PROVINCE OF BRITISH COLUMBIA
MINISTRY OF ENVIRONMENT AND PARKS
WATER MANAGEMENT BRANCH

FISHTRAP/PEPIN/BERTRAND CREEKS
WATER MANAGEMENT BASIN PLAN

GROUNDWATER COMPONENT

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SYNOPSIS

Fishtrap, Pepin and Bertrand Creek watersheds encompass an area of approximately 111 km^2 (43 sq. mi.). The surficial deposits provide the physical framework controlling groundwater flow and occurrence. These deposits are divided into five hydrostratigraphic units and are classified on the basis of grain size and depositional environment. Presently, it appears, groundwater demand is not exceeding the annual recharge and there is further potential for groundwater development in the three watersheds.

Future recommended initiatives include establishing observation wells in areas of high irrigation demand, quantifying present and projected municipal, industrial and irrigation use from groundwater, further studies regarding identification of sources of high nitrate-nitrogen concentrations in the water table aquifer and obtaining information from Washington State officials regarding groundwater use from the aquifers just south of the study area.

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1. INTRODUCTION

In the Fraser-Delta Strategic Environmental Management Plan (August 1985) Report, it was recommended that of the six high demand areas for irrigation water supply, that the potential for further groundwater development to augment surface water supplies within the Pepin Creek, Fishtrap Creek and Bertrand Creek watershed areas, be assessed in more detail.

The purpose of this office groundwater study of available well record data, geologic maps and hydrogeologic reports, is to provide Ministry of Environment and Parks' Regional staff with an assessment of the groundwater conditions to assist them in resolving significant low flow water supply/use problems in the Fishtrap Creek, Pepin Creek and Bertrand Creek watershed areas.

2. LOCATION, TOPOGRAPHY AND SURFACE DRAINAGE

Figure 1 shows the general location of the study area within the Fraser Lowland. Figure 2 is a detailed location map of the Fishtrap/Pepin/Bertrand Creek drainage basins which encompass most of the eastern portion of Township 10, Township 13, and much of the western portion of Township 16, E.C.M.

Fishtrap Creek, Pepin Creek and Bertrand Creek drain south across the international border into the Nooksack River drainage system in Washington State.

Within Canada, these three creeks drain an area of approximately 111.3 km^2 (43 sq. mi.). The major portion drained, lies between elevations of 46 to 137 m (150 to 450 ft.) above sea level.

The western portion of the study area comprises part of the Langley Upland (see Figure 2). It is an area of uneven topography attributed to modification by stagnant melting ice masses from the last glaciation. The land surface is hilly and in the Bertrand Creek watershed reaches a maximum elevation of over 137 m (450 ft.) above sea level. The Canadian portion of the Bertrand Creek basin covers an area of 49.6 km^2 (19.15 sq. miles), whereas Pepin Creek and Fishtrap Creek drain an area of 60.5 km^2 (23.36 sq. mi.) (Currie, 1984).

The southeastern portion of the study area comprises part of the Abbotsford Upland, as shown on Figure 2. This is part of a broad outwash plain which extends across the Canadian border southwest to the Nooksack River floodplain. In Canada this outwash plain terminates to the west at the Langley Upland, at a ridge of ice-contact deposits (Easterbrook, 1966).

3. CLIMATE

According to Halstead (1986), the Fraser-Delta region can be characterized as having a warm rainy winter and a relatively cool dry summer. During winter, a fairly steady succession of cloudy, rainy conditions exist, whereas the summers have frequent long periods of sunny weather and temperatures are warm and rainfall is low.

Records from a number of gauging stations in the Fraser Lowland indicate that approximately 75% of the precipitation falls during the period October to March (Halstead, 1986). For the ten-year period, 1969 to 1978, an average precipitation of 1 497 mm (59 in.) has been measured at the Abbotsford Airport, elv. 58 m (190 ft.) a.s.l. In the Langley Upland portion of the study area, at CFB Aldergrove, elv. 76 m (249 ft.) a.s.l., located just north of Aldergrove near the topographic divide of Bertrand Creek watershed and the Salmon River basin, an average annual precipitation of 1 620 mm (64 in.) was measured during the same period.

During the period from June to September, the climate in this area is usually dry and may be subject to drought conditions, whereas from October to March, when precipitation is heaviest, evaporation and evapotranspiration are at a minimum. At this time, most of the precipitation is available to percolate into the soils and subsoils to eventually recharge the aquifers (Halstead, 1986).

4. BEDROCK GEOLOGY

Only a few boreholes have penetrated bedrock in the study area. Tertiary bedrock comprised of sandstones, siltstones, etc., has been reported by Halstead (1986) at these locations. The depths to bedrock have been reported at: 259 m (850 ft.) at the Geological Survey of Canda test hole located just north of Aldergrove (on the NE 1/4 of Section 30, Township 13); approx. 230 m (755 ft.) near Bertrand Creek at Section 11, Township 10; and approx. 130 m (425 ft.) southwest of Clearbrook at Section 18, Township 16 (see Figure 3).

5. SURFICIAL GEOLOGY

Figure 4 shows the distribution of surficial sediments in the study area. Glaciomarine stony silt to loamy clay of the Fort Langley formation are exposed on the Langley Upland and cover much of the Bertrand Creek watershed.

Knowledge of the Langley Upland stratigraphy was enhanced by the drilling of the GSC test well north of Aldergrove. The stratigraphic section is complex, indicating repeated glaciations as well as eustatic changes of sea level (Halstead, 1966). Figure 5 is a log of this Aldergrove test well. Halstead noted that although only one till sheet could be positively identifed in the 231 m (758 ft.) section of Pleistocene deposits, the presence of stony clays suggests repeated glacio-marine conditions, indicating at least four glaciations. The stony clays from 4.3 m to 85.6 m (14 to 281 ft.) were correlated with the last ice advance. The till at 85.6 to 99 m (281 to 215 ft.) was correlated with the Surrey till recognized throughout the Fraser Valley. The material from 99 to 171.6 m (325 to 563 ft.) was tentatively correlated with the Quadra sediments. An older glacio-marine deposit is represented by the blue clay with stones from 172 to 201 m (564 to 660 ft.). A stony fat blue clay lies at the base of this section and is underlain by a remnant till, which, it is believed, sits on top of Tertiary sediments.

Till, glaciofluvial, glaciolacustrine and ice-contact deposits were left upon retreat of a valley glacier which occupied the Sumas Valley during the final stages of deglaciation of the Fraser Lowland. An extensive area of glacial, fluvial and ice-contact deposits consisting of gravel, sand and lenses of till were laid down in the study area. These deposits mantle the Abbotsford Upland and were designated as Abbotsford Outwash (Armstrong, 1960). The deposits from this valley glaciation mantle nearly all of Fishtrap Creek and Pepin Creek basins, and to a lesser extent, Bertrand Creek basin (Figure 4). Collectively, these deposits are termed Sumas Drift (Armstrong, 1981).

Bog, swamp, peat and shallow lake deposits occur in all three creek basins and are outlined on the surficial geology map (Figure 4).

These surficial deposits of glacial and non-glacial materials provide the physical framework which controls the configuration and character of the groundwater flow systems.

6. HYDROGEOLOGY

The predominant source of recharge to groundwater is precipitation, and its hydraulic behaviour is governed by topography, distribution of surficial deposits, climate and vegetation. Precipitation replenishes the soil moisture and eventually reaches the water table to replenish the groundwater aquifers. In the study area, this recharge occurs mainly during the winter months (Halstead, 1986). During the growing season, evapotranspiration may exceed the average seasonal precipitation.

The Fishtrap/Pepin/Bertrand basin area, within Canada, is predominantly in a recharge area, with the creeks acting as local discharge zones. A number of springs in the study area also reflect local discharge areas, and are even responsible for maintaining flow in Fishtrap Creek.

The study area is underlain by surficial materials whose depositional environments are fluvial, marine and glacial. The deposited material varies significantly in its content of voids or pore spaces, and hence in its ability to store and transmit water (Halstead, 1986). Halstead subdivided these deposits on the basis of grain size and depositional environment and characterized them into five hydrostratigraphic units, A to E. The distribution of the hydrostratigraphic units within the Bertrand/Pepin/Fishtrap basin area, as derived by Halstead (1986), is illustrated in the hydrogeological fence diagram, Figure 3. The creek systems have been superimposed on this diagram to correlate surface/groundwater conditions.

Hydrostratigraphic Units

Unit A:

This hydrostratigraphic unit includes clay, stony clay and silty clays with varying stone content, as well as silty lenses, sandy silts, and in some places, marine shells. The proportion of clay is 10% to 50%; silt, 35% to 75%; and sand, 5% to 60%. These materials were mainly derived from ice sheets eroding in the sea during the overall retreat of the last major Fraser Lowland ice, and occur at or near surface throughout the western (Bertrand Creek basin) and the northern part of the study area. Unit A also includes the Fort Langley formation shown on the surficial geology map (Figure 4); and although geologically younger, post-glacial deposits, such as floodplain deposits and peat overlying the stony clays.

Halstead (1986) notes that Unit A is commonly less than 30 m (98 ft.) thick, and at or near its base, a sand layer with thin lenses of till forms a permeable unit which yields water adequate for domestic supplies. Water analyses indicate the pH range to be 6 to 8, and the total dissolved solids as less than 120 ppm.

Unit B:

Unit B consists of a unit of low permeability stony clays with shells of glacio-marine origin. In the GSC test hole, just north of Aldergrove, 56 m (184 ft,) of this unit was penetrated. This unit does not provide sufficient volume of water to be economic.

Unit C:

This unit consists mainly of glaciofluvial sand and gravel deposited by meltwater streams. Meltwater streams issuing from stagnant melting ice masses in the vicinity of Sumas Mountain built up a plain of sand and gravel with lenses of till that occupies 20 km^2 (7.7 sq. mi.) south of Abbotsford and extends beyond the Abbotsford Airport. This area is referred to as the Abbotsford Upland (Figure 2), and extends westward into an area of hummocky topography with meltwater channels, outwash gravels and ice-contact morainal deposits south of Aldergrove.

These permeable sands and gravels overlie Unit B (the stony clay), and contain water table aquifers which supply water for many municipal and irrigation wells. Spring discharge of groundwater is common and is responsible for maintaining the flow of Fishtrap Creek. This unit has excellent water quality with total dissolved solids less than 120 ppm and pH ranges from 6.5 to 7.6.

Unit D:

This unit consists of till deposits comprised of heterogeneous mixtures of clay, silt, sand, gravel and boulders.

Interbedded water-bearing sand and gravel lenses, generally to depths of 90 m (295 ft.) within these till deposits, constitute major confined aquifer systems, with water quality characteristically of the sodium-bicarbonate type and total dissolved solids less that 500 mg/L.

Unit E:

Unit E comprises mostly older marine sediments interbedded with estuarine and fluvial deposits consisting of fine sand, silt and clayey silts. Halstead notes that all drill holes to depths of more than 90 m (295 ft.) have penetrated these materials. Water quality is characteristically of the sodium-chloride type, and total dissolved solids range fom 750-6,000 ppm, suggesting that these groundwaters have had a considerable residence time.

Unit F:

This unit consists of bedrock, found at depths greater than 130 m (425 ft.). In the study area, this has been identified as Tertiary bedrock in the few boreholes that have penetrated it. No significant amounts of groundwater are known to have been developed from this bedrock unit within the Bertrand/Pepin/Fishtrap basin area.

Groundwater Occurrence and Movement

A review of the approximately 1,350 well records for the study area, inspection of the surficial geology map (Figure 4) and the hydrogeological fence diagram (Figure 3), indicate much of the area drained by Fishtrap and Pepin Creeks is geologically different than the area drained by Bertrand Creek. Bertrand Creek flows over glacio-marine clays and silts for most of its length, and in several areas over sand and gravel outwash deposits. During the dry periods, Bertrand Creek has gone dry along these more permeable deposits. The hydraulic relationships and the groundwater regime may vary considerably over any particular reach due to the variable nature and somewhat complex distribution of unconsolidated deposits underlying the watershed (Kohut, 1985).

Pepin Creek and Fishtrap Creek flow over permeable sand and gravel deposits (referred to as the Abbotsford Outwash) in their lower reaches. In these areas these thick highly permeable water-bearing gravels feed these creeks.

