APPENDIX K

EMERGENT NOXIOUS WEED CONTROL
FINAL REPORTS

Emergent Noxious Weed Control Final Reports:

- **Elements of the Environment**
- **Characterization of Exotic Spartina Communities in Washington State**
- **Characterization of Invasive Loosestrife Species in Washington State**
- **Mechanical Control of Emergent Noxious Weeds**
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U.S. Army Corps of Engineers
Seattle District

EMERGENT NOXIOUS WEED CONTROL

Purple loosestrife, *Lythrum salicaria*

FINAL REPORTS

January

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January 1993

EMERGENT NOXIOUS WEED CONTROL

Submitted to:

**Washington State
Department of Ecology**

Prepared by:

**Army Corps of Engineers
Seattle District
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With assistance from:

**Army Corps of Engineers
Waterways Experiment Station**

Ebasco Environmental

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INTRODUCTION

BACKGROUND

The State of Washington is preparing an Environmental Impact Statement (EIS) on state-wide emergent noxious weed control. Six state agencies are co-leads on the project: Departments of Agriculture, Natural Resources, Ecology, Fisheries, and Wildlife, and the State Noxious Weed Board. Ecology is acting as nominal lead and coordinating the EIS. Management and control of the following species will be considered in the EIS: cordgrass (*Spartina patens*, *S. alterniflora*, and *S. anglica*); Purple Loosestrife (*Lythrum salicaria* and *L. virgatum*); Garden Loosestrife (*Lysimachia vulgaris*); Giant Hogweed (*Heracleum mantegazzianum*); Indigo Bush (*Amorpha fruticosa*). The Corps of Engineers is assisting this effort under the Planning Assistance To States Program (PAS) of the 1974 Water Resources Development Act. PAS provides Corps expertise to State planning efforts for the development, utilization, and conservation of water and related land resources under a cost-share agreement (30% state/70% federal in FY 1992). These reports present information for use in the EIS.

OBJECTIVES

The objectives of these reports, in order of presentation, are to:

1. Describe general air, water and geographic environmental parameters in Washington State.

2. Characterize communities and describe habitat values of *Spartina patens, S. alterniflora and S. anglica* in Washington State.

3. Characterize communities and describe habitat values of *Lythrum salicaria* and *L. virgatum* in Washington State.

4. Evaluate the mechanical control alternative for emergent noxious weed control.

5. Provide federal regulatory authorities for control of emergent noxious weeds.

6. Evaluate impacts of noxious weed control on tribal rights and cultural resources.

ELEMENTS OF THE ENVIRONMENT

ELEMENTS OF THE NATURAL ENVIRONMENT

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1.0 EARTH

1.1 GEOLOGY/TOPOGRAPHY

Washington State has a complex geology which has been strongly shaped by two major forces, volcanism (including seismic activity) and glaciation. Certain geomorphic features can be traced back as far as the Paleozoic Era (over 400 million years ago) while others formed within what is considered the Recent Epoch (10 thousand years ago to the present). Landforms vary from high mountains to river valleys to lava plains with elevation ranging from sea level to over 4200 m (14,000 ft) (Franklin and Dyrness 1973).

Evidence of past and present volcanic activity in Washington is extensive. Western Washington has five major active volcanic peaks while eastern Washington contains one of the largest fissure basalt flows in the world - the Columbia Plateau - a formation dating back to 25 million years (Harris 1988). In addition, tremendous amounts of ash and other volcanic ejecta (pumice, rock fragments) have blanketed most of Washington over its geologic history. Mudflows, triggered by volcanic activity, have also shaped part of the landscape, especially around Mt. Rainier. Volcanic activity in its many forms can be traced back as far as 36 million years ago and continues today (Harris 1988).

Northern Washington was covered by the Cordilleran Ice Sheet during several glacial episodes, with the most recent episode occurring 10 to 12 thousand years ago (Franklin and Dyrness 1973). The ice sheet extended down to about 48 km (30 miles) south of Olympia. Concurrently, large alpine glaciers advanced and retreated with the ice sheets. Several alpine glaciers exists today on the taller Cascade and Olympic peaks.

These glacial periods formed many of the unique features of Washington's landscape, such as precipitous mountain peaks, long U-shaped valleys and graveled outwash plains. Additionally, the Columbia Plateau in eastern Washington was heavily shaped from recurring Bretz Floods which were caused by repeated breaching of ice dams on the large pluvial (glacial) lakes that dominated the interior of the western United States during the glacial episodes (Harris 1988). Pluvial Lake Missoula (in present day Montana and Idaho) was responsible for most of the major floods through Washington. These floods caused several interesting landscape features such as the Potholes and Channel Scablands and numerous dry river beds. Also, dunes of wind blown rock flour (loess) from the retreating glaciers is responsible for the rolling landscape of the Palouse in eastern Washington.

Although glaciation and volcanic activity have dominated the Washington landscape, sedimentary and metamorphic rock are also abundant. The Coast Ranges and the Willapa Hills have extensive areas of sandstone/siltstone deposits and shale as well as areas of basalt. In addition, the North Cascades are largely sedimentary mountains (Franklin and Dyrness, 1973).

1.2 SOILS

The geologic complexity of Washington has supported the development of soils equally interesting in their diversity. Many of these soils are also relatively young due to the comparatively recent episodes glaciation and volcanism (Franklin and Dyrness 1973). Consequently, many of them have not had the time to develop into text book examples of soil profiles with several different layers or horizons. A soil horizon is a relatively distinct layer within the soil profile that has some set of properties produced by soil-forming processes (interaction with climate, parent material, leaching or deposition, hydrologic regime, etc.) through time (USDA 1975). In theory, the more developed the soil, the more horizons that are distinguishable within the soil profile; a "poorly developed" soil would have very few horizons (Brady 1974). A geologically young soil will usually have only two to three horizons.

