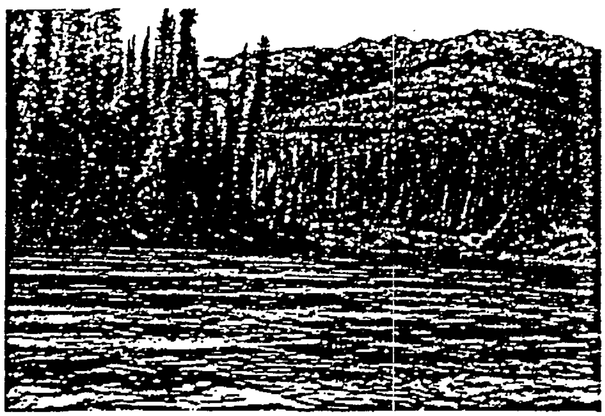
HORIZ.	VERT.	HORIZ.	VERT.
25'	2209.6	425'	2154.4'
30'	2209.2	430'	2146.0'
185'	2188.6'	435'	2147.2'
210'	2183.6'	445'	2150.2'
235'	2176.4'	455'	2153.2'
255'	2171.2	470'	2154.2'
307'	2166.8'	475'	2162.2'
360'	2165.0'	483'	2165.5'
373'	2164.3	493'	2169.2'
375'	2162.2	510'	2170.2'
390'	2157.2'	580'	2171.1'
395'	2157.6'	675'	2170.4
410'	2155.0'	775'	2169.1'
415'	2156.2'	825'	2169.6'
417'	2154.1'	875'	2168.5'
420'	2154.6'		
Water Surface Elevation @			2162.2'

CROSS SECTION U2: M'Clintock River near Whitehorse



NOTES:

- Elevations are relative to geodetic datum.
- Cross-section viewed looking downstream.



Viewing downstream

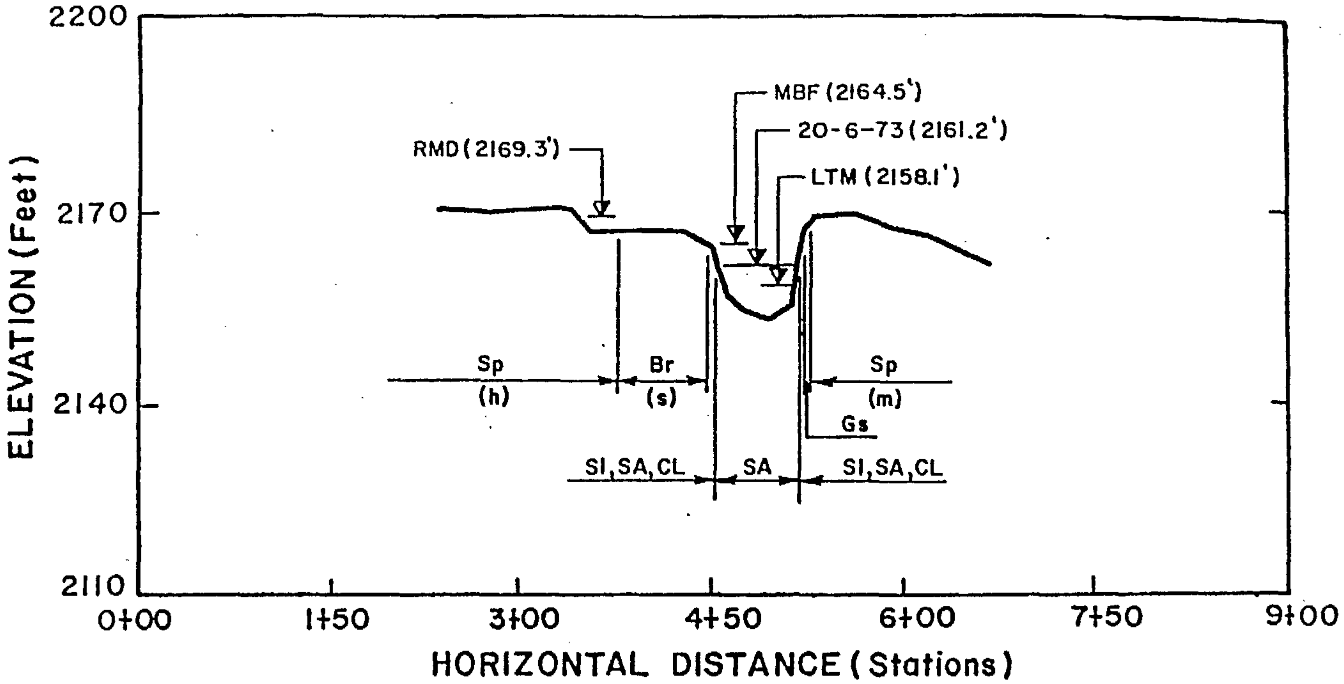
Viewing right bank

CROSS-SECTION COORDINATES

HORIZ.	VERT.	HORIZ.	VERT.
85	2163.8	390	2155.3
150	2166.9	400	2155.8
200	2171.1	410	2158.8
225	2171.2	415	2161.7
530	2168.5	425	2165.4
315	2164.2	440	2167.4
320	2161.6	477	2169.0
330	2156.8	515	2169.5
340	2153.7	590	2170.2
350	2154.8	640	2170.4
360	2154.6	715	2169.4
370	2153.8	815	2168.6
380	2154.8		

Water Surface Elevation @ 2161.7

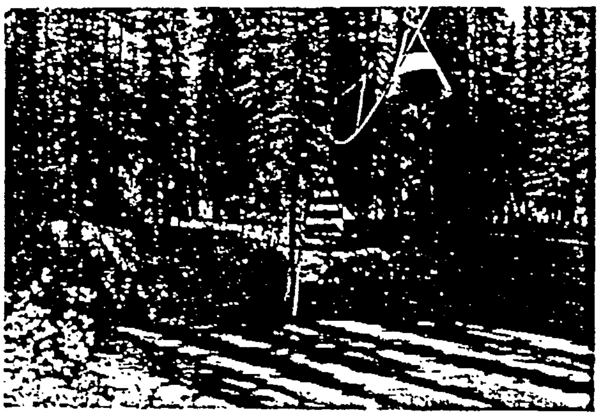
CROSS SECTION U1: M'Clintock River near Whitehorse



NOTES:

- Elevations are relative to geodetic datum.
- Cross-section viewed looking downstream.

Viewing left bank



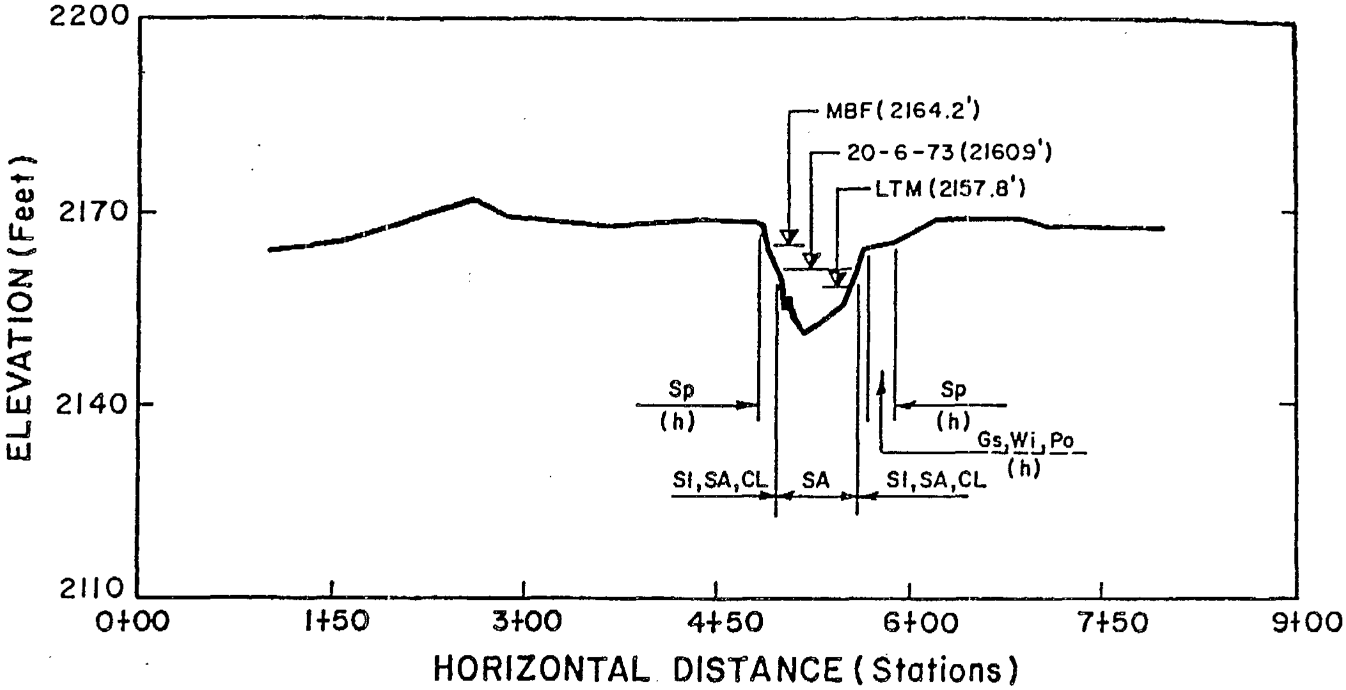
Viewing right bank

CROSS-SECTION COORDINATES

HORIZ.	VERT.	HORIZ.	VERT.
235'	2169.8'	495'	2152.9'
240'	2170.2'	405'	2153.1'
277'	2169.7'	513'	2155.2'
335'	2170.5'	515'	2161.2'
340'	2170.0'	519'	2164.8'
355'	2166.6'	521'	2167.0'
377'	2166.9'	530'	2168.9'
429'	2166.7'	560'	2169.3'
451'	2164.4'	590'	2167.2'
455'	2161.2'	615'	2166.4'
465'	2156.2'	640'	2164.0'
475'	2154.4'	665'	2161.8'
485'	2153.7'		

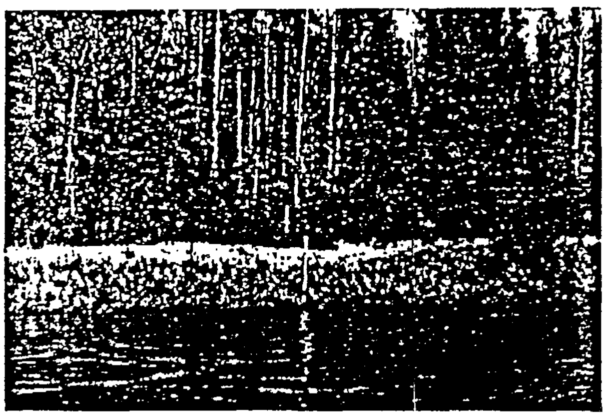
Water Surface Elevation @ 2161.2'

CROSS SECTION G: M'Clintock River near Whitehorse



NOTES:

- Elevations are relative to geodetic datum.
- Cross-section viewed looking downstream.



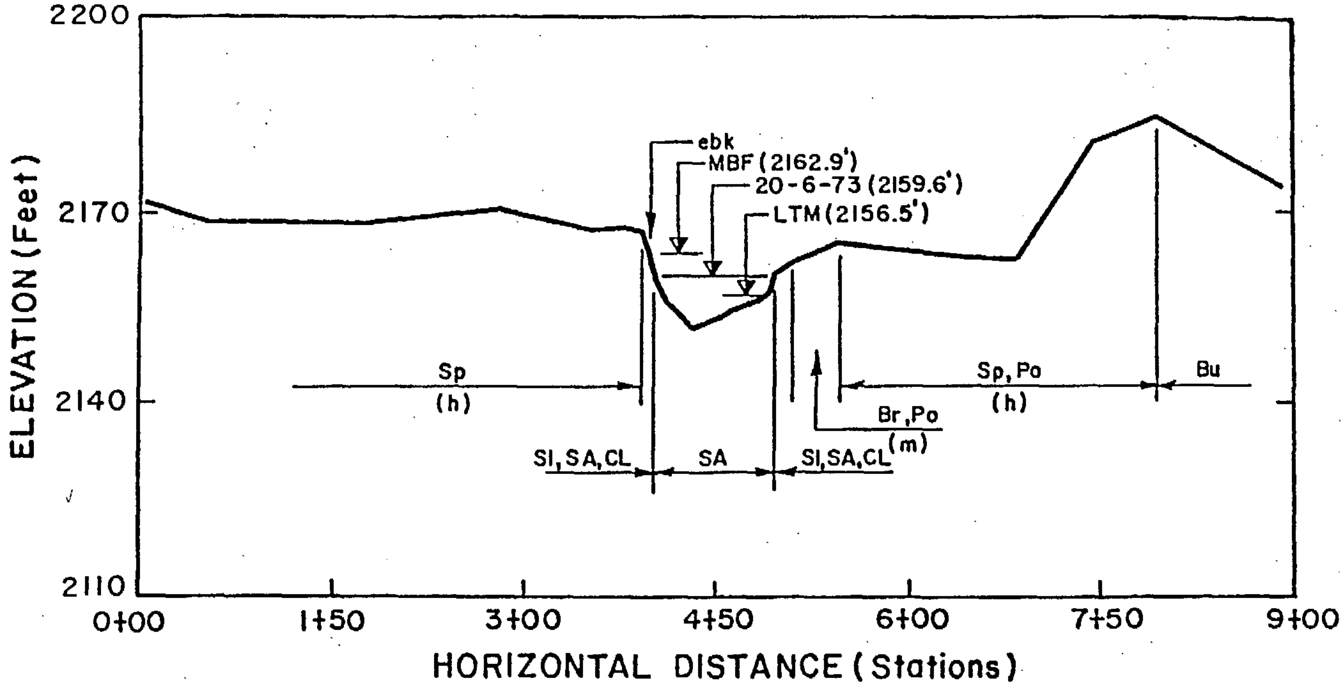
Viewing right bank

CROSS-SECTION COORDINATES

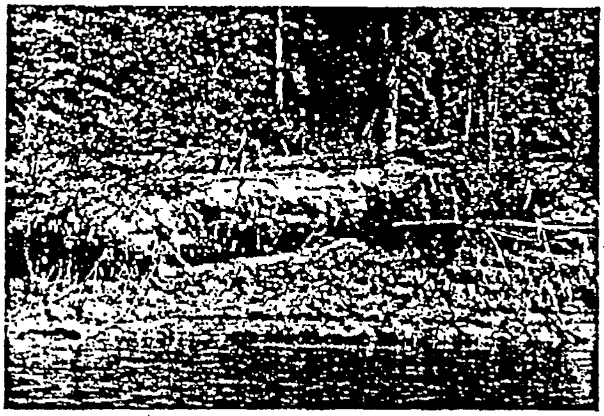
HORIZ.	VERT.	HORIZ.	VERT.
100'	2164.1'	512'	2155.0'
160'	2165.7'	520'	2151.0'
210'	2168.9'	530'	2152.5'
260'	2172.4'	535'	2153.5'
285'	2169.7'	540'	2154.2'
365'	2168.3'	550	2155.5'
435'	2169.0'	560'	2160.9'
482'	2169.0'	565'	2164.6'
487'	2168.2'	590'	2165.6'
491'	2164.9'	620'	2169.1'
500'	2160.9'	685'	2169.2'
505'	2157.0'	710'	2167.7'
510'	2154.0'	800'	2167.7'

Water Surface Elevation @ 2160.9'

CROSS SECTION D1: M'Clintock River near Whitehorse



NOTES:
- Elevations are relative to geodetic datum.
- Cross-section viewed looking downstream.



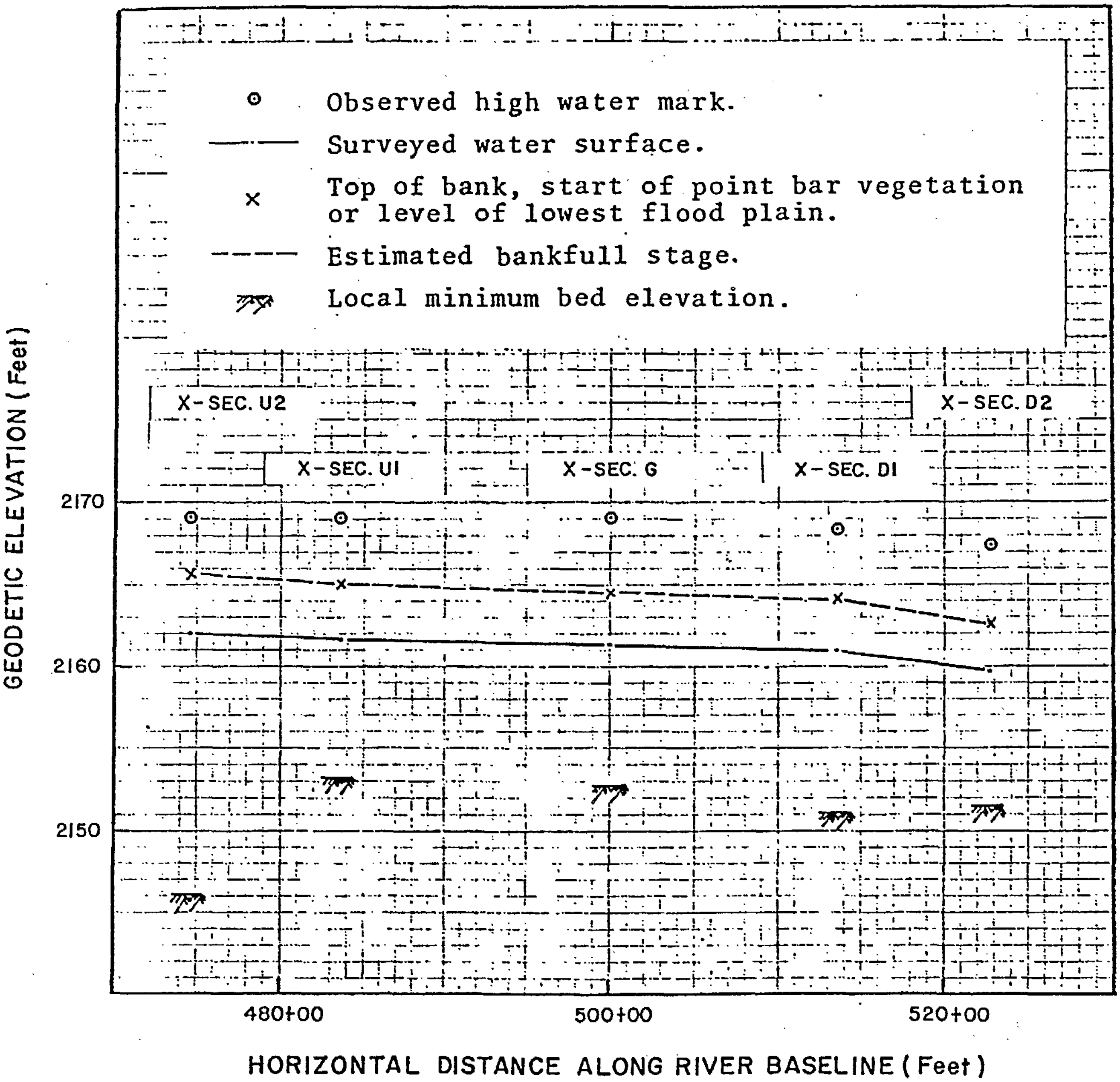
View of eroding left bank

CROSS-SECTION COORDINATES

HORIZ.	VERT.	HORIZ.	VERT.
3'	2171.6'	483'	2156.1'
53'	2168.2'	493'	2157.4'
178'	2168.4'	495'	2159.6'
282'	2170.5'	497'	2160.4'
352'	2167.0'	510'	2162.3'
381'	2167.6'	545'	2165.3'
391'	2167.0'	645'	2162.9'
403'	2159.6'	685'	2162.6'
413'	2155.6'	745'	2181.0'
433'	2151.5'	795'	2185.0'
453'	2153.3'	895'	2174.0'
463'	2154.6'		

Water Surface Elevation @ 2159.6'

CROSS SECTION D2: M'Clintock River near Whitehorse

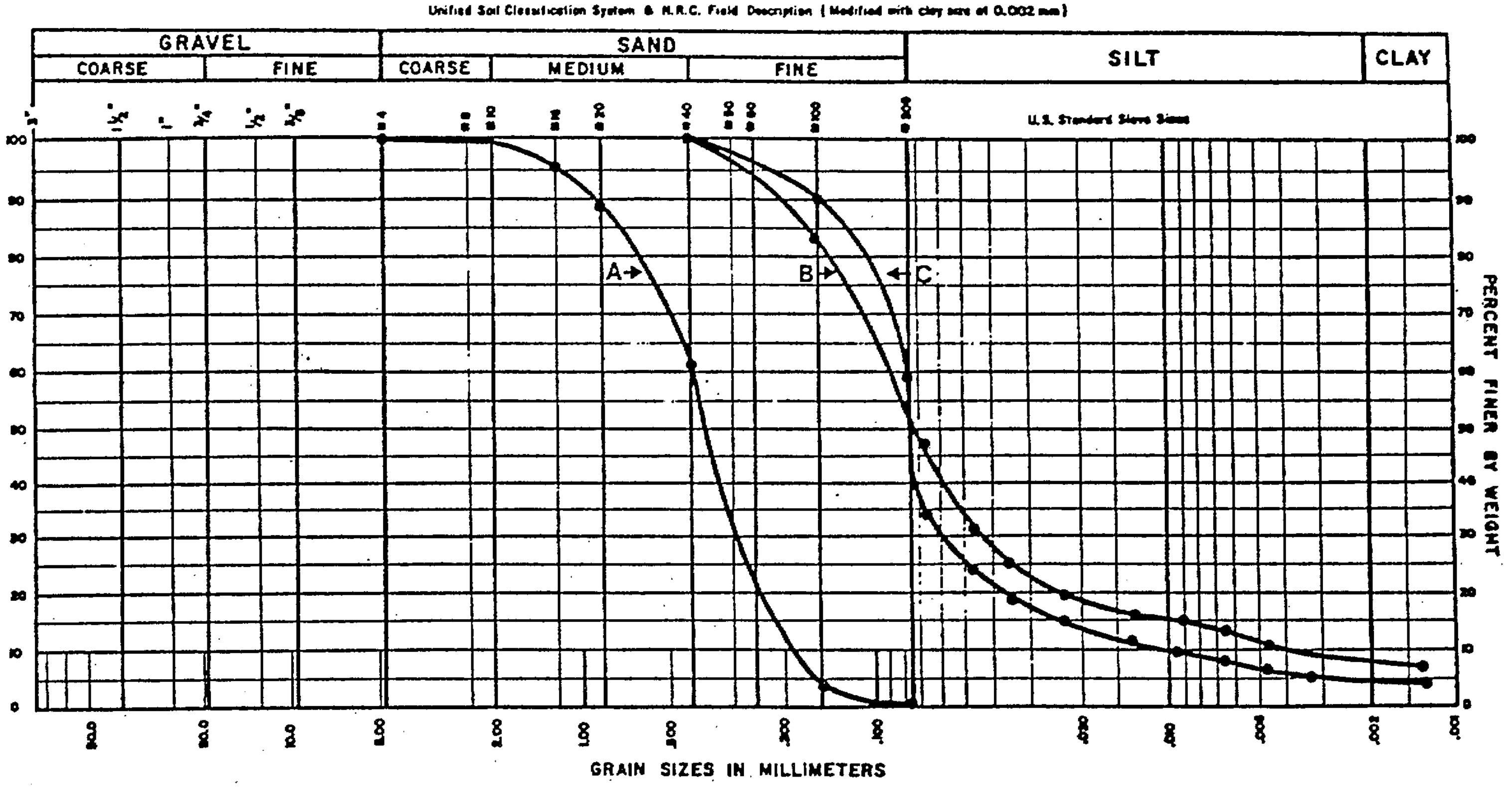


LONGITUDINAL CHANNEL PROFILES OF STUDY REACH

M'Clintock River near Whitehorse

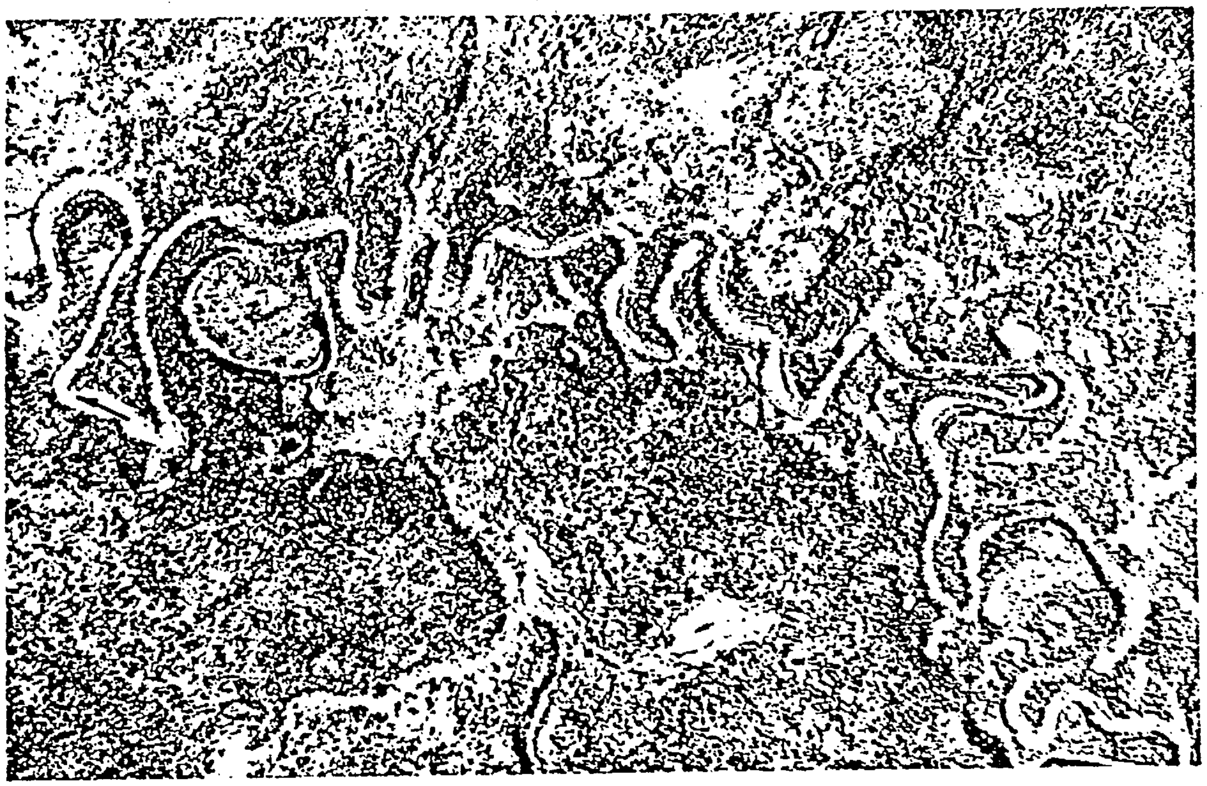
GRAIN SIZE ANALYSIS: M'Clintock River near Whitehorse

STATION 9AB8 - PLATE 11



SAMPLE	LOCATION	CLASSIFICATION	Clay	Silt (%)	Sand	Gravel
A	Mid-channel X-sec G	Well graded medium to find SAND (SW)			100	
B	Left bank X-sec G	Clayey silty SAND to sandy SILT (SM-ML)	8.0	45.0	47.0	
C	Right bank X-sec G	Slightly clayey very sandy SILT (ML)	5.0	54.0	41.0	

Recent Photo 1971



Historic Photo 1946

Scale 1" to 1000' (Approx.)

