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Gig Harbor ground water management plan -- Task 3, Hydrogeological summary report

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GIG HARBOR GROUND WATER MANAGEMENT PLAN
TASK 3
HYDROGEOLOGICAL SUMMARY REPORT

Prepared for

TACOMA PIERCE COUNTY HEALTH DEPARTMENT

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Gig Harbor Peninsula Ground Water Management Area Hydrogeological Summary Report

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Section 1
INTRODUCTION

The purpose of this report is to provide a mid-project review and summary of pertinent hydrogeological conditions on the Gig Harbor Peninsula as necessary to proceed with management planning in the Ground Water Management Program (GWMP). The Task 3 report is a companion document to the Task 2 report and supports the identification of data collection needs outlined in the DCAP. The Task 3 report is not intended to provide a complete picture of the hydrogeology since this evaluation will not be finished until the completion of data collection and final project report preparation. This task report documents the current conceptual model of the hydrogeologic system and provides information necessary for selection of monitoring wells.

The hydrogeological summary presented in this report is developed based on a review of the existing data base, including the evaluation of potentiometric profiles and cross sections generated from this data. This review also incorporates data developed from new well construction in the area which has been monitored as part of the study.

Section 2
GROUND WATER MANAGEMENT AREA DESCRIPTION

2.1 TOPOGRAPHY AND SURFACE FEATURES

The Ground Water Management Area (GWMA) varies in elevation from sea level to approximately 400 feet elevation and is characterized by rolling terrain with glacially sculpted surface features. The area is dissected by several small stream valleys and incised by various bays and inlets of Puget Sound. Over much of the eastern and southern boundaries, the Puget Sound shoreline slopes range from steep to precipitous. As a general rule, upland areas range from 100 to 300 feet while the valley areas are 0 to 150 feet in elevation. The surface topographic features are representative of massive glacial scouring (ice erosion) and do not show strong indications of precipitation based (water erosion) processes.

2.2 SUBAREA DEFINITIONS

The study area is separated into five geophysical regions and ten drainage areas. The geophysical regions are separated by sea water and stream channels and include: (1) Fox Island - separated from the Peninsula by Hale Passage; (2) The Wollochet Highland area bounded by Hale Passage, Horsehead Bay, Wollochet Bay, and the Artondale Creek Valley; (3) the Purdy uplands bounded by Burley Lagoon, the McCormick, North, and Crescent Creek valleys, and the county line; (4) the Gig Harbor Uplands bounded by The Narrows, Gig Harbor, Henderson and Wollochet Bays and the Artondale, North and McCormick Creek valleys; and (5) the Crescent Creek uplands bordered by the Crescent Creek Valley and Colvos Passage. These geophysical regions correspond to topography and define discharge boundaries for the Upper Aquifer zones. The "Sea Level" aquifer underlies all of these regions as an incomplete but generally contiguous aquifer zone.

These five geophysical regions may be subdivided further into ten hydrologic zones (reference Zones I through X on Figure 1) based on watershed divisions and discharge patterns in the Upper aquifer, i.e., surface drainage and ground water flow discharge patterns. For example, the Gig Harbor upland area is composed of portions of Zones II, III, IV, VI, VIII, and IX, each of which represents a separate ground water discharge area. As seen in Figure 2-1, Zone II lies only partially in Gig Harbor uplands geophysical region and also the drainage from several geophysical regions discharges into Gig Harbor. Zone II includes all areas discharging to Gig Harbor either directly or through North or Crescent Creeks, although portions of Zone II are included in the Purdy and Crescent Creek Upland geophysical regions.

Overall, the study area boundaries are Puget Sound on all sides except the north, where the boundary is administrative and coincides with the Kitsap County line. Although this boundary is not geologically chosen, preliminary indications based on contour plots for both the "Upper" and "Sea Level" aquifer zones are that ground water flow in this region roughly parallels the county line and provides a "no flow" boundary.

2.3 GEOLOGY

The Gig Harbor Peninsula lies within the southern reaches of the Puget Sound Lowland between the central Cascade Range to the east and the southern Olympic Mountains to the west. The Puget Sound Lowland is part of a large glacial drift plain formed by multiple glaciations that occurred in the region. The complicated history of glacial erosional and depositional events separated by long periods of non-glacial deposition has created a complex assortment of unconsolidated sediments beneath the study area. The thickness of these sediments on the Gig Harbor Peninsula is not known, but they are believed to be up to 2,000 feet thick. Consolidated rock formations have not been encountered in any wells drilled in the study area.

2.3.1 Glacial Deposits

Outwash sands and gravels were deposited by meltwater streams in front of the glaciers during their advance. Advance outwash deposits commonly consist of poorly sorted sand and gravel to the size of cobbles and boulders. These outwash gravels are generally the most permeable of glacial deposits.

Glacial till is an unsorted to poorly sorted mixture of material with particle sizes ranging from clay-size particles to boulders. Till results from the grinding and compaction of granular material worked by the advancing and overriding glacier. Consequently, till is very dense and generally exhibits low hydraulic permeability. Hydrologically restricting zones (aquitards) between aquifers are generally composed of till materials in the study area.

As the glaciers receded, meltwater streams again deposited coarse sand and gravel over the previously compacted till. Recessional outwash, similar in character to advance outwash, tends to exhibit moderate to high permeabilities.

The typical glacial sequence consists of:

- Recessional outwash (loose sand and gravel, grading finer upward)
- Till (compacted silty gravel, poorly sorted)
- Advance outwash (sand and gravel, grading coarser upward)

The unconsolidated glacial and interglacial deposits are Quaternary in age (up to 2 million years age). Much of the Gig Harbor Peninsula is mantled by a veneer of glacial till of the youngest (Vashon) glacial period with the valleys containing predominantly glacial outwash and recent alluvium. Small sand deposits of recessional outwash overlie the till in a few areas of the Peninsula (i.e., near Harbor Heights in the Gig Harbor area). All of the peninsula's known ground water reserves are contained in these Quaternary sediments.

2.3.2 Stratigraphy/Cross Sections

The geologic deposits on the peninsula are divided into 12 hydrostratigraphic layers on the basis of depositional origin, environmental situation, and hydraulic permeability. The hydrostratigraphic layers presented in Table 1 are based on the interpretation of mapped surface deposits and the logs of nearly 500 wells. The depositional environment (glacial or non-glacial) and the grain size were the fundamental criteria for the division. For the purpose of this study, a hydrostratigraphic layer is a group of sediments that were deposited in the same environment at approximately the same geologic time, and have some degree of conformity with ground water occurrence.

The hydrostratigraphic layers are depicted in four geologic cross sections (Figures 2-2, 2-3, 2-4, and 2-5). The locations of four cross sections were chosen to give the best areal coverage of Gig Harbor Peninsula geology (see Figure 2-6). The cross sections were drawn as straight lines through the areas with the most reliable and abundant geological information. Once the location of the cross section trace was chosen and the topography plotted, selected wells with adequate geologic logs lying within approximately 1/2 mile of the cross section were projected onto the cross section.

The written lithologic descriptions of the projected wells have been simplified for easy reference into a standardized numbering scheme based on grain size. The system uses the following convention: #1-gravel; #2-sand; #3-silt or clay; #4-hardpan or till (a mix of all sizes); and #5-bedrock (not present in this study area). An assortment of grain sizes such as gravel and sand is shown as a of grain sizes in a particular strata leads to a fractional grade, e.g., 1.2 for gravel with some sand (see key to cross sections). In addition to the numbered sequences, peat and fossil shell occurrences, water levels, and screened or perforated water bearing zones are indicated on the well logs and cross sections. Where available, calculated hydraulic transmissivities are noted adjacent to the tested interval.

The hydrostratigraphic symbols used in this study are modified from the Brown & Caldwell (1985) Clover Creek-Chambers Creek study for the Tacoma-Pierce County Health Department. Recently, J. B. Noble (Noble, 1990) has proposed a stratigraphic revision of regional geologic names for coastal Pierce County with suggested correlations to the Brown & Caldwell hydrostratigraphic layer designations. Noble's proposed revision has provided modified or new geologic names which are applicable to the Gig Harbor Peninsula. This proposed hydrostratigraphic nomenclature is included in Appendix A.

Each hydrostratigraphic layer is highly variable in thickness, grain size, and permeability. Their heterogeneity can be clearly seen on each cross section by the variability of grain size within a short distance. In general, layers Ar, Aa, A2, C, E, and G behave as aquifers and Layers At, A1, B, D, and F act as aquitards. A general description of each hydrostratigraphic layer, starting with oldest and deepest, is given below.

<u>Hydrostratigraphic Layer G</u> is the oldest glacial deposit recognized in the study area. This unit is encountered in only the deepest wells of the peninsula (see well 17FO2 on cross section A-A' and 16KO1 on cross section C-C'). This glacial deposit is of unknown areal extent and is up to 100 feet thick. When penetrated, as in the City of Gig Harbor well (Well 17FO2) south of the city near SR 16, this layer has been highly productive. The layer is located 450 to 600 feet below sea level.

