CANOE CREEK INDIAN BAND

EVALUATION OF GROUNDWATER RESOURCES ON CANOE CREEK INDIAN RESERVES NO. 1, NO. 2 AND NO. 3 AND DOG CREEK INDIAN RESERVE NO. 2

PACIFIC HYDROLOGY CONSULTANTS LTD.

MAY 19, 1988

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May 19, 1988

Canoe Creek Indian Band
Administration Office
General Delivery
DOG CREEK, B. C. V0L 1J0

Dear Sirs:

We herewith submit our report in regard to an evaluation of the groundwater resources on Canoe Creek Indian Reserves No. 1, No. 2 and No. 3 as it affects the feasibility of increasing existing groundwater supplies and of developing new supplies for both irrigation and domestic use. The report also discusses the feasibility of obtaining groundwater of better quality to supply two existing homes on Dog Creek I. R. No. 2 which are presently supplied from individual drilled wells.

We have revised our draft report of April 25 to reflect the additions requested at the meeting of May 10 at the Band Office.

We would be pleased to answer any questions which may arise from the report.

Yours truly,

PACIFIC HYDROLOGY CONSULTANTS LTD.

E. Livingston

E. Livingston, P. Eng.

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CANOE CREEK INDIAN RESERVES NO. 1, NO. 2, AND NO. 3
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1.0 INTRODUCTION

The purpose of this report is to present the results of a field reconnaissance carried out to investigate the groundwater resources on Canoe Creek Indian Reserves No. 1, No. 2 and No. 3. This report also briefly discusses the groundwater quality from two existing wells on Dog Creek Indian Reserve No. 2.

From discussions with Chief Agnes Jack and Mr. David Archie, the specific issues to be considered in this study were defined as follows:

1. Canoe Creek I. R. No. 1 - Investigate the alternatives - in particular, groundwater - for increasing the source of domestic water to the Canoe Creek Village System to meet future demands.

2. Canoe Creek I. R. No. 2 - Investigate the feasibility of diverting water northward from Big Bar Lake into Indian Meadows Creek for use in irrigating land on Canoe Creek I. R. No. 2.

3. Canoe Creek I. R. No. 3 - Investigate the feasibility of using gravity irrigation of agricultural land along Spring Gulch and of obtaining a supply of groundwater at the site of the abandoned Village northeast of the head of Spring Gulch.

4. Dog Creek I. R. No. 2 - Investigate the feasibility of obtaining groundwater of better quality to supply two existing homes on Dog Creek I. R. No. 2, which are presently supplied from individual drilled wells.

In addition to E. Livingston's field visit of April 12 and 13, the following sources of information have been used in preparation of this report:

1. Geological Survey of Canada Bulletin 196 by H. W. Tipper, 1971, **Glacial Geomorphology and Pleistocene History of Central British Columbia** and, in particular, Geological Survey of Canada Map 1292A, **Surficial Geology Taseko Lakes British Columbia** at a scale of 1:250,000.

3. 1:50,000 scale topographic maps NTS 92 0/8, **EMPIRE VALLEY**; NTS 92 0/9, **DOG CREEK**; and NTS 92 P/5, **JESMOND.**

4. Vertical air photos: Roll BCC711, No.'s 81, 82, 83, 181, 182 and 183 from 1987 at a scale of 1:15,000; Roll BC80130, No.'s 84 to 90, inclusive, from 1980 at a scale of 1:20,000; Roll BC7654, No.'s 250 to 256, inclusive, at a scale of 1:20,000; Roll BC80111, No.'s 153 to 157, inclusive, at a scale of 1:15,000; Roll BC79027, No.'s 1, 2 and 3 at a scale of 1:40,000; Roll BCC514, No.'s 70 to 75, inclusive, at a scale of 1:15,000.

5. A discussion with Action Drilling Ltd., who drilled several wells on the Dog Creek Reserves in 1982.

6. Chemical analyses of water, from two domestic water wells on Dog Creek I. R. No. 2 and for water from the Canoe Creek Village System, provided by Ms. Heidi Schreiner, Environmental Health Officer, Health and Welfare Canada.

2.0 GEOLOGY

The subject area is underlain by sedimentary and volcanic rocks of the Marble Canyon Formation of Mississippian-Triassic age overlain in the upland or plateau areas by basaltic volcanics of Miocene-Pliocene age. The Marble Canyon Formation at Canoe Creek Village, and also at Dog Creek Village, consists largely of volcanic rocks; these underlying volcanic rocks of the Marble Canyon Formation are probably much less permeable than the overlying basaltic volcanics which are more intensely fractured.

