

2.1 NATURAL ENVIRONMENT

Olympic Peninsula landscapes, and the region's flora and fauna, have been shaped by the geology and climatic history of the region. The landscapes have been reworked by the persistent, long-term action of gradual environmental changes such as glaciation and mountain-building. They have responded to erratic, catastrophic events, such as major floods, fires, and the breaching of glacial lakes. And they evidence the pervasive effects of human influences. The wildlife and plantlife of the peninsula reflect this long, complex, and significantly altered character.

This section discusses the many factors that define the current condition of the natural environment of WRIA 18. This is a diverse area with important differences across its full extent. Consequently, the discussion below contains some information that is generally applicable to the entire planning area. In addition, much work has been done in specific areas within WRIA 18 that makes it possible to present more detailed information relating to portions of the WRIA, especially in distinguishing between East WRIA 18 and West WRIA 18. Where possible and appropriate, information here is presented separately for these eastern and western portions.

2.1.1 Geography

West WRIA 18 – Elwha Morse Planning Area

West WRIA 18 (WRIA 18W) includes, on the west, the Elwha River and its tributaries, Morse Creek on the east, and the smaller, urban drainages between, including Dry, Tumwater, Valley, Peabody, White, Ennis, and Lees creeks. The headwaters of the Elwha River and Morse Creek lie in the Olympic Mountains. The smaller streams originate in foothills to the north of the main Olympic range and along the northern boundary of Olympic National Park. All these streams drain into the Strait of Juan de Fuca.

WRIA 18 lies primarily in east-central Clallam County, on the Olympic Peninsula, from approximately 36 to 55 miles east of the Pacific Ocean, with a very small percentage in Jefferson County. West WRIA 18 is bounded by the Strait of Juan de Fuca to the north; the Coville Creek and Lake Crescent/Lyre River watersheds (eastern end of WRIA 19), Soleduck, Bogachiel, and Hoh rivers (eastern end of WRIA 20), and Queets and Quinault rivers (eastern end of WRIA 21) to the west; the Quinault (WRIA 21) and Dosewallips (WRIA 16) rivers to the south; and the Bagley/Siebert/McDonald Creek and Dungeness River watersheds (western end of WRIA 18E) to the east (Figure 1.1-1). The area of the West WRIA 18 watershed is approximately 468 square miles. Roughly 80% of WRIA 18W is within the boundaries of Olympic National Park. This portion includes about 80% of the Elwha River watershed, about 30% of the Ennis Creek watershed and about 60% of the Morse Creek watershed.

Altitudes in West WRIA 18 range from sea level to about 300 feet in the central plain and to 1500 feet in the hills. Mountain peaks defining the watershed south boundary range over 7700 feet. Coastal lowlands and shoreline features of importance include:

- The bluffs on the west bank of the mouth and lower reach of the Elwha River, which slough substantial material into the river and on into the Strait;

- The beach/shoreline of the Elwha River delta on the reservation of the Lower Elwha Klallam Tribe (in part for historic and potential shellfish habitat);
- The extensive high coastal bluffs extending east of the Elwha River delta as far as the base of Ediz Hook, which, along the base of their eastern half, are armored by the City's industrial waterline and associated protective riprap;
- The prominent spit that forms Port Angeles Harbor, Ediz Hook, which historically was formed by Elwha River sediments carried by longshore currents, and which now is periodically reinforced with extensive riprap by the ACOE;
- Port Angeles Harbor (in part for historic and potential shellfish habitat), which currently supports some commercial aquaculture;
- The outlets of the several urbanized watersheds, including Tumwater, Valley, Peabody, White, and Ennis Creeks, all of which have been significantly altered and which are now confined to culverted or tightly channelized mouths, and some of which historically (especially Ennis Creek) were important occupation sites of the Lower Elwha Klallam Tribe (in part for historic and potential shellfish habitat);
- The mouth of Morse Creek, historically a significant shellfishing site.

East WRIA 18 -- Dungeness Planning Area

The eastern portion of the Elwha/Dungeness Water Resource Inventory Area (WRIA 18) lies in eastern Clallam and Jefferson Counties, on the Olympic Peninsula, approximately 55-80 miles east of the Pacific Ocean. East WRIA 18 is bounded by the Strait of Juan de Fuca to the north, the Morse Creek watershed (West WRIA 18) to the west, the Dosewallips River watershed to the south (part of WRIA 16), and the Big and Little Quilcene River watersheds and the Miller Peninsula (part of WRIA 17) to the east (Figure 1.1-2).

Altitudes in East WRIA 18 range from sea level to about 300 feet in the central plain and to 2600 feet in the hills (Burnt Hill). Mountain peaks defining the watershed's south boundary range over 7700 feet. Coastal lowlands and shoreline features of importance include (DQ Plan 1994):

- The bluffs west of Dungeness Spit, and the elevated coastal plain to the west of the Dungeness drained by Siebert and McDonald creeks, which have cut deep canyons into the land surface, exposing bedrock in a few areas;
- Dungeness Bay, a major tidewater feature on the Strait of Juan de Fuca, into which the river empties;
- The Dungeness Spit, formed and maintained by longshore currents, together with Graveyard Spit, is designated as a National Wildlife Refuge by the USFWS;
- A coastal area largely at sea level extending east from the Dungeness estuary and including Jamestown, the property purchased as homeland by the JSKT in the 1870s;
- Meadowbrook, Cooper, Cassalery, and Gierin creeks, all fed from groundwater springs and irrigation ditch tailwaters, discharging to the Strait between Dungeness Bay and Sequim Bay;

- Graysmarsh, now a diked freshwater marsh, but originally a salt marsh (until a control gate was built at the mouth of Gierin Creek), marking the end of the low eastern coastal plain;
- Coastal bluffs reemerging again to the east, broken by a narrow defile leading to the beach at Port Williams, once an important shipping point for Sequim;
- Receding bluffs as Gibson Spit forms to the south, enclosing the lagoon at Washington Harbor, the mouth of Bell Creek (which drains the uplands of Happy Valley and the north flank of Burnt Hill, flowing through eastern Sequim);
- Sequim Bay, an important shellfish habitat almost totally enclosed by Travis Spit, characterized by broad tidal flats to the south, deepening to 60 feet in the middle and containing several deeper trenches along the northwest side reaching 120 feet in depth (it harbors a large marina and is bordered by Sequim Bay State Park to the west and private residences on both sides);
- Johnson Creek, entering Sequim Bay at the John Wayne Marina, and Dean Creek entering at the south end of the Bay;
- Jimmycomelately (JCL) Creek entering at the south end of the Bay; and
- The Miller Peninsula bluffs ranging from 120 to 320 feet in height across a 4-mile peninsula to Diamond Point, at the entry to Discovery Bay.

WRIA 17 Planning Area

Among the features listed above are several that lie within WRIA 17, including Dean, Johnson, and JCL creeks. This portion of WRIA 17 has been included in the WRIA 18 watershed plan by formal agreement between the initiating governments of WRIAs 17 and 18. These features are addressed in this plan because they are functionally integrated with the East WRIA 18 irrigation system (Johnson Creek) or are subject to active restoration planning by WRIA 18 governments (e.g., Sequim Bay, Jimmycomelately and Dean Creeks).

2.1.2 Climate

Overviews of regional climate are provided in the DQ Plan (1994), the *Final Environmental Impact Statement (FEIS) for the Clallam County Comprehensive Plan* (CCDCCD 1995a), and Thomas et al (1999), while the *Soil Survey of Clallam County Area, Washington* (United States Department of Agriculture (USDA) Soil Conservation Service (SCS) 1987; hereafter referenced as SCS 1987) provides a more localized perspective. A particularly detailed review of the interaction between climatic factors such as precipitation, snowpack, temperature, El Niño, and others, and the dynamics of the Dungeness River (and to a lesser extent, other Olympic Peninsula streams) is found in *Keys to Understanding the Natural History of the Dungeness River Watershed* (Clark and Clark 1996) (see Box 1, page 2.1-10). Clallam County has a temperate maritime climate characterized by cool, dry summers and mild, wet winters. Average summer temperatures generally range in the 60s and 70s, while winter temperatures remain in the lower 40s to 50s. Snow and freezing temperatures are uncommon along coastal areas, but persist throughout most of the year in the higher altitudes (CCDCCD 1995a).

Clallam County precipitation rates vary greatly depending on elevation and the orographic influence of the Olympic Mountains (CCDCD 1995a). WRIA 18 overall experiences a large range in precipitation due in part to the rainshadow effect of the Olympic Mountains. Moist, marine air being carried in the predominantly northeastern airflow, is lifted orographically by the Olympics, thereby causing extreme precipitation--particularly at higher elevations along the southwestern flank and along the crest of the Olympics. Throughout the North Olympic Peninsula, about 75 percent of the annual precipitation falls between October and March. In WRIA 18 (both West and East), most precipitation falls as rain below 1500 feet, as rain and snow between 1500 and 3000 feet, and as snow above 3000 feet (CCDCD 1995a).

Long-term climatic change is being studied with increasing emphasis. Factoring in this increasingly available information will significantly enhance future watershed planning for WRIA 18 and throughout the North Olympic Peninsula.

West WRIA 18 – Elwha Morse Planning Area

Coastal precipitation within WRIA 18W ranges from about 40 to 60 inches in the western part of the area to about 20 inches in the eastern part of the area in the coastal lowland of the Morse Creek drainage. This represents significant variation within the roughly 20-mile distance.

Total average annual precipitation at Port Angeles is given by SCS (1987) as 25.32 inches, of which roughly 20 percent usually falls in April through September. The 20 percent exceedances for precipitation are 21.27 inches (80 percent of years will be higher) and 29.2 inches (80 percent of years will be lower).

Much of the higher elevation precipitation (which accounts for the bulk of the precipitation that falls in WRIA 18W) accumulates as snowpack, subsequently contributing to sustained spring and summer runoff. Storm tracks crossing the Pacific, and reaching land in these latitudes during the winter, bring storms, while relatively dry weather typically begins in July and lasts until mid-fall. Winter season snowfall ranges from less than an inch along the coast, to as much as 30 inches at elevations below 3000 feet. At elevations less than 1500 feet, snowfall generally melts within two weeks, and winters free of snow are not uncommon along the coast. However, at elevations above 5500-6000 feet, winter precipitation may range as high as 500 inches of snow. Higher elevations are snow-covered from November to well past June, with maximum seasonal snowpack above timberline exceeding 10 to 15 feet. For WRIA 18W, seasonal precipitation increases from mid-September to a winter maximum during December and January and then recedes to a summer minimum in August. The WRIA 18W regional precipitation gradient shows increasing precipitation to the southwest and west. This increase coincides with increasing elevation to the southwest, and fading significance of the rain shadow to the west.

The SCS (1987) states that average relative humidity for the region runs 70 percent in midafternoon, increases at night and is 90 percent at dawn. The percentage of possible sunshine is 45 percent in summer and 20 percent in winter.

The SCS overview of climate (based on records from 1951 through 78) reports that the average winter temperature at Port Angeles is 41°F, and the average daily minimum is

35°F. In summer, the Port Angeles average temperature is 59°F, with an average daily maximum of 69°F. The 10% exceedance (one year in ten) last freeze ($\leq 28^\circ\text{F}$) in spring occurs later than April 6; the first freeze ($\leq 28^\circ\text{F}$) in fall occurs earlier than October 21 one year in ten. The growing season at Port Angeles is 182 days in length nine years of ten (at a 32°F daily minimum temperature criteria). The average daily maximum ranges from 45°F in January to 69°F in July, with daily minimums ranging from 33°F in January to 51°F in August.

In *Keys to an Understanding* (Clark & Clark, 1996), the mid- and long-term changes in regional climate are detailed from historic records. In general, precipitation and snowpack are seemingly in decline and at significantly depressed levels, and temperatures evidence corresponding (increasing) trends.

East WRIA 18 – Dungeness Planning Area

The Sequim-Dungeness area has a temperate marine climate with cool, wet winters and warm, dry summers. Winter storm tracks cross the Pacific, reaching land in these latitudes, relieving relatively dry weather that lasts through mid-fall. The SCS (1987) states that average relative humidity for the region runs 70% possible sunshine is 45% in summer and 20% in winter.

Air temperatures in this area are moderate throughout the year. The average monthly maximum ranges from 45°F in January to 72°F in July; monthly minimums range from 32°F in January to 51°F in August (Thomas et al. 1999). The SCS reports (based on records from 1951 through 78) that the average winter temperature at Sequim is 40°F, and the average daily minimum is 34°F. In summer, the Sequim average temperature is 60°F, with an average daily maximum of 69°F. The last freeze in spring occurs later than March 24, on average, only one year in ten; and the first freeze in fall occurs earlier than November 15, on average, one year in ten. In nine years of ten, the growing season at Sequim is at least 172 days long (using a 32°F daily minimum temperature criteria).

The Dungeness River Basin and adjacent watersheds lie in the heart of the rainshadow of the Olympic Mountains to the south and west. Most precipitation in the area arrives in weather systems moving across the peninsula from the Pacific Ocean, and the moisture they contain has been greatly reduced as they move up and over the mountainous terrain. Sequim monthly precipitation data (1932 through 1991) reported in the DQ Plan (1994: Figure 2.56) shows peaks occurring from November through January and lows in July and August. Thomas et al (1999) reports that 38% of average annual precipitation falls in winter (December through February) and 14% in summer (June through August), with 20% in spring (March through May) and 28% in fall (September through November). Further analysis of Thomas et al (1999) reveals that the highest -month period for average annual precipitation (in Sequim area) is the period of November through January, with 43% of the annual total, while the summer period is the lowest.

Total annual precipitation at Sequim is given by SCS (1987) as 16.2 inches. The 20 percent exceedances for precipitation are 14 inches (80% of years will be higher) and 18.3 inches (80% of years will be lower). Average annual rainfall ranges from 15 inches in the north to 35 inches in the hills to the south and southwest. Precipitation isohyets are presented in both the DQ Plan (1994) and Thomas et al (1999). The upper Dungeness

and Gray Wolf verge on the 80-inch annual precipitation isohyetal; average annual precipitation drops to less than 40 inches by the point at which they join at Dungeness Forks. The lowlands average 20 inches per year south of Sequim, and less in the lower Dungeness Valley, Sequim and the Miller Peninsula. The 15-inch isohyetal crosses the lower Dungeness, Meadowbrook, Cassalery, and Gierin Creek drainages. Precipitation for the Thomas et al study area, which presents the best available water budget for East WRIA 18, averaged 21 inches.

Much of the higher elevation precipitation (which accounts for the bulk of the precipitation that does fall in East WRIA 18) accumulates as snowpack, which subsequently contributes to sustained spring and summer runoff. Average seasonal snowfall in Sequim is 6-8 inches (SCS 1987), but the number of days of snow cover varies greatly from year to year.

Long term climate

El Niño/La Niña cycles involving large scale Pacific Ocean and atmospheric oscillations contribute to longer-term weather patterns that fluctuate between wetter and dryer periods. Climatological evidence indicates a warming and drying period lasting from 10,000 years ago until 4,000 to 6,000 years ago (the “climatic optimum”), succeeded by several shorter cooling periods and a marked warm period about 600 years ago (the “medieval optimum”). The “little ice age” then ensued, bringing a colder, wetter climate lasting until the late nineteenth century and enlarging Olympic glaciers and ice fields. These have dwindled in the past century, and global warming may shift the season of precipitation, leading to smaller winter snow packs and potentially critical effects on late-summer and early fall stream flows in Pacific Northwest rivers and streams.

It is difficult to reach conclusions about climate changes since the last glaciation, and what effect those changes may have on the dynamic climate as it has been experienced to date. In 1994, authors of the DQ Plan were careful of over-concluding from recent climatic fluctuations, commenting that “much is unclear about climate changes” since the last glaciation, and stating “we’re dealing with fluctuations in a dynamic system, and not with documented trends or cycles.” Thomas et al (1999) also found no significant increasing or decreasing trend for precipitation in the 1923-1996 period of record. However, recent modeling conducted by the University of Washington suggests that the global warming effects cited are probable (US Global Change Research Program 1999).

2.1.3 Geology

Overviews of the geologic history of Clallam County and the Olympic Peninsula are available in the FEIS for the Comprehensive Plan (CCDCD 1995a) and (Tabor and Cady 1978). The Olympics are composed mainly of basalt and sedimentary rocks formed from sediments deposited from ancient oceans. Glaciers have been the primary sculptors of the mountains, foothills, and coastal lowlands. In Clallam County, geologic hazards include areas subject to flooding, landslides, erosion and seismic hazards, or earthquakes. Geologic evidence suggests that at least six subduction earthquakes (magnitude 8 or greater) have occurred on the Olympic Peninsula.

The Olympic Peninsula is geologically very young, its oldest rocks a dark, oceanic crustal basalt (ca. 50 million years) that are everywhere evident in the region. Forming at an oceanic ridge and transported toward the North American continental plate, this piece of

plate apparently broke off, surfaced and docked against the continental margin. Chapter 4 of the *Keys to an Understanding of the Natural History of the Dungeness River Watershed* (Clark and Clark 1996) summarizes a complex literature suggesting that the Olympic mountains emerged above sea level about 12 million years ago due to an arching of the subducting Juan de Fuca plate. The source of the marine sedimentary rocks comprising the Olympic Subduction Complex (OCS) appears to be erosion from further east in Washington (perhaps in part from the developing Cascades) deposited by westward-flowing rivers and submarine flows onto the Juan de Fuca plate and subsequently rising as an accretionary wedge. Although as much as 12 km of accreted material has been worn away by erosion, the accretionary wedge remains perhaps 30 km thick between the Olympic peaks and the subducting plate. While still submerged, thick sequences of marine sediments were deposited, forming sedimentary strata prominent on the shoreline of the Strait of Juan de Fuca and cropping out throughout the region. The Olympic Mountains consist of this lighter rock of sedimentary origin that was scraped off the subducting oceanic crust. These core rocks of the Olympics are severely twisted, folded, and metamorphosed from the heat and pressure of the subduction and subsequent uplift. Faults that circle the Peninsula along the north, east and south mark their contact with the peripheral rocks.

Geologic composition of the north central Olympic Peninsula is quite varied. The central core of the Olympic Mountains, and the region to the west and southwest of the Olympics, consists of a subduction complex that includes marine sandstone and other sedimentary rocks. These rocks are Eocene (35.4 to 56.5 million years) in age. Surrounding the Olympics is a sequence of marine volcanic and sedimentary rocks of Miocene to Paleocene (~16.3 to 60 million years) in age. These units are separated from the Olympic subduction complex by a series of thrust faults dominated by the Hurricane Ridge thrust fault. This thrust fault series is present in the study area. The Olympic core subduction complex that is to the south and southwest of these faults is being thrust under the surrounding units toward the coast, which lie to the north and northeast of the fault.

The most influential geologic event contributing to drainage development and shaping of the present landscape has been the Fraser glaciation, which reached a maximum and rapid decline immediately following the maximum of widespread continental glaciation that occurred during the Pleistocene. Extensive glaciation of the northern end of the Olympic Peninsula, associated with the Fraser, occurred about 15,000 years ago just as the last advance of Pleistocene continental glaciers was coming to an end. This extensive glaciation covered Vancouver Island and the Pacific ranges in Canada. During the Fraser glacial maximum, movement of the ice southward caused one glacial lobe to move into the Puget Sound Lowland, while another lobe moved westward along the Strait of Juan de Fuca and around the northern end of the Olympic Peninsula. The glacial ice penetrated upland into the Olympic Mountains and covered most of the northwestern end of the Olympic Peninsula. This glaciation declined rapidly after about 13,500 years ago. Glacial till and morainal material from this glaciation is found extensively along the coast as surficial deposits that penetrate upland into most of the glacially dominated valleys of the region. Stream alluvium in many valleys is derived from this glacial material. Within WRIA 18W, glacial material has a thickness of generally less than 300 feet and covers the intervening elevated lands between the valleys of coastal streams. For some developments in the vicinity of Port Angeles, wells have been placed in glacial material that covers the intervening elevated land adjacent to the north-trending stream valleys.

Many wells, however, are completed in Tertiary sandstone beneath the glacial material. These wells generally service residences located in these areas. At somewhat higher elevations, stream baseflow is supported by groundwater discharges to the stream that come from groundwater seepage from this glacial material.

Drainage and erosion from the uplifted mountains have cut deep river channels radially out from the Olympic peaks. The Elwha and the Dungeness/Gray Wolf river systems drain from these central core rocks of the mountains, cutting through the horseshoe of peripheral rocks to empty into marine waters. Overlain on this geology are the repeated reshaping of the region brought about by the advance and recession of glaciers over the past two million years, ending about 10,000 years ago. Three or more continental glaciers are believed to have advanced into Washington from the north during the Pleistocene Epoch (10,000 to 1.6 million years before present) (Thomas et al 1999).

Although alpine glaciers extended down the major river courses, these continental ice sheets moving down from British Columbia did the major work on Olympic Peninsula foothills and lowlands. Burying the area under up to 4,000 feet of ice, massive sheets advanced up the valleys, creating various glacial features. On the Dungeness, the advance extended almost to Royal Creek, trapping a glacial lake at 3,300 feet between the Vashon ice-sheet front and the higher mountain topography with its alpine glaciers. The USFS provides a map (Map 4 in DAWACT 1995) showing deposits of the continental ice sheets, glacier limits, and glaciolacustrine (glacial lake) deposits in the East WRIA 18 area, where much more geologic fieldwork has been conducted.

Repeated episodes of advance and recession, called glaciations, resulted in thick accumulations of glacial and interglacial deposits throughout the region. The youngest of these, known as the Everson drift, was left by the last great ice sheet, the Vashon Stade of the Fraser glaciation, which advanced about 18,000 years before present and began recession with climatic warming about 13,500 years before present.