<u>Hydrostratigraphic Layer F</u>, a non-glacial deposit, consists generally of silt and clay. This layer is up to 200 feet thick and is encountered at depths from 250 to 500 feet below sea level. Due to its fine-grained nature, this layer is generally not permeable enough to allow the completion of production wells and is considered an aquitard. No wells on the peninsula are known to be completed in this layer.

Hydrostratigraphic Layer E is a glacial deposit of poorly sorted sand, gravel, and silt. This layer is up to 200-feet thick in some areas. Its areal extent is not well known due to a paucity of deep well data. This layer produces moderate amounts of ground water (see wells 35RO1 and 36RO2, cross section B-B') but is often bypassed for deeper, more productive zones.

Hydrostratigraphic Layer D is a non-glacial deposit of fine sand, silt, and clay. No wells are known to be completed in this layer and it generally acts as an effective aquitard. Thickness of Layer D is up to 200 feet and this deposit is encountered from above sea level to 300 feet below sea level.

Hydrostratigraphic Layer C is a glacial unit that is generally coarse-grained consisting of sand and gravel (previous reports referred to this strata as related to "Fox Island Drift"). This layer is a major producer of ground water for the peninsula. This unit comprises much or all of the extensive "Sea Level" aquifer (see Section 3.5).. A large percentage of the more productive wells on the Gig Harbor Peninsula are completed in this highly heterogeneous layer. A thickness of up to 250 feet has been noted in some areas. It is encountered from 150 feet above sea level to as deep as 150 feet below sea level.

Hydrostratigraphic Layer B has been identified as the interglacial Kitsap Formation by Garling and others (1958). The composition of Layer B is highly variable ranging from sand to clay. This generally fine-grained deposit commonly acts as an aquitard of varying effectiveness and thickness. The layer is less permeable than, and retards the ground water flow from, the Upper aquifer to the Sea Level aquifer. Thickness ranges from 100 feet in some areas to very thin or non-existent in other areas. Layer B is encountered from approximately 200 feet above to 100 feet below sea level.

Hydrostratigraphic Layer A2 is generally poorly sorted sand, gravel, silt, and clay. This layer comprises much of the Upper aquifer zone. Numerous wells, especially domestic wells, are completed in this layer. Layer A2 is encountered between 250 feet above sea level to sea level. This layer is found up to 200 feet thick, but is generally much thinner (about 50 feet thick).

<u>Hydrostratigraphic Layer A1</u> is an interglacial deposit consisting of mostly silt and clay. This sporadic layer was deposited immediately prior to the Vashon glaciation (approximately 26,000 years ago). These deposits were later scoured and eroded as the Vashon glacier overrode the region. These deposits occur over sporadic and limited areas and are generally thin (i.e., 25 to 50 feet thick at the most). Layer A1 is encountered from 150 to 100 feet above sea level. The layer locally serves as an effective aquitard that perches a water table above deeper water-bearing zones.

<u>Hydrostratigraphic Layer Aa</u> is a glacial deposit consisting predominantly of sand, and sand and gravel outwash deposits. As the Vashon glacier advanced from the north, the meltwater from the glacier deposited the sand and gravel as outwash. This deposit is up to 125 feet thick and is encountered from 300 to 150 feet above sea level. Previous reports referred to this layer as the Vashon Outwash. Many wells, especially domestic wells, are completed within this layer.

<u>Hydrostratigraphic Layer At</u> (formerly referred to as the Vashon Till) is predominantly glacial till, a very poorly sorted mixture of gravel, sand, silt, and clay. The layer was deposited as a veneer of material draped over the upland areas as the glacial sheet occupied the Gig Harbor Peninsula region. Layer At is up to 75 feet thick and is found at the highest ground elevations on the peninsula down to sea level. Layer At is generally of low permeability and yields only small amounts of water from perched zones contained in small, more permeable pockets within the till deposits.

<u>Hydrostratigraphic Layer Ar</u> is a locally occurring glacial deposit consisting predominantly of sand, and sand and gravel. Layer Ar was deposited as a thin layer (generally less than 50 feet) mainly in the upland areas and on hill tops (see cross section A-A' and D-D') as the Vashon glaciers receded from the region. Although this layer is generally

well sorted and relatively coarse grained, very few wells are completed in this layer due to its limited saturated thickness and sporadic occurrence on the Gig Harbor Peninsula.

Hydrostratigraphic Layer Qal is recent alluvium consisting of sand and gravel. This layer was deposited on valley floors by the present day streams. No wells are known to be completed within this layer.

2.4 CLIMATE

The climate of the area is relatively uniform and is characterized as a moist, cool maritime climate. Average winter temperatures are generally above freezing, and typical daytime summer temperatures are less than 85°C. Approximately 42 inches of rain fall on the area per year (NOAA-Tacoma Weather Station - 30 year average), almost wholly in the form of rain. Roughly 70 percent of the rainfall occurs from October through May. Estimates of evapotranspiration range from 18 to 24 inches (based on estimates for the Clover/Chambers Creek Basin, see Brown and Caldwell, 1985; WSU, 1968) leaving 24 to 18 inches of rainfall as percolation or as runoff.

Because of the mild maritime climate, the vegetative growth on the peninsula tends to be lush with softwoods (Douglas fir, western red cedar, western hemlock) being the dominant native tree species. Substantial volumes of pacific red alder, big leaf maple and other hardwood species comprise second and third growth forests in addition to conifers. The dense forest or brush cover mediates runoff and provides for greater uptake of water as well as a potential for nutrient release (alder is a substantial nitrogen "fixer") into the perched aquifer. The thick vegetation also tends to obscure the exact boundaries of minor and potentially significant surface features including areas of rapid infiltration or recharge.

The effect of the seasonally wet climate is to cause significant aquifer recharge during the winter months (November-March) with little or no hydrologic input to ground water during directly from precipitation show higher elevations in spring and tend toward lowest levels in October, before the rainy season commences.

Drost (1982) prepared a presumptive water budget for the Gig Harbor Peninsula in which he estimated that over 85 percent of the moisture input to the area is via rainfall, of which over 60 percent is lost via surface discharge and evapotranspiration. Of the remaining 40 percent (7.2 to 9.6 inches/year), Drost estimates that only 40 percent (a total of 16 percent net - or 2.9 to 3.8 inches/year) is available for deep percolation to the "Sea Level" and deeper aquifers. He does not estimate the proportion of this flow that is lost to discharge to Puget Sound or percolates to the deepest zone.

Assuming an average infiltration of 8.4 inches and a total catchment (peninsula) area of 50 square miles, the total aquifer resource is estimated at roughly 220,000 acre-feet/year. Using Drost's estimates, this resource is divided 60 percent (133,000 acre-feet/year) to the Upper and perched aquifer zones and 40 percent to the Sea Level or deeper aquifers. This is equivalent to an annual water supply of approximately 230,000 gallons/acre/year. An average household may use 100,000 to 150,000 gallons per year.

Section 3
HYDROGEOLOGY

3.1 GENERAL DESCRIPTION

The repeated sequence of alternating glacial and non-glacial deposition created numerous aquifers and aquitards in the Gig Harbor Peninsula region. Several aquifer zones have been identified within the Gig Harbor Peninsula study area. They include: perched ground water zones; the Upper aquifer; the Sea Level aquifer; and at least two deeper aquifer systems. Several aquitards, including one (Layer B) that commonly separates the Upper aquifer from the Sea Level aquifer, have been identified. These aquifers and aquitards are discussed in greater detail below.

3.2 PERCHED GROUND WATER ZONES

On the Gig Harbor Peninsula, several shallow, mostly dug wells, are completed in water-bearing zones near the surface. These zones exist mostly as perched zones that are localized where impervious layers prevent or greatly hinder the downward percolation of ground water. In some cases, the perched water is above an unsaturated layer. These perched aquifers are characterized by water levels that are much higher (nearer to the ground surface) than the Upper aquifer. These zones commonly occur as pockets of permeable material within the much less permeable glacial till. The localized nature of these perched aquifers limits the quantities of ground water that can be withdrawn from them. As a result, water withdrawal from these zones is limited almost exclusively to individual domestic supply wells.

3.3 UPPER AQUIFER

The Upper aquifer is prevalent throughout the Gig Harbor Peninsula. The Upper aquifer is found within hydrostratigraphic Layer A2 and, in some areas in the North, Layer Aa.

differences in his aquifer is comprised of sand and gravel with thick sequences of sand. Those hydrostratigraphic layers are generally less than 100 feet thick but may be as much as 200 feet thick. The actual zones from which ground water is utilized are much thinner.

A contour map of the water table surface was constructed using the construction water levels of wells completed within the Upper aquifer (see Figure 3-1). The Upper aquifer is characterized by an intermediate water level (between the water levels of the perched system and the Sea Level aquifer) that generally mimics topography, i.e., the higher the ground elevation, the higher is the Upper aquifer water level. This characteristic provides a water table surface with "hills and valleys" much like the ground surface. For a visual aid, a three-dimensional plot was made using the water level information in the data base (see Figure 3-2). This plot clearly shows the undulatory shape of the water table surface.