Many soils may also be poorly developed because of the great topographic relief in parts of Washington. In the steep mountainous areas, soils are constantly moving downslope in response to gravity. This may happen catastrophically in the form of landslides or may move more slowly through soil creep. Consequently, many of the soils on steep slopes may have a thin horizon right over bedrock or parent materials (Franklin and Dyrness 1973).

Many of the soils of Washington have either developed in volcanic ejecta (lava, ash, pumice, etc.) or contain at least some ash and/or pumice. Amounts of incorporated ash and pumice are often small, however, and difficult to identify without laboratory work (Franklin and Dyrness 1973). The level of volcanic influence is proportionate to the proximity of a site to volcanic activity and, in the case of aerial born ejecta (ash), the distance from the source and the prevailing wind direction during eruption. For example, many of the soils of eastern Washington have significant ash components and, in some cases, very distinct thick layers of ash. The prevailing westerly winds carried the bulk of the volcanic ash eastward to be deposited in these regions. Western

Washington, in contrast, has not experience as heavy ash an fall-out because winds generally do not blow east to west. However, some western Washington soils can have a significant amount of incorporated ash/pumice because of close proximity to the volcanic eruptions.

2.0 AIR

2.1 CLIMATE

The location of the State of Washington on the windward coast in mid-latitudes is such that the climatic elements combine to produce a predominantly marine-type climate west of the Cascades, while the east side climate possess both continental and marine characteristics. Considering its northerly latitude, Washington climate is mild (NOAA 1974).

The varied terrain, the Pacific ocean, and the semipermanent high and low pressure regions over the North Pacific have a strong influences on the climate. The western and eastern slopes of the mountain ranges (Olympics and Cascades) create dramatic "rain shadow" effects while the semi-permanent pressure systems create a seasonal summer drought/winter rain precipitation regime. Lastly, the Pacific Ocean has a modifying effect on the climate, especially in western Washington, resulting in less severe winters and cooler summers.

The prevailing wind direction is westerly with the majority of the rainfall occurring between November and April (NOAA 1974). The Olympic mountains cause the first orographic uplift of air masses which results in significant precipitation on the western slopes. Average annual precipitation is well over one hundred inches. On the eastern slope of the Olympics, there is a significant rain shadow effect with average annual precipitation in the 50 cm (20 in) range or lower. Precipitation amounts increase to approximately 1 m (40 in) on the eastern shores of Puget Sound. The second orographic uplift results in heavy precipitation on the western slopes of the Cascades with average annual measurements around 2.5 m (100 in). There is a significant rain shadow on the eastern slopes which results in desert conditions in the Columbia Basin (less than 25 cm/10 in per year). Finally, there is another gradual increase in precipitation eastward when air masses encounter increased elevations around Spokane and toward the Idaho Panhandle (around 50 cm/20 in per annum) (NOAA 1974).

Western Washington has cool summers and mild, wet winters. Precipitation is usually in the form of rain, except in the higher elevations. Rainfall is usually light to moderate and continuous over time, as opposed to heavy downpours over short periods. Severe storms have occurred but are not common, except on the Pacific Coast where gale force winds frequently occur during the winter months (NOAA 1974).

East of the Cascade mountains, winters are colder, summers are warmer and there is generally less precipitation than in the western part of the state. However, some of the same influences as western Washington keep most of eastern Washington from experiences the extremes of a truly continental climate. The westerly winds, carrying the relatively moist air from the Pacific allows for generally milder conditions than those found further east. However, the continental air masses can occasionally influence this area which results in episodes of extremes in winter cold and summer heat. As with western Washington, precipitation occurs mostly during the winter months. Isolated thunder storms can occur during July and August, but do not result in significant rainfall (NOAA 1974).

2.2 AIR QUALITY

Air quality, in the state of Washington, is highly variable depending upon the location and weather conditions. In the urbanized areas of Puget Sound, many areas are "nonattainment" areas for carbon monoxide, ozone, or particulates. Activities involving aerial spraying of herbicides or burning must determine: (1) whether the location is a nonattainment area, or near such areas; (2) what the local regulations and permit requirements are, or if burn bans, etc. are in effect; (3) if any burning will introduce particulates that violate NAAQ standards; and, (4) the weather patterns on the day of control activities.

3.0 WATER

3.1 SURFACE WATER MOVEMENT

The hydrologic characteristics of Washington, and other west coast states, are clearly distinguishable from the rest of the United States. Active tectonic forces, glaciation, and volcanism that have lifted, built, and eroded the land. This, in combine with wet winters and summer drought, create a highly variable hydrologic regime that is characterized by occasional catastrophic events of scour, deposition, and flooding.

The total annual discharge of small streams exceeds that of the larger river systems that transect Washington. This condition is unusual among the physiographic regions of the U.S. for the following reasons: (1) the diversion and pumping of surface and ground water for agricultural and industrial uses, (2) the extensive dam and catchment systems which have disrupted almost all of the larger streams and rivers; (3) increased evaporation by the creation of the unnatural impoundments refereed in (2); and (4) the abundance of small coastal and lowland streams that are hydrologically isolated from higher-order river systems (Collins 1985).

3.1.1 WETLANDS

Wetlands are found throughout the Washington landscape in a variety of types and forms. Although wetlands are found on only 2% of the surface areas, they exhibit a complexity reflective of the active geologic past and are relatively new features on the landscape (Tiner 1984). Perhaps the oldest present day wetlands are the peat systems (bogs and fens) which can date back to the last retreat of the glaciers (Franklin and Dyrness 1973).

Wetlands in Washington contain native species that are adapted to the natural environment, including natural environmental disturbances such as fire, floods, and seasonal and long term drought. However, many "weed" species have invaded the native wetland flora in the past century and spread vigorously. There are several factors which may contribute to the rapid spread of a weed in a new area. These plant species may have been introduced without diseases, insects pests, and other competitive plant species that help keep it in check in its native area. Also, a plant species may be invading areas that presently are unvegetated by native species. Lastly, many of these species have special adaptations which allow rapid and highly successful reproduction in a new area. These mechanisms may include vegetative reproduction and the production of a huge number of seeds per plant (especially if the seeds are spread by wind, water, or animal vectors). Disturbance to the soil by human activities greatly enhances the efficiency of the invading species (Dennis 1980).

