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Assessment of Coastal Water Resources and Watershed Conditions at Ebey's Landing National Historical Reserve (Washington)

Natural Resource Report NPS/NRWRD/NRTR—2007/369

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Upper right, Penn Cove, Photograph by Kristen Keteles
Center right, prairie, Photograph by Capt. M.W. Bronson
Lower left, Coupeville wharf, Photograph by Kristen Keteles
Lower right, Ebey's shoreline, Photograph by Leigh Smith

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Natural Resource Technical Report NPS/NRWRD/NRTR-2007/369

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As with any report of this nature that is so dependent on literally thousands of hours of work by individuals making observations, collecting data, performing analyses, and archiving time series, we recognize our debts.

Commonly used abbreviations

USACE	US Army Corps of Engineers
BOD	Biological Oxygen Demand
DAP	Domoic Acid Poisoning
DPM	Deep Percolation Method
EBLA	Ebey's Landing National Historical Reserve
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
GNOME	General NOAA Modeling Environment
GPD	Gallons Per Day
HAB	Harmful Algal Bloom
MPN	Most Probable Number
NAS-Whidbey	Whidbey Naval Air Station
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NPS WRD	National Park Service Water Resources Division
NWFSC	Northwest Fisheries Science Center (National Oceanic and Atmospheric Administration)
PSAMP	Puget Sound Ambient Monitoring Program
PSAT	Puget Sound Action Team
PSP	Paralytic Shellfish Poisoning
SJDF	Strait of Juan de Fuca
STORET	Environmental Protection Agency's STOrage and RETrieval database f or water quality, biological, and physical data sets contributed by state environmental agencies, EPA and other federal agencies, universities, private citizens, and others
TMDL	Total Maximum Daily Loads
WDOE	Washington Department of Ecology
WDOH	Washington Department of Health
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WRIA	Water Resource Inventory Areas
WSCC	Washington State Conservation Commission
WSDOT	Washington State Department of Transportation
WSF	Washington State Ferries
WSU	Washington State University

Executive Summary

Ebey's Landing National Historical Reserve (Reserve, or EBLA) protects a cultural landscape representative of 19th Century exploration and settlement in the Puget Sound region of western Washington. Designated in 1978, the reserve includes rolling uplands, woodlands, prairies, and is bounded on the west by a strip of coastal cliffs open to Admiralty Inlet and on the east by a wide protected bay. Whidbey Island, on which EBLA is located, is a large island surrounded by the deep fjord-like estuary of central Puget Sound. More than 100 historic structures within EBLA have been placed on the national register and display the architecture characteristic of this area over 100 years ago. EBLA is managed by a "trust board" on which nine individuals constitute the "superintendent" and represent a partnership between the National Park Service, the town of Coupeville, Washington State Parks and Island County. Approximately 90% of the land is privately held and administered by state and local jurisdictions and the remainder is owned by or under easement to the National Park Service or Washington State Parks.

The purpose of this report is to review existing knowledge about the water resources and to provide an assessment of water resource conditions within EBLA. We identify existing information concerning water resources and monitoring relative to this task. We assess gaps in information as well as document concerns relative to water resource management now and in the future.

In order to perform this assessment, we review the site itself, its hydrology and water resources including associated biological resources. The key foci are on water quality data sources, water quality degradation and sources of pollutants including non-point sources. In addition to water quality assessment we examine other areas of concern including harmful algal blooms, non-native and invasive species, harvest and collection of organisms, habitat modification, shoreline development and zoning, water withdrawals, erosion, effect of Elwha Dam removal, oil spills, land and water-based recreation, tsunami hazard and climate change as they relate to management of EBLA.

Based on available data, there appear to be no major unrecognized water resource problems. However, we acknowledge a moderate degree of uncertainty in this assessment due to data limitations.

Projected population growth and associated increases in human activities could impose stress on water resources and lead to increases in nutrient loading, hypoxic events, or exposure to pathological conditions associated with the presence of fecal coliform bacteria. Our recommendations incorporate projections of population growth and suburbanization in the vicinity of EBLA, and are strongly influenced by our estimation of the uncertainty associated with the limited available data. Now may be a critical time to establish a more solid baseline in order to more accurately assess potential impacts associated with growth and development and with the regional impacts of climate change.

In recognition of the trust board management approach for EBLA, we suggest that a water resource management plan be developed that would 1) outline the goals and objectives of water resource management within EBLA and 2) defines levels of acceptable water resource condition. This planning effort requires the participation of multiple partners who have varied management jurisdiction. In reviewing available information, we have formed concerns that relate to 1) lack of direct knowledge of current conditions and 2) lack of established threshold values for future conditions. The marine environment that potentially affects EBLA is beyond its management authority. Therefore, we recommend that EBLA develop mechanisms to participate in or link to regional initiatives that are attempting to establish broader management control, e.g., oil spill prevention, nearshore restoration, nutrient loading, and recreational and commercial harvest.

Our assessment of the condition of water resources in EBLA is summarized in Table i. A brief explanation of our ratings is as follows. For all seven water bodies, we use 'OK' to indicate conditions that we know to be acceptable (no shading) and to indicate conditions for which there is no evidence of degradation or potential degradation (shading). Deviations from this rating are based on 1) known degradation of existing, intermittent, or potential nature (no shading) or 2) suspected degradation of existing, intermittent, or potential nature, for which there limited data (shading); these latter ratings are based on our best professional judgment and are associated with a higher degree of uncertainty than other ratings. For many attributes data are not sufficient to inform a rating (ID with shading). Additional detail and justification for these ratings are provided in Section D. This assessment is followed by recommendations for actions that could contribute to the protection of water resources with EBLA (Table ii).

Table i. Condition of water resources in EBLA.

Stressor/ Environmental Indicator	Penn Cove	Grasser's Lagoon	Kennedy's Lagoon	Admiralty Inlet/ SJDF	Crockett Lake	Perego's Lagoon	Lake Pondilla
WATER QUALITY INDICATOR							
Nutrients	IP	ID	ID	OK	ID	ID	ID
Dissolved Oxygen	EP	ID	ID	OK	ID	ID	ID
Fecal Bacteria	EP	ID	ID	PP	ID	ID	ID
Toxic Compounds	PP	ID	PP	ID	ID	ID	ID
LAND-USE RELATED STRESSORS							
Septic / Wastewater	IP	ID	ID	OK	OK	NA	OK
Stormwater Runoff	IP	PP	PP	OK	ID	NA	OK
Agricultural Runoff	NA	NA	NA	ID	ID	NA	OK
Aquaculture	PP	NA	NA	NA	NA	NA	NA
HABITAT MODIFICATION							
Shoreline Modification	EP	EP	EP	PP	EP	OK	OK
Coastal Erosion	OK	OK	OK	PP	OK	OK	NA
RECREATIONAL USAGE							
Fishing	OK	OK	OK	OK	OK	OK	ID
Shellfish Harvesting	OK	OK	OK	OK	OK	OK	NA
OTHER STRESSORS/ INDICATORS							
Non-Native Invasive Species	EP	EP	EP	PP	EP	EP	OK
Harmful Algal Blooms	IP	ID	ID	OK	OK	OK	OK
Fuel / Oil Spills	OK	OK	OK	PP	PP	PP	OK

Definitions: EP=existing problem, PP=potential problem, IP=intermittent problem, OK=no detectable problem, ID=insufficient data to evaluate, shaded=limited data.

Table ii. Recommendations

- More frequent monitoring of dissolved oxygen levels in Penn Cove
- More extensive monitoring of dissolved oxygen levels in Penn Cove
- Careful tracking and evaluation of the permit process for expansion of wastewater treatment facilities or other point sources of potential pollutants
- Regular monitoring and reporting of biocide applications, on-site sewage disposal, and run-off from dairy and other farming and road maintenance activities
- Management of surface water to minimize impacts to nearshore environments and maximize recharge of the sole source sea level aquifer
- Further development of partnerships with local entities working to reduce non-point source pollution
- Development and implementation of regular monitoring programs at Crockett Lake and Lake Pondilla
- Development of measures to protect and preserve the sea level aquifer under coastal development and climate change scenarios
- Establishment of connections to regional-scale management initiatives in Puget Sound
- Development of goals and objectives for water resource management, and development of a water resource management plan

A. Park and Regional Description

A.1. Background

A.1.a. Physical Setting and Management Framework

Ebey's Landing National Historical Reserve (Reserve, or EBLA) was designated by Congress in 1978 as a unique type of area managed by National Park Service. The purpose of this designation was "to preserve and protect a rural community which provides an unbroken historic record from 19th century exploration and settlement in Puget Sound to the present time" (http://www.nps.gov/ebla/home.htm).

The Reserve comprises an area of approximately 17,572 acres, consisting of 13,617 acres of land and 3,955 surface acres of water in Penn Cove (Figures 1 and 2). Approximately 2,023 acres are protected with NPS-held conservation easements and 684 acres are NPS-owned in fee. Coupeville, the county seat, is an incorporated community and the entire Reserve, including the town, is a National Register historic district called the Central Whidbey Island Historic District.

The Reserve is a mixture of State, private and federally owned lands and waters constituting one of the most intact 19th Century cultural landscapes in Washington. Most (90%) of the land within the Reserve is in private ownership with public lands being in state or National Park Service ownership. Agricultural/open space constitutes 42% of the Reserve, woodlands comprise 36%, residential use accounts for 11.4%, wetlands occupy 5% and, and urban and commercial uses constitute 1% (http://www.nps.gov/ebla/adhi/adhi1.htm).

The Reserve is located within the Puget Lowland of northwestern Washington State. The region is one of high seismic activity, underlain by active faults with the potential to cause earthquakes and trigger submarine landslides, turbidity flows, and tsunamis. The region was glaciated repeatedly during the Pleistocene. The most recent event occurred about 16,400 years ago (Haugerud et al. 2003). Glaciers shaped the landscape through erosion and deposition, creating outwash plains as well as deep troughs and terminal moraines that now are inundated. Surrounded on all sides by water, the climate is moderate. The Reserve lies within the rain shadow of the Olympic Mountains, and consequently receives only about half of the annual rainfall (about 20 inches) typical of the southern tip of Whidbey Island and this relative aridity contributes to its unique character.

The Reserve is unique in that it is the first historical reserve in the National Park System. It is a "partnership" park that uses a cooperative strategy to bring together private and public resources at the local, state, and federal level. Instead of a typical park superintendent, policy oversight of the Reserve is managed by the Trust Board, consisting of nine members representing the four governmental partners. The nine members include seven local residents (three appointed by the town of Coupeville, four appointed by Island County), and one representative each from Washington State Parks and the National Park Service. Each Trust Board member serves a four-year term.

The Reserve is the first NPS unit to be managed by a trust board entity. The Trust Board employs a Reserve Manager to oversee the day-to-day operation of the Reserve. The Reserve Manager is assisted by staff composed of both NPS employees and Trust Board employees. Currently, the Reserve Manager is the only full-time staff employed by the board. The Trust Board has primary management responsibility for volunteer programs, and partnership and community planning functions. The Board shares responsibility with the National Park Service in the functional areas of administration, interpretation, maintenance, land protection, and resource management.

Figure 1. Lidar image of EBLA. Image courtesy of Island County.

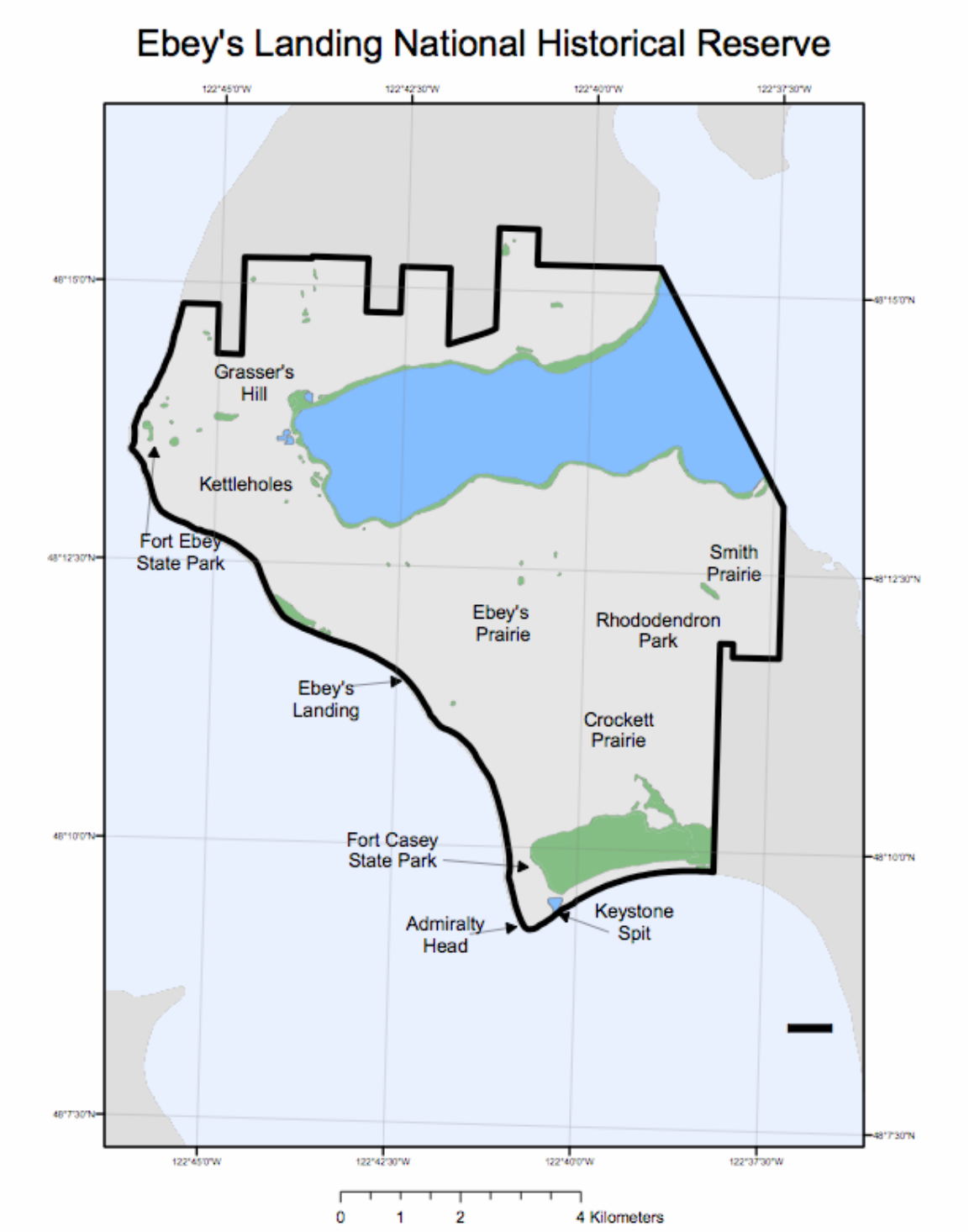

Figure 2. Terrestrial features and place names. Reserve boundaries in black.

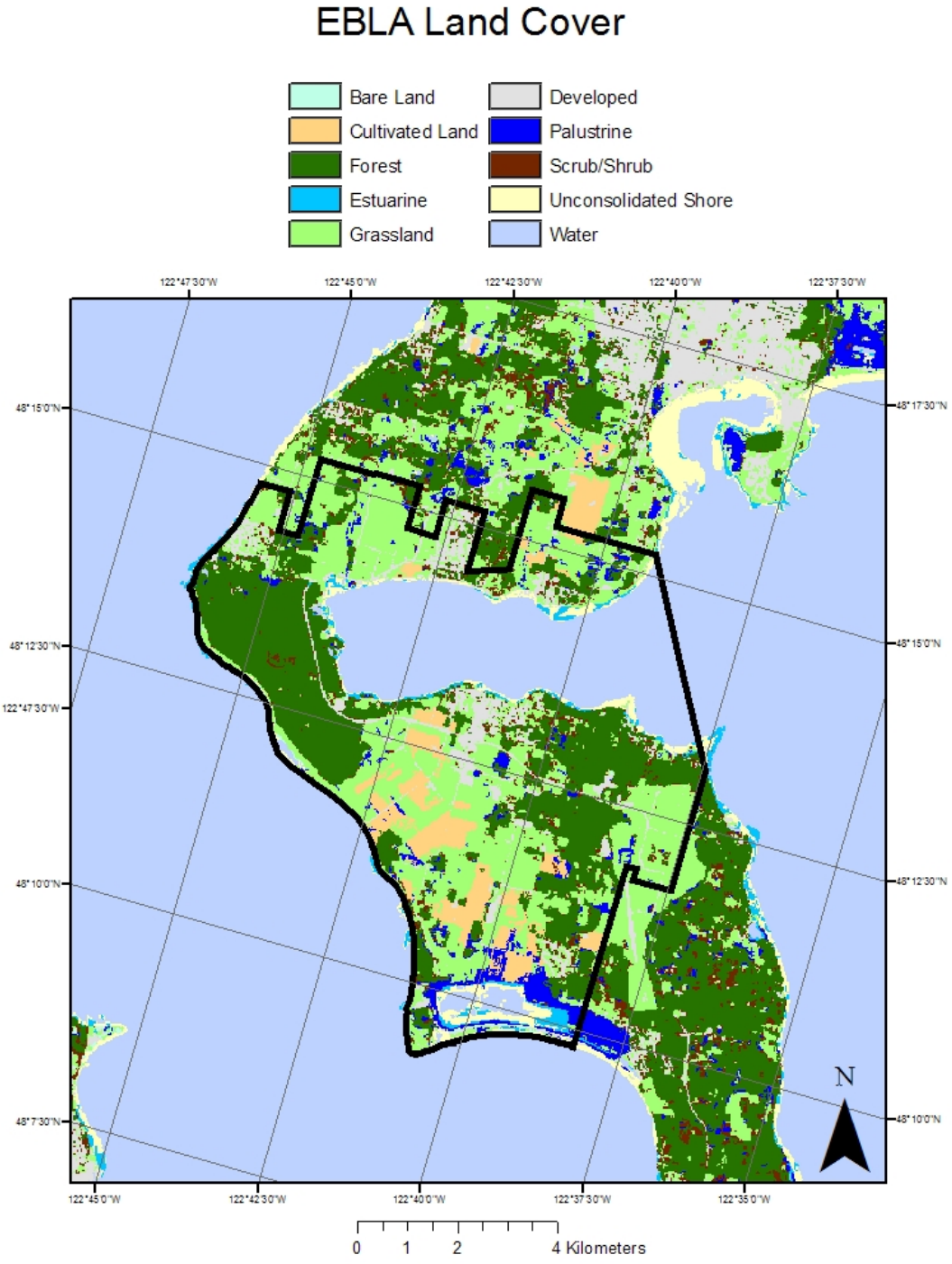

Figure 3. Land cover in Reserve and adjacent areas.

The physical landscape within the Reserve consists of five distinct habitats: the west coastal strip, Penn Cove, woodlands, prairies and uplands. The coastal strip is an 8-mile long band of bluffs and low ravines above a thin band of sandy beach on the western edge of the Reserve. In places the coastal area is lined with driftwood. Penn Cove is a

deeply incised bay on the eastern edge of the Reserve. It is fairly shallow and protected with sandy beaches and low bank waterfront. Small lagoons along the west side produce suitable habitats for waterfowl and migratory birds. Total shorelines within the Reserve stretch about 25 miles http://www.nps.gov/ebla./theland.htm.

Land cover within the Reserve is dominated by forest and grassland (Figure 3). Two large forested tracts exist within the Reserve and they are mostly undeveloped. They encompass 4,500 acres and contain interesting kettle wetland formations that resulted from glacial retreat processes some 13,000 years ago. The prairies are the remains of three large lakebeds that formed after the retreat of the glaciers. They occupy about 5,000 acres. Above the prairies stand the rolling hills of the uplands.

EBLA exists as a cultural landscape of small farms, hedgerows, wooded lots, and pastures scattered over the prairies and uplands. This cultural landscape is embedded in a maritime setting. A prominent example of this the historic town of Coupeville, situated on the shores of Penn Cove, the largest water body within the Reserve. Smaller water bodies within the Reserve include the coastal lagoons of Perego's Lagoon, Crockett Lake, Grasser's Lagoon, Kennedy's Lagoon. Freshwater bodies include Lake Pondilla, a kettle pond, and several small wetlands scattered across the Reserve.

The Reserve is situated within the western hemlock vegetation zone where the original tree species vegetation consisted predominantly of hemlocks, Douglas fir, western red cedar and red alder with an understory consisting of salal, Oregon grape, sword fern, and bracken fern. Pacific madrone and native rhododendron are less common but scenic parts of the vegetation. The glacial history contributes to the existence of some rare species of flowers as well as the garry oak (NPS, 2005).

A.1.b. Site History

This National Park unit represents a unique compromise between federally-conferred protection of a nationally significant area and locally-maintained control of private and local interests. In the early 1970s there was active debate in the region over how to protect the unique character of the area, in particular Ebey's prairie. This discussion began when the descendents of the original Donation Claim homestead found that their farming activity was no longer sufficiently profitable and sought zoning changes from the county government to allow alternative uses in 1968. Open space and public access advocates opposed the rezoning while property rights advocates supported the rezoning proposals. This led to a proposal to designate a national seashore and historic site for the western shoreline. The NPS was asked to review the proposal for its suitability. The reconnaissance team concluded that Ebey's Landing should be protected but felt that the area proposed lacked the "size and recreational opportunity" to be designated a national seashore http://www.nps.gov/ebla/adhi/adhi1.htm.

Advocates did not cease in their search for mechanisms for protection of this area. They eventually proposed a unique new kind of national park that Congress designated in 1978. EBLA is a blend of national management with state and local management. The

Reserve is the first in the NPS system to be managed by a trust board. The "superintendent" of the area is a composite of nine individuals who represent four governmental partners, i.e., the town of Coupeville, Washington State Parks, Island County and the National Park Service (http://www.nps.gov/ebla/adhi/adhi1.htm). At the present time it is envisioned that the NPS land ownership or scenic easements will not exceed 12% of the total area. Private lands in the Reserve remain under the zoning authority of local government. Due to the unique character of the cultural landscape, a variety of special districts exist as an overlay for the purposes of county zoning. WDNR leases tidelands for commercial aquaculture in Penn Cove.

This rare combination of national, state, and local management and the intention to preserve a working landscape complicates water resource management. In most NPS designations there exists a management goal to avoid degradation of natural resource values, including water resources. In EBLA there is implicit recognition that continuation of practices to farm, graze and accommodate growth will require adjustments in natural resource values. Consequently, within EBLA, managers must seek compromises between existing land use practices and resource protection.

A.1.c. Human Utilization

The earliest archeological records of Native American use in this area date from about 10,000 years before present. The Skagit Tribe is clearly associated with use of multiple sites within the area starting around 1300, particularly within the vicinity of Penn Cove. The large prairies were burned and mulched by these tribe members to cultivate the starchy roots of plants like camas and bracken fern which were used as food. On first contact with outsiders around 1790, the native American population was estimated to number about 1,500. The native population declined to just a few families by 1904 (http://www.nps.gov/ebla/thepeople.htm). It is understood that the western Washington tribes living on the rivers and coast used this most narrow portion of Whidbey Island as a portage point between what is now known as Penn Cove and Ebey's Landing in trading with other Puget Sound and Olympic peninsula tribes.

Captain George Vancouver was the first explorer to visit Puget Sound and his reports of its features and mild climate encouraged settlement. The primary mechanism for settlement came with the passage of the Donation Land Law by the US Congress in 1850. That legislation granted US citizens free land in the then named "Oregon Territory" on the condition that they would establish homesteads for a period of at least four years (http://www.nps.gov/ebla/adhi/adhi1.htm). The prairies and nearby lands with their rich alluvial soils and treeless character attracted early settlement. The protected harbor made Coupeville an early port city in the region. Some commercial fishing for salmon and groundfish was based out of Penn Cove but fishing was not on the scale of other Puget Sound communities. A major influx of people came with the development of Fort Casey Military Reservation in the late 1890s (http://www.nps.gov/ebla/thepeople.htm).

Agriculture and grazing continue to be the major land uses and it is still possible to see remnants of fence lines, hedgerows, and the routes of major roads that date to the earliest

settlements. Very little of the original forest cover exists today, most having been logged and cleared for agricultural use. Substantial forested areas persist, as noted above, and consist of second and third-growth hemlock and Douglas fir. Commercial fishing is diminished and recreational fishing for salmon and groundfish is relatively modest in the vicinity of the Reserve.

While agriculture remains active today, increasing residential use of the land by commuters, retirees, and vacationers is apparent. Recent enterprise is seen in the development of aquaculture of mussels in Penn Cove in 1975 and its expansion to a major regional producer. Tourism associated with the natural assets of Whidbey Island is supporting development of service infrastructure in the form of motels, restaurants and shops as well as interpretation. This tourism includes the scenic natural and historical assets of the EBLA. Camping and associated outdoor activities are encouraged at State Parks.

In a regional context, EBLA is located within the highly urban estuary of Puget Sound. The coastal population surrounding Puget Sound is among the largest and fastest-growing the US. The region is home to more than six million people distributed between the major urban centers of Seattle and Vancouver and dispersed among extensive sub-urban and semi-rural settings. Across the region, land- and water-use practices cause impacts to the coastal environments through forest practices, agriculture, land clearing, construction of dams and dikes, point-source pollution (sewage disposal, industrial discharge), and non-point source pollution (surface water run-off, fossil fuel combustion, atmospheric deposition). Fresh water, sediments, particulates, and dissolved compounds all are discharged into coastal waters around Puget Sound. The surrounding marine environments have been altered or affected by shoreline modification, dredging and filling, cable and pipeline installation, bridge construction, vessel operations, fishing practices, aquaculture, and the introduction of toxic contaminants. Alone and in combination, these activities alter sediment flow, increase the incidence of diseases in fish and wildlife, and reduce primary and secondary productivity. The area is important for shipping and oil transport, and the Juan de Fuca corridor is among the most active shipping areas in the world, with the associated risk of chronic and catastrophic spills.

A.2. Hydrology

A.2.a. Oceanographic Setting

EBLA exists within the larger oceanographic setting of Puget Sound and the eastern Strait of Juan de Fuca. Puget Sound is a fjord-type estuary that was carved by glaciers and sub-glacial erosion. Boulder moraines deposited by the glaciers form sills that restrict circulation within Puget Sound and adjoining regions. Today, Puget Sound is bounded by shallow sills at its northern and southern ends. The northern sill, which crosses Puget Sound at Admiralty Inlet and connects to EBLA at Admiralty Head, exerts a strong influence on regional circulation and constitutes a physiographic reference point of importance in describing oceanic influences in EBLA. Seaward of Admiralty Inlet, Puget Sound is connected to the coastal ocean via the Strait of Juan de Fuca (Matsuura and Cannon 1997). The coastal ocean here is influenced by large-scale oceanographic features associated with the North Pacific Gyre, including the California, Alaska, and Davidson currents, and is characterized by upwelling, downwelling, and complex eddy fields.

Circulation within the Puget Sound and Strait of Juan de Fuca is estuarine in character, driven by outflow from several larger and numerous smaller rivers. Among these, the Skagit River is a primary source of fluvial forcing. The long-term average near-surface flow through the estuary is seaward (Cannon 1978, Holbrook et al. 1980, Thomson 1981), reaching an estimated speed of 6 km/day through the Strait of Juan de Fuca (Pashinski and Charnell 1979). This seaward flow of surface water is balanced by a landward flow of oceanic water at depth. Vigorous mixing between deep and surface waters occurs at sills (Ebbesmeyer and Barnes 1980; Holbrook et al. 1980, Cannon and Bretschneider 1986; Crean et al. 1988, LeBlond et al. 1994).

Estuarine circulation patterns are modified by swift tidal currents that reach speeds of several knots. Intense tidal flows cause vertical mixing (Griffin and LeBlond 1990, LeBlond et al. 1994) and create tidal eddies that entrain and redistribute buoyant and suspended particles (Ebbesmeyer et al. 1991). Wind forcing further influences circulation and mixing at the surface and to depths of about 100 m (Matsuura and Cannon 1997). Tidal forces tend to dominate circulation over periods of less than 10 hours; other forces dominate over longer periods.

Periodic reversals of the typical estuarine flow patterns occur, during which oceanic surface waters are injected into the eastern Strait of Juan de Fuca. Flow reversals are infrequent and are most often associated with winter storm events of short (<10 days) duration (Thomson 1981; Holbrook and Halpern 1982; Ebbesmeyer et al. 1995).

Puget Sound is divided into sub-basins distinguished by geomorphology and other physical characteristics. Of the five sub-basins commonly identified (North Puget Sound, Main Basin, Whidbey Basin, South Puget Sound, Hood Canal), the shoreline of EBLA spans three: North Puget Sound, Main Basin, and Whidbey Basin (Figure 4).