3.4 AQUITARD

The aquitard that exists between the aforementioned Upper aquifer and the Sea Level aquifer (described below) is hydrostratigraphic Layer B (formerly referred to as the Kitsap formation). This aquitard is generally a semi-permeable to permeable deposit that, where present, retards ground water percolation from the Upper aquifer down to the Sea Level aquifer. The aquitard is encountered from 200 feet above sea level to 100 feet below sea level. Thicknesses of up to 100 feet have been noted in some areas of the peninsula. In other areas, layer B is not found and the transfer of ground water between the Sea Level and Upper aquifer may be relatively unimpeded. The effectiveness of Layer B as an aquitard is dictated by a combination of its composition and thickness. The Upper aquifer is widely used by individual as well as the medium-sized to smaller public water supplies particularly in the Purdy upland region.

3.5 SEA LEVEL AQUIFER

The Sea Level aquifer is generally pervasive throughout the Gig Harbor Peninsula. The Sea Level aquifer is largely contained in hydrostratigraphic Layer C and is predominantly composed of sand, and gravel mixed with sand. The Sea Level aquifer is encountered from 150 feet above to 150 feet below sea level and is up to 200-feet thick.

A contour map of the potentiometric surface of the Sea Level aquifer was constructed using water level data for wells completed in Layer C (see Figure 3-3). The Sea Level aquifer is characterized by a low elevation water level (i.e., near sea level in areas close to the shoreline). The potentiometric surface of the Sea Level aquifer, much like the water table surface of the Upper aquifer, mimics topography but with a reduced amplitude underneath the areas of high and low topography. This is clearly seen when comparing three-dimensional plots of the Upper and Sea Level aquifer potentiometric surfaces (see Figures 3-2 and 3-4) for the Gig Harbor area. At present, the Sea Level aquifer constitutes the primary resource for the larger public and municipal water supplies.

3.6 DEEPER AQUITARDS AND AQUIFERS

Below the Sea Level aquifer is an alternating sequence of deposits that generally behave as aquitards and aquifers. The hydrostratigraphic Layers D and F are believed to act as aquitards and Layers E and G are generally considered aquifers. The hydrologic characteristics of these deposits are not well known due to the lack of deep well data.

There is sparse data on the aquifer within Layer E, but it is not known to be a major source for ground water. The aquifer zones in Layer G appear to be more productive than in Layer E. The few deep wells that have been drilled bypassed Layer E in favor of Layer G.

Given the information from the few existing deep wells, it is thought that Layer G may have major ground water potential on the Gig Harbor Peninsula. However, the areal extent and range of thickness of Layers E and G are not known since the number of wells penetrating these zones is limited.

The deeper, fine-grained, interglacial deposits in the study area, Layers D and F, generally act as aquitards of varying effectiveness. Hydrostratigraphic Layers D and F are encountered only in the deepest wells on the peninsula and their general thickness and areal extent are unknown.

Section 4
WATER USAGE

4.1 POPULATION DISTRIBUTION

The population (roughly 20,000) of the Gig Harbor peninsula is concentrated in the Gig Harbor area and along the SR 16 corridor. Gig Harbor is the only incorporated entity in the study area, and has a population of approximately 3,000. Throughout the remainder of the area, the population is distributed in medium to small communities, rural, and rural-residential developments. The distribution of public water systems throughout the study area (with a high concentration in the Gig Harbor and SR 16 areas) reflects this dispersion of population. In addition, in areas where the shoreline is accessible, there are increased densities of development within access and view distance of Puget Sound.

There are a few areas with significantly reduced populations and few water supply wells. These areas include the northwest central portion of the Gig Harbor uplands (Region 4) and the northern portion of the Purdy uplands area toward the Kitsap County line.

Future land use and population projections are discussed in more detail in Section 5.1, Population Forecast, of the Task 2 Report (Land and Water Use Background Report).

4.2 SURFACE/PERCHED AQUIFERS

As indicated previously, the shallow and perched aquifers (alluvium and perched till aquifers) are currently used to only a minor extent due to their infrequent occurrence and unreliable nature. This use is not anticipated to change in the future.

4.3 UPPER AQUIFER

As noted in Section 3, the major sources of water supply are the Upper and Sea Level aquifers, with a few wells (notably Gig Harbor wells) in the deeper zones. Well records and logs indicate that the sea level provides the main source for the larger purveyors (class 1 and 3), especially in the Gig Harbor (and south) area. In the northern portion of the peninsula, there are fewer large supply systems and that fact, coupled with an apparently higher productivity, has led to a greater reliance of the Upper aquifer. However, there is little hard data in the actual water purportage rates either regionally or by individual districts or supply systems.

A more detailed description of existing water supply systems and their management under the Consolidated Water Supply Plan is included in Section 6 of the Task 2 Report.

4.4 REGIONAL WATER USE

As noted in paragraph 2.4, Climate, Drost estimates regional recharge for the entire study area. A comparison of water recharge vs. water use estimates is given in Table 4-1.

As these very approximate estimates indicate, local consumption of the aquifer could easily deplete supplies on a local basis (525,600 gallon/acre/year usage vs. 270,000 gallon/acre/year supply) under relatively optimistic assumptions concerning recharge. As noted in Drost (1982), this recharge deficit may be split 60 to 40 percent between the Upper and Sea Level aquifers with only 108,000 gallon/acre/year reaching the primary supply (Sea Level) aquifer.

On an average area-wide basis, roughly 220,000 acre-feet/year are supplied by recharge, while the potential for usage ranges from the current 100,000 acre-feet/year (current) to 300,000 acre-feet/year under conditions of rapid growth to a population double the current population by the year 2010.

Table 4-1

ANNUAL WATER BUDGET/USAGE

	---- Estimated Range ----		
Annual Precipitation	43 inches (3.5 feet)		
Evapotranspiration	18 inches (1.5 feet)	to	24 inches (2.0 feet)
Runoff	14 inches (1.17 feet)	to	11 inches (9.1 feet)
Net Percolation	10 inches (.83 feet) (36,150 ft^3/acre = (270,000 gal/acre)	to	7 inches (.58 feet) (25,250 ft^3/acre = (189,000 gal/acre)
Population Density	0.2 families/acre (5 acre min)	to	3.0 families/acre
Water Usage (4.0 persons/family)	@ 100 gpcd* 29,200 gal/acre	to	@ 120 gpcd * 525,600 gal/acre

* gpcd = gallons per capita per day

These estimations indicate that potential water resource problems may be anticipated, both locally and regionally as the area continues to develop, assuming these estimates are based on accurate assumptions. The final project report will provide a management evaluation based on a continuing refinement of these estimates.

Section 5
WATER QUALITY

5.1 DATA SOURCES/LIMITATIONS

The current water quality data base consists primarily of data summaries from USGS water supply studies (Drost, 1982) and data available in the WDOE PCSTORET and EPA STORET data systems. This data is adequate for a preliminary review, but is inadequate for full aquifer characterization due to limitations on the number of sites sampled, the parameters tested, the appropriateness of sampling points (i.e., sampling points may be from multiple connected wells or from water system outlets following storage systems), and the detection limits and quality control protocols. This data base comprises roughly 80 wells from the Drost study and 50 wells from the EPA STORET and PCSTORET systems. The Drost data represent single event data in the late 1970s, while the STORET and PCSTORET data comprise, generally, one to five samples taken between 1978 and 1986.

The aquifer systems are divided between surface-perched, Upper, and Sea Level aquifers. The data base contains little or no data for the surface or perched aquifer zone. The remaining data are distributed between remaining Upper and Sea Level aquifers.

5.2 SURFACE/PERCHED WATER

There is virtually no information on water quality for this uppermost zone since this aquifer is only very locally usable for individual domestic water supply. In general, this aquifer zone is found in the southernmost portion of the peninsula and in the central-northern zones with depths to water of less than 100 feet. It might be expected that water quality in this zone would show strong impacts from surface activities or local surficial soil and geological configurations (peaty areas, iron soils, septic systems, etc.), but this has not been tested.

5.3 UPPER AQUIFER

The Upper aquifer (referred to as the Colvos Sand member aquifer in Drost) occurs in the Vashon Drift above the Kitsap Formation aquitard and is a major source of water supply for individual and small water systems. This aquifer, based on the potentiometric surface conformity with the topography, is at least indirectly tied to surface water recharge and surface water comprises the recharge source for this aquifer zone. It might be expected that water in this zone would be potentially variable in quality depending on the geology and the local degree of connection between this aquifer and either the perched aquifer zones or the sources of surface recharge; however, the limited data base makes it difficult to identify definite trends.

Data summarized in Drost (approximately eight wells in this Upper aquifer), and in the STORET data base (~10 wells) indicate, generally, very low levels of chloride (1-6 ppm) and low conductivities (85-150 umhos). The DROST records indicate some wells with iron staining and at least one with odor problems. The limited data for nitrate-N (averaging <1.0 ppm) indicate individual wells that have nitrate elevations due to impacts from surface sources. There are no indications of salt water intrusion in this zone since this aquifer lies entirely above sea level.

