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OFR 1977-08

HYDROGEOLOGY OF HIGHWAY CORRIDORS

JASPER NATIONAL PARK

by

D. Bernard
Groundwater Division
Alberta Research Council
March 1977

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ABSTRACT

Hydrogeological mapping was carried out in the highway corridors of Jasper National Park. A set of eleven 1:50,000 hydrogeological maps and seven profiles are presented. These show qualitative estimates of well yields based on geology, aquifer thickness, assumed permeability, spring discharge rates, and topographic position. Geology and hydrochemistry are also presented on the maps.

The use of groundwater for water supply is very feasible within most valley areas of Jasper National Park. An excellent aquifer consisting of recent deposits of sand and gravel occurs in the Athabasca River Valley. Wells completed in this unit can yield greater than 10 l/s. Other surficial deposits such as colluvium and till may produce yields of up to approximately 10 l/s. Bedrock formations are generally poor aquifers.

INTRODUCTION

In April of 1976 the Resource Studies Branch of Parks Canada approached the Groundwater Division of the Alberta Research Council regarding hydrogeological mapping in Jasper National Park. This is a continuation of the biophysical resource inventory program which is being carried out in both Banff and Jasper National Parks. Groundwater potential of Banff Park was completed by Nielsen (1975) using interpretations of the surficial geology maps of Bayrock and Reimchen (1975).

Twelve 1:50,000 scale overlay map sheets are presented with this report. The maps predominately show well yields with geology and hydrochemistry subdued. Seven profiles have been included at sites outlined in the original terms of reference (see Appendix 1). Three side maps of the study area are also presented which show data density, profile locations, and total dissolved solids (see side maps 1,2,3).

LOCATION

The area covered by the hydrogeological maps consists basically of the highway valleys and their respective watersheds, and extends from townships 37 to 47 and from range 23 W5 to range 3 W6 (see side map 1). The study area covers 1500 km^2.

WORK DONE

Fieldwork was begun in early June, 1976 and was completed in September, 1976. A small survey of winter flow rates of known springs was carried out in December, 1976. Over 150 water samples were collected, of which approximately 100 were spring samples. The remaining 50 samples were collected from surface water such as rivers, lakes, and ponds which were thought to have a high component of groundwater (see Appendix 2). All springs encountered were sampled, and characteristics such as aquifer lithology, flow rate, water temperature, and elevation recorded (see Appendix 3). Nine springs were sampled at biweekly intervals throughout the summer (see Appendix 4). Hydrogeologically important surficial material and bedrock were examined and their locations plotted on the maps and noted in Appendix 5. A surface resistivity survey at some profile locations was carried out by G. McClymont.

ACKNOWLEDGMENTS

The Jasper Park Warden Service, in particular A. Stendie, W. Thordarson, and R. Haney, provided excellent advice and support. Assistance in the field was capabably given by P. Bernard. All samples were analyzed by the Geochemical Laboratory Staff of the Alberta Research Council. The paper was critically read by R. Barnes and D. Hackbarth.

GEOLOGY

BEDROCK GEOLOGY

The geology of the Rocky Mountains is extremely complex due to extensive folding and faulting. A relatively complete and thick succession of sediments are found ranging in age from Precambrian in the west to Cretaceous in the east. The stratigraphy of the map area is shown in Figure 1. For detailed bedrock geology the reader is referred to Mountjoy, 1961, and Price and Mountjoy, 1970.

A detailed breakdown of the geology into specific formations or groups was not considered to be hydrogeologically important and therefore was not included. Rock formations are grouped according to similarities of important hydrogeological units. These units may contain a number of different lithologies that are hydrogeologically similar.

Precambrian rocks outcrop extensively in the western and central areas of Jasper National Park. They are composed of the Proterozoic Miette Group sandstones, siltstones, slates and conglomerates (Charlesworth et al. 1967). They are only slightly fractured and are very poor aquifers. Numerous lakes near Jasper townsite are situated on this massive, relatively impermeable unit.

Figure 1: Stratigraphic Sequence (Mountjoy, 1961, Jackson, 1975, Barnes, 1976)

Era	Period	Group	Formation	Thickness (m)	Gross Lithology
Mesozoic	Lower Cretaceous	Blairmore Gp.	Mtn. Park Fm.	120 – 150	cherty and calcareous sandstone, coal, minor shale
			Luscar Fm.	300 – 600	
			Cadomin Fm.		conglomerate
	Jurassic		Nikanassin Fm.	300 – 620	cherty sandstone, minor shale
			Fernie Gp.	210 – 360	shale, minor limestone
	Triassic		Spray River Gp.	210 – 770	siltstone, minor limestone
Paleozoic	Permian-Pennsylvanian		Rocky Mountain Gp.		quartzose sandstone, siltstone, minor carbonates
	Mississippian	Rundle Gp.	Mt. Head Fm.	75 – 125	Massive limestone, dolomite, minor calcareous siltstone
			Turner Valley Fm.	50 – 130	
			Shunda Fm.	60 – 120	
			Pekisko Fm.	39 – 95	
			Banff Fm.	150 – 230	thinly bedded limestone, shale, siltstone
	Upper Devonian		Palliser Fm.	220 – 280	massive dolomite
			Alexo Fm.	30 – 190	arenaceous dolomite
		Fairholme Gp.	Southesk/Mt. Hawk Fm.	75 – 220	vuggy limestone, dolomite and mudstone
			Cairn/Perdrix Fm.	60 – 110	pyritic, calc[illegible] shale
			Maligne and Flume Fm.	50 – 90	argillaceous and cherty limestone and dolomite
	Ordivician		Skoki Fm.	0 – 450	limestone, shaly limestone, calcareous shale
	Upper Cambrian		Lynx Gp.	670-1260	limestone, dolomite, minor shale
			Arctomys Fm.	190 – 250	shale, thinly bedded limestone and dolomite
			Pika Fm.	160 – 220	flaggy limestone, dolomite
			Eldon Fm.	160 – 250	massive limestone with minor calcareous shale beds
			Stephen Fm.		
			Cathedral Fm.	470 – 610	
			Mt. White Fm.		thinly bedded shale, limestone
	Lower Cambrian		Gog Gp.	850-1750	thick bedded quartzite
Pre-cambrian	Proterozoic		Miette Gp.	4650	argillaceous sandstone, siltstone, shale, slate

Lower Cambrian Gog Group rocks conformably overlie the Miette Group. This unit consists predominately of sandstone and quartzite. It is not as massive as the Miette Group rocks yet appears to be more resistant to weathering as it forms the peaks of a number of mountains such as Mount Edith Cavell and Pyramid Mountain. The Gog Group is slightly more fractured and thinly bedded than the Miette Group; however, it is still considered to be a poor aquifer. These two units are often grouped together on the maps.

Carbonates dominate in rocks of Middle Cambrian through to Devonian age. The majority of Cambrian limestones are found in the area of the Columbia Ice-fields. They are quite thinly bedded with some fracturing. Devonian rocks of the Fairholme Group consist of a number of thin formations predominately of limestone with lesser amounts of siltstone and shale. These are usually similar in structure to the Cambrian rocks. Except for a thin band of impermeable shale, the Perdrix Formation, this unit forms a fair aquifer. The upper part of the Devonian is composed of massive dolomitic limestone of the Palliser Formation. It is extremely resistant to erosion and invariably forms many high peaks in the eastern portions of the study area.

The most prospective bedrock aquifer of the study area is the Mississippian Banff Formation. This unit consists of thinly bedded, highly fractured limestones, siltstones and shales. It is a recessive unit with minor valleys commonly formed in it which are capable of intercepting runoff.

Mississippian Rundle Group rocks consist primarily of limestones with some thinly bedded siltstones and shales. They are usually moderately fractured and fair aquifers.

Siltstones and shales of the Triassic Spray River Group form a fairly thin unit of limited areal extent. They are usually thin-bedded and fractured which causes them to be one of the better bedrock aquifers.

The Jurassic Fernie Group and Cretaceous Nikanassin Formation outcrop only in the eastern portion of the study area. These units consist of siltstones, shales, and some coal. They are considered to be fairly good bedrock aquifers.

SURFICIAL GEOLOGY

Where present, surficial deposits are the most important aquifer. These deposits have been delineated on the maps as Quaternary units. Only three hydrogeologically different types of surficial deposits have been shown. Detailed surficial geology has been shown on the terrain analysis maps of Reimchen (1976).

