



FRASER RIVER
UPSTREAM STORAGE STUDY

RIVER REGIME AND SEDIMENT STUDIES

DR. A.N.T. VARZELIOTIS
JULY 1974

NOTE

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JOINT ADVISORY BOARD'S FRASER RIVER UPSTREAM
STORAGE REVIEW REPORT DATED DECEMBER 1976.

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Inland Waters Directorate
Pacific and Yukon Region
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FRASER RIVER UPSTREAM STORAGE STUDY

TASK # 58

River Regime and Sediment Studies

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July 1974

10349

ABSTRACT

The construction of System E would affect the geometry of the Fraser River to some extent. Most important would be the long term deprivation of the ecologically important Fraser River Delta by as much as one quarter of its present sediment nourishment, in addition to the ever-increasing removal of sediment by dredging. A program of reservoir sedimentation evaluation is proposed.

RESUME

La construction du réseau E influencerait la géométrie du fleuve Fraser dans une certaine mesure. Encore plus significatif serait la perte d'au moins un quart de l'alimentation sédimentaire de l'important delta écologique du fleuve Fraser, y compris l'enlèvement soutenu des sédiments au moyen de dragage. Un programme d'évaluation de la sédimentation des réservoirs est proposé.

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RIVER REGIME AND SEDIMENT STUDIES

1. AUTHORITY

The 1968 Federal-Provincial Fraser River Flood Control Agreement provided for a review of the "System E" upstream storage projects in the Fraser River Basin.

The sedimentation study reported herein was authorized by the former Fraser River Joint Program Committee and undertaken by the Water Planning and Management Branch, Department of the Environment, as part of that review.

2. PURPOSE OF THE SEDIMENTATION STUDY

The purpose of the sedimentation study has been outlined by the Fraser River Joint Program Committee in the "Terms of Reference for Upstream Storage Studies" dated September 1971 and includes the following tasks:

- i. Review available sediment data.
- ii. Review available aerial photography.
- iii. Carry out field inspections to identify areas of potential change.
- iv. Evaluate techniques to measure change.
- v. Recommend a program to measure change.

The above listed tasks refer to sedimentation in reservoirs and to the effects of reservoirs on the streambed economy of the river downstream of the dams and upstream of the reservoirs. Of special interest are the effects on the Lower Fraser Valley of the possible partial sediment starvation that "System E" may impose on the Fraser River.

It should be noted that items i, ii, iii and iv are steps toward the achievement of item v. This report presents the work done and recommendations for a program to evaluate sedimentation changes in the reservoirs and the rivers.

3. THE AREA

The reservoirs covered by the study are those in the "System E" complex as defined in the "Final Report of the Fraser River Board on Flood Control and Hydroelectric Power in the Fraser River Basin - Victoria, British Columbia, September 1963".

"System E" is well described in the aforementioned report. Therefore only a brief reminder is justified for the completeness of the present report. "System E" consists of eight projects named and located as follows: the Grand Canyon project on the Upper Fraser River, the Lower McGregor project on the McGregor River, the Cariboo Falls project on the Cariboo River, and the Clearwater sub-system which includes the Hobson Lake, Clearwater-Azure, Hemp Creek, Clearwater and Granite Canyon projects. Plate 1 shows the watersheds and the location of the "System E" projects.

The drainage areas of "System E" are all adjacent to each other and total 12,395 square miles, comprising about 15% of the total drainage area of the Fraser River above Hope (84,000 square miles) where the Lower Fraser Valley starts.

The Lower Fraser River starts at Hope and runs for about 98 river miles to its delta in the Georgia Strait. The Lower Fraser River has a relatively mild gradient and consists of two reaches, each with distinct characteristics. The reach downstream of Mission is subject to tidal influences, has a very flat gradient and corresponding cross-section. Upstream of Mission, the river has a steeper gradient than its downstream reach and is not estuarine. The steeper gradient of the Mission-Hope reach is associated with coarse bed material and the sediment load is composed partly of such material. In the Mission-to-sea reach, the riverbed consists mainly of sands and finer material and so does the sediment load of the river.

4. THE GENERAL PROBLEM

Reservoirs affect sedimentation in three broad ways. Firstly, they constitute stilling basins where the absence of appreciable velocity causes no bedload movement through the

reservoir and where the absence of turbulence cannot support the sediment entering the reservoir in suspension; therefore they cause deposition. The sediment deposits in the upstream end of the reservoirs in the form of deltas, which advance with time. The reservoir suffers loss of capacity as sediment deposits occupy live storage space.

Of importance is the fact that the reservoir retention of sediment causes corresponding reduction in the sediment load of the river. Depending on its magnitude, the reduction of the sediment load of a river may affect the aquatic economy of the river and this effect is carried out throughout the rivercourse and as far as the river delta front.

Secondly, the formation of deltas at the upstream end of reservoirs causes the current to slacken and this results in sediment deposition which becomes evident as a general raising of the riverbed. This causes the gradient of the river to flatten further upstream and thus the phenomenon propagates itself until a rather steep reach of the river arrests the advancement. Thus, depending on the valley, floods may occur, inundating lands which were safe prior to the construction of the reservoir.