The plateau is covered with a blanket of glacial debris which is largely compact till. A sandy soil about one metre thick has developed on the till since the last regional glaciation of the area which ended about 12,000 years ago. At the time of the melting of the regional ice, very large streams of meltwater flowed from the plateau to the Fraser River. These streams cut deep valleys; Canoe Creek flows in one of these valleys.

During the time of deglaciation, the Fraser River became blocked somewhere downstream by a dam of ice and glacial debris; this dam created a very large lake that extended up the tributary valleys which, at the time, were largely filled in with sediment from the meltwater. This sediment varies from gravel to clay and silt which was partly deposited as the thin-bedded (varved) lake beds that are exposed at the Dog Creek Spring. When the blockage in the Fraser River collapsed, the huge lake was released as a very large flood. Water also flowed at high rates down the tributary valleys like Canoe Creek; this rapid flow removed much of the accumulated sediment and produced the topography which is seen today.

3.0 GROUNDWATER HYDROLOGY

The source of groundwater which discharges in springs or in creeks is precipitation on the plateau areas. The precipitation, mostly snowmelt in the spring, moves down through the soil and then more slowly through the glacial deposits into the underlying fractured volcanic rocks. Apparently the permeability of the basaltic volcanic rocks is higher than that of the underlying Marble Canyon rocks so that much of the water tends to flow along the contact to discharge as springs. The flow system is long enough and the velocity of flow is slow enough so that the spring discharge tends to be almost constant throughout the year.

The water in the small creek which supplies Canoe Creek Village is probably groundwater discharging from the bottom of the volcanic flows further up the valley. This is probably also the case at Spring Gulch on Canoe Creek I. R. No. 3.

4.0 GROUNDWATER SUPPLY

4.1 Canoe Creek I. R. No. 1

4.1.1 Existing Situation

The existing situation with respect to water supply at Canoe Creek Village may be summarized as follows:

1. There are 11 domestic connections to the present water distribution system. This may increase to 20 connections in future.

2. The capacity of the source for the system is adequate for present demands. It consists of a buried groundwater collection pipe that discharges into a wooden sump, from which 38 mm ($1\frac{1}{2}$") diameter PVC pipe conveys the water to a concrete reservoir located a short distance north of the Canoe Creek Road. The intake structure was constructed in 1987 and is in very good condition.

3. The buried concrete reservoir, with a capacity in the range of 30,000 to 40,000 igals, feeds the system by gravity.

4. The distribution system from the reservoir was constructed recently. It consists of 150 mm (6") diameter mains with six fire hydrants.

5. The chemical and bacteriological quality of the water is satisfactory.

6. The Village does not have electric power at this time, but hydro' power is expected to reach the Village later in the year. Water use is expected to increase when electric power is available.

7. The capacity of the system should be increased to meet future demands.

The Canoe Creek Village water source is from stream sediments in a narrow rock valley about one km north of the reservoir. The flow in the stream is small and an examination of the streambed indicates that it remains fairly constant throughout the year. This is in contrast to the next small valley a short distance to the east, where there are short periods of very high flow during which large amounts of debris, including large boulders, are discharged at the mouth of the creek. At the time of E. Livingston's visit of April 12, the flow from this creek was much larger than that of the Village Creek source. The conductivity of this water, measured with a field instrument, was about 380 microsiemens; this is somewhat lower than the 480 microsiemens obtained for the Village source and may indicate that it contains more snowmelt water. An examination of aerial photography covering the area (Roll BCC711; Photo No.'s 80 through 82) shows that creeks have very small steep catchment areas which are being enlarged by erosion northward into the plateau. The catchment areas are comparable in size; there is no indication as to why there is such a large difference in the flow between the two creeks.

4.1.2 Alternatives for Increasing the Village Source Capacity

There are two alternatives for increasing the capacity of the source supplying Canoe Creek Village. These are:

1. Improve the existing intake to collect additional water.
2. Carry out test-production drilling.

From observations in the field, it is our opinion that the capacity of the intake can be increased considerably by the following:

a. arranging intake pipes to intercept subsurface flow across the full width of the streambed;
b. lowering the intake pipes close to the bottom of the sump;
c. lowering the outlet pipe close to the bottom of the sump.