In the southeastern part of the study area, ice-contact gravel and sand, together with the outwash plains, constitute important water table aquifers that yield adequate supplies of groundwater for irrigation, and industrial and municipal supplies (Halstead, 1966).

The drill log for the GSC test hole at Aldergrove (Figure 5), indicates the presence of two major aquifers above 124 m (407 ft.) depth and no aquifers of any significance below this depth. The Langley Upland hydrostratigraphy, greatly enhanced as a result of drilling the Aldergrove testhole, consists of a fluvial sand aquifer at an average depth of 30 m (98 ft.). This aquifer is part of hydrostratigraphic Unit A, and is the source of groundwater to most domestic wells in the Langley Upland area and larger groundwater users (Halstead, 1986). Underlying this aquifer and extending to approximately sea level, is a stony clay (hydrostratigraphic Unit B) overlying till. Below this till, a number of test holes have encountered a confined gravel and sand aquifer with ample yield.

An assessment of the surficial geology, hydrogeological fence diagram and well records indicate that a portion of the flow in Howes Creek may, by groundwater flow, be feeding Pepin Creek. From 272nd Street to 16th Avenue, Howes Creek flows over permeable sands and gravels which are likely free-draining and underlain by clay. Pepin Creek is about 46 m (150 ft.) lower in elevation. This difference in hydraulic head may result in a significant amount of water flowing from Howes Creek to Pepin Creek (Penner, 1985). Figure 6, showing evelations of water levels in the study area and inferred direction of regional flow, supports this theory of underflow between these creeks.

In the lower reaches of Bertrand Creek, stony clays up to 100 m (328 ft.) or more, overlie a thin till or fine sand below which a deep aquifer, associated with a regional flow system, contains groundwater with excessive chlorides.

The Abbotsford Upland part of the study area is underlain by permeable water-bearing sand and gravel deposits. This aquifer is part of hydrostratigraphic Unit C shown on the hydrogeological fence diagram Figure 3.

For the most part, groundwater occurs under water table conditions. Figure 7 is a map showing depth to non-pumping water levels for the total study area (feet below ground), based on historic data. It basically shows a greater depth to water in the northern higher elevations. Spring discharges and flowing conditions are also shown. Shallow groundwater levels in the area between Laxton Lake and Judson Lake to just west of Fishtrap Creek indicate that the lake level and creek levels are surface expressions of the water table.

Figure 6 displays the contoured elevations of historic non-pumping water levels above sea level. This map has been used to determine the inferred directions of local groundwater flow systems. The general groundwater flow for the study area appears to be in a southerly direction, toward the State of Washington. Where two aquifers exist, some detail has been superimposed over the other aquifer on both Figure 6 and Figure 7. This detail is very incomplete and further delineation of these aquifers could be carried out as more hydrogeologic and hydrochemical data becomes available. As the water level information utilized in the preparation of these maps is based on historic data obtained at various times of the year and from wells of differing depths, the maps may not be entirely representative of water level conditions in localized areas.

Groundwater Level Trends

Figure 8 shows the long-term (1970-1986) hydrograph for B.C. Ministry of Environment and Parks Observation Well #2. This well is located in the Abbotsford Upland area, just south of the Abbotsford Airport (see Figure 9). Water level data has been recorded on a continuous basis at this site since 1972.

The hydrograph shows that groundwater levels respond directly to precipitation. This response corresponds to increased precipitation during the winter months. This effect of precipitation on the groundwater levels is striking with annual fluctuations of over 3 m (10 ft.) recorded in some years. The years of above average water levels correspond to periods of above average precipitation, and the years of below average water levels correspond to periods of below average precipitation. The general trend of the hydrograph shows there has been no long-term decline to suggest that groundwater withdrawals are exceeding recharge to the aquifer. However, Kohut (1987) noted that during field inventory work carried out in 1985 and 1986, that several individuals reported lower groundwater levels in wells located in Section 1, Tp. 13 (south of Abbotsford Airport) and Sections 3, 4, 8 and 9 of Tp. 16 (east of the Airport).

Groundwater Recharge Estimates

Groundwater recharge is that part of precipitation that infiltrates into the ground and percolates downward to recharge the groundwater regime. Estimates of this recharge are important for assessing the amount and rate at which groundwater can be withdrawn on an annual basis without "mining" (i.e. groundwater withdrawals exceeding recharge) the aquifer (Todd, 1980).

For recharge estimates, the study area has been divided into two areas: the Fishtrap Creek/Pepin Creek basins and the Bertrand Creek basin. This was decided on the basis of surficial geology. Fishtrap Creek and Pepin Creek basins are, for the most part, immediately underlain by outwash sands and gravels which are porous and therefore have excellent infiltration properties for rainfall. Bertrand Creek basin occupies part of the Langley Upland, much of which is underlain by glacio-marine stony silts to loamy clays which are relatively impervious, and would not provide as favorable a medium for recharging the groundwater reservoirs. It also is an area of uneven topography and greater relief, which promotes greater surface runoff.

For the purpose of this study, underflow that may originate from outside the boundaries of the study area is not considered and is in addition to the available supply estimated for the two areas.

Fishtrap Creek and Pepin Creek Basins

Kohut (1987) estimated the recharge for the Abbotsford Upland using two methods: the water balance method of Thornthwaite and Mather (1957), and by analyzing available long-term hydrographs. The water balance method indicates recharge to the Abbotsford Upland could be as high as 63 percent of the mean annual precipitation. He obtained figures of 18 to 81 percent of the mean annual precipitation using the well hydrograph method. He assumed a probable specific yield value of 0.25, which is representative of fine to coarse sand and gravel. Using this figure, recharge to the Abbotsford Upland would be in the range of 37 to 81 percent, which is comparable to the results of the water balance method.

The minimum figure of 37 percent is used below to calculate the annual recharge to the groundwater in the Fishtrap/Pepin Creek basins, assuming a basin area of 60.5 km^2 (6.5 x 10^8 sq. ft.) and an average annual rainfall of 1500 mm (4.92 ft.) measured at the Abbotsford Airport.

Therefore the average minimum annual recharge calculation is:

$$(60.5\ km^2) \times (0.37)(1.5\ m) = 33.6 \times 10^6\ m^3$$
$$= 7.3 \times 10^9 \text{ Imperial gallons (approx. 37 cfs).}$$

Bertrand Creek Basin

In the Bertrand Creek basin there is a lack of observation well data and surface runoff figures. However, using 10 percent as a conservatively low value for recharge from precipitation, and assuming a basin area of 49.6 km^2 (5.34 x 10^8 sq. ft.), and an average annual rainfall of 1625 mm (5.33 ft.), measured at CFB Aldergrove, the estimated average annual recharge calculation is:

$$(49.6\ km^2) \times (0.10)(1.625\ m) = 8.1 \times 10^6\ m^3$$
$$= 1.8 \times 10^9 \text{ Imperial gallons (approx. 9 cfs).}$$

This 10 percent recharge figure is likely quite conservative as the recessional channel and floodplain deposits located along much of Bertrand Creek and its tributary, Howes Creek, are probably highly permeable and would allow a much larger percentage of the precipitation to infiltrate to the groundwater reservoirs. The fact that Bertrand Creek has gone dry during dry periods in areas where it flows over sand and gravel deposits, provides evidence there are areas of highly permeable materials.

Groundwater Use

Groundwater is used for many purposes in the study area, including: municipal, irrigation, stock watering, industrial supplies, and domestic requirements. The location of wells having individual capacities >25 gpm are shown on the map of reported high capacity wells (Figure 9). This map shows a range of well capacities and water use, where it is reported. The Abbotsford Upland is an area of high groundwater use for irrigation purposes, especially southeast of Fishtrap Creek, whereas less irrigation wells are shown in the Pepin Creek, Bertrand Creek basins.

Kohut (1987) states that since 1960, general groundwater use has increased significantly in the Abbotsford Upland area. He further states that irrigation use appears to be increasing with the shift to "big gun type" irrigators which require more water to operate and larger wells to maintain instantaneous flow requirements. Kohut (1987) stated that for the Abbotsford Uplands area annual groundwater use, based in part on a door-to-door survey, is estimated at 2.6×10^9 Imp. gallons (13.4 cfs).

It is difficult to quantify the actual amount of groundwater use within this study area as the extent of industrial pumping is not accurately known, and most irrigation wells are unmetered. Also, the demand for irrigation water depends on several factors, such as: weather, types of crops grown and methods of irrigation. There also may be a number of wells not in use, or additional wells in use but not reported. However, a rough estimate of the potential amount of annual groundwater use can be made based on the following assumptions:

1. Domestic wells - 500 gal. per day for 365 days
2. 25-99 gpm capacity wells - Avg. 60 gpm x 100 days (ie: growing season)
3. 100-199 gpm capacity wells - Avg. 150 gpm x 100 days (" " ")
4. 200-499 gpm capacity wells - Avg. 300 gpm x 100 days (" " ")
5. 500-999 gpm capacity wells - Avg. 750 gpm x 100 days (" " ")
6. 1000-2000 gpm capacity wells - Avg. 1500 gpm x 100 days (" ")

Groundwater use figures are given only in gallons per minute since most well records do not define the rate in Imperial or U.S. gallons per minute, or in litres per second.

Fishtrap Creek and Pepin Creek Basins

Calculations for groundwater use are shown below:

Capacities in GPM	No. of Reported Wells	Gallons Per Year
Domestic wells (i.e. <25 gpm)	507	$.09 \times 10^9$
25 - 99	96	$.83 \times 10^9$
100 - 199	42	$.88 \times 10^9$
200 - 499	48	2.42×10^9
500 - 999	4	$.43 \times 10^9$
1000 - 2000	3	$.65 \times 10^9$
	Total	5.3×10^9

(This is equivalent to approx. 27 cfs)

Bertrand Creek Basin

Figure 9, showing reported high capacity wells, indicates that the major groundwater withdrawals are occurring north and east of the confluence of Bertrand Creek and its tributary, Howes Creek. No wells are reported with capacity of 100 gpm or greater in the entire south and western portion of the Bertrand Creek basin.

Calculations for groundwater use are shown below:

Capacities in GPM	No. of Reported Wells		Gallons Per Year
Domestic Wells	569		$.1 \times 10^9$
25 - 99	60		$.52 \times 10^9$
100 - 199	9		$.19 \times 10^9$
200 - 499	11		$.55 \times 10^9$
500 - 999	1		$.11 \times 10^9$
		Total	1.47×10^9

(This is equivalent to approx. 7.5 cfs)

Factors Impacting Groundwater Use

1. As the aquifers underlying the study area extend southerly into the State of Washington, it is quite possible that large groundwater withdrawals on the south side of the border could have impacts on groundwater conditions in the study area. The present extent of groundwater use south of the border is not precisely known, therefore, the impact of groundwater utilization south of the border, upon well use within the study area, cannot be assessed at this time.

2. To date, there are no reported incidences of surface water-groundwater conflicts within the study area. Potential for such conflicts can occur along stream courses where groundwater wells may be hydraulically connected to surface water, and large quantities of groundwater are extracted during low flow periods. Further detailed field studies, including monitoring of creek flows, would be required to assess this more adequately.

3. There are no reported incidences of well interference problems within the study area. However, in the Abbotsford Uplands area, Kohut (1987) states that some shallow wells in topographically higher regions are particularly susceptible to these effects and a deepening of a number of these wells has been necessary in the past. The potential for such conflicts can occur where high producing wells are constructed near each other, and simultaneous pumping occurs.

Water Budget

For the Abbotsford Upland area, Kohut (1987) compared the estimated aquifer withdrawal in 1985 and the estimated average annual recharge. Indications are that pumping approached 45 percent of the annual recharge. The remaining 55 percent of the recharge is lost through natural discharge from springs, flow into deeper and contiguous aquifers, and evapotranspiration. Part of the groundwater withdrawn is returned to the aquifer by return flow. From this assessment, Kohut concluded that groundwater pumping in the Abbotsford Upland area is not exceeding the annual recharge.

