

PROJECT NUMBER D707101

EVALUATION OF
MAXIMUM GROUNDWATER POTENTIAL
FROM WELLS IN THE SOUTHWEST CORNER
OF D.L. 28
WEST OF THE ISLAND HIGHWAY
AT DEEP BAY

Prepared for
DEEP BAY WATERWORKS DISTRICT
R.R. 1, Site 150, C-4
BOWSER, B.C. V0R 1G0

Prepared by
PACIFIC HYDROLOGY CONSULTANTS LTD.
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AUGUST 15, 1995



August 15, 1995

Deep Bay Waterworks District
R.R. 1, Site 150, C-4
BOWSER, B.C. VOR 1G0

Attention: Mr. E.R. DeCosta
Chairman of the Trustees

Subject: Evaluation of Maximum Groundwater Potential from Wells in the Southwest Corner of D.L. 28 West of the Island Highway at Deep Bay

Dear Sirs:

1.0 INTRODUCTION

The purpose of this letter is to report on the first phase of a two-phase investigation to further evaluate the feasibility of constructing additional production wells on the four hectare (10 acre) triangular parcel of land containing Deep Bay Waterworks District (DBWD) Wells 4-77, 5-85 and 6-90 and consisting of the southwest corner of D.L. 28 on the west side of the Island Highway at Deep Bay on Vancouver Island. This investigation has been carried out in accordance with a letter dated October 29, 1993 from Pacific Hydrology Consultants Ltd. (PHCL) to DBWD and, as subsequently discussed in several telephone discussions since that time between Ann Badry, P. Geo., Hydrogeologist/Manager of PHCL, and either Mr. Frank Hieronymi, Works Superintendent for DBWD, or Mr. John Motherwell, P. Eng., of John Motherwell & Associates Engineering Ltd. (JMAEL). Initially, approval to carry out this evaluation was given by the District on December 17, 1993. Subsequently, the terms of reference were modified as dictated by the course of events, with completion of the project delayed pending resolution of property ownership.

Included in Appendix A are area and water well location maps (Figures 1 and 2, Pages A - 1 and A - 2); Figure 2 shows the locations of the DBWD wells referred to in this letter-report, as well as the locations of other test holes which have been used to interpret the distribution and thickness of the Quadra Sand Aquifer in the area of D.L. 28 and to construct hydrogeological cross-sections A - A' and B - B' (Figures 3 and 4, Pages A - 3 and A - 4).

The hydrogeological cross-sections are included to illustrate the known distribution and thickness of the Quadra Sand Aquifer in the area proposed for the installation of two or more additional production wells, as well as to illustrate certain features of the hydrogeology of the area which have some bearing on concerns raised by various agencies as to the potential impacts which could result from the proposed increased groundwater withdrawal from the southwest corner of D.L. 28. Selected details about the wells and test holes used to construct the hydrogeological cross-sections are contained in Tables 1 and 2 in



Appendix B. Proposed locations for Wells 7 and 8 are shown on Figure 5 in Appendix A (Page A - 5). Also shown on Figure 5, as discussed later in this report, is an estimated wellhead protection area (WHPA) for each of the existing DBWD water supply wells located in the southwest corner of D.L. 28.

Background information concerning groundwater supply development and an evaluation of groundwater supply potential on D.L. 28 west of the Island Highway at Deep Bay, specifically, and in the Deep Bay area in general, is contained in the following documents prepared by PHCL (or its predecessor company, E. Livingston Associates, ELA) for either DBWD or JMAEL, in the period 1978 to present:

1. A letter-report from ELA (A. Badry) to JMAEL dated February 8, 1978 "Re: Well Construction and Testing, Deep Bay Waterworks District", which discussed the results of a test drilling program of three test holes to develop additional groundwater for the Deep Bay water system and the completion of two of these as screened wells - a well along Gainsburg Road, which is now utilized as a Provincial Observation Well (310) and Production Well 4-77, which is located in the southwest corner of D.L. 28.
2. A letter-report from PHCL dated June 21, 1985 to JMAEL on the subject "Construction and Testing of Deep Bay Waterworks District Well No. 5".
3. A letter from PHCL dated June 8, 1988 to DBWD on the subject "Selection of a Site for Proposed Well No. 6 for Deep Bay Waterworks District".
4. A letter-report from PHCL dated February 27, 1989 to JMAEL on the subject "Selection of a Site for Proposed Well No. 6 for Deep Bay Waterworks District".
5. A report from PHCL dated December 27, 1990 to DBWD titled "Construction and Testing of Deep Bay Waterworks District Well No. 6".
6. A letter-report from PHCL dated December 20, 1991 to DBWD on the subject "Groundwater Supply Potential in the Southwest Corner of D.L. 28 west of the Island Highway at Deep Bay".
7. Miscellaneous correspondence and other information in PHCL's files concerning groundwater supply issues at Deep Bay - in particular, work carried out for Genstar Development Company to evaluate the feasibility of developing sufficient quantities of groundwater on adjacent D.L. 1 and D.L. 86 to the west to support a community water system to serve 230 residential units proposed for that area.

In preparing this letter-report, all background information contained in the above documents was reviewed and summarized as required, and the following three published Geological Survey of Canada documents relevant to the surficial geology and hydrogeology of the Deep Bay area were also again reviewed:

1. GSC Paper 77-17, **Quadra Sand: A Study of the Late Pleistocene Geology and Geomorphic History of Coastal Southwest British Columbia**; by J.J. Clague, 1977, 24 pp.
2. GSC Memoir 318, **Surficial Geology of Horne Lake and Parksville Map-Areas, Vancouver Island British Columbia**; by J.G. Fyles, 1963, 142 pp.

3. GSC Bulletin 144, **Groundwater Resources of the Coastal Lowland and Adjacent Islands, Nanoose Bay to Campbell River, East Coast, Vancouver Island**; by E.C. Halstead and A. Treichel, 1966, 42 pp.

To assist in an evaluation of groundwater supply potential and implications of increased groundwater source development by the installation of additional water supply wells in the southwest corner of D.L. 28 at Deep Bay, PHCL also obtained the following information from government agencies:

- Water level data from February 1990 to March 1995 for Provincial Observation Well No. 310, from which an hydrograph has been constructed (see Figure 6 in Appendix A).
- Precipitation data for Little Qualicum Hatchery Station and Mud Bay Station.

As mentioned previously, recent concerns have been expressed by several government agencies as to the possible impact to the groundwater regime and, in particular, to Gainsburg Swamp, that may result from the withdrawal of additional groundwater on D.L. 28. Correspondence concerning this issue, most of which has been forwarded to PHCL by DBWD, includes the following:

1. A letter dated June 14, 1995 from Qualicum Band of Indians to the attention of T.K. Ovanin, R.P.F., Ministry of Environment, Lands and Parks "Re: Application by Deep Bay Waterworks District - #1406967".
2. A facsimile message dated June 19, 1995 from Bonnie Blue of Regional District of Nanaimo to Pacific Hydrology stating that RDN wishes to have assurance that the installation of additional water supply wells on the subject parcel of land will not have any impact on the naturally occurring water levels and, as such, that withdrawal of additional groundwater will not pose any threat to the wildlife habitat represented by the natural wetland, locally referred to as Gainsburg Swamp.
3. A letter dated June 26, 1995 from Deep Bay Waterworks District to Ministry of Environment, Lands & Parks (Attention: Mr. T.K. Ovanin, R.P.F., Land Officer) on the subject "Application to Lease Crown Land for Additional Well Sites".

For easy reference, copies of the above-listed documents are included in Appendix C.

2.0 AQUIFER HYDROGEOLOGY

2.1 Quadra Sand Aquifer Distribution

Details about the character, extent and distribution of the Quadra Sand in the Deep Bay area are important because the Quadra Sand is the aquifer which yields water to the Deep Bay Waterworks District Wells, as well as to other water supply wells in the area, at Bowser and at the Provincial Seed Orchard located

on D.L. 86 south of the DBWD Wells. In the Deep Bay area, the Quadra Sand seems to occur at an elevation of 30 m (100 ft) or more; at some locations, the Sand is overlain by thin remnants of silt or glacial till but, at other locations within short distances, the Sand extends to surface, as it does at the sites of the DBWD Wells in the southwest corner of D.L. 28. A few available deep lithologs from test holes in the subject area indicate that the Quadra Sand is underlain by stony silt, till and/or compact silt and silty sand; the underlying complex of sediments is probably best described as ice-contact sediments which were deposited by or in contact with glacial ice.

The distribution of the thickest part of the saturated Quadra Sand is important, since the likelihood of constructing a well(s) of sufficient capacity for the Deep Bay Water System is greatest where the saturated aquifer thickness is greatest. Although test drilling in the Deep Bay area to date has shown that the distribution of the Quadra Sand is uneven, it is not possible from present subsurface information to delineate the area(s) of greatest saturated thickness, except to say that the saturated thickness apparently increases to the south and east. This is consistent with mapping by Clague (GSC reference 1 listed above), which shows Deep Bay as the northern extent of the Sand. Figure 2 in Appendix A includes Clague's map of the regional distribution of the Quadra Sand along the east coast of Vancouver Island.

2.2 Groundwater Hydrology

The majority of recharge to the Quadra Sand Aquifer originates inland to the south, with movement of water through the Aquifer from the recharge area toward the discharge end of the groundwater flow regime that terminates at the sea. Where the Quadra Sand becomes thinner and probably pinches out completely, as illustrated on the hydrogeologic cross-section of Figure 4, persistent springs and swampy conditions prevail due to continuous groundwater discharge from the outcropping Sand.