West WRIA 18

Within WRIA 18W, a series of fault-defined blocks forms a horst and graben sequence that extends in an east-west direction along the north flank of The Foothills. These structures have influenced, to a significant extent, the development of drainage configurations and the particular location of streamcourses. The faults defining these structures trend in a northerly direction away from, and perpendicular to, the east-west trending thrust-fault sequence that is found just to the south. The streamcourse of Ennis Creek is developed along the presumably well-fractured crest of a noticeable, north-trending horst that separates two dominant graben-like structures on either side of it. The highland basin drained by Ennis Creek is composed, in part, of the same igneous bedrock that is exposed along the core of the horst in the vicinity of The Foothills and Mt. Pleasant. The highland drainage of Ennis Creek, as well as some of the upland drainages to the south of Ennis Creek, and virtually all of the drainage of Little River, have been developed on this harder igneous bedrock material. Drainages that are developed in higher elevation, harder bedrock material, are usually very well integrated. In comparison, the drainage of Lees Creek, to the east of Ennis Creek, originates at lower elevations, on softer glacial drift and morainal material within the graben-like structure that is adjacent to the Ennis Creek horst. The sparse drainage within higher elevation areas of the Lees Creek watershed is

developed on resistant marine sediments that are within the area that is down-faulted adjacent to the horst. The development of deep and very well-drained soils on the moderately resistant sandstone within steeper, higher elevation areas of the Lees Creek watershed has precluded it from any well-developed integration. The drainages of White and Peabody creeks, which are in the graben to the west of Ennis Creek, have developed under similar circumstances to those of Lees Creek. South of these drainages, a broad horst holds the headwater drainages of Valley and Tumwater creeks. These headwater drainages are developed on the same igneous bedrock unit that predominates along the crest of The Foothills.

Drainage has also been altered by ice-blocked valleys during the Fraser glacial maximum, and by post-glacial landslides. Of particular note is the wind gap existing in The Foothills at the head of Valley Creek, which penetrates into the drainage of Little River. This feature indicates that the headwaters drainage of Valley Creek was diverted into Little River, possibly because the drainage of Valley Creek was blocked by ice and the headwaters drainage became ponded. Once ponded water spilled into the receiving tributary of Little River, a new streamcourse was established for the previous Valley Creek headwater tributary, thereby carrying this water into the Little River drainage. The Indian Creek drainage appears to have been blocked by a massive landslide that further increased the depth and size of Lake Crescent, and separated the lake from Lake Sutherland. Once blocked, Lake Crescent spilled over an opportunistically low divide that had previously separated the lake from the drainage of Lyre River.

North-flowing streams in the Port Angeles area have generally removed glacial material and have exposed the local bedrock units along, and in the immediate vicinity of, the streamcourse. North of The Foothills, the folded Tertiary sandstone unit that is overlain by glacial material, is the bedrock unit generally exposed along streamcourses. This sandstone unit, which apparently has a low permeability, may be of importance in conducting groundwater to streams. At many locations along the contact of the overlying glacial material and this sandstone unit, groundwater may be observed seeping from the base of the more permeable overlying glacial material, thereby forming a spring or large seep area that provides water to the stream. Some of these seeps may cover a considerable distance along the valley of the streamcourse. Groundwater may also discharge to the stream through the sandstone where the permeability of the sandstone is sufficient. Many wells in the Port Angeles area derive water from this sandstone aquifer.

Near the mouth of Morse Creek, and also that of the Elwha River, the valley bottom of the stream has been filled by alluvium deposited by the stream. Deposition of this alluvium was after the termination of the last major glaciation. This valley-fill alluvium forms an aquifer that is in hydraulic connection with the stream and contains water that comes from the stream. This type of aquifer, particularly along the lower Elwha, is an important resource providing drinking water to the Lower Elwha Klallam Reservation. Wells penetrating this aquifer are pumping water that is generally recharged by the river. In areas where groundwater flow indicates that groundwater seepage from valley springs is recharging this aquifer, groundwater is discharged to the river through this aquifer. These aquifers are of limited extent, and have very limited storage. Water provided by such aquifers is predominantly diverted from the stream that is associated with the aquifer. These aquifers narrow markedly in an up-valley direction, within a short distance of the coast and are of importance in the study area near the coast. These aquifers are also in

hydraulic connection with the sea, thereby requiring careful consideration of well placement and design to prevent drawing salt water into the pumping well.

East WRIA 18 – Dungeness

Overviews of regional geologic history are provided in the Clark's *Keys to An Understanding of the Natural History of the Dungeness River System* (Clark and Clark 1996) (Box 1), the Bureau of Reclamation's *Physical Processes, Human Impacts, and Restoration Issues of the Lower Dungeness River* (Bountry et al 2002), the USGS *Hydrogeologic Assessment of the Sequim-Dungeness Area* (Thomas et al 1999), and the DQ Plan (1994). Thomas et al (1999) focus on the lower hills and lowland valleys of the Sequim-Dungeness area, covering 116 square miles, with a core study area of 74 square miles (Figure 2.1-1). Schasse and Logan's (1998) *Geologic Map of the Sequim 7.5 Minute Quadrangle, Clallam County, Washington* contains more recent and detailed technical information for the quadrangle, including a plate, description and mapping of geologic units, and records of selected water wells used in constructing cross-sections.

The following discussion summarizes the descriptions of geology contained in these sources.

The Sequim-Dungeness area is underlain by as much as 2,000 to 2,500 feet of unconsolidated Quaternary deposits of largely glacial origin (Thomas et al 1999), and they cover most of the East WRIA 18 lowlands (Figures 2.1-2 and 2.1-3). Consisting of multiple layers, these are described as "outwash silts, sands and gravels from advancing and regressing glaciers, unsorted tills deposited under the ice or as moraines, rocks and sediments dropped by drifting icebergs, and silts and clays deposited in glacial lake bottoms" (DQ Plan 1994). The edge of these unconsolidated deposits at the base of the Olympic Mountains formed the southern study boundary of the Thomas et al hydrogeologic assessment.

Box 1: Keys to an Understanding of the Natural History of the Dungeness River System, by Virginia and Welden Clark (1996)

Provides a description of the Dungeness River and its first, second, and third order tributaries. Table 1-1 in the Clarks' *Keys* is organized by river mile and provides elevation, gradient, and geographic features. The *Dungeness River Area Watershed Management Plan* (DWMC and CCDCD 1993) provides detailed watershed characterizations for Bagley, Siebert, McDonald, Cassalery, and Gierin Creeks, as well as the Dungeness River. Orsborn (1987:Table 12-1) contains a detailed summary of basin characteristics for seven subbasins of the Dungeness-Gray Wolf river system. A detailed topographic and geographical description of the watershed is also given in the DQ Plan (1994). Figure 2-4 in Orsborn and Ralph (1994) graphically depicts elevation gradients for the Dungeness mainstem and tributaries.

Figure 2.1-1. Generalized surficial geology... PLEASE OPEN SEPARATE FILE.

This page intentionally left blank.

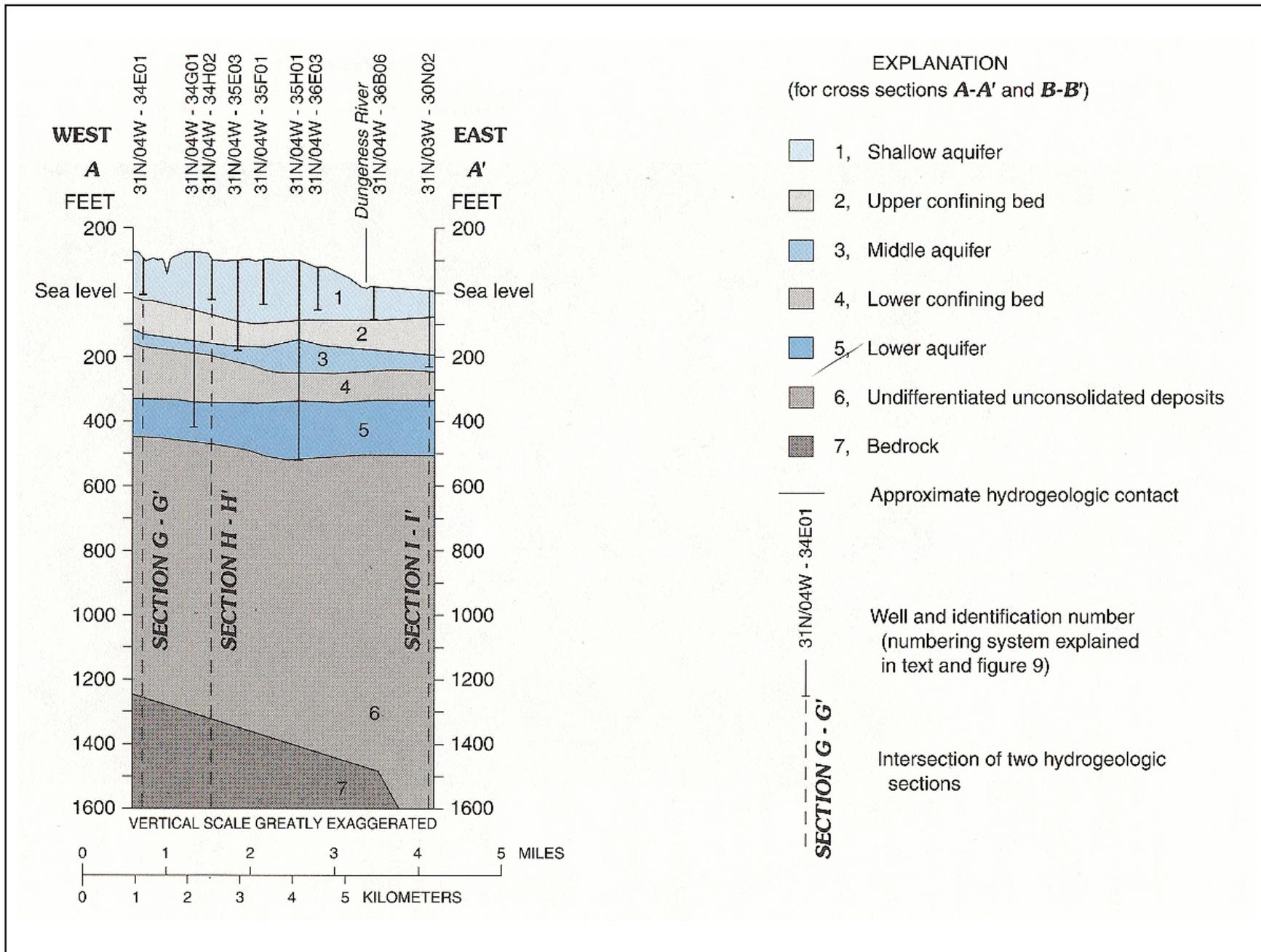


Figure 2.1-2. Hydrogeologic cross section A-A', Sequim-Dungeness area, Washington (Thomas et al. 1999).

This page intentionally left blank.

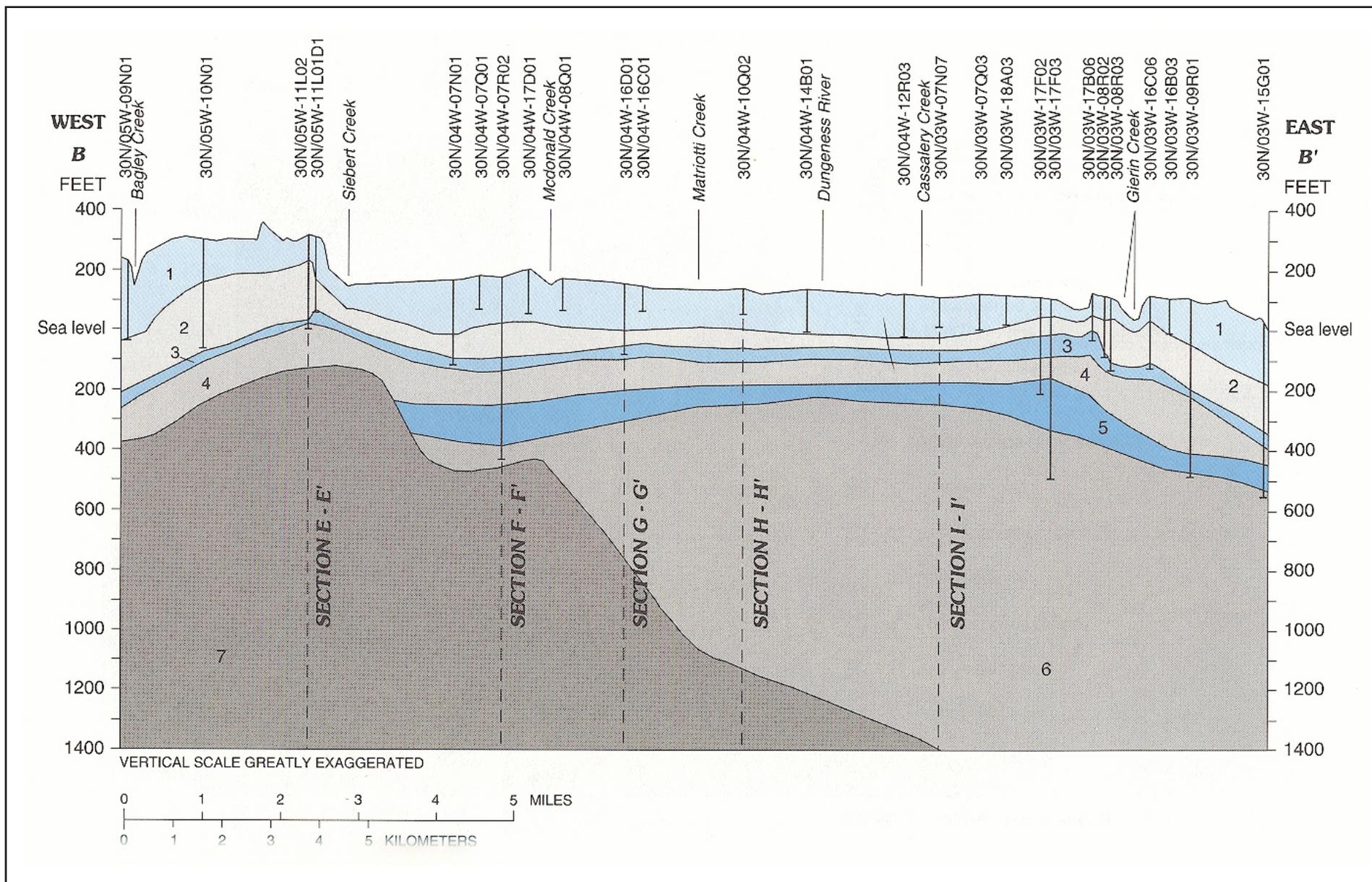


Figure 2.1-3. Hydrogeologic cross section B-B', Sequim-Dungeness area, Washington (Thomas et al. 1999).

This page intentionally left blank.

Nonglacial surficial geologic units in the Sequim-Dungeness area are alluvium of several ages, beach deposits and peat and marsh deposits. Alluvium was deposited along the present floodplain of the Dungeness River and varies in composition from gravels to finer-grained sands, silts and clays. An older alluvium, found mostly east of the Dungeness River, is a floodplain terrace deposit of the ancestral river and exhibits a wide range of lithology. "Much of the sediment carried out of the mountains onto the lowlands and to marine waters is reworked glacial drift that was carried into the lower and mid-elevations of the mountain terrain by the earlier cordilleran glaciations" (DQ Plan 1994).

With relatively rapid termination of the last glacial episode, technically referred to as the Vashon Stade of the Fraser glacial period (c. 13,000 BP), sea levels rose more quickly than the land itself rebounded and coastal lowlands were submerged under marine waters for a time. Coastal bluffs were formed by gradual wind and wave erosion at a rate of about 1 vertical foot per year, "suggesting total retreat of the coastline of the Strait of perhaps two miles in places" (DQ Plan 1994).

The DQ Plan (1994) speculates that a typical cross section of the Sequim-Dungeness peninsula would show considerable variability and probable discontinuities in the aquifers and confining layers. Each of the continental ice sheets would have approached the Dungeness River Basin almost head-on, riding over the preexisting land surface, foothills, and up the river valley into its middle reaches.

The advances and retreats of these ice fronts introduced complexity by creating ephemeral lakes and streams at the foothills ahead, scouring some preexisting materials while riding over others, and depositing layers of lodgment till consisting of saturated silts and clays with poorly sorted sands, gravels, and larger rock. This lodgment till, consolidated under the pressure of ice up to 1 mile thick, has remained as largely impermeable confining layers, or "hardpan" (DQ Plan 1994). Thomas et al (1999) identifies large areas of Vashon till and reworked till, as well as Everson sand and Everson glaciomarine drift and Vashon outwash in the more northerly portions of the Sequim-Dungeness area.

The DQ Plan notes that the Dungeness River's flow would have been diminished and augmented at different times by alpine glaciers. It was dammed by the advancing ice sheets, ponded in ephemeral glacial lakes (leaving deposits of clay and silt), and increased by precipitation coincident with the cool, humid glacial climate. As the glacial ice sheets receded or wasted, unplugging glacial lakes, enormous melt waters would have been released, carrying outwash bedload and forming temporary and shifting drainage channels. Some outflows occurred under or in contact with the wasting ice sheet, leaving deposits of the type known as eskers or kame terraces. Erratic outwash patterns would have trended northwest to the opening tidal waters; these are visible in the bluffs near Green Point. Recessional outwash left well-sorted sand and gravel deposits (possibly visible in the sinuous ridges of the Potholes/Dungeness Estates and Hogback Road) together with poorly-sorted mud flows on the emerging land surfaces. There is evidence that the late stage of recession of the Vashon Stade was catastrophic, resulting in floating bergs that deposited drift over large areas (the Everson Drift is the surface "cliff-forming" layer of glacial deposit atop the coastal bluffs) (DQ Plan 1994).

2.1.4 Soils

The SCS *Soil Survey of Clallam County Area* (fieldwork conducted in 1979 and issued in 1987) remains definitive. The SCS describes and maps 11 soil units for the Clallam County area. Five of these occur on lowland terraces, escarpments, flood plains and alluvial fans; three occur on hills; one occurs on foothills; and two occur on mountains.

Broad land use considerations stated by the SCS for these soils include:

- The two units mapped for mountains are suitable for use as forest land but not most other uses due to steep slopes. One of these, the Terbies-Louella occupies all of the mountain areas mapped by the SCS in WRIA 18.
- One of the hillside units (Elwha-Clallam-Catla) was also dominantly forested at the time of the survey in 1979 (SCS 1987). It consists of shallow to moderately deep soils over very compact glacial till on slopes of up to 35 percent. It is accessible and is both farmed and used for residential development. Nonetheless, the SCS found this soil poorly suited to farming, and suitable for residential development only with caution as to construction technique and septic design. The Elwha-Clallam-Catla unit occupies foothills throughout WRIA 18 and, from roughly Siebert Creek west to the Elwha River, it extends northward all the way to the Strait. Throughout WRIA 18, it is bordered to the south by the Terbies-Louella unit and, in the Sequim-Dungeness valley (east of Siebert Creek), it does not extend to the Strait, but rather it transitions to the north into two major lowland units (Carlsborg-Puget-Dungeness and Hoypus-Sequim-Agnew).
- The soil units on terraces and flood plains (found north of the Elwha-Clallam-Catla unit from Siebert Creek east to Sequim Bay) are the Carlsborg and Sequim soils units (Carlsborg-Puget-Dungeness and Hoypus-Sequim-Agnew). These units occupy the Sequim-Dungeness valley and are considered most suitable for farming. In spite of the fertile nature of these soils themselves, the SCS states that farmlands in the eastern part of the area (corresponding to East WRIA 18) require irrigation due to the poor to excessively drained character of the soils.
- Most of the prime farmland identified by the SCS in the Clallam County area occurs along river terraces, particularly the Dungeness River. Soils meeting all of the requirements for prime farmland (Agnew silt loam, Cassalery (SCS spells this differently than the creek is spelled) fine sandy loam, Dungeness silt loam, and Puget silt loam) occupy only 1.8 percent of Clallam County. But they occur extensively along the Dungeness River, in the Sequim-Dungeness valley, in the lower 3 miles of Morse Creek and in the lower Elwha River valley up through Indian Creek to its origin in Lake Sutherland.
- Soils suitable for farming are also those most commonly suitable for residential development. The 1970s were a building boom period, and SCS noted conversion occurring at an increasing rate (see Section 2.2).
- Septic design is critical on soil units that have restricted permeability or which are excessively drained. The potential for groundwater contamination from poorly designed septic tank absorption fields was rated “a definite hazard” on the Sequim, Carlsborg, and Neilton soils. These units occupy the Sequim-Dungeness valley, lower Morse Creek, and lower Elwha River/Indian Creek valleys.

West WRIA 18 – Elwha Morse Planning Area

The soils of West WRIA 18 have not received the significant broad-based study that has occurred in East WRIA 18. They are understood almost entirely based on the 1979 SCS study (published in 1987).

West WRIA 18 has a more simplified soil profile that consists of the Terbies-Louella unit in the mountains and upper foothills, and the Elwha-Clallam-Catla soils in the lower foothills and extending to the Strait. As mentioned above, the only other soils found are the Carlsborg and Neilton units in the lower Morse and Elwha/Indian valleys.

The Terbies-Louella soils of the higher elevations are generally well-drained and typically steep and deep. The steepness of the slopes means they are poorly suited to support anything other than forestry activities, though there are many rural residences with wells and septic systems found throughout this soil type.

The Elwha-Clallam-Catla soils of the lower elevations are moderately well-drained and can be found from steep slopes to level ground. Consisting mostly of gravelly sandy loams, these soils are most suited to supporting forestry, while residential use is limited by the poor septic tank absorption due to wetness, steepness, and shallow depth.

East WRIA 18 – Dungeness River: Upper and Lower Watershed

The soils of the upper Dungeness River basin are typical of the Olympic Peninsula mountainous regions. Their high erosion potential is related to slope steepness and high rainfall. This soil is susceptible to disturbance in unprotected areas (e.g., logging, road building, and especially clear-cutting). These soils tend to be shallow, well-drained, with low to moderate water retention and high infiltration rates. The steep slopes and unstable soils lend themselves to land and debris sliding, contributing sediment load to the river. The USFS (see Map 3 in DAWACT 1995) maps areas with high susceptibility to mass wasting, which are visibly concentrated in the upper watershed above the Dungeness Forks and in the upper Siebert Creek, McDonald Creek and Canyon Creek watersheds.