The most important surficial deposits are the fluvial and glaciofluvial sands and gravels of the Athabasca River Valley. These deposits are found in the bottom of the Athabasca River Valley from the East Park Gate to the northern edge of the Columbia and Chaba Icefields. The sands and gravels are well sorted and exhibit extremely high permeability. They are usually in excess of 50 m thick; the greatest thicknesses being in the Jasper Lake area. No test drilling has been done to determine actual thickness of this unit. Numerous outcrops of this unit can be seen near Jasper townsite (see Appendix 5).

Colluvium, or gravity fall material, usually occurs on valley sides as wedge-shaped talus deposits. It is very poorly sorted and usually highly permeable. Where colluvium occurs in areas of shallow slope it may be an excellent aquifer; however, it is usually located in areas of steep slope. Numerous springs can often be found discharging from the base of these slopes. An excellent example of springs discharging from the base of colluvial debris can be found near the Columbia Icefields (see Appendix 5).

Glacial till consists of coarse, unsorted moraine deposits. Most of the tills found in the study area are pre-Wisconsin in age; however, in the larger valleys Wisconsin age tills occur as lateral and end moraines. Where tills are found in topographically low areas, such as valley fill debris, they are usually excellent aquifers. Generally, till forms high moraine ridges on valley sides where storage of groundwater is minimal.

HYDROGEOLOGY

GROUNDWATER YIELDS

The maps represent an interpretation of surface hydrogeological features. Yield areas are based on field observations of springs, seeps, slope, and geology. Rates of discharge from springs and seeps were often used as a guide to potential well yields (see Appendix 3). Detailed qualitative information such as pump tests and drill hole lithologs were not available. As a result, the maps should be construed as interpretations of available data, conditions, and assumptions.

Groundwater movement and occurrence is governed by a combination of factors which are:

1. Permeability is usually the most important hydrogeological parameter. It directly affects the volume of water that can pass through a rock of soil.

2. Thickness, slope, and topographic position of a particular aquifer affect the volume of available water that can be stored within it.

3. Climate controls the amount of water that can enter or recharge the system.

Yield areas on the maps and profiles were delineated on the basis of the above factors, available field and published data, and four assumptions outlined by Todd (1959) and Tokarsky (1974) which are:

1. Geology largely determines rock permeability.

2. Topography, and to a lesser extent geology, largely determine saturation conditions.

3. Areas of similar geology and topography will have similar yields.

4. Aquifer yields are markedly lower in topographically high areas than in lower areas.

The alluvial sands and gravels of the Athabasca River Valley are the most suitable aquifer for the completion of water wells. Yields of greater than 10 l/s can be expected. This unit is recharged by surface runoff and infiltration from aquifers on the valley sides. Highest yields are found where the unit is at maximum thickness, usually in the middle of the valley. The majority of wells in use at present are completed in this aquifer. Conventional rotary drilling rigs are not feasible as circulation is easily lost within the highly permeable sands. Cable tool or air hammer drilling rigs are more suited to drilling in gravels. Proper screening, completion, and development of wells is necessary to ensure maximum yield and usefulness of the well. Groundwater requirements within the study area can best be fulfilled by wells completed in the sands and gravels of the Athabasca River Valley.

The only bedrock aquifer capable of yields exceeding 10 l/s is the Mississippian Banff Formation. Although no wells have been completed in this unit, numerous large springs have been found discharging from it (see Appendix 3). Outcrops of this formation are extremely localized, however, and found only in the area mapped as 83 EI/E (see Appendix 5).

Wells completed in till or colluvium could yield from 1 to 10 l/s where topography and slope conditions are favorable.

The majority of bedrock aquifers and those surficial aquifers of unsuitable geological characteristics have been assigned yield ranges from 0.1 to 1 l/s. However, local variations such as aquifer thickness, elevation, lithology, or structure could affect this yield range. Should wells be required in these areas, detailed local field investigations should be carried out.

Yields of less than 0.1 l/s were assigned to the Precambrian and Lower Cambrian rocks. Areas where slopes are very steep or the elevation is over 2000 m were also assigned these values.

FLOW SYSTEMS

Due to the lack of subsurface information, accurate delineation of water table and groundwater flow was impossible. A hypothetical diagram of mountain groundwater flow, based on field observations, is presented in Figure 2.

Water recharges the system at high elevations from precipitation or infiltration from glaciers. This water moves through the system primarily as localized, shallow flow characterized by springs and surface flow. This water eventually reaches the main valley either in the form of groundwater or as surface runoff. Some water may infiltrate directly downward to discharge in the valley deposits. In the case where these deposits are thin or of low permeability most of the water will discharge directly into a valley stream. It should be noted that in many cases the water table is below the river level. This occurs when the river bed is sealed and rendered impermeable by the deposition of glacier rock flour (Nielsen, 1975).

KARST HYDROLOGY

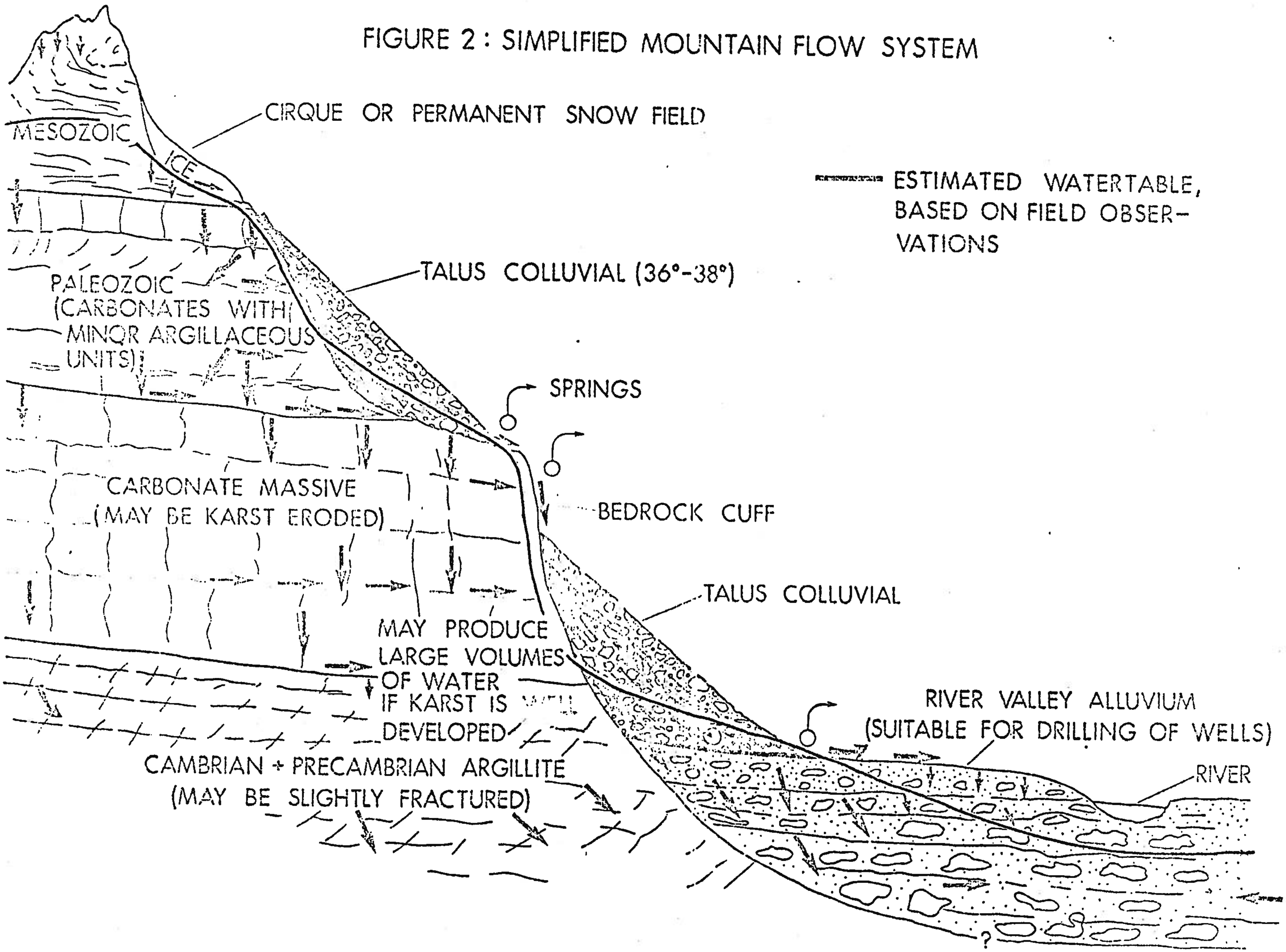
An interesting hydrogeological feature of carbonate rocks is the development of karst solution cavities and conduits. Legrand and La Moreaux (1973) outlined three requirements necessary for the development of karst. Firstly, water rich in carbon dioxide must be available to recharge the system. Secondly, sufficient permeability must be available to recharge the system. This may be in the form of joints or bedding planes. Thirdly, water must be able to discharge from the system.