COMPARATIVE AERIAL PHOTOGRAPHS: M'Clintock River near Whitehorse

CHANNEL HYDRAULICS TABLE

M'Clintock River near Whitehorse

CROSS SECTION	STAGE	WATER SURFACE ELEV. (FT)	AREA $(FT)^2$	SURFACE BREADTH (FT)	MEAN DEPTH (FT)	MEAN VELOCITY (FT/SEC)
U2	S	2162.2	810	100	8.1	1.2
	MBF	2165.5	1180	125	9.4	1.7
	LTM	2159.1	515	90	5.7	0.7
U1	S	2161.7	585	95	6.2	1.7
	MBF	2165.0	930	115	8.1	2.1
	LTM	2158.6	310	80	3.8	1.2
G	S	2161.2	380	60	6.3	2.6
	MBF	2164.5	595	70	8.5	3.3
	LTM	2158.1	200	55	3.7	1.8
	RMD	2169.3	1350	270	5.0	2.7
D1	S	2160.9	380	60	6.4	2.6
	MFB	2164.2	600	70	8.3	3.3
	LTM	2157.8	210	50	4.2	1.7
D2	S	2159.6	495	90	5.4	2.0
	MFB	2162.9	845	120	7.0	2.3
	LTM	2156.5	230	80	2.9	1.6

MEAN VALUES FOR STUDY REACH

STAGE	GAUGE HT. (FT)	DISCHARGE (CFS)	DEPTH (FT)	AREA (FT)	VELOCITY (FT/SEC)	ROUGHNESS* COEFF. (η)
S	5.93	994	6.5	530	1.9	.063
MBF	9.2	1950	8.3	830	2.4	.059
LTM	2.8	364	4.1	293	1.2	.073

Notes:
S - Surveyed
MBF - Mean Bank Full (taken from longitudinal profile Plate 10)
LTM - Long Term Mean (extrapolated from gauge location)
RMD - Recorded Maximum Daily
* - Computed using Surveyed Water Surface Slope = 0.053%

APPENDIX C

Example Tabulations of Hydraulic/Morphologic Data Presentations

APPENDIX A.—*Channel-shape characteristics of rivers at stage corresponding to mean annual discharge*

[Data on width, area, mean velocity, and mean depth represent approximations to the average and vary somewhat, depending on the particular section where measurements are made]

	Years of record	Mean annual discharge (cfs)	Width (feet)	Area of cross section (square feet)	Mean velocity (fps)	Mean depth (feet)	Drainage area (square miles)
Mobile River Basin							
Tombigbee River at Aberdeen, Miss.	19	2,863	142	1,633	1.8	11.5	2,210
Buttahatchee River near Caledonia, Miss.	11	1,066	152	1,973	0.5	13.0	823
Tombigbee River at Columbus, Miss.	30	5,791	270	3,220	1.8	11.9	4,490
Sipsey River near Elrod, Ala.	11	715	93	650	1.1	7.0	515
Tombigbee River near Coatopa, Ala.	19	21,450	458	10,240	2.2	22.3	15,500
Tombigbee River near Leroy, Ala.	19	26,250	513	13,360	2.0	26.0	19,100
Scioto River Basin							
Scioto River at LaRue, Ohio	18	198	90	342	.6	3.8	255
Scioto River near Prospect, Ohio	15	452	125	300	1.5	2.4	571
Scioto River near Dublin, Ohio [1]	26	743	200	860	.9	4.3	988
Scioto River at Columbus, Ohio	26	1,308	280	1,093	1.2	3.9	1,624
Scioto River near Circleville, Ohio	8	1,815	280	3,030	.6	10.8	2,635
Scioto River at Chillicothe, Ohio	26	3,289	200	1,840	1.8	9.2	3,847
Tennessee River Basin							
French Broad River at Rosman, N. C.	12	229	77	151	1.5	2.0	67.9
French Broad River at Calvert, N. C.	23	335	92	168	2.0	1.8	103
Catheys Creek near Brevard, N. C.	4	34	25.3	22.7	1.5	.9	11.7
Davidson River near Brevard, N. C.	26	125	55	88.0	1.4	1.6	40.4
French Broad River at Bent Creek, N. C.	13	1,589	296	828	1.9	2.8	676
French Broad River at Hot Springs, N. C.	13	2,511	190	1,115	2.2	5.9	1,567
French Broad River near Newport, Tenn.	26	2,764	346	1,833	1.5	5.3	1,858
Watauga River near Sugar Grove, N. C.	6	154	64	115	1.3	1.8	90.8
Noland Creek near Bryson City, N. C. [2]	12	42.8	30.1	57.2	.8	1.9	13.8
Tennessee River at Knoxville, Tenn.	48	12,820	933	13,450	1.0	14.4	8,934
St. Lawrence River Basin							
St. Joseph River near Blakeslee, Ohio	6	292	95	266	1.1	2.8	369
Maumee River at Antwerp, Ohio	22	1,547	245	1,078	1.4	4.4	2,049
Tiffin River at Stryker, Ohio	14	292	72	348	.8	4.8	444
Tiffin River near Brunersburg, Ohio	7	448	85	332	1.4	3.9	766
Auglaize River near Fort Jennings, Ohio	21	278	100	285	1.0	2.8	333
Ottawa River at Allentown, Ohio	16	119	61	97	1.2	1.6	168
Ottawa River at Kalida, Ohio	5	141	80	128	1.1	1.6	315
Blanchard River near Findlay, Ohio	18	219	65	114	1.9	1.8	343
Blanchard River at Glendorf, Ohio	7	548	80	304	1.8	3.8	643
Blanchard River near Dupont, Ohio	7	452	120	646	.7	5.4	749
Auglaize River near Defiance, Ohio	27	1,598	285	1,054	1.5	3.7	2,329
Maumee River near Defiance, Ohio	19	3,612	440	1,826	2.0	4.2	5,530
Maumee River at Waterville, Ohio	22	4,260	730	1,644	2.6	2.2	6,314
Yellowstone River Basin							
Yellowstone River at Corwin Springs, Mont.	37	2,969	242	813	3.6	3.4	2,630
Yellowstone River at Billings, Mont.	16	6,331	253	1,343	4.8	5.3	11,180
Wind River near Dubois, Wyo.	3	177	68	97	1.8	1.4	233
Wind River near Burris, Wyo.	3	828	134	335	2.5	2.5	1,220
Wind River near Crowheart, Wyo.	3	1,315	155	372	3.5	2.4	1,920
Wind River at Riverton, Wyo.	34	1,106	159	318	3.5	2.0	2,320
Popo Agie River near Riverton, Wyo.	6	683	123	406	1.7	3.3	2,010
Bighorn River at Thermopolis, Wyo.	42	1,908	218	543	3.5	2.5	8,080
North Fork Owl Creek near Anchor, Wyo.	5	10.2	17	9.3	1.7	.6	58.2
Owl Creek near Thermopolis, Wyo.	10	45.5	26	24.1	1.9	.9	484
Gooseberry Creek near Grass Creek, Wyo.	4	20.8	19.5	10.9	1.9	0.6	155
Bighorn River at Manderson, Wyo.	6	1,950	258	650	3.0	2.5	11,900
Medicine Lodge Creek near Hyattville, Wyo.	5	38	24	21	1.8	.9	86
Greybull River at Meeteetse, Wyo.	27	364	87	122	3.0	1.4	690
Greybull River near Basin, Wyo.	17	200	77	100	2.0	1.3	1,130
Bighorn River at Kane, Wyo.	19	2,383	175	627	3.8	3.6	15,900
Bighorn River near St. Xavier, Mont.	13	3,676	264	1,296	2.8	4.9	----------
Bighorn River near Hardin, Mont.	14	4,535	371	1,855	2.4	5.0	20,700
Little Bighorn River at Stateline, near Wyola, Mont.	5	154	41	68	2.3	1.6	199
Little Bighorn River below Pass Creek, near Wyola, Mont.	5	202	57	86	2.4	1.5	429
Little Bighorn River near Crow Agency, Mont.	8	294	96	116	2.5	1.2	1,190
Bighorn River near Custer, Mont	4	4,390	420	1,850	2.4	4.4	----------
Yellowstone River near Sidney, Mont.	13	11,860	308	3,750	3.2	11.9	----------
Red Fork near Barnum, Wyo	1	50	25	26	1.9	1.0	142
Middle Fork Powder River above Kaycee, Wyo.	1	74	41	56	1.3	1.4	450
Middle Fork Powder River near Kaycee, Wyo.	11	157	54	77	2.0	1.4	960
North Fork Powder River near Hazelton, Wyo.	2	13	16	15	.9	.9	25
North Fork Powder River near Mayoworth, Wyo.	8	39	22	26	1.5	1.2	69
South Fork Powder River near Kaycee, Wyo.	2	48	57	27	1.8	.5	1,150
Powder River at Sussex, Wyo.	1	136	84	75	1.8	.9	3,090
Middle Fork Crazy Woman Creek near Greub, Wyo.	6	20	19	15	1.3	.8	83
North Fork Crazy Woman Creek near Buffalo, Wyo.	3	21	19	19	1.1	1.0	52
North Fork Crazy Woman Creek near Greub, Wyo	1	22	24	18	1.2	.7	174
Crazy Woman Creek near Arvada, Wyo.	3	63	33	38	1.7	1.1	956
Powder River at Arvada, Wyo.	31	434	112	138	3.2	1.2	6,050
North Fork Clear Creek near Buffalo, Wyo.	1	16	23	19	.8	.8	29
Clear Creek near Buffalo, Wyo.	3	70	42	39	1.8	.9	120
South Fork Rock Creek near Buffalo, Wyo.	1	17	20	19	1.0	.9	44
Rock Creek near Buffalo, Wyo.	5	37	19	23	1.6	1.2	60
South Piney Creek at Willow Park, Wyo.	3	47	33	33	1.4	1.0	29
Piney Creek at Kearney, Wyo.	9	101	45	69	1.5	1.5	106
Piney Creek at Ucross, Wyo	1	70	55	63	1.2	1.1	267
Clear Creek near Arvada, Wyo.	12	222	94	124	1.8	1.3	1,110
Little Powder River near Broadus, Mont.	2	56	24	29	1.9	1.2	----------
Powder River at Moorhead, Mont.	17	526	124	211	2.5	1.7	8,030
Powder River near Locate, Mont.	12	763	168	273	2.8	1.6	12,900

See footnotes at end of table

DATA TABLE FOR U.S. RIVERS BY LEOPOLD AND MADDOCK (1953)

TABLE 8—RELATION OF BANK-FULL WIDTH AND MEAN ANNUAL DISCHARGE

Serial No.	River basin	River	Gauging station	Catchment area sq. miles:	Annual rainfall: inches	Annual evaporation: inches	Annual run-off: inches	Mean annual discharge: cusec/sq. mile	Mean annual discharge: cusec	Width (bank-full stage): feet
1	Thames	Thames	Teddington	3,810	28·2	19·0	9·2	0·677	2,580	257
4		Blackwater	Swallowfield	146	26·8	19·0	7·8	0·575	84	35
5	Severn	Severn	Bewdley	1,650	35·5	20·0	15·5	1·132	1,867	170
7		Avon	Evesham	855	25·9	19·0	6·9	0·508	434	97
8		Stour	Kidderminster	118	27·0	19·0	8·0	0·589	69·5	34
9	Avon (Bristol)	Avon	Bath	617	32·3	19·0	13·3	0·980	604	97·3
10		,,	Melksham	257	30·4	20·0	10·4	0·766	196	48·75
11		Semington Brook	Semington	60·9	29·3	19·0	10·3	0·759	46·4	33·5
14	Wye	Wye	Cadora	1,560	39·8	20·0	19·8	1·46	2,280	210
15		,,	Belmont	749	47·1	19·0	28·1	2·07	1,550	158
18	Cheshire	Weaver	Ashbrook	248	29·5	18·0	11·5	0·847	210	58
20	Northumberland	Tyne	Barrasford	403	40·4	12·0	28·4	2·09	842	210
22	Trent	Trent	Nottingham	2,804	29·96	18·0	11·96	0·881	2,470	181
23		Derwent	Derby	432	37·6	17·0	20·6	1·518	655	98
25	Gt. Ouse	Ouse	Brownshill	1,170	24·2	17·0	7·2	0·53	620	97
26		,,	Bedford	543	25·2	17·0	8·2	0·604	328	85
27		Cam	Bottisham	313	23·3	16·0	7·3	0·538	169	76
28		Lark	Isleham	180	23·9	17·0	6·9	0·508	91·5	47
29	Dee & Clwyd	Dee	Erbistock	401·5	51·5	19·0	32·5	2·395	962	168

TABLE 11.—VALUES OF SLOPE, SILT FACTOR, AND DETAILS OF BED AND BANK MATERIAL

Serial No.	River basin	River	Gauging station	Bank-full discharge: cusecs	Approximate bed-slope	Bed material	Bank material	Silt factor $f = \frac{3}{4}\frac{V^2}{d}$
1	Thames	Thames	Kingston	11,150	0·00065	Gravel	Loamy, clay with bands of sand	1·09
2		,,	Day's Weir	4,820	0·000358	Gravel	Loamy clay, with bands of sand	0·93
3		Wey	Tilford	742	—	Sand and gravel	Sand and gravel	3·24
4		Blackwater	Swallowfield	450	0·00091	Sand and gravel	Sand	4·0
5	Severn	Severn	Bewdley	10,000	0·00061	Rock, sandstone	Clayey sand	1·26
6		,,	Montford	7,000	—	Hard boulder clay	Silty clay	1·04
7		Avon	Evesham	3,500	0·000598	Clayey gravel, with mud	Silty clay	1·43
8		Stour	Kidderminster	500	0·00111	Sand and gravel, some silt	Clayey sand	0·835
9	Avon (Bristol)	Avon	Bath	4,200	0·000532	Silt	Silty clay	0·464
10		,,	Melksham	1,500	0·000506	Coarse sand	Loamy clay	0·255
11		Semington Brook	Semington	450	0·000426	Sand and gravel	Silty sand	1·09
12	Mersey	Mersey	Irlam Weir	5,000	0·00125	Silt	Sandy silt	4·08
13		Irwell	Adelphi Weir	9,000	0·000845	Sandy gravel 2 in. down	Silty sand	2·43
14	Wye	Wye	Cadora	18,020	0·00041	Silt and boulders	Sandy loam	1·26
15		,,	Belmont	10,896	0·0005	Rock, with boulders up to 12 in. dia.	Silt, loam	1·52
16		,,	The Nyth, Erwood	15,568	0·00132	Rock, with boulders up to 2 ft dia.	Loamy clay	2·72
17		,,	Rhayader	2,169	—	Sand and gravel	Sandy loam	5·74
18	Cheshire	Weaver	Ashbrook	2,500	0·001	Gravel, 3 in. down, occasional 6 in.	Left bank clay, and right bank silt	2·98
19	Northumberland	Derwent	Eddy's Bridge	650	0·004	Gravel	Silty gravel	—
20		Tyne	Barrasford	14,630	0·0025	Gravel	Silty gravel	3·62
21	Hampshire	Wallington	North Fareham	325	—	Flints 2 in. to fine, occasional 6 in.	Clay, clayey loam	—
22	Trent	Trent	Nottingham	11,750	0·000378	Gravel 2 in. down, occasional outcrops, shale, marl	Silty clay	1·41
23		Derwent	Derby	2,500	0·00042	Sand and gravel, 3 in. down	Sandy loam	1·45
24		Dove	Rocester	1,400	0·00146	Gravel, 4 in. to fine	Sandy loam	2·86
25	Great Ouse	Ouse	Brownshill	2,300	0·000109	Sandy silt overlying gravel, 97·75% passing No. 7 sieve	Clay	0·555
26		,,	Bedford	2,620	0·000265	Sandy silt overlying gravel, 94% passing No. 7 sieve	Clay and gravel	1·29
27		Cam	Bottisham	1,240	0·000083	Clayey silt, sand, 92·5% passing No. 7 sieve	Clay	0·389
28		Lark	Isleham	300	0·000279	Sandy silt, 91·75% passing No. 7 sieve	Sandy silt	0·189
29	Dee and Clwyd	Dee	Erbistock	6,000	0·00187	Gravel 2 in.–¼ in., occasional 9 in. boulders	Sandy loam	3·13

NIXON'S (1959) TABLES OF DATA FOR BRITISH RIVERS

PROPOSED SET OF KEY DATA

It is proposed that the regime of a homogeneous length of river may be described by means of the key data set out and explained herein. To specify exactly what is meant by homogeneous is difficult without giving examples. In approximate terms, the writers mean a length that exhibits fairly consistent characteristics from one end to the other, with no abrupt changes in geologic setting, channel pattern, discharges, slope, cross sections, or boundary materials.

The proposed key data are arranged into four groups: I.—geographic features; II.—hydrologic and hydraulic data; III.—materials and sediment; and IV.—channel processes. They are set out in the style of a specification, in the interests of brevity.

I.—Geographic Features.

1. Location.—Include a map and general reference.

2. Climate.—Describe general type, with any special features that might affect river regime.

3. Geologic Setting.—Describe, in a few sentences, the type of terrain traversed by the river, and its geologic history and associated land-forms. Photographs may be helpful.

4. Vegetation.—Include descriptions of vegetation on flood plain, on river banks, and within channel.

5. Channel Pattern (sometimes called "river trace" or "stream form").—[Th]is means the appearance of the channel or channels in plan. Include: detail map, diagram or airphoto; proposed type description; average meander wavelength; width of meander belt; and sinuosity ratio.

Possible type descriptions include "meandering," "braided," "straight," and qualifications thereof. (The writers propose that "meandering" be used as a description of pattern only, without reference to channel processes.) Pattern descriptions are examined subsequently. Meander dimensions are illustrated in Fig. 1.

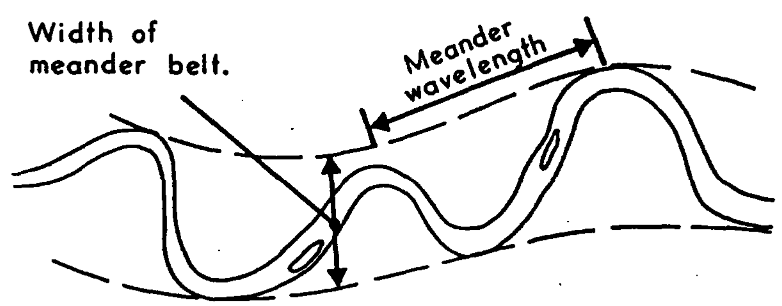


FIG. 1.—KEY MEANDER DIMENSIONS

The sinuosity ratio is the length along a major channel divided by the length along the center of a meander belt.

6. Drainage Area.—Show on general map and quote figure.

II.—Hydrologic and Hydraulic Data.

1. Discharge and Stage Spectrum.—Quote discharges and corresponding relative water-surface levels for the following key flows: reference low water; long-term mean; median, once-in-10-yr, and once-in-100-yr floods, [ba]sed on statistical analysis; maximum and minimum recorded flows, stating [pe]riod of record; and bankfull.

Indicate annual distribution of flow by a hydrograph or table of monthly means. Stage-discharge and flood-frequency curves may be shown. By reference low water, the writers mean an arbitrary low stage that serves as a base for describing relative stages and that may be shown on longitudinal and cross profiles.

Bankfull stage is defined as that level above which there is substantial over-spill on to the flood plain over an appreciable length of channel. Where it is difficult or impossible to select a representative value, it may be preferable to adopt an arbitrary reference high stage that appears approximately related to the capacity of the channel.

Quote additional levels for northern rivers where ice conditions are significant, as follows: normal winter ice cover; and highest recorded stage during breakup.

2. Water Temperatures and Ice Phenomena.—Water temperatures: long-term mean; maximum and minimum; and yearly distribution. Ice phenomena: mean dates of freezeup and breakup; ice thicknesses; and special effects of ice on regime.

3. Channel Slope.—Channel slope, is the fall per unit length along the center line of the major channel at a consistent stage of flow. Include: average over length being described; indication of local variations; and longitudinal profile, especially where slope varies significantly.

4. Channel Cross Sections.—Quote dimensions as averages over a number of measured sections, together with a statistical measure of dispersion. Averages and standard deviations are proposed for the following quantities: cross-sectional area of flow; water-surface width; mean depth, computed as area/surface width; and maximum observed depth. These values are to be quoted at the following key stages: reference low water; long-term mean flow; median annual flood; and bankfull.

For rivers with highly variable cross sections, special attention should be given to relatively straight sections with two well-defined stable banks, and dimensions for such sections may be quoted separately from over-all averages.

Cross-sectional shape and the relationship of channel to flood plain may be conveyed by showing a number of typical sections. As cross-sectional profiles may change appreciably with stage, indicate flow conditions at time of survey.

5. Velocities and Hydraulic Roughness.—Using discharge, slope, and cross-sectional data given under items II-1, II-3, and II-4, compute and tabulate values of mean velocity and over-all roughness coefficient for an average section at several key stages. Data on velocity distributions, both horizontal and vertical, are also of considerable value. A stage-velocity curve may be shown.

III.—Materials and Sediment.

1. Bed Material.—Include: median equivalent diameter of average sample (stating methods of sampling and analysis); largest size moved in flood or at specified stages; grain-size distribution curves; indication of grain shapes; average specific gravity; and photograph of typical bed material in place.

Difficulties involved in gravel sampling and analysis are described subsequently.

2. Subbed and Subsurface Materials.—Include a summary of available information on materials and strata beneath the channel and flood plain. If possible, show principal strata boundaries, particularly the alluvium-bedrock boundary, on the longitudinal profile and cross sections. Note occurrence of bedrock outcrops in the channel. Geological valley cross sections are of great value.

3. Bank Material.—Because of the wide variations that may occur in the nature of river banks from point to point, properties are perhaps best conveyed by description and photographs. Relative heights of definite and persistent breaks in stratification—for example between gravel and sand—should be quoted. Note vegetation cover, any artificial protection, and any evidence of landslides.

4. Suspended Sediment.—Where measurements are available, include: long-term mean load; mean and maximum concentrations; annual distribution of load or concentration, for example, by monthly means; and typical grain-size distributions.

5. Bed Load.—Where measurements or estimates are possible, include: long-term mean bed-load or bed-material discharge; bed-load charge or discharge corresponding to key discharges; and indicate methods used to arrive at quoted figures.

Difficulties involved in defining, measuring, and estimating bed load are described subsequently herein.

IV.—Channel Processes.

1. Lateral Shift and Bank Erosion.—Convey patterns of channel shift and associated erosion and deposition by means of a composite map showing changes in channel position over a period of time. Proposed supplementary numerical data include: average plan rate of erosion (e.g., square feet per year per mile of channel); maximum observed rate of bank recession (e.g., feet per year); and average rate of meander migration down-valley (e.g., feet per year).

2. Bed Morphology.—The writers propose the following data, where practicable, on bed forms and processes: detail map, diagram, or airphoto illustrating pattern of major shoals and bars; detail longitudinal profile showing depth variation along channel at a specified stage of flow; dimensional statistics and/or profiles of intermediate and minor bed forms at specified stages of flow; scour depths observed at high stages of flow, particularly in bends and constrictions and alongside steep banks, bridge piers, and other structures; and rates of downstream migration of major and minor forms.

3. Degradation and Aggradation.—Where data are available, show any trend to vertical degradation or aggradation by means of a "specific gage" curve showing changes with time of water levels corresponding to specified discharges.

An effort has been made to include in the preceding set of key data all factors that may be significant determinants or indicators or river regime. It is hoped that it may constitute a convenient check list for any river investigation. In any particular case, the person responsible may use his judgement as to which items may be omitted or treated perfunctorily. It is suggested that an effort should be made, in preparing papers and reports on specific river problems and investigations, to include as many as practicable of the proposed key data, perhaps in the form of an appendix.

The writers suggest that in view of international interest in river classification and the growing predominance of the International System of Units, data should be reported in both metric and foot-pound-second (fps) units.