The period of recharge to the Quadra Sand Aquifer occurs during the winter season of high precipitation that extends from the end of November to April. This is shown by the response of the water level in Provincial Observation Well No. 310, where highest groundwater levels consistently have occurred in early March to mid-April, with the lowest water levels occurring near the end of November, following which the water level rise begins. The hydrograph for Well No. 310 (see Figure 6, Page A - 6, Appendix A) indicates that the patterns of recharge and, consequently, the high water level in the Quadra Sand Aquifer in the Deep Bay area varies somewhat from year to year; however, the apparent differences may be due in part to the fact that the hydrograph is plotted from month-end water level data, suggesting that care must be exercised in drawing precise conclusions from the hydrograph.

There is no question that the existence of Provincial Observation Well No. 310 is an important part of management of the groundwater resource at Deep Bay and, since Well No. 310 is located outside the main influence of the withdrawal of groundwater by the Deep Bay Wells, it is particularly effective for monitoring natural groundwater fluctuations. Attention is drawn to several features of the hydrograph for

Provincial Observation Well No. 310 that illustrate the behaviour of the groundwater regime in the Deep Bay area - at least, since the start of water level records in February 1990:

- Despite the fact that water use in the Deep Bay system has been increasing, the low water level that occurred during the period since water level records began was in the Fall of 1990, at the end of the first year of records and before the installation of Well 6-90.
- As mentioned above, the low water level in the Aquifer varies from year to year - perhaps due to variations in the timing and patterns of recharge.
- For each year of record, there is a rapid rise in the water level in the Aquifer as soon as evapotranspiration ends in the late fall and precipitation starts; the water level decline through the summer season of "no recharge" to the low water level in the fall occurs more gradually and, since the end of evapotranspiration in the subject area probably coincides with the onset of the winter rains, it is not possible from information on hand to separate out the interrelationship and individual roles of evapotranspiration and precipitation, nor is it necessary; however, all indications are that the yield of the Quadra Sand Aquifer is precipitation dependent, with rapid recovery of the water table once fall precipitation starts.
- There is no evidence that increasing withdrawal by the existing Deep Bay Water Supply Wells in the period February 1990 to March 1995 has had any impact on the groundwater regime at Deep Bay; further, information on interference between wells is also known from the response of the pumping test of the most recent of the DBWD water supply wells, 6-90, during which Well 5-85 was pumped simultaneously and which continued pumping beyond the termination of the pumping of Well 6-90.
- PHCL's report of December 27, 1990 stated that it was not possible to address the question as to whether additional groundwater was available for withdrawal by other water supply wells in the area of Wells 4-77, 5-85 and 6-90 and that one or two seasons of simultaneous use, during which the water level in Provincial Observation Well No. 310 was observed would assist in a rational decision about the installation of additional water supply wells in that area. Figure 6, the hydrograph for Provincial Observation Well No. 310, clearly shows that present withdrawal of groundwater by the Deep Bay Wells is not "mining" the groundwater, as would be indicated by a steady decline in the water level in Well No. 310 and, therefore, in the aquifer. Despite increased withdrawal rates by the Deep Bay Wells between 1990 and 1995, complete seasonal recovery of the water level in the aquifer has occurred each year since records started; this is shown by the hydrograph for Provincial Observation Well No. 310 and is reflected in continued overflow (groundwater discharge) from the Quadra Sand Aquifer.

An important issue with respect to the groundwater regime in the Deep Bay area, with which approving agencies are most concerned is, as mentioned in the Introduction, possible impacts to Gainsburg Swamp due to increased groundwater withdrawal by DBWD from additional wells proposed to be installed on D.L. 28. The large seasonal fluctuation in the water level in the Quadra Sand Aquifer shown by the response of the water level in Provincial Observation Well No. 310 is consistent with the observations by long-time local residents that the overflow at Gainsburg Swamp varies considerably throughout the year, with substantial overflow during the winter months as soon as the capacity of the Quadra Sand to accept

water has been exceeded and the Sand can't hold additional water, to a situation where there is very little or no overflow at the end of the summer.

Despite the significant seasonal variation in the water level in the Quadra Sand Aquifer, which is interpreted to occur naturally, largely due to significant withdrawals of shallow groundwater by vegetation through the processes of evaporation and transpiration, the development and withdrawal of additional groundwater through the installation of other wells in the Aquifer on the southwest part of D.L. 28, is not likely to have any effect on the behaviour of the overflow at Gainsburg Swamp. Evidence for drawing this conclusion includes the following:

- Pumping tests of existing DBWD Wells on the subject parcel of land showed that insignificant interference occurred between the Wells which have a horizontal separation distance of about 200 m (660 ft); for example, PHCL's report of December 27, 1990 titled "Construction and Testing of Deep Bay Waterworks District Well No. 6" indicates that interference drawdown of less than 0.06 m (0.2 ft) occurred in Well 5-85 due to the pumping of Well 6-90 at a constant rate of 9.09 l/sec (144 USgpm). Such an interference is insignificant but is not surprising, since the capture zone for each of the Wells is expected to be elliptical in the direction of groundwater flow, interpreted from area topography to be approximately southwest to northeast.
- The lack of any trend to a decline in the water level, as illustrated on the hydrograph for Provincial Observation Well No. 310, despite the increasing withdrawal of groundwater by the Deep Bay Wells, is confirmation that additional groundwater is available for exploitation.
- The existing DBWD water supply wells are not located directly upslope of Gainsburg Swamp such that their cone of influence does not extend a sufficient lateral distance to intercept groundwater that would potentially reach the Swamp.

3.0 POTENTIAL CAPACITY OF QUADRA SAND AQUIFER AT DEEP BAY

PHCL's report of December 27, 1990 titled "Construction and Testing of Deep Bay Waterworks District Well No. 6", as well as a subsequent letter-report of December 20, 1991 titled "Groundwater Supply Potential in the Southwest Corner of D.L. 28 West of the Island Highway at Deep Bay", stated that the limitation to the withdrawal of groundwater by wells in the area of Deep Bay Wells 4-77, 5-85 and 6-90 is the ability of any particular well to withdraw water from the fine-grained Sand Aquifer.

Based on estimates of the amount of groundwater potentially moving through the Quadra Sand Aquifer at Deep Bay, there is substantially more water available for exploitation than the present wells are able to withdraw, with the limitation imposed by the ability to install efficient water wells that can each individually withdraw as much as possible of the water which is moving through the sediments toward the sea. If any additional wells installed on D.L. 28 are constructed and tested at the end of the summer

drought, groundwater development can be managed to the extent that there will be no surprises with respect to potential negative impacts to other existing wells or to Gainsburg Swamp, as individual well capacities and well interferences will be measured at the time of minimum groundwater conditions.

4.0 WELL SITE SELECTION

PHCL'S letter-report of December 20, 1991 noted that simulation of interference drawdown by a computer model indicated that 170 to 185 m (560 to 610 ft) is a suitable spacing for keeping interference between wells in the Quadra Sand Aquifer on D.L. 28 to a minimum. If so, it was further stated that two additional wells on the subject triangular parcel of land would be feasible. In the aforementioned report of December 20, 1991, attention was also drawn to the fact that actual interference drawdowns in Wells 4-77 and 5-85 during a pumping test of Well 6-90 were 0.05 and 0.06 m (0.16 and 0.19 ft), respectively, indicating that closer well spacing without significant interference may be possible.

Figure 5 shows possible locations for two additional wells (7-95 and 8-95) on the subject triangular parcel of land in the southwest corner of D.L. 28. However, as previously discussed in former reports/letter-reports and also in this letter-report, test-production drilling and testing should be carried out at the first (7-95) of these sites before proceeding with installation of the second well (8-95), with the location of the second or additional wells adjusted to reflect information from the testing of Well 7-95, assuming of course that suitable conditions are encountered to justify the installation of a screened well at the site of proposed Well 7-95. Since specific local site conditions determine whether installation of a well of economic capacity is feasible, it is not possible to guarantee success at the site of proposed Well 7-95 and/or to specify the number and spacing of additional wells at this time, and it is certainly possible that test-production drilling at one or both of the two proposed sites and/or at other sites may not encounter a sufficient thickness of saturated Sand in which to construct a well of economic capacity.

5.0 WELLHEAD AND AQUIFER PROTECTION

As shown by the lithologies of sediments encountered in the drilling of the DBWD Wells on the subject triangular parcel of land, there is little protection against the introduction of pollutants/contaminants directly into the near-surface water table; therefore, DBWD must continue to be diligent to ensure that the important groundwater resource represented by the Quadra Sand Aquifer and the Wells is protected for long-term use. To give some idea of the area of particular concern, a wellhead protection area (WHPA) has been delineated for each of the existing water supply wells on D.L. 28. While such a procedure is rather mechanical, it provides a basis for estimating the area in which particular attention should be given to wellhead/aquifer protection, as indicated by the aquifer parameters at the site of each particular well.