Soils in the lower Dungeness basin are:

- alluvial, deposited during episodes of valley flooding;
- valuable for agriculture due to the fine texture of the sediment deposited;
- rich in minerals not typically found in soils which have developed in place from a single parent material;
- agriculturally productive.

2.1.5 Hydrology and Geohydrology

Elements of a water budget include precipitation, evapotranspiration, runoff, infiltration, stream flows, surface storage, aquifer storage, groundwater flows, surface-groundwater interactions (gaining and losing reaches, or discharge and recharge areas), and seasonal variations.

Perry (2001) presents a thorough summary of these elements. He describes the principal inputs as precipitation in the form of rain and snow, as well as condensation occurring

whenever air/ground/humidity conditions interact to produce it. This incoming water then moves through the watershed in various ways. It may either be absorbed or otherwise incorporated directly into surface features or it may be returned to the atmosphere. The portion that is returned to the atmosphere may return as water that is intercepted from reaching the ground by plants and other surfaces, from which the intercepted water evaporates or sublimates (transformed from solid snow or ice directly back to vapor), or by being taken up into the plant tissues but then “exhaled” (transpiration) as part of their biological processes.

Water returned to the atmosphere remains in the watershed and moves along various pathways. It can be directly intercepted, absorbed, and kept by plants. It can reach the ground and be absorbed into the ground or held in the form of ice or snow. It can reach the ground and then be taken in by plants. Or it can reach the ground and add to open water, landing in or flowing directly (runoff) into surface streams and other water bodies such as lakes, ponds, and wetlands.

Some water absorbed into the ground may percolate comparatively quickly down into an underlying aquifer, but most absorbed water will tend to stay within the soil layers until they are saturated. Once the soil profile is saturated, additional water will more quickly move on as surface drainage or percolate down to any underlying aquifer(s). This water will also interact back and forth with surface streams (resulting in gaining and losing reaches) in complex processes influenced by many physical, hydrologic, and climatic variables.

Water held in the form of snow and ice represents a very important component of the overall water budget. As stored water, it provides long-term, usually stabilizing inputs to the water cycle, especially during those times of year when there is less precipitation. The melting water will progress along all the same surface and subsurface routes as described above. In this region, there are important occasions when the presence of snow and ice can contribute to destabilizing inputs, referred to as “rain-on-snow” events. In these events, new precipitation (in the form of rain) falls on surfaces covered by snow and ice. The presence of this snow and ice prevents the rain from being captured and the precipitation promptly becomes surface drainage and streamflow. This component of flow is compounded by the warmth of the rain, causing snow and ice to thaw, and adding melt water to the total flow. Rain-on-snow events in this region tend to produce some of the highest streamflows of the entire annual cycle. Recent study indicates that climate warming is causing increased frequency of “rain on snow” events.

Plants play a major role in the water cycle, especially in forested watersheds with large plant biomass. Tremendous amounts of water are taken up by plants and either converted into plant growth or transpired back into the atmosphere. Though not a significant factor in the climate of WRIA 18, riparian vegetation, especially vegetation overhanging streams, can also perform an important function through the mechanism of “fog drip”. In this process, when temperature and humidity conditions are right, water accumulating on leaf surfaces (from condensation and other origins) drips off the plants and falls to the ground or into the stream.

Once water gets to the ground and is not held in the form of snow and ice or taken up in some fashion by plants, it enters into the complex set of interactions between soils, geologic structure, groundwater, aquifers, wetlands, springs & seeps, and surface waters.

Through the annual cycle and throughout the watershed, water is moving back and forth within this complex. In periods of high input, water will saturate the soils, flow to surface waters, and recharge aquifers. In periods of low input, water will be drawn (discharge) from groundwater in soils, from aquifers, and from surface features such as wetlands. It then moves downgradient and, wherever it feeds surface streams, provides the critical baseflow for the stream.

Water flowing through these various pathways continues its cycle by leaving the watershed. As noted above, this output can be via the “short-circuited” routes of evaporation, transpiration, or sublimation or it can be via the most obvious route, runoff. Runoff in WRIA 18 ultimately takes surface water back to salt water, either within surface streams, as coastal surface runoff, or as subsurface seepage from the many coastal seeps and springs.

Finally, of course, the saltwater evaporates, joining the atmospheric source for the precipitation that renews the cycle. The watershed’s water budget, then, is the quantification of each of the pieces of this cycle, including the human-induced components.

West WRIA 18

A comprehensive water budget has not been prepared for West WRIA 18. The Bureau of Reclamation (Perry 2001) has developed hydrographs for West WRIA 18 streams but was not able to develop a West WRIA 18-wide water budget due to uncertainties as to how to handle the stormwater component, particularly in the City of Port Angeles. An analysis of well log data for aquifer storage and recovery opportunities by Pacific Groundwater Group is ongoing and is providing some insight into the groundwater component of a West WRIA 18 water balance.

East WRIA 18

Much regional scale hydrologic/geohydrologic work has been conducted in East WRIA 18. The 1994 DQ Plan recommended a comprehensive water resources study, encompassing hydrology and geohydrology and addressing both the quantity and quality of surface and groundwater in the region. One element of this recommendation was completed with the Thomas et al (1999) *Hydrogeologic Assessment of the Sequim-Dungeness Area*.

Thomas et al (1999) developed two water budgets for their Sequim-Dungeness study area, which approximates the lower elevations of East WRIA 18. One budget reflected actual conditions as measured during the study period (December 1995 to September 1997); the second presented a long-term estimate of water budget. Table 2.1-1 and Figure 2.1-4 represent the Thomas et al (1999) water budgets.

Precipitation

As described above, much of East WRIA 18 and the Dungeness River Basin lie within the Olympic rainshadow. Precipitation does not vary uniformly with topography, and water availability is influenced by vegetation interception and transpiration, evaporation, sublimation from snowpack, surface runoff, soil moisture capacity, infiltration and

Table 2.1-1. Average Annual Water Budget for Sequim-Dungeness Area as Estimated by Thomas et al (1999)

Hydrologic Component	Study Period (Dec. 1995 – Sept. 1997)			Long-term Average		
	inches per year	acre-feet per year	cfs	inches per year	acre-feet per year	cfs
PRECIPITATION	27.9	173,000	238.4	20.6	127,000	176.0
SURFACE RUNOFF	3.7	22,900	31.6	--	--	--
EVAPOTRANSPIRATION	15.4	95,300	131.6	--	--	--
GROUNDWATER RECHARGE						
Precipitation	8.6	53,200	73.5	5.4	19,100	46.0
Subsurface inflow	2.7	16,700	23.0	2.7	10,500	23.0
Irrigation	3.1	19,200	26.5	--	--	--
Dungeness R. leak	3.3	20,300	28.0	3.3	20,300	28.0
Subtotal	17.7	109,400	151.0	--	--	--
GROUNDWATER DISCHARGE						
Subsurface outflow	--	--	--	--	--	--
Flow to Dungeness	3.2	19,500	27.0	3.2	19,500	27.0
Flow to other streams	4.6	28,200	39.0	4.6	28,200	39.0
Flow to springs	--	--	--	--	--	--
Net well withdrawal	0.6	3,740	5.2	--	--	--
Subtotal	17.7	109,400	151.0			

Source: Thomas et al 1999 (from Tables 13 & 14)

groundwater discharge, and hydraulic continuity between surface and groundwaters. Recent research on the effects of global warming in the Pacific Northwest region does not necessarily suggest that the area will receive less water in the form of precipitation, but does suggest that water may become less available during some seasons as the timing of precipitation shifts and less of it accumulates in snowpack (US Global Change Research Program 1999). Table 2.1-2 (based on Figure 2.55 in DQ Plan 1994) summarizes gross water inputs to the eastern portions of the planning area from annual precipitation.

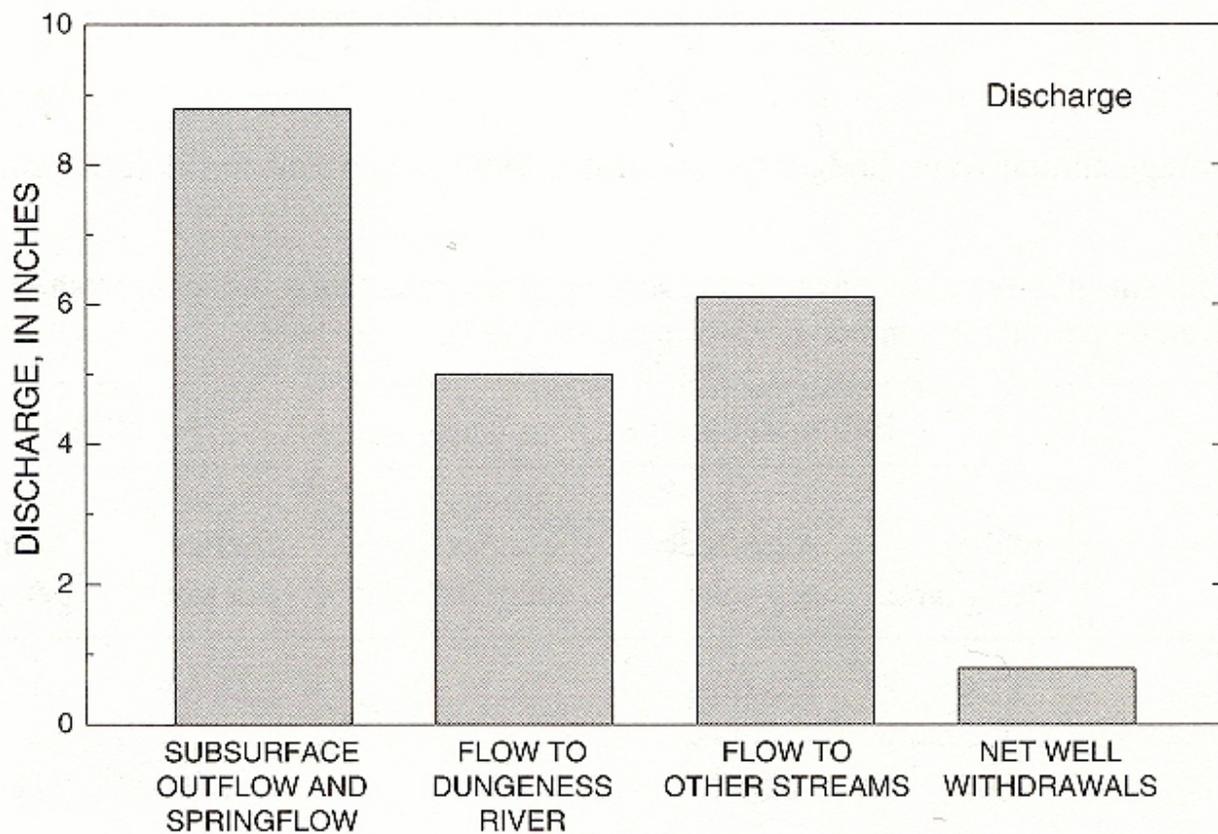
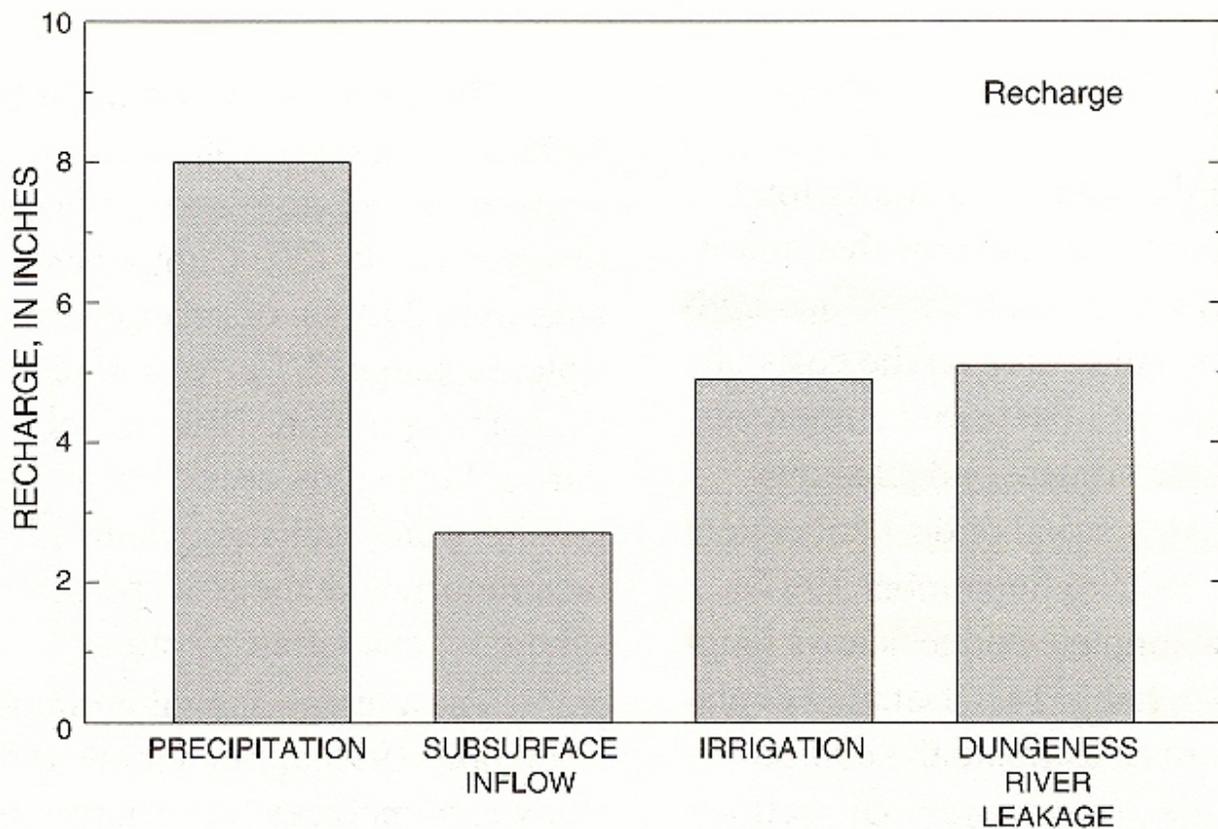


Figure 2.1-4. Average annual ground water budget for primary study area during December 1, 1995 to September 30, 1997, Sequim-Dungeness area, Washington (Thomas et al. 1999).

This page intentionally left blank.

Table 2.1-2. Estimated Annual Water Resource from Precipitation for Selected Sub-areas of the Dungeness River Basin and East WRIA 18

Sub-Area	Area	Average Annual Precipitation	Equivalent Annual Water Quantity from Precipitation	
	square miles	inches/year	acre-feet/year	cfs equivalent
Upper Dungeness watershed*	155	63	527,000	728
Lower Dungeness watershed**	116	29	179,000	247
Jimmycomelately Creek	26	36	50,000	69
Miller Peninsula	34	24	44,000	61
TOTAL	331	44	800,000	1,105

*The Upper Dungeness watershed ends with the inclusion of the Caraco Creek subwatershed.

**The Lower Dungeness watershed, in this table, begins with the Canyon Creek subwatershed and also includes all smaller independent watersheds from Bagley Creek to Bell Creek, inclusive.

Source: modified from DQ Plan 1994, Figure 2.55

Annual average surface flows in the Dungeness amount to little more than half (53%) of the equivalent annual precipitation in the upper Dungeness alone and 40% of the combined upper and lower Dungeness precipitation. This suggests that infiltration and evapotranspiration are consuming half or more of the incoming water supply.

Thomas et al (1999) estimated 27.9 inches (238.4 cfs) of precipitation input to their study area (the Sequim-Dungeness area below the bedrock-dominated areas of the Olympic Mountains) for a study period from December 1995 to September 1997. A long-term estimate of annual precipitation was also made, amounting to 20.6 inches (176 cfs). Thomas et al estimated a long-term average recharge to groundwater from precipitation of 5.4 inches or 33,300 acre-feet per year, equivalent to a flow of 46 cfs. A long-term estimate of the portion of precipitation entering surface runoff was not made, but for the study period, it totaled 3.7 inches or 22,900 acre-feet per year (equivalent to 31.6 cfs).

Interception and Evapotranspiration

Thomas et al (1999) also estimated evapotranspiration (ET) at 15.4 inches (131.6 cfs) for 1995-1997. Thomas et al assigned forests an average interception value of 20% in their study, and assumed that grassland had no interception of precipitation. KCM (1990) estimated lake evaporation for the Dungeness watershed as a whole at 21 inches, or 2,500 acre-feet/year. The potential ET at the Sequim weather station (based on a 1919-1979 period of record) was reportedly 30.2 inches and was considered representative of the entire watershed by KCM. The actual annual average ET at the Sequim weather station was 13.8 inches, a value in reasonable agreement with the Thomas et al estimate. Evapotranspiration ranged from 12.7 inches at the waterfront to 18.8 inches “near the southern border of the lower basin.”

Hydrology

Dungeness River Annual Hydrograph

A detailed hydrologic analysis of the Dungeness River Basin is provided in Orsborn (1987). Subsequent sections of this chapter describe existing information on flows for East WRIA 18 drainages. Thomas et al (1999) classifies streams in the area into two types based on the source of flow: (1) snowmelt and (2) groundwater discharge (supplemented by irrigation tailwaters). Snowmelt and rainfall runoff produce most of the flow in the larger streams with upper watersheds in the hills or mountains to the south. Groundwater discharge and tailwaters feed the smaller streams with watersheds contained entirely in the lower hills and lowland plain. The two types of stream size exhibit distinctly different flow patterns. Larger streams (Dungeness, Siebert, and McDonald) have high flows in the winter and spring, and low flows during the remainder of the year. The smaller streams (Bell, Gierin, Cassalery, and others) have relatively constant flows over the entire year.

Small Streams Hydrology

A number of researchers have noted that the lower Dungeness River tributaries and independent drainages of East WRIA 18 are primarily low gradient streams flowing through agricultural areas and the urbanizing areas surrounding Sequim. Many of these are influenced by groundwater and may receive significant contribution to flow from irrigation recharge. Direct surface connections to the irrigation system and irrigation recharge resulted in increased stream flows in the independent drainages and some lower tributaries, and lengthened such streams as Bell, Gierin, Cassalery, Cooper, Hurd, and Matriotti creeks (Haring 1999). Water conservation improvements are expected to lower the shallow aquifer water table and reduce stream length.

The DQ Plan (1994) raised the concern that insufficient long-term flow data has been collected for most of the smaller streams to provide a meaningful baseline. This situation is being addressed through the installation of WDOE-funded telemetry gaging stations at eight locations throughout WRIA 18. The stations are located at Jimmycomelately Creek (near mouth), Dungeness River (near mouth), McDonald Creek (at Hwy 101), Siebert Creek (at Old Olympic Hwy), Morse Creek (below aqueduct), Ennis Creek (near mouth), Little River (near mouth), and Morse Creek (upgrade of existing station at Four Seasons Ranch). In addition, stream gages are being installed at three locations in the Indian Creek watershed, including: near the mouth, just below Lake Sutherland, and near Maple Grove (in a wetland complex along the north shore of Lake Sutherland).

The USGS conducted a program of stream gaging as part of the DQ project and Chapter 4 of the DQ Plan provides a detailed inventory of stream flow measurements at each of the creeks in East WRIA 18. Other measurements have been taken from time to time on various creeks and data has been partially compiled for this synthesis.

Instream Flows on Small Streams

Hiss (1993a) developed salmon and steelhead flow recommendations for fifteen north Olympic Peninsula streams based on the toe width method. Earlier instream flow recommendations made by WDFW's predecessor agency are summarized in Hiss (1993a):

Table 1). In 1997, Ecology developed flow recommendations for thirteen East WRIA 18 streams and stream reaches using the same method. They reflect calculations of fish production potential if water were available, not necessarily what the currently found instream hydrology might support. For example, Ecology lists a 15 cfs flow recommendation for McDonald Creek during July-September, whereas the WUA reports typically supplementing up to the full amount of its 5 cfs water right from McDonald Creek with water from the Dungeness River during this period in order to avoid drying up the creek (Mike Jeldness, pers. comm. August 17, 2000).

Table 2.1-3 summarizes gage flow records obtained from the USGS (unpublished file data), USFWS (Hiss 1993a), and Ecology (1997) for the smaller streams of East WRIA 18. Where monthly means have been calculated they are reported; other data is summarized in terms of the range of flow records from the various measurements that have been taken.

Surface Water

The DQ Plan (1994) estimated a total equivalent annual water quantity from precipitation by sub-area. Summing those areas that fall within East WRIA 18 yields a total estimate of 881,000 acre-feet per year (1,217 cubic feet per second (cfs)).

Thomas et al (1999) provide long-term estimates for precipitation and for precipitation recharge to groundwater for the most arid part of East WRIA 18. Long-term estimates are not given for evapotranspiration or surface runoff, and the study period coincides with a relatively wet period in East WRIA 18. If the same ratio of surface runoff to evapotranspiration applied to the long-term as characterized during the study period, the long-term average surface runoff from precipitation would be 2.95 inches per year (18,200 ac-ft or 25 cfs), and long-term evapotranspiration would be 12.3 inches per year (76,000 ac-ft or 105 cfs).

If the simplifying assumption is made that long-term runoff bears about the same ratio to total precipitation as it did for the study period, roughly 13 percent of incident precipitation might be available as surface runoff. Applying this to the 881,000 acre-feet estimated in the DQ Plan yields an estimate of roughly 117,000 acre-feet or 160 cfs. Considering that the measured average annual flow of the Dungeness River is 384 cfs, it is readily apparent that this estimating procedure is unsatisfactory (this probably simply indicates that most incident precipitation occurs and runs off in the upper watershed). Therefore, average annual flow data for the Dungeness River and other available records and synthetic hydrographs for streams and creeks in East WRIA 18 probably represent the best available data for estimating surface water availability. Known annual average flow data for the smaller streams in East WRIA 18 are summarized in Table 2.1-4.

Perry (Unpublished data 2003) has developed synthetic hydrographs for the small streams of East WRIA 18. For additional insight into the water budgets for these streams, their hydrographs are presented in each stream's subsection and summarized in Table 2.1-4.