Annual recharge calculations prepared for the Fishtrap Creek and Pepin Creek basins using Kohut's minimum recharge figure of 37 percent, gave an estimate of 7.3 x 10^9 Imperial gallons (37 cfs) of recharge. The groundwater use was estimated at 5.3 x 10^9 gallons per year (27 cfs). This figure is most likely highly overestimated if comparing it to Kohut's estimate of 13.4 cfs for groundwater use within the Abbotsford Uplands area where the majority of high capacity wells occur. From these theoretical figures, the amount of groundwater that may be available in this area for further development is estimated to be at least 10 cfs.

In the Bertrand Creek portion of the study area, the recharge rate was calculated using a conservative 10 percent infiltration figure for annual precipitation. A recharge estimate of 1.8 x 10^9 Imperial gallons (9 cfs) was derived with total groundwater use calculated at approximately 1.47 x 10^9 gallons per year (7.5 cfs). From these theoretical figures it is evident that there is further potential for groundwater development in this area.

As the calculations for all recharge and groundwater use calculations were obtained from quite conservative rates of recharge and use, it appears that both the Fishtrap/Pepin Creek basins plus the Bertrand Creek basin have further potential for groundwater development.

To obtain more accurate groundwater budget calculations, further data would be required on actual pumpage rates in the study area. Observation wells could be useful (particularly in areas of high irrigation demand, and especially in the Bertrand Creek basin where none exist) in obtaining relevant data so that more accurate calculations of recharge and effects of groundwater withdrawal can be determined.

7. HYDROCHEMISTRY

Groundwater recharge takes place in the Langley and Abbotsford Uplands and follows paths that are local, intermediate and regional in extent. Local flow systems are present in hydrostratigraphic Unit C and are also recognized in the uplands in hydrostratigraphic Unit A. This groundwater has a relatively short residence time, likely not over 25 years, and its total dissolved solids content does not exceed 120 mg/L (Halstead, 1986). Intermediate flow systems, with water in the age range of probably 10 to 100 years, occur in confined aquifers and multi-till sequences, such as hydrostratigraphic Unit D. The chemical evolution of groundwater from these zones has progressed with total dissolved solids ranging up to 500 mg/L. Residence time probably spans hundreds of years in the regional flow systems. These are present in hydrostratigraphic unit E, and chemical evolution has produced groundwater with total dissolved solids as high as 6,000 mg/L (Halstead, 1986).

Selected Chemical and Physical Parameters

Chloride

Chlorides can result from dissolution of minerals, but in the study area Halstead (1987) suggests that chlorides are likely derived from connate waters in the unconsolidated silty clays deposited under marine conditions. Isotope (O^{18}) studies may be useful in determining whether these waters are of meteoric origin or connate. In the lower reaches of Bertrand Creek, especially in Section 12 and 13 of Township 10, where stony clays up to 100 m (328 ft.) or more overlie a thin till or fine sand, a regional flow system yields groundwater with high chlorides. A number of test holes have been abandoned in the area because of chlorides exceeding 2,000 ppm (Halstead, 1986). Figure 10 is a map of the study area showing the distribution of known chlorides in the regional flow systems. The high chloride area in the lower reaches of Bertrand Creek is contoured on this map and also an area of high chloride is found in the middle to upper reaches of Fishtrap Creek basin.

The Guidelines for Canadian Drinking Water Quality (1978) has set the objective concentration for chloride at less than 250 mg/L. Groundwater with chloride concentrations above this level can have a significant corrosion effect and can be a problem to people with heart and kidney ailments.

Nitrates

Nitrates in groundwater can occur from a number of sources: the atmosphere, legume plants, decaying plant debris, manure, sewerage, nitrogenous fertilizers and industrial wastes. Where values are greater than 10 mg/L, NO_3 as N, contamination from manure, sewerage or septic tank discharge is suspect. According to the Guidelines for Canadian Drinking Water Quality (1978), the maximum acceptable concentration of nitrate in drinking water is 10 mg/L as nitrate-nitrogen. Values greater than 10mg/L may cause infantile methemoglobinemia.

It is not uncommon for shallow dug wells within water table aquifers to become contaminated by leachate from manure stockpiles. The highly soluble nitrates are readily transported to the water table, especially with the heavy winter rains (Halstead, 1986).

Figure 11 shows nitrate-nitrogen concentrations for a number of wells and springs in the study area. The concentrations range up to 39.8 mg/L. These wells with higher concentrations appear to be associated with water table conditions and many of these are quite shallow. As can be seen in Figure 11, all wells with reported nitrate-nitrogen concentrations of 10 mg/L or greater are found within the areas of more permeable sand and gravel water table aquifers. Ongoing investigations of nitrate conditions in the Lower Fraser Valley area by provincial (Kwong, 1986a, 1986b) and federal government agencies are being undertaken, including the Abbotsford Upland area.

Sodium

Figure 12 is a map of the study area showing the known sodium concentrations in groundwater. Much higher concentrations have been found in the Bertrand Creek basin than Pepin and Fishtrap basins. Concentrations in the water table aquifers are very low, often under 10 mg/L, whereas, in the deeper confined aquifers concentrations range as high as 1,263 mg/L.

The Guidelines for Canadian Drinking Water Quality (1978) recommends that health authorities should be notified when the sodium concentrations exceed 20 mg/L, as sodium intake can be significant to people suffering from hypertension or congestive heart failure, as they may require a sodium-restricted diet.

High sodium concentration can be very significant as related to irrigation. Base exchange reactions with soils can lead to the creation of alkali soil which has limited agricultural value (Halstead, 1986).

Halstead (1986) reports that the quality of water from the lower aquifer encountered in the G.S.C. test hole at Aldergrove, has a high sodium-bicarbonate content (sodium tested at 305 mg/L, bicarbonate 678 mg/L). This indicates that use of the lower aquifer may be limited for irrigation purposes.

Specific Conductance

Specific conductance is a term that refers to the electrical conductivity of water at 25°C due to the presence of dissolved minerals. In general, specific conductance multiplied by a factor of .65 gives an estimate of the total dissolved solids in groundwater (Halstead, 1986).

The specific conductance readings are displayed on Figure 11. This map basically shows that wells completed in local shallow flow systems have low total dissolved solids content (conductivity usually less than 200 micromhos/cm at 25°C), whereas wells completed in intermediate or regional deeper flow systems have correspondingly higher specific conductance values. Higher specific conductance values up to 6,800 micromhos/cm at 25°C in the regional flow systems of the study area can be attributed to high sodium chloride content in the groundwater.

Pollution

Groundwater within portions of the study area, such as the Abbotsford Upland and other areas underlain by surficial water-bearing sands, silts and gravel deposits, is vulnerable to pollution. The study area is agriculturally oriented and common sources of potential contamination are: fertilizers, pesticides, and animal wastes.

Figure 11 displays nitrate-nitrogen concentrations. This map shows that relatively high concentrations often are found in association with water table conditions, indicating that groundwater contamination from nitrate-nitrogen is occurring.

The federal and provincial governments have taken groundwater samples from a limited number of wells in the Abbotsford Upland area where there is intensive agricultural pesticide use, in order to assess potential aquifer contamination from pesticides. Results to date have shown only localized amounts (in ppb's) in a few wells. Further research is required to assess the significance of these results.

8. CONCLUSIONS AND RECOMMENDATIONS

The Fishtrap/Pepin/Bertrand Creek basins comprise an area of 111 km^2 (43 sq. mi.), much of which are underlain by major aquifers.

The southern reaches of Fishtrap and Pepin Creek basins are underlain by a succession of sand and gravel deposits which mainly constitute a high yield water table aquifer. This aquifer supplies water for industrial, municipal, irrigation and domestic use. Presently, it appears, groundwater pumping is not exceeding the annual recharge and additional groundwater supplies could be readily developed. The annual recharge to the Fishtrap and Pepin Creek basins was estimated at 1,048 L/s (37 cfs) with average annual use determined at approx. 765 L/s (27 cfs). These are fairly conservative figures.

Groundwater levels are closely tied to the lakes, and groundwater discharge is a major flow component of Fishtrap Creek. Indications are that underflow from the Howes Creek watershed could be a major component to Pepin Creek flow. Groundwater quality overall, is quite good in the Fishtrap and Pepin Creek basins but the underlying permeable sand and gravel aquifer is susceptible to pollution, as indicated by locally high nitrate-nitrogen concentrations measured in samples of groundwater from wells in this area.

Water budget calculations, plus Kohut's conclusions regarding the Abbotsford Upland, give evidence there is further potential for groundwater development in the Fishtrap Creek and Pepin Creek basins.

The Bertrand Creek watershed is geologically quite different from the Fishtrap Creek watershed and Pepin Creek watershed. Bertrand Creek flows over glacio-marine clays for most of its length. The basin is known to be underlain in places by at least two confined aquifers. Recharge to these aquifers is hard to quantify as long-term observation well hydrographs are not available. Also, the annual runoff from the basin is not known but is likely substantial as much of the basin is underlain by impervious clays.

Although there is a lack of good quality recharge and aquifer withdrawal data, a water budget was estimated. An infiltration rate of 10 percent was used for recharge calculations. The annual recharge to the Bertrand Creek basin was estimated at 9 cfs and the average annual use as 7.5 cfs. As these calculations for recharge and groundwater use were obtained from conservative estimates, indications are there is further potential for groundwater development.

In the lower reaches of Bertrand Creek a regional flow system yields groundwater with excessive chlorides. The GSC test hole in the upper reaches tested water in the lower aquifer and found it had a high sodium-bicarbonate content. High chlorides have also been found in a regional flow system in the Fishtrap/Pepin Creek basin. Groundwater development below 122 m (400 ft.) depth is not recommended.

The following recommendations are provided for consideration:

1. As the aquifers underlying the study area are an important source of water for industrial, municipal, domestic and agricultural purposes, monitoring of the resource is recommended. This can be accomplished by establishing an observation well in Fishtrap Creek, Bertrand Creek, and Pepin Creek basins, located in areas of high irrigation demand, to monitor water level trends and groundwater quality.

2. Undertake additional investigations of present and projected municipal, industrial and irrigation use of groundwater in the study area to better define quantitative estimates.

3. Monitor the annual flow of the creeks in the study area to better define the water budget.

4. Carry out further studies regarding high nitrate-nitrogen concentrations and possible pesticide contamination in the water table aquifers.

5. Obtain groundwater data from Washington State officials to ascertain the significance of groundwater use in their portion of the water basins of Fishtrap/Pepin/Bertrand Creeks.