At Deep Bay, a reasonable approach to defining a WHPA is to use the following uniform-flow analytical model:

$$X_L = \text{downgradient well capture} = Q/2\pi Kbi$$

$$Y_L = \text{width of upgradient zone of influence} = 2 (Q/2Kbi)$$

where, Q = rated capacity for Well 6-90 = 818 m³/day, (9.5 l/sec; 125 igpm);

K = hydraulic conductivity = 70 m/day (230 ft/day) based on an average aquifer transmissivity of 1240 m²/day (1.0 x 10⁵ USgpd/ft), and an average saturated aquifer thickness of 17.7 m (58 ft);

b = average saturated aquifer thickness = 17.7 m (58 ft);

i = hydraulic gradient = 0.0015 (estimated from topography and static water levels).

$$X_L = 818 \text{ m}^3/\text{day}/(6.28)(70 \text{ m/day})(17.7 \text{ m})(0.0015) \approx 70 \text{ m (230 ft)}$$

$$Y_L = 2[818 \text{ m}^3/\text{day}/(2)(70 \text{ m/day})(17.7 \text{ m})(0.0015)] \approx 440 \text{ m (1440 ft)}$$

As calculated above, therefore, the WHPA for Well 6-90 is an area approximately 440 m (1440 ft) wide extending about 70 m (230 ft) downgradient, as shown on Figure 5 (Page A - 5). The WHPA, along with the upgradient area to the groundwater divide (recharge area), should be kept free of storage and/or disposal of potential contaminants such as hydrocarbons (for example, heating and fuel oil), fertilizer, pesticides and domestic waste; further, general activities which could jeopardize the water supply wells/aquifer should be avoided. WHPA's for Wells 4-77 and 5-85, as calculated on the same basis as outlined above for Well 6-90, are:

- for Well 4-77, an area approximately 730 m (2400 ft) wide that extends about 120 m (390 ft) downgradient; and,
- for Well 5-85, an area 305 m (1000 ft) wide that extends about 50 m (160 ft) downgradient.

For DBWD Wells 4-77 and 5-85, the assumed respective saturated aquifer thicknesses during the time of minimum groundwater conditions are an estimated 13.4 and 19.8 m (44 and 65 ft); assumed respective aquifer transmissivities from pumping test data analysis are 497 and 643 m²/day (4.0 x 10⁴ and 1.2 x 10⁵ USgpd/ft); and, respective rated well capacities are 6.28 and 7.42 l/sec (83 and 98 igpm; 100 and 118 USgpm). While such calculations, which are based on certain assumptions, need to be kept in proper perspective, they provide a good approximation of the area of concern; it is evident that the aquifer characteristics and conditions, as presently understood, suggest that it would be advisable to protect the entire subject southwest corner of D.L. 28 as a Well Field for DBWD, regardless as to whether the proposed test-production drilling at proposed sites 7-95 and 8-95 confirms that hydrogeologic conditions are suitable for the installation of additional production wells to supply the DBWD system. Attention is drawn to the fact that the above calculations, based on a slightly different approach than the computer modelling of 1990, generally confirm the conclusion drawn in 1990 that a horizontal separation distance of 200 m (660 ft) for additional wells is realistic; thus, such a distance should be observed in the siting of at least the next well (7-95). Well spacing for a proposed eighth Well should be readdressed once results are available from the construction and testing of Well 7-95.

It should be noted that the downgradient well capture areas extend across the Island Highway, raising the issue of possible impacts to groundwater quality from highway road salting. This issue was previously addressed on Page 11 of PHCL's report of December 27, 1990 concerning the construction and testing of Well 6-90 as follows: "Since the natural groundwater gradient is toward the sea, highway salting is not a serious concern and salt contamination from this source is easy to detect; further, such contamination would not be permanent, as natural flushing would occur once the practise is stopped." It seems likely that, since highway road salting would take place at the time of maximum groundwater conditions, it would be diluted by groundwater moving away from the WHPA such that it would not influence the groundwater quality. It would be a simple matter to periodically measure the conductivity of the water from the DBWD Wells located on D.L. 28 to determine whether there is any increasing trend.

6.0 SUMMARY AND CONCLUSIONS

A review of the hydrogeology of the Deep Bay area, which has been carried out to assess the issue of maximum groundwater potential on the triangular parcel of land that forms the southwest corner of D.L. 28, leads to the following summary:

1. At Deep Bay, which is located at the northern end of the Quadra Sand deposit on the east coast of Vancouver Island, the distribution of the Sand has been shown by drilling of test holes and water wells to be uneven, thinning to the north.
2. Where the Quadra Sand has a sufficient saturated thickness, it is an aquifer capable of yielding groundwater to community water supply wells.
3. The groundwater regime at Deep Bay is generally well understood:
 - recharge to the regime and, therefore to the Quadra Sand Aquifer, is from the higher topographic area on the inner part of the Island;
 - movement of the groundwater, which is controlled by gravity, across the subject D.L. 28, is interpreted to be southwest to northeast toward the discharge end of groundwater flow at the sea;
 - where the highly permeable Quadra Sand, which carries a considerable amount of groundwater, terminates, the outcropping Sand discharges water in springs and swamps.
 - in any particular year, there is a large natural fluctuation in the water level in the Quadra Sand Aquifer and, consequently, also in the amount of discharge to the springs and swamps;
4. During the period of record starting in February 1990, the hydrograph for Provincial Observation Well No. 310, which is located in a thinner part of the Quadra Sand to the north of the DBWD Wells, has shown a water table fluctuation averaging 2.7 m (8.9 ft), but which was as much as 3.5 m (11.5 ft) in the Fall of 1990 to the Spring of 1991; however, increasing use from the DBWD Wells has not resulted in a continuous water level decline that would signify over-exploitation.

5. At the present well spacing of about 200 m (660 ft), interference between production wells has been shown by the pumping test of Well 6-90 to be insignificant.
6. Test-production drilling at any particular location is required to determine whether, in fact, hydrogeologic conditions are suitable for the construction of a community water supply well of economic capacity.

Based on present understanding of the groundwater flow regime of the Deep Bay area, and taking into account the known distribution of the Quadra Sand in that area, the following conclusions are reached with respect to the development of additional groundwater supply from wells installed on D.L. 28, as well as to protection of the groundwater regime:

1. All evidence is that increased withdrawal of groundwater by installing additional wells on the triangular parcel of land that forms the southwest corner of D.L. 28 on which existing DBWD Wells 4-77, 5-85 and 6-90 are located, will not result in negative impacts to existing Wells or to the groundwater regime, including Gainsburg Swamp.
2. In fact, since the distribution of the saturated thickness of Quadra Sand cannot be predicted at any particular location in the Deep Bay area, which is located at the northern extremity of the Sand deposit, there is no guarantee that conditions elsewhere on D.L. 28 are suitable for the installation of additional wells of economic capacity.
3. Provided that installation of test-production wells, and particularly testing of such wells, proceeds in a rational manner, with the drilling and testing of any well carried out such that well and aquifer pumping tests can be conducted at the end of the summer drought season when groundwater conditions are minimum, further confirmation can be obtained that negative impacts will not result to existing wells and/or to the groundwater regime (Gainsburg Swamp).
4. Since the Quadra Sand Aquifer extends to surface on D.L. 28 and is not protected by a cover of sediments of low permeability that would provide natural protection, it is particularly important that DBWD continues to be vigilant to ensure long-term protection of the important Quadra Sand Aquifer. Contamination from petroleum products continues to represent the greatest hazard to the Quadra Sand Aquifer because hydrocarbons have a tendency to adhere to sediment grains and are difficult to remove once they have entered the groundwater regime, in contrast to other water soluble chemicals, such as highway salt, that will become diluted and carried away with the natural movement of groundwater once the source is removed.
5. Delineation of WHPA's for existing Wells 4-77, 5-85 and 6-90, based on known conditions at the sites of each of the Wells, shows that it would be advisable to define the entire triangular parcel of land forming the southwest corner of D.L. 28 as a WHPA for the DBWD Well Field, even if test-production drilling shows that it is not possible to construct additional wells of economic capacity on the parcel.

7.0 RECOMMENDATIONS

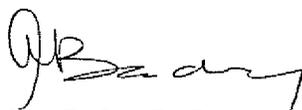
In consideration of present understanding of the hydrogeology of the Quadra Sand Aquifer at Deep Bay and of the implications of the hydrogeology with respect to the development of additional groundwater from the Aquifer, the following recommendations are made concerning management of the Aquifer as a long-term water supply source for Deep Bay Waterworks District:

1. Continue monitoring the water level in Provincial Observation Well No. 310 to ensure that there are no sudden surprises with respect to groundwater recharge to the Quadra Sand Aquifer in the subject area.
2. Continue to collect data on water consumption (withdrawal) from the existing DBWD Wells and any new wells, as well as the response of the water level to pumping by the individual wells, so as to confirm drawdown cones around the wells and around the Well Field, particularly at the end of the summer drought.
3. If possible, proceed as soon as possible with the drilling of an additional well and, if the drilling is successful in encountering a substantial thickness of saturated sand, complete the construction of the well and conduct the testing of the well so as to: evaluate its response to individual pumping at the end of the summer drought and maximum use of the existing wells; and, monitor the effects of such pumping at a time when groundwater conditions are at a minimum in the Aquifer prior to the start of the fall precipitation.
4. To assist in evaluating the feasibility of installing one or more other wells, in addition to 7-95, conduct an aquifer test in which all four wells (4-77, 5-85, 6-90 and 7-95) are pumped simultaneously. During such testing observe the water levels in the District's other wells, as well as in Provincial Observation Well No. 310.
5. Based on the results of installing Well 7-95 and on the response of Well 7-95 to individual and combined pumping, carry out additional groundwater modelling, as may be appropriate, to evaluate how much additional groundwater may be available for exploitation without resulting in negative impacts.
6. Depending on the results of the individual testing of Well 7-95, and an aquifer test during which all wells are pumped, carry out groundwater modelling, as may be appropriate to estimate whether and, if so, how much more groundwater may be available and, if appropriate, consider drilling at one or more additional sites to confirm that the construction of an additional well is feasible, at such time as it may be required.
7. Control activities in the estimated WHPA around each Well, and be vigilant to ensure that activities in the main recharge area upgradient of the Wells are compatible and do not pose a threat to the valuable groundwater resource represented by the DBWD Wells and the Quadra Sand Aquifer.