Average-year surface water available for the Dungeness and tributaries is drawn from the DQ Plan (1994) analysis of incremental flows, updated to include the most recent water

Table 2.1-5. Recorded Monthly Flows for East WRIA 18 Smaller Streams.

Stream		Recorded Flows (cfs)											
		J	F	M	A	M	J	J	A	S	O	N	D
Bagley	mean												
	range				2-21	1.3-2	1.1-1.6	0.7-1.4	0.7-1.3	0.6-2.0	1.0-1.9	5.3	
Bell	mean												
	range	7.2			2.4-6.8	3.4-7.3	2.7-8.8	3.5-5.4	2.4-4.5	2.0-5.7	2.1-3.9	7.7	
Canyon	mean												
	range	4.9		4.9	1.0-23	1.1-4.3	0.1-15	0.1-4.3	0.1-1.9	0.5-2.2	0.7	3.0	
Cassalery (mouth)	mean												
	range			5.5	3.7-5.4	3.4-4.8	2.6-6.3	2.8-6.9	3.8-4.7	2.2-5.2	2.5-5.1	2.7	
Chicken Coop	mean												
	range	0.5		1.3	0.2-1.4	0.2-1.7	0.1-2.2	trace - 0.3	dry - 0.2	trace -0.2	0.1-0.8	4.0	
Dean	mean												
	range								trace	0.2	3.7		
Gierin	mean												
	range								3.4	1.7	1.0	2.1	
Hurd	mean												
	range	1.7		2.1-2.9	1.7-3.2	2.3-6.9	4.6-7.4	2.1-8.0	2.5-5.2	2.9-6.7	1.1-4.0	4.2	
Jimmy Come Lately	mean							2.2	1.7	1.6			
	range	22		10	2.5-27	2.6-24	1.7-49	1.1-6.3	0.7-3.2	0.5-6.4	0.4-8.9	29.9	
Johnson	mean												
	range					2.3-3.6	1.4-2.4	1.4-4.4	0.7-2.1	0.3-3.0	1.0-1.6	4.9	
Matriotti	mean												
	range	6.3		12	5.7-11	6.1-11	5.9-11	0.1-18	4.6-11	4.0-14.9	1.8-5.2	6.7	
McDonald	mean												
	range				10-20	8.1-15	1.7-25	1.7-6.6	1.7-3.3	0.1-4.2	0.2-11	17.8	
Meadowbrook	mean												
	range				3.6-6.7	4.4-6.8	2.4-5.0	3.8-5.9	2.8-5.4	2.9-5.2	1.1-4.3	5.9	
Siebert	mean	44	40	22	15	11	8	5	4	4	7	20	27
	range	9.7			8.7-14	5.6-9.2	8.0	3.2-5.6	3.6-5.5	3.6-6.0	2.6-8.6	20.1	

years (through 2002) as summarized by Welden Clark (pers. comm. Clark 2003) (see Section 2.8). The average yearly Dungeness flow, including all tributary flows, is 384 cfs.

Dry-year surface water available for the Dungeness and tributaries is based on analysis of spreadsheet data for Dungeness Flows from 1924-2003 (Clark, pers. comm. 2003). Defining a “dry year” as the 90 percent exceedance flow, the Dungeness River dry year average annual flow is 262 cfs.

Table 2.1-4. Surface Water Flows in East WRIA 18 Drainages.

Drainage	Dry Year (90% Exceedance) (cfs)		Average Annual Flow (cfs)	Average Annual Volume (acre-feet)
	August-Sept.	Annual		
Bagley Creek	0	4.5	14.6	10,570
Siebert Creek	2.6	7.0	16.5	11,964
McDonald Creek	11.5	36.6	83.7	60,594
Dungeness River	142	262	384	278,000
Matriotti Creek	0	3.0	11.1	8,036
Bear Creek	0	3.0	10.0	7,239
Canyon Creek	6.6	20.2	47.3	34,242
Cassalery Creek	0	0.2	0.8	579
Gierin Creek	0	0.3	1.3	941
Bell Creek	0	2.4	8.5	6,153
Johnson Creek	1.2	5.0	13.2	9,556
Dean Creek	1.5	4.7	11.2	8108
Jimmycomelately Creek	5.9	24.1	62.7	45,391

Source: USGS (unpublished file data), USFWS (Hiss 1993a), Ecology (1997) and Perry (unpub. data 2003).

During August-September (the low flow period), the 90 percent exceedance flow is 142 cfs. In only one of 69 years (1977) did winter low flows fall below the August-September low flow. The lowest August-September flows on record are 119 cfs (three times). For the full year, the lowest annual flow was 197 cfs (1977). Average August-September low flows are 207 cfs. Correlations between the half-month flow data for August and September and the flow data for the six-month summary periods (October-March and April-September) show that October half-months are not consistently identified with low flows, but August and September half-month flow data show strong correlations with the “dry” season, though poor correlation with the “wet” storm season (October-March) (Virginia Clark and Welden Clark, pers. comm. 2000).

Average annual and average dry year flows are assumed to be independent of year. However, by 2020 surface water availability is expected to be reduced due to reduced irrigation recharge (as conservation measures are implemented). Irrigation recharge feeds both the Dungeness River and other streams. Groundwater discharges 27 cfs to the Dungeness River and 39 cfs to other streams in the Sequim-Dungeness area (Thomas et al 1999). Given that irrigation recharge contributed 17.5 percent of total groundwater recharge during the Thomas et al study period (a long-term average was not calculated for irrigation recharge), 4.7 cfs of Dungeness River recharge and 6.8 cfs of recharge to other streams could be attributable to irrigation recharge under current conditions, if 1996 is representative. Assuming the full structural program of water conservation improvements recommended by Montgomery Water Group (1999) is implemented, irrigation recharge could be reduced by 72 to 85%. This would reduce recharge to the Dungeness River by up to 4.0 cfs and to the other streams by up to 5.8 cfs. Although in a dry year irrigation recharge would presumably contribute a greater proportion of total recharge, the absolute value of irrigation recharge to streams probably would not change greatly between dry and normal years.

Geohydrology

The region's geologic and climatic history has left a pattern of complex stratification and variation. This has resulted in the correspondingly complex patterns of hydraulic continuity and of confined and unconfined aquifers now present in the region. Recalling the geology discussed above, the Sequim-Dungeness area is overlain with thick accumulations of glacial and interglacial deposits in the form of unconsolidated sediments. These deposits are generally heterogeneous and may be discontinuous in places.

Foothills descend from the core rocks of the Olympic Mountains; a broad coastal plain and small peninsulas overlie oceanic-basalt and marine sedimentary bedrock formations that dip steeply down to the north from their foothill exposures. The unconsolidated deposits thin toward the south, where bedrock is at or near land surface, and thicken to the northeast reaching a maximum thickness of 2,500 feet at the coast.

A generalized geologic section from the foothills to the Strait dips gently northward to saltwater and contains alternating water-holding aquifers in layers of unconsolidated sediments and confining layers of variable impermeability (DQ Plan 1994, Thomas et al 1999). Historically, planning documents have inferred the presence of several aquifers at various depths.

The *Sequim-Dungeness Regional Comprehensive Plan* (CCDCD 1994) asserted that beneath the regional planning area there are "up to three aquifers and two confining units." The City of Sequim (Polaris Engineering and Surveying, Inc. 1993) also described three aquifers. It states that "there are now a number of wells drawing from the lower artesian aquifer, several drawing in excess of 500 gpm, that indicate the presence of a confined aquifer of great quantity beneath the Sequim Prairie."

Thomas et al (1999) confirmed and elaborated this general picture, delineating three aquifers and two confining beds in the unconsolidated sediments, overlying a lower unit of undifferentiated (not yet fully described) sediment above bedrock. Earlier, Jones (1996)

had delineated these five hydrogeologic units and provided geologic cross-sections.¹ However, notwithstanding the detailed analysis by the USGS, there does not yet exist an estimate of the actual quantity of water present or available in the aquifers underlying the Sequim-Dungeness area. Thomas et al consider that the aquifers are not receiving long-term recharge, and hence have no “sustainable yield” in the sense that withdrawals will either decrease natural discharge or storage, or both.

Pacific Groundwater Group (PGG) produced further groundwater analysis in 1999 for the WUA, as part of the Comprehensive Water Conservation Plan (MWG 1999). Because it appears to be based on reworking the data reported by Drost (1983, 1986) and preliminary data later published by Thomas et al, the following synthesis focuses on the work of Thomas et al. (A 2003 groundwater model being used for further study at the time of this plan incorporated the work of Thomas. Appendix 2-A contains updated information on the results of the use of that model.)

In general, the aquifers as described by Thomas et al (1999) are coarse-grained unconsolidated deposits and the confining beds are fine-grained unconsolidated deposits. Groundwater may be perched, unconfined, or confined. The thinner edges of a hydrogeologic unit may be unsaturated, but most parts contain at least some groundwater. The aquifers and confining beds have variable boundaries and hydraulic properties. Because of the heterogeneity of the deposits, Thomas et al (1999) simplified considerably to describe the groundwater system. Although the aquifers are generally coarse-grained deposits, local lenses of fine-grained clays or silts may affect permeability and flow within an aquifer. The confining beds are generally fine-grained, but local lenses of coarser sand or gravels can yield moderate amounts of water. Because the confining beds are not impermeable, some groundwater moves vertically through them. The lower boundary of the regional groundwater system is considered the top of bedrock, while the upper boundary is the water table (Thomas et al, 1999). Thomas et al found lateral correlations of hydrogeology difficult because of uneven distributions of areal data and possibly different depositional environments. The hydrogeology of the Miller Peninsula and of the area west of Siebert Creek was noted as particularly difficult. Further refinement of Siebert Creek stratigraphy was done in 2003.

Groundwater moves into the Sequim-Dungeness area as subsurface flow from bedrock through the southern boundary (i.e., downslope from the Olympic Mountains). The general horizontal direction of groundwater flow in the area is to the north, approximately paralleling the Dungeness River, discharging into the Strait of Juan de Fuca, Sequim Bay and Discovery Bay. Groundwater levels fluctuate seasonally with variation in recharge and discharge. Vertical flow between aquifers is generally downward to the south and upward to the north (near the Strait) (Simonds and Sinclair 2002).

Overall water level changes during a period from 1978 to 1997, as analyzed by Thomas et al (1999), were generally small and showed a geographic pattern of being limited to a 7-square mile area east of the Dungeness River. MWG (1999) associated this area of groundwater level decline with the City of Sequim Silberhorn Well Field, and in an area about 1.3 miles northeast of that well field. Reportedly, water levels near the well field have stabilized although a number of wells continue to be drilled in the area (Ann Soule, Clallam County, pers. comm. February 2001). Water levels in the area are generally considered to

¹See also the DNR geologic maps of the Sequim (1998) and Carlsborg (2000) quadrangles.

be associated with Sequim withdrawals, reduced irrigation recharge, and domestic well withdrawals. The PGG (1995) had documented a 19-foot decline in the vicinity of the Silberhorn Well Field as part of work to assist the City of Sequim assess changes in water levels and explore new groundwater supply sources.

Thomas et al (1999) also noted a clear distinction in water level response between areas where the shallow aquifer is recharged predominantly from precipitation when contrasted with areas where it is recharged predominantly from irrigation. Areas recharged by precipitation showed little overall water level change, while those recharged by irrigation showed declines in water level that averaged about 4 feet in each of four test wells between 1978 and 1997.

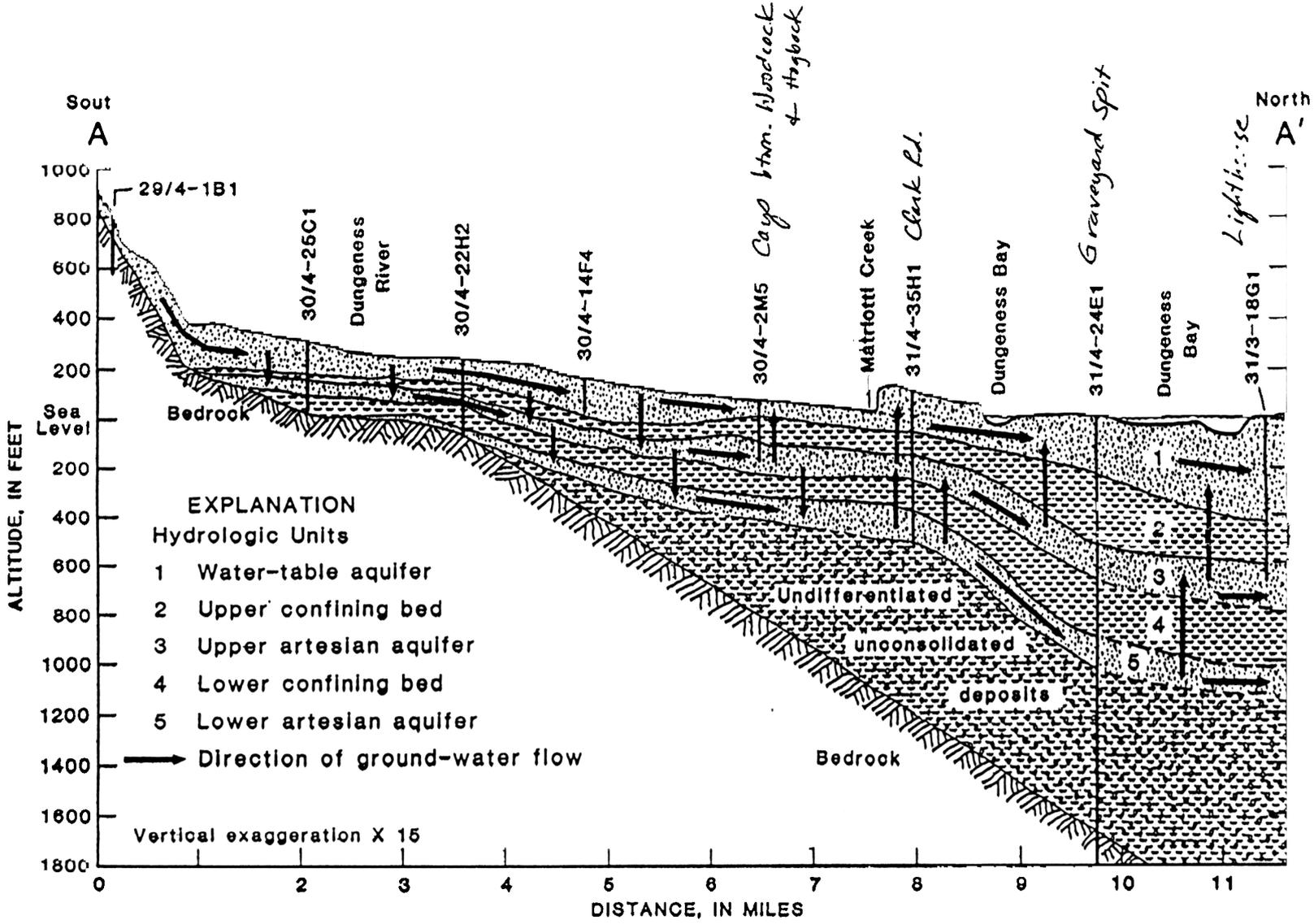
The Shallow Aquifer

The shallow aquifer described by Thomas et al (1999) extends throughout the Sequim-Dungeness study area wherever bedrock is not present at land surface. It contains alluvium, older alluvium, Everson sand, Everson glaciomarine drift, Vashon recessional ice-contact and outwash deposits, Vashon till and reworked till, and Vashon advance outwash. Because surficial deposits are complex and discontinuous, the shallow aquifer was not delineated into individual coarse- and fine-grained deposits. For the most part, its upper boundary is the water table, but shallow clay deposits locally confine small parts of the aquifer throughout the area. The water table rises and falls seasonally. Although there is a considerable range of potentiometric surface in the shallow aquifer (from about 20 feet above land surface where locally confined to more than 200 feet below land surface), the average depth to water was 40 feet. About 90% of the water levels measured in wells had depths of less than 100 feet (Thomas et al 1999).

Water levels in the shallow aquifer typically rise in the fall and winter with increased recharge from precipitation. Irrigation recharge to the shallow aquifer occurs primarily during the summer (see discussion below). The shallow aquifer can be a recharge, discharge, or no-flow boundary², depending on its closeness to land surface, the time of year, and nearby direction of groundwater flow. Water flows into the water table in most areas during the winter (through infiltration and percolation), but can flow out of the water table if it is close to land surface and can move upward by capillary action or be taken up by roots and transpired by plants. Precipitation increases from north to south, increasing the available water for groundwater recharge in the southern parts of the aquifer. Groundwater generally moves into the shallow aquifer through the southern boundary to discharge to streams, springs and, along the coast, to saltwater. The water level gradient ranges from about 250 feet per mile in the south to about 40 feet per mile in the north. Average velocities across the study area range from about one foot per day in the southern hills, to 4 feet/day near Sequim and in the north, and about 8 feet/day in the Dungeness River valley. Lateral boundaries are generally established by bedrock outcrops to the south, saltwater to the north and east, and by Morse Creek to the west. Figure 2.1-4 (above) shows the groundwater budget operating within this groundwater system. Figure 2.1-5 shows the relative physical relationships within this groundwater system.

²In others words, the shallow aquifer both gains and loses water to the surface and to the middle aquifer below at different locations in the Thomas et al study area. At other locations, no water flows from the shallow aquifer to the surface or middle aquifer.

Figure 2.1-5. Conceptualized Groundwater System: East WRIA 18 (Figure 12 from Drost 1983)



This page intentionally left blank.

The Middle Aquifer and its Upper and Lower Confining Beds

An upper confining bed, comprising mainly pre-Vashon silts and clays, lies beneath the shallow aquifer. This confining bed contains locally discontinuous lenses of water-bearing sand and gravel. It has a typical thickness of about 75 feet, ranging from 30 to 110 feet. Its thickness decreases from about 110 feet in the west to about 60 feet in the Miller Peninsula and increases from about 60 feet in the south to 90 feet in the north. Three percent of the wells studied by Thomas et al were completed in thin lenses of groundwater in this bed. The shallow and middle aquifers interact through the upper confining bed.

The middle aquifer, which underlies the upper confining bed, contains pre-Vashon glacial outwash deposits of sand and gravel and interglacial coarse deposits. The aquifer is present in the middle, northern, and eastern parts of the Sequim-Dungeness area, but not in the southern and southwestern parts. It does not occur in the bedrock-dominated landscape of the Olympic Mountains that make up the southern portion of East WRIA 18. The middle aquifer has a typical thickness of about 40 feet and ranges from 10 to 70 feet, decreasing from east to west and from north to south. Thirteen percent of Thomas et al's study wells were completed in this aquifer. Because the middle aquifer is recharged both by downward flow from the shallow aquifer above and by upward flow from the lower aquifer below, its water level fluctuations do not necessarily follow precipitation or irrigation. Its water levels have changed only slightly (average change, 2 feet for three wells) over the 20-year period (1978-1997) analyzed by Thomas et al (1999).

The lower confining bed underlies the middle aquifer and is composed of till and interbedded clay, silt, and fine-grained sand. It also may contain discontinuous lenses of water-bearing sands. Few wells penetrate this unit, but its extent is thought to be similar to that of the middle aquifer. Its typical thickness is about 100 feet, ranging from 10 to 300 feet.

In the southern part of the Thomas et al study area, groundwater moves downward into the middle aquifer through the upper boundary, and in the northern part water moves upward and out of the aquifer. Flow directions across the lower boundary are similar. A small amount of recharge may be provided from bedrock to the south, but Thomas et al state that this is uncertain. The potentiometric surface varies from about 30 feet above land surface to more than 300 feet below land surface.³ In the primary Thomas et al study area, the average depth was 90 feet, and 60 percent of well water levels were less than 100 feet. On the Miller Peninsula, the average depth was considerably greater, 160 feet, and only 15 percent of wells had water levels of less than 100 feet. Again, the direction of groundwater flow is generally south to north, with a gradient of about 30 feet per mile in the primary study area and about 200 feet per mile on the Miller Peninsula. The average velocity was about one foot/day in the primary study area (see Figure 2.1-1).

The Lower Aquifer and Underlying Materials

The lower aquifer, underlying the lower confining bed, is composed of sand with thin lenses of sand and gravel, silt, and clay. Less data were available to characterize this aquifer, as few wells are completed in it, but it is considered to cover an area similar to the

³This is now under study by the Ecology regional hydrogeologist.

middle aquifer. Thus, the lower aquifer is present in the northern and eastern parts of the Sequim-Dungeness area, where unconsolidated deposits are up to 2500 feet thick, and absent to the south and southwest where they are much thinner (and extending to the point of being nonexistent in areas where the underlying bedrock and other geologic formations rise to the surface). Its typical thickness is about 90 feet, ranging from 10 to 180 feet. Six percent of Thomas et al study wells (44 wells out of 771 total) were completed in this aquifer. Groundwater flows downward, through the confining bed, from upslope of the lower aquifer in the south (see Figure 2.1-5). Further north, groundwater flows upward across this interface. The potentiometric surface varies from 20 feet above land surface to 400 feet below land surface, with an average depth to water of 110 feet in the primary study area (60% of the ~640 wells in the primary study area had water levels that were less than 100 feet). Again, depths were greater on the Miller Peninsula, which averaged 240 feet to water (no wells less than 100 feet to water level). Data were insufficient to measure groundwater flow directions, but Thomas et al (1999) believe that flows are probably from south to north, as in the shallow and middle aquifers.

Undifferentiated unconsolidated deposits lie between the lower aquifer and bedrock. Not adequately defined as yet, this unit is thin to the south and more than 1,000 feet thick in the northern parts of the Sequim-Dungeness area. Thomas et al (1999) comment that there may be productive aquifers in the thicker northern deposits.

Beneath the unconsolidated sediments are Tertiary consolidated rocks, referred to as bedrock in the Thomas et al (1999) hydrogeologic assessment. Bedrock exposed in the area includes sedimentary and volcanic rocks. The sedimentary rocks are marine sandstone, siltstone, mudstone, and conglomerate. The volcanic rocks are submarine basalt flows and breccias. Bedrock crops out in the foothills along the Olympic Mountains and in the valleys along McDonald and Siebert creeks.

