Watershed Research in the Saskatchewan River Headwaters

by

W. W. Jeffrey

Reprinted from the Proceedings of the
Fourth Hydrology Symposium on Research Watersheds.
Ontario Agricultural College, Guelph, May 1964.

WATERSHED RESEARCH IN THE SASKATCHEWAN RIVER HEADWATERS[1]

W. W. Jeffrey[2]

ABSTRACT

Watershed Research in the Saskatchewan River Headwaters

Watershed research begun in 1960, with initial emphasis placed upon instrumentation of experimental basins. Marmot Creek Basin was selected to study the hydrology of spruce-fir forest. In late 1962, the first streamgauge was constructed, following installation of five meteorological stations earlier in the year. During 1963, meteorological instrumentation was expanded and additional controls installed on the three main tributary streams. Basin inventory, comprising soil and geophysical survey, habitat-type mapping, timber inventory and improved aerial photography was begun. Groundwater measurement is envisaged.

A second experimental basin has now been chosen. The hydrology of montane trembling aspen forests and associated grasslands will be studied there, through instrumentation emplaced in 1964. Other basins with lodgepole pine cover will be selected in 1964. Meteorological and hydrometric networks are simultaneously being critically examined and improved.

Studies to establish the relationships between various environmental and biological factors have commenced. Land classification methods have been explored. Studies to classify surficial deposits on the basis of relative susceptibility to erosion when disturbed by logging have followed.

Various surveys and data compilations, to provide essential information on the headwaters area as a whole, have begun.

INTRODUCTION

The headwaters of the Saskatchewan River is one of the most important water-producing areas in Canada. The Saskatchewan River Basin, in common with other areas, is undergoing considerable development in irrigation, industrial activity and municipal growth.

Such development brings with it pressure upon water resources. This may express itself in shortages of high quality water for industrial purposes, or it may appear as a pollution problem in surface or ground-water supplies from industrial or municipal

[1] Contribution No. 625, Forest Research Branch, Canada Department of Forestry.

[2] Research Officer, Forest Research Branch, Canada Department of Forestry, Calgary, Alberta and Co-ordinator, East Slopes (Alberta) Watershed Research Program.

sewerage. It may take the form of seasonal water shortages for one or all water uses. Conflicts in use may arise when water users find supply becoming inadequate for their combined needs.

These difficulties will most likely be experienced in comparatively arid regions such as the Canadian Prairies, and certainly such pressures will arise more rapidly there than in more humid regions.

These remarks are pertinent to the East Slopes (Alberta) Watershed Research Program, inasmuch as they show its economic justification, as well as its scientific foundation. Almost all the surface water supply of the Saskatchewan River Basin comes from the mountains and foothills.

The East Slopes (Alberta) Watershed Research Program began in 1960, although interest in the headwaters was present for some time previous. Ultimate program objectives are regarded as essentially practical, being derived directly from the likelihood of downstream water problems. The program is carried out by a number of agencies, both Federal and of the Province of Alberta. A steering Committee, composed of members of participating agencies, decides upon the overall development of the program and assigns funds to it. In Alberta, a Technical Co-ordinating Committee forwards proposals to the Steering Committee for examination and action.

UNDERLYING PHILOSOPHY OF THE PROGRAM

To fulfill program objectives, three types of studies are envisaged: (1) reconnaissance studies and networks to provide information on the headwaters area as a whole, (2) plot studies to establish interrelationships between water and other ecosystem-factors, and (3) gauged basin studies to test promising techniques.

The program begins with an initial, exploratory phase. This is necessitated by lack of preliminary information upon which to base detailed, long-term research priorities and projects.

However, it is imperative to begin institution of gauged basin projects, which require many years to instrument and calibrate. Certain obvious major research priorities may safely be selected on the basis of present information. Moreover, such basins, once operational, provide valuable information to the initial research phase. Gauged basin projects have two main objectives, (1) to provide information on the hydrology of separate portions of the Saskatchewan River headwaters, and (2) a treatment objective, through which the effects of purposive treatment (or treatments) are assessed quantitatively. This combination of objectives enables maximum research results to be obtained.

The hydrologic information provided by gauged basins is intermediate between the broad data supplied by networks and the specific facts obtained from specialized plot studies. Gauged basin instrumentation is integrated into climatological, snow measurement, and hydrometric networks. Network instrumentation and gauged basin instrumentation are mutually supplementary.

Because of the long period required to calibrate gauged basins prior to application of treatment experiments, it has been obligatory to concentrate effort initially in basin instrumentation. This report deals primarily with this development. However, it is hoped that gauged basin studies will be seen, not as something separate, but as part of a more comprehensive program.

Gauged basin projects all have "treatment" objectives, in addition to their first objective of providing essential hydrologic data. A treatment experiment may be a manipulative trial, in which the factor changed generally is vegetation, though snowpack may also be munipulated. By "trial" is meant the application of a standard technique, such as commercial timber harvest. There is a second type of treatment experiment, which is possibly of greater value. This type, in contrast to the trial, is purposive. It seeks to test the hypothesis that a certain desired effect is obtained by prescription of a scientifically based manipulation technique.

Clearly, without plot studies, the second type of treatment experiment cannot be applied, since only through plot studies can its scientific foundation be obtained. Purposive treatment experiments are regarded not as simple and crude trials of gross cover disturbance, but rather as integrators of plot study results, in which the essentially qualitative results of plot studies are expressed in an integrated and quantitative manner. Furthermore, lacking plot studies, the trial type of manipulation experiment cannot be understood, nor can its results be factorially interpreted. Plot studies can rewardingly be undertaken during the initial phase, provided sufficient caution is used, and only topics which are undoubtedly of high priority and in which knowledge is obviously needed are chosen for research.

The short-term, exploratory phase of the watershed research program, therefore, presently embraces: (1) implementation of gauged basin studies, (2) data collection dealing with the headwaters area as a whole, through networks, reconnaissance studies, and compilation of existing information, and (3) implementation of plot studies on topics of evident priority.

Three gauged basin studies are currently contemplated. The first, the Marmot Creek Project, is concerned with subalpine spruce-fir forest and its eventual manipulation. This basin has received most of its basic instrumentation. The second project, the Streeter Basin Project, deals with montane aspen forest and associated grasslands in the southern portion of the headwaters area. This basin, selected in November, 1963, will receive its basic instrumentation in 1964. The third project will be concerned with lodgepole pine forest in the northern portion of the headwaters area. This project, it is proposed, will have two gauged basins, each carrying a different developmental stage of lodgepole pine forest. These basins will be selected in 1964.

The planning and development of climatological and hydrometric networks is underway. Groundwater inventory of the headwaters area is contemplated, and reconnaissance study of surficial deposits, groundwater and soils has begun. A program is proposed to increase knowledge of sediment production within the headwaters area, and an inventory of water quality is under study. In plot studies, a modest beginning has been made.

Since the research program is in a very early state, this report is strictly narrative in nature, very few results having yet been obtained.

GENERAL DESCRIPTION OF THE AREA

The area served by watershed research comprises the mountains and foothills of the Saskatchewan River Basin. Most of the headwaters area belongs to the Crown. Provincial lands include the Rocky Mountain Forest Reserves (8,953 sq. miles) and the green zone outside the eastern boundary of the reserves (3,000 sq. miles approx.). National Parks lands include Banff National Park (2,564 sq. miles), Waterton Lakes National Park (203 sq. miles), and a portion of Jasper National Park (445 sq. miles approx.). About 232 sq. miles of Indian Reserves within the green zone are also included. Total area is therefore about 15,400 sq. miles. The eastern boundary of the foothills is regarded as the 4,000-foot contour of elevation.

The economic and social importance of any headwaters area is directly proportionate to the existing and potential development of the whole basin. In the Saskatchewan River Basin the total urban population in 1956 was 814,963 (Prairie Provinces Water Board, 1960). The present urban population is probably over one million. Present irrigation development is not more than forty percent of ultimate capacity (Prairie Provinces Water Board, 1960).

Detailed studies of the contribution of the mountains and foothills region to streamflow are not available. However, the South Saskatchewan River at Saskatoon derives 94% of its mean annual flow from the mountains and foothills, the North Saskatchewan River at Prince Albert 90% (Prairie Provinces Water Board, 1960). In addition, the mountains and foothills yield other valuable resources; for example, much of the hydro-electric power produced in the basin.

Recreation is probably, next to water supply, the main resource. Recreation demands have risen steadily in recent years. Opening of the Roger's Pass route through Banff National Park has resulted in an appreciable increase in summer tourist pressure.

Forest products and grazing are valuable resources in provincial lands, though in comparison to water and recreation, they seem of minor importance. Coal is the most important mineral produced. Production fluctuates with economic conditions; recently demands have increased.

Topography, geology and soils

The Rocky Mountains rise along a gently sinuous line, their ranges carved from a thick series of sedimentary strata, rather simply folded. The foothills are an outer belt of lower, less rough topography. Mountains and foothills together consist of parallel, aligned or overlapping ranges running north to north-west, having precipitous eastern faces and more gentle western slopes (Can. Dept. Mines and Tech. Surv., 1957b). The highest peaks in the area reach 12,000 feet, while peaks of 9,000 to 10,000 feet are common.

The mountains and foothills region have three sub-divisions: (1) foothills, (2) front ranges, and (3) main ranges. The youngest rocks are in the foothills, geology becoming progressively older to the west. The foothills, mainly of Mesozoic rocks, are characterized by sub-parallel thrust faults. Faults of the foothills commonly are widely spaced and steeply inclined. The front ranges are formed primarily of Devonian and Carboniferous strata. South of the Crowsnest Pass, they are represented by two main thrust sheets containing Proterozoic and Paleozoic rocks. North of the Crowsnest Pass, the front ranges are composed of two to five thrust sheets whose exposed rocks are mainly Devonian and Carboniferous with some Cambrian and early Mesozoic strata. These thrusts extend 100 to 300 miles. Their massive carbonate rocks form linear ranges.

Structure of the main ranges is practically unknown. In the Bow Valley the eastern margin of the main ranges is marked by the Castle Mountain thrust, which brings a thick folded succession of Proterozoic and Cambrian rocks over late Paleozoic strata. Beyond an anticline to the west, Cambrian and Ordovician strata, mainly west-dipping, are broken by one or two major faults.

Surficial geology is not well known. Most of the area has been glaciated, though part of the Porcupine Hills is thought unglaciated. Tills vary from highly calcareous to acid. Many valleys are filled with deep glacial deposits.

The soils of the mountains proper are poorly understood, being generally cited as "undifferentiated mountain soils". Observation suggests predominant mountain soils to be Grey-Wooded and Podzolic.

Climate and hydrology

McKay, Curry and Mann (1963) have summarized data on climate, with some information on runoff. Their maps show present density of meteorological instrumentation.

Generally speaking, water yield is greatest in the back ranges (Ibid: Table 5) and lowest in the eastern valleys and plains. Evaporation is probably greatest in the foothills. There appears to be no significant variation in evapo-transpiration from south to north (Laycock, 1957).

Streamflow peaks vary from May to August, depending on basin characteristics. The foothills give their greatest runoff from March to May, with some minor flow in summer following long, heavy rains. Most of the area gives its greatest discharge during June and July (Laycock, 1957). Water yield is much more variable from east to west than from north to south. Some main rivers are glacial-fed. Release of melt waters by glaciers is especially important for late season flow.

Vegetative cover

Lodgepole pine forest occupies large surfaces in both foothills and mountains. This cover is primarily of fire origin. In the south, the Porcupine Hills have stands of montane douglas-fir (Pseudotsuga menziesii Mirb. Franco) and lodgepole pine (Pinus contorta Dougl. var. latifolia Englm.), with appreciable areas of aspen (Populus tremuloides Michx.) scrub forest. In the more remote mountain valleys and cirques large blocks of subalpine spruce-fir (Picea — Abies) forests have survived past burning. Its area is being progressively reduced by logging.

In the south, grasslands are important for domestic livestock and big game production. Timberline is at about 7,500 feet elevation. Above timberline the vegetation is alpine tundra, which is little known.

Disturbance agencies

National parks and provincial forest reserves have marked differences in degree of soil disturbance. This is due to a fundamental policy difference between the two areas. In the national parks the main disturbance agency is road building, which is followed by roadside mulching and seeding to stabilize bared soil surfaces. The only other major influence in the national parks is elk grazing, which has caused some cover depletion and soil disturbance.

Soil erosion is more prevalent in the forest reserves. Road building and elk overpopulation cause sediment movement in provincial lands, but two other major disturbance agencies are also present there. Such trails show increased soil movement after construction. Many revegetate quickly, but others have gullied. The second major activity is logging. Timber extraction techniques in the forest reserves are generally poor. A combination of tractor skidding, steep, poorly located skid roads, tree-length truck skidding and poorly engineered, badly drained haul roads contributes greatly to erosion and sedimentation.

In the past, fire has caused erosion in both federal and provincial lands. Fire control is now quite effective. In the provincial area, domestic livestock grazing is permitted, and in places has created compaction and erosion.

Avalanches occur on some steep slopes. Some avalanche paths seem to produce snow slides annually; others are active only at long intervals. Avalanches apparently are more common on east than on west-facing slopes. Torrents occur in some areas. Their rubble builds up alluvial fans. Due to absence of development, avalanches and torrents are not currently a great hazard, nor do they give rise to much concern. Increased population pressure may eventually change this hazard rating.

RESEARCH INTO THE HYDROLOGY OF SPRUCE-FIR FORESTS

Spruce-fir forest is the primary source of lumber in the headwaters. As a result erosion and sedimentation associated with logging are concentrated in this type. Timber harvesting has had two major influences upon watershed management. Firstly, the lands already cutover have undergone changes and presumably now show different water yield characteristics than when they supported undisturbed forest. Secondly, if more desirable cutting techniques and cover arrangements can be developed, the possibility of their economical application is greater than in other types.

It was desirable to have a gauged basin in which treatment experiments could be be carried out. Marmot Creek Basin was chosen for this purpose. This basin is central to research into the hydrology of spruce-fir forests.

INITIAL PHASE SHORT-TERM RESEARCH

Two main categories are considered.

Problems of erosion and sedimentation

Erosion and sedimentation are caused by logging procedures used. Erosion control research has been carried out in other areas to allow timber harvest to be undertaken with minimum erosion, sedimentation and site modification. Accordingly, the initial approach to the erosion problem is one of trial rather than experimentation. This allows future appraisal of research needs, in relation to optimal, as opposed to current, logging practices. A model logging operation was therefore envisaged. If problems of erosion from logging persist in such a trial, a genuine research problem is demonstrated.

A study of surficial deposits supporting spruce-fir forests was undertaken. This study attempts the classification of surficial deposits in respect of their susceptibility to erosion when disturbed by harvest cutting and associated activities, primarily roadbuilding and timber extraction.

Problems of hydrologic characteristics and water yield

While it is necessary to provide data upon which management policy and practice can be based, research needs go beyond this. The interrelationships of water, soil, forest, climate and other ecosystem-factors must be investigated, to provide a base for long-term research and for comparison with other forest types.

Forests have two main effects upon water yield and regime: (1) influence upon precipitation (interception, snow accumulation, snowmelt acceleration or retardation) and (2) effect on soil characteristics and stored soil moisture. (This involves study of infiltration, litter, consumptive use, and seasonal soil moisture storage.)

Research into snow accumulation and melt most rapidly provides information of benefit to management, allowing eventual adaptation of cutting regulations. None of these studies need necessarily be confined to spruce-fir forests. Other forest types may be examined simultaneously.

LONG-TERM RESEARCH

Long-term research needs in spruce-fir forests, though difficult to predict, require some priority scale. The rate of depletion of spruce-fir forests through cutting is not known. Because of the possibility of rapid depletion, research into the manipulation of merchantable spruce-fir forests cannot be accorded high priority. Such studies might require 20 years; and there might then remain no considerable area wherein to apply techniques developed. Between 6,500 to 7,500 feet elevation, the forest is administratively reserved against cutting, because of its presumed importance for watershed values. This zone, in its protected status, remains and may lend itself to purposive manipulation. In the initial phases of research, this protected zone will be assessed.

Distinct from questions of research dealing with eventual manipulation is study of hydrologic characteristics of spruce-fir forest sites. Regardless of cover depletion rates, these sites will remain. The initial program of study will allow their long-term needs to be evaluated.

Long-term research in spruce-fir forests will be based on the findings of the initial phase. Such research will probably involve determination of the hydrologic characteristics of spruce-fir forest sites and establishment of timber harvest effects upon water yield in Marmot Creek Basin. The manipulation of protected, high-elevation spruce-fir forest will be appraised during the initial phase. The same is true of erosion associated with logging.

In water yield maintenance and improvement, studies of lodgepole pine forest are thought to be of generally higher overall priority.

THE MARMOT CREEK PROJECT

The Marmot Creek Project is the first of three gauged basin projects. Marmot Creek Basin was selected for study in August, 1962. It is located in the Kananaskis River Valley, about 10 miles south of the Trans-Canada Highway at a point 50 miles west of Calgary, along the Forestry Trunk Road running from Seebe, Alberta to Coleman, Alberta. Latitude and Longitude of the basin are 55° 57' N., 115° 10' W. Total area of the basin in 3.63 sq. miles, approximately.

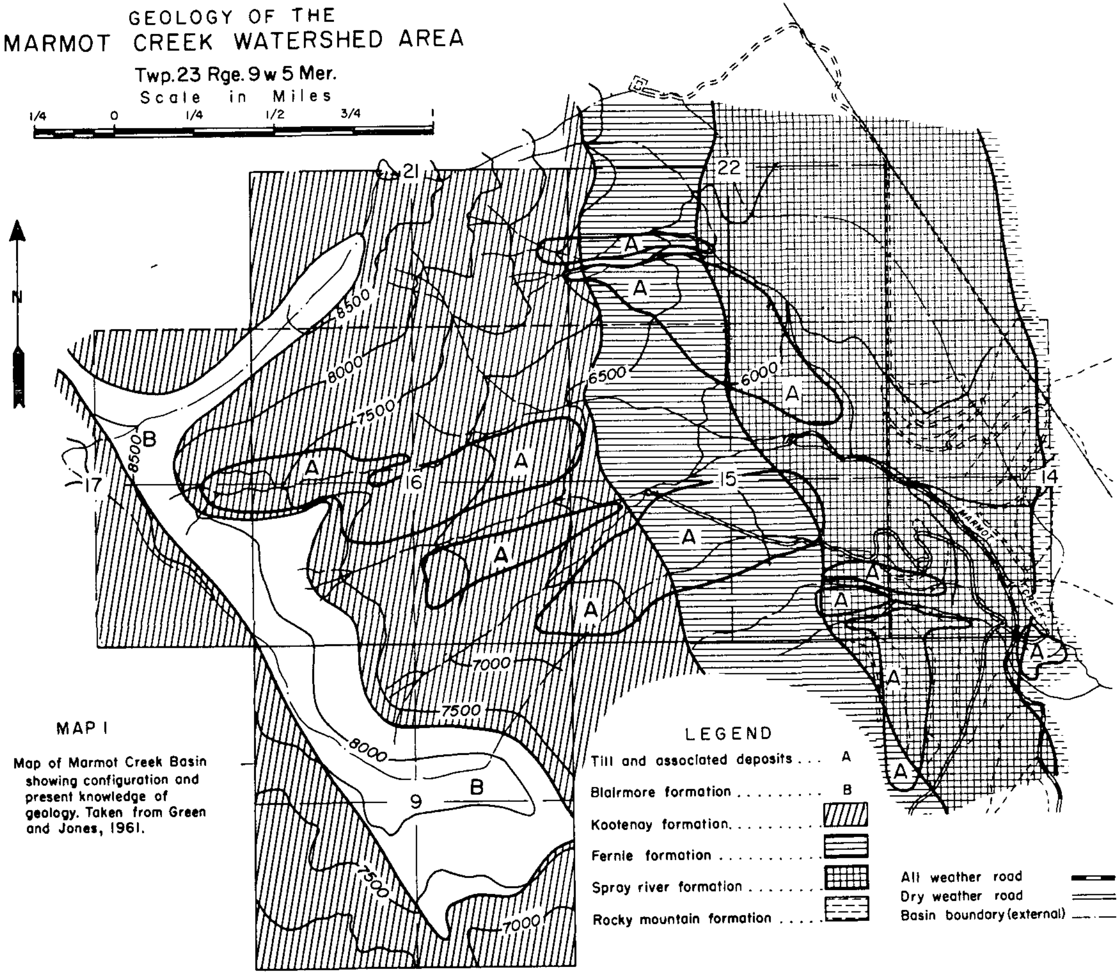
At its lower limit, elevation is around 5,200 feet; its highest point is over 9,000 feet. There are three sub-basins, whose sizes are 0.8, 1.1 and 1.0 sq. miles respectively. (The discrepancy in total areas is due to an area between the sub-basin confluences and the lower basin boundary (Map 1).

The uppermost reaches (above 7,500 feet elevation) carry alpine tundra. Between 6,000 feet and 7,500 feet elevation the cover is mature subalpine spruce-fir forest. The most prominent species are alpine fir and engelmann spruce, though lodgepole pine and alpine larch (*Larix lyallii* Parl.) are also found, the latter uniquely at higher elevations. Below 6,000 feet young lodgepole pine forest has resulted from a fire which burned over that area in 1936.

The basin is generally east-facing (Map 1). Its slopes tend to be very steep.

Preliminary geological evaluation

Choice of the basin was made following reconnaissance by members of the Technical Co-ordinating Committee. The most important factor leading to choice was geological and groundwater study by the Research Council of Alberta in June 1961.