North Puget Sound comprises the region north of Admiralty Inlet. Within this region, it is the eastern basin of the Strait of Juan de Fuca (hereafter, ‘eastern basin’) that borders the western shore of EBLA. The eastern basin is bounded at its southern end by the sill at Admiralty Inlet, and at its western end by a sill just west of Port Angeles. Surface waters enter the eastern basin from Puget Sound and from Georgia Strait, and exit via the western Strait of Juan de Fuca. Although the net near-surface flow is seaward, a number of recurrent tidally-generated eddies ring the eastern basin. Among these are two that are proximal to EBLA and likely influence local circulation patterns in the vicinity of the Reserve’s western shore of (Ebbesmeyer et al. 1991). Within EBLA, shores bordering the eastern basin experience greater oceanic influence and are exposed to more energetic storm swells than are shores elsewhere in the Reserve.

The Main Basin, also known as Central Puget Sound, comprises the region of Puget Sound between Admiralty Inlet in the north and Tacoma Narrows in the south. The region is less oceanic in character than is the eastern basin. Circulation in the Main Basin is driven by estuarine forcing that is constrained by the sill at Admiralty Inlet, causing some fraction of surface water to be retained and mixed with deeper water within the basin. Additional mixing occurs at Triple Junction, where the Main Basin converges with the Whidbey Basin and Admiralty Inlet. A comparatively small amount of shoreline within EBLA borders the Main Basin.

The Whidbey Basin comprises the region to the north and east of the Main Basin. The Whidbey Basin is substantially shallower than the Main Basin or the eastern basin of the Strait of Juan de Fuca, and is characterized by a higher percentage of tidelands. Circulation in the Whidbey Basin is driven by outflow from the Skagit, Snohomish, and Stillaguamish Rivers, which establish a net southward flow at the surface along the length of Saratoga Passage. The entire eastern shore of EBLA borders the Whidbey Basin.

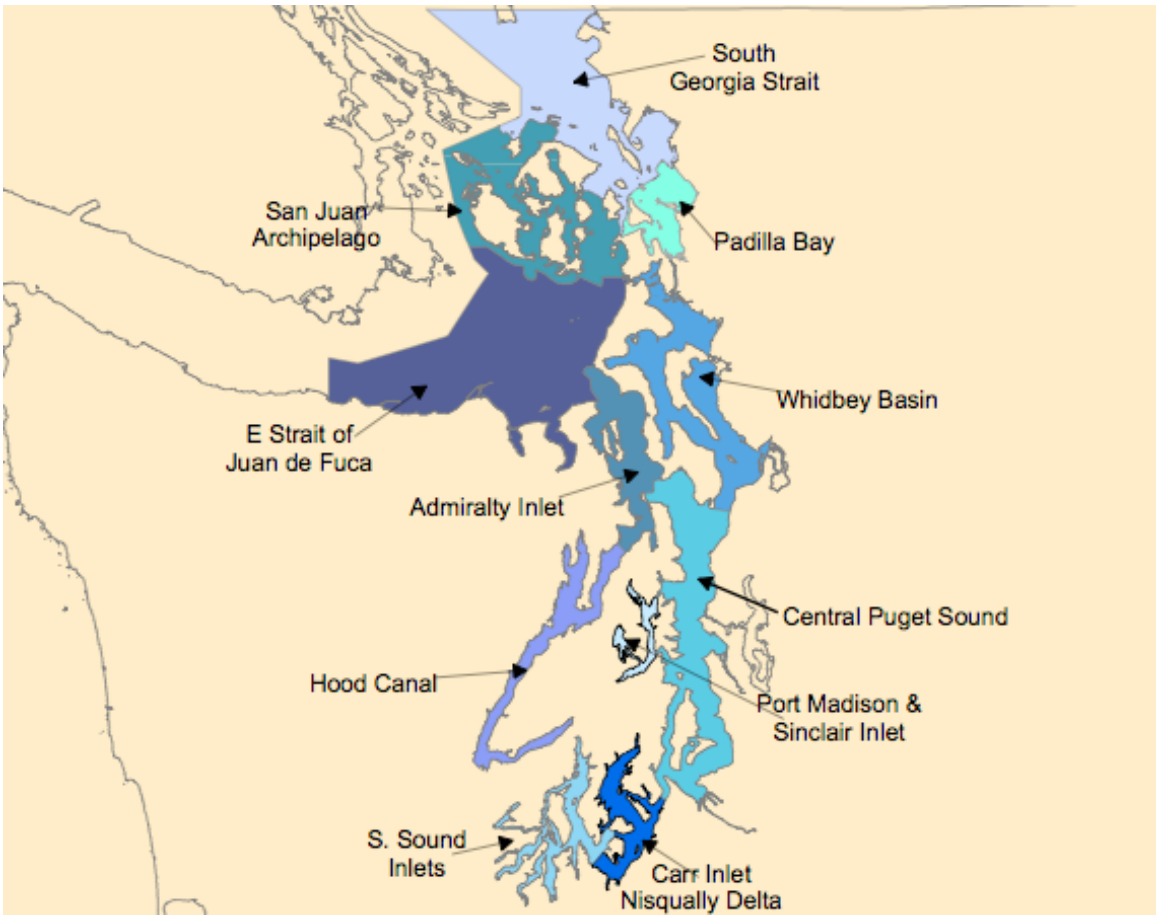

Figure 4. Sub-basins of Puget Sound (basins in various shades of blue). EBLA is located at the approximate confluence of Admiralty Inlet and the eastern Strait of Juan de Fuca.

A.2.b. Hydrology and Nearshore Processes

EBLA lies within a region of temperate marine climate characterized by wet winters and dry summers. Average annual air temperatures range from about 42-60^{o}F. Average annual precipitation in the vicinity of EBLA is the lowest on Whidbey Island, measuring 21-23 inches, with slightly higher values to the immediate north and south of the Reserve (USGS 2004).

Soils in the vicinity of EBLA consist primarily of unconsolidated sediments of fine-grained glacial till and coarse-grained glacial outwash. These unconsolidated sediments contain an aquifer at depths of slightly above sea level to about 200 feet below sea level (referred to as the sea level aquifer). Excluding withdrawals for human use, regional groundwater recharge is in approximate balance with the sum of runoff to the ocean, gaining reaches of streams, and plant transpiration. Water is withdrawn from this aquifer for household use and for use in irrigation, commercial and industrial applications. Withdrawals have the potential to lower ground-water levels, decrease outflow to natural discharge areas and streams, and to increase saltwater intrusion into the aquifer.

Modeling of recharge potential using the Deep Percolation Method (DPM) indicates that recharge typically is greater in areas of coarse-grained sediments than in areas of fine-grained sediment, ranging from > 20 inches per year in coarse-grained sediments to <10 inches per year in fine-grained sediments (USGS 2004). According to DPM models, recharge in the vicinity of EBLA averages about 0-8 inches per year. An alternate method of estimating recharge via chlorinity gave a combined average of 2 inches per year for Whidbey and Camano Islands; this may represent a lower bound on recharge estimates (USGS 2004).

Within EBLA, the shore zone is composed almost entirely of sand and gravel beaches. Immediately shoreward of these beaches are feeder bluffs or sediment deposition zones (Admiralty Inlet), or feeder bluffs and modified shorelines (Penn Cove). Regionally, large amounts of sediment, nutrients, and contaminants are introduced to Puget Sound via rivers. In the vicinity of EBLA, the Skagit River likely is the single largest source of sediment to the Penn Cove area; sources of sediment to Admiralty Inlet are diverse.

A.2.c. Water Resources

Watersheds are delineated by the US Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 sub-regions, 352 accounting units, and 2262 cataloguing units. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the hydrologic unit system is used to identify any hydrologic area. The 6 digit accounting units and the 8-digit cataloguing units are generally referred to as basin and sub-basin, respectively. HUC is defined as the Federal Information Processing Standard (FIPS) and generally serves as the backbone for the country's hydrologic delineation. However, the HUC system is only rarely used in Washington State because the system is at variance with the State's Water Resource Inventory Area (WRIA) system, which pre-dates the HUC system and is mandated by statute. Washington's WRIA system, developed by the state in the 1960s, specifies 25 WRIAs in Washington's coastal zone; in comparison, the HUC system identifies 28 HUC-8 watersheds in the same region. EBLA is located within HUC 17110019, which comprises Puget Sound south of Admiralty Inlet; and within WRIA 06, which encompasses Island County (consisting of Whidbey and Camano Islands). In this case, the WRIA designation refers to a smaller area than the HUC-8 designation.

Water resources within EBLA (Figure 5) are predominantly marine and are composed of Penn Cove, which is fully encompassed by EBLA, as well as marine shorelines along the eastern Strait of Juan de Fuca, Admiralty Inlet and Admiralty Bay. Associated with these marine areas are smaller lagoons and brackish lakes. Surface freshwater resources are restricted to Lake Pondilla and a few adjacent wetlands that have formed in kettle holes, and a freshwater wetland in the vicinity of Prairie Center. The most important groundwater resource is a sea level aquifer that is the sole source of household and agriculture water for the area.

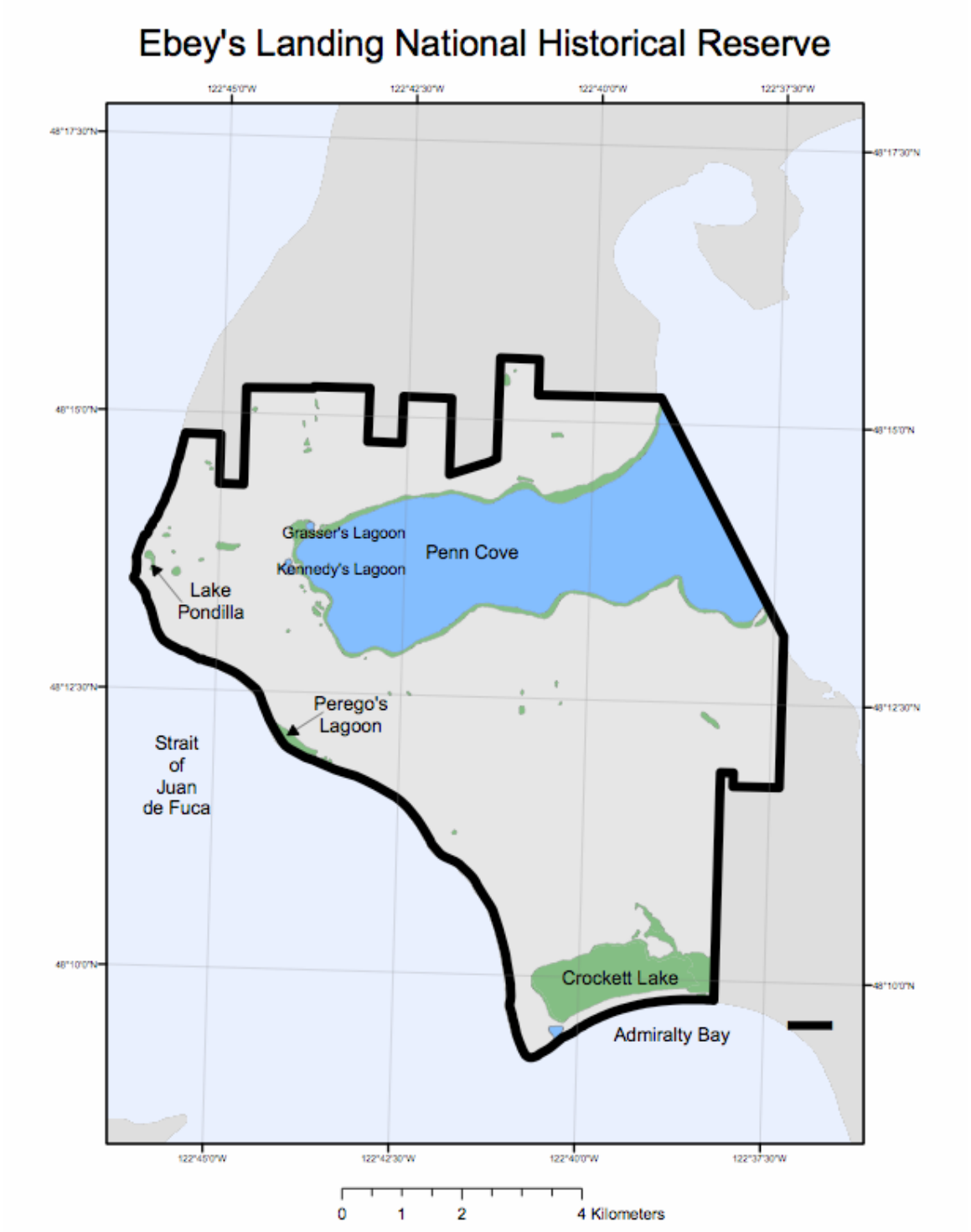

Figure 5. Water bodies of Ebey's Landing National Historical Reserve.

Penn Cove

Penn Cove comprises the largest and most important water resource within EBLA. It is estuarine in character, being influenced by fluvial forcing from rivers entering Saratoga

Passage and the Whidbey Basin from the mainland. The Skagit River dominates fluvial forcing in the vicinity of Penn Cove; the Stillaguamish and Snohomish Rivers make smaller contributions to estuarine processes. Penn Cove is utilized for commercial and recreational purposes, including aquaculture, fishing, boating, and swimming.

Grasser's Lagoon
Grasser's Lagoon is located in the northwest corner of Penn Cove. The lagoon occupies about 40 acres and brackish in nature, composed of mudflats and a fringing saltmarsh, with freshwater inputs from adjacent upland areas. The lagoon is used by shorebirds, salmon, and forage fish, and is reportedly highly productive.

Kennedy's Lagoon
Kennedy's Lagoon is located in the western end of Penn Cove. The lagoon is open to Penn Cove, is brackish in character, and contains mudflats and a narrow fringing saltmarsh, with eelgrass in the deeper areas. Freshwater is supplied to the lagoon as runoff from upland areas. A tide gate at the mouth of the lagoon remains open, allowing tidal flow into the lagoon.

Admiralty Inlet
Admiralty Inlet is a relatively narrow passage that connects Puget Sound proper with the Strait of Juan de Fuca. The Admiralty Inlet is deeper and more dynamic than Penn Cove, and substantial differences in oceanographic character exist between the eastern and western shores of EBLA. The passage is a major shipping corridor and experiences heavy use by recreational boaters.

Admiralty Bay
Admiralty Bay (Figure 6) is situated at the extreme southern end of the Reserve. The bay contains a WSDOT ferry terminal and has been extensively modified via armoring and repeated dredging. Impacts of the ferry terminal within the bay are substantial, but under the current configuration, impacts are relatively limited in spatial extent.

Crockett Lake
Crockett Lake (Figures 6 and 7) is a shallow water body situated on the southern edge of EBLA. The lake occupies a basin of about 4 km^2 and is situated behind a gravel bar up to 4 m in height that separates the lake from adjacent Admiralty Inlet. Originally a tidal lagoon, the lake is now comprises a shallow, brackish system of wetlands of about 700 acres. The shallow lakebed is largely composed of peat and supports a mosaic of vegetated areas and unvegetated mudflats. The area is important as a foraging and rearing habitat for salmonids, and as a foraging area for local and migratory birds. The lake has been highly modified over the course of the last Century. Among these modifications is a tide gate that regulates flow from Admiralty Inlet.

In January, 2006, the US Fish and Wildlife Service Federal Assistance Program announced that it will make funds available to Washington State Parks and Recreation to purchase 355 acres of wetlands for permanent protection at Crockett Lake, to be managed in partnership with several entities including the National Park Service.

Perego's Lagoon

Perego's Lagoon (alternately referred to Perego's Lake; Figures 8 and 9) is a relatively small high-salinity lagoon situated on the shore of Admiralty Inlet between Point Partridge and Ebey's Landing. The lagoon is separated from Admiralty Inlet by a narrow beach of sand and gravel and is backed by a high bluff. The lagoon is characterized by vegetation typical of high-salinity marshes. The aquatic invertebrate fauna is depauperate. Stickleback fish occur in the lagoon, presumably feeding on insect larvae found there. The phytoplankton community appears to be dominated by small algal flagellates that can produce dense algal blooms (M. Dethier, University of Washington, personal communication).

Figure 6. Admiralty Bay (lower center) and Lake Crockett (upper right).
Source: WDOE Shoreline Aerial Photos (http://apps.ecy.wa.gov/shorephotos/)

Figure 7. Lake Crockett, west end.
Source: WDOE Shoreline Aerial Photos (http://apps.ecy.wa.gov/shorephotos/)

Figure 8. Perego's Lagoon, north end. Color of water in main portion of lagoon suggests algal bloom at time of photo.
Source: WDOE Shoreline Aerial Photos (http://apps.ecy.wa.gov/shorephotos/)

Figure 9. Perego's Lagoon and Admiralty Inlet. Photo taken after winter (2006) storm recharge of lagoon. Photo courtesy of Leigh Smith, NPS.

Lake Pondilla

Lake Pondilla (Figure 10) is located in the northwestern region of EBLA near Point Partridge. The lake occupies a depression, or kettle, formed as glacial ice deposited during the last glaciation melted. It is situated within a forested area of Fort Ebey State Park; an adjacent swampy area separates the lake from Admiralty Inlet. Recreational fishing for bass occurs in the lake.

Figure 10. Lake Pondilla and Point Partridge.
Source: WDOE Shoreline Aerial Photos (http://apps.ecy.wa.gov/shorephotos/)

Land Cover Types

Land cover types within EBLA as designated by the National Wetlands Inventory (NWI) are shown in Figure 11; associated acreages are given in Table 1.

Table 1. NWI Land Types

NWI Land Type	acres
Marine and coastal	3698 .4
Wetland	998.8
Stream and riparian	0
Upland	13422.0

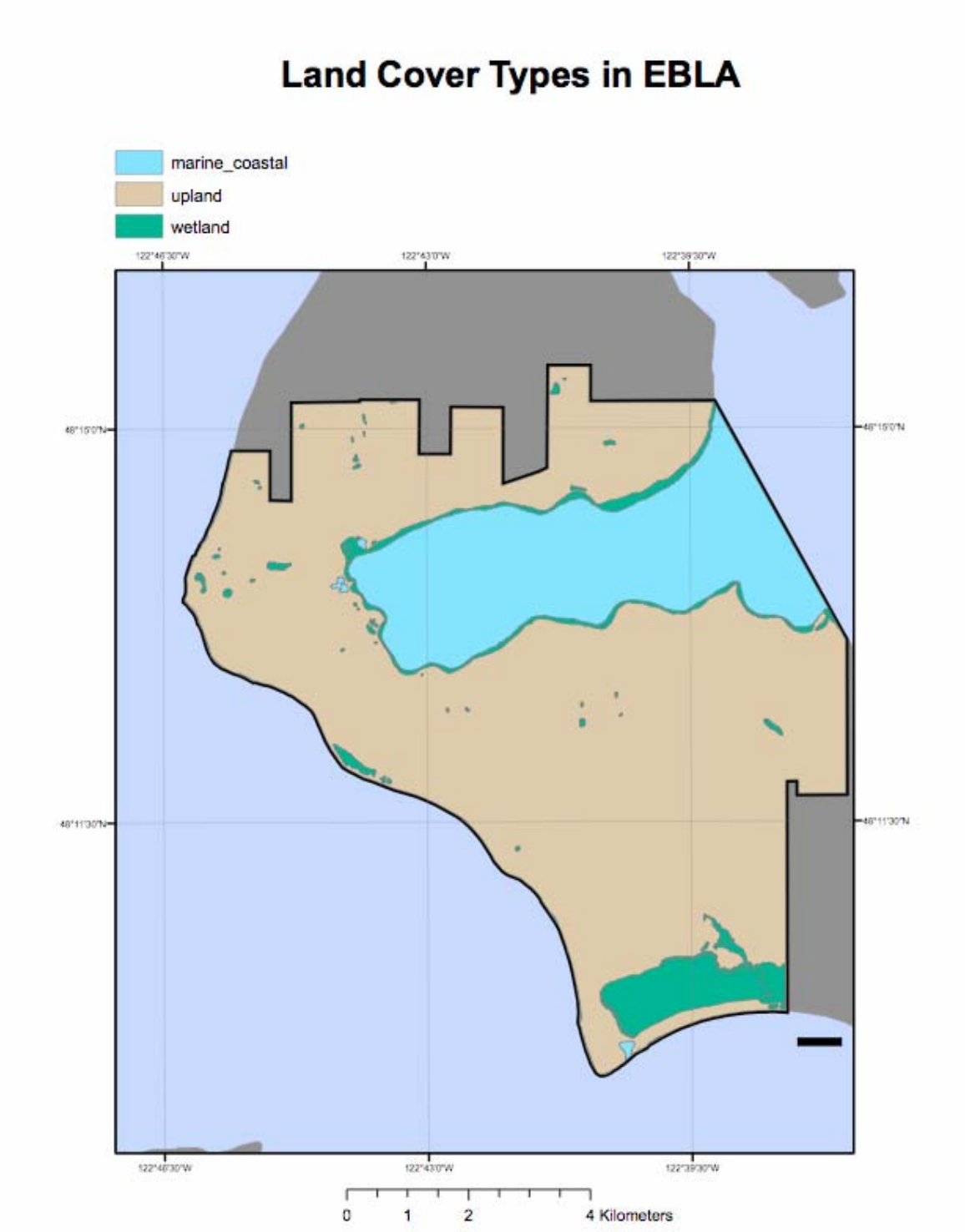

Figure 11. NWI Land Cover Types.

A.3. Biological Resources

A comprehensive, systematic inventory of living marine and aquatic resources in EBLA does not exist. A number of sources treat selected groups of taxa on a regional basis, and from these the biological resources of EBLA can be inferred. Among these sources are relatively recent treatments concerning salmon recovery (WRIA 6 Multispecies Salmon Recovery Plan 2005, http://www.salmoninfo.org/), forage fish and eelgrass data collected by the Island County Marine Resources Committee (http://www.islandcountymrc.org/), and various data collected by the WSU Beach Watchers (http://www.beachwatchers.wsu.edu/). Less recent treatments of regional biota are provided in Weber (1980) and in Kozloff (1983). Some of the earliest collections of seaweeds in the region were made in the early 1900s in the vicinity of EBLA by N.L. Gardner, a schoolteacher from Coupeville; these now constitute historical specimens, many of which are archived at the University of California, Berkeley.

We used spatially-explicit data from WDFW (by permission) and from WDNR to create maps of the distribution of representative marine species within EBLA (Figures 12-17). WDNR produced and released the Shorezone Atlas, a publically-available product created from an inventory of approximately 3,000 miles of saltwater shorelines throughout Washington state. Intertidal areas were surveyed between 1994 and 2000 using helicopter-based aerial videography that was used to characterize physical and biological attributes of the shoreline. We extracted key variables from the Shorezone Atlas to include in this report.

A.3.a. Marine Intertidal and Shallow Subtidal

Intertidal shorelines within EBLA are composed almost entirely of mixed sand and gravel; consequently, the rich biota common to rocky intertidal shores elsewhere in the region is largely absent from EBLA. Within Puget Sound, the intertidal biota of mixed sand and gravel beaches typically includes epibenthic organisms such as littorine snails, barnacles, small mussels, ephemeral algae (e.g., *Ulva* and *Porphyra*), and epibenthic diatoms. Infaunal invertebrates typically include several species of shrimp, bivalves, and polychaete worms. Forage fish species (surf smelt, sand lance) use sand and gravel beaches for spawning. Eelgrass is common in shallow subtidal areas.

The intertidal and shallow subtidal biota of Penn Cove is characterized by patchy eelgrass beds. Algal species include sea lettuce (*Ulva* spp), the red alga *Porphyra*, and the rockweed, *Fucus*. Benthic invertebrates include barnacles (*Balanus glandula*), ghost shrimp (*Callianassa californiensis*), mud shrimp (*Upogebia pugettesnis*), several bivalve species (blue mussels (*Mytilus trossulus*), the invasive Mediterranean mussel (*Mytilus galloprovincialis*), the invasive Pacific oyster (*Crassostrea gigas*), heart cockles (*Clinocardium nutallii*), hardshell clams (*Protothaca staminea, Tresus nutallii*, and *Saxidomus giganteus*), geoduck (*Panope generosa*)), seastars (*Pisaster sp*.), and green urchins (*Strongylocentrotus droebachiensis*). The non-native invasive cordgrass,

Spartina anglica, has been reported from Penn Cove. Sand lance spawning beaches occur in Penn Cove. Habitat suitable for use by juvenile salmonids occurs in Penn Cove, and both Grasser's and Kennedy's Lagoons have been identified as juvenile salmonid habitat. Crabs of the genus *Cancer* would typically be expected to occur in subtidal areas such as those found in Penn Cove; the WDFW geospatial data base indicates that *Cancer* crab species are absent from Penn Cove.

The Admiralty Inlet shore of EBLA is more dynamic than the shore of Penn Cove, and is more similar to other exposed sand and gravel shores in northern Puget Sound. Narrow beds of the bull kelp, *Nereocystis lutkeana*, occur in shallow subtidal areas. Associated with these kelp beds are an understory canopy of bladed algae and kelp-associated benthic invertebrates. The intertidal sandy shores support a limited infaunal community, but macroscopic epibenthic organisms are not abundant. Where rock, cobble, or rip-rap occurs, intertidal epibenthic communities typical of rocky shores develop. These include the rockweed *Fucus*, barnacles (*Balanus glandula* and *Chthamalus dalli*), littorine snails (*Littorina spp*.), and associated species.

A.3.b. Other Habitats

The biota of other aquatic habitats within EBLA tend to be less well described than the intertidal biota. Crockett Lake contains rooted vegetation and invertebrate species associated with brackish marshes and is heavily used by resident and migrating bird species. The Lake is reportedly used as a rearing area for juvenile salmonids. Perego's Lagoon comprises a hypersaline coastal lagoon in which phytoplankton are the main primary producers; rooted vegetation occurs at the edges. Epibenthic marine invertebrates are largely absent from the Lagoon. The fish fauna is dominated by sticklebacks (M. Dethier, University of Washington, personal communication). The biota of Lake Pondilla remains largely unstudied.

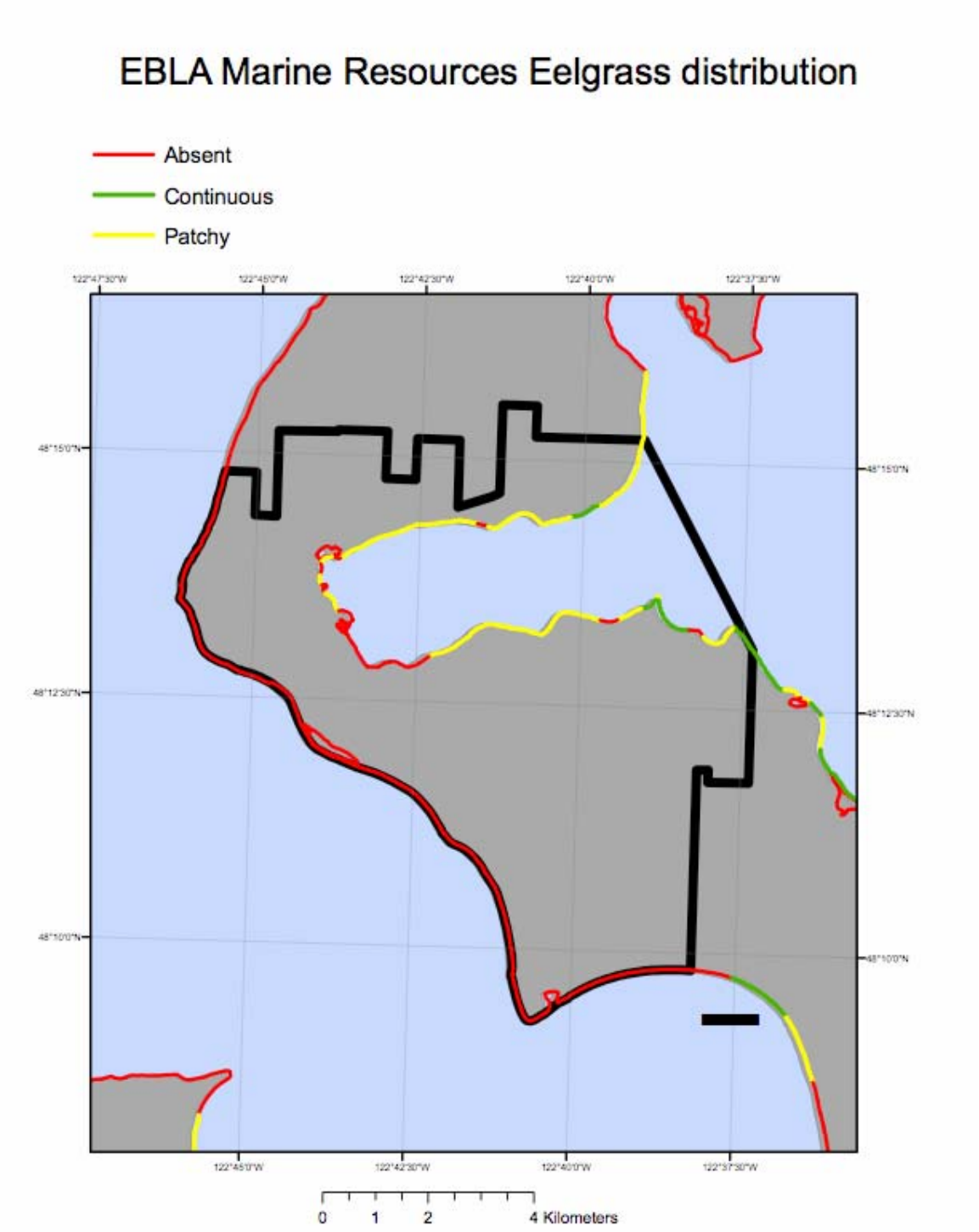

Figure 12. Eelgrass distribution in the vicinity of EBLA. Map created using Washington State Shorezone Atlas.

