Technical Memorandum

To: Ann Soule, Clallam County

From: Peter Schwartzman & Jeff Witter, Pacific Groundwater Group

Re: Hydrogeologic Screening for Sequim Pilot Infiltration Test

Date: August 21, 2007

This memorandum presents Pacific Groundwater Group's (PGG's) hydrogeologic screening of five sites east of the Dungeness River for suitability for infiltration of reclaimed water and/or surface water diversions. This analysis corresponds to Task 5f of the Dungeness Aquifer Recharge (AR) project scope and includes recommendations regarding the design and implementation of a pilot recharge project along with concurrent monitoring.

PGG's assessment of site suitability for infiltration is based on readily available information regarding surficial soils, surficial and sub-surface geology, depth to groundwater, generalized groundwater flow directions, locations of nearby wells, and locations of nearby surface-water features. Geologic characterization was based on descriptions of hydrogeologic units and cursory review of individual well logs, although PGG's prior hydrogeologic characterization of the City's Reclaimed Water Demonstration Site (PGG, 2000) and Robinson and Noble's prior characterization of the Shaw gravel pit (R&N, 2002) supported more detailed characterization at these locations.

Our assessment suggests that shallow subsurface sediments are relatively coarse-grained, which typically corresponds to relatively high transmitting capacity for infiltrated water. However, well logs typically report variable clay contents, which could locally reduce infiltration capacity. Testing and/or the installation of shallow monitoring wells would be required to evaluate site infiltration capacities. The infiltration capacity of several sites (Site "HW-3", the Demonstration Site and the Gravel Pit) could be limited by relatively shallow depths to groundwater and/or underlying low permeability units, depending on the actual transmitting capacity of the shallow coarse-grained sediments. Depths to groundwater immediately underlying the other two sites are not documented.

A general description of the proposed infiltration sites and selection of preferred sites is presented in section 1. Background hydrogeology is discussed in section 2. Infiltration potential at each of five preferred study sites is presented in sections 3 through 7. A summary of findings and considerations for site selection is presented in Section 8.

The Technical Advisory Group (TAG) has chosen to pursue further investigation of testing at Site HW-3 (due to ready availability of reclaimed water) and either Site HW-2 or the gravel pit (due to potential availability of storm runoff routed through the irrigation ditches). Recommendations for testing at these sites are also presented in Section 8.

PGG's work was performed, and this report prepared using generally accepted hydrogeologic practices used at this time and in this vicinity for exclusive application to the study area and for the exclusive use of Clallam County. This is in lieu of other warranties, express or implied.

1.0 DESCRIPTION OF SITES

The City of Sequim provided PGG with coordinates for 19 potential infiltration sites, as shown on **Figure 1**. The sites included retention ponds, detention ponds, a gravel pit, the City's Re-Use Demonstration Site at Carrie Blake Park, and possible excavation of an infiltration pond on property adjacent to the Sequim City Shop[1]. The retention and detention ponds occur along State Route 101 (SR-101) and are currently used for runoff from the highway. The ponds were identified based on their ability to store water without prior knowledge of their infiltration characteristics. The City defines retention and detention ponds in the following manner (Dueno, 2007):

> A retention pond is designed to hold a specific amount of water indefinitely. Usually the pond is designed to have drainage leading to another location when the water level gets above the pond capacity, but still maintains a certain capacity.
>
> A detention pond is a low lying area that is designed to temporarily hold a set amount of water while slowly draining to another location. They are more or less designed for flood control when large amounts of rain could cause flash flooding if not properly addressed.

Prior to performing the analyses detailed in this memo, PGG pre-selected the most favorable of the 19 infiltration sites based on surficial soils. Soil types are mapped on **Figure 2**, and associated soil descriptions are presented in **Appendix A**. Soils at several of the western sites have been removed during construction of the SR-101 bypass and various commercial sites; however, the original (mapped) soil types reflect parent sedimentary materials that are generally still relevant for site selection. Based on the saturated hydraulic conductivity (permeability) of the most restrictive soil layer, PGG classified soils into groupings of moderate-to-high, low, and very low permeability. Infiltration sites located on moderate-to-high permeability soils were selected for further investigation within this hydrogeologic screening.

Selected sites are indicated on both figures, as delineated by purple outlines that outline the general area of study surrounding each site. In some cases, several infiltration sites are contained in a single area of investigation (9 potential recharge sites are condensed into 5 study sites). Along with the Demonstration Site and the gravel pit, 3 study sites occur along the highway (HW-1, HW-2 and HW-3). The remainder of this report uses the term "study site" to refer to the 5 study areas rather than the individual locations for potential infiltration provided by the City.

[1] The coordinates also included two culvert locations, which were not considered in this analysis.

The preferred retention and detention ponds along Highway 101 occupy areas ranging from 0.3 to 1.8 acres. The gravel pit occupies 6.8 acres, and the Reuse Demonstration Site occupies about 29 acres. The size of the infiltration basin selected for pilot infiltration testing, and ultimately for a long-term infiltration facility, will depend on the quantity of water to be infiltrated and other hydrogeologic factors. The City is currently capable of producing about 0.5 mgd (0.8 cfs) of Class A reclaimed water, and expects to produce as much as 2.0 mgd (3.1 cfs) by 2025 based on growth projections and treatment plant capacity. Other factors to be considered include the infiltration potential of the soil, depth to groundwater, aquifer properties (e.g. transmissivity, hydraulic conductivity), the proximity to surface-water features and potential sites of spring discharge, and the proximity to downgradient domestic wells.

2.0 HYDROGEOLOGIC OVERVIEW

The surficial geology of the study area was mapped by Othberg and Palmer (1979) and was recently revised by Schasse and Logan (1998). As shown on **Figure 3**, all 5 of the study sites are mapped on "older alluvium" (Qoa) deposited during Holocene and late Pleistocene times. Schasse and Logan describe Qoa as:

> "Stratified cobbly gravel, sand and gravel, sand, silt, and clay; brown to dark reddish brown; consists of cobble gravels near Sequim and upslope to the southwest to progressively finer grain sizes downslope to the northeast, following the underfit streams, Cassalery, Gierin and Bell Creeks. These exposures are flood-plain terrace deposits of an ancestral Dungeness River whose current channel and flood plain have moved west; this alluvium probably represents older deposition by an early Dungeness River (Othberg and Palmer, 1970).
>
> The unit is mapped on the basis of geomorphology and texture. Thickness is varied and ranges from a few feet to more than 70 feet near the centers of former floodplain channels now occupied by these deposits. On aerial photographs, unit Qoa has an anastomosing appearance that strongly resembles a braided stream pattern.
>
> Unit Qoa overlies till and ice-contact deposits of the Vashon glacial stade (units Qgt_v and Qgo_{vi}); at shallow depth it may locally lie disconformably on glaciomarine drift of the Everson Insterstade (unit $Qgdm_e$). Water well logs indicate that the unit overlies older nonglacial fluvial channel sands and gravels, overbank silts, and estuarine silty clay deposits in the lower drainage of present-day Bell Creek. These deposits can be seen in the bluff exposures at nearby Washington Harbor."

PGG's cursory review of well logs in the Qoa suggests that the shallowest sediments (directly underlying the land surface) are generally coarse grained, but exhibit variable contents of clay binder. Well logs sometimes report clean sands, gravels and/or cobbles, but sometimes report clay bound gravels and/or cobbles. Variable distribution of clay-bound zones is consistent with the lateral and vertical variability associated with stream channel migration in alluvial environments. Some driller's logs mention shallow "hardpan", which may be indicative of cemented alluvial deposits. Glacial till is unlikely to be present in the alluvial Qoa deposits, although it may underlie the Qoa.

The Qoa deposits occupy a broad terrace to the east and northeast of the modern Dungeness River that reflects the geographic range of the ancient Dungeness River. In places, the ancient Dungeness River eroded drainage pathways through Vashon till (Qgt_v) in order to discharge to marine water. While the four westernmost study sites occur on the broad Qoa terrace east of the Dungeness River, the Demonstration Site occurs in a relatively wide, gentle valley that runs between upland outcrops of Qgt_v. Qgt_v is also mapped south of the four westernmost sites at distances ranging from one mile (Site HW-1) to about 500 feet (Site HW-3).

The groundwater flow system of the Sequim-Dungeness Peninsula was characterized by the U.S. Geological Survey (Thomas et al., 1999). The USGS characterization describes a stratified system of geographically extensive aquifers and aquitards consisting of a "shallow aquifer" underlain by a fine-grained "upper confining bed", a confined "middle aquifer", a "lower confining bed", a "lower aquifer", and deeper undifferentiated sediments. Over most of the peninsula, all or some of these six hydrostratigraphic units overlie Tertiary bedrock of sedimentary and volcanic origin. The total thickness of unconsolidated sediments beneath the peninsula ranges from zero feet in the south (where bedrock is exposed on the land surface) to as much as 2,500 feet in the northeast.

The shallow aquifer is composed of a variety of geologic materials, including: stream alluvium, glaciomarine drift, glacial outwash, ice contact deposits, and glacial till. Given the range of geologic materials present, the texture of the shallow aquifer can vary from fine-grained, to coarse-grained, to heterogeneous (locally variable). The thickness of the shallow aquifer beneath the study areas is mapped as ranging from 100 to 200 feet (ibid.). These estimated thicknesses suggest that the USGS include various geologic units that underlie the Qoa in their definition of the shallow aquifer. The aquifer is generally unconfined but can exhibit some local confinement and shallow perching with the occurrence of glaciomarine drift or till. In the overall study area, the USGS characterization shows that groundwater flow in the shallow aquifer is generally north/northeast, that the upper confining bed is between 50-100 feet thick, and that a downward vertical gradient occurs across the upper confining bed.

PGG reviewed the locations of municipal, domestic and monitoring wells in the overall study area. The City's Silberhorn Wellfield is located immediately southwest (upgradient) of study site HW-1 and its Port Williams Wellfield is located about a mile northwest of the Demonstration Site (**Figure 1**). Domestic well data were downloaded from Ecology's well log database, are their distribution is shown on **Figure 3**. Clallam County's database of monitored wells was reviewed for wells that could provide information regarding seasonal water-level variations in the shallow aquifer. Only one well was found within ½ mile of the sites; this well (30N/04W-24R01) is 272 feet deep and is not completed in the shallow aquifer.

Various surface-water features occur near the five study sites reviewed in this memorandum. **Figure 1** shows the occurrence of streams, ditches and wetlands based on GIS data obtained from Clallam County. Bell Creek is identified in bold, and passes within several hundred feet of study site HW-3. The creek reportedly exhibits a minor trickle of perennial flow near the upstream side of HW-3 and ephemeral flow near the downstream side of HW-3 (Gaither, 2007). Further downstream, Bell Creek reportedly exhibits ephemeral flow on the upstream side of the Demonstration Site and gains perennial flow as it passes through the site (ibid). Hydrogeologic investigation by PGG (2000) showed that Bell Creek is perched above the water table of the shallow aquifer on the west side of the Demonstration Site, and similar in stage to the water table on the east side of the site. Similar stream stage and water-table elevations suggest a hydraulic connection between the shallow aquifer and Bell Creek east of the Demonstration Site. Ditches are shown near sites HW-2 and HW-3, and on the western and northern boundaries of the Demonstration Site. However, several portions of the ditch system are being re-routed and/or piped, greatly affecting the areas historically receiving artificial recharge. Most ditches typically flow only when diversions are occurring and are therefore likely to be perched above the shallow water table (i.e. not in hydraulic continuity with local groundwater). The nearby ditches were not analyzed for flow regime; thus connections with groundwater are uncertain. Wetlands, a likely indication of shallow groundwater, are noted on the study areas surrounding HW-3 and the Demonstration Site.

3.0 SITE HW-1

Study site HW-1 is located along SR-101 immediately east of River Road. The study site contains two detention ponds. The western detention pond occupies an area of 0.85 acres and the eastern detention pond occupies 1.26 acres (Dueno, 2007).

3.1 SOILS

Soil mapping performed by the NRCS indicates that prior to grading, Site HW-1 occured predominantly on Carlsborg gravelly sandy loam (map unit 6). This soil occurs on alluvial fans and terraces, is derived from alluvium, is somewhat excessively drained, and is moderately permeable. NRCS estimates that saturated hydraulic conductivity values for a typical soil profile range from 4-12 feet/day. Gravelly and cobbly sand are common components of this soil type; the NRCS does not report silt in significant quantities.

3.2 HYDROGEOLOGY

3.2.1 Well Depths and Well Yields

The distribution of wells listed in Ecology's well log database is shown on **Figure 3** and the well logs are summarized on **Table 1**. Ecology's database lists sixty-nine wells located near study site HW-1. Of these three have been abandoned, eight are vadose zone borings that did not reach groundwater (SD Deacon/Home Depot), and twenty are not completed wells but instead are resource protection soil borings installed at Walmart and Costco.

Total depth of the domestic wells most commonly falls in the range 80 – 130 feet below land surface (bls). Resource protection borings and wells range from 12 – 31 feet bls; however they may not have encountered groundwater.

Out of the 69 listings in the Ecology well log database, only 38 are completed domestic wells that provided well yield information. Yields from these 38 wells ranged from 7 – 60 gpm with an average value of 27±13 gpm (1σ standard deviation). Visual observation of the data revealed well yields in the range 10 – 40 gpm for most of the wells. Such yields are considered to be moderate for domestic wells.

3.2.2 Groundwater Levels and Flow Directions

Groundwater levels for completed wells on study site HW-1 range from 10 – 83 feet bls with an average value of 47±17 feet bls (1σ sd). For most of the completed wells, depth to water is 30 – 70 feet bls. All wells listed in the quarter-quarter section containing the two detention ponds show depths to water in excess of 40 feet bls. Well logs from this quarter-quarter section do not mention shallower occurrence of groundwater. West of the detention ponds, depths to water in the previously noted four soil borings (Emconn Sequim) are unusually shallow at ~10 feet bls and indicate a shallow water table in this vicinity. One shallow well (28 foot total depth) located a the quarter-quarter section east of the detention ponds has a water level of only 18 feet bls.

Groundwater flow direction is generally to the NNE (Thomas et al., 1999).

3.2.3 Aquifer Materials and Hydraulic Properties

The surficial geology of study site HW-1 is identified as unit Qoa (**Figure 3**), described earlier in this report. PGG performed a cursory geologic review of the well logs located on study site HW-1. Almost all well logs note coarse-grained materials (gravels, cobbles, “rocks”) in the shallow subsurface, and a significant portion of the logs also mention associated clay content to various degrees. Some drillers mention clay content more often than others, and potential differences may exist between local drillers in geologic interpretation approaches. However, it is not uncommon for alluvial materials to exhibit coarse material with clay.

The well logs reviewed for this site evaluation are listed in **Table 1**. Among the logs located in the quarter-quarter section closest to the detention ponds (T30N/R4W-24SESW), some note clay content in the uppermost materials while others do not. In the quarter-quarter section south of the ponds, *most* logs mention clay content immediately below land surface. In the quarter-quarter section to the east, most logs report some clay or “hardpan” in the uppermost sediments (although several do not report clay in the top 3-13 feet). Logs and soil borings to the west of the ponds report coarse shallow materials with varying clay content, and two logs report “hardpan” of “till”. Similar variability in clay content is reported in domestic well logs to the north; however, none of the shallow resource protection borings at Costco, Home Depot and Wal-Mart report clay in the 20-30 feet penetrated.

The horizontal hydraulic conductivity of the shallow aquifer was mapped based on well specific capacities by Thomas et al. (1999). At study site HW-1, the shallow aquifer shows a mapped hydraulic conductivity of 40 feet/day. Site HW-1 lies very close to the border of two regions with different horizontal hydraulic conductivities. Immediately to the east of Site HW-1, mapped hydraulic conductivity is 110 feet/day. As most of the wells are not completed in the uppermost portions of the shallow aquifer (interpreted by Thomas et al as 100-200 feet thick in the overall study area), these hydraulic conductivity values may not reflect the hydraulic properties of the sediments immediately beneath the land surface. The influence of variable clay content on the hydraulic conductivity of otherwise coarse-grained materials is unknown. Better definition of the hydraulic conductivities of these shallow sediments can only be achieved through testing.

3.3 INFILTRATION POTENTIAL AND RELATED CONSIDERATIONS

Site HW-1 has a moderate infiltration potential based on the hydraulic conductivity of soils and the shallow aquifer. Testing would be required to better define the hydraulic conductivity of the sediments closest to the land surface. Depth to groundwater in wells completed in the immediate vicinity of the detention ponds appears to provide sufficient vertical separation between the water table and the surface to accommodate infiltration. A single monitoring well could be installed near the detention ponds to confirm the absence of shallow (perched) groundwater.

Surface-water features near the detention ponds are predominantly unlined irrigation ditches (**Figure 1**). If the ditches are perched above the shallow water table, infiltration has a lower probability of discharging to the ditches. Domestic wells occur in quarter-quarter sections immediately upgradient and downgradient of the detention ponds. Better well locations and more detailed water-level mapping may be needed to ascertain whether domestic wells are likely to capture infiltrated water.

4.0 SITE HW-2

Study site HW-2 is located north of SR-101 immediately west of South 7th Avenue. The study site contains a single detention pond that occupies 0.55 acres (Dueno, 2007).

4.1 SOILS

NRCS soil mapping shown on **Figure 2** indicates that the detention pond on study site HW-2 occurs in an area occupied by Carlsborg gravelly sandy loam (map unit 6) prior to grading. This soil occurs on alluvial fans and terraces, is derived from alluvium, is somewhat excessively drained, and is moderately permeable. NRCS estimates that saturated hydraulic conductivity values for a typical soil profile range from 4-12 feet/day. Gravelly and cobbly sand are common components of this soil type; the NRCS do not report silt in significant quantities.

To the southeast of the detention pond, Sequim very gravelly sandy loam (map unit 63) is found. This soil occurs on alluvial fans and terraces, is derived from alluvium, is somewhat excessively drained, and is highly permeable. NRCS estimates that saturated hydraulic conductivity values for a typical soil profile range from 12-40 feet/day. Gravelly and cobbly sand are common components of this soil type; the NRCS do not report silt in significant quantities.

4.2 HYDROGEOLOGY

4.2.1 Well Depths and Well Yields

The distribution of wells listed in Ecology's well log database is shown on **Figure 3**. The database lists 11 wells located near Site HW-2. The majority of these wells are located upgradient (southwest) of the site.

Well depths typically range from 80 – 185 feet bls (**Table 2**). The shallowest well in the study area is 40 feet deep and is located on Daisy Lane, upgradient of the pond about 900 feet south of SR101 (T30N/R3W-30NWNW).

Well yield ranged from 8 – 65 gpm with an average value of 24±18 gpm (1σ sd). Visual observation of the data reveal well yields in the range 10 – 30 gpm for most of the wells. Such yields are considered to be moderate for domestic wells.