The above data supports the assumption that the Upper aquifer is characteristically low in dissolved constituents and does not show widespread contamination from surface activities. However, contamination that is present is likely to be local and related to specific land use activities in the immediate vicinity of specific wells and is not likely to be adequately detected with the existing data base.

5.4 SEA LEVEL AQUIFER

The Sea Level aquifer (referred to in Drost as the Salmon Springs aquifer) is generally separated from the Upper aquifer by the Kitsap formation. Again, the data are somewhat limited, primarily from Drost (single sample data from approximately 50 wells) and approximately 30 multiple time records from the DSHS and EPA STORET records.

The data indicate a similar aquitard chemistry to that observed in the Upper aquifer with low background levels of chloride (2-5 ppm), nitrate-N (<2.0 ppm), and dissolved solids (conductivity at 75-180 umhos). These wells show a considerably greater degree of variation due to both a more extensive data base as well as additional hydrogeologic influences on water quality. Although in general chloride shows background levels similar to the Upper aquifer in the 2-5 ppm range, several wells in the Horseshoe Bay area show the influence of saline intrusion with chloride levels as high as 300 ppm. Conductivity levels parallel the chloride in that general levels are in the 75-180 range with salt water intrusion wells showing levels over 1,000 umhos/cm.

Nitrate-N levels also show generally low levels similar to those noted in the Upper aquifer (typical values range from 0.01 to 0.50 ppm as NO_3-N), but with a significant number of wells showing levels in excess of 1.0 ppm. In some situations, these levels appear to correlate with high levels of dissolved solids, but in other cases this correlation is not apparent. Since this aquifer is exposed to salt water intrusion as well as to surface activities, particularly on the margins of the peninsula, these elevated nitrate levels may represent surface contamination in areas where the Kitsap aquitard (layer B) is not present. However, as with the Upper aquifer, the data are too spatially scattered to provide more than a general indication of contamination susceptibility.

As with the Upper aquifer, the DROST data indicate many well waters which exhibit staining due to high iron levels; however, only one well is noted as registering an offensive odor.

5.5 DEEPER AQUIFERS

The data base for the deeper aquifer zones is similar to but more restricted than that for the Sea Level aquifer. The Drost data contains single time samples from approximately 44 locations. The STORET data base contains records from approximately 15 wells in these deeper zones. As with the Upper aquifer, natural chloride and conductivity levels are low (2-20 ppm and 80-200 umhos/cm, respectively), with considerable individual variations within these ranges. Nitrate-N levels show a similar pattern to the Sea Level aquifer but, notably, exhibit a somewhat lower rate of occurrence of high levels (i.e., >1.0 ppm) than in the Sea Level aquifer. Iron staining is reported for many wells, while salty taste is reported for several high chloride wells and bad odor/taste (sulfide) is reported in at least five wells listed by DROST. Total coliform organisms are reported in two wells of these.

5.6 SUMMARY

Overall, the various aquifers under investigation appear to bear marked resemblances to one another. This is true for the Upper and the Sea Level, as well as deeper aquifers. There are no data for the perched aquifer zones. The low level differences in mineralization noted in wells indicates, presumably, different ages of otherwise similarly sourced water for all three zones. This is consistent with the hydrologic assumption that all aquifer zones in the study area are connected and that recharge is ultimately from surface infiltration for all three aquifers. The numerical differences in chemical concentrations, as measured by calcium, chloride, and hardness levels, are small and consistent with this assumption. Hardness levels in the Upper aquifer are in the 30-90 mg/L range (using data from PCSTORET), while levels in the 20-80 ppm range are typical for the non-saline wells in the Sea Level aquifer. Calcium levels follow a similar pattern. These observations are consistent with the general hydrogeological interpretation of the aquifer zones in the Gig Harbor study area.

As noted previously, there are some indications of quality variations in both the Upper and Sea Level aquifers, but the wide spatial distribution and question concerning data consistency make it impossible to clarify these indications.

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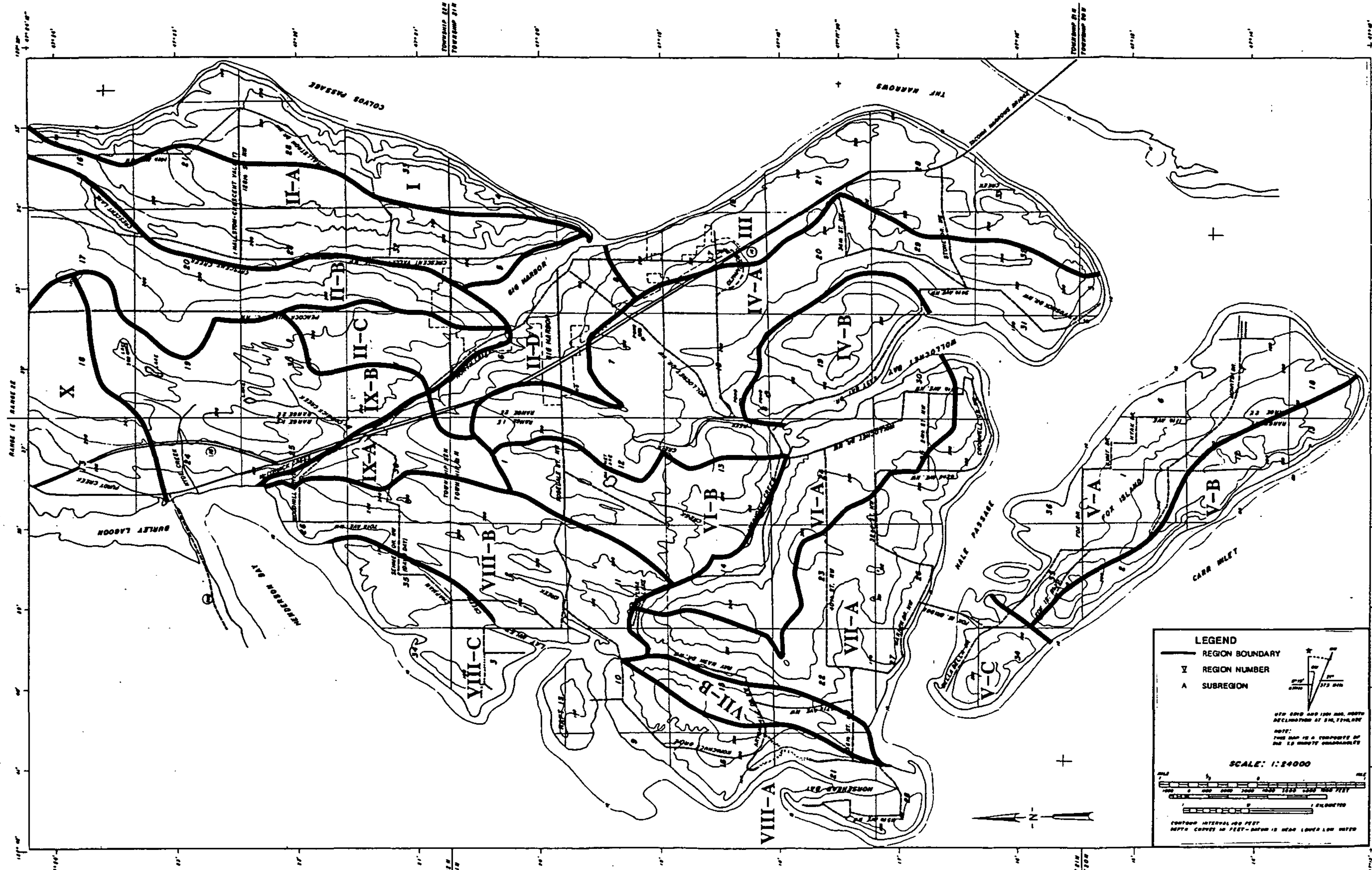