Several recently introduced wetland plant species have proven to have a competitive advantage over native species in colonizing existing wetland habitats. Perhaps the most wide spread example is reed canarygrass (*Phalaris arundinacea*), a wetland species thought to be originally from Eurasia (Hitchcock, *et.al.* 1969). It was commonly used in commercial pasture grass mixtures and consequently received a widespread introduction into Washington. It has become such a successful invader and colonizer that it often dominates wetland communities, especially in recently disturbed areas. Although not yet as well distributed as the reed canarygrass, purple loosestrife (*Lythrum salicaria*) shares some of the same preferences for rapidly colonizing newly disturbed locations (Welling and Blecker 1990).

Washington wetlands are also vulnerable for invasion by non-native species that are able to colonize areas that were previously uncolonized or sparsely colonized by native species. The most obvious examples of this are the eurasian watermilfoil (*Myriophyllum spicatum*) invasion of our freshwater lakes and the invasion of tidal flats by Spartina species (*Spartina alterniflora; S. townsendii; S. anglica; S. patens*). These species experience little, if any, interspecific competition from native species (Sayce 1988).

3.1.2 HYDRIC SOILS

Hydric soils are those soils that are saturated, flooded, or ponded long enough in the growing season to develop anaerobic (or reduced oxygen conditions) in the upper part of the soil profile. The anaerobic conditions effect the production, growth, and survival of plants.

However, hydric soils can form in any substrate type from very fine to very coarse materials including areas of both glacial and volcanic origin. They can also consist of organic soils (peats and mucks). Hydric soils are found in virtually every landscape within the state.

Each specific area addressed for emergent aquatic plant control will have to be evaluated based on the hydric soil characteristics at that location. Along river edges, the soils are often gravelly or sandy; while around lake edges and emergent wetlands the soils are much finer and tend to trap pollutants. Along the coast, the soils are also quite variable ranging from rocky shorelines in northern Puget Sound to sand along the western coast to silts and clays in estuary slackwaters. Many soil types can support invasive hydrophytic plant species. For example, Spartina spp. have been found in all substrate types (very fine to very coarse materials). It is more likely that the hydrologic regime of a given wetland determines the probability of invasion more so than the substrate.

3.2 GROUNDWATER

Groundwater levels and movement are difficult to characterize in western Washington. Groundwater in eastern Washington can be as low as 115 feet below the ground surface, (USGS 1991) or essentially at, or above, the surface in irrigation influenced areas, such as near the Potholes and wasteway areas. Many areas that were formerly desert, in eastern Washington, have become wetlands since the large amount of irrigation has been undertaken (Driscoll 1992). These wetlands are largely influenced by groundwater only.

3.3 WATER QUALITY

Stream quality sampling in Washington indicates that streams and lakes east of the Cascades have a higher pH and higher alkalinities than those west of the Cascades. Eastern Washington rivers generally had pH's ranging from 7 - 8.5 with alkalinities from 20 - 120 mg/L $CaCO_3$. Western Washington rivers generally had pH's ranging from 6.4 - 7.4 and alkalinities from 5-20 mg/L $CaCO_3$. The annual mean specific conductance at sampling locations east of the Cascades was 151 microsiemens, whereas the annual mean conductance west of the Cascades was 69 microsiemens. Dissolved solids concentrations are lowest during high stream flows and highest during low flows in summer. Rivers in eastern Washington ranged from 20-185 mg/L dissolved solids. Rivers in western Washington ranged from 28-76 mg/L dissolved solids. Rivers, in general, have fecal coliform/fecal streptococci counts within the "ideal" range. However, two rivers (1 in eastern WA and 1 in western WA) notably had extremely high counts; the Yakima River and the Puyallup River both had counts well over 100 colonies/100 mL. Rivers in agricultural areas in many parts of the state had higher nitrogen and phosphorus, and pesticide levels than in other areas. Western Washington rivers generally had higher sediment loadings than those in the eastern part of the state; the Toutle River was notably high, probably from volcanic ash. Rivers in eastern Washington had greater water temperature variations, generally from 0 - 20°C, whereas rivers in western Washington generally ranged from 2 - 15°C (USGS 1992).

Tidally influenced and marine waters have more static water quality parameters than do rivers and lakes. In Puget Sound, the surface temperature ranges from 7 - 13°C (45 - 55°F), while the deep water stays about 6°C (43°F) all year round. Salinity in Puget Sound ranges from 20 - 30 ppt. (PSWQA 1988). In brackish tidally influenced estuaries, the salinity ranges from 20-30 at the mouth, to 0 ppt at the limit of saltwater intrusion. Along the Pacific coast of Washington, the temperature ranges are similar to Puget Sound. Marine salinities range from 30 - 35 ppt. The tidal regime along the west coast of the U.S. is mixed semi-diurnal, which gives two high tides of unequal height and two low tides of unequal height. The time between high and low tides averages about six hours, with longer times for transitions between very high and very low tides (USDC 1991). The lowest low daytime tides typically occur in the summer months.

4.0 GENERAL CHARACTERISTICS OF MAJOR PHYSIOGRAPHIC REGIONS

4.1 COASTAL RANGES/OLYMPIC PENINSULA

The Coast Ranges (including the Olympia Mountains) of Washington has extensive sandstone and siltstone deposits, shale and basalt. The soils, in this area, from sandstone, siltstone and shale are typically acidic, well drained, with high organic content soils (Umbrepts) that range from silts to clays (Franklin and Dymess 1973).