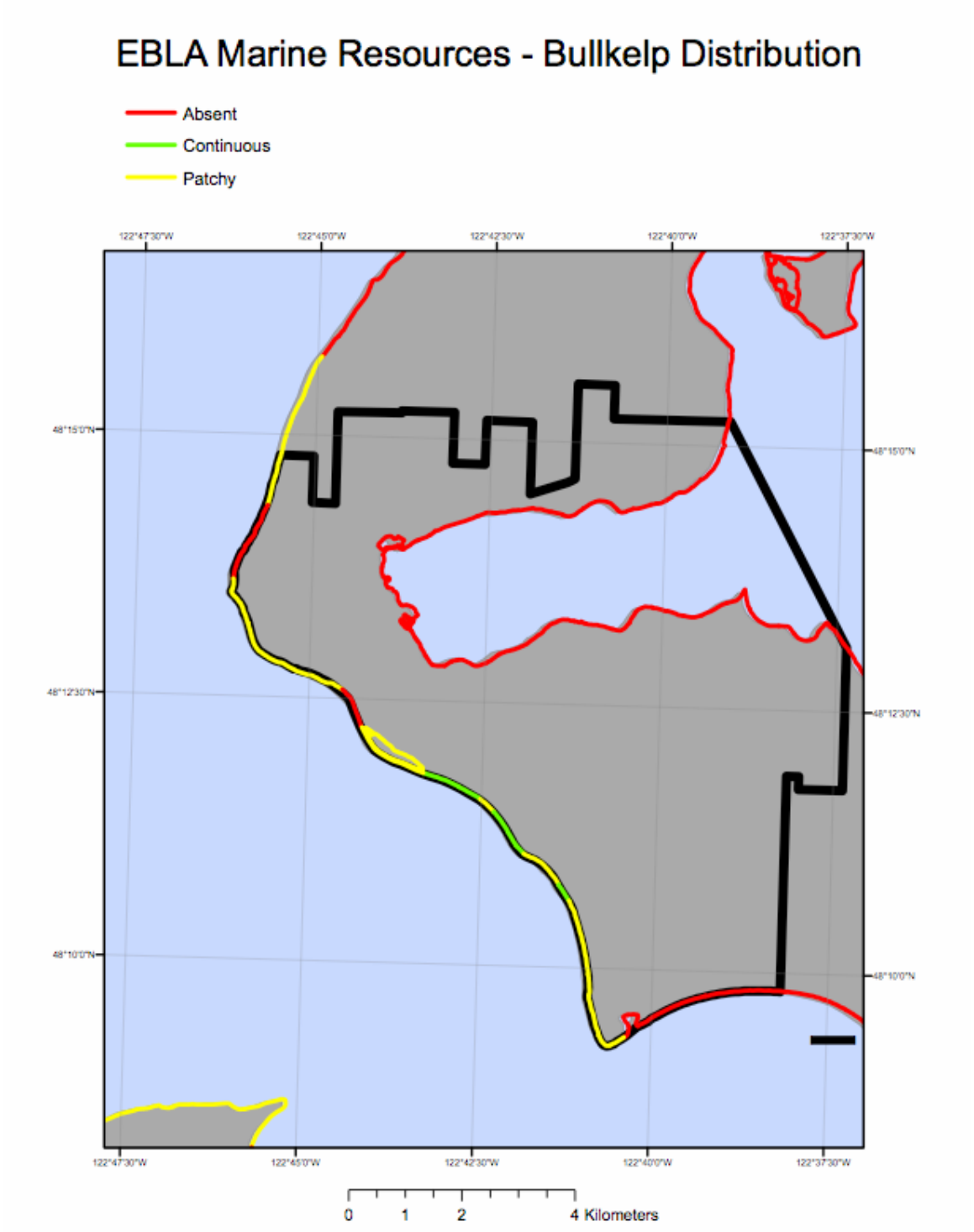

Figure 13. Bull kelp distribution in the vicinity of EBLA. Map created using Washington State Shorezone Atlas.

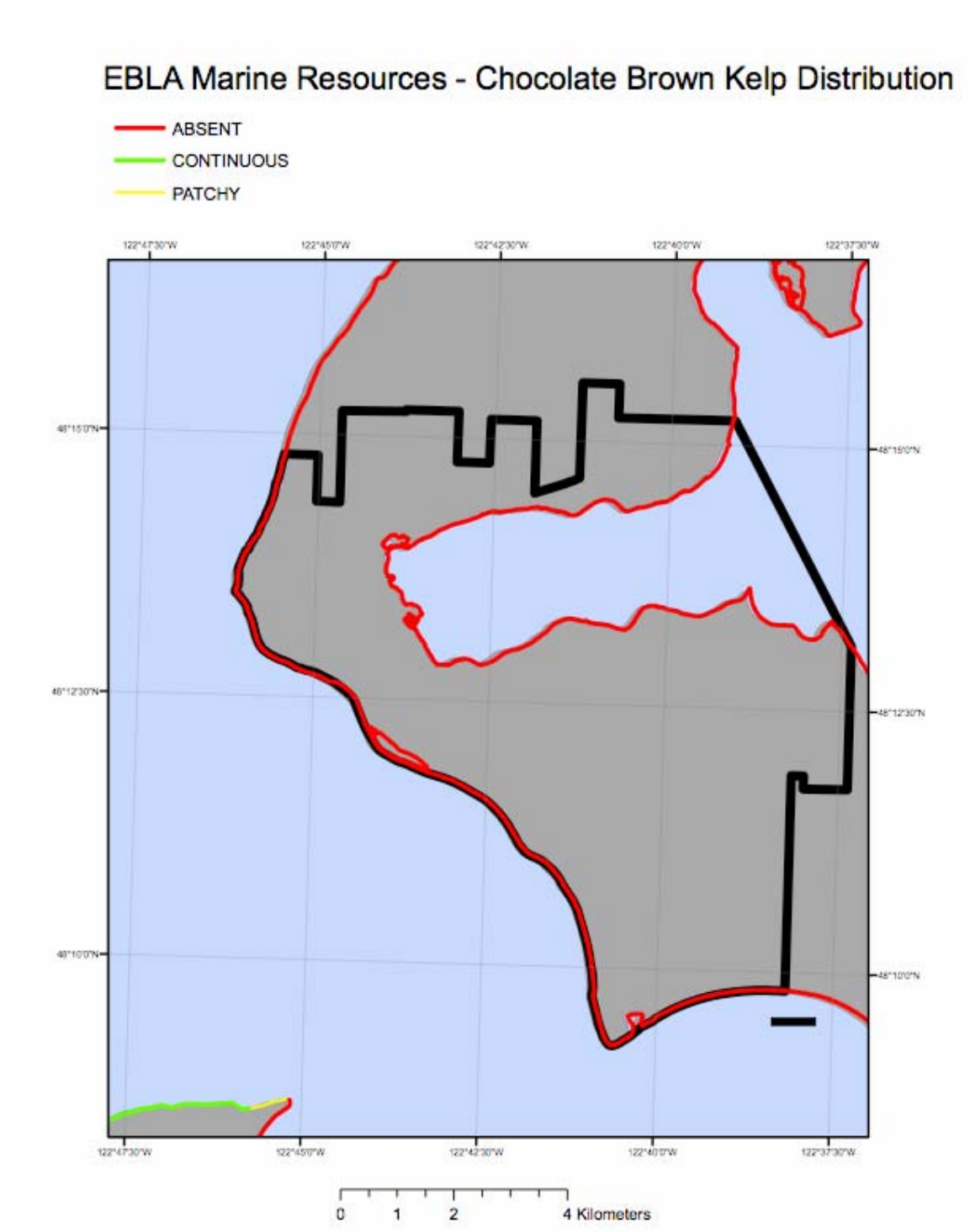

Figure 14. Chocolate-brown kelp distribution in the vicinity of EBLA. Map created using Washington State Shorezone Atlas.

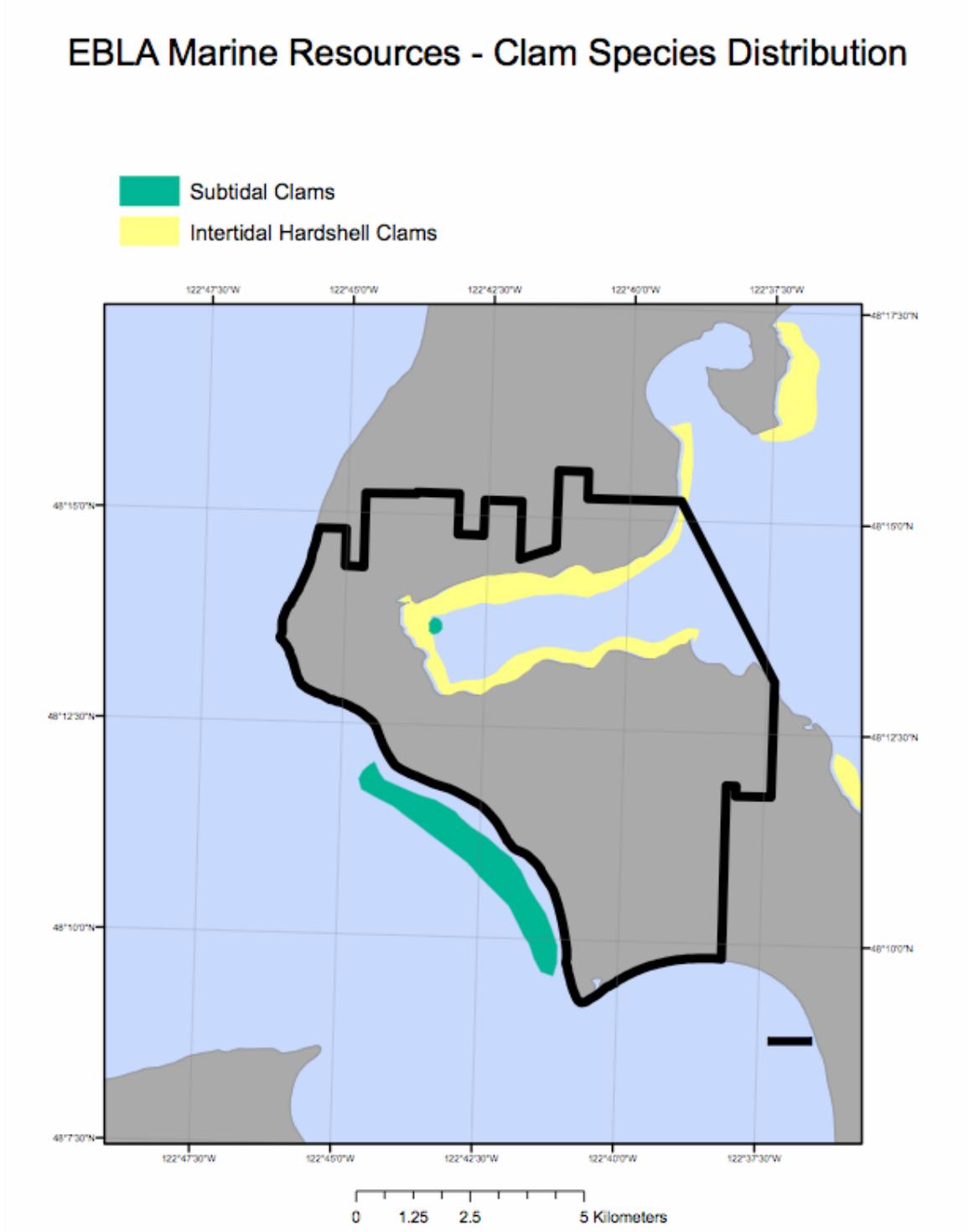

Figure 15. Clam distribution in the vicinity of EBLA. Map created from WDFW geospatial data.

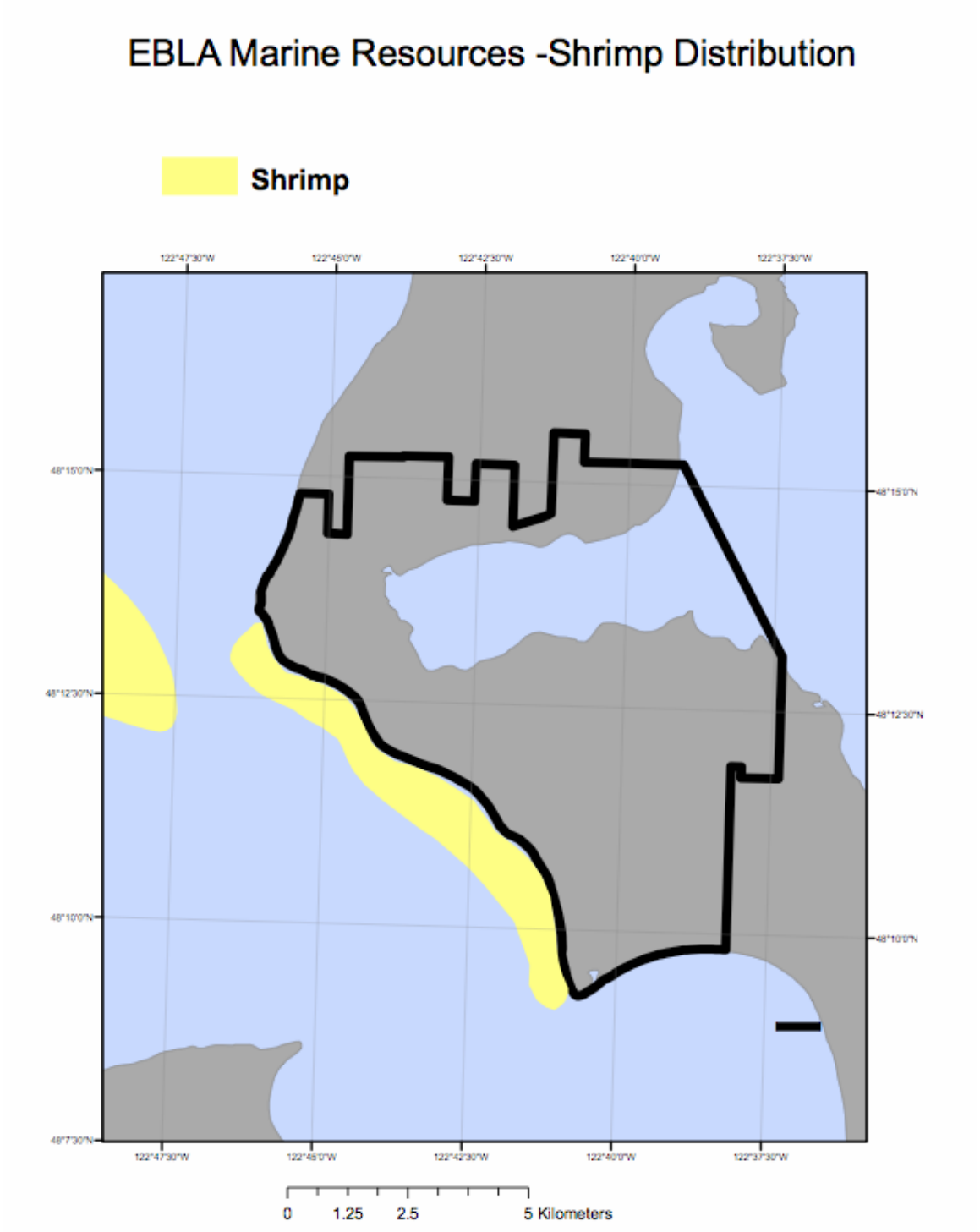

Figure 16. Shrimp distribution in the vicinity of EBLA. Map created from WDFW geospatial data.

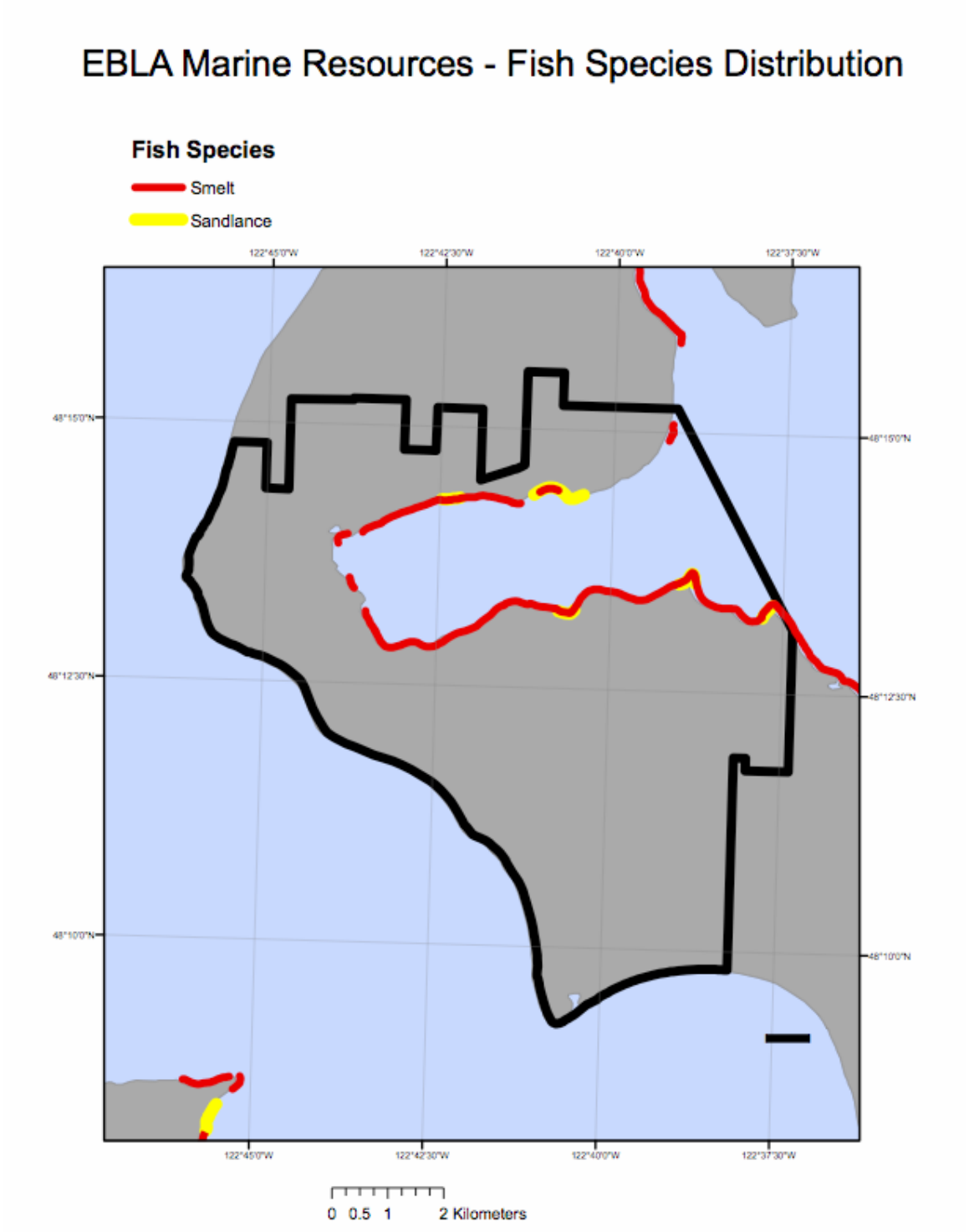

Figure 17. Surf smelt and sand lance distribution in the vicinity of EBLA. Map created from WDFW geospatial data.

B. Water Resources Assessment

B.1. Water quality

Our review of existing sources of marine water quality data for EBLA yielded two kinds of information: marine water quality data collected by state and other agencies and assessments of marine water quality drafted by federal, state and local agencies. We also obtained three previous assessments of marine water quality that synthesize the results of the data collection efforts described above:

- National Park Service's Water Resources Division's Baseline Water Quality Inventory Report for EBLA, completed in 2000.
- The Washington State Department of Ecology (WDOE) produces periodic reports evaluating marine water quality for Puget Sound, Willapa Bay and Grays Harbor based on data they have collected through the Marine Waters Monitoring Program and in partnership with the University of Washington. The most recent assessment recompiled and analyzed water quality data for the years 1997-2000 for Penn Cove, Saratoga Passage and Admiralty Inlet among other locations (Newton et al. 2002).
- A special report prepared by the Washington State Department of Health (WDOH) in 2003 at the request of EBLA staff, describing levels of fecal coliform levels in the marine waters of Penn Cove and Point Partridge on the Admiralty Inlet side (Determan 2003a). The Washington State Department of Health publishes annual reports on the status of shellfish growing areas statewide, addressing levels of fecal coliform, paralytic shellfish poisoning-causing organisms, and domoic acid statewide.

B.1.a. Water Quality Sampling

Most of the marine water quality data discussed in this report comes from the Washington State Department of Ecology (WDOE) and Washington State Department of Health (WDOH). In the past, the Washington State University Extension Beachwatchers program has used volunteers to monitor stormwater quality and possibly marine water quality (NPS 2000). Some of their results have been reported to STORET. Our efforts to retrieve marine water quality data from STORET also indicated that the National Park Service has collected limited amounts of marine water quality data for EBLA at specific sites. Given the apparently sporadic nature of the sampling and the lack of documentation of methods and quality control measures for the latter two sources, we focused our assessment on the Washington State data sources.

WDOE has monitored water quality in greater Puget Sound since 1967 through the Marine Waters Monitoring Program. WDOE maintains five sampling stations within the vicinity of EBLA (Figure 18):

- PNN001, located within EBLA in Penn Cove; sampled monthly from 1973-1988, then again on a monthly basis throughout 1994, 1996, 1997, 1998; monitored on a 3-year rotation after 1998

- SAR003, located in deep water in Saratoga Passage off East Point; sampled on a monthly basis from 1978 to the present; WDOE has also collected sediment quality data for this site on an annual basis since 1989
- SKG003 – A Skagit Bay station north of EBLA, located off Strawberry Point on north Whidbey Island, monitored on a 3 year rotation
- ADM001 – A deep water station south of EBLA
- ADM 002 – A deep water station located north of Quimper Peninsula (near Point Townsend).

WDOE collects two types of water quality data at each station: water samples taken at discrete depths (0.5m, 10m and 30m) for fecal coliform bacteria, chlorophyll a, phaeopigment, nitrate, nitrite, ammonium, orthophosphate, silicate and Secchi disk depth, and depth profiles of temperature, salinity, density, light transmission and pH taken at 0.5 m intervals. Discrete sample data have been collected from 1973 to the present while detailed profile data have been collected since 1990. However, discrete sample data collection procedures varied significantly prior to 1990 (WDOE 2006a). Chemical contamination, plankton species (e.g., toxic blooms), and changes in flushing characteristics are not monitored. Some stations are monitored on a monthly basis every year; others are monitored monthly for 12 months every 3 years ("rotating basis stations").

Data from 1990 and later for these and other stations monitored by WDOE's Marine Waters Monitoring Program are available online at:
http://www.ecy.wa.gov/programs/eap/mar_wat/mwm_intr.html
From the WDOE website we downloaded both discrete sample and profile data for the five stations within and adjacent to EBLA from this website on 12/14/05. Only data meeting WDOE's quality control rankings of "1 - State of art method, adequate QC" and "2 - Less precise method or QC" (WDOE website, accessed 5/18/05) were analyzed (WDOE 2006a).

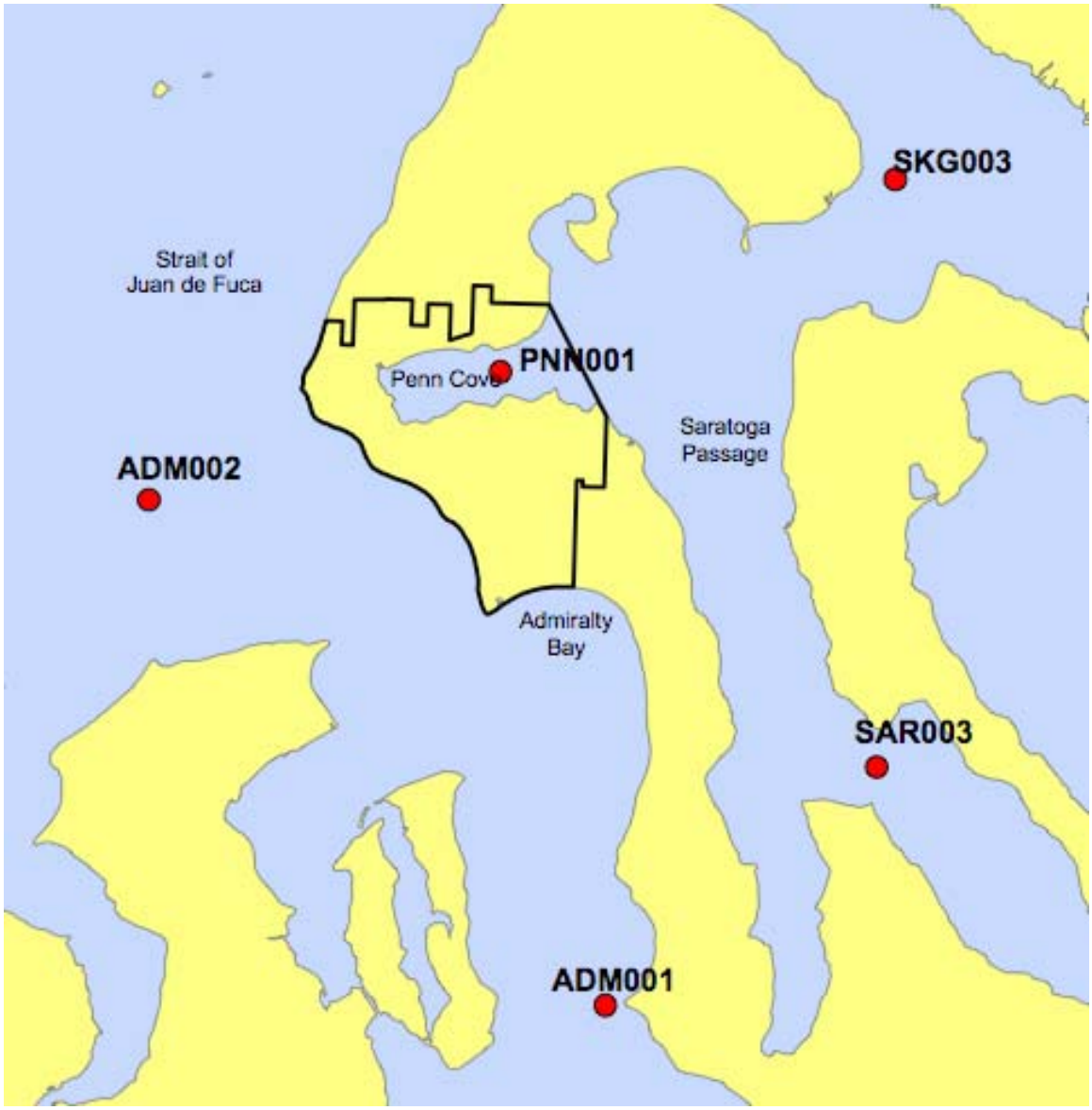

Figure 18. Washington State Department of Ecology sampling stations in the vicinity of EBLA.

Representative water quality data from three stations (PNN001, SAR003, and ADM002) and two depths (10 m and 30 m) are shown in Figures 19-22. At 10 m depth, levels of dissolved oxygen, chlorophyll a, phosphate, and nitrate at 10 m are similar between stations over time (Figures 19 and 21). At 30 m depth, dissolved oxygen tends to be lower in Penn Cove than at other stations (Figure 20), but other water quality parameters are similar between stations (Figures 20 and 22).