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Figure 2-1

GIG HARBOR PENINSULA

HYDROLOGIC REGIONS

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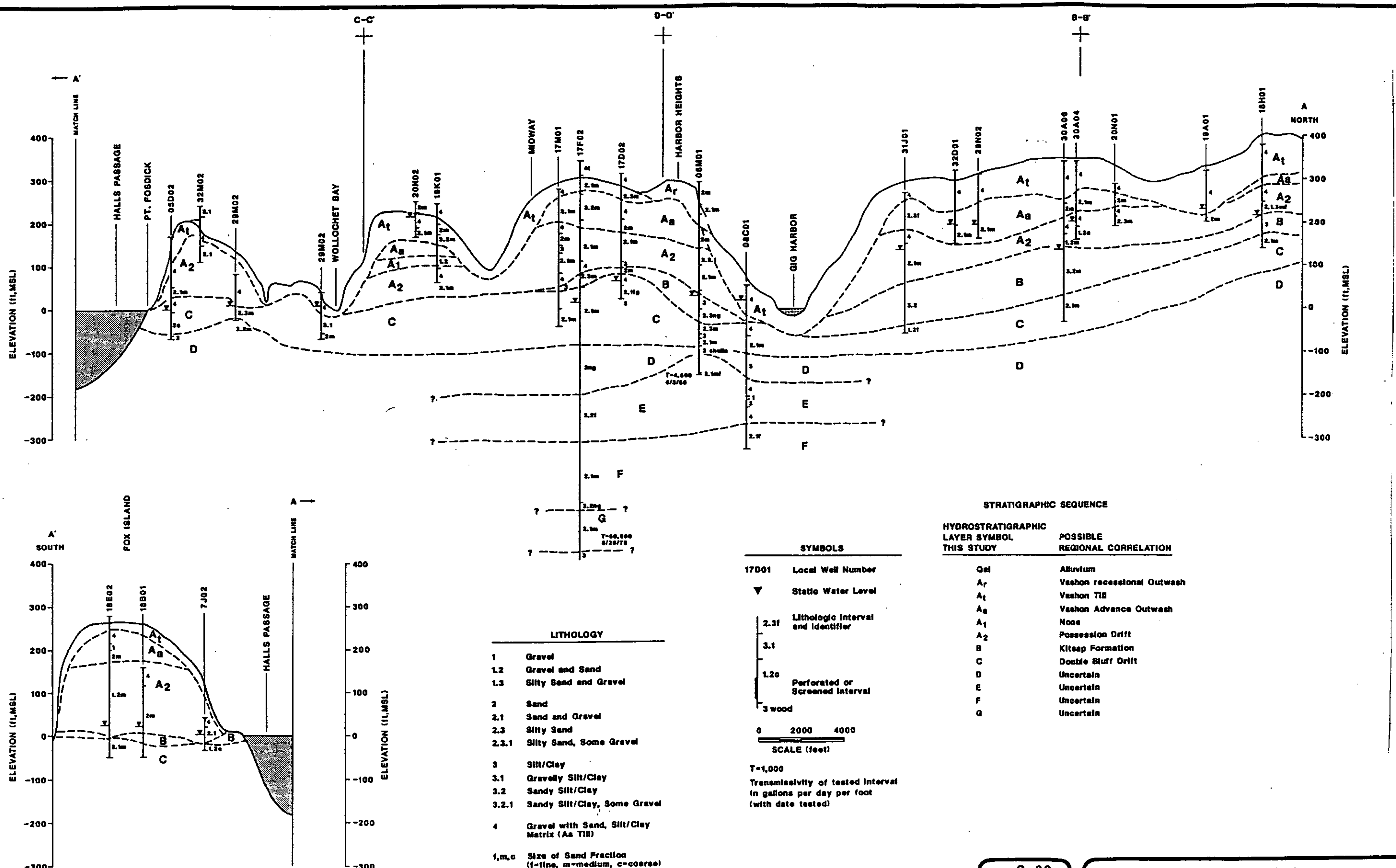

LITHOLOGY

1	Gravel
1.2	Gravel and Sand
1.3	Silty Sand and Gravel
2	Sand
2.1	Sand and Gravel
2.3	Silty Sand
2.3.1	Silty Sand, Some Gravel
3	Silt/Clay
3.1	Gravelly Silt/Clay
3.2	Sandy Silt/Clay
3.2.1	Sandy Silt/Clay, Some Gravel
4	Gravel with Sand, Silt/Clay Matrix (As Till)
f,m,c	Size of Sand Fraction (f=fine, m=medium, c=coarse)
peat	Peat Occurrences
wood	Wood Occurrences

SYMBOLS

17D01	Local Well Number
▼	Static Water Level
2.3f, 3.1, 1.2c, 3 wood	Lithologic Interval and Identifier; Perforated or Screened Interval

0 2000 4000
SCALE (feet)

T=1,000
Transmissivity of tested interval in gallons per day per foot (with date tested)

STRATIGRAPHIC SEQUENCE

HYDROSTRATIGRAPHIC LAYER SYMBOL THIS STUDY	POSSIBLE REGIONAL CORRELATION
Qal	Alluvium
A_r	Vashon recessional Outwash
A_t	Vashon Till
A_s	Vashon Advance Outwash
A_1	None
A_2	Possession Drift
B	Kitsap Formation
C	Double Bluff Drift
D	Uncertain
E	Uncertain
F	Uncertain
G	Uncertain

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Figure 2-2
GIG HARBOR PENINSULA
GROUND WATER MANAGEMENT STUDY
GEOLOGIC CROSS-SECTION A-A'

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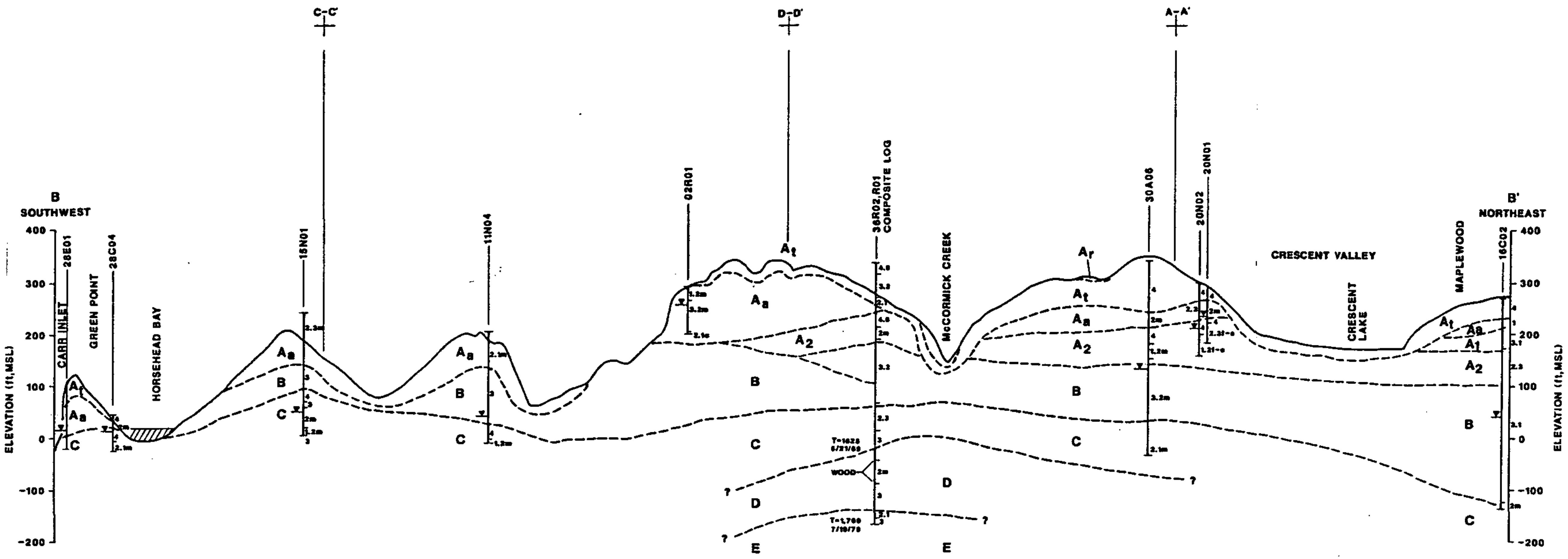

STRATIGRAPHIC SEQUENCE

LITHOLOGY	
1	Gravel
1.2	Gravel and Sand
1.3	Silty Sand and Gravel
2	Sand
2.1	Sand and Gravel
2.3	Silty Sand
2.3.1	Silty Sand, Some Gravel
3	Silt/Clay
3.1	Gravelly Silt/Clay
3.2	Sandy Silt/Clay
3.2.1	Sandy Silt/Clay, Some Gravel
4	Gravel with Sand, Silt/Clay Matrix (As Till)
f,m,c	Size of Sand Fraction (f=fine, m=medium, c=coarse)
peat	Peat Occurrences
wood	Wood Occurrences

SYMBOLS	
17D01	Local Well Number
▼	Static Water Level
2.3f / 3.1 / 1.2c / 3 wood	Lithologic interval and identifier; Perforated or Screened Interval
0 2000 4000	SCALE (feet)
T=1,000	Transmissivity of tested interval in gallons per day per foot (with date tested)

HYDROSTRATIGRAPHIC LAYER SYMBOL THIS STUDY	POSSIBLE REGIONAL CORRELATION
Qal	Alluvium
A_r	Vashon recessional Outwash
A_t	Vashon Till
A_a	Vashon Advance Outwash
A_1	None
A_2	Possession Drift
B	Kitsap Formation
C	Double Bluff Drift
D	Uncertain
E	Uncertain
F	Uncertain
G	Uncertain