The coastal Washington receives the full force of incoming storms from the Pacific. Heavy rains and gale force winds are not uncommon during the winter months. This area receives some of the highest rainfalls in the continental United States (highest annual amount recorded at 4.75 m (187 in) at Wynoochee Oxbow). Winter temperatures are generally mild at the lower elevations (high 9•C/ 48•F, low 0•C/ 32•F) with snowline at about 450 - 900 m (1,500 - 3,000 ft) in midwinter. Summer temperatures are also mild with a summer maximum average of 21•C (70•F) on the coast and 24•C (75•F) further inland (NOAA 1974).

Regional hydrology is characterized by short streams and rivers that originate in the nearby mountains and flow westward to narrow estuaries on the Pacific coast. The high level of annual precipitation guarantees that most streams and rivers are perennial. However, seasonal wetlands (dry during the summer months) are not uncommon in the upper reaches of the drainages. Flooding during the winters months in the lowland areas is a common occurrence. Peak flood events occur in November-December and may occur again in some of the drainage that receive extensive snowmelt from the Olympic Mountains (Collins 1985).

4.2 PUGET TROUGH

The Puget Trough region has relatively low elevations with moderate topographic relief. The Trough is largely inside the terminal moraine of the Vashon glacier and contains many lakes and poorly drained depressional areas underlain by glacial drift (Franklin & Dymess 1973). South of the terminal moraine, is a large area of sand and gravel glacial outwash. Most soils are glacial material that is acidic and influenced by coniferous forests. Soil texture is typically gravelly sandy loam underlain by loose gravel/sand or hard, cemented till material (Franklin and Dyrness 1973).

Annual precipitation ranges from 0.8 - 1.0 m (32 - 40 in) from the Canadian border to Seattle, then gradually increasing to 1.1 m (45 in) in the Centralia area. Precipitation occurs primarily in the winter months, although rainfall events can occur during the summer. Summer precipitation is usually brief in extent and of mild intensity. Winters are mild with occasional snowfall. Winter maximum temperatures range from 4 to 7°C (40 to 45°F) with temperatures seldom dropping below -12°C (10°F). Summers are also quite mild with average maximum temperature at around 24°C (75°F). Temperatures can occasionally reach 32°C (90°F) or higher, but average only 3 to 5 days of the summer (NOAA 1974).

This region contains several moderate sized rivers that have their headwaters in the surrounding mountains. Most of the flow comes from the Cascades as the western side of the Puget South trough is in the rain shadow of the Olympic Mountains. Historic floodplains were very broad with meandering river beds which flowed westward toward extensive estuaries on Puget Sound. Seasonal flooding supported broad expanses of forested wetlands and shallow lakes and ponds. Settlement brought considerable changes of the hydrologic regime through flood control and land drainage efforts. Almost all of the rivers were subject to flood control projects such as channelization, levee construction, and dredging in addition to impoundments in their upper reaches. Many of the estuarine salt marsh and freshwater tidal wetlands were also diked and converted to agriculture (Collins 1985).

Damaging floods occur, especially during the November peak flows. Flooding events have been exacerbated in recent years by the extensive development in the floodplains and on the surrounding hillsides (Collins 1985).

Many of the Puget Trough wetlands have been lost or degraded due to human activities. Those that remain include the remnants of the vast floodplain wetlands, current floodplain wetlands, lake/pond marginal systems, and isolated seeps, bogs, and fens (Tiner, 1985).

4.3 CASCADES

The Northern Cascades are largely sedimentary mountains with great topographic relief. The river valleys are very deep and steep; however, the gradient is quite low until within 4.8-6.4 km (3-4 miles) of the mountain divide. The soils of this region are extremely complex because of the great variability of parent materials combined with the effects of glaciation (Franklin & Dyrness 1973).

The Southern Washington Cascades are predominantly andesite and basalt volcanic flows. The soils in this area, derived from volcanic ash and pumice, are frequently poorly developed and range from gravelly sandy loam to silt loam. Some soils derived from basalt and andesite are generally loam to clay loam underlain by clay loam or silty clay loam. Alluvial deposits along the major rivers are coarse textured (Franklin & Dyrness 1973).

The Cascades (both north and south physiographic regions) receive heavy precipitation due to orographic uplift of the moisture laden westerly winds. Annual precipitation ranges from 1.5 to 2.5 m (60 to 100 in), with the heaviest precipitation on the western slopes. Winter snowfall ranges from 1.3 to 1.9 m (50 to 75 in) in the lower elevations increasing to 10.2 to 15.2 m (400 to 600 in) at 1200 m (4000 ft) and above. Snowfalls can be quite heavy on the taller peaks. Mt. Rainier and Mt. Baker hold records for the greatest seasonal snowfalls in the continental United States (over 25 m/1,000 in was recorded at Paradise, on Mt. Rainier). Snow can remain at the higher elevations until June or early July. Winter temperatures are more extreme than the coastal regions, but are still comparatively mild. Mid-winter maximum temperatures range from 4°C (40°F) in the lower elevations to -1°C (30°F) at the higher. Summers are also relatively mild with summer maximum temperatures at 24°C (75°F), although it can occasionally drop below freezing above 1200 m (4000 ft) (NOAA 1974).

The Cascades can be characterized by fairly low gradient upper drainages that become steep river valleys in the lower elevations. The headwaters of the major drainages of the Puget lowland originate in the western slopes, while smaller drainages flow eastward toward the Columbia. High flows occur both in the winter months and spring. Highest flow peaks occur usually during November and December with occur ion major flood event. These have occurred during heavy storms with warm temperatures which prohibit snow accumulation in the higher altitudes. A second peak occurs in the spring. Catastrophic flood events are less common during this peak due to decreased precipitation levels as the weather moves toward summer drought conditions. Wetlands occur on the narrow floodplains and also in isolated alpine and subalpine meadows (Collins 1985).