Because of the location of the intake facility, only handwork is feasible to improve the intake. It is probably best to dig an access trench on grade in order to drain the trenches in which the infiltration pipes are to be placed. Intake pipes should extend across the streambed on both sides of the sump to intercept more of the underflow. We suggest using 100 mm (4") diameter Big-O drain pipe buried in fine gravel; such gravel can be produced onsite by shovelling sediment from pits on the valley sides against a sloping screen.

The intake for the Village, as mentioned previously, consists of a new wooden sump, about 1½ to 2 m deep, with an hinged cover. Water enters the sump by way of a smaller antechamber through an opening covered with stainless steel screen. The water flows from the sump to the conrete reservoir by a 38 mm (1½") diameter PVC pipeline buried about 1 m below ground at the sump. Water is collected from the sand and gravel on the upstream side of the sump by means of a black perforated plastic pipe of unknown length which is buried about 1 m below ground surface. A small stream of surface water was flowing past the intake structure at the time of E. Livingston's visit of April 12; this shows that the intake is not collecting the total flow. There is also probably additional underflow through the stream sediments on both sides of the sump and below the elevation of the intake pipe; this underflow is not being collected by the existing intake.

Subsurface conditions at Canoe Creek Village are unknown and can only be determined by drilling. If water demand in future exceeds the capacity of an improved intake, or if, for some other reason, it is necessary to obtain water from a drilled well, it should be possible to construct a successful well(s) in the Village. The Village is located on a sloping surface of sediments deposited in the past by the small creek in which the Village Intake is constructed. This sloping mass of sediment, which probably consists mostly of sand and gravel, is called a fan. There are numerous such fans in the Valleys of Canoe Creek and Dog Creek. They are comparatively young features and some of the fans, for example the one east of the Village, are still being deposited. Other fans may have been deposited only in the past when the climate was wetter than it is today. Most such fans are composed largely of sand and gravel. In some situations, the sand and gravel is quite clean and conditions are favourable for construction of medium capacity wells. In other situations, the fans contain much silt and very fine sand along with the gravel; in such fans, it may be difficult to construct even low capacity wells. The fans may be deposited over old stream deposits which may also be favourable for the construction of wells.

Action Drilling Ltd. reports in a telephone discussion (Livingston, Shuit) that they have constructed two water wells at the B. C. Cattle Company Ranch, directly downstream of Canoe Creek I. R. No. 1, which show that conditions are probably suitable for constructing irrigation wells. Similar conditions may exist upstream at the Village. If the Band decides to construct a drilled well at Canoe Creek Village, either now or in the future, a site in the vicinity of the new Church is a reasonable first site for a test-production well. Although groundwater quality is unknown, it is expected to be satisfactory; it may, however, be somewhat more mineralized than that of water from the present source.

If test-production drilling is carried out at Canoe Creek Village and is successful in locating sufficient quantities of groundwater for irrigation use, it is feasible to install two submersible pumps in the same well so that one well can be used for both irrigation and community use. However, this means that the well must be constructed with a large enough casing diameter so that the smaller pump for the Village supply can be installed on a separate drop pipe above the irrigation pump. Considering the limited area suitable for irrigation on Canoe Creek I. R. No. 1, the diameter of an irrigation well would likely be 200 or 250 mm (8 or 10"); however, a 300 mm (12") or larger diameter well would be required to provide enough space for two pumps.

In a case such as this, where there is no information on groundwater conditions, exploration for irrigation water is usually carried out on the basis of 200 mm (8") diameter test-production drilling with successful wells completed as production wells. It is difficult to economically justify the drilling of a 300 mm diameter test hole. If 200 mm diameter drilling is carried out and is successful, such a well can be used for irrigation with a separate well constructed for Village supply. For a demand up to 3.0 L/sec (40 igpm), a 150 mm (6") diameter well casing is adequate; for a quantity greater than 3.0 L/sec, a domestic water supply well should be 200 mm in diameter.

All things considered, there is probably no particular advantage to a dual pump installation.

4.2 Canoe Creek I. R. No. 2

On April 13, E. Livingston visited the old ditch on Big Bar Creek below Big Bar Lake where the Band plans to divert water northward into Indian Meadows Creek for use in irrigating land on Canoe Creek I. R. No. 2. David Archie noted in a discussion with Ed Livingston that the old ditch will need to be extended to reach the land where the irrigation is planned; however, E. Livingston observed that it is in good condition and can probably be rehabilitated by simple cleaning. The ditch presently carries water for a short distance to a point where the flow is diverted back into Big Bar Creek. The flow on April 13, at the time of E. Livingston's visit, was small.