Rocky Mountain carbonate rocks are generally quite impermeable and consequently karst flow is seldom developed extensively. In the few cases where karst is well developed, such as in the Maligne River Valley, it is usually very localized. Ford (1967) did extensive studies to locate and map the extent of the Maligne River Karst. Attempts were made to locate possible caves or conduits using geoelectrical subsurface techniques (Ford, 1971). Due to the extremely localized nature of karst, it has not been allocated high yield areas on the map.

SPRINGS

Natural discharge phenomena such as springs, seeps, and ponds were used to

FIGURE 2 : SIMPLIFIED MOUNTAIN FLOW SYSTEM



supplement sparse water well data and were plotted on the maps (see Legend). Springs discharging from a particular aquifer provide an indication of possible rates of production from wells tapping that aquifer (Tokarsky, 1974). Field measurements of temperature, conductivity, pH, and flow rate were taken wherever possible.

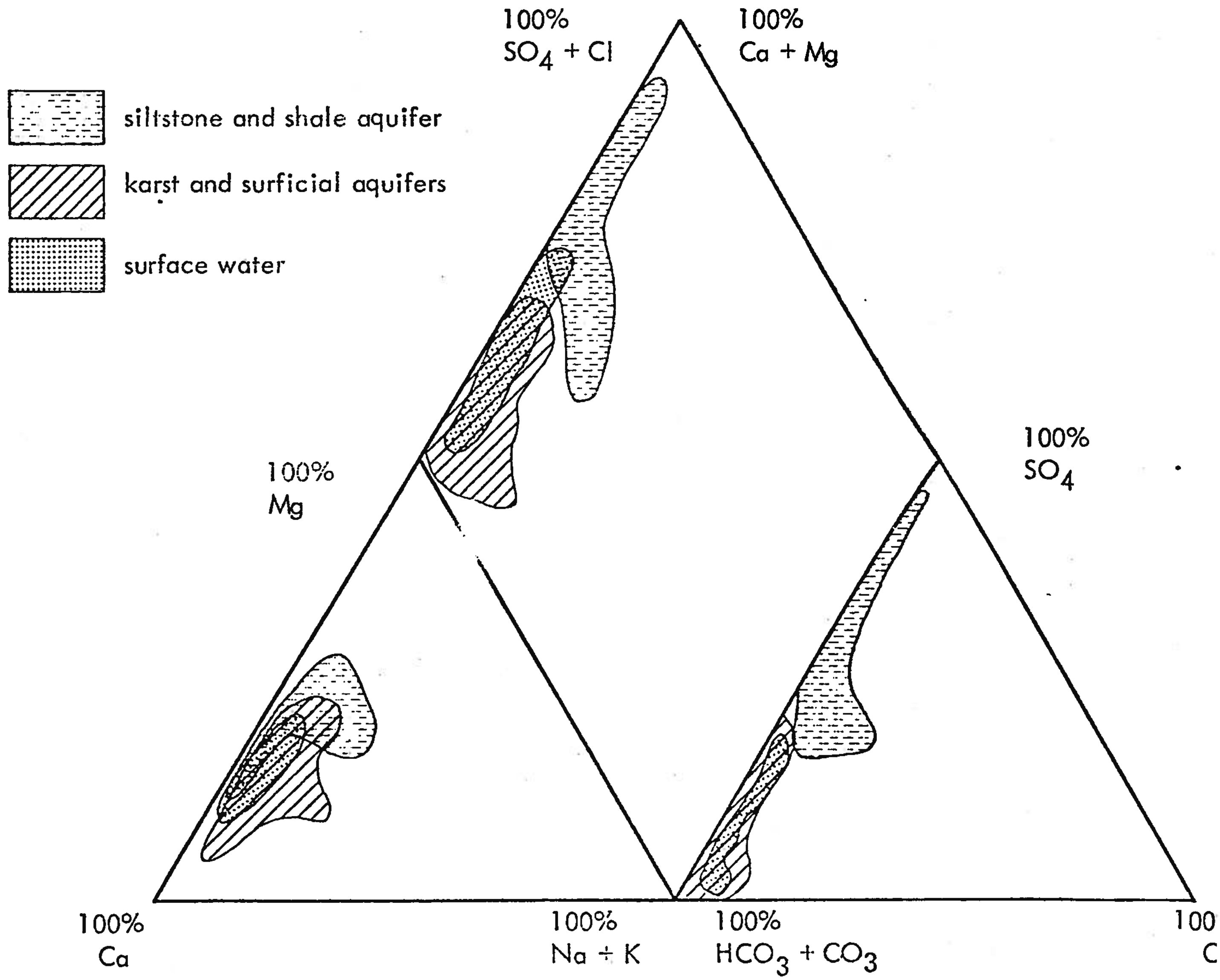
Some yield areas have been outlined on the basis of spring discharge measurements (see Appendix 3). Wells completed in the same bedrock aquifer as a spring will never yield as much water as the spring due to ineffeciences in well design, well loss, and the amount of fracturing intersected. However, wells completed in surficial deposits where permeability is not affected by fracturing may yield higher volumes than springs from that aquifer. Flow rates of most springs, particularly from surficial aquifers, are quite constant. A number of springs are sampled at biweekly intervals throughout the summer to measure possible differences in chemistry and flow rates. The data from these springs is presented in Appendix 4. It was found that, with the exception of karst springs, little or no variance in flow or chemistry was found. A number of karst springs in the Maligne Canyon which were sampled during the summer were dry in the winter. Consequently, the use of karst springs as year round water supply is normally not feasible.

HYDROCHEMISTRY

Water quality throughout the entire area, except for some minor, local occurrences of sulfate groundwater, is excellent for domestic purposes. Generally total dissolved solids are less than 350 mg/l (see side map 3). Bicarbonate is normally the dominant anion and calcium and magnesium the dominant cations. Sulfate-rich groundwater usually occurs in fractured siltstones or shales.

A Piper diagram showing equivalents per million (epm)percentages of various ions dissolved in water is presented in Figure 3. Frequently groundwater can be distinguished from surface water because it has a higher percentage of sodium, potassium, sulfate, and chloride. In this area, however, this cannot be easily done since residence time of groundwater, except for deep bedrock aquifers, is very short. Groundwater thus remains relatively

Figure 3: Piper Plot of Water Chemistry



per cent of total equivalents per million similar to surface water with respect to chemistry. Springs from the siltstone or shaley aquifer type contain higher amounts of sulfate than surficial or karst springs likely due to their longer residence time.

CONCLUSIONS AND RECOMMENDATIONS

The most important aquifers in the highway corridors of Jasper National Park are the sands and gravels of the Athabasca River Valley. Wells could produce greater than 10 l/s with proper drilling and completion techniques. Wells completed in this aquifer can be expected to satisfy most groundwater requirements.

In areas where yields are indicated to be less than 1 l/s, the capability of wells to supply water is questionable. Drilling in these areas becomes costly due to inaccessability and ruggedness of terrain as well as to relatively poor production from these aquifers. Should a well supply be required outside of the main valley, a detailed groundwater investigation should be carried out since the production from aquifers there will likely be poor.

In some areas a combination of methods such as wells, infiltration galleries, spring catchments, or surface water could be constructed to provide a permanent water supply. Should a year round source be needed in undeveloped areas, it is recommended that springs be utilized. Many springs have been documented that could, with a minimum of cost and construction, be used to provide a permanent water supply.

It is suggested that in the future the drilling and pump testing of wells be carefully supervised. Well locations should be planned carefully in conjunction with the maps. Pump tests should be carried out in the presence of personnel aquainted with pump testing procedures. For example, all the wells drilled in 1976 for Parks Canada in Jasper National Park were pump tested, but not one test was carried out such that the results were of any use.