The contents of this report and attachments have been researched in order to address concerns raised by approving agencies and others about the proposal by DBWD to withdraw additional groundwater from the triangular parcel of land that forms the southwest corner of D.L. 28. In the event that it is necessary for PHCL to be of further assistance concerning the subject of this letter or any other groundwater issue, please do not hesitate to contact the undersigned.

Yours truly,

PACIFIC HYDROLOGY CONSULTANTS LTD.



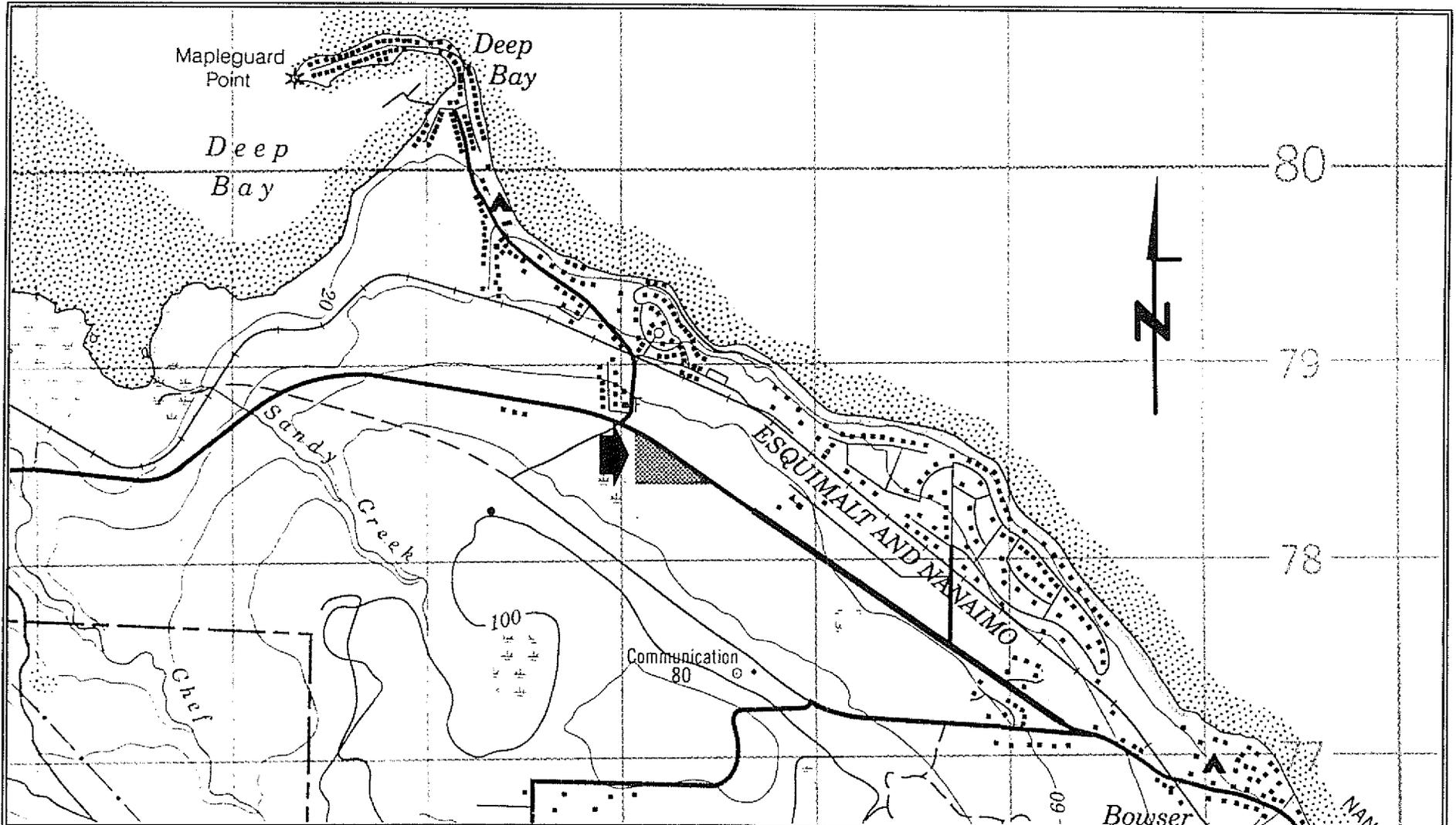
Ann Badry, P. Geo.,
Hydrogeologist/Manager

Attachments



APPENDIX A

ILLUSTRATIONS



Notes:

1. The base map is 1:50,000 scale topographic N.T.S. 92F/7, **Horne Lake**, enlarged to an approximate scale of 1:30,000; contour interval is 20 metres.
2.  indicates the approximate location of the subject parcel of land (southwest corner of D.L. 28).

PROJECT NO.: D707101

PROJECT:
DEEP BAY WATERWORKS DISTRICT

LOCATION: Southwest Corner of D.L. 28
Newcastle District, Deep Bay, B.C.



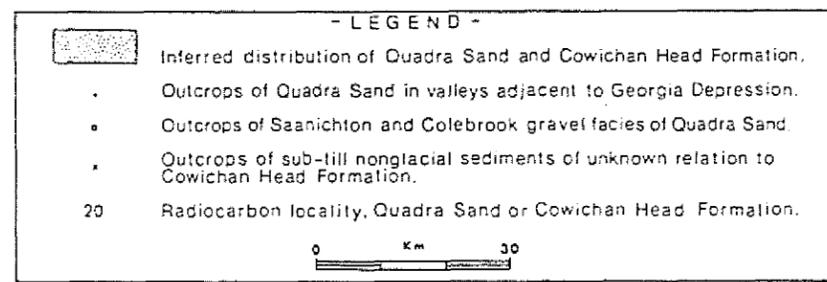
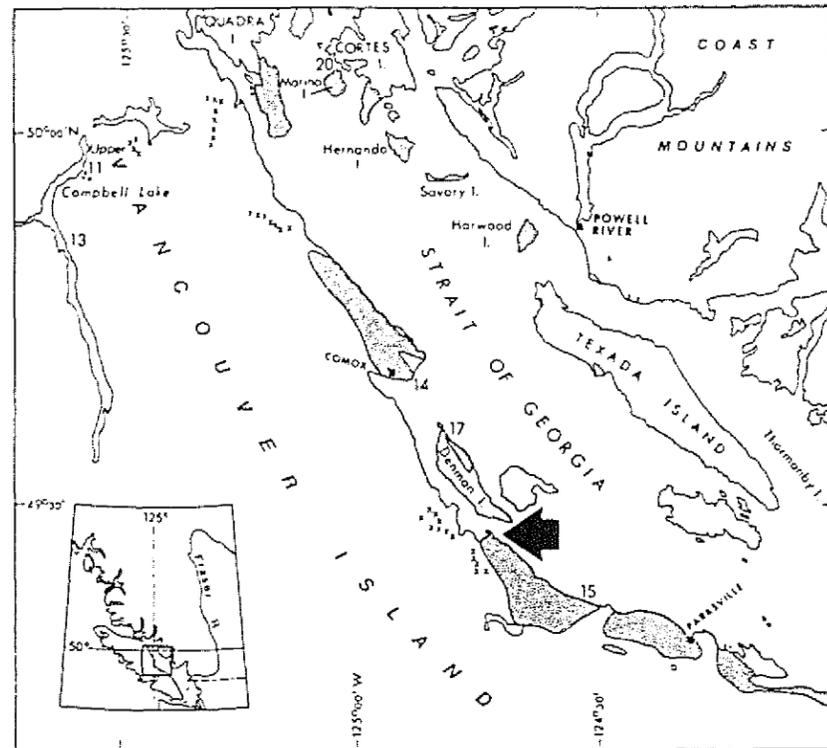
**PACIFIC HYDROLOGY
CONSULTANTS LTD.**
CONSULTING HYDROGEOLOGISTS