The 1:50,000 scale topographic map covering this area (NTS 92 P/5, **JESMOND**) is not up-to-date, in that areas which are shown as swamps are actually lakes due to damming by beavers and, in one place - probably on District Lot 5155 - due to the construction of a small dam. The purpose of this dam is not clear. It seems likely that the dam is constructed under a water license; if so, it may have some effect on the Band's license application to divert water a short distance upstream.

The obvious first step is to review the water licenses on Big Bar Creek before proceeding with any work on the diversion. If there is sufficient water available, the cost of the scheme should be estimated. This cost can then be compared to the estimated cost of irrigation based on pumping from wells located close to each piece of land that requires irrigation. Without some exploration drilling, it is not possible to say whether irrigation wells can be constructed or how much they will cost; however, as mentioned previously for Canoe Creek I. R. No. 1, the wells at the B. C. Cattle Company Ranch, directly downstream of Canoe Creek I. R. No. 1, give some encouragement that irrigation wells can be constructed. If conditions are good, an irrigation well equipped with a pump will probably cost $25,000., or more (not counting power line costs). If such installations are feasible, they may be more economical than the proposed diversion which would also require the use of pumps.

4.3 Canoe Creek I. R. No. 3

4.3.1 Irrigation of Agricultural Land Along Spring Gulch

On April 12, Livingston and Archie walked up Spring Gulch from the Dog Creek Road to where the water originates at elevation about 915 m (3000 ft). There are several seepage areas but most of the water flows out of a pile of broken rock at the base of the bluffs formed by the volcanic flows which, as mentioned previously in the description about the geology of the area, overlie the Marble Canyon Formation. The flow does not seem to increase or decrease from the source area downstream to the road; on April 12, the flow was estimated to be about $7\frac{1}{2}$ L/sec (100 igpm). The conductivity of the water in Spring Gulch, which was measured by a field meter to be about 320 microsiemens, indicates that the water is suitable for irrigation; however, this should be discussed further with agriculture experts knowledgeable about irrigation water quality and local soil conditions.

In order to properly design a gravity flow irrigation scheme, it is essential to determine the flow in Spring Gulch, especially in the latter part of the irrigation season. For this purpose, a small weir (see Appendix A) can be installed on the stream in the vicinity of the road crossing. An alternative method for measuring the streamflow is to collect the water at the road culvert into a length of pipe from which the water can be directed into an open barrel. The flow can then be measured by timing the filling of the barrel.

4.3.2 Groundwater Supply for Reoccupation of the Village Site Northeast of the Head of Spring Gulch

The abandoned village is located on top of the plateau close to the head of Spring Gulch. It is underlain by glacial sediments, probably till, which overlie the basaltic volcanic flows. There is no surface water nearby; therefore, the most feasible water supply is from a well or wells. If our concept of the groundwater hydrology is correct, there is likely to be some water at the contact of the basaltic volcanic rocks with the underlying sedimentary and volcanic rocks. Since this contact zone is draining westward, as shown by the flow in Spring Gulch, wells should be located as far east as possible.

There is no certainty that there is a significant amount of water at the contact, because the contact is probably irregular due to the fact that the topographic surface of the older rocks was probably irregular when it was buried by advancing lava flows. Water at the contact will tend to accumulate in the valleys of the old topographic surface which existed before the lava flows covered the area. This may also explain why the source of Spring Gulch is local in extent.

If drilling is carried out, the driller should look for the contact at the bottom of the volcanic flows. The contact is likely to be a zone of weathering with brown, orange and red colors; there may be some baked sediment at the contact. The depth to this contact is unknown but it is not likely to be less than 40 m (122 ft). It is probably possible to get water in the older rocks below the contact; therefore, if no water is found at the contact, drilling should be continued for at least 50 m (150 ft) below the contact.

Since plans call for only three or four residences at the site of the abandoned village, before proceeding with any exploratory drilling, the Band may wish to consider the economic feasibility of pumping water from the spring at the head of Spring Gulch to the village site. This feasibility can be checked by the following procedure:

1. Identify a place where it is possible to construct a sump or tank to catch a flow of 0.3 L/sec (4 igpm).

2. Measure the difference in elevation between the sump and the proposed location of the homes by an altimeter or some other method.