MAP LEGEND

I Geology

1. An observed and hydrogeologically important bedrock outcrop. (Numerical subscript cross-referenced in Appendix 5). X_1

2. An observed and hydrogeologically important outcrop of surficial deposits (Numerical subscript cross-referenced in Appendix 5). Xs_1

3. Bedrock Geology

   Areas where bedrock forms the major aquifer are delineated as follows:

A Geologic System Units

		Prefix Abbreviation
	Precambrian	PЄ
Paleozoic	Cambrian	Є
	Ordovician	O
	Devonian	D
	Mississippian	M
Mesozoic	Triassic	Ћ
	Jurassic	J
	Cretaceous	K

B Aquifer

	Suffix Abbreviat
limestone	lst
conglomerate	cong
dolomite	dol
dolomitic limestone	dls
quartzite	qtz
sandstone	ss
shale	sh
siltstone	sts
slate	sl

NB: The lithological symbol is prefixed by the abbreviations from the appropriate geological system unit. Where fracture permeability is present, a suffix F, is added. F

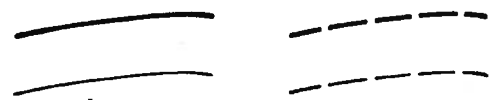
4. Surficial Geology

Areas where surficial deposits form the major aquifer are delineated as follows:

A	Geologic System Unit		Prefix Abbreviation
		Quaternary	Q
B	Aquifer		Suffix Abbreviat
		till	t
		colluvium	col
		alluvium	all

Contacts between geological system units

Contacts within geological system units



known assumed

NB: Some surficial deposits are subdivided according to their thickness, and topographic position, though the lithology is the same.

5. Structural Geology

Hydrogeologically important thrust faults.

a) main maps (teeth on upper plate)

known assumed

b) profiles (arrows show direction of displacement)

II HYDROGRAPHY

1. Natural pond or water hole with no surface outlet (P, if permanent, T if temporary)

2. Surface water sample

3. Lake or slough, perennial

4. Slough, marsh, muskeg

5. Glacier — G

III HYDROMETRY

1. Stream gauging station
   a) Location — Δ
   b) Information
      1) Mean annual discharge in cubic feet per second — 360
      2) Year observations commenced — 1914
      3) Number of years for discharge mean — 11
      4) Drainage area in square miles — 665

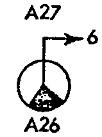
2. Lake level recording station — Δ

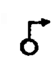
IV HYDROGEOLOGY

1. Springs (for spring details see Appendix 3) — Maps / Profiles

   a) Spring, flow rate unknown (number below indicates sample number, see Appendix 2)

   b) Spring, flow rate known (number indicates discharge in litres per second)



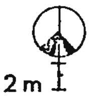
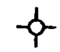


   c) Spring, with discharge and hydrochemistry over a period of time (see Appendix 4)

   d) Groundwater generated depression or discharge feature

   e) Groundwater generated slump

   f) Seepage line or spring line

		Maps	Profiles
2.	Water wells (for details see Appendix 1)		
a)	Water well, depth known	 1 mm = 2 m	
b)	Water well, not in use		
c)	Water well, shallow (number below indicates well number, for details see Appendix 2).	 D 11	
3.	Artificial Works		
a)	Storage reservoir		
b)	Gravel pit		
c)	Sewage lagoon		
d)	Infiltration gallery		
e)	Dam		
4.	Flow Directions		
a)	Line of hydrogeological profile	A  A′	
b)	Groundwater flow direction		
c)	Flow into profile	⊗	

V GROUNDWATER PROBABILITY

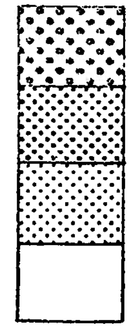
1. Probable Yields of Wells
(yield in litres/second)

>10

1-10

0.1-1

<0.1



Yield Boundary — known — assumed

2. Groundwater Prospects with the Above Yield Categories:

Prospects delineated within geological system unit

Prospects delineated between geological system unit

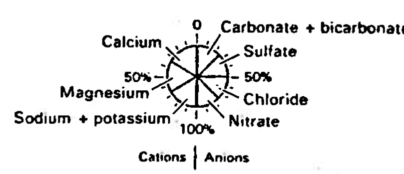
known — assumed

The geological description of an aquifer is suffixed by a number (1 - 6) with the lower number indicating the more prospective zone within a yield area.

VI HYDROCHEMISTRY

1. Representation of chemical data within a well or spring symbol. Hydrochemical data are indicated on the symbol as epm percentages of total anions or cations. For detailed chemical analyses see Appendix 2.

NB: For convenience percentages are expressed to the nearest 10 percent.



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Appendix 1: Terms of Reference

HYDROGEOLOGY OF THE HIGHWAY CORRIDORS OF

JASPER NATIONAL PARK, ALBERTA

Terms of Reference

1. The highway corridors are defined on the accompanying map and correspond exactly with Jasper National Park planning unit zones III, IV and V, which are described as areas of high intensity use.

   The corridors may be referred to as:
   a) Fiddle River Valley (Miette Hot springs)
   b) Yellowhead corridor
   c) Maligne Valley
   d) Icefields parkway corridor
   e) Highway #93A corridor.

2. A total of seven hydrogeological profiles will be constructed, the exact positions of which are not exactly defined, but will be in the general area of the following localities:
   a) Pocahontas
   b) Pyramid Mtn. to Signal Mtn., passing through Jasper Townsite
   c) The Whistlers to Mt. Collin, passing through Jasper Townsite
   d) North end of Maligne Lake
   e) Athabasca Falls
   f) The confluence of Pobokton Creek and Sunwapta River
   g) Columbia Icefields.

3. The hydrogeological maps will be presented at a scale of 1:50,000 as mylar overlays. Hydrogeological information will include well yield areas, aquifer lithology, recharge and

discharge areas, the position of hydrogeologically important fault systems and specific features such as wells, springs and sample locations.

4. The hydrogeological profiles will be presented as Diazo prints with a horizontal scale of 1:50,000 and a vertical scale of 1:12,000. Data presented on the profiles will include geology, vertical changes in well yields, hydrochemistry and groundwater flow patterns.

5. The hydrogeological map and profiles format will follow as closely as possible Alberta Research Council's legend and guide for the preparation and use of the Alberta hydrogeological reconnaissance map series (Badry, 1972). New symbols and modifications to this format may be introduced as the above legend was specifically prepared for 1:250,000 scale maps. At the scale of 1:50,000 significantly more hydrogeological data may be represented and a more diverse classification of specific features such as springs may therefore be possible. Owing to the anticipated scarcity of drill hole data it may not be possible to accurately define the configuration of the water table or aquifer thickness. However, until some field work has been carried out, such statements are slightly ambiguous.

6. In addition to the hydrogeological maps and profiles a report will be compiled describing and expounding the hydrogeology of the area, and including a map legend and table of hydrochemical analyses carried out by Alberta Research Council during 1976. A bibliography would probably also be of use.

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APPENDIX 2: SAMPLE LOCATIONS AND CHEMISTRY