SET OF KEY RIVER DATA AS PROPOSED
BY NEILL AND GALAY (1967)

4.1. Description Of Fields And Codes

cc	Information and Codes	Format
2-3	River type code: ij i= 0; perennial flow 1; intermittent flow j= 0; non-alluvial or bedrock channel 1; silt/clay bed and banks 2; sand bed, silt/clay banks 3; sandy meandering 4; sandy braided 5; stable gravel 6; wandering gravel 7; gravel paved/armoured 8; gravel braided 9; cobble torrents	I2
4-6	Accession number: klm A unique number between 000 and 999	I3
8	Gauge code: n n= 0; section not associated with a streamgauge 1; section associated with a streamgauge (see dictionary)	I1
10-12	Discharge and survey code: ijk i= 0; discharge based on statistical or stability criterion then j= 1; mean annual discharge 2; 2-yr flood or 2.3-yr flood 5; 5-yr flood 8; reference discharge (see dictionary) 9; dominant discharge defined on stability criteria i= 1; bankfull discharge then j= 0; method of determination	3I1

Table 1: Hydraulic Geometry Data

No.	G	qc	Q	S	w	d	v	λ	ξ	I	D(1)	Dc	D(2)	Dc	User Remarks
00001	1	132	7782	.00074	479.	5.82	2.80		1.01	1	46	33	81	73	
00001	1	012	1120	.00074	341.	2.25	1.46		1.01	1	46	33	81	73	
00001	1	022	6084	.00074	475.	4.99	2.56		1.01	1	46	33	81	73	
00001	1	052	6933	.00074	475.	5.36	2.71		1.01	1	46	33	81	73	
00002	1	132	121	.00540	51.	1.15	2.04		1.2	1	42	33	78	73	
00002	1	012	8	.00540	24.	.48	.67		1.2	1	42	33	78	73	
00002	1	022	48	.00540	40.	.85	1.40		1.2	1	42	33	78	73	
00002	1	052	84	.00540	47.	1.03	1.76		1.2	1	42	33	78	73	
01001	1	121	2265	.00010	197.	5.15	2.21			1			.04	71	
02001	1	012	4.28	.00038	10.	.94	.46		2.16	0	0.40	31	0.65	71	
02002	1	012	5.15	.00038	14.	.84	.36		2.10	0	0.65	31	1.60	71	
02003	1	132	12.0	.00640	17.	.93	.75			0	0.50	31			
02004	1	132	396	.00050	39.	7.19	.14			1	.33	31	.79	71	
02004	1	012	6	.00050	22.	.42	.70			1	.33	31	.79	71	
02004	1	022	79	.00050	30.	1.79	1.46			1	.33	31	.79	71	
02004	1	052	141	.00050	33.	2.92	1.46			1	.33	31	.79	71	
02005	1	132	148	.00020	42.	3.77	.94	800	1.7	1	.29	31	.45	71	
02005	1	012	12	.00020	28.	1.00	.45	800	1.7	1	.29	31	.45	71	
02005	1	022	148	.00020	42.	3.77	.94	800	1.7	1	.29	31	.45	71	
02006	1	132	130	.00051	46.	3.20	.88		1.4	1	.31	31	1.35	71	
02006	1	012	6	.00051	17.	.60	.60		1.4	1	.31	31	1.35	71	
02006	1	022	48	.00051	33.	1.73	.82		1.4	1	.31	31	1.35	71	
02006	1	052	121	.00051	46.	3.04	.88		1.4	1	.31	31	1.35	71	
02007	1	132	2605	.00009	442.	5.33	1.10		1.35	1	.19	31	.37	71	
02007	1	012	767	.00009	384.	2.65	.76		1.35	1	.19	31	.37	71	
02007	1	022	2605	.00009	442.	5.33	1.10		1.35	1	.19	31	.37	71	
02008	1	101	15	.00150	18.	.86	.98		1.77	1	1.1	31	1.7	51	
02009	1	101	129	.00090	29.	2.47	1.82		1.87	1	1	31	4	51	
03001	1	012	68	.00028	159.	.72	.60	3200	1.1	0	0.35	31			
03001	1	022	368	.00028	192.	2.22	.86	3200	1.1	0	0.35	31			

Reach No.	BASIN and River names	HYDROMETRIC STATION DATA: Name(s) and Water Survey of Canada Index number(s)	Operating period(s)	Operating seasons	Type of gauge	Location: Latitude/ Longitude/ Legal survey	Drainage area [sq mi]	Length from source/ Mouth or border [mi]	Elevation of gauge zero/ Gauge for zero flow [ft]	Quality of rating curve	Engineering works affecting flow: Type	Engineering works affecting flow: Starting date
1	2	3	4	5	6	7	8	9	10	11	12	13
1	PEACE/ MACKENZIE Peace	at Hudson Hope 7EF-1	1917-22 1950-	17-22 May-Nov. 50- Y	17- M	56° 01' 39" 121° 53' 56" 80-25-6	27,800	365 758	1,468.96 2.0	Slightly unstable	W.A.C. Bennett dam	Oct.1967
2		near Taylor 7FD-2	1944-50 1952-	44-50 May-Oct. 52- Y	44- R	56° 08' 09" 120° 40' 13" 82-17-6	38,300	425 698	1,313.23 -2.0	Moderately unstable	W.A.C. Bennett dam	Oct.1967
3		at Dunvegan Bridge 7FD-3	1960-	60- May-Oct.	60- M	55° 55' 00" 118° 37' 00" 7-80-4-6	50,200	538 585	1,104.50 4.0	Stable	W.A.C. Bennett dam	Oct.1967
4		at Peace River 7HA-1	1915-32 1957-	15-32 Y 57- Y	15-62 M 63- R	56° 14' 41" 117° 18' 46" 31-83-21-5	72,000	602 521	1,000.52 17.0	Slightly unstable	W.A.C. Bennett dam	Oct.1967
5		near Carcajou 7HD-1	1960-67	60-67 May-Oct.	60-65 M 66-67 R	57° 44' 30" 117° 01' 55" 3-101-19-5	81,000	767 356	824.55 -7.0	Moderately unstable	W.A.C. Bennett dam	Oct.1967
6		at Fort Vermilion 7HF-1	1915-22 1960-	15-22 May-Nov. 60- Y	15-62 M 63- R	58° 23' 15" 115° 02' 05" 24-108-12-5	86,000	868 255	798.91 1.8	Moderately unstable	W.A.C. Bennett dam	Oct.1967
7		at Peace Point 7KC-1	1959-	59- Y	59-60 M 61- R	59° 06' 50" 112° 25' 35" 35-116-15-4	113,000	1,061 62	680.28 3.0	Slightly unstable	W.A.C. Bennett dam	Oct.1967
8	Smoky	at Prudent's Ranch at Smoky at Watino 7GJ-1	1915-22 1955-	15-22 Y 55- Y	15-54 M 55- R	55° 24' 56" 117° 37' 19" 34-77-24-5	18,500	304 41	1,226.17 1.0	Slightly unstable		
9	Wapiti	near Grande Prairie 7GE-1	1917-18 1960-	17-18 Misc. 60- Y	17-59 M 60- R	55° 04' 20" 118° 48' 10" 23-70-6-6	4,350	147 25	1,680 approx. -0.8	Stable		
10	Little Smoky	near Guy 7GH-2	1959-	59- Y	59-62 M 63- R	55° 27' 55" 117° 09' 40" 33-74-21-5	4,130	327 39	1,580 approx. 6.0	Slightly unstable		
11	Notikewin	at Manning 7HC-1	1961-	61- Y	61- M	56° 55' 25" 117° 37' 35" 28-91-23-5	1,810	166 56	1,480.19 2.1	Moderately unstable		
12	ATHABASCA/ MACKENZIE Athabasca	at Jasper 7AA-2	1913-31	13-31 Y	13-31 M	52° 52' 35" 118° 04' 08" 15-45-01-6	1,580	65 837	3,370 approx. Unknown	Slightly unstable		
13		at Entrance 7AD-1 at Hinton 7AD-2	1915-39 1955-	15-39 Y 55- Y	15-60 M 61- R	53° 24' 45" 117° 35' 15" 22-51-25-5	4,000	127 775	3,128.51 3.8	Stable		
14		near Whitecourt (near Windfall) 7AE-1	1960-67 (1968-)	60- Y	60-67 M 68- R	54° 09' 10" 115° 43' 15" 34-59-12-5	7,300 (Whitecourt)	254 648	2,255.67 2.0	Unknown		
15		at Athabasca 7BE-1	1913-31 1938-	13-31 Y 38-50 May-Oct. 51- Y	13-59 M 59- R	54° 43' 20" 113° 17' 10" 20-66-22-4	29,600	467 435	1,662.97 -2.0	Stable		
16		below McMurray 7DA-1	1957-	57- Y	57- R	56° 43' 53" 111° 24' 09" 5-90-09-4	50,000	717 184	774.17 Unknown	Slightly unstable		
17		at Embarras Airport 7DD-1	1959-60 1964-	59-60 May-Oct. 64- May-Oct.	59- R	58° 12' 15" 111° 23' 32" 15-106-09-4	58,700	830 72	700.40 Unknown	Unknown		
18	Wildhay	near Hinton 7AC-1	1965-	65- May-Oct.	65- R	53° 31' 24" 117° 56' 49" 29-52-27-5	373	40 47	4,100 approx. 1.0	Slightly unstable		

Reach No.	HYDROLOGIC DATA: Long-term mean discharge [cfs]/ Years of data	Minimum flow recorded [cfs]/ Date	Maximum flow recorded/ Type/ Date/ Max. stage	Flood frequency estimates: 2-yr [cfs]/ 5-yr [cfs]/ 10-yr [cfs]/ 50-yr [cfs]	Flood frequency estimates: No. of years/ Last yr used	Flow duration estimates: 0.5% [cfs]/ 2% [cfs]/ 10% [cfs]/ 50% [cfs]	Flow duration estimates: No. of years/ Last yr used	CHANNEL GEOMETRY AND HYDRAULICS: Length of reach [ft]/ Number of X-sections/ Date of survey	Slope surveyed at site/ From map	Channel geometry: conditions on day of survey/ long-term mean/ 2-year flood/ 5-year flood: Discharge [cfs]	Area [ft²]	Width [ft]	Depth [ft]	Velocity [ft s⁻¹]	Bankfull conditions (valley flat level): Dschge [cfs]/ Stage [ft]/ Return period [yrs]	Area [ft²]/ Width [ft]/ Depth [ft]/ V_m [ft s⁻¹]	Engineering works in reach	Representativeness of reach
1	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	39,600 14	3,480 28/11/52	311,000 MD 14/6/64 21.3	215,000 245,000 260,000 290,000	26 1968	300,000 228,000 110,000 28,000	5 1964	64,900 5 5/68	0.00074 0.00058	28,000 39,600 215,000 245,000	6,960 8,330 25,600 27,500	980 1,120 1,560 1,560	7.1 7.4 16.4 17.6	4.0 4.8 8.4 8.9	275,000 29.4 27	29,900 1,570 19.1 9.2		Representative
2	51,700 14	6,000 est 24/3/52	410,000 Inst. 31/5/48 21.1	255,000 290,000 310,000 --	22 1967	340,000 265,000 152,000 29,000	5 1964	58,100 3 5/68	0.00069 0.00059	29,000 51,700 255,000 290,000	15,000 18,900 40,100 42,800	1,700 1,720 1,790 1,800	8.8 11.0 22.4 23.7	1.9 2.7 6.4 6.8	318,000 22.0 13	44,800 1,800 24.8 7.1	Bridge	Representative
3	56,000 est 8	19,020 30/8/61	391,000 MD 14/6/64 35.2	290,000 345,000 375,000 --	8 1967	350,000 270,000 160,000 --	5 1967	12,300 6 7/8/68	0.00022 0.00025	15,700 56,000 290,000 345,000	4,800 11,000 35,000 40,000	1,310 1,310 1,540 1,550	3.7 8.4 22.7 25.9	3.3 5.1 8.3 8.6	530,000 38.4 >100	57,000 1,560 36.6 9.3	Bridge	Two small streams join; representative
4	63,700 25	6,350 28/3/19	549,000 Inst. 11/7/65 40.5	315,000 390,000 435,000 530,000	29 1970	377,000 277,500 172,000 29,500	26 1967	10,900 6 27/7/68	0.00035	34,000 63,700 315,000 390,000	13,900 17,500 34,800 37,800	1,380 1,540 1,860 1,900	10.1 11.4 18.8 19.9	2.4 3.6 9.8 10.3	--	--	Bridge	Smoky confluence 5 mi. U/S of gauge; representative
5	66,600 est 8	25,890 2/9/61	429,000 MD 18/6/64 39.0	340,000 410,000 455,000 --	8 1967	434,000 310,000 180,000 28,800	5 1967	10,600 8 5/8/68	0.000074 0.000094	40,000 66,600 340,000 --	15,100 21,600 62,100 --	1,540 1,830 2,030 --	9.8 11.8 30.6 --	2.7 3.1 5.5 -	352,000 37.0 2.5	64,000 2,030 31.5 5.5		Representative
6	75,300 est 8	6,820 8/12/64	421,000 MD 16/6/64 34.0	340,000 385,000 410,000 --	12 1967	363,000 305,000 213,000 30,600	7 1967	36,000 8 12/8/69	0.000041 0.000094	37,500 75,300 340,000 385,000	24,000 32,000 71,000 77,000	1,830 2,020 2,730 2,890	13.1 15.8 26.0 26.6	1.6 2.4 4.8 5.0	--	--	Bridge	Representative
7	80,500 7	9,600 7/4/62	421,000 MD 20/6/64 --	320,000 380,000 410,000 --	11 1970	386,000 335,000 223,000 40,700	7 1967	27,100 6 15/8/70	0.000074 0.00010	41,500 80,500 320,000 380,000	19,000 29,900 64,200 69,600	1,890 2,110 2,380 2,390	10.1 14.2 27.0 29.1	2.2 2.7 5.0 5.5	590,000 42.9 >100	88,900 2,420 36.7 6.7		Representative
8	13,400 16	494 12/12/56	195,000 Inst. 10/7/65 24.9	85,000 120,000 145,000 --	21 1967	93,700 62,400 36,000 6,300	17 1967	25,400 8 31/7/68	0.00052	18,200 13,420 85,000 120,000	5,240 4,600 12,300 15,300	772 740 890 900	6.8 6.2 13.8 17.0	3.5 2.9 6.9 7.8	192,000 25.1 25	21,000 920 22.8 9.1	Bridge	Little Smoky confluence just U/S; representative
9	4,100 6	142 19/2/61	96,400 Inst. 9/7/65 20.5	29,500 56,000 79,000 --	8 1967	30,900 19,800 11,000 1,500	6 1967	15,400 9 13/7/68	0.00051	6,350 4,100 29,500 56,000	2,178 1,730 4,800 6,900	406 386 552 597	5.3 4.5 8.7 11.6	2.9 2.4 6.1 8.1	--	--	Bridge	Representative
10	1,980 6	23 13/2/62	37,500 Inst. 29/4/65 19.2	24,000 32,500 38,000 --	7 1967	24,200 15,800 5,500 368	6 1967	8,750 7 1/8/68	0.00094 0.8011	860 1,980 24,000 32,500	810 1,030 3,000 3,400	251 263 326 337	3.2 3.9 9.2 10.1	1.1 1.9 8.0 9.6	65,000 19.9 >100	4,600 365 12.6 14.1	Bridge	Representative
11	593 5	0 Sev.occ.	17,800 MD 23/5/64 8.5	8,500 15,200 20,800 --	7 1967	11,400 5,600 1,590 58	5 1967	7,500 10 3/8/68	0.8014 0.8012	2,280 593 8,500 15,200	640 375 1,350 2,000	146 131 201 224	4.4 2.9 6.7 8.9	3.6 1.6 6.3 7.6	25,000 16.9 17	2,750 242 11.4 9.1	Bridge	Representative
12	3,190 14	130 30/1/29	21,800 Inst. 13/7/16 10.0	16,000 19,200 21,000 --	17 1931	16,600 13,640 9,450 895	16 1931	16,000 5 15/7/68	0.8030 0.8015	13,500 3,190 16,000 19,200	1,800 870 2,150 2,490	345 195 377 405	5.4 4.5 5.7 6.1	7.3 3.7 7.4 7.7	31,000 11.1 >180	3,550 480 7.4 8.7	Bridge	Mietta confl. not representative U/S of gauge
13	6,600 26	250 26/4/37	53,000 MD 17/6/33 19.0	32,000 38,000 42,000 49,000	34 1964	32,200 25,800 17,600 2,290	33 1967	18,000 7 5/7/68	0.00092 0.8010	27,200 6,600 32,000 38,000	4,820 1,820 5,320 5,900	620 405 627 637	7.8 4.5 8.5 9.3	5.6 3.6 6.0 6.4	--	--	Major intake	Representative
14	9,730 6	828 30/3/64	75,200 MD 10/7/65 17.4	46,500 63,000 74,000 --	10 1969	44,400 34,300 24,180 5,330	6 1967	31,400 9 8/8/67	0.8012	19,000					--	--	Bridge	Not representative; confluence of 3 rivers. Ext. gravel bars
15	15,200 30	1,610 14/12/56	199,600 Inst. 10/6/54 25.8	66,000 98,000 120,000 172,000	50 1970	80,000 58,200 35,000 8,960	31 1967	17,800 7 29/7/69	0.00029 0.00024	16,500 15,240 66,000 98,000	5,520 5,250 13,000 17,000	936 930 1,040 1,100	5.9 5.6 12.6 15.5	3.0 2.9 5.1 5.8	300,000 33.0 >180	36,000 1,290 28.0 8.3	Bridge	Representative
16	22,800 8	3,410 4/2/64	150,600 Inst. 30/6/60 13.7	78,000 102,000 119,000 --	12 1970	101,000 69,800 50,100 15,000	9 1967	8,780 7 25/7/69	0.00023 0.00011	24,000 22,800 78,000 102,000	6,840 6,600 18,200 22,000	1,480 1,470 1,770 1,830	4.6 4.5 10.3 12.1	3.4 3.5 4.3 4.6	--	--		Clearwater River confluence U/S; representative
17	27,100 est 8			92,000 120,900 141,200 --	12 1970	120,400 88,000 59,400 --	9 1967	34,000 7 23/8/70	0.000090 0.00018	29,800 27,100 92,000 --	11,600 10,900 25,400 --	1,300 1,260 1,450 --	8.9 8.7 17.5 --	2.6 2.5 3.6 -	92,000 16.0 2	25,400 1,450 17.5 3.6		Pattern somewhat different outside reach; moderately representative
18	283 est 12	29 17/3/65	3,870 Inst. 11/7/65 9.0	1,700 3,000 -- --	6 1970	2,040 1,480 937 131	12 1967	4,060 7 24/6/68	0.0054 0.0049	485 283 1,700 3,000	179 130 370 520	92 79 130 153	1.9 1.6 2.8 3.4	2.7 2.2 4.6 5.8	4,300 8.9 12	640 168 3.8 6.7	Bridge	Representative

DATA TABLE FOR ALBERTA RIVERS BY KELLERHALS ET AL (1972)

TABLE 1-1. BASIC DATA TABLE FOR FIRST 18 REACHES (PEACE/ATHABASCA)

GEOGRAPHIC FEATURES

Reach No.	General setting: Terrain surrounding valley (32)	General setting: Mean Jan temp °F/ Mean July temp/ Mean annual precip. [in] (33)	Valley features: Description (34)	Valley features: Depth [ft]/ Top width [mi]/ Bottom width [mi] (35)	Valley features: Terraces (36)	Channel features, environment, and processes: Description of valley flat/ Width [mi] (37)	Channel pattern (38)	Relation of channel to valley (39)	Sinuosity/ Wave length/ Belt width [mi] (40)	Lateral activity/ Lateral stability (41)
1	Moderately forested foothills, no cultivation.		Stream-cut valley. N-wall grass or bare, S-wall moderately forested.	- 2.0 0.70	Several continuous levels, some cultivated.	Fragmentary and narrow, moderately forested and partly cultivated. 0.20	Straight with occasional islands, mid-channel bars. Minor debris jams.	Partly entrenched and confined.	1.01 - -	Stable
2	Moderately forested and partly cultivated plains, lacustrine deposits.		Deep, stream-cut valley, occasional slumps. N-wall grass or bare, S-wall moderately forested.	600 2.50 0.80	Several fragmentary levels, mainly cultivated.	Fragmentary and narrow, moderately forested, not cultivated. 0.30	Fairly straight and split, mid-channel bars, minor debris jams.	Partly entrenched and confined.	1.01 - -	Active. Slightly unstable.
3	Partly cultivated and moderately forested lowlands (till plain).	2 57 17	Deep, stream-cut valley. Old, probably inactive slumps. Bare or moderately forested valley walls.	650 0.85 0.35	One fragmentary terrace level (corresponds to valley flat).	Narrow and fragmentary, cultivated. 0.10	Sinuous, without islands. Point bars.	Entrenched, typical for long reach.	1.04 - -	Stable
4	Cultivated, partly built-up, or moderately forested plain. Hummocky till.	-8 57 16	Deep, stream-cut valley with occasional slumps.	650 3.00 0.80	Two fragmentary levels, cultivated and built-up (lower level corresponds to valley flat).	Fragmentary and narrow, partly built-up, partly cultivated. 0.50	Sinuous, with occasional islands, mid-channel bars.	Partly entrenched and confined.	1.10 - -	Stable
5	Moderately forested and partly cultivated lowlands; some muskeg.	-8 57 15	Stream-cut valley with stabilized slumping; moderately forested or bare walls.	250 2.50 1.25	One fragmentary level; corresponds to valley flat.	Fragmentary and narrow, moderately forested and not cultivated. 0.70	Irregular meanders with frequent islands; point bars.	Partly entrenched and frequently confined.	1.80 6.20 6.00	Entrenched loop development. Stable
6	Sparsely forested lowlands; some muskeg, no cultivation, humus, till.	-8 57 15	Stream-cut valley; with bare or shrub-covered walls.	100 1.30 1.00	Two fragmentary levels; lowest level corresponds to valley flat.	Fragmentary and narrow, covered with shrubs. 0.30	Irregular and split, mid-channel and point bars.	Partly entrenched and confined.	1.30 - -	Downstream progression. Slightly unstable.
7	Moderately forested plains; some muskeg, no cultivation.	-8 57 15	Stream-cut valley; with bare or shrub-covered walls.	75 1.00 8.50	Two fragmentary levels; lowest corresponds to valley flat.	Fragmentary and narrow, moderately forested and not cultivated. 0.30	Irregular; mid-channel and point bars; tortuous meanders downstream.	Partly entrenched and confined.	1.05 - -	Stable
8	Moderately forested and partly cultivated lowlands, humus, till.	8 56 17	Deep, stream-cut valley; with frequent slumps, shrub-covered or moderately forested walls.	500 3.00 1.20	Several continuous levels.	Fragmentary and narrow, sparsely forested and not cultivated. 0.08	Irregular meanders with occasional islands; point and mid-channel bars.	Partly entrenched and frequently confined; constricted by slump.	1.30 2.20 1.50	Downstream progression. Slightly unstable.
9	Sparsely forested, and partly cultivated plain; some muskeg.	5 59 17	Deep, stream-cut valley; with occasional slumps; sparsely forested or bare walls.	450 1.00 0.35	Two fragmentary levels.	Fragmentary and narrow, covered with shrubs or partly cultivated. 0.10	Sinuous with occasional islands; mid-channel and point bars.	No obvious degrading or aggr. and confined.	1.10 - -	Downstream progression. Stable
10	Mainly cultivated or sparsely forested plain; thin lacustrine deposits on till.	8 55 19	Stream-cut (in shale) valley; shrub-covered or sparsely forested walls; frequent slumps.	300 1.20 0.15	Several fragmentary levels; lowest corresponds to valley flat.	Fragmentary and narrow, moderately forested and not cultivated. 0.08	Irregular meanders with occasional islands, mid-channel and point bars.	Entrenched; controlled by large slumps.	1.70 1.20 0.90	Entrenched loop development. Slightly unstable.
11	Mainly cultivated plain.	8 59 17	Wide, stream-cut valley, occasional slumps, moderately forested valley walls.	100 1.00 0.15	Several continuous levels, partly built-up.	Fragmentary and narrow, moderately forested, no cultivation. 0.05	Irregular, almost tortuous meanders with pool and riffle sequence; diagonal and point bars.	Entrenched	2.18 0.90 0.00	Entrenched loop development. Moderately unstable.
12	Mountainous area, partly built-up, partly forested.		Wide, mountain valley with one lateral constriction, moderately forested valley wall.	- - 1.25	Several continuous levels; two low ones, including valley flat.	Fragmentary and of moderate extent, moderately forested, no cultivation. 0.10	Sinuous and braided; diagonal and mid-channel bars.	Frequently confined and not obviously aggr. or degrading.	1.10 - -	Laterally active. Moderately unstable.
13	Foothills, partly built-up, partly forested.	12 56 21	Ill defined, stream-cut valley in wide valley; moderately forested valley walls.	500 2.50 0.30	Three continuous levels, lowest corresponds to valley flat.	Indefinite and narrow, moderately forested, no cultivation. 0.15	Straight with occasional islands; mid-channel bars.	Entrenched between terraces.	1.00 - -	Stable
14	Moderately forested plain, partly cultivated and urbanized.	9 59 21	Stream-cut valley with occasional slumps, sparsely forested valley wall, some bedrock cliffs.	250 2.50 1.50	Two continuous levels.	Fragmentary and narrow, sparsely forested or shrub covered, no cultivation. 0.30	Sinuous and split; mid-channel and point bars.	Not obviously degrading or aggr., occasionally confined.	1.20 - -	Moderately unstable.
15	Moderately forested plain, partly cultivated and built-up.	7 59 20	Stream-cut valley with occasional slumps, moderately forested valley walls.	250 1.50 0.20	Two fragmentary low levels and one high level. Lowest level corr. to valley flat.	Fragmentary and narrow, moderately forested and partly built-up. 0.10	Irregular with occasional islands; no island in surveyed reach.	Entrenched	1.20 - -	Stable
16	Moderately forested lowlands, no cultivation.	3 60 19	Stream-cut valley with moderately forested valley walls.	250 2.00 0.00	One continuous level; limestone bench.	No valley flat present.	Straight with occasional islands; mid-channel bars.	Entrenched	1.00 - -	Stable
17	Moderately forested plain, some muskeg, no cultivation.	3 60 19	Stream-cut valley with moderately forested valley walls, near delta.	50 2.10 2.00	One fragmentary level.	Continuous and wide, moderately forested, no cultivation. 2.0	Irregular meanders with occasional islands; point bars and mid-channel bars.	Not obviously degrading or aggr., occasionally confined.	1.35 3.50 1.50	D/S progression of meanders. Moderataly unstable.
18	Heavily forested foothills, not cultivated.	11 52 20	Stream-cut valley in wide valley, moderately forested valley walls.	250 0.80 0.40	Two continuous levels.	Fragmentary and of moderate extent, moderately forested, no cultivation. 0.08	Irregular with occasional islands, pool and riffle sequence, mid-channel and diagonal bars.	Not obviously degrading or aggr., confined by bedrock.	1.20 - -	Slightly unstable.