3. Measure the approximate length of pipeline and power line required to reach a pump at the spring.

4. Obtain prices for pipeline, power line, pumps, pumphouse, controls and, if required, for chlorination equipment.

5. Compare the estimated cost of pumping the water from the spring with the estimated cost of a completed well equipped with a pump which is located near the site of the proposed new homes.

If the estimated costs of the two systems are similar, the lack of risk favours using the spring rather than carrying out exploratory drilling whose success is rather uncertain.

4.4 Dog Creek I. R. No. 2

The two residents presently occupying Dog Creek I. R. No. 2, Alfred and Evelyn Sargent and Eric Archie, obtain their water suppy from drilled wells. Both report that the quality of the water from the wells is very poor. Ms. Heidi Schreiner, Environmental Health Officer, Health and Welfare Canada, has provided analyses of water from each of these wells; the analyses are summarized in a table in Appendix B. Ms. Schreiner reports that the Sargent and Archie Wells are equipped with water treatment units (softeners) and she has provided an analysis of treated water from the Archie Well; for comparison to the natural groundwater, this analysis is also included in the summary table in Appendix B.

From the summary table included in Appendix B, the situation with respect to the quality of groundwater from the Archie and Sargent Wells on Dog Creek I. R. No. 2 may be summarized as follows:

1. The groundwater from the Sargent Well is a magnesium + calcium/bicarbonate water. It is very hard but otherwise seems to be quite a good quality groundwater - about what is expected in the dry Interior of B. C. where the bedrock includes limestone.

2. The untreated groundwater from the Archie Well, as represented by a sample collected in 1984, is much more highly mineralized than the groundwater from the nearby Sargent Well. The natural groundwater from the Archie Well is a magnesium + calcium/bicarbonate + sulphate water which is extremely hard but otherwise should be suitable for domestic use.

3. The treated groundwater from the Archie Well, as represented by a sample collected in 1986, is a sodium/bicarbonate water which is extremely soft and has an high content of sodium as a result of the softening process.

A water which is very hard is not considered to be dangerous to health; rather, high hardness is objectionable for aesthetic reasons in that soap will not lather and tends to form a scum on the water, the skin may become irritated, scale may form in hot water tanks and in kettles, etc. However, an high sodium content in water which is used for drinking or in food preparation is of concern to individuals on a sodium restricted diet. **Health and Welfare Canada's Guidelines for Canadian Drinking Water Quality 1978** state that **...The appropriate health authorities should be notified where the sodium concentration exceeds 20 mg/L.**

The table in Appendix B clearly shows that the waters from the Archie and Sargent Wells, as represented by the 1984 samples of untreated water, are distinctly different and, therefore, are likely to be from different sources. However, it has not been possible to correlate the chemical analyses with the drillers' logs of the wells. The logs of several wells on Reserves in the area were provided by Action Drilling Ltd. but, because they are identified only by house site numbers and also because records at the Band Office do not show the locations or owners of the numbered house sites, it is not possible to match the logs to the appropriate wells. Since the wells were constructed several years ago, Action Drilling is unable to specify where a particular well was drilled.

At this time, it seems unlikely that drilling of additional wells on Dog Creek I. R. No. 2 will obtain water which is significantly different from that in the existing wells. However, since the analyses show that the water from the Sargent Well is much better than that from the Archie Well, the Band may wish to consider whether it is feasible to connect the Archie House to the Sargent Well. This, of course, can only be done if the well has sufficient capacity.

5.0 ESTIMATED COSTS OF IMPROVING EXISTING FACILITIES OR OF DEVELOPING GROUNDWATER SOURCES

It is difficult to estimate the costs required to carry out some aspects of the various improvements which may be carried out on existing facilities on the Canoe Creek Reserves; the same is true in regard to estimating costs of test-production drilling as so little is known about subsurface conditions or about the depth of well which may be required. However, the cost estimates which are provided following are believed to be realistic.

5.1 Canoe Creek I. R. No. 1

The cost of improving the existing Canoe Creek Village Intake is estimated to be as follows:

1.	Improve trail to Intake site	$ 500.
2.	Dig trenches	750.
3.	Screen gravel	300.
4.	Install pipes, etc.	500.
5.	Materials (Big-O pipe, construction cloth, etc.)	500.
6.	Miscellaneous	500.
		$ 3,050.