Thirdly, the introduction of the reservoir storage modifies the flow of the river downstream of the dam, reducing the peaks and augmenting the low discharges of the pre-dam conditions. Usually the low flows in the natural river are not significant to the sedimentation processes, however, the reservoir-augmented flows may be substantial enough to affect sedimentation. Moreover, the waters flowing past the reservoir are sediment free and thus they can only cause erosion since they do not possess sediment loads from which to deposit. Degradation of the riverbed is mainly felt immediately downstream of the dam and before the first control point, which consists of non-erodible points or stretches of the river, such as bedrock outcrops and reaches through heavy rock accumulation. Thereafter, degradation occurs at diminishing rates between successive control points.

These phenomena commence immediately after the introduction of the reservoir into the watercourse and continue until a new regime is established. The transitional period is rather long, however, most of the effects are felt during the first two or three years after construction, tapering off thereafter.

Those effects must be predicted with some good degree of accuracy prior to the construction of reservoirs, and once the project is implemented the changes should be monitored and assessed so corrective measures can be taken and knowledge can be gained for application in future designs.

5. APPROACHES TO SOLUTION

Sedimentation is part of mobile boundary hydraulics which is somewhat less than an inexact science. The available "theory" applies mostly to canals and canalized rivers running on beds and banks consisting of material similar to the material comprising their sediment load. The rivers of System E are very different from those which can be analyzed by the available theories, therefore the subject cannot be approached from the theoretical standpoint.

Since the problem cannot be approached theoretically, it must be dealt with on the basis of measurements of pertaining quantities, establishment of correlations and relationships and intelligent extrapolation of deductions to assess the post-project conditions, and that is the essence of the Committee's directions.

Unfortunately, the data available on System E rivers are rather sparse, as indicated by the list in the following chapter. However, on the basis of this information and other related knowledge, predictions of the effects of System E are made and a program to measure change has been assembled and presented herein. Since the present study is preliminary in scope, since more data will be available for the final design, and since the proposed program is easily amendable to reflect better understanding of the situation, it is deemed that the present work is satisfactory to the needs at this stage of the study of System E.

6. SEDIMENT MEASUREMENTS AND OTHER INFORMATION
UTILIZED IN THE PRESENT STUDY

The most upstream sediment measuring stations in the Fraser River are the Hansard station, which commenced operation in 1972, and the Marguerite station which was established in 1971. In the Lower Fraser Valley there are the Hope, Agassiz, Mission and Port Mann stations. The Hope station and the Port Mann station have been in operation since June 1965. The Agassiz station has operated continuously since June 1966 and the Mission station since May 1965. Only suspended sediment is collected at the Hope station, while both suspended and bed sediment loads are measured at the Agassiz, Mission and Port Mann stations. These stations are shown on Plate 2.

Although the aforementioned sediment stations have been in operation for relatively short periods, they have produced a fair picture of sediment transport by the Fraser River, especially in the Lower Fraser Valley. The deficiency arises mainly from the sparsity of stations above Hope.

In 1972, Water Survey of Canada carried out eight samplings of suspended sediment in the Clearwater River at Clearwater, especially for the purpose of the present study. Moreover, two series of "grab-samples" were taken in June and August 1972 at selected points in the rivers of System E to obtain an indication of sediment size, consistency and concentration at the locations tested. Those samples served only to complement the visual inspections of the rivers and have no other value; therefore the results of their analyses are not included in this report.

Of great importance are the water discharge data and there are quite a few measurement stations in the System E rivers. A list of the water measuring stations, along with the length of their records, is as follows:

- i. Clearwater River near Clearwater Station,
1914-1928 and 1950 to present.
- ii. Clearwater River at outlet Clearwater Lake,
1954 to present.
- iii. Clearwater River at outlet Hobson Lake,
1960 to present.

- iv. Cariboo River near Keithley Creek,
1961 to present.
- v. Bowron River near Hansard,
1954 to present.
- vi. Fraser River at Hansard,
1954 to present.
- vii. McGregor River at Lower Canyon near Upper Fraser,
1960 to present.
- viii. Fraser River at Hope,
1912 to present.

There are a few more water discharge measuring stations on the Fraser River and its tributaries, however the most important to the present study are the ones listed above.

Review of existing aerial photography is of no significant value to the present study. It is high level photography and although indications on the sediment characteristics of the rivers can be obtained it cannot provide the specific information required for the evaluation of the sediment problems related to System E planning.

Three inspection trips have been carried out to provide first-hand knowledge of the rivers and their sedimentation characteristics and to help in planning for sediment data collection.

7. ASSESSMENT OF SEDIMENTATION

After consideration of the existing data under the knowledge acquired by inspection of the rivers of System E, the situation appears as follows:

i. The Clearwater Sub-system

The Clearwater sub-system consists of the following reservoirs: Hobson Lake, Clearwater-Azure and Hemp Creek and the following run-of-the-river hydropowerplants; Granite Canyon and Clearwater. The drainage area of Hemp Creek, the most downstream of the three reservoirs, is about 3,840 square miles or about 4.6% of Fraser River drainage area at Hope which is about 84,000 square miles.