* SAMPLE No.		EASTING	NORTHING	ELEV.	STATIC LEVEL	WELL DEPTH	FIELD TEMP	DATE	Ca	Mg	Na	K	HCO3	SO4	Cl	NO3	SiO2	pH	TDS
A	1	429300	5863500	1003			9.0	030676	26.0	10.1	1.3	1.3	90	39.0	4	0.3	4.5	7.6	172
A	2	429900	5862000	1028			6.0	40676	34.0	13.8	2.5	0.8	149	20.3	6	2.5	3.9	7.8	229
A	3	428700	5860300	1000			5.0	40676	31.0	10.9	2.5	0.8	124	17.3	2	1.4	3.0	7.7	191
A	4	431725	5864050	1063			7.0	40676	24.0	7.5	0.1	0.8	88	20.6	2	0.7	1.6	7.7	144
A	5	431675	5864875	1033			7.0	40676	25.0	7.8	0.1	0.8	93	16.6	2	0.6	1.6	7.7	146
A	6	430500	5859800	1075			7.0	50676	31.0	11.0	7.5	0.4	144	18.0	4	0.6	7.5	7.3	217
A	7	430000	5856400	1094			8.0	80676	91.0	40.0	30.0	1.7	437	88.0	4	1.2	15.9	7.6	693
A	8	425160	5856250	1268			2.0	80676	43.0	15.1	3.8	0.4	203	19.7	4	3.0	8.1	7.7	293
A	9	425600	5856400	1161			3.0	90676	27.0	8.1	15.0	3.3	129	6.7	6	3.6	5.4	7.9	201
A	10	448600	5885600	1458			3.0	90676	41.0	12.9	3.8	0.6	178	6.1	4	2.7	4.9	7.7	241
A	11	426975	5873000	1018			5.0	170676	36.0	9.6	2.5	0.4	115	21.7	4	0.9	0.6	7.6	190
A	12	424625	5875875	1048			6.0	170676	36.0	9.8	2.5	0.4	137	9.0	4	0.4	0.8	7.7	199
A	13	425500	5879525	1063			5.0	170676	26.0	4.8	2.5	0.4	93	3.0	4	0.2	0.1	7.4	134
A	14	428900	5882100	1033			4.0	170676	41.0	12.8	1.2	0.4	129	31.6	4	0.4	0.1	7.6	221
A	15	428625	5881675	1024			9.0	170676	98.0	35.0	5.0	1.3	200	194.0	2	0.9	4.6	7.6	536
A	16	426425	5880800	1033			6.0	170676	41.0	9.9	3.8	0.8	134	25.3	2	0.3	2.2	7.5	217
A	17	429600	5874050	1063			4.0	180676	30.0	10.3	1.5	0.4	122	15.7	2	0.2	2.1	7.5	162
A	18	427625	5676025	1048				180676	64.0	17.4	7.5	0.8	166	81.0	4	0.8	3.6	7.7	341
A	19	441625	5835275	1215			5.0	170976	12.6	6.4	2.5	1.3	44	22.3	2	0.4	4.6	7.5	92
A	20	450700	5825600	1276			7.0	190676	52.0	14.3	2.5	0.6	207	8.7	2	0.4	8.4	8.0	[illegible]
A	21	451800	5824600	1291			5.0	200676	37.0	12.3	2.5	0.4	163	5.7	2	1.1	0.5	7.8	224
A	22	461400	5818200	1367			6.0	200676	12.3	3.4	2.5	0.8	54	1.7	4	0.2	[illegible]	7.3	79
A	23	470100	5811500	1519			4.0	200676	5.1	2.3	1.2	0.8	27	3.0	4	0.9	3.5	7.7	44
A	24	477275	5798500	1550			10.0	200676	30.0	14.4	2.5	2.0	124	25.0	2	2.2	1.7	7.7	202
A	25	428075	5877875	1003			9.0	230676	121.0	91.0	5.0	2.1	261	443.0	4	0.6	6.7	7.8	926
A	26	428600	5878900	1003			9.0	230676	84.0	22.0	3.8	0.4	183	134.0	2	0.6	0.5	7.8	430
A	27	428600	5978900	1003			7.0	230676	96.0	33.0	6.2	1.3	190	222.0	4	0.7	4.3	7.7	553
A	28	430325	5680575	1003			5.0	230676	33.0	8.1	2.5	0.1	127	10.0	2	1.2	2.0	7.7	184
A	29	435550	5889850	995			5.0	240676	60.0	18.0	2.5	1.7	163	76.0	4	0.2	3.9	8.0	325
A	30	437250	5894030	987			4.0	250676	61.0	36.0	6.2	2.5	305	45.1	4	0.2	6.3	7.9	460
A	31	438075	5895250	987			4.0	250676	56.0	18.0	5.0	2.1	232	24.0	2	0.6	4.5	7.8	340
A	32	439325	5894725	1063			4.0	250676	44.0	16.9	8.7	1.7	203	21.7	4	0.3	3.8	8.0	300
A	33	444875	5697275	1033			6.0	260676	52.0	14.4	2.5	1.7	146	75.0	4	0.3	3.2	8.0	296
A	34	434275	5832600	1246			3.0	270676	6.7	2.8	2.5	1.3	29	3.0	2	0.7	2.1	6.7	48
A	35	434800	5886200	1018			6.0	280676	95.0	34.0	5.0	1.7	249	167.0	2	0.3	6.6	7.9	554
A	36	432025	5881700	1003			4.0	280676	67.0	19.8	2.5	1.3	212	73.0	4	0.2	4.7	8.1	360
A	37	431200	5861100	1003			6.0	290676	46.0	13.9	3.8	2.5	159	37.5	4	0.3	3.9	7.9	267
A	38	444225	5896450	1003			6.0	290676	44.0	11.9	2.5	1.3	159	21.7	4	0.2	3.3	8.1	245
A	39	428475	5678650	1003			6.0	290676	92.0	30.0	3.8	1.3	124	380.0	4	0.3	5.9	8.0	640
A	40	436650	5861960	1276			10.0	050776	76.0	12.7	1.3	0.4	281	1.5	4	0.3	14.6	8.1	377
A	41	441500	5860675	1367			5.0	50776	29.0	8.8	2.5	0.8	117	9.7	4	0.2	3.3	7.9	172
A	42	451325	5855900	1306			4.0	60776	62.0	17.7	6.3	2.5	178	80.0	4	0.2	4.2	7.9	351
A	43	451925	5852975	1519			7.0	60776	53.0	12.4	2.5	1.3	205	7.7	4	0.3	7.5	8.0	291
A	44	454250	5846700	1550			4.0	60776	26.0	7.1	3.8	1.7	49	44.2	4	0.3	4.0	8.0	136
A	45	440425	5898150	1003			10.0	80776	45.0	16.3	6.3	2.1	129	[illegible]	4	0.9	2.6	7.6	267
A	46	436675	5897625	1033			9.0	90776	62.0	25.0	3.8	1.7	300	12.0	4	0.3	7.1	8.0	409
A	47	481025	5790375	1914			3.0	120776	48.0	13.8	1.2	1.2	181	10.0	4	0.3	8.3	7.6	260
A	48	475550	5802200	1671			5.0	120776	29.0	14.8	1.2	0.4	137	9.8	4	0.1	4.7	7.9	196
A	50	425425	5884350	1367			5.0	140776	53.0	17.0	1.2	0.1	205	22.2	4	0.2	4.7	7.6	303
A	51	444050	5857500	1823			3.0	160776	35.0	14.0	3.8	0.8	159	8.0	4	0.3	6.7	8.0	225