Groundwater Budget

Thomas et al (1999) attribute 41% of groundwater withdrawals to public water supply and 26% to domestic wells (see Figure 2.1-4). Montgomery Water Group (1999) estimated somewhat less groundwater, 1,251 acre-feet per year, were withdrawn from domestic wells in the Sequim-Dungeness area in 1996. Montgomery Water Group also estimated 2,003 acre-feet per year were withdrawn from public supply wells in that year. The sum of the two, 3,254 acre-feet per year is about 80% of the Thomas et al estimate and 84% of the estimate derived above from population projections. Montgomery Water Group also estimated 4 acre-feet withdrawn for commercial and industrial use and 89 acre-feet withdrawn for golf courses.

Thomas et al (1999) report that there has been concern about a slight decline in the water table of the surficial aquifer in the Sequim-Dungeness area, and noted a general decline in a 7-square-mile area east of the Dungeness River. They do not provide an estimate of the volume of water stored in the three aquifers delineated. An estimate of annual groundwater recharge for the entire East WRIA 18 planning area is also unavailable. The Thomas et al study estimates groundwater recharge only to the boundary formed between unconsolidated deposits and bedrock outcrops in the foothills of the Olympic Mountains.

Thomas et al (1999) state that a simple comparison between groundwater recharge and withdrawals is not a good indicator of the quantity of water that is potentially available for groundwater development. They state that any additional withdrawal superimposed on a previously stable groundwater system must be balanced by a decrease in discharge, a loss in storage in the system (reflected by lower water levels), an increase in recharge, or a combination of these. Considering the groundwater system of the Sequim-Dungeness area, Thomas et al judged the possibility of increased recharge on a long-term basis to be remote, pointing to trends of increased residential development and decreased irrigation (which in turn reduces recharge). Additional withdrawals, therefore, were considered to probably result in (1) a decrease in natural discharge and/or (2) a loss in storage. Thomas et al conclude that the magnitude of sustainable groundwater development depends on acceptability of water level declines and decreases in natural discharge (which could affect instream flows). The greatest effects of increased groundwater withdrawals (and decreased irrigation recharge) are expected on the shallow aquifer. If new well drilling is directed to the second aquifer or below, it may be reasonable to assume that the greatest effect on the groundwater system of the Sequim Dungeness area would be decreased discharge to saltwater, which was unavailable to human use or environmental benefit in any event.

Based on the Thomas et al conclusion, the amount of water recognized in groundwater certificates, permits and claims for East WRIA 18, plus the amount represented in existing exempt wells, is used as a proxy for groundwater available⁴. Table 2.1-5 allocates groundwater among the three aquifers and the remaining hydrogeologic units based on the allocation of well withdrawals estimated by Thomas et al: (67% from the shallow aquifer, 13% from the middle aquifer, 7% from the lower aquifer, and the remaining 13% from the other hydrogeologic units).

The Thomas et al study period was wetter than the long-term average. In the wetter period, groundwater recharge from precipitation was not only greater, but proportionately greater (31% of total precipitation in the study period, versus 26% long-term average). It seems reasonable that groundwater recharge would decrease during a dry year, so that groundwater availability would be less in a dry year than an average year. As a rough approximation, based on the comparison between recharge in the wetter short-term and drier long-term average periods in Thomas et al (1999), it is assumed that groundwater availability is reduced by 20% in a dry year. In projecting groundwater availability to the year 2020, it is assumed that withdrawals shift from the shallow to the middle aquifer at a rate of 2% per year. (This is for illustrative purposes only; there is no empirical basis for this rate.)

⁴This assumes that Ecology's grant of water rights indicates that water society has considered and accepted the declines in groundwater level or reductions in groundwater storage associated with these rights, inasmuch as a public welfare criterion is included in Ecology's certification of them.

**Table 2.1-5. Groundwater Availability in East WRIA 18
(relative proportion from each aquifer in parentheses)**

Aquifer	Average Year (acre-feet)		Dry Year (acre-feet)	
	2000	2020	2000	2020
Shallow Aquifer	12,858 (67%)	8,828 (46%)	10,286 (67%)	7,062 (46%)
Middle Aquifer	2,495 (13%)	5,777 (34%)	1,996 (13%)	5,220 (34%)
Deep Aquifer	1,343 (7%)	1,343 (7%)	1,075 (7%)	1,075 (7%)
Other Layers (confining beds, undifferentiated deposits, bedrock)	2,495 (13%)	2,495 (13%)	1,996 (13%)	1,996 (13%)
TOTAL	19,191	19,191	15,353	15,353

Source: derived from Thomas et al 1999

NOTES

Groundwater average year availability is assumed determined by sum of existing water rights and claims, and exempt well withdrawals.

Dry year availability is roughly approximated as 80% of average year availability.

Distribution of withdrawals by aquifer in year 2002 is based on Thomas et al 1999. Year 2020 distribution assumes a 2% per year shift in groundwater withdrawals from the shallow to the middle aquifer.

Groundwater Recharge and Discharge

Issues and Analysis in the DQ Plan

The DQ Plan (1994) reported that past research has shown a substantial degree of hydraulic continuity between surface and groundwaters in the Dungeness system. Both gaining and losing stream reaches (reflecting groundwater discharge and recharge) are seen, and the patterns of continuity and flow can be complex when basin boundaries are convoluted and the subsurface strata are non-uniform. This has been corroborated by two subsequent studies (see discussion below).

The groundwaters of the coastal lowlands adjacent to mountain foothills, where most of the population resides, are recharged both from foothill slopes and by direct precipitation on the uplands and lowlands. Surface runoff following storm events typically enters the small and often intermittent drainages of the foothills, but infiltration also occurs on the slopes, leading to shallow subsurface flows and deeper recharge. Precipitation tends to be greater on the foothill areas than in the valleys. Hillside vegetation, together with the typically deeper and more porous hillside soils, may enhance infiltration in these foothills. However, in the lowland plains more remote from mountains and foothills, infiltration and

recharge from local precipitation and irrigation were considered the principal source of groundwater, at least in the unconfined and shallower aquifers (DQ Plan 1994).

At the time of the DQ Plan, it was thought that large areas remote from the foothills and the main river channel depend more upon subsurface flow of groundwaters, evidenced by spring-fed emergent streams and wetlands. Meadowbrook, Cooper, Cassalery and Gierin creeks were cited as examples (DQ Plan 1994). Later, the Washington Pollution Control Hearings Board (PCHB) (Thomas et al 1999) asserted that preliminary hydrogeology "indicate[s] that much of the groundwater in the region drains directly into Puget Sound (sic) and does not return to rivers and streams. Return flows may not be a significant portion of instream flow."⁵

The DQ Plan (1994) held that groundwater on the Miller Peninsula (east of Sequim Bay) and on the coastal plain west of the Dungeness River appeared to be recharged from local precipitation together with infiltration and subsurface flow from the north and northwest flanks of Blyn Mountain and Blue Mountain, respectively. The DQ Plan states that precipitation is limited in the rainshadow, evapotranspiration is believed significant, and developing adequate well yields is problematic.

Issues and Analysis in the USGS Hydrogeology Assessment (1999)

- The Thomas et al (1999) assessment largely confirmed the broad outlines of hydrogeology contained in the DQ Plan (1994), as well as the high aquifer recharge areas mapped in the Clallam County Profile (CCDCD 1992, Map III-2). Thomas et al found that groundwater in the area is recharged from infiltration and percolation of precipitation, percolation of unconsumed irrigation water, leakage from irrigation ditches, subsurface inflow through the southern study area boundary (i.e., underflow from bedrock aquifers carrying water from upslope mountains and foothills), and leakage from streams, primarily from the Dungeness River. Groundwater discharges as subsurface flow to saltwater bodies, flow to streams, flow to springs, and as withdrawals from wells. Thomas et al estimated recharge to the shallow aquifer, but the quantity of vertical flows between aquifers was not estimated.
- Generally, the greater the precipitation (which increases to the south), the greater the recharge. Thomas (pers. comm., July 17, 2001) commented that the data showed that irrigation water loss drives the rise and fall of the water table adjacent to the ditches and irrigated fields. In most other areas, the seasonal fluctuation of the water table is dominated by precipitation. Near the Dungeness River, the fluctuations appear to be controlled by losses from the river. The interaction of the river and groundwater is mostly confined to the areas near the river. Groundwater discharges to small streams probably vary throughout the year according to the gradient between shallow groundwater and stream flow. In areas controlled by irrigation recharge, the lowest groundwater levels occur in January-March; elsewhere they occur in the late summer (Thomas pers. comm. 2001). Other factors influencing the amount and areal distribution of recharge are soil type, surficial geology, vegetation, slope, and land use changes to land

⁵ Note that the PCHB was referring to irrigation return flows to the mainstem. Thomas et al (1999) later indicated that 43% of the groundwater in the region drains to salt water; see discussion below.

cover. Urban land cover, specified for about 0.6 square miles in central Sequim and an additional 0.1 square miles on the Miller Peninsula, was calculated to reduce recharge by 30%.

- Thomas et al (1999) estimated recharge for a study period from December 1995 to September 1997 and provided some long-term estimates as well (Table 2.1-1, above). Average annual recharge was estimated to be 17.7 inches (156 cfs) for the study period. Less than half (8.6 inches or 74 cfs) was from precipitation, calculated as a net of input precipitation, surface runoff, and evapotranspiration. (Long-term recharge from precipitation was estimated at 5.4 inches or 46 cfs.) Other components included 2.7 inches (23 cfs) from subsurface inflow (the same value was estimated for long-term recharge); 3.1 inches (26 cfs) from irrigation; and 3.3 inches (28 cfs) from Dungeness River leakage.
- Thomas et al note that recharge from infiltration and percolation of precipitation accounts for about 40% of total recharge, while the remaining 60% comes from subsurface inflow, Dungeness River leakage, and irrigation. About 43% of groundwater discharge is estimated to be subsurface outflow to saltwater and springs, 24% is to the Dungeness River, 29% is to other streams, and 4% is to net well withdrawals (defined as the difference between volume pumped and expected septic and irrigation return flows). Thomas et al assert that this distribution implies that “potential decreases in discharge could have appreciable effects on streamflow in the Sequim-Dungeness area.” However among groundwater discharge flows, only net well withdrawals are subject to direct human intervention and this is only 4% of the total.
- Soils with small vertical hydraulic conductivity (glaciomarine sediments and very fine alluvium, and till) show small infiltration rates and gradual increases in recharge with increases in precipitation. Recharge is greater and increases rapidly with increased precipitation in areas of glacial outwash or coarse alluvial soils, because the maximum precipitation (50 inches per year) is much less than the vertical hydraulic conductivity of 23 feet/day. Average annual recharge ranged from 11% of average precipitation in glaciomarine sediments and very fine alluvium to 48% in outwash and coarse alluvium. Average recharge through till soils was 25% of precipitation. Thomas et al report large amounts of recharge in the upper valleys and side slopes of Siebert and McDonald creeks, where precipitation is higher, but speculated that this recharge probably moves quickly through shallow deposits to discharge into the streams.
- Discharge from the groundwater system during the study period was considered to balance groundwater recharge (17.7 inches or 151 cfs), but not all components were estimated (in particular, subsurface outflow and flow to springs were not estimated). Groundwater discharge occurs as subsurface flow to saltwater, to springs, and to rivers and streams. Thomas et al did not estimate flows to saltwater or springs, but note that the latter is probably small compared with the sum of subsurface flow to saltwater bodies and flow to streams. They calculated that discharge to the Dungeness River (in the reach between Woodcock Road and the Railroad Bridge), at 3.2 inches (27 cfs), nearly balances recharge from the river (see further discussion below including a more recent study by Simonds and Sinclair 2002, Section 3.2.3). Flow to other streams was estimated at 4.6 inches (39 cfs), and net withdrawals by wells were estimated to

be 0.6 inches (5.2 cfs). The unaccounted discharges, amounting to 9.3 inches (79.8 cfs) are probably largely to saltwater.

Irrigation Recharge

As in many areas in which irrigation has become established over decades, unconsumed irrigation water has become a part of an established system of water use that encompasses more than just the agricultural community itself. Irrigation recharge occurs from water leaking from irrigation ditches or streams and by percolation of unconsumed irrigation water. Montgomery Water Group (1999) states that it is generally recognized that irrigation has altered ecosystems within the Dungeness Valley, artificially altering groundwater levels, recharge zones, and groundwater discharge patterns. Over the past 100 years, irrigation-dependent and irrigation-augmented wetlands have developed and streams have been extended beyond their natural reaches. Irrigation runoff and tailwaters also have artificially supplemented natural or preexisting wetlands and streams. Numerous irrigation ditches have been used as conduits for stormwater runoff from roads and development, altering natural runoff patterns that once fed wetlands and streams and recharged groundwater.

These effects and the relation between the groundwater and surface water systems have been of particular concern to East WRIA 18 planning bodies for some time. Drost (1983, 1986) concluded that leakage from the irrigation system⁶ was the largest source of recharge to the groundwater system in the Sequim-Dungeness peninsula, an opinion reversed by Thomas et al (1999). At the time, Drost believed that terminating all irrigation could reduce head throughout the groundwater system and lower groundwater tables by 20 feet, with some areas becoming completely unsaturated. More than 20 percent of the wells considered by Drost were thought to be at risk of running dry in such a scenario. However, these results were somewhat inconclusive, as Drost also found that groundwater levels might decrease as little as 3 feet and in some areas could rise due to replacing open canals and laterals that currently intercept shallow groundwater flow. Montgomery Water Group (1999) found the maximum decrease to be somewhat less than 20 feet. More recently, the EIS for the Water Users' Association *Conservation Plan* (Foster Wheeler 2003), using more precise modeling, indicates a maximum decrease of only 10 to 11 feet.

The DQ Plan (1994) also expressed concern that groundwater on the Miller Peninsula (east of Sequim Bay) and on the coastal plain west of the Dungeness River appeared to be recharged from irrigation water. And the *Sequim-Dungeness Regional Comprehensive Plan* (CCDCD 1994) noted that the shallow aquifer is the most affected by irrigation ditch leakage. The Regional Plan expressed concern that water levels would decline with efficiency improvements (less recharge) or greater pumping. The DQ Plan (1994) cited studies by Clallam County and Ecology that found well water levels had not been dropping precipitously at the time, but some wells, particularly shallow ones, needed to be deepened or replaced. These changes were believed to relate to irrigation ditch flows. Although drilling deeper wells may be expedient in the short term, the County was concerned that the long-run recharge of deeper aquifers in the Sequim-Dungeness area may come from percolation from shallower aquifers above. Thomas et al (1999) allay this

⁶About 90% of irrigation recharge originates from ditches, not from on-farm application (Thomas et al 1999).

concern somewhat by reporting that the middle and lower aquifers actually discharge water upward in the northern part of the Sequim-Dungeness area.

Thomas et al (1999), in response to these concerns, addressed irrigation recharge in detail. They divided irrigation recharge into two components: percolation of unconsumed irrigation water applied to crops, and leakage from irrigation ditches. A simple model, which summed total irrigation diversions and precipitation, accounted for evapotranspiration, and subtracted tailwaters, estimated percolation of unconsumed irrigation water and leakage from ditches. Most of the irrigation ditches have been constructed in surficial soils or sediments, and leakage is controlled by the permeability of these materials, the size of the ditches, and the depths of water in the ditch.

Thomas et al (1999) constructed a water budget for these components for the 1996 and 1997 irrigation seasons. Estimated average annual recharge for the study period (December 1995 to September 1997) was 2.8 inches (23.7 cfs) for ditch leakage and 0.3 inches (2.8 cfs) for percolation of unconsumed irrigation water.

Irrigation recharge was not estimated by Thomas et al (1999) for long-term average annual conditions. However, Pacific Groundwater Group (PGG) estimated that annual average recharge attributable to irrigation ditches and on-farm water use amounts to 29.02 cfs (including 44.13 cfs during the irrigation season, and 20.95 cfs during the off-season) (Montgomery Water Group 1999). The predicted average annual recharge rate with all proposed ditches being lined was 4.55 cfs.⁷ PGG's model indicated that the Dungeness River would lose 11.7 cfs of irrigation recharge, which would mean that it would convert from a gaining to a losing stream, but that the loss would be more than offset by a gain from avoided diversions through water conservation.

Thomas et al (1999) observed that, in areas where the shallow aquifer recharge is predominantly from precipitation, water levels changed little over 20 years (1978-1997), whereas in areas where recharge was predominantly from irrigation, water levels had declined. For those areas recharged primarily by precipitation, water levels in wells completed in the shallow aquifer declined an average of 2 feet (three wells). In those areas recharged predominantly by irrigation, the decline averaged 6 feet (four wells). A decline in the magnitude of seasonal water level fluctuation was also reported, and was attributed to decreased recharge from irrigation. Areas with significant irrigation recharge to groundwater lie along both sides of the Dungeness River and in the area between Siebert and McDonald creeks. Thomas et al (1999) state that any area with total recharge greater than 20 inches is considered heavily influenced by recharge from irrigation.

The *Comprehensive Water Conservation Plan* (MWG 1999) also analyzed the effects of reduced irrigation diversions on recharge, concluding that this could cause a gradual return to ground and surface water conditions that existed before agriculture artificially changed water regimes. Montgomery Water Group used an updated version of the Drost model and built on an earlier irrigation ditch leakage assessment (MWG 1993). It was concluded that drawdown attributable to reduced irrigation recharge ranged from 0 to 20 feet for the shallow aquifer and from 0 to 12 feet for the middle aquifer. The *Comprehensive Water Conservation Plan* states that groundwater discharges 15.64 cfs to surface water streams on the Sequim-Dungeness peninsula, and that lining the irrigation

⁷No proposals are being considered to line all ditches, however.

ditches will decrease this discharge by 5.65 cfs, to 9.99 cfs. The proposed improvements are predicted to affect the Dungeness River and the smaller streams in differing fashion. The volume of water in the Dungeness is expected to increase 5 to 18%, while water in the smaller streams may decrease by 34 to 63%. Montgomery Water Group (1999) states that the upper reaches of many streams, including Bell, Gierin, Hurd, Woodcock, and Matriotti creeks could be dewatered, affecting salmon spawning and rearing habitat. However, MWG also acknowledges that the experimental irrigation shutdown was too short to conclusively define these effects. Montgomery Water Group did not consider Meadowbrook and Cassalery creeks dependent upon irrigation (although neighboring residents have contacted Clallam County regarding loss of head in Cassalery Creek; Ann Soule, pers. comm. 2001). They were therefore considered to be unaffected. Spill from the irrigation network would continue into Johnson Creek. Irrigation water conveyance would also be reduced in McDonald and Matriotti creeks.

Prior to 1996, 29.3 miles of the total irrigation system length of 163 miles had been "tightlined," or converted from open ditch conveyance to piped conveyance. Since that time, an additional 104,000+ feet (~19.7 miles) of irrigation ditches have been tightlined, representing about 1/3 of the maximum remainder possible (not all of the system is feasible for tightlining) and about 40% of the feasible remainder. (pers. comm. Jeldness, June 2003).

Subsurface Inflow

Water moves into the groundwater system as subsurface inflow into unconsolidated deposits, primarily along their southern boundary with bedrock. Subsurface inflow may occur as near-surface flow through soils and through the veneer of unconsolidated bedrock into the shallow aquifer (only the shallow aquifer extends to the Thomas et al southern study boundary). Subsurface inflow also may enter groundwater vertically, from bedrock underlying the unconsolidated deposits in the Sequim-Dungeness area into the hydrogeologic units directly over the bedrock. Thomas et al (1999) did not estimate vertical inflow. Average annual lateral subsurface inflow to the Thomas et al study area was estimated to be 23 cfs. Pacific Groundwater Group estimated recharge from bedrock aquifers at 35.4 cfs (MWG 1999).

Leakage from Streams

Leakage from streams provides an additional pathway for surface water inputs (e.g., from precipitation) to enter groundwater. Thomas et al found that this leakage generally occurred in the southern part of their Sequim-Dungeness area (and possibly in the portion of East WRIA 18 extending further south), where water levels in streams are higher than the water table. They estimated average annual leakage from the Dungeness River (during their study period) at 28 cfs, and considered leakage from other streams negligible (only upper Bear Creek, at 0.12 cfs, had measured losses). The Dungeness River had two reaches in which Thomas et al measured losses: between the USGS gaging station and the railroad bridge (16 cfs), and between Woodcock Road and Schoolhouse Road (12 cfs). Simonds and Sinclair (2002) later measured gains and losses in five Dungeness River reaches, and found that the river lost water above about RM 3.7, but that gains occurred in three localized reaches below RM 3.7 (they also found small gains in seepage results between RM 8.1 and RM 5.5, but losses in the same reach as measured by mini-

piezometers). Conductivity values ranged from 1 to 29 feet per day and were not converted to cfs equivalents.

Septic Recharge

Pacific Groundwater Group estimated an average 2.38 cfs annual recharge to groundwater from septic systems (in the Drost groundwater study area covering Siebert Creek east to the west shore of Sequim Bay, from the Strait south to federal lands) based on 70% of estimated residential water use (350 gallons per day (gpd) per household), plus an estimated 30 inches per year application of treated wastewater from the Sunland residential development (applied to a 30-acre area) (MWG 1999).

Critical Aquifer Recharge Area

Recognizing these sensitive recharge dynamics, Clallam County and other local governments have worked to establish Critical Aquifer Recharge Areas (CARAs) which enables closer attention to and management options for protecting and improving recharge conditions. Figures 2.1-6a and 6b present lands designated by Clallam County as CARAs.