The mean flow past the Hemp Creek damsite is 7,950 cfs, representing about 8.3% of the mean flow at Hope which is 95,800 cfs. The flow through the Clearwater sub-system of damsites, in the present

undammed state, passes through natural lakes which act as stilling basins extracting the sediment. Thus, there is no appreciable amount of sediment to be entrapped by man-made reservoirs in the Clearwater sub-system.

Although there are no reliable values of the present day sediment load past the Hemp Creek site, a rough estimate is that it is in the order of 1% of the total annual sediment discharge at Hope, which, naturally, is much less than the water discharge ratio of the two locations. The name "Clearwater" depicts sediment conditions of the river and the effect of the Clearwater dams on the Thompson and Fraser Rivers will be rather insignificant.

ii. The McGregor

The McGregor site, if developed for diversion, is bound to have consequences both within the Fraser watershed and the Peace River watershed. Although the effects of the diversion on the Parsnip River valley will be quite significant they are not examined here since the present report is limited to the Fraser River drainage. It is considered, however, that an extensive study is necessary to evaluate the effects of diversion on the Parsnip River valley.

The McGregor River at the damsite drains about 1,840 square miles lying in the northernmost part of the Fraser drainage. This makes it a little more than 2% of the Fraser drainage at Hope. The mean outflow from the McGregor River is about 8,750 cfs, representing about 9.1% of the mean flow of the Fraser River at Hope.

The contribution of the McGregor River to the sediment load of the Fraser River has not been determined by field measurements; however, field observations, consideration of the drainage area, and the water balance allow an estimate of the sediment discharge. Accordingly, the sediment yield of the McGregor River is taken as being in the order of 10% of that of the Fraser at Hope and that is assumed to be the reduction of the Fraser sediment load due to damming the McGregor River.

Development of the McGregor site without diversion would not alter appreciably the situation insofar as the Fraser drainage is concerned. The only difference it would make would be felt in the short stretch of the McGregor River between the damsite and its confluence with the Fraser River and will result from the difference in flows, through that reach, between diversion and non-diversion development.

iii. Grand Canyon Reservoir

The damsite of the Grand Canyon reservoir is on the main stem of the Fraser River, just upstream of Hansard and upstream of the mouth of the McGregor River. As such, it bears more significance on the sediment regime of the Fraser River than the other reservoirs of System E, considered individually or collectively.

The Grand Canyon dam will block a drainage area of about 5,550 square miles which represents about 6.6% of the Fraser drainage area at Hope. The mean flow past the Grand Canyon damsite is about 17,300 cfs which represents about 18% of the mean Fraser River discharge at Hope.

The sediment discharge past Hansard in 1972 was over 4,600,000 tons while at Hope it was 32,081,000 tons; therefore the Hansard sediment discharge was 14.4% of that at Hope.

The Marguerite station is the next downstream sediment measuring station and drains an area of approximately 38,500 square miles representing a little over 47% of the drainage area at Hope. The 1972 data for the Marguerite station indicate that the total sediment load of the Fraser at Marguerite is in the order of 51% of that of the Fraser River at Hope.

In view of the above and visual inspections of the areas involved, it is estimated that the total sediment load of the Fraser at the Grand Canyon damsite is about 15% of that of the Fraser River at Hope.

iv. Cariboo Falls Reservoir

The Cariboo Falls damsite is located near the outlet of Cariboo Lake. The lake acts as a stilling basin and therefore the outflow is rather free of sediment.

Although there are no sediment measurements near the Cariboo Falls damsite, it can be assumed that the Quesnel River contribution to the sediment load of the Fraser is rather insignificant. Consequently, the construction of the reservoir cannot be expected to have any serious consequences on the sediment regime of the Fraser.

v. The Fraser River Upstream of Hope

The construction of System E reservoirs will affect the sediment regime of the Fraser River from beyond the upstream end of the Grand Canyon reservoir to the delta front in the Strait of Georgia. These effects will result from the deprivation of sediment introduced by the reservoirs and from the changed distribution of the water discharge over the year.

The first effect to be felt will be the degradation of the riverbed downstream of the Grand Canyon dam. The degradation is arrested by control points which, in this case, consist of non-erodible areas of the riverbed and banks.

Although there are no detailed surveys, it appears that the first control point downstream of the Grand Canyon damsite is Giscome, and therefore it is expected that the most severe degradation of the riverbed will occur in the reach of the river between the dam and Giscome. Undoubtedly, beyond Giscome there are many control points and the regulation of flows and sediment discharge is bound to cause further degradation of the riverbed between such control points.

vi. Fraser River from Hope to Sand Heads

The retention of sediment by the System E reservoirs and the modification of the hydrograph, which is the main purpose of System E, could have significant effects on the sediment regime of this reach of the Fraser River.