SAMPLE No.		EASTING	NORTHING	ELEV.	STATIC LEVEL	WELL DEPTH	FIELD TEMP	DATE	Ca	Mg	Na	K	HCO3	SO4	Cl	NO3	SiO2	pH	TDS
A	52	456200	5841800	1762			7.0	170776	9.6	4.0	2.5	0.8	44	3.0	2	0.7	5.3	7.7	67
A	53	430200	5883150	1003			7.0	190776	77.0	34.0	6.2	2.1	195	143.0	4	0.1	8.5	6.2	462
A	54	441400	5839550	1155			9.0	260776	41.0	21.9	10.0	1.7	205	10.8	10	1.9	13.1	7.7	305
A	55	431750	5850500	1109			10.0	260776	12.1	4.1	2.5	0.8	51	9.2	2	0.4	4.5	8.2	82
A	56	441300	5836675	1215			6.0	260776	14.6	5.0	2.5	1.3	68	5.6	2	0.6	3.7	7.9	100
A	57	434300	5846375	1101			8.0	270776	26.4	10.0	6.3	0.6	122	17.4	2	0.6	9.1	7.8	136
A	59	441500	5933050	1215			10.0	270776	51.0	9.4	1.3	0.6	181	10.7	2	0.4	4.9	7.9	257
A	59	458775	5819825	1458			5.0	300776	16.8	3.2	2.5	0.8	76	1.6	2	0.2	3.3	8.2	103
A	60	466025	5813950	1489			9.0	310776	6.2	1.1	1.3	0.4	24	1.3	2	0.3	2.2	8.0	37
A	61	477300	5799000	1610			2.0	310776	27.1	11.8	1.3	0.4	137	9.3	2	0.3	4.0	8.2	159
A	62	482950	5787250	1884			8.0	310776	32.0	12.1	1.3	0.4	122	25.2	2	1.0	3.6	7.9	196
A	63	467125	5785125	2006			3.0	310776	38.0	7.3	1.3	0.4	142	6.4	2	0.2	5.1	6.0	200
A	64	473375	5811900	1732			3.0	10876	50.0	21.3	2.5	0.8	185	72.0	2	0.3	5.5	8.0	334
A	65	429500	5844900	1458				50876	56.0	20.8	2.5	1.3	254	21.7	2	0.4	10.0	8.3	360
A	66	426900	5840850	1580				50876	30.0	10.9	2.5	0.8	112	25.5	2	1.1	5.8	8.0	135
A	67	458675	5845900	2310				70876	5.7	2.9	1.3	0.8	31	2.8	2	0.6	1.2	7.5	46
A	68	441700	5392575	1276			7.0	220876	73.0	14.4	3.8	1.3	281	7.9	2	0.4	5.5	8.1	354
A	69	445300	5857850	1398			4.0	230876	29.0	13.6	2.5	0.8	156	4.8	2	0.4	4.6	8.2	213
A	70	485150	5787500	2310			8.0	240876	32.0	5.1	2.5	0.8	115	3.0	2	0.2	3.3	7.8	161
A	71	462325	5790600	2066			8.0	240876	46.0	9.7	3.8	1.3	134	19.0	2	0.2	4.2	7.6	216
A	72	455800	5815300	1367			8.0	280876	38.0	6.0	2.5	1.3	137	4.1	2	0.6	10.0	6.1	192
A	73	447800	5861550	1519			3.0	310876	38.0	9.8	1.3	0.4	122	25.2	2	0.6	3.1	7.7	199
A	74	420375	5860600	1443			10.0	20976	37.0	9.7	5.0	0.8	149	8.2	2	0.1	7.1	7.3	212
A	75	433625	5859375	1884			5.0	30976	9.8	3.1	2.5	0.1	39	6.2	2	0.9	4.8	6.7	64
A	76	428600	5078900	1003			5.0	50976	57.0	29.0	33.0	2.9	227	102.0	16	1.4	5.6	7.8	408
A	77	407575	5859775	1124			6.0	60976	39.0	17.7	6.3	1.3	173	30.8	2	0.4	7.9	7.3	195
B	1	431500	5864300	1063			7.0	40676	23.0	7.2	1.3	1.3	85	19.7	2	0.3	1.1	7.7	140
B	2	423300	5956725	1063			4.0	90676	6.5	2.0	0.1	0.4	27	6.0	2	1.8	2.4	7.8	45
B	3	425375	5860900	1124			11.0	130676	33.0	12.8	7.5	0.8	151	16.7	2	0.6	5.5	8.0	224
B	4	427350	5872200	1033			6.0	160676	46.0	14.9	1.2	0.4	144	44.7	2	0.6	3.3	7.6	234
B	5	425100	5877925	1048			7.0	170676	32.0	8.9	1.2	0.4	120	6.3	4	0.1	2.3	7.6	173
B	6	430000	5871025	1033			10.0	180676	27.0	7.4	2.5	0.4	105	10.5	2	0.4	1.1	7.6	156
B	7	443225	5896050	987			6.0	260676	42.0	11.3	2.5	0.8	146	27.0	4	0.4	3.2	7.9	234
B	8	449150	5886575	1428			3.0	260676	58.0	15.3	2.5	0.8	222	15.2	4	0.3	5.0	8.0	316
B	9	436600	5838175	1215				200876	13.5	6.2	2.5	0.8	51	17.2	4	0.3	3.6	7.8	96
B	10	431375	5888475	1079			12.0	300676	225.0	56.0	5.0	3.3	227	956.0	4	0.7	7.2	6.0	1477
B	11	437150	5861025	1276			8.0	50776	34.0	8.4	3.8	0.8	132	8.2	4	0.1	2.6	7.3	192
B	12	440025	5898300	1003			10.0	80776	48.0	14.7	2.5	0.4	161	35.0	4	0.1	2.4	8.0	265
B	13	436000	5897000	1033			5.0	100776	51.0	16.7	2.5	2.5	207	10.0	4	0.3	4.9	7.3	294
B	14	433150	5893750	1003			9.0	100776	86.0	25.0	6.2	0.4	173	147.0	4	0.3	3.5	7.7	442
B	15	443350	5858575	1762			8.0	160776	20.0	10.0	1.2	1.2	98	6.3	4	0.4	3.2	8.0	141
B	16	454525	5841025	1854			11.0	170776	42.0	7.2	1.2	0.4	159	2.3	4	0.2	6.7	8.1	217
B	17	429675	5883175	1124			7.0	200776	62.0	26.0	2.5	0.4	183	82.0	8	0.7	7.1	7.8	304
B	18	441175	5837375	1231			6.0	260776	10.3	4.0	1.3	1.3	48	4.4	2	0.3	2.4	7.9	73
B	19	402900	5860075	1337			8.0	280376	53.0	10.8	2.5	0.8	198	4.8	2	0.3	8.7	7.6	272
C	2	429500	5861650	1021			11.0	40676	33.0	13.1	2.5	0.4	146	26.0	4	0.9	3.2	8.1	226
C	3	433200	5846400	1215			15.0	70676	37.0	15.0	10.0	1.3	168	38.0	2	0.2	4.6	8.1	272
C	5	432800	5836000	1003			15.0	280676	15.5	4.8	3.8	0.4	56	7.7	4	0.3	2.8	7.5	93
C	6	427600	5877850	1003			14.0	290676	70.0	30.0	6.2	1.7	149	157.0	4	0.3	2.9	7.6	416
C	7	428875	5893350	1246			15.0	20776	39.0	20.8	2.5	0.4	149	52.0	4	0.6	4.2	7.6	268
C	8	430075	5893325	1246			15.0	20776	39.0	20.8	2.5	0.4	149	72.0	4	0.6	4.2	7.6	246
C	9	457350	5842850	1580			9.0	70776	73.0	34.0	3.8	0.4	154	199.0	4	0.2	2.6	7.3	469
C	10	439425	5698150	1003			13.0	80776	40.0	12.9	2.5	0.4	151	27.8	4	0.3	0.9	8.0	239
C	11	430925	5383650	1003				190776	103.0	85.0	15.0	6.2	515	90.0	10	0.7	6.2	7.8	825