AREA LOCATION AND REGIONAL TOPOGRAPHY

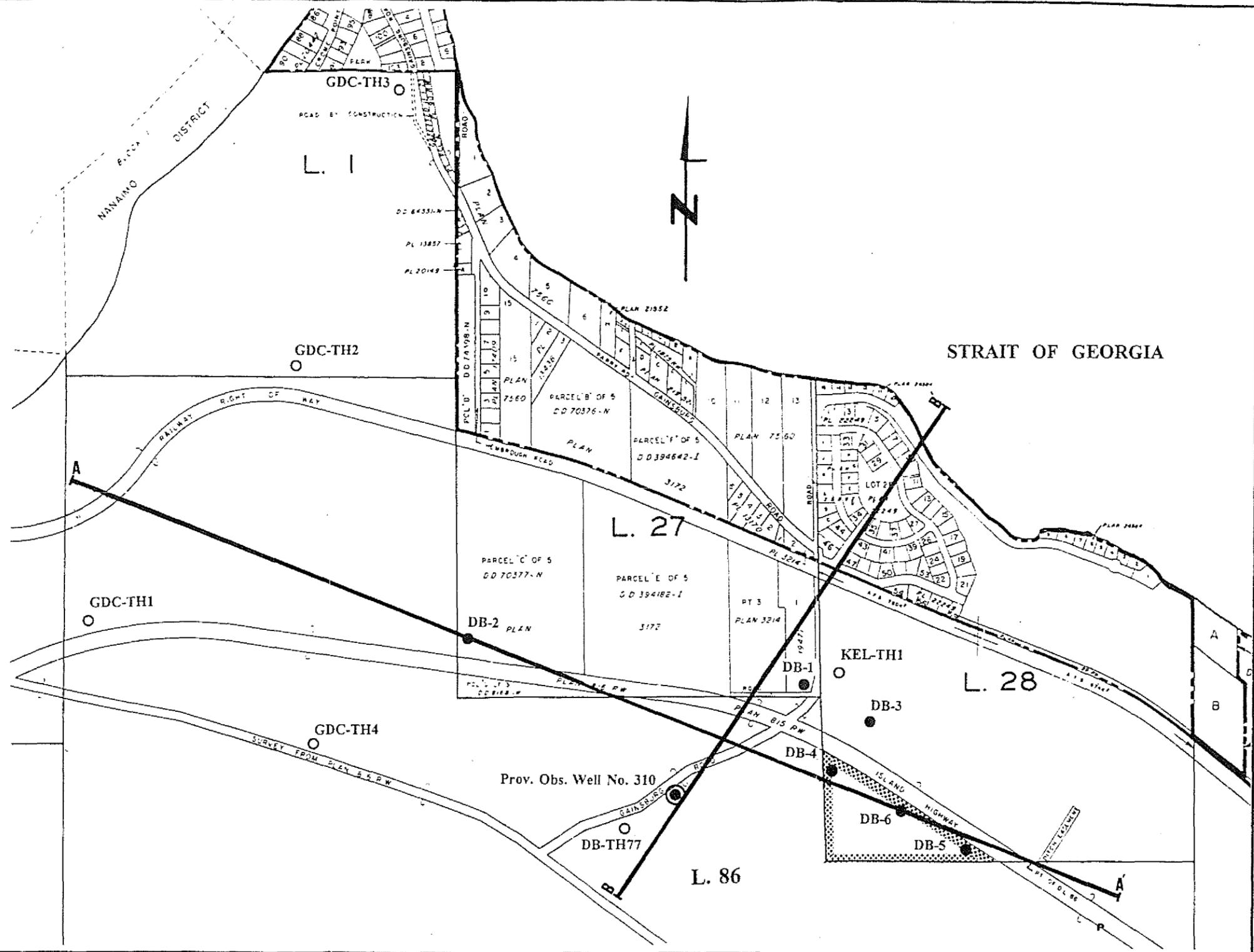
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msc

FIGURE:
1



Source: GSC Paper 77-17, Quadra Sand: A Study of the Late Pleistocene Geology and Geomorphic History of Coastal Southwest British Columbia; by J.J. Clague. 1977, 24 pp.



- Notes:
1. The base map is a Water Rights Branch Reference Map, I.D. Plan 402 (Ref. Map 92F/7). Newcastle District, of scale 1 in = 800 ft, reduced to an approximate scale of 1:10,000.
 2. denotes line of schematic hydrogeological cross-section (see Figures 3 and 4, Pages A - 3 and A - 4).
 3. indicates approximate (unsurveyed) respective location of a community water supply well, Provincial Observation Well No. 310 and a test hole, as identified (for well details, see Table 1 and 2 in Appendix B).

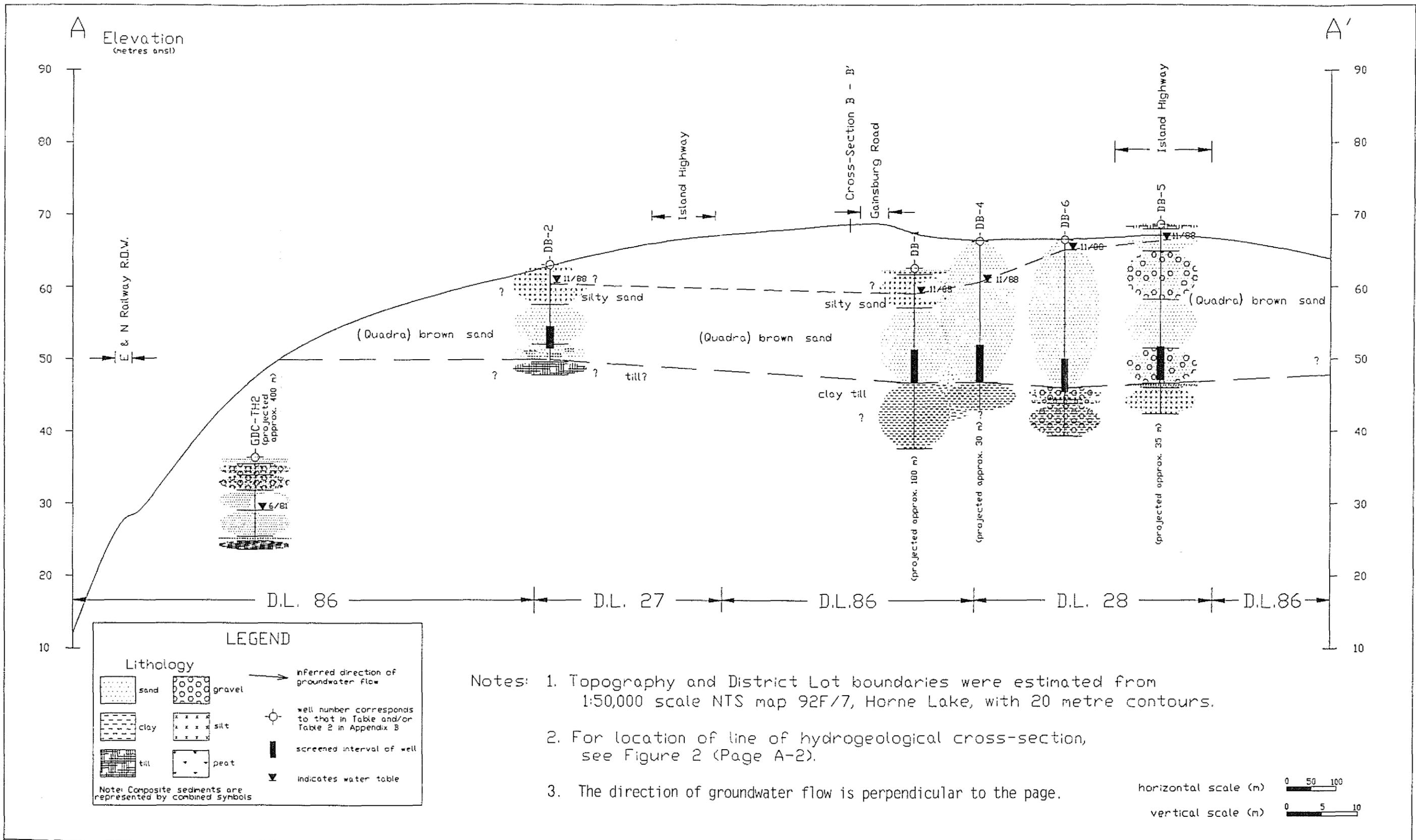
PROJECT NO.: D707101
 PROJECT:
DEEP BAY WATERWORKS DISTRICT
 LOCATION: Southwest Corner of D.L. 28
 Newcastle District, Deep Bay B.C.