Of particular interest is the Chilliwack stretch of the Lower Fraser due to the present delicate balance of conditions and the nature of these conditions. The river gradient changes in this area from the relatively steep gradient of the reach between Hope and Chilliwack to the mild gradient of the river downstream of Chilliwack. Thus, in this area, the riverbed consists mainly of gravel brought down by the energy associated with the steep gradient of the river. Downstream of this reach, the bed and the banks consist of material in the sand range and the sediment load of the river is also in the sand range which can be transported with the energy associated with the mild river gradient.

Since the gravel cannot be transported through this reach, it deposits there and undergoes a process of grinding. In the judgement of the writer significant grinding occurs when average flows are reached. Sand is produced and is transported through the next reach of the river to the river delta. Measurable gravel motion commences when the rising stage of the hydrograph approaches the 250,000 cfs range and ceases when the descending leg of the hydrograph is somewhat higher than that, referring to Agassiz. During this period, naturally, grinding reaches its highest intensity. It should be noted however that the rate of increase in the grinding process subsides beyond certain velocities.

If System E is implemented, the discharge will be modified and flows capable of inducing the grinding process would be available for a longer percentage of time than at present. Of course, the present day peaks which induce the most intensive grinding would be reduced; however, in the judgement of the writer, in the post-System E period more gravel grinding would occur in the Chilliwack area. If it is assumed that present conditions are balanced, i.e. that as much sediment goes out of the reach as enters the reach, then over some unspecified period of time in the post-System E period, and until stable conditions are re-established, more sediment would exit than enter. Consequently, the bed would erode

and the mild river gradient would tend to extend upstream. Since there is a control point in the vicinity of Hope, the river gradient between Hope and Chilliwack would tend to become steeper, thereby accelerating the processing of incoming gravel into sand. The magnitude of the gradient shift cannot be predicted at this time; however, this shift would cause erosion in the Chilliwack-Kent areas and further upstream, tapering off at Hope. This process, if anything, would increase the gravel beds in the area because the most downstream location of gravel at present would not be greatly affected. It should be emphasized that the change in gradient at present and in the future would be gradual over the reach.

The above comments apply to regulation of the river without any additional diversion. In the event of diversion of the McGregor River the total flow would be reduced and therefore the total energy available for grinding would also be reduced. Due to the lack of information the effect of this reduction cannot be determined at this time.

The effect of System E on the lowest part of the Fraser, that is downstream of Mission, is deemed to be only marginal and will occur slowly since the reach is tidal and the dominant tidal influences will continue in the presence of System E.

vii. The Fraser River Delta

The sediment transported by the Fraser River through its mouth on the Georgia Strait is mostly deposited on the tidal flats and the delta front. The rest is deposited beyond the delta and is lost as far as the delta is concerned. Although there is no quantitative assessment of the amount of sediment deposited beyond the delta it can be safely assumed that this amount is rather small.

Thus, most of the sediment load of the Fraser River arrives at its mouth. Littoral currents lift and transport sediment, but this transport can be viewed as being rearrangement of sediment in the delta with some sediment, of course, being transported beyond and outside the delta. However, the present balance is such that the delta front advances into the Strait of Georgia. According to Mathews and Shepard^{1/}, on the aggregate, the delta front is now advancing at the average rate of $7\frac{1}{2}$ feet a year.

The deprivation of the Fraser of some of its sediment, due to sediment retention by the System E reservoirs, will be manifested in the delta. This deprivation has been estimated herein to be in the order of one quarter of the total present day sediment load carried by the Fraser River at Hope.

Sediment shifting occurs along and beyond the delta front due to littoral currents and other causes. This process will remain generally unaffected by the reduced sediment nourishment of the delta. Therefore the reduction in the amount of sediment is brought to the delta by

^{1/} "Sedimentation of Fraser River Delta, British Columbia" by F.P. Shepard and W.H. Mathews - Bulletin of the American Association of Petroleum Geologists, August 1962.

the river, for all practical purposes will cause a reduction in the advancement of the delta. That is, it is expected that the advance of the delta front will be affected by the total sediment load reduction imposed by System E. This has been estimated as being about 25% of the mean annual sediment load of some 20-22 million tons per annum. Although exact figures are not available, it is expected that the delta front will continue to advance at a slower rate than the present if System E is implemented. This retardation of the delta advance may have ecological and other consequences.

8. THE PERIOD OF ADJUSTMENT

The occurrence and the duration of the effects of System E on sedimentation are of interest in the present study. Some sedimentation phenomena occur quickly, others occur slowly, some lead to a new permanent regime, and some others are of a cumulative nature.

In general, erosion effects occur rapidly in response to causes, or at least the bulk of the effects result quickly and thereafter the effects are felt at a rapidly diminishing rate.

Degradation of the riverbed downstream of a newly erected dam occurs very rapidly. In the case of System E this will probably occur during the first five to ten years, depending on the releases, the size of the natural freshets and the distance from the dam.

Aggradation of riverbeds upstream of the reservoirs occurs at a slower rate than degradation since it depends not only on the level of the reservoir and the drawdown pattern but on the amount of incoming sediment. In a sense it is an ongoing process which can stop only when the river can carry the incoming sediment through the reach.