SAMPLE No.	EASTING	NORTHING	ELEV.	STATIC LEVEL	WELL DEPTH	FIELD TEMP	DATE	Ca	Mg	Na	K	HCO3	SO4	Cl	NO3	SiO2	pH	TDS
C 12	431700	5884775	1003				190776	87.0	70.0	12.5	2.9	159	393.0	8	0.8	7.4	8.1	733
C 13	432000	5885700	1003				190776	45.0	46.0	35.0	2.5	183	125.0	52	0.3	3.2	8.2	489
C 14	432400	5886450	1003				190776	59.0	18.6	11.2	0.8	171	72.0	14	1.0	3.5	7.8	348
C 15	440725	5836750	1246			14.0	260776	37.0	27.3	2.5	1.7	231	1.7	2	3.9	14.2	8.0	307
C 16	456625	5820925	1398			12.0	300776	33.0	9.4	2.5	1.7	134	4.4	2	0.6	7.6	7.8	188
C 17	453550	5823000	1474			15.0	300776	24.7	6.2	2.5	1.3	105	1.3	2	1.3	0.6	7.8	144
C 18	472500	5809075	1595			7.0	310776	7.3	1.5	1.3	0.4	24	2.4	2	0.4	5.2	7.2	40
C 19	449200	5859800	1519			14.0	310876	47.0	8.2	1.3	0.4	159	14.2	2	0.7	3.6	7.7	233
C 20	451300	5857350	1489			14.0	310876	37.0	12.7	1.3	0.4	115	40.4	2	0.2	4.2	7.6	209
C 21	420475	5860900	1443			14.0	20976	34.0	9.3	5.0	0.8	139	7.9	2	2.2	6.1	7.6	200
C 22	421750	5857950	1170			14.0	20976	37.0	4.5	2.5	0.4	46	7.9	2	0.3	4.0	7.1	101
C 23	439000	5838400	1215				150976	33.0	8.6	0.1	0.4	146	2.0	2	0.3	12.3	7.5	193
D 1	429875	5861900	1030	0.3	0.6	7.0	40676	81.0	23.0	1.3	2.1	339	29.4	4	0.3	7.5	7.1	460
D 2	429875	5861875	1030	0.3	0.6	6.0	40676	44.0	18.9	5.0	0.8	27	4.0	0	0.7	5.2	7.5	102
D 3	434250	5845050	1079	2.1	9.4	11.0	80676	47.0	20.7	8.8	0.4	239	38.0	4	0.3	6.2	8.2	358
D 4	426400	5862925	1176	1.8	4.3	11.0	80676	41.0	20.0	7.5	2.9	205	35.1	8	0.3	8.3	7.7	329
D 5	429500	5867850	1018		36.5		160676	49.0	26.0	6.2	0.8	215	37.7	10	0.6	6.3	7.5	346
D 6	429650	5867350	1019	15.2	23.7		160676	69.0	23.0	3.8	0.1	256	33.6	4	7.3	7.4	7.3	397
D 7	426400	5873850	1015	6.7	15.8	4.0	160676	34.0	8.5	2.5	0.1	122	19.0	0	0.6	2.2	7.7	187
D 8	426850	5873725	1015	17.6	31.0	4.0	160676	39.0	9.1	2.5	0.1	129	25.6	4	0.6	2.4	7.8	210
D 9	427150	5874325	1015			5.0	200776	34.0	11.1	2.5	0.4	115	26.7	6	0.9	3.0	8.1	197
D 10	427200	5873950	1015			4.0	200776	36.0	11.7	3.8	0.8	115	30.2	6	0.4	2.3	7.9	204
D 11	441450	5931650	1200			4.0	270776	31.0	10.0	1.3	8.0	134	7.9	2	0.4	4.5	8.1	195
D 12	428350	5854825	1042	6.1	23.1	5.0	220876	28.0	9.0	3.8	8.0	110	17.8	2	0.1	4.1	7.6	179
D 13	427000	5873300	1015	7.9	21.9		270876	39.0	11.0	3.8	13.0	117	31.5	2	0.8	2.4	8.1	216
D 14	430000	5862000	1021	3.6	9.1		270876	45.0	18.3	3.8	13.0	190	25.4	2	0.4	5.3	7.3	243
D 15	429800	5861650	1030	6.7	12.2		270876	40.0	16.3	3.8	8.0	166	22.9	2	0.3	6.4	7.8	259
E 1	484450	5784350	1975				50976	21.0	5.8	1.3	1.0	83	5.7	2	0.2	1.5	7.4	121
E 2	464200	5784400	1975			3.0	50976	14.2	3.7	1.3	0.4	54	7.9	2	0.7	0.9	7.4	85
H 1	430400	5855825	1124				150976	27.0	108.0	3.0	12.9	629	160.0	6	0.9	1.2	7.6	947
H 2	431675	5854175	1033			5.0	150976	46.0	16.3	3.8	0.4	193	34.6	4	0.2	7.4	7.7	298
H 3	432025	5846175	1185			6.0	150976	42.0	29.6	11.3	1.3	268	19.8	4	0.6	17.0	6.9	377
H 4	441100	5829900	1063			6.0	150976	13.9	3.7	1.5	3.0	54	7.5	4	0.7	2.8	6.7	89
H 5	439750	5833000	1063			9.0	150976	18.8	12.6	1.3	0.8	124	1.2	4	0.4	8.6	7.3	163
H 6	447550	5824500	1306			6.0	150976	16.9	4.8	3.8	0.4	73	11.4	4	0.3	8.8	7.4	115
H 7	455350	5823350	1337			5.0	150976	38.0	8.8	2.5	0.4	151	6.0	4	0.1	6.6	7.1	211
H 8	456250	5819250	1337			8.0	150976	35.0	16.3	0.1	0.1	171	16.0	4	0.2	6.9	7.8	243
H 9	470350	5812075	1641				150976	6.2	1.3	2.5	2.0	26	2.3	4	0.4	4.2	6.4	46
H 10	431925	5861675	1155			7.0	160976	23.6	9.2	1.0	1.0	110	14.7	4	0.3	6.9	7.4	165
H 11	455000	5854750	1914			7.0	160976	30.0	4.2	0.1	0.1	107	3.8	4	0.4	2.2	7.1	150
H 12	458575	5851900	2066			2.0	160976	22.0	5.7	0.1	0.1	93	3.4	4	0.7	1.8	6.8	129
H 13	459325	5846050	1732			3.0	160976	36.0	4.4	0.1	0.1	124	4.5	4	0.9	2.6	7.6	174
H 14	458550	5836800	1641			3.0	160976	13.7	4.3	1.0	1.0	59	10.5	4	0.2	4.0	7.5	94
H 15	454600	5842800	1732			4.0	160976	11.7	5.5	0.1	0.1	54	5.2	4	0.3	5.6	7.0	81
H 16	425325	5872300	1124			9.0	170976	54.0	13.8	1.3	0.4	220	14.2	4	1.7	5.5	7.9	310
H 17	430825	5887400	1094			9.0	170976	368.0	86.0	6.3	1.7	117	1098.0	2	0.2	13.3	7.5	1680
H 18	432375	5891950	1003			6.0	170976	84.0	32.0	6.3	1.3	200	171.0	4	0.3	6.5	7.3	499
H 19	441250	5898000	1003				170976	37.0	25.1	5.0	0.4	156	60.0	2	0.3	3.4	7.4	266
H 20	436125	5889000	1003			5.0	170976	54.0	17.1	3.8	1.3	168	57.0	2	1.0	4.9	7.8	304
H 21	430250	5869400	1003			10.0	170976	43.0	10.1	3.1	1.3	154	18.8	2	0.4	5.4	7.5	233
H 22	421625	5856850	1063			8.0	170976	49.0	10.2	10.0	0.8	176	12.6	8	0.2	10.2	7.0	267
H 23	418850	5857525	1048			9.0	170976	53.0	16.8	8.8	0.8	222	15.3	10	0.2	8.6	7.6	332
H 24	414300	5857600	1246			11.0	170976	23.0	15.3	6.5	0.8	137	14.1	2	0.9	3.2	7.9	200

* The letter preceeding sample number indicates the type of water sample:

A,H,	springs	D	wells
B	streams	E1	ice
C	lakes	F2	snow

Appendix 3: Characteristics of Springs

Sample Number	Spring[1] Characteristics	Permeability[2] Type	Aquifer[3] Structure	Aquifer[4] Lithology	Flow Rate l/s	Flow Rate[5] Variability	Remarks
A 1	I	F	3	dls	150.0	a	near thrust fault
A 2	I	I	3	s & g	8.0	a	
A 3	VI	I	3		0.09	b	seepage
A 4	I	C	3	lst	1.5	c	
A 5	II	C	3	lst	75.0	b	spring catchment
A 6	I	I	4	s & g	2.8	b	
A 7	III	I	2	g	0.2	b	
A 8	I	I	4	col	0.2	c	base of rock-fall
A 9	I	I	4	col	0.2	c	
A10	I	F	2	dol	15.0	a	
A11	II	I	3	s & g	7.5	a	gravel pit
A12	I	C	3	lst	4.5	b	
A13	II	F	3	dls	75.0	a	near thrust fault
A14	I	C	3	lst	14.0	c	
A15	II	F	2	sts	0.2	a	sulfur spring
A16	I	I	4	s & g	150.0	a	
A17	I	C	3	dls	26.0	b	
A18	II,V	F,C	3	dls	15.0	b	
A19	I	I	1	g	7.5	a	
A20	I	I	1	g	23.0	b	
A21	I	I	1	g	1.9	a	
A22	II	I	2	s & g	1.5	a	Bubbling Springs
A23	I	I	2	g	30.0	a	
A24	II	I	2	g	-	-	pond
A25	VI	F	2	sts	0.1	b	thrust fault seep
A26	II	F	2	sts	6.1	a	contact between lst and sts
A27	II	F	2	lst, dol	1.5	c	sulfur discharge nearby
A28	I	F	2	sts, lst	30.0	a	flows from Banff Fm.
A29	I	I	3	s & slt	-	a	flows from base of river bank
A30	V	F	2	s & slt	3.0	a	tufa deposit
A31	II	I	2	s & g	23.0	a	Pocohontas Warden water supply
A32	II	I	2	s & g	30.0	a	
A33	I	I	4	col	7.6	b	
A34	I	F	2	sts	60.0	a	
A35	III	I	1	s,sh,g	23.0	b	
A36	I	F,C	2	dls	2.7	c	
A37	I	I	4	g	0.3	a	
A38	II	F	3	dls	0.1	b	small discharge pond
A39	I	F	2	sts,lst	53.0	a	Banff Fm.
A40	IV	I	2	s,sh	0.1	b	

