

PRELIMINARY ASSESSMENT OF GROUNDWATER PROSPECTS
FOR THE
UPPER COLUMBIA STRATEGIC PLAN

From

Groundwater Section
Water Management Branch
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A PRELIMINARY ASSESSMENT OF GROUNDWATER PROSPECTS FOR THE
UPPER COLUMBIA STRATEGIC PLAN

INTRODUCTION

The purpose of this contribution is to provide an assessment of the extent to which groundwater may contribute to water supply capability in the Upper Columbia River Valley, and also to provide an estimate of costs to obtain additional groundwater data. Information available on file in the Groundwater Section used to compile this contribution consisted of water well records, well location maps, and groundwater, geological and soils reports and maps.

GEOGRAPHY

The Upper Columbia Valley lies within the Rocky Mountain Trench and the area studied extends northwest for a distance of about 155 kilometers from Canal Flats at the south end of Columbia Lake to the Village of Golden situated at the confluence of the Kicking Horse River with the Columbia River. The valley bottom ranges from about 1 to 3 kilometers in width and is flanked by steeply rising valley walls. A common feature in the valley of the mouths of tributary creeks is the frequent occurrence of numerous alluvial fans, numbering about 40 and ranging in size up to about 1.3 square kilometers. The largest fans occur at Canal Flats and at the mouths of Dutch, Windermere and Canyon Creeks.

Another distinctive feature of the Upper Columbia Valley is the occurrence, at Parson, of a ledge on the east side of the valley about 120 metres or more above the valley bottom. "The ledge, half a mile (or 1 kilometer) or more wide, is the remnant of an earlier rock valley bottom ..." (Kelley & Holland, 1961, p. 25). To the north of Parson and running beyond Golden, this ledge occurs on both sides of the valley. Many short gullies have been cut into the surficial deposits

occurring below the remnant of this former rock valley bottom and very occasionally springs have been mapped well below this level.

GEOLOGY

Bedrock Geology

The Upper Columbia River, from Canal Flats to Golden, closely follows the boundary separating bedrock formations of the Proterozoic Era occurring only on the west side of the river from bedrock formations of the Paleozoic Era on the east and partly on the west sides of the river. The main rock types occurring on the west side of the river from Canal Flats to Harrogate are sandstone, conglomerate and limestone. The main rock types mapped on the entire east side throughout the study area and on both sides of the river from Harrogate to Golden are limestone and shale.

Surficial Geology

Field observations by Kelley and Holland (1961, p. 25) show much of the area is covered by till, which is an unsorted deposit of sand, silt, clay and boulders; by stratified glacio-lacustrine silt; by alluvial fan deposits commonly composed of gravel, sand, silt and clay materials, and by glacial outwash deposits comprising sand and gravel.

Drill hole logs indicate quite a variation in the occurrence of surficial materials comprising the valley fill deposits to depths of about 90 metres below the level of the Columbia River. The total thickness of valley fill deposits below river level is not known. However, these may be very thick as is the case in much of the Okanagan River Valley where thicknesses up to 300 to 600 metres are known to occur.

From a study of some of the drill hole logs, which are predominantly for locations along the east side of the valley, it is possible to form some idea of the regional geology of the surficial deposits but correlation of logs appears to be justified

only on a local scale. Difficulties in attempting to correlate drilling logs is illustrated by the cross section (Figure 1) from Canal Flats to Golden. Along much of the Upper Columbia Valley till has been recorded at elevations close to, and to heights of over 150 metres above river level, with thicknesses ranging up to 60 metres thick. In places near Radium and Brisco, the till is reported to be underlain by clay over 60 metres thick and by silt about 120 metres thick, or by sand and gravel locally known to exceed 30 metres thick.

Many drill hole logs show mainly sand and gravel deposits from ground surface with some clay beds or lenses. These are mainly associated with alluvial fan deposits which are found at the mouths of many of the numerous tributary creeks occurring throughout the study area. Most of these drill holes are less than 30 metres deep and many are less than 15 metres deep. These limited drilling depths restrict understanding of the geology and thickness of the various fan deposits.

HYDROGEOLOGY

Source, Occurrence and Movement of Groundwater

The sources from which groundwater supplies are known to be obtained are predominantly sand and gravel beds or lenses, however, groundwater supplies are sometimes obtained from shales and sandstone in the area.