The effects of System E on the Lower Fraser River are expected to be felt rather slowly, especially the change in the gradient between Chilliwack and Hope. The period of adjustment to a new steeper gradient is expected to be in the order of two decades.

The delta front will experience a permanent change in the rate of its advancement and this change will occur in a matter of

five to ten years after construction of System E. The delay is due to the fact that in the first years of operation of System E, the sediment load of the river at its mouth could remain unaffected, or affected very little on either the positive or negative side because of erosion downstream of the dams which, during the first years, will be at its maximum.

9. THE PROGRAM TO MEASURE CHANGE

In accordance with the previous evaluation of the sedimentation aspects related to System E, the following program to measure anticipated change is hereby recommended.

A. Immediate Future Program

This part of the program is recommended for implementation prior to the construction of System E. Indeed, this part of the program refers to construction of what is presently being done in anticipation of implementation of System E. It concerns collection of data and accumulation of knowledge to be used in the detailed design of System E.

First, the Marguerite and the Hansard sediment measuring stations should be kept in operation. These stations will provide the minimum required sediment information for the design of System E.

Secondly, reconnaissance of the rivers at high and low waters should continue to allow personnel to develop the understanding of the river processes necessary in sedimentation studies of projects such as System E.

Since sediment data are sparse and the aforementioned program is rather limited, it would be very desirable to institute more sediment measuring stations in the Fraser River and its tributaries. However, at the present time such stations cannot be justified solely on the basis of System E studies. Most likely locations of additional stations are: Fraser River at Quesnel and Lytton; Nechako River above Prince George; and Chilcotin River before its confluence with the Fraser. These are mentioned only as an

additional justification in case consideration is given to improving the existing program of data collection in the Fraser River Basin.

B. Program to Commence with the Operation of System E

The evaluation of the effects of dams on the sediment regime is done by surveys of aggradation and degradation on the watercourse. Traditionally, survey lines are established and permanently identified for repetition of surveys to assess the change which occurred in the interval of successive surveys. The portions of the lines above water are surveyed by conventional land survey methods and the underwater portions are sounded by echo sounders. Such survey lines are usually referred to as "ranges".

This approach has been adopted here and "ranges" have been selected in all the areas which are most likely to be affected by sedimentation. Plates 3, 4, and 5 show the ranges in the reservoirs, downstream of the dams, and upstream of the reservoirs, as described in the following.

However, the advent of the HYDAC-100 SYSTEM allows departure from the traditional way of sounding the underwater portion of the ranges. The HYDAC-100 SYSTEM has been recently developed and tested with participation of the Water Survey of Canada and consists of a pair of telurometers mounted on a boat and electronically connected to echo sounding equipment. The boat travels the area to be surveyed in a sweeping fashion and the telurometers provide the coordinates of points for which sounding depths are recorded automatically. Thus, instead of lines, entire areas are surveyed with great precision and in a very short time. The data collected are then electronically processed to provide a detailed contour map of the surveyed area.

In the case of the System E projects, the magnitude of the work involved indicates that serious consideration should be given to the higher quality and efficiency of surveys and to the cost savings which could be realized through the use of a HYDAC-100 SYSTEM. Only the above water part of the ranges remains to be surveyed manually while the whole underwater area between the indicated ranges would be HYDAC surveyed.

The program recommended covers areas susceptible to change in all but the Clearwater sub-system reservoirs, as follows:

i. Riverbed Degradation Downstream of Reservoirs

The Clearwater sub-system		nothing
The McGregor Dam	(Plate 3)	2 ranges
The Grand Canyon Dam	(Plate 4)	8 ranges
The Cariboo Falls Dam	(Plate 5)	nothing

ii. Reservoir Sedimentation

The Clearwater sub-system		nothing
The McGregor Dam	(Plate 3)	15 ranges
The Grand Canyon Reservoir	(Plate 4)	17 ranges
The Cariboo Falls Reservoir	(Plate 5)	4 ranges

iii. Riverbed Aggradation Upstream of Reservoirs

The Clearwater sub-system		nothing
The McGregor Dam	(Plate 3)	9 ranges
The Grand Canyon Reservoir	(Plate 4)	11 ranges
The Cariboo Falls Reservoir	(Plate 5)	2 ranges

The program outlined above is a minimum program and it should be reviewed at the time of design of the System E projects and periodically thereafter under the light of information generated by it.

10. SUMMARY

The preliminary study indicates that the implementation of System E in the Fraser River watershed will affect substantially the sediment regime of the river:

- about 25% of the present annual sediment load will be entrapped by reservoirs.
- the loss of reservoir capacity due to silting is bound to be very light for the Grand Canyon and the McGregor reservoirs and rather insignificant for the others.
- riverbed aggradation will occur upstream of the reservoirs but flooding, if it occurs, would not affect developed areas.

- riverbed degradation will occur downstream of the reservoirs mainly in the reach between the dams and the first control points in the river, thereafter tapering off at successive reaches between control points.
- the Lower Fraser will be affected insofar as the mild, estuarine reach from the sea to Mission will tend to extend upstream causing the steeper gradient from Chilliwack to Hope to become even steeper.
- the Fraser delta will receive 25% less than the present sediment nourishment and, consequently, its advance will be retarded.