4.2.2 Groundwater Levels and Flow Directions

Depth to water in the 11 wells investigated near HW-3 range from 24 – 125 feet with an average value of 69±36 feet bls (1σ sd). For most of the wells, depth to water is 45 – 75 feet bls. Near Site HW-2, only one well shows evidence of a shallow water table (24 foot depth to water in the upgradient well on Daisy Lane).

Groundwater flow in the shallow aquifer is generally to the NNE (Thomas et al., 1999).

4.2.3 Aquifer Materials and Hydraulic Properties

The surficial geology of study site HW-2 is identified as unit Qoa (**Figure 3**), described in detail earlier in this report. Well logs at the site are listed on **Table 2**. A cursory review of the logs indicates generally coarse-grained materials in the shallow sub-surface with variable clay content. On some well logs clay appears to dominate the shallow sediments; whereas a smaller portion of the logs bear little or no mention of clay content immediately below the land surface. These observations are consistent with the range of textures included in the general Qoa description previously noted.

The horizontal hydraulic conductivity of the shallow aquifer was mapped based on well specific capacities by Thomas et al. (1999). At Site HW-2, the shallow aquifer shows a mapped hydraulic conductivity of 29 feet/day. Site HW-2 lies very close to the border of two regions with different horizontal hydraulic conductivities. Immediately to the north of Site HW-2, mapped hydraulic conductivity is 110 feet/day. As most of the wells are not completed in the uppermost portions of the shallow aquifer (interpreted by Thomas et al as 100-200 feet thick in the overall study area), these hydraulic conductivity values may not reflect the hydraulic properties of the sediments immediately beneath the land surface. Better definition of the hydraulic conductivities of these shallow sediments can only be achieved through testing.

4.3 INFILTRATION POTENTIAL AND RELATED CONSIDERATIONS

Site HW-2 has a moderate infiltration potential based on the hydraulic conductivity of soils and the shallow aquifer. Testing would be required to better define the hydraulic conductivity of the sediments closest to the land surface. Depth to groundwater in wells completed in the vicinity of the detention pond appears to provide sufficient vertical separation between the water table and the surface to accommodate infiltration. A single monitoring well could be installed near the detention pond to confirm the absence of shallow (perched) groundwater.

Unlined irrigation ditches occur east and southeast of the detention pond (**Figure 1**). If the ditches are perched above the shallow water table, infiltration has a lower probability of discharging to the ditches. Domestic wells predominantly occur in quarter-quarter sections immediately upgradient of the detention ponds, thus suggesting that few domestic wells are likely to capture significant concentrations of infiltrated water.

5.0 SITE HW-3

Study site HW-3 is located along SR-101 west of Sequim Avenue. The study site contains two retention ponds and one detention pond. The northern retention pond occupies an area of 1.06 acres, the southern retention pond occupies 1.78 acres, and the detention pond occupies 0.27 acres (Dueno, 2007). In addition, the City could construct an infiltration pond near the City Shop, just north of SR-101.

5.1 SOILS

NRCS soil mapping indicates that the retention and detention ponds on Site HW-3 occur on soils previously mapped as Sequim very gravelly sandy loam (map unit 63) prior to grading. This soil occurs on alluvial fans and terraces, is derived from alluvium, is somewhat excessively drained, and is moderately permeable. NRCS estimates that saturated hydraulic conductivity values for a typical soil profile range from 12-40 feet/day. Gravelly and cobbly sand are common components of this soil type; the NRCS do not report silt in significant quantities.

South of the ponds, the NRCS map Clallam gravelly sandy loam (map unit 12). This soil occurs on hillslopes, is derived from till, is moderately well-drained, but is has very low permeability. NRCS estimates that saturated hydraulic conductivity values for a typical soil profile range from 0-0.1 feet/day. High drainage capacity apparently occurs in the upper portions of the soil profile which overlie the low hydraulic conductivity layer. Gravelly and cobbly sand are common components of this soil type; the NRCS do report silt in significant quantities.

5.2 HYDROGEOLOGY

5.2.1 Well Depths and Well Yields

The distribution of wells listed in Ecology's well log database is shown on **Figure 3**. The database lists only 3 wells located within the study site. The quarter-quarter sections listed for these wells are northeast and northwest of the ponds. Improved well locations are needed to ascertain whether the wells are actually downgradient of the ponds. The total depths of the three wells are 59 feet bls for one well and 157 feet bls for the two other wells (**Table 3**). Well yields ranged from 20 – 40 gpm with an average value of 32±11 gpm (1σ sd). Such yields are considered to be moderate for domestic wells.

5.2.2 Groundwater Levels and Flow Directions

Depth to groundwater in the 3 wells investigated near HW-3 ranged from 22 – 85 feet bls (**Table 3**). Review of the well logs indicates that one of the deep wells (T30N/R3W-20SWSW) encountered water at 48 feet, but was completed considerably deeper. Wetlands mapped between the retention and detention ponds and southeast of the detention pond may indicate shallow or perched groundwater.

Groundwater flow in the shallow aquifer is generally to the NNE (Thomas et al., 1999).

5.2.3 Aquifer Materials and Hydraulic Properties

While the surficial geology at the ponds is identified as unit Qoa (described in detail earlier in this report), it is worth noting the proximity of till-derived soils (**Figure 2**) and till (Qgtv on **Figure 3**) to the south. Specifically, both well logs located east of the detention pond mention till-like materials such as "brown gravelly clay from 1-36 feet" and "brown cemented clay, gravel and large rocks from 8-37 feet". Given the proximity of the pond to the till contact, till may underlie the pond locations. Wetlands mapped on study site HW-3 (**Figure 1**) may indicated shallow groundwater perched upon till. Drilling or backhoe exploration would be needed to determine the presence of shallow till.

The horizontal hydraulic conductivity of the shallow aquifer was mapped based on well specific capacities by Thomas et al. (1999). At Site HW-3, the shallow aquifer shows a mapped hydraulic conductivity of 29 feet/day. Site HW-3 lies very close to the transition to an adjacent region with higher horizontal hydraulic conductivities. Immediately to the north of Site HW-3, this region has mapped hydraulic conductivity is 110 feet/day. As most of the wells are completed deeper in the shallow aquifer (interpreted by Thomas et al as 100-200 feet thick in the overall study area), these hydraulic conductivity values may not reflect the hydraulic properties of the sediments immediately beneath the land surface, to which infiltrated water will be applied. Better definition of the hydraulic conductivities of these shallow sediments can only be achieved through testing.

5.3 INFILTRATION POTENTIAL AND RELATED CONSIDERATIONS

Despite the fact that the permeability of soils and the shallow aquifer in the vicinity of the ponds has been characterized as moderate-to-high, the infiltration capacity of the site may be compromised by occurrence of shallow till. Wetlands are mapped on both the till-covered area, and between the ponds within the Qoa (**Figure 1**). The occurrence of a wetland on the Qoa very close to the ponds suggests shallow or perched groundwater. If this is the case, the vertical distance between the land surface and the water table may not be sufficient to accommodate significant rates of infiltration. Additional site exploration, such as excavation of test pits and/or boreholes, would be needed to better characterize conditions and suitability for infiltration. Among the available infiltration features, a to-be-constructed pond near the City Shop is farthest from the exposed till, and is therefore most recommended for infiltration testing.

Bell Creek runs between the retention and detention ponds, and may be associated with the nearby wetland (**Figure 1**). A small stream and an irrigation ditch also discharge into Bell Creek, and a second irrigation ditch crosses the southeast portion of the site. Steve Gaither of the Highland Irrigation Company reports the following information about surface-water features at HW-3 (Gaither, 2007):

- The irrigation ditch that discharges into Bell Creek is now fully piped. The newly piped section runs from the northern end of the piped section shown on Figure 1 directly east to Bell Creek.
- Immediately upstream of the site where this irrigation ditch enters Bell Creek, the creek exhibits a small perennial flow (<5 gpm) likely supplied by groundwater.
- Farther downstream, the groundwater baseflow in Bell Creek disappears before it reaches the SR-101 bypass.
- The small stream tributary to Bell Creek has no groundwater baseflow, and hasn't exhibited consistent flow in 8 to 10 years. The stream does flow during storm events.

If portions of Bell Creek within site HW-3 are hydraulically connected to a shallow or perched water table, infiltrated water may increase the length of reach exhibiting (minor) perennial flow on Bell Creek. Domestic wells are apparently relatively sparse in the study area, thus suggesting less likelihood that wells will capture significant concentrations of infiltrated water.

6.0 GRAVEL PIT SITE

The gravel pit study site is located about 1,500 feet south of SR-101 along East Silberhorn Road. The "Shaw Pit" occupies an area of 6.8 acres (Dueno, 2007).

6.1 SOILS

NRCS soil mapping indicates that the pit was excavated into an area of Carlsborg gravelly sandy loam (map unit 6). This soil occurs on alluvial fans and terraces, is derived from alluvium, is somewhat excessively drained, and is moderately permeable. NRCS estimates that saturated hydraulic conductivity values for a typical soil profile range from 4-12 feet/day. Gravelly and cobbly sand are common components of this soil type; the NRCS do not report silt in significant quantities.

Mapped directly southeast of the pit is the Sequim-McKenna-Mukilteo complex. These soils occur on alluvial fans, terraces, and depressions; are derived from alluvium, glacial drift, and mixed organic material; are somewhat excessively drained to poorly drained; and have very low to moderately high permeability. Because the soil complex groups three soil types, hydraulic conductivity for various profiles within the complex are estimated to range from 0-40 feet/day. This soil complex contains a variety of components including gravelly and cobbly sand, silt, and organic material. Given the coincident surficial geology described below (i.e. Qoa), this local soils are likely to be in the upper end of this permeability range.

6.2 HYDROGEOLOGY

6.2.1 Well Depths and Well Yields

The distribution of wells listed in Ecology's well log database is shown on **Figure 3**. The database lists 23 wells located within the study site. Well depths most commonly fall in the range 80 – 150 feet bls, although two 41-foot wells are noted in the quarter-quarter sections north of the pit (**Table 4**).

Twenty-three wells are located near the Gravel Pit site. Well yield ranged from 8 – 290 gpm with an average value of 53±68 gpm (1σ sd). Visual observation of the data revealed well yields in the range 10 – 75 gpm for most of the wells. Such yields are considered to be moderate-to-high for domestic wells.

More detailed characterization of domestic well locations near the Shaw Pit is presented by Robinson & Noble (R&N, 2002). PGG was provided this report after completing our evaluation of local wells. Further characterization of near-site wells should include the information presented in the R&N report.

6.2.2 Groundwater Levels and Flow Directions

Depth to water in the 23 wells investigated at the Gravel Pit site range from 21 – 125 feet bls with an average value of 60±26 feet bls (1σ sd). For most of the wells, depth to water is 40 – 85 feet. Two wells, one located in each of the quarter-quarter sections north of the gravel pit, show evidence of a shallow water table (21 – 24 foot depth to water). Additionally, a test boring drilled on the floor of the Shaw Pit showed a static water level 4.2 feet below the bottom of the pit (R&N, 2002). This water level is approximately 20 feet below the original, undisturbed grade of the gravel pit.

Based on regional groundwater flow directions for the USGS definition of the shallow aquifer, flow to the NNE is expected in the site vicinity (Thomas et al., 1999). However, water-table elevations in 5 wells in the immediate vicinity of the pit show groundwater flow slightly west of north with a gradient of 0.023 (R&N, 2002).

6.2.3 Aquifer Materials and Hydraulic Properties

The surficial geology of the gravel pit site is identified as unit Qoa, described in detail earlier in this report. The pit is located over a quarter mile northwest of the contact between Qoa and Qgtv (**Figure 3**). Well logs are listed on **Table 4**. A cursory review of well logs generally suggests coarse-grained materials in the shallow subsurface, with variable amounts of cementation and clay. Well logs northwest of the gravel pit in T30N/R4W-25NENE rarely (but occasionally) report fine-grained textures within 40-50 feet of land surface, whereas well logs northeast of the gravel pit in T30N/R3W-30NWNW more commonly note shallow clay-bound material. Logs from wells to the southeast (T30N/R4W-25NESE) and logs located only to the quarter-section (T30N/R4W-25NE) variably note the occurrence of shallow “hardpan”. Actual conditions in the immediate vicinity of the pit are unknown; however, its former use suggests that predominantly coarse-grained materials were encountered at least as deep as the bottom of the pit.

Robinson & Noble installed a shallow exploration well in the bottom of the gravel pit. Drilling encountered a permeable upper unit to a depth of 15 feet (R&N, 2002). The local water table aquifer was present, as evidenced by damp-to-wet conditions observed during drilling from 9 to 15 feet bls and a static water level of 4.2 feet bls with the temporary well casing set 10 feet into the ground[2]. A clay rich ("hardpan") aquitard unit was encountered from 15 feet bls to the bottom of the boring (at 25 feet bls). R&N note that the clay reach unit likely represents a continuous layer beneath the pit bottom that forms a cap protection the principal aquifer in the area (the regional shallow aquifer). Additionally, they note that the clay-rich unit appears to slope downwards to the north, which greatly reduces or eliminates the tendency of the pit to fill with water.

The horizontal hydraulic conductivity of the shallow aquifer was mapped based on well specific capacities by Thomas et al. (1999). At the gravel pit site, the shallow aquifer shows a mapped hydraulic conductivity of 29 feet/day; however, the site lies very close to the transition to another region with mapped hydraulic conductivity of 110 feet/day. As most of the wells are not completed in the uppermost portions of the shallow aquifer (interpreted by Thomas et al as 100-200 feet thick in the overall study area), these hydraulic conductivity values may not reflect the hydraulic properties of the sediments immediately beneath the land surface. The influence of variable clay content on the hydraulic conductivity of otherwise coarse-grained materials is also unknown. Better definition of the hydraulic conductivities of these shallow sediments can only be achieved through testing.

6.3 INFILTRATION POTENTIAL AND RELATED CONSIDERATIONS

The gravel pit site has a moderate infiltration potential based on the hydraulic conductivity of soils and the shallow aquifer. Testing would be required to better define the hydraulic conductivity of the sediments closest to the land surface. Depth to groundwater immediately beneath the pit shows limited (4.4 feet) vertical separation between the water table and the surface to accommodate infiltration. This vertical separation may limit the infiltration capacity at the pit. Infiltration testing would be needed to determine whether the hydraulic conductivity of the shallow water-table aquifer is sufficiently high to offset the limited vertical separation and therefore accommodate sufficient rates of infiltration.

Surface-water features near the pit include several open irrigation ditches, one of which passes very close to the pit. If the ditches are perched above the shallow water table, infiltration has a lower probability of discharging to the ditches. Most nearby domestic wells included in Ecology's well log database occur in the quarter-quarter sections north of the pit. A subset of these wells is likely to occur downgradient of the pit. Robinson & Noble's more detailed study of the pit (R&N, 2002) shows several active domestic wells immediately east of the pit, and individual deeper wells both immediately north and west of the pit. Many of the additional wells at greater distance from the pit were identified as inactive (no longer used) by Robinson & Noble.

[2] These two observations appear to be contradictory and are not resolved in R&N's 2002 report. A static water level of 4.2 feet bls in permeable materials would typically be associated with unconfined conditions and would cause wet soils to be observed up to that depth (rather than 9 to 15 feet bls). The unconfined (or confined) nature of the shallow aquifer beneath the gravel pit should be confirmed during site exploration.

7.0 REUSE DEMONSTRATION SITE

The City's Reuse Demonstration Site occupies about 29 acres north of Carry Blake Park, east of downtown Sequim between N. Blake Avenue and N. Rhodefer Road. Most of the site is occupied by a field that could accommodate a large infiltration pond. The blue diamond shown on Figure 1 is within the Demonstration Site; however, the study area shown for the site (purple outline) includes Carry Blake Park to the south and surrounding areas to the north, east and west. PGG (2000) previously characterized hydrogeologic conditions at the Demonstration Site, and much of the text below is from PGG's prior report.

7.1 SOILS & SURFICIAL GEOLOGY

NRCS soil mapping shown on **Figure 2** indicates that the Demonstration Site occurs predominantly on Sequim very gravelly sandy loam (map unit 63). NRCS descriptions indicate that this soil occurs on alluvial fans and terraces, is derived from alluvium, is somewhat excessively drained, and is highly permeable. NRCS estimates that saturated hydraulic conductivity values for a typical soil profile range from 12-40 feet/day. Whereas gravelly and cobbly sand are common components of this soil type, the NRCS do not report silt in significant quantities. NRCS soil descriptions are presented in **Appendix A**.

During site characterization, PGG excavated five soil test pits on the Demonstration Site to depths ranging from 6 to 13.5 feet. The test pit locations are shown in **Appendix B** on Figure 3. Excavation typically encountered dry, light brown, slightly silty, gravelly, cobbly fine-to-medium sand in the uppermost 3 to 9 feet. In some cases, a significant increase in the presence of cobbles and boulders was noted at depths exceeding 2 to 3 feet. The light brown soil horizon generally graded into moist, gray, silty, gravelly sand with occasional cobbles towards the bottom of the test pits before encountering the unconfined water table. Relative to the NRCS description, PGG noted a slightly greater presence of silt in the soil profile.

NRCS soil mapping also shows Sequim-McKenna-Mukilteo complex (map unit 64) to the south and east of the Demonstration Site. This complex occupies a thin strip along the southern boundary of the actual Demonstration Site property. The three referenced soil types are not differentiated within this complex. The "Sequim" portions of the complex are described above. McKenna soils occur on terraces and in depressions, are derived from glacial drift, and are considered to be poorly drained. Typical profiles include a dense, restrictive layer at 20-40 inches that supports a shallow, perched water table within a foot of the land surface. Typical hydraulic conductivity for the most restrictive layer is on the order of 0.1 feet/day. Mukilteo soils also occur on terraces and in depressions, are poorly drained, but are derived from organic materials. Typical profiles consist of muck and mucky peat. Mukilteo soils support shallow water tables (within a foot of the land surface) and have hydraulic conductivities typically ranging from 1-4 feet/day. Based on the occurrence of wetlands south and east of the Demonstration Site (Figure 1) and characterization of the surficial geology (discussed below), the Sequim-McKenna-Mukilteo complex appears to be associated with wetland deposits.

7.2 HYDROGEOLOGY

The Demonstration Site is situated in a relatively wide, gentle valley filled in with older alluvium (Qoa) The valley follows an east-west orientation from downtown Sequim towards "the lagoon" north of Washington Harbor. Bell Creek flows in the valley center along the southern boundary of the Demonstration Site. However, this "underfit" stream is too small to explain the width of the valley, which ranges from about ¾ mile wide at the Demonstration Site and to about ¼ mile near the harbor. Older alluvium (Qoa) is contained within the valley, thus forming a channelized depositional feature. Vashon glacial till (Qvt) is noted on the upland hillsides that flank the north and south sides of the valley. The till is a relatively dense, variably textured material that drillers often refer to as "hardpan". The till was deposited by "smearing" over the landscape during the Vashon glaciation. It exhibits relatively low permeability, which may limit downward infiltration of groundwater recharge and cause shallow perched conditions.