4.4 OKANOGAN HIGHLANDS

The Okanogan Highlands were repeatedly covered by glacial ice, as was the Northern Cascades. Slopes are moderate here and bisected by several broad river valleys. The soils are also very complex here, even though many are derived from glacial till material. At high elevations, the soils are poorly developed, whereas along the river valleys and at the southern margin of the province, the soils are typically composed of glacial till or glacial outwash sands and gravels (Franklin & Dyrness 1973).

The relatively high elevations of the Okanogan Highlands result in more precipitation than the Columbia Basin to the south. Winters temperatures can be quite severe when weather patterns are dominated by continental air masses out of the northeast (temperatures of -34°C (-30°F) have been recorded in some locations). Precipitation can range from 28 cm (11 in) per annum in the valleys to over 71 cm (28 in) in the higher elevations of the northeastern portion of the State. Spokane receives approximately 43 cm (17 in). Snowfall ranges from 30 inches in the lower elevations to over 1.8 m (70 in) the higher. January maximum temperatures are between -2.2°C (28°F) and 0°C (32°F). Summers can be quite warm, with a few days every summer over the 38°C (100°F) mark. Thunderstorms are not uncommon in the summer, some producing hail (NOAA 1974).

In the Okanogan Highlands slopes are extensively bisected by several broad river valleys. Precipitation is not high, but flood events can occur, especially during the early winter months. Spring flow is primarily from snow melt. Wetlands are found associated with the rivers and in isolated areas fed by ground or surface waters. The isolated wetlands are usually seasonal, although peat systems that are saturated year around are not uncommon (Collins 1985).

4.5 COLUMBIA RIVER BASIN

The Columbia River Basin was covered with enormous flows of basalt, ranging from 600 - 1500 m (1980 - 4950 ft) thick. Much of the area was deeply cut and scoured by the Bretz Floods and has many deep channels. There are numerous soils in this area, but they are typically low in organic content and often have carbonate horizons. The textures range from silt loam to clay loam (Franklin & Dyrness 1973).

The Columbia River Basin receives the least amount of precipitation in the State, ranging from 18 to 38 cm (7 to 15 in). As with the Okanogan highlands, temperatures can be quite extreme in the winter if the weather is influenced by continental air masses with recorded temperatures in some areas of -34•C (-30•F). Summers are also quite warm with similar temperature and thunder storm patterns as the Okanogan Highlands (NOAA 1974).

The Columbia River Basin has been extensively modified by several major impoundments along the Columbia River and its tributaries. The river itself is highly regulated for use for irrigation, commerce, flood control, and electrical power generation. Several small drainages empty the surrounding highlands, however, many of them are annual streams which dry up during the summer months (Collins 1985).

The historic seasonal flood plains and wetlands of the Columbia are rarely inundated due to the strict control of the river water. However, irrigation and the numerous impoundments have altered the ground water and surface water patterns which have inadvertently created wetlands. The best example is that of Potholes Reservoir where the water in the wetland systems surrounding the area rise and fall with the Reservoir water level (Driscoll 1992).

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CHARACTERIZATION OF EXOTIC *SPARTINA* COMMUNITIES IN WASHINGTON STATE

CHARACTERIZATION OF EXOTIC *SPARTINA* COMMUNITIES IN WASHINGTON STATE

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1.0 INTRODUCTION

The objectives of this study were to characterize the existing state of the exotic smooth cordgrass (*Spartina alterniflora* Loisel.) and common cordgrass (*Spartina townsendii* H. & G. Groves/*Spartina anglica* C.E. Hubbard) communities as well as document the existing natural marsh communities surrounding and adjacent to *Spartina* spp. in Washington state.[1] *Spartina alterniflora* is native to the Atlantic and Gulf coasts of the United States and was introduced, presumably with oyster spat in the 1890's, to Willapa Bay, Washington (K. Sayce 1988). S. *alterniflora* is also present in other areas of Washington and California (Frenkel & Boss 1988). The *S. alterniflora* study sites chosen were in Willapa Bay (as described above); Gray's Harbor, Washington, where it was likely spread from Willapa Bay; and in Padilla Bay, Washington, where it was planted between 1940 and 1946 by the Dike Island Gun Club for beach stabilization (Parker & Aberle 1979). S. *townsendii* is a sterile hybrid of S. *alterniflora* and S. *maritima* (Curt.) Fernald. S. *anglica* is the fertile product of amphidiploidy of *S. townsendii* (Marchant 1967). The two species are practically indistinguishable in the field. One or both of these species are present in Port Susan Bay, Camano Island and Skagit Bay (Aberle 1990). Most of the following discussion will focus on *S. alterniflora* because it is the primary species present in Washington state; and all quantitative data was obtained for *S. alterniflora*.

S. alterniflora is found primarily in the intertidal zone, with some variation attributed to mean tidal range. (McKee & Patrick 1988) In its native habitat, *S. alterniflora* dominates, almost exclusively, the lower intertidal zone and may occur, although not as a dominant species, in the upper intertidal zone along with *S. patens*, *Distichlis spicata* and/or *Juncus* spp. (McKee & Patrick 1988; Bertness 1991). In McKee & Patrick's (1988) review of the relationship of *S. alterniflora* to tidal datums, *S. alterniflora* ranged from a maximum of +0.7 m above mean high water (MHW) to a minimum of -0.24 m below mean low water (MLW). (Tides on the east coast are diurnal, as opposed to the west and gulf coasts where tides are mixed.) The variation of growth above and below the intertidal zone may be attributable to differences in the mean tidal range (MTR) at a location, or biotic and abiotic interactions. –

Spartina spp. are deep-rooted perennial grasses that generally lose their above-ground biomass yearly in their native habitat (Aberle 1990; Sayce 1988). In non-competitive situations, *Spartina* will grow in circular colonies or clones. As the clones grow large enough to merge, a nearly continuous marsh develops (Caldwell 1957). The colonies can propagate by either seeds or