MAP I

Map of Marmot Creek Basin showing configuration and present knowledge of geology. Taken from Green and Jones, 1961.

The basin had previously undergone geological mapping as part of a general program by Crockford (1949). The work of Green and Jones (1961) was a reconnaissance and is the basis of present geological knowledge.

The basin consists of four poorly developed glacial cirques with intervening ridges, each cirque being drained by a small stream or streams. Over half of the basin is covered by surficial materials which include till, outwash deposits, talus and, to a small extent, river terrace deposits. Bedrock outcrops are uncommon in the lower parts of the basin, but are predominant in the upper portions. Where superficial deposits are deep, the streams have moderately deep, V-shaped valleys, but have not cut through surficial deposits to bedrock; so that they flow over gravel or till or between large boulders.

The bedrock geology of the area shows rocks which range in age from late Paleozoic to early Cretaceous. These are sub-divided into five formational units (Green and Jones, 1961).

The Rocky Mountain Formation is composed of hard compact dolomite, dolomitic sandstone, and quartzite. This crosses the lower portion of the basin. The Spray River Formation consists predominantly of thin bedded siltstones and forms a band approximately one mile wide through the eastern portion of the basin. The Fernie Formation does not outcrop in the basin itself, but forms a band estimated to be about 1/3 of a mile in width across the basin. This rock unit consists predominantly of dark grey to black shale. The Kootenay Formation is the thickest (3,400 feet) and the predominant rock unit. It is formed of sandstone and shale, with a number of coal seams towards the base. A few scattered outcrops are present along the banks of streams, but the formation is predominantly exposed on the higher slopes above treeline. The Blairmore Formation, of which the basal member is the Cadomin Conglomerate, is exposed almost continuously in the headwaters area of the basin. Other strata of the Blairmore Formation, exposed in the headwalls, consist predominantly of sandstones and conglomerates. Present geological knowledge is shown in Map 1.

Pleistocene and recent deposits of varying thickness overlie bedrock. These deposits are predominantly till with abundant boulders, though local areas with outwash sand and gravel are also found. These deposits appear fairly thick, 20, to 40 feet in depth.

A major objective in geological and groundwater study was to establish the general characteristics of groundwater geology. The materials forming bedrock, consisting of sandstones, siltstones, shales, conglomerates, coal seams, dolomite, quartzite and limestone are generally well-indurated, well-cemented and relatively impermeable. For this reason, they were thought probably to contribute little groundwater to flow. The rocks appear well jointed and are in some cases fractured. As such, they probably possess some fracture permeability. Whether or not this fracture permeability persists at depth is not known, but it was believed doubtful that any significant groundwater is contributed.

The deep surficial deposits appear very coarse and contain a high fraction of boulders. These deposits are fairly permeable and probably have a moderate infiltration capacity. Precipitation no doubt percolates down through them to bedrock. The pressure gradients of the water-table are thought to be steep, in outline probably roughly conforming to the topography. Direction of groundwater discharge is considered to be towards the drainage channel of Marmot Creek (Green and Jones, 1961).

Research objectives

Research objectives of the Marmot Creek Project were established by a Co-ordinator's Working Group. These research objectives are: (1) to establish the hydrology, particularly relating to precipitation, runoff and groundwater, and their interrelationships, within the basin, (2) to establish the effect of commercial timber harvest, and subsequent regrowth, in subalpine spruce-fir forest, upon water yield and regime and upon groundwater factors, and (3) eventually, and dependent upon the results of preliminary research, to develop methods and establish the effects of purposive manipulation in high elevation, protected spruce-fir forest (6,500 feet elevation to timberline) upon water yield and regime.

The first two objectives are concrete. The information they supply is obviously of value. The third objective is somewhat provisional, inasmuch as it is dependent upon the results of preliminary research. The high elevation, protected spruce-fir forest may not readily lend itself to purposive manipulation. It may be found to be intrinsically of satisfactory hydrologic efficiency. Its total area on provincial lands may be insufficient to justify detailed quantitative study. Should inventory show sustained yield timber harvest in merchantable spruce-fir forest to take place over appreciable areas, another objective similar to objective (3), but relating to merchantable spruce-fir forest, may be added.

The first objective is attained through measurement of precipitation, runoff and groundwater within the basin over a period of years. It requires permanent installations to measure these factors and continuous collection of data.

To attain the second objective, the same hydrologic data are used. It is necessary to measure streamflow and groundwater in the three sub-basins and to derive correlations between sub-basins. When high correlation is attained, commercial timber harvest, based on the best techniques available, is carried out on one sub-basin. The effect of timber harvest is derived statistically from the relationship of actual and calculated flow in the treated sub-basin. Attainment of this objective will require measurements over a long period in order to evaluate fully the effects of cutting and regrowth.

Preliminary plot studies in uncut, partially cut and cutover areas will provide qualitative evaluation of the effects of timber harvest upon factors such as snow accumulation and melt, microclimate, infiltration and litter, consumptive use, interception and stemflow, and seasonal storage opportunity. To attain the third objective, a similar approach can be used.

In planning the Marmot Creek Project, two categories of activity were set up: (a) essential development and (b) basin inventory. Essential development includes all continuing activities: viz., streamgauging, sediment and water quality data collection, meteorological instrumentation, groundwater instrumentation, road maintenance and construction, and forest insect and disease survey.

Basin inventory is designed to furnish data essential to understanding of the basin. It includes topographic mapping, soil survey, forest habitat-type mapping, geophysical survey, geological mapping, aerial photography, forest inventory and area-elevation mapping.

Essential development in Marmot Creek Basin

1. Streamgauging

Streamgauging is the responsibility of Water Resources Branch, Canada Department of Northern Affairs and National Resources. The streamgauging program is described in Appendix 1.

In October 1962, a main control was built on the main Marmot Creek channel. This is a 120°, V-notch sharp-crested weir with a maximum capacity of 150 cfs. This control was emplaced where a bedrock sill allows total streamflow to be measured. At the same time, temporary controls were built on all three sub-basins. These controls were replaced in August, 1963.

A 2.5-foot head H-type flume, capacity 19 cfs approximately, was built on Cabin Creek (Map 2), the most northerly sub-basin. The H flume was preferred to a V-notch control because of depth of surficial deposits present and difficulty of moving construction equipment to the site. The H flume has good accuracy at low flows and will pass sediment and debris at higher flows.

On the other two sub-basins, identical 90°, V-notch, sharpcrested weirs were installed. Their capacity is 30 cfs approximately. Adequate pool design ensures no side or bed interference at peak flows and provides room for debris storage. The pools are log-cribbed, and bentonite mud is used to minimize seepage. The theoretical rating of all controls is checked by current-meter readings.

2. Sediment data collection

This work is the responsibility of Water Resources Branch, Canada Department of Northern Affairs and National Resources. Depth integrating sediment samples are taken at the main streamgauge, daily during high flow, and weekly otherwise. Sediment levels to date have been very low.

3. Water quality data collection

Samples were collected by Canada Water Resources Branch and analyzed by Industrial Waters Section, Canada Department of Mines and Technical Surveys after transshipment to Ottawa. Sampling interval was daily until August, somewhat less frequently thereafter. This sampling continues. The results of water quality analysis are given in Appendix II.

4. Meteorological instrumentation

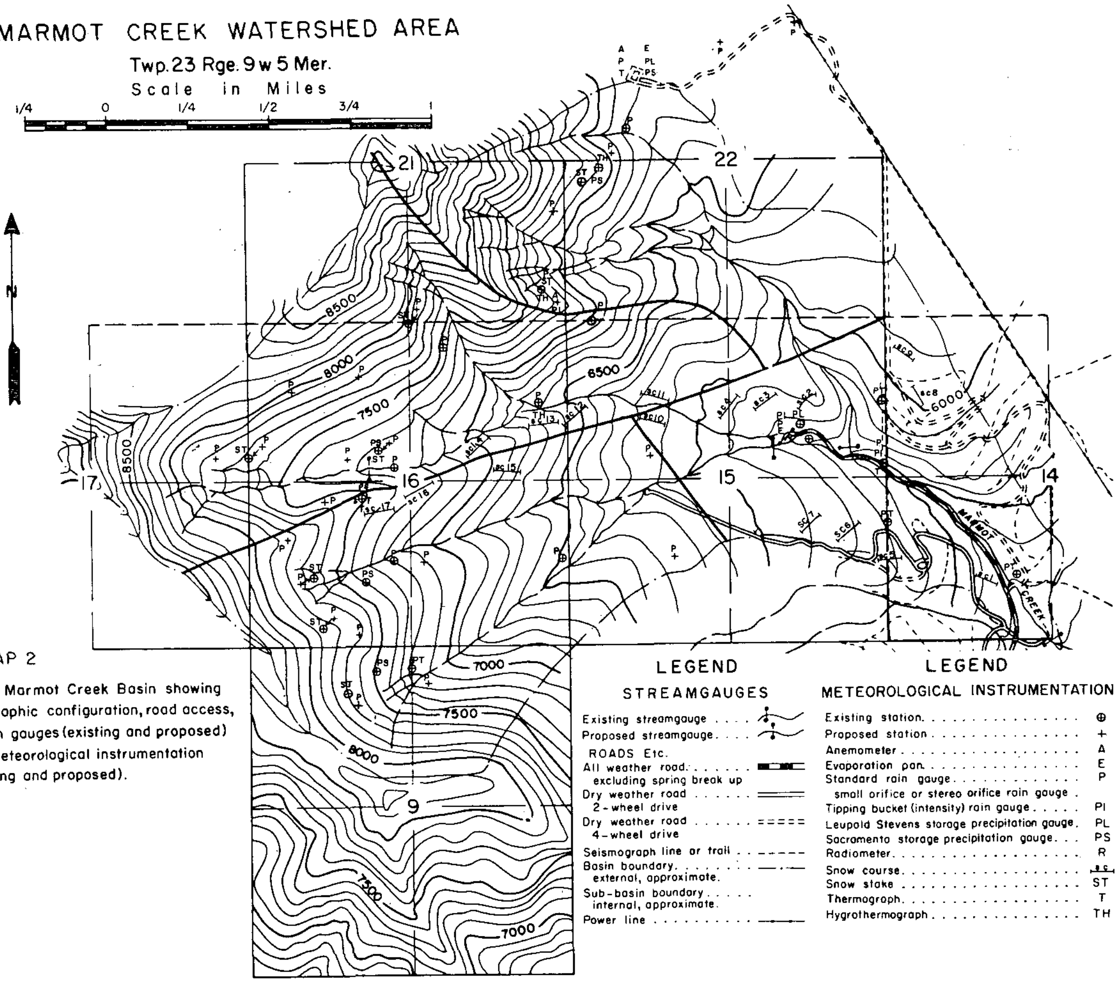
Meteorological instrumentation is undertaken by Meteorological Branch, Canada Department of Transport. Work began in 1962. During that year, five sites were set up to provide data for a portion of the season. At the same time, reconnaissance was carried out to determine accessibility and locate potential sites at higher levels. Later a Leupold-Stevens precipitation recorder was set up. Five snow stakes were emplaced in 1962 and three snow courses put into operation. These were read throughout the winter, the former by telescope, the latter by ground survey. In spring, 1963 a helicopter trip was made into the upper reaches of the basin to assess snow conditions. During 1963, meteorological instrumentation was greatly expanded. The present instrumentation network is shown in Map 2. In summary, it consists of the following:

Precipitation	Temperature and Humidity
12 standard rain gauges	5 max. — min. temperature recorders
2 tipping bucket rain gauges	3 hygrothermographs
1 long-term Leupold-Stevens recorder	2 thermographs
9 snow stakes	Radiation
5 Sacramento gauges	1 CSIRO net radiometer
18 snow courses	

Appendix III summarizes meteorological results.

5. Groundwater instrumentation

This has been planned since the inception of the project, but, due to lack of funds, Research Council of Alberta has been unable to emplace any instrumentation.



MAP 2

Map of Marmot Creek Basin showing topographic configuration, road access, stream gauges (existing and proposed) and meteorological instrumentation (existing and proposed).

6. Road construction

Road construction is the responsibility of Alberta Forest Service, with layout and supervision supplied by Eastern Rockies Forest Conservation Board.

Roads have been improved and new roads extended. About 5,000 feet of new road were built. In the north vehicular travel in summer to 6,800 feet elevation and in the south to 6,400 feet is now possible (Map 2).

7. Forest insect and disease survey

Checks are made by Forest Entomology and Pathology Branch, Canada Department of Forestry, to determine whether any potentially injurious conditions are present.

Basin inventory

1. Topographic mapping

Topographic mapping is the responsibility of Water Resources Branch, Alberta Department of Agriculture. A contour map (scale 1" = 500'; contour interval 20') was prepared by Alberta Department of Lands and Forests from ground survey carried out by Alberta Water Resources Branch in 1962. A mosaic was also prepared.

During 1964, it is proposed to survey all internal and external boundaries and to mark them on the ground. Permanent bench marks are also being provided.

2. Soil survey

Soil survey is carried out by Alberta Soil Survey (Canada Department of Agriculture and Research Council of Alberta). It began in 1963 and will continue in 1964. Five distinct soil types were found: (1) Bisequa Grey-Wooded, (2) Podzol, (3) Regosol, (4) Alpine Black and (5) Organic.

The sequence of soil development appears to be controlled by elevation and by nature of the underlying strata (carbonated versus non-carbonated). Bisequa Grey-Wooded soils occur at lower elevations, while in mid-slope positions Podzols are most prominent. Regosols and alpine soils occur at higher elevations, at or above timberline.

3. Geophysical survey

Geophysical survey attempted to determine depth of surficial deposits. The work was done by Research Council of Alberta. Using a Hunting FS2 hammer seismic instrument, 32 stations were occupied. These stations were concentrated in areas of deeper deposits, delineated by Green and Jones (1961). Difficulty was experienced because of deep moss and organic materials, in addition to ground noise resulting from streamflow and wind movement.

4. Mapping of habitat-types

This work was done by Forest Research Branch, Canada Department of Forestry. The basis for habitat-type mapping is an existing ecological (soil-vegetation) classification (Ogilvie, 1964). The basin has been subdivided into nine forest and nine alpine habitat-types.

5. Aerial photography

Large scale aerial photography was undertaken by Alberta Forest Service, to provide photography of scale 1" = 660'.

6. Forest inventory

The aim of this work by Alberta Forest Service is to provide an accurate estimate of both timber volumes and areas of different forest types.

7. Area-elevation, slope-area, and stream profile computations

This work follows Linsley, Kohler and Paulus (1949: 245–252). It is being undertaken by Eastern Rockies Forest Conservation Board.

Results

The program is too new to yield many results. However, Appendix I by D.A. Davis treats streamflow and sediment data in Marmot Creek Basin, while Appendix II by J.F.J. Thomas deals with surface water quality in the same area. Interesting preliminary results are contained in both of these analyses.

Appendix III by A.S. Mann gives some of the data obtained to date in the meteorological instrumentation program.

Further work proposed

The work proposed largely involves continuation of existing programs. Sediment and water quality data collection will be continued. Geological mapping to refine the reconnaissance map of Green and Jones (1961) will be undertaken by Research Council of Alberta. Soil survey, forest inventory and topographic mapping will be continued and some trail construction implemented.

A considerable area in the basin lies above timberline. There is, therefore, a possibility that flows from the forested portion of the area might be masked by larger flows from the alpine zone. Only the forested area is considered for treatment experimentation. Accordingly, an attempt will be made to separate the alpine contribution from flows from the forested portion, to help establish treatment experiment results.

Reconnaissance of the upper reaches showed one of the three sub-basins to have a complicated pattern of groundwater disappearance and re-emergence. A second channel subdivided within the forest zone and, moreover, had different baseflow characteristics than other sub-basins. Only one sub-basin was suitable for further streamgauging instrumentation around timberline. This is Middle Fork, the central sub-basin. A flume will be installed around timberline (Map 2), to measure alpine flows, and thereby to determine the streamflow contribution originating in the forest area.

During 1964 a beginning will be made on groundwater instrumentation. Work will initially be concentrated around streamgauging locations. Instrumentation at each location will include several piezometers tied into one or more simple wells with automatic water-level recording equipment.

During 1964 the precipitation network will be expanded by installation of 17 additional standard rain gauges and 5 intensity recorders (Map 2). A major meteorological station will be set up at 6,800 feet elevation and wind equipment installed at 7,500 feet elevation. This intensification should then provide sufficient instrumentation.

INDIVIDUAL INVESTIGATIONS

The importance of individual studies must be stressed. In spruce-fir forests, the aims of individual investigations are: (1) to establish, in a qualitative but comprehensive manner, the influence of the various ecosystem-factors one upon another, and the manner and relative importance of their interactions, and (2) to provide a basis for the intelligent prescription of treatment experiments.

The program of individual investigations, begun in 1963, is in its infancy. It will provide the groundwork for hypotheses upon which more penetrating research may be based and indicate those avenues of study which appear potentially most rewarding.

Some studies have been integrated with similar research in lodgepole pine forest.

These studies consist of:

(1) interception and stemflow studies
(2) soil moisture (consumptive use) studies
(3) soil temperature studies
(4) forest litter studies
(5) snow accumulation and melt studies
(6) erosion hazard studies.

A model logging operation was also envisaged, but no progress has been made.

Interception and stemflow studies

These studies are carried out by Forest Research Branch, Canada Department of Forestry, and Meteorological Branch, Canada Department of Transport. Plots have completely random sampling points, through which five standard rain gauges are randomly rotated. Gross precipitation is measured in adjacent openings and, in one plot, at canopy height. Some plots also have different types of trough gauges and measure stemflow by means of plastic stem collars. Rain gauges are randomized after each storm. Five standard gauges have been found inadequate, and it is planned to increase the number to ten.

Soil moisture (consumptive use) studies

Neutron scattering equipment (Troxler Electronic Laboratories, Raleigh, North Carolina) is used in this investigation. At present the study consists of four 50' × 50' plots, in which ten vertical aluminum access tubes are randomly located in each plot. Soil type is lacustrine sand, which facilitated the installation of access tubes by orchard-type soil auger. Readings are taken at one-foot depths. A probe containing a small radium-beryllium radioactive source is lowered into the tubes and, by means of a BF_3 sensor, transmits the return rate of slow neutrons to a readout instrument.

These studies will be expanded into different soil and cover types. The present seeks to determine whether, in varying densities of lodgepole pine, there are marked differences in the amount and regime of soil moisture depletion. In a fifth plot, six tubes have been installed to 15 feet to study the influence of lodgepole pine on soil moisture depletion at greater depths.

In Marmot Creek Basin, a companion study using Colman soil moisture units was begun in the fall of 1963. This study will determine changes in soil moisture which occur under mature spruce-fir forest, cutover spruce-fir forest and young lodgepole pine forest, on similar soil. Six ranks of Colman soil moisture units are envisaged. Colman soil moisture units were used because access tubes for the neutron equipment could not be installed with hand equipment, due to rock in the profile.

Soil temperature studies

These studies use temperature readings from the aforementioned Colman soil moisture units.

This study was prompted by the discovery in July, 1963 of concrete soil frost beneath mature spruce-fir forest. If this is found to be widespread in occurrence, it has significant hydrologic implications. The studies measure soil temperatures at depths from the soil-humus interface down to 72 inches and are merely a beginning. Excavation to determine soil frost occurrence, depth and type is envisaged.

Forest litter studies

These Forest Research Branch studies are also at an embryonic stage. They test devices to measure the amount of rainfall absorbed by litter in both spruce-fir and lodgepole pine forests, and collect litter samples from uncut spruce-fir, cutover spruce-fir and young lodgepole pine stands, for analysis of water-retaining capacity in the laboratory.

Spruce-fir forests on Marmot Creek Basin commonly have considerable litter depth, especially where there is a bryophyte layer. The combination of bryophyte layer, forest litter and decayed wood may at times attain depths of 12 or more inches. This litter cover must absorb a considerable portion of precipitation experienced.

Snow accumulation and melt studies

These studies are a joint Meteorological Branch and Forest Research Branch responsibility. Some snow courses in Marmot Creek Basin have a dual function, having been located in different topographic situations and forest types.

A study of snow accumulation and melt under different densities of lodgepole pine was begun in 1962–63. Snowpack at low elevations was found to be ephemeral, and results have not been encouraging.

Erosion hazard studies

These studies are undertaken by Forest Research Branch, with the assistance of Research Council of Alberta and the University of Alberta.

Erosion hazard studies are designed to evaluate the relative susceptibility to erosion of different types of surficial deposits supporting spruce-fir forests when disturbed by harvest cutting and associated activities. Surficial deposits are being examined and classified in a meaningful, purposive scheme which will be of direct benefit to forest managers in the avoidance of erosion and site deterioration. They were begun in 1963.

The study will describe and delineate those surficial deposits most susceptible to erosion. Bases for determination are expected to be the type and genesis of surficial deposits, along with lithological composition.

An investigation of land-vegetation typology, carried out early in the program, may provide some guidelines. Its results are given by Jeffrey, Bayrock, Lutwick and Dormaar (1964). Surficial deposits were classified according to their relative susceptibility to erosion hazard, which in turn appeared affected by relative $CaCO_3$ concentration in the deposit. A tentative classification of surficial deposits, soils and vegetation in a small valley was produced.

One conclusion was that classification of surficial deposits alone provided information of considerable value. This is, in any case, an essential percursor to integrated land-vegetation typology.