Topography and well logs in the vicinity of the Demonstration Site suggest that the older alluvial channel cuts through the surrounding till. This conclusion is based on driller's logs for nearby domestic wells compiled from Department of Ecology and the deepest (80-foot) on-site monitoring well. The presence of shallow till is consistent with the surficial geology mapped on Figure 1 in **Appendix B**. Figure 2 in **Appendix B** presents a hydrogeologic cross section constructed across the Bell Creek valley. The section shows Qvt on top of the hills north and south of the valley, overlying older undifferentiated sediments of Quaternary age (Qu). Qoa occupies the top 15 to 45 feet beneath the valley floor, and is underlain by the finer grained Qu sediments.

7.2.1 Nearby Wells

A search of Clallam County's well database in 2000 and Ecology's current database showed 18 domestic wells located within approximately ¼ mile of the Demonstration Site[3]. Driller's logs were compiled for 12 of these wells. Nine of the wells are relatively shallow (<70 feet deep), and are typically completed within 40 feet of the land surface. The remaining nine domestic wells range from 91 to 290 feet deep. Figure 1 in **Appendix B** presents a map of the approximate well locations, with domestic wells placed at the center of the quarter-quarter section indicated on each well log (except where roads and patterns of habitation supported better location). **Table 4** presents a summary of data from the domestic wells. Well yields vary from low (≤10 gpm) to moderate (11 gpm-60 gpm).

During characterization of the Demonstration Site, the City of Sequim installed five temporary piezometers (now abandoned) and four monitoring wells. The monitoring wells

[3] A recent search of Ecology's well database shows no wells drilled after 2000 near the Demonstration Site. Clallam County's database includes 3 wells more than Ecology's database.

ranged in total depth from 17-81 feet, were screened near the water table (<20 feet below land surface), and were installed with flush-mount monuments. The monitoring wells are summarized below (note that Well MW-1 is located off the Demonstration Site at Carrie Blake Park). The temporary piezometers were installed on the Demonstration Site during excavation of soil test pits and were constructed by inserting 4-inch PVC pipe with slotted bottoms into the test pits and backfilling the hole around the pipe. Test pit depths ranged from 10-13 feet, as excavation could not proceed much below the water table. Locations of monitoring wells and temporary piezometers are shown on Figure 3 in **Appendix B**.

Monitoring Wells on the Demonstration Site

Well ID	Drilled Depth (Feet BLS)	Screen Interval (Feet BLS)	Depth to Water Range 7/00-5/01 (Feet)
MW-1	22	7.8-17.8	10.6-11.5
MW-2	81	7-17	6.2-9.0
MW-3	20	9.5-19.5	4.0-5.3
MW-4	17	4.6-14.6	4.1-5.4

(Depth to water is measured from the top of PVC casing, which is close to land surface.)

7.2.2 Groundwater Levels and Flow Directions

Wells within the Bell Creek Valley near the Demonstration Site exhibit depths to water ranging from flowing (i.e. above land surface) to 134 feet below land surface (**Table 4**). Shallower wells (<100 feet bls) exhibit shallow water levels (<32 feet bls, including flowing wells). Deeper wells exhibit variable depths to water, ranging from 35 to 134 feet bls.

Monitoring wells and temporary piezometers installed on the Demonstration Site show shallow depths to water. Onsite monitoring wells (MW-2, MW-3 and MW-4) are located towards the southern boundary of the Demonstration Site near Bell Creek (see locations on Figure 5 in **Appendix B**). As summarized above, depth to water in these wells ranged from 4 to 9 feet below land surface and showed seasonal variations ranging from 1.3 to 2.8 feet over a 10-month monitoring period between July 2000 and May 2001. Some of the temporary piezometers (TP-2, TP-3 and TP-4) are located farther from Bell Creek. TP-2 and TP-3 are located on the west side of the Demonstration Site near Blake Road. Water levels in these piezometers ranged from 9.7 to over 10.9 feet bls (TP-2) and from 12.0 feet to over 13.2 feet bls (TP-3) during a monitoring period ranging from June 1999 to August 2000[4]. TP-4 is located on the east side of the site near Rhodefer Road, and showed depths to water ranging from 4.2 to 6.1 feet bls, with a range in seasonal variation of 1.9 feet. Thus, groundwater is deepest (>12 feet bls) in the northwest corner of the Demonstration Site.

[4] During some months, depth to water exceeded the maximum depth of the temporary piezometer and could not be measured.

Groundwater flow directions in the uppermost aquifer were evaluated in August, 2000 based on water-table elevations measured in the four monitoring wells and three of the temporary piezometers (those exhibiting saturation). The data were used to prepare a water level contour map (Figure 5 in **Appendix B**) that shows groundwater flow to the northeast. This flow direction is consistent with the general flow pattern delineated by the USGS (ibid). A second "snapshot" of water level elevations, taken in June 1999 based on the five temporary piezometers, showed good agreement with those observed in August 2000.

Comparison of surface-water elevations in Bell Creek (and associated ponds) to adjacent groundwater elevations allows a qualitative assessment of the hydraulic connection between the creek and the shallow, uppermost aquifer. On the western side of the Demonstration Site, the stage of Bell Creek is significantly higher than groundwater elevations. This difference suggests that Bell Creek is perched above lower permeability materials that prevent streambed seepage from elevating aquifer levels to the measured stream stage. While seepage is insufficient to mound the water table up to the stream stage elevation, some seepage from the creek is indicated by the downward vertical gradient. Existing data are insufficient to determine whether the rate of suggested streambed seepage is significant. Lack of direct connection to shallow groundwater immediately west of the Demonstration Site is supported by flow observations by Steve Gaither of the Highland Irrigation District, who reports that streamflow in this location is entirely supplied by irrigation discharge (Gaither, 2007). East of the Demonstration Site, Gaither reports year-round baseflow in Bell Creek. Towards the eastern side of the site, groundwater and Bell Creek elevations become fairly similar. This combined information suggests a likely hydraulic connection between shallow groundwater and Bell Creek towards the east side of the site. Similar relationships between surface-water and groundwater elevations are noted between the shallow aquifer and the irrigation ditch on the north side of the Demonstration Site based on June, 1999 water levels.

Shallow groundwater also occurs in areas east of the Demonstration Site, as indicated by the large wetland complex east of Rhodefer Road. Domestic wells located east of the Demonstration Site tend to draw from deeper water-bearing units. Well E, shown on Figure 2 in **Appendix B**, was completed at moderate depth (120 feet bls, later deepened to 210 feet bls) and showed a depth to groundwater of 35 feet bls when originally drilled in 1989. Based on a prior visit to the well owner, PGG was informed that shallow groundwater has been observed within feet of the land surface. Thus, the area east of the Demonstration Site exhibits either: 1) shallow groundwater with strong downward vertical gradients, or 2) perched groundwater above the shallow regional aquifer. Continuous saturation, rather than perched conditions, was observed at the Demonstration Site.

7.2.3 Aquifer Materials and Hydraulic Properties

At the Demonstration Site, drilling and excavation associated with four monitoring wells, five test pits and other installations has revealed an uppermost aquifer comprised of up to 42 feet of relatively permeable Qoa deposits. The Qoa is gravelly with varying amounts of silt, sand and cobbles close to the land surface, but may become finer-grained with depth. Given the nature of alluvial deposition, the thickness and texture of water-bearing Qoa is likely to vary beneath the Demonstration Site.

Driller's logs for domestic wells that surround the site in the Bell Creek valley near the Demonstration Site show a rocky topsoil underlain by various combinations of clay, sand, gravel and rocks. The rocky clay, sand and gravel typically contain the uppermost aquifer that was observed on the demonstration site and likely supports wetlands to the east. Deeper wells show that the rocky mixture is typically underlain by finer grained sediments such as sand, silt and clay. Well logs sometimes mention trace occurrence of wood in these finer grained sediments. The finer sediments reflect a lower energy depositional environment, whereas the rocky sediments represent higher energy stream deposition.

The USGS characterization represents the shallow aquifer in the site vicinity as up to 200 feet thick, but includes few wells in the area (Thomas, 1999). Alternatively, the finer grained Qu sediments may actually represent the upper confining bed. Groundwater level differences across the Qu suggest its role as a confining unit. Groundwater levels are typically lower in wells completed at depth within the Qu than in shallow Qoa or Qu wells (see Figure 2 in **Appendix B**). Additional evaluation would be required to better resolve hydrogeologic interpretations by the USGS and PGG.

The horizontal hydraulic conductivity of the shallow aquifer was mapped based on well specific capacities by Thomas et al. (1999). At the Demonstration Site, the shallow aquifer shows a mapped hydraulic conductivity of 110 feet/day. As most of the wells are completed at depth within the shallow aquifer (interpreted by Thomas et al as 200 feet thick below the Demonstration Site), these hydraulic conductivity values may not reflect the hydraulic properties of the sediments immediately beneath the land surface, to which infiltrated water will be applied. Better definition of the hydraulic conductivities of these shallow sediments can only be achieved through testing.

7.3 INFILTRATION POTENTIAL AND RELATED CONSIDERATIONS

The Demonstration Site appears to have a moderate-to-high infiltration potential based on soils and shallow-aquifer hydraulic conductivity. The degree to which silt content in the uppermost sediments affects infiltration potential is unknown. Infiltration potential of the site is likely limited by the relatively shallow depths to groundwater. Infiltration potential would be greatest in the northwest corner of the site, where monitoring has shown depths to water exceeding 12 feet bls. Depth to groundwater is shallower closer to Bell Creek, especially in the southeast corner of the site. The observed range of minimum depth to groundwater (4 to 12 feet bls) is small relative to common requirements for infiltration. The amount of mounding associated with applied infiltration will depend on the hydraulic conductivity of the shallow sediments. Mounding will reduce the depth to groundwater beneath the site, and appearance of the water table at the land surface can only be avoided if the hydraulic conductivity of the shallow sediments is sufficiently high relative to the rate of infiltrated water.

Besides Bell Creek, surface water features surrounding the Demonstration Site include ditches to the north and west, a large wetland complex to the east, and minor wetland along Bell Creek to the south. Rising groundwater levels associated with infiltration might be expressed as increased groundwater discharge to the wetlands and to portions of Bell Creek (possibly on the east side of the Demonstration Site and farther east offsite). The wetland complex exhibits surface flow, some of which likely discharges to Bell Creek.

Several domestic wells occur in the quarter-quarter sections downgradient of the Demonstration Site (**Figure 3**). The degree to which infiltrated water would reach these wells is unknown. Infiltrated water would initially reside in the shallow groundwater system expressed by the near-surface water table and wetlands east and south of the Demonstration Site. Some of the infiltrated water may migrate vertically downwards through the lower permeability sediments which create a downward gradient between the shallow aquifer and water-bearing units tapped by wells.

8.0 FINDINGS AND RECOMMENDATIONS

8.1 SITE CHARACTERISTICS

The findings presented above are summarized on **Table 6**. PGG's preliminary investigation indicates that:

- Shallow sediments are typically coarse-grained and have variable clay content. The hydraulic conductivity of surficial soils and the shallow aquifer have been characterized as moderate-to-high, which is favorable for infiltration. However, the role of clay binder on the hydraulic conductivity of the uppermost sediments is not known. Hydraulic testing would be needed to determine the water transmitting capacity of the uppermost sediments, to which infiltration would be applied.
- Sites HW-1 and HW-2 are generally surrounded by domestic wells with moderate depths to water (e.g. 30 – 80 feet bls); however, each of these sites also has neighboring domestic wells with relatively shallow depths-to-water (10-25 feet bls). Installation of onsite monitoring wells would be needed at these sites to identify the uppermost occurrence of shallow groundwater.
- The gravel pit is generally surrounded by domestic wells with moderate depths to water (e.g. 40 – 85 feet bls); however, two neighboring domestic wells have relatively shallow depths-to-water (21-24 feet bls). Shallow groundwater observed 4 feet below the bottom of the pit and a hardpan layer observed 15 feet below the bottom of the pit will limit the infiltration capacity; however, the site may still infiltrate sufficient water for the project purpose.

- The Demonstration Site has relatively shallow depths to groundwater in onsite monitoring wells, but deeper water levels in surrounding domestic wells. Shallow groundwater will likely limit infiltration capacity at this site.
- Shallow groundwater is suggested at site HW-3 based on the occurrence of wetlands and shallow subsurface till. Shallow groundwater and till will likely limit infiltration capacity at this site. The City's Shop is farther from surficial exposures of till. Testing at this site is preferred due to possibly deeper occurrence of till.
- Sites HW-1 and the gravel pit appear to have the greatest numbers of downgradient wells. Domestic wells located downgradient of the Demonstration Site are completed in deeper portions of the flow system than the shallow aquifer observed onsite. This observation may be true for other sites considered for infiltration.
- A source of water is required for infiltration testing. The City of Sequim has reclaimed water available at site HW-3 and the Demonstration Site. Stormwater runoff, conveyed by irrigation ditches, passes close to the gravel pit and Site HW-2 (and may be available at other sites via irrigation ditches and/or siphons). Potable water is available close to the gravel pit, the Demonstration Site, and Site HW-3.

8.2 CONSIDERATIONS FOR SITE SELECTION

- Suitability for infiltration depends on depth to the water table and the local hydraulic conductivity of sediments immediately underlying the land surface (and possibly the shallow aquifer as a whole). For a given infiltration rate, infiltration capacity is increased with deeper groundwater occurrence, a thicker sequence of unsaturated sediments and higher hydraulic conductivity of shallow sediments.
- Other considerations for infiltration suitability include hydraulic connections between shallow subsurface sediments and groundwater sensitive features and facilities. Shallow groundwater sensitive features and facilities can include basements, septic drainfields, storm ponds, slopes, wetlands, wells, lakes and streams.
- Water table mounding from infiltration can cause increased discharge to existing groundwater-supported surface-water bodies. In some cases, such as baseflow to Bell Creek, this can be desirable. The desirability of potential increases in groundwater discharge to wetlands has not yet been discussed on a specific wetland basis. Travel times between the infiltration site and nearby discharge areas should be assessed.
- Infiltration of reclaimed wastewater should consider the occurrence of downgradient water supply wells. Travel times between the infiltration site and downgradient wells should similarly be assessed.
- Water table mounding from infiltration can cause the water table to rise and intersect shallow features on the land surface such as ditches, depressions, or the bottoms of hillslopes. This can cause formation of springs, standing water, or baseflow in ditches. More detailed site evaluation and/or infiltration testing are required to ascertain whether prolonged infiltration would have such effects and whether these effects would be problematic.

- Along with hydrogeologic conditions, the proximity of readily available source water for infiltration may affect ranking of sites. Water quantity, seasonality of supply, and water quality should be considered.

8.3 REGULATORY CONSIDERATIONS

Regulations and/or guidance may differ for testing a reclaimed water infiltration site vs. long-term operation of a reclaimed water infiltration facility. PGG contacted Kathy Cupps, Department of Ecology's lead for reclaimed water, to discuss regulatory requirements for reclaimed water. Ecology is presently working on defining regulations for reclaimed water. Although regulations have not yet been put into place, standards and guidance exist for reclaimed water.

Relevant standards include:

- Water reclamation and reuse standards (Publication 97-23)
- Criteria for Sewage Works Design, Chapter E-1 (Water Reclamation and Reuse)

Ms. Cupps indicated that infiltrated reclaimed water should meet drinking water standards, groundwater quality standards *and* antidegradation standards (the latter two are defined in WAC 173-200). There is some flexibility in the requirement to meet antidegradation standards such that conditions of overriding public interest would allow some degradation of water quality (within the groundwater quality standards) if a public benefit ensues from the infiltration of the reclaimed water.

Until Ecology completes its reclaimed water regulations, the agency is using best professional judgment to oversee reclaimed water projects. Ms. Cupps recommended that the City of Sequim take the following steps to identify their responsibilities in performing an infiltration test using reclaimed water:

- The City should speak with regional permit manager for their reclaimed water permit to determine whether the permit needs to be altered to use the water for infiltration during the testing phase.
- The City should contact Ecology's regional hydrogeologist to define requirements for the test. (Currently there is no regional hydrogeologist in the SW region, so the City should contact the region's Municipal Facilities Supervisor (Greg Zentner) to obtain a hydrogeologist contact at Ecology. The hydrogeologist may request a proposal from the City in order to assess requirements for testing.

On the local level, testing may require performing a SEPA checklist and a grading permit. The City or the County could act as SEPA lead agency. Their determination (e.g. an MDNS or DNS) would then go to Ecology for review. A grading permit was required for a recent test by PGG involving a 50ft x 50ft infiltration pond.

It should be noted that performing infiltration tests with potable water, rather than reclaimed water, may significantly reduce regulatory requirements for performing the test. Testing with potable water could conceivably be performed without any permits accept for a grading permit if excavation is required for the infiltration pond.

8.4 SITE SELECTION BY THE TAG

- The Technical Advisory Group (TAG) led by Clallam County met on June 20th and July 25th, 2007 to select preferred sites for pilot infiltration testing.
- Based on availability of reclaimed water at the Demonstration Site and at HW-3, the TAG decided to pursue testing at HW-3. Two locations were suggested for infiltration testing: the detention pond by the on-ramp and the 6 acre property (formerly owned by "Mego") west of the City Shop, at 2nd and Hemlock
- Although the gravel pit and sites HW-1 and HW-2 have no readily available sources of reclaimed water for infiltration testing, the TAG is interested in testing either the gravel pit or Site HW-2 due to: 1) its proximity to the Eureka ditch, 2) the capability to route stormwater into the gravel pit via the existing ditch system, and 3) the TAG's preference for the western sites based on location and potentially better hydrogeologic conditions.

8.5 RECOMMENDATIONS FOR TESTING SITE HW-3

- The City Shop site is preferred over the detention pond due to its greater distance from the surficial exposure of glacial till and the fact that the infiltration pond can be excavated to the size/dimension best suited to test design. If the detention pond were used for testing, access to the site would need to be negotiated and the bottom of the pond would likely require scraping.
- PGG recommends that infiltration testing should be performed, if possible, using potable water rather than reclaimed water. Use of potable water would reduce the regulatory requirements for testing and reduce public involvement/concern.
- The coordinator of the infiltration test should develop a plan for public notification and involvement commensurate with the testing performed. Contact with local residents during field investigations should be coordinated with this plan.
- Hydrogeologic characterization and hydraulic testing, described below, should be performed by a qualified hydrogeologist.
- Field investigations should include an inventory of local wells and mapping of groundwater sensitive features. The well inventory could simply identify residences not supplied by pubic water systems, or could include visits with residents, matching of well logs on record with Ecology and Clallam County, and interviews to gather additional information and obtain access for water-level measurement and sampling.

Locations of directly inventoried wells and groundwater sensitive features should be recorded with GPS.