Groundwater occurs in the void or open spaces in the unconsolidated deposits and in the bedrock. The capacity of the bedrock or unconsolidated deposits to act as reservoirs of groundwater depends upon porosity which is the percentage of the total volume of a rock type or materials such as sand and gravel occupied by open spaces. Porosity is commonly low in fractured

bedrock so that relatively lower volumes of groundwater occur in bedrock compared to surficial deposits to a given depth.

While porosity influences the volume of groundwater in storage it is permeability, the ability of water to move through the open spaces, as well as the size of the open spaces which governs well yields. Clay is an example of material of high porosity, about 65 percent, but very small open spaces permitting only very limited movement of groundwater. Clean sand and gravels have lower porosity, about 35 percent, but larger open spaces allowing easy movement of groundwater. Well yields may be very small from clay and amount to only a small number of gallons per day, but yields from sand and gravel may often be measured as many hundreds, sometimes thousands, of gallons per minute.

Because of commonly low porosity and permeability of fractured bedrock, well yields from bedrock are usually small. However, in the study area large openings developed by solution of limestone and dolomite rocks may sometimes form passage ways for small to large underground streams. Wells intersecting such streams may have quite high yields. The water issuing as hot springs in the Upper Columbia Valley flows through solution channels in limestone and dolomite rocks.

The movement of groundwater is controlled chiefly by topography and is modified by geology with flow being from areas of topographic highs to topographic lows. On a regional scale groundwater flow is from upland areas (areas of groundwater recharge) to lowland areas or river valleys (areas of groundwater discharge). It should also be mentioned that recharge to aquifers in the main valley may occur by loss of water from tributary creeks into and through sand and gravel deposits underlying creeks beds.

Groundwater Data

The total number of water well records and test holes on file for the study area is just over 300. This data has been summarized and salient information is presented in 14 separate groupings in Table 1, "A Summary of Water Well Data." This schedule states the ranges of well depths, water levels and well yields, types of aquifer materials and some comments, mainly on water quality and occurrence of well groupings. Most of the well yields have been estimated by well drillers from short bail or pump tests and there is only a limited amount of pump test data available for calculating well yields or for aquifer assessment. Locations of the well groupings are shown on Figure 2. Groundwater data is also available for five observation wells which were monitored continuously between December 1969 and February 1977 in the Athalmer area. Data on chemical quality of groundwater in the study area is limited to some partial Hach kit analyses and three full laboratory analyses.

Groundwater Use

From the available information, groundwater resources in the valley are known to be developed to supply domestic, tourist accommodation, municipal, industrial and possibly for irrigation requirements. The majority, about three quarters of the wells, have been installed to meet domestic needs assumed to be less than 1/4 L/s (litres per second) or 3 Igpm (Imperial gallons per minute). Also, for about one-quarter of the wells there is no reported use.

Some wells have been constructed to serve or supplement municipal water supply requirements at Golden, Invermere, and Wilmer. Groundwater extraction for industrial use is small but is known to occur at Golden where it is developed for use by Allison Concrete Ltd., Kicking Horse Forest Products and Dominion Dairy. Groundwater development for municipal and industrial use gives a

TABLE 1

A Summary of Water Well Data

| Locality and Map Group Number | Range of: | | | | Aquifer Material | Reported Quality | |
|--------------------------------------|--------------------|--------------------------|---------------------------|-------------------------|---------------------|---------------------|----------------------|
| | No. of Wells | Well Depths (feet) | Water Levels (feet) | Well Yields (gpm) | | | |
| Canal Flats | 1 | 25 | 10-160 | 10-140 | 5- 130 | G,s | Hard |
| Thunder Hill Park | 2 | 6 | 40-613 | 0- 19 | 0- 25 | B | - |
| Fairmont Hot Springs | 3 | 11 | 10-180 | 4- 24 | 10- 20 | G,b | Hard |
| Northeast side of Windermere Lake | 4 | 61 | 6-540 | 0-161 | 3- 400 | G&S,fs | Hard |
| Athlmerre Invermere | 5 | 47 | 5-300 | 0-191 | 4-1000 | S&G,sts, b | Moderate- ly hard |
| Wilmer | 6 | 11 | 10-195 | 5-142 | 0- 250 | S&G | - |
| Dry Gulch Creek | 7 | 9 | 70-660 | 35-408 | 9- 25 | S&G,st,b | - |
| Radium Junction | 8 | 10 | 18-369 | 12-230 | 3- 25 | S&G | - |
| Edgewater | 9 | 20 | 8-240 | 10- 65 | 0- 10 | G,fs | Moderate- ly hard |
| Brisco | 10 | 6 | 12-461 | 5- 36 | - | S&G | Very hard |
| Harrogate- Spillimacheen | 11 | 8 | 16-116 | 10- 86 | 2- 30 | G | Hard |
| Parson - Castledale | 12 | 11 | 12-260 | 4- 43 | 4- 50 | S&G,cl,b | - |
| Nicholsen | 13 | 30 | 12-125 | 4- 50 | 1/4-15 | G,s | - |
| Golden | 14 | 65 | 12-218 | 10- 60 | 2-2000 | G,s | - |