**PACIFIC HYDROLOGY
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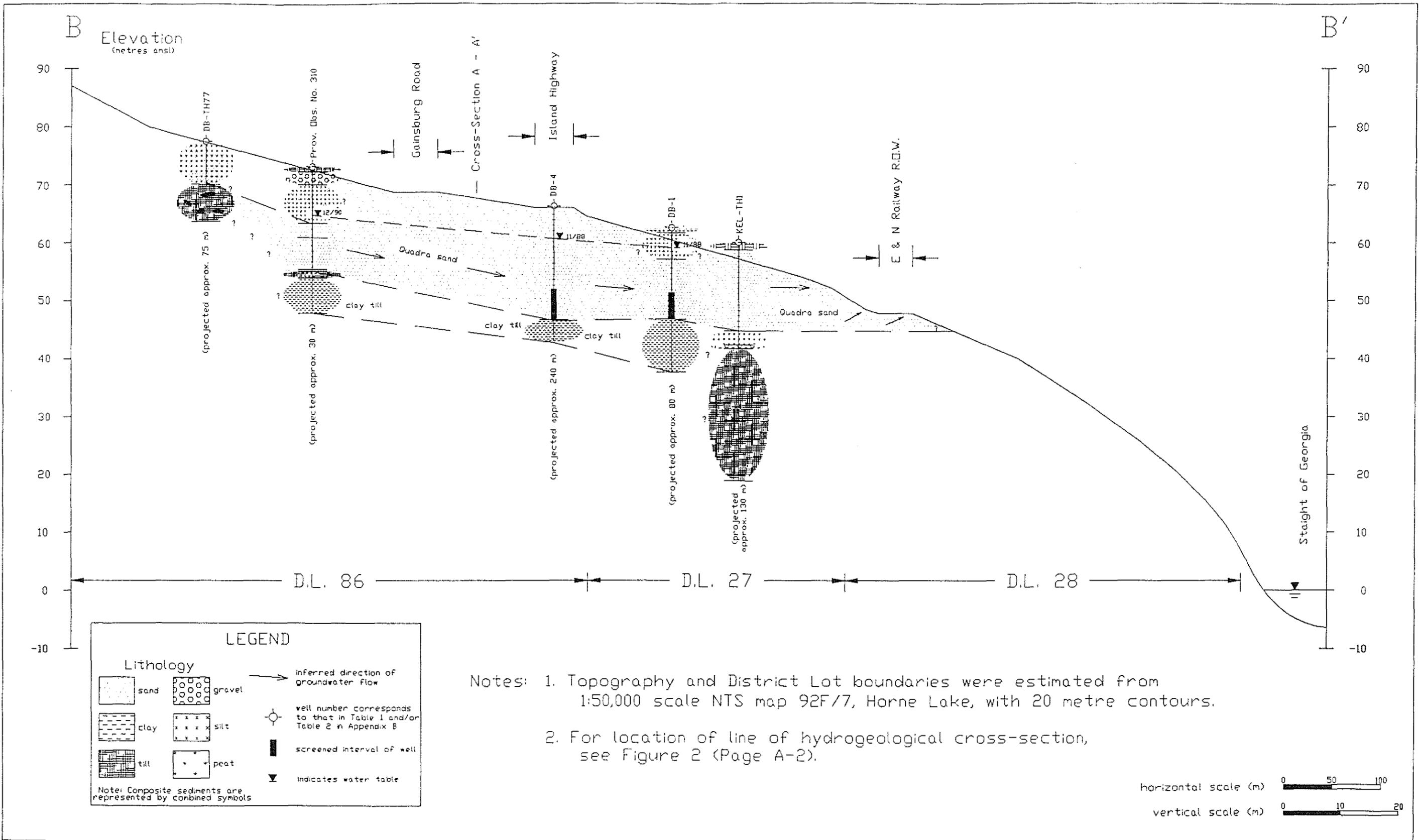
SITE AND WELL LOCATION

DATE: 06/20/95	DRAWN BY: mc	FIGURE: 2
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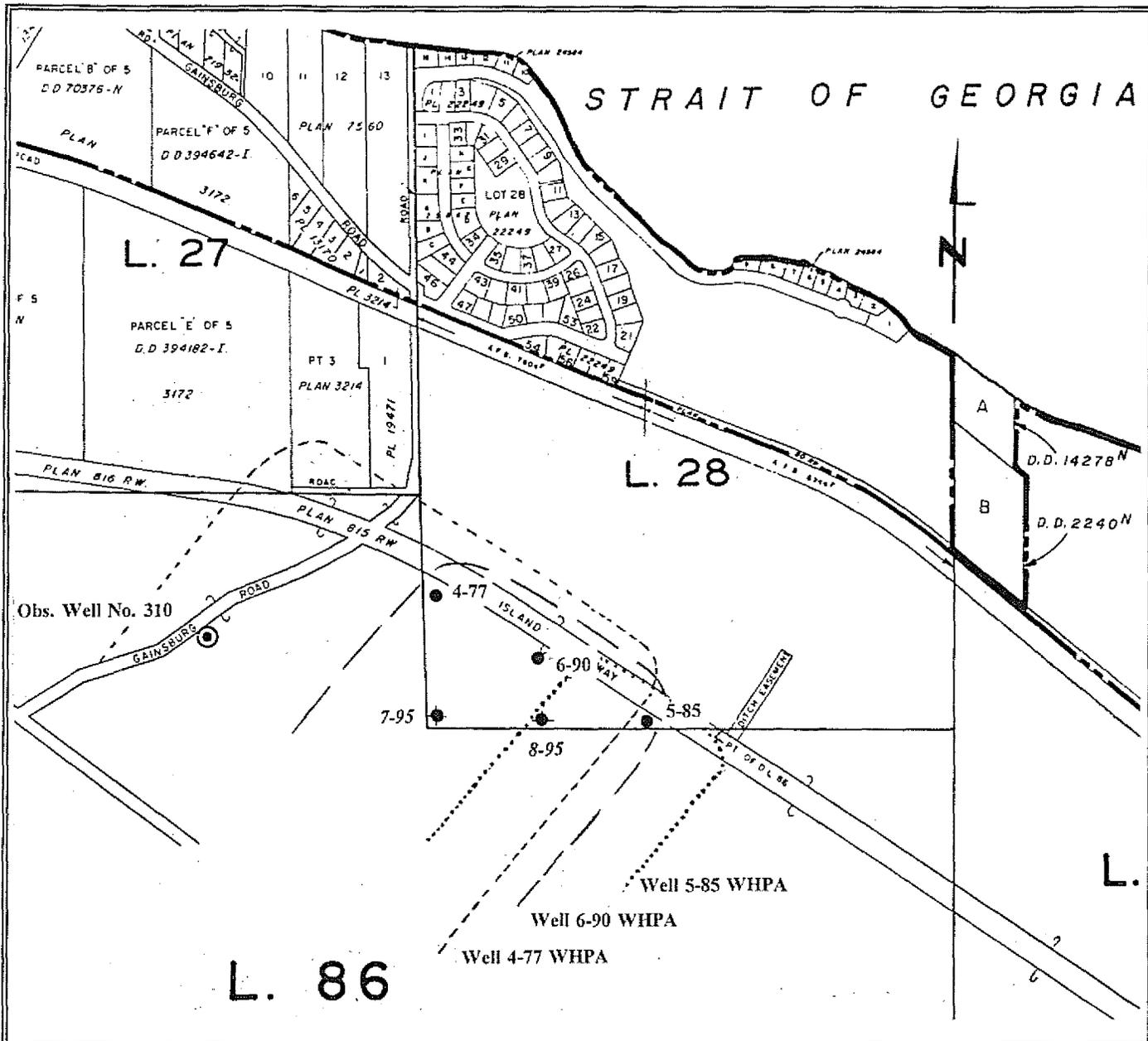
PACIFIC HYDROLOGY CONSULTANTS LTD. Consulting Hydrogeologists

Project: DEEP BAY WATERWORKS DISTRICT	Project No: D707101	Location: DEEP BAY AREA	Date: 19 June, 1995
Title: SCHEMATIC HYDROGEOLOGIC CROSS-SECTION A - A'			Drawn By: MSC Figure: 3



PACIFIC HYDROLOGY CONSULTANTS LTD. Consulting Hydrogeologists

Project: DEEP BAY WATERWORKS DISTRICT	Project No: D707101	Location: DEEP BAY AREA	Date: 19 June, 1995
Title: SCHEMATIC HYDROGEOLOGIC CROSS-SECTION B - B'			Drawn By: MSC Figure: 4



Notes:

1. The base map is a 1:9600 scale plan of Deep Bay Waterworks District prepared by Water Rights Branch (I.D. Plan 402).
2.  denotes approximate location of an existing Deep Bay Waterworks District Well and Provincial Observation Well No. 310, as identified.
3.  denotes locations of proposed test-production drilling sites for Wells 7-95 and 8-95.
4.  outlines WHPA for each existing well.

PROJECT NO.: D707101

PROJECT:
DEEP BAY WATERWORKS DISTRICT

LOCATION: Deep Bay on the east coast
of Vancouver Island



**PACIFIC HYDROLOGY
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**WELL LOCATIONS
AND
WELLHEAD PROTECTION AREAS**