- Given concern regarding the possible occurrence of shallow till, it may be most effective to begin the site investigation by excavating one-or-more backhoe test pits onsite. Excavations should be performed near but not below the anticipated infiltration pond and backfilled after interpretation of the soil profile. Onsite soil profiles should be compared for consistency with NRCS soils descriptions. If shallow till is encountered within 10 feet of the land surface, the site should be removed from consideration. Greater thicknesses of permeable sediments above shallow till increase the infiltration capacity of the site.
- At least three monitoring wells should be installed on site. Sonic drilling is recommended to best characterize sub-surface conditions. The first boring should be the deepest, thus allowing identification of possible confining units in the USGS upper aquifer. This well should be completed at depth in the uppermost water-bearing zone or possibly below a shallow confining unit (if encountered). If the first boring suggests insufficient aquifer thickness, aquifer permeability, or freeboard (unsaturated zone thickness), the site could be removed from consideration.
- The other two borings should be completed across the shallow water table. The first well should be located next to the initial deep well, and the second well should be located approximately 10-30 feet away. Screen lengths of 10-20 feet (centered on the water table) are recommended. At least one of the shallow wells should be tested to estimate the hydraulic properties of the aquifer. Injection testing is preferred over pumping tests. Soil samples obtained during drilling could be sent to a laboratory for grain-size and hydraulic conductivity analyses.
- If the water table beneath the site is relatively shallow, it may be worthwhile to add a third shallow well to allow triangulation of groundwater elevations for definition of groundwater flow direction and gradient. The City could obtain relative wellhead elevations using a level and rod. While it may also be possible to use domestic wells, few domestic wells are located near the site and existing wells may be located at greater depth in the aquifer.
- Design of monitoring wells should take into account variability of groundwater elevations, if possible. PGG's review of County data indicated no nearby shallow wells with monitoring data. However, review of data from other shallow wells with similar nearby irrigation regimes may be useful. Long-term monitoring should be initiated onsite in the deeper well and one shallow well as soon as possible. A minimum frequency of monthly measurements is recommended.
- Soil permeability has been estimated by the NRCS estimates. If soil profiles observed during excavation appear to differ from NRCS descriptions, ring infiltrometer testing is recommended to better estimate onsite soil permeability. The infiltration pond should be designed based on aquifer properties estimated by testing of the shallow monitoring well, estimates of soil permeability, and available water quantity. Given the NRCS estimate of soil permeability (12-40 feet/day), a 30-ft x 30-ft square pond could infiltrate 55-185 gpm (0.08-0.27 mgd) unless limited by the transmitting capac-

ity of underlying sediments or the thickness of unsaturated zone between the bottom of the pond and the water table.

- Prior to performing the infiltration testing, background groundwater level monitoring should be performed for at least one week. Onsite monitoring wells should be fitted with transducers. If incorporated into the monitoring network, neighboring private wells should optimally be fitted with transducers. However, daily manual measurements (taken when not influenced by pumping) would suffice for background data.
- The infiltration test should be performed by maintaining a constant discharge into the infiltration pond. Discharge should be estimated during pond design, as noted above. Total discharge volume should be recorded with a cumulative flow meter, and the stage and wetted area of the pond should be documented throughout various stages of the testing. If manual measurement is performed on offsite wells, measurement frequency should be increased to at least several times per day and influences of pumping should be avoided.
- Optimally, infiltration testing should be performed for a minimum of three days. Longer periods are desirable if sufficient source water is available. If possible, an "adaptive" approach to testing should be taken, such that data are collected and evaluated during the test, and test duration and discharge rate are adjusted to optimize the effectiveness of the test.
- After infiltration is discontinued, groundwater level monitoring should be continued to observe recovery. For shorter tests (e.g. 3 to 7 days), monitoring should continue for one-to-two times the infiltration period. Longer infiltration tests will require longer recovery monitoring, but monitoring periods may not increase in direct proportion to the testing period. Reduced relative periods of post-infiltration monitoring may be indicated if water levels exhibit full recovery or become dominated by background trends.
- If a long test is performed, groundwater sensitive features should be observed to watch for the possible appearance of shallow groundwater intersecting the land surface.
- The TAG has expressed interest in using water quality testing as a means of tracking infiltrated water. This could potentially be performed based on native groundwater quality if the infiltrated water is significantly different from the shallow groundwater onsite, or based on introduction of tracers such as bromide. The chemistry of the infiltrated water must differ sufficiently from background chemistry to be detected downgradient. Groundwater transport analysis would be needed to calculate reasonable differences in chemistry (e.g. tracer concentrations), and multiple water-quality samples would be needed to statistically characterize water quality to discern breakthrough of the infiltrated water. Based on the proximity of the onsite monitoring wells, detection of infiltrated water is expected in these wells. Therefore, downgradient private wells would be targeted for water-quality monitoring. The level of effort involved in this approach, and the concern it might raise for local residents, may not be justified by the information gained. While detection of tracer in a downgradient well is conclusive, multiple variables affecting transport cause lack of detection to be

inconclusive regarding future (long-term) potential for transport to these wells. We do not recommend pursuing this task.

8.6 RECOMMENDATIONS FOR TESTING THE GRAVEL PIT OR HW-2

Despite the fact that reclaimed water is not currently readily available at any of the western-most sites (HW-1, HW-2, gravel pit), the TAG has expressed interest in investigating infiltration at one of these sites. The source of water for testing would be stormwater, using existing irrigation ditches for conveyance. The Eureka Ditch runs adjacent to both the gravel pit and Site HW-2, and is or can be connected with the Highland ditch, which receives high volumes of seasonal runoff from the south. This section provides considerations for testing one of these two western sites.

- As discussed above, infiltration testing should be performed (if possible) using potable water rather than stormwater. Use of potable water to perform the test would greatly reduce some of the potential difficulties described below. Once the infiltration capacity of the site is evaluated, various sources (stormwater, extension of reclaimed water pipelines) can be considered.
- The monitoring guidelines presented above are also applicable to either the gravel pit or Site HW-2. The numbers of monitoring wells, their design and relative penetration into the shallow aquifer, their locations relative to the infiltration pond and the general testing/monitoring schedule all generally apply to these sites.
- Any available monitoring data from near-site wells should be reviewed to evaluate seasonal water-level variations. Long-term monitoring should be initiated in newly installed monitoring wells to define seasonal trends.
- During testing, the stormwater should optimally be discharged into an infiltration pond of controlled dimension. Both sites already contain depressions of given size that can receive water during a runoff event (0.55 acres at HW-2 and the 6.8-acre gravel pit). Excavating a smaller pond within the gravel pit could be complicated by the already limited freeboard between the pit bottom and the water table (4.2 feet)[5]; however, it may be possible to construct a berm to contain stormwater within a portion of the pit. Given these dimensional constraints, selection between these two sites will depend on the quantity of stormwater expected, its rate of delivery, the extent to which the infiltration footprint can be adjusted, the storage capacity at either site, and the hydraulic parameters that affect infiltration rate.
- Selection between the two sites must occur prior to investing in site characterization and instrumentation. Based on the NRCS-reported soil permeabilities (4-12 ft/day) and the dimensions noted above, Site HW-2 could accommodate between 1.1-3.3 cfs. The gravel pit would likely accommodate higher flows; however, given the limited freeboard, infiltration from the pit cannot be similarly estimated based on soil permeabilities and the assumption of vertical flow. A better understanding of the expected

[5] Note prior observation that Robinson & Noble (2002) report a depth to water of 4.2 feet, but observation of wet sediments at 9 feet during drilling.

runoff hydrograph is needed to select between the sites. Site selection should also reference information available in addition to that presented in this memorandum. Such information could include *both* hydrogeologic reports developed by Robinson & Noble for the Shaw gravel pit and WDOT logs of soil borings for installation of pilings at the 7th Ave overpass near Site HW-2 (if available).

- Use of stormwater for infiltration testing is sub-optimal due to the uncontrolled delivery to the infiltration feature (regarding rate, overall volume, and timing) and the high likelihood of suspended sediment (turbidity) which can clog the bottom of the pond and reduce infiltration during testing. Under these conditions, a test could yield a rough estimate of infiltration capacity, but would not likely support refined estimation of aquifer properties.

- During testing with stormwater runoff, monitoring of inflow would optimally include the rate of inflow, the stage of the infiltration pond, and the wetted dimensions of the pond. All of these factors are likely to change over time, thus complicating refined analysis of the inflow data. Monitoring of inflow rate would likely require construction of a weir instrumented with a pressure transducer. A transducer could also be used to measure the stage of the pond. The ability/ease of monitoring pond dimension over time will depend on the geometry of the infiltration feature.

- If stormwater runoff contains significant suspended sediment, clogging of the pond could provide an inaccurately low estimate of infiltration capacity. In this case, infiltration capacity can be improved (during both testing and long-term operation) by constructing a settling pond to remove sediment prior to introduction to the infiltration facility. It may be desirable to line the pond during testing; however the pond could be unlined for long-term use. A stormwater engineer should be consulted regarding design of the settling pond.

- Because stormwater runoff becomes available during rainfall events, it is possible that groundwater responses to infiltration testing at the pit are influenced by both the test and the rainfall event. Differentiation between these two responses requires that aquifer responses to rainfall events are uniquely defined through either onsite monitoring during non-test periods or monitoring of nearby shallow wells outside the geographic influence of the test. Private wells (preferably unused) or additional monitoring wells located offsite may be used for this purpose.

- In order to route the stormwater to the selected site, it will be necessary to coordinate any modifications of the ditch systems with the relevant irrigation districts. Other required coordination includes:
    - Developing an MOU between the County, applicable irrigation boards, and possibly the City and/or WDOT.
    - Coordinating volunteer staffing for stormwater routing and monitoring during testing.
    - Obtaining landowner permission for use and transmission of stormwater to either infiltration site.

- Any additional permitting required for testing. (Stormwater management should conform with local and state guidelines).

- Given the uncontrolled nature of stormwater generation, the delivery system should include built-in design and control to avoid flooding. Consultation between the irrigation districts and a stormwater engineer may be required to design and construct these safety measures.
- If potable water is used for testing, an MOU may be required between the City and the County regarding use of the City's potable water during the test period.

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Table 1. Ecology Well Database for the Vicinity of Site HW-1

Well owner name	Well depth	Well diameter	Depth to Water	Test rate	Drawdown	Test type	Test duration	Legal Location	Well Completion
	feet	inches	feet	gal/min	feet		hours		date
FRANK BROOKS	120	6	58	40	n.r.	air	1	T30N/R4W-25NENW	7/24/1991
HOWARD BAKER	79	6	51	15	18	bailer	n.r.	T30N/R4W-25NENW	8/2/1982
MR. BAGLEY	79	6	36	25	18	bailer	n.r.	T30N/R4W-25NENW	9/30/1975
RALPH GALLANT	81	6	49	25	10	bailer	n.r.	T30N/R4W-25NENW	9/14/1982
ROBERT CUMMINGS	79	6	50	25	19	bailer	n.r.	T30N/R4W-25NENW	11/6/1981
RUTH SILSBEE	118	6	68	20	n.r.	air	1	T30N/R4W-25NENW	6/11/2004
BILL KIMBALL	84	6	54	20	12	bailer	1	T30N/R4W-24SESW	12/16/1992
HENRY ZALEWSKE	124	6	52	60	n.r.	bailer	n.r.	T30N/R4W-24SESW	5/10/1978
JOE AUSTIN	103	6	59	12	n.r.	air	1	T30N/R4W-24SESW	7/16/1993
JOHN FREITAS	90	6	64.5	10	21	pump	1	T30N/R4W-24SESW	12/7/1996
LOUISE HAUSCHILD	78	6	40	20	n.r.	air	1	T30N/R4W-24SESW	7/18/1990
LOUISE HAUSCHILD	80	6	40	20	n.r.	air	1	T30N/R4W-24SESW	7/18/1990
LOUISE HAUSCHILD	101	6	61	18	4	bailer	2	T30N/R4W-24SESW	1/16/1995
ADAMS CURT	236	6	76	40	n.r.	air	2	T30N/R4W-24SESE	
BOB BAUBLITS	62	6	34	35	n.r.	air	2	T30N/R4W-24SESE	5/18/1996
CARL BERGER	276	6	61	30	60	bailer	n.r.	T30N/R4W-24SESE	5/22/1975
LEN BROCK	81	6	48	20	75	bailer	1.5	T30N/R4W-24SESE	8/2/1989
MILTON LENZ	28	6	18	20	27	bailer	2	T30N/R4W-24SESE	9/13/1979
MRS. LENZ	138	6	48	60	n.r.	air	2	T30N/R4W-24SESE	10/20/1989
ART SIMMONS	122	6	42	50	n.r.	air	1.5	T30N/R4W-24SWSE	11/30/1990
ARTHUR SIMMONS	101	6	54	40	n.r.	air	2	T30N/R4W-24SWSE	3/18/1997
BOB WELKAFF	100	6	47	30	n.r.	air	1	T30N/R4W-24SWSE	2/2/1992
C. P. LELAND	91	6	48	12	n.r.	bailer	n.r.	T30N/R4W-24SWSE	5/2/1974
CL - BENSEN	102	6	47	23	23	bailer	2	T30N/R4W-24SWSE	10/27/1976
DON HENDRIKSON	100	6	50	30	n.r.	air	1	T30N/R4W-24SWSE	1/31/1992
EMCON SEQUIM*	12	n/a	10.3	n/a	n/a	n/a	n/a	T30N/R4W-24SWSE	8/7/1998
EMCON SEQUIM*	12	n/a	10.5	n/a	n/a	n/a	n/a	T30N/R4W-24SWSE	8/7/1998
EMCON SEQUIM*	12	n/a	11.1	n/a	n/a	n/a	n/a	T30N/R4W-24SWSE	8/7/1998
EMCON SEQUIM*	12	n/a	9.9	n/a	n/a	n/a	n/a	T30N/R4W-24SWSE	8/7/1998
GORDON SCHMELZER	100	6	46	30	n.r.	bailer	n.r.	T30N/R4W-24SWSE	3/27/1975
JEHOVAH'S WITNESSES	120	6	35	40	40	bailer	1.5	T30N/R4W-24SWSE	4/4/1989
JEOF BOURQUIN	100	6	40	30	20	bailer	1	T30N/R4W-24SWSE	6/24/1990
L. STEWART	77	6	50	7	75	bailer	1.5	T30N/R4W-24SWSE	6/4/1987
PAUL MCHUGH	102	6	65	20	n.r.	air	1.5	T30N/R4W-24SWSE	10/1/2002

Table 1. continued

Well owner name	Well depth	Well diameter	Depth to Water	Test rate	Drawdown	Test type	Test duration	Legal Location	Well Completion
TOM KELVIE	119	6	61	20	n.r.	air	1	T30N/R4W-24SWSE	9/5/1994
WILLIAM HALEY SR.	127	6	34	25	25	bailer	1	T30N/R4W-24SWSE	7/24/1987
CHARLES CORTE	80	6	46	30	n.r.	bailer	n.r.	T30N/R4W-24SENW	10/17/1980
FAITH BAPTIST CHURCH	90	6	56.5	8	n.r.	bailer	n.r.	T30N/R4W-24SENW	3/21/1974
FAITH BAPTIST CHURCH**	77	6	n/a	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	3/6/2001
JIM KONNZ	121	6	83	20	n.r.	air	1	T30N/R4W-24SENW	11/11/1992
JOHN EILMAN	126	6	47	45	20	bailer	1	T30N/R4W-24SENW	2/23/1984
JOHN OSTBAND	80	6	44	30	n.r.	bailer	1	T30N/R4W-24SENW	11/6/1980
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
KLEINFELDER (SEQUIM COSTCO)*	20	n/a	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	7/1/2005
S D DEACON CORP OF WA**	90	5	n/a	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	8/5/2004
S.P. & HAZEL TAGUE	90	5	61	10	12	bailer	4	T30N/R4W-24SENW	4/4/1978
SD DEACON CORP OF WA**	90	6	n/a	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	8/3/2004
SD DEACON (HOME DEPOT)*	29	18	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	11/9/2004
SD DEACON (HOME DEPOT)*	29	18	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	11/9/2004
SD DEACON (HOME DEPOT)*	31	18	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	11/9/2004
SD DEACON (HOME DEPOT)*	28	18	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	11/9/2004
SD DEACON (HOME DEPOT)*	29	18	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	11/9/2004
SD DEACON (HOME DEPOT)*	29	18	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	11/10/2004
SD DEACON (HOME DEPOT)*	29.5	18	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	11/10/2004
SD DEACON (HOME DEPOT)*	29	18	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	11/11/2004
WALMART*	25	2	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	8/7/2004
WALMART*	25	2	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	8/7/2004
WALMART*	30	2	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	8/7/2004
WALMART*	30	2	n.r.	n/a	n/a	n/a	n/a	T30N/R4W-24SENW	8/7/2004

n.r. = not reported
n/a = not applicable
* soil boring for resource protection
** well abandoned