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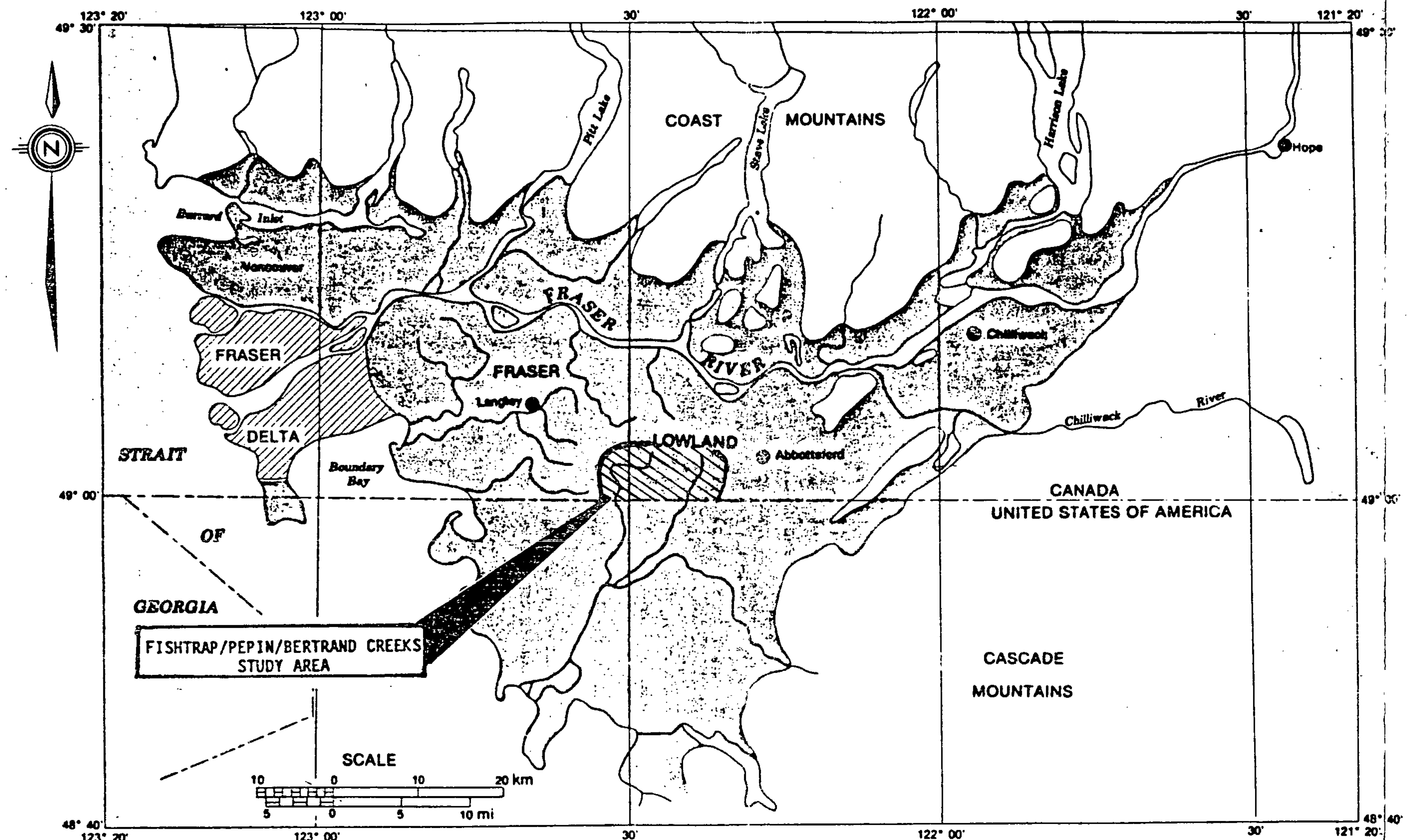
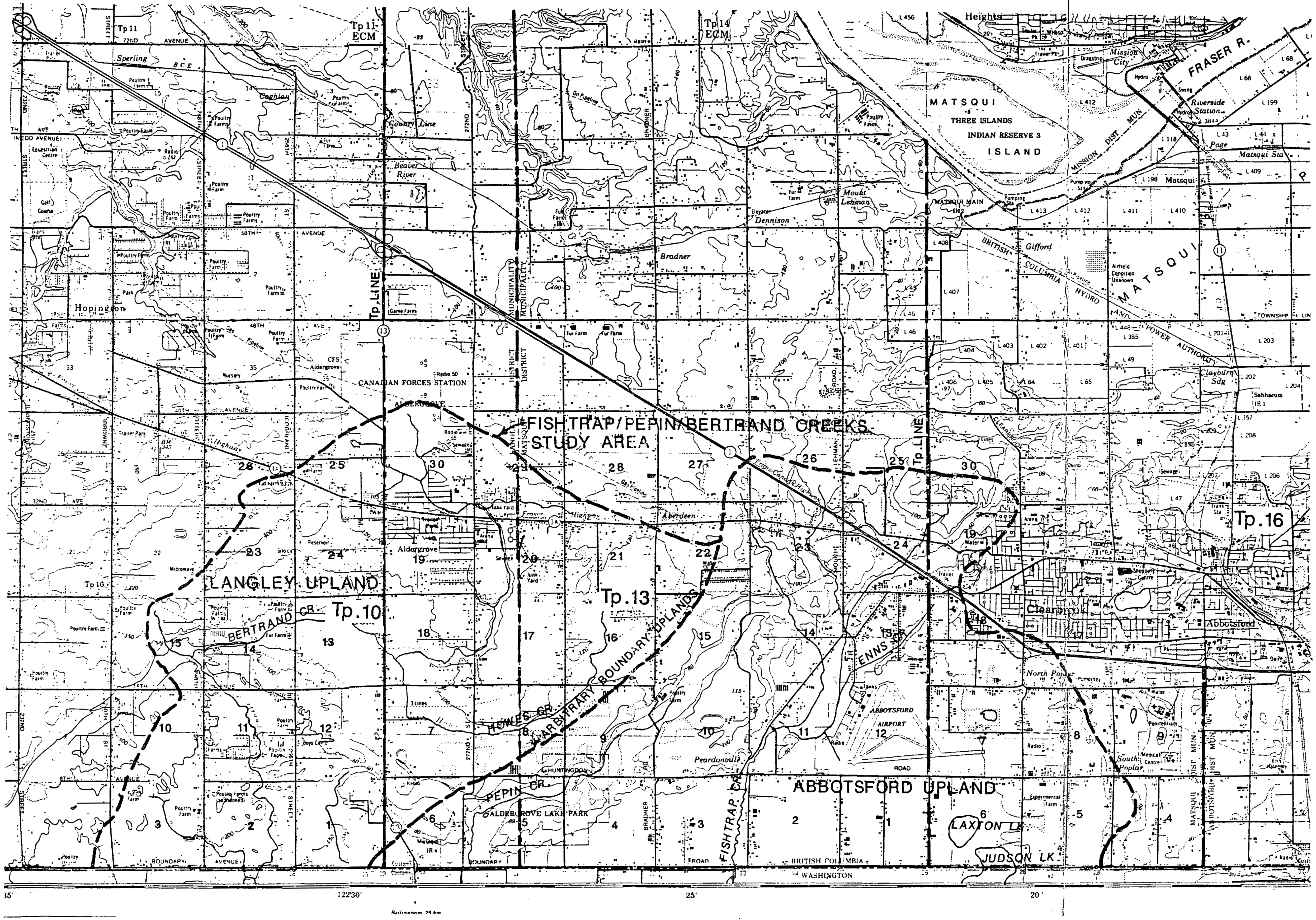
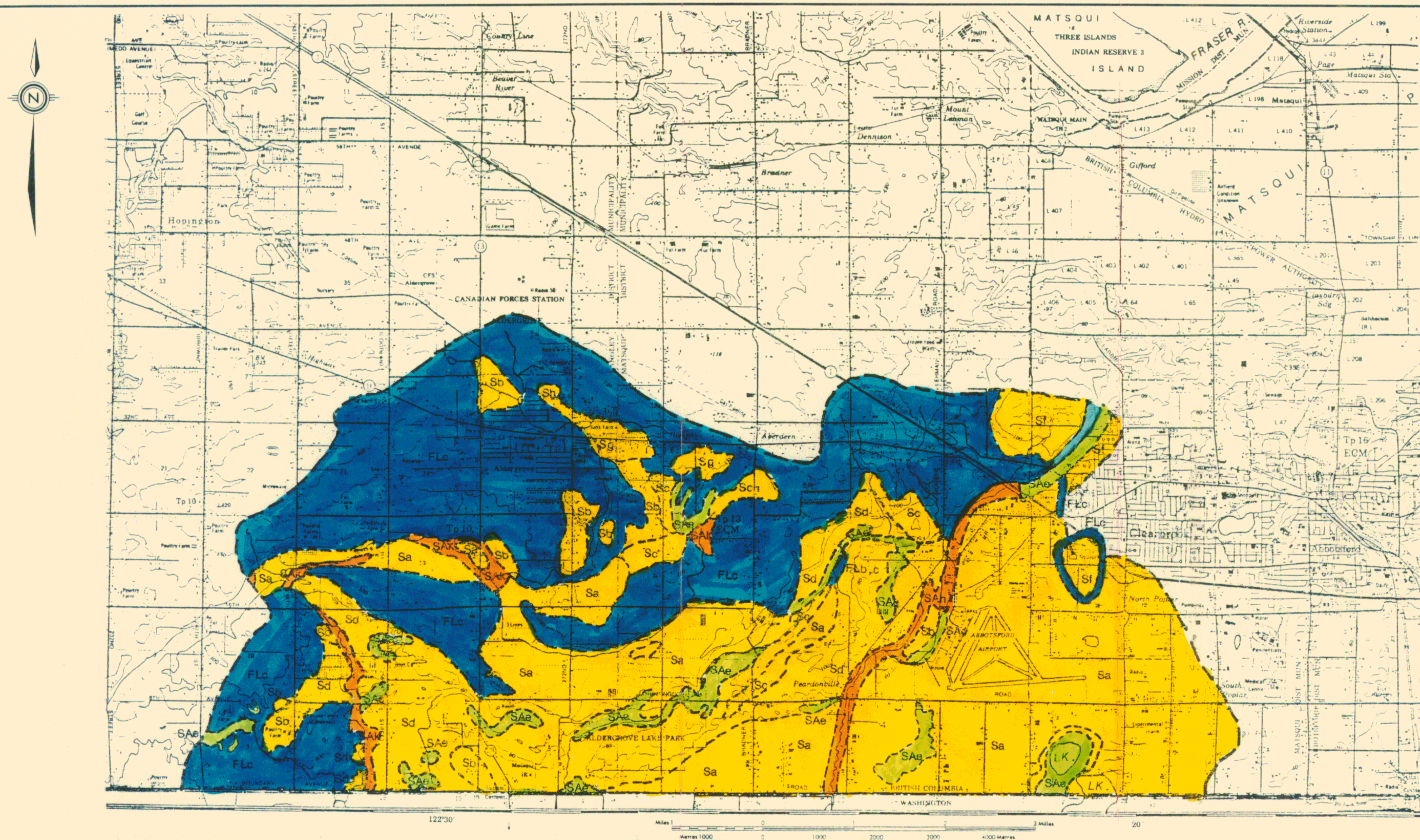


Province of British Columbia Ministry of Environment and Parks Water Management Branch	TO ACCOMPANY REPORT ON FISHTRAP/PEPIN/BERTRAND CREEKS WATER MANAGEMENT BASIN PLAN GROUNDWATER COMPONENT	FIGURE 1: LOCATION MAP

87-32-1



Province of British Columbia Ministry of Environment and Parks Water Management Branch	TO ACCOMPANY REPORT ON FISHTRAP/PEPIN/BERTRAND CREEKS WATER MANAGEMENT BASIN PLAN GROUNDWATER COMPONENT	FIGURE 2: STUDY AREA



LEGEND

POSTGLACIAL

SALISH SEDIMENTS

SAb-e — Bog, swamp, and shallow lake deposits SAe upland peat up to 8+m thick

SAh-k — Stream deposits, includes channel fill, floodplain, and overbank sediments: SAh, lowland stream channel fill and overbank sandy loam, and clay loam; in places contains disseminated organic material; up to 6 m thick. SAk, lowland stream channel fill sand and gravel, minor silt, and clayey silt, up to 5 m thick

PLEISTOCENE

SUMAS DRIFT

Sa,e,i — Recessional glaciofluvial deposits: Sa, recessional channel and floodplain deposits laid down by proglacial streams; gravel and sand up to 40 m thick.

Sb,c **Sd** — Recessional ice-contact deposits: Sb, ice-contact gravel and sand containing till lenses and clasts of Fort Langley glaciomarine sediments (FLc), 2 to 5 m thick, overlying FLc: Sc, ice-contact gravel and sand containing till lenses and clasts of Fort Langley glaciomarine sediments (FLc), 2 to 5 m thick, overlying FLb,e: Sd, ice-contact gravel and sand containing till lenses and clasts of Fort Langley glaciomarine sediments (FLc), 5

Sf,g — Lodgment and minor flow till: Sg, sandy till and substratified drift 0.5 to 2m. thick in most places overlying Fort Langley glaciomarine sediments (FLc)

FORT LANGLEY FORMATION

FLa,c,d — Glaciomarine deposits, marine sediments, and minor till: FLc, glaciomarine stony silt to loamy clay.