Figure 2.1-6a

Critical Aquifer Recharge Areas East WRIA 18

1 0 1 Miles

Strait of Juan de Fuca
Small Tributaries

Inner
Dungeness
Bay

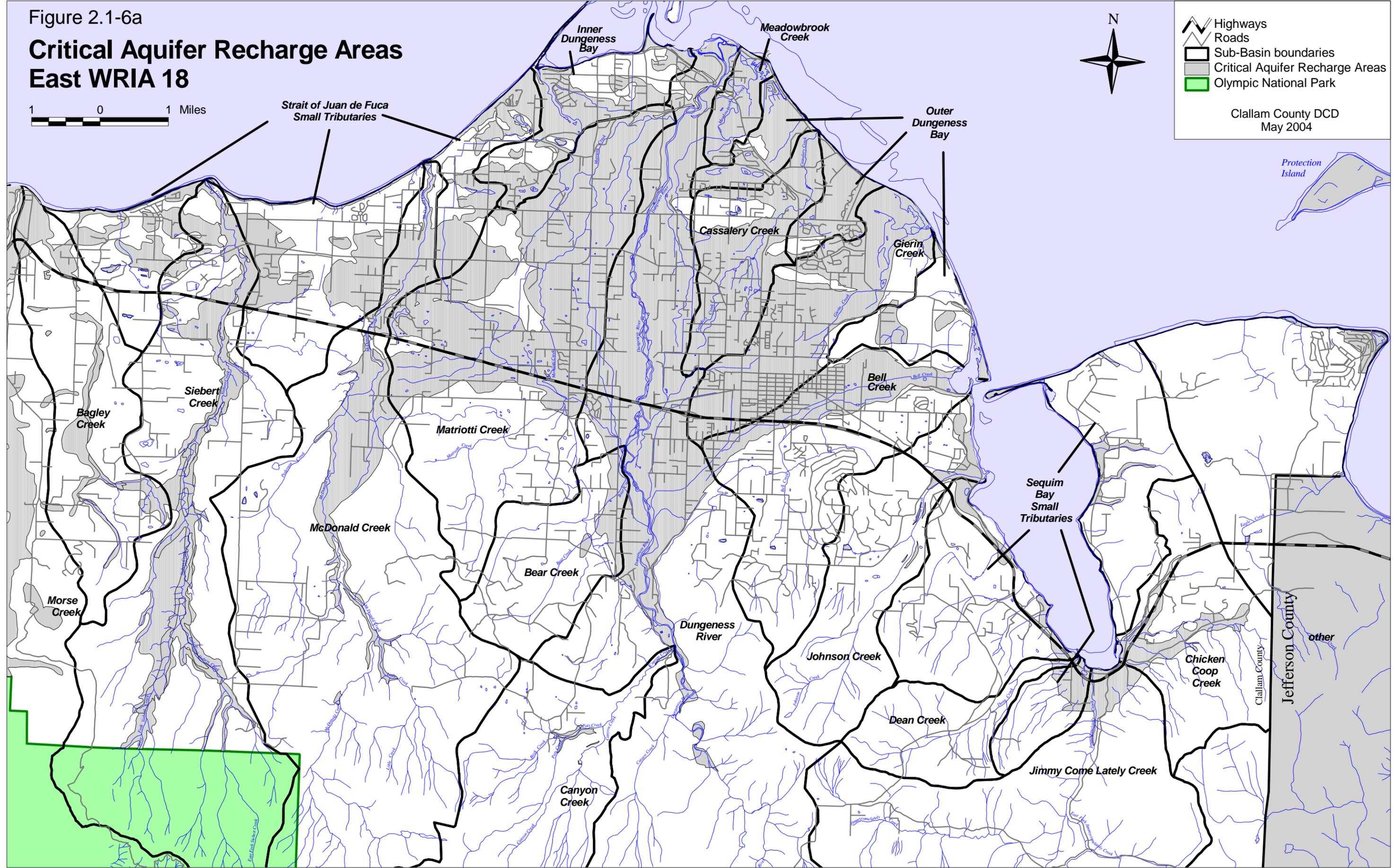
Meadowbrook
Creek



- Highways
- Roads
- Sub-Basin boundaries
- Critical Aquifer Recharge Areas
- Olympic National Park

Clallam County DCD
May 2004

Protection
Island



This page intentionally left blank.

Figure 2.1-6b

Critical Aquifer Recharge Areas West WRIA 18

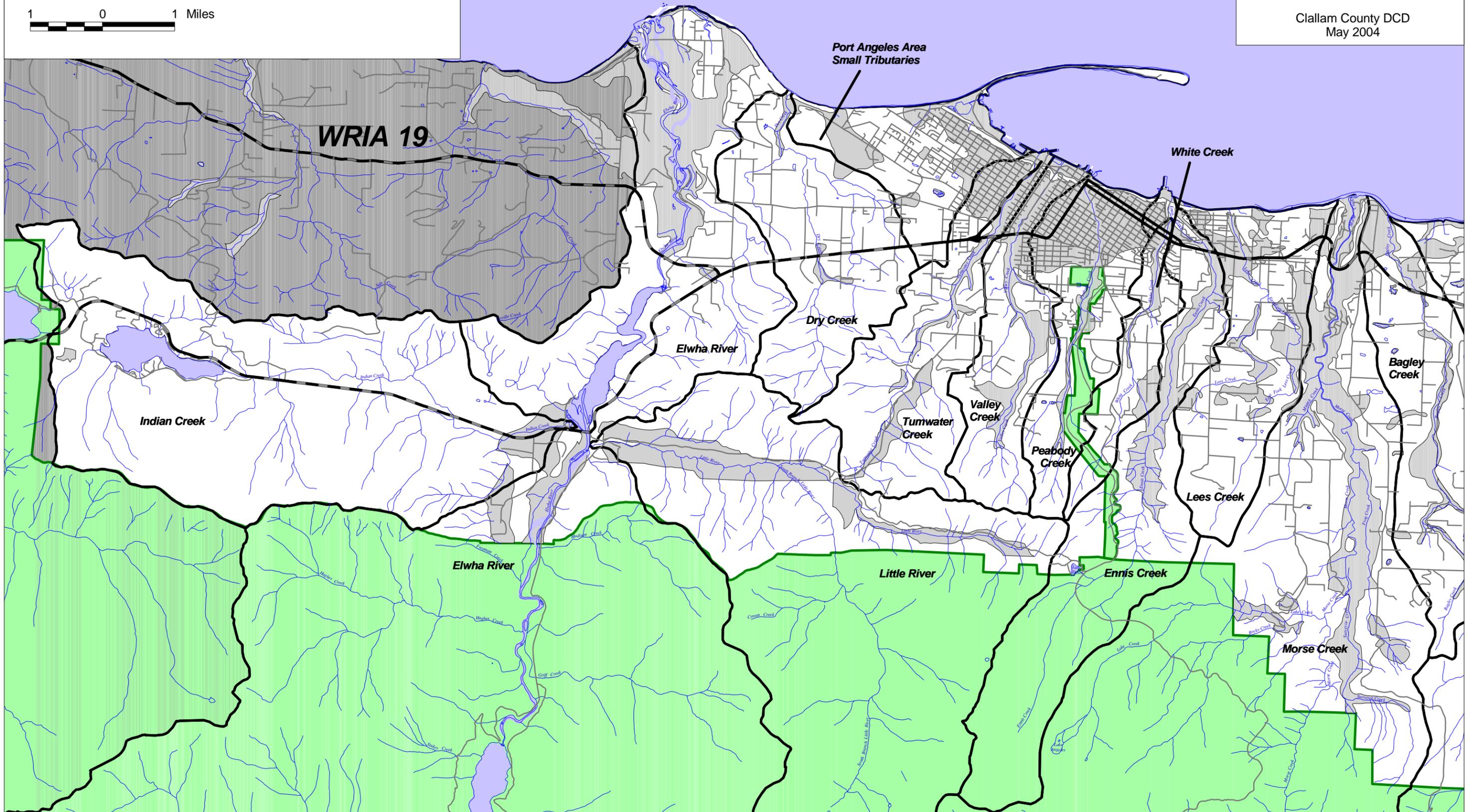
1 0 1 Miles

Strait of Juan De Fuca



- Highways
- Roads
- Sub-Basin Boundaries
- Critical Aquifer Recharge Areas
- Olympic National Park

Clallam County DCD
May 2004



This page intentionally left blank.

Return Flows

A significant portion of water withdrawn is returned to ground or surface freshwaters or discharged to marine waters after use. Significant sources of return flows in WRIA 18 and their estimated volumes are:

- **Irrigation recharge** to groundwater from percolation of unused water and leakage from ditches. Thomas et al (1999) estimated irrigation recharge to groundwater in their East WRIA 18 study area at 3.1 inches (26 cfs).
- **Irrigation tailwaters** discharge to freshwater at six locations, and ranged from 0.7 to 8.2 cfs during the 2001 irrigation season (WUA 2001). As a proportion of total outtake, tailwaters ranged from 4 to 12%.
- **Septic system recharge** to groundwater returns about 70% of indoor household use. For the WRIA 18 population not served by public sewer systems, this amounted to about 841 MGY or 2581 acre-feet/year (equivalent to a sustained annual flow of 3.57 cfs if it all contributed to stream baseflow).
- **Treated wastewater** discharged to Port Angeles Harbor by the City of Port Angeles
- **Reused water** produced by the City of Sequim. Plant design capacity is 0.67 MGD, which is applied to irrigate City public lands, discharged to Bell Creek (0.2 cfs).
- **Reused water** produced by the Sunland project, amounting to 130,000 gallons per day infiltrated to recharge groundwater.
- **Nippon industrial effluent** discharged to the Strait of Juan de Fuca, which averages 8 to 9 MGD (about 95% of Nippon water use) (Dean Reed, pers. comm. February 6, 2003).

Water Quality Constraints to Water Present and Available

Water quality does not at present constrain the quantity of water available for use in WRIA 18. There are areas with elevated nitrate concentrations and wells with unacceptable chloride levels, but neither nitrates nor seawater intrusion have compromised water supplies in general (see discussion of water quality for further detail).

2.1.6 Biology

The *Clallam County Profile* (CCDCD 1992, PSCRBT 1991 and USFS 1995) provides general descriptions of native vegetation, fish, and wildlife. Flora and fauna found throughout WRIA 18 are discussed at length in the EIS for restoration of the Elwha River (USDI et al 1996). Detailed lists of plant and animal species known to occur in the Sequim-Dungeness area are appended to the SEPA Checklist prepared for the WUA *Comprehensive Water Conservation Plan* (See MWG 1999: Appendix F).

Vegetation

Prior to European exploration, WRIA 18, and the Olympic Peninsula generally, was heavily forested to the saltwater edge, except for occasional meadows, prairies, open water, and wetland areas. Western red cedar and Douglas fir were the dominant conifer tree species.

Western hemlock was scattered in all native conifer stands. The climax forests of western red cedar, western hemlock, and Sitka spruce are renowned for producing trees of impressive size. Old-growth stands are primarily confined to public lands. Pre-climax, long-lived Douglas fir is abundant on elevations less than 3000 feet and in the drier areas. Western red cedar occurs principally on wet flatlands and valley bottoms, and Sitka spruce is confined almost exclusively to the western peninsula lowlands (west of WRIA 18), which receive abundant rainfall and summer fog. Western hemlock is dominant on the wetter west side. Higher elevations support subalpine fir, mountain hemlock, Alaska yellow cedar, and scattered pockets of Engelmann spruce. Deciduous hardwoods are found within the conifer stands, primarily in riparian zones such as stream corridors and wetlands, including red alder, bigleaf and vine maples, willow, and black cottonwood. Pacific madrona, a broadleaf evergreen, also grows at lower elevations. The Olympic Peninsula has great wetland diversity and supports more rare plant species than any other part of the state. The presence of glacial refugia from the Vashon glaciation and of the Olympic rain shadow has resulted in a particularly unusual vegetative community in the dry coastal areas of the East WRIA 18 area where drought-tolerant plants such as prickly-pear cactus, Rocky Mountain juniper, and lodgepole pine are present.

Riparian Areas

The DQ Plan (1994) summarizes the importance of riparian areas in maintaining suitable salmonid habitat (being updated in *Recommended Land Protection Strategies for the Dungeness Riparian Area*. Draft, May 2003, by Hansi Hals and the Dungeness River Restoration Work Group, Prepared for Dungeness River Management Team). Important functions and values include:

- *Stabilizing stream banks from erosion:* large trees provide local channel stability and resist erosional forces, allowing other vegetative layers to develop, binding soil in root structures, and improving bank stability.
- *Providing cover for hiding and resting:* undercut banks and large woody debris (LWD) fall in or hang over streams, often forming pools in which fish can rest, hide, and feed. Off-channel habitats are similarly created and maintained by LWD, and overhanging vegetation provides structural cover to protect juveniles from predators and to allow separation from competitors.
- *Affording access to habitat:* LWD can create step pool habitat along steep gradients, allowing fish to reach upper streams through a series of small jumps rather than swim long distances against a swift current.
- *Spawning gravel:* The presence of LWD in channels helps to sort, clean, and stabilize spawning gravels.
- *Moderating stream temperatures:* Riparian shading helps attenuate both winter and summer stream temperatures. This is particularly important when lethal temperatures are approached or exceeded. Reducing temperature improves resistance to disease and infection. Warm temperatures can block salmonid up-migration, delay out-migration, and direct spawning to less preferred habitats.
- *Capturing sediments:* Water quality and spawning gravel improve as sediment is trapped by bank vegetation. The riparian zone buffers polluted upland runoff, such as phosphorous and nitrogen from fertilizers and heavy metals from urban

and road runoff. The velocity of surface runoff is slowed in passing through riparian vegetation; sediments settle out. Riparian plants also take up nutrients that would discharge into the stream if no riparian buffer was available.

- *Energy dissipation:* Bank vegetation and LWD obstruct flow and absorb stream energy. Overbank flows lose velocity against riparian trees and shrubs; LWD slows channel velocity locally; the scouring of beds and banks also absorbs energy. When energy is dissipated gradually along the stream, erosion is minimized.
- *Moderating flood flows:* Flood flows are attenuated as riparian corridors reduce velocity and trap sediments. Stream banks built from sediments provide rooting medium and improve stability. Both recharge and discharge to groundwater are affected. Bank-building and riparian vegetation establishment effectively raises the water table, increasing wet season storage and dry season flow. Perennial flow can be reestablished or maintained with adequate riparian vegetation.
- *Providing food:* Terrestrial insects, a key food for juvenile salmonids, fall into the stream from overhanging vegetation. Leaf litter and large organic debris also support terrestrial and aquatic arthropods. As litter and debris decompose, nutrients are provided for other organisms.

Haring (1999) provides a concise overview of riparian functions and importance, noting that the riparian zone consists of the areas of living and dead vegetative material adjacent to a stream. They extend from the edge of the average high water mark of the wetted channel toward the uplands to a point where the zone ceases to have an influence on the stream channel. Riparian forest characteristics in ecologically healthy watersheds are strongly influenced by climate, channel geomorphology, and where the channel is located in the drainage network. Large-scale natural disturbances (fires, severe windstorms, debris flows) can dramatically alter riparian characteristics. These natural events are typically infrequent, with recovery to healthy riparian conditions normally requiring extended periods of time following the disturbance event. The width of the riparian zone and the extent of the riparian zone's influence on the stream are strongly related to stream size and drainage basin morphology. In a basin unimpacted by humans, the riparian zone would exist as a mosaic of tree stands of different acreage, ages (e.g. sizes), and species. Functions of riparian zones include providing hydraulic diversity, adding structural complexity, buffering the energy of runoff events and erosive forces, moderating temperatures, and providing a source of nutrients. They are especially important as the source of LWD in streams which directly influences several habitat attributes important to anadromous species. In particular, LWD helps form and maintain the pool structure in streams, and provides a mechanism for sediment and organics sorting and storage upstream and adjacent to LWD formations. Pools provide a refuge from predators and high-flow events for juvenile salmon, especially coho that rear for extended periods in streams.

Haring (1999) also summarized the effects of human activities on riparian zones noting that they are impacted by all types of land use practices. In general, riparian forests can be completely removed, broken longitudinally by roads and laterally by bridges and culverts, and their widths can be reduced by land use practices. Further, species composition can be dramatically altered when native, coniferous trees are replaced by exotic species, shrubs, and deciduous species. Deciduous trees are typically of smaller diameter than coniferous forests and decompose faster than conifers, so they do not persist as long in

streams and are vulnerable to washing out from lower magnitude floods. Once impacted, the recovery of a riparian zone can take many decades as the forest cover reestablishes, and coniferous species recolonize. Changes to riparian zones affect many attributes of stream ecosystems. For example, stream temperatures can increase due to the loss of shade, while streambanks become more prone to erosion due to elimination of the trees and their associated roots. Perhaps the most important impact of riparian changes is a decline in the frequency, volume, and quantity of LWD due to altered recruitment from forested areas. Loss of LWD results in a significant reduction in the complexity of stream channels including a decline of pool habitat, which reduces the number of rearing salmonids. Loss of LWD affects the amount of both overwintering and low flow rearing habitat, as well as providing a variety of other ecological functions in the channel.

West WRIA 18

There have been limited studies or inventories of riparian resources in West WRIA 18 other than the work of Haring (1999) in the Limiting Factors Analysis. That document provides stream-specific discussions of riparian zones. They are provided in the stream-specific sections of this chapter, below. In addition to Haring, Valley Creek has had riparian inventory work done by Frisch (2002) and McHenry & Odenwaller (1998).

East WRIA 18

Riparian resources are inventoried along the Dungeness River and in the smaller stream corridors of East WRIA 18 in the USFS *Dungeness Area Watershed Analysis* (DAWACT 1995). Riparian reserve widths are defined and mapped for the Dungeness River and smaller streams and wetlands. The streams are classified according to their large woody debris recruitment potential, estimated percent cover by various tree types, and estimated percent shade cover. Clearcut timber harvest and road density in riparian zones are reported by drainage. The Limiting Factors Analysis for WRIA 18 (Haring 1999) also provides an assessment of riparian condition for each subbasin in East WRIA 18. The LFA notes a widespread loss of riparian function in WRIA 18 due to removal and alteration of natural riparian vegetation.

Wildlife

A total of 60 species of mammals, 21 species of amphibians and reptiles, 82 species of resident birds, and 220 migratory bird species have been identified on the Olympic Peninsula. Large mammals include Roosevelt elk, black bear, mountain lion, bobcat, coyote, mountain goat, black-tailed deer, and mule deer.

Federally listed wildlife species known or with potential to occur in WRIA 18 include the bald eagle, marbled murrelet, and northern spotted owl (all threatened). Candidate and state-listed species include an amphibian (Van Dyke's salamander), several birds (common loon, golden eagle, Brandt's cormorant, Northern goshawk, Vaux's swift, Lewis woodpecker, pileated woodpecker, purple martin, and western bluebird), and two mammals (sea otter and fisher).

Anadromous and Freshwater Fish

Overview of Salmonid Habitat Requirements

Pacific salmon are anadromous species, emerging as fry and rearing in fresh water, migrating as smolts out to sea, and returning as adults back from the ocean to their natal streams to spawn. Chinook and coho juveniles rear in fresh water up to one year before emigrating, whereas chum and pink require little or no fresh water rearing and migrate to sea almost immediately upon emerging from the spawning gravel. Salmon development is directly related to temperature, which affects the timing of hatch, emergence from spawning gravel beds, growth and migration, including both the timing and the route taken. **Table 2.1-6** gives the range of spawning temperature preferences for each species of concern within WRIA 18.

Table 2.1-6. Temperature Preferences and Lethal Limits for WRIA 18 Salmonids.

Species	Temperature (°C)		
	Spawning	Incubation	Lethal Limit
Chinook	5.6 - 13.9	5.0 - 14.4	21
Coho	4.4 - 9.4	4.4 - 13.3	21
Chum	7.2 - 12.8	4.4 - 13.3	21
Pink	7.2 - 12.8	4.4 - 13.3	21
Steelhead	3.9 - 9.4		21
Cutthroat Trout	6.1 - 17.2		21

Source: Orsborn and Ralph 1994 modified by P. Crain (pers. comm. April, 2003)

The WRIA 18 LFA summarizes “broad consensus” that salmon require (Haring 1999):

- cool, clean, well-oxygenated water;
- instream flows that mimic the natural hydrology of the watershed, maintaining adequate flows during low-flow periods and minimizing the frequency and magnitude of peak flows (stormwater);
- clean spawning gravels not clogged with fine sediment or contaminated with toxic materials;
- presence of instream pools that will support juvenile rearing and resting areas for returning adults;
- abundance of instream large woody debris, particularly large key pieces that provide cover, create pools, and provide habitat diversity;
- free, unobstructed migration for juveniles and adults to and from the stream of origin;
- broad, dense riparian stands of mature conifer that provide cover, shade, LWD recruitment; and
- estuarine conditions that support production of prey organisms for juvenile outmigrants as well as for juvenile salmonid rearing and for returning adults.

Other characteristics of highly productive salmon streams have been identified to include:

- Abundant instream food supplies;
- Suitable substrate for insect production; and
- Stable stream configuration.

Table 2.1-7 summarizes these requirements as they apply to WRIA 18 streams in order to present an overall assessment of the severity of the principal habitat-limiting factors affecting salmonid stocks.

The LFA (Haring 1999) contains useful background chapters discussing the relative role of habitat in healthy populations of natural spawning salmon and of habitat limiting factor elements. The limiting factor elements discussion treats fish passage barriers; floodplain functions and human impairment of floodplains; streambed sedimentation and human effects on sediment processes; riparian zones and human impacts; water quantity; and estuarine habitat.

Fish Occurrence and Distribution

Anadromous fish include chinook, coho, chum, and pink salmon, and steelhead. Native resident freshwater fish include bull trout, a species of char, as well as brook, cutthroat, and rainbow trout, and whitefish. The Olympic mud minnow is also known to occur. Most resident fish thrive upstream from anadromous fish barriers. Table 2.1-8 shows the distribution of the more prevalent salmonid species with East WRIA 18 rivers and streams (those locations reported by other sources, but not confirmed by Haring 1999, are denoted with question marks). Table 2.1-9 shows general timing of salmon life stages. Haring (1999, Table 4) provides a detailed table documenting salmon and steelhead presence on a stream-by-stream basis, including GIS reference, WRIA codes, uppermost extent, source, and comments.

Native stocks use habitat in the Dungeness and smaller streams, as well as the estuarine and nearshore marine waters within the WRIA. In terms of production, the DQ Plan (1994) notes the importance of the many small creeks, streams, wetlands and sloughs to the total abundance of salmon.