Table 2. Ecology Well Database for the Vicinity of Site HW-2

Well owner name	Well depth	Well diameter	Depth to Water	Test rate	Drawdown	Test type	Test duration	Legal Location	Well Completion
	feet	inches	feet	gal/min	feet		hours		date
RICK CROOT	207	6	112	20	70	bailer	n.r.	T30N/R3W-19SWSE	3/10/1986
AL RASMUSSEN	102	6	47	28	14	bailer	1.5	T30N/R3W-30NWNW	11/10/1986
ANN RUSSELL	116	6	76	30	n.r.	air	2	T30N/R3W-30NWNW	11/22/1996
CARL REVARD	100	6	47	8	33	bailer	1.5	T30N/R3W-30NWNW	4/2/1976
ED SOUTHERLAND	172	6	47	20	65	bailer	n.r.	T30N/R3W-30NWNW	5/30/1974
FRITZ FLEGEL	119	6	46	65	n.r.	bailer	1.5	T30N/R3W-30NWNW	10/5/1978
JANET LAURENSON	93	6	57	10	10	bailer	2	T30N/R3W-30NWNW	3/20/1969
JON PATERSON	185	6	125	50	18	pump	2	T30N/R3W-30NWNW	
LOREN MEYER	41	6	24	10	11	pump	1	T30N/R3W-30NWNW	7/9/1990
MRS. KNUDSON	172	6	125	15	n.r.	air	2	T30N/R3W-30NWNW	8/8/1991
TED BURR	90	6	50	12	20	bailer	1.5	T30N/R3W-30NWNW	1/17/1979

n.r. = not reported

Table 3. Ecology Well Database for the Vicinity of Site HW-3

Well owner name	Well depth	Well diameter	Depth to Water	Test rate	Drawdown	Test type	Test duration	Legal Location	Well Completion
	feet	inches	feet	gal/min	feet		hours		date
FONES NOWELL	156	6	80	20	5	bailer	1.5	T30N/R3W-20SWSW	6/9/1976
TOM SCHAAFSME	157	6	85	37	63	bailer	1	T30N/R3W-20SWSW	11/21/1984
LORRAINE HARRIS	59	6	22	40	n.r.	bailer	1	T30N/R3W-19SE	3/14/1979

n.r. = not reported

Table 4. Ecology Well Database for the Vicinity of the Gravel Pit Site

Well owner name	Well depth	Well diameter	Depth to Water	Test rate	Drawdown	Test type	Test duration	Legal Location	Well Completion
	feet	inches	feet	gal/min	feet		hours		date
AL RASMUSSEN	102	6	47	28	14	bailer	1.5	T30N/R3W-30NWNW	11/10/1986
ANN RUSSELL	116	6	76	30	n.r.	air	2	T30N/R3W-30NWNW	11/22/1996
CARL REVARD	100	6	47	8	33	bailer	1.5	T30N/R3W-30NWNW	4/2/1976
ED SOUTHERLAND	172	6	47	20	65	bailer	n.r.	T30N/R3W-30NWNW	5/30/1974
FRITZ FLEGEL	119	6	46	65	n.r.	bailer	1.5	T30N/R3W-30NWNW	10/5/1978
JANET LAURENSON	93	6	57	10	10	bailer	2	T30N/R3W-30NWNW	3/20/1969
JON PATERSON	185	6	125	50	18	pump	2	T30N/R3W-30NWNW	
LOREN MEYER	41	6	24	10	11	pump	1	T30N/R3W-30NWNW	7/9/1990
MRS. KNUDSON	172	6	125	15	n.r.	air	2	T30N/R3W-30NWNW	8/8/1991
TED BURR	90	6	50	12	20	bailer	1.5	T30N/R3W-30NWNW	1/17/1979
ARCHIE TANNEHILL	98	6	45	30	30	bailer	1.5	T30N/R4W-25NENE	6/7/1989
BILL NOLL	139	6	58	30+	17	bailer	1.5	T30N/R4W-25NENE	9/30/1997
DORN ANDERSON	96	6	42	37	23	bailer	1	T30N/R4W-25NENE	8/21/1986
GARY EAST	130	6	55	50	3	bailer	4	T30N/R4W-25NENE	
K G DT COPR.	101	8	48	100	34	pump	8	T30N/R4W-25NENE	5/26/1973
KGAT CORP.	100	6	52	70	25	pump	7	T30N/R4W-25NENE	1/2/1974
LOREN MEYERS	41	6	21	10	15	bailer	1.5	T30N/R4W-25NENE	8/24/1979
SAI. YOUNG	121	6	80	15	25	bailer	3	T30N/R4W-25NENE	5/18/1983
GAR EAST	136	8	60	290	29	pump	6.3	T30N/R4W-25NE	
LOMA VISTA / EVERGREEN UTIL.	129	8	50	198	28	pump	8	T30N/R4W-25NE	9/30/1988
LUCILLE BERG	119	6	54	50	n.r.	bailer	2	T30N/R4W-25NESE	6/16/1977
ROBERT REANDEAU	144	6	84	30	n.r.	air	1	T30N/R4W-25NESE	6/13/2005
ROBERT REANDEAU	143	6	83	30	n.r.	air	2	T30N/R4W-25NESE	6/7/2005

n.r. = not reported

Table 5. Summary of Domestic Wells Surrounding the Demonstration Site

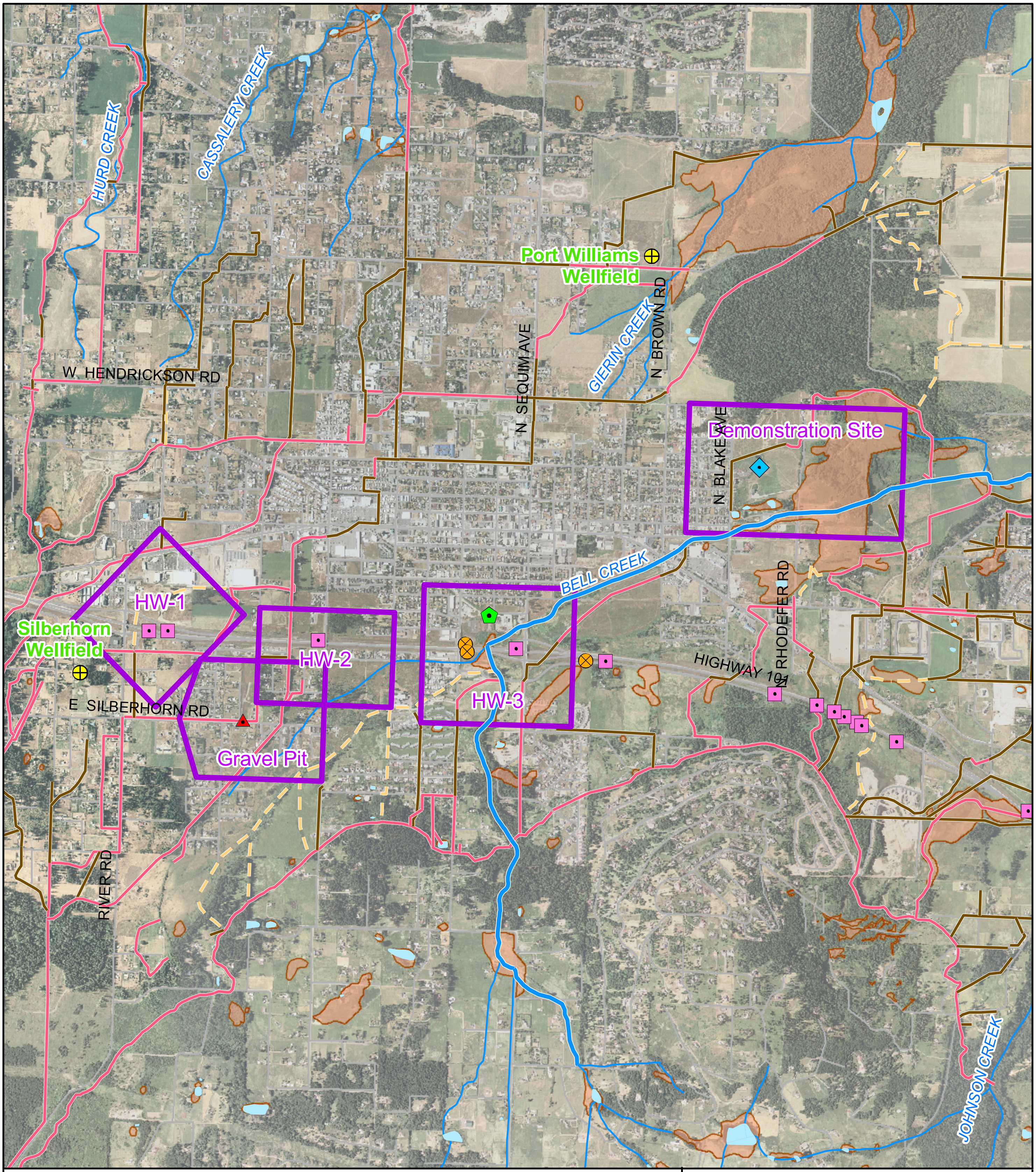
Well ID	Location ID	Owner	Drilled Depth (ft)	Completion Depth (ft)	Drill Date	Depth to Water (ft)	Test Well Yield (gpm)	Test Drawdown or Stem Setting (ft)	Test Type	Test Duration (hrs)
A	30N/03W-20A01	Blake, Ed	34	34	1956	N/L	N/L	N/L	N/L	N/L
P	30N/03W-20B01	N/L	N/L	23	1/50	0				
Q	30N/03W-20K71	Schmuck	121	91	11/95	N/L	30	40	Bailer	2
R	30N/03W-20K72	Smith	50	50	10/94	31	10	10	Bailer	1
O	30N/03W-21(NW)	Holgerson, Family LPS	183	182	10/96	49	60	80	Air	3
S	30N/03W-21D01	N/L	N/L	230	10/80	58				
E	30N/03W-21D71	Angiuli, Jerry	120*	117	12/89	35	25	95	Air	2
F	30N/03W-21D72	Holgerson, Hill	227	227	6/85	50	40	25	Bailer	4
G	30N/03W-21D73	Holgerson, Hill	230	230	10/79	58	60	4	Bailer	3
I	30N/03W-21E71	Holgerson, Hill	25	25	8/83	8	16	7	Bailer	2
H	30N/03W-21E72	Holgerson, Hill	42	26	11/73	8	9	N/L	Bailer	N/L
J	30N/03W-21M01	Baker, Chuck	69	68	10/75	13	6	47	Bailer	1
K	30N/03W-21M71	Gloor, Tom	30	30	5/87	6	2.5	14	Bailer	N/L
M	30N/03W-21M71	Sage, Marylin	28	28	7/83	Flowing	4	n/a	Artesian	N/L
L	30N/03W-21M72	Benson, Jim	31	27	3/86	Flowing	10	21	Bailer	1
N	30N/03W-21M72	Gloor, Otto	190	166	1/82	53	8	95	Bailer	N/L
T	30N/03W-21M76	Kreml	290	290	7/96	132	12	60	Bailer	1
U	30N/03W-21M77	Kreml	178	178	8/94	134	10	80	Bailer	3

NOTES:
Wells were selected within approximately one quarter mile of the Demonstration Site.
N/L = not listed.
Source: Clallam County Well Database, 2000 + Ecology Well Database, 2007
*Deepened to 221 feet in 1990

Table 6 - Infiltration Potential Matrix

Study Site	Facility size	Soil Hydraulic Conductivity	Shallow Aquifer Hydraulic Conductivity*	Depth to Groundwater (below land surface)	Surface water features	Nearby Wells (1/4 mile)	Notes
HW-1	Detention ponds: 0.85 and 1.26 acres	4 - 12 ft/day	40 ft/day; 110 ft/day nearby	Generally 30 - 70 ft, 10 feet in QQ section west of ponds, 18 ft in QQ section east of ponds	Ditches to south and north	38 wells, both upgradient and downgradient	
HW-2	Detention pond: 0.55 acres	4 - 12 ft/day	29 ft/day; 110 ft/day nearby and downgradient	45 - 75 ft, and one shallow well @ 24 ft south of pond	Ditch to west, ephemeral stream to southeast	11 wells, 10 of them upgradient	
HW-3	Retention ponds: 1.06 and 1.78 acres; detention pond: 0.27 acres	12 - 40 ft/day	29 ft/day; 110 ft/day nearby and downgradient	3 wells: 22 ft, 85 ft & 80 ft (water noted @ 48 ft)	Bell Creek, wet-lands, ephemeral stream to west, ditch to southeast	3 wells to the north and east (possibly downgradient)	Possible shallow till and shallow groundwater. May limit infiltration capacity.
Gravel Pit	Pit: 6.8 acres	4 - 12 ft/day	29 ft/day; 110 ft/day nearby	4 feet below bottom of pit. Domestic wells 40 - 85 ft, with two shallow wells @ 21-24 feet	Several ditches, one very close to pit	23 wells, most to the north, some likely downgradient	Shallow groundwater and hardpan below bottom of pit. Could limit infiltration capacity.
Demonstration Site	Up to 29 acres	12 - 40 ft/day	110 ft/day	>12 ft in the NW corner of the site, 4-9 ft along the southern site boundary	Bell Creek south of site, ditch to northeast, wetlands south and east	Several downgradient wells, completed deeper than shallow water bearing unit	Shallow depths to groundwater may limit infiltration capacity. Will depend on hydraulic conductivity of shallow aquifer.

*Shallow aquifer hydraulic conductivity estimated by Thomas et al (1999) based on well specific capacities, and may not reflect properties of uppermost sediments.



Preferred Infiltration Sites

- Gravel Pit
- Detention Pond
- Retention Pond
- Demonstration Site
- City Shop Site

- Wetlands
- Infiltration Study Sites
- Streams
- Irrigation Ditch
- Irrigation Pipe
- Abandoned Ditch

Wellfield

0 Feet 2,000

Aerial Photo 2006

N

Figure 1

Proposed Infiltration Sites

PGG

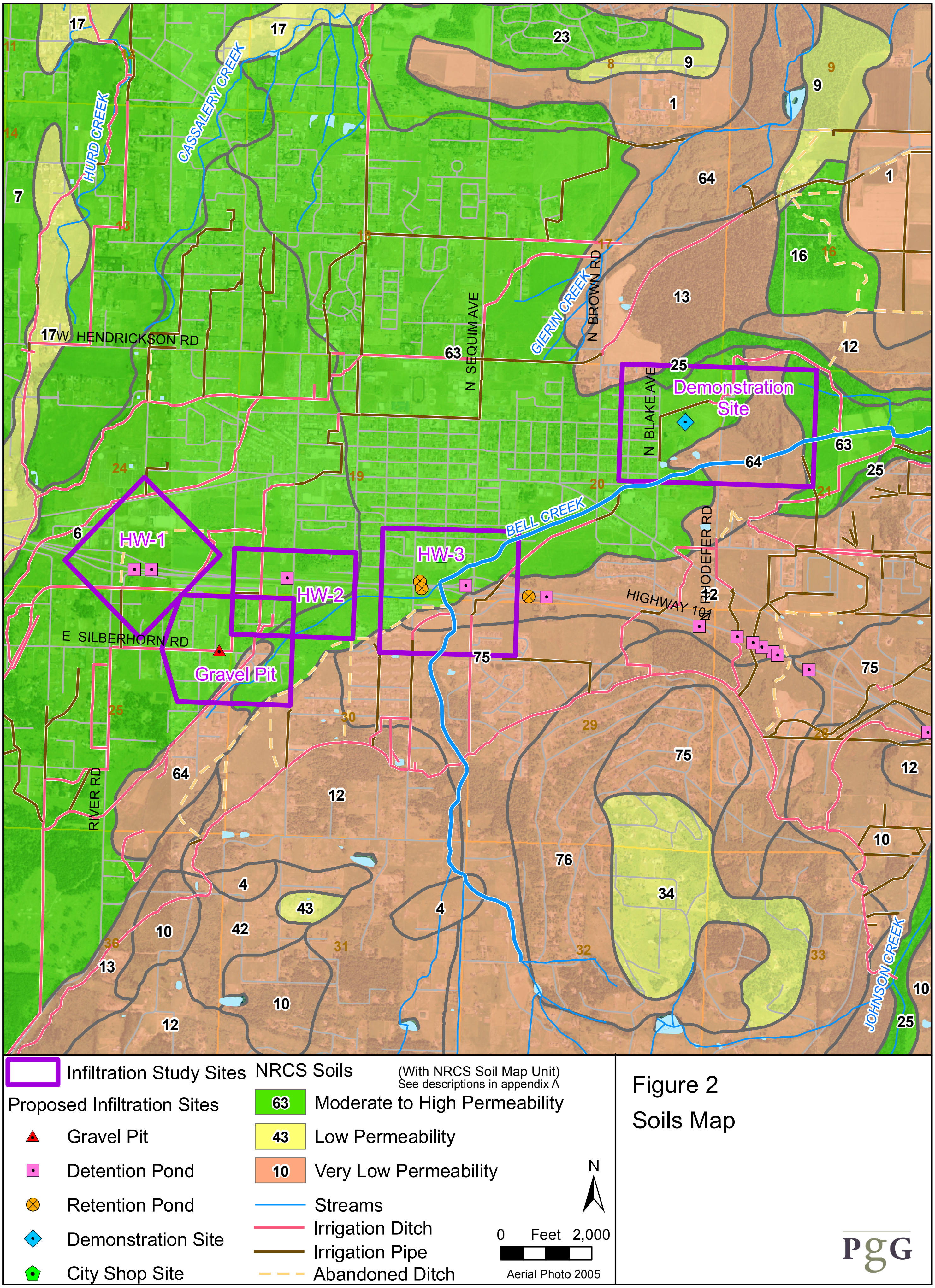
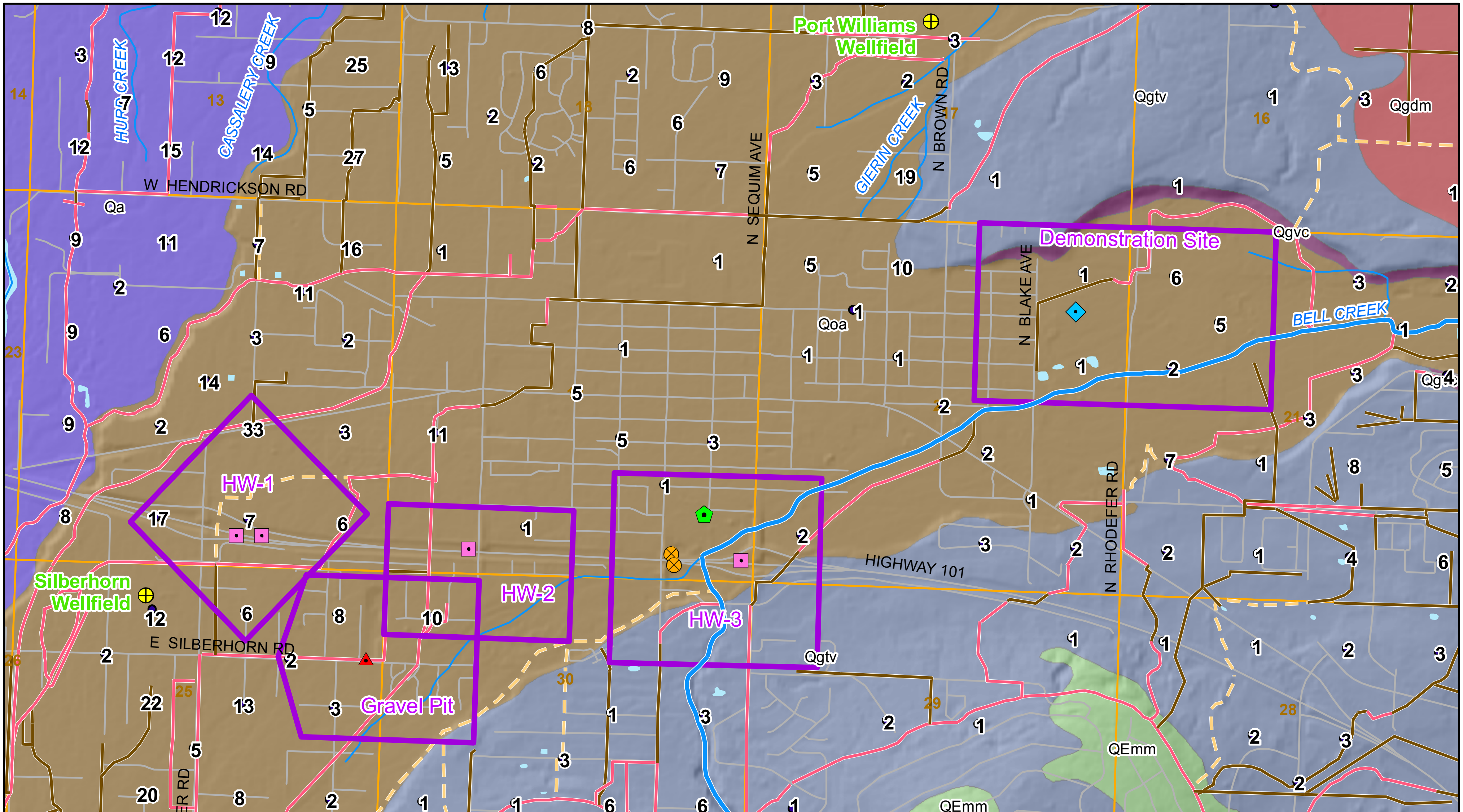