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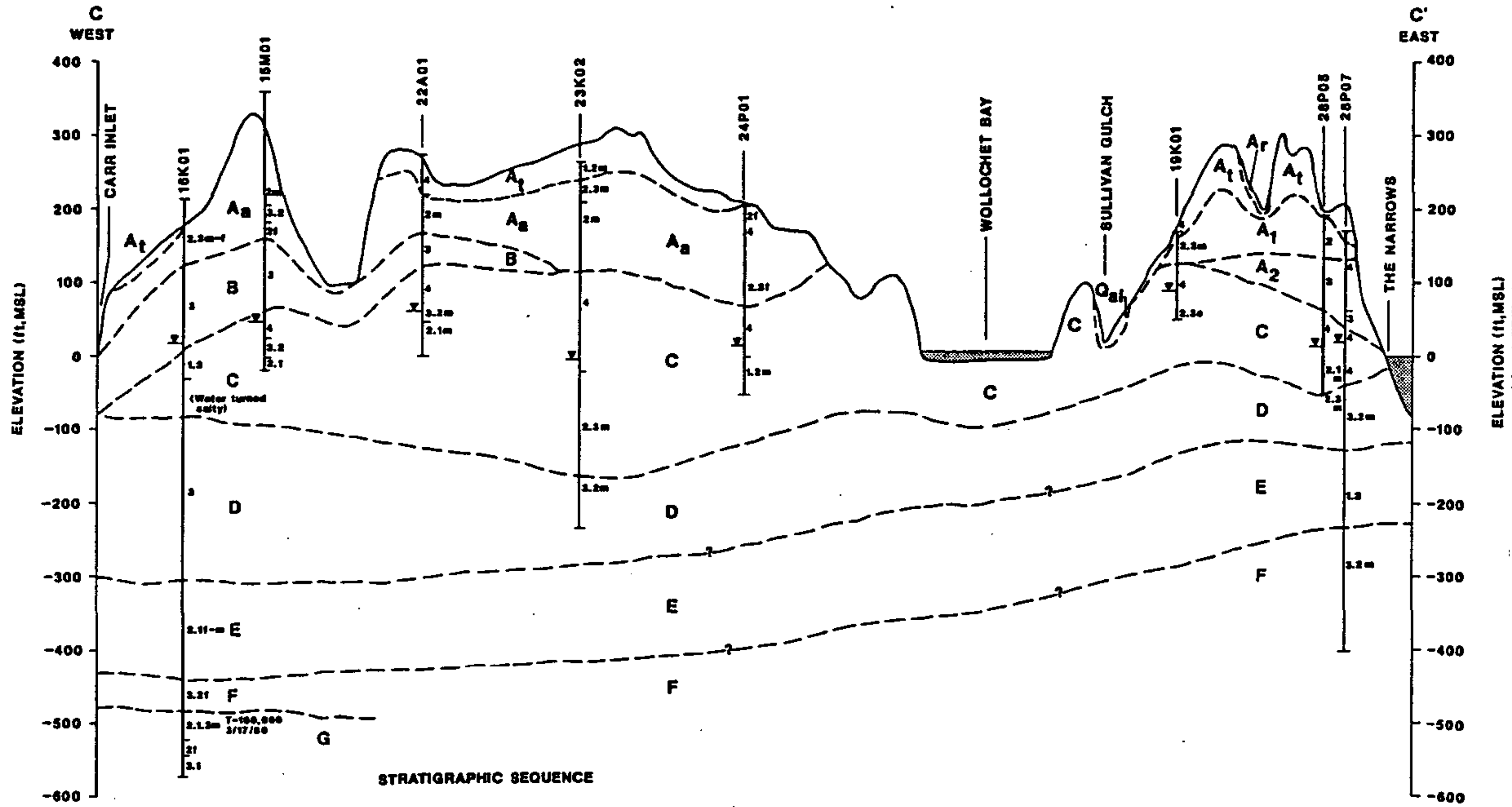
Figure 2-3
GIG HARBOR PENINSULA
GROUND WATER MANAGEMENT STUDY
GEOLOGIC CROSS-SECTION B-B'

131245



SYMBOLS

17D01 Local Well Number

▼ Static Water Level

2.3f, 3.1 Lithologic Interval and Identifier

1.2c Perforated or Screened Interval

3 wood

0 2000 4000
SCALE (feet)

T=1,000
Transmissivity of tested interval in gallons per day per foot (with date tested)

LITHOLOGY

1	Gravel
1.2	Gravel and Sand
1.3	Silty Sand and Gravel
2	Sand
2.1	Sand and Gravel
2.3	Silty Sand
2.3.1	Silty Sand, Some Gravel
3	Silt/Clay
3.1	Gravelly Silt/Clay
3.2	Sandy Silt/Clay
3.2.1	Sandy Silt/Clay, Some Gravel
4	Gravel with Sand, Silt/Clay Matrix (As Till)
f,m,c	Size of Sand Fraction (f=fine, m=medium, c=coarse)
peat	Peat Occurrences
wood	Wood Occurrences

STRATIGRAPHIC SEQUENCE

HYDROSTRATIGRAPHIC LAYER SYMBOL THIS STUDY	POSSIBLE REGIONAL CORRELATION
Qal	Alluvium
A_r	Vashon recessional Outwash
A_t	Vashon Till
A_a	Vashon Advance Outwash
A_1	None
A_2	Possession Drift
B	Kitsap Formation
C	Double Bluff Drift
D	Uncertain
E	Uncertain
F	Uncertain
G	Uncertain

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Figure 2-4
GIG HARBOR PENINSULA
GROUND WATER MANAGEMENT STUDY
GEOLOGIC CROSS-SECTION C-C'

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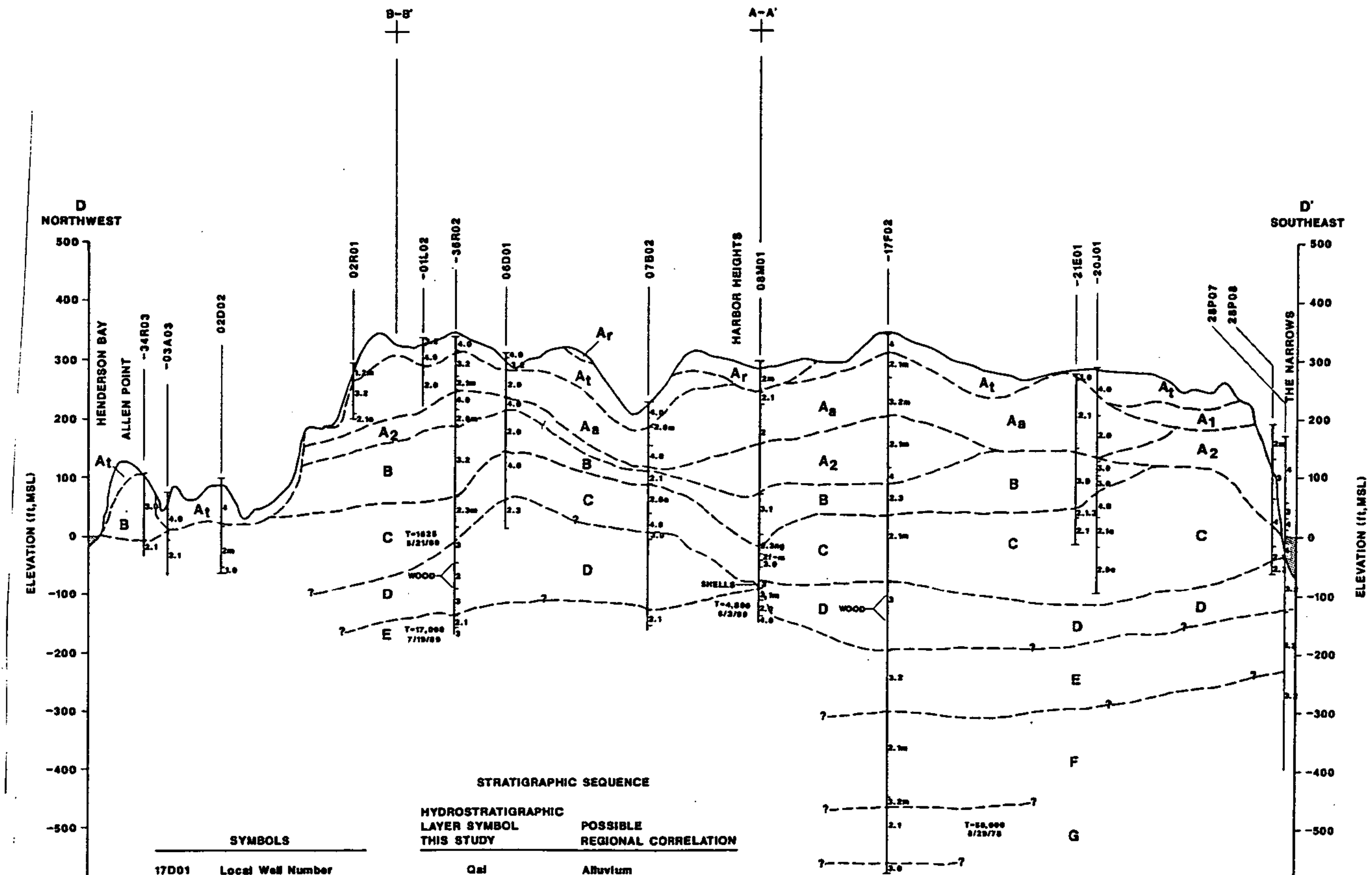