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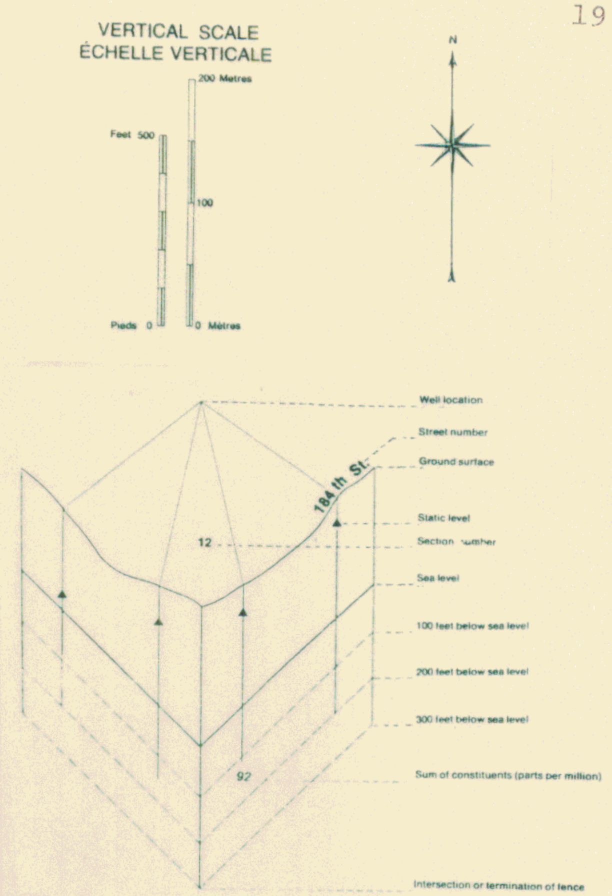
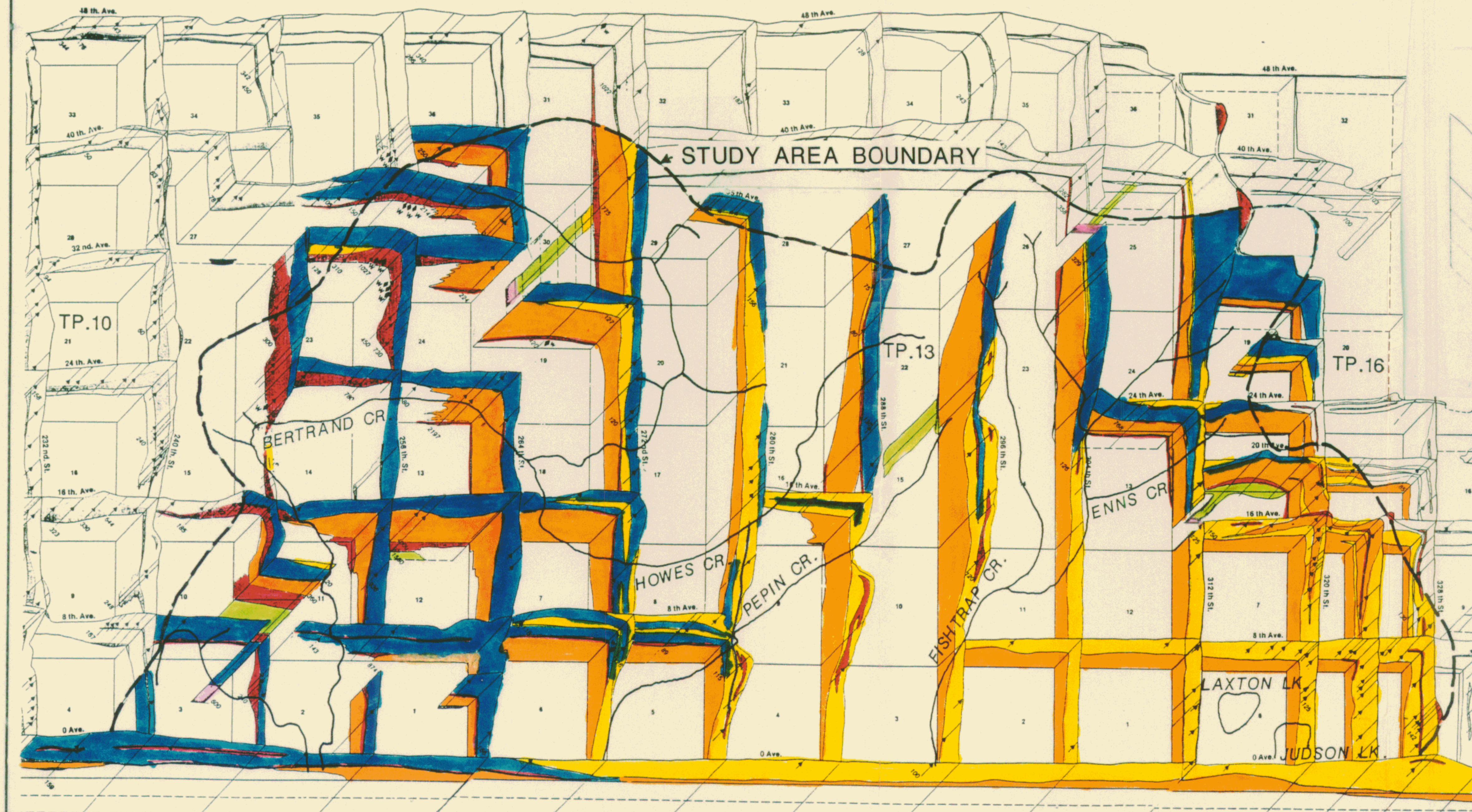
TO ACCOMPANY REPORT ON
FISHTRAP/PEPIN/BERTRAND CREEKS
WATER MANAGEMENT BASIN PLAN
GROUNDWATER COMPONENT

FIGURE 4:
SURFICIAL GEOLOGY
(after ARMSTRONG, 1980)

87-32-4





HYDRO-STRATIGRAPHIC UNIT	DESCRIPTION
A	THIS HYDROSTRATIGRAPHIC UNIT INCLUDES CLAY, STONY CLAY AND CLAY-LIKE DEPOSITS REPORTED IN DRILLERS' LOGS. MUCH OF THE UNIT INCLUDES STONY SILTY CLAYS WITH THE STONE CONTENT VARYING FROM SCARCE TO MANY. THE UNIT ALSO CONTAINS SILTY LENSES, SANDY SILTS AND IN PLACES MARINE SHELLS ARE ABUNDANT. THE DEPOSITIONAL ENVIRONMENT WAS MAINLY MARINE BUT PERMEABLE FLUVIAL MATERIALS ARE ALSO INCLUDED. WELLS HAVE BEEN COMPLETED IN THIS UNIT AND GROUNDWATER IS AVAILABLE AT DEPTHS COMMONLY UP TO 100 FEET (30 M) WITHIN THE MORE PERMEABLE ZONES. WATER QUALITIES ARE OF THE HCO_3 TYPE WITH TOTAL DISSOLVED SOLIDS LESS THAN 150 PARTS PER MILLION
B	THIS UNIT IS ALSO OF GLACIO-MARINE ORIGIN AND CONSISTS OF STONY CLAYS WITH SHELLS. THE STONE CONTENT AS WELL AS THE CLAY CONTENT IS APPARENTLY GREATER THAN IN THE ABOVE UNIT AND DRILLERS' LOGS REFER TO IT AS 'STICKY-STONY-CLAY'. IN PLACES THE UNIT MAY BE MORE THAN 100 FEET (30 M) THICK AND NOWHERE PROVIDES WATER IN SUFFICIENT VOLUME TO BE ECONOMIC
C	SAND AND GRAVEL DEPOSITED BY MEELTWATERS ISSUING FROM WASTING ICE MASSES ACCUMULATED AS OUTWASH APRONS AND DELTAS THAT COVER EXTENSIVE AREAS AT OR NEAR THE PRESENT LAND SURFACE. THESE HYDROSTRATIGRAPHIC UNITS ARE UP TO 100 FEET (30 M) THICK AND CONSTITUTE FREE WATER-TABLE AQUIFERS THAT FUNCTION AS SPONGES TO COLLECT FOR GROUNDWATER STORAGE ALMOST ALL THE PRECIPITATION FALLING ON THEIR SURFACE. WATER QUALITIES ARE OF THE HCO_3 TYPE WITH LESS THAN 100 PARTS PER MILLION TOTAL DISSOLVED SOLIDS. IN PLACES THESE UNITS PROVIDE PRODUCTION WELLS WITH VOLUMES RANGING FROM 100 TO MORE THAN 2000 IMPERIAL GALLONS PER MINUTE (450 TO 9000 LITRES PER MIN.). ELSEWHERE HYDROSTRATIGRAPHIC UNITS OF SIMILAR ORIGIN OCCUR AT DEPTH AS CONFINED AQUIFERS ASSOCIATED WITH DRIFT DEPOSITS REPRESENTATIVE OF EARLIER GLACIATIONS. WATER QUALITIES ARE OF THE $NAHCO_3$ TYPE WITH TOTAL DISSOLVED SOLIDS GREATER THAN 200 PARTS PER MILLION
D	MATERIALS DEPOSITED BY MELTWATERS AND GLACIER ICE DURING EXPANSION AND THINNING COMPRISE THIS HYDROSTRATIGRAPHIC UNIT. THE MATERIALS INCLUDE TILLS OR DIAMICTONS TOGETHER WITH SANDS AND GRAVELS. IN PLACES WHERE THICK TILLS OR DIAMICTONS ARE ENCOUNTERED WITH INTERBEDDED, WATER-BEARING SAND AND GRAVEL LENSES, IT IS ASSUMED THAT THE UNIT AS A WHOLE IS REPRESENTATIVE OF A SINGLE DRIFT SHEET RATHER THAN MULTIPLE TILL UNITS. MASSIVE TILL UNITS MORE THAN 100 FEET (30 M) THICK MAY REPRESENT TWO TILL UNITS BACK TO BACK. ISOLATED TILL LENSES ARE ENCOUNTERED IN PLACES AT OR NEAR THE SURFACE AND THESE ARE REMNANTS FROM THE FINAL STAGES OF WASTING ICE AFTER THE LAST GLACIATION. INTERCONNECTING PERMEABLE GRAVEL AND SAND LENSES FUNCTION AS CONDUITS FOR THE MOVEMENT AND STORAGE OF LARGE VOLUMES OF GROUNDWATER AND HENCE THE HYDROSTRATIGRAPHIC UNIT AS A WHOLE IS PRODUCTIVE. WATER QUALITIES ARE OF THE HCO_3+CL TYPE WITH TOTAL DISSOLVED SOLIDS LESS THAN 300 PARTS PER MILLION
E	SILTS, CLAYEY SILTS AND FINE SANDS, DEPOSITED IN FLUVIAL, ESTUARINE AND MARINE ENVIRONMENTS COMPRISE THIS HYDROSTRATIGRAPHIC UNIT. ALTHOUGH THIS UNIT PROVIDES FOR THE STORAGE AND MOVEMENT OF LARGE VOLUMES OF GROUNDWATER, IT IS NOT PARTICULARLY ATTRACTIVE AS AN AQUIFER BECAUSE WATER QUALITIES ARE OF THE $CL+SO_4$ TYPE
F	BEDROCK IS IDENTIFIED WHEN THE MATERIAL RETURNED WITH DRILLING MUDS OR BAILER SAMPLES INCLUDES ORGANIC AND COAL-BEARING MORE INDURATED SILTS, SHALES AND SANDSTONE. CRYSTALLINE GRANITIC TYPE ROCKS AND BASALTS THAT COMPRISE MUCH OF THE MOUNTAINS BORDERING THE AREA HAVE NOT BEEN IDENTIFIED FROM BORE HOLES REPRESENTED ON THE FENCE DIAGRAMS
♦ W	ORGANIC MATERIAL, PEAT OR WOOD REPORTED AT THIS HORIZON

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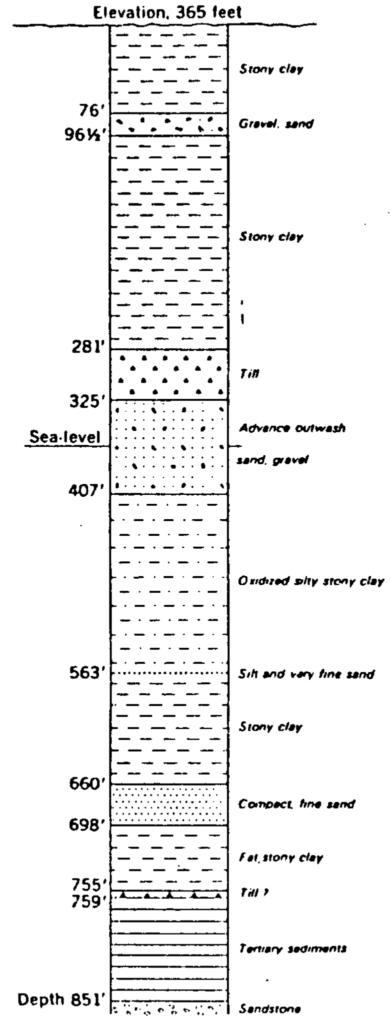
Water Management Branch