Studies of precipitation measurement

Three studies are included here since they are carried out in Marmot Creek. The first of these studies is the volumetric assessment of snowpack by photogrammetric methods. This is a feasibility study to determine whether or not is possible to estimate snowpack volumes with useful accuracy using photogrammetry. Studies are made by Meteorological Branch with Prairie Farm Rehabilitation Administration providing supporting analyses.

If the difference in elevation between snow-free and snow-covered states is known for an area, the volume of the snow cover may readily be computed. The volume may be converted to water equivalent using density measurements obtained on the ground, thereby providing information which is required for quantitative studies of the water balance.

Photogrammetry may be used to determine elevations from aerial photography. It is proposed to investigate if it may be used successfully in snow photography and, if so, what level of accuracy may be obtained. The basin snowpack was photographed in Spring, 1963 (scale: 1,320 feet =1 inch). Should this assessment prove favorable, it is proposed to analyse photography of the 1964 snow pack and verify the analysis by field survey. Ground surveys will be made coincidentally by helicopter parties.

The second study is comparison of catch in different rain gauge types. This study is undertaken by Meteorological Branch in Marmot Creek Basin, comparing catch in standard, small orifice and sloped orifice rain gauges at the same site.

The third study is of rainfall measurement in frost clearings. It will be undertaken by Meteorological Branch in Marmot Creek Basin, to determine the effect of opening size, and of gauge position within openings, upon rainfall catch.

As mentioned earlier, these studies represent no more than a rudimentary beginning to a program of research in spruce-fir forests. Work will be intensified and expanded in the future.

RESEARCH INTO THE HYDROLOGY OF RANGELANDS AND ASSOCIATED FOREST TYPES

The only research presently underway is concentrated in montane aspen forest and associated grasslands. These lie exclusively in the southern portion of the area, mostly in the Porcupine Hills. However, it is believed that this research will eventually embrace all rangelands and associated non-commercial forest types. The project is only just beginning. A basin has been selected, and a limited start made on reconnaissance study.

In this project, the approach differs somewhat in emphasis from that of the spruce-fir forest research program. In the latter, a basin was chosen and a program of research defined and built up around that basin. In these studies, a program of research was defined and planned, and steps made to select a basin to fulfill the objectives of the research program. The distinction is largely one of emphasis. The general procedure followed is taken as a guide for the future.

The woody vegetation in the drier eastern portions of the southern mountains and foothills is already subject to removal to supply more grazing capacity. Existing ranges are fully stocked at present management intensities. Because of economic pressures, it appears reasonable to assume that there will be a strong incentive to livestock producers towards removal of forest and shrub vegetation (primarily aspen and willow) and conversion of such areas to grassland. Such a trend will present problems of range and watershed management.

The following long-term objectives of study were accordingly accepted by the Technical Co-ordinating Committee in February, 1963: (1) to assess the suitability of existing methods of forest removal and conversion to grassland in the montane aspen forest of the Saskatchewan River headwaters, from the standpoints of range management (including big game) and watershed preservation, and to develop satisfactory methods, if necessary, (2) to choose a suitable basin in which to gather information on hydrology, particularly relating to precipitation, runoff and groundwater, and to their interrelationships, (3) to establish, by means of plot studies, the effect of forest removal and conversion to grassland, upon sedimentation (water quality), water yield and water regime, and upon rangeland productivity, and (4) finally, within the basin chosen, upon culmination of adequate and satisfactory plot studies, to carry out an experiment (or experiments) to assess the integrated effect of forest removal and conversion to grassland upon water quality, yield and regime.

The research objectives of the study program and of the gauged basin itself are effectively identical. The gauged basin supplies an instrumented research area and a tool to provide an integrated hydrologic result from treatment, at the same time providing essential hydrologic data of wider interest.

To attain these objectives, it will be necessary to: (1) carry out reconnaissance and plot studies in the aspen forest and associated grassland, in order to establish its characteristics, to assess conversion methods and their effects, and to develop suitable techniques, (2) choose, instrument and calibrate a suitable basin, and collect necessary hydrologic data, and (3) carry out a gauged basin experimental treatment (or treatments).

RECONNAISSANCE AND PLOT STUDIES

It is presently necessary to carry out reconnaissance studies of the aspen forest, associated shrub types (primarily willow), and associated grasslands, to determine their main pedological (including geological) and ecological characteristics. When the main subtypes are established, it will probably then be desirable to establish comparative infiltration characteristics. These two initial studies undoubtedly are essential, and at their conclusion a basis for further research will be available. This reconnaissance was begun in 1963 by Canada Department of Agriculture, Research Branch.

Presently, long-term objectives of reconnaissance and plot studies leading to and culminating in gauged basin experimental treatment are considered to be: (1) to establish and compare the characteristics (primarily pedological, geological, ecological and chorologic) of aspen forests and associated grasslands, (2) to review, compare and select, (and as necessary, to develop and test) methods of aspen forest removal and conversion to grassland, (3) to develop and test methods of maintaining artificially established grasslands in good condition from a range yield standpoint, and of fully utilizing their production, (4) to study, assess and establish (and if necessary, to counteract) the effect of forest cover removal and subsequent grassland establishment upon sedimentation, water quality, infiltration and overland flow, (5) to compare forest and both natural and artificial grasslands, from the standpoint of consumptive water use and water yield by research into plant-soil-water relationships, and (6) to establish the importance of the aspen forest to big game, primarily to mule deer and elk.

Very little has yet been done to implement these study objectives.

THE BASIN SELECTION PROCESS

Since the gauged basin is the subject of considerable investment in initial capital expenditure and of continuing disbursement of manpower, its choice and the initial evaluation leading to choice are important. Based upon this philosophy, it is considered more important to make a good selection of a suitable gauged basin than it is to install instrumentation before a certain deadline or during a certain year. It is desirable to carry out a series of initial assessments of candidate basins, these assessments, in sequence of occurrence in time, being:

(a) Air photo examination. The whole area involved in the ecological, climatic and geological types under consideration is examined, and tentative selection on aerial photos made of a number of candidate basins.

(b) Preliminary examination. This is carried out by ground and by aerial study. It requires on-the-spot examination to compare field impressions with those obtained from aerial photographs.

All candidate basins are then subjected to title search for mineral leases, etc. This allows an early beginning to work on the problem of existing leases for mineral development, especially oil and gas exploration.

(c) Geologic and groundwater evaluation. This is a ground reconnaissance by geologists and hydrogeologists. It is a key operation, much subsequent work and, to a large extent, the final selection, being based on it. Its objective is to determine the suitability of the basins geologically, and from a groundwater standpoint. Some basins which have outstanding geological flaws are given little further study, other than documentation of the factor making them unsuitable. Other basins, appearing more promising, are given more detailed study, designed to uncover any less prominent undesirable features and to allow each to be assessed in comparison to the others.

(d) Assessment of suitability for streamgauging. This requires reconnaissance to determine whether suitable sites exist in the surviving candidate basins.

(e) Land inventory and timber cruise. This assessment is approximate and is carried out in those basins surviving geologic and groundwater assessment. The areas and locations of different land conditions within candidate basins are approximately derived. At the same time, forest insect and disease assessment is carried out.

(f) Assessment of road access. By this evaluation, access and power supply into candidate basins are taken into account, and assessment made of the access improvement required in each candidate basin, if it were the final selection.

(g) Assessment of suitability for meteorological instrumentation. This is self-explanatory.

(h) Preliminary appraisal of basin hydrology in surviving candidate basins. As a result of the steps above, a number of candidate basins remain and are ratable in terms of relative suitability. It remains to determine how best to obviate the risk of choosing a basin whose hydrograph is atypical of other basins of similar size and configuration. Originally it was thought that temporary stream-gauge controls in four or five promising basins might be erected and hydrometric data collected for a minimum of one year. Upon analysis, there appeared a number of possible disadvantages to such a procedure. Finally, it was decided that assessment of existing hydrometric records for the area concerned would provide sufficient information to minimize the risk of poor selection.

By means of the steps outlined, a reservoir of comparative knowledge is built up and a reasonable basis for final selection is obtained.

RESULT OF BASIN SELECTION PROCESS

By air photo examination, and use of topographic and forest cover maps, a total of thirteen candidate basins was selected. Aerial reconnaissance of the whole montane aspen-associated grassland complex, including the thirteen candidate basins, was then undertaken by fixed-wing aircraft.

It was desirable to develop certain criteria for the selection of candidate basins. Insofar as gauged basin experimentation is concerned, two alternatives are available: (1) Selection of a basin of dendritic drainage pattern, as in the Marmot Creek Project. This was thought the better method for studies of streamflow and groundwater, though no great advantage accrues to treatment studies, In brief, it allows more versatility in objectives. (2) The second method involves the use of several small basins, separated one from another in a non-dendritic drainage pattern. Such basins have similar characteristics (configuration, aspect, elevation, geology, cover, etc.). This method restricts the possibilities of hydrologic study and largely limits the objectives of study to treatment experiments. For the above reasons, a dendritic drainage pattern was considered desirable.

The other criteria used were various. Cover is important because of study objectives; contiguous areas for plot studies are also desirable. The upper margin of the basin should not be too high in elevation, so that results of treatment will not be overshadowed volumes of runoff from untreated areas (cf. Marmot Creek Project). Good definition of sub-basin boundaries is important, in order to minimize the possibilities of inter-flow between sub-basins and to allow clear delimitation of areas to be treated. A relatively narrow outlet in the main channel was considered more desirable than a broad outlet. Large areas of marsh and organic soil types were believed undesirable, as were numerous beaver ponds.

Using these different criteria, the original thirteen candidate basins, chosen by photogrammetric examination, were reduced to eight. Three had non-dendritic, and the remainder dendritic, drainage patterns.

The third stage in the selection process was geologic and groundwater evaluation, which was carried out by Research Council of Alberta. During this step, as anticipated, some basins were rejected as undesirable. In fact, the eight candidate basins were reduced to three, four being rejected on the basis of geological complexity and a fifth on complexity of topographic form.

Meteorological Branch evaluated the suitability of candidate basins for meteorological instrumentation. All basins were of approximately equal merit. Forest Entomology and Pathology Branch examined candidate basins to assess insect and disease conditions. No undesirable conditions were found. Eastern Rockies Forest Conservation examined basins for leases, road access and power supply. Two candidate basins were part of a Crown grazing lease. Road access was not problematical, and provision of power was possible. Alberta Forest Service estimated the area of different vegetation types in all three basins. One basin contained a high proportion of coniferous forest. Ecological and pedological conditions were assessed by Research Branch, Canada Department of Agriculture. All basins were similar. Water Resources Branch, Canada Department of Northern Affairs and National Resources, evaluated basins for streamgauging suitability and made preliminary evaluation of basin hydrology. All basins were of approximately equal merit, though one basin, appearing to have one channel which carried little flow, was less desirable than the others.

These reports from different agencies, co-operating in the selection process, formed the basis of discussion for a Co-ordinator's Wording Group. Three basins and a fourth possibility, namely a portion of one of the three basins rather than its whole area, were considered. During the Working Group meeting, each factor was carefully weighed and evaluated. One of the three surviving candidate basins was rejected, largely because of the high proportion of coniferous forest it contained. Another was thought undesirable because it had one sub-basin with little flow. Three sub-basins were believed desirable, since this would allow (a) one control sub-basin, (b) one sub-basin in which a simple clearing trial could be initiated, and (c) one sub-basin in which purposive vegetation manipulation could be attempted. Choice remaining was between one area with three sub-basins, one of questionable value, and another area with only two sub-basins.

It was decided that the area with two sub-basins be chosen and that, in addition, another small basin, a little removed, also be instrumented. The main two-sub-basin area would serve for hydrologic studies and provide one control sub-basin plus one treatment sub-basin, while the separate area would provide the second treatment sub-basin desired.

The area chosen, therefore, represented a combination of the two original alternatives (dendritic and non-dendritic). The area is known as Streeter Basin and lies in T. 13, R. 1, W. of 5 Mer. in Sections 21, 22, 27 and 28, in the Porcupine Hills, at Lat. 50° 7' N., Long. 114° 3' W., approximately. The upper margin is at 5,300 feet elevation, its lower limit at 4,500 feet, approximately. The basin is smaller in size than Marmot Creek, its total area being about one sq. mile.

FUTURE WORK IN STREETER BASIN

Selection of the basin was made in November, 1963. Plans for future development comprise: (a) essential development and (b) basin inventory.

(a) Essential development

A high proportion of flow comes from springs. In addition to four streamgauges, it will be necessary to instrument two major springs. Not only does spring flow create additional requirements of surface flow measurement; it also poses a problem of groundwater study. Intensive groundwater instrumentation is believed absolutely mandatory.

1. Streamgauging

Six streamgauges are required, two on major springs. A simple V-notch control with F-type recorder will suffice for the springs, but in the main controls the situation is more complicated. Reconnaissance has shown that sediment movement is to be expected during high flows, and it will be necessary to plan controls capable of passing considerable sediment, which might result from treatment experiments.

Accordingly, the controls must be of a flume type. A number of alternatives are available; for instance, San Dimas flume, trapezoidal Venturi flume or H-type flume with sloping floor. Choice is further made difficult by the need to measure low flows with high accuracy, which requires adaptation of some of these structures. San Dimas flume with small V-notch combinations would suffice, as would the trapezoidal Venturi flume with bolt-on V-notch. The H-flume gives high accuracy at low flows, but would not be useful where bedload was appreciable. The decision on the controls to be chosen is still under review. The need for sediment basins to collect sediment below the flumes is also being evaluated. Selection of streamgauging sites is carried out by Canada Water Resources Branch, in on-the-ground consultation with Research Council of Alberta groundwater personnel, to ensure locations satisfactory for all purposes.

Sediment and water quality sampling will begin in 1965.

2. Meteorological instrumentation

The most important meteorological parameters are precipitation, wind direction and speed, temperature, humidity and solar radiation. Sufficient density of instrumentation is planned to allow assessment of the effects of aspect, exposure, elevation and vegetative cover. The instrumentation planned is such as to require only weekly attention.

Reconnaissance will seek to establish whether or not there are areas where persistent, as distinct from ephemeral, snowpack exists. Until this is established, no snowcourses or snow stakes are planned.

3. Geological mapping and groundwater instrumentation

During 1964, a detailed geological survey will be undertaken. In groundwater study the Marmot Creek Project has priority, the full groundwater instrumentation program in Streeter Basin being scheduled for 1965.

4. Roads and power

Road access sufficient to allow access to streamgauge locations and permit four-wheel drive vehicles to reach the top of the basin is planned. Power provision in the basin is under review.

5. Insect and disease survey

Regular checks of insect and disease conditions, similar to those in Marmot Creek Basin, are planned.

(b) Basin inventory

Basin inventory is essentially the same as in Marmot Creek Basin. It consists of (1) survey and topographic mapping (Water Resources Branch, Alberta Department of Agriculture), (2) soil survey (Alberta Soil Survey), (3) vegetation mapping (Research Branch, Canada Department of Agriculture, with assistance from Eastern Rockies Forest Conservation Board), (4) aerial photography (Alberta Forest Service), and (5) forest inventory (Alberta Forest Service).

The main difference from Marmot Creek is in geophysical survey, which is not planned for the Streeter Basin Project, to some extent because its results were not promising in Marmot Creek and also because it is relatively simple to arrive at the same result through pilot drilling.

RESEARCH INTO THE HYDROLOGY OF LODGEPOLE PINE FORESTS

Studies of the hydrology of lodgepole pine forest are accorded high priority. Lodgepole pine forest is the most abundant cover type in the Saskatchewan River headwaters. It is presently subject to only limited exploitation for sawtimber and poles. In the future, however, commercial exploitation of lodgepole pine forests may be intensified. There have been reports of commercial groups being interested in the establishment of a pulp mill. Such trends require the watershed research program to work towards developing recommendations in: (a) avoidance of damaging conditions resulting from intensified exploitation of lodgepole pine forests and (b) maintaining or improving water yield and/or regime, through manipulation of lodgepole pine cover. In addition, it is clear that any program of watershed improvement must take cognizance of lodgepole pine forests because of that forest's very abundance.

In order to carry out this research, it will be necessary (a) to implement gauged basin studies through choice, instrumentation, calibration and eventual modification of suitable gauged basins, and (b) to carry out reconnaissance and plot studies to elucidate the vital interrelationships of hydrologic factors in lodgepole pine forests, culminating in intelligent prescription of treatment experiments.

Research into the hydrology of lodgepole pine forests is the third major undertaking in the watershed research program. At present a general plan, including study objectives, has received approval.

Lodgepole pine in the headwaters area may be said to occur in two main forms: (a) merchantable forests, i.e., forests suitable for commercial exploitation, primarily pulpwood and poles, but including some sawtimber stands, and (b) overdense, sapling stands, i.e., non-merchantable forests, characterized by low height, high density and poor growth. It goes without saying that there are a number of intergradations between these two main types. Because of the possibility of intensified commercial interest in merchantable lodgepole pine forests, it is obviously essential to carry out research into this type of cover, and to establish (a) the effect of commercial cutting on watershed values, and (b) the optimal arrangement of cover for watershed management.

The overdense, sapling stands are not suitable for commercial development. These stands cover appreciable areas and are a considerable problem to management. Interest in these stands is keen among forest managers, and lively concern is felt regarding the possibility of their improvement. Nothing is known of their hydrologic characteristics. It is, therefore, desirable to establish (a) the effect of conventional stand improvement practices upon watershed values, (b) the possibility of radically altering conventional stand improvement practices to attain desired objectives in both watershed and forest management, (c) the changes in hydrologic characteristics attendant upon natural development of these stands towards maturity, and (d) and optimal cover arrangement in these stands for watershed management.

Accordingly, it is proposed that two gauged basins be selected, supporting, respectively, (1) merchantable lodgepole pine forest and (2) overdense, sapling lodgepole pine forest. These basins should be located in reasonably close proximity, one to another, and should have similar geological characteristics.

Objectives of research into the hydrology of lodgepole pine forests are:

(1) to establish the hydrology, particularly relating to precipitation, runoff and groundwater within the basins chosen,

(2) to establish the effect of commercial timber harvest, and subsequent regrowth, in merchantable lodgepole pine forests upon water yield, regime and quality,

(3) to establish the effect of purposive manipulation in merchantable lodgepole pine forests upon water yield, regime and quality, and

(4) to establish the effect of purposive manipulation in overdense, sapling lodgepole pine forests upon water yield, regime and quality.

These objectives are attained through the usual sequence, i.e., (a) reconnaissance and plot studies, (b) selection of suitable basins, followed by instrumentation, calibration and data collection, and (c) application of treatment experiments. The same selection process will be used as in the Streeter Basin Project, basins being selected following the same sequence of evaluation.

BROAD INVESTIGATIONS OF AN INVENTORY NATURE

Though the watershed research program has, in its initial stages, concentrated upon implementation of gauged basin studies, some progress has also been made in certain broad, inventory studies. Such studies were recommended by Jeffrey (1961) and have the aim of providing information on the whole headwaters areas. They have a reconnaissance role and are invaluable in research planning. The Saskatchewan River headwaters area is relatively poorly understood. Considerable importance has therefore been attached to implementation of broad, inventory-type studies and compilations.

Climatic records in the Saskatchewan River headwaters have been brought up to date, compiled and analyzed by McKay, Curry and Mann (1963). This work makes readily available all available knowledge on climate. A similar study is underway in existing hydrometric data. This is being done by Water Resources Branch, Canada Department of Northern Affairs and National Resources. These two compilations of existing data will provide assistance in subdivision of the headwaters into component hydrologic zones.

Very little is known of sediment production, and therefore it is difficult to evaluate whether a serious problem exists. Whether disturbance activities, such as timber harvesting and road building, are actually a valid source of concern is not known. If sediment production in the headwaters, in comparison to the plains, is negligible, it can be decided that sediment production and erosion control do not require intensive research attention. Sediment production is currently considered to be probably of relatively minor importance, but this assessment is subjective.

Water Resources Branch, Canada Department of Northern Affairs and National Resources, is considering the needs of sediment survey in the headwaters, with a view to answering these questions. One fullscale, sediment sampling station is proposed for 1964.

Very little is known of water quality, and there is practically no knowledge of variation in water quality. A preliminary sampling program was carried out in Fall, 1963 by Industrial Waters Section, Canada Department of Mines and Technical Surveys. Upon analysis of these data, Industrial Waters Section proposes to develop a plan of water quality sampling. The influence of coal mining upon water quality will also be studied.

There exists virtually no knowledge of surficial deposits or soils in the headwaters area; nor have groundwater resources been inventoried. Exploratory survey of surficial deposits, groundwater and soil is being undertaken by Alberta Soil Survey. This work began in 1963 with air photo interpretation. Ground survey will follow.

In the Rocky Mountain Forest Reserves, a forest inventory has just been completed. This inventory provides data of direct value in research planning.

These broad inventory type studies are most valuable. They provide data which is essential for determination of priorities and intelligent planning of research development. A number of similar studies were proposed by Jeffrey (1961). Their feasibility awaits further assessment.

Expansion of existing climatological and hydrometric networks has been undertaken by two sub-committees of the Technical Co-ordinating Committee. These committees aim at the intensification of existing networks throughout the headwaters. The climatological network development is based upon principles outlined by McKay (1961). The function served by good networks is vital, and the need for expanded networks in the headwaters area is obvious.

CONCLUSION

The foregoing has shown program development, through three main projects seeking eventually to establish effects of vegetation manipulation on water yield, regime and quality. These projects concern (1) subalpine spruce-fir forest (Marmot Creek Project), (2) aspen forest and associated grasslands (Streeter Basin Project) and (3) lodgepole pine forest.