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1 Saltmeadow cordgrass (*Spartina patens*) is also present at one location in Washington state (Dosewallips State Park), but is not described in detail in this report because of its limited distribution. In addition, the single patch has become the subject of recent eradication efforts. The only other known location is in the Siuslaw Estuary of Oregon (Frenkel, 1988).

rhizomes. Seed viability is quite variable ranging from 0.4% (S. *alterniflora*) one year in Willapa Bay (Sayce 1988) to ~6% (*S. anglica*) in England (Marks & Truscott 1985) to over 50% (*S. alterniflora*) in experimental germination of east coast seeds (Seneca 1974). Colonies can grow in a broad range of substrates from silt and clays to sands and gravels or cobbles (Landin 1990). The underground biomass of roots and rhizomes stabilize sediments while the dense above-ground culms can trap significant amounts of new sediment (Gleason *et al.* 1979). This accretion of sediment causes the elevation of a growing *Spartina* marsh to rise noticeably above the tidal flats. Eventually, enough sediment is accreted to raise the elevation to high marsh and *Spartina* is replaced by other species, such as pickleweed (*Salicornia* spp.) and salt grass (*Distichlis spicata*). Native Pacific coast salt marsh species, such as *Triglochin maritimum*, trap sediment and advance out into the tideflats in a similar manner (Johannessen 1964). A fully developed *Spartina* marsh is characterized by large meadows at intertidal marsh elevations interspersed with deep steep-sided tide channels.

Native *Spartina* marshes are highly productive and important contributors to estuarine food webs. Numerous species of macroinvertebrates live in these marshes and their associated tidal channels, such as snails, clams, fiddler crabs, blue crabs, grass shrimp, amphipods, isopods and saltmarsh insects (LaSalle *et al.* 1991). Additionally, several types of fish have been found to frequent *Spartina* marshes; fundulus, weakfish, bay anchovy, Atlantic silverside and Atlantic menhaden. Populations of some species, such as the marsh clam, may be inhibited by the dense root mat in *Spartina* marshes (Capehart & Hackney 1989). Additionally, it is estimated that insects that feed upon *Spartina alterniflora* may consume about 10% of the annual primary production (Kraeuter & Wolf 1974).

2.0 STUDY AREAS

2.1 WILLAPA BAY

Willapa Bay, located in southwestern Washington State, is a bar built estuary bounded on the west by the Long Beach Peninsula and on the east by the Willapa Hills. Several small drainages which originate in the Willapa Hills enter the bay from the west. The bay area is approximately 32,400 hectares (81,000 acres) at Mean Higher High Water (MHHW) (AFEF 1991). Willapa Bay contains extensive tideflats with fringing salt marsh vegetation.

Five study areas where designated in the bay: (1) north of Bay Center along the northern edge of the bay; (2) the Palix River mouth; (3) Porter Point in the southern end of the bay; (4) Oysterville on the west side along the Long Beach Peninsula; and (5) Leadbetter Point, also on the Long Beach Peninsula (Figures 1-4). These sites were chosen to represent a wide range of environments in which *Spartina alterniflora* (hereafter referred to as "*Spartina*") is found, as well as for ease of access.

2.2 GRAYS HARBOR

Grays Harbor is a large natural harbor located to the immediate north of Willapa Bay. Sand spits border the mouth of the Bay both north and south (West Port peninsula and Ocean Shores peninsula). Grays Harbor comprises approximately 25,100 hectares (62,750 acres) of water, tidal marshes and shoreline. Several drainages enter the bay, including the Chehalis River at the eastern edge, the Elk and Johns Rivers from the south, and the Humptulips and Hoquiam from the north. The bay has extensive tideflats and fringing salt marshes.

One study site was chosen in Grays Harbor at Damon Point on the Ocean Shores peninsula. This is the only area that *Spartina* has been reported in Grays Harbor (Figure 5). It has also been recently discovered in the Copalis River mouth to the immediate north of Grays Harbor (F. Weinmann, pers. comm., 1992).

2.3 PADILLA BAY

Padilla Bay is located in northwestern Washington State near the town of Bay View. The bay is part of the historic Skagit River Delta and covers approximately 5,700 hectares (14,250 acres). Most of the bay's acreage is proposed for inclusion in the Padilla Bay National Estuarine Research Reserve (WA Dept of Ecology 1992). Fresh water inflow is from agricultural runoff channels that run through agricultural fields and across the tideflats. Padilla Bay, like Willapa Bay, contains extensive tideflats in addition to extensive eel grass beds (*Zostera* spp.) with some fringing salt marsh communities.

Spartina is very localized in Padilla Bay, found only in the southern portion of the bay, around Dike Island and Telegraph Slough. It was purposefully introduced to the island between 1940-1946 by the Dike Island Gun Club to help stabilize beach sediments. One study site was located on Dike Island and one site in the adjacent Telegraph Slough where additional *Spartina* patches have become established (Figure 6).

2.4 LIVINGSTON BAY

Livingston Bay is located in Puget Sound, on the southeastern shore of Camano Island. The Bay is a small natural embayment characterized by gravel beaches. There is a well established population of *S. anglica/townsendii* along the entire beach front.

One site was chosen on a private beach on the north east corner of the bay (Figure 7).