Without more precise information on subsurface conditions, it is difficult to estimate the costs of test-production drilling in the Village. The cost of a successful 150 mm (6") diameter screened well to a depth of 30 m (100 ft), including pump testing, is estimated to be as follows:

1.	Move equipment and crew to and from Canoe Creek	$ 500.

2.	Install 4 m of surface casing, provide drive shoe and overlap casing and drill and case 26 m of 150 mm (6") diameter hole	3,000.
3.	Provide 2.4 m (8 ft) of stainless steel well screen	800.
4.	Hourly work to install screen, develop well, etc.	2,500.
5.	Carry out a 24 hour pumping test	2,500.
6.	Engineering, supervision, sieve analyses, reporting, etc.	3,000.
		$ 12,300.

If the drilling of a 150 mm diameter test-production well to a depth of 30 m in the Village is completely unsuccessful, the "risk" cost of such drilling is estimated to be **$4,500.**, including engineering.

5.2 Canoe Creek I. R. No. 2

As discussed previously, if for some reason it is not feasible to divert water from Big Bar Creek for irrigating land on Canoe Creek I. R. No. 2, and if test-production drilling is carried out to develop a ground-water source, under favourable conditions an irrigation well equipped with a pump is estimated to cost **$25,000.** If, however, a program of three 200 mm (8") diameter test-production wells to an average depth of 46 m (150 ft) is carried out and is completely unsuccessful, the "risk" cost will also be an estimated **$25,000.**, including engineering.

5.3 Canoe Creek I. R. No. 3

The cost to construct a weir on Spring Gulch to determine the flow, especially during the latter part of the irrigation season, is estimated to be as follows:

1.	Prepare site and install weir	$ 750.
2.	Materials - lumber, sacks, etc.	250.
		$ 1,000.

The cost to drill two test-production wells at the site of the abandoned Village northeast of the head of Spring Gulch, completing one as a successful rock well and pump testing it, is estimated to be as follows:

1.	Move equipment and crew to the site	$ 500.
2.	Drill and case 4 m of 200 mm (8") diameter hole	500.
3.	Provide 150 mm (6") casing shoe	100.
4.	Provide and install 3 m of 150 mm diameter casing	100.
5.	Drill and case 15 m of 150 mm diameter hole	1,200.
6.	Drill 75 m of 150 mm diameter rock hole	5,400.
7.	Hourly work to develop well, etc.	1,000.
8.	Pumping test	4,000.
9.	Engineering, supervision, reporting, etc.	3,500.
		$ 16,300.

The "risk" cost to drill two unsuccessful test wells to an average depth of 45 m is estimated to be **$9,000.**, including engineering.

The cost of a pipeline, pumps, pumphouse, controls and chlorination equipment to bring water from the spring at the head of Spring Gulch to the site of the abandoned Village is estimated to be in the range of **$30,000.** to **$40,000.**, not including the cost of the power line.

6.0 SUMMARY AND CONCLUSIONS

The results of this investigation of the groundwater resources on Canoe Creek Indian Reserves No. 1, No. 2 and No. 3, may be summarized as follows:

1. The capacity of the buried intake which presently supplies the Canoe Creek Village Water System can probably be increased by improving the existing intake so that it collects additional water. It should also be possible to construct a successful well(s) in the Village.

2. All indications are that an old irrigation ditch on Big Bar Creek can be rehabilitated by simple cleaning for use in diverting water northward into Indian Meadows Creek. The ditch will need to be extended to reach the land on Canoe Creek I. R. No. 2 where the irrigation is planned; however, before proceeding with any work on a diversion, the status of all water licenses on Big Bar Creek should be reviewed. If water is available, the cost of an irrigation scheme based on diverting water from Big Bar Creek should be compared with the estimated cost of irrigation based on pumping from wells located close to each piece of land that requires irrigation; in considering such estimates, it must be kept in mind that test-production drilling will be required to prove up groundwater sources adequate for irrigation.

3. In order to design a gravity flow irrigation scheme for irrigation of agricultural land along Spring Gulch on Canoe Creek I. R. No. 3, it is essential to determine the flow in Spring Gulch, especially in the latter part of the irrigation season. This can be done either by installing a weir on the stream in the vicinity of the road crossing or by collecting the water at the road culvert into a pipe, from where it can be directed into an open barrel for measurement by timing the filling of the barrel.