Figure 2

Soils Map

PGG



Surficial Geology
(Shasse & Logan, 1998)

- QEmm
- Qa
- Qgdm
- Qgtv
- Qgvc
- Qoa

4 Number of Well logs by Quarter-Quarter Section
(No value indicates zero reported wells)

Proposed Infiltration Sites

- Gravel Pit
- Detention Pond
- Retention Pond
- Demonstration Site
- City Shop Site

- Infiltration Study Sites
- Streams
- Irrigation Ditch
- Irrigation Pipe
- Abandoned Ditch
- Wellfield

0 Feet 2,000

N

Figure 3
Surficial Geology

PgG

Appendix A

NRCS Soils Information

Map Unit Description

Clallam County Area, Washington

1 Agnew silt loam, 0 to 8 percent slopes

Setting

Landscape: Plains
Elevation: 50 to 400 feet
Mean annual precipitation: 20 to 20 inches
Mean annual air temperature: 48 to 48 degrees F
Frost-free period: 170 to 200 days

Composition

Agnew and similar soils: 90 percent
Minor components: 6 percent

Description of Agnew

Setting

Landform: Terraces
Parent material: Glaciomarine deposits

Properties and Qualities

Slope: 0 to 8 percent
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low or moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 48 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: High (about 11.4 inches)

Interpretive Groups

Land capability classification (irrigated): 3w
Land capability (non irrigated): 2w

Typical Profile

0 to 8 inches: silt loam
8 to 46 inches: silty clay loam
46 to 60 inches: stratified sandy loam to silty clay loam

Minor Components

Bellingham

Percent of map unit: 3 percent
Landform: Depressions

Puget

Percent of map unit: 3 percent
Landform: Terraces

4 Bellingham silty clay loam

Setting

Landscape: Outwash plains
Elevation: 10 to 600 feet
Mean annual precipitation: 35 to 60 inches
Mean annual air temperature: 50 to 50 degrees F
Frost-free period: 150 to 210 days

Composition

Bellingham and similar soils: 85 percent
Minor components: 12 percent

Description of Bellingham

Setting

Landform: Depressions on terraces
Parent material: Alluvium

Properties and Qualities

Slope: 0 to 3 percent
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low or moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very high (about 12.3 inches)

Interpretive Groups

Land capability (non irrigated): 5w

Typical Profile

0 to 9 inches: silty clay loam
9 to 60 inches: silty clay loam

Minor Components

Mckenna

Percent of map unit: 6 percent
Landform: Depressions

Puget

Percent of map unit: 6 percent
Landform: Terraces

Map Unit Description

Clallam County Area, Washington

6 Carlsborg gravelly sandy loam, 0 to 5 percent slopes

Setting

Landscape: Alluvial plains
Elevation: 50 to 500 feet
Mean annual precipitation: 20 to 20 inches
Mean annual air temperature: 48 to 48 degrees F
Frost-free period: 170 to 200 days

Composition

Carlsborg and similar soils: 100 percent

Description of Carlsborg

Setting

Landform: Terraces, alluvial fans
Parent material: Alluvium

Properties and Qualities

Slope: 0 to 5 percent
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very low (about 1.9 inches)

Interpretive Groups

Land capability classification (irrigated): 6s
Land capability (non irrigated): 6s

Typical Profile

0 to 9 inches: gravelly sandy loam
9 to 20 inches: very gravelly loamy sand
20 to 60 inches: extremely gravelly loamy sand

7 Carlsborg-Dungeness complex, 0 to 5 percent slopes

Setting

Landscape: River valleys
Elevation: 30 to 300 feet
Mean annual precipitation: 17 to 25 inches
Mean annual air temperature: 48 to 50 degrees F
Frost-free period: 170 to 200 days

Composition

Carlsborg and similar soils: 50 percent
Dungeness and similar soils: 30 percent
Minor components: 4 percent

Description of Carlsborg

Setting

Landform: Terraces
Parent material: Alluvium

Properties and Qualities

Slope: 0 to 5 percent
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very low (about 1.9 inches)

Interpretive Groups

Land capability classification (irrigated): 6s
Land capability (non irrigated): 6s

Typical Profile

0 to 9 inches: gravelly sandy loam
9 to 20 inches: very gravelly loamy sand
20 to 60 inches: extremely gravelly loamy sand

Description of Dungeness

Setting

Landform: Terraces
Parent material: Alluvium

Properties and Qualities

Slope: 0 to 5 percent
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high or high (0.57 to 1.98 in/hr)
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Moderate (about 8.4 inches)

Interpretive Groups

Land capability classification (irrigated): 2e
Land capability (non irrigated): 2e

Typical Profile

0 to 8 inches: silt loam
8 to 42 inches: stratified fine sandy loam to silty clay loam
42 to 60 inches: stratified coarse sand to silt loam

Minor Components

Puget

Percent of map unit: 4 percent
Landform: Terraces

9 Cassolary fine sandy loam, 0 to 8 percent slopes

Setting

Landscape: Hills
Elevation: 50 to 500 feet
Mean annual precipitation: 16 to 30 inches
Mean annual air temperature: 48 to 50 degrees F
Frost-free period: 160 to 200 days

Composition

Cassolary and similar soils: 85 percent
Minor components: 6 percent

Description of Cassolary

Setting

Landform: Hillslopes
Parent material: Glacial drift and glaciomarine deposits

Properties and Qualities

Slope: 0 to 8 percent
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: About 36 to 48 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: High (about 9.3 inches)

Interpretive Groups

Land capability classification (irrigated): 2e
Land capability (non irrigated): 2e

Typical Profile

0 to 8 inches: fine sandy loam
8 to 22 inches: very fine sandy loam
22 to 60 inches: stratified fine sandy loam to silty clay loam

Minor Components

Puget

Percent of map unit: 6 percent
Landform: Terraces

10 Catla gravelly sandy loam, 2 to 15 percent slopes

Setting

Landscape: Hills
Elevation: 100 to 400 feet
Mean annual precipitation: 21 to 21 inches
Mean annual air temperature: 48 to 48 degrees F

Composition

Catla and similar soils: 100 percent

Description of Catla

Setting

Landform: Hillslopes
Parent material: Till

Properties and Qualities

Slope: 2 to 15 percent
Depth to restrictive feature: 10 to 20 inches to Dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low or moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 6 to 18 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very low (about 1.2 inches)

Interpretive Groups

Land capability (non irrigated): 6w

Typical Profile

0 to 3 inches: gravelly sandy loam
3 to 12 inches: gravelly sandy loam
12 to 14 inches: gravelly sandy loam
14 to 60 inches: gravelly sandy loam

12 Clallam gravelly sandy loam, 0 to 15 percent slopes

Setting

Landscape: Hills
Elevation: 40 to 1800 feet
Mean annual precipitation: 23 to 23 inches
Mean annual air temperature: 48 to 48 degrees F
Frost-free period: 160 to 200 days

Composition

Clallam and similar soils: 85 percent
Minor components: 3 percent

Description of Clallam

Setting

Landform: Hillslopes
Parent material: Till

Properties and Qualities

Slope: 0 to 15 percent
Depth to restrictive feature: 20 to 40 inches to Dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low or moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 18 to 36 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very low (about 2.4 inches)

Interpretive Groups

Land capability classification (irrigated): 4e
Land capability (non irrigated): 4s

Typical Profile

0 to 10 inches: gravelly sandy loam
10 to 28 inches: very gravelly sandy loam
28 to 60 inches: very gravelly sandy loam

Minor Components

Mckenna

Percent of map unit: 3 percent
Landform: Depressions

13 Clallam gravelly sandy loam, 15 to 30 percent slopes

Setting

Landscape: Hills
Elevation: 40 to 1800 feet
Mean annual precipitation: 23 to 23 inches
Mean annual air temperature: 48 to 48 degrees F
Frost-free period: 160 to 200 days

Composition

Clallam and similar soils: 100 percent

Description of Clallam

Setting

Landform: Hillslopes
Parent material: Till

Properties and Qualities

Slope: 15 to 30 percent
Depth to restrictive feature: 20 to 40 inches to Dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low or moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 18 to 36 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very low (about 2.4 inches)

Interpretive Groups

Land capability (non irrigated): 4e

Typical Profile

0 to 10 inches: gravelly sandy loam
10 to 28 inches: very gravelly sandy loam
28 to 60 inches: very gravelly sandy loam

16 Dick loamy sand, 0 to 15 percent slopes

Setting

Landscape: Outwash plains
Elevation: 0 to 500 feet
Mean annual precipitation: 21 to 21 inches
Mean annual air temperature: 50 to 50 degrees F
Frost-free period: 160 to 200 days

Composition

Dick and similar soils: 85 percent

Description of Dick

Setting

Landform: Outwash terraces
Parent material: Glacial outwash

Properties and Qualities

Slope: 0 to 15 percent
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High or very high (5.95 to 19.98 in/hr)
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Low (about 3.5 inches)

Interpretive Groups

Land capability classification (irrigated): 4s
Land capability (non irrigated): 4s

Typical Profile

0 to 3 inches: loamy sand
3 to 22 inches: sand
22 to 48 inches: stratified sand to loamy sand
48 to 60 inches: stratified gravelly sand to gravelly loamy sand

Map Unit Description

Clallam County Area, Washington

17 Dungeness silt loam

Setting

Landscape: River valleys
Elevation: 30 to 300 feet
Mean annual precipitation: 17 to 25 inches
Mean annual air temperature: 48 to 50 degrees F
Frost-free period: 170 to 200 days

Composition

Dungeness and similar soils: 85 percent
Minor components: 4 percent

Description of Dungeness

Setting

Landform: Terraces, flood plains
Parent material: Alluvium

Properties and Qualities

Slope: 0 to 5 percent
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high or high (0.57 to 1.98 in/hr)
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Moderate (about 8.4 inches)

Interpretive Groups

Land capability classification (irrigated): 2e
Land capability (non irrigated): 2e

Typical Profile

0 to 8 inches: silt loam
8 to 42 inches: stratified fine sandy loam to silty clay loam
42 to 60 inches: stratified coarse sand to silt loam

Minor Components

Puget

Percent of map unit: 4 percent
Landform: Depressions

23 Hoypus gravelly sandy loam, 0 to 15 percent slopes

Setting

Landscape: Outwash plains
Elevation: 50 to 1000 feet
Mean annual precipitation: 24 to 24 inches
Mean annual air temperature: 48 to 48 degrees F

Composition

Hoypus and similar soils: 100 percent

Description of Hoypus

Setting

Landform: Outwash terraces
Parent material: Glacial outwash

Properties and Qualities

Slope: 0 to 15 percent
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High or very high (5.95 to 19.98 in/hr)
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very low (about 2.5 inches)

Interpretive Groups

Land capability (non irrigated): 4s

Typical Profile

0 to 3 inches: gravelly sandy loam
3 to 10 inches: gravelly sandy loam
10 to 31 inches: very gravelly loamy sand
31 to 45 inches: very gravelly sand
45 to 60 inches: gravelly sand

25 Hoypus gravelly loamy sand, 30 to 65 percent slopes

Setting

Landscape: Outwash plains
Elevation: 50 to 1000 feet
Mean annual precipitation: 24 to 24 inches
Mean annual air temperature: 48 to 48 degrees F

Composition

Hoypus and similar soils: 100 percent

Description of Hoypus

Setting

Landform: Outwash terraces
Parent material: Glacial outwash

Properties and Qualities

Slope: 30 to 65 percent
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High or very high (5.95 to 19.98 in/hr)
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very low (about 1.8 inches)

Interpretive Groups

Land capability (non irrigated): 7e

Typical Profile

0 to 4 inches: gravelly loamy sand
4 to 15 inches: gravelly loamy sand
15 to 60 inches: very gravelly sand

34 Louella gravelly loam, 10 to 30 percent slopes

Setting

Landscape: Mountains
Elevation: 200 to 2000 feet
Mean annual precipitation: 30 to 45 inches
Mean annual air temperature: 46 to 48 degrees F
Frost-free period: 150 to 190 days

Composition

Louella and similar soils: 100 percent

Description of Louella

Setting

Landform: Mountain slopes
Parent material: Residuum and colluvium, both derived from basalt and flow breccia

Properties and Qualities

Slope: 10 to 30 percent
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high or high (0.57 to 1.98 in/hr)
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Moderate (about 7.3 inches)

Interpretive Groups

Land capability (non irrigated): 4e

Typical Profile

0 to 11 inches: gravelly loam
11 to 47 inches: gravelly loam
47 to 60 inches: gravelly sandy loam

42 McKenna gravelly silt loam

Setting

Landscape: Hills
Elevation: 50 to 1000 feet
Mean annual precipitation: 30 to 60 inches
Mean annual air temperature: 48 to 52 degrees F
Frost-free period: 150 to 180 days

Composition

Mckenna and similar soils: 85 percent
Minor components: 3 percent

Description of Mckenna

Setting

Landform: Depressions, drainageways
Parent material: Glacial drift

Properties and Qualities

Slope: 0 to 5 percent
Depth to restrictive feature: 20 to 40 inches to Dense material
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low or moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Low (about 4.1 inches)

Interpretive Groups

Land capability (non irrigated): 6w

Typical Profile

0 to 8 inches: gravelly silt loam
8 to 18 inches: gravelly loam
18 to 24 inches: very gravelly loam
24 to 32 inches: very gravelly sandy loam
32 to 60 inches: very gravelly sandy loam

Minor Components

Bellingham

Percent of map unit: 3 percent
Landform: Depressions

43 Mukilteo muck

Setting

Landscape: Valleys
Elevation: 0 to 500 feet
Mean annual precipitation: 40 to 70 inches
Mean annual air temperature: 48 to 52 degrees F
Frost-free period: 150 to 250 days

Composition

Mukilteo and similar soils: 85 percent
Minor components: 8 percent

Description of Mukilteo

Setting

Landform: Depressions
Parent material: Mixed organic material

Properties and Qualities

Slope: 0 to 1 percent
Drainage class: Very poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high or high (0.57 to 1.98 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very high (about 26.9 inches)

Interpretive Groups

Land capability (non irrigated): 5w

Typical Profile

0 to 10 inches: muck
10 to 60 inches: mucky peat

Minor Components

Bellingham

Percent of map unit: 8 percent
Landform: Depressions

Map Unit Description

Clallam County Area, Washington

63 Sequim very gravelly sandy loam

Setting

Landscape: River valleys
Elevation: 20 to 300 feet
Mean annual precipitation: 18 to 18 inches
Mean annual air temperature: 48 to 48 degrees F
Frost-free period: 170 to 200 days

Composition

Sequim and similar soils: 100 percent

Description of Sequim

Setting

Landform: Alluvial fans, terraces
Parent material: Alluvium

Properties and Qualities

Slope: 0 to 5 percent
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High or very high (5.95 to 19.98 in/hr)
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very low (about 1.7 inches)

Interpretive Groups

Land capability classification (irrigated): 6s
Land capability (non irrigated): 6s

Typical Profile

0 to 10 inches: very gravelly sandy loam
10 to 23 inches: extremely cobbly loamy sand
23 to 60 inches: extremely cobbly sand

64 Sequim-McKenna-Mukilteo complex

Setting

Landscape: River valleys
Elevation: 100 to 300 feet
Mean annual precipitation: 18 to 70 inches
Mean annual air temperature: 48 to 52 degrees F
Frost-free period: 150 to 250 days

Composition

Sequim and similar soils: 35 percent
Mckenna and similar soils: 35 percent
Mukilteo and similar soils: 20 percent
Minor components: 3 percent

Description of Sequim

Setting

Landform: Alluvial fans, terraces
Parent material: Alluvium

Properties and Qualities

Slope: 0 to 5 percent
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High or very high (5.95 to 19.98 in/hr)
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very low (about 1.7 inches)

Interpretive Groups

Land capability classification (irrigated): 6s
Land capability (non irrigated): 6s

Typical Profile

0 to 10 inches: very gravelly sandy loam
10 to 23 inches: extremely cobbly loamy sand
23 to 60 inches: extremely cobbly sand

Description of Mckenna

Setting

Landform: Depressions, terraces
Parent material: Glacial drift

Properties and Qualities

Slope: 0 to 5 percent
Depth to restrictive feature: 20 to 40 inches to Dense material
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low or moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Low (about 4.1 inches)

Interpretive Groups

Land capability (non irrigated): 6w

Typical Profile

0 to 8 inches: gravelly silt loam
8 to 18 inches: gravelly loam
18 to 24 inches: very gravelly loam
24 to 32 inches: very gravelly sandy loam
32 to 60 inches: very gravelly sandy loam

Description of Mukilteo

Setting

Landform: Depressions, terraces
Parent material: Mixed organic material

Properties and Qualities

Slope: 0 to 1 percent
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high or high (0.57 to 1.98 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Very high (about 26.9 inches)

Interpretive Groups

Land capability (non irrigated): 5w

Typical Profile

0 to 10 inches: muck
10 to 60 inches: mucky peat

Minor Components

Bellingham

Percent of map unit: 3 percent
Landform: Depressions

75 Yeary gravelly loam, 0 to 15 percent slopes

Setting

Landscape: Hills
Elevation: 200 to 1500 feet
Mean annual precipitation: 28 to 28 inches
Mean annual air temperature: 48 to 48 degrees F
Frost-free period: 160 to 200 days

Composition

Yeary and similar soils: 85 percent
Minor components: 4 percent

Description of Yeary

Setting

Landform: Hillslopes
Parent material: Glaciomarine or glaciolacustrine deposits over till

Properties and Qualities

Slope: 0 to 15 percent
Depth to restrictive feature: 20 to 40 inches to Dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low or moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 18 to 36 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Low (about 4.5 inches)

Interpretive Groups

Land capability classification (irrigated): 3e
Land capability (non irrigated): 3e

Typical Profile

0 to 7 inches: loam
7 to 38 inches: gravelly clay loam
38 to 60 inches: loam

Minor Components

Mckenna

Percent of map unit: 4 percent
Landform: Depressions

Map Unit Description

Clallam County Area, Washington

76 Yeary gravelly loam, 15 to 35 percent slopes

Setting

Landscape: Hills
Elevation: 200 to 1500 feet
Mean annual precipitation: 28 to 28 inches
Mean annual air temperature: 48 to 48 degrees F
Frost-free period: 160 to 200 days

Composition

Yeary and similar soils: 100 percent

Description of Yeary

Setting

Landform: Hillslopes
Parent material: Glaciomarine or glaciolacustrine deposits over till