CHANNEL BED AND BANKS / ICE

Reach No.	Channel bed (42)	Bed material D_{90} [mm]/ D_{65} [mm]/ D_{50} [mm] (43)	Description and number of samples (44)	Channel bank materials (45)	Percent of length alluvial: Left bank/ Right bank (46)	ICE: Freeze-up dates: Earliest/ Latest/ Mean/ Number of years (47)	ICE: Break-up dates: Earliest/ Latest/ Mean/ Number of years (48)
1	Shallow alluvium, (gravel) over shale and sandstone. At least one sandstone outcrop.	81 53 46	GIM 22	Gravel overlain by silt; easily erodible rock.	40 40	November 1 December 23 November 22 20	February 20 May 15 April 30 23
2	Approx. 20 ft of gravel over soft cohesive bedrock (shale).	81 57 41	GBN 4	Gravel overlain by silt; easily erodible rock.	30 40	October 23 December 28 November 22 16	April 1 May 9 April 28 18
3	Approx. 60 ft of gravel over soft cohesive and easily erodible bedrock (shale and sandstone).	127 70 53	GBNP 3	Gravel overlain by silt; easily erodible rock.	90 0	--	April 20 May 5 April 28 3
4	Shallow (15 ft) gravel over soft cohesive (shale) bedrock.			Gravel overlain by silt; moderately erodible rock.	0 180	October 16 November 24 November 4 30	April 14 May 5 April 24 29
5	Predominantly sand with local gravel.			Silt, sand and gravel; easily erodible rock.	40 60	--	--
6	Predominantly sand with local gravel.	0.51 8.34 0.31	S 4	Gravel overlain by silt; easily erodible rock.	70 40	October 22 November 16 November 4 12	April 15 May 11 May 2 14
7	Shallow sand with local gravel over easily erodible shale.	0.27 0.23 0.22	S 3	Silt and sand; easily erodible rock.	80 20	October 26 November 15 November 5 12	April 15 May 14 May 4 12
8	Approximately 35 ft of gravel over clay.	171 112 80	GBNP 8 S 1	Gravel overlain by silt; easily erodible rock.	80 70	October 26 November 12 November 5 15	April 11 April 30 April 18 15
9	Shallow (15 ft) gravel over soft cohesive clay.	94 62 48	GBN 1 GBNP 6 S 1	Sand and gravel; easily erodible rock; till.	50 80	October 20 November 22 November 6 11	April 5 April 29 April 20 11
10	Predominantly gravel.	183 180 73	GBN 2 GBNP 1 S 1	Gravel overlain by silt; easily erodible rock; till.	20 20	October 26 November 12 November 3 12	April 18 April 24 April 17 12
11	Shallow gravel over soft cohesive shale.			Silt and sand; easily erodible rock.	40 40	October 20 November 9 October 30 12	April 17 May 5 April 24 11
12	Predominantly gravel.	132 82 60	GBN 2 GBNP 2	Sand to cobbles, and resistant rock.	180 95	October 17 November 29 November 5 17	February 29 April 30 April 7 17
13	Gravel, thickness of alluvial banks probably small.	86 56 43	GBN 1	Sand and gravel; moderately erodible rock.	80 100	October 25 December 6 November 10 37	March 19 April 30 April 12 36
14	Gravel.	100 61 52	GBN 2 GBNP 1 S 1	Sand and gravel; non-alluvial material unknown.	90 100	November 1 November 15 November 7 7	April 24 May 8 April 28 7
15	Shallow (8 ft) gravel with local sand over soft cohesive clay.			Sand and gravel; non-alluvial material unknown.	70 70	October 14 November 29 November 4 35	April 2 May 9 April 23 30
16	Shallow sand with local gravel over limestone.			Clay and silt (cohesive); erodible rock.	30 10	October 22 November 18 November 5 12	April 16 May 7 April 28 12
17	Probably deep sand.	0.37 0.23 0.19	S 2	Silt and sand; clay and silt (cohesive).	100 180	October 31 1	May 21 1
18	Gravel over easily erodible sandstone.	78 51 42	GBN 1 S 2	Sand and gravel; moderately erodible rock.	100 80	October 26 1	April 30 May 11 May 3 5

DATA TABLE FOR ALBERTA RIVERS BY KELLERHALS ET AL (1972)

TABLE 1-1. BASIC DATA TABLE FOR FIRST 18 REACHES (PEACE/ATHABASCA)

TABLE II DISCHARGE AND GEOMETRY OF RIVERS AT BANKFULL

River	*Bankfull flow (m^3/s)*	*Water surface width (m)*	*Mean depth (m)*	*Water surface slope ($\times 10^{-4}$)*
Afon Lwyd	64	17.36	1.78	44
Alwen 1–5	10	14.04	0.73	64
Alwen 5–9	10.7	9.84	0.73	130
Arrow	29.5	13.73	1.34	45
Ceiriog 1–3	66	17.63	1.79	48
Ceiriog 4–7	66	19.03	1.36	105
Derwent	140	34.37	3.06	17
Eachaig	58	18.41	1.36	57
Exe	67	31.01	1.77	18
Glen	25	25.12	0.78	52
Irfon A	66	26.34	1.16	24
Irfon C	81	28.67	1.63	14
Kent	170	39.90	1.89	74
Lune	260	55.78	2.77	7
Otter	14.2	16.73	0.69	32
Rookhope	36.5	13.70	1.06	137
Tees	370	58.00	3.60	15
Teign	66	19.03	2.47	14
Trent	2.7	5.24	0.65	23
N Tyne	212	42.64	2.09	36
Usk	157	39.33	2.64	9
Wye	550	59.35	4.19	7
Wyre	38	19.48	1.67	20

DATA TABLES FOR BRITISH RIVERS
BY CHARLTON ET AL (1978)

DETAILS OF BED MATERIAL

Intermediate axis grain sizes – (mm)					*Minor axis grain sizes – (mm)*		*Specific gravity*		*Amplitude of bed undulations (m)*	*Wavelength of undulations (m)*
D_{90}	D_{84}	D_{65}	D_{50}	D_{10}	D_{90z}	D_{50z}	*Mean*	*Standard deviation*		
140	123	88	75	45	81	41	2.58	0.03		
284	235	141	106	39	128	43	2.76	0.17		
305	248	149	113	43	144	47	2.76	0.17		
91	70	51	41	20	40	17				
137	112	83	71	38	56	27	2.63	0.09		
215	158	102	82	37	82	33	2.63	0.09		
129	126	80	63	29	56	26				
135	122	90	74	40	85	36				
81	72	54	43	26	40	20			0.35	300
159	146	82	63	27	105	40			0.5	180
84	71	51	39	18	44	18				
85	78	63	55	28	41	24			0.1	60
200	184	143	113	53	157	64	2.62	0.06		
163	144	99	75	39	94	42	2.60	0.14		
108	96	72	57	26	59	30			0.1	100
315	269	124	89	36	192	50	2.71	0.25	0.2	80
204	164	115	77	29	127	46				
94	84	61	51	27	49	23			0.1	60
93	78	46	33	16	36	17			0.1	50
264	217	136	104	37	148	62				
172	148	99	72	38	106	43	2.54	0.07		
55	45	34	28	15	32	16			0.3	120
81	68	49	40	21	51	25	2.49	0.10	0.3	100

TABLE IV SHAPE OF BED MATERIAL PARTICLES

River	*Major – Intermediate axis ratio X:Y*				*Intermediate – Minor axis ratio Y:Z*				*Shape factors*		
	Maximum	*Mean*	*Minimum*	*Standard deviation*	*Maximum*	*Mean*	*Minimum*	*Standard deviation*	*Corey*	*Krumbein*	*Wentworth*
Afon Lwyd	3.25	1.45	1.00	0.34	6.00	1.99	1.02	0.84	0.48	0.29	2.40
Alwen 1–5	4.32	1.52	1.00	0.42	8.50	2.50	1.00	1.09	0.39	0.24	3.10
Alwen 5–9											
Arrow	4.29	1.52	1.00	0.47	10.00	2.61	1.00	1.31	0.38	0.23	3.21
Ceiriog 1–3	4.50	1.63	1.00	0.48	13.50	3.07	1.00	1.71	0.33	0.18	3.98
Ceiriog 4–7											
Derwent	3.48	1.48	1.00	0.38	13.35	2.65	1.01	1.63	0.40	0.24	3.23
Eachaig	3.74	1.50	1.00	0.41	7.25	2.29	1.00	0.94	0.42	0.25	2.80
Exe	3.60	1.55	1.00	0.45	8.50	2.39	1.00	1.07	0.40	0.23	2.98
Glen	3.31	1.53	1.00	0.40	5.50	1.70	1.00	0.58	0.53	0.32	2.12
Irfon A	3.47	1.53	1.00	0.44	9.50	2.64	1.00	1.34	0.38	0.23	3.27
Irfon C	4.44	1.61	1.01	0.58	7.90	2.45	1.00	1.21	0.39	0.22	3.13
Kent	3.68	1.47	1.00	0.36	20.67	1.83	1.00	1.46	0.53	0.32	2.23
Lune	2.69	1.42	1.01	0.31	11.82	1.92	1.00	0.82	0.50	0.32	2.29
Otter	2.80	1.41	1.00	0.38	8.52	2.03	1.00	0.85	0.47	0.31	2.42
Rookhope	3.64	1.44	1.00	0.37	7.66	1.93	1.03	0.86	0.50	0.32	2.31
Tees	3.63	1.42	1.00	0.30	12.30	1.99	1.00	1.09	0.49	0.32	2.40
Teign	4.46	1.55	1.00	0.47	10.63	2.46	1.00	1.38	0.41	0.25	3.08
Trent	3.53	1.52	1.00	0.57	20.80	2.76	1.00	2.28	0.43	0.27	3.42
N Tyne	4.16	1.45	1.00	0.38	5.36	1.83	1.00	0.69	0.52	0.32	2.22
Usk	3.07	1.38	1.00	0.30	5.96	1.83	1.02	0.68	0.53	0.35	2.16
Wye	3.27	1.51	1.00	0.39	8.80	2.09	1.00	1.08	0.47	0.28	2.56
Wyre	3.92	1.43	1.00	0.35	5.66	1.73	1.00	0.69	0.55	0.35	2.09
Mean	3.37	1.49	1.00	0.41	9.91	2.22	1.00	1.12	0.45	0.29	2.73
Standard deviation	1.57	0.06	0.00		4.26	0.38	0.01		0.06	0.06	0.51

Corey's shape factor $\frac{Z}{\sqrt{XY}}$, Krumbein's sphericity $\frac{YZ}{X^2}$, Wentworth's flatness ratio $\frac{X+Y}{2Z}$

TABLE V PROPERTIES OF BANK MATERIAL

River	*Intermediate axis grain size – (mm)*					*Unconfined compression strength – ($N/m^2 \times 10^3$)*	*Vegetation on banks*
	Average			*Toe of bank*			
	B_{90}	B_{50}	B_{90} *maximum*	B_{90} *mean*	B_{90} *minimum*	*Average*	
Afon Lwyd	0.28	–	7.90	0.26	0.22	39.5	T
Alwen 1–5	0.66	0.37	5.80 S	0.34 S	0.32 S	25.6	G
Alwen 5–9	0.51	0.19	5.80 S	0.33 S	0.60 S	23.2	T
Arrow	0.31	–	28.50	0.63	0.34	51.4	T
Ceiriog 1–3	0.48	0.13	0.36	0.35	0.34	23.3	T
Ceiriog 4–7	0.31	0.23	12.20	0.30	0.25	70.9	T
Derwent	0.27	0.10	–	0.27	–	–	T
Eachaig	0.37	0.13	0.39	0.32	0.25	24.8	T
Exe	0.20	0.16	51.00 S	43.50 S	0.24 S	26.1	G
Glen	0.43	0.14	0.45	0.43	0.42	10.3	G
Irfon A	–	–	73.00	41.20	0.65	37.8	G
Irfon C	0.40	0.12	1.30	0.53	0.29	30.1	T
Kent	–	–	1.20	0.96	0.73	–	T
Lune	0.23	0.09	0.26	0.23	0.21	26.2	G
Otter	0.27	0.14	26.50 S	0.37 S	0.25 S	25.8	G
Rookhope	0.47	0.17	1.05	0.75	0.39	31.2	T
Tees	0.34	0.13	0.46	0.33	0.26	19.9	T
Teign	0.30	0.14	68.00	50.80	0.26	15.7	T
Trent	0.31	0.13	0.40	0.32	0.24	36.7	G
N Tyne	0.32	0.19	3.50	3.25	0.28	–	T
Usk	0.24	0.10	0.33	0.28	0.24	21.3	G
Wye	0.14	–	0.32	0.23	0.17	16.0	G
Wyre	0.27	0.13	0.41	0.30	0.23	39.9	G

S indicates that values refer to one bank only, the other bank being composed of substantially larger material.
T trees or heavy vegetation on banks.
G grass or light vegetation on banks.

APPENDIX D

Coding of Major Geomorphic and Physiographic Characteristics of a River Reach (Bray, 1972)

APPENDIX D

Bray 1972
(Generalized Regime - Type Analysis of Alberta Rivers)

CODING OF THE MAJOR GEOMORPHIC AND PHYSIOGRAPHIC CHARACTERISTICS OF A RIVER REACH

G.1 Introduction

The system of numeric codes described in this appendix was developed to permit the stratification of river data on the basis of geomorphic and physiographic factors. The coding system can also be used as a check list for preliminary river surveys. The length of river which can be considered a "reach" for the present codes is variable. The main criterion is that the reach should be geomorphologically homogeneous. Non-homogeneous reaches should be divided into homogeneous elements for separate coding.

The general principles on which the coding system is based are as follows:

1. The coding proceeds from a broad view of the general setting of the reach to a relatively detailed description of the channel banks and bed;
2. The codes are based on data that may be obtained from maps, air photos and from field surveys;
3. The codes incorporate relatively standard terminology;
4. The codes are quantitatively defined wherever possible;
5. The range of codes for any specific classification is as small as possible;
6. The codes are supplemented by comments in situations that are not readily described numerically. The extent to which the coded features are typical for the particular river is also noted in comments;
7. Multiple codes are used in cases where one code is not adequate. Multiple codes are arranged in decreasing order of dominance or importance.

Many of the codes are open to subjective and inconsistent application. For example, the channel patterns "irregular" and "irregular meanders" may be difficult to separate consistently; however, no matter which code is selected, the reach is definitely different from those classified as "straight", or "tortuous".

The major headings used for the coding are as follows:

1. General description of the terrain in the vicinity of the surveyed reach above valley.
2. Valley characteristics above valley flat.
3. Terraces.
4. Relation of channel to valley.
5. Description of valley flat.
6. Description of channel.
7. Lateral channel activity.
8. Channel banks and bed.
9. Bed rock below channel.

In the following section the codes are outlined in detail. Examples are provided in cases where the code may be difficult to interpret. In all codes a "-1" is used to mean "unknown", and a "blank" or a "0" means that the code is not applicable.

Special coding sheets GEOG1 and GEOG2 shown in FIGURE B.1 and B.2 have been constructed to facilitate the coding of a river reach. The codes presented in this appendix have been developed jointly by the writer and Dr. R. Kellerhals, Department of Civil Engineering, University of Alberta.

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RIVER DATA SHEET No. Geog. 1/71

GEOGRAPHIC FEATURES

Reach Name:______________________ Reach No:________ Date of Analysis:____________ Analysis By:______________

Scale of Air Photos:______________ Scale of Map:______________

NOTE: Complete codes by circling the appropriate number(s). Use "-1" for "unknown" and "0" for "not applicable".

General Description of the Terrain in the Vicinity of the Surveyed Reach, above Valley

Terrain:
1 mountainous
2 foothills
3 uplands
4 hills
5 plains
6 lowlands

Vegetation:
0 0 0 not applicable
1 1 1 almost none
2 2 2 grass
3 3 3 shrubs
4 4 4 sparsely forested, 0-25%
5 5 5 moderately forested, 25-75%
6 6 6 heavily forested, 75-100%
7 7 7 swamp or muskeg

Forest type:
0 0 0 not applicable
1 1 1 deciduous
2 2 2 coniferous

Comments:______________

Land use:
0 0 no cultivation or built-up area
1 1 partly cultivated
2 2 mainly cultivated
3 3 partly built-up
4 4 urbanized

Surficial geology:
1 1 1 bedrock
2 2 2 ground moraine
3 3 3 hummocky moraine
4 4 4 lacustrine deposits
5 5 5 glacio-fluvial dep.
6 6 6 fluvial deposits
7 7 7 aeolian deposits

Valley Characteristics above Valley Flat

Valley measurements:
____within reach
____within reach and immediate vicinity
depth:__________ft.
top width:__________mi.
bottom width:__________mi.

Slumping of valley walls:
0 none
1 occasional
2 frequent

Length of reach with slumping valley walls (contact length in percent of total length of banks):__________

Vegetation on valley wall:
0 0 not applicable
1 1 almost none
2 2 grass
3 3 shrubs
4 4 sparsely forested
5 5 moderately forested
6 6 heavily forested
7 7 swamp or muskeg

Forest type on valley wall:
0 0 not applicable
1 1 deciduous
2 2 coniferous

Comments:______________

Terraces

Terrace presence:
0 none
1 indefinite
2 fragmentary
3 continuous

Number of levels:
0 not applicable
1 one level
2 two levels
_ __ levels
9 several levels

Comments (in particular land use and vegetation):______________

Relation of Channel to Valley

Valley type:
0 not applicable
1 stream cut valley
2 stream cut valley in wide valley
3 wide mountainous valley

If no valley:
0 valley present
1 on alluvial fan
2 on alluvial plain
3 in delta
4 in old lake

Underfit:
0 not applicable or not obviously underfit
1 obviously underfit

Local lateral constriction:
0 none
1 one
2 two
_____ cases
9 several cases

Relation of channel to valley bottom (vertical):
0 not applicable
1 not obviously degrading or aggrading
2 partly entrenched
3 entrenched
4 aggrading

Relation of channel to valley walls or to high, resistant terraces (lateral):
0 not applicable (no valley or free)
1 occasionally confined
2 frequently confined
3 confined
4 entrenched

Comments:______________

FIGURE B.1

Sample copy of Coding Sheet Geog.1

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DEPARTMENT OF CIVIL ENGINEERING

RIVER DATA SHEET No. Geog. 2/71

GEOGRAPHIC FEATURES - (Cont'd.)

Reach Name: ______________________ Reach No: __________

Description of Valley Flat

Presence:
0 none
1 indefinite
2 fragmentary
3 continuous

Extent:
0 none
1 narrow (< 1 W_s)
2 moderate (1-5 W_s)
3 wide (> 5 W_s)

Average width ______ mi.
Maximum width ______ mi.
Channel length with valley flat on left ______ %
on right ______ %

Vegetation:
0 0 not applicable
1 1 almost none or bare
2 2 grass
3 3 shrubs
4 4 sparsely forested
5 5 moderately forested
6 6 heavily forested
7 7 swamp or muskeg

Forest type:
0 0 not applicable
1 1 deciduous
2 2 coniferous

Land use:
0 0 not cultivated, not built-up
1 1 partly cultivated
2 2 mainly cultivated
3 3 partly built-up
4 4 mainly built-up

Comments: ______________________

Channel Description (near long-term mean)

Channel pattern:
1 straight
2 sinuous
3 irregular
4 regular meanders
5 irregular meanders
6 tortuous meanders

Islands:
0 none
1 occasional
2 frequent
3 split
4 braided

Type of flow:
1 uniform water surface
2 uniform with rapid in reach
3 uniform with boils and irregularities
4 pool and riffle sequence
5 tumbling flow

Bar type:
0 0 0 none
1 1 1 point bars
2 2 2 side bars
3 3 3 mid-channel bars
4 4 4 diagonal bars
5 5 5 large dunes

Meander dimensions:
belt width ______ mi.
wave length ______ mi.
sinuosity ______

Natural obstructions:
0 0 none
1 1 logs
2 2 beaver dams
3 3 boulders (lag material)
4 4 vegetation

Degree of obstruction:
0 0 none
1 1 acc. minor
2 2 acc. major
3 3 frequent minor
4 4 frequent major

Comments: ______________________

Lateral Channel Activity

Lateral activity:
0 not detectable
1 downstream progression
2 progression and cut-offs
3 mainly cut-offs
4 entrenched loop development
5 laterally active but not 1-4

Lateral stability:
0 stable
1 slightly unstable
2 moderately unstable
3 highly unstable

Comments: ______________________

Channel Banks and Bed

Alluvial bank material.
0 0 0 no alluvial banks
1 1 1 clay and silt (cohesive)
2 2 2 silt and sand (non-cohesive)
3 3 3 sand and gravel (< 64 mm)
4 4 4 sand to cobbles
5 5 5 sand overlain by silt
6 6 6 gravel overlain by silt
7 7 7 cobbles overlain by silt

Non-alluvial bank material:
0 0 0 alluvial bank material
1 1 1 lacustrine deposits
2 2 2 till
3 3 3 easily erodible rock
4 4 4 moderately erodible rock
5 5 5 resistant rock
6 6 6 boulders

Percentage of left bank in alluvium ______ %
Percentage of right bank in alluvium ______ %

Bank vegetation:
0 none
1 weak
2 good
3 very strong

Predominant bed material:
1 sand
2 sand with local gravel
3 gravel
4 gravel with local sand
5 sand and gravel

Depth of alluvium:
0 no alluvium
1 shallow
2 moderate
3 deep

Estimated depth of alluvium ______ ft.

Reference or comments: ______________________

Bed Rock Below Channel

Presence of rock outcrops in channel bed:
0 none
1 one occurrence
2 two occurrences
______ occurrences
5 several occurrences

Rock type at channel base:
0 0 0 not applicable (none for great depth)
1 1 1 compact clay
2 2 2 shale
3 3 3 limestone
4 4 4 sandstone
5 5 5 conglomerate
6 6 6 granite
7 7 7 ______

Erodibility:
0 0 0 not applicable
1 1 1 soft cohesive
2 2 2 easily erodible
3 3 3 moderately erodible
4 4 4 resistant

Comments: ______________________

FIGURE B.2

Sample Copy of Coding Sheet Geog.2

B.2 Codes for the General Description of the Terrain in the Vicinity of the Surveyed Reach Above Valley

The codes give a rough description of the terrain within approximately 3 mi. radius of the study reach. Normally, a few aerial photographs at and near the reach and a topographic map provide all the data for this code. In the case of normal prairie rivers with well defined valleys cut into the surrounding plains, it is important to apply these "terrain" codes to the area outside the river valley, since other codes will describe the river valley. In mountainous areas the use of these codes is somewhat questionable as the valleys cover essentially the entire area. One can either consider this coding to apply to the higher regions of mountainous valleys or use not applicable ("0") codes.

Terrain: This code corresponds to the physiographic regions given in Atlas of Alberta (1969) and can be obtained there.

Code: 1 mountainous

2 foothills

3 uplands

4 hills

5 plains

6 lowlands

Vegetation: Multiple coding is generally necessary with the most dominant vegetation type being coded first.

Code: 0 not applicable

1 almost none

2 grass

3 shrubs

4 sparsely forested, 0 - 25% of area in forested portion

5 moderately forested, 25 - 75% of area in forested portion

6 heavily forested, 75 - 100% of area in forested portion

7 swamp of muskeg

Forest type: This code is used to describe the forest type in the vegetation code. In most cases it is associated with codes 4, 5, 6, or 7 in the vegetation code.

Code: 0 not applicable

1 deciduous

2 coniferous

Land use: This is a multiple code used to indicate the relative influence of man on the area near the study reach.

Code: 0 no cultivation or built-up areas

1 partly cultivated

2 mainly cultivated

3 partly built-up

4 urbanized

Surficial geology: This code refers mainly to glacial or preglacial deposits, as they dominate the Alberta landscape.

Code: 1 bedrock

2 ground moraine

3 hummocky moraine

4 lacustrine deposits

5 glacio-fluvial deposits

6 fluvial deposits

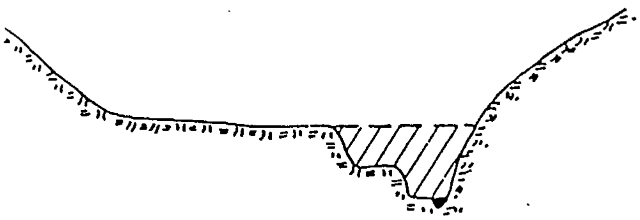
7 aeolian deposits

Comments: Comments should be used liberally to supplement the codes by describing characteristic features of the area.

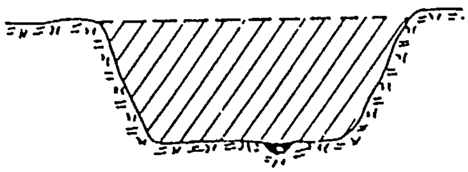
B.3 Valley Characteristics Above Valley Flat

The following codes describe the valley above the valley flat. Valley measurements are made with reference to a major plain area. In situations where the stream has no valley (fans, deltas) or where the valley is not stream cut, "0" codes may be unavoidable.

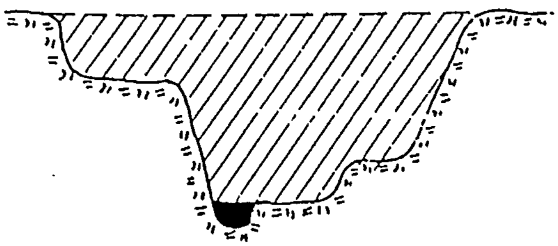
The shaded portions in the following sketches define the valley to which these codes refer. These illustrations show that the major plain is considered to be the upper limit of the defined valley.