Sample Number	Spring[1] Character-istics	Permea-[2] bility	Aquifer[3] Structure	Aquifer[4] Lithology	Flow Rate l/s	Flow Rate[5] Varia-bility	Remarks
A41	I	I	2	s,g	775.0	b	discharge into Maligne River
A42	I	I	2	lst,sts	775.0	a	
A43	IV	I	3	t,slt	0.2	a	slump area
A44	I	I	2	col	775.0	a	
A45	I	F	2	lst	-	a	
A46	I	I	1	sts	0.84	a	Miette Cabin Spring
A47	I	I	3	g	3.0	c	
A48	I	I	1	s & g	1.5	b	discharge pipe beside highway
A49	I	I	4	col	3.8	a	
A50	I	I	4	col	3.8	a	
A51	I	I	3	col	2.5	a	
A52	I	I	3	s,g	45.0	b	Maligne Lk. water supply
A53	I	C	3	lst	3.0	c	disaster point
A54	I	I	1	col	0.2	a	
A55	II	I	3	g	11.0	a	
A56	I	I	1	g	15.0	a	gravel pit discharge
A57	II	F	3	ss	4.0	a	
A58	V	I	3	s,g	1.9	b	gravel pit discharge
A59	I	I	1	col	11.0	a	
A60	I	I	1	col	7.6	a	
A61	I	I	2,31	lst,dol	0.2	b	Beauty Creek Hostel water supply
A62	I	I	1	col	7.6	a	
A63	I	I	1	col	0.2	b	
A64	I	I	1	col	0.8	a	
A65	I	I	3	col,t	0.1	b	
A66	I	I	1	col	0.2	b	
A67	I	I	1	col	11.0	b	
A68	I	I	1	t,sh	0.2	a	
A69	I	I	1	col	3.8	a	
A70	I	I	4	col	-	b	
A71	I	F,C	1	dls	2.3	a	
A72	II	I	3	col	-	a	
A73	I	I	4	col	-	a	
A74	I	I	1	col,bldrs	0.6	a	
A75	I	I	1	col	3.0	a	
A76	III	F	2	dol,sts	0.1	a	
A77	I	I	3	t	2.3	b	

Explanation of Codes

1.	Characteristic feature of springs	I	drained
		II	ponded
		III	soap hole, quicksand, marshy discharge
		IV	mud flow
		V	mineral deposit
		VI	seepage
2.	Nature of rock openings	I	intergranular
		F	fracture
		C	cavity
3.	Structure of aquifer	1	veneer
		2	interlensed or interbedded
		3	thick formation
		4	clastic wedge (as in colluvial screen and perhaps some alluvial fans)

4. Lithology of aquifer, according to the following code:

Material	Coded Symbol
boulders	bldrs
colluvium	col
dolomite	dol
dolomitic limestone	dls
gravel	g
limestone	lst
quartzite	qtz
sand	s
sand and gravel	s & g
sandstone	ss
shale	sh
silt	slt
siltstone	sts
till	t

5. Variability

a) constant
b) sub-variable
c) variable

Appendix 4: Cyclic Discharge Measurement and Hydrochemical Analyses

Sample			Location		Elevation	epm % Cation				epm % Anions					
#	Mo.	Day	Easting	Northing	Meters	% Ca	% Mg	% Na	% K	% HCO_3	% SO_4	% Cl	% NO_3	TDS	Dis-charge
1A	07	12				42.8	47.5	8.1	1.6	52.5	30.3	16.4	0.7	44	12
1B	08	03				37.6	45.1	13.2	4	50.5	42.0	7.1	0.4	40	8
1C	08	17	441625	5838275	1220	40.2	43.2	12.7	3.9	48.3	44.3	6.8	0.6	40	10
1D	08	28	(Map Sheet	83C/12)		37	41	18.3	3.7	53.9	39.5	6.3	0.4	50	11
1E	09	05				39.5	43.7	12.8	3.9	45.8	46	7.2	1.0	44	9.0
2A	07	12				69.6	28.3	1.3	0.8	92.2	4.7	3.0	0.1	170	
2B	08	03				61.6	34.4	3.1	0.9	88.6	9.7	1.5	0.3	186	
2C	08	17	450700	5825600	1280	64.4	31.6	2.9	1.1	94.2	4	1.5	0.3	168	
2D	08	28	(Map Sheet	83C/12)		65	31.3	2.9	0.9	88	9.6	1.5	0.1	196	
2E	09	05				66.3	29.8	2.8	1.1	93.9	4.3	1.5	0.2	148	
3A	07	12				67.9	30.3	1.5	0.3	92.3	4	3.6	0.2	152	1.0
3B	08	03				64.3	31.3	3.4	1	94.3	3.8	1.8	0.0	160	1.0
3C	08	17	451800	5824600	1310	65	30.4	3.5	1.1	93.4	4.5	1.9	0.2	120	1.2
3D	08	28	(Map Sheet	83C/12)		67.8	28.8	3.1	0.3	93.6	4.2	1.9	0.3	188	1.2
3E	09	05				67.3	30.3	1.7	0.6	93.5	4.3	1.8	0.4	116	1.2
4A	07	12				64.9	28.8	5.2	1	84.1	4.7	10.7	0.5	56	
4B	08	03				62.3	29.6	6	2.2	77.2	3.1	19.7	0.0	46	
4C	08	17	461400	5818200	1494	63.9	27.9	6	2.2	89.2	4.9	5.5	0.5	26	
4D	08	28	(Map Sheet	83C/12)		64.8	27.9	6.2	1.1	90.3	3.6	6.1	0.0	68	
4E	09	05				64.5	26.8	6.4	2.3	87.1	5.2	6.1	1.6	34	
5A	07	12				56.4	41.2	2	0.4	82.8	14.6	2.3	0.3	74	
5B	08	03				53.3	40.8	4.5	1.4	85.1	12.4	2.4	0.2	94	

Sample			Location		Elevation	epm %Cation				epm % Anions					
#	Mo.	Day	Easting	Northing	Meters	% Ca	% Mg	% Na	% K	%HCO_3	%SO_4	% Cl	% NO_3	TDS	Dis-charge
5C	08	17	477275	5798500	1615	54.5	39.9	4.7	0.9	86.9	10.5	2.4	0.3	90	
5D	08	28	(Map Sheet 83C/6)			58.2	39.1	2.4	0.4	85.3	10.8	2.4	1.5	136	
5E	09	04				55.6	39.1	4.5	0.8	85.5	11.6	2.4	0.6	78	
6A	07	12				66.3	31.4	1.4	0.8	90.0	6.3	3.4	0.1	142	
6B	08	03				64.9	30.4	2.8	1.9	88.7	9.5	1.5	0.3	188	
6C	08	17	481025	5790375	1890	63.8	33	2.7	0.5	89.5	9	1.5	0.0	192	
6D	08	28	(Map Sheet 83C/6)			68.4	27.7	3.5	0.4	90.7	7.9	1.3	0.1	252	
6E	09	04				69.5	27.4	2.4	0.7	89.9	8.6	1.3	0.2	194	
7A	07	20				65.4	33	1.3	0.2	33.1	65.3	1.4	0.2	502	
7B	08	03				62.5	35.8	1.4	0.3	25.6	73.6	0.7	0.1	496	
7C	08	18	428475	5878650	1005	60.3	36.4	2.8	0.4	22.6	76.6	0.8	0.1	472	
7D	08	29	(Map Sheet 83E/1E)			61.9	35.8	2.1	0.3	25.5	73.7	0.7	0.0	544	
7E	09	05				65.3	32.3	2	0.4	30.	69.1	0.7	0.2	528	
8A	07	20				63.8	31.5	3.7	1.0	73.1	24.7	2.1	0.1	130	
8B	08	03				62.3	32.9	4	0.8	76.1	21.6	2.1	0.2	152	
8C	08	18	435100	5891000	1000	63.3	32.1	3.5	1.1	76.4	21.5	1.9	0.2	158	
8D	08	29	(Map Sheet 83E/1E)			64.2	31.8	3.3	0.6	73.5	24.4	1.9	0.2	166	
8E	09	05				62.7	32.6	3.4	1.4	71.7	26	1.8	0.4	130	
9A	07	20				63.7	27.0	7.3	2	87.8	9.1	2.2	0.9	232	
9B	08	03				55.2	38.3	5.6	0.9	88.2	10.3	1.4	0.1	198	
9C	08	18	438075	5895250	990	62.6	30.8	5.7	0.9	88.5	9.7	1.2	0.5	206	
9D	08	29	(Map Sheet 83F/4W)			53	40.2	6.2	0.6	85.1	12.6	1.7	0.6	146	
9E	09	05				66.5	28.6	4.3	0.7	89.1	9.3	1.1	0.5	222	

Appendix 5: Hydrogeologically Important Rock Outcrops

Outcrop Number	Location		Description
	Easting	Northing	
X1	432300	5864000	Outcrop of Palliser Lst (springs in Maligne Canyon).
X2	430700	5880300	Banff Limestone discharging large springs.
X3	472700	5808800	Fractured Gog Group sandstone from rock slide. Typical colluvial material.
XS1	427050	5859900	Alluvial river gravels near Jasper (good aquifer material)
XS2	426600	5858500	Alluvial river gravels near Jasper (good aquifer material)
XS3	452600	5850750	Typical colluvial debris.
XS4	481000	5789900	Large colluvial deposit with springs discharging at base.