11. RECOMMENDATIONS

The program summarized in item 9 is a fair program for the evaluation of the sedimentation aspects of System E. However, due consideration should be given to the benefits associated with the implementation of this program, hence the following comments.

- i. The reaches of the rivers upstream from the reservoirs are not appreciably developed. Consequently, when aggradation of riverbed occurs, with the associated flooding, this would not affect development. Nonetheless, it may affect the ecology of these valleys, in either positive or negative ways. This implies that before the ranges upstream of the reservoirs are established a valuation of this part of the program should be done, mainly from the ecological point of view.
- ii. The expected loss of reservoir capacity due to siltation is rather small compared to their initial capacity. Moreover, prior to construction the areas to be flooded are bound to be topographically mapped. Therefore, even in the event that evaluation of siltation appears to be necessary after construction, and no provisions have been made prior to construction, this can be done with substantial accuracy by referring to topography and successive surveys by HYDAC. Consequently, this part of the program can be omitted unless other considerations dictate its implementation.

- iii. The evaluation of riverbed erosion downstream of the dams is of greater importance because (a) it may affect developments, and (b) it may have consequences on the regime of the rivers as far downstream as the Fraser River delta. Accordingly this part of the program is of most importance and therefore it is recommended for implementation.
- iv. The continuation of the sediment measuring stations at Marguerite and Hansard is essential because of the sparsity of data on the Fraser River above Hope. The same applies to visual inspection and acquisition of knowledge of the Fraser and its tributaries.

Therefore, it is recommended that at least the program including items 9.A and 9.B.i be adopted.