4. For reoccupation of the abandoned Village located northeast of the head of Spring Gulch on Canoe Creek I. R. No. 3, alternative sources of water supply are a well(s) and the spring at the head of Spring Gulch. There is a reasonable chance of obtaining water at the contact of the basaltic volcanic rocks with the underlying sedimentary and volcanic rocks. The flow in Spring Gulch shows that the contact zone between the two types of rocks is draining westward; therefore, test wells should be located as far east as possible. If no water

is present at the contact zone, drilling should be continued into the underlying sedimentary and volcanic rocks.

5. Chemical analyses of the natural groundwater from the two domestic water wells on Dog Creek I. R. No. 2 show that both waters are very hard; however, the water from the Sargent Well is much less mineralized and, therefore, is of better quality than water from the Archie Well. Treatment of the water from the Archie Well results in an extremely soft water in which the sodium content is very high. It has not been possible to correlate water quality with the driller's logs of the wells so the reason for the better quality groundwater in the Sargent Well is unknown. It seems unlikely that drilling of additional wells on the Reserve will obtain water of much different quality than that from the existing wells.

6. Costs of improving existing facilities or of developing groundwater sources on the Canoe Creek Reserves are difficult to estimate because there are so many unknowns. However, the cost estimates given following are believed to be realistic.

   a. **Canoe Creek I. R. No. 1**

- Improve existing Intake	**$3,050.**
- Construct and test a successful 150 mm (6") diameter well in the Village	**$12,300.**
- "Risk" cost of test-production drilling in the Village	**$4,500.**

   b. **Canoe Creek I. R. No. 2**

- Construct, test and equip a successful irrigation well with a pump	**$25,000.**
- Drill three 200 mm (8") diameter unsuccessful test-production wells to an average depth of 45 m	**$25,000.**