These three gauged basin projects, of which one (Marmot Creek is underway, one (Streeter Basin) is beginning, and the third is in a very early stage of development, are to be fully supported by an adequate series of reconnaissance and plot studies. Such individual investigations are of high importance, inasmuch as they furnish the basis of planning manipulation treatments or of understanding results of simple trials. At the same time, the whole headwaters area is subject to inventory and study through a number of broad investigations of a more general nature, whose purpose is to determine the actual range of conditions existent. Such information will furnish a base for future research planning and for eventual extrapolation of study results.

Though these three basin projects provide a presently adequate facility for water yield improvement research, it is possible that a small alpine basin to study snowpack manipulation could also fruitfully be selected.

All three basins, for reasons of land ownership, are or will be located in the area of Mesozoic rocks, the important Paleozoic area being neglected. It is desirable that "bench-mark" gauged basins be located in the Paleozoic area. These basins would have the objective of collecting necessary hydrologic data on precipitation, runoff and groundwater. They would have no treatment experiment function.

Progress of individual studies to date is disappointing. It is intended to intensify these appreciably. A trial of optimal timber harvesting techniques in spruce-fir forests, to allow evaluation of problems of erosion and sedimentation is also desirable. Studies of snow should be greatly intensified, and preliminary evaluation of potential avalanche hazard undertaken in the future.

REFERENCES

CROCKFORD, M. B. B. 1949. Geology of the Ribbon Creek area, Alberta. Res. Coun. Alberta Rept. No. 52, 67 pp.

CAN. DEPT. MINES & TECHNICAL SURVEYS. 1957a. Geology and economic minerals of Canada. Can. Dept. Mines & Tech. Surv., Geol. Surv., Econ. Geol. Ser. No. 1.

CAN. DEPT. MINES & TECHNICAL SURVEYS. 1957b. Atlas of Canada. Can. Dept. Mines & Tech. Surv., Geol. Br., Ottawa.

GREEN, R. & J. F. JONES. 1961. Geology and groundwater study of the Marmot Creek Basin Res. Counc. Alberta. Typewritten report.

JEFFREY, W. W. 1961. Prerequisites and priorities for watershed research in the Eastern Rockies, Alberta (a tentative, initial appraisal). Can. Dept. Forestry, Forest Research Branch. Mimeo.

JEFFREY, W. W., L. A. BAYROCK, L. E. LUTWICK and J.F. DORMAAR. 1964. Land-vegetation typology in the upper Oldman River Basin, Alberta. Can. Dept. Forestry, Forest Research Branch (In Press).

LAYCOCK, A.H. 1957. Precipitation and streamflow in the mountains and foothills region of the Saskatchewan River Basin. Prairie Provinces Water Board, Report No. 6.

LINSLEY, R. K., M. A. KOHLER and J. L. H. PAULUS. 1949. Applied Hydrology. McGraw – Hill, New York.

McKAY, G. A., G. E. CURRY and A. S. MANN. 1963. Climatic records for the Saskatchewan River Headwaters. Can. Dept. Agric., Prairie Farm Rehab. Admin., Engineering Branch.

McKAY, G. A. 1961. Whether observation network in the Eastern Rockies. Can. Dept. Agric., Prairie Farm Rehab. Admin., Engineering Branch. Mimeo.

OGILVIE, R. T. 1964. Ecology of the forests in the Rocky Mountains of Alberta. Can. Dept. Forestry. Forest Research Branch (In Press).

PRAIRIE PROVINCES WATER BOARD. 1960. Preliminary studies for the development of integrated basin plans for the Nelson River Drainage Basin, Volume II. Regina, Sask. Mimeo.

APPENDIX I

COLLECTION AND COMPILATION OF STREAMFLOW DATA IN MARMOT CREEK BASIN

D.A. Davis[1]

In Marmot Creek basin there are three major sub-basins, of approximately equal size, varying from 0.8 to 1.1 square miles, and forming a dendritic drainage pattern. Stream gradients are steep, exceeding five per cent in most reaches. Sub-basin elevations range from 5,300 to approximately 9,000 feet. In general, the stream bed material consists of large boulders with some rough gravel. Approximately 30 to 50 per cent of each sub-basin is alpine, the remaining portion being covered by mature spruce-fir forest with some young lodgepole pine forest in the lower reaches.

The tributaries originate as sidehill springs near the lower limit of the alpine zone in areas of broken sandstone and shale deposits. Discharge rises rapidly in May, stays relatively high in June and July, mainly due to snowmelt and then recedes gradually to a base winter flow. Interception rates and sub-surface storage are large, helping to smooth out the effects of rainfall on streamflow.

Streamflow measurement

Assessment of future basin treatment studies will require estimates of post-treatment flow by correlation with adjacent sub-basin flow; therefore streamflow measurement error must be kept as small as possible. A measurement error of ± 2 per cent has been set as the objective in Marmot Creek Basin, this error limit being consistent with practical field measuring devices.

Freezing conditions serious enough to affect streamflow measurement stations occur during five months of the year. Since accurate records must be collected during this period, the types of instruments and controls which may be used are limited to those which can be heated or protected with a minimum of difficulty.

Also, long periods of unattended reliable operation during extremely cold or wet weather are necessary because of the remoteness of the basin.

Streamflow measurement stations have been installed near the mouths of the three sub-basins and also on the combined stream some distance below the three for a check on flow and as a central station for measurement of sediment and water quality.

Main station: For water budget studies it is advantageous to measure total flow as opposed to surface runoff only. With this in mind, the main station has been constructed on a quartzite-dolomite exposed bedrock formation which acts as a cutoff wall across the lower end of the research area.

[1] Engineer, Water Resources Branch, Canada Department of Northern Affairs and National Resources, Calgary, Alberta.

A four-foot 120° V-notch weir was chosen as the control because ponding without leakage is possible at this site; there is adequate drop below the weir; and the notch gives good accuracy throughout the design flow range of 0.1 to 150 cfs.

The stream gradient is steep at the site, making it impossible to obtain a pool large enough to eliminate velocity of approach at high flows without either building the weir excessively high or enlarging the stream channel by blasting. Neither alternative was practical. Instead, current-meter measurements have been made to define accurately the stage-discharge relation. Two baffles have been constructed in the stream channel above the weir to dissipate energy and ensure a straight, even stream approach to the weir. These pools also act as storage for bedload material which might otherwise affect the weir rating through accumulation in the weir pond.

The Stevens A-35 recorder installed at the main station is fitted with a negator spring-driven clock and will run unattended for periods of up to three months. The ratio between the vertical movement of the water surface and the resulting movement of the pen is 1:1 which makes it possible to detect water level changes of 0.002 foot, or flow changes of approximately one per cent. A hook gauge is used to obtain water level in the weir pond.

A bridge has been constructed across the notch for use in taking suspended sediment samples in the middle of the notch.

Icing of the weir notch in winter is prevented by placing an insulated hood over the lower section. The hood extends into the water on the pool side of the notch but is of sufficient size to prevent obstruction of flow. Two thermostatically controlled heat lamps prevent ice forming on or below the notch. The location of the gauge well in the weir pool eliminates the problem of frozen intakes. A small heat lamp is sufficient to keep the well free of ice. Power is supplied through a 110-volt distribution system to the weir site.

Lower tributary: The channel of Cabin Creek, the lowest tributary, is composed of fairly deep till deposits. These make weir-type controls impractical since seepage would be difficult to eliminate. This sub-basin has less vegetative cover than the other two and probably develops more sediment at peak discharges.

A 2.5-feet head H-flume was chosen as the most satisfactory control. Accuracy is good throughout the entire flow range of 0.02 to 19 cfs and the flume is self-cleaning at high flows. Most important, disturbance of the stream channel during installation is small. There is no ponding and consequently no increase in seepage.

The negator spring-driven Stevens A-35 recorder will detect stage changes of 0.002 foot and will operate without attention for three months. One source of error in flume operation is in obtaining an accurate water level to which to relate the recorder. This problem was overcome by installing a manometer on the side of the float well which can be read to ± .002 foot. Discharge is determined by using the theoretical stage-discharge curve and recorder chart. The validity of this stage-discharge relation will be checked by field measurement.

For winter operation the front part of the flume is insulated and a propane burner placed inside. A small propane pilot light keeps the well free of ice.

Upper tributaries: The two upper tributaries, Middle Creek and Twin Creek, are similar in size and basin characteristics. Both stream channels are boulder-strewn but underlying materials are shallower and less pervious than the Cabin Creek channel. Identical 2.5-feet head 90° V-notch weirs have been constructed at both sites, every care being taken not to increase seepage. The weir pools were excavated so that the notch was constructed at approximately the original stream grade. The backfill behind the pool side logs was mixed with high swell bentonite mud and bentonite mud was also placed on the pool bottom. Thus no additional sub-surface seepage has been introduced by construction. The weir ponds have been constructed large enough to ensure that velocity of approach would not affect the stage-discharge relationship. Cadmium plating on the weir crest and a bedload collection pool above the weir pond should keep the weir rating constant for some time to come.

Winter operation is facilitated by a hood and lamp setup similar to that described for the main station. Negator spring-drive Stevens A-35 recorders have been installed at both sites with a chart ratio identical to the one described for the main station. Water level in the weir ponds is obtained by hook gauge.

Preliminary results

Streamflow: Excellent records have been obtained at the main station for over a year and no modifications seem necessary. Mean daily flows have been computed using the recorder chart and current meter developed stage-discharge rating table. Flow in inches of runoff, acre-feet and cfs-days have been tabulated by months and is given in Table 1, where the monthly and instantaneous maxima and minima are also shown.

The discharge records for the sub-basin sites were collected at temporary streamflow stations for most of the summer of 1963. The probable error in these records is in the neighbourhood of five per cent. The weirs and flume replacing the temporary stations have been in operation only a few months but seem to be giving reliable records. Discharge records are tabulated by month in Tables 2 to 4.

Discharge hydrographs of the streamflow records obtained during 1963 and 1964 are shown in Figs. 1 to 4 and a plot of accumulated runoff in Fig. 5. It appears that the two upper tributaries, Middle and Twin Creeks, are similar in discharge characteristics. Yields from these two basins were almost identical for the summer period with a time shift reflecting the difference in aspect. Looking ahead, it would seem that a good correlation between the two discharges should exist, thus making it possible to calibrate one before treatment. Cabin Creek, on the other hand, has quite different hydrograph characteristics.

Sediment: Depth integrated sediment samples were taken during the summer of 1963 in the middle of the V-notch at the main station. Upstream turbulence should ensure a well-distributed suspended sediment load. Samples were taken daily during the high water period and twice weekly and later weekly as the flow receded.

Laboratory analyses show low sediment concentration, even during peak flows. Because of this low concentration, the suspended sediment was not subjected to grain size analysis. A maximum of 87 ppm was recorded during the summer rain peak of 17 cfs per square mile. The median sediment concentration for the open-water season was about 3 ppm.

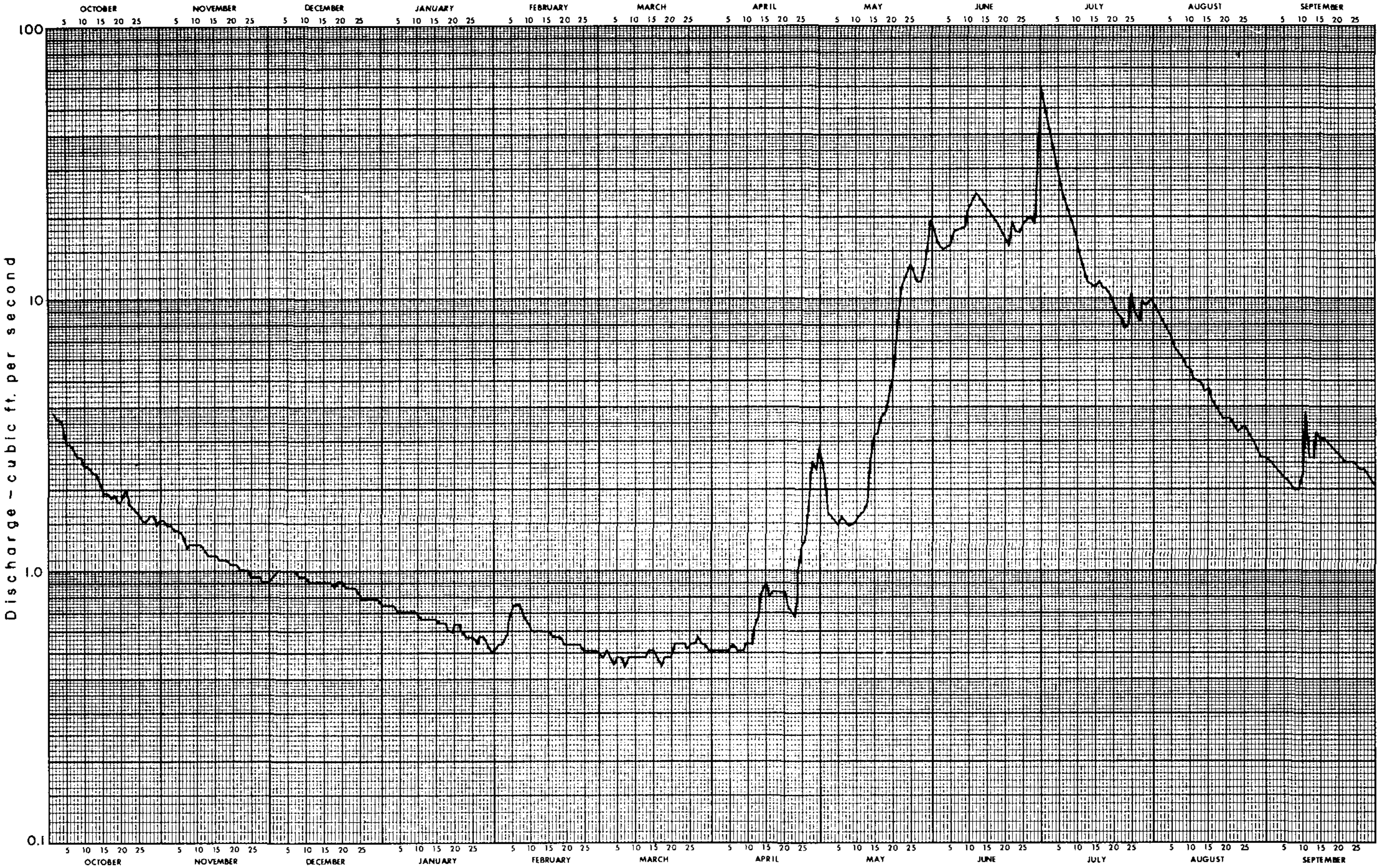
Construction of the weirs and improvement of the road system caused some channel disturbance but did not raise the suspended sediment concentration to above 20 ppm. It is expected that the higher spring runoff flows will cause some increase in suspended sediment because of this disturbance.

Figure 1

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES - WATER RESOURCES BRANCH

HYDROGRAPH FOR Marmot Creek - Main Stem Station No. 5BF-16 R 187 (1-62)

for year ending 30 September 1963



Plotted by D.D. Checked by Approved by Date

Marmot Creek - Main Stem

TABLE 1

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES-WATER RESOURCES BRANCH R 79B (1-62)

Daily Gauge Height in feet and Discharge in ______ cubic feet per second for year ending 30 September 19 63

Drainage area 3.63 square miles

Station No. 5BF-16

Day	October Gauge Height	October Discharge	November Gauge Height	November Discharge	December Gauge Height	December Discharge	January Gauge Height	January Discharge	February Gauge Height	February Discharge	March Gauge Height	March Discharge
1		3.8	1.90	1.53	1.79	0.95	1.74	0.75	1.68	0.54	1.66	0.48
2		3.6	1.89	1.47	1.80	1.00	1.74	0.75	1.68	0.54	1.67	0.51
3		3.6	1.89	1.47	1.80	1.00	1.74	0.75	1.69	0.57	1.66	0.48
4		3.3	1.88	1.41	1.80	1.00	1.73	0.71	1.72	0.67	1.65	0.45
5		2.9	1.88	1.41	1.80	1.00	1.73	0.71	1.74	0.75	1.66	0.48
6		2.9	1.87	1.36	1.80	1.00	1.73	0.71	1.74	0.75	1.66	0.48
7		2.7	1.84	1.20	1.80	1.00	1.73	0.71	1.74	0.75	1.65	0.45
8		2.6	1.85	1.25	1.79	0.95	1.73	0.71	1.72	0.67	1.66	0.48
9		2.6	1.85	1.25	1.79	0.95	1.73	0.71	1.71	0.64	1.66	0.48
10		2.4	1.85	1.25	1.79	0.95	1.72	0.67	1.70	0.60	1.66	0.48
11		2.4	1.85	1.25	1.78	0.91	1.72	0.67	1.70	0.60	1.66	0.48
12	2.01	2.28	1.84	1.20	1.78	0.91	1.72	0.67	1.70	0.60	1.66	0.48
13	2.01	2.28	1.83	1.15	1.78	0.91	1.72	0.67	1.70	0.60	1.66	0.48
14	1.98	2.06	1.83	1.15	1.78	0.91	1.72	0.67	1.70	0.60	1.67	0.51
15	1.96	1.92	1.83	1.15	1.78	0.91	1.72	0.67	1.70	0.60	1.67	0.51
16	1.96	1.92	1.82	1.10	1.78	0.91	1.71	0.64	1.69	0.57	1.66	0.48
17	1.95	1.85	1.82	1.10	1.78	0.91	1.71	0.64	1.69	0.57	1.65	0.45
18	1.96	1.92	1.82	1.10	1.77	0.87	1.70	0.60	1.69	0.57	1.66	0.48
19	1.94	1.78	1.81	1.05	1.78	0.91	1.70	0.60	1.68	0.54	1.66	0.48
20	1.94	1.78	1.81	1.05	1.78	0.91	1.71	0.64	1.68	0.54	1.66	0.48
21	1.97	1.99	1.81	1.05	1.77	0.87	1.71	0.64	1.68	0.54	1.68	0.54
22	1.94	1.78	1.80	1.00	1.77	0.87	1.70	0.60	1.68	0.54	1.68	0.54
23	1.93	1.72	1.80	1.00	1.77	0.87	1.69	0.57	1.68	0.54	1.68	0.54
24	1.92	1.65	1.80	1.00	1.76	0.83	1.69	0.57	1.67	0.51	1.67	0.51
25	1.91	1.59	1.79	0.95	1.75	0.79	1.69	0.57	1.67	0.51	1.68	0.54
26	1.90	1.53	1.79	0.95	1.75	0.79	1.68	0.54	1.67	0.51	1.68	0.54
27	1.90	1.53	1.79	0.95	1.75	0.79	1.69	0.57	1.67	0.51	1.69	0.57
28	1.91	1.59	1.78	0.91	1.75	0.79	1.69	0.57	1.67	0.51	1.68	0.54
29	1.91	1.59	1.78	0.91	1.75	0.79	1.68	0.54			1.68	0.54
30	1.89	1.47	1.78	0.91	1.75	0.79	1.67	0.51			1.67	0.51
31	1.90	1.53			1.74	0.75	1.67	0.51			1.67	0.51
total		68.56		34.53		27.79		19.84		16.44		15.48
mean		2.21		1.15		0.90		0.64		0.59		0.50
ac-ft		136		68.5		55.1		39.4		32.6		30.7
max.		3.8		1.53		1.00		0.75		0.75		0.57
min.		1.47		0.91		0.75		0.51		0.51		0.45
*												
Adjusted for												
mean												
cfsm		0.61		0.32		0.25		0.18		0.16		0.14
in.		0.70		0.35		0.28		0.20		0.17		0.16
ac-ft												

Day	April Gauge Height	April Discharge	May Gauge Height	May Discharge	June Gauge Height	June Discharge	July Gauge Height	July Discharge	August Gauge Height	August Discharge	September Gauge Height	September Discharge
1	1.67	0.51	2.01	2.28	2.94	17.8	3.90	52.9		9.26 e	2.04	2.52
2	1.67	0.51	1.92	1.65	2.86	15.7	3.72	44.6		8.74	2.03	2.44
3	1.67	0.51	1.91	1.59	2.84	15.2	3.54	37.2		8.20		2.34 e
4	1.67	0.51	1.90	1.53	2.85	15.4	3.40	32.0		7.66		2.25
5	1.67	0.51	1.89	1.47	2.86	15.7	3.28	27.8		7.14 e		2.16 e
6	1.68	0.54	1.91	1.59	2.94	17.8	3.18	24.6	2.40	6.61	1.98	2.06
7	1.67	0.51	1.90	1.53	2.94	17.8	3.11	22.5	2.38	6.31	1.97	1.99
8	1.67	0.51	1.89	1.47	2.95	18.0	3.05	20.8	2.36	6.03	1.97	1.99
9	1.68	0.54	1.89	1.47	3.00	19.4	2.97	18.6	2.33	5.62	2.01	2.28
10	1.68	0.54	1.90	1.53	3.07	21.4		16.7 e	2.32	5.49	2.18	3.84
11	1.68	0.54	1.91	1.59	3.10	22.2	2.82	14.7	2.29	5.10	2.05	2.60
12	1.70	0.60	1.92	1.65	3.18	24.6	2.74	12.9	2.28	4.98	2.05	2.60
13	1.72	0.67	1.94	1.78	3.16	24.0	2.68	11.6	2.27	4.86	2.12	3.23
14	1.76	0.83	2.05	2.60	3.12	22.8	2.67	11.4	2.25	4.62	2.10	3.05
15	1.78	0.91	2.12	3.23	3.09	21.9	2.66	11.2	2.26	4.74	2.10	3.05
16	1.75	0.79	2.12	3.23	3.06	21.1	2.68	11.6	2.22	4.28	2.09	2.96
17	1.76	0.83	2.17	3.73	3.03	20.3	2.65	11.0	2.20	4.06	2.08	2.87
18	1.76	0.83	2.18	3.84	2.99	19.2	2.64	10.8	2.18	3.84	2.07	2.78
19	1.76	0.83	2.22	4.28	2.96	18.3	2.62	10.4	2.16	3.63	2.06	2.69
20	1.76	0.83	2.29	5.10	2.90	16.7	2.58	9.60	2.16	3.63	2.05	2.60
21	1.74	0.75	2.40	6.61	2.86	15.7	2.54	8.88	2.16	3.63	2.04	2.52
22	1.73	0.71	2.56	9.24	3.01	19.7	2.52	8.54	2.14	3.43	2.04	2.52
23	1.72	0.67	2.68	11.6	2.94	17.8	2.48	7.86	2.12	3.23	2.04	2.52
24	1.78	0.91	2.72	12.4	2.94	17.8	V	7.96	2.13	3.33	2.04	2.52
25	1.84	1.20	2.77	13.5	2.98	18.9	2.62	10.4	2.14	3.43	2.03	2.44
26	1.86	1.30	2.74	12.9	3.01	19.7	2.53	8.71	2.12	3.23	2.02	2.36
27	1.96	1.92	2.68	11.6	3.02	20.0	2.50	8.20	2.10	3.05	2.02	2.36
28	2.04	2.52	2.68	11.6	2.98	18.9	2.59	9.79	2.08	2.87	2.01	2.28
29	2.02	2.36	2.76	13.3	V	31.5	2.58	9.60	2.08	2.87	2.00	2.21
30	2.08	2.87	2.92	17.3	4.04	59.8	2.60	9.98	2.06	2.69	1.98	2.06
31			3.00	19.4			2.59	9.79	2.05	2.60		
total		28.06		186.59		625.1		512.61		149.16		76.09
mean		0.94		6.02		20.84		16.54		4.81		2.54
ac-ft		55.7		370		1240		1020		296		151
max.		2.87		19.4		59.8		52.9				3.84
min.		0.51		1.47		15.2		7.86		2.60		1.99
*												
Adjusted for												
mean												
cfsm		0.26		1.66		5.74		4.56		1.33		0.70
in.		0.29		1.91		6.40		5.25		1.53		0.78
ac-ft												

Computed from Table No. 1, dated July 2, 1963 from 12 October to 30 September

from ______ to ______

Station established 12 October 1962. Record of station "Marmot Creek near Mouth" used 1 to 11 October.

e - Estimated - 1 to 5 August and 3 to 5 September 1963.