TO ACCOMPANY REPORT ON
FISHTRAP/PEPIN/BERTRAND CREEKS
WATER MANAGEMENT BASIN PLAN
GROUNDWATER COMPONENT

FIGURE 3:
HYDROGEOLOGICAL FENCE DIAGRAM
(after HALSTEAD, 1986)

87-32-3



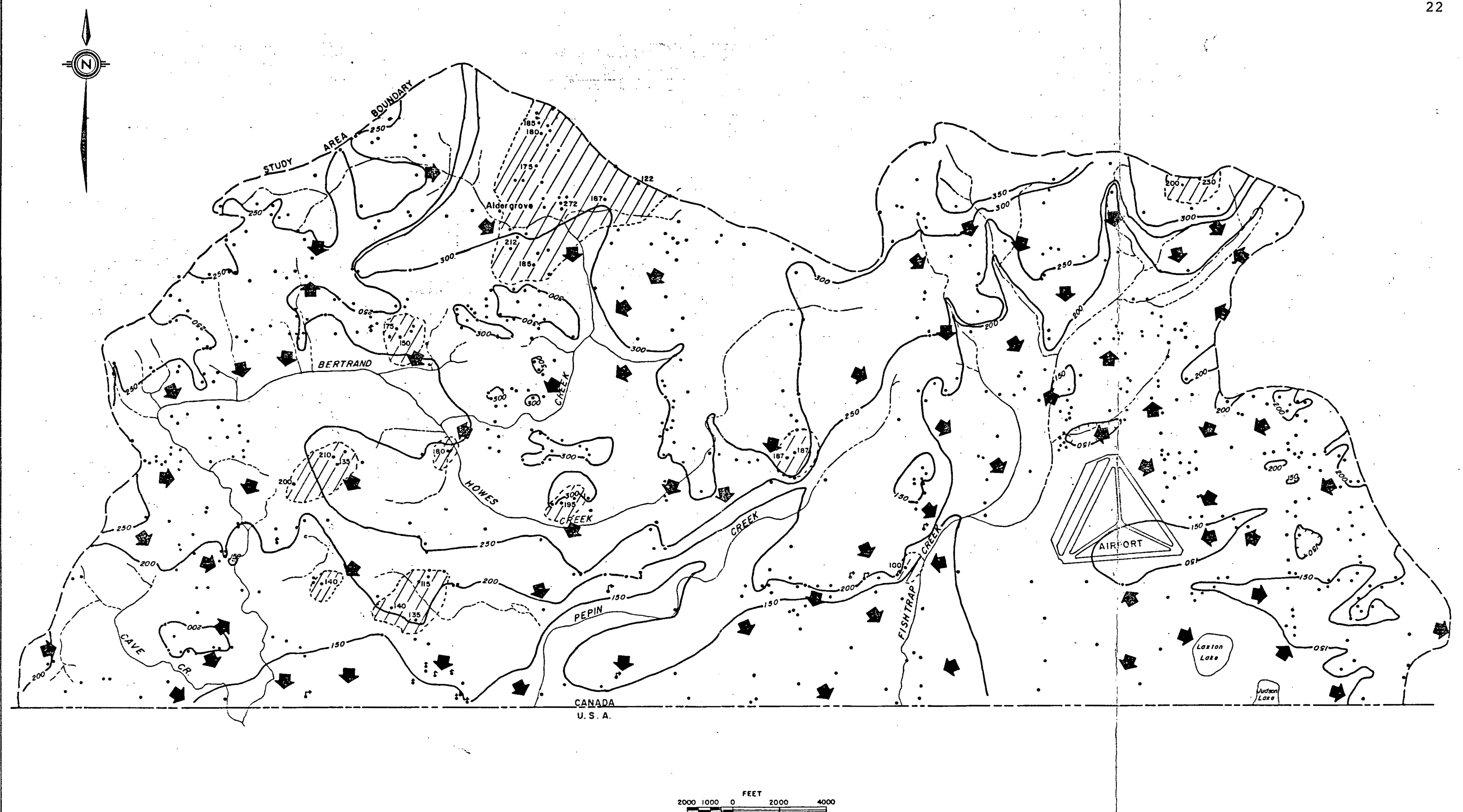
LOG OF HOLE

The elevation of the test hole is 365 feet above sea-level.

Material	Thickness (feet)	Depth (feet)
Oxidized stony clay	14	14
Blue stony clay, drilled open hole	62	76
Silty sand, water, static level, 40 ft;	8	84
Coarser sand, at 88 ft. clay lenses	4	88
Fine to coarse sand, some gravel, samples collected at 2 ft. intervals and a mechanical analysis run on a composite sample	8 1/2	96 1/2
Blue clay, stony, shell fragments at 120 ft.	113 1/2	210
Fine silty sand, some water	2	212
Stony blue clay	69	281
Till	46	325
Coarse sand, gravel, dirty outwash, water-bearing; sieve analysis of material 329 to 336 ; 338 to 344	19	344
Medium to coarse sand, some gravel	21	365
Medium to coarse sand, clay lenses	19	384
Medium to coarse sand	4	388
Medium to fine sand, clay lenses	4	392
Medium to fine sand	8	406
Fine sand, silted	1	407
Silty, stony clay, oxidized	156	563
Silt and very fine sand	1	564
Blue clay, odd stones, hydrometer analysis of material 659 to 660	96	660
Fine to medium sand, silted, compact	8	668
Fine to medium sand, clay lenses	4	672
Fine to medium sand, compact	9	681
Fine to medium sand	8	689
Boulder, granitic type	2	691
Hard packed fine sand	2	693
Fine sand, clay lenses	5	698
Stony fat blue clay	57	755
Till-like material; bailer samples mostly soled(?) pebbles and clayey silt	4	759
Gritty, varicoloured clay with organic material; lenses of white material dissolve in HCl leaving shards of quartz; at 773 feet woody material and at 779 a shell fragment	24	783
As above with more coal, probably fusane	68	851
Sandstone	1	852

	Province of British Columbia Ministry of Environment and Parks Water Management Branch	TO ACCOMPANY REPORT ON FISHTRAP/PEPIN/BERTRAND CREEKS WATER MANAGEMENT BASIN PLAN GROUNDWATER COMPONENT	FIGURE 5: STRATIGRAPHY OF ALDERGROVE TEST HOLE (after HALSTEAD, 1966)

87-32-5



LEGEND

—200— DEPTH TO WATER LEVEL-CONTOUR (CONTOUR INTERVAL-50 FEET)

INFERRED DIRECTION OF GROUNDWATER FLOW (EAST OF FISHTRAP CREEK FROM A. KOHUT 1987.

DENOTES GENERALIZED AREAS WHERE SOME REPORTED WATER LEVELS ARE FOR A DEEPER AQUIFER

•140 REPORTED WELL IN DEEPER AQUIFER (ELEVATION OF WATER LEVEL IN FEET)

• REPORTED WELL

REPORTED SPRING

REPORTED FLOWING WELL

NOTE: ELEVATION OF WATER LEVEL IN WELLS FOR MAJOR DEVELOPED AQUIFER. (FEET ABOVE SEA LEVEL) BASED ON REPORTED HISTORIC NON-PUMPING WATER LEVELS.

REFERENCES		
DWG No	DESCRIPTION	DATE

REVISIONS		
No	DESCRIPTION	DATE

SURVEYED
DATE
DESIGNED D. JOHANSON
CHECKED
DATE
DRAWN
APPROVED
HEAD, DRAFTING SECTION
DATE AUG. 1987

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FISHTRAP/PEPIN/BERTRAND CREEKS
WATER MANAGEMENT BASIN PLAN
GROUNDWATER COMPONENT
FIGURE 6
WATER LEVEL ELEVATIONS

ENGINEER DATE | RECOMMENDED DATE | APPROVED DIRECTOR DATE

FILE NO 0346695-2
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NTS MAP NO 92G/1
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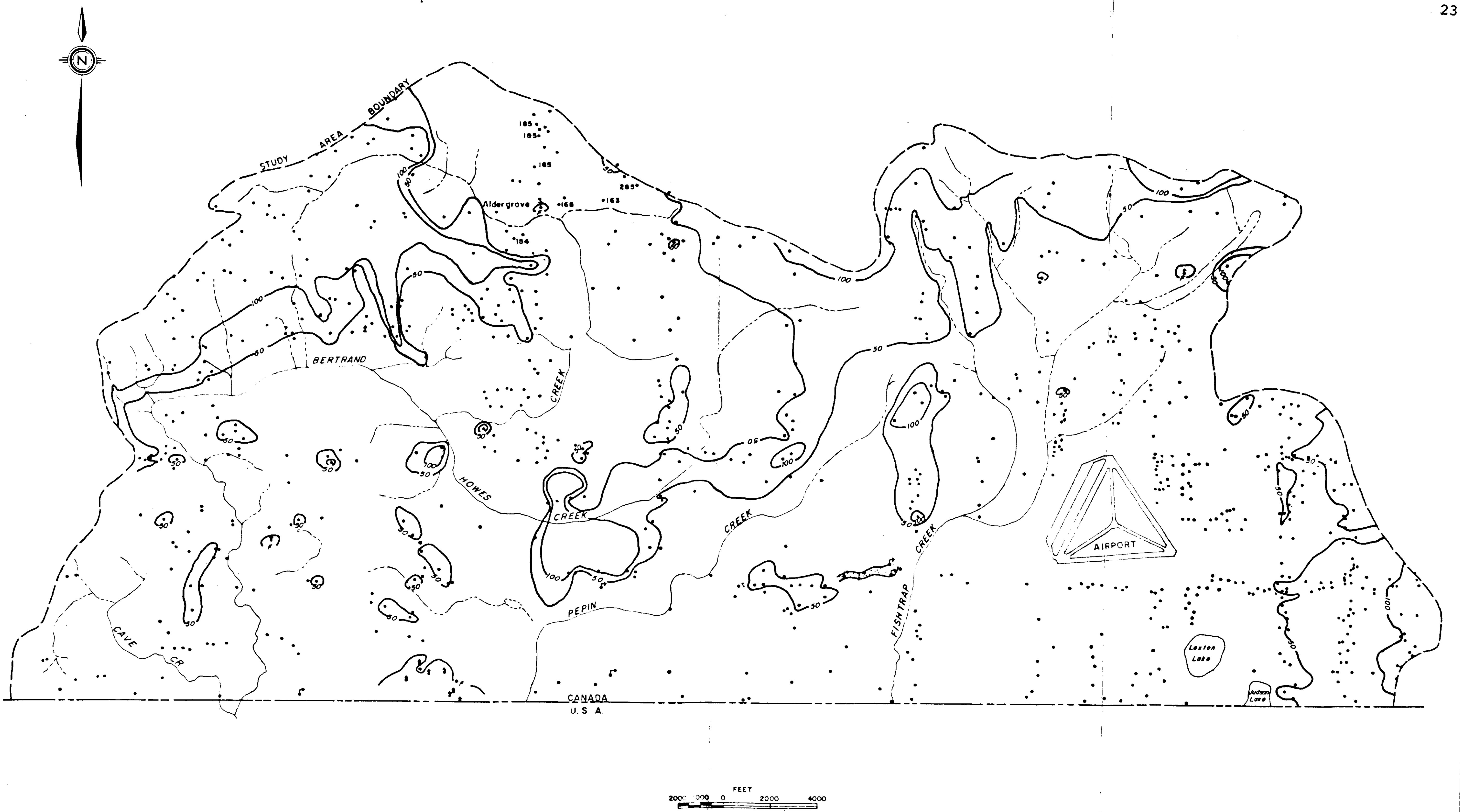

LEGEND

- —100— DEPTH TO WATER LEVEL - CONTOUR (CONTOUR INTERVAL - 50 FEET
- — F — AREA OF FLOWING ARTESIAN WELLS
- • REPORTED WELL
- REPORTED FLOWING ARTESIAN WELL
- REPORTED SPRING
- •165 REPORTED WELL IN DEEPER AQUIFER (DEPTH TO NON - PUMPING WATER LEVEL IN FEET)
- AREA OF REPORTED SPRING DISCHARGE

NOTE DEPTH TO NON-PUMPING WATER LEVELS IN WELLS (FEET BELOW GROUND LEVEL) BASED ON HISTORIC REPORTED WATER LEVELS.