Salmonid distribution is not entirely well documented in the rivers and streams of WRIA 18. The 1994 DQ Plan cautions that the distribution of salmonids seen in the region today is not necessarily representative of their pre-European distributions. Haring (1999) states that historic distribution may be significantly influenced simply by the total numbers of fish, with less area used as abundance declines. Most current distribution information is based on stock assessment work beginning about 1965 to 1970, and may represent a more confined distribution than occurred historically. In general, the geographic distribution of suitable habitats for salmonids has been sharply curtailed, and they are not as widely distributed as they once were.

Table 2.1-7. Assessment of Habitat Limiting Factor Severity for Major Salmonid-Bearing Watersheds within WRIA 18.

Stream	WRIA Index	Fish Access	Floodplain Connectivity	Channel Conditions			Riparian Condition	Water Quality			Hydrology		Estuarine	Lack of Nutrients
				LWD	Pools	Substrate		Temp/DO*	Fecal*	Toxics*	Peak Flow	Low Flow		
Bell Creek	18.0001	DG	NA	P2	P2	P2	P2	P1	P1	DG	F2	P2	F2	DG
Gierin Creek	18.0004	G2	G2	P2	P2	P2	G2	G1	DG	DG	G2	G2	F2	DG
Cassalery Creek	18.0015	P1	G2	P1	P1	F2	P1	F-G1	P1	DG	G2	G2	P2	DG
Cooper Creek	18.0017	P2	G2	P2	P2	P2	P2	P-G1	F1	DG	G2	G2	P2	DG
Dungeness River	18.0018	F2	P1	P1	P1	P1	P-F1	P1	G2	DG	P2	P1	P2	DG
Meadowbrook Cr.	18.0020	G2	G2	P2	P2	P2	P2	P1	P1	DG	G2	G2	NA	DG
Matriotti Creek	18.0021	F2	G2	P2	P2	P2	P1	P1	P1	DG	G2	G2	NA	DG
Hurd Creek	18.0028	F2	G2	P2	F2	F-G2	F2	P2	?	DG	NA	NA	NA	DG
Bear Creek	18.0030	F2	P2	P2	P2	F2	F2	G2	DG	DG	P2	P2	NA	DG
Canyon Creek	18.0038	P2	P2	P-F2	P-G2	P-G2	P-G2	G2	DG	DG	DG	DG	NA	DG
Gray Wolf River	18.0048	G2	G2	F2	F2	G2	G2	G2	G2	DG	G2	G2	NA	DG
Gold Creek	18.0121	P2	P2	F2	P2	P2	P2	DG	DG	DG	P2	NA	NA	DG
McDonald Creek	18.0160	G2	F2	P1	P-F1	P1	F2	P-F1	F1	DG	F2	NA	G2	DG
Siebert Creek	18.0173	G2	G2	P1	P1	P1	G2	F1	G1	DG	P2	G2	G2	DG
Bagley Creek	18.0183	P1	F2	F2	P2	P2	F2	G2	P1	DG	P2	NA	G2	DG
Morse Creek	18.0185	G2	P2	P2	P1	P1	F2	DG	DG	P2	P2	G2	P2	DG
Lees Creek	18.0232	P2	G2	P2	P2	P2	P2	G1	G1	F3	F2	NA	F2	DG
Ennis Creek	18.0234	F1	P2	P2	P-G2	F2	G2	DG	DG	P2	G2	G2	P2	DG
Peabody Creek	18.0245	P1	P2	P2	P2	P2	P2	DG	DG	P3	P2	F2	P2	DG
Valley Creek	18.0249	P3	P3	P3	P3	P3	P3	G3	F3	DG	P1	F2	P2	DG
Tumwater Creek	18.0256	F2	P2	P2	P2	P2	F2	DG	DG	DG	P2	DG	P2	DG
Dry Creek	18.0265	G2	F2	P2	P2	P2	F2	P1	DG	DG	P2	P2	F2	DG
Elwha River	18.0272	P1	F2	P2	F2	P1	G2	P1	DG	G2	G2	G2	F2	P1
Bosco Creek		G2	F2	G2	G2	F2	F2	G2	DG	DG	DG	F2	NA	DG

* Clallam County may have water quality data that has not been incorporated in this document; Source: Haring 1999.

Habitat Condition Ratings

G = Average habitat condition considered to be good for the listed watershed

F = Average habitat condition considered to be fair for the listed watershed

P = Average habitat condition considered to be poor for the listed watershed

DG = Data Gap

Basis for Designated Habitat Condition Rating

1= Quantitative studies or published reports documenting habitat limiting factor.

2= Personal experience of TAG members.

3= Reports by TAG members not based on personal experience.

Table 2.1-8. Distribution of Salmonid Species in WRIA 18

East WRIA 18						
Stream	Chinook	Coho	Chum	Pink	Steelhead	Cutthroat Trout
Bagley		X			X	X
Bear		X	Fall		Winter	X
Beebe		X	Fall	lower	Winter	X
Bell		X	Fall?		Winter	X
Cameron	Spring/Summer	X		upper		X
Canyon		X		upper	Winter	X
Cassalery		X			Winter	X
Chicken Coop		X				X
Cooper		?	Fall?		Winter?	X
Dean		X			Winter?	X
Duncan Slough		X				
Dungeness River	Spring/Summer	X	Fall, Summer	upper,lower	Summer, Winter	X
Gierin		X			Winter?	X
Gold		X		upper	Winter	X
Grand	Spring/ Summer	X		upper	Summer, Winter	X
Gray Wolf	Spring/ Summer	X	?	upper	Summer, Winter	X
Hurd		X	Fall, Summer	lower	Winter	X
JCL		X	Summer		Winter	X
Johnson		X			Winter	X
Lotzgesell		X			Winter	X
Matriotti		X	Fall, Summer	lower	Winter	X
McDonald		X	Fall (E?)		Winter	X
Meadow	Spring/ Summer	X	Fall	lower	Winter	X
Meadowbrook		X	Fall?		Winter	X
Mud		X			Winter	X
Siebert		X	Fall (E?)		Winter	X
Woodcock		X			Winter	X
West WRIA 18						
Stream	Chinook	Coho	Chum	Pink	Steelhead	Cutthroat Trout
Elwha River	Spring* ,Summer/ Fall	X	Summer, Fall	upper, lower	Summer, Winter	X
Indian Creek* **	Summer/ Fall	X	Fall	upper	Winter	X
Little River**	Summer/ Fall	X	Fall	upper	Winter	X
Dry Creek		X (E?)			Winter (E?)	X
Tumwater Creek		X	Fall (E?)		Winter	X
Valley Creek		X			Winter	X
Peabody Creek		X (E?)			Winter (E?)	X
White Creek		X	Fall (E?)		Winter	X
Ennis Creek		X	Fall (E?)		Winter	
Lees Creek		X (E?)			Winter (E?)	X
Morse Creek	Spring/ Summer (E?)	X	Summer, Fall***	X	Summer, Winter	X

* Indian Creek/Lake Sutherland currently contain kokanee, which are expected to eventually resume as a Sockeye stock, once the dams are removed

** Distribution for Elwha Spring Chinook, Indian Creek, and Little River are as projected following dam removal

*** A Summer chum run for Morse Creek is inferred from limited observations, in spite of the lack of targeted surveys

Sources: Washington Department of Ecology 1997, Montgomery Water Group 1999, Haring 1999

Table 2.1-9. Timing of Life History Stages for Anadromous Salmonids in WRIA 18.

Species	Life Stage	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook	Migration												
	Spawning												
	Rearing												
	Incubation												
Pink	Migration												
	Spawning												
	Rearing												
	Incubation												
Coho	Migration	W								H	H	W	W
	Spawning												
	Rearing												
	Incubation												
Summer Chum	Migration												
	Spawning												
	Rearing												
	Incubation												
Fall Chum	Migration												
	Spawning												
	Rearing												
	Incubation												
Summer Steelhead	Migration												
	Spawning												
	Rearing												
	Incubation												
Winter Steelhead	Migration												
	Spawning												
	Rearing												
	Incubation												
Char	Spawning												
	Rearing												
	Incubation												

Main activity
 Some occurrences
 H = Hatchery run
 W = Wild run

Source: Haring 1999, revised by Entrix 2003

Haring (1999) also notes stream gradient breaks above which salmon are presumed not to occur. For chum, the break occurs at a sustained 8% gradient; for other species of salmon and steelhead, the break is assumed to occur at a sustained 12% gradient.

Declines and Listings

Salmonid stocks and species are in serious decline throughout WRIA 18. NOAA Fisheries has listed Hood Canal summer chum and Puget Sound spring Chinook as threatened under the ESA. Dungeness River Chinook are part of the Puget Sound Chinook Evolutionarily Significant Unit (ESU). Summer chum is also listed for JCL Creek (threatened, as part of Hood Canal summer chum ESU) and bull trout is listed as threatened by the USFWS. The Olympic mud minnow is a candidate species.

Other salmonid stocks are listed in critical condition locally by the WDFW. Pink salmon stocks, though critically depressed and at risk of extinction on the Dungeness, are not listed under the ESA because the stock is not considered genetically distinct from Puget Sound pink salmon (which does not qualify for listing). The upper and lower Dungeness pink salmon stocks, the Dungeness spring/summer Chinook, and the Dungeness summer and winter steelhead stocks are all critical or potentially critical. Figure 2.1-7 and Table 2.1-10 summarize state and federal status for all fish stocks within WRIA 18.

Haring (1999) updates the WDFW Salmon and Steelhead Stock Inventory (SASSI) (WDF et al 1993), and contains detailed data as to the runs, abundance, timing, and distribution of salmonids. Haring (1999) also provides graphs showing escapements and redd counts for WRIA 18 salmon and steelhead stocks over the period of record (1968-1999). Drawing on these sources, a species-by-species overview is provided as part of the discussion of salmonid stocks in the Dungeness (see Section 2.8.6).

Salmon Recovery

The WRIA 18 Limiting Factors Analysis (LFA) contains useful background discussing the relative role of habitat in healthy populations of natural spawning salmon and habitat limiting factor elements (Haring 1999). The limiting factor elements discussion treats fish passage barriers; floodplain functions and human impairment of floodplains; streambed sedimentation and human effects on sediment processes; riparian zones and human impacts; water quantity; and estuarine habitat. The NOPL Strategy (2001), drawing on the LFA and other information, provides the following ranking of salmonid productivity potential as a guide for habitat restoration throughout WRIA 18:

- Highest potential (Tier 1): Elwha and Dungeness rivers (including tributaries), Morse Creek
- Moderately High potential (Tier 2): Jimmycomelately Creek
- Moderate potential (Tier 3): Valley, Bagley, Siebert, McDonald, Meadowbrook, Cooper, Cassalery, Gierin, and Bell creeks
- Lower potential (Tier 4): Dry, Tumwater, Peabody, White, Ennis, and Lees creeks

Figure 2.1-7. WRIA 18 Salmon Stock Status. PLEASE SEE SEPARATE FILE.

This page intentionally left blank.

Table 2.1-10. WRIA 18 Salmon and Steelhead Stock Designations and Associated Status.

Stock	WDFW SASSI Status (1992)	Haring Updated Status Recommendation (1999)	ESA Listing Status, Date
Dungeness Spring/Summer Chinook	Critical	Critical	Threatened, 3/24/99
Elwha/Morse Creek Summer/Fall Chinook	Healthy	Depressed/Critical	Threatened, 3/24/99
Elwha Spring Chinook	Not Identified as Distinct Stock	Critical/Extinct	Threatened, 3/24/99
Dungeness Summer Chum	Not Identified as Distinct Stock	Depressed/Critical	Threatened, 3/25/99
Dungeness River/East Strait tribs Fall Chum	Unknown	Critical	Not Warranted
Elwha Fall Chum	Unknown	Critical	Not Warranted
Dungeness Coho	Depressed	Depressed	Candidate, 7/14/97
Morse Creek Coho	Depressed	Depressed	Candidate, 7/14/97
Dry Creek Coho	Not Identified as Distinct Stock	Unknown (very low numbers)	Candidate, 7/14/97
Elwha Coho	Healthy	Healthy	Candidate, 7/14/97
Upper Dungeness Pink	Depressed	Depressed	Not Warranted
Lower Dungeness Pink	Critical	Critical	Not Warranted
Morse Creek Pink	Not Identified as Distinct Stock	Depressed/Critical	Not Warranted
Elwha Pink	Critical	Critical	Not Warranted
Dungeness Summer Steelhead	Depressed	Critical	Not Warranted
Morse Creek Summer Steelhead	Not Identified as Distinct Stock	Unknown	Not Warranted
Elwha Summer Steelhead	Depressed	Critical	Not Warranted
Dungeness Winter Steelhead	Depressed	Critical	Not Warranted
Morse Creek/Independents Winter Steelhead	Depressed	Depressed	Not Warranted
Port Angeles Area Winter Steelhead	Not Identified as Distinct Stock	Unknown	Not Warranted
Elwha Winter Steelhead	Depressed	Depressed	Not Warranted
Cutthroat trout	special concern	not included	Not Warranted
Bull trout		not included	Threatened, 11/1/99

Sources: Haring 1999, MWG 1999

The LFA also states that restoration of the marine nearshore habitat should be considered a high priority. Stream reaches and other habitats identified in the LFA as important to ensure continued function of high quality salmonid habitat, or which are critical to restoration of natural floodplain function, include:

- Washington Harbor, at the mouth of Bell Creek
- Gierin Creek, particularly with respect to maintaining or restoring the integrity of Graysmarsh
- Wetland areas in lower Meadowbrook Creek
- Dungeness River habitats, including the Severson property from Highway 101 northward to about 800 feet downstream of the Railroad Bridge; the east bank of the Dungeness from Railroad Bridge upstream for approximately 2000 feet; and forested riparian and side channel habitat from Woodcock Road (Ward Bridge) upstream to Dungeness Meadows dike
- Beebe Creek, which, although artificially constructed, is considered to provide very productive habitat for chum and other salmonids and a stable habitat base in the lower Dungeness Valley where other mainstem and tributary habitat has been significantly affected
- Existing riparian habitat in the Gray Wolf Canyon to Three Forks

These areas are considered a foundation upon which habitat restoration and salmonid recovery could be most effectively built. The LFA notes that protection of still-functional salmonid habitat is typically always more cost effective and functionally effective than restoration of degraded habitat.

The LFA takes note of significant improvements made through restoration efforts on the Dungeness River and independent drainages of East WRIA 18, but cautions that instream flows may still be below recommended minimum levels and advocates for continued restoration. In particular, restoration of floodplain function in the severely constricted reaches of the lower Dungeness River (below Ward Bridge) would benefit Chinook, pink, and early chum stocks.

Introduced Species/Predation

Haring (1999) states that the presence of invasive species was not identified as a significant habitat limiting factor in the freshwater streams of WRIA 18.

Harvest

Northwest salmon fisheries are regulated by the State of Washington, Indian Tribes, and under international agreements. The Pacific Fisheries Management Council, a public forum established by the federal government, is charged with regulating ocean fisheries in federal waters off the Washington, Oregon, and California coasts. The Council meets each spring to assess the status of Chinook and coho stocks and to establish sport and commercial ocean fishing regulations for the coming season. The Council consists of state, tribal, and industry representatives from the three coastal states, plus Idaho. The National Marine Fisheries Service provides federal oversight. While the Council plans

ocean fisheries, state and tribal managers plan fisheries for state waters, creating one comprehensive fishing plan (JSKT 2000).

Fisheries managers regulate harvest based on run size, and allocate the available resource to achieve desired escapement goals. Biological, climatic, and other data are used to forecast fish production and survival. Canadian fisheries along the west coast of Vancouver Island, north shore of the Strait of Juan de Fuca, and in the Georgia and Johnstone straits intercept significant numbers of Dungeness-origin salmon as they return. Harvest levels are based on the projected surplus after escapement (the number of fish needed to spawn to insure stock maintenance) and international harvest are taken into account. Half the harvest is allocated to tribal fishers and the remainder to non-Indian commercial and sport fishers. Timing, areas open to fish, and gear are regulated to protect critical stocks. Most biologists agree that a terminal fishery, targeting specific stocks as they return to spawn, is a more effective management technique than mixed stock fisheries (JSKT 2000).

Washington Department of Fish & Wildlife

Commercial and recreational fisheries by non-Indians are conducted primarily in marine waters. No freshwater commercial fisheries are conducted by non-Indian fishermen, according to the DQ Plan (1994). Surplus hatchery coho are harvested in Dungeness Bay in a commercial net fishery. A limited freshwater recreational fishery exists in various streams throughout the region, depending on stock abundance and status.

Tribes

The landmark 1974 Boldt decision (US v. State of Washington, February 12, 1974) awarded co-management of the fisheries resource to the treaty Tribes in Washington. It also affirmed the Tribes' treaty right to take half of the harvestable surplus of salmon and steelhead passing through or returning to their "usual and accustomed fishing grounds and stations."

Three tribes have treaty fishing rights in WRIA 18: the Lower Elwha Klallam, the Jamestown S'Klallam, and the Port Gamble S'Klallam tribes. These, together with the Skokomish Tribe, are the descendants of the original signatories to the 1855 Treaty of Point No Point. Today's Point No Point Treaty Council is a fisheries management consortium formed to coordinate fishing and enforcement among the four tribes. Within the Council, the Lower Elwha Klallam Tribe has primary management responsibility for West WRIA 18, and the Jamestown S'Klallam Tribe has primary management responsibility for East WRIA 18.

Tribal fisheries occur for commercial, subsistence, and ceremonial purposes, both taking Dungeness-origin fish and intercepting other stocks migrating through the waters. A tribal commercial troll fishery is conducted in the Strait of Juan de Fuca for coho and Chinook. Surplus hatchery coho are harvested in Dungeness Bay by both treaty and non-Indian fishermen. The S'Klallam tribes have not fished for pink or Chinook salmon with nets in the Dungeness River since the Boldt decision, nor have they fished for hatchery steelhead in the river for more than 10 years (JSKT 2000).

International

The Canadian government controls salmon harvest in Canadian waters. The Pacific Salmon Treaty between the United States and Canada controls the taking of salmon as they migrate through one another's waters. The Pacific Salmon Commission meets annually to negotiate harvest shares, seasons, and regulations for the coming season.

Hatchery Production

Hatchery successes may come at the expense of wild runs (JSKT 2000). Wild fish must compete with large hatchery populations for food and habitat. Ocean fishing targeted on hatchery runs may deplete wild stocks taken incidentally.

The WDFW operates three hatcheries in WRIA 18 (two on the Dungeness system and one on the Elwha), and the Lower Elwha Klallam Tribe operates an additional facility on the Elwha. Hatchery purposes include provision of fish for recreational and commercial fishing opportunities and preservation and restoration of threatened or endangered fish species, such as salmon. This preservation/reservation purpose is served, in part, through the captive chinook broodstock program, based at the Hurd Creek facility that has been maintained for over twelve years.

The state's hatchery program is funded through state, federal, and local funds. State funds include revenues from fishing licensees; federal funds pay to help offset Columbia/Snake River dams impacts on fisheries; and local funds pay to mitigate fish impacts from municipal power utilities and public utility districts. Overall, state funding for hatcheries has declined over the past decade, and state-funded facilities tend to be in greater disrepair and have more limited staff than federally- or locally-funded facilities.

Wetlands

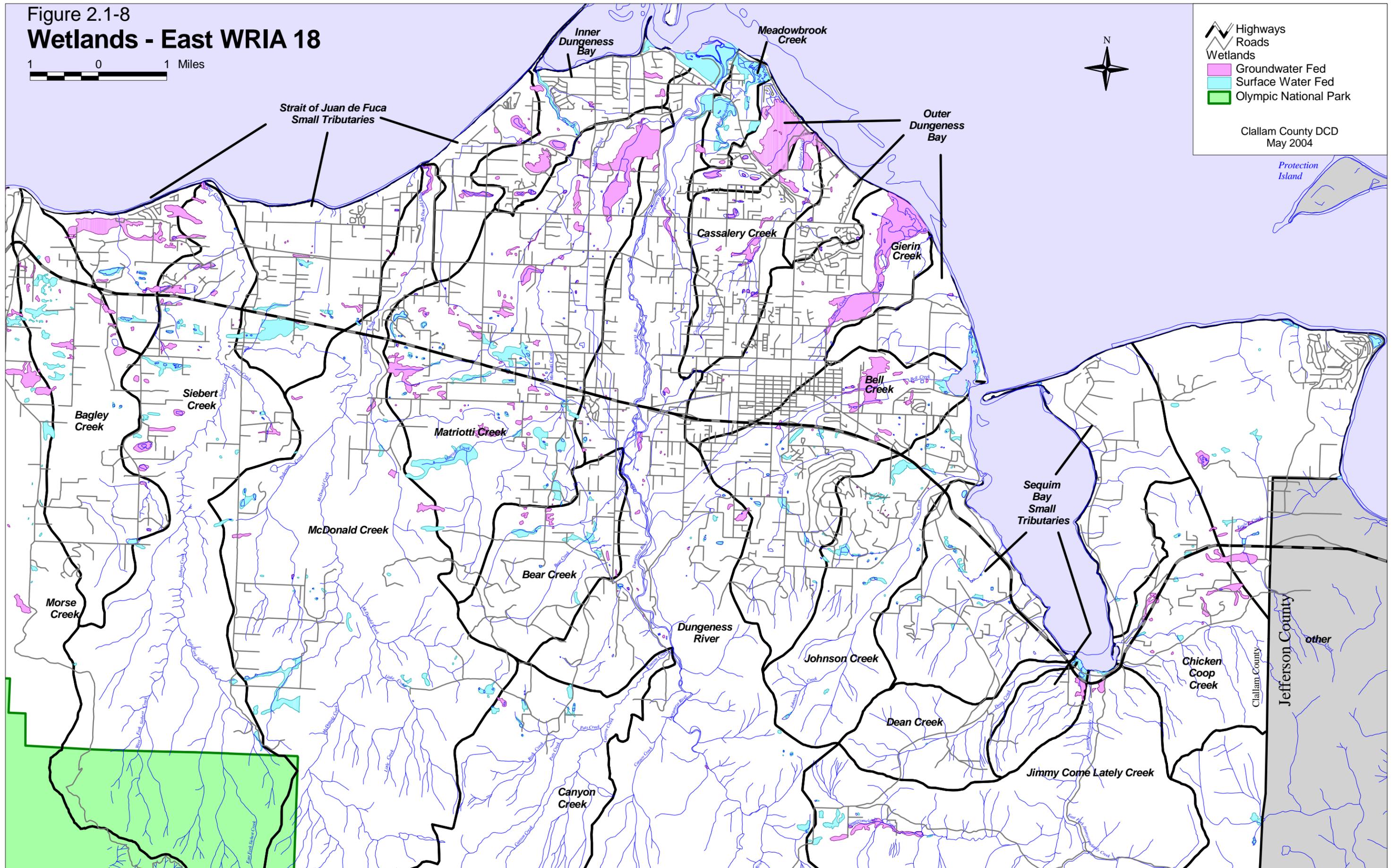
Wetlands functions and values for fish include the production of preferred food organisms and the sheltering of juveniles during their spring out-migration. Coho, which rear in freshwater for up to 18 months, are particularly dependent upon wetlands for critical overwintering habitat. Wetlands also recharge groundwater and filter contaminants out of surface water. Intertidal wetlands and nearshore shallow water habitat provide a transitional refuge for juveniles as they undergo physiological adaptation to saltwater. Food resources available in healthy wetlands are associated with high growth rates for young fish. Figures 2.1-8 and 2.1-9 show the location of wetlands in WRIA 18 East and West, respectively. More detailed wetland location information can be found at the Clallam County website at www.clallam.net.