Notes: G = Gravel; S = Sand; St = Silt; Fs = Fine Sand; StS = Silty Sand;
Cl = Clay; B = Bedrock

Upper case letters "S" denote main aquifer material; lower case letters "s"
denote minor aquifer material

more reliable indication of possible well yields with yields reported to be in the range of 18 L/s (240 Igpm) to 120 L/s (1600 Igpm). It is also quite possible that groundwater supplies are or could locally be developed for irrigation purposes for growing vegetables and small fruits.

Brief mention will be made here to the occurrence of hot springs in the valley. These occur at Radium and Fairmont and form a tourist attraction of major importance. The springs issue from solution channels in dolomite and limestone rocks and it is considered that the water has come from depths as much as 1290 metres.

Flow from Radium Hot Springs is about 30 L/s (400 Igpm) and the water temperature is about 42°C. The water may be described as calcium sulphate plus bicarbonate type with total dissolved solids of about 706 mg/L.

The combined discharge of several hot springs at Fairmont is over 37.5 L/s (500 Igpm) and the temperature of the springs ranges from about 36°C to 49°C. The waters may be described as mainly calcium sulphate type with some magnesium bicarbonate and high in total dissolved solids, about 2000 mg/L.

Springs in both localities are radioactive with those at Radium being the most radioactive in Canada. For further information on hot springs in the Upper Columbia the reader is referred to van Everdingen (1972).

Groundwater Prospects

General

Most of the wells are unevenly distributed along the Columbia River Valley, occurring mainly in groups associated with the human settlement pattern. Due to the distribution

of data and the shallow depths of most wells, only limited delineation of the areal extent and thickness of aquifers is possible. Each locality where wells occur requires detailed groundwater study using large-scale maps which is beyond the scope of this report. However, from the data supplied on reported well yields, 69 wells yield up to 1.5 L/s (20 Igpm), 30 wells yield up to 7.5 L/s (100 Igpm), 17 wells yield up to 37.5 L/s (500 Igpm), and six wells yield up to 120 L/s (1600 Igpm).

Alluvial Fan Deposits

The largest fans occur at Canal Flats and at the mouths of Dutch, Windermere and Canyon Creeks. These fans and several somewhat smaller fans as at the mouths of creeks such as Madias, Stoddart, and Holt Creek may sometimes be important sources of groundwater supply. Groundwater supplies may sometimes be obtained near the mouths of other tributary creeks where fan development is absent, such as Kinderley and Horsethief Creeks.

The data concerning well yields suggest that groundwater prospects may often be favourable in the alluvial fan deposits. The developed aquifer materials within these fans are primarily permeable sands and gravels mostly penetrated to depths of less than 30 metres below ground surface, but the thickness of these fan deposits is usually unknown. Some idea of groundwater prospects is given by well data at places such as:

1. Canal Flats where yields up to 30 L/s (400 Igpm) are reported from depths as shallow as 11 metres. Only four of the 25 wells exceed 15 metres in depth and only one is greater than 30 metres deep. With the Kootenay River flowing across the south end of this fan and undoubtedly contributing to recharge of the fan deposits, there is

probably considerable potential for groundwater development here.

2. Windermere. Wells in this locality are commonly less than 15 metres deep with yields reported up to 1.5 L/s (20 Igpm). Three drill holes in and near Windermere, about 60 to 120 metres deep show thick low permeable materials, mainly clay overlying bedrock. It is suggested that groundwater supplies may only be obtained from shallow sand and gravel deposits and that additional exploration and test pumping be conducted either close to Windermere Creek or about one kilometer north of Windermere.