LITHOLOGY	
1	Gravel
1.2	Gravel and Sand
1.3	Silty Sand and Gravel
2	Sand
2.1	Sand and Gravel
2.3	Silty Sand
2.3.1	Silty Sand, Some Gravel
3	Silt/Clay
3.1	Gravelly Silt/Clay
3.2	Sandy Silt/Clay
3.2.1	Sandy Silt/Clay, Some Gravel
4	Gravel with Sand, Silt/Clay Matrix (As Till)
f,m,c	Size of Sand Fraction (f=fine, m=medium, c=coarse)
peat	Peat Occurrences
wood	Wood Occurrences

SYMBOLS

- 17D01 — Local Well Number
- ▼ — Static Water Level
- 2.3f, 3.1 — Lithologic Interval and Identifier
- 1.2c — Perforated or Screened Interval
- 3 wood

0 2000 4000
SCALE (feet)

T=1,000
Transmissivity of tested interval in gallons per day per foot (with date tested)

STRATIGRAPHIC SEQUENCE

HYDROSTRATIGRAPHIC LAYER SYMBOL THIS STUDY	POSSIBLE REGIONAL CORRELATION
Qal	Alluvium
A_r	Vashon recessional Outwash
A_t	Vashon Till
A_a	Vashon Advance Outwash
A_1	None
A_2	Possession Drift
B	Kitsap Formation
C	Double Bluff Drift
D	Uncertain
E	Uncertain
F	Uncertain
G	Uncertain

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Figure 2-5
GIG HARBOR PENINSULA
GROUND WATER MANAGEMENT STUDY
GEOLOGIC CROSS-SECTION D-D'

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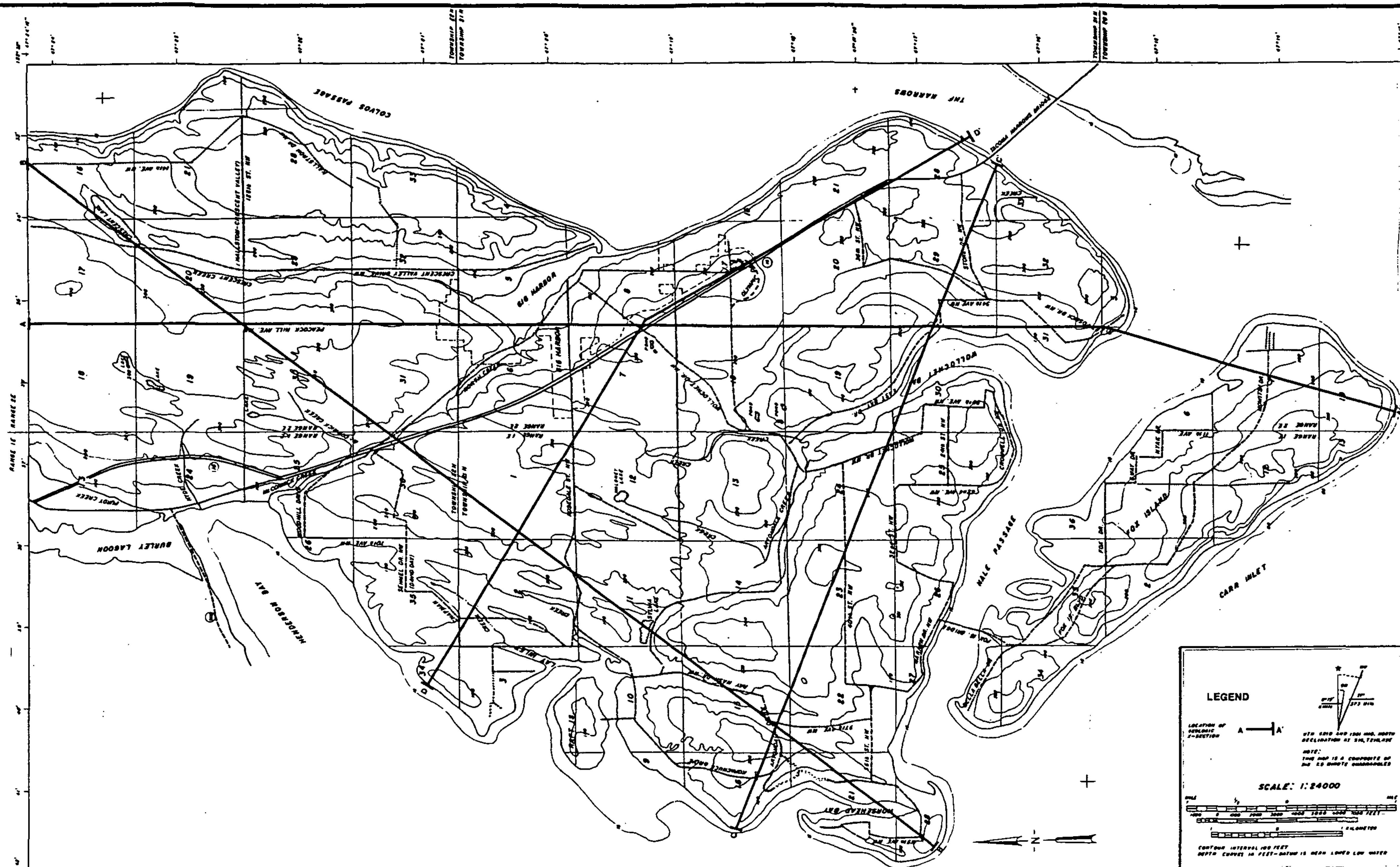

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Figure 2-6
GIG HARBOR PENINSULA
CROSS-SECTION LOCATION MAP

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Figure 3-1
GIG HARBOR PENINSULA
POTENTIOMETRIC SURFACE CONTOURS OF UPPER AQUIFER ZONE

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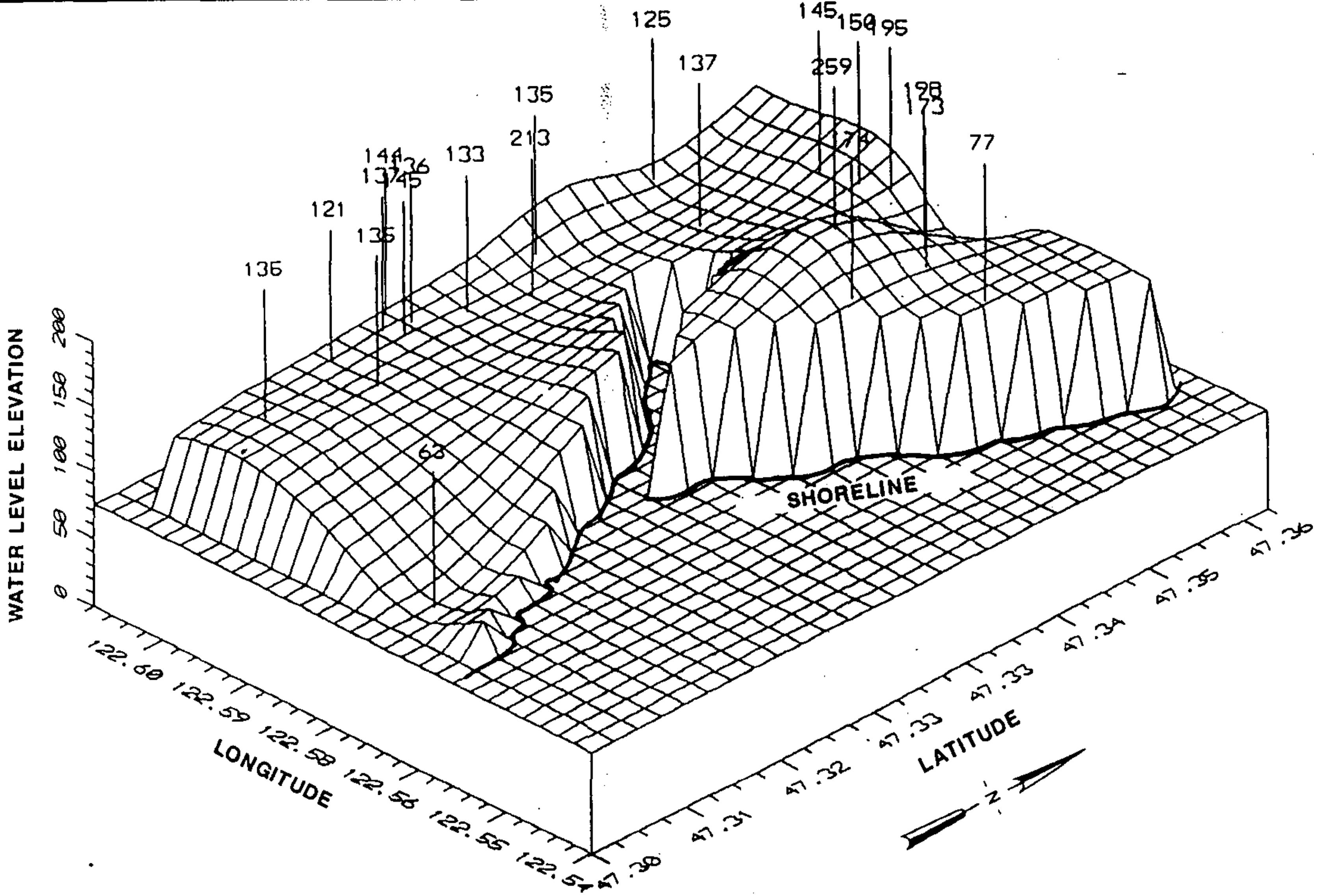