Figure 2.1-8
Wetlands - East WRIA 18

1 0 1 Miles

- Highways
- Roads
- Wetlands
 - Groundwater Fed
 - Surface Water Fed
 - Olympic National Park

Clallam County DCD
May 2004



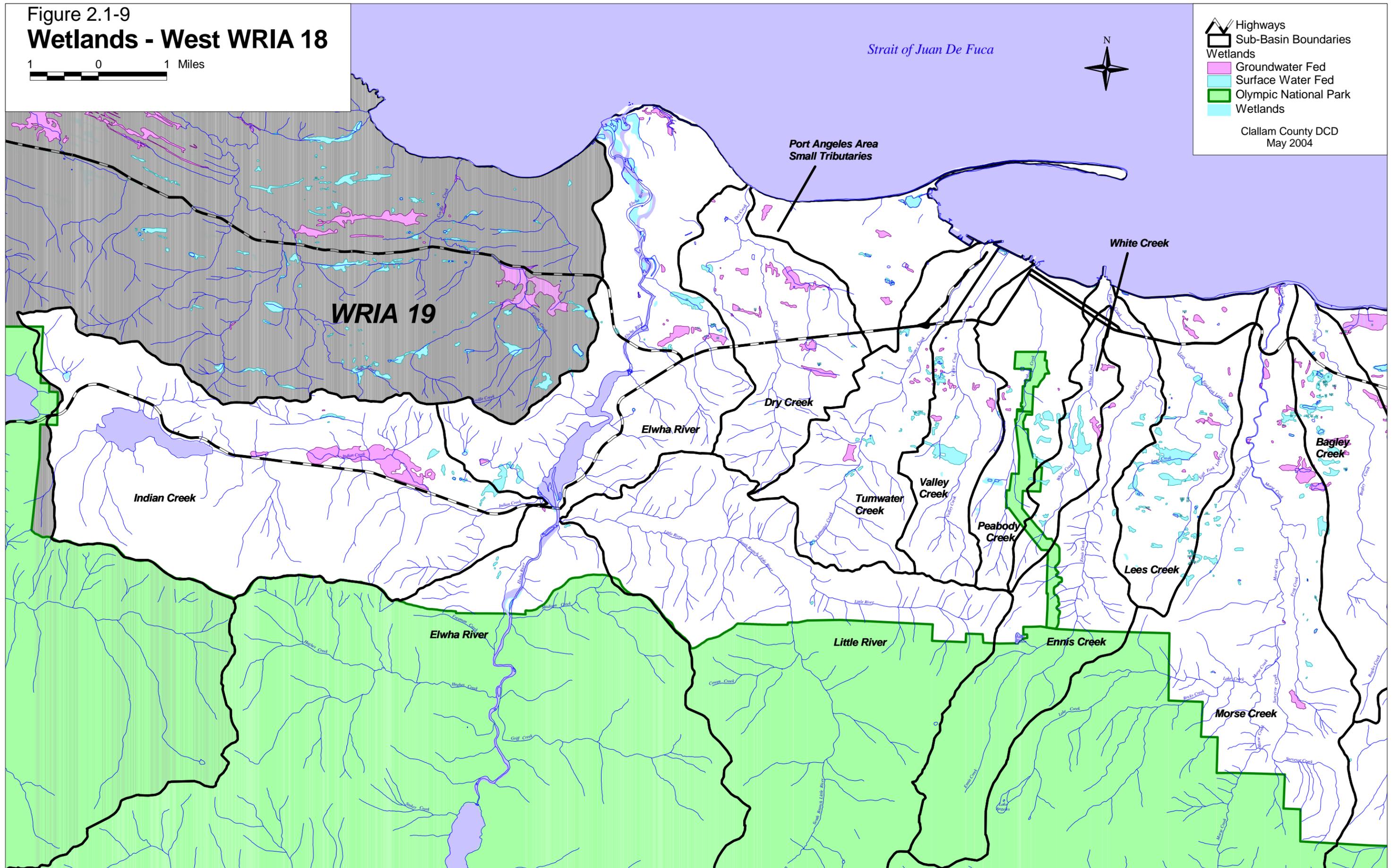
This page intentionally left blank.

Figure 2.1-9
Wetlands - West WRIA 18

1 0 1 Miles

- Highways
- Sub-Basin Boundaries
- Wetlands
 - Groundwater Fed
 - Surface Water Fed
 - Olympic National Park
 - Wetlands

Clallam County DCD
 May 2004



This page intentionally left blank.

East WRIA 18

Wetlands have been the focus of several inventories, sometimes including riparian corridors within the broad definition of wetlands. According to the *Dungeness River Area Watershed Management Plan* (DWMC and CCDCD 1993), there are 4,574 acres of wetlands in the Dungeness watershed, many of them small ponds. The CCDCD's (1995b) updated wetland inventory of the Dungeness and Sequim Bay watersheds enumerated a total of 353 regulated wetlands totaling 4,525 acres. The County also counted 174 artificially created wetlands totaling 156 acres, primarily ponds associated with irrigation ditches, gravel pits and residential landscaping. The majority of these ponds were located in areas underlain by very coarse materials deposited by streams and glacial outwash. The County states that natural wetlands generally do not form in these areas, except at groundwater discharge points. The USFS (DAWACT 1995) also reviews and maps wetlands and riparian reserve areas in the Dungeness Area Watershed.

The CCDCD's (1995b) *Assessment of Wetland Functions and Wetland Management Guidance for the Lower Dungeness River Area and Sequim Bay Watersheds* defines seven major landforms and associated hydrologic characteristics that were used to establish seven wetland hydrology types:

- (1) Perched water table, discharges to stream
- (2) Storage on till for detention/retention, initiates stream
- (3) Locally perched water table, no outflow, or outflow only during extreme storm events
- (4) Aquifer discharges to wetland
- (5) Aquifer discharges to wetland and initiates or supplements stream flow
- (6) Aquifer discharges to marine environment, tidally influenced
- (7) Perched water table, discharges to aquifer

Types 1, 2 and 7 occur on glacial till and account for 1,188 acres or 26.5% of the total. Type 3 accounts for 301 acres (6.7%) and occurs on all types of surficial geology. Types 4, 5 and 6 total 3,000 acres (65.8%) and occur on more permeable geologic units below 200 feet in elevation.

Seven habitat functional indicators were used to characterize overall wetland potential for indigenous species and habitat diversity, including habitat size and diversity, significant habitat features, plant community and upland habitat types, water availability, and management or modifications. A watershed functional assessment of the role played by wetlands within the watershed and landscape looked at floodflow desynchronization; stream flow and channel maintenance; groundwater recharge; temperature maintenance; sediment, toxicant and bacterial retention; nutrient removal and transformation; and prevention of seawater intrusion. Both the habitat and watershed functional analyses are detailed in the *Assessment* (CCDCD 1995b). The wetland inventory update, Geographic Information Systems (GIS) overlay analysis, and wetland characterization provided field confirmation of wetland locations; characterized wetlands by hydrology type; characterized fish and wildlife habitat indicators; summarized current management and known alterations; and identified conflicts between development and wetland protection.

The CCDCD's (1995b) identification of wetlands at risk included parcels entirely classified as wetlands, parcels without sufficient area for a building site, and parcels that would be filled by planned highway projects. Ten percent of all wetlands were in designated urban growth or high intensity rural zones. Management recommendations addressed water quality; fish and wildlife; wetland buffers; priorities for wetland acquisition, restoration and enhancement; mitigation of impacts; stormwater management; and other items. Elements of this *Assessment* and its management recommendations have been incorporated into the County's updated Critical Areas Ordinance.

The *Sequim-Dungeness Regional Comprehensive Plan* (CCDCD 1994, Figures 8 and 9) maps regulated wetlands. Regulated wetlands are particularly concentrated along the coastal area east of Dungeness Bay. *The Dungeness River Area Watershed Management Plan* (DWMC and CCDCD 1993) provides detail on wetlands functions and values, including:

- Water quality protection and improvement
- Storm and flood water control
- Groundwater exchange
- Habitat for fish and wildlife
- Aesthetic values
- Recreational use
- Educational opportunities

The *Dungeness River Area Watershed Management Plan* (DWMC and CCDCD 1993) counted 521 wetlands, comparable to the County's combined total of 527 natural and manmade wetlands. The Plan states that these wetlands occupy 2.6% of watershed land area, while an additional 2.7% of the watershed contains hydric soils, one of the three factors that determine wetlands. Gierin Creek has 16% of its land area in wetlands, whereas Caraco Creek, the Gray Wolf River and Royal Basin each have less than 1% in wetlands. Important wetlands profiled in the Dungeness River Area Watershed Management Plan include the area of Dungeness Spit, Graveyard Spit and Dungeness Bay; Towne Road Pothole; Cranberry Lake; Pat's Prairie; and Graysmarsh. Others are protected or planned for acquisition as county parks, including Port Williams Tide Flats, Cline Spit, and Dungeness Recreation Area.

An assessment of wetlands associated with irrigation canals within the Water Users Association is contained in Appendix D of the Comprehensive Water Conservation Plan (Montgomery Water Group 1999). The report concludes that while some of the artificial wetlands associated with use of irrigation waters would be lost, others would remain, albeit in a somewhat diminished capacity. Planned conservation improvements would eliminate wetland or riparian vegetation along 69 miles of open canal proposed to be piped (out of a total of 138 miles), and would regularly maintain the remaining 69 miles of open canal in order to remove vegetation or replace it with more drought-tolerant species.

West WRIA 18

Wetlands for much of West WRIA 18 were surveyed and summarized as part of the development of the City of Port Angeles' *Stormwater Management Plan* (Economic and Engineering Services, Inc. 1996). The plan included a complete inventory of wetlands from the Elwha River east to Morse Creek. The detailed study, found in the plan's Technical Appendix Volume II, identified 23 wetlands within the City (not including the Elwha River watershed or tributaries). It also quantified the percent acreage of wetlands in each subwatershed (Table 2.1-11).

Table 2.1-11. Wetland Acreage, Percent of Total Subwatershed, City of Port Angeles.

Subwatershed	Wetland Percent of Total Acreage
Elwha River	5%
Indian Creek	3%
Little River	<1%
Dry Creek	3%
Tumwater Creek	2%
Valley Creek	5%
Peabody Creek	3%
White Creek	7%
Ennis Creek	<1%
Lees Creek	7%
Morse Creek	2%

Source: EES 1996, Table 2-10

Nearshore/Marine Environment and Species

As noted in the North Olympic Peninsula Lead Entity (NOPLE) regional restoration plan (NOPLE 2001), the nearshore area, and estuaries in particular, are critical to juvenile Pacific salmon for feeding, rearing, and migrating. Juvenile chum and Chinook salmon, in particular, are recognized as being fundamentally dependent on nearshore ecosystems. This fact is of heightened significance to the North Olympic Peninsula, given that ESA-listed Hood Canal/Eastern Strait of Juan de Fuca summer chum salmon and Puget Sound Chinook salmon occur throughout many of our nearshore ecosystems. Chinook and chum stocks in the western Strait of Juan de Fuca, while not currently listed by ESA, are considered to be at critical or depressed levels. However, the importance of the nearshore is not restricted to chum and Chinook salmon alone. All salmon must migrate through the nearshore, both as juveniles heading to sea and as adults returning to spawn. Hence, the nearshore within the WRIA 18 planning area supports multiple species and stocks of Pacific salmon that originate not only from watersheds within this planning area, but also from outside this area. The nearshore is increasingly being recognized as a critical, year-round component of Pacific salmon life histories. It is also known that the nearshore supports the life history of forage fish species such as surf smelt (*Hypomesus pretiosus*),

sand lance (*Ammodytes hexapterus*), and herring (*Clupea harengus*), as well as crustaceans and macro-invertebrates, all of which are critical prey for Pacific salmon.

The North Olympic Peninsula Lead Entity (2001) defined the nearshore as “the area adjoining the land and the sea, and the coupled ecological processes (geological, primary and secondary productivity, sediment, and hydraulic processes) that affect this area’s ability to function in support of Pacific salmon.” They further described that estuaries are considered part of the nearshore and are recognized as a vital connection to the watersheds (NOPL 2001). Thus, the inland extent of what is considered nearshore encompasses any habitat that is tidally influenced, including tidal freshwater, brackish, and marine habitats. The offshore extent of what is considered nearshore is more difficult to define because it varies significantly depending on natural geologic, topographic, and marine characteristics. Within some portions of the WRIA 18 planning area, the offshore extent of the nearshore could be defined as the lower-limit of the photic zone (approximately -30 feet MLLW). In other portions of the planning area, the nearshore could extend much further offshore.

The North Olympic Peninsula Lead Entity (2001) describes the nearshore as the interface between riverine and marine ecosystems and that it is the principal source of interaction between people and the sea. Because of their focal location within the landscape, nearshore ecosystems are tremendously dynamic and complex, and they provide a wide array of functions for multiple plant and animal species, including Pacific salmon and their prey (Shreffler and Thom 1993 as cited in NOPL 2001). Nearshore ecosystems produce, trap, cycle, and export energy; filter domestic wastes; retain and modulate freshwater runoff; buffer adjacent land areas from the force of marine waters; provide critical habitat for fish and wildlife migrations, feeding, refuge, and reproduction; and moderate extremes in air and water temperature (Duxbury 1987, Thom 1987 as cited in NOPL 2001).

From a landscape ecology perspective, nearshore ecosystems are ecologically connected to riverine and marine ecosystems (NOPL 2001). Pacific salmon are often used as an indicator of the response of ecosystems to environmental and anthropogenic change, because their life cycle integrates changes across the continuum of ecosystems from watershed to nearshore to ocean (Bottom et al. 1998 as cited in NOPL 2001). When nearshore ecosystems become structurally or functionally disconnected or fragmented, because of either environmental or anthropogenic change, ecological processes are lost or degraded and Pacific salmon are adversely affected (Spence et al. 1996 as cited in NOPL 2001). Reduced connectivity increases fragmentation that alters the diversity of habitats at all landscape scales (Wissmar and Simenstad 1998 as cited in NOPL 2001). The National Research Council report on Restoration of Aquatic Ecosystems (National Research Council 1992 as cited in NOPL 2001) stressed that failure to restore aquatic ecosystems promptly will result in sharply increased rates of extinction of species or ecosystem types, and in permanent ecological damage.

Historically, it was felt that juvenile salmon could be found in nearshore environments only during what has commonly been called the “fish window” from approximately April through September. However, recent evidence from nearshore beach seining surveys suggests that juvenile salmon can be found within the matrix of nearshore habitats (e.g., eelgrass beds, mudflats, marshes, and channels) year-round. Thus, the nearshore is increasingly

recognized as a critical, year-round component of Pacific salmon life histories. Furthermore, restoration work in a specific watershed may be wasted if the estuary for that watershed is disconnected or dysfunctional.

In the marine waters bordering the WRIA 18 planning area, abundant fish, shellfish, and marine mammals can still be found. The tidal environments provide for many species of clams, oysters, crabs, scallops, shrimp, and abalone, as well as octopus, sea urchins, sea cucumbers, and the largest variety of starfish in the world. Large marine mammals include sea otters, seals, dolphins, and Orca whales. Seal haulouts occur at the end of Dungeness Spit, at Graveyard Spit, and at Cline Spit Island.

More information is available on limiting factors in freshwater than in saltwater. Factors limiting saltwater production remain less well understood and with a few notable exceptions may be environmental factors beyond the reach of local human control. The notable exceptions include the loss of estuarine habitat, pollution of nearshore marine habitat, high seas fishing, and possible global climatic effects associated with the release of greenhouse gases.

Anadromous Fisheries Use

Out-migrating smolts use estuarine and nearshore marine environments as critical transition zones as they undergo sometimes dramatic physiological changes preparatory to spending the bulk of their lives in saltwater. Survival during this extremely vulnerable life stage is directly related to the amount and quality of food and shelter available in this transitional habitat.

Shellfish Use

The harvest of shellfish is regulated both for resource conservation and for public health. Health risks are associated with marina operations, sewage discharge, and marine toxins such as paralytic shellfish poisoning. The Washington Department of Health (DOH) monitors health risks and imposes area closures when necessary (see also Sec. 3.2.8, Clean Water District). Section 2.8.5 discusses the history of fecal coliform sampling in Dungeness Bay and the closure of commercial shellfish harvest in about 300 acres of the Bay due to fecal coliform contamination. Tidelands from Port Williams south along the west shore of Sequim Bay to just below the John Wayne Marina are closed year-round due to pollution at the marina and the City of Sequim's sewage outfall. Seasonal closures are imposed on tidelands adjacent to the offshore boat mooring site at Sequim Bay State Park.

Shorelines and Vegetation

The WRIA 18 LFA (Haring 1999) describes shoreline armoring, eutrophication, and loss of eelgrass habitat in the estuarine and nearshore waters along the full extent of the WRIA 18 shoreline.

A key nearshore habitat concern is the loss of eelgrass (*Zostera marina*) habitat in the intertidal and shallow subtidal area. Eelgrass provides valuable habitat for a variety of marine species, including very productive rearing habitat for juvenile salmonids and

spawning habitat for herring. It is likely that extensive eelgrass meadows have been eliminated with the filling of intertidal areas from Washington Harbor west to Port Angeles (Haring 1999). Haring identifies no reduction in kelp habitats in WRIA 18.

Ulva species, an opportunistic green macroalgae, form dense mats that reduce light and oxygen and create an anoxic environment. Ulvoid blooms, promoted by nutrient loading, appear to have a negative impact on nearshore invertebrate and fish communities, as well as on other vegetated habitats, such as eelgrass beds. Ulvoid mats may affect habitat conditions by changing the physical hydrography of the intertidal area. Physical changes may include a decrease in water flow, increased sedimentation, and a decrease in tidal flushing. These mats may also prevent access to benthic prey by creating a barrier over the substrate. They may smother benthic shellfish, directly or through creating anoxic conditions. Ulvoid mats have been observed in Dungeness Bay, along the Jamestown shoreline, and in and immediately outside the mouth of Washington Harbor. They appear to be associated with an overall 31 percent decline in eelgrass from 1987 to 1993 (Haring 1999).

West WRIA 18 – Elwha Morse Planning Area

Armoring is found along 90 percent of the WRIA 18W shoreline, from Morse Creek west to the Elwha River (Haring 1999). Much of this armoring occurred early in the 20th century, in support of establishment of the downtown waterfront activities, the industrial water line, and a now-abandoned railroad line. The armoring, which has occurred in many forms (rip-rap, sheet piling, wall-and-fill areas, etc.), significantly altered, curtailed or eliminated important shoreline current and sediment processes. This, in turn, obliterated extensive intertidal areas that would have been extremely productive for eelgrass, baitfish, and shellfish.

East WRIA 18 – Dungeness Planning Area

Intertidal and subtidal areas within East WRIA 18, particularly Sequim Bay, support a wide variety of shellfish and other marine invertebrates. Some of the more popular commercial and recreational varieties include clams, oysters, shrimp, crab, sea urchins, and sea cucumbers. These marine resources are widespread through the region, on both private and public tidelands. Natural clam production in Sequim Bay supports businesses owned by tribal and non-Indian ventures alike. Clam, oyster, and shrimp resources in both Sequim and Dungeness Bays support tribal commercial, subsistence, and ceremonial fisheries, including a commercial shellfish plant operated by the Jamestown S'Klallam Tribe in Dungeness Bay. Shellfish have been a principal food source for the Tribes since time immemorial (DQ Plan 1994).

Haring (1999) indicates that shoreline armoring in WRIA 18 east of Morse Creek appears limited to the area from the Three Crabs Restaurant on Dungeness Bay east to the mouth of Cooper Creek, about two-thirds of which is described as armored. The armored shoreline just to the east of the restaurant is said to be actively prograding, while the unarmored shoreline immediately to the west (at the mouth of Meadowbrook Creek) is described as actively eroding. These effects are considered to result from armoring of shoreline further east. From the mouth of Cooper Creek to the mouth of Washington Harbor, the shoreline has little armoring.

Clark and Clark (1996) report that the original town of Dungeness was moved from the inner to the outer Dungeness Bay in 1857 due to concerns that the inner bay was filling with silt. This coincides with diking of salt marsh habitat at the mouth of the Dungeness River, according to Haring (1999). The lowermost part of the Dungeness River was likely channelized at about the same time (ca. 1855), and the two activities have been implicated in “catastrophically high” rates of the Dungeness delta progradation, a process that can also be seen on Jimmycomelately Creek (Haring 1999).

This page intentionally left blank.