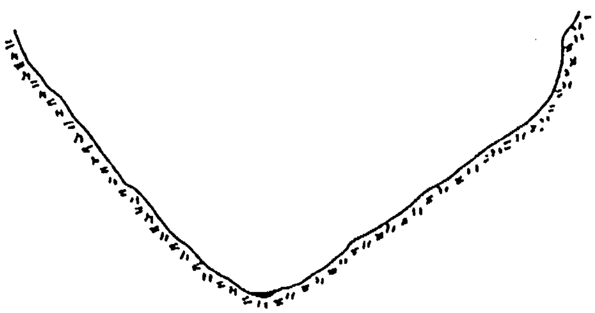
Valley in wide glaciated valley



Trench like valley

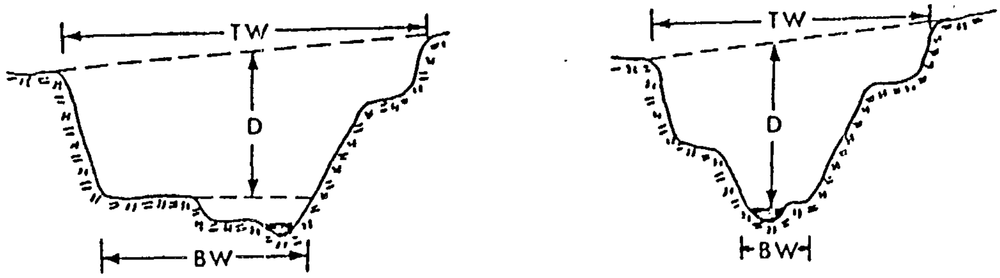


Valley with terraces



Not applicable (mountainous)

Valley measurements: The valley measurements consist of roughly estimated averages for the reach or for the reach and its immediate vicinity. The measurements are defined in the following sketches.



where: D = depth in feet usually to the nearest contour interval on a topographic map unless more detailed data are available

TW = top width of the valley in miles

BW = bottom width of valley in miles

A zero may be used for any of the above three parameters, if there is no valley, or if the measurement is not applicable (e.g. TW for some large mountain valleys).

With the above parameters a rough estimate of the volume of material removed per lineal foot along the channel may easily be computed and the average slope of the valley walls may be estimated as:

$$V_{slope} = \frac{2D}{TW - BW}$$

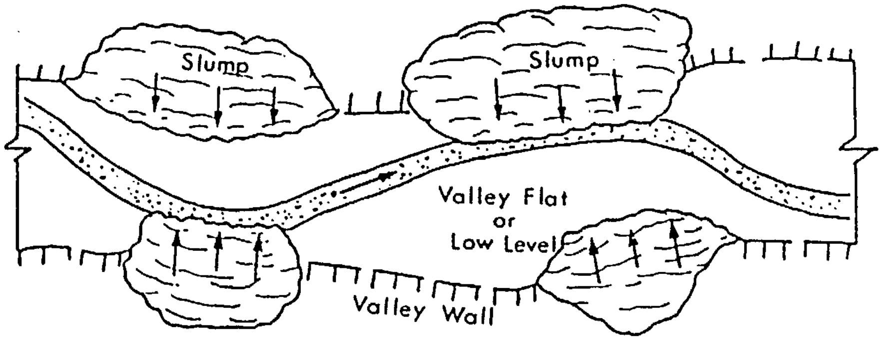
Slumping of valley walls: This code describes the presence of massive slumping of the valley walls in a qualitative manner. The code is not to refer to the small local failures which often occur at bends.

Code: 0 none

1 occasional

2 frequent

Length of reach with slumping valley walls: The massive slumps in contact with the channel impose a control on channel development. It is therefore, important to estimate the length of contact of massive slumps with the channel of the present river. A quantitative code in percent is used to express the total length of massive slump contact with the channel banks in the reach.



For the above case the code would be 15 percent. (Approximately 20 percent of the left bank and 10 percent of the right bank are in contact with massive slumps.)

Vegetation on valley walls: The type of vegetation on the valley walls gives an indication of the general environment and of the ease with which material may be transported from the valley walls to the valley flat or to the channel. This code only applies to the valley wall above the valley flat or above the high water line. Another code will deal with the influence of vegetation on the banks of the channel below the high water line.

Code: 0 not applicable

1 essentially bare

2 grass

3 shrubs

4 sparsely forested

5 moderately forested

6 heavily forested

7 swamp or muskeg

Forest type above valley flat:

Code: 0 not applicable

1 deciduous

2 coniferous

Comments: Additional information such as the difference between north-exposed and south-exposed valley sides, etc., should be noted here. The representativeness of the study reach for longer reaches of the river should also be noted.

B.4 Coding for Terraces

The study of terraces along a river reach can generally provide some information concerning the geologic history of the river and of the valley. At the very least the presence of terraces indicates that the river has had an opportunity for lateral development at some earlier time.

One difficulty of dealing with terraces is the definition of the term. What is a low terrace to some may be a flood plain to others as it is difficult to distinguish between the two without very extensive analysis. Here, the lowest terrace is defined as the first flat area in the valley above the present river which appears to be subject to infrequent flooding only (return periods in the order of 10 years or greater). The lowest terrace is often identical with the valley flat (see Section G.6).

Terrace presence:

Code: 0 none

1 indefinite: small flat areas that may be terraces

2 fragmentary: well defined, but small and discontinuous

3 continuous: terraces are present almost continuously along the valley. Any particular terrace level need not be continuous.

Number of levels: The number of terrace levels may give an indication of the relative frequency of lateral traverses of the valley made by the channel during the valley development. Only a detailed analysis could lead to a truly quantitative evaluation of this code.

Code: 0 not applicable

1 one level

2 two levels

(n) (n) levels

9 several levels

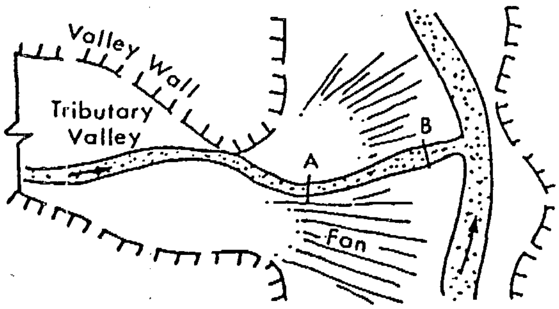
Comments: A brief note on land use and vegetation on the terraces should be added. The representativeness of the coded reach for the river valley in general is also of interest. A note should be made to indicate if the lowest terrace corresponds to the valley flat.

B.5 Coding for Relation of Channel to Valley

This code deals with the relation of the present river to the valley in which it is flowing.

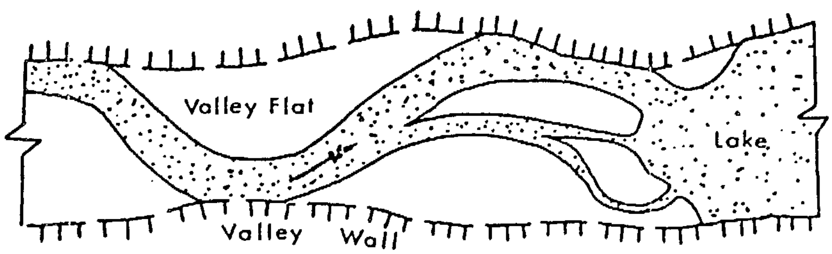
Valley type:

Code: 0 not applicable: mainly situations where the river has no valley of its own, e.g. deltas and fans. Note that this code applies to fans in valleys, if the fan is associated with a tributary valley.



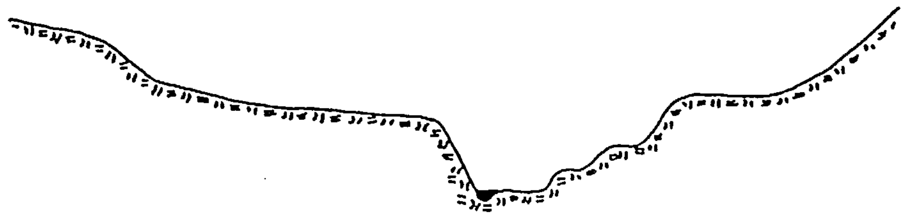
The reach $\overline{AB}$ has no valley

Rivers may flow on deltaic or fan deposits inside their own valley, in which case another code would apply.



1 stream cut valley: most valleys on the plains and narrow mountainous valleys fall into this category. The valley may not have been cut by the present rivers.

2 stream-cut valley in wide valley: a common situation in the foothills of Alberta. The wide valleys are the result of glacial processes.



3 wide mountainous valley: streams in valleys between mountains where the present valley shape is mainly the result of glacial processes.

If no valley: This code gives the reason why the river may not have a valley.

Code: 0 valley present

1 on alluvial fan

2 on alluvial plain

3 in delta

4 in old lake

Underfit: This code is used to point out those channels which are obviously flowing in valleys that have been excavated by larger, earlier rivers.

Code: 0 not applicable or not obviously underfit

1 obviously underfit

Local lateral constriction: Local constrictions of the valley by rock spurs, lava flows, moraines, tributary fans, etc. are listed.

Code: 0 none

1 one case

2 two cases

3 three cases

(n) (n) cases

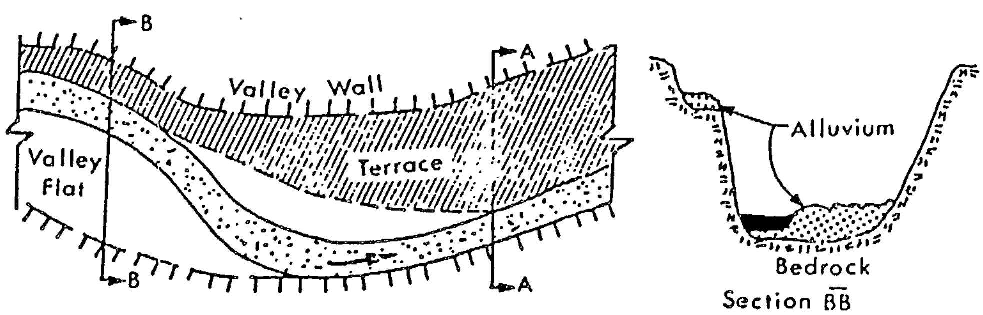
9 several cases

Relation of channel to valley bottom (vertical): This code indicates the state of the vertical activity of the channel with reference to the valley bottom. For this code the valley bottom is that observed on aerial photographs.

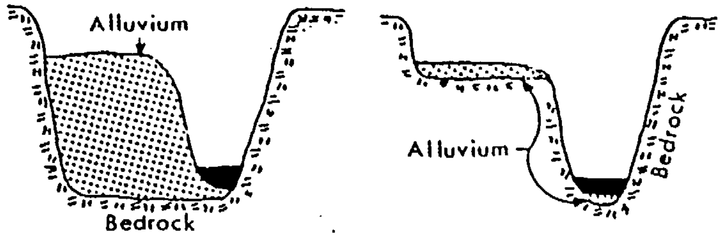
Code: 0 not applicable: situation with no valley

1 not obviously degrading or aggrading: mainly river reaches associated with a prominent and frequently flooded valley flat, which appears to be a flood plain in the geomorphic sense.

2 partly entrenched: some segments of the study reach are entrenched, either in non-alluvial material (bedrock, till, etc.) or in major alluvial terrace deposits.



(continued)



Two Possible Situations at Section $\overline{AA}$

The river is entrenched at Section $\overline{AA}$ (in both situations shown), but not entrenched at Section $\overline{BB}$.

3 entrenched

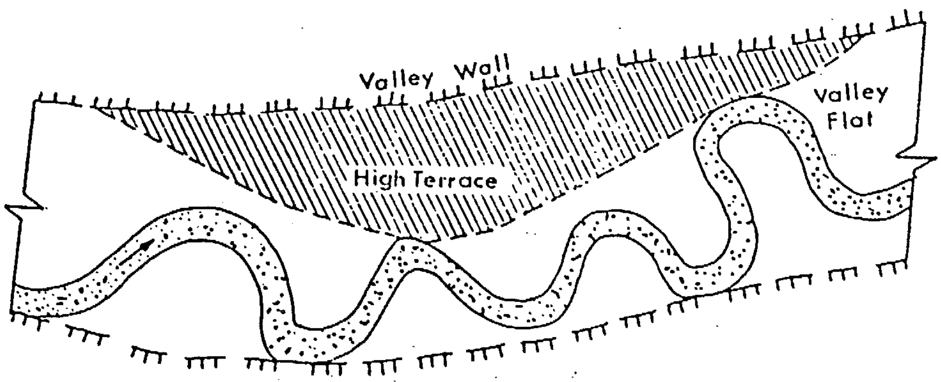
4 aggrading

Relation of channel to valley walls or to high, resistant terraces: This code deals with the restraints on lateral development (meandering) of the channel imposed by valley walls or high terraces.

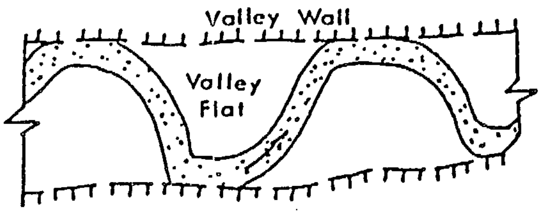
Code: 0 not applicable (no valley or free)

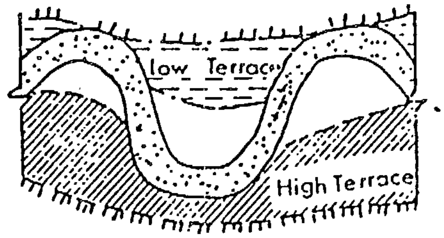
1 occasionally confined: the river is occasionally deflected by the valley wall or by a terrace

2 frequently confined: the river is frequently deflected by the valley wall or by a terrace



3 confined: the river is regularly deflected by the valley walls or by terraces.





4 entrenched

Comments: The subject matter of the above codes is open to widely differing interpretations. The situation should always be described verbally, even if the codes seem to fit well. As before, the representativeness of the coded reach should also be noted.

G.6 Codes for Description of Valley Flat

In the context of this code, the valley flat is the lowest flat associated with the present river and is subject to frequent or occasional flooding. In geomorphological terms it may be a flood plain or a low terrace. In engineering terms it is always a flood plain. The use of the term valley flat implies that no specific genetic meaning is intended, but it is to be considered as a readily observable physical feature. In some cases it is difficult to assure that the selected valley flat is at a constant genetic level along the river reach.

The valley flat codes also apply to cases where there is no valley. The flat associated with an alluvial fan, for example, should be considered to be the valley flat for the purposes of coding.

Presence:

Code: 0 none: this applies to entrenched channels

1 indefinite: small flat areas

2 fragmentary: a definite valley flat is present for some distance along the reach.

3 continuous: a well defined valley flat is present on at least one side of the channel along most of the length of the reach.

Lateral extent: The purpose of this code is to evaluate the approximate extent of the valley flat.

Code: 0 none

1 narrow (less than 1 river width at bankfull stage)

2 moderate (between 1 and 5 river widths at bankfull stage)

3 wide (greater than 5 river widths at bankfull stage).

Average width of valley flat, in mi.: The average width is based on the width of a rectangle of area equal to that of the valley flat and with the length of the rectangle approximately equal to the length of valley flat in contact with the river. The flat on both sides of the channel is considered when making an estimate of the average width of valley flat.

Maximum width of valley flat, in mi.

Channel length with valley flat on left, percent

Channel length with valley flat on right, percent

Vegetation for valley flat: The type of vegetation on the valley flat may indicate the relative resistance offered to overbank flow.

Code: 0 not applicable

1 almost none or bare

2 grass

3 shrubs

4 sparsely forested

5 moderately forested

6 heavily forested

7 swamp or muskeg

Forest type:

Code: 0 not applicable

1 deciduous

2 coniferous

Valley flat land use:

Code: 0 not cultivated, not built-up

1 partly cultivated

2 mainly cultivated

3 partly built-up

4 urbanized

Comments: At least a note on representativeness.

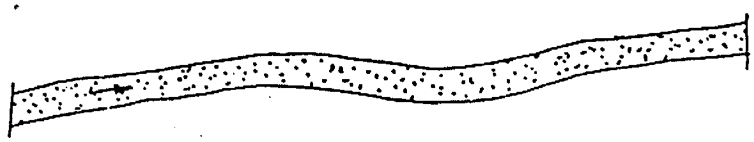
Some additional information concerning the presence of a low level bench, a vegetation trim line, or a valley flat is noted in the hydraulic geometry data. The approximate return period, at which the river stage reaches these features is also given there.

G.7 Coding for Channel Description

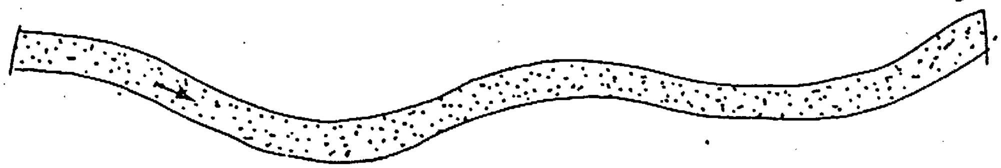
This section deals primarily with the planimetric aspects of the reach, as it appears near long-term-mean stage. This rather low stage is used here because air photos rarely show the channels at flows near bankfull.

Channel pattern:

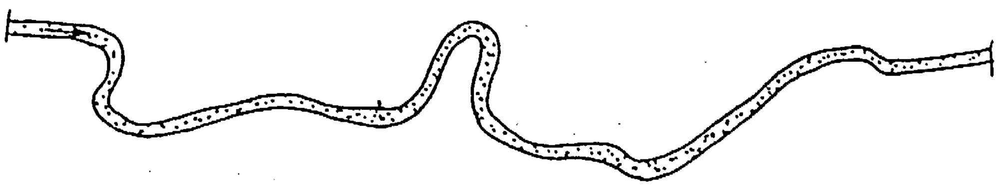
Code: 1 straight: very little curvature within reach.



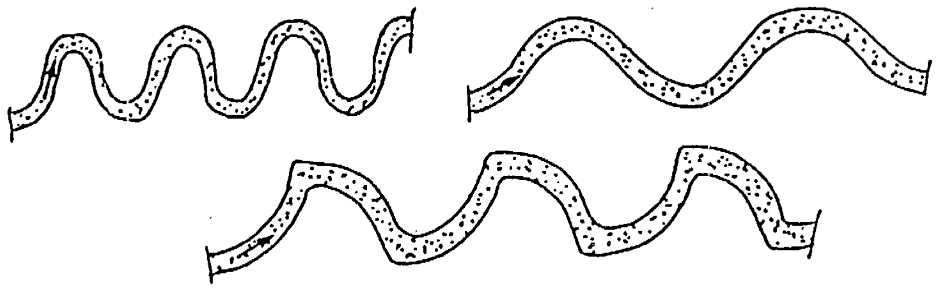
2 sinuous: slight curvature with a belt width or deviation of less than approximately two channel widths.



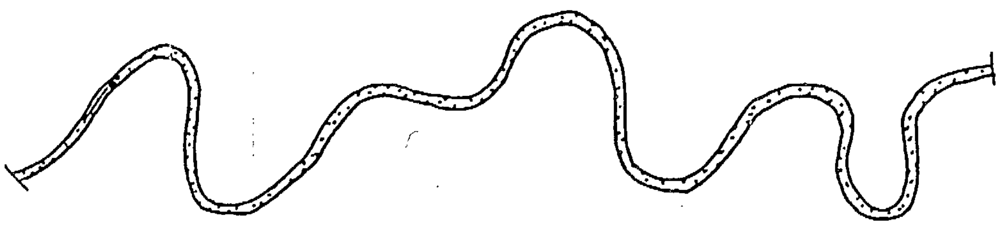
3 irregular: a channel pattern which cannot be considered straight or sinuous and does not have a repeatable pattern. This code also applies to structurally controlled, geometric patterns (add appropriate comments).



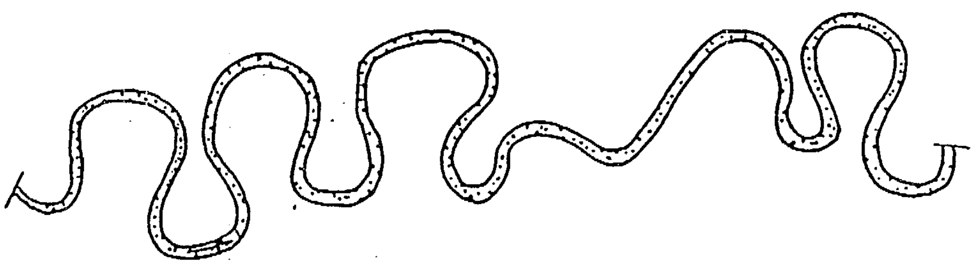
4 regular meanders: this channel pattern is characterized by a repeatable pattern. The angle that the channel makes with the valley axis at the cross-over is less than, or equal to 90°.



5 irregular meanders: a repeatable pattern is detectable in the channel plan but it cannot be considered regular.



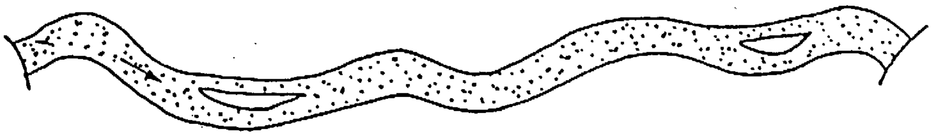
6 tortuous meanders: the channel plan is more or less repeatable but is different from the regular meander in that the angle between the channel and the valley axis at cross-overs is frequently greater than 90°.



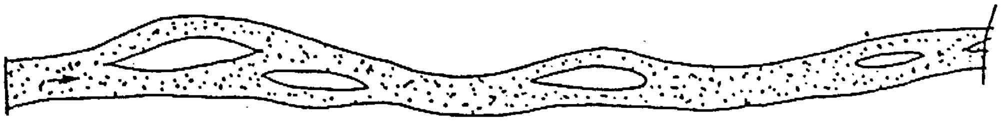
Islands:

Code: 0 none

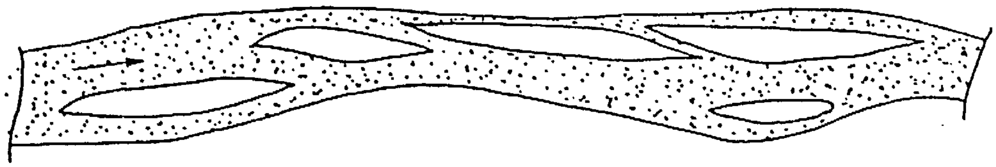
1 occasional: the islands should be relatively stable and have some vegetation. It should generally be possible to consider the surface of the islands as part of the valley flat. No overlapping of islands, the average spacing being 10 or more river widths.



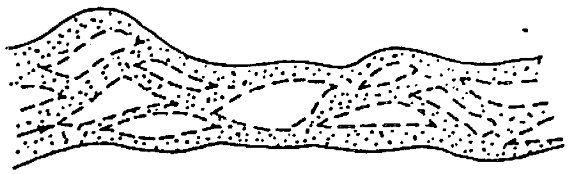
2 frequent: in appearance the islands should be as above, but there may be infrequent overlapping, with the average spacing being less than 10 river widths.



3 split: the islands are stable, as above and overlap frequently or continuously. The number of flow channels is usually two or three.



4 braided: in this case the islands are characterized by being unstable and overlapping. They may have some vegetation. The number of flow channels is greater than two.



Type of flow: This code classifies the river reach according to the type of energy dissipation indicated by the water surface.

Code: 1 uniform water surface

2 uniform with rapid in reach: this is not a pool and riffle sequence but is indicative of a non-uniformity in the reach.

3 uniform with boils and irregularities: irregular water surface indicating a channel with high velocities and generally high Froude number.

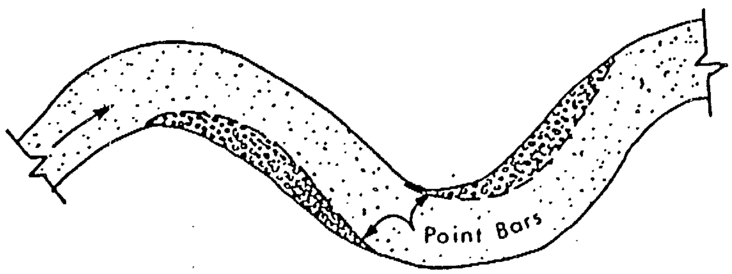
4 pool and riffle sequence: pools and riffles (rapids) at relatively uniform spacing. Most of the energy is lost in the riffles.

5 tumbling flow: most mountainous streams are characterized by this type of flow. Jets, wakes and hydraulic jumps account for part of the energy loss.

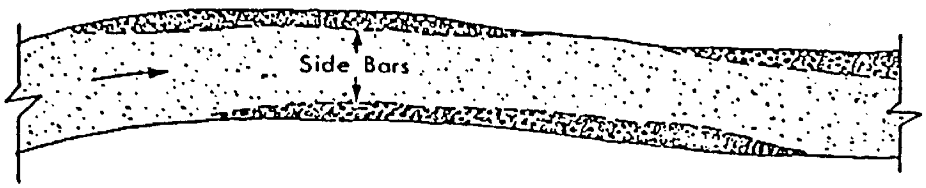
Bar type: Bars differ from islands (considered above) by being largely unvegetated and submerged at or below bankfull stage.