Properties and Qualities

Slope: 15 to 35 percent
Depth to restrictive feature: 20 to 40 inches to Dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low or moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 18 to 36 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate maximum: 0 percent
Gypsum maximum: 0 percent
Available water capacity: Low (about 4.5 inches)

Interpretive Groups

Land capability classification (irrigated): 6e
Land capability (non irrigated): 4e

Typical Profile

0 to 7 inches: loam
7 to 38 inches: gravelly clay loam
38 to 60 inches: loam

Physical Soil Properties

Clallam County Area, Washington

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
1:														
Agnew	0-8	---	---	10-20	0.65-0.85	1.40-4.00	0.18-0.21	0.0-2.9	3.0-5.0	.37	.37	5	5	56
	8-46	---	---	20-35	1.25-1.45	1.40-4.00	0.17-0.20	3.0-5.9	1.0-3.0	.32	.32			
	46-60	---	---	15-30	1.20-1.40	0.42-1.40	0.17-0.20	0.0-2.9	0.5-1.0	.32	.32			
4:														
Bellingham	0-9	---	---	27-40	0.90-1.00	4.00-14.00	0.30-0.40	3.0-5.9	3.0-9.0	.28	.28	5	7	38
	9-60	---	---	35-60	1.40-1.50	0.42-1.40	0.15-0.20	6.0-8.9	1.0-3.0	.24	.24			
6:														
Carlsborg	0-9	---	---	5-15	0.85-1.25	14.00-42.00	0.08-0.10	0.0-2.9	1.0-4.0	.15	.24	5	4	86
	9-20	---	---	0-5	0.85-1.25	42.00-141.00	0.02-0.04	0.0-2.9	0.5-1.0	.10	.15			
	20-60	---	---	0-5	0.85-1.25	42.00-141.00	0.01-0.03	0.0-2.9	0.0-0.5	.05	.15			
7:														
Carlsborg	0-9	---	---	5-15	0.85-1.25	14.00-42.00	0.08-0.10	0.0-2.9	1.0-4.0	.15	.24	5	4	86
	9-20	---	---	0-5	0.85-1.25	42.00-141.00	0.02-0.04	0.0-2.9	0.5-1.0	.10	.15			
	20-60	---	---	0-5	0.85-1.25	42.00-141.00	0.01-0.03	0.0-2.9	0.0-0.5	.05	.15			
Dungeness	0-8	---	---	10-20	0.85-1.10	4.00-14.00	0.18-0.20	0.0-2.9	2.0-5.0	.43	.43	5	5	56
	8-42	---	---	5-15	1.20-1.45	4.00-14.00	0.15-0.17	0.0-2.9	0.5-2.0	.37	.37			
	42-60	---	---	0-10	1.30-1.60	4.00-14.00	0.06-0.10	0.0-2.9	0.0-0.5	.24	.28			
9:														
Cassolary	0-8	---	---	5-15	0.85-1.10	4.00-14.00	0.12-0.15	0.0-2.9	1.0-3.0	.24	.24	5	3	86
	8-22	---	---	5-10	1.30-1.50	4.00-14.00	0.13-0.17	0.0-2.9	0.5-1.0	.37	.37			
	22-60	---	---	10-20	1.25-1.45	1.40-4.00	0.14-0.18	0.0-2.9	0.0-0.5	.20	.20			

Physical Soil Properties

Clallam County Area, Washington

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
10:														
Catla	0-3	---	---	5-15	0.90-1.10	4.00-14.00	0.08-0.10	0.0-2.9	2.0-5.0	.20	.28	2	4	86
	3-12	---	---	5-15	1.20-1.40	4.00-14.00	0.08-0.10	0.0-2.9	0.5-2.0	.20	.32			
	12-14	---	---	5-15	1.30-1.45	4.00-14.00	0.06-0.08	0.0-2.9	0.0-0.5	.10	.32			
	14-60	---	---	5-15	1.70-2.00	0.01-0.42	0.00	0.0-2.9	0.0-0.5	.10	.32			
12:														
Clallam	0-10	---	---	5-15	0.90-1.10	4.00-14.00	0.08-0.11	0.0-2.9	3.0-5.0	.10	.24	3	4	86
	10-28	---	---	5-15	0.85-1.10	4.00-14.00	0.06-0.10	0.0-2.9	0.5-3.0	.10	.28			
	28-60	---	---	5-15	1.75-2.00	0.01-0.42	0.00	0.0-2.9	0.5-1.0	.10	.28			
13:														
Clallam	0-10	---	---	5-15	0.90-1.10	4.00-14.00	0.08-0.11	0.0-2.9	3.0-5.0	.10	.24	3	4	86
	10-28	---	---	5-15	0.85-1.10	4.00-14.00	0.06-0.10	0.0-2.9	0.5-3.0	.10	.28			
	28-60	---	---	5-15	1.75-2.00	0.01-0.42	0.00	0.0-2.9	0.5-1.0	.10	.28			
16:														
Dick	0-3	---	---	0-3	1.25-1.45	42.00-141.00	0.06-0.08	0.0-2.9	0.0-1.0	.24	.24	5	2	134
	3-22	---	---	0-3	1.40-1.60	42.00-141.00	0.04-0.08	0.0-2.9	0.0-0.5	.20	.20			
	22-48	---	---	2-8	1.40-1.60	42.00-141.00	0.04-0.08	0.0-2.9	0.0-0.5	.17	.20			
	48-60	---	---	2-8	1.40-1.60	42.00-141.00	0.03-0.07	0.0-2.9	0.0-0.1	.15	.24			
17:														
Dungeness	0-8	---	---	10-20	0.85-1.10	4.00-14.00	0.18-0.20	0.0-2.9	2.0-5.0	.43	.43	5	5	56
	8-42	---	---	5-15	1.20-1.45	4.00-14.00	0.15-0.17	0.0-2.9	1.0-2.0	.37	.37			
	42-60	---	---	0-10	1.30-1.60	4.00-14.00	0.06-0.10	0.0-2.9	0.5-1.0	.24	.28			

Physical Soil Properties

Clallam County Area, Washington

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
23:														
Hoypus	0-3	---	---	5-10	1.20-1.40	42.00-141.00	0.07-0.10	0.0-2.9	1.0-4.0	.15	.24	5	4	86
	3-10	---	---	5-10	1.35-1.55	42.00-141.00	0.05-0.08	0.0-2.9	0.5-1.0	.05	.17			
	10-31	---	---	0-3	1.35-1.55	42.00-141.00	0.01-0.03	0.0-2.9	0.5-1.0	.05	.17			
	31-45	---	---	0-3	1.40-1.55	42.00-141.00	0.01-0.03	0.0-2.9	0.0-0.5	.05	.17			
	45-60	---	---	0-3	1.45-1.60	42.00-141.00	0.05-0.08	0.0-2.9	0.0-0.1	.05	.15			
25:														
Hoypus	0-4	---	---	2-5	1.25-1.45	42.00-141.00	0.03-0.05	0.0-2.9	1.0-3.0	.15	.17	5	2	134
	4-15	---	---	5-10	1.35-1.55	42.00-141.00	0.05-0.08	0.0-2.9	0.5-1.0	.05	.17			
	15-60	---	---	0-3	1.40-1.55	42.00-141.00	0.01-0.03	0.0-2.9	0.0-0.5	.05	.17			
34:														
Louella	0-11	---	---	5-15	0.85-1.10	4.00-14.00	0.11-0.13	0.0-2.9	3.0-5.0	.24	.28	5	6	48
	11-47	---	---	20-30	1.20-1.40	4.00-14.00	0.11-0.14	0.0-2.9	1.0-3.0	.20	.28			
	47-60	---	---	5-15	1.25-1.45	4.00-14.00	0.08-0.12	0.0-2.9	0.5-1.0	.17	.32			
42:														
McKenna	0-8	---	---	10-25	1.15-1.35	4.00-14.00	0.16-0.19	0.0-2.9	3.0-15	.24	.32	3	7	38
	8-18	---	---	20-35	1.25-1.45	0.42-1.40	0.12-0.16	3.0-5.9	1.0-3.0	.20	.32			
	18-24	---	---	20-35	1.25-1.45	0.42-1.40	0.12-0.15	3.0-5.9	1.0-3.0	.15	.32			
	24-32	---	---	10-20	1.25-1.45	0.42-1.40	0.04-0.07	0.0-2.9	1.0-2.0	.10	.37			
	32-60	---	---	10-20	1.75-2.00	0.01-0.42	0.00	0.0-2.9	0.5-1.0	.10	.37			
43:														
Mukilteo	0-10	---	---	10-35	0.25-0.60	4.00-14.00	0.30-0.60	---	20-40	.02	.02	3	2	134
	10-60	---	---	10-35	0.25-0.60	4.00-14.00	0.30-0.60	---	20-30	.02	.02			

Physical Soil Properties

Clallam County Area, Washington

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensi-bility	Organic matter	Erosion factors			Wind erodi-bility group	Wind erodi-bility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
63:														
Sequim	0-10	---	---	5-15	0.85-1.10	42.00-141.00	0.05-0.07	0.0-2.9	2.0-5.0	.10	.24	5	5	56
	10-23	---	---	0-5	0.85-1.10	42.00-141.00	0.02-0.04	0.0-2.9	1.0-2.0	.10	.17			
	23-60	---	---	0-5	0.85-1.10	42.00-141.00	0.01-0.02	0.0-2.9	0.5-1.0	.05	.17			
64:														
McKenna	0-8	---	---	10-25	1.15-1.35	4.00-14.00	0.16-0.19	0.0-2.9	3.0-15	.24	.32	3	7	38
	8-18	---	---	20-35	1.25-1.45	0.42-1.40	0.12-0.16	3.0-5.9	1.0-3.0	.20	.32			
	18-24	---	---	20-35	1.25-1.45	0.42-1.40	0.12-0.15	3.0-5.9	1.0-3.0	.15	.32			
	24-32	---	---	10-20	1.25-1.45	0.42-1.40	0.04-0.07	0.0-2.9	1.0-2.0	.10	.37			
	32-60	---	---	10-20	1.75-2.00	0.01-0.42	0.00	0.0-2.9	0.5-1.0	.10	.37			
Sequim	0-10	---	---	5-15	0.85-1.10	42.00-141.00	0.05-0.07	0.0-2.9	2.0-5.0	.10	.24	5	5	56
	10-23	---	---	0-5	0.85-1.10	42.00-141.00	0.02-0.04	0.0-2.9	1.0-2.0	.10	.17			
	23-60	---	---	0-5	0.85-1.10	42.00-141.00	0.01-0.02	0.0-2.9	0.5-1.0	.05	.17			
Mukilteo	0-10	---	---	10-35	0.25-0.60	4.00-14.00	0.30-0.60	---	20-40	.02	.02	3	2	134
	10-60	---	---	10-35	0.25-0.60	4.00-14.00	0.30-0.60	---	20-30	.02	.02			
75:														
Yeary	0-7	25-50	30-50	15-25	0.80-1.00	4.00-14.00	0.11-0.13	0.0-2.9	3.0-5.0	.24	.28	3	6	48
	7-38	20-50	25-50	18-30	0.80-1.00	1.40-4.00	0.10-0.14	0.0-2.9	0.5-3.0	.20	.28			
	38-60	---	---	18-35	1.50-2.00	0.42-1.40	0.00	0.0-2.9	0.3-0.8	.20	.28			
76:														
Yeary	0-7	25-50	30-50	15-25	0.80-1.00	4.00-14.00	0.11-0.13	0.0-2.9	3.0-5.0	.24	.28	3	6	48
	7-38	20-50	25-50	18-30	0.80-1.00	1.40-4.00	0.10-0.14	0.0-2.9	0.5-3.0	.20	.28			
	38-60	---	---	18-35	1.50-2.00	0.42-1.40	0.00	0.0-2.9	0.3-0.8	.20	.28			

Engineering Properties

Clallam County Area, Washington

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				Pct	Pct					Pct	
1:												
Agnew	0-8	Silt loam	CL, CL-ML	A-4, A-6	0	0	95-100	90-100	85-95	65-90	20-30	5-15
	8-46	Clay loam, Silty clay loam, Silt loam	CL	A-6	0	0	95-100	90-100	85-95	65-85	25-35	10-20
	46-60	Stratified sandy loam to silty clay loam	CL, CL-ML	A-4, A-6	0	0	95-100	95-100	60-90	50-85	20-30	5-15
4:												
Bellingham	0-9	Silty clay loam	MH, ML	A-7	0	0	100	95-100	90-100	60-80	40-55	15-25
	9-60	Clay, Silty clay, Silty clay loam	CH, CL	A-7	0	0	100	95-100	95-100	85-100	45-65	20-40
6:												
Carlsborg	0-9	Gravelly sandy loam	SM	A-1, A-2, A-4	0	0-10	65-80	55-75	35-50	15-40	0-14	NP
	9-20	Very cobbly loamy sand, Very gravelly loamy sand, Very gravelly sand	SM, SP-SM	A-1	0	15-35	55-65	35-55	20-40	5-20	0-14	NP
	20-60	Extremely cobbly loamy sand, Extremely gravelly loamy sand, Extremely gravelly sand	GP, GP-GM	A-1	0	35-50	20-55	10-35	5-30	0-10	0-14	NP

Engineering Properties

Clallam County Area, Washington

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				Pct	Pct					Pct	
7:												
Carlsborg	0-9	Gravelly sandy loam	SM	A-1, A-2, A-4	0	0-10	65-80	55-75	35-50	15-40	0-14	NP
	9-20	Very cobbly loamy sand, Very gravelly loamy sand, Very gravelly sand	SM, SP-SM	A-1	0	15-35	55-65	35-55	20-40	5-20	0-14	NP
	20-60	Extremely cobbly loamy sand, Extremely gravelly loamy sand, Extremely gravelly sand	GP, GP-GM	A-1	0	35-50	20-55	10-35	5-30	0-10	0-14	NP
Dungeness	0-8	Silt loam	ML	A-4	0	0	100	95-100	85-100	80-100	15-20	NP-5
	8-42	Stratified fine sandy loam to silty clay loam	ML	A-4	0	0	100	95-100	70-100	50-95	15-20	NP-5
	42-60	Stratified coarse sand to silt loam	ML, SM	A-2, A-4	0	0	85-100	75-100	40-85	30-60	0-14	NP
9:												
Cassolary	0-8	Fine sandy loam	SM	A-2, A-4	0	0	95-100	90-100	50-70	25-40	15-20	NP-5
	8-22	Fine sandy loam, Sandy loam, Very fine sandy loam	CL-ML, ML	A-4	0	0	95-100	90-100	60-90	50-70	15-30	NP-10
	22-60	Stratified fine sandy loam to silty clay loam	CL, CL-ML, SC, SC-SM	A-4, A-6	0	0	95-100	85-100	75-90	35-80	15-40	5-20

Engineering Properties

Clallam County Area, Washington

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				Pct	Pct					Pct	
10:												
Catla	0-3	Gravelly sandy loam	SM	A-2	0	0-5	85-95	55-75	40-55	25-35	20-30	NP-5
	3-12	Gravelly fine sandy loam, Gravelly loam, Gravelly sandy loam	SM	A-2, A-4	0	0-5	85-95	55-75	30-60	25-45	20-30	NP-5
	12-14	Gravelly sandy loam, Very gravelly loam	GM	A-1, A-2	0	0-15	40-85	30-75	25-40	20-35	20-30	NP-5
	14-60	Gravelly sandy loam, Very gravelly loam	GM	A-1, A-2	0	0-15	40-85	30-75	25-40	20-35	20-30	NP-5
12:												
Clallam	0-10	Gravelly sandy loam	SM	A-1, A-2	0	0-10	70-90	60-75	40-60	15-35	15-25	NP-5
	10-28	Very gravelly loam, Very gravelly sandy loam	GM, GP-GM	A-1	0	0-15	35-55	25-45	15-35	5-25	20-30	NP-5
	28-60	Very gravelly loam, Very gravelly sandy loam	GM, GP-GM	A-1	0	0-15	35-55	25-45	15-35	5-25	20-30	NP-5
13:												
Clallam	0-10	Gravelly sandy loam	SM	A-1, A-2	0	0-10	70-90	60-75	40-60	15-35	15-25	NP-5
	10-28	Very gravelly loam, Very gravelly sandy loam	GM, GP-GM	A-1	0	0-15	35-55	25-45	15-35	5-25	20-30	NP-5
	28-60	Very gravelly loam, Very gravelly sandy loam	GM, GP-GM	A-1	0	0-15	35-55	25-45	15-35	5-25	20-30	NP-5

Engineering Properties

Clallam County Area, Washington

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				Pct	Pct					Pct	
16:												
Dick	0-3	Loamy sand	SM	A-1, A-2	0	0	95-100	85-100	45-60	10-35	0-14	NP
	3-22	Fine sand, Loamy sand, Sand	SM, SP-SM	A-1, A-2, A-3	0	0	95-100	85-100	40-60	5-35	0-14	NP
	22-48	Stratified sand to loamy sand	SM, SP-SM	A-1, A-2, A-3	0	0	95-100	85-100	40-55	5-30	0-14	NP
	48-60	Stratified gravelly sand to gravelly loamy sand	SM, SP-SM	A-1	0	0	70-85	60-75	35-45	5-25	0-14	NP
17:												
Dungeness	0-8	Silt loam	ML	A-4	0	0	100	95-100	85-100	80-100	15-20	NP-5
	8-42	Stratified fine sandy loam to silty clay loam	ML	A-4	0	0	100	95-100	70-100	50-95	15-20	NP-5
	42-60	Stratified coarse sand to silt loam	ML, SM	A-2, A-4	0	0	85-100	75-100	40-85	30-60	0-14	NP

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				Pct	Pct					Pct	
23:												
Hoypus	0-3	Gravelly sandy loam	SM	A-1, A-2	0	0	60-80	50-75	30-50	15-30	0-14	NP
	3-10	Gravelly loamy sand, Gravelly sandy loam, Very gravelly loamy sand	GM, SM	A-1	0	0-15	55-65	40-55	25-40	15-25	0-14	NP
	10-31	Very gravelly fine sand, Very gravelly loamy sand, Very gravelly sand	GM, GP-GM	A-1	0	0-5	35-55	25-45	15-40	5-15	0-14	NP
	31-45	Very gravelly loamy sand, Very gravelly sand, Extremely gravelly sand	GP, GP-GM, SP, SP-SM	A-1	0	0-10	40-60	25-50	15-30	0-15	0-14	NP
	45-60	Gravelly sand, Very gravelly sand	GM, GP-GM, SM, SP-SM, SW-SM	A-1	0	0-15	50-80	40-70	20-40	5-15	0-14	NP
25:												
Hoypus	0-4	Gravelly loamy sand	SM	A-1	0	0	60-80	50-75	25-50	10-20	0-14	NP
	4-15	Gravelly loamy sand, Gravelly sandy loam, Very gravelly loamy sand	GM, SM	A-1	0	0-15	55-65	40-55	25-40	15-25	0-14	NP
	15-60	Very gravelly loamy sand, Very gravelly sand, Extremely gravelly sand	GP, GP-GM, SP, SP-SM	A-1	0	0-10	40-60	25-50	15-30	0-15	0-14	NP