V - Subdivided.

*

Accuracy Excellent.

Add ______ feet to convert gauge height to ______

For the year:

- Maximum Instantaneous ~~Daily~~ Gauge Height 4.08 ft at 1 A.M. 30 June 63
- Minimum Instantaneous ~~Daily~~ Gauge Height 1.63 ft at 6 A.M. on 4 March 63
- Maximum Instantaneous ~~Daily~~ Discharge 61.9 cfs at G.H. 4.08 ft at 1 A.M. 30 June 63
- Minimum Instantaneous ~~Daily~~ Discharge 0.39 cfs at G.H. 1.63 ft at 6 A.M. on 4 March 63

Annual Summary	
total	1760.25
mean	4.82
ac-ft	3490
max.	59.8
min.	0.45
*	
Adjusted for	
mean	
cfsm	1.33
in.	18.02
ac-ft	

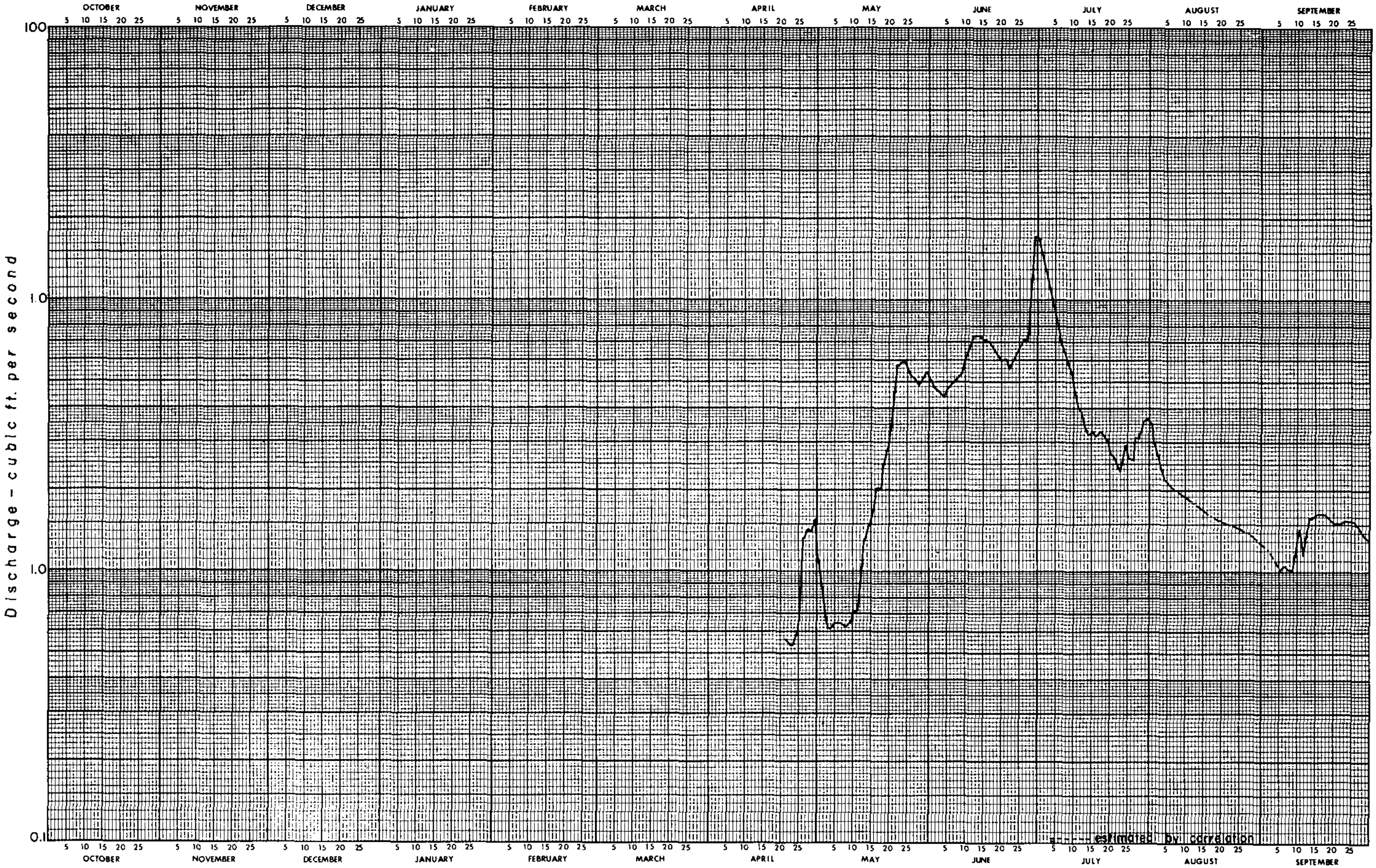
	Ice Period Gauge Height	Ice Period Discharge	Open Water Period Gauge Height	Open Water Period Discharge	Summary
Computed by					
Checked by					
Date					

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES - WATER RESOURCES BRANCH

Figure 2

HYDROGRAPH FOR Middle Fork Creek - near Seebe Station No. R187 (1-62)

for year ending 30 September 1963



Plotted by D.D. Checked by ______ Approved by ______ Date ______

Middle Fork Creek near Seebe TABLE 2

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES–WATER RESOURCES BRANCH R 79B (1-62)

Daily Gauge Height in feet and Discharge in ______ cubic feet per second for year ending 30 September 19 63

Drainage area 1.10 square miles Station No. 5BF-17

Day	October Gauge Height	October Discharge	November Gauge Height	November Discharge	December Gauge Height	December Discharge	January Gauge Height	January Discharge	February Gauge Height	February Discharge	March Gauge Height	March Discharge
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
total												
mean												
ac-ft												
max.												
min.												
*												
Adjusted for												
mean												
cfsm												
in.												
ac-ft												

Day	April Gauge Height	April Discharge	May Gauge Height	May Discharge	June Gauge Height	June Discharge	July Gauge Height	July Discharge	August Gauge Height	August Discharge	September Gauge Height	September Discharge
1				1.2		5.3		17.0		3.5		
2				0.9		5.0		14.4		3.1		
3				0.7		4.7		12.5		2.8		1.2 e
4				0.6		4.5		10.3		2.5		
5				0.6		4.4		9.4		2.2		
6				0.6		4.8		8.4			1.22	1.01
7				0.6		4.9		7.4			1.23	1.04
8				0.6		5.1		6.7		2.0 e	1.22	1.01
9				0.6		5.3		6.0			1.22	1.01
10				0.6		5.6		5.4			1.27	1.20
11				0.7		6.3		4.7			1.33	1.45
12				0.7		6.8		4.1			1.26	1.16
13				0.9		7.4		3.8		1.8 e	1.30	1.32
14				1.3		7.5		3.4			1.36	1.59
15				1.5		7.4		3.2			1.36	1.59
16				1.7		7.1		3.3			1.37	1.64
17				2.0		7.1		3.1			1.37	1.64
18				2.0		6.8		3.3		1.6 e	1.37	1.64
19				2.5		6.5		3.2			1.36	1.59
20				2.8		6.2		3.0			1.35	1.54
21				3.6		5.9		2.8			1.34	1.50
22		0.6		4.7		6.0		2.7			1.34	1.50
23		0.5		5.7		5.5		2.4		1.5 e	1.35	1.54
24		0.5		5.8		6.0		2.4			1.35	1.54
25		0.6		6.0		6.5		2.9			1.35	1.54
26		0.9		5.5		6.9		2.7			1.35	1.54
27		1.3		5.3		7.1		2.6			1.34	1.50
28		1.5		5.1		7.1		3.1		1.4 e	1.33	1.45
29		1.4		4.8		11.3		3.0			1.31	1.36
30		1.6		5.3		17.4		3.6			1.30	1.32
31				5.5				3.7				
total				80.4		198.4		164.5		57.0		41.22
mean				2.59		6.61		5.31		1.84		1.37
ac-ft				159		394		326		113		81.8
max.				6.0		17.4		17.0		3.5		1.64
min.				0.6		4.4		2.4				1.01
*												
Adjusted for												
mean												
cfsm				2.35		6.01		4.83		1.67		1.25
in.				2.72		6.71		5.56		1.93		1.39
ac-ft												

Computed from Table No. ______, dated ______ from ______ to ______
from ______ to ______

Record 22 April to 5 August obtained at temporary station.

e - Estimated, 6 August to 5 September; obtained by correlation with station "Marmot Creek Main Stem".

Record 6-30 September at weir.

*

Accuracy Good, except for correlated period which is fair.

Add ______ feet to convert gauge height to ______

For the year:

Maximum Instantaneous / Daily Gauge Height ______ ft at ______

Minimum Instantaneous / Daily Gauge Height ______ ft at ______

Maximum Instantaneous / ~~Daily~~ Discharge 20.1 cfs at G.H. ______ ft at 1 A.M. 30 June 1963

Minimum Instantaneous / Daily Discharge ______ cfs at G.H. ______ ft at ______

Annual Summary	
total	
mean	
ac-ft	
max.	
min.	
*	
Adjusted for	
mean	
cfsm	
in.	
ac-ft	

	Ice Period Gauge Height	Ice Period Discharge	Open Water Period Gauge Height	Open Water Period Discharge	Summary
Computed by					
Checked by					
Date					

Twin Creek near Seebe — TABLE 3

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES–WATER RESOURCES BRANCH — R 79B (1-62)

Daily Gauge Height in feet and Discharge in ______ cubic feet per second for year ending 30 September 19 63

Drainage area 1.02 square miles — Station No. 5BF-18

Day	October Gauge Height	October Discharge	November Gauge Height	November Discharge	December Gauge Height	December Discharge	January Gauge Height	January Discharge	February Gauge Height	February Discharge	March Gauge Height	March Discharge
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
total												
mean												
ac-ft												
max.												
min.												
*												
Adjusted for												
mean												
cfsm												
in.												
ac-ft												

Day	April Gauge Height	April Discharge	May Gauge Height	May Discharge	June Gauge Height	June Discharge	July Gauge Height	July Discharge	August Gauge Height	August Discharge	September Gauge Height	September Discharge
1				0.2		5.6		17.5				
2						4.4		13.4				
3						4.2		11.0		2.5 e		0.9 e
4				0.4 e		4.8		8.7				
5						5.2		7.8				
6						6.2		6.9			1.08	0.74
7						6.2		6.1				
8				0.5		6.2		5.7		1.7 e		
9				0.5		6.5		5.2				0.9 e
10				0.5		7.0		4.6				
11				0.5		7.7		4.2				
12				0.5		10.5		3.8				
13				0.5		9.9		3.7		1.5 e		
14				0.5		9.3		3.5				1.0 e
15				0.5		9.0		3.5				
16				0.5		9.3		3.5				
17				0.5		9.0		3.5			1.19	1.12
18				0.7		8.2		3.3		1.3 e	1.19	1.12
19				0.8		8.0		3.2			1.18	1.08
20				1.0		7.4		3.0			1.17	1.04
21				1.4		7.0		2.8			1.16	1.01
22		0.4		2.0		7.7		2.5			1.15	0.97
23		0.4		2.6		7.0		2.2		1.2 e	1.15	0.97
24		0.4		2.9		6.5					1.14	0.94
25		0.4		3.1		6.5		2.7 e			1.12	0.87
26		0.4		3.3		7.0					1.12	0.87
27		0.3		3.0		6.7					1.11	0.84
28		0.3		3.0		6.5				1.0 e	1.10	0.80
29		0.2		3.7		9.6		2.9 e			1.09	0.77
30		0.2		4.7		21.4					1.09	0.77
31				6.5								
total				46.3		230.5		152.2		47.0		27.91
mean				1.49		7.68		4.91		1.52		0.93
ac-ft				91.8		457		302		93.2		55.4
max.				6.5		21.4		17.5				1.12
min.				0.2		4.2		2.2				0.77
*												
Adjusted for												
mean												
cfsm				1.46		7.53		4.81		1.49		0.91
in.				1.69		8.40		5.55		1.71		1.02
ac-ft												

Computed from Table No. ______, dated ______ from ______ to ______
from ______ to ______

Record obtained at temporary station 22 April - 23 July 1963.

Record 24 July to 16 September obtained by correlation with station "Marmot Creek Main Stem".

Record obtained at weir site 17 to 30 September.

* e - Estimate of flow.

Accuracy Good, except for periods of estimated flow which are fair.

Add ______ feet to convert gauge height to ______

For the year:

Maximum	Instantaneous / Daily	Gauge Height ______ ft at ______	
Minimum	Instantaneous / Daily	Gauge Height ______ ft at ______	
Maximum	Instantaneous / ~~Daily~~	Discharge 25.2 cfs at G.H. ______ ft at 2 A.M. 30 June 63	
Minimum	Instantaneous / Daily	Discharge ______ cfs at G.H. ______ ft at ______	

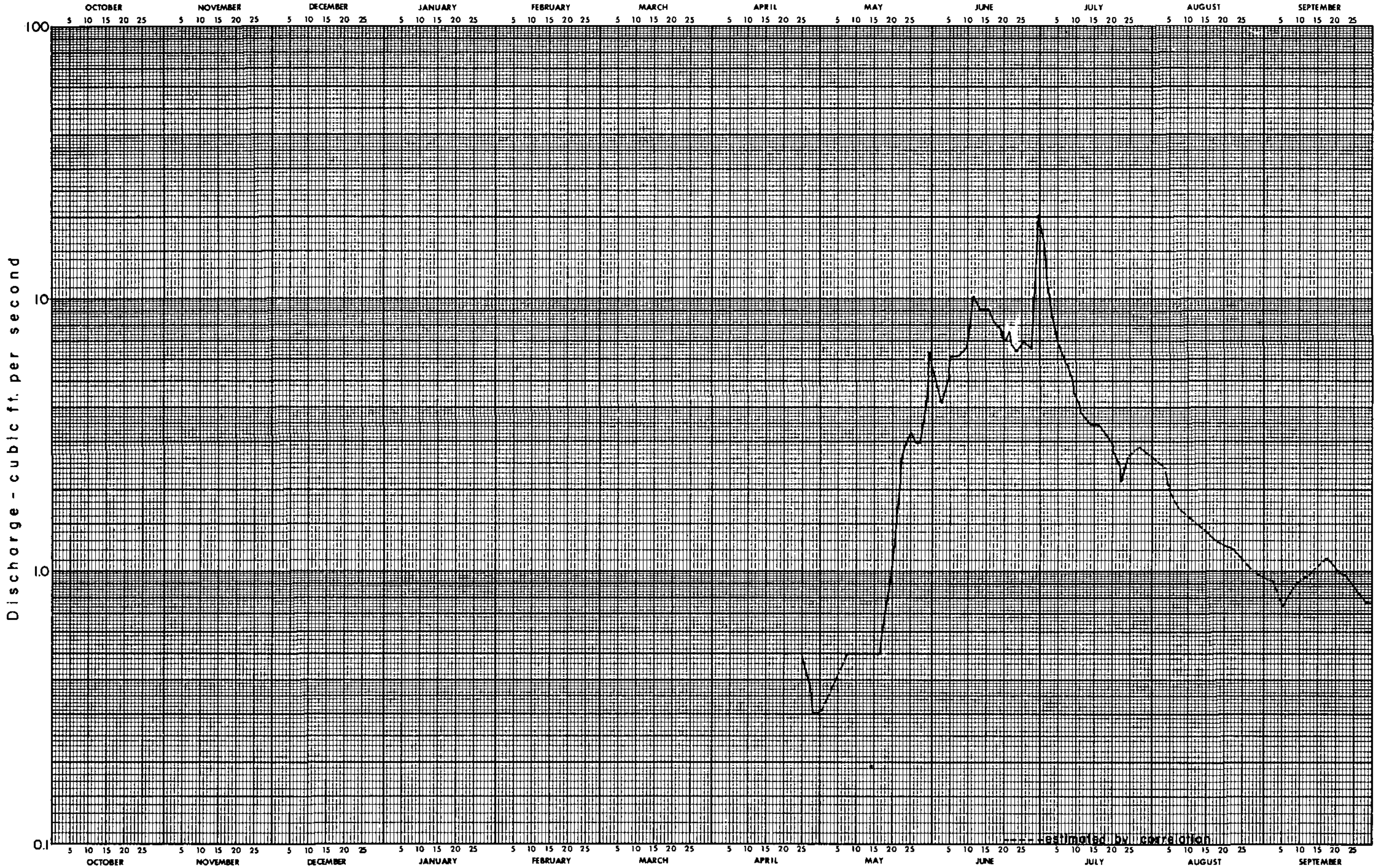
Annual Summary	
total	
mean	
ac-ft	
max.	
min.	
*	
Adjusted for	
mean	
cfsm	
in.	
ac-ft	

	Ice Period Gauge Height	Ice Period Discharge	Open Water Period Gauge Height	Open Water Period Discharge	Summary
Computed by					
Checked by					
Date					