Code: 0 none

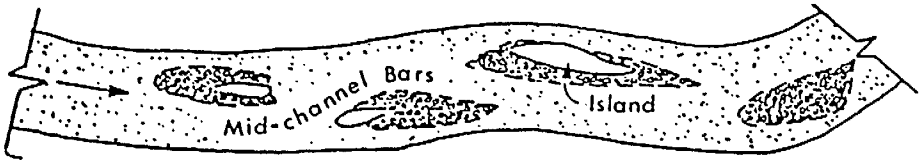
1 point bars



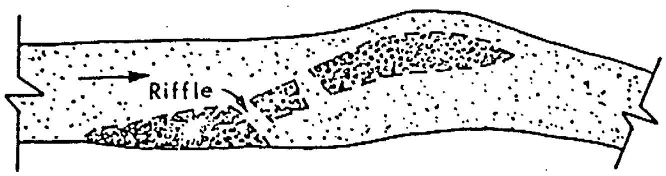
2 side bars



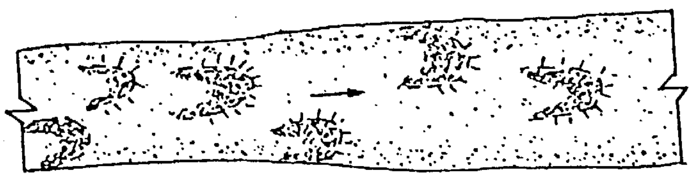
3 mid-channel bars



4 diagonal bars (mainly gravel): this applies to bars which extend part way across or all the way across the channel. A riffle may sometimes be considered a diagonal bar.



5 large dunes: a feature occurring in certain sand-bed rivers. Linguoid bars with gentle up-stream slope and steep downstream slope (at angle of repose).



Meander dimensions: If the channel plan is classified as meandering, it should be possible to obtain an estimate of the average meander dimensions. A somewhat longer portion of the river than the study reach may have to be used to make the necessary measurements. If several wavelengths and belt widths are measured, present the average for the reach. If the channel plan is not considered to have a repeatable pattern, enter "0" for the meander dimensions.

Meander wavelength (mi.)

Meander belt width (mi.)

Sinuosity: the definition of sinuousity used is the thalweg length divided by the valley axis length between two points on the channel. This definition is satisfactory except for those cases where the valley is entrenched. In such cases, the sinuosity as defined above may be approximately 1.00, although the channel is not straight in plan.

If the reach is similar to the channel upstream and downstream of the surveyed reach, the sinuosity is usually determined between the contour lines used to establish the topographic slope. In cases where the study reach is not typical of a longer portion of the river, the sinuosity is presented for the reach only and a note is made to indicate the variability of channel plan shape. The value for sinuosity is presented to three significant digits but only two are justified in most cases.

Natural obstructions: Certain natural obstructions can have far-reaching effects on channel slope, type of flow, and channel pattern. This code attempts to recognize and identify them. Man-made obstructions are given in the coding related to the surveyed reach.

Code: 0 none

1 logs

2 beaver dams

3 boulders (lag material)

4 vegetation

Degree of obstruction:

Code: 0 none

1 occasional minor

2 occasional major

3 frequent minor

4 frequent major

Comments: The extent to which the study reach described here is typical of the river beyond the study reach should always be noted. If the channel pattern is stage dependent, this should also be noted.

G.8 Codes for Lateral Channel Activity

This code attempts to describe the predominant type of lateral channel activity in the reach. One difficulty of using this code is that it may not be possible to distinguish the presently active process from processes which may have been active at earlier periods.

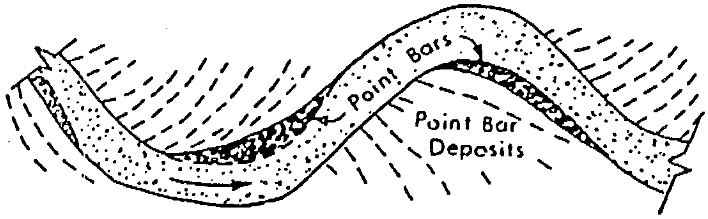
Some common features which assist in the evaluation of this code are meander scrolls (point bar deposits), meander scars, lineated vegetation, cut-offs, etc.

Lateral activity

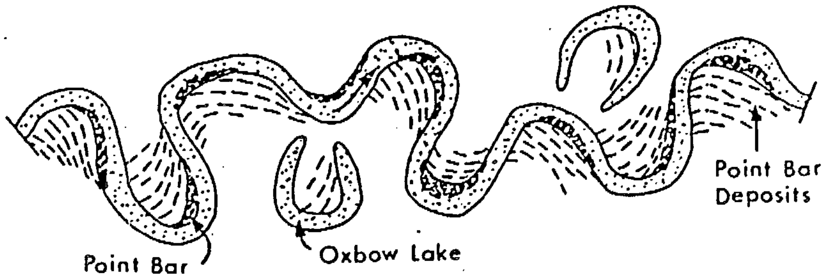
Code: 0 not detectable: this code is used if no signs of lateral channel activity are noted.

1 downstream progression: the whole meander pattern moves

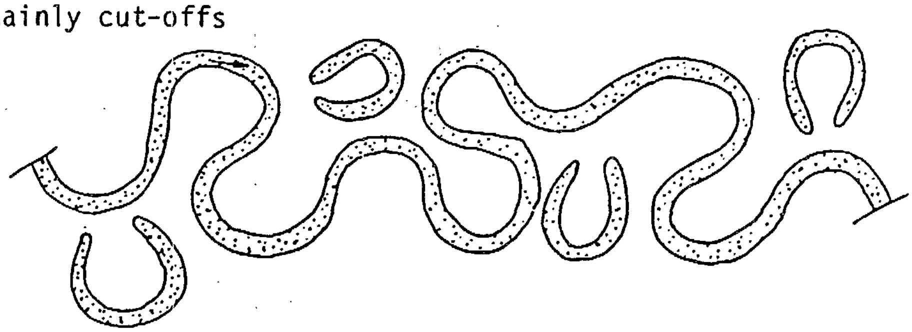
down-valley without forming cut-offs. Frequently associated with regular, confined meanders.



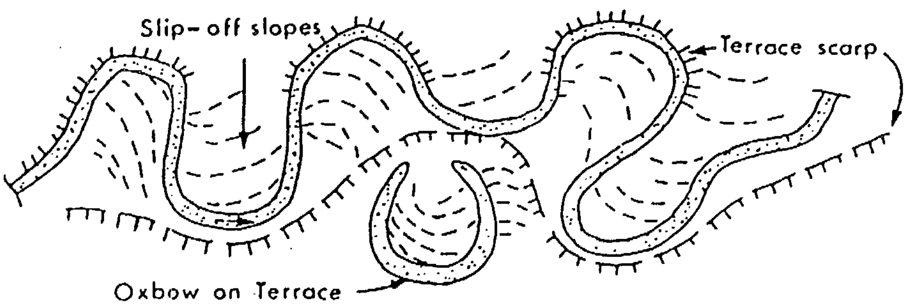
2 progression and cut-offs



3 mainly cut-offs



4 entrenched loop development: occurs with rivers entrenched in relatively easily erodible materials. Generally associated with irregular or contorted meanders. Slip-off slopes are formed on the inside of the meander bends.



5 laterally active but not 1-4: this code is used for gravel rivers which exhibit irregular lateral activity.

Lateral stability: The degree of lateral stability may be estimated from air photos on the basis of plant growth, occurrence of vertical but banks, eroded fields, etc. The conclusions may be somewhat biased if the air photos were taken shortly after a major flood.

This code is to apply to activity of the present river.

Code: 0 stable: bank vegetation is well developed with no evidence of recent bank erosion.

1 slightly unstable: localized bank erosion.

2 moderately unstable: a considerable part of the total length of either bank is subject to erosion or is being newly formed. Vegetation (if present) also indicates channel shift. Presence of vertical alluvial banks or very steep non-alluvial banks.

3 highly unstable: clear evidence that the channel has changed position in recent past. Little opportunity for growth of well established vegetation on the valley flat.

An indication of vertical stability in the reach may be obtained from the stability of a stage-discharge relation if there is one available in the reach.

Comments: Note the rate of lateral movement if it can be estimated from comparison between old and new photos or maps. Comment on representativeness of coding.

G.9 <u>Codes for Channel Banks and Bed</u>

This code applies to the channel bed and to those banks which are subject to attack by the river; that is, the banks below the valley flat or below the estimated two-year flood.

Alluvial bank material:

Code: 0 no alluvial bank material

1 clay and silt (cohesive)

2 silt and sand (non-cohesive)

3 sand to gravel (< 64 mm.)

4 sand to cobbles

5 sand overlain by silt

6 gravel overlain by silt

7 cobbles overlain by silt

Non-alluvial bank material: Rock types are not used, since one rock type may not always fall into the same category concerning erodibility.

Code: 0 alluvial bank material

1 lacustrine deposits

2 till

3 easily erodible rock: this code applies to rock types that weather into fine material and are relatively easily eroded. Weathered shale usually fits into this category.

4 moderately erodible rock

5 resistant rock: granites or hard sandstones fall into this category.

6 boulders

Length of river bank on left with alluvial banks (percent)

Length of river bank on right with alluvial banks (percent)

These estimates are best made during a field visit but rough estimates may be made from aerial photographs. The greatest difficulty arises with channels in the early stages of entrenchment. The appearance of the banks may not indicate that the base of the channel is cut in bed rock.

Bank vegetation: As above, this code also applies to the banks below the valley flat or below the level corresponding to the two-year flood. The code evaluates the importance of bank vegetation on the stability of the bank. No vegetation type is noted since there may be considerable variation in the vertical and between sections. Most emphasis should be placed on banks which are subject to some attack by the river.

Code: 0 none: no vegetation or no effective vegetation. Vegetation on the valley flat may offer little resistance to lateral development, unless it is deep-rooted.

1 weak: this could apply to sparse shrubs.

2 good

3 very strong: e.g. a dense growth of willows, or alders overhanging the channel. A well sodded bank may also fit here.

Predominant bed material type: This code categorizes the channels by the bed material type.

Code: 1 sand

2 sand with local gravel

3 gravel

4 gravel with local sand

5 sand and gravel

Depth of alluvium: In some cases a rough estimate of the depth of alluvium may be available from field observations or from test holes shown on bridge plans, etc. The depths are expressed in terms of the mean depth associated with a high flow (say bankfull discharge or a 10 year flood). The high flow does not have to be precisely defined for this evaluation.

Code: 0 no alluvium: stream essentially on bed rock through entire reach.

1 shallow: less than 1/2 times the estimated flood depth.

2 moderate: between 1/2 and 1-1/2 times the estimated flood depth.

3 deep: greater than 1-1/2 times the estimated flood depth.

Estimated depth of alluvium (feet):

Comments: The reference for the depth of alluvium should be noted along with any necessary qualifying statement.

B.10 Codes for Bed Rock Below Channel

Presence of rock outcrops in channel bed: The number of observed bedrock outcrops is coded. There may naturally be more outcrops than those noted.

Code: 0 none

1 one occurrence

2 two occurrences

(n) (n) occurrences

9 several occurrences

Bedrock type at channel base or below alluvium: This is a multiple code, with the dominant or first code applying to the actual outcrops if any. Otherwise, the codes apply to the bedrock under the alluvium if it is known.

Code: 0 not applicable: in this case the depth of alluvium is greater than about three times the 25-year flood depth.

1 compact clay

2 shale

3 limestone

4 sandstone

5 conglomerate

6 granite

Bedrock erodibility: This code describes the bedrock type in the above code.

Code: 0 not applicable

1 soft cohesive: this would apply to compact clays and to some types of shale.

2 easily erodible

3 moderately erodible

4 resistant

Comments: If the reach has been inspected in the field it should be possible to expand considerably on the above codes.

APPENDIX E

Example of an Extensive "Research" Level
Hydraulic/Morphologic Data Presentation (Bray, 1972)

APPENDIX E

EXAMPLE OF DATA FOR A TYPICAL REACH

H.1 General

The purpose of this appendix is to present an example of the general type of data available for a typical study reach used in this investigation. No discussion is presented to amplify the figures which are presented in this example. Additional information concerning some of the figures may be obtained by consulting other relevant appendices.

Only one example of each type of data is given, for instance, only one cross-section plot is shown. Not all reaches have exactly the same data available, but the example presented is typical.

H.2 Typical Data for a Reach

The reach used for this example is the Lobstick River near Styal. This reach was surveyed by the writer during the summer of 1970. The data for the reach are presented in the following order:

1. General Reach Data
    1. General data for reach.
    2. Topographic map of the reach and vicinity.
    3. Stereo-pair for reach (1" = 1320').
    4. Geographical description of reach and vicinity (2 coded sheets).
    5. Sketch map to show location of cross-sections, photographs, bed material samples, and geomorphic features.
2. Hydrologic Data
    1. Hydrometric station description (Water Survey of Canada).

2. Rating curve applicable for the date of survey (Water Survey of Canada).

3. Long-term mean discharges and flow duration data (Hydrology Branch, Water Resources Division, Alberta Department of the Environment).

4. Flood frequency data for hydrometric station.

5. Flood frequency plot.

3. Slope Data

 1. Comparison of photo distances and field distances.

 2. Data for water surface profile on date of survey.

 3. Plot of longitudinal water surface profile.

 4. Determination of topographic slope and summary of field slope data.

4. Hydraulic Geometry Data

 1. Typical cross-section plot.

 2. Estimation of average elevation of the low level bench.

 3. Estimation of average elevation of the valley flat.

 4. Extrapolation of the rating curve to the adopted elevation of the valley flat.

 5. Summary of stage-discharge relations for various characteristic discharges.

 6. Computer print-out of the hydraulic geometry data for a cross-section.

 7. Computer print-out of the average hydraulic geometry and characteristic flow parameters for the reach.

5. Supplementary Data

 1. Field check sheet for valley and channel data.

 2. Field check sheet for bank characteristics.

 3. Field notes, comments and further description of each cross-section.

 4. Typical field photographs on date of survey.

No bed material data are presented since a complete example of the method of recording and storing bed material data is given in APPENDIX D.

General Data for Reach

Reach Name: Lobstick River near Styal, Alberta

Research Council of Alberta Number: 116

Water Survey of Canada Code: 7BB003

Date of Survey:

Water Surface Profile 5 Jun. 1970
Stage: 1.66 ft.; Discharge: 50 cfs.

Cross-section: 8 Jun. 1970
Stage: 1.48 ft.; Discharge: 38 cfs.

Length of reach:	4491 ft.
Length below gauge:	2314 ft.
Number of cross-sections:	10
Drainage area above reach:	671 square miles
Long term mean discharge:	137 cfs. (11 yrs.)

Comments: The reach is located about 5 valley miles upstream from its confluence with the Pembina River. There is natural storage upstream, as the river is the outlet from Chip Lake.

FIGURE H.1 GENERAL DATA FOR REACH

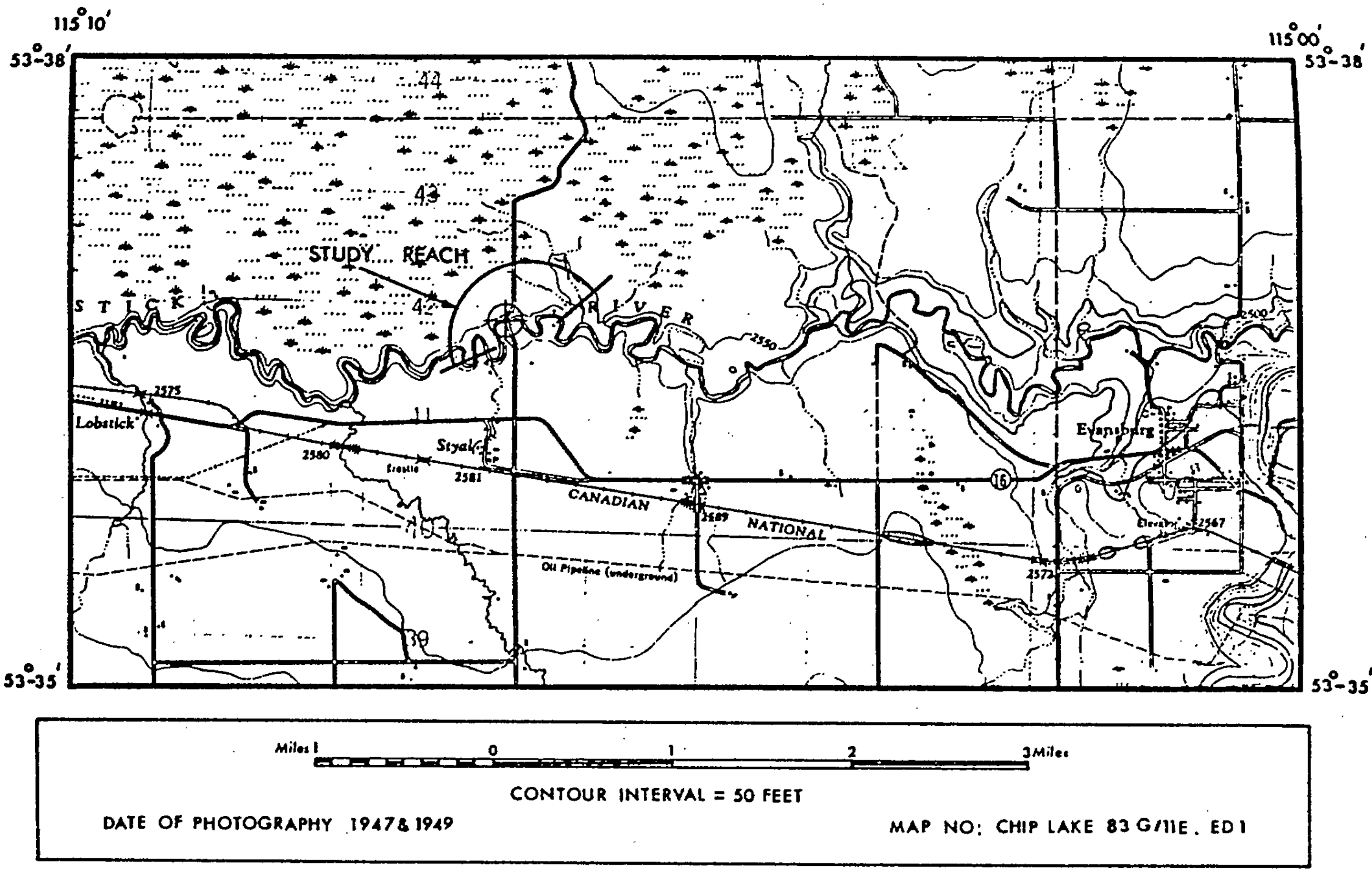


FIGURE H.2 TOPOGRAPHIC MAP OF REACH AND VICINITY

SCALE: 0 1320 2640 3960 5280 ft.

REACH: LOBSTICK RIVER NEAR STYAL RCA # 116

FIGURE H.3 STEREO TRIPLET OF STUDY REACH AND VICINITY.

RESEARCH COUNCIL OF ALBERTA
HIGHWAY AND RIVER ENGINEERING DIVISION
UNIVERSITY OF ALBERTA
DEPARTMENT OF CIVIL ENGINEERING

RIVER DATA SHEET No. Geog. 1/71

GEOGRAPHIC FEATURES

Reach Name: LOBSTICK R. NR. STYAL Reach No: 116 Date of Analysis: 9 MAR 1971 Analysis By: D.I.BRAY
Scale of Air Photos: 1" = 1320' Scale of Map: 1:50,000

NOTE: Complete codes by circling the appropriate number(s). Use "-1" for "unknown" and "0" for "not applicable".

General Description of the Terrain in the Vicinity of the Surveyed Reach, above Valley

Terrain:
1 mountainous
2 foothills
3 uplands
4 hills
(5) plains
6 lowlands

Vegetation:
0 0 0 not applicable
1 1 1 almost none
2 2 (2) grass
3 3 3 shrubs
4 4 4 sparsely forested, 0-25%
(5) 5 5 moderately forested, 25-75%
6 6 6 heavily forested, 75-100%
7 (7) 7 swamp or muskeg

Forest type:
0 (0) (0) not applicable
(1) 1 1 deciduous
2 2 2 coniferous

Comments: ____________

Land use:
0 (0) no cultivation or built-up area
(1) 1 partly cultivated
2 2 mainly cultivated
3 3 partly built-up
4 4 urbanized

Surficial geology:
1 1 1 bedrock
2 2 2 ground moraine
(3) 3 3 hummocky moraine
4 4 4 lacustrine deposits
5 5 5 glacio-fluvial dep.
6 6 6 fluvial deposits
7 7 7 aeolian deposits

Valley Characteristics above Valley Flat

Valley measurements:
✓ within reach
___ within reach and immediate vicinity
depth: 50 ft.
top width: 0.20 mi.
bottom width: 0.04 mi.

Slumping of valley walls:
(0) none
1 occasional
2 frequent

Length of reach with slumping valley walls (contact length in percent of total length of banks): 0

Vegetation on valley wall:
0 0 not applicable
1 1 almost none
2 2 grass
3 3 shrubs
4 4 sparsely forested
(5) (5) moderately forested
6 6 heavily forested
7 7 swamp or muskeg

Forest type on valley wall:
0 0 not applicable
1 (1) deciduous
(2) 2 coniferous

Comments: ____________

Terraces

Terrace presence:
0 none
1 indefinite
(2) fragmentary
3 continuous

Number of levels:
0 not applicable
1 one level
2 two levels
__ ___ levels
(9) several levels

Comments (in particular land use and vegetation): ____________

Relation of Channel to Valley

Valley type:
0 not applicable
(1) stream cut valley
2 stream cut valley in wide valley
3 wide mountainous valley

If no valley:
(0) valley present
1 on alluvial fan
2 on alluvial plain
3 in delta
4 in old lake

Underfit:
(0) not applicable or not obviously underfit
1 obviously underfit

Local lateral constriction:
(0) none
1 one
2 two
___ cases
9 several cases

Relation of channel to valley bottom (vertical):
0 not applicable
1 not obviously degrading or aggrading
(2) partly entrenched
3 entrenched
4 aggrading

Relation of channel to valley walls or to high, resistant terraces (lateral):
0 not applicable (no valley or free)
1 occasionally confined
2 frequently confined
(3) confined
4 entrenched

Comments: ____________

FIGURE H.4 GEOGRAPHICAL DESCRIPTION OF TERRAIN AND RELATION OF CHANNEL TO VALLEY

RESEARCH COUNCIL OF ALBERTA
HIGHWAY AND RIVER ENGINEERING DIVISION
UNIVERSITY OF ALBERTA
DEPARTMENT OF CIVIL ENGINEERING

RIVER DATA SHEET No. Geog. 2/71

GEOGRAPHIC FEATURES - (Cont'd.)

Reach Name: LOBSTICK RIVER NEAR STYAL, ALTA. Reach No: 116

Description of Valley Flat

Presence:
0 none
1 indefinite
2 fragmentary
3 continuous

Extent:
0 none
1 narrow (< 1 Ws)
2 moderate (1-5 Ws)
3 wide (> 5 Ws)

Average width 0.02 mi.
Maximum width 0.04 mi.
Channel length with valley flat on left 30 %
on right 50 %

Vegetation:
0 0 not applicable
1 1 almost none or bare
2 2 grass
3 3 shrubs
4 4 sparsely forested
5 5 moderately forested
6 6 heavily forested
7 7 swamp or muskeg

Forest type:
0 0 not applicable
1 1 deciduous
2 2 coniferous

Land use:
0 0 not cultivated, not built-up
1 1 partly cultivated
2 2 mainly cultivated
3 3 partly built-up
4 4 mainly built-up

Comments: VALLEY FLAT OF LIMITED EXTENT

Channel Description (near long-term mean)

Channel pattern:
1 straight
2 sinuous
3 irregular
4 regular meanders
5 irregular meanders
6 tortuous meanders

Islands:
0 none
1 occasional
2 frequent
3 split
4 braided

Type of flow:
1 uniform water surface
2 uniform with rapid in reach
3 uniform with boils and irregularities
4 pool and riffle sequence
5 tumbling flow

Bar type:
0 0 0 none
1 1 1 point bars
2 2 2 side bars
3 3 3 mid-channel bars
4 4 4 diagonal bars
5 5 5 large dunes

Meander dimensions:
belt width 0.15 mi.
wave length 0.20 mi.
sinuosity 1.20

Natural obstructions:
0 0 none
1 1 logs
2 2 beaver dams
3 3 boulders (lag material)
4 4 vegetation

Degree of obstruction:
0 0 none
1 1 occ. minor
2 2 occ. major
3 3 frequent minor
4 4 frequent major

Comments:

Lateral Channel Activity

Lateral activity:
0 not detectable
1 downstream progression
2 progression and cut-offs
3 mainly cut-offs
4 entrenched loop development
5 laterally active but not 1-4

Lateral stability:
0 stable
1 slightly unstable
2 moderately unstable
3 highly unstable

Comments:

Channel Banks and Bed

Alluvial bank material:
0 0 0 no alluvial banks
1 1 1 clay and silt (cohesive)
2 2 2 silt and sand (non-cohesive)
3 3 3 sand and gravel (< 64 mm)
4 4 4 sand to cobbles
5 5 5 sand overlain by silt
6 6 6 gravel overlain by silt
7 7 7 cobbles overlain by silt

Non-alluvial bank material:
0 0 0 alluvial bank material
1 1 1 lacustrine deposits
2 2 2 till
3 3 3 easily erodible rock
4 4 4 moderately erodible rock
5 5 5 resistant rock
6 6 6 boulders

Percentage of left bank in alluvium 80 %
Percentage of right bank in alluvium 80 %

Bank vegetation:
0 none
1 weak
2 good
3 very strong

Predominant bed material:
1 sand
2 sand with local gravel
3 gravel
4 gravel with local sand
5 sand and gravel

Depth of alluvium:
0 no alluvium
1 shallow
2 moderate
3 deep
-1

Estimated depth of alluvium — ft.