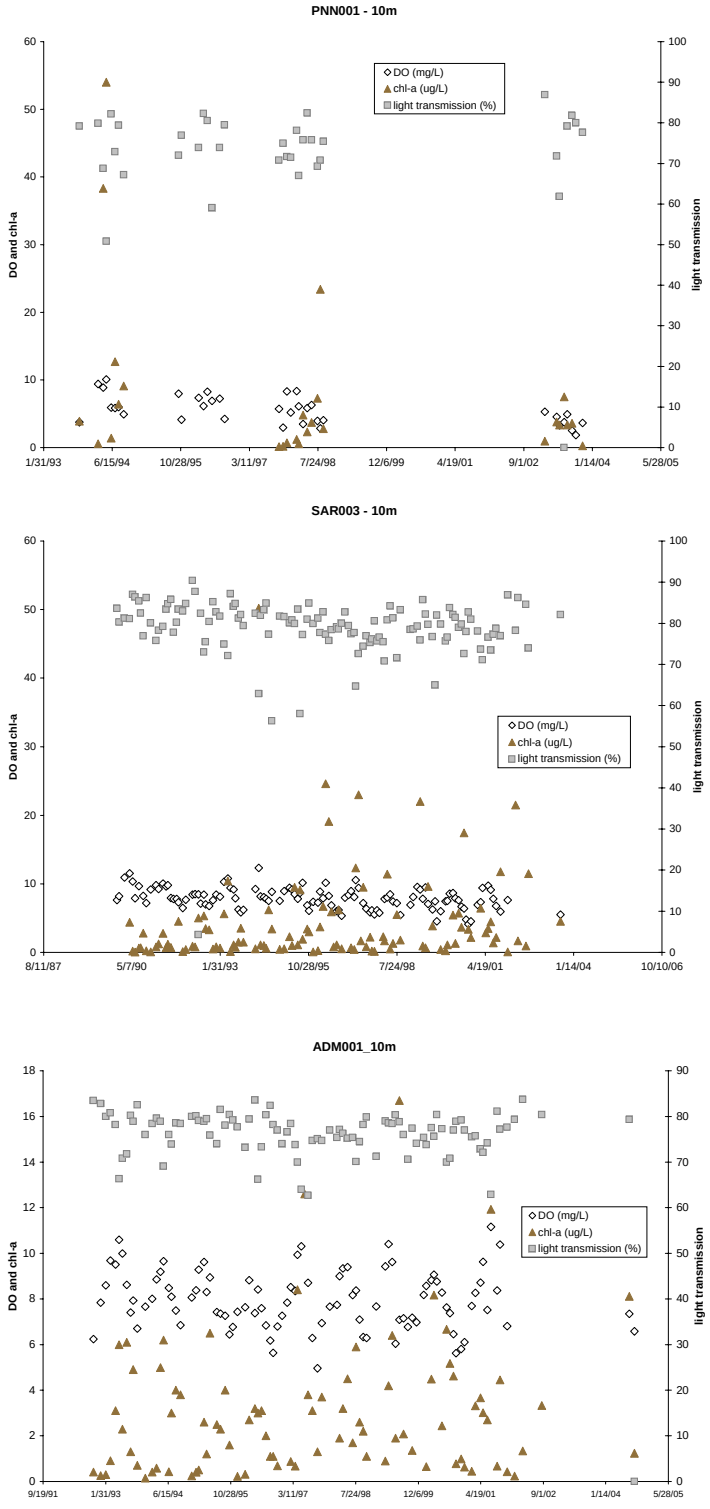

Figure 19. Dissolved oxygen (mg/L), chlorophyll a (µg/L), and light transmission at 10 m depth in Penn Cove (top), Saratoga Passage (middle) and Admiralty Inlet (bottom). See Figure 18 for location of sampling stations. Source of data: WDOE.

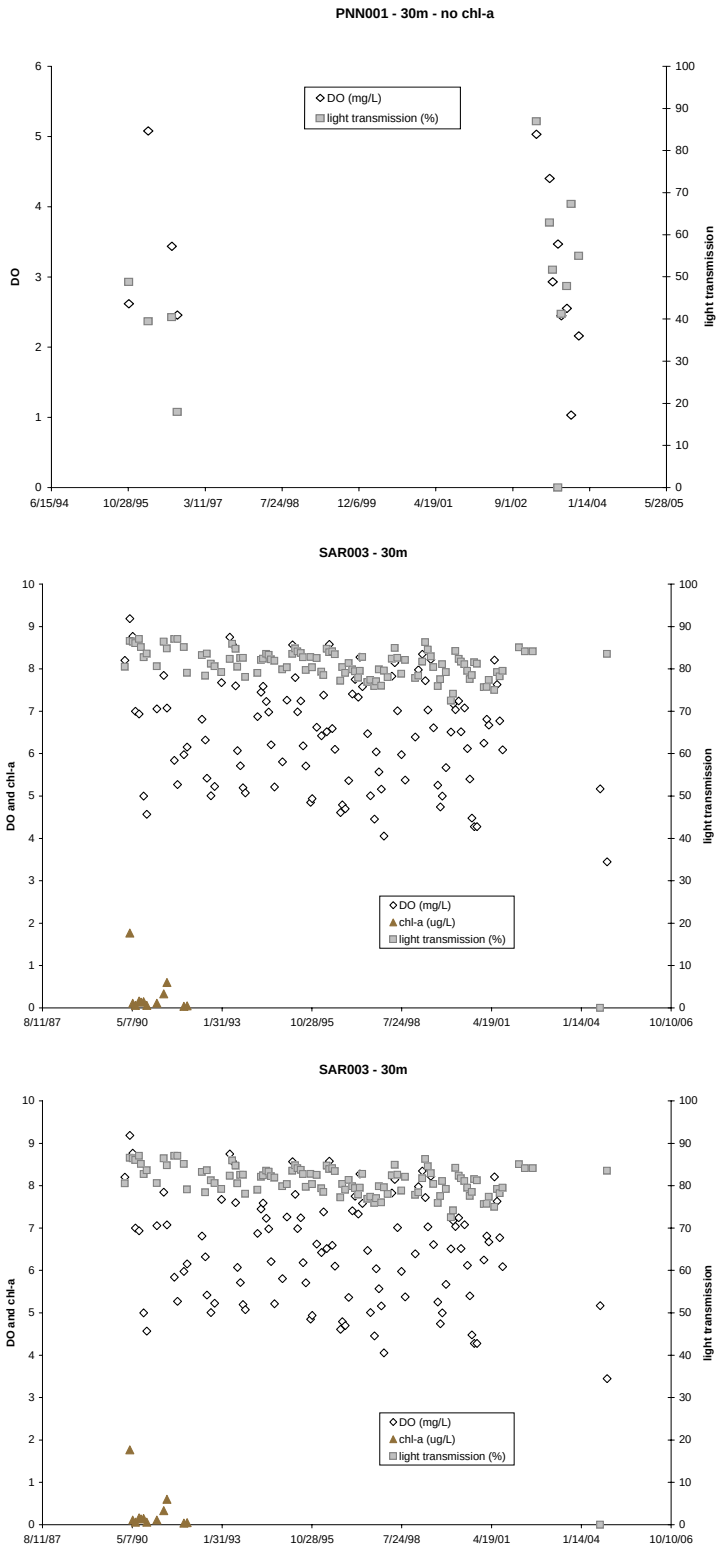

Figure 20. Dissolved oxygen (mg/L), chlorophyll a (µg/L), and light transmission at 30 m depth in Penn Cove (top), Saratoga Passage (middle) and Admiralty Inlet (bottom). See Figure 18 for location of sampling stations. Source of data: WDOE.

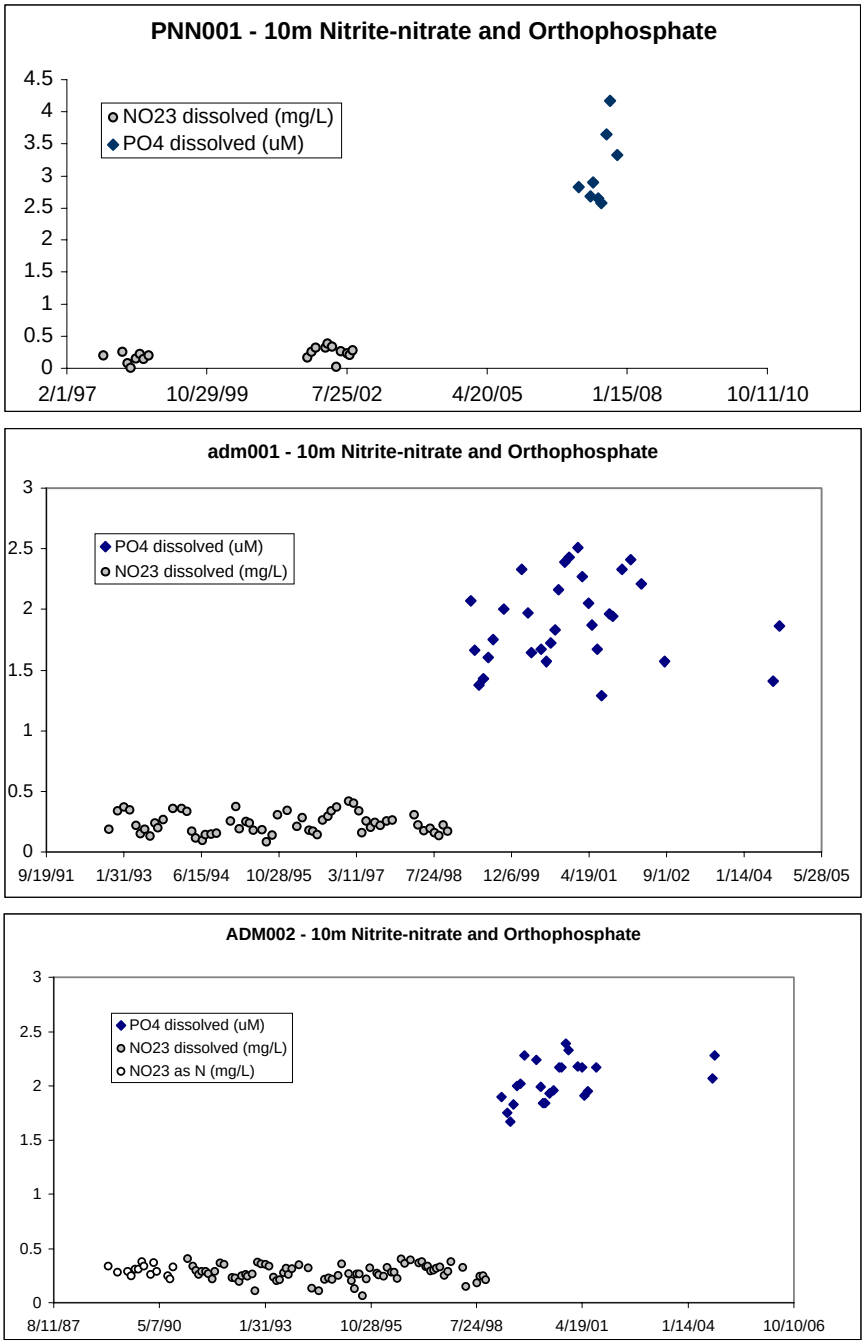

Figure 21. Phosphate (µg/L) and nitrate (mg/L) at 10 m depth in Penn Cove (top), Saratoga Passage (middle) and Admiralty Inlet (bottom). See Figure 18 for location of sampling stations. Source of data: WDOE.

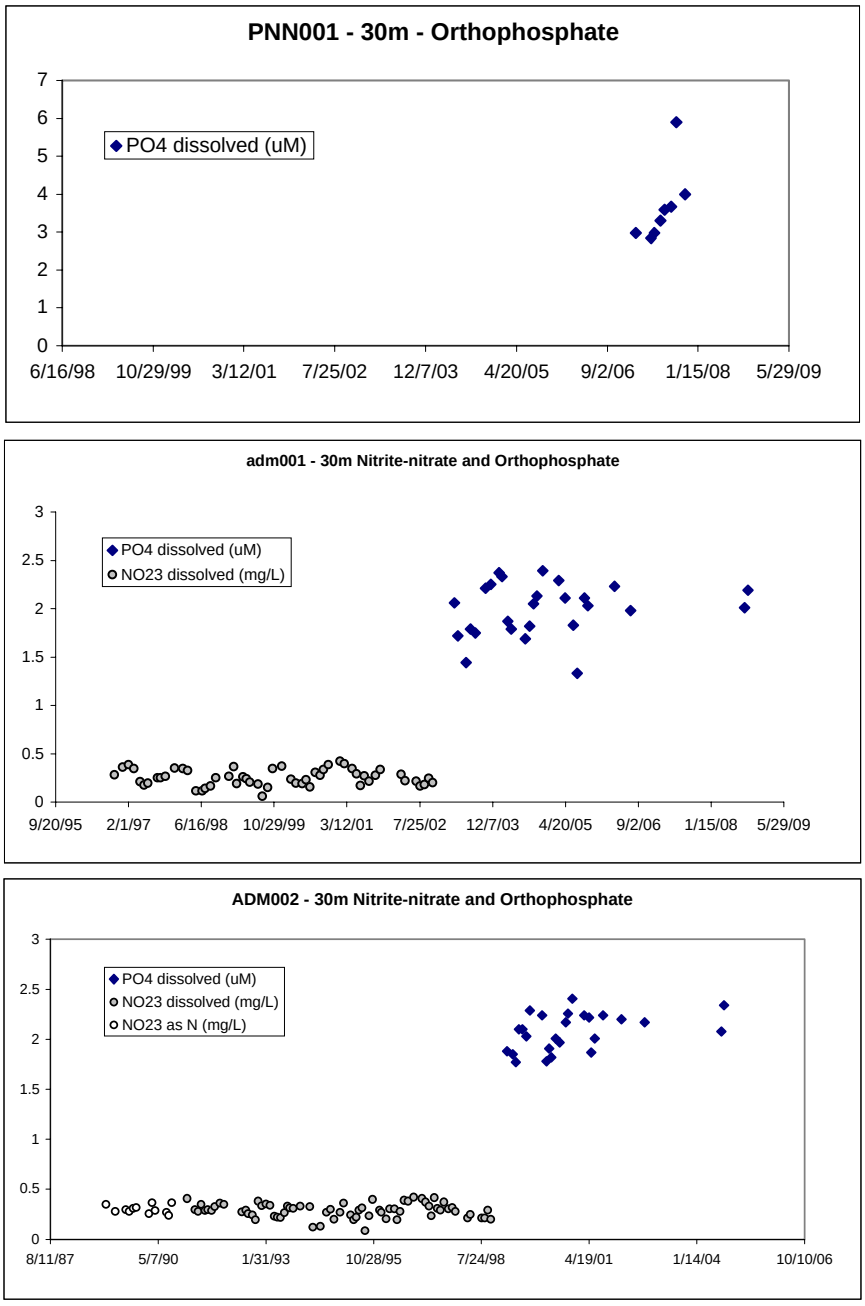

Figure 22. Phosphate (µg/L) and nitrate (mg/L) at 30 m depth in Penn Cove (top), Saratoga Passage (middle) and Admiralty Inlet (bottom). See Figure 18 for location of sampling stations. Source of data: WDOE.

The Washington State Department of Health (WDOH) monitors quality of waters within and adjacent to EBLA as part of its efforts to ensure the safety of shellfish harvested for human consumption. In commercially harvested shellfish growing areas, the WDOH Food Safety and Shellfish Program monitors fecal coliform bacteria, temperature and salinity on a near-monthly basis within commercial shellfish growing areas. Two such areas lie within EBLA: Penn Cove and Point Partridge (located on the Admiralty Inlet side). In Penn Cove, WDOH has collected water quality data from 18 separate monitoring stations located around the perimeter of the Cove on a near-monthly basis since 1988. On the Admiralty Inlet side, WDOH monitors water quality at three stations along the shore between Hastie Lake Road and Crosby Road. WDOH monitored these stations on a near-monthly basis from 1996 through 2003, and has monitored them only sporadically since then (March and July 2004, Jan. 2005). We requested and obtained the raw data collected by WDOH at these locations from 1988 through March 2005 (Don Melvin, WDOH, personal communication, 6/16/2005).

WDOH also monitors molluscan shellfish tissue samples taken from shellfish growing areas and recreational harvesting areas for marine biotoxins, specifically saxitoxins (algal compounds responsible for paralytic shellfish poisoning) and domoic acid. In the summer months, WDOH also monitors levels of the bacterium *Vibrio parahaemolyticus* levels in shellfish and closes harvest areas when bacteria levels are high. Commercial growing areas are monitored more frequently, depending partly upon the level of harvesting activity. If conditions are such that biotoxin problems are more likely, WDOH increases the monitoring frequency of both commercial and recreational areas WDOH 2006). WDOH does not currently monitor changes in phytoplankton assemblages in Puget Sound.

B.1.b Water Quality in Penn Cove

WDOE produces periodic reports evaluating marine water quality for Puget Sound, Willapa Bay, and Grays Harbor based on data they have collected through the Marine Waters Monitoring Program and in partnership with the University of Washington. The most recent assessment recompiled and analyzed water quality data for the years 1997-2000 for Penn Cove, Saratoga Passage and Admiralty Inlet, among other locations (Newton et al. 2002). In addition to evaluating the water quality conditions and the sensitivity of particular areas and sub-basins to water quality problems, WDOE also attempted to evaluate the contributions of climate conditions to the patterns observed. The study identified nine stations of the highest (marine) water quality concern on a statewide basis for the stations assessed during WY 1998 – WY 2000. Among these were two stations in the vicinity of EBLA: Penn Cove and Saratoga Passage, which were identified based on levels of dissolved oxygen, ammonium, nitrate and nitrite observed during that period.

We found no water quality data specific to Kennedy's Lagoon and Grasser's Lagoon, both of which are located in Penn Cove. In the absence of samples from within these lagoons, we cannot evaluate the condition of these resources.

Nutrients and Dissolved Oxygen
We obtained WDOE data for the Penn Cove station, PNN001 (WDOE 2006a). Since 1990, WDOE has collected water quality samples in Penn Cove during water years 1994, 1996, 1998 and 2003.

WDOE's most recent report of water quality in Puget Sound, Willapa Bay and Grays Harbor provides marine water quality data for the years 1997-2000 for Penn Cove, Saratoga Passage and Admiralty Inlet (Newton et al. 2002). The report cites Penn Cove as one of nine stations at which marine water quality in 1998-2000 was of high concern. Newton et al. (2002) concluded that Penn Cove tends to show strong, persistent stratification that likely leads to the natural development of seasonally low dissolved oxygen levels. In both 1994 and 1998, extremely low dissolved oxygen concentrations were observed; in 1998 low dissolved oxygen concentrations were not as extreme as in 1994 but low dissolved oxygen concentrations were observed more frequently.

Our review of the raw data collected by WDOE in 2003, the only year in which data were collected for Penn Cove since 1998, showed that dissolved oxygen concentrations below 5 mg/L were recorded in every month that data were collected (from February through August, and November). Dissolved oxygen concentrations less than 3 mg/L were recorded in May (2.9 mg/L), July (2.3 mg/L), August (2.4 mg/L) and November (2.0 mg/L).

While cautioning that dissolved oxygen concentrations can be very dynamic, Newton et al. (2002) concluded that conditions in Penn Cove "*do appear to be declining and DO concentrations are at biologically relevant low concentrations with alarming frequency in this area. Anthropogenic activities (both present and future) that add nutrients, stimulate plankton production, decrease circulation, or increase oxygen demand within the Cove should be carefully evaluated. Further monitoring and study is highly recommended*."

Water quality assessments commissioned by Island County in the mid-1990s as part of the county's efforts to develop a non-point source pollution action plans reviewed the long-term monitoring data collected by WDOE at the Penn Cove station (PNN001) and the fecal coliform data collected by WDOH. The consultant concluded that "preliminary data analysis indicates that water quality problems may exist in Penn Cove." They characterized Penn Cove as "a poorly mixed bay, with very high spring and summer algal growth, and anoxic conditions at depths below 10 to 12 meters in the fall," and suggested that Penn Cove may be nitrogen-limited and thus sensitive to anthropogenic inputs of nitrogen (Herrera Environmental Consultants 1995).

Bacterial Contamination
As part of the state shellfish sanitation program, WDOH has monitored fecal coliform levels at 18 stations in Penn Cove on a near-monthly basis since 1988 (Figure 23). From the individual sample results (given as most probable number or MPN), WDOH calculates two statistics for each station: a geometric mean and 90th percentile, both

based on the 30 most recent samples for each station. These statistics are then compared with the National Shellfish Sanitation Program criteria for shellfish growing areas of a geometric mean equal to or less than 14 MPN/100 mL and a 90th percentile equal to or less than 43 MPN/100mL (if no point sources are present) or 10% of the results are not to exceed 43 MPN/100mL (where point sources are present). WDOH also provides these results to the Washington State Puget Sound Ambient Monitoring Program, which reports fecal coliform levels using the 90th percentile statistic.

We obtained the raw results for the more than 3200 samples that have been collected from 1988 through early 2005 from WDOH (Don Melvin, WDOH, personal communication, 1/25/06). Calculating geometric means for the large number of samples for Penn Cove and Point Partridge was beyond the scope of this report, but the instantaneous values for fecal coliform show that the standard has been exceeded in both places since 1990. In Penn Cove, there have been 53 days where at least one station (and often multiple ones) returned readings greater than 14 MPN/ 100mL.

In 2003, at the request of EBLA staff, WDOH prepared a special report describing levels of fecal coliform in the marine waters of Penn Cove and Point Partridge, on Admiralty Inlet (Determan 2003a). The report focused on the fecal coliform levels measured in 2002 and used the more sensitive 90th percentile statistic. Determan's analysis found that in 2002 none of the 18 stations in Penn Cove exceeded the National Shellfish Sanitation Program's limit of 43 MPN/100 mL. The highest calculated values were for Station 205, near Coupeville, and did not exceed 20 MPN/100 mL. Seven other stations exceeded 10 MPN/100 mL. Determan performed a second analysis of levels of fecal coliform pollution at those stations for calendar year 2002. This analysis indicated that fecal coliform levels increased at four stations in Penn Cove declined at four other sites. The four sites that exhibited an increase in fecal coliform were Station 202, east of Coupeville at Lovejoy Point; Station 218, west of Coupeville; Station 217, at the mouth of Grasser's Lagoon, and Station 220, further west of Coupeville (Determan 2003a). The report concluded that "although a few stations in Penn Cove show evidence of increasing pollution, overall pollution conditions were good during calendar year 2002."

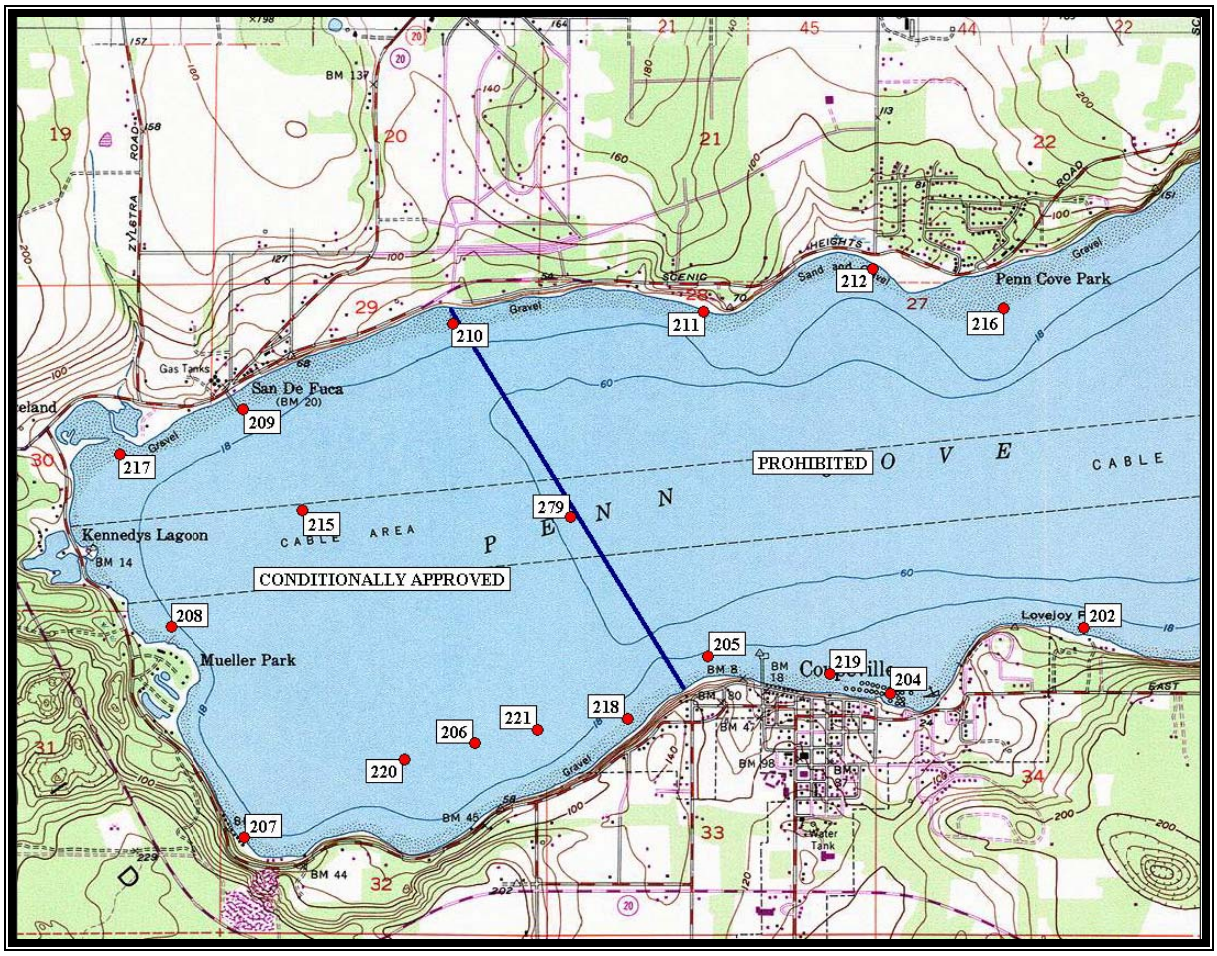

Figure 23. Locations of Washington Department of Health fecal coliform monitoring stations. (Map provided by Don Melvin, WDOH; created using TOPO! ® © 2002 National Geographic Society).

Contaminants

Although WDOE conducts a sediment monitoring program as part of the Puget Sound Ambient Monitoring Program (PSAMP), no past or current sediment monitoring stations are located in Penn Cove. The closest monitoring station, Marine Sediment Station 18, is located in Saratoga Passage just outside the mouth of Penn Cove and near the mouths of Crescent Bay and Oak Harbor to the north. The results for this station are discussed in the Saratoga Passage section.

In 1997, the Washington Department of Ecology and the National Oceanic and Atmospheric Administration (NOAA) embarked on a 3-year cooperative project to assess the degree and extent of sediment contamination in Puget Sound. In the first phase of the project, 100 samples were collected from sites throughout northern Puget Sound, including a site in Penn Cove. A series of biological and chemical toxicology tests were performed on the samples. Overall, the results indicated that sediments from Saratoga Passage (including Penn Cove) "were among the least toxic in these tests" (Long et al.

1999). The report noted no exceedances of Washington State Sediment Quality Standards for the Penn Cove station.

Herrera Environmental Consultants (1995) reported that sediment samples from Kennedy's Lagoon taken in a previous study (URS 1994) detected arsenic, copper, lead, nickel and zinc. Although the levels of the metals did not exceed relevant marine sediment standards, the levels were higher than normal for non-urban bays in Puget Sound.

Marine Biotoxins/Harmful Algal Blooms
WDOH manages two biotoxin monitoring programs: a broader, general program in which biotoxins are monitored in numerous bivalve species collected by state, tribal, county, and local agencies as well as commercial shellfish ventures and volunteer organizations, and an early-warning "Sentinel Monitoring Program" using blue mussels (*Mytilus trossulus, Mytilus galloprivincialis* and *Mytilus californianus*) sampled at specific points throughout the marine waters of Washington State. When the level of paralytic shellfish poisoning (PSP) in a single sample of a particular shellfish species exceeds the US Food and Drug Administration (FDA) action level of 80 µg of PSP toxin in 100 g of shellfish tissue, WDOH closes commercial and recreational harvest areas for that species. The areas are reopened only when continued monitoring assures a return to safe conditions (Determan 2003b).

We obtained from WDOH biotoxin data collected through general biotoxin monitoring program in Penn Cove from 1990 through October 2005 (Jerry Borchert, WDOH, personal communication, 11/10/05). During this period a total of 933 samples were tested for biotoxins. The large number of samples is a result of the frequent monitoring required of commercial shellfish operations; this dataset also includes samples taken by the Island County Health Department and the Washington State University Extension's Beachwatchers Program. These data show that the FDA Action level was exceeded in November/December 1998 and October 2001 for PSP. Domoic acid was detected by this sampling program for the first time in 2005, with a high of 68 µg of per 100 g of shellfish tissue. Domoic acid previously had been detected in 1997 (Trainer et al. 1998) in directed sampling of an algal bloom.

WDOH prepared a special report on paralytic shellfish poisoning patterns in Puget Sound shellfish observed in the Sentinel Monitoring Program in 2001 (Determan 2003b). In 2001, Penn Cove fell into the "low" impact category, defined as PSP levels ranging from 80-499 µg per 100 grams of shellfish tissue.