SEDIMENT AND RIVER REGIME



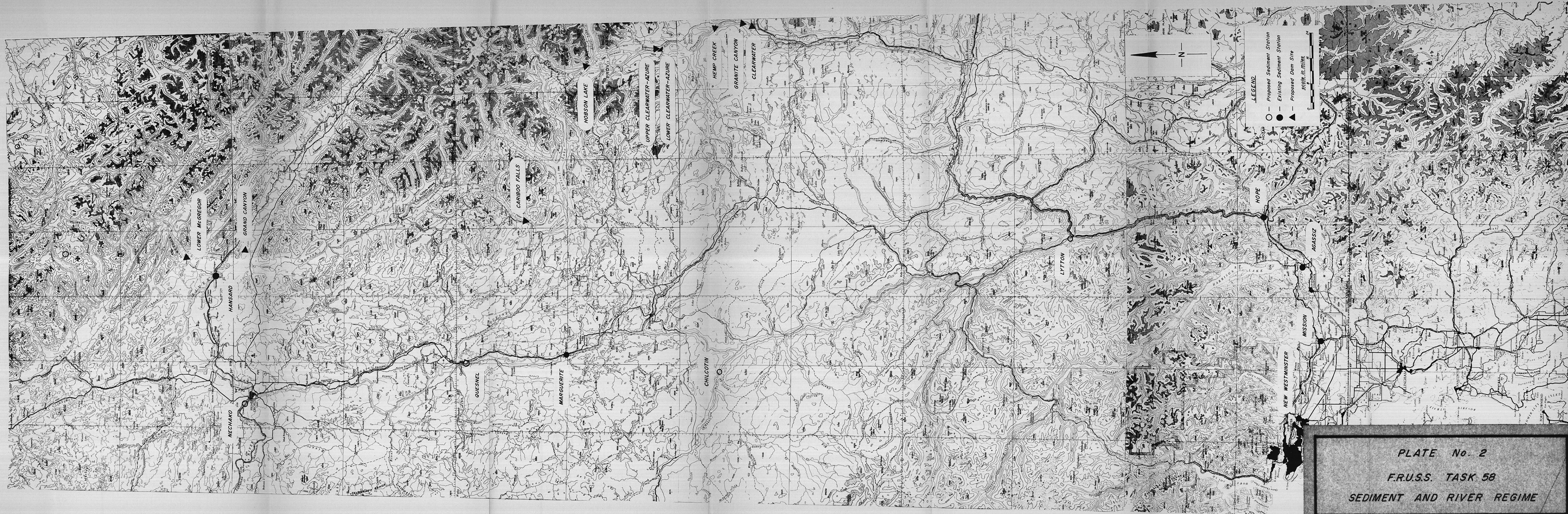


PLATE No. 2
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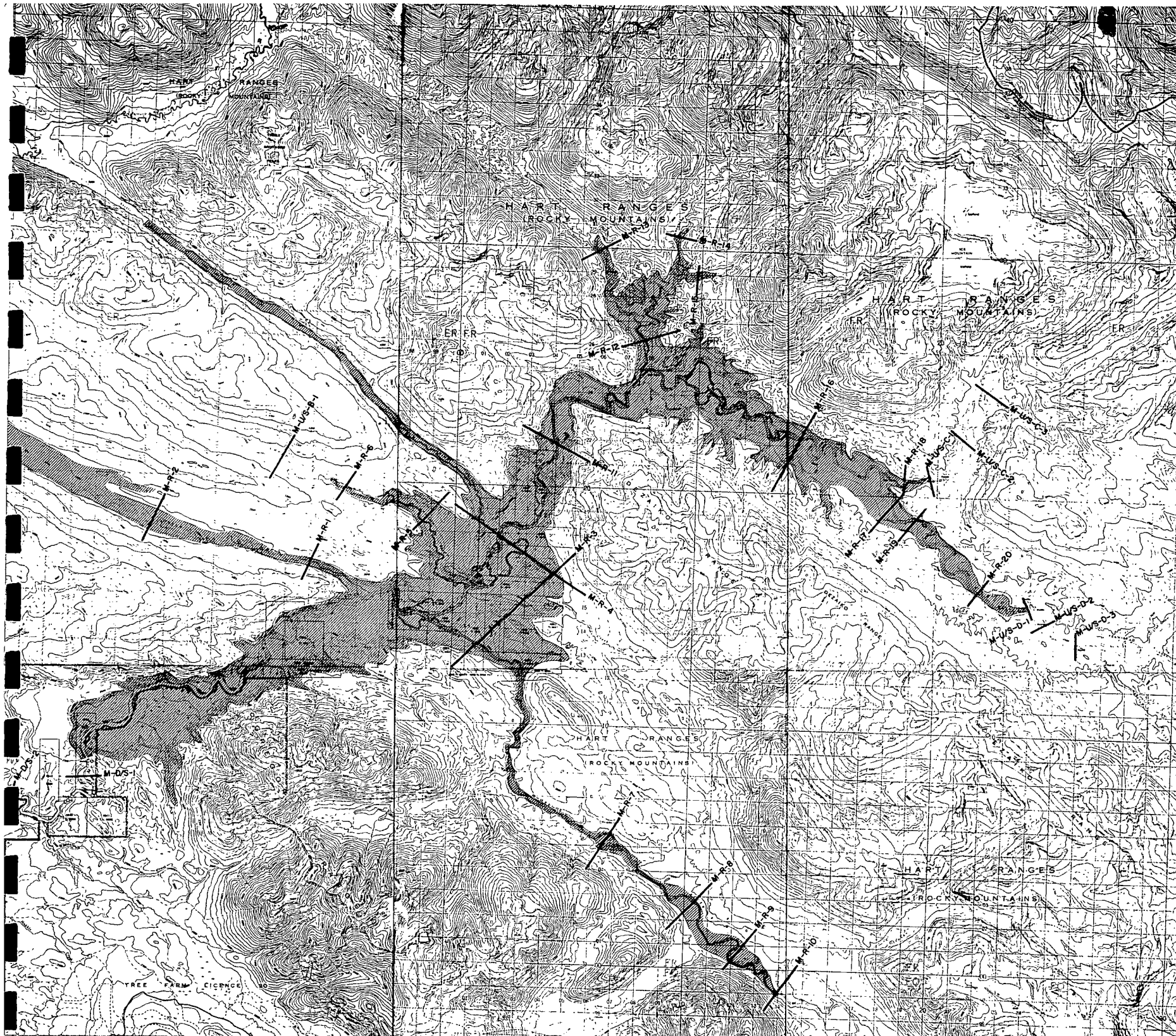


PLATE No. 3

F.R.U.S.S. TASK 58

SEDIMENT AND RIVER REGIME

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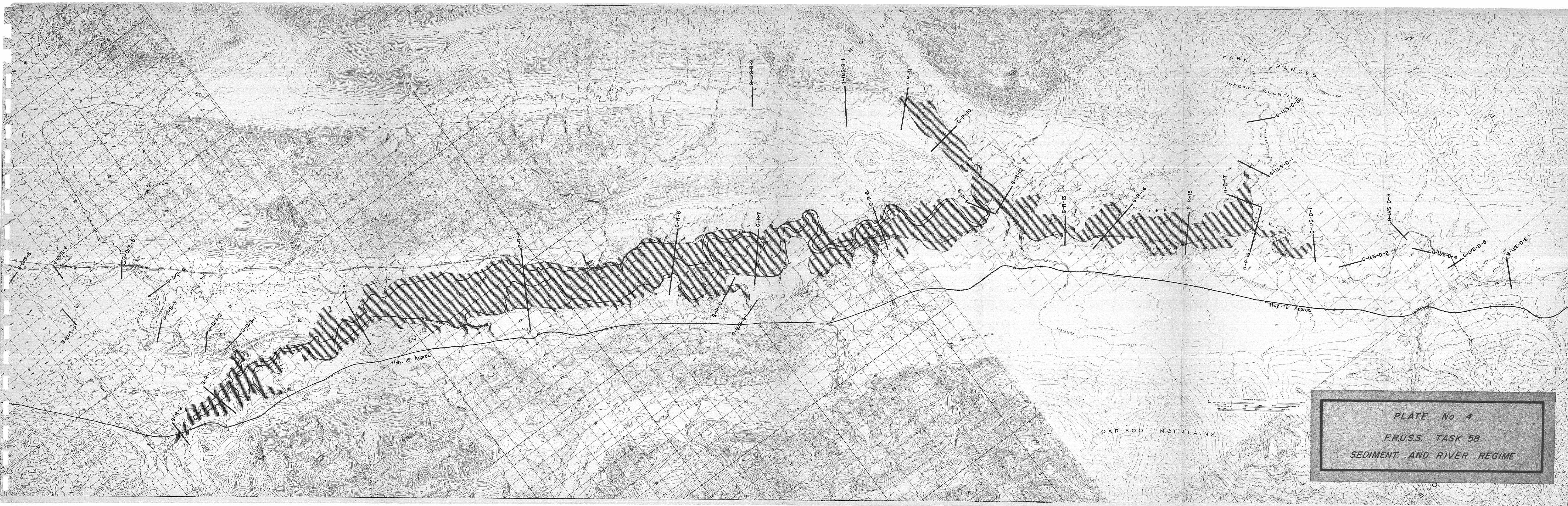