REFERENCES		
DWG No	DESCRIPTION	DATE

REVISIONS		
No	DESCRIPTION	DATE
1	REMOVED SHALLOW AQUIFER AREA, ADDED WELL DEPTH	FEB. 1988

SURVEYED
DATE
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DATE AUG. 1987

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FISHTRAP / PEPIN / BERTRAND CREEKS
WATER MANAGEMENT BASIN PLAN
GROUNDWATER COMPONENT
FIGURE 7:
REPORTED WATER LEVELS

FILE NO 0346695-2
ENG PROJECT NO
NTS MAP NO 92 G/1
SCALE AS SHOWN
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REV
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ENGINEER DATE | RECOMMENDED DATE | APPROVED DIRECTOR DATE

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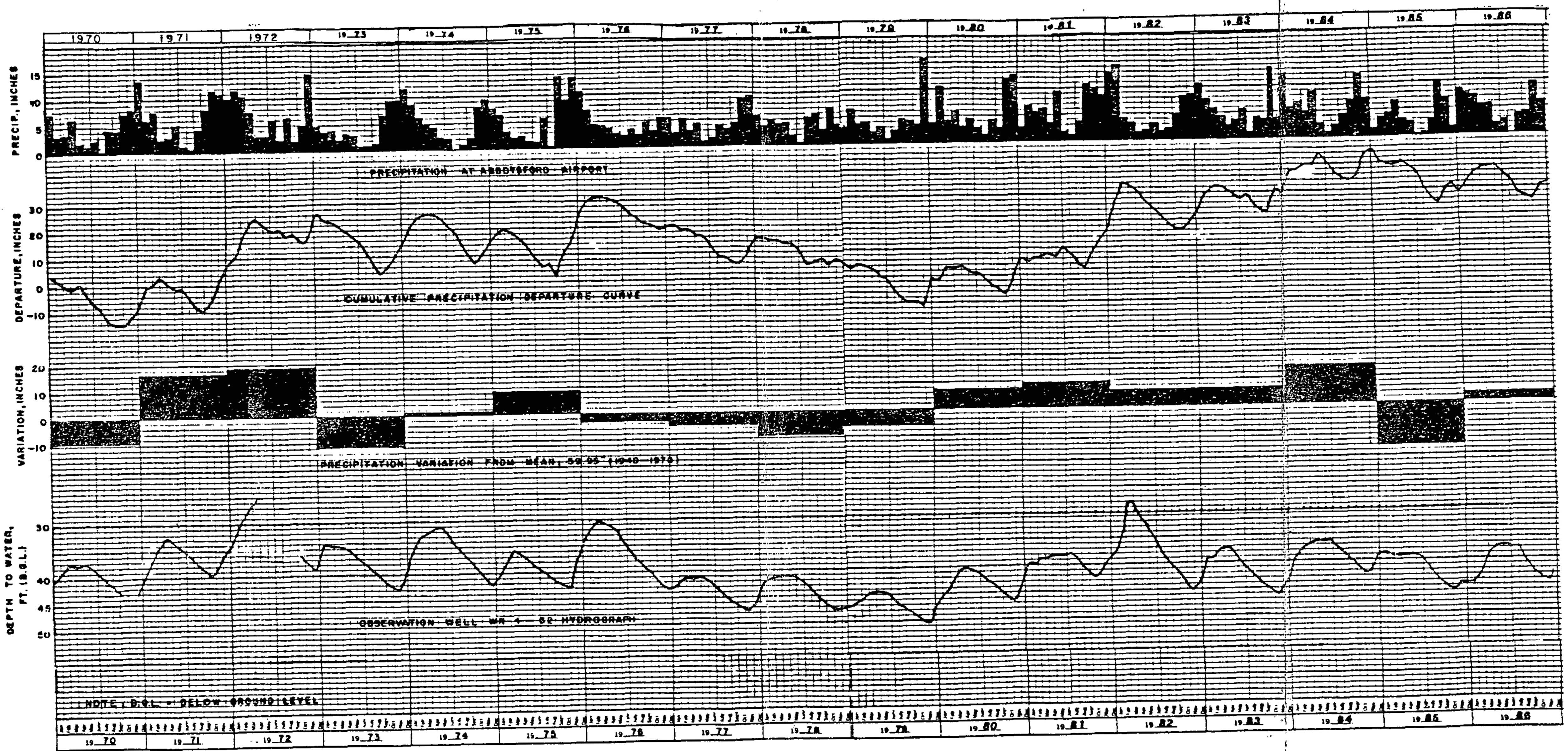

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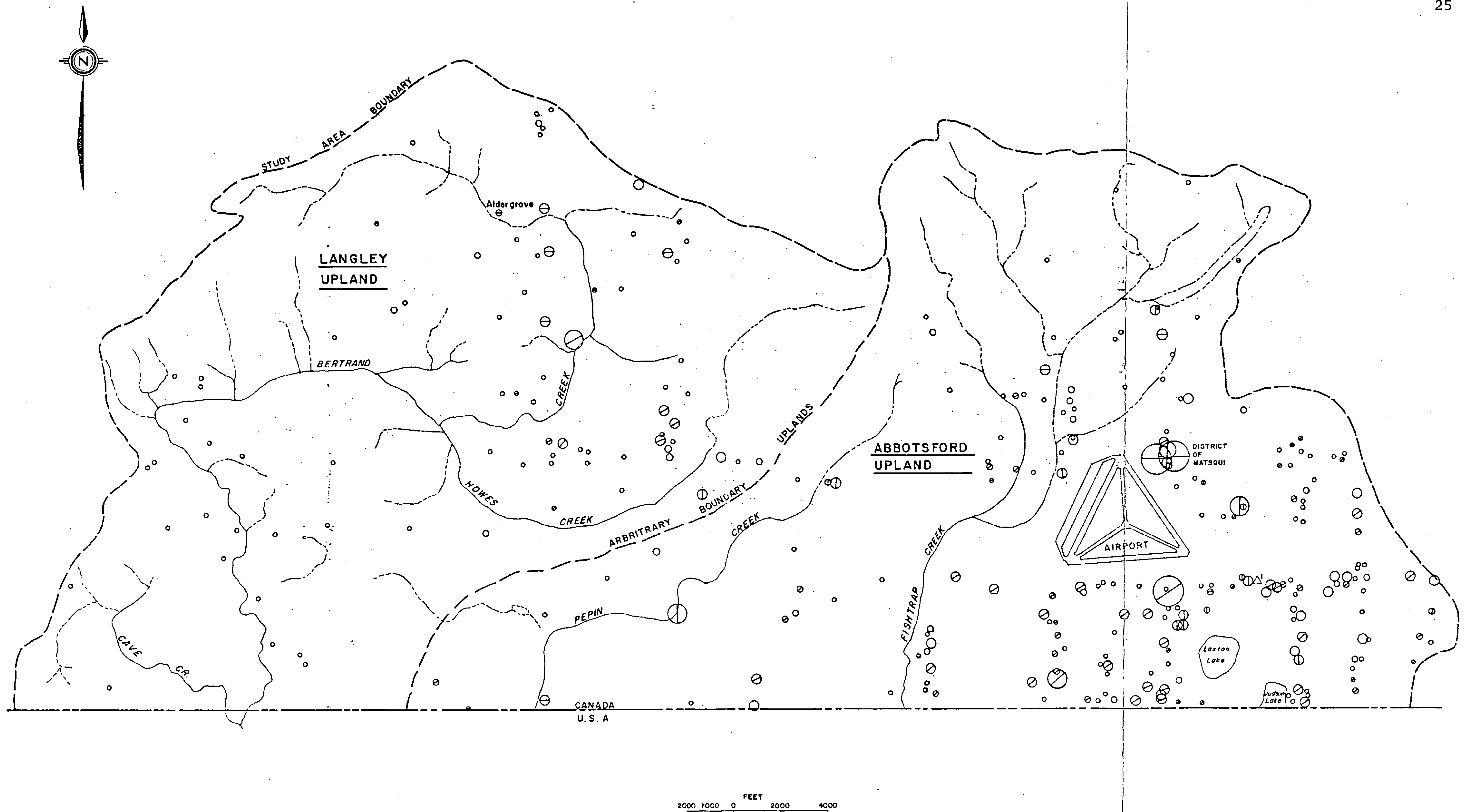
87-32-8



LEGEND

- 25-99
- 100-199
- 200-499
- 500-999
- 1000+

REPORTED WELL CAPACITIES IN GPM

- INDUSTRIAL INCLUDES FOOD PROCESSING, FISH HATCHERY
- MUNICIPAL AND WATER DISTRICTS
- IRRIGATION AND OTHER AGRICULTURAL USE
- USE NOT REPORTED
- OBSERVATION WELL

REFERENCES		
DWG No	DESCRIPTION	DATE

REVISIONS		
No	DESCRIPTION	DATE

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DATE ____
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HEAD DRAFTING SECTION DATE AUG. 1987

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FISHTRAP/PEPIN/BERTRAND CREEKS
WATER MANAGEMENT BASIN PLAN
GROUNDWATER COMPONENT
FIGURE 9:
REPORTED HIGH CAPACITY WELLS AND OBSERVATION WELLS

ENGINEER ____ DATE | RECOMMENDED ____ DATE | APPROVED DIRECTOR ____ DATE

FILE NO 0346695-2
ENG PROJECT NO
NTS MAP NO 92G/1
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SHEET ___ OF ___