FIGURE 1.
STUDY SITE #1; NORTH OF BAY CENTER, WA
(FROM BAY CENTER QUADRANGLE, 7.5 MINUTE SERIES, USGS)

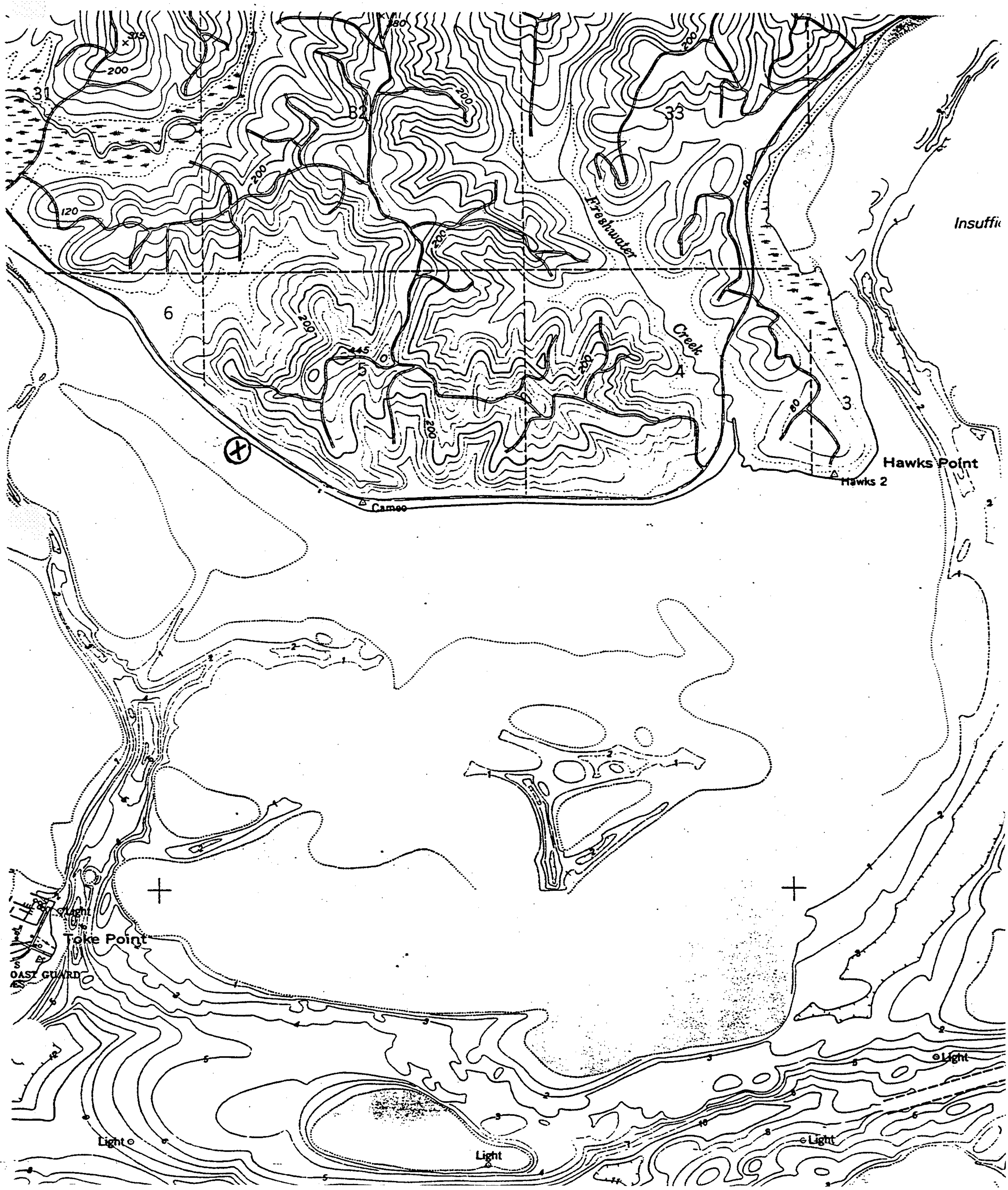


FIGURE 2.
STUDY SITE #2; PALIX RIVER BRIDGE, WILLAPA BAY
(FROM NEMAH QUADRANGLE, 7.5 MINUTE SERIES, USGS)