Glacial Outwash Deposits

Water well records from wells completed in sand and gravel deposits as at the mouths of Toby Creek (Hodge, 1980) and Kicking Horse River show groundwater prospects are quite favourable. Near Toby Creek well yields are reported to be as high as 30 L/s (400 Igpm) and up to 75.0 L/s (1000 Igpm) near the Kicking Horse river.

Till and Clay Deposits

There are some locations where the geology appears to be unfavourable for the development of groundwater supplies such as near Edgewater, Dry Gulch Creek and Brisco. Though well yields up to 2/3 L/s (8 Igpm) have been reported near Edgewater, some wells yield very limited groundwater supplies and several dry holes have been drilled in this locality to depths of about 60 metres penetrating mainly clay deposits. Near Dry Gulch Creek some test holes range from 135 to 255 metres deep and penetrate thick sections of clay and till deposits. Four wells yield groundwater at rates reported to range from 1/2 L/s (6 Igpm) to 1.5 L/s (20 Igpm). At Brisco

two drill holes were reported to be dry to depths of about 60 and 140 metres and penetrated mainly clay. Two wells do produce adequate and two others inadequate supplies of water for use but actual yields are unknown.

Groundwater prospects at a number of localities have been indicated in Table 2, "Groundwater Prospects in Selected Localities." which shows the number of well records, ranges of well depths and reported yields, and the major aquifer materials. The data indicate that at some sites such as near Windermere, Shuswap, Wilmer and Hospital Creeks, there would appear to be potential for increased groundwater supplies. However, detailed office and field studies are required in each area. The localities listed in Table 2 are shown on Figure 3.

With regard to the prospects of obtaining groundwater supplies at depths of 150 metres or more below river level nothing is presently known about the thicknesses or types of deposits filling the Upper Columbia Valley. It is likely, however, that the unconsolidated deposits may be several hundred metres in maximum thickness. From what is known of the variation in types and thicknesses of surficial deposits in the Okanagan River Valley groundwater supplies can be obtained from depths as much as 370 m below ground surface. With the knowledge that groundwater supplies can be obtained from considerable depths in the Okanagan River Valley, the potential for obtaining groundwater supplies from similar depths in the Upper Columbia Valley should not be discounted.

Bedrock Aquifers

Very little information is available on groundwater prospects from bedrock sources as there are records on file

TABLE 2 - Groundwater Prospects in Selected Localities

| | Identified Surface Water Shortage Sites | No. of Well Logs Reported | Total Depth Range | Reported Well Yield Range | Major Aquifer Materials | Comments on Quality | Comments |
|---|--|---------------------------|-------------------|---------------------------|---|-----------------------|----------|
| A | Midstream/Fairmont Zoolspring Creek | 13 | 10' to 180' | Inadequate to 20 gpm | Mostly gravels | - | |
| B | Windermere Creek near Windermere | 22 | 12' to 380' | 4 to 200 gpm | Sand and/or gravels | - | |
| C | Goldie Creek | 0 | | | | - | |
| D | Toby Creek near Mouth | 5 | 10' to 135' | 8 gpm to 10 gpm | Sand and gravel | - | |
| E | Shuswap Creek | 4 | 61' to 110' | 20 to 30 gpm | Sand and gravel | No data on quality | |
| F | Wilmer Creek near Wilmer | 6 | 26' to 195' | 1 to 250 gpm+ | Sand and/or gravels | | |
| G | Bruce Creek near Wilmer | 0 | | | | - | |
| H | Stoddart Creek near Athalmer | 2 | 72' to 197' | 3 gpm | Gravels, clay and sand | No data | |
| I | Dry Gulch Creek near Radium Junction | 5 | 70' to 625' | 0 to 19 Igpm | Mostly gravel and sand, some clay | - | |
| J | Forster Creek | 1 | 180' | 6 gpm | Gravel | - | |
| K | Sinclair Creek at Radium Hot Springs | 0 | | | | - | |
| L | Macaulay Creek near Edgewater | 2 | 60' and 165' | 6 gpm | Boulders and clay | - | |
| M | Fraling Creek | 2 | 96' | 10 to 15 gpm | Gravel with clay bands | No data | |
| N | Soles Creek | 1 | 30' | Good | Gravels | - | |
| O | Beard Creek | 0 | | | | - | |
| P | Pagliari Creek near Golden | 1 | 125' | 12.5 gph | Red clay (6' to 125') | - | |
| Q | Horse Creek | 5 | 100' to 160' | 2 to 10 gpm | Gravels | - | |
| R | Hospital Creek above North Ford and Hospital Creek North Fork near Golden | 8 | 8' to 2118' | 0 to 60 gpm | Gravel, sand, clay and boulders | No data on quality | |
| | Hotspring Creek | | | | | | |
| | Warm Springs | | | | | | |
| | Bower Creek near Mouth | | | | | | |