DATE:
08/04/95

DRAWN BY:
ab

FIGURE:
5

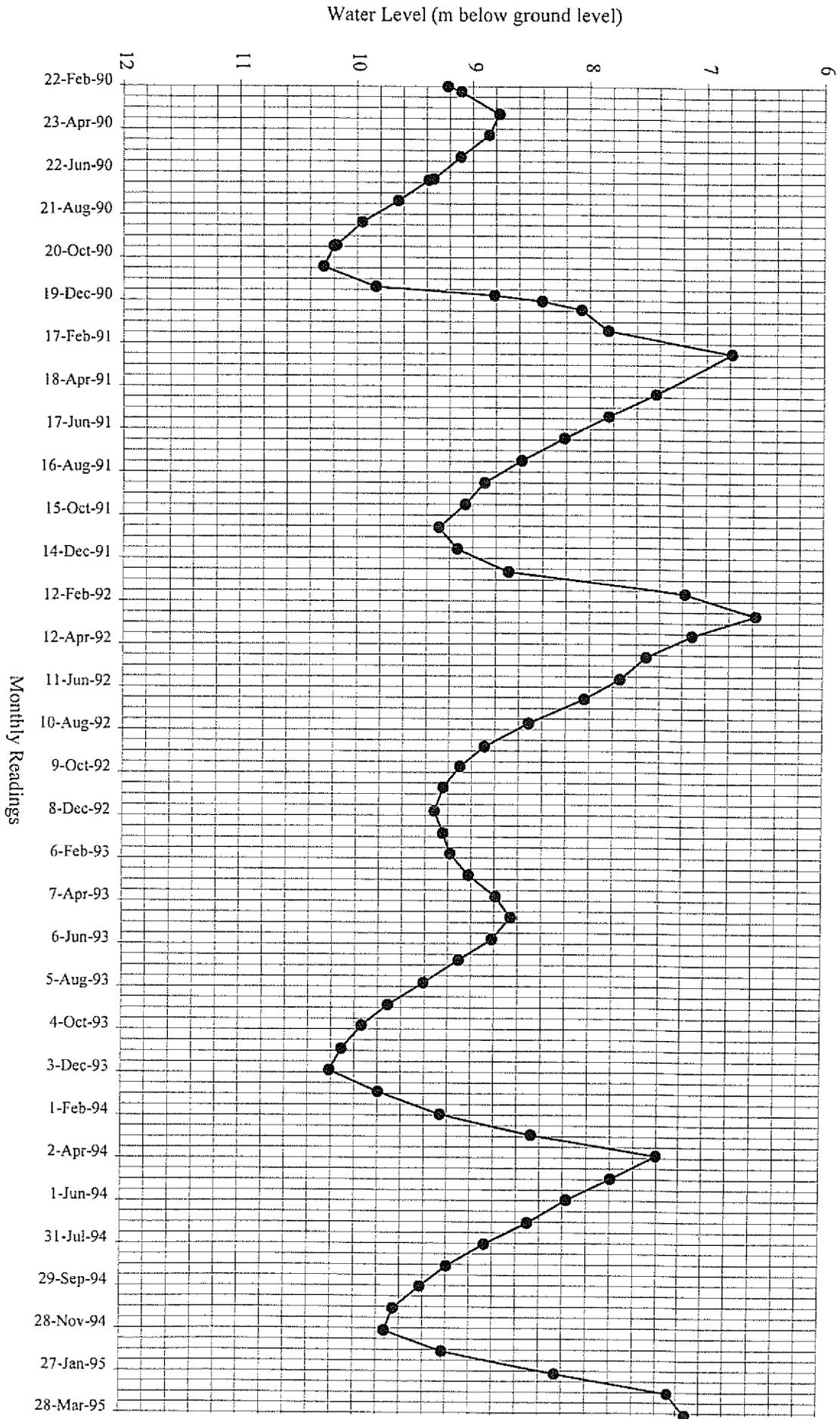


Figure 6. Hydrograph for Provincial Observation Well No. 310 at Deep Bay

APPENDIX B

**SELECTED DETAILS ABOUT DEEP BAY WATERWORKS DISTRICT WELLS
AND
AREA TEST HOLES**

Table 1. Selected Details for Deep Bay Waterworks District Water Supply Wells and Provincial Observation Well No. 310

Well	Completed Depth		Static Water Level		Interval		Driller's Litholog	Remarks
	m	ft	m	ft	m	ft		
							Sediment Description	
1-73	15.9 (09/73)	52.0	2.2 (09/10/73)	7.33	0 - 0.9 0.9 - 5.5 5.5 - 15.8 15.8 - 25.0	0 - 3 3 - 18 18 - 52 52 - 82	silty sand and gravel silty sand with water below 3.0 m (10 ft) brown fine sand clay till.	200 mm (8") diameter well; completed with a 4.9 m (16 ft) long screen assembly containing 4.6 m (15 ft) of 0.254 mm (0.010") slot Johnson stainless steel well screen, with the assembly set from 11.0 to 15.8 m (36 to 52 ft); well capacity rated at 4.16 l/sec (66 USgpm; 55 igpm) in 1973.
2-73	11.6 (09/73)	38.0	1.6 (09/11/73)	5.25	0 - 5.5 5.5 - 11.0 11.0 - 13.4 13.4 - 15.2	0 - 18 18 - 36 36 - 44 44 - 50	silty sand brown fine sand interbedded sand and silt light grey soft till.	200 mm (8") diameter well; completed with a 3.35 m (11 ft) long screen assembly containing 3.0 m (10 ft) of 0.254 mm (0.010") slot Johnson stainless steel well screen, with the assembly set from 8.2 to 11.6 m (27 to 38 ft); capacity rated at 2.40 l/sec (38 USgpm; 32 igpm) in 1973.
3-69	16.4 (06/69)	53.7	0.8 (09/11/73)	2.65	0 - 1.2 1.2 - 4.3 4.3 - 16.2	0 - 4 4 - 14 14 - 53	soil till sand.	200 mm (8") diameter well; completed with a 4.2 m (13.7 ft) long well screen assembly containing 3.0 m (10 ft) of 0.254 mm (0.010") slot Johnson stainless steel well screen, with the assembly set from 12.2 to 16.4 m (40 to 53.7 ft); capacity rated at 5.68 l/sec (75 igpm) in 1973.
4-77	19.3 (09/77)	63.5	4.5 (01/16/78)	14.79	5.6 (11/88)		Well reported to have been drilled entirely in sand; brown sand and clay encountered at a depth of 19.5 m (64 ft).	200 mm (8") diameter well; completed with a 5.0 m (16½ ft) long screen assembly consisting of 1.5 m (5 ft) of 0.330 mm (0.013") slot Johnson stainless steel well screen over 3.0 m (10 ft) of 0.381 mm (0.015") slot screen, with the assembly set from 14.3 to 19.3 m (47 to 63½ ft); capacity rated at 6.37 l/sec (84 igpm) from a pumping test carried out in January 1978.

Table 1. Selected Details for Deep Bay Waterworks District Water Supply Wells and Provincial Observation Well No. 310 (cont'd)

Well	Completed Depth		Static Water Level		Interval		Driller's Litholog Sediment Description	Remarks
	m	ft	m	ft	m	ft		
	5-85	21.5 (06/85)	70.5	1.3 (06/11/85) 2.1 (11/88)	4.15 7.01	0 - 0.6 0.6 - 3.7 3.7 - 6.1 6.1 - 7.3 7.3 - 7.9 7.9 - 10.4 10.4 - 17.1 17.1 - 17.7 17.7 - 22.0 22.0 - 22.6 22.6 - 23.2 23.2 - 26.2	0 - 2 2 - 12 12 - 20 20 - 24 24 - 26 26 - 34 34 - 56 56 - 58 58 - 72 72 - 74 74 - 76 76 - 86	
6-90	23.2 (12/90)	76.0	0.6 (12/19/90)	1.95	0 - 20.4 20.4 - 22.0 22.0 - 22.6 22.6 - 27.1	0 - 67 67 - 72 72 - 74 74 - 89	yellow-brown medium sand; water-bearing below 7.6 m (25 ft) grey-brown silt and gravel grey-brown sand and gravel containing chunks of peat grey compact clay and gravel.	200 mm (8") diameter well; completed with a 6.9 m (22.7 ft) long well screen assembly containing 1.5 m (5 ft) of 0.330 mm (0.013") slot Johnson stainless steel well screen over 3.0 m (10 ft) of 0.305 mm (0.012") slot screen over 2.1 m (7 ft) of pipe, with the assembly set from 16.9 to 23.2 m (55.3 to 76 ft); capacity rated at 9.5 l/sec (125 igpm) from a pumping test carried out in December 1990, with provision for interference from other wells pumping and a lower static water level at the time of minimum groundwater levels.

Table 1. Selected Details for Deep Bay Waterworks District Water Supply Wells and Provincial Observation Well No. 310 (cont'd)

Well	Completed Depth		Static Water Level		Interval		Driller's Litholog Sediment Description	Remarks
	m	ft	m	ft	m	ft		
	<i>Prov. Obs. No. 310</i>	18.1 (06/77)	59.5	8.9 (06/26/77)	29.22	0 - 0.9 0.9 - 3.0 3.0 - 9.8 9.8 - 12.2 12.2 - 17.7 17.7 - 18.0 18.0 - 19.2 19.2 - 25.3	0 - 3 3 - 10 10 - 32 32 - 40 40 - 58 58 - 59 59 - 63 63 - 83	

B
1
3

- Notes: 1. Measurements are referenced to ground level.
2. Locations of wells are shown on Figure 2 (Page A - 2).