Engineering Properties

Clallam County Area, Washington

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				Pct	Pct					Pct	
34:												
Louella	0-11	Gravelly loam	CL-ML, SC-SM	A-4	0	0	75-85	65-75	50-70	40-55	20-30	5-10
	11-47	Gravelly clay loam, Gravelly loam	SM	A-2, A-4	0	0	65-85	55-75	40-60	30-50	20-35	NP-10
	47-60	Gravelly coarse sandy loam, Gravelly loam, Gravelly sandy loam	SC-SM, SM	A-1, A-2, A-4	0	0	65-85	55-75	30-60	20-50	15-25	NP-10
42:												
McKenna	0-8	Gravelly silt loam	GM, ML	A-4	0	0-5	60-80	55-75	55-65	40-60	20-40	NP-10
	8-18	Gravelly clay loam, Gravelly loam, Gravelly silt loam	CL, CL-ML, GC, GC-GM, SC	A-4, A-6	0	0-5	65-90	55-75	45-65	40-60	25-40	5-15
	18-24	Very gravelly clay loam, Very gravelly loam, Very gravelly silt loam	GC, GC-GM	A-2, A-4, A-6, A-7	0	0-5	30-60	25-50	20-50	20-45	25-45	5-20
	24-32	Very gravelly sandy loam	GC-GM, GM	A-1, A-2	0	0-5	30-50	25-40	20-30	10-25	20-30	NP-10
	32-60	Very gravelly sandy loam	GC-GM, GM	A-1, A-2	0	0-5	30-50	25-40	20-30	10-25	20-30	NP-10
43:												
Mukilteo	0-10	Muck	OH, PT	A-8	0	0	100	100	85-100	80-100	---	---
	10-60	Mucky peat	PT	A-8	0	0	100	100	85-100	80-100	---	---

Engineering Properties

Clallam County Area, Washington

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				Pct	Pct					Pct	
63:												
Sequim	0-10	Very gravelly sandy loam	GM, SM	A-1	0	10-15	50-65	40-55	25-40	10-25	0-14	NP
	10-23	Very cobbly loamy sand, Extremely cobbly loamy sand, Very gravelly loamy sand	GM, GP-GM, SM, SP-SM	A-1	0	15-45	45-65	25-55	20-40	5-20	0-14	NP
	23-60	Extremely cobbly sand, Very gravelly loamy sand, Very gravelly sand	GP, GP-GM, SP, SP-SM	A-1	0	20-45	45-60	20-50	15-35	0-10	0-14	NP
64:												
McKenna	0-8	Gravelly silt loam	GM, ML	A-4	0	0-5	60-80	55-75	55-65	40-60	20-40	NP-10
	8-18	Gravelly clay loam, Gravelly loam, Gravelly silt loam	CL, CL-ML, GC, GC-GM, SC	A-4, A-6	0	0-5	65-90	55-75	45-65	40-60	25-40	5-15
	18-24	Very gravelly clay loam, Very gravelly loam, Very gravelly silt loam	GC, GC-GM	A-2, A-4, A-6, A-7	0	0-5	30-60	25-50	20-50	20-45	25-45	5-20
	24-32	Very gravelly sandy loam	GC-GM, GM	A-1, A-2	0	0-5	30-50	25-40	20-30	10-25	20-30	NP-10
	32-60	Very gravelly sandy loam	GC-GM, GM	A-1, A-2	0	0-5	30-50	25-40	20-30	10-25	20-30	NP-10

Engineering Properties

Clallam County Area, Washington

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				Pct	Pct					Pct	
64:												
Sequim	0-10	Very gravelly sandy loam	GM, SM	A-1	0	10-15	50-65	40-55	25-40	10-25	0-14	NP
	10-23	Very cobbly loamy sand, Extremely cobbly loamy sand, Very gravelly loamy sand	GM, GP-GM, SM, SP-SM	A-1	0	15-45	45-65	25-55	20-40	5-20	0-14	NP
	23-60	Extremely cobbly sand, Very gravelly loamy sand, Very gravelly sand	GP, GP-GM, SP, SP-SM	A-1	0	20-45	45-60	20-50	15-35	0-10	0-14	NP
Mukilteo	0-10	Muck	OH, PT	A-8	0	0	100	100	85-100	80-100	---	---
	10-60	Mucky peat	PT	A-8	0	0	100	100	85-100	80-100	---	---
75:												
Yeary	0-7	Loam	CL, SC	A-6	0	0	90-95	60-75	50-70	40-60	25-35	10-15
	7-38	Clay loam, Gravelly clay loam, Gravelly loam	CL, GC, SC	A-6	0	0-10	65-85	60-85	55-65	40-60	25-40	10-20
	38-60	Clay loam, Gravelly clay loam, Gravelly loam, Loam	CL, GC, SC	A-6	0	0	65-85	60-85	55-65	40-60	25-40	10-20

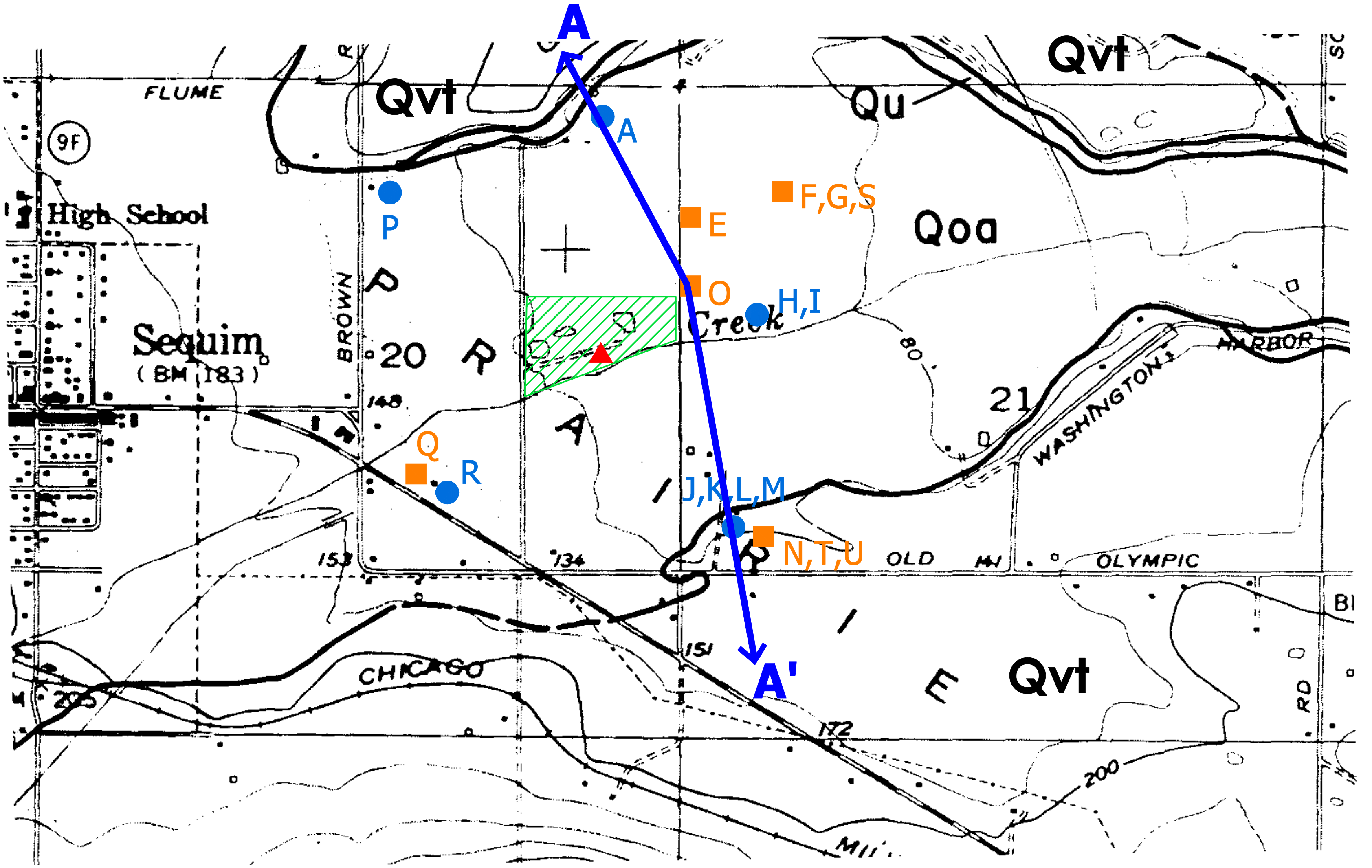
Engineering Properties

Clallam County Area, Washington

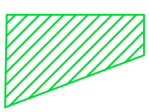
Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				Pct	Pct					Pct	
76:												
Yeary	0-7	Loam	CL, SC	A-6	0	0	90-95	60-75	50-70	40-60	25-35	10-15
	7-38	Clay loam, Gravelly clay loam, Gravelly loam	CL, GC, SC	A-6	0	0-10	65-85	60-85	55-65	40-60	25-40	10-20
	38-60	Clay loam, Gravelly clay loam, Gravelly loam, Loam	CL, GC, SC	A-6	0	0	65-85	60-85	55-65	40-60	25-40	10-20

Appendix B

Demonstration Site Hydrogeologic Characterization



Legend



Demonstra-tion Site

A — A' X-Section Trace

● C Shallow Domestic Well (<70 feet)

■ N Deep Domestic Well (91-290 feet)

▲ On-Site Monitoring Well

Surficial Geology

Qoa - Older Alluvium

Qvt - Vashon Till

Qu - Undifferentiated

Surficial geology from Othberg & Palmer, 1979

0 600 1200

Scale in Feet

Contour Interval 40 Feet

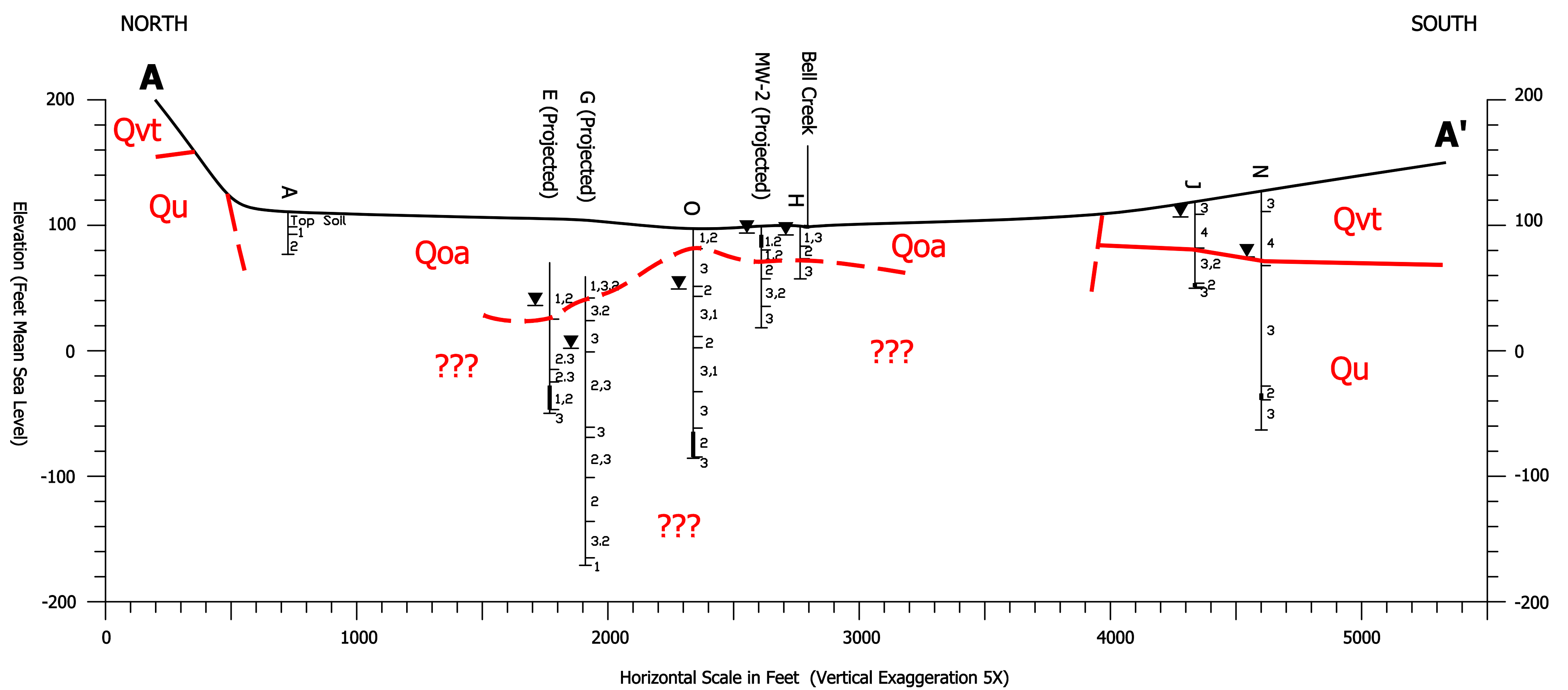
Figure 1

Surficial Geology and Neighboring Well Locations

CITY OF SEQUIM DEMONSTRATION SITE

JZ9708, DEMO-SITE3.DWG, 9/00

Pacific Groundwater Group



Legend

NOTES:

See Figure 1 for map view of cross-section trace.

Marked wells are projected onto trace from distances large as 1000 feet.

Land surface topography is approximate.

Surficial geologic contacts from Othberg & Palmer (1979).

WELL LOG

F — Well ID

Soil Description

Water Level

Screen

SOIL DESCRIPTIONS

1 = GRAVEL
2 = SAND
3 = SILT/CLAY
4 = TILL
"," = and
"." = modifier

For Example:
1,2 = Sand and Gravel
2.3 = Silty Sand
1,2.3 = Silty Sand and Gravel

GEOLOGIC DESCRIPTIONS

Qvt - Vashon Till
Qoa - Older Alluvium
Qu - Undifferentiated Quaternary Deposits
??? - Finer Grained Sediments (Possibly Upper Confining Bed)

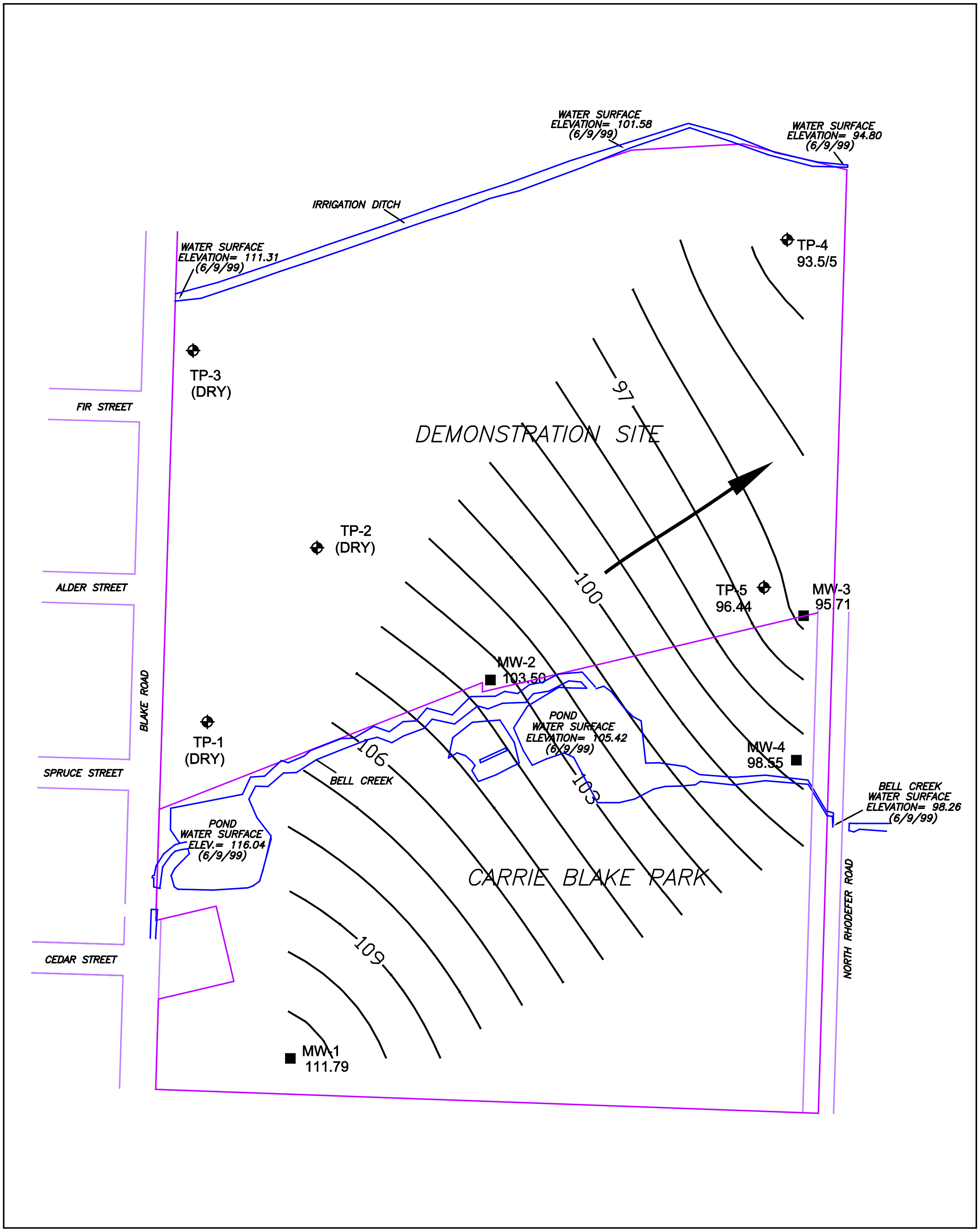
Geologic contacts are dashed where inferred.

Figure 2
Hydrogeologic Cross-Section Across Bell Creek Valley

CITY OF SEQUIM
DEMONSTRATION SITE

Pacific Groundwater Group

JZ9708, DEMP-XSECT3.DWG, 9/00



Legend

TP-2 106.90 — Temporary Piezometer/ Water Level Elevation

MW-1 99.61 — Monitoring Well/ Water Level Elevation

106 — Water Table Elevation Contour (feet msl)

— Groundwater flow Direction

N

0 75 150
Scale in Feet

Note: Water table elevations from 8/3/00 and 8/4/00.

Figure 5
Groundwater Flow Directions in August, 2000

CITY OF SEQUIM
DEMONSTRATION SITE

Pacific Groundwater Group

JZ9708, WATLEV00.DWG, 7/99