Reference or comments:

Bed Rock Below Channel

Presence of rock out-crops in channel bed:
0 none
1 one occurrence
2 two occurrences
____ occurrences
5 several occurrences

Rock type at channel base:
0 0 0 not applicable (none for great depth)
1 1 1 compact clay
2 2 2 shale
3 3 3 limestone
4 4 4 sandstone
5 5 5 conglomerate
6 6 6 granite
7 7 7 ________
-1

Erodibility:
0 0 0 not applicable
1 1 1 soft cohesive
2 2 2 easily erodible
3 3 3 moderately erodible
4 4 4 resistant
-1

Comments:

FIGURE H.5 GEOGRAPHIC FEATURES RELATED TO THE VALLEY FLAT AND THE CHANNEL BED AND BANKS

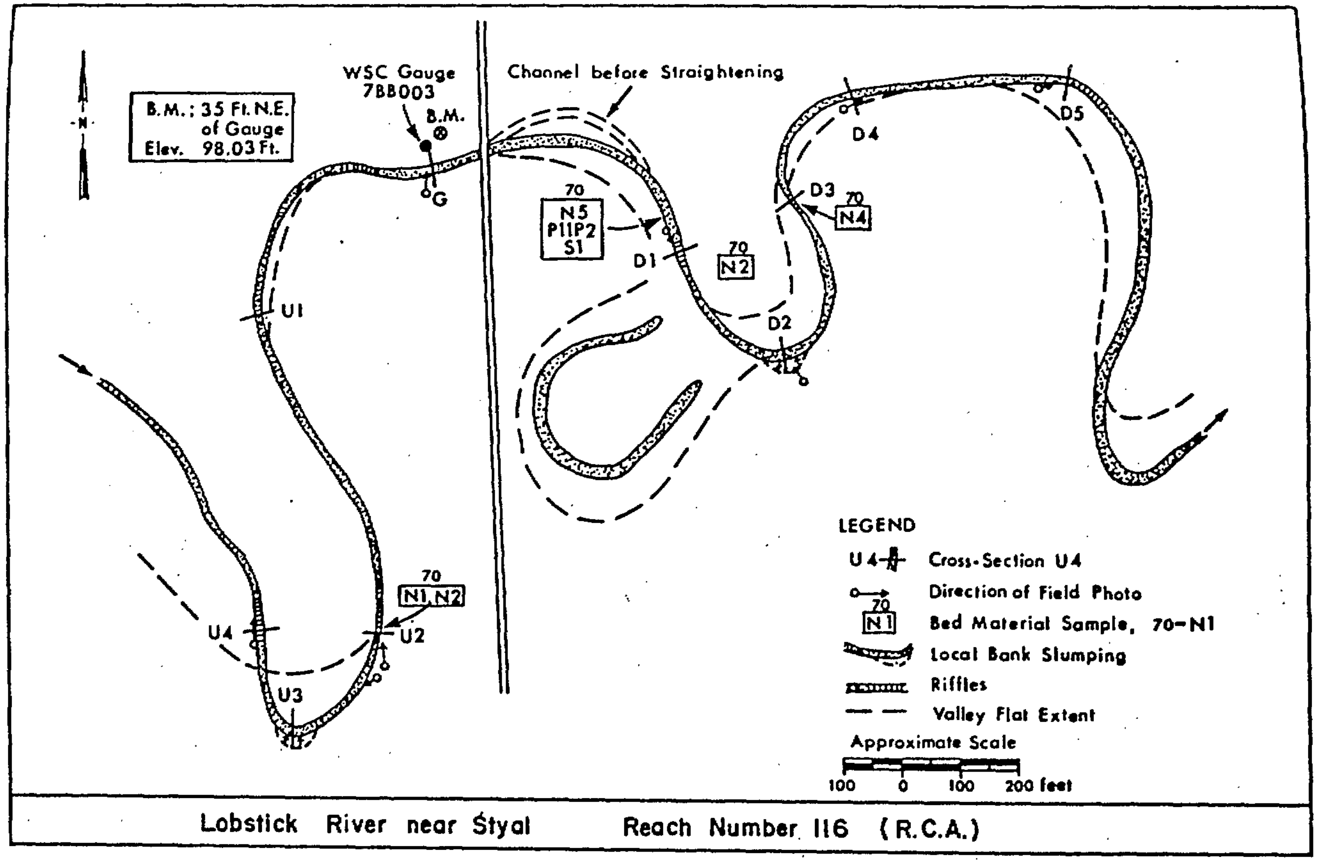


FIGURE H.6 SKETCH MAP SHOWING LOCATION OF CROSS-SECTIONS, FIELD PHOTOGRAPHS, BED-MATERIAL SAMPLE SITES, AND GEOMORPHIC FEATURES

DEPARTMENT OF NORTH... AFFAIRS AND NATIONAL RESOURCES ... WATER RESOURCES BRANCH

1968

STATION DESCRIPTION FOR PUBLICATION

Station No.

Lobstick River near Styal 07BB003

Location: Lat. 53° 36' 45", long. 115° 06' 20", Alberta, in NE. ¼ sec. 28, tp. 53, rge. 8, W. 5th Mer., about four miles above confluence with Pembina River twelve miles downstream from Chip Lake and one mile north of Styal.

Drainage Area: 671 square miles.

Gauge: Recording installed November, 1966, about twenty feet below former manual gauge location.

Period of Record: Continuous January, 1955, to December, 1968; miscellaneous measurements in 1954.

Mean Discharge: (12 years) 133 cfs.

Extremes Recorded:

Maximum	Daily	June 29, 1965 (g.h. 9.22)	3,380 cfs.
Minimum	Daily	At various times	0 cfs.

Revisions:

Remarks: Records good. During the period 1913 to 1923, data were collected at a site near the confluence with Pembina River, about four miles downstream, and published under the title "Lobstick River near Entwistle".

FIGURE H.7 HYDROMETRIC STATION DESCRIPTION

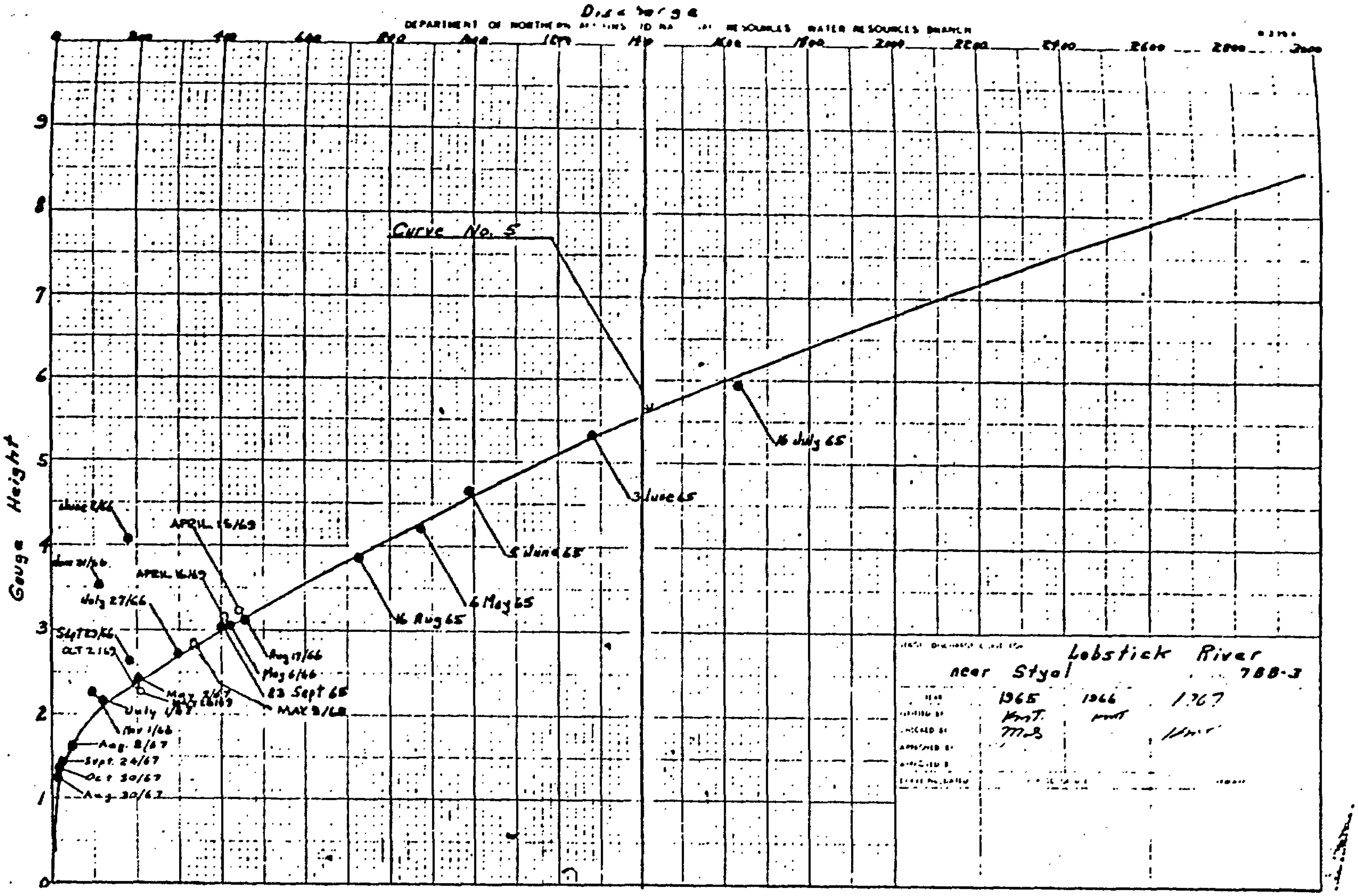


FIGURE H.8 RATING CURVE APPLICABLE FOR DATE OF SURVEY

FLOW DURATIONS FOR STATION 07BB003

LOBSTICK RIVER NEAR STYAL
NO. OF YEARS OF RECORD 14
DRAINAGE AREA 671.0 SQ.MS.

	COMPLETE PERIODS	MEAN	FREQUENCIES .0010	.0050	.0100	.0200	.0500	.1000	.2000	.5000	.9000	.9500	.9900
JAN-DEC CFS	11	136.5	1880.0	1280.0	1050.0	778.0	532.0	338.0	167.0	74.0	6.3	0.0	0.0
% OF MEAN			1377.6	937.9	769.4	570.1	389.8	247.7	122.4	54.2	4.6	0.0	0.0
MAR-OCT CFS	12	171.6	1880.0	1260.0	1010.0	732.0	505.0	323.0	156.0	51.0			
% OF MEAN			1095.5	734.2	588.6	426.6	294.3	188.2	90.9	29.7			
APR-OCT CFS	12	189.1	1880.0	1260.0	1010.0	732.0	505.0	322.0	154.0	41.3			
% OF MEAN			994.0	666.2	534.0	387.0	267.0	170.2	81.4	21.8			
MAY-SEP CFS	13	193.0	1760.0	1190.0	927.0	684.0	422.0	248.0	108.0				
% OF MEAN			911.7	616.4	480.2	354.3	218.6	128.5	55.9				
JUN-SEP CFS	13	165.6	1760.0	1190.0	884.0	525.0	282.0	140.0	65.4				
% OF MEAN			1063.0	718.7	533.9	317.1	170.3	84.6	39.5				

Source: Water Resources Division,
Alberta Department of the Environment

FIGURE H.9 LONG-TERM MEAN DISCHARGES AND FLOW DURATION DATA

#116 LOBSTICK RIVER NEAR STYAL 7BB003

ANALYSIS USES ANNUAL MAXIMUM DAILY MEAN DISCHARGES

BASIC DATA AND TRANSFORMATIONS OF ORDERED DATA

YEAR	FLOW,CFS	CODE	**	ORD	YEAR	PROB	TR,YRS	X	LOG10(X)	X**0.33
1915	723.0	0	**	1	1965	0.048	21.00	3380.0	3.529	15.007
1916	1071.0	0	**	2	1920	0.095	10.50	2690.0	3.430	13.907
1917	2014.0	0	**	3	1917	0.143	7.00	2014.0	3.304	12.628
1918	373.0	0	**	4	1916	0.190	5.25	1071.0	3.030	10.231
1919	283.0	0	**	5	1921	0.238	4.20	874.0	2.942	9.561
1920	2690.0	0	**	6	1963	0.286	3.50	840.0	2.924	9.435
1921	874.0	0	**	7	1915	0.333	3.00	723.0	2.859	8.975
1922	294.0	0	**	8	1962	0.381	2.62	686.0	2.836	8.819
1956	662.0	0	**	9	1956	0.429	2.33	662.0	2.821	8.715
1957	239.0	0	**	10	1967	0.476	2.10	662.0	2.821	8.715
1958	510.0	0	**	11	1966	0.524	1.91	620.0	2.792	8.527
1959	151.0	0	**	12	1964	0.571	1.75	559.0	2.747	8.237
1960	427.0	0	**	13	1958	0.619	1.62	510.0	2.708	7.989
1961	170.0	0	**	14	1960	0.667	1.50	427.0	2.630	7.530
1962	686.0	0	**	15	1918	0.714	1.40	373.0	2.572	7.198
1963	840.0	0	**	16	1922	0.762	1.31	294.0	2.468	6.649
1964	559.0	0	**	17	1919	0.810	1.24	283.0	2.452	6.565
1965	3380.0	0	**	18	1957	0.857	1.17	239.0	2.378	6.206
1966	620.0	0	**	19	1961	0.905	1.11	170.0	2.230	5.540
1967	662.0	0	**	20	1959	0.952	1.05	151.0	2.179	5.325
							MEAN =	861.4	2.783	8.788

FIGURE H.10 FLOOD REQUENCY DATA FOR HYDROMETRIC STATION

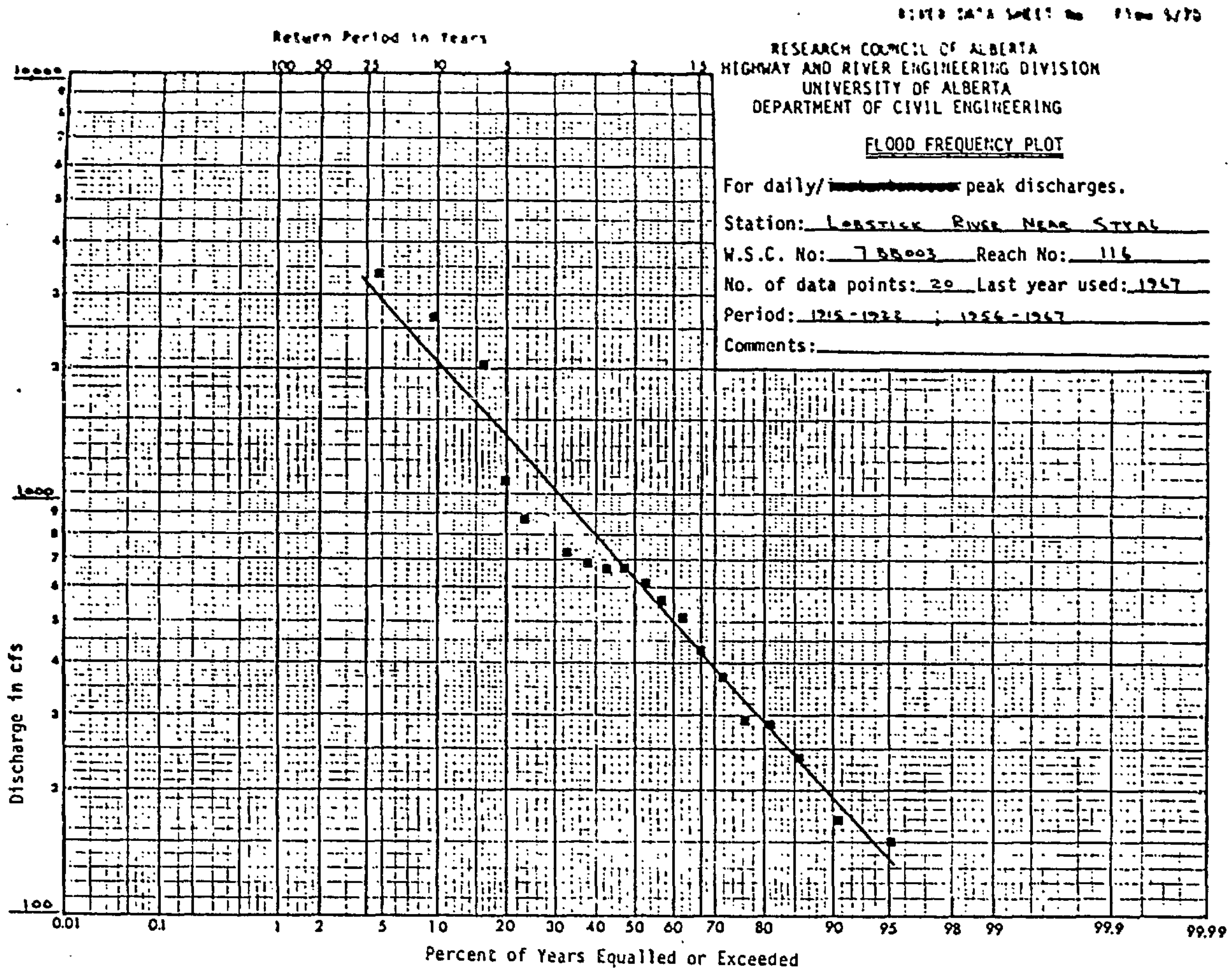


FIGURE H.11 LOG-NORMAL FLOOD FREQUENCY PLOT

RESEARCH COUNCIL OF ALBERTA
HIGHWAY AND RIVER ENGINEERING DIVISION
UNIVERSITY OF ALBERTA
DEPARTMENT OF CIVIL ENGINEERING

RIVER DATA SHEET No.
Slope 1/70

DATA FOR SLOPE DETERMINATION

Reach Name: Lobstick River near Styal Reach No. 116

Date of Survey: 5 June 1970 Analysis By: D.I. Bray

COMPARISON OF PHOTO DISTANCES AND FIELD DISTANCES

Photograph No.: c 61.22.610 - 5324 YC 446A - 63

Map Name: Chip Lake Scale: 1:50000 Date of Map: 1960

Distance on Map Between Reference Points = 1.52 ins. (6320 ft.)

Distance on Photo Between Reference Points = 4.70 ins.

Scale for Photograph: 1.00 inch on Photo = 1345 ft. on Ground

0.10 inch on Photo = 134 ft. on Ground

Stations	Distance on photo in 0.10" units	Distance from photo, ft.	Distance from stadia, ft.	Comment
U5 - U4				
U4 - U3	2.4	322	474	
U3 - U2	3.1	415	372	
U2 - U1	4.5	603	512	
U1 - G	4.6	616	819	
G - D1	6.3	845	639	
D1 - D2	3.1	415	404	
D2 - D3	3.6	482	484	
D3 - D4	2.9	388	314	
D4 - D5	3.1	415	473	
	Σ	4501	4491	

Percent Difference in Distance (Stadia Basis)

$$= \frac{4501 - 4491}{4491} \times 100 = \frac{1000}{4491}$$

$$= 0.2 \%$$

Comments:

FIGURE H.12 COMPARISON OF PHOTO AND FIELD DISTANCES

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UNIVERSITY OF ALBERTA
DEPARTMENT OF CIVIL ENGINEERING

RIVER DATA SHEET No.
Slope 2/70

DATA FOR WATER SURFACE PROFILE ON DATE OF SURVEY

Reach Name: LOBSTICK RIVER NEAR STYAL Reach No. 116

Date of Survey: 5 JUNE 1970 Surveyed By: D.I. BRAY

Stage: 1.66 FT. Discharge: 50 CFS.

Cross-section	Elevation of W.S. ft.	Stadia distance ft.	Accumulated distance ft.	Accumulated distance from gauge	Comments
U4	89.50		0	2177	IN RAPID
	89.18	120	120	2057	BOT. RAPID
U3	89.10	354	474	1703	
U2	88.95	372	846	1331	20' U/S OF TOP OF RAPID
	88.57	120	966	1211	BOT. RAPID
U1	88.10	392	1358	819	
	88.10	100	1458	719	TOP. RAPID
	86.77	100	1558	619	BOT. RAPID
	86.76	429	1987	190	TOP RAPID
	86.42	50	2037	140	BOT. RAPID
G	86.41	140	2177	0	
	86.07	619	2796	619	TOP RAPID
D1	85.85	20	2816	639	IN RAPID
	85.39	60	2876	699	BOT. RAPID
D2	84.97	344	3220	1043	
	84.71	444	3664	1487	TOP RAPID
D3	84.24	40	3704	1527	BOT. RAPID
D4	84.22	314	4018	1841	
D5	83.75	473	4491	2314	

Comments: POOL AND RIFFLE SEQUENCE

FIGURE H.13 DATA FOR WATER SURFACE PROFILE

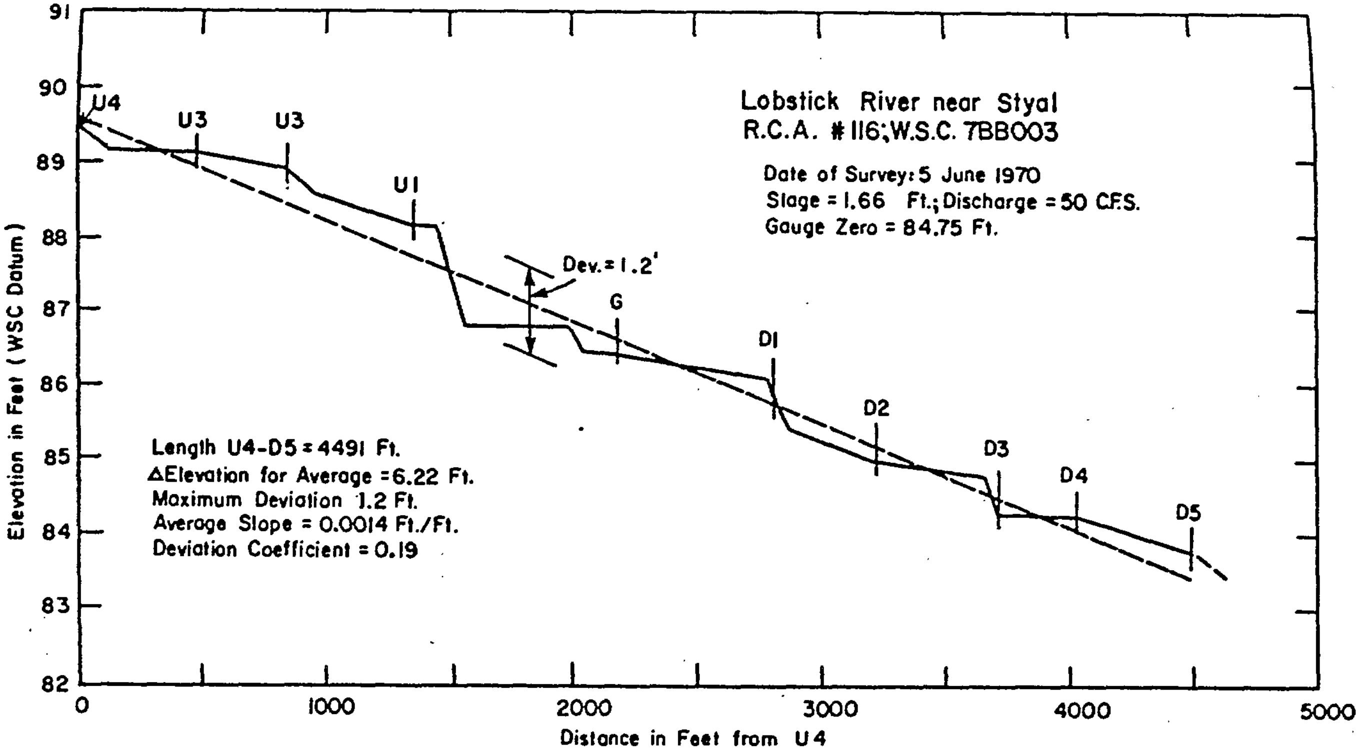

FIGURE H.14 PLOT OF LONGITUDINAL WATER SURFACE PROFILE

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UNIVERSITY OF ALBERTA
DEPARTMENT OF CIVIL ENGINEERING

RIVER DATA SHEET No.
Slope 3/70

DETERMINATION OF TOPOGRAPHIC SLOPE

Reach Name: Lobstick River near Styal Reach No. 116

Analysis By: D.I. Bray Date: 2 Sep 1970

Map Name(s) Chip Lake Number 83G/11E Scale 1:50000 Date 1960

Number ____ Scale ____ Date ____

Contour ft.		River distance ft.		Valley distance ft.
2250		63,900		
2200				

Topographic Slope = (2250 − 2200) / 63,900 = 0.00072 %; Sinuosity (for reach) = 4491 / 2370 = 1.90

SUMMARY OF FIELD SLOPE DATA

Field Distance: 1. By Tape ② By Stadia

Vertical Control: ① Levelling 2. Photogrammetry 3. Maps

Shape of Water Surface Profile:

1. Very close to average ② Moderately close to average
3. Not very close to average but acceptable

First and Last X-sections in Reach Used to Obtain Slope = U4 − D5

Distance Between First and Last X-sections = 4491 Ft.

Vertical Difference for Average Slope = 6.22 Ft.

Maximum Deviation from Average Slope = 2.2 Ft

Average Slope for Reach = 0.0014 Ft/Ft

Comments: Slope is flatter above reach. Greatest portion of length used to determine slope was above reach. Sinuosity is for reach.