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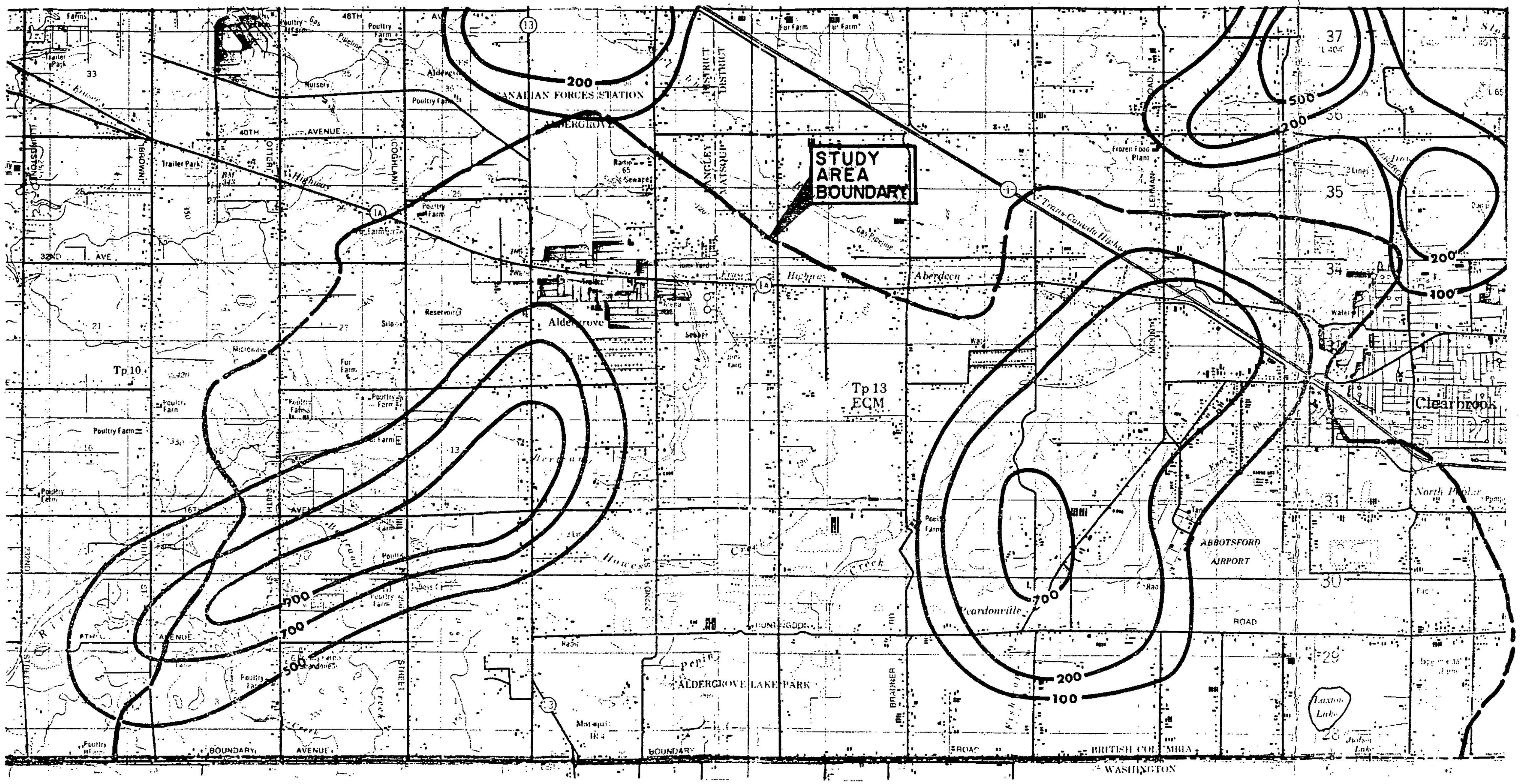
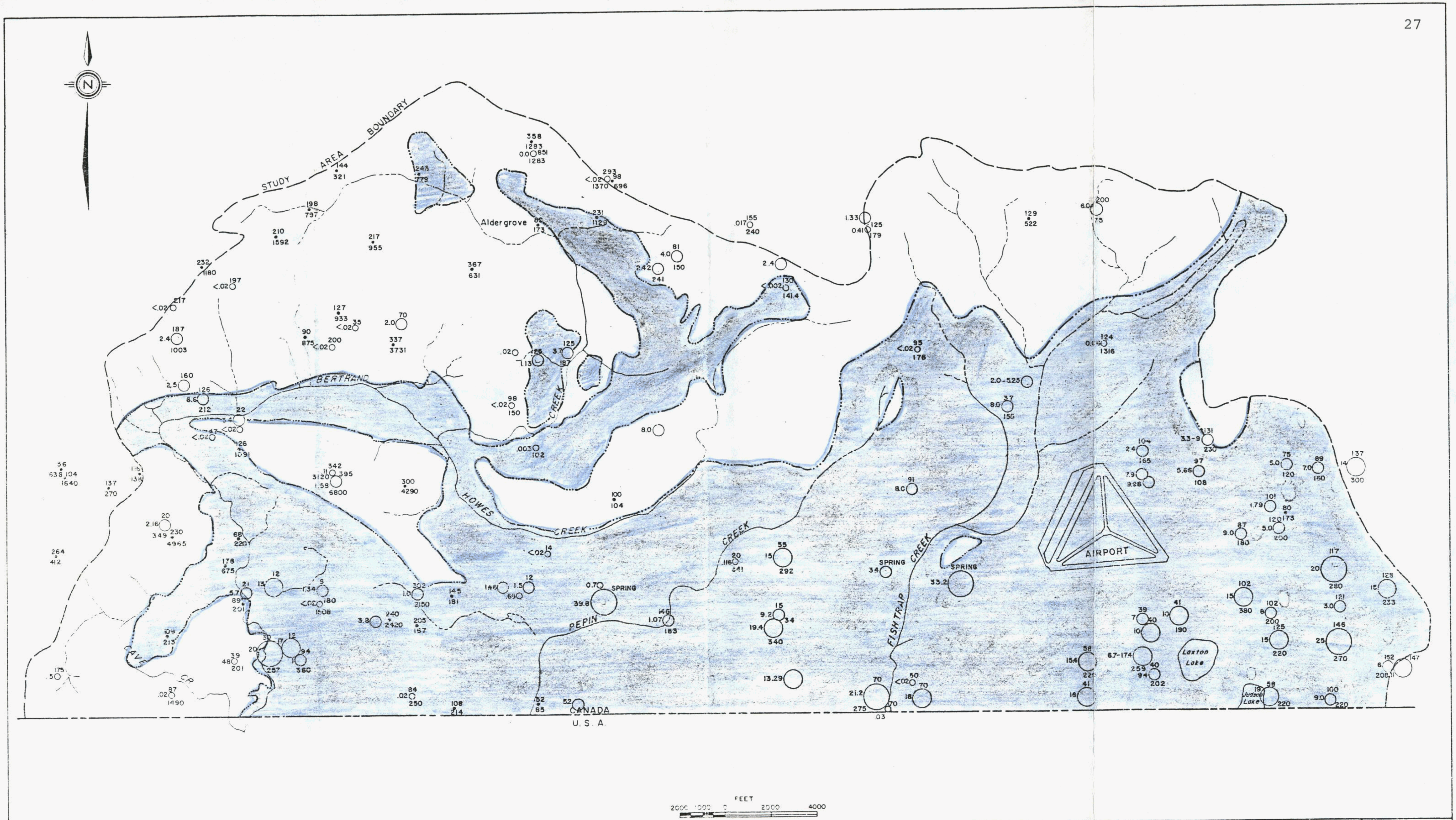


500 LINE OF EQUAL CHLORIDE VALUE, NUMBER INDICATES MG/L.

Province of British Columbia Ministry of Environment and Parks Water Management Branch	TO ACCOMPANY REPORT ON FISHTRAP/PEPIN/BERTRAND CREEKS WATER MANAGEMENT BASIN PLAN GROUNDWATER COMPONENT	FIGURE 10: DISTRIBUTION OF CHLORIDES IN REGIONAL FLOW SYSTEMS (after HALSTEAD,1986)

87-32-10



LEGEND

- 0 - 0.99
- 1.0 - 9.9
- 10 - 19.9
- 20.0 +

mg/l REPORTED NITRATE-NITROGEN CONCENTRATIONS

87 - WELL DEPTH IN FEET
.02
1490 - CONDUCTIVITY OF GROUNDWATER AT 25°C

108
214 WELL WITH CONDUCTIVITY READING BUT NO NITRATE-NITROGEN DATA

WATER TABLE AQUIFER (BASED ON SURFICIAL GEOLOGY)

REFERENCES		
DWG No	DESCRIPTION	DATE

REVISIONS		
No	DESCRIPTION	DATE

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DATE
DESIGNED D. JOHANSON
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DATE
DRAWN
APPROVED
HEAD, DRAFTING SECTION
DATE AUG. 1987
ENGINEER DATE RECOMMENDED DATE APPROVED DIRECTOR DATE

Province of British Columbia — Ministry of Environment and Parks — WATER MANAGEMENT BRANCH

FISHTRAP / PEPIN / BERTRAND CREEKS
WATER MANAGEMENT BASIN PLAN
GROUNDWATER COMPONENT
FIGURE 11:
OCCURRENCE OF NITRATE-NITROGEN CONCENTRATIONS IN GROUNDWATER

FILE NO 0346695-2
ENG. PROJECT NO
NTS MAP NO 92 G/1
SCALE AS SHOWN
NEGATIVE NO
DRAWING NO 87-32-11
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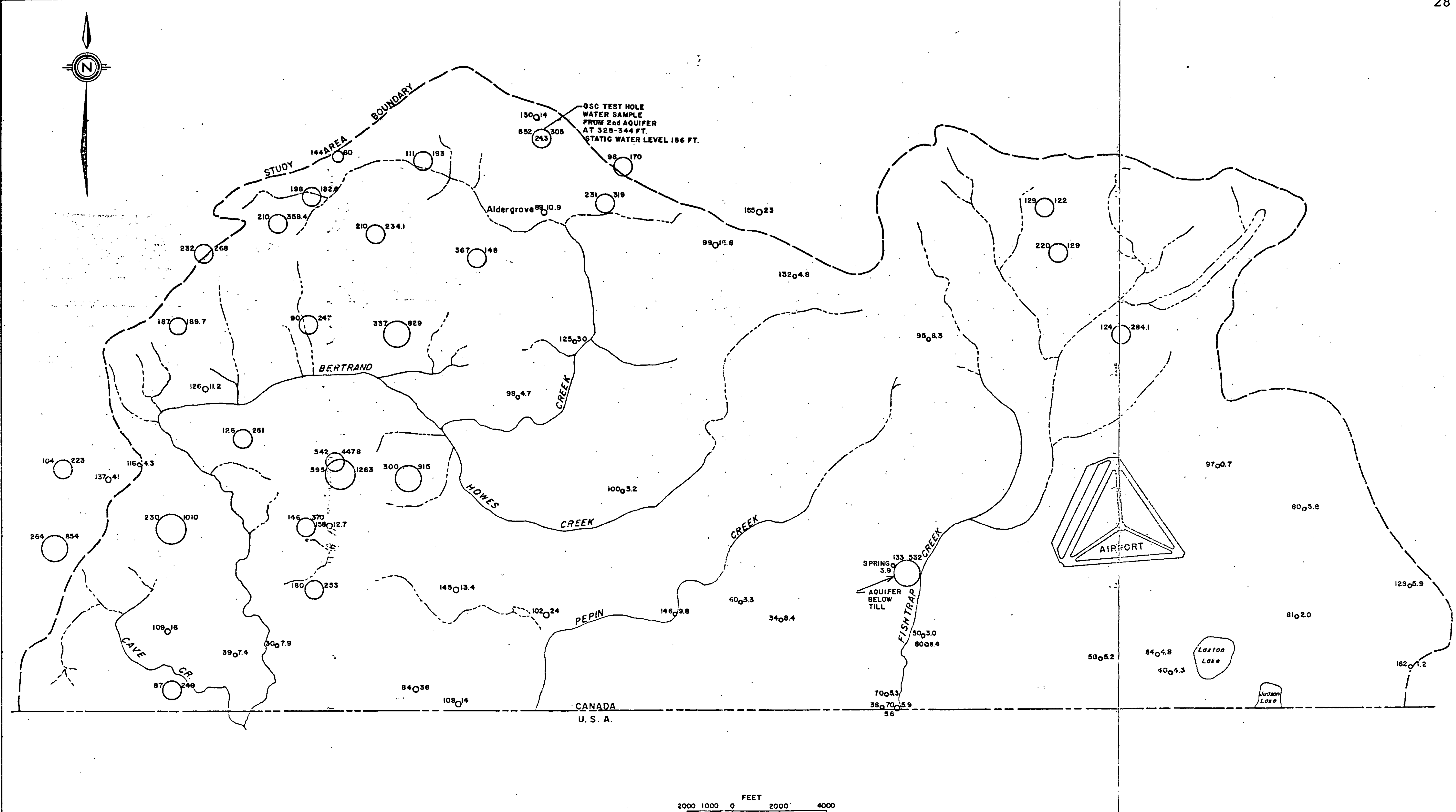

LEGEND

- 0-9.9
- 10-49.9
- 50-99.9
- 100-499.9
- 500-999.9
- 1000+

mg/l REPORTED SODIUM CONCENTRATIONS

WELL DEPTH IN FEET
852 (24.3) 305 - SODIUM CONTENT IN mg/l
SODIUM ABSORPTION RATIO (SAR)
WELL IS LOCATED AT CENTER OF CIRCLE

REFERENCES		
DWG No	DESCRIPTION	DATE

REVISIONS		
No	DESCRIPTION	DATE

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DATE AUG. 1987

Province of British Columbia
Ministry of Environment and Parks
WATER MANAGEMENT BRANCH

FISHTRAP/PEPIN/BERTRAND CREEKS
WATER MANAGEMENT BASIN PLAN
GROUNDWATER COMPONENT
FIGURE 12

OCCURRENCE OF SODIUM CONCENTRATIONS IN GROUNDWATER

FILE NO 0346695-2
ENG PROJECT NO
NTS MAP NO 92G/1
SCALE AS SHOWN
NEGATIVE NO
DRAWING NO. 87-32-12
REV.
SHEET OF

ENGINEER DATE | RECOMMENDED DATE | APPROVED DIRECTOR DATE

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