B.1.c. Water Quality in Saratoga Passage

Nutrients and Dissolved Oxygen
WDOE monitors water quality at Station SAR003, a deep-water (~122 m) station located in Saratoga Passage between Whidbey and Camano Islands that is influenced by several rivers including the Skagit and Stillaguamish, on an annual basis. WDOE's most recent

report of water quality in Puget Sound, Willapa Bay and Grays Harbor provides water quality data for the years 1997-2000 for Saratoga Passage (Newton et al. 2002). In this assessment, the Saratoga Passage station (SAR003) was identified as one of nine stations of highest marine water quality concern statewide during 1998-2000. According to Newton et al. (2002), SAR003 generally experiences strong, persistent stratification with the pycnocline typically within the upper 10 - 20 m (Newton 2002). Over the preceding decade, WDOE's monitoring data suggests that this station has shown increasing frequency and severity of low DO events, with one or two low dissolved oxygen occurrences in the range of 4.4-5 mg/L per year consistently, although there is significant interannual variability. In late 1997 and early 1998, the Saratoga Passage station experienced unprecedented low dissolved oxygen levels of less than 3 mg/L.

Our review of the data collected by WDOE since 2000 indicates that dissolved oxygen levels have fallen below 5mg/L in October and December 2001, in June through September 2002, and in the months of March, April, August and November of 2003. Most low dissolved oxygen readings occurred in deep water (below 60 m depth); however, dissolved oxygen levels of less than 5 mg/L were observed at shallower depths in October 2001 (17 m) and in September 2002 (12 m depth).

Water quality assessments commissioned by Island County in the mid-1990s as part of the county's efforts to develop a non-point source pollution action plan reviewed the long-term monitoring data collected by WDOE. Station SAR 003 was found to have higher chlorophyll a levels and lower nutrients and dissolved oxygen levels than the main basin of Puget Sound, particularly in the fall months. Algal blooms may have been responsible for the low dissolved oxygen levels observed (Herrera Environmental Consultants 1995, 1998).

Bacterial Contamination

We found no data regarding fecal coliform levels in Saratoga Passage in the vicinity of EBLA.

Contaminants

WDOE has conducted a sediment monitoring program as part of the Puget Sound Ambient Monitoring Program (PSAMP) since 1989. Baseline data assessing the toxicity and chemical contamination of the sediments and characterizing infaunal invertebrate assemblages were collected at 76 stations from 1989 through 1995. Thirty-four stations were sampled annually while the remaining forty-two stations were sampled on a three-year rotational schedule (WDOE website, accessed 6/21/05). Marine Sediment Station 18, located just outside the mouth of Penn Cove at the mouths of Crescent Bay and Oak Harbor and Marine Sediment Station 19, located south of EBLA and coinciding with water quality monitoring Station SAR003, were both sampled on an annual basis. WDOE's final report for the period 1989-1995 noted that samples taken at Station 19 (Saratoga Passage) had exceeded the Washington State Sediment Quality Standards for phenol in 1989; detectable concentrations of arsenic, copper and nickel were also found in several years (Llanso et al. 1998). The report noted no exceedances for Station 18 (Oak Harbor) but did note that accumulations of chromium were found in samples taken there.

In 1997, the Washington Department of Ecology and the National Oceanic and Atmospheric Administration (NOAA) embarked on a 3-year cooperative project to assess the degree and extent of sediment contamination in Puget Sound. In the first phase of the project, 100 samples were collected from sites throughout northern Puget Sound, including four sites in Saratoga Passage (Figure 24). A series of biological and chemical toxicology tests were performed on the samples. Overall, the results indicated that sediments from Saratoga Passage "were among the least toxic in these tests" (Long et al. 1999). A single sample, taken from the Saratoga Passage/East Whidbey Island station exceeded Washington State Sediment Quality Standards for phenol but no other exceedances of state standards were found.

WDOE continues to monitor 10 of the original 76 stations; however, the Saratoga Passage stations are not among those monitored. WDOE is in the process of redesigning its sediment monitoring program to focus sampling efforts to better characterize sediments found near rural and urban areas, sites for which there is the greatest need to characterize ambient conditions, rather than basins and passages (WDOE Marine Sediment Monitoring website, http://www.ecy.wa.gov/programs/eap/mar_sed/, last accessed 3/11/06). This may reduce the likelihood of future sediment sampling in Saratoga Passage.

The WDOE data were reviewed by Herrera Environmental Consultants (1998), who concluded that "sediments at this station are silt…Although marine sediment standards have not been exceeded for any contaminant, elevated levels of organic compounds and metals were found in Saratoga Passage compared to non-urban bays in Puget Sound."

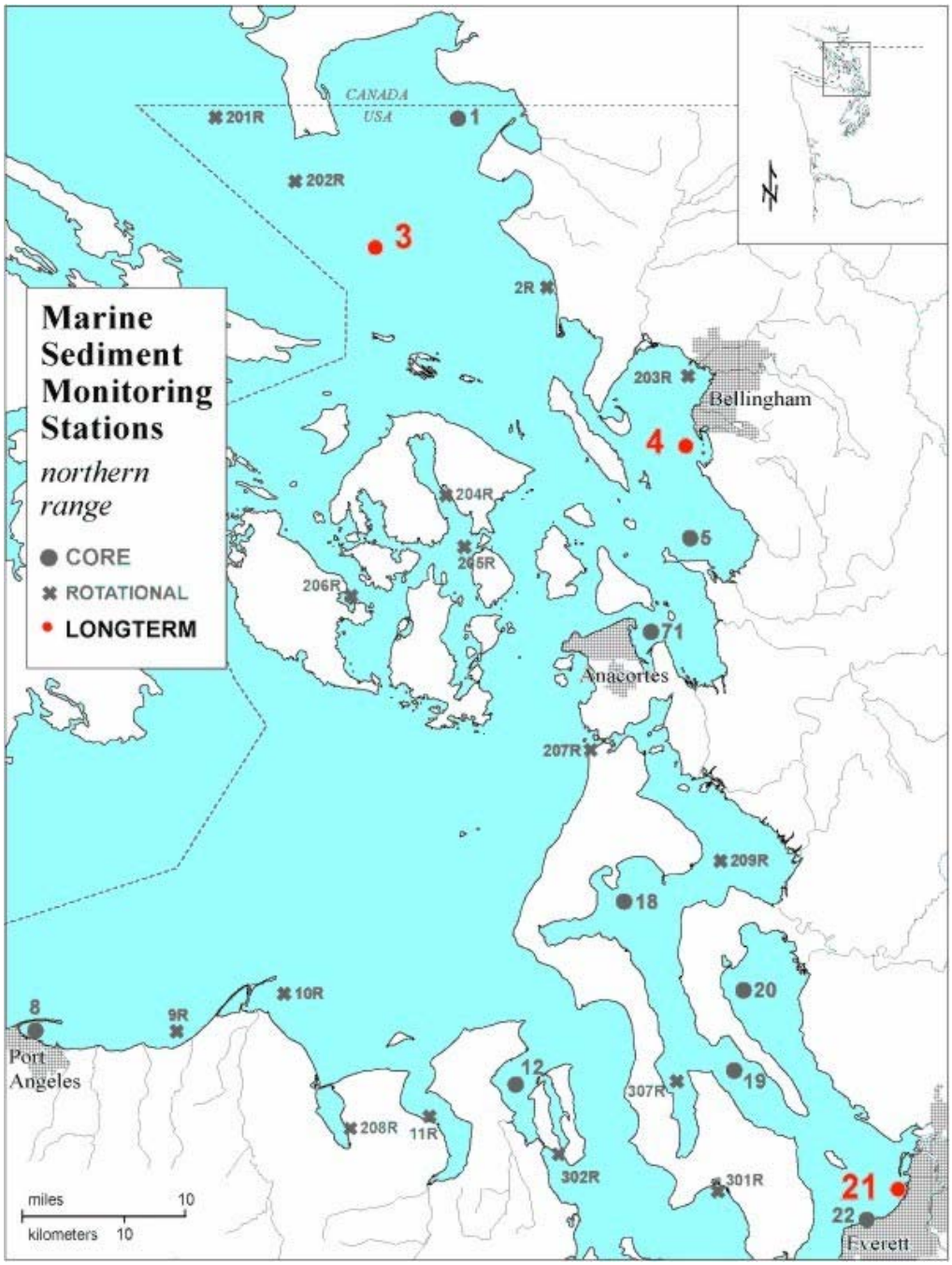

Figure 24. Washington Department of Ecology Marine Sediment Monitoring Stations. (WDOE Marine Sediment Monitoring Program website, http://www.ecy.wa.gov/programs/eap/mar_sed/maps/fig5_8.jpg; last accessed 3/11/06).

Marine Biotoxins/Harmful Algal Blooms
We found not data concerning marine biotoxin levels in shellfish in Saratoga Passage in the vicinity of EBLA.

B.1.d. Water Quality in Admiralty Inlet

Nutrients and Dissolved Oxygen
We obtained WDOE data for two stations in Admiralty Inlet, ADM 001 and ADM 002 (WDOE 2006a). Station ADM 002 is located in deep water to the west of EBLA, just north of the Quimper Peninsula; it is the station closest to EBLA. A second station, ADM 001, is located to the south of EBLA off Bush Point. WDOE has collected water quality samples annually at ADM 002 since 1989, and annually at ADM 001 since 1992.

WDOE's most recent report of water quality in Puget Sound, Willapa Bay and Grays Harbor provides marine water quality data for the years 1997-2000 for Admiralty Inlet (Newton et al. 2002). Station ADM 002 showed dissolved oxygen concentrations of less than 5 mg/L on several occasions. However, Newton et al. (2002) consider these seasonally low dissolved oxygen concentrations a natural phenomenon resulting from upwelled outer coastal waters entering Puget Sound. These upwelled waters are characterized by naturally low levels of dissolved oxygen. This station is physically dynamic and is typically only moderately stratified (if at all) during the months of May to September. Nonetheless, the seasonally low dissolved oxygen levels found at ADM 002 range from 3.3. to 5.3 mg/L and are low enough to induce biological stress (Newton et al. 2002).

Bacterial Contamination
Point Partridge, located on the northern shore of EBLA on Admiralty Inlet, is the site of a shellfish growing area that is monitored by WDOH. WDOH monitors water quality at three stations along the shore between Hastie Lake Road and Crosby Road (Figure 25). WDOH has maintained a more sporadic sampling schedule at Point Partridge, with six months of sampling in 1995, no sampling in 1996-1997, and sampling roughly six months per year since 1998 with the exception of a yearlong gap from mid 1999-mid 2000 (Determan 2003a).

As described above, from the individual sample results (given as most probable number or MPN), WDOH calculates two statistics for each station: a geometric mean and 90th percentile, both based on the 30 most recent samples for each station. These statistics are then compared with the National Shellfish Sanitation Program criteria for shellfish growing areas of a geometric mean equal to or less than 14 MPN/100 mL and a 90th percentile equal to or less than 43 MPN/100mL (if no point sources are present), or 10% of the results are not to exceed 43 MPN/100mL (where point sources are present).

We obtained the raw results for the 245 samples that have been collected since 1996 through January 2005 from WDOH (Don Melvin, WDOH, personal communication, 6/16/2005). Calculating geometric means for the large number of samples for was

beyond the scope of this report, but the instantaneous values for fecal coliform exceeded the geometric mean standard of 14 MPN/100 mL for at least one station at Point Partridge on 14 separate occasions, out of a total of 57 sampling days. High concentrations of fecal coliform were found most frequently at Station 114 (6 occasions, max of 920 MPN/100mL).

In 2003, at the request of EBLA staff, WDOH prepared a special report describing levels of fecal coliform in the marine waters of Penn Cove and Point Partridge (Determan 2003a). The report focused on the fecal coliform levels measured in 2002 and used the more sensitive 90th percentile statistic. Determan's analysis found that in 2002 none of the three stations at Partridge Point exceeded the National Shellfish Sanitation Program's limit of 43 MPN/100 mL. Two stations (113 and 114) had values exceeding 10 MPN/100 mL; however, there were insufficient data to allow testing for trends. Based on plots of the available data, Determan (2003a) concluded that pollution conditions at the two stations seemed to be improving.

Marine Biotoxins/Harmful Algal Blooms

We obtained the biotoxin data collected through WDOH general biotoxin monitoring program for Partridge Point from 1998 through September 2005 (Jerry Borchert, personal communication, 11/10/05). During this period, a total of 24 samples were analyzed. These data show no exceedances of the FDA Action level for PSP.

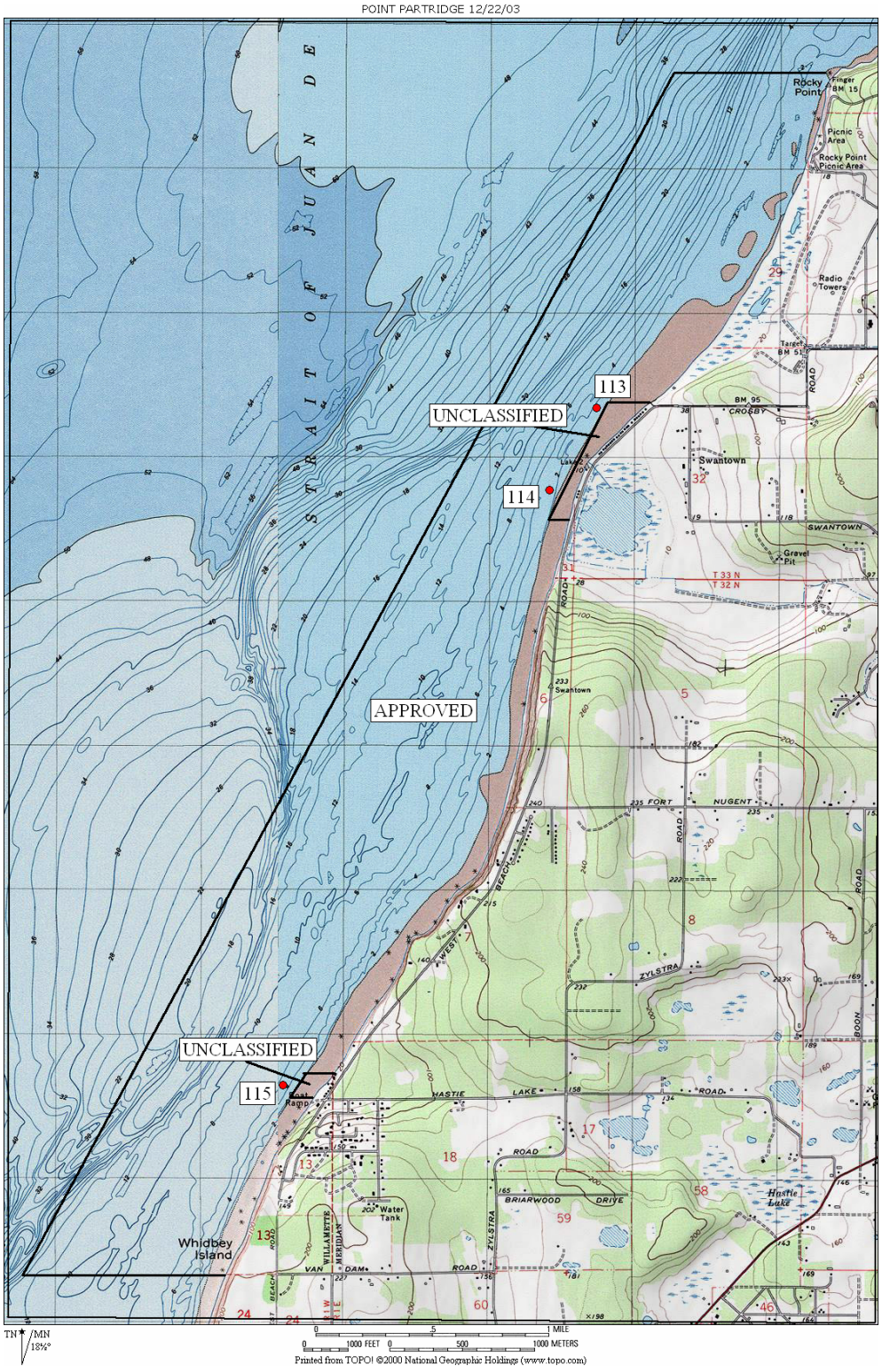

Figure 25. Washington Department of Health fecal coliform monitoring stations on Admiralty Inlet shore of EBLA. (Map provided by Don Melvin, WDOH; created using TOPO!® © 2002 National Geographic Society).

B.2. Threats to Water Quality

Penn Cove is classified as Class A marine water under Washington State regulations. It is currently listed on the state 303(d) list for dissolved oxygen and pH (WDOE 2006a). It was previously listed for fecal coliform in 1996 (WDOE 1996) and for dissolved oxygen in 1998 (WDOE 2000). Saratoga Passage (Station SAR003) is not currently listed on the state 3030(d) list, but was classified as "waters of concern" (Category 2 under Washington State law) for dissolved oxygen. Saratoga Passage (Station SAR003) was listed on the state 303(d) list in 1996 for PCBs and pH (WDOE 1996) and for dissolved oxygen and pH in 1998 (WDOE 2000). As a result of the 303(d) listing, WDOE must develop total maximum daily load (TMDL) limits for dissolved oxygen and pH inputs into Penn Cove.

Admiralty Inlet (Station ADM001) was considered for inclusion on the 2004 and 1998 303(d) list for dissolved oxygen but was ultimately rejected because the observed dissolved oxygen exceedances were thought to be due to upwelling of oxygen-poor oceanic deep water (WDOE 1996, 2006a).

In August 2000, the NPS Water Resources Division (NPS WRD) completed a baseline water quality data inventory and analysis report for EBLA (NPS 2000). This was an effort to retrieve and describe existing data concerning surface water quality —both marine and freshwater— collected by various agencies and housed in the EPA national databases, including STORET. The data, covering the years 1932-1996, were then assessed against published EPA water quality criteria and instantaneous concentration values selected by NPS WRD to identify potential water quality problems within the study area. For the marine waters, the results indicated that dissolved oxygen levels exceeded the EPA criterion for the protection of marine aquatic life of 4 mg/L at several stations, including Penn Cove, Saratoga Passage and Admiralty Inlet near Port Townsend intermittently between 1932 and 1987.

WDOH's Shellfish Growing Area Classification Program evaluates and monitors all commercially harvested shellfish growing areas in Washington State. A growing area's classification is determined by conducting a "sanitary survey," which evaluates the results of a shoreline survey conducted to identify and assess possible pollution sources, the results of fecal coliform monitoring performed by WDOH in that area and an assessment of how weather conditions, tides, currents, and other factors may affect the distribution of pollutants in the area. WDOH conducts a sanitary survey and reassesses the classification of a growing area periodically.

The western portion of Penn Cove currently is classified as "Conditionally Approved" for commercial shellfish harvest, while the eastern portion is classified as "Prohibited". "Conditionally Approved" indicates that the shellfish growing area meets the criteria for "Approved" status under certain predictable conditions. When those conditions are not met, the area is temporarily closed to harvest for a predetermined length of time. The "Prohibited" classification indicates that fecal material, pathogenic microorganisms, or poisonous or harmful substances may be present in concentrations that pose a health risk

to shellfish consumers, or that the area has not undergone a sanitary survey. This represents an improvement from 1985, when fecal coliform levels forced a complete closure of Penn Cove for commercial shellfish harvest. Once conditions improved, WDOH opted to retain the "Conditionally Approved" rating rather than "Approved" due to ongoing operating problems at the Penn Cove Park wastewater treatment facility (one of two treatment facilities discharging into Penn Cove). Because there exists the potential for a sewage 'upset' at either treatment plant discharging into Penn Cove, it is unlikely that the "Conditionally Approved" rating will be lifted. Should an accidental release of sewage occur, WDOH regulations require that the Penn Cove shellfish growing area be closed for a minimum number of days. (WDOE 2005a).

B.3. Sources of Pollutants

B.3.a. Point Sources

Penn Cove

Two wastewater treatment facilities discharge into Penn Cove, the Penn Cove Park wastewater treatment plant and the Coupeville wastewater treatment plant. Previous surveys (Coastal Geologic Services, Inc. and Island Environmental and Technical Services 2004) have identified three stormwater-only outfalls discharging to Penn Cove in the Coupeville area. Farther north on the Saratoga Passage side, two facilities discharge into Oak Harbor (Crescent Harbor and Oak Bay Harbor). Although outside EBLA boundaries, their operation may impact Penn Cove water quality, depending upon tidal currents.

Until the 1990s, both of the wastewater systems discharging Penn Cove only had primary treatment. Though both plants upgraded to secondary treatment in the mid-1990s, WDOH documents and NPDES permit documents for both plants indicate a number of operating difficulties at both plants (WDOH 1995a, 1995b; WDOH 2004, 2005). Also, both systems suffer from significant inflow and infiltration of stormwater, which can overwhelm the plants' treatment system during intense rainfall events resulting in the discharge of undertreated and possibly untreated wastewater into Penn Cove. In the mid-1980s, operating difficulties at the Penn Cove Park wastewater treatment facility were thought to be responsible for high fecal coliform bacteria levels that forced a complete closure of Penn Cove for commercial shellfish harvest.

The Penn Cove Park wastewater treatment system discharges into Penn Cove offshore of the boat launch at the end of Monroe's Landing Park in 50 ft of water. The plant is relatively small, serving only 176 residences and no industrial dischargers with a maximum capacity of 60,000 gallons per day (GPD), but typically treats roughly 15-20,000 GPD in the summer and 22,000-38,000 GPD in the winter. Significant technological and operational improvements have been made at this facility over the last 15 years, leading to an improvement in effluent quality. The discharge pipe currently does not have diffuser ports but is required to install a diffuser not later than October 2006 due to inadequate diffusion at present. The only documented toxic substance

present in the effluent is chlorine, and the plant installed a dechlorination facility in 2003 to address this (WDOE 2005).

The Penn Cove Park Water and Sewer District is in the process of obtaining permission from WDOE to increase the rated capacity of the system from a current maximum capacity of 60,000 gallons per day to 100,000 gallons per day (WDOE 2005). (The actual facility will not expand; instead, this would allow the existing plant to handle greater capacity, which the operators believe it can accommodate under existing conditions.) Under Washington State growth management regulations, allowing additional development in an area requires certification of adequate water supply and wastewater treatment infrastructure. Thus, the proposed expansion of the facility will likely allow additional development to occur in the area. If the plant is re-rated to 100,000 gallons per day, the biological oxygen demand (BOD) and total suspended solids (TSS) loading design criteria will also increase (BOD from 88 to 147 lb/day, TSS from 97 to 162 lbs/day). This means that should development occur to use the additional plant capacity, the overall biological oxygen demand and suspended sediment load to Penn Cove from this facility will increase.

The Coupeville wastewater treatment system is much larger, treating 0.25 million gallons per day (MGD) and serving a combination of residential and industrial customers. Industrial users include the county jail, hospital, school, and restaurants. It discharges from a 1450 ft long pipe into Penn Cove at a depth of 20 feet offshore of the treatment plant (WDOH 2004). The treatment system also includes a pump station and 12" overflow pipe that discharges to the shoreline at the intersection of Front and Alexander Streets (Coastal Geologic Services, Inc. and Island Environmental and Technical Services. 2004). This plant reached capacity within the last few years, and as of 2004 was "currently operating at or slightly above design organic and solids loadings during winter months and is in need of expansion" (WDOH 2004).

Memoranda prepared by WDOH illustrate various operating difficulties including possibly excessive oil and grease in the system from restaurants, fluctuating chlorine residuals, winter flows exceeding design criteria due to inflow and infiltration, and possible sewage spills from 'lift stations' (which may include the pump station at Front and Alexander Streets) into Ebey's landing and Penn Cove (WDOH 1995b). From 2000-2004, the plant had no fecal coliform or TSS violations, two months of BOD exceedances, and four chlorine exceedances. Chlorine and ammonium are the only two toxics that have been identified in the effluent (WDOH 2004).

The Town of Coupeville is in the process of upgrading the plant. The Phase I upgrade was intended to provide more reliable secondary treatment and expanded capacity from 0.25 MGD to 0.44 MGD. Phase II will replace chlorine disinfection system with ultraviolet and add an oxidation ditch. The state has opted not to set an ammonium limit for this plant at this time, citing a lack of 'valid' ambient background data for making such a determination, but is requiring quarterly monitoring of effluent ammonium concentrations (WDOH 2004).

The city of Coupeville maintains a partially piped stormwater collection system. Outside of Coupeville city limits, Island County is responsible for surface water management and manages a ditch and culvert system. Island County has recently compiled data on the county infrastructure has been collected and compiled into a series of Drainage Infrastructure notebooks, one of which is located at the County Courthouse, which are currently being digitized and should be completed in September 2005 (Island County 2001; personal communication, 6/17/05).

In their 2004 survey of the Coupeville shoreline, Coastal Geologic Services, Inc. and Island Environmental and Technical Services (2004) surveyed the stormwater-only outfalls discharging to Penn Cove in the Coupeville area. One outfall, located at Thomas Coupe Park, discharges stormwater that has been treated at the Coupeville wastewater treatment facility. Two small outfalls are located on either side of the Coupeville wharf. One discharges untreated stormwater, while the other may be the overflow pipe for the wastewater pump station at Front and Alexander Streets. Coastal Geologic Services et al. (2004) also noted the presence of several small outfalls scattered along the shoreline that handle local runoff or private discharge (e.g., from roof downspouts). They note that the Coupeville stormwater/sewage treatment outfall has been listed on the Washington State Department of Ecology's 303-d list twice in the recent past (1996 and 1998) (Coastal Geologic Services, Inc. and Island Environmental and Technical Services 2004).

A survey of stormwater quality performed in 1994-1995 identified significant problems in stormwater quality in the Coupeville area that may affect water quality in Penn Cove. In that survey, as part of the North Whidbey Island Baseline Water Quality Monitoring Program, Herrera Environmental Consultants sampled stormwater quality from the stormwater outfall located at Alexander and Front Streets in Coupeville in order to characterize stormwater quality from this urban area. They collected three sets of samples through the winter of 1994-1995, capturing representative water samples for a moderate fall storm, a moderate fall/winter storm, and a moderate winter/spring storm. In addition, a single set of sediment samples were taken from each sampling station. In general, the quality of the stormwater discharged through this outfall was poor, with "elevated levels of suspended solids, turbidity, nutrients, copper, lead, zinc, fecal coliform bacteria and total petroleum hydrocarbons" (Herrera Environmental Consultants 1995). The samples violated state water quality standards for Class A waters for pH on one occasion and for turbidity and fecal coliform bacteria levels on all sampling dates. The highest fecal coliform bacterial level measured was 5,200 MPN/100mL, more than five times the state limit. These data were also evaluated in the National Park Service's Ebey's Landing Baseline Water Quality Inventory Report (as Station EBLA 13); the water quality samples also exceeded NPS Water Resources Division screening criteria for turbidity and bathing water criteria for total coliform levels (NPS 2000).

The City of Coupeville is expected to complete a comprehensive stormwater plan in 2005. This plan, an NPDES permit requirement, must outline a program to control stormwater runoff and specify a means to evaluate effectiveness of the overall program in reducing pollutant impacts on surface water. The plan likely includes the results of

stormwater quantity monitoring and any stormwater quality monitoring done to develop the plan. Our efforts to obtain the draft plan have been unsuccessful to date.

In the past, the Washington State University Extension Beachwatchers program has used volunteers to monitor stormwater quality (NPS 2000) and possibly marine water quality, but we were not able to obtain their protocols or results.

Admiralty Inlet

No wastewater outfalls are located on the Admiralty Inlet side of EBLA. A military wastewater treatment facility (NAS-Whidbey Ault Field) discharges to West Beach, north of EBLA boundaries.

Along the Admiralty Inlet side of EBLA, Island County is responsible for surface water management in areas outside the Coupeville city limits; for this the County maintains and manages a ditch and culvert system. Island County has recently compiled data on the county infrastructure that has been collected and compiled into a series of Drainage Infrastructure notebooks, one of which is located at the County Courthouse. Digitization of these reports was scheduled for completion in September 2005 (Island County 2001; personal communication, 6/17/05). No comprehensive survey of point sources of stormwater discharge has been performed, although this may become possible using the drainage infrastructure information compiled by Island County.

Herrera Environmental Consultants (1998) identified a stormwater outfall on Hill Road, approximately 0.2 miles south of Ebey Road, that contains a perennial stream that has been piped across pastures. WDOE records indicate a drainage pipe discharging directly onto the beach 100 feet east of last house on east side of Main St. as well as 3 outlets to a ditch draining ditch at head of ravine north of Ebey House.

In 1997, as part of the Central/South Whidbey Island Baseline Water Quality Monitoring Program, Herrera Environmental Consultants sampled water quality from the Hill Road outfall in order to characterize stormwater quality from this largely (95%) agricultural area (Herrera Environmental Consultants 1998). Agricultural uses within the watershed draining to this stream/outfall included two large dairies that also grow feed crops plus a few small farms at the time the report was written. Three sets of samples were collected in February and March 1997 representing a range of flow velocities, plus base flow samples in August 1997 (representing dry conditions). A single set of sediment samples from this station were taken in July 1997. Water quality results for the February/March samples were “extremely poor,” with elevated turbidity, total suspended solids, nitrate, total phosphorus, ammonium, copper and fecal coliform bacteria levels. Ammonium and dissolved copper levels exceeded the acute criteria for toxic substances in freshwater, and turbidity and fecal coliform bacteria levels greatly exceeded state standards (Herrera Environmental Consultants 1998). Herrera Environmental Consultants (1998) further noted that “discharge waters at Ebey during winter water quality monitoring were brownish green in color and smelled highly of manure.” Sediment quality at this location was also quite poor, with high levels of fine particles, total organ carbon and copper. No

pesticides, herbicides or petroleum hydrocarbons were detected in the sediments (Herrera Environmental Consultants 1998).