FIGURE H.15 DETERMINATION OF TOPOGRAPHICS SLOPE AND SUMMARY OF FIELD SLOPE DATA

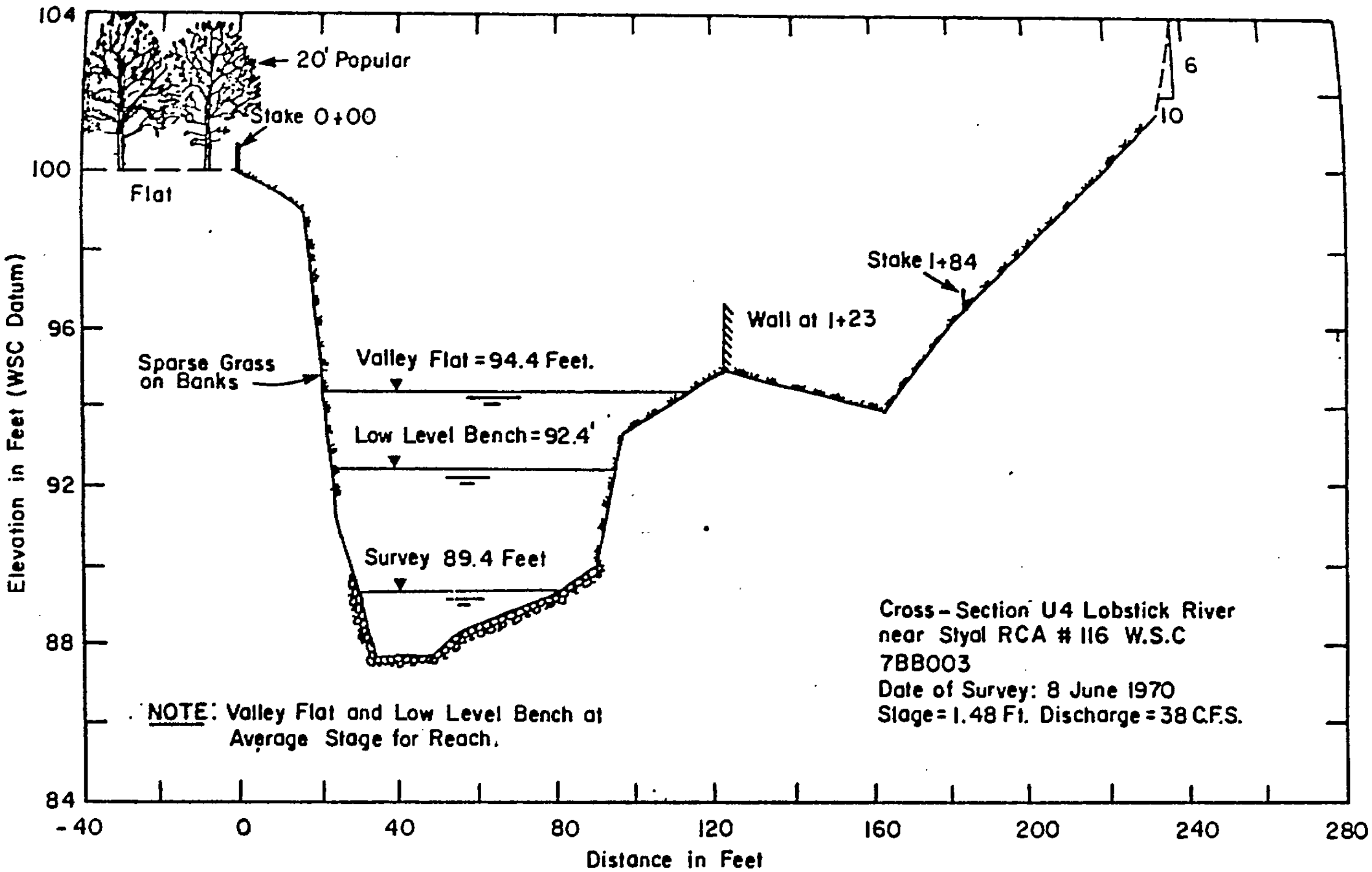

FIGURE H.16 TYPICAL CROSS-SECTION PLOT

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DEPARTMENT OF CIVIL ENGINEERING

RIVER DATA SHEET No.
Flow 1/70

ESTIMATION OF BANKFULL DISCHARGE FOR REACH

Reach Name: Lobstick River near Styal Reach No.: 116

Date of Survey of X-Sections: 8 Jun 1970

Analysis: By D.L. Bray Date: 3 Sep 1970

Bankfull: (1) Low level bench 2. Trim line 3. Major valley flat

Section	Elevation at bankfull ft.	W.S. elev. on day of survey ft.	Difference in elevation ft.	W.S. elevation for estimated bankfull ft.	Comment
U4	—	89.4	—	92.4	No LL bench
U3	—	89.0	—	92.0	"
U2	—	88.8	—	91.8	"
U1	91.2	87.9	3.3	90.9	
G	89.3	86.2	3.1	89.2	
D1	88.8	85.6	3.2	88.6	
D2	—	84.7	—	87.7	No LL bench
D3	86.4	84.1	2.3	87.1	
D4	86.6	84.1	2.5	87.1	
D5	86.8	83.7	3.1	86.7	
		Σ	17.5		

Average Difference in Elevation 2.91 ft.

Accepted Difference in Elevation for Bankfull 3.00 ft.

Stage at Gauge on Date of Survey 1.48 ft.

Stage at Gauge Corresponding to Bankfull 4.48 ft.

Discharge Corresponding to Bankfull 960 cfs.

Return Period Associated with Bankfull Discharge 3.1 yrs.

Rating Curve: Curve No. 5 ; Most recent point 1969; Max. stage obs. 5.95 ft.

Frequency Curve: No. of years of data 20 ; Last year used 1967

Comments:

FIGURE H.17 ESTIMATION OF AVERAGE ELEVATION OF THE LOW LEVEL BENCH

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UNIVERSITY OF ALBERTA
DEPARTMENT OF CIVIL ENGINEERING

RIVER DATA SHEET No.
Flow 1/70

ESTIMATION OF BANKFULL DISCHARGE FOR REACH

Reach Name: Lobstick River Near Styal Reach No.: 116

Date of Survey of X-Sections: 8 Jun 1970

Analysis: By D. I. Bray Date: 4 Dec 1970

Bankfull: 1. Low level bench 2. Trim line ③ ~~Major~~ Valley flat

Section	Elevation at bankfull ft.	W.S. elev. on day of survey ft.	Difference in elevation ft.	W.S. elevation for estimated bankfull ft.	Comment
U4	94.0	89.4	4.6	94.4	Wall @ 1+23
U3	—	89.0	—	94.0	Wall @ 0+15
U2	94.6	88.8	5.8	93.8	
U1	93.2	87.9	5.3	92.9	
G	—	86.2	—	91.2	
D1	92.2	85.6	6.6	90.6	
D2	—	84.7	—	89.7	Wall @ 0+44
D3	88.4	84.1	4.3	89.1	Wall @ 0+48
D4	89.4	84.1	5.3	89.1	
D5	90.0	83.7	6.3	88.7	
			Σ 38.2		

Average Difference in Elevation 5.46 ft.

Accepted Difference in Elevation for Bankfull 5.00 ft.

Stage at Gauge on Date of Survey 1.48 ft.

Stage at Gauge Corresponding to Bankfull 6.48 ft.

Discharge Corresponding to Bankfull 1950 cfs.

Return Period Associated with Bankfull Discharge 2.1 yrs.

Rating Curve: Curve No. 5 ; Most recent point 1969 ; Max. stage obs. 5.95 ft.

Frequency Curve: No. of years of data 20 ; Last year used 1967

Comments: Maximum depth of water at any wall = 0.3 ft.

FIGURE H.18 ESTIMATION OF THE AVERAGE ELEVATION OF THE VALLEY FLAT

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DEPARTMENT OF CIVIL ENGINEERING

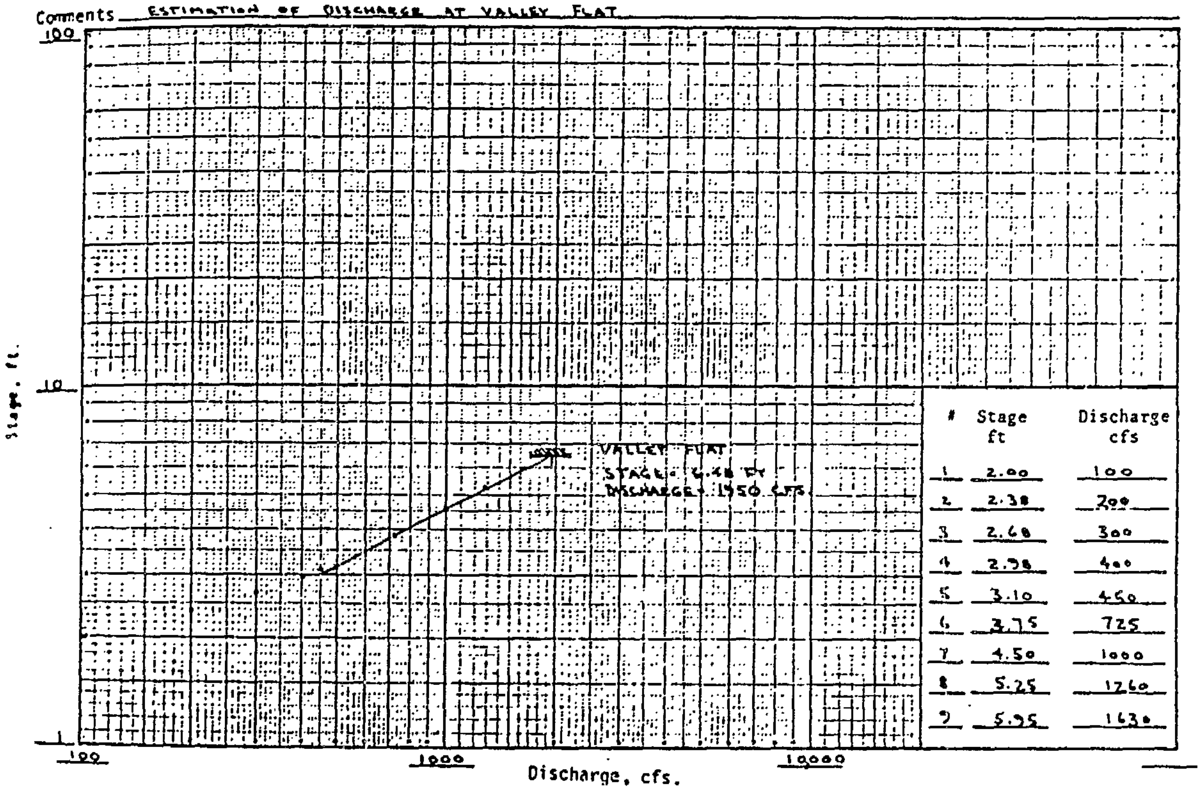
RIVER DATA SHEET No: Flow 4/70

STAGE-DISCHARGE CURVE

Station: LOBSTICK RIVER NEAR STYAL W.S.C. No: 7BB 003 Reach No: 116

Rate Curve No: 5 ; Date of Most Recent Measurement 1962 ; Max. Observed Discharge: 1630 cfs

Comments ESTIMATION OF DISCHARGE AT VALLEY FLAT



#	Stage ft	Discharge cfs
1	2.00	100
2	2.38	200
3	2.68	300
4	2.98	400
5	3.10	450
6	3.75	725
7	4.50	1000
8	5.25	1260
9	5.95	1630

FIGURE H.19 EXTRAPOLATION OF THE RATING CURVE TO THE ADOPTED ELEVATION OF THE VALLEY FLAT

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DEPARTMENT OF CIVIL ENGINEERING

RIVER DATA SHEET No.
Flow 2/70

STAGE-DISCHARGE RELATIONSHIPS FOR REACH

River Reach: LOBSTICK RIVER NEAR STYAL, ALTA Reach No. 116

Date of Survey: 8 JUN 1970 Analysis By: D.I. BRAY

Date of Rating Curve: 1967 - 1970 Curve No. C5
(Date Closest to Survey)

Stability of Rating Curve:
- (1.) Stable for entire range of flows (circled)
- 2. Unstable for low flows only
- 3. Unstable for high flows only
- 4. Unstable for all flows

Degree of Stability:
- 1. Highly stable
- (2) Slightly unstable (circled)
- 3. Moderately unstable
- 4. Highly unstable

Elevation of Gauge Zero = 84.75 ft.; approximate Gauge at Zero Flow = 0.1 ft.

Discharge level	Discharge (cfs)	Stage (ft.)	Elevation (ft.)	Comment
Date of survey of X-sect.	38	1.48	86.23	
Long-term mean (full year)	137	2.16	86.91	
Long-term mean (Mar.-Oct.)	172			
Long-term mean (Apr.-Oct.)	189	2.36	87.11	
1.5 year flood (DAILY)	420	3.05	87.80	
2 year flood (DAILY)	620	3.71	88.46	
5 year flood (DAILY)	1360	5.53	90.28	
10 year flood (DAILY)	2060	—	—	ABOVE VALLEY FL.
25 year flood (DAILY)	3200	—	—	ABOVE VALLEY FL.
50 year flood ( )	—	—	—	
100 year flood ( )	—	—	—	
0.5% flow dur. (APR.-OCT)	1260	5.32	90.07	
1% flow dur. (APR.-OCT)	1010	4.75	89.50	
5% flow dur. (APR.-OCT)	505	3.35	88.10	
10% flow dur. (APR.-OCT)	322	2.80	87.55	
50% flow dur. (APR.-OCT)	41			Return Period
Low Level Bench	960	4.63	89.38	3.7 yrs.
Trim Line	—	—	—	— yrs.
Major Valley Flat	1950	6.48	91.23	9.1 yrs.

Comments: ______

FIGURE H.20 SUMMARY OF STAGE-DISCHARGE RELATIONS FOR VARIOUS CHARACTERISTIC DISCHARGES

116 LOBSTICK RIVER NEAR STYAL   WATER SURVEY CODE: 78B03

CROSS-SECTION DATA FOR X-SECTION U4   DATE OF SURVEY: 8JUN70

X	Y	X	Y	X	Y	X	Y	X	Y
0.0	100.1	11.0	99.1	23.0	92.3	25.0	91.2	31.0	89.4
35.0	87.7	49.0	87.8	58.0	88.5	81.0	89.4	91.0	90.1
98.0	93.4	123.0	95.0	165.0	93.9	184.0	96.5		

SECTION PROPERTIES FOR X-SEC U4 : WALLS AT -999. 123. -999. -999. FOR ALL FLOWS

FLOW	WS.EL.	CODE	AREA	WS	WP	DM	RH	DMAX	VM	WS/WP	DM/RH	DMAX/DM	WS/DM
38.	89.40	SURVEY	48.	50.	50.	0.96	0.95	1.70	0.79	0.99	1.01	1.77	52.0
137.	90.08	LTM:YEAR	86.	62.	62.	1.39	1.38	2.38	1.59	0.99	1.01	1.71	44.6
189.	90.28	LTM:4-10	99.	63.	64.	1.56	1.55	2.58	1.91	0.99	1.01	1.65	40.6
420.	90.97	1.5YR FL	144.	67.	68.	2.14	2.12	3.27	2.92	0.99	1.01	1.53	31.3
620.	91.63	2 YR FL	189.	70.	71.	2.70	2.66	3.93	3.27	0.98	1.02	1.46	25.9
1360.	93.45	5 YR FL	323.	78.	80.	4.15	4.05	5.75	4.21	0.97	1.03	1.38	18.7
1260.	93.24	0.5% DUR	307.	76.	78.	4.02	3.92	5.54	4.11	0.98	1.03	1.38	19.0
1010.	92.67	1% DUR	264.	74.	76.	3.57	3.49	4.97	3.82	0.98	1.02	1.39	20.8
505.	91.27	5% DUR	164.	69.	70.	2.39	2.36	3.57	3.08	0.99	1.01	1.49	28.7
322.	90.72	10% DUR	127.	66.	66.	1.93	1.91	3.02	2.53	0.99	1.01	1.56	34.0
960.	92.55	LL BENCH	255.	74.	75.	3.47	3.39	4.85	3.76	0.98	1.02	1.40	21.2
1950.	94.40	VAL FLAT	405.	94.	97.	4.29	4.19	6.70	4.82	0.98	1.02	1.56	22.0

1. All units are ft-lb-sec units.

Note: This cross-section (U4) is the same as that used for the typical cross-section plot in FIGURE H.16.

FIGURE H.21 COMPUTER PRINT-OUT OF THE HYDRAULIC GEOMETRY FOR A CROSS-SECTION

• 116 LCRSTICK RIVER NEAR STYAL WATER SURVEY CODE: 78803

• 116 DATE OF SURVEY 8JUN70 STAGE FOR SURVEY = 1.48 FT.
LIMITING STAGE FOR ANALYSIS = 6.48 FT.

• 116 RATING CURVE: C5 1967; GAUGE ZERO = 84.75 FT.

STAGE	Q	STAGE	Q	STAGE	Q	STAGE	Q	STAGE	Q
1.25	20.	2.40	200.	3.05	420.	6.00	1600.	6.48	1950. *

SUMMARY FOR REACH: NUMBER OF X-SEC = 10 SLOPE FOR REACH = 0.001400 FT/FT.
X-SECTIONS USED: U4, U3, U2, U1, G, 01, 02, 03, 04, 05

FLOW	STAGE	CODE	AREA	CVA	WS	CVWS	DM	WS/DM	VM
38.	1.48	SURVEY	91.	0.44	56.	0.12	1.62	34.7	0.42
137.	2.16	LTM:YEAR	131.	0.30	62.	0.10	2.12	29.2	1.05
189.	2.36	LTM:4-10	144.	0.27	63.	0.10	2.28	27.8	1.31
420.	3.05	1.5YR FL	189.	0.21	67.	0.10	2.80	24.0	2.22
620.	3.71	2 YR FL	235.	0.17	71.	0.10	3.30	21.6	2.64
1360.	5.53	5 YR FL	377.	0.13	87.	0.15	4.34	20.0	3.61
1260.	5.32	0.5% DUR	359.	0.13	85.	0.15	4.23	20.1	3.51
1010.	4.75	1% DUR	313.	0.14	79.	0.14	3.96	20.0	3.23
505.	3.35	5% DUR	209.	0.19	69.	0.10	3.03	22.8	2.41
322.	2.80	10% DUR	172.	0.23	66.	0.10	2.61	25.2	1.87
960.	4.63	LL BENCH	303.	0.14	78.	0.14	3.90	19.9	3.17
1950.	6.48	VAL FLAT	464.	0.12	96.	0.13	4.82	20.0	4.20

FLOW	CODE	V*	V/V*	TAU	N	V**2/D	V**3/WS	WS/D**.5
38.	SURVEY	0.27	1.54	0.142	0.184	0.11	0.00	9.12
137.	LTM:YEAR	0.31	3.38	0.185	0.088	0.52	0.02	5.29
189.	LTM:4-10	0.32	4.10	0.199	0.074	0.76	0.04	4.60
420.	1.5YR FL	0.36	6.25	0.245	0.050	1.76	0.16	3.29
620.	2 YR FL	0.39	6.84	0.288	0.047	2.11	0.26	2.86
1360.	5 YR FL	0.44	8.16	0.379	0.041	3.00	0.54	2.35
1260.	0.5% DUR	0.44	8.04	0.369	0.042	2.92	0.51	2.39
1010.	1% DUR	0.42	7.65	0.346	0.043	2.64	0.43	2.49
505.	5% DUR	0.37	6.53	0.264	0.048	1.92	0.20	3.08
322.	10% DUR	0.34	5.45	0.228	0.057	1.34	0.10	3.67
960.	LL BENCH	0.42	7.55	0.341	0.044	2.57	0.41	2.51
1950.	VAL FLAT	0.47	9.01	0.421	0.038	3.66	0.77	2.18

ALL UNITS ARE FT.-LB.-SEC. UNITS

FIGURE H.22 COMPUTER PRINT-OUT OF THE AVERAGE HYDRAULIC GEOMETRY AND CHARACTERISTIC FLOW PARAMETERS FOR THE REACH

RIVER DATA TABLES - CROSS SECTION DESCRIPTION - TABLE 1

LOCATION Lobstick River near Styal, Alta	DISCHARGE 38 cfs			DATE 8 Jun 1970			RECORDER D.I. Bray			
X-SECTION CODE	U4	U3	U2	U1	C1	D1	D2	D3	D4	D5
VALLEY DATA										
VALLEY LANDFORM										
- Narrow	✓	✓	✓	✓	✓	✓	✓			
- Medium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
- Wide										
- Wide Terrace										
- Alluvial Plain										
- Delta										
- Alluvial Fan										
- Irregular Bedrock										
VALLEY PATTERN										
- Straight										
- Meander	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
- Irregular										
SUDDEN VALLEY VARIATION (Constriction, Direction)										
- Upstream										
- Downstream										
CHANNEL DATA										
NUMBER OF CHANNELS										
- Low Water	1	1	1	1	1	1	1	1	1	1
- High Water	1	1	1	1	1	1	1	1	1	1
CHANNEL PATTERN (local)										
- Straight	✓		✓	✓	✓	✓		✓		
- Regular Meander										✓
- Tortuous Meander										
- U-Shape Meander		✓					✓		✓	
- Irregular Meander										
- Confined Meander										
- Split										
- Braided										
CHANNEL BED										
- Boulders		✓	✓	✓	✓	✓	✓	✓		✓
- Cobbles	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
- Pebbles										
- Gravel	✓	✓	✓	✓	✓	✓	✓		✓	✓
- Sandy										
- Silty					✓		✓		✓	
- Rounded	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
- Angular										
APPROXIMATE WATER										
- Depth (ft)	1	2½	1½	2	2	1	3	1	3	1
- Speed (ft/sec)	-	-	-	-	-	-	-	-	-	1.4
- Colour	Light brown →									
SLOPE VARIATION										
- Rapids										
- Falls										
- Pools		✓		✓	✓		✓		✓	
- Riffles	✓		✓ Top of riffle			✓		✓		✓

FIGURE H.23 FIELD CHECK SHEET FOR VALLEY AND CHANNEL DATA

RIVER DATA TABLES - CROSS SECTION DESCRIPTION - TABLE 2

LOCATION Lobstick River near Styal, Alta | DISCHARGE 38 cfs | DATE 8 Jun 1970 | RECORDER D.I. Bray

X-SECTION CODE	U4 L	U4 R	U3 L	U3 R	U2 L	U2 R	U1 L	U1 R	G L	G R	D1 L	D1 R	D2 L	D2 R	D3 L	D3 R	D4 L	D4 R	D5 L	D5 R
BANK CHARACTERISTICS																				
SHAPE																				
- Concave	✓			✓	✓	✓	✓							✓		✓	✓		✓	
- Convex			✓					✓	✓	✓	✓	✓	✓		✓			✓		✓
- Complex		✓																		
GRADIENT	✓																			
- Cliffed (vertical)																			✓	
- Steep				✓		✓	✓		✓					✓		✓	✓			
- Mild		✓	✓		✓			✓		✓	✓	✓	✓		✓			✓		✓
APPROXIMATE HEIGHT (ft)	7	3	3	30	2	7	5	3	20	20	5	5	2	50	2	5	30	2	10	3
BANK MATERIAL																				
- Stable		✓	✓		✓				✓	✓	✓	✓	✓		✓			✓		✓
- Intermediate	✓					✓	✓	✓								✓			✓	
- Unstable				✓										✓			✓			
- Bedrock																				
- Coarse	✓																			
- Silt Clay	✓	✓	✓	✓	✓?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
- Sand																				
- Glacial Till																				
- Boulders																				
- Cobbles																				
- Pebbles																				
- Rounded																				
- Angular																				
OVERFLOW																				
- Liable		✓	✓		✓			✓					✓		✓		✓		✓	
- Not Liable	✓			✓		✓	✓		✓	✓	✓	✓		✓		✓		✓		✓
CHANNEL SHIFT																				
- Point Bars			✓										✓					✓		
- Bank Erosion	✓			✓		✓	✓	✓	✓ ?	✓	✓ ?	✓		✓		✓	✓		✓	
- Abandoned Channels											✓	✓								
- Oxbow Lakes																				
- Flats																				
- Islands																				
VEGETATION AMOUNT																				
- Absent		✓							✓	✓						✓		✓	✓	✓
- Sparse	✓		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓		✓			
- Dense																				
- Over-hanging																				
TYPE																				
- Grass		✓	✓		✓				✓	✓						✓		✓	✓	✓
- Weed			✓																	
- Brush					✓	✓	✓	✓			✓	✓	✓		✓					
- Willow																				
- Tree (1) poplar	✓											✓					✓			
(2) spruce				✓										✓						
(3)																				

FIGURE H.24 FIELD CHECK SHEET FOR BANK CHARACTERISTICS

RIVER DATA TABLES - CROSS SECTION DESCRIPTION

LOCATION Lobstick River near Styal, Alta	DISCHARGE 30 cfs	DATE 8 Jun 1970	RECORDER D.I. Bray

X-SECTION CODE	COMMENTS - FURTHER DESCRIPTION
U4	AT HEAD OF RAPIDS HIGH TERRACE ON LEFT BOULDERS AND GRAVEL HALF WAY UP LEFT BANK
U3	BANK EROSION ON OUTSIDE OF BEND. SOME LOCAL SLUMPING EVIDENT POINT BAR OF SANDY SILT LARGE BOULDERS (1'Φ) AT BOTTOM OF POOL
U2	15' ABOVE HEAD OF RIFFLE RAPID ABOUT 100' LONG LEFT BANK COULD EASILY BE FLOODED
U1	ABOUT 160' U/S OF RAPID POOL WITH FLAT BOTTOM AND STEEP
G	BRIDGE DOES NOT AFFECT FLOWS SECTION IN POOL, RAPID ENDS ABOUT 150' U/S RECORDING GAUGE AT SECTION SOME ARTIFICIAL STRAIGHTENING BETWEEN G AND D1
D1	ABOUT 20' D/S FROM HEAD OF RAPID RIGHT BANK LOW, LEFT BANK HIGHER
D2	STEEP BANK ON OUTSIDE OF BEND, SOME LOCAL SLUMPING DEEPEST CROSS-SECTION IN REACH
D3	30' BELOW TOP OF RAPID
D4	EVIDENCE OF FAILURE ON LEFT BANK (LOCAL) CAN SEE POINT BAR DEVELOPMENT ON RIGHT
D5	ABOUT 20' ABOVE RAPID (RIFFLE) TERRACE ON LEFT; LOWER FLAT ON RIGHT

FIGURE H.25 FIELD NOTES, COMMENTS AND FURTHER DESCRIPTIONS OF EACH CROSS-SECTION

a) Lobstick river near Styal. Looking upstream from a point near cross-section U4.
Date: 8 June 1970. Reference: RS-70-1-9.

b) Lobstick river near Styal. Looking upstream toward cross-section U3 at the bend. Note active erosion at outside of bend. The trees are tilted toward channel.
Date: 8 June 1970. Reference: RS-70-1-10.

c) Lobstick river near Styal. Looking downstream towards cross-section U2. Man at center of channel on line of cross-section U2. Note the riffle just below cross-section U2. Pool and riffle sequence typical for reach.
Date: 8 June 1970. Reference: RS-70-1-11.

d) Lobstick river near Styal. Looking downstream toward cross-section D2 at bend from cross-section D1.
Date: 8 June 1970. Reference: RS-70-1-13.

FIGURE H.26 TYPICAL FIELD PHOTOGRAPHS ON DATE OF SURVEY