PLATE No. 4
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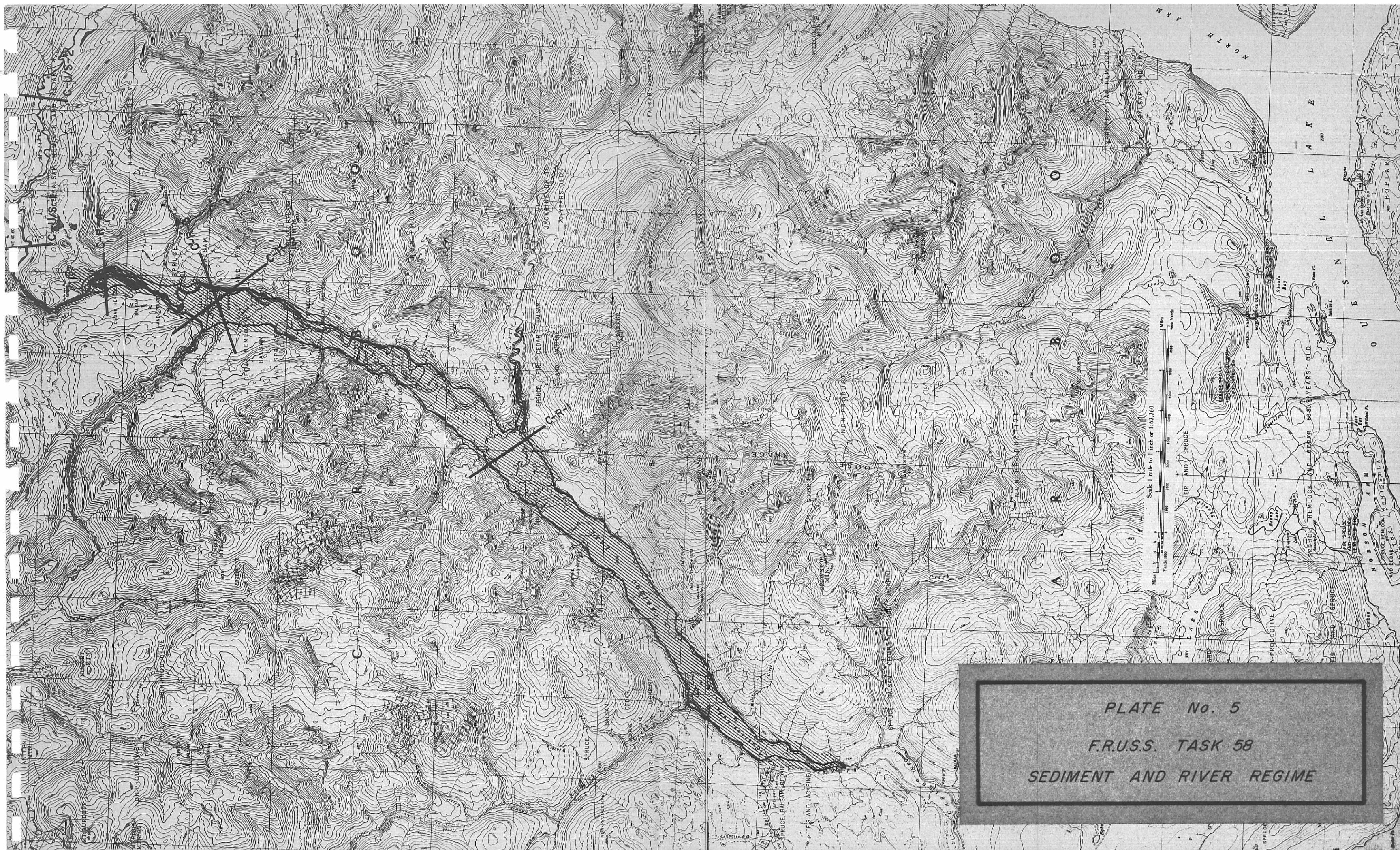


PLATE No. 5
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