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Figure 3-2
GIG HARBOR PENINSULA
PERSPECTIVE DIAGRAM
UPPER AQUIFER ELEVATIONS

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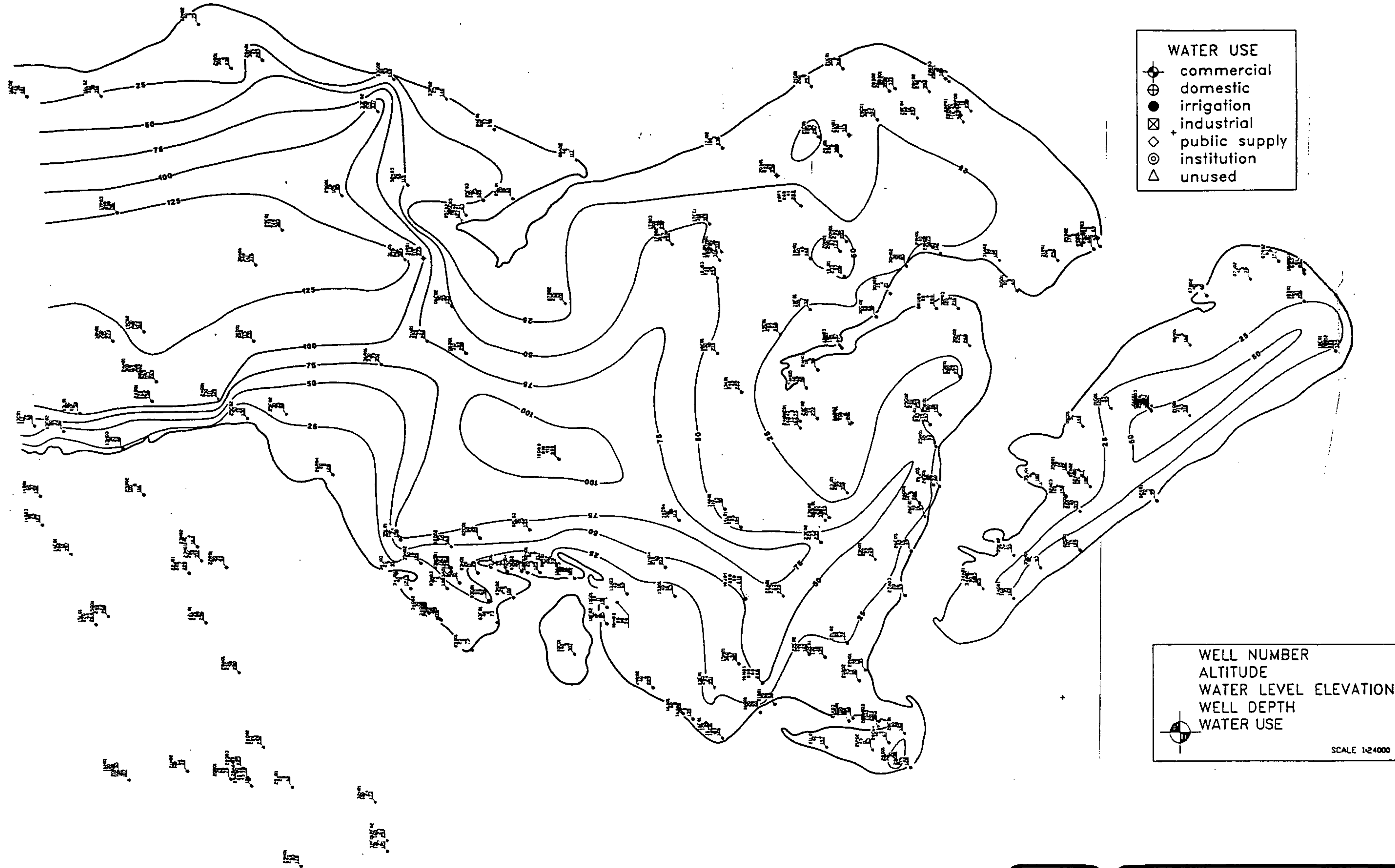

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Figure 3-3
GIG HARBOR PENINSULA
POTENTIOMETRIC SURFACE CONTOURS OF SEA LEVEL AQUIFER ZONE

133396

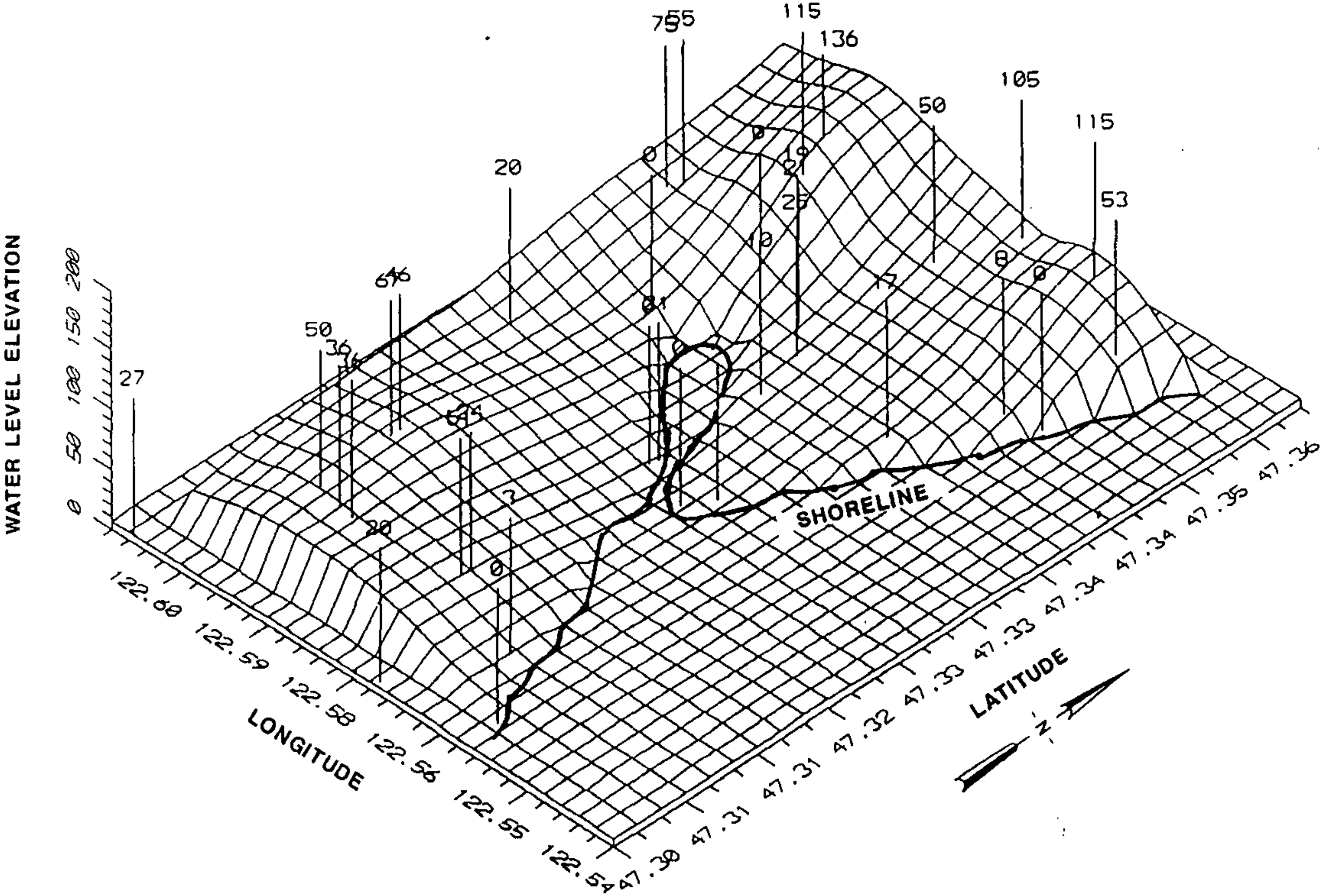

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Figure 3-4
GIG HARBOR PENINSULA
PERSPECTIVE DIAGRAM
SEA LEVEL AQUIFER ELEVATIONS

APPENDIX A

PROPOSED HYDROSTRATIGRAPHIC NOMENCLATURE REVISIONS

(ROBINSON & NOBLE)

STRATIGRAPHIC SEQUENCE

Hydrostratigraphic Layer Symbol This Study	Formation Names Proposed by Noble (in preparation)
Qal	-----
A_r	Vashon Drift
A_t	Vashon Drift
A_a	Vashon Drift
A_1	Discovery Formation
A_2	Narrows Drift
B	Kitsap Formation
C	Flett Creek Drift
D	Clover Park Formation
E	Lakewood Drift
F	Gravelly Lake Formation
G	Lone Star Drift

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