Table 2. Selected Details for Test Holes in the Deep Bay Area

Test Hole	Total Depth		Static Water Level		Driller's Litholog		Remarks	
					Interval			Sediment Description
	m	ft	m	ft	m	ft		
<i>GDC-TH1</i> ¹	7.6	25	≈3.0 (07/14/81)	≈10.0	0 - 0.9 0.9 - 2.4 2.4 - 3.4 3.4 - 4.6 4.6 - 5.2 5.2 - 7.3 7.3 - 7.6	0 - 3 3 - 8 8 - 11 11 - 15 15 - 17 17 - 24 24 - 25	dark brown, loose sand and gravel light brown, loose sand and gravel light brown, silty sand light brown, silty sand; water-bearing blue silt blue clay with some stones blue till.	200 mm (8") diameter test hole; casing recovered and site abandoned.
<i>GDC-TH2</i>	12.8	42	≈7.3 (07/15/81)	≈24	0 - 0.9 0.9 - 2.4 2.4 - 4.6 4.6 - 7.3 7.3 - 11.0 11.0 - 11.6 at 12.8	0 - 3 3 - 8 8 - 15 15 - 24 24 - 36 36 - 38 at 42	dark brown, sandy soil dark brown, loose, silty sand and gravel light brown, tight, silty sand and gravel light brown, clean, loose sand light brown loose sand; water-bearing compact blue silt and sand blue till.	One 1.5 m (5 ft) long Johnson stainless steel well screen with 0.381 mm (0.015") slots set from 9.1 to 10.7 m (30 to 35 ft); well capacity less than 0.76 l/sec (10 igpm) so all materials were recovered and the site abandoned.
<i>GDC-TH3</i>	9.5	31	≈2.1 (07/21/81)	≈7.0	0 - 0.6 0.6 - 1.5 1.5 - 2.1 2.1 - 3.1 3.1 - 7.0 7.0 - 9.5 at 9.5	0 - 2 2 - 5 5 - 7 7 - 10 10 - 23 23 - 31 at 31	dark brown, loose gravelly soil light brown, compact silty sand and gravel light brown, loose silty sand light brown, silty sand, loose; water-bearing blueish, slightly silty sand blue silt with some rocks blue till.	One 1.5 m (5 ft) long Johnson stainless steel well screen with 0.381 mm (0.015") slots set from 5.5 to 7.0 m (18 to 23 ft); well capacity less than 0.38 l/sec (5 igpm) so all materials were recovered and the site abandoned.
<i>GDC-TH4</i>	11.3	37	6.1 (07/27/81)	20	0 - 0.5 0.5 - 6.1 6.1 - 9.1 9.1 - 10.1 10.1 - 11.3 at 11.3	0 - 1½ 1½ - 20 20 - 30 30 - 33 33 - 37 at 37	dark brown, compact sand and gravel brown loose sand light brown, loose sand with silty layers; water-bearing brown silty sand blue clay blue till.	

Table 2. Selected Details for Test Holes in the Deep Bay Area (cont'd)

Test Hole	Total Depth		Static Water Level		Interval		Driller's Litholog Sediment Description	Remarks
	m	ft	m	ft	m	ft		
	<i>KEL-TH1</i> ¹	41.2	135	-	-	0 - 1.2 1.2 - 15.2 15.2 - 17.7 17.7 - 18.3 18.3 - 41.2	0 - 4 4 - 50 50 - 58 58 - 60 60 - 135	
<i>DB-TH77</i> ¹	13.7	45	-	-	0 - 7.3 7.3 - 13.7	0 - 24 24 - 45	brown silty sand till and boulders.	200 mm (8") diameter test hole drilled in the 1977 exploration program for Deep Bay Waterworks that resulted in the completion of Well 4 on D.L. 28 south of the Island Highway; the Quadra sand was very thin at this site and did not extend below the water table; all materials were recovered from the unsuccessful test hole and the site was abandoned.

Notes: 1. Abbreviations: GDC = Genstar Development Company; KEL = Kopina Estates Ltd.; DB = Deep Bay.
2. For locations of wells, see Figure 2 (Page A - 2).

APPENDIX C

SELECTED CORRESPONDENCE



Qualicum Band of Indians

5850 River Road
Qualicum Beach, B.C.
V9K 1Z5

Tel: (604) 757-9337
Fax: (604) 757-9898

June 14, 1995

Ministry of Environment,
Lands and Parks
Lands Regional Operations Dept.
Vancouver Island Region
851 Yates Street
Victoria, B.C.
V8V 1X4

Attn: T.K. Ovanin, R.P.F.

Dear Sir:

Re: Application by Deep Bay Waterworks District - #1406967

Please forgive the delay in answering your letter of January 31, 1995.

Since the Qualicum Band is in the process of filing a Statement of Intent with the British Columbia Treaty Commission we are reluctant to grant approval to the application as it has been presented.

We do, however, recognize the responsibility that we have as neighbours so will not stand in the way of the Waterworks District in their pursuit of an adequate water supply.

We are prepared to allow the issuance of Right-of-Ways over two additional individual wellsites identified for development within the area described, see attachments.

Yours truly,

A handwritten signature in cursive script, appearing to read "G. Michael Recalma".

G. Michael Recalma
Councillor

A handwritten signature in cursive script, appearing to read "Bill R. Recalma".

Bill R. Recalma
Councillor

Encl. (1)

RESPONSE SUMMARY

A. First Nations Interest Associated with this land.

1. Aboriginal rights

The Qualicum Band is in the process of filing a Statement of Intent with the British Columbia Treaty Commission.

2. Traditional significance

The area in question lies well within an important part of our Claim area.

3. Other interests

B. Impact of Proposed Use of this land on First Nations Interests.

water Rights will form a significant part of our Claim. Therefore we are not prepared to allow lease of the entire area proposed.

In a spirit of co-operation, we are prepared to allow the issuance of Right-of-Ways over two, only, additional individual well sites identified for development within the area described.

Response Summary

- 2 -

C. Please indicate your preference concerning the outcome of this application.

Approval recommended

Approval recommended subject to specific conditions or requirements listed above

see 'B' on previous page.

Approval not recommended, Please list reasons:

D. If you have recommended that this application not be approved, please suggest an alternate location where it would not impact on your interests.

REGIONAL DISTRICT OF NANAIMO

6300 Hammond Bay Road, Nanaimo, British Columbia
Mailing Address: P.O. Box 40, Lantzville, B.C., V0R 2H0
Telephone: (604) 390-4111
Facsimile: (604) 390-4163

TO: Anne Bodrey
DEPT: Pacific Hydrology
FAX NO: 683-9676
NO. PAGES: 1
FROM: Bonnie Blue
DATE: June 19, 1995
TIME: 1:30

MESSAGE:

Anne: Sorry for the delay in following up our conversation last Thursday concerning Gainsburg Swamp.

As part of the referral process for Deep Bay Waterworks' proposed new wells, the RDN was given the opportunity to comment. For your information, our response expressed our concern regarding the impact of additional wells on the water levels of Gainsburg Swamp. We suggested that an assessment of this issue be undertaken.

We would be satisfied if, in your report, you simply explained or stated that the wells will have no impact on the naturally occurring water levels and hence pose no threat to the wildlife habitat that the natural wetland provides..

I am not aware of the comments of other agencies. You may need to ask Tom Ovanin at BC Lands what the other concerns were, if any.

Thanks, Bonnie

DEEP BAY

WATERWORKS DISTRICT

R.R.1, SITE 150, C-4, BOWSER, B.C. V0R 1G0

TELEPHONE 757-9312

June 26, 1995

Ministry of Environment, Lands & Parks,
Lands Regional Operations Department,
Vancouver Island Region,
851 Yates Street,
Victoria, B.C. V8V 1X4

Your File: 1406967

Attention: Mr. T.K. Uvanin, R.P.F., Land Officer

Subject: Application to Lease Crown Land for Additional Well Since

Dear Sir:

Further to our recent telephone discussions and your letter dated June 13, 1995. Please allow me to reply to the issues raised in point form.

- 1) Potential Impact of Proposed Wells on Gainsburg Swamp. Pacific Hydrology Ltd., Vancouver, B.C., is finalizing the second phase of a detailed study relative to the "Quadra Sands" groundwater aquifer and the rainwater charged surface water level behavior of Gainsburg Swamp.

The D.B.W.D. in co-operation with the Ministry of Environment, Groundwater Section, has been operating an Observation Well equipped with a chart recorder since February, 1990. This well is located on Gainsburg Road in the vicinity of Gainsburg Swamp. Monthly collected charts are on file with the Ministry, with copies being retained by the D.B.W.D.

Verbal professional opinions expressed by Pacific Hydrology Ltd. indicate that no measurable linkages exist between well water extraction rates and/or the occasional fluctuations of ground or surface water levels.

This writer has been living in the Deep Bay area since 1978 and can attest from personal observations that Gainsburg Swamp has and is overflowing in the winter and early spring months, and virtually dry late summer and early autumn months.

This naturally occurring phenomenon existed prior and subsequent to the installation of #5 Well (100 g.p.m.) and #6 Well (125 g.p.m.).

Long time residents still living in the area, readily recall skating parties in the winter, and digging peat in summer for pocket money in years gone by. Although not scientific, such statements should not be completely discarded.

Gainsburg Swamp Preservation. The Deep Bay Waterworks District is fully committed to the preservation of this local wildlife habitat and was an early signatory supporting the proposal of declaring Gainsburg Swamp as designated Green Belt area under the R.D.N. Parks Planning.

A substantial clean up campaign of illegally dumped motor vehicles, household appliances, and other refuse was totally sponsored by the D.B.W.D. in the past, with annual budget allocations and actions as the need arises.

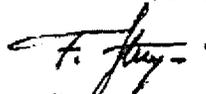
The honeycombed trail network of abandoned logging roads is being extensively utilized much to the enjoyment by local residents and visiting tourists for recreation and therapeutic recommended hiking.

- 2 -

- 2) Proposed Well Site Locations and Access. Pacific Hydrology Ltd. and John Motherwell & Associates Engineering Ltd. will identify the specific wellsite locations.
No additional access from the Island Highway will be required as the existing road accesses for #5 and/or #6 Well can be utilized.
- 3) Response by Qualicum Band of Indians. The Band's reply was sent to you June 14, 1995 stating "We are prepared to allow the issuance of Right-of-Ways over two additional wellsites identified for development with the area described.

Yours truly,

DEEP BAY WATERWORKS DISTRICT

Frank Hicronymi
Operations Co-Ordinator

kb

cc: John Motherwell, P.Eng., Victoria
Ann Badry, Pacific Hydrology Ltd., Vancouver
Rob Lapham, Planning Dept., R.D.N. - Nanaimo
AJ Kohut, Groundwater Section, BC Environment, Victoria
Leonard Krog, M.L.A. - Parksville