for only 11 wells and test holes drilled into the bedrock. Most of these wells are reported to be completed in shale and the highest reported well yields are 1.5 L/s (20 Igpm) for three of the wells. Three drill holes were reported to be dry.

Reference has previously been made to the occurrence of groundwater in solution channels in limestone and dolomite rocks. However, there are no records on file of wells being completed in these rock types though groundwater supplies could be developed from wells intersecting streams within these rocks.

Groundwater Quality

Information on groundwater quality in the Columbia River Valley is very limited and much of this is only for field Hach kit measurements of pH or comments from well owners that the water is "hard." Only three full laboratory chemical analyses are on file. These are for groundwaters in the Kirk Subdivision at Radium and at Wilmer and at Athalmer. These analyses show groundwaters may be described as of calcium and magnesium bicarbonate type low in total dissolved solids. The total solids are in the range of about 200 to 300 mg/L. The hardness values range from about 130 to 260 mg/L.

Arsenic was present in the sample taken at Radium and was reported to be 0.012 mg/L. This concentration slightly exceeds the acceptable level of 0.01 mg/L of the Canadian Drinking Water Standards (Health and Welfare Canada, 1968) but falls below the upper permissible limit of 0.05 mg/L. Gummer and Block (1979) have found arsenic originating from the bedrock springs to be ubiquitous in the water of the Sinclair Creek Basin. Kohut (1980) has suggested that ... Under pumping conditions arsenic levels in the groundwater of

the surficial deposits adjacent to Sinclair Creek would not be expected to increase to the median levels observed in Sinclair Creek but strongly advises wells to be located away from Sinclair Creek. To date the groundwater conditions in the vicinity of Radium have not been adequately investigated. Additional test drilling in the Radium area is warranted to locate groundwater sources that are removed from Sinclair Creek.

One further comment is made in reference to groundwater quality. This concerns the fact that good waste disposal practices are recommended to prevent possible groundwater pollution as many wells withdraw water supplies from shallow water table (unconfined) aquifers in alluvial fans and glacial outwash deposits. Areas which may be quite sensitive to contaminants reaching aquifers include Canal Flats and in the Edelweiss area near Golden.

RECOMMENDATIONS FOR FURTHER DATA COLLECTION

Collection of Additional Water Well Data

It is recommended that additional water well data be collected for some wells and also for wells for which records are not available on Groundwater Section files. About 3 man weeks should be allowed for this work. The type of data to be collected would include well depth, water level, well log, well yield and comments on water quality. Field work should include taking conductivity readings and field tests of chemical quality of well water samples and a very limited number of groundwater samples for laboratory chemical analysis. It is suggested such work is assigned to technical staff and approximate costs have been estimated as follows:

| | |
|-----------------------------------|----------------------------|
| 1. Salaries | \$ 1,150. |
| 2. Field expenses | \$ 1,125. |
| 3. Laboratory chemical analyses . | \$ 2,700. (for 15 samples) |
| | <hr/> |
| | \$ 4,975. |