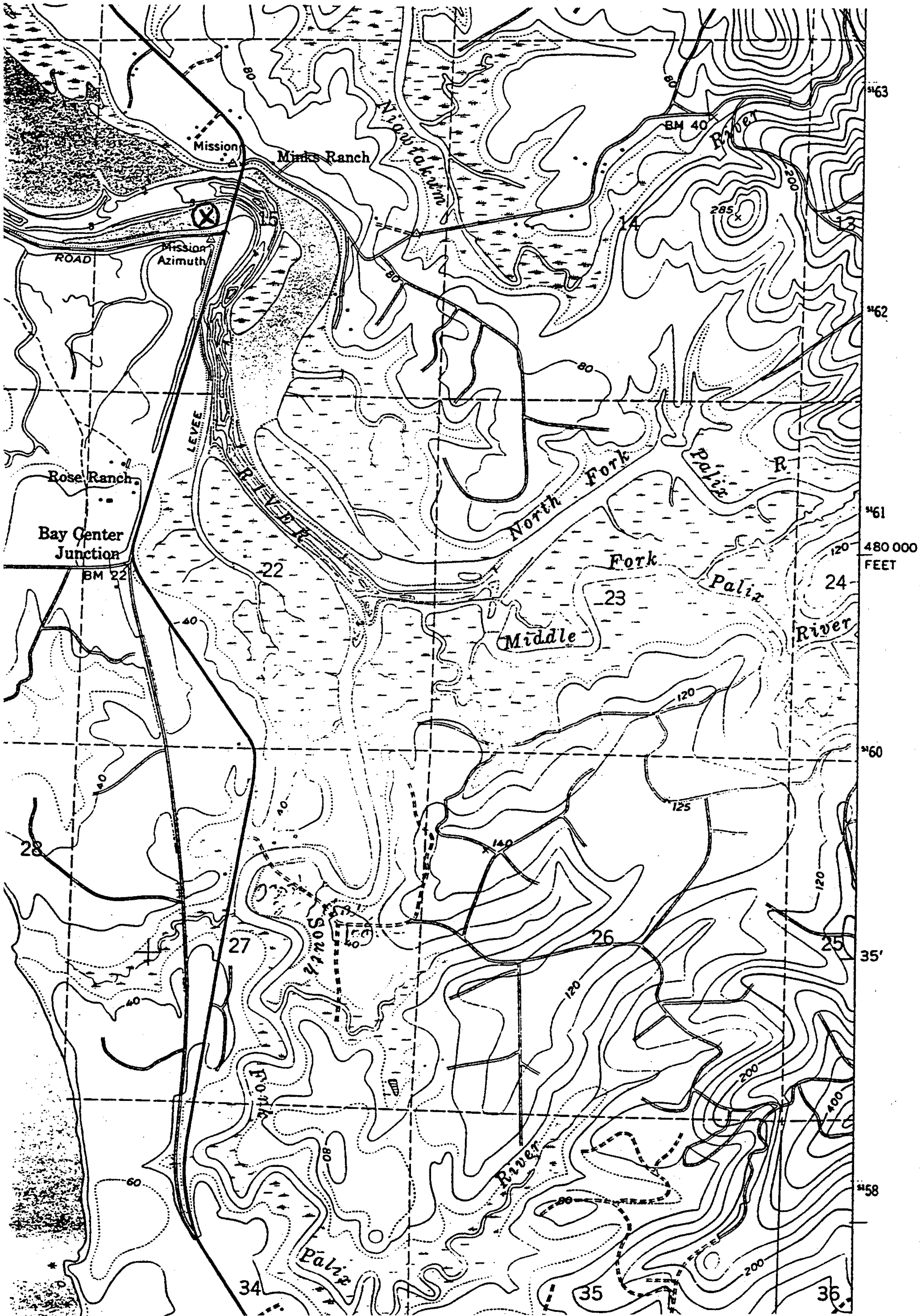


FIGURE 3.
STUDY SITE #3; PORTER POINT, WILLAPA BAY
(FROM LONG ISLAND QUADRANGLE, 7.5 MINUTE SERIES, USGS)

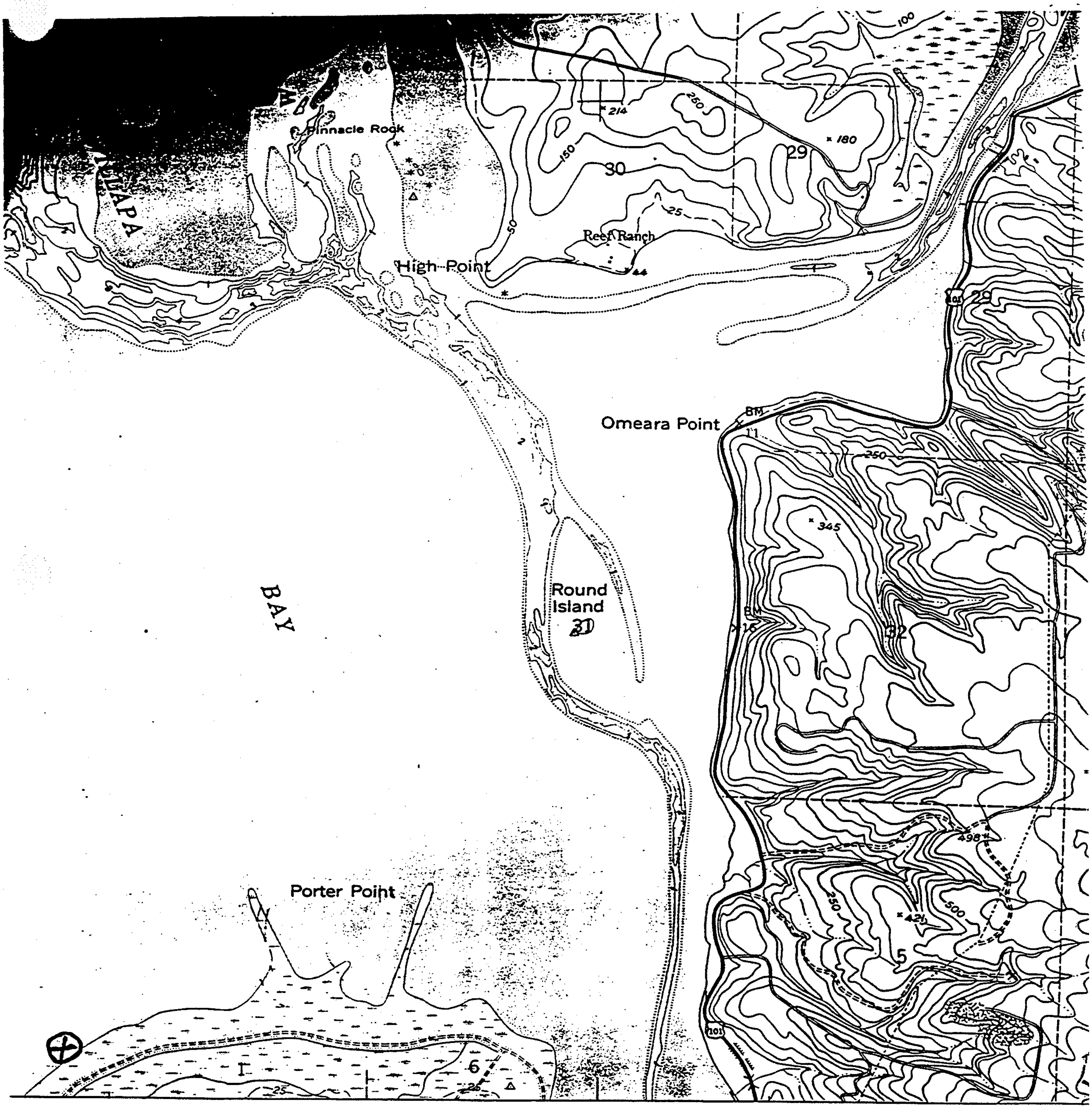


FIGURE 4.
STUDY SITES #4,5; OYSTERVILLE, WA & LEADBETTER POINT (FROM OYSTERVILLE QUADRANGLE, 7.5 MINUTE SERIES, USGS)