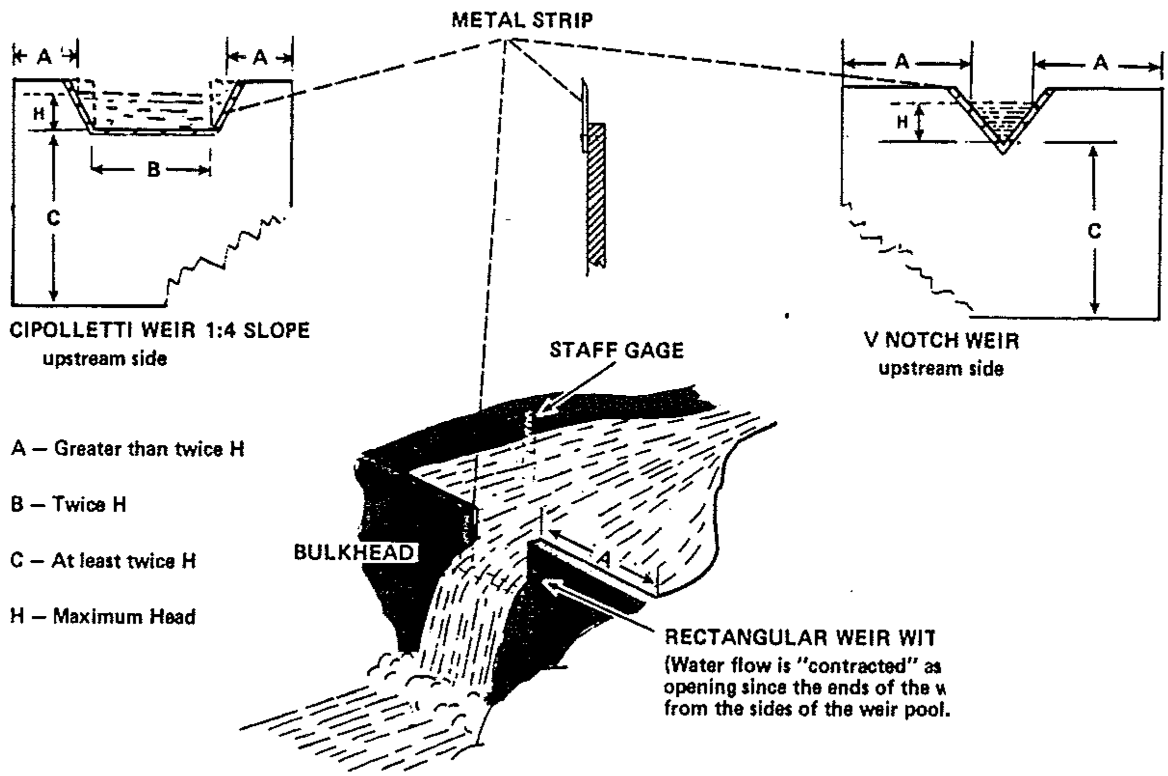
   c. **Canoe Creek I. R. No. 3**

- Construct a weir on Spring Gulch	**$1,000.**
- Drill two test-production wells at the site of the abandoned Village, complete one as a successful rock well and carry out pump testing	**$16,300.**
- "Risk" cost of drilling two unsuccessful test wells to an average depth of 45 m	**$9,000.**
- Convey water from the spring at the head of Spring Gulch to the site of the abandoned Village (excluding power line costs)	**$30,000.** to **$40,000.**

APPENDIX A

TYPICAL WEIR CONSTRUCTION FOR STREAM GAUGING

FIGURE 1	TYPICAL WEIR CONSTRUCTION FOR STREAM GAUGING



Notes:

1. The diagram is taken from **Stevens Water Resources Data Book**, 2nd Edition, published by Leupold & Stevens, Inc., P. 41.
2. Triangular or V-notch weirs are generally used to measure smaller flows while rectangular weirs are used to measure larger flows.

APPENDIX B

GROUNDWATER QUALITY

GROUNDWATER QUALITY
DOG CREEK I. R. NO. 2 AND CANOE CREEK VILLAGE

Constituent		WELLS ON DOG CREEK I. R. NO. 2 — Eric Archie — Nov. 21, 1984 (untreated) (1)	WELLS ON DOG CREEK I. R. NO. 2 — Eric Archie — Sept. 8, 1986 (treated) (2)	WELLS ON DOG CREEK I. R. NO. 2 — E. Sargent — Nov. 21, 1984 (untreated) (1)	CANOE CREEK VILLAGE SOURCE — June 10, 1985 (untreated) (3)
PHYSICAL PARAMETERS					
pH		7.56	7.42	8.10	8.00
Conductivity (micromhos/cm)		972.	994.	540.	551.
True Color [Pt-Co Scale](Cu)		5.	<5.	<5.	<5.
Turbidity (NTU)		5.0	0.50	<1.0	2.2
Hardness (mg/L)		519.	1.0	339.	347.
DISSOLVED ANIONS (mg/L)					
Alkalinity: Bicarbonate	HCO	466.	550.	399.	420.
Carbonate	CO	-	nil	-	-
Hydroxide	OH		nil		
Chloride	Cl	<0.50	1.48	<0.50	<0.50
Sulfate	SO	140.	45.	24.	18.7
Nitrate and Nitrite	N	0.003	0.48	0.13	0.016
Fluoride	F	0.27	0.15	0.18	0.22
DISSOLVED METALS (mg/L)					
Calcium	Ca	102.	0.19	52.0	41.5
Magnesium	Mg	64.4	0.11	51.0	59.1
Sodium	Na	6.55	256.	6.42	10.6
Potassium	K	2.20	0.22	1.83	2.14
Iron	Fe	0.16	0.036	<0.03	<0.03
Manganese	Mn	0.058	<0.003	<0.005	<0.005
Silica	SiO	16.8	17.4	18.0	23.8
Copper	Cu	<0.005		0.027	0.044
Lead	Pb	<0.05		<0.05	<0.05
Zinc	Zn	0.015		0.051	0.37
Cadmium	Cd	<0.002		<0.002	<0.002
Arsenic	As				<0.10
Barium	Ba				0.015
Chromium	Cr				<0.002
TOTAL METALS (mg/L)					
Iron	Fe	0.36	<0.030	<0.03	<0.03
Manganese	Mn	0.065	<0.003	<0.005	<0.005
Arsenic	As		<0.001		
Barium	Ba		<0.001		
Cadmium	Cd		<0.001		
Chromium	Cr		0.002		
Copper	Cu		0.001		
Lead	Pb		0.002		
Zinc	Zn		<0.010		

Sources of information:

(1) - Analytical Service Laboratories Ltd. File No. 1428A; November 30, 1984.

(2) - Can Test Ltd. File No. 13291F; October 7, 1986 (sample through softener).

(3) - Analytical Service Laboratories Ltd. File No. 1890A; June 25, 1985.