The National Park Service's Ebey's Landing Baseline Water Quality Inventory Report reviewed stormwater quality data for the South Main Street outfall/K Canal (Station EBLA 009), which flows to Admiralty Inlet via a county drainage ditch, collected by the Island County Beachwatchers Program in winter 1995-1996 (NPS 2000). The results exceeded NPS Water Resources Division criteria for turbidity and bathing water criteria for fecal coliform, drinking water criteria for lead and acute freshwater criteria for copper (by a factor of 3) and zinc (by a factor of 5) on multiple occasions.

B.3.b. Non-point Source Pollution

Within EBLA boundaries, only areas within Coupeville city limits and the Penn Cove Sewer District are served by a wastewater treatment facility; all other residential areas use on-site sewage disposal (septic) systems. Older septic systems, built to serve a disposal rather than treatment need, or with septic systems intended to handle seasonal use rather than year-round use, and/or those that have not been properly maintained may impact nearshore water quality. In addition to these sources, rental properties have been identified as having a higher failure rate (Island County Public Works 2003). The Central/South Whidbey Non-point Pollution Prevention Plan, adopted in 2003, includes a proposed project that would identify 'hot spots' of increased failure rates using dyes and sanitary surveys based on records and site visits to evaluate the extent of this project among the five highest priority projects. However, this project has not yet been implemented (Island County Public Works 2003). Island County also conducts outreach and education programs to address this problem, including a low-income loan program to fund repairs to on-site sewage system.

The Central/South Whidbey Non-point Pollution Prevention Plan, which covers the area just south of Penn Cove to the southern end of Whidbey Island, identifies the following activities as significant non-point sources (Island County Public Works 2003). Although this plan covers many areas outside EBLA, given the multiple kinds of development and human uses occurring within EBLA, this list is likely representative of the sources contributing to poor stormwater quality within EBLA. Water quality impacts from agricultural activities are discussed in the next section.

- Residential use of pesticides/herbicides and fertilizers.
- Inadequate erosion control and other BMPs for residential construction.
- Onsite disposal and/or burning of construction site wastes.
- Inappropriate disposal and/or illegal dumping of household, small business, commercial and agricultural hazardous wastes
- Chemical waste spills on Route 20
- Untreated stormwater runoff from impervious surfaces
- Poorly functioning, broken or inadequate existing oil/water separators

- Poorly functioning privately maintained stormwater treatment facilities (particularly commercial facilities)
- Roadside application of herbicides and pesticides
- Sediment loading due to inadequate forestry management practices on small private parcels and inappropriate and destructive logging practices
- Conversion of forested lands to developed residential or commercial lands, thereby increasing stormwater quantity
- Increased untreated surface runoff resulting from loss of critical ecological features on individual parcels (habitat, native vegetation, mature trees, riparian corridors, and others). As more parcels are developed, increased sediment loads enter down slope wetlands and streams, adversely effecting water quality, wildlife habitat, and the overall function and values of the ecosystem.

The Central/South Whidbey Non-point Pollution Prevention Plan lists 30 top priority actions to be taken to prevent and reduce non-point pollution. The following were listed as the top 10 priorities, in order of priority (Island County Public Works 2003):

- Sound Home Gardening Workshops: Workshops covering appropriate garden chemical usage and alternative products and methods. Recommend 12 clinics per year
- On-Site Sewage System Outreach Workshops: Continue support and funding for current education efforts by Washington State University Cooperative Extension Waste Wise and the Island County Health Department.
- On-Site Sewage System Program Support: Continued funding of the low income on-site sewage system loan program.
- Best Management Practices County Staff Support: Continue support and funding for BMP workshops geared for builders, developers, homeowners. Voluntary certification program. User-friendly BMP pamphlets.
- Inventory of Hot Spots/ Sanitary Survey: Identify potential hot spots for potential on-site system failures, conduct a sanitary survey, education and technical assistance to homeowners. (Identified in the plan as needing further study)
- Clean and Simple Project: Distribution of cleaning buckets with alternative (safe) products.
- Alternative Weed Control Program: Develop program to eliminate roadside application of herbicides and pesticides near fish supporting creeks and other critical areas. Review feasibility of alternatives to spraying in other areas.
- Stormwater Study/ Basin Planning Effort: Implementation of a basin and sub-basin planning process by Island County. Using a comprehensive, scientific and analytical process, identify key issues and appropriate long-term drainage and watershed solutions. (Identified as needing further study in the plan)
- Notice Submittal Program: As part of the future permit approval process, require "submittal of notice" to Island County after each service/maintenance of stormwater infrastructure. (Identified as needing further study in the plan)
- Farm-to-Garden Link: Farm-to-garden manure exchange program, linking farmers with gardeners. Program can be expanded to meet increasing demands for compost/amended soil/mulch material. Technical assistance and education for manure management.

We found no marine or stormwater quality data for Grasser's and Kennedy's Lagoon. The Island County Salmon Recovery Plan mentions that potential water quality degradation may occur in these lagoons as a result of non-point runoff from the surrounding residential properties and from the roadways (Island County 2005). Both receive freshwater from surface runoff, and water circulation in Kennedy's Lagoon is partially restricted by a tide gate, although the gate remains in the open position.

Agricultural Uses

The majority of farming activity on Whidbey Island occurs on small farms of one to 15 acres. These farms tend to be non-commercial operations with livestock, particularly horses and cattle, with smaller numbers of sheep, goats and other animals (Island County Public Works 2003). In addition to small farms, there exists one large dairy farm and two manure lagoons with a combined capacity of 10 million gallons. Due in part to significant efforts by the Whidbey Conservation District, many small farms are already implementing best management practices (BMPs).

With regard to agricultural use, The Central/South Whidbey Non-point Pollution Action Plan (Island County Public Works 2003) identified the following factors for consideration in pollution management:

- Inadequate mud management, causing high levels of erosion and sedimentation. This mud is often contaminated with high levels of manure.
- Manure from livestock. The lack of proper manure management can result in contaminated runoff.
- Direct impacts from common farming practices such as livestock trampling creek banks and/or grazing in wetlands; reduction of wildlife and protective buffers around natural systems by vegetation management to the edge; and ditching which removes the hydrology of the wetland area.
- Runoff from barn tops and other structures draining in and out of manure holding and animal containment areas.
- Spills and leaks of pesticides, herbicides, fertilizers and volatile chemicals leaching into ground water and surface water.
- Inadequate animal waste management (not all commercial farms are required to follow the same standards for waste management as are commercial dairy farms).
- Erosion and sedimentation from livestock impacts in sensitive areas.
- Increased herbicide use to control fallow land weed seed banks.

The 1997 Central/South Whidbey Island Baseline Water Quality Monitoring Program (Herrera Environmental Consultants 1998) included a stormwater sample from an outfall draining an agricultural area within EBLA that included two large dairy farms plus several small farms. Results indicated "extremely poor" water quality and the authors noted that the "discharge waters at Ebey during winter water quality monitoring were brownish green in color and smelled highly of manure."

These observations implicate agricultural uses as a past and possibly current threat to the nearshore water quality of Admiralty Inlet. In 1988, WDOE took enforcement actions

against a local dairy farmer for repeated incidents of discharging dairy waste into Admiralty Inlet via a drainpipe emptying directly onto a beach. Fecal coliform levels in the discharge were 460 times more than the allowed levels (WDOE 1988).

NPS staff must track all herbicides and pesticides in use on NPS-owned lands within EBLA, and to do so must obtain this information from farmers and contractors. Many farmers contract weed and pest control to an outside company so the farmers may have little documentation or direct knowledge of what agrochemicals are applied to their fields (Leigh Smith, personal communication, 1/18/05).

Commercial Shellfish Operations

Commercial shellfish farming occurs in Penn Cove and is likely to interact with water quality conditions there. According to Penn Cove Shellfish, adult mussels are able to filter nearly 15 gallons of water per day, removing up to 60% of the plankton from the water they take in (Penn Cove Shellfish, LLC 2006). In addition to growing mussels on rafts, Penn Cove Shellfish also uses Penn Cove to raise juvenile clams that are then transferred to Willapa Bay to reach market size; the mature clams are then returned to Penn Cove for depuration and storage on rafts until they are sold. Consequently, shellfish aquaculture in Penn Cove has the potential to remove phytoplankton cells from the water column and may help prevent the formation of algal blooms there. Viable shellfish aquaculture requires that state water quality standards be met, and triggers increased sampling of water quality in the vicinity of aquaculture installations. The continued presence of commercial shellfish operations in Penn Cove indicates that state standards are (usually) met, and provides a check on water quality that would not otherwise exist.

However, given the strong, persistent stratification of the water column that occurs seasonally in Penn Cove, it is likely that the water quality benefits provided by the shellfish farming that occurs in Penn Cove are mostly limited to the surface layer. Under conditions of stratification, shellfish farming on rafts could conceivably produce a net negative impact to deeper waters via materials excreted by mussels (fecal pellets and pseudofeces). Consequently, the export, deposition, and accumulation of waste products could impact benthic communities and sediment quality in areas where shellfish are farmed.

Superfund Sites

Two current Superfund sites are located north of EBLA that have the potential to affect marine water quality within EBLA boundaries. The Whidbey Island Naval Seaplane Base on Crescent Harbor, just north of EBLA, is a former National Priorities List (Superfund) site. A coastal wetland is located 200 ft from the site. The site was removed from the list in 1995. Contaminants found at this site included heavy metals, pesticides and PAHs. All contaminated soil was removed. The EPA's website states that "the groundwater and surface water may have been contaminated with heavy metals; however, the groundwater is not potable" and apparently was not tested (US EPA 1996).

The Whidbey Island Naval Air Station's Ault Field, located near the shoreline of Admiralty Inlet just north of Oak Harbor, was formerly listed on the "National Priorities

List" of Superfund sites. The EPA's website notes that this site included a landfill located on the beach, pollution of ditches that flowed towards a nearby lagoon and bay prior to excavation and capping, and pollution of groundwater at sea level by volatile organic compounds. The main cleanup activities have been completed; however volatile organic compounds continue to be found in groundwater samples and may require additional remedial work.

Other

The Central/South Whidbey Non-point Pollution Action Plan identified drums of chemicals and other toxic materials that wash up on the beach as health hazard to property owners and a potential source of pollution, particularly as landowners often do not know who to contact to report and properly dispose of them (Island County Public Works 2003).

Creosote coatings on logs release compounds into the marine environment that can be toxic to marine life, especially plankton and larvae. A cooperative effort between Washington State Parks, WDNR, the Island County Marine Resources Committee and others to remove creosote drift logs from beaches in Island County is underway.

Ferry operations at the Keystone Terminal, located within EBLA on Admiralty Inlet, may be another source of water quality contaminants through accidental spills. The Washington State Department of Transportation has proposed expanding the Keystone Terminal. Initial environmental impact assessment documents associated with this proposal include consideration of impacts to aquatic resources and surface water resources (CH2M Hill 2004); a detailed environmental impact analysis of the four options under consideration is scheduled to begin in spring 2006.

C. Other Areas of Concern

In this section we briefly treat other potential threats to water resources within EBLA. The list is not comprehensive, but is intended to reflect the nature and range of threats that could occur within the Reserve. The threats listed below differ in their characteristic scales, level of risk, likelihood of occurrence, and reversibility. They are not equally amenable to local or regional management, and some may not require management at the scale of EBLA.

C.1. Harmful Algal Blooms

Harmful algal blooms (HABs) represent a growing threat to regional water quality; consequently, we treat the topic in more detail in this section.

Toxins produced by phytoplankton appear to have been present throughout the region for centuries (reviewed in Horner et al., 1997). Within Puget Sound, HABs that cause paralytic shellfish poisoning (PSP) and domoic acid poisoning (DAP) are of most concern. WDOH monitors beaches around Puget Sound for biotoxins and pollution and issues public notices regarding shellfish harvest closures based on this monitoring. Information is made available to the public via their website: http://ww4.doh.wa.gov/scripts/esrimap.dll?name=bioview&Cmd=Map&Step=1 and the Marine Biotoxin Hotline (1-800-562-5632). However, WDOH does not release to the public information regarding causes of specific closures, so it is impossible to discern the number of closures that are due to HABs.

C.1.a. Penn Cove

A bloom of the diatom *Pseudonitzschia* occurred in Penn Cove in 1997 (Trainer et al. 1998). *Pseudonitzschia* species are known to produce the potent toxin domoic acid that is harmful to humans. This event was first identified by WDOH, which detected elevated levels of domoic acid in commercially grown shellfish in the cove. The development and dissipation of the bloom was closely followed by researchers (Trainer et al. 1998). Four species of *Pseudonitzschia* were found in samples from the Cove. The bloom appears to have been initiated by physical conditions that included strong discharge from the Skagit River, heavy rainfall, and strong south and southeasterly winds, followed by a period of weak winds, high insolation, and the formation of a freshwater lens at the mouth of the cove. These conditions led to stratification within the Cove and conditions favorable to bloom formation.

Communication with WDOH indicates that few additional data exist regarding the occurrence of HABs in Penn Cove. However, the 1997 event indicates that Penn Cove is susceptible to the formation of HABs. Human use of Penn Cove could be impacted by HABs, for example via impacts to commercial aquaculture and recreational clam harvest.

C.1.b. Admiralty Inlet

HABs have not been reported from the Admiralty Inlet shore of EBLA. Stratification of the water column and retention of water masses are less likely to occur on this shore, which is characterized by swift tidal currents and open, exposed shores. Consequently, the physical conditions that favor bloom formation are less likely to occur on the Admiralty Inlet shore of EBLA.

C.2. Non-native and Invasive Species

Seventy-six non-native species have been reported from marine and estuarine environments in the Puget Sound Region (Wonham and Carleton 2005). A large fraction of these were introduced with the growth of the oyster industry in the middle of the past century; other introductions have come from ballast water and other intentional and unintentional sources.

Several non-native species appear to be established within EBLA (NPS 2005). All are species that are common throughout Puget Sound: the Manila clam (*Venerupis philippinanrum*), the Pacific oyster (*Crassostrea gigas*), the Eastern softshell clam (*Mya arenaria*), and the beach grass *Ammophila arenaria*. The brown alga *Sargassum muticum* was introduced to Puget Sound with early aquaculture endeavors. The species now is common throughout much of Puget Sound. *Sargassum* is likely to occur in shallow subtidal areas of Penn Cove and may occur in rocky areas along Admiralty Inlet. The green crab (*Carcinus maenas*), an invasive species of concern on Washington's outer coast, has not been found on Whidbey Island to date (NPS 2005). Atlantic salmon occur throughout Puget Sound, where they are of concern because of potential impacts to native salmonids, but they are unlikely to impact biological resources within or adjacent to EBLA.

C.2.a. Penn Cove

The physical attributes and human uses of Penn Cove are similar to those that favor biological invasion elsewhere in Puget Sound. Consequently, biological invasion is more likely to occur in Penn Cove than on the Admiralty Inlet side of EBLA.

Spartina anglica, a highly invasive cordgrass that significantly alters mudflat habitats, has been found in Penn Cove near Coupeville, in Grasser's Lagoon (WSCC 2000), and in Kennedy's Lagoon (NPS 2005). It has not yet been found on the Admiralty Inlet side of the island, and is less likely to occur there because of habitat requirements. While there are no specific reports of damage caused by *Spartina* within EBLA, its potential to alter habitat and displace native biota has been documented elsewhere Washington State. *Spartina* has been treated by mowing followed by spraying with the herbicide glyphosate by the Island County Noxious Weed Board. The county has also explored shading and

manual removal. *Spartina* has been successfully removed from other areas in Puget Sound (for example, the Padilla Bay National Estuarine Research Reserve and Argyle Lagoon on San Juan Island), but removal is highly labor-intensive and creates a large amount of physical disturbance. Dense populations of *Spartina* exist elsewhere in Island County (for example, in Triangle Bay on Camano Island); nearby source populations are numerous, so repeated introductions of *Spartina* to EBLA are likely. Dethier and Hacker (2004) provide a comprehensive treatment of the problem in Puget Sound.
The purple varnish clam (*Nuttallia obscurata*) has been found within Penn Cove. The Mediterranean mussel, *Mytilus galloprovincialis*, is used in aquaculture in Penn Cove and common in other areas of Puget Sound, including the nearby Padilla Bay National Estuarine Research Reserve. The species occurs within EBLA outside of aquaculture operations. This species can be difficult to identify because it is morphologically indistinguishable from the native mussel, *Mytilus trossulus*; its impacts are not known.
The Pacific oyster, *Crassostrea gigas*, is grown in aquaculture in Penn Cove. It occurs in Penn Cove outside aquaculture operations, where it interacts with the local biota.

The invasive tunicate, *Didemnum sp*., recently has been reported from several sites around Puget Sound (www.wsg.washington.edu/research/ecohealth/june05invader.pdf). *Didemnum* appears to have been introduced to Puget Sound via ballast water; the mechanism of spread within the Sound has not yet been identified. Within Puget Sound, *Didemnum* has been found in marinas, on artificial reefs, and in the vicinity of shellfish farms. Consequently, Penn Cove is a likely site of eventual invasion by this species. *Didemnum* is highly undesirable and has caused negative impacts to biological communities and human uses of the marine environment in other areas where it occurs.

C.2.b. Admiralty Inlet

The number and biomass of invasive marine species on the Admiralty Inlet shore of EBLA is unquantified. However, there is no evidence that the area is substantially invaded by non-native marine species. Based on evidence from other areas of similar habitat within the region, *Sargassum muticum* could become established in shallow intertidal areas along Admiralty Inlet as the species expands throughout northern Puget Sound. Once established, Sargassum could displace native species, as has been demonstrated in the San Juan Archipelago and the southern Strait of Georgia. In upland areas along the Admiralty Inlet shore, exotic species include Canadian thistle (*Cirsium arvense)*, which covers less than 5% of the area surrounding Crockett Lake (Sheldon & Associates 2001).

C.3. Harvest and Collection of Organisms

C.3.a. Penn Cove

A substantial amount of human harvest of marine resources occurs in Penn Cove. These are attributable both to aquaculture activities and to recreational harvest. Shellfish are the

primary target of harvest in the Cove. Currently, the eastern half of Penn Cove is closed to human harvest and the western half is conditionally approved for harvest (Determan 2003). Significant recreational harvest occurs in Kennedy's Lagoon and on other clam beaches in Penn Cove. The Washington Department of Fish and Wildlife operates a public beach on the south side of Penn Cove that is "one of the most productive hard-shell clam beaches in the state." A recreational groundfish sport fishery of unknown size exists in Penn Cove (NPS 2005).

C.3.b. Admiralty Inlet

Commercial and recreational harvest of shellfish and finfish occurs along the Admiralty Inlet shores of EBLA. For example, the Skagit System Cooperative currently has harvest interest in a geoduck bed at Point Partridge (Determan 2003a).

In the late 1960s salmon fishermen lobbied to open a herring fishing season off West Beach, Whidbey Island. A Herring Migration Study was undertaken and an experimental season was opened on West Bach. The catch was 116 tons; this relatively small amount was attributed to migration out of the area into other established herring fisheries (Pasquale 1970). It is unclear whether or not subsequent attempts to launch a herring fishery were made.

More recently, reports have documented Admiralty Bay's use as a sport and commercial fishing ground (WSCC 2000). It is unclear exactly what species are targeted in these fisheries.

C.4. Habitat Modification

C.4.a. Penn Cove

Several types of habitat modification have occurred in Penn Cove. The most prevalent of these is shoreline armoring. The Penn Cove shoreline is the most heavily armored within EBLA; this occurs in the form of bulkheads, riprap, and docks and piers. An Island County Beach Watchers study found that along the north side of Penn Cove, 24.5% of the shoreline is armored; the west side is 15.6% armored and the south side, 31.5% (Farmer and Holmes 2003; Figure 26). Washington State DNR has identified that 33% of the shoreline in the vicinity of Coupeville is armored.

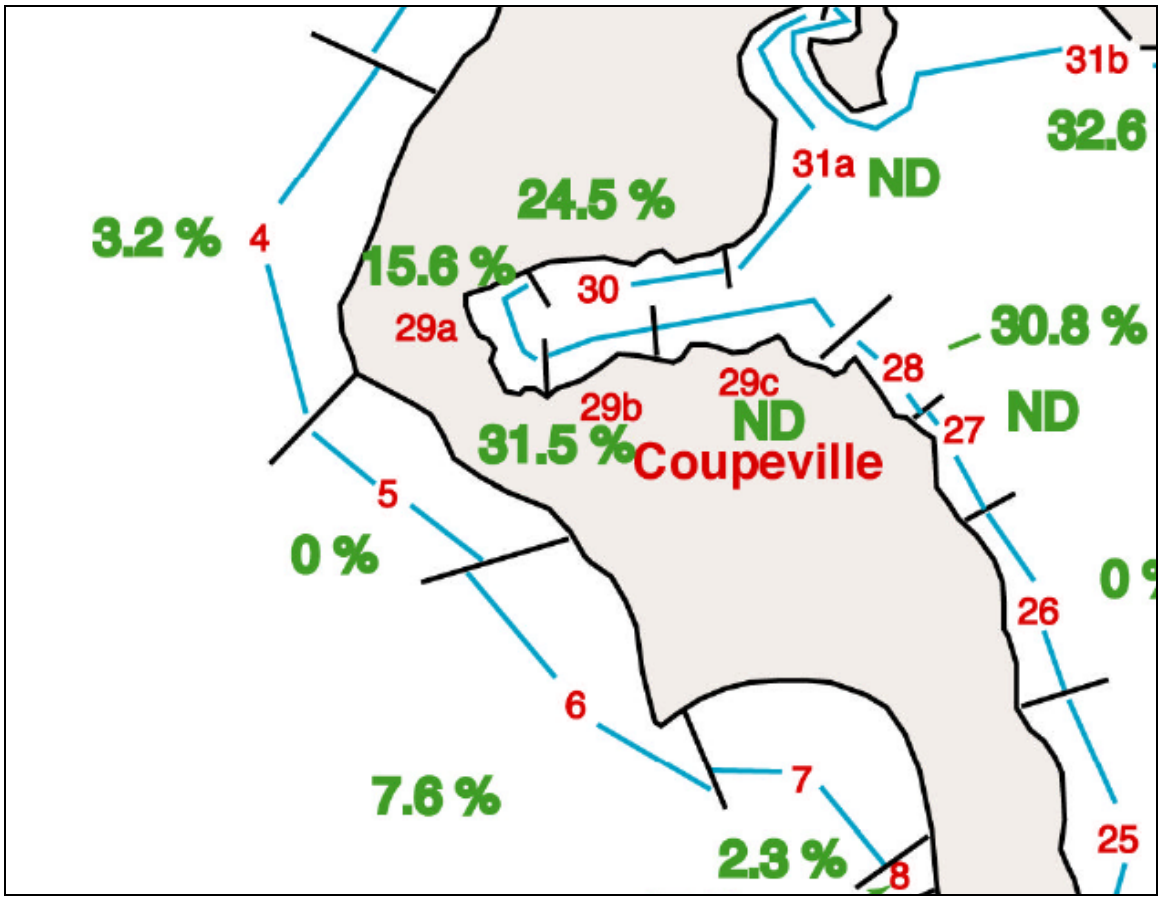

Figure 26. Shoreline Armoring. Source: Farmer and Holmes 2003.

Several sites within Penn Cove have been the focus of more in-depth studies regarding habitat modification. These sites, Kennedy's Lagoon, Grasser's Lagoon, and Coupeville, are described below.

Kennedy's Lagoon
A tide gate at the entrance to Kennedy's Lagoon partially blocks fish passage. Some residential development exists around the lagoon, and in these areas riparian vegetation has been removed and replaced with lawns. The lagoon is used by local residents for recreation (WSCC 2000). There is extensive shoreline armoring in the northern part of the lagoon (Sheldon & Associates 2001).

Grasser's Lagoon
Grasser's Lagoon is less significantly altered than Kennedy's Lagoon and there is no impediment to tidal flooding (WSCC 2000). However, there is very little riparian vegetation between the lagoon and the surrounding roads, but no studies have examined the effects of the vegetation removal on the habitat of the lagoon.

Coupeville
Approximately 33% of the shoreline in the Town of Coupeville is armored (WDNR 2001). This has significantly reduced the level of riparian vegetation along the shoreline;

2001 estimates placed the amount of shoreline exhibiting native vegetation at 55% (WDNR 2001). In addition, the eastern portion of the Coupeville shoreline is largely composed of creosote wood, which is known to have negative impacts on marine water quality (Coastal Geologic Services, Inc. and Island Environmental and Technical Services 2004). There are numerous overwater structures within the Town of Coupeville; these significantly impact benthic habitat (Coastal Geologic Services, Inc. and Island Environmental and Technical Services 2004).

C.4.b. Admiralty Inlet

Admiralty Inlet is less affected by shoreline armoring and other forms of habitat disruption. There is very little shoreline development along the northern portion of the western shore of EBLA, and the development that exists is largely composed of single family residences. The two sections of beach surveyed by the Island County Beach Watchers in their shoreline armoring survey from Point Partridge to Fort Casey were characterized by a maximum of 7.6% armoring; the section bordering Keystone Spit is 2.3% armored (Farmer and Holmes 2003).

Perego's Lagoon
A 2003 study (Dethier 2003) reported that Perego's Lagoon has changed very little since the late 1800s. The only major change noted is the natural creation of a small pond that was formed in the 1980s when a storm breached the berm in front of the lagoon and subsequently reformed in a different location. Dethier (2003) identified little anthropogenic influence on the Lagoon. Perego's Lagoon was identified by the Washington State Conservation Commission as one of the best examples in WRIA 6 of an intertidal environment that resembles the natural ecosystem. It is currently managed as a protected area by the NPS (WSCC 2000).

Crockett Lake
One of the most heavily modified areas on the western shore of the Reserve is Crockett Lake. This salt marsh, which historically provided habitat important to migrating Puget Sound salmon stocks (WSCC 2000) has been modified repeatedly and the water levels manipulated for the past half a century.

At the time of European settlement, Crockett Lake was a tidal lagoon that fluctuated in size and covered up to 600 acres when full. It was separated from Admiralty Bay by Keystone Spit, an 800 foot wide sandy bar. It experienced regular flushing of seawater and freshwater inputs from groundwater (NPS 1993).

The road to Fort Casey cut off the original salt marsh from Admiralty Bay when it was constructed (WSCC 2000). The installation of tide gates by Island County Drainage District No. 6 in order to drain the lake in 1948 modified the lake substantially, restricting inundation and controlling water levels. In 1953, use of the tide gates reduced the lake size to approximately 10 acres. The lands surrounding the lake were converted into agriculture and Keystone Spit was developed into a residential neighborhood. Then, in

1974, the tide gates rusted and salt water was again allowed to inundate the marsh through these gates. Because the drainage district was no longer active, the gates remained in this condition for some time. By 1982 the lake had grown to 750 acres in size (NPS 1993).

Residents of Telaker Shores, a housing development near the lake, reformed the drainage district and, without obtaining a permit, restored the functionality of the tide gates in 1982. This action, which dropped the water level of the lake, was taken in response to flooding of residential properties along the spit. Seattle Pacific University, a major landowner in the area, desired that lake levels be restored to natural conditions and filed suit, and a series of legal battles followed. NPS did not join the suit but encouraged the drainage district to restore natural conditions by maintaining a water level that would restore mudflat habitat and support wildlife in the area.

The drainage district commissioned Entranco Engineers in 1986 to determine optimal levels for the lake in order to reduce flooding of residences along the lake. This study recommended maintaining base lake levels of 2 to 3 feet, and found that the existing management regime was adequate for maintaining these levels (Entranco Engineers, Inc. and Independent Ecological Services 1986).

Residents of the area began having problems with mosquitoes in 1989 or 1990 (NPS 1993). These residents manipulated the tide gates in order to lower the lake levels and, with state approval, used biological and chemical control methods to control the mosquitoes. A resulting study recommended maintaining the lake level at 5.5 feet to submerge mosquito habitat. It also recommended allowing regular tidal flushing would also likely help solve this problem (Island County Health Department 1990).

Modifications to Crockett Lake have resulted in degraded nearshore habitat important to migrating salmon. The tide gates prevent salmon from entering the lake and riparian vegetation has been degraded due to development (WSCC 2000).

A 1993 National Park Service report recommended studying how to achieve natural conditions despite manipulated lake levels. Island County commissioned an Estuarine Restoration Plan from Sheldon & Associates, Inc. in 2001. The goals for restoration included reestablishing a free exchange of saltwater between the lake and Admiralty Bay, restoring fish access to the marsh, and enhancing wildlife habitat. The report recommended creating cooperative agreements with public landowners to restore the marsh, undertaking a hydrologic assessment of the impacts of creating openings to other wetlands in restoring marsh habitat, removing the tide gate and installing a bridge, filling in ditches to allow tidal channels to form, among other things.