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES - WATER RESOURCES BRANCH

Figure 3 HYDROGRAPH FOR Twin Creek near Seebe Station No. R 187 (1-62)

for year ending 30 September 19



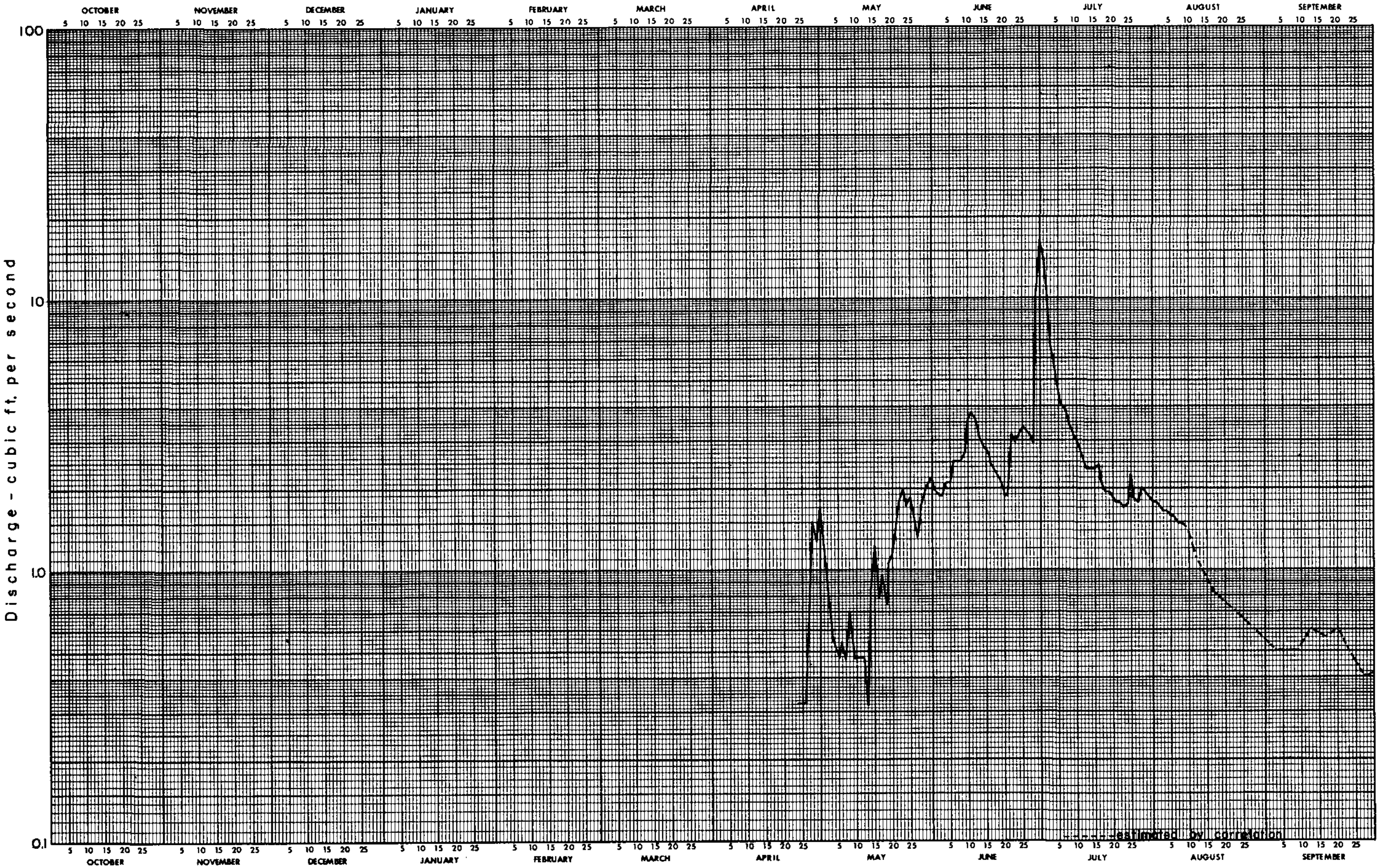
Plotted by______ Checked by______ Approved by______ Date______

Figure 4

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES - WATER RESOURCES BRANCH

HYDROGRAPH FOR Cabin Creek - near Seebe Station No. R 187 (1-62)

for year ending 30 September 1963



Plotted by D.D. Checked by Approved by Date

Cabin Creek near Seebe TABLE 4

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES–WATER RESOURCES BRANCH R 79B (1-62)

Daily Gauge Height in feet and Discharge in ______ cubic feet per second for year ending 30 September 19 63

Drainage area 0.82 square miles Station No. 5BF-19

Day	October Gauge Height	October Discharge	November Gauge Height	November Discharge	December Gauge Height	December Discharge	January Gauge Height	January Discharge	February Gauge Height	February Discharge	March Gauge Height	March Discharge
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
total												
mean												
ac-ft												
max.												
min.												
*												
Adjusted for												
mean												
cfsm												
in.												
ac-ft												

Day	April Gauge Height	April Discharge	May Gauge Height	May Discharge	June Gauge Height	June Discharge	July Gauge Height	July Discharge	August Gauge Height	August Discharge	September Gauge Height	September Discharge
1				1.2		2.0		13.7		1.8		
2				0.9		1.9		9.6		1.7		
3				0.7		1.9		6.9		1.6		0.4 e
4				0.5		2.1		5.5		1.6		
5				0.5		2.1		4.5		1.6		
6				0.5		2.5		4.0		1.6	0.42	0.40
7				0.5		2.5		3.7		1.5		
8				0.7		2.5		3.4		•1.5		
9				0.5		2.8		3.1		1.4		0.4 e
10				0.5		3.5		3.0				
11				0.5		3.8		2.7				
12				0.5		3.6		2.5		1.1 e		
13				0.3		3.2		2.3				
14				0.9		2.9		2.3				0.5 e
15				1.2		2.7		2.3				
16				0.8		2.5		2.4				
17				0.9		2.3		2.1			0.45	0.46
18				0.8		2.2		1.9		0.8 e		
19				1.0		2.1		1.9				
20				1.1		1.9		1.8				0.5 e
21				1.5		1.9		1.8				
22				1.8		3.2		1.8				
23				2.0		2.9		1.7		0.7 e		
24		0.3		1.7		3.2		1.8				
25		0.3		1.9		3.4		2.2				0.4 e
26		0.3		1.5		3.3		1.8				
27		0.7		1.3		3.2		1.8				
28		1.5		1.7		2.9		2.0		0.6 e		0.3 e
29		1.3		1.9		9.9		1.9				
30		1.7		2.1		16.4		1.8			0.37	0.31
31				2.2				1.8				
total				34.1		101.3		100.0		32.0		12.77
mean				1.10		3.38		3.23		1.03		0.43
ac-ft				67.6		201		198		63.5		25.3
max.				2.2		16.4		13.7		1.8		
min.				0.3		1.9		1.7				
*												
Adjusted for												
mean												
cfsm				1.34		4.12		3.94		1.26		0.52
in.				1.55		4.59		4.54		1.45		0.58
ac-ft												

Computed from Table No. ______, dated ______ from ______ to ______
from ______ to ______

Record for 24 April to 9 August obtained at temporary station.

e - Estimates in August and September obtained by correlation with station "Marmot Creek Main Stem".

*

Accuracy Good except for periods of estimated record which are fair.

Add ______ feet to convert gauge height to ______

For the year:

Maximum Instantaneous / Daily Gauge Height ______ ft at ______

Minimum Instantaneous / Daily Gauge Height ______ ft at ______

Maximum Instantaneous / ~~Daily~~ Discharge 20.0 cfs at G.H. ______ ft at 1 A.M. 30 June 1963

Minimum Instantaneous / Daily Discharge ______ cfs at G.H. ______ ft at ______

	Ice Period Gauge Height	Ice Period Discharge	Open Water Period Gauge Height	Open Water Period Discharge	Summary
Computed by					
Checked by					
Date					

Annual Summary	
total	
mean	
ac-ft	
max.	
min.	
*	
Adjusted for	
mean	
cfsm	
in.	
ac-ft	

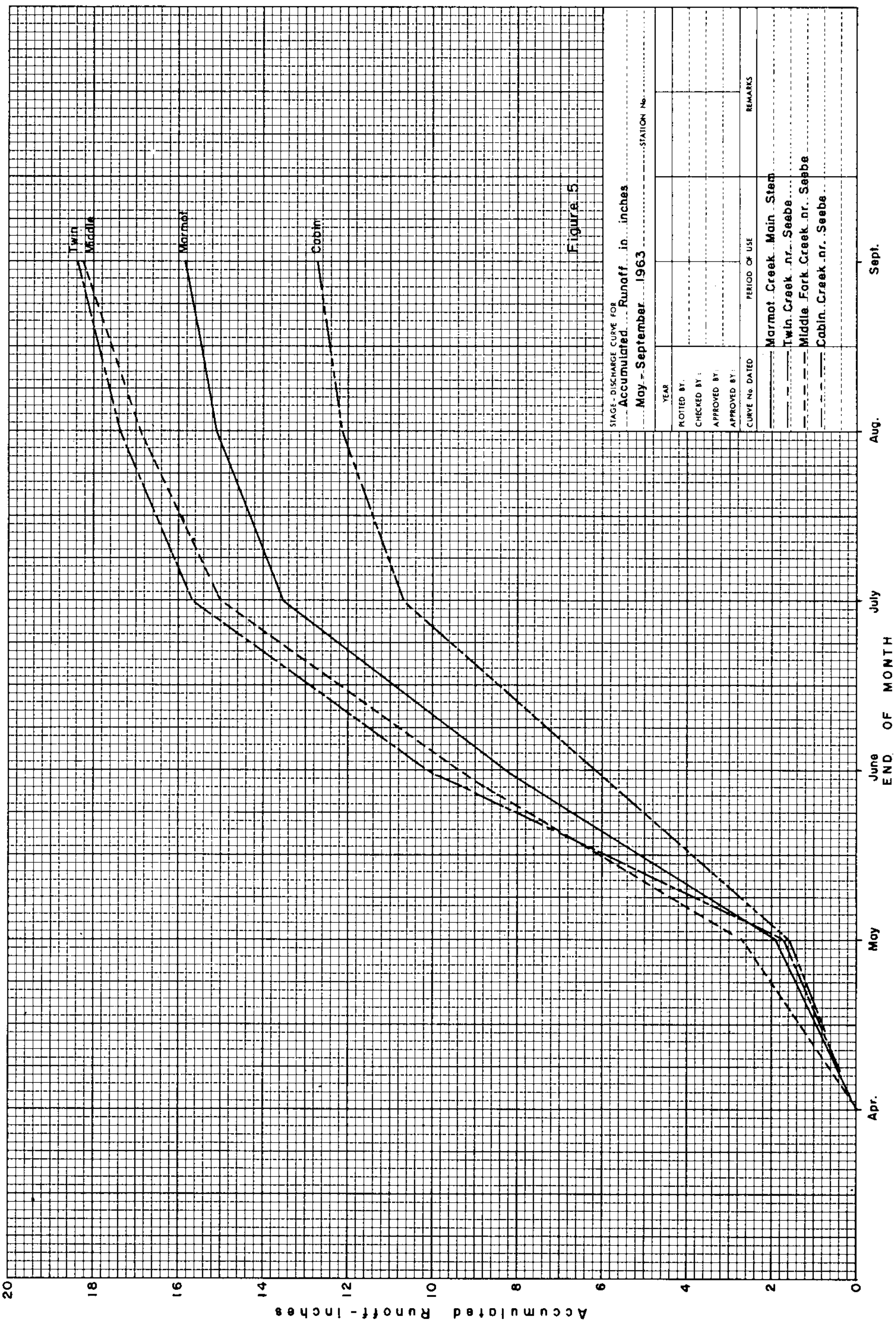


Figure 5
STAGE-DISCHARGE CURVE FOR
Accumulated Runoff in inches
May - September 1963
STATION No.
YEAR
PLOTTED BY:
CHECKED BY:
APPROVED BY:
APPROVED BY:
CURVE No. DATED
PERIOD OF USE
REMARKS
Marmot Creek Main Stem
Twin Creek nr. Seebe
Middle Fork Creek nr. Seebe
Cabin Creek nr. Seebe
Twin
Middle
Marmot
Cabin
Apr.
May
June
July
Aug.
Sept.
END OF MONTH
20
18
16
14
12
10
8
6
4
2
0
Accumulated Runoff - inches

APPENDIX II

SURFACE WATER QUALITY IN MARMOT CREEK BASIN

PROGRESS REPORT FOR PERIOD MAY TO SEPTEMBER, 1963

J.F.J. Thomas[1]

INTRODUCTION

A survey of surface water quality in Marmot Creek Basin was started in late May, 1963. In the latter part of September when the writer visited the area to review the survey program, additional samples of stream waters were collected for chemical analysis. This report details the findings of this water quality survey up to the end of September, 1963.

SAMPLING PROCEDURE

Samples of Marmot Creek water have been collected at the main streamgauging station, at the lower boundary of the basin, by officers of Water Resources Branch, Department of Northern Affairs and National Resources, Calgary, Alberta.

Daily sampling (12 fl. oz. samples) was initially requested for a period of several months with submission of the samples in lots of about 12 directly to the Industrial Waters Section's Laboratory at Ottawa, Ontario. The frequency of sampling was decreased by the collector after about 1½ months operation, samples then being collected at intervals of from 4 to 10 days until about August 30; since then weekly sampling has been carried out. The sampling interval was somewhat erratic during much of July and August (see Table 1).

During the visit to the basin on September 30, the writer requested weekly sampling be carried out and personally collected samples of the several small creeks which combine to form Marmot Creek, namely Middle Fork, Twin, and Cabin Creeks. These samples were collected directly from the stream; either near their mouths or at the discharge-measuring stations recently installed on these streams.

Discharge records on these tributary streams were not available at the time this report was prepared.

[1] Head, Industrial Waters Section, Mines Branch, Canada Department of Mines and Technical Surveys, Ottawa, Ontario.

ANALYSIS OF CREEK WATERS

The daily samples, received in lots of 12, were combined in proportion to the stream discharge, that is, the volume of each sample in the final composite (usually a 2 liter volume) is directly proportional to the discharge of that day. The number of samples that were combined varied with the discharge and with the specific conductance of each sample. In no case did the specific conductance of any sample in the composite deviate more than 15 per cent from the mean conductance of all the samples included: similarly the discharge of any one day during the composite period did not deviate 15 per cent from the mean discharge for the period.

A relatively complete chemical analysis was made of the composite sample, but such an analysis was not possible on later samples because insufficient water was received. Only major constituents, with some variation in the ones selected for test, were determined on these samples.

The limited amount of analytical data available at this time prevents drawing definite conclusions on water quality and on quality-quantity relationships.

However, Table 1 shows that Marmot Creek water is appreciably mineralized, most of which is hardness salts. The water increases in hardness from medium-hard in early June to very hard (over 180 ppm as $CaCO_3$ late in August and September. Some non-carbonate hardness (calcium sulphate) is present but most of the mineral content is calcium and magnesium bicarbonates. This type of water is to be expected in the calcareous Rocky Mountain area.

Alkali salts are very low and heavy metals are almost absent in these waters.

Fig. 2 further illustrates the preponderance of hardness salts. As the specific conductance of Marmot Creek water increases steadily after about June 1, the total hardness increases in an almost parallel relationship. Non-carbonate hardness (sulphate) shows only a slight increase over this period, again confirming that the increase in mineral content is primarily due to solution of carbonates.

The limited data on the tributary streams show that these are also hard bicarbonate waters, similar in character to Marmot Creek water. There is some difference in the quality of these waters, Cabin Creek water containing more minerals and harder on September 30 than either Middle Fork or Twin Creek waters. The average hardness and specific conductance of Cabin and Middle-Twin Creeks is 193 and 351, respectively; these values are quite close to those found for Marmot Creek water on September 25, namely 189 and 347.

Ribbon Creek, another stream of the same character in the general area of the Project, is somewhat softer and has a greater proportion of sulphate iron.

Water from the Kananaskis River, into which both Marmot Creek and Ribbon Creek eventually flow, is also a hard bicarbonate water and has a higher sulphate to bicarbonate ratio than Marmot Creek. On the basis of one day sampling, this river is very similar in quality to Middle Fork water.

Although insufficient data are available, turbidity in these waters is evidently not appreciable. The heavy rainfall about July 1, shown in the discharge curves of Figs. 1 and 2, only resulted in a turbidity of 2 units.

Fig. 1 is a plot of the discharge of Marmot Creek versus the mineral content (specific conductance) of the water over the period of daily sampling. The mineral content parallels the discharge during most of June. Heavy rainfall about July 1 resulted in a considerable increase in discharge. This increase was not reflected in the mineral-content curve, which continued its steady rise up to mid-July. After a high about July 1, discharge decreased rapidly. These curves indicate that the increased discharge in July is due not only to rainfall but probably includes increased discharge from mineralized swamps and springs. Since the water of Cabin Creek is harder and more mineralized than the other tributary streams, information on the discharges of all tributaries, as well as such parameters as rainfall, must be considered when interpreting the steady rise in mineral content with decreasing flow up to the middle of July. Normally this type of relationship indicates a greater percentage of ground water in the stream flow. The average discharge and the specific-conductance values for the composite samples over the period of daily sampling are also shown in Fig. 1.

Fig. 2 which is a plot of discharge, total hardness, specific conductance and non-carbonate hardness over the entire sampling period, further illustrates the negligible effect the rapid run-off of July 1 had on Marmot Creek water quality. The increase in specific conductance with corresponding decrease in discharge following this storm, already shown in Fig. 1, continued until the end of September. Prior to the spring break-up a quality-survey program for 1964 will be submitted. It is probable that daily sampling will be requested at least for the period of the spring break-up with twice-monthly (fortnightly) sampling thereafter on Marmot Creek,a sufficient quantity of sample being obtained to permit a more complete analysis to be made.

A somewhat similar programme is contemplated for the tributary streams and if at all possible monthly sampling of these and Marmot Creek should be considered of the winter periods.

The assistance of the Water Resources Branch, Department of Northern Affairs and National Resources, Calgary, in collecting and shipping samples and supplying discharge data in this survey is greatly appreciated.

TABLE I

Chemical Analyses of Surface Waters in the Marmot Creek Project

No.	Date of sampling	Storage period (Days)	Stream discharge (Second-feet): On sampling date	Stream discharge: Monthly mean	Water temperature (°F.)	Oxygen consumed by $KMnO_4$	Carbon dioxide (calculated) (CO_2)	pH	Colour (Hazen) (Units)	Turbidity (Units)	Redox potential (mV)	Suspended matter: Dried at 105°C.	Suspended matter: Ignited at 550°C.	Residue on evaporation dried at 105°C. (Dissolved solids): P.P.M.	Residue: Tons per acre-foot	Residue: Tons per day	Loss on ignition at 550°C.	Specific conductance K x 10^6 at 25°C.	Calcium (Ca)	Magnesium (Mg)
RIBBON CREEK* near MOUTH																				
1	Sept. 30/63	16:21			49.5	.....	1	8.2	0	0.3	-459							253	35.3	10.4
* Sampled from shore																				
MARMOT CREEK* at lower boundary of PROJECT AREA																				
2	May 21/63	:72	12.2		41.0	.....	3	7.9	10	.....	-446							252	33.8	12.5
3	May 28 - June 9†	9 av.	12.7 av.		.....	2.3	1.5	8.1	10	0	-443	.....	.....	120	0.163	4.1 av.	42.8	202	26.6	9.4
4	June 10 - June 21†	27 av.	13.6 av.		.....	.....	2	8.1	10	0	-444	.....	.....	.....			.....	207	27.0	10.0
5	June 22 - June 29†	47 av.	13.5 av.		.....	.....	2	8.1	15	0.1	-438	.....	.....	.....			.....	241	32.9	11.9
6	June 30 - July 4†	45 av.	16.8 av.		.....	3.3	2	8.1	15	2	-396	.....	.....	.....			.....	254	34.2	12.0
7	July 5 - July 10†	39 av.	13.8 av.		.....	.....	2	8.1	10	0.3	-397	.....	.....	.....			.....	262	35.8	13.3
8	July 15	28:	11.4		.....	.....	.....	8.0	10	.....	-407	.....	.....	.....			.....	281	39.9	14.5
9	July 18	110:	11.9		42.5	.....	3	7.9	.....	.....	.....	.....	.....	.....			.....	278	35.4	15.8
10	July 23	105:	11.2		42	.....	3	7.9	.....	.....	.....	.....	.....	.....			.....	280	38.5	14.9
11	July 29	99:	11.7		42	.....	3.5	7.9	.....	.....	.....	.....	.....	.....			.....	309	39.5	16.5
12	Aug. 6	91:	10.8		44	.....	2.5	8.1	.....	.....	.....	.....	.....	.....			.....	306	39.9	16.7
13	Aug. 12	89:	10.0		45	.....	3	8.0	.....	.....	.....	.....	.....	.....			.....	321	43.9	16.8
14	Aug. 16††	81:	10.0		46.5	.....	3	8.0	.....	.....	.....	.....	.....	.....			.....	303	43.6	17.3
15	Aug. 16†††	81:	9.75		46	.....	3	7.8	.....	.....	.....	.....	.....	.....			.....	342	46.2	16.9
16	Aug. 26	71:	9.25		44	.....	2.5	8.1	.....	.....	.....	.....	.....	.....			.....	347	47.2	17.5
17	Aug. 27	70:	9.20		47	.....	6.5	7.7	.....	.....	.....	.....	.....	.....			.....	353	45.8	18.5
18	Aug. 29	70:	9.30		45	.....	4	7.9	.....	.....	.....	.....	.....	.....			.....	352	50.1	16.7
19	Sept. 4	63:	9.05		44	.....	2	8.2	.....	.....	.....	.....	.....	.....			.....	347	47.8	16.7
20	Sept. 11	56:	9.70		46.5	.....	6	7.7	.....	.....	.....	.....	.....	.....			.....	351	49.9	16.9
21	Sept. 19	48	9.35		45	.....	6	7.7	.....	.....	.....	.....	.....	.....			.....	321	47.1	16.2
22	Sept. 25	42:	9.05		43	.....	1	8.4	.....	.....	.....	.....	.....	.....			.....	347	46.0	18.1
CABIN CREEK, TRIBUTARY to MARMOT CREEK																				
23	Sept. 30/63	16:21			.....	.....	3	8.1	0	0	-477	.....	.....	.....			.....	399	53.1	19.7
* Sampled near mouth																				
MIDDLE (Fork) and TWIN CREEKS, TRIBUTARY to MARMOT CREEK																				
24	Sept. 30/63	16:21			43.0	.....	0.8	8.5	5	0	-460	.....	.....	.....			.....	303	42.2	13.7
* Sampled near mouth																				
MIDDLE (Fork) CREEK, TRIBUTARY to MARMOT CREEK																				
25	Sept. 30/63	16:21			43.2	.....	2	8.1	5	0	-467	.....	.....	.....			.....	320	42.0	15.4
* Sampled near mouth																				
KANANASKIS RIVER, near MOUTH																				
26	Oct. 2/63	19:21	.		54.5	.....	1.5	8.2	0	0	-448	.....	.....	.....			.....	322	47.4	12.5

No.	Iron (Fe): Total	Iron (Fe): Dissolved	Manganese (Mn): Total	Manganese (Mn): Dissolved	Aluminum (Al)	Copper (Cu)	Zinc (Zn)	Alkalis: Sodium (Na)	Alkalis: Potassium (K)	Ammonia (NH_4)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4): Total	Phosphate (PO_4): Dissolved	Silica (colorimetric) (SiO_2)	Boron (B)	Hardness as $CaCO_3$: Non-carbonate	Hardness as $CaCO_3$: Total	Sum of constituents	Per cent sodium	Sodium absorption ratio	Saturation index	Stability index	No.
RIBBON CREEK* near MOUTH																												
1	.....	.....	.....	.....	.....	.....	.....	0.5	0.3	.....	0.0	128	22.9	0.3	0.23	0.2	.....	.....	2.7	...	25.5	131	135	0.8	0.019	+0.4	7.4	1
MARMOT CREEK* at lower boundary of PROJECT AREA																												
2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0	147	.....	0.0	.....	.....		.....	.....	...	15.0	136	.....	.....	.....	.....	.....	2
3	.....	Trace	.....	0.00	0.02	0.00	0.00	0.6	0.4	0.0	0.0	116	9.2	0.3	0.11	0.3	<0.1	.....	4.4	...	9.9	105	108	1.2	0.025	+0.1	7.9	3
4	.....	Trace	.....	0.00	.....	.....	.....	0.6	0.4	.....	0.0	120	10.3	0.0	0.09	0.1	.....	.....	4.2	...	10.4	108.5	112	1.2	0.025	+0.1	7.9	4
5	.....	0.00	.....	0.00	.....	.....	.....	0.6	0.4	.....	0.0	145	11.6	0.3	0.08	0.1	.....	.....	4.0	...	14.5	131	133	1.0	0.025	+0.3	7.5	5
6	.....	Trace	.....	0.00	0.05	.....	0.00	0.6	0.5	0.0	0.0	152	10.9	0.3	0.15	0.1	<0.1	.....	5.3	...	10.4	135	139	0.9	0.022	+0.3	7.5	6
7	.....	0.00	.....	0.00	0.01	.....	.....	0.6	0.4	.....	0.0	135	12.3	0.1	0.11	0.1	<0.1	.....	5.4	...	12.5	140	144	0.9	0.022	+0.3	7.5	7
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0	175	.....	0.0	.....	.....	.....	.....	.....	.....	17.2	159	.....	.....	.....	.....	.....	8
9	.....	.....	.....	.....	.....	0.001	0.000	.....	.....	.....	0.0	168	.....	<0.05	.....	.....	.....	.....	.....	.....	16.0	155.5	.....	.....	.....	.....	.....	9
10	.....	.....	.....	.....	.....	.....	.....	0.7	0.5	.....	0.0	179	.....	<0.05	.....	.....	.....	.....	.....	.....	15.8	158	.....	.....	.....	.....	.....	10
11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0	181	15.7	0.2	.....	.....	.....	.....	.....	.....	18.0	166.5	.....	.....	.....	.....	.....	11
12	.....	.....	.....	.....	.....	0.000	0.005	.....	.....	.....	0.0	183	.....	<0.05	.....	.....	.....	.....	.....	.....	18.5	168.5	.....	.....	.....	.....	.....	12
13	.....	.....	.....	.....	.....	.....	.....	0.8	0.5	.....	0.0	195	.....	0.1	.....	.....	.....	.....	.....	.....	18.7	179	.....	.....	.....	.....	.....	13
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0	202	15.7	<0.05	.....	.....	.....	.....	.....	.....	19.0	185	.....	.....	.....	.....	.....	14
15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0	205	15.7	0.2	.....	.....	.....	.....	.....	.....	17.0	185	.....	.....	.....	.....	.....	15
16	.....	.....	.....	.....	.....	0.000	0.000	.....	.....	.....	0.0	207	.....	<0.5	.....	.....	.....	.....	.....	.....	20.5	190	.....	.....	.....	.....	.....	16
17	.....	.....	.....	.....	.....	.....	.....	1.1	0.7	.....	0.0	210	.....	0.4	.....	.....	.....	.....	.....	.....	17.5	189.5	.....	.....	.....	.....	.....	17
18	.....	.....	.....	.....	.....	0.000	0.003	.....	.....	.....	0.0	211	.....	<0.05	.....	.....	.....	.....	.....	.....	20.9	194	.....	.....	.....	.....	.....	18
19	.....	.....	.....	.....	.....	.....	.....	1.0	0.5	.....	0.0	208	.....	<0.05	.....	.....	.....	.....	.....	.....	17.5	188	.....	.....	.....	.....	.....	19
20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0	213	16.0	0.2	.....	.....	.....	.....	.....	.....	19.1	194	.....	.....	.....	.....	.....	20
21	.....	.....	.....	.....	.....	0.000	0.002	.....	.....	.....	0.0	198	.....	0.5	.....	.....	.....	.....	.....	.....	21.9	184.5	.....	.....	.....	.....	.....	21
22	.....	.....	.....	.....	.....	.....	.....	1.9	0.5	.....	1.4	195	.....	0.5	.....	.....	.....	.....	.....	.....	27.1	189.5	.....	.....	.....	.....	.....	22
CABIN CREEK, TRIBUTARY to MARMOT CREEK																												
23	.....	.....	.....	.....	.....	0.000	0.000	1.3	0.6	.....	0.0	243	16.5	0.3	0.12	0.2	.....	.....	6.6	...	14.4	214	218	1.5	0.045	+0.7	6.7	23
MIDDLE (Fork) and TWIN CREEKS, TRIBUTARY to MARMOT CREEK																												
24	.....	.....	.....	.....	.....	.....	.....	0.8	0.5	.....	2.3	162	23.8	0.1	0.12	0.2	.....	.....	4.4	...	24.6	162	168	1.1	0.028	+0.8	6.9	24
MIDDLE (Fork) CREEK, TRIBUTARY to MARMOT CREEK																												
25	.....	.....	.....	.....	.....	0.000	0.000	0.7	0.6	.....	0.0	158	37.1	0.05	0.14	0.1	.....	.....	4.2	...	38.5	168	178	0.9	0.023	+0.4	7.3	25
KANANASKIS RIVER, near MOUTH																												
26	.....	.....	.....	.....	.....	.....	.....	0.9	0.3	.....	0.0	167	30.9	0.3	0.22	Trace	.....	.....	3.3	...	32.8	170	176	1.1	0.030	+0.6	7.0	26

* Sampled at gauge usually between 0900 and 1000 hr
† Composite of daily samples according to discharge
†† 1020 hr
††† 0900 hr

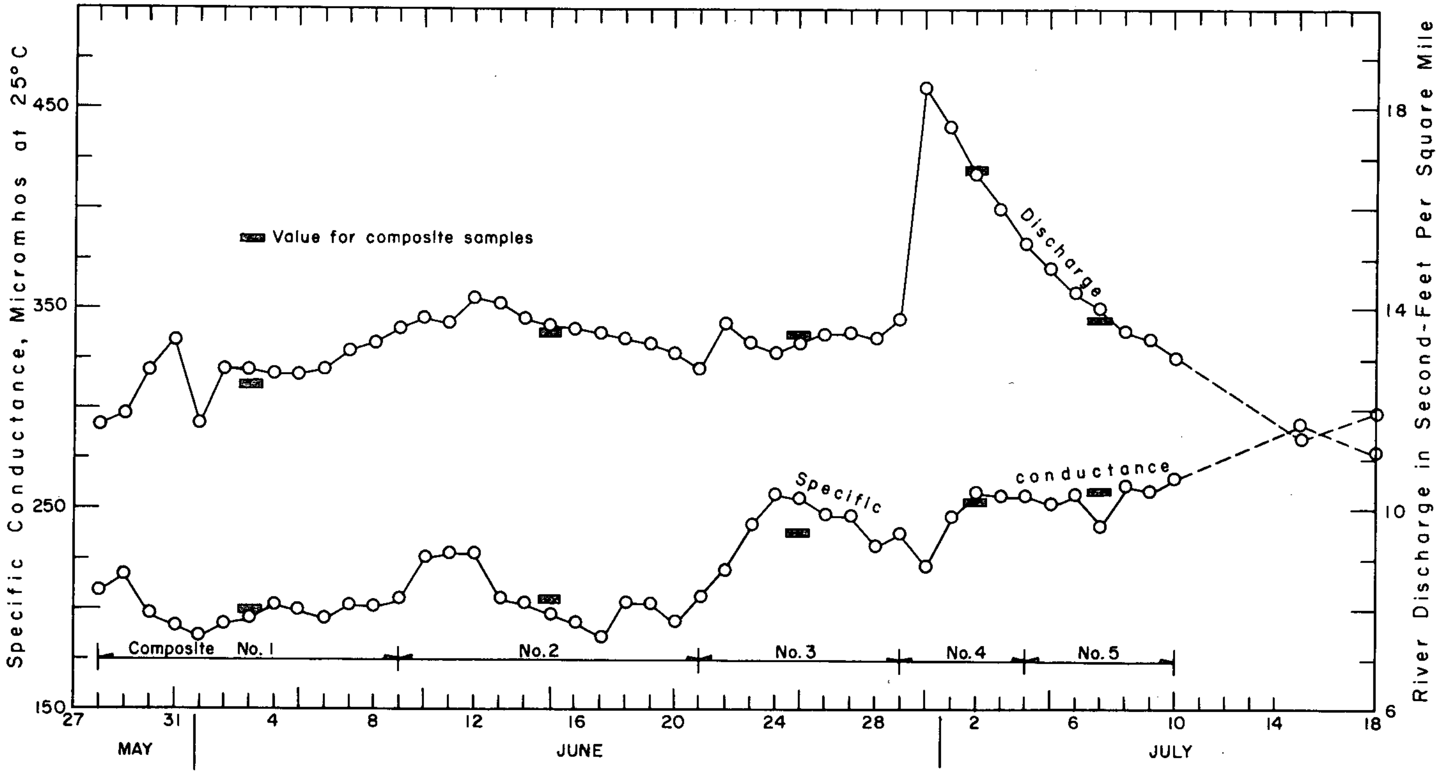


Figure 1 - Daily Relationship between Specific Conductance and Creek Discharge, Marmot Creek at Gauge, May 28, 1963 - July 18, 1963.

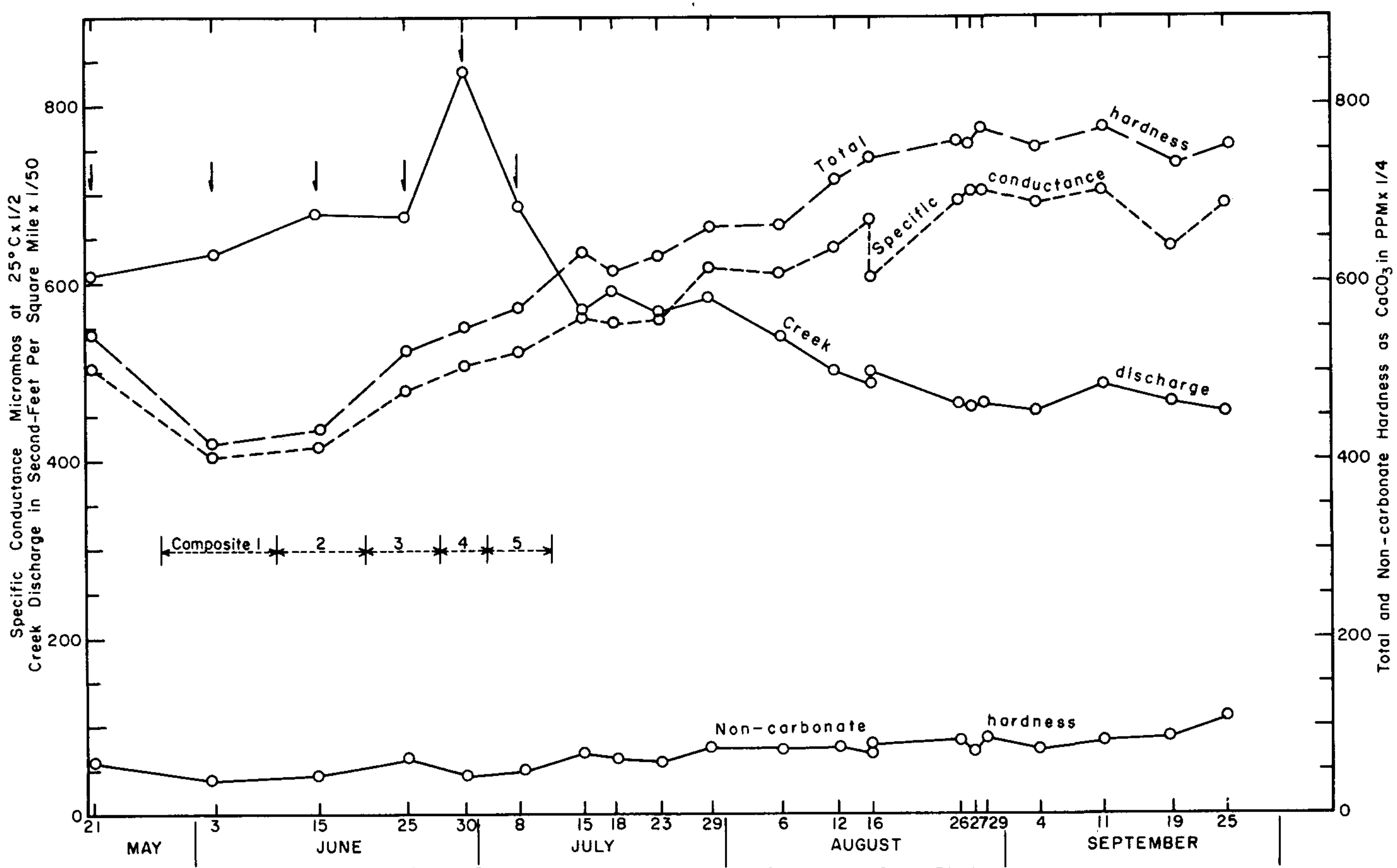


Figure 2- Relationship between Mineral Content and Creek Discharge, Marmot Creek at Gauge, May 21, 1963—September 25, 1963.
↓ Composite daily samples (*see also* Figure 1); values thereafter are for spot samples.

APPENDIX III

METEOROLOGICAL INSTRUMENTATION IN MARMOT CREEK BASIN

A. S. MANN[1]

This appendix outlines the development of the meteorological instrumentation network in Marmot Creek basin. A summary of data gathered in the first full season of operation is included.

In 1961, when this project was in its early stages, several major problems were evident:

1. the need for staff
2. the need for transportation
3. the selection of instrumentation
4. the selection of network sites

By the end of 1962 the first two problems were at least partially resolved. The selection of instruments and the location of network sites were interdependent factors. This was due to the lack of conventional exposure sites, and the relatively difficult access to all parts of the basin above 6000 feet MSL.

Network Development

The selection of sites was based on the following considerations:

1. to sample the full range of elevation within the basin to the extent that significant differences in meteorological factors due to elevation might be determined.
2. in each sub-basin to sample each major slope to the extent that difference in meteorological factors due to aspect might be determined.
3. to sample items of special interest, such as snow accumulation, on the south edge of the basin.
4. (a) to maintain optimum exposure – clear of obstructions and away from excessively steep slopes and
   (b) to maintain good accessibility in the interests of complete records.

The overall plan which evolved within these restrictions can be outlined as follows:

1. A basic year-round network of 5 Sacremento type precipitation storage gauges at high levels – above 7000 feet MSL – and one Leupold-Stevens recording precipitation gauge in the lower basin – 5600 feet MSL – which can be attended at monthly intervals. All sites chosen are relatively level and gauge openings are horizontal.
2. This network is backed up by 9 snow stakes, and a series of 17 snow courses. Some of the snow stakes are visible from the trunk road which runs by the basin and these are read at monthly intervals by telescope. The others will be read once

[1] Meteorological Officer, Meteorological Branch, Canada Department of Transport, Edmonton, Alberta.

or twice during the winter season by aircraft reconnaissance. The lower six snow courses will be read at monthly intervals and the remainder at high levels will be covered once or twice a season by a crew flown in by helicopter.

3. In the summer months this basic network is expanded by the addition of 9 ordinary and small orifice Meteorological Branch type rain gauges at levels between 6500 and 7500 feet MSL which are read at weekly intervals. At this time 5 ordinary gauges are also installed in the lower basin, three of which are read on a daily basis and two weekly. All are installed with orifice parallel to the slope.

4. Precipitation intensity is recorded on an annual basis by the Leupold-Stevens recording precipitation gauge in the lower basin. Two other intensity recorders of the Meteorological Branch type are also in operation in the lower basin in the summer months. This particular aspect will be expanded to higher levels next season.

5. A basic year round network of 5 temperature recorders is maintained in the lower basin. In the summer months this network is extended with an additional 5 thermographs to 6500 – 7500 feet MSL.

6. At 2 of the high thermograph sites, humidity is also measured.

7. Evaporation measurements are made during the summer months at one site in the lower basin using a standard class A pan.

8. Solar radiation measurements are made in the lower basin through an arrangement of 2 all-wave net radiometers of the CSIRO type. One is exposed six feet above the forest canopy and the other six feet above the forest floor. The tree cover in this area is mature spruce about 55 feet high.

9. Wind measurements have been made at one point in the lower basin for part of one season. The site is poorly exposed and the equipment will be moved next season.

The density of the present network is a minimum with respect to temperature and precipitation to permit any valid evaluation of inter-basin and inter-elevation differences. The relocation of a few existing sites for better exposure and the addition of about one temperature and three precipitation sampling sites (summer only) in each of the three upper sub-basins will represent optimum conditions.

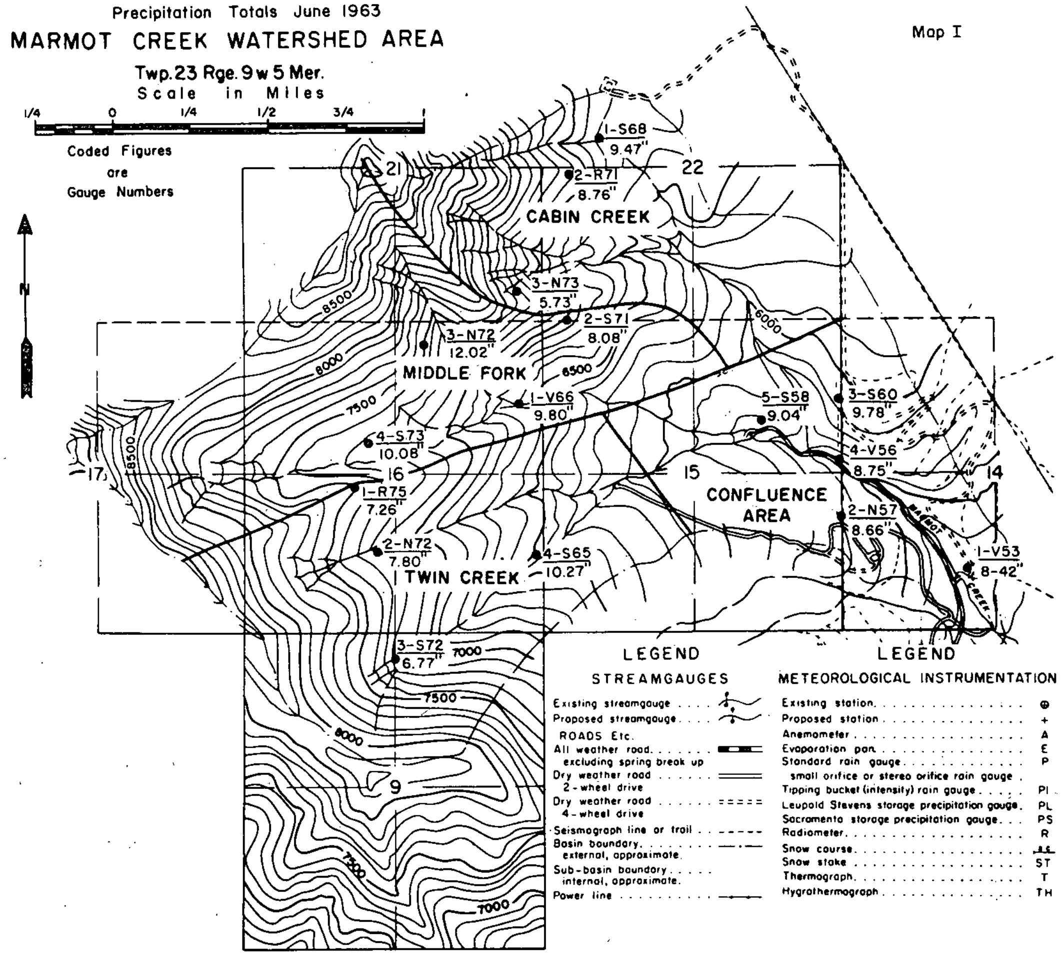
Summary of Results

The distribution of precipitation in the basin, at the different sampling sites, is shown for June, July, August and September, 1963 in Maps 1, 2, 3 and 4 respectively. Total precipitation for June to September, 1963 inclusive is given by Map 5. All figures are corrected for gauge inclination.

Some of the sites have less-than-ideal exposure, which is reflected in gauge catch, 25 for example at the head of Twin Creek. This is probably due to the shelter of the ridge which forms the southwest boundary of the basin. The catch at gauge 3-N73 in Cabin Creek (Map 1 et seq.) was consistently low, probably due to excessive slope steepness. Similarly, at gauge 2-S71 in Middle Fork the low catch is thought to be attributable to over-exposure on a ridge crest.

Comparison of the catch of (1) ordinary rain gauge (2) small orifice rain gauge, and (3) Leupold-Stevens precipitation recorder for three summer months, showed the Leupold-Stevens recorder to have an overcatch of 3.8% and the small orifice gauge an undercatch of 1.8% in relation to the ordinary gauge.

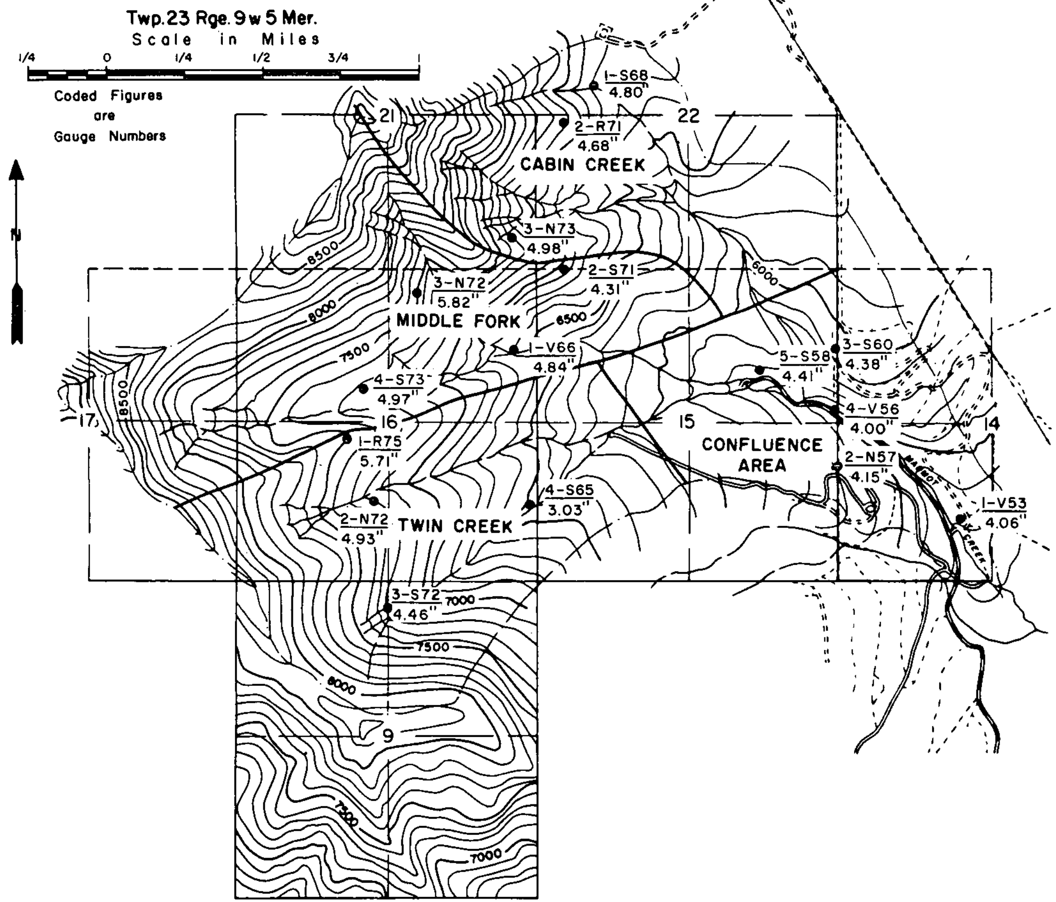
Daily maximum and minimum temperatures throughout 1963, taken at station 1-V53 in the confluence area (Map 1), are shown in Fig. 1.

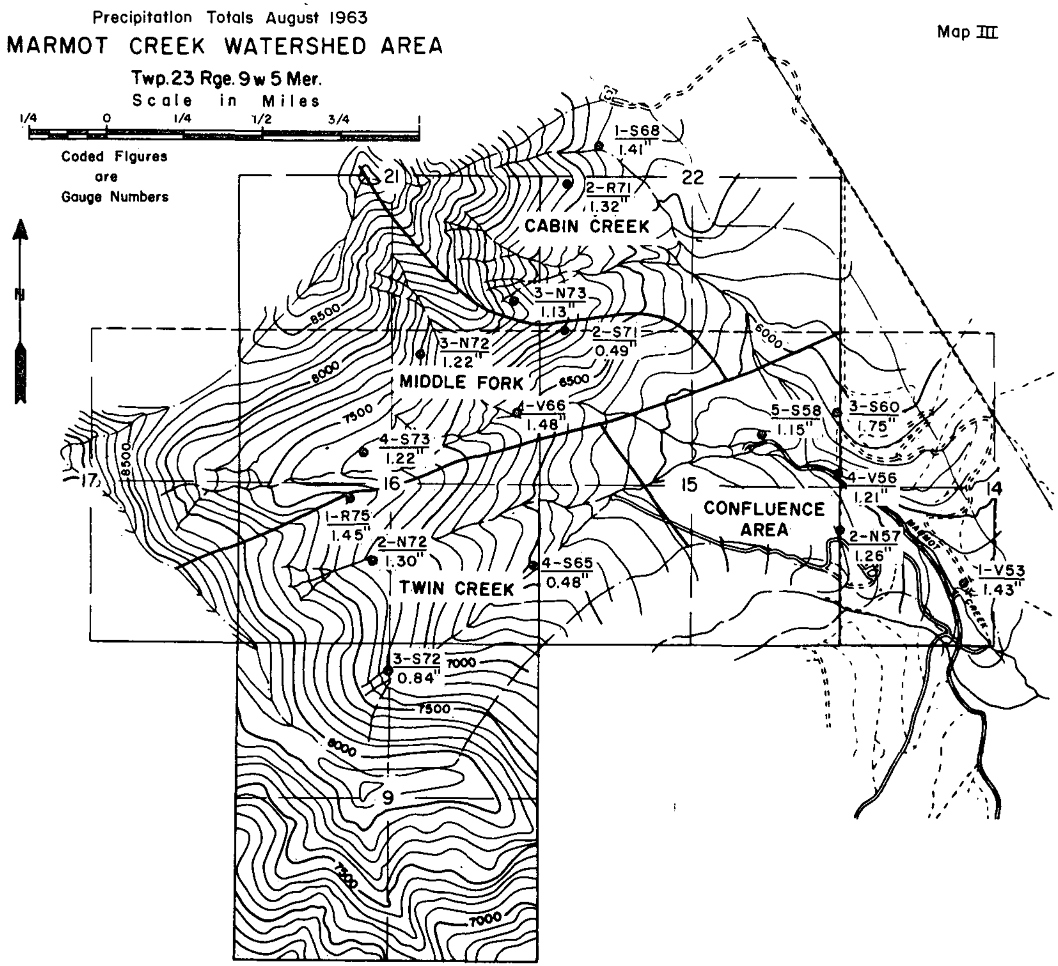

Precipitation Totals June 1963
MARMOT CREEK WATERSHED AREA
Twp. 23 Rge. 9 w 5 Mer.
Scale in Miles
1/4 0 1/4 1/2 3/4 1
Coded Figures are Gauge Numbers
N
Map I
1-S68 9.47"
2-R71 8.76"
CABIN CREEK
3-N73 5.73"
2-S71 8.08"
3-N72 12.02"
MIDDLE FORK
1-V66 9.80"
4-S73 10.08"
1-R75 7.26"
2-N72 7.80"
TWIN CREEK
4-S65 10.27"
5-S58 9.04"
3-S60 9.78"
4-V56 8.75"
CONFLUENCE AREA
2-N57 8.66"
1-V53 8-42"
3-S72 6.77"
21
22
17
16
15
14
9
8500
8000
7500
7000
6500
6000
MARMOT CREEK
LEGEND
STREAMGAUGES
Existing streamgauge
Proposed streamgauge
ROADS Etc.
All weather road, excluding spring break up
Dry weather road 2-wheel drive
Dry weather road 4-wheel drive
Seismograph line or trail
Basin boundary, external, approximate
Sub-basin boundary internal, approximate
Power line
LEGEND
METEOROLOGICAL INSTRUMENTATION
Existing station
Proposed station +
Anemometer A
Evaporation pan E
Standard rain gauge P
small orifice or stereo orifice rain gauge
Tipping bucket (intensity) rain gauge PI
Leupold Stevens storage precipitation gauge PL
Sacramento storage precipitation gauge PS
Radiometer R
Snow course
Snow stake ST
Thermograph T
Hygrothermograph TH

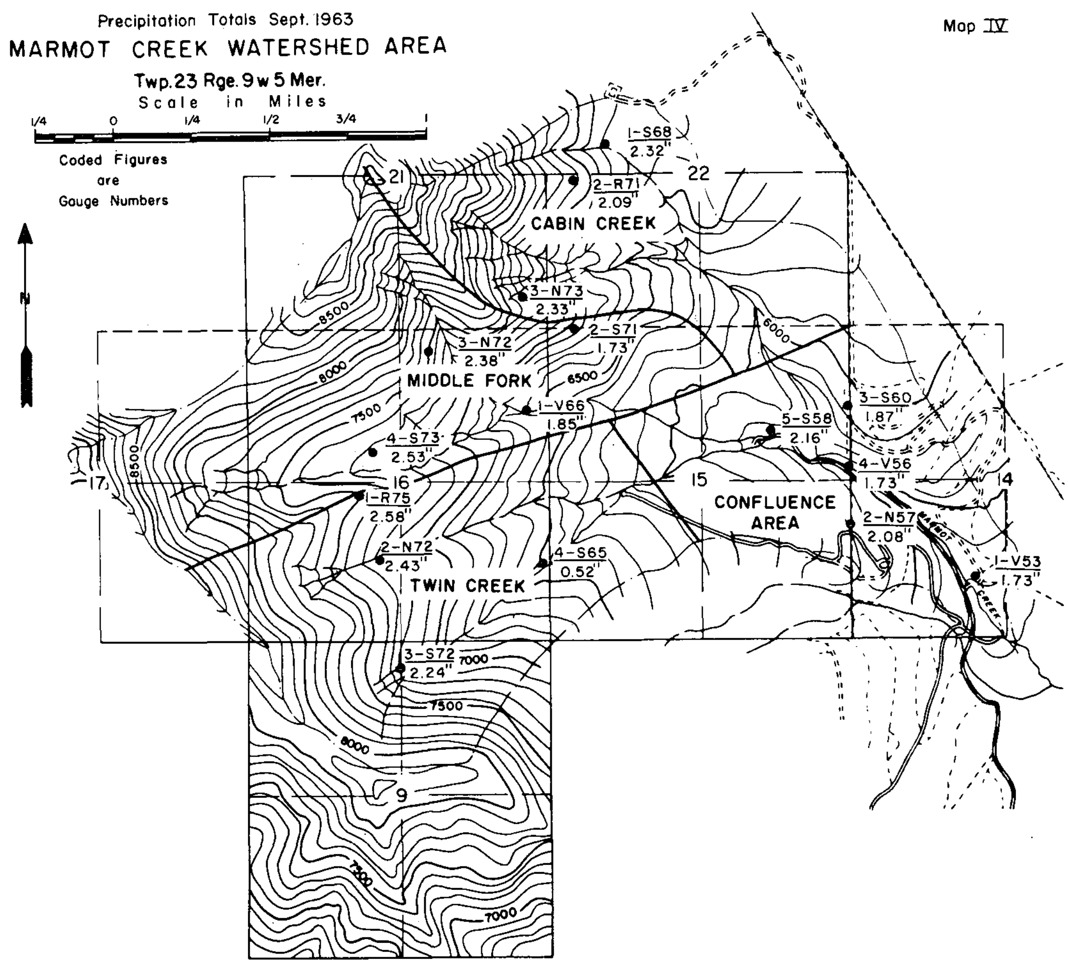
Map II

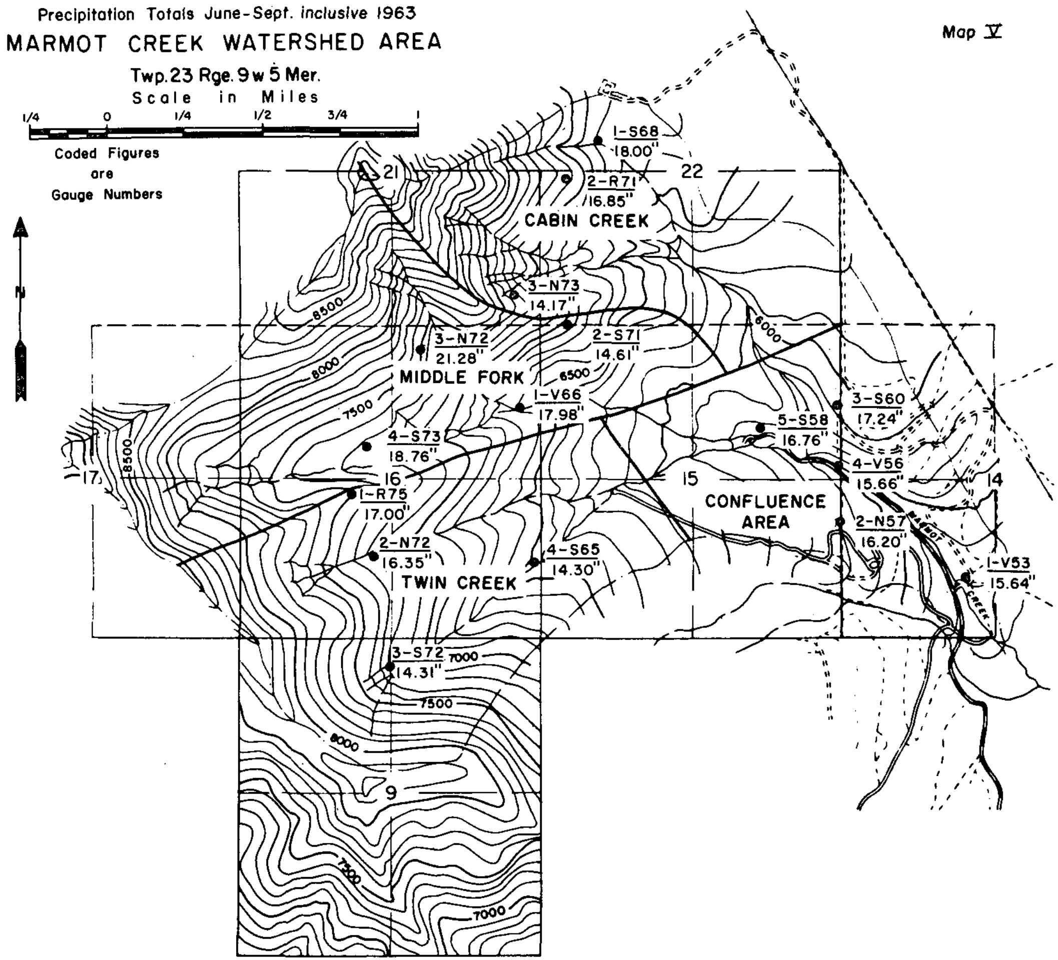
Precipitation Totals July 1963

MARMOT CREEK WATERSHED AREA




Precipitation Totals August 1963
MARMOT CREEK WATERSHED AREA
Twp. 23 Rge. 9 w 5 Mer.
Scale in Miles
1/4 0 1/4 1/2 3/4
Coded Figures are Gauge Numbers
N
Map III
1-S68 1.41"
2-R71 1.32"
CABIN CREEK
3-N73 1.13"
2-S71 0.49"
3-N72 1.22"
MIDDLE FORK
4-V66 1.48"
4-S73 1.22"
1-R75 1.45"
2-N72 1.30"
4-S65 0.48"
TWIN CREEK
3-S72 0.84"
5-S58 1.15"
3-S60 1.75"
4-V56 1.21"
CONFLUENCE AREA
2-N57 1.26"
1-V53 1.43"
21
22
17
16
15
14
9
8500
8000
7500
7000
6500
6000
MARMOT CREEK


Precipitation Totals Sept. 1963
MARMOT CREEK WATERSHED AREA
Twp. 23 Rge. 9 w 5 Mer.
Scale in Miles
1/4 0 1/4 1/2 3/4 1
Coded Figures are Gauge Numbers
N
Map IV
CABIN CREEK
MIDDLE FORK
TWIN CREEK
CONFLUENCE AREA
MARMOT CREEK
1-S68 2.32"
2-R71 2.09"
3-N73 2.33"
2-S71 1.73"
3-N72 2.38"
1-V66 1.85"
4-S73 2.53"
1-R75 2.58"
2-N72 2.43"
4-S65 0.52"
3-S72 2.24"
5-S58 2.16"
3-S60 1.87"
4-V56 1.73"
2-N57 2.08"
1-V53 1.73"
21
22
17
16
15
14
9
8500
8000
7500
7000
6500
6000


Precipitation Totals June-Sept. inclusive 1963
MARMOT CREEK WATERSHED AREA
Twp. 23 Rge. 9 w 5 Mer.
Scale in Miles
1/4 0 1/4 1/2 3/4 1
Coded Figures are Gauge Numbers
N
Map V
CABIN CREEK
MIDDLE FORK
TWIN CREEK
CONFLUENCE AREA
MARMOT CREEK
1-S68 18.00"
2-R71 16.85"
3-N73 14.17"
2-S71 14.61"
3-N72 21.28"
1-V66 17.98"
4-S73 18.76"
1-R75 17.00"
2-N72 16.35"
4-S65 14.30"
3-S72 14.31"
5-S58 16.76"
3-S60 17.24"
4-V56 15.66"
2-N57 16.20"
1-V53 15.64"
21
22
17
16
15
14
9
8500
8000
7500
7000
6500
6000

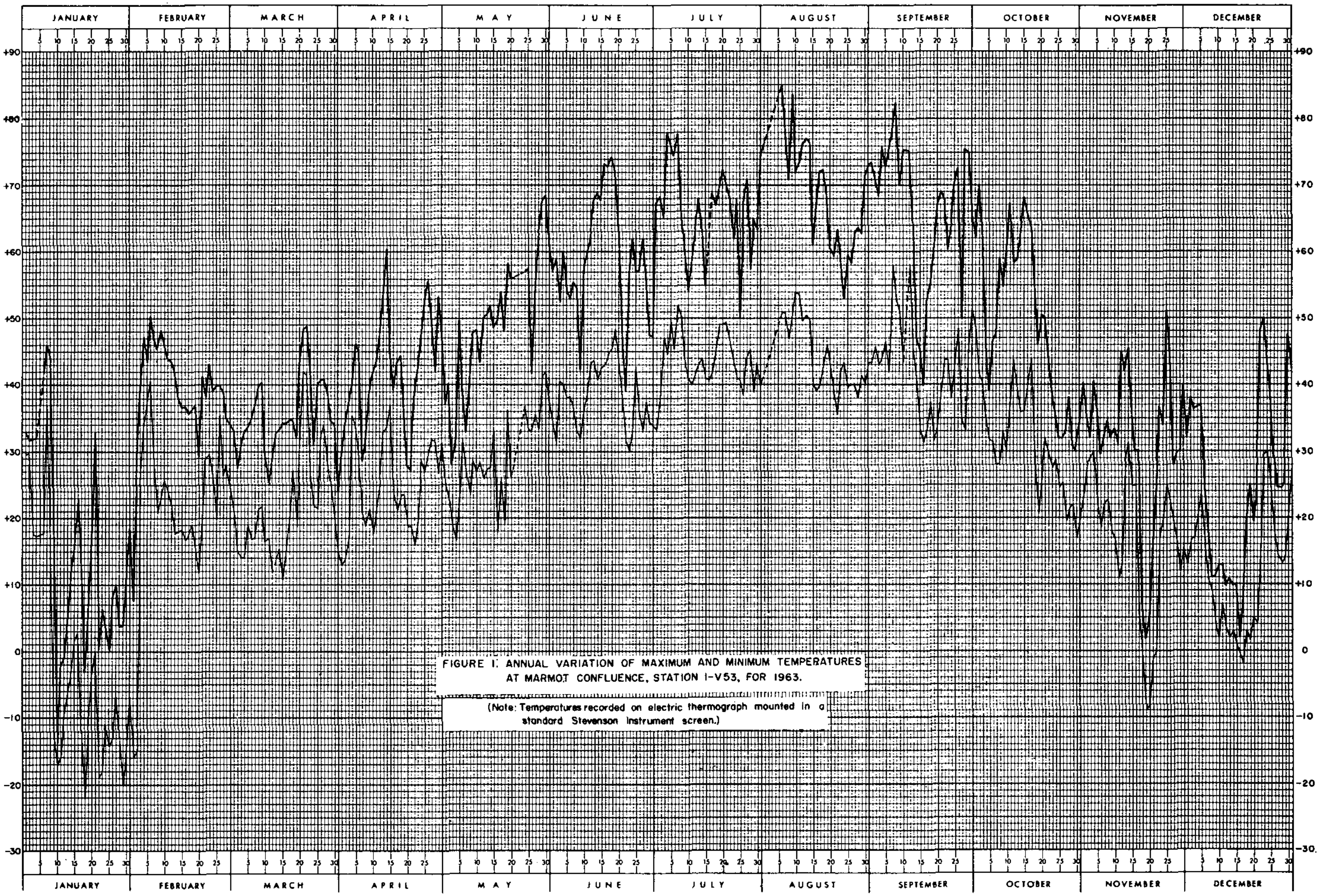


FIGURE 1. ANNUAL VARIATION OF MAXIMUM AND MINIMUM TEMPERATURES AT MARMOT CONFLUENCE, STATION I-V53, FOR 1963.

(Note: Temperatures recorded on electric thermograph mounted in a standard Stevenson instrument screen.)