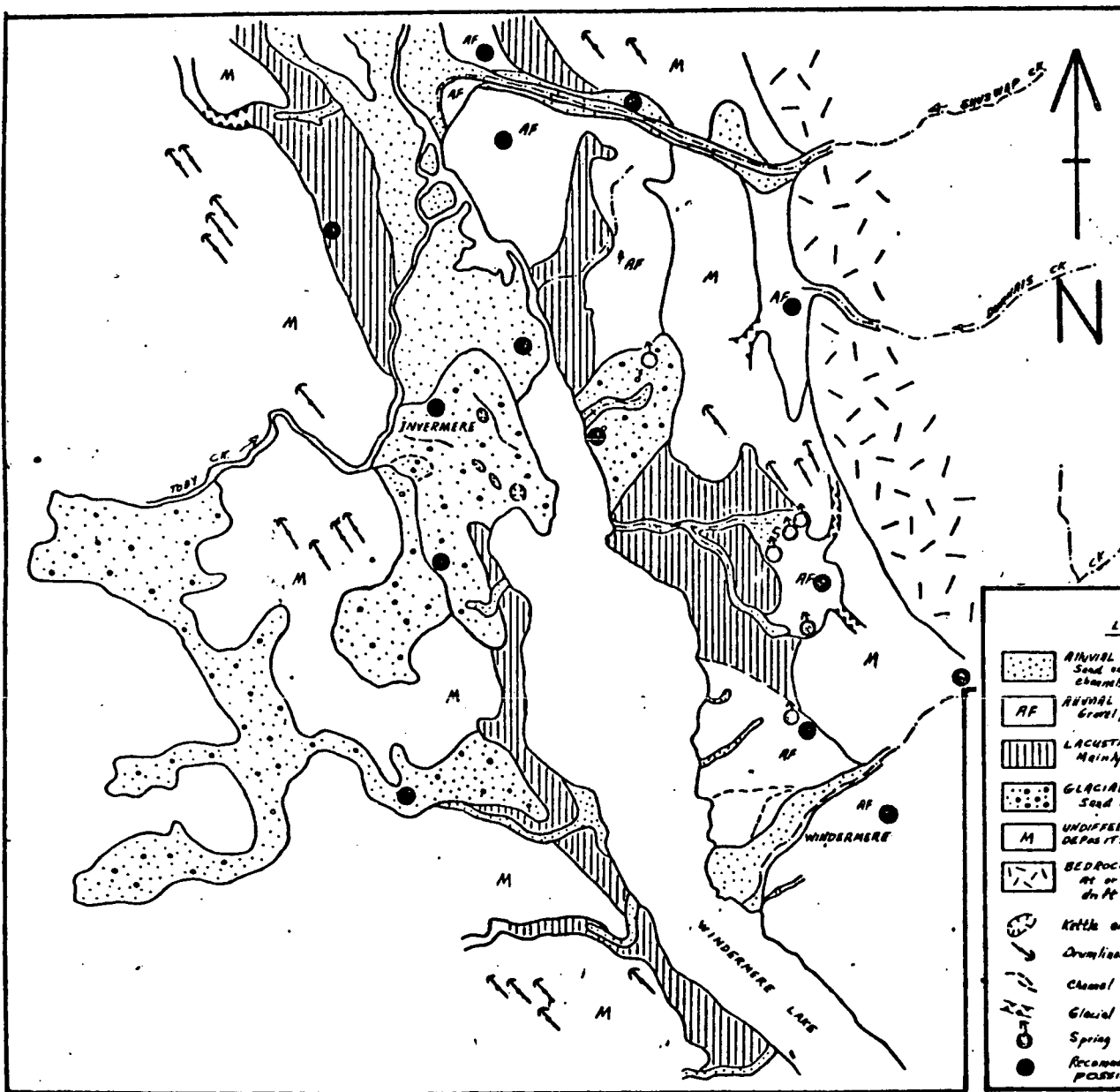
Following upon an office review of additional water well data collected from a field inventory program, consideration should be given to selecting possible sites for test drilling and pump testing programs.

Groundwater Exploration Programs

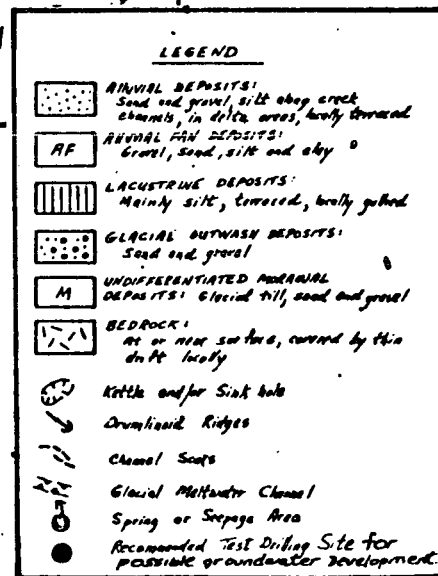
There are a number of sites throughout the Upper Columbia River Valley which warrant further groundwater investigation in order to understand the aquifer potential for groundwater development. These areas include locations identified in Table 2, all of which are presently experiencing surface water supply shortages. Groundwater could possibly provide an alternative water supply to meet the requirements of these areas. A groundwater test drilling program should therefore be considered in order to more fully understand the groundwater potential in these areas.

The number and siting of test wells will depend upon local water supply requirements. Glacial outwash deposits and alluvial fan deposits provide good prospects for groundwater development, and for the Invermere-Windermere area specific test drilling sites are recommended and shown on Figure 4, (Hodge, 1980).

Cost estimates for example purposes have been prepared for test drilling in surficial deposits for 8-inch diameter wells to be completed to depths of about 15 metres (50 feet) and 30 metres (100 feet) and 90 metres (300 feet), Appendix A. These cost estimates have been prepared for drilling by the cable-tool method or by rotary drilling with a driven casing. Costs total \$8,800, \$11,800 and \$22,700, respectively. Costs given here are for contract costs only and do not include engineering supervisory costs. The foregoing estimates have been provided as a guide to the costs of groundwater exploration in aquifers known to occur at



~~MAP SHOWING PRELIMINARY SURFICIAL
GEOLOGY AND SITES WHERE TEST
DRILLING IS RECOMMENDED~~



Note: Geology based on air photo interpretation and available soils and land form mapping from Resource Analysis Branch, Ministry of Environment.

15

Province of British Columbia
Ministry of the Environment
ENVIRONMENTAL AND ENGINEERING SERVICE
WATER INVESTIGATIONS BRANCH

From TO-ACCOMPANY REPORT ON
Preliminary Assessment of Groundwater
Conditions in the Invermere - Windermere
Area.

SCALE: 1" = 1.2 Miles

DATE
FEB. 1980

A. P. Kohut ENGINEER

FILE No. DWG. No. Figure 4

depths of 15 metres (50 feet), 30 metres (100 feet), and 90 metres (300 feet), as is the case in the Upper Columbia River Valley.

SUMMARY

The area covered in this study of groundwater resources in the Upper Columbia River Valley ranges from Canal Flats at the south end of Columbia Lake to Golden, a distance of about 155 kilometers. Geological and soils maps and reports indicate the bedrock is comprised mainly of shale, sandstone and limestone, and that much of the area is covered by till, alluvial and glacial outwash deposits.

The alluvial and glacial outwash deposits are the major developed sources of groundwater supply in the area. A review of over 300 water well records show over half of the wells obtain groundwater at less than 15 metres below ground surface and less than one quarter are more than 30 metres deep. Well yields are reported for only 127 or about one-third of the wells. The yields of 11 wells are reported to range from about 30 L/s (400 Igpm) to 120 L/s (1600 Igpm) and of 22 others from about 4 L/s (50 Igpm) to 30 L/s (400 Igpm). Most of these wells are located at Golden and in the area from Winderemere to Invermere. Though the majority of wells have been constructed to meet domestic water supply requirements and have no reported yield, there are many wells reported to yield up to 4 L/s (50 Igpm) located throughout the study area.

Table 2 lists a short summary of water well data for localities experiencing surface water supply shortages. The existing information and data require detailed office study accompanied by field work, including test drilling and test pumping before making conclusive statements about groundwater potential in each of the areas.

It is estimated that costs to collect some additional water well data and groundwater samples for laboratory chemical analysis will be about \$5,000 and require about three weeks field work. Costs of

exploratory test drilling and test pumping for individual wells ranging from 15 to 90 metres deep will be about \$8,800 to \$22,700.

Very limited information is available on groundwater quality. The groundwaters are low in total dissolved solids, 200 to 300 mg/L but generally hard and may be described as a calcium and magnesium bicarbonate type. The only important known water quality problem is the occurrence of arsenic in groundwaters in the vicinity of Sinclair Creek.

In the Upper Columbia Valley sites for waste disposal to the ground should be carefully selected and monitored to minimize risk of groundwater pollution as numerous wells obtain supplies from shallow aquifers in the area.

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APPENDIX A

Estimates of Itemized Costs for an 8" Diameter
15 Metres (50 Feet) Deep, Test-Well
in Overburden Using Cable-Tool Method
or Rotary Drilling with a Driven Casing

| <u>ITEM</u> | <u>COST</u> |
|--|-------------|
| 1. Mobilization and Demobilization (lump sum) | \$ 500. |
| 2. 8-inch drive shoe (each) | \$ 185. |
| 3. 50 feet of 8-inch cased drilling (\$38/ft.) | \$ 1,900. |
| 4. 10 feet of 8-inch screen and fittings (lump sum) .. | \$ 1,000. |
| 5. Hourly work (set screen, bail test, well develop- ment, etc., calculated at \$80/hour) | \$ 1,600. |
| 6. Standby Time (\$60/hr.) | \$ 480. |
| 7. Mobilization and demobilization of pump and equipment (lump sum) | \$ 500. |
| 8. Install and remove pump and discharge pipe (lump sum) | \$ 500. |
| 9. 24-hour pumping test (\$50/hr.) | \$ 1,200. |
| 10. Pumping crew standby (\$40/hr.) | \$ 120. |
| | <hr/> |
| Sub-total | \$ 7,985. |
| | <hr/> |
| + 10% Contingencies | \$ 799. |
| | <hr/> |
| TOTAL | \$ 8,774. |
| | <hr/> |

Estimates of Itemized Costs for an 8" Diameter
30 Metres (100 Feet) Deep, Test-Well
in Overburden Using Cable-Tool Method
or Rotary Drilling with a Driven Casing

| <u>ITEM</u> | <u>COST</u> |
|--|-------------|
| 1. Mobilization and Demobilization (lump sum) | \$ 500. |
| 2. 10-inch drive shoe (each) | \$ 300. |
| 3. 20 feet of 10" cased drilling (\$48/ft.) | \$ 960. |
| 4. 8-inch drive shoe (each) | \$ 185. |
| 5. 20 feet of 8-inch overlap (\$16.25/ft.) | \$ 325. |
| 6. 80 feet of 8-inch cased drilling (\$38/ft.) | \$ 3,040. |
| 7. 10 feet of 8-inch screen and fittings (lump sum) .. | \$ 1,000. |
| 8. Hourly work (set screen, bail test, well develop- ment, etc., calculated at \$80/hour) | \$ 1,600. |
| 9. Standby Time (\$60/hr.) | \$ 480. |
| 10. Mobilization and demobilization of pump and equipment (lump sum) | \$ 500. |
| 11. Install and remove pump and discharge pipe (lump sum) | \$ 500. |
| 12. 24-hour pumping test (\$50/hr.) | \$ 1,200. |
| 13. Pumping crew standby (\$40/hr.) | \$ 120. |
| Sub-total | \$10,710. |
| + 10% Contingencies | \$ 1,070. |
| TOTAL | \$11,780. |

Estimates of Itemized Costs for an 8" Diameter
90 Metres (300 Feet) Deep, Test-Well
in Overburden Using Cable-Tool Method
or Rotary Drilling with a Driven Casing

| <u>ITEM</u> | <u>COST</u> |
|--|-------------|
| 1. Mobilization and Demobilization (lump sum) | \$ 500. |
| 2. 10-inch drive shoe (each) | \$ 300. |
| 3. 100 feet of 10" cased drilling (\$48/ft.) | \$ 4,800. |
| 4. 8-inch drive shoe (each) | \$ 185. |
| 5. 100 feet of 8-inch overlap (\$16.25/ft.) | \$ 1,625. |
| 6. 200 feet of 8-inch cased drilling (\$38/ft.) | \$ 7,600. |
| 7. 10 feet of 8-inch screen and fittings (lump sum) .. | \$ 1,000. |
| 8. Hourly work (set screen, bail test, well develop- ment, etc., calculated at \$80/hour) | \$ 1,840. |
| 9. Standby Time (\$60/hr.) | \$ 480. |
| 10. Mobilization and demobilization of pump and equipment (lump sum) | \$ 500. |
| 11. Install and remove pump and discharge pipe (lump sum) | \$ 500. |
| 12. 24-hour pumping test (\$50/hr.) | \$ 1,200. |
| 13. Pumping crew standby (\$40/hr.) | \$ 120. |
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| Sub-total | \$20,650. |
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| + 10% Contingencies | \$ 2,061. |
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| TOTAL | \$22,711. |
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