While this study represents a preliminary step toward restoration of Crockett Lake, it indicates that Island County is committed to exploring restoration efforts and working with other public landowners toward this restoration. The Washington State Conservation Commission also identified Crockett Lake as deserving of protection and in need of restoration (WSCC 2000). The US Fish and Wildlife Service Federal Assistance Program

recently has awarded funds for the purchase of up to 355 acres of wetlands for permanent protection at Crockett Lake, to be managed by partnership entities including the National Park Service.

C.5. Shoreline Development and Zoning

Washington State's Shoreline Management Act requires local jurisdictions to develop a Shoreline Master Plan (SMP) in order to determine what types of uses will be allowed on marine shorelines. As part of their SMP, Island County in 2004 produced a zoning map indicating shoreline land use designations throughout the county. This map, a portion of which is reproduced in Figure 27, indicates that the Admiralty Inlet shore of EBLA is designated almost entirely as "Natural", with only a small amount of shoreline designated "Shoreline Residential". Shores within Penn Cove are designated predominantly as "Shoreline Residential", interspersed with smaller amounts of "Conservancy", "Rural" and "Urban" designations.

C.5.a. Penn Cove

The shoreline along Penn Cove is largely designated as "Shoreline Residential", defined as an area "that has been modified from its natural state by residential unit construction. Much of it is also zoned "Rural Environment," defined as "an area of low intensity development, including but not limited to agriculture, large residential lots, low intensity commercial or recreational uses" (Island County Planning Department 2001). The Rural Environmental designation protects agricultural lands, encourages low density housing, and encourages the responsible use of fertilizers and pesticides.

The Town of Coupeville is zoned as "Urban Environment," "an area of intensive development including but not limited to urban density residential, commercial, and industrial uses" (Island County Planning Department 2001). This designation encourages development in already urbanized areas and gives priority to water-dependent and water-oriented uses. This zoning designation also has a policy of not allowing development to "significantly degrade the quality of the environment."

C.5.b. Admiralty Inlet

The bulk of the Admiralty Inlet shoreline is zoned as "Natural Environment," defined as "an area relatively free of human influence, chiefly valued for its undisturbed natural features" (Island County Planning Department 2001). This characterization strictly restricts development and requires that permitted developments provide detailed environmental data in order to protect existing ecosystems.

"Conservancy Environment" designation is also prevalent along the Admiralty Inlet shore of EBLA. This is defined as "an area which permits varying densities of human activity,

while refining the aesthetic, cultural, ecological, historic and recreational resources" (Island County Planning Department 2001). This designation restricts development, encourages public access and preservation of historic character of the area and forbids commercial and industrial uses.

The shoreline along Keystone Spit and along part of the northern edge of EBLA are designated as "Shoreline Residential Environment," defined above. This zone allows residential development and encourages developers to preserve vegetation and control erosion.

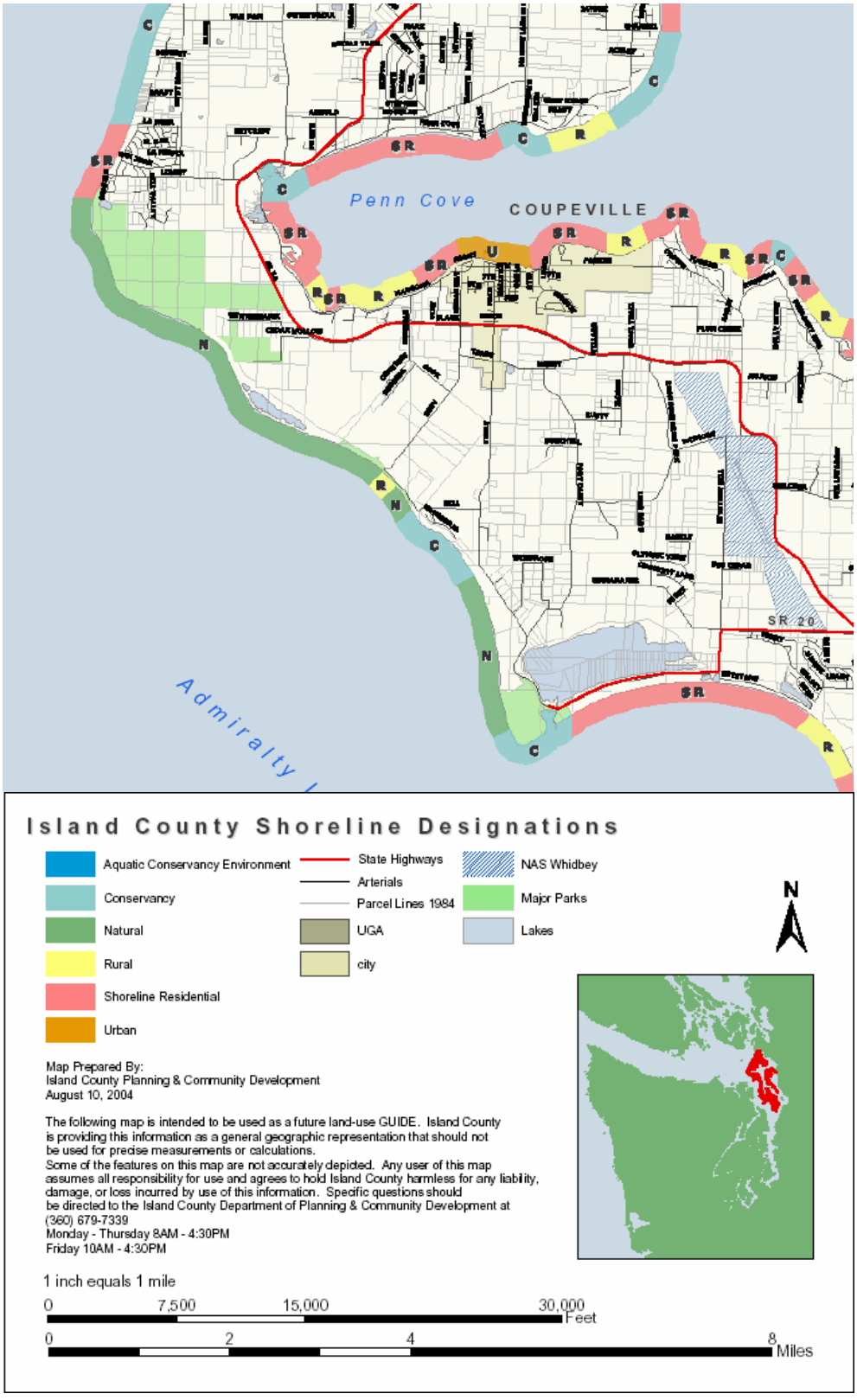

Figure 27. Island County Shoreline Designations in the vicinity of EBLA. Source: Island County.

C.6. Keystone Ferry Terminal

Washington State Department of Transportation (WSDOT) operates a ferry terminal in Keystone Harbor on Admiralty Bay that services a route between Port Townsend and Whidbey Island (Figure 28). This terminal experiences seasonal fluctuations in traffic volume. For example, 111,118 riders were reported in August 2003 and 34,669 riders in January 2004. Washington State Ferries (WSF, a division of WS DOT) projects that this route will experience an increase in ridership of 45% by 2030 (WSDOT 2004). Keystone Harbor has been substantially armored and is subjected to repeated dredging in order to maintain appropriate depths for ferry traffic (Sheldon & Assoc. 2001). The impacts of this dredging operation are not reported.

Washington State Ferries currently is examining a series of potential improvements to the Keystone Harbor and ferry terminal. Although several alternatives for relocating or rebuilding the terminal were examined, the options proposed for future study all involve expanding the existing terminal and potentially relocating or extending the jetty at the mouth of Keystone Harbor (CH2M Hill 2004). This project could potentially impact water resources in Keystone Harbor, Crockett Lake, and Admiralty Bay. Alternatives are described in The Keystone Harbor Study Report (http://www.wsdot.wa.gov/Ferries/projects/keystoneharbor/keystoneReport.htm)

Figure 28. Keystone Ferry Terminal and surrounding areas. Source: WSDOT 2005 (http://www.wsdot.wa.gov/Ferries/projects/keystoneharbor/keystoneReport.htm)

C.7. Water Withdrawals

Withdrawal of groundwater from the sea level aquifer for household, commercial, agricultural, and industrial could grow to exceed the rate of recharge. This could reduce the volume of the aquifer and cause saltwater intrusion to the aquifer, especially under the combined pressures of population growth and climate change.

According to the USGS, water use in Island County in the year 1995 was apportioned as shown in Table 2.

Table 2. Water use in Island County in 1995, by user group.
Source: USGS (data extracted from http://water.usgs.gov/watuse/)

User	Mgal/day (total withdrawal)
Public Supply	9.97
Commercial Water Use	0.01
Domestic Water Use	0.95
Industrial Water Use	0.01
Livestock Water Use	0.28
Irrigation Water Use	2.96
Total	14.18

C.8. Erosion

Shorelines within the Reserve are susceptible to erosion and accretion. The Washington Coastal Atlas, maintained by the Washington State Department of Ecology, offers rudimentary mapping of sediment transport along the coastline. The location and direction of drift cells that transport sediment are shown in Figure 29.

Rates of shoreline erosion will likely be sensitive to changes associated with climate change (Section C.13).

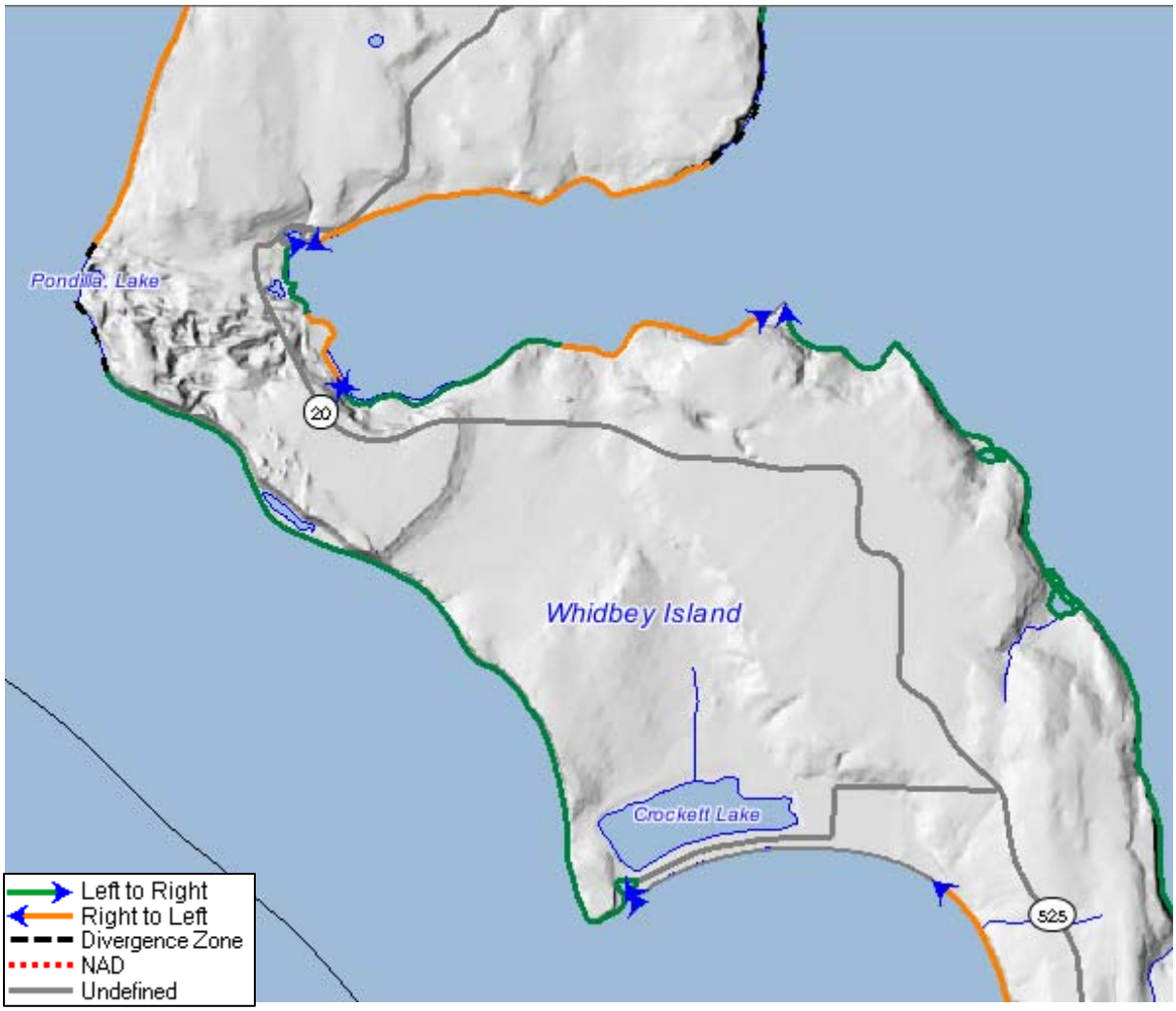

Figure 29. Drift Cells. Source: WDOE 2006c.

Concerns exist regarding erosion within the town of Coupeville. A report was prepared by the US Army Corps of Engineers (USACE) in response to a request by Coupeville to address a shoreline erosion problem. The report determined economic feasibility, but did not substantively address effects of erosion remediation on the environment or adjacent beaches. The report recommended that USACE conduct a study of erosion control at Coupeville (USACE 1989).

Shipman (2004) reports that approximately 50% of the shoreline in Island County is unstable, compared with 58% in King County and 3% in San Juan County (the maximum and minimum values reported for Puget Sound, respectively). This suggests that shorelines within Island County are relatively susceptible to erosion, compared with shorelines in other areas of Puget Sound.

C.9. Elwha Dam Removal

Two large dams on the Elwha River (Clallam Co., WA) are scheduled for removal beginning in 2007. The dams, built in 1910 and 1926, are located on the northern Olympic Peninsula, to the west of EBLA. Since their construction, they have substantially reduced sediment flux to nearshore zone and have impacted the historic spawning habitat of native salmonids. Thirteen million m^3 of sediment are forecast to be released to downstream and nearshore areas with the breaching of the dams, which will occur over a period of several years. While the impacts of sediment release are expected to be greatest along the northern shore of the Olympic Peninsula, it is possible that sediment flux will be affected throughout the eastern Strait of Juan de Fuca, and the western shore of EBLA could be impacted. The most likely impact would be increased sedimentation in some shoreline areas.

C.10. Oil and Fuel Spills

Admiralty Inlet is a heavily used shipping channel for vessels moving toward ports in Puget Sound including the major cargo ports of Seattle and Tacoma. Areas near Anacortes and Bellingham house many oil refineries that also transport materials via shipping channels near Whidbey Island. Oil spills have occurred in Puget Sound in recent years and there is reason for ongoing concern regarding impacts of future spills.

A study undertaken in 1980 sought to characterize the habitats and organisms found on Whidbey Island (Weber 1980) in order to establish a baseline inventory of resources that could be used to determine pre-spill conditions, should a spill occur. Although parts of this report may remain current and relevant, substantial changes to living marine resources throughout Puget Sound over the past decades suggest that many findings may be out of date.

The National Oceanic and Atmospheric Administration (NOAA) has developed a spill trajectory model entitled GNOME (the General NOAA Oil Modeling Environment) (NOAA 2005). This is a computer program that can be used to predict the path of an oil spill based on wind, currents, and other forces. This highly refined model is most useful when an actual spill has just occurred, and provides less utility in modeling spills in general. It can be accessed on their website at http://response.restoration.noaa.gov/software/gnome/gnome.html.

C.11. Land-based and Water-based Recreation

Numerous types of recreational activities occur within EBLA, but few of these have a direct impact on marine water resources, and the extent of impact of these activities remains undocumented.

Recreational Boating
Recreational boating is common in or near the Reserve. Penn Cove is used by many recreational boaters, and Kennedy's Lagoon in the cove is used as a recreational pond by residents near the area (WSCC 2000). Penn Cove is also occasionally visited by personal watercraft users, and their use is regulated by the town of Coupeville (NPS 2005). There is a recreational boat launch and an underwater dive park located in Keystone Harbor (CH2M Hill 2004). In Admiralty Inlet, Admiralty Bay is used for recreational boating (WSCC 2000).

Although there are few data on the extent of recreational boating within the boundaries of EBLA, limited documentation of the impacts of boating activities on water resources exists. A 2001 report by Island County Public Works identified recreational boating as a significant source of non-point source pollution. Problems identified include direct discharge of human waste and gray water; direct discharge from holding tanks; engine exhaust; hazardous chemical spills or discharges; litter and garbage dumping from boats; invasive species transported by bilge water, hulls, and bait containers. The report attributes most of these sources to inadequate, overcrowded, inconvenient, inoperable, or nonexistent pump out facilities and lack of public education/awareness. While the report lists many of the problems, it does not provide detailed geographic information regarding impacts (Island County Public Works 2003).

Visitor Use
According to the Washington State Conservation Commission, approximately 500,000 people visit the Fort Casey/Crockett Lake area annually (WSCC 2000).
Swimming Beaches
Numerous public swimming beaches are located within the Reserve. WDOH monitors water quality at swimming beaches around the state as part of its BEACH program (WDOH 2005a). Specific threats to water quality are listed in the appropriate section above. WDOH publishes the results of monitoring at swimming beaches at their website: http://www.doh.wa.gov/ehp/ts/WaterRec/beach/default.htm. While no beaches in the Reserve currently are sampled for water quality, they are listed on the WDOH website as potential swimming beaches. These include Penn Cove Park, Monroes Landing, Penn Cove Tidelands, West Penn Cove Beach, Coupeville Wharf, Town Boat Launch, and Long Point Beach in Penn Cove; and Keystone Beach Tidelands, Keystone Ferry Terminal, Fort Casey State Park, Ebey's Landing State Park, Fort Ebey State Park, and Libbey Beach County Park on the Admiralty Inlet side. There are no data available on visitor use of these sites or impacts from this use.

C.12. Tsunami Hazards

Low-lying areas of Puget Sound shoreline are vulnerable to tsunami hazard generated by earthquakes that occur along the Cascadia Subduction Zone. Modeling of the hazards found in Whidbey Island show that there are some areas within EBLA that may be vulnerable to inundation. In Penn Cove, Kennedy's Lagoon, Mueller Point, and Long Point could be inundated to levels of 0.5 to 2 meters. Keystone Spit, Crockett Lake, and

the surrounding area could experience similar levels of inundation, but over a much larger continuous area (Walsh et al. 2005).

C.13. Climate Change

EBLA is susceptible to the regional impacts of climate change. According to Canning (2002), a number of impacts associated with climate change are anticipated to occur within the Puget Sound region over the next 50-100 years. These include

- long-term rise in sea-level
- growing frequency and magnitude of coastal erosion, shoreline retreat, and storm surge
- changes in the tidal prism and salinity of semi-enclosed bays
- inundation of low-lying coastal areas and wetlands
- sea water intrusion into coastal aquifers
- rising water tables
- increased winter rainfall and associated landslides

The magnitude of these impacts within EBLA has not yet been estimated. However, general expectations are as follows.

Although global mean sea level rise has been on the order of 1 to 3 mm/year over the past century, recent research suggests that the rate of ice cap melting and thus the rate of sea level rise may be much more rapid that previously anticipated.

A number of factors influence actual local changes in sea level. Because of regional variations in atmospheric pressure, currents, and seawater temperature, new predictions suggest that sea level rise in the Eastern Pacific will exceed the global average by more than 20 cm over next 100 years. Local vertical land movement, including isostatic rebound and tectonic subduction, can also play a large role in apparent sea level changes, particularly in tectonically active regions such as Washington State. In the absence of more complete, site-specific information, it is reasonable to expect that EBLA will experience rates of sea level rise similar to the average for the Eastern Pacific.

Models from the University of Washington's Climate Impacts Group/JISAO suggest that the Pacific Northwest will experience warmer, wetter winters, warmer summers, decreased flow of freshwater in summer, and increased water flow in fall and winter. These changes are likely to impact aquifer recharge rates, rates of seawater intrusion into aquifers, and the frequency of water shortages in summer. In some places, rates of coastal erosion could increase due to the combination of predicted changes in sea level and predicted increase in intensity and frequency of winter storms. Within EBLA, the exposed bluffs facing Admiralty Inlet may be most at risk of erosion. According to Shipman (2004), bluff recession typically is caused by removal of material from the toe of the bluff by wave action, followed by mass-wasting from the unstable bluff slope. As the west-facing bluffs within EBLA are exposed to

increasing wave action and elevated sea levels, wave-induced erosion at the toe of the bluff likely will accelerate. Approximately 50% of the shoreline of Island County has been designated as unstable (Shipman, 2004).

In low-lying areas, sea level rise coupled with increased intensity and frequency of winter storms could cause substantial inundation. Perego's, Grasser's, and Kennedy's Lagoons are at risk of inundation that could eventually lead to their elimination. Keystone Spit could be vulnerable to breaching in severe winter storm events, with substantial negative consequences for infrastructure (roads, structures, campgrounds, and ferry transportation) and the environment.

Recent recognition of the potential affects of ocean acidification due to increasing dissolution of CO_2 in seawater (Orr et al. 2005) suggests that over a period of 50-100 years, Puget Sound could experience changes in pH that could disrupt biological processes to an unknown degree. If such alterations occur, then marine communities in the vicinity of EBLA could change substantially from their present condition.

D. Recommendations

D.1. Condition Overview

We summarize the condition of water resources in EBLA in Table 3, based on our review of available data and on our best professional judgment. We rate the level of uncertainty in this estimate as moderate, due to the absence of comprehensive time-series data. We offer brief justification and rationale for our assessment in Tables 4-10 and in the text following. More comprehensive treatment of specific factors, stressors, and conditions is provided in Section B, above.

A brief explanation of our ratings is as follows. For all seven water bodies, we use 'OK' to indicate conditions that we know to be acceptable (no shading) and to indicate conditions for which there is no evidence of degradation or potential degradation (shading). Deviations from this rating are based on 1) known degradation of existing, intermittent, or potential nature (no shading) or 2) suspected degradation of existing, intermittent, or potential nature, for which there limited data (shading); these latter ratings are based on our best professional judgment and are associated with a higher degree of uncertainty than other ratings. For many attributes data are not sufficient to inform a rating (ID with shading).

Table 3. Condition of water resources in EBLA.

Stressor/ Environmental Indicator	Penn Cove	Grasser's Lagoon	Kennedy's Lagoon	Admiralty Inlet/ SJDF	Crockett Lake	Perego's Lagoon	Lake Pondilla
WATER QUALITY INDICATOR							
Nutrients	IP	ID	ID	OK	ID	ID	ID
Dissolved Oxygen	EP	ID	ID	OK	ID	ID	ID
Fecal Bacteria	EP	ID	ID	PP	ID	ID	ID
Toxic Compounds	PP	ID	PP	ID	ID	ID	ID
LAND-USE RELATED STRESSORS							
Septic / Wastewater	IP	ID	ID	OK	OK	NA	OK
Stormwater Runoff	IP	PP	PP	OK	ID	NA	OK
Agricultural Runoff	NA	NA	NA	ID	ID	NA	OK
Aquaculture	PP	NA	NA	NA	NA	NA	NA
HABITAT MODIFICATION							
Shoreline Modification	EP	EP	EP	PP	EP	OK	OK
Coastal Erosion	OK	OK	OK	PP	OK	OK	NA
RECREATIONAL USAGE							
Fishing	OK	OK	OK	OK	OK	OK	ID
Shellfish Harvesting	OK	OK	OK	OK	OK	OK	NA
OTHER STRESSORS/ INDICATORS							
Non-Native Invasive Species	EP	EP	EP	PP	EP	EP	OK
Harmful Algal Blooms	IP	ID	ID	OK	OK	OK	OK
Fuel / Oil Spills	OK	OK	OK	PP	PP	PP	OK

Definitions: EP=existing problem, PP=potential problem, IP=intermittent problem, OK=no detectable problem, ID=insufficient data to evaluate, shaded=limited data.

Table 4. Abbreviated explanation of ratings for Penn Cove.

Stressor/ Environmental Indicator	Penn Cove	Abbreviated Explanation for Rating
WATER QUALITY INDICATOR		
Nutrients	**IP**	High nutrients can cause algal blooms when stratification is present
Dissolved Oxygen	**EP**	Algal blooms cause hypoxic events
Fecal Bacteria	**EP**	Repeated exceedances of bacterial standards
Toxic Compounds	**PP**	high levels of phenol detected at 1 station; occasional exceedances for biotoxins
LAND-USE RELATED STRESSORS		
Septic / Wastewater	**IP**	Occasional stormwater infiltration of facility; occasional exceedances for BOD, chlorine
Stormwater Runoff	**IP**	Elevated levels of suspended solids, turbidity, nutrients, copper, lead, zinc, fecal bacteria, total petroleum hydrocarbons
Agricultural Runoff	**NA**	
Aquaculture	**PP**	Potential *benefit* to surface water quality; potential *detriment* to benthic communities and habitats
HABITAT MODIFICATION		
Shoreline Modification	**EP**	Shoreline modified for commercial and residential use; overwater structures; creosote
Coastal Erosion	**OK**	No evidence of problem
RECREATIONAL USAGE		
Fishing	**OK**	Not different from regional status
Shellfish Harvesting	**OK**	Not different from regional status
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	**EP**	Non-native invasive species (including aquaculture escapees) are abundant
Harmful Algal Blooms	**IP**	Seasonal stratification intermittently causes algal blooms
Fuel / Oil Spills	**OK**	No evidence of degradation from fuel/oil spills

Definitions: EP=existing problem, PP=potential problem, IP=intermittent problem, OK=no detectable problem, ID=insufficient data to evaluate, shaded=limited data.

Table 5. Abbreviated explanation of ratings for Grasser's Lagoon.

Stressor/ Environmental Indicator	Grasser's Lagoon	Abbreviated Explanation for Rating
WATER QUALITY INDICATOR		
Nutrients	**ID**	Insufficient data to evaluate
Dissolved Oxygen	**ID**	Insufficient data to evaluate
Fecal Bacteria	**ID**	Insufficient data to evaluate
Toxic Compounds	**ID**	Insufficient data to evaluate
LAND-USE RELATED STRESSORS		
Septic / Wastewater	**ID**	Insufficient data to evaluate
Stormwater Runoff	**PP**	Potential runoff from nearby road
Agricultural Runoff	**NA**	
Aquaculture	**NA**	
HABITAT MODIFICATION		
Shoreline Modification	**EP**	Lagoon has been modified
Coastal Erosion	**OK**	No indication of problem
RECREATIONAL USAGE		
Fishing	**OK**	Not different from regional status
Shellfish Harvesting	**OK**	Not different from regional status
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	**EP**	*Spartina* invasive in lagoon
Harmful Algal Blooms	**ID**	Insufficient data to evaluate
Fuel / Oil Spills	**OK**	No fuel/oil spills reported

Definitions: EP=existing problem, PP=potential problem, IP=intermittent problem, OK=no detectable problem, ID=insufficient data to evaluate, shaded=limited data.

Table 6. Abbreviated explanation of ratings for Kennedy's Lagoon.

Stressor/ Environmental Indicator	Kennedy's Lagoon	Abbreviated Explanation for Rating
WATER QUALITY INDICATOR		
Nutrients	**ID**	Insufficient data to evaluate
Dissolved Oxygen	**ID**	Insufficient data to evaluate
Fecal Bacteria	**ID**	Insufficient data to evaluate
Toxic Compounds	**PP**	High levels of some metals detected
LAND-USE RELATED STRESSORS		
Septic / Wastewater	**ID**	Insufficient data to evaluate
Stormwater Runoff	**PP**	Potential runoff from nearby roads
Agricultural Runoff	**NA**	
Aquaculture	**NA**	
HABITAT MODIFICATION		
Shoreline Modification	**EP**	Tide gate and armoring exist
Coastal Erosion	**OK**	No indication of problem
RECREATIONAL USAGE		
Fishing	**OK**	Not different from regional status
Shellfish Harvesting	**OK**	Not different from regional status
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	**EP**	*Spartina* invasive in lagoon
Harmful Algal Blooms	**ID**	Insufficient data to evaluate
Fuel / Oil Spills	**OK**	No fuel/oil spills reported

Definitions: EP=existing problem, PP=potential problem, IP=intermittent problem, OK=no detectable problem, ID=insufficient data to evaluate, shaded=limited data.

Table 7. Abbreviated explanation of ratings for Admiralty Inlet/Strait of Juan de Fuca.

Stressor/ Environmental Indicator	Admiralty Inlet/ SJDF	Abbreviated Explanation for Rating
WATER QUALITY INDICATOR		
Nutrients	**OK**	No reported degradation
Dissolved Oxygen	**OK**	No reported degradation
Fecal Bacteria	**PP**	
Toxic Compounds	**ID**	Insufficient data to evaluate
LAND-USE RELATED STRESSORS		
Septic / Wastewater	**OK**	No reported degradation
Stormwater Runoff	**OK**	No reported degradation
Agricultural Runoff	**ID**	Insufficient data to evaluate
Aquaculture	**NA**	No aquaculture installations
HABITAT MODIFICATION		
Shoreline Modification	**PP**	Potential expansion of ferry terminal
Coastal Erosion	**PP**	Bluffs vulnerable to erosion
RECREATIONAL USAGE		
Fishing	**OK**	Not different from regional status
Shellfish Harvesting	**OK**	Not different from regional status
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	**PP**	Potential for invasion by *Sargassum*
Harmful Algal Blooms	**OK**	None reported
Fuel / Oil Spills	**PP**	Hazard from shipping traffic

Definitions: EP=existing problem, PP=potential problem, IP=intermittent problem, OK=no detectable problem, ID=insufficient data to evaluate, shaded=limited data.

Table 8. Abbreviated explanation of ratings for Crockett Lake.

Stressor/ Environmental Indicator	Crockett Lake	Abbreviated Explanation for Rating
WATER QUALITY INDICATOR		
Nutrients	**ID**	Insufficient data to evaluate
Dissolved Oxygen	**ID**	Insufficient data to evaluate
Fecal Bacteria	**ID**	Insufficient data to evaluate
Toxic Compounds	**ID**	Insufficient data to evaluate
LAND-USE RELATED STRESSORS		
Septic / Wastewater	**OK**	
Stormwater Runoff	**ID**	Insufficient data to evaluate
Agricultural Runoff	**ID**	Insufficient data to evaluate
Aquaculture	**NA**	
HABITAT MODIFICATION		
Shoreline Modification	**EP**	Lake heavily modified; tide gate present
Coastal Erosion	**OK**	No evidence of erosion
RECREATIONAL USAGE		
Fishing	**OK**	Not different from regional status
Shellfish Harvesting	**OK**	Not different from regional status
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	**EP**	Several invasive plant species in/around lake
Harmful Algal Blooms	**OK**	None reported
Fuel / Oil Spills	**PP**	Hazard from shipping traffic

Definitions: EP=existing problem, PP=potential problem, IP=intermittent problem, OK=no detectable problem, ID=insufficient data to evaluate, shaded=limited data.

Table 9. Abbreviated explanation of ratings for Perego's Lagoon.

Stressor/ Environmental Indicator	Perego's Lagoon	Abbreviated Explanation for Rating
WATER QUALITY INDICATOR		
Nutrients	**ID**	Insufficient data to evaluate
Dissolved Oxygen	**ID**	Insufficient data to evaluate
Fecal Bacteria	**ID**	Insufficient data to evaluate
Toxic Compounds	**EP**	Creosote drift logs
LAND-USE RELATED STRESSORS		
Septic / Wastewater	**OK**	No wastewater introductions to lagoon
Stormwater Runoff	**OK**	Lagoon remote from impervious surfaces
Agricultural Runoff	**NA**	
Aquaculture	**NA**	
HABITAT MODIFICATION		
Shoreline Modification	**OK**	No modification
Coastal Erosion	**OK**	No evidence of erosion
RECREATIONAL USAGE		
Fishing	**OK**	Not different from regional status
Shellfish Harvesting	**OK**	Not different from regional status
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	**EP**	Invasive plant species on margins of lagoon
Harmful Algal Blooms	**OK**	None reported
Fuel / Oil Spills	**PP**	Hazard from shipping traffic

Definitions: EP=existing problem, PP=potential problem, IP=intermittent problem, OK=no detectable problem, ID=insufficient data to evaluate, shaded=limited data.

Table 10. Abbreviated explanation of ratings for Lake Pondilla.

Stressor/ Environmental Indicator	Lake Pondilla	Abbreviated Explanation for Rating
WATER QUALITY INDICATOR		
Nutrients	**ID**	Insufficient data to evaluate
Dissolved Oxygen	**ID**	Insufficient data to evaluate
Fecal Bacteria	**ID**	Insufficient data to evaluate
Toxic Compounds	**ID**	Insufficient data to evaluate
LAND-USE RELATED STRESSORS		
Septic / Wastewater	**ID**	No wastewater introductions to lake
Stormwater Runoff	**ID**	Lake remote from impervious surfaces
Agricultural Runoff	**NA**	
Aquaculture	**NA**	
HABITAT MODIFICATION		
Shoreline Modification	**OK**	No modification
Coastal Erosion	**NA**	
RECREATIONAL USAGE		
Fishing	**NA**	
Shellfish Harvesting	**NA**	
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	**PP**	Vulnerable to invasion; bass introduced
Harmful Algal Blooms	**OK**	None reported
Fuel / Oil Spills	**OK**	No evidence of degradation

Definitions: EP=existing problem, PP=potential problem, IP=intermittent problem, OK=no detectable problem, ID=insufficient data to evaluate, shaded=limited data

D.1.a. Penn Cove, Grasser's Lagoon, and Kennedy's Lagoon

The condition of water resources in Penn Cove varies in space and time. Newton et al. (2002) identified Penn Cove as one of several locations in Puget Sound in which dissolved oxygen frequently declines to levels that are "biologically relevant", and cautions that "the net effect of oxygen depletion in marine waters may be a shift in species composition, a decrease in population numbers and species diversity with a resulting decrease in amount and type of biomass, a disruption of the usual predator-prey

interaction, and a shift in the expected trophic pathways. These combined effects can result in reduced availability and subsequent harvest of marine resources. Because the consequences of eutrophication are large, understanding its potential in local waters is important." Within Penn Cove, strong seasonal stratification can promote algal blooms and cause dissolved oxygen levels to decline. Additions of nutrients and contaminants from upland sources can further impact water quality. The town of Coupeville is the most proximal source of upland inputs to Penn Cove, but the cove is also vulnerable to terrigenous inputs from mainland sources via rivers. The Skagit River in particular has the potential to impact water quality in Penn Cove because of its size (it is the largest river emptying into Puget Sound) and its proximity.

WDOH has closed a large portion of the Penn Cove to shellfish harvest. The remainder of the cove is granted conditional approval, which is suspended when state health standards are not met, as has occurred on some occasions. Fecal coliform has exceeded state standards at some stations in Penn Cove on an intermittent or regular basis. One of these stations is located at the mouth of Grasser's Lagoon.

Habitat modification in Penn Cove is moderate, consisting primarily of overwater structures that negatively impact benthic habitats. Within the Town of Coupeville, approximately 30% of the shoreline is modified.

D.1.b. Admiralty Inlet, Crockett Lake, and Perego's Lagoon

Along the Admiralty Inlet shore of the Reserve, nutrient concentrations, dissolved oxygen, and chlorophyll levels all appear to be within acceptable ranges, and harmful algal blooms have not been reported from Admiralty Inlet in the vicinity of EBLA. Fecal coliform has exceeded state standards on some occasions.

The condition of water resources in Admiralty Inlet is influenced by tidal forcing that creates strong, localized flows. Under normal circumstances, these flow conditions cause advection of dissolved and particulate matter, exporting them from the vicinity of EBLA. These same forces can import dissolved and particulate matter as well as toxins and contaminants to the vicinity of EBLA. Consequently, the condition of water resources in Admiralty Inlet is highly vulnerable to events that impair water quality elsewhere in the Puget Sound. The Admiralty Inlet shore of EBLA therefore is vulnerable to wastewater and stormwater disposal in the highly urban areas of Puget Sound, and to spills of oil, fuel, and other contaminants and toxins that could occur in the eastern Strait of Juan de Fuca or the Main Basin of Puget Sound.

There exists no regular monitoring of water quality in Crockett Lake. The condition of water within Crockett Lake will be influenced by seawater inputs from Admiralty Inlet and by freshwater inputs from upland sources, including stormwater. Consequently, the condition of water in the lake can be expected to reflect the condition of these external sources. Crockett Lake has been highly modified over the course of the last century. Protections are now in place to restore and maintain tidal flow into the lake, and most of

the wetland acreage is now or soon will be protected from development. Consequently, current conditions within the lake are likely to remain stable or improve over the next decade.

The condition of Perego's Lagoon is not regularly monitored, and water quality data do not exist. The location of the lagoon is remote from suburbanization and coastal development on Whidbey Island, hence the lagoon is unlikely to be impacted by wastewater and stormwater. Water conditions in Admiralty Inlet could have the single greatest impact on water quality in Perego's Lagoon.

D.1.c. Lake Pondilla

We found no data that could indicate the condition of water resources in Lake Pondilla with regards to nutrients, fecal bacteria, dissolved oxygen, algal blooms, metals, or toxicants. The lake is situated in a forested area and lies partially within a state park. Although bass have been introduced to the lake, the habitat does not appear to have been substantially modified, and the lake is unlikely to be directly impacted by suburbanization or coastal development. Lake Pondilla is formed within a glacial kettle and represents a rare habitat type within the region; it consequently may deserve special consideration in the development of management and monitoring plans.

D.2. Recommendations

The designated purpose to of EBLA is to preserve and protect a functioning rural community and the unbroken historic record that is represents. As a consequence of this purpose, EBLA is situated within a working landscape populated by residents who own much of the land and use the land and adjacent waters for residential, commercial, agricultural, and recreational purposes. In addition, EBLA attracts large numbers of recreational visitors from the greater Puget Sound region. Consequently, EBLA is faced with local threats to water resources that accompany these varied purposes and uses. This situation offers managers the opportunity and challenge to determine acceptable levels of impact to local water resources that are consistent with the designated purposes of the Reserve.

Superimposed on these local stresses are regional processes that affect water resources. Regional processes are particularly important in determining the condition of marine water resources in the vicinity of the Reserve.

In offering recommendations, we acknowledge that substantial uncertainty exists in our evaluation of several aspects of water resource condition. This uncertainty reflects the limitations of the data. Consequently, our recommendations largely entail suggestions for closing data gaps, especially those pertaining to water resources that could become impaired in the near-to-mid-term future.

We summarize our recommendations in Table 11, and briefly justify each in the sections following.

Table 11. Recommendations

- More frequent monitoring of dissolved oxygen levels in Penn Cove
- More extensive monitoring of dissolved oxygen levels in Penn Cove
- Careful tracking and evaluation of the permit process for expansion of wastewater treatment facilities or other point sources of potential pollutants
- Regular monitoring and reporting of biocide applications, on-site sewage disposal, and run-off from dairy and other farming and road maintenance activities
- Management of surface water to minimize impacts to nearshore environments and maximize recharge of the sole source sea level aquifer
- Further development of partnerships with local entities working to reduce non-point source pollution
- Development and implementation of regular monitoring programs at Crockett Lake and Lake Pondilla
- Development of measures to protect and preserve the sea level aquifer under coastal development and climate change scenarios
- Establishment of connections to regional-scale management initiatives in Puget Sound
- Development of goals and objectives for water resource management, and development of a water resource management plan

D.2.a. Penn Cove

Within EBLA, water resources within Penn Cove are in the poorest condition, although conditions in the western part of the cove are still sufficiently good to allow commercial shellfish aquaculture that meets state standards. Many of the threats to water quality in Penn Cove are local, and therefore are potentially amenable to local management. Given the difficulties in assessing the relative contributions of natural factors versus anthropogenic effects to low dissolved oxygen conditions, Newton et al. (2002) encourage "analysis of a variety of factors including flushing time, DO concentration of incoming ocean water (which may be related to upwelling intensity), river runoff (which may stimulate flushing but increase stratification), sunlight, and anthropogenic or natural increase in nutrient supply (stimulating organic production for nutrient-limited populations)."

Regarding measurement of dissolved oxygen in Penn Cove, we recommend:

- ***More frequent monitoring of dissolved oxygen levels in Penn Cove.*** *Washington State monitors water quality at this station on a rotating schedule and in recent years has sampled only in 1998 and 2003, despite frequent occurrences of dissolved oxygen levels below 3 mg/L. More frequent monitoring would increase*

temporal resolution, and could help to discriminate between natural and anthropogenic forcing of hypoxia. We recommend that monitoring for DO in Penn Cove be conducted on an annual basis, at an absolute minimum. Annual sampling should occur during the period when low DO is most likely to occur, in order to increase the likelihood of detecting hypoxic events. A more comprehensive sampling schedule would include monthly or semi-monthly samples during periods of likely hypoxic events.

- ***More extensive monitoring of dissolved oxygen levels in Penn Cove**. Currently, dissolved oxygen is measured at only one site at the mouth of Penn Cove (PNN001). Increasing the number of sampling stations would increase spatial resolution in detection of low DO. Additional stations could be added to 1) target potential problem areas or 2) provide representative coverage throughout Penn Cove, for example by establishing permanent sampling stations along one or more transects.*

The Penn Cove Park wastewater treatment system is in the process of obtaining permission from WDOE to increase the rated capacity of the system from a current maximum capacity of 60,000 gallons per day to 100,000 gallons per day. (The actual facility will not expand; instead, the proposed expansion would allow the existing plant to handle greater capacity, which the operators believe it can accommodate under existing conditions.) Under Washington State growth management regulations, allowing additional development in an area requires certification of adequate water supply and wastewater treatment infrastructure. Thus, the proposed expansion of the facility will likely allow additional development to occur in the area. If the plant is re-rated to 100,000 gallons per day, the biological oxygen demand (BOD) and total suspended solids (TSS) loading design criteria will also increase (BOD from 88 to 147 lb/day, TSS from 97 to 162 lbs/day). Consequently, should development increase to the limit of the proposed additional plant capacity, the overall biological oxygen demand and suspended sediment load to Penn Cove from this facility will increase. Such an increase would increase the likelihood of hypoxia in Penn Cove.

The Coupeville wastewater treatment plant also is in the process of expanding the capacity of its system. Increasing the capacity of the plant to handle current loads will undoubtedly reduce water quality impacts in the short-term. However, depending upon the amount of the expansion, it is possible that the expansion will enable additional development to occur within the area served by this plant, thus resulting in higher BOD and sediment loads to Penn Cove in the longer term, and an associated increase in the likelihood of hypoxia.

Given the increasing incidence and severity of low dissolved oxygen events in Penn Cove, proposals to increase the BOD, TSS and nitrogen loading to this impaired water body merit detailed review and analysis. In particular, close attention should be paid to the assumptions used in estimating the effluent dispersal and impacts. In our review of plant permit documents we noted the following issues that warrant examination:

a) In reviewing the Coupeville wastewater treatment plant's 2004 NPDES application, WDOH determined that there were no data on the background levels of ammonium in Penn Cove (WDOH 2004). As a result of this lack of data, WDOE assumed an ambient ammonium concentration of zero in modeling the potential impacts of the effluent and determined that ammonium limits were not warranted. However, our review of the water quality data collected by WDOE's Marine Water Monitoring Program in 2003 indicated that ammonium concentrations greater than 1 µM were observed in eight of the nine months sampled and ammonium concentrations greater than 8 µM were observed on three separate occasions (WDOE 2006).

b) In the NPDES permit materials, WDOH noted that there was uncertainty regarding the methods used to measure of ammonium in the effluent. The 2004 NPDES permit requires that effluent ammonium concentrations be monitored; the results of this monitoring should be closely tracked.

Regarding the proposed expansion of watewater treament facilities emptying into Penn Cove, we recommend:

- ***Careful tracking and evaluation of the permit process and accompanying environmental studies.***

D.2.b. Marine, Estuarine, and Freshwater Water Resources

Non-point source pollution increases the likelihood of hypoxia and contamination in Penn Cove, and contributes to the degradation of water resources elsewhere in the Reserve. Sources of non-point pollution included agriculture and dairy farm run-off, on-site sewage disposal (including septic systems), and the application of biocides in agricultural, household, and roadside settings. Very little monitoring of these sources of non-point source pollution occur.

The Central/South Whidbey Non-point Pollution Prevention Plan lists 30 top priority actions to be taken to prevent and reduce non-point pollution. The National Park Service could partner with local agencies to support and track the implementation of these actions. The top 10 priority actions are listed in Section B of this report; the following actions merit particular consideration by NPS:

Best Management Practices County Staff Support: Continue support and funding for BMP workshops geared for builders, developers, homeowners. Voluntary certification program. User-friendly BMP pamphlets.

Inventory of Hot Spots/ Sanitary Survey: Identify potential hot spots for potential on-site system failures, conduct a sanitary survey, education and technical assistance to homeowners. (Identified as needing further study in the plan)

Stormwater Study/ Basin Planning Effort: Implementation of a basin and sub-basin planning process by Island County. Using a comprehensive, scientific and analytical process, identify key issues and appropriate long-term drainage and watershed solutions. (Identified as needing further study in the plan)

Farm-to-Garden Link: Farm-to-garden manure exchange program, linking farmers with gardeners. Program can be expanded to meet increasing demands for compost/amended soil/mulch material. Technical assistance and education for manure management is provided.

Regarding reduction in non-point source pollution throughout EBLA, we recommend:

- ***Regular monitoring and reporting of biocide applications, on-site sewage disposal, and run-off from dairy and other farming and road maintenance activities***
- ***Management of surface water to minimize impacts to nearshore environments and maximize recharge of the sea level aquifer.***
- ***Development of partnerships with local entities working to reduce non-point source pollution.***

D.2.c. Brackish and Freshwater Water Resources

Very little information exists regarding the condition of resources at Crockett Lake, and virtually no information exists for Lake Pondilla. Both constitute important water resources within EBLA. Management of these areas would be enhanced by the existence of baseline water quality data and regularly repeated sampling to indicate trends.

Regarding the condition of Crockett Lake and Lake Pondilla, we recommend:

- ***Development and implementation of regular monitoring programs.***

D.2.d. Groundwater Resources

Consideration of groundwater resources was largely beyond the scope of this report. However, we caution that protection of the sole-source aquifer should be a priority as coastal development and suburbanization of the area proceed, and as climate impacts cause changes in the regional hydrologic cycle.

Regarding the condition of groundwater resources, we recommend:

- ***Development of measures to protect and preserve the aquifer under coastal development and climate change scenarios.***

D.2.e. Regional Influences

Regional influences on the condition of marine water resources are likely to dominate and overwhelm local influences. Regional marine and climate stressors are too great for NPS to manage in isolation. Consequently, effective management of marine water resources will require a regional perspective. Among stressors that require a regional perspective are management of shipping to prevent oil and other hazardous spills, overall management of nutrient loading in Puget Sound, and management of commercial and recreational harvest of marine organisms. Restoration of salmon and other threatened and endangered species similarly requires a regional perspective. Numerous efforts are underway including the Northwest Straits Initiative, The Governor's Puget Sound Partnership, and the Puget Sound Nearshore Ecosystem Restoration Program. Island County is already participating in the Shared Strategy for Salmon. EBLA needs to assess how it can contribute to and benefit from these initiatives while recognizing that its individual role in such partnerships is time consuming and often requires commitments of resources. At a minimum, EBLA can monitor these processes with the intent to encourage aspects that benefit protection of water resources within its jurisdiction.

Regarding consideration of regional issues, we recommend:

- ***Establishment of connections to regional-scale management initiatives in Puget Sound.***

D.2.f. Goal Setting and Management Planning

EBLA represents a unique public-private partnership formed to protect a cultural landscape. Regarding water resource management, the ostensible goal is to support BMPs for resource management and to allow multiple uses to occur subject to local management and zoning regulations. This goal may be perceived as less restrictive of land use practices than what would be otherwise expected in a NPS managed area. Consequently, it would therefore be useful for the EBLA trust board to acknowledge this difference, address explicitly its intent with respect to water resource management goals, and develop a water resource monitoring and management plan.

Regarding water resource management planning, we recommend:

- ***Development of goals and objectives for water resource management, and development of a water resource management plan.***

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Appendix A. Habitat Classification and Percent Cover

Table A1. Percent Cover by NWI Class Code and Name

NWI Class	NWI Class Name	#	Percent Cover
E1ABM	Estuarine Subtidal Aquatic Bed Irregularly Exposed	1	0.02
E1OWL	Estuarine Subtidal Open Water Subtidal	3	20.35
E2AB/USN	Estuarine Intertidal Aquatic Bed/Unconsolidated Shore Irregularly Exposed	8	1.21
E2EMN	Estuarine Intertidal Emergent Regularly Exposed	1	0.02
E2EMP	Estuarine Intertidal Emergent Irregularly Flooded	2	0.03
E2USN	Estuarine Intertidal Unconsolidated Shore Regularly Exposed	4	0.45
L1OWH	Lacustrine Limnetic Open Water Permanently Flooded	1	0.13
L2OWH	Lacustrine Littoral Open Water Permanently Flooded	1	2.65
M1OWL	Marine Subtidal Open Water Subtidal	1	0.02
M2AB/USN	Marine Intertidal Aquatic Bed/Unconsolidated Shore Irregularly Exposed	2	0.03
PABH	Palustrine Aquatic Bed Permanently Flooded	1	<0.01
PEM/SSA	Palustrine Emergent/Scrub Shrub Temporarily Flooded	1	0.04
PEM/SSC	Palustrine Emergent Seasonally Flooded	1	0.05
PEMA	Palustrine Emergent Temporarily Flooded	6	0.05
PEMC	Palustrine Emergent Seasonally Flooded	9	0.58
PEMF	Palustrine Emergent Semipermanently Flooded	3	0.02
PEMFX	Palustrine Emergent Semipermanently Flooded Excavated	1	0.01
PEMH	Palustrine Emergent Permanently Flooded	1	0.01
PEMHX	Palustrine Emergent Permanently Flooded Excavated	1	<0.01
PFOC	Palustrine Forested Seasonally Flooded	3	0.10
POWF	Palustrine Open Water Semipermanently Flooded	1	0.01
POWH	Palustrine Open Water Permanently Flooded	3	0.02
POWHH	Palustrine Open Water Permanently Flooded Diked/Impounded	4	0.03
POWHX	Palustrine Open Water Permanently Flooded Excavated	5	0.03
PSS/EMC	Palustrine Scrub-Shrub/Emergent Seasonally Flooded	2	0.03
PSSA	Palustrine Scrub-Shrub Temporarily Flooded	1	0.01
PSSC	Palustrine Scrub-Shrub Seasonally Flooded	6	0.03
PUSC	Palustrine Unconsolidated Shore Seasonally Flooded	1	0.01
U	Upland	1	74.08

Appendix A, continued

Penn Cove

Estuarine Subtidal Open Water Subtidal

Crockett Lake

Lacustrine Littoral Open Water Permanently Flooded

Crockett Lake estuary covers between 600 and 700 acres and is located in Coupeville, on the western side of Whidbey Island. It consists of brackish marsh, freshwater marsh and mudflats.

Source of fresh water

No freshwater streams enter this wetland but there is freshwater runoff from the land.

Plants

Achillea millefolium, Agrostis sp.*, Atriplex patula, Distichlis spicata,* Grasses, pasture*, Grindelia integrifolia, Potentilla anserine, Rorippa nasturtium - aquaticum, Rumex* sp.*, Salicornia virginica, Salix* sp.*, Scirpus acutus, Scripus americanus, Triglochin maritimum,* and *Typha latifolia.*

Man made obstructions to the estuary

Ditches and culverts connect the eastern half of the wetland to a low mud flat area in the western portion. The tidegate is no longer working. Roads on three sides provide barriers for the lake and have replaced the beach berm.

Description of the historic estuary

Historically, Crockett Lake was an open saltmarsh with a narrow channel at each end that connected it to Admiralty Inlet.

Perego's Lagoon

Lacustrine Limnetic Open Water Permanently Flooded

Grasser's Lagoon

Classes ranked in order of acreage
Estuarine Intertidal Aquatic Bed/Unconsolidated Shore Irregularly Exposed
Estuarine Subtidal Aquatic Bed Irregularly Exposed
Estuarine Intertidal Emergent Regularly Exposed
Estuarine Intertidal Emergent Irregularly Flooded

Grasser's Lagoon estuary covers about 40 acres and is located in the northwest corner of Penn Cove, on the eastern shore of central Whidbey Island. It has an open water lagoon, mudflats covered with algae, fringing saltmarsh and a beach berm. It is privately owned.

Source of fresh water

There are no streams that enter the lagoon. Fresh water is primarily from surface runoff from the road.

Plants
Distichlis spicata, Fucus gardneri, Grindelia integrifolia, Mahonia nervosa, Plantago maritima, Rosa pisocarpa, Rubus procerus, Salicornia virginica, Spartina anglica, Symphoricorpus albus, and *Triglochin maritimum.*

Man made obstructions to the estuary
Rt. 20 provides a barrier on the west and north edges of the lagoon and there has been substantial clearing of vegetation from portions of the buffer. There has been some armoring of the beach.

Kennedy's Lagoon

Palustrine Open Water Permanently Flooded Diked/Impounded

Kennedy's Lagoon covers about 18 acres of wetland located on the west end of Penn Cove on the eastern shore of Whidbey Island, just north of Coupeville. It is mostly open water with a small amount of mudflats and narrow fringing saltmarsh. There are eelgrass beds in this lagoon.

Source of fresh water
Freshwater is primarily from runoff. There are no freshwater streams feeding into the lagoon. A tidegate is permanently open allowing water to flow freely in and out of the estuary.

Plants
English ivy, *Rosa nutkana, Salicornia virginica, Symphoricorpus albus,* and *Zostera marina.*

Man made obstructions to the estuary
Kennedy's Lagoon was diked when a road was constructed and a tidegate installed.

Description of the historic estuary
Historically Kennedy's Lagoon was an open bay with a more extensive saltmarsh.

Appendix B. Water Quality Standards

Table B1. EPA Water Quality Standards for Marine Waters

EPA Water Quality Standards for Marine waters		Source
Dissolved Oxygen (DO)	Criteria evaluated for freshwater levels only. Coldwater values were used because the EPA identifies the presence of salmonid species to be indicitave of coldwater areas. The acute lethal limit for salmonids is at 3 mg/L, but the coldwater minimum has been established at 4 mg/L due to more sensitive insect poopulations. Because the criteria are generalized, it is required that states evaluate the species in their own waters to establish appropriate minimum levels of dissolved oxygen.	U.S. EPA. 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003; EPA Gold Book
Temperature	For marine aquatic life, the maximum increase in the weekly average temperature due to artificial causes is 1°C (1.8°F) during all seasons of the year, and daily temperature cycles of a body of water are not to be altered, neither in amplitude nor frequency.	EPA Gold Book
pH	Shall fall between the range of 6.5-8.5	EPA Gold Book
Turbidity		
Toxic Substances		
Primary Contact Recreation		Source
Fecal Coliforms	The median value for a fecal coliform standard is 15 per 100mL and the 90th percentile should not exceed 43 for a 5-tube, 3-dilution method.	EPA Gold Book

Appendix B, cont. Water Quality Standards

Table B2. Washington State Water Quality Standards and recommended threshold values

Water Quality Parameter	Freshwater Standard	Marine Water Standard
Fecal Coliform	a geometric mean £ 50 cfu/100 mL, with less than 10% of samples exceeding 100 cfu/100 mL	a geometric mean £ 14 cfu/100 mL, with less than 10% of samples exceeding 43 cfu/100 mL.
Dissolved Oxygen	> 9.5 mg/L.	> 7.0 mg/L.
Total Dissolved Gas	< 110 percent of saturation at any point of sample collection	
Temperature	£ 16° C	£ 13° C
pH	6.5 - 8.5	7.0 - 8.5
Turbidity	< 5 NTU over background, with a background of < 50 NTU. If background is > 50 NTU, shall not exceed a 10% increase	
Toxic, Radioactive and Deleterious Materials	concentration below those that adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota or adversely affect public health.	
Aesthetic Value	shall not be impaired (including senses of sight, smell, touch or taste	

Water Quality Parameter	Recommended threshold values
Nitrate (N)	< 1.25 mg/L
Total Suspended Solids (TSS)	£ 50 mg/L

Source: San Juan County Water Action Plan and Characterization Report

Appendix C. Non-native invasive species reported by DeRivera et al. (unpublished) from Padilla Bay National Estuarine Research Reserve. Species are listed alphabetically within each class. NIS designates a confirmed non-indigenous species.

Cnidaria, Hydrozoa
Campanulariidae
Clytia hemisphaerica
Clytia sp.
Eudendrium sp.
Gonothyraea sp.
Laomedea sp.
Obelia longissima
Obelia sp.

Mollusca, Gastropoda Nudibranchia
Cumanotus sp.
Dendronotus frondosus
Eubranchus rupium
Hermissenda crassicornis

Crustacea, Cirripedia
Balanus crenatus
Balanus glandula
Balanus improvisus ***NIS***

Urochordata, Ascidiacea
Botrylloides sp.
Botrylloides violaceus ***NIS***
Botryllus schlosseri ***NIS***
Corella inflata
Corella willmeriana
Molgula manhattensis ***NIS***
Styela sp.

Bryozoa
Bowerbankia sp.
Bugula pacifica
Bugula sp.
Celleporella hyalina
Cribrilina corbicula
Cryptosula pallasiana ***NIS***
Membranipora villosa
Schizoporella sp.
Schizoporella unicornis ***NIS***
Tubulipora tuba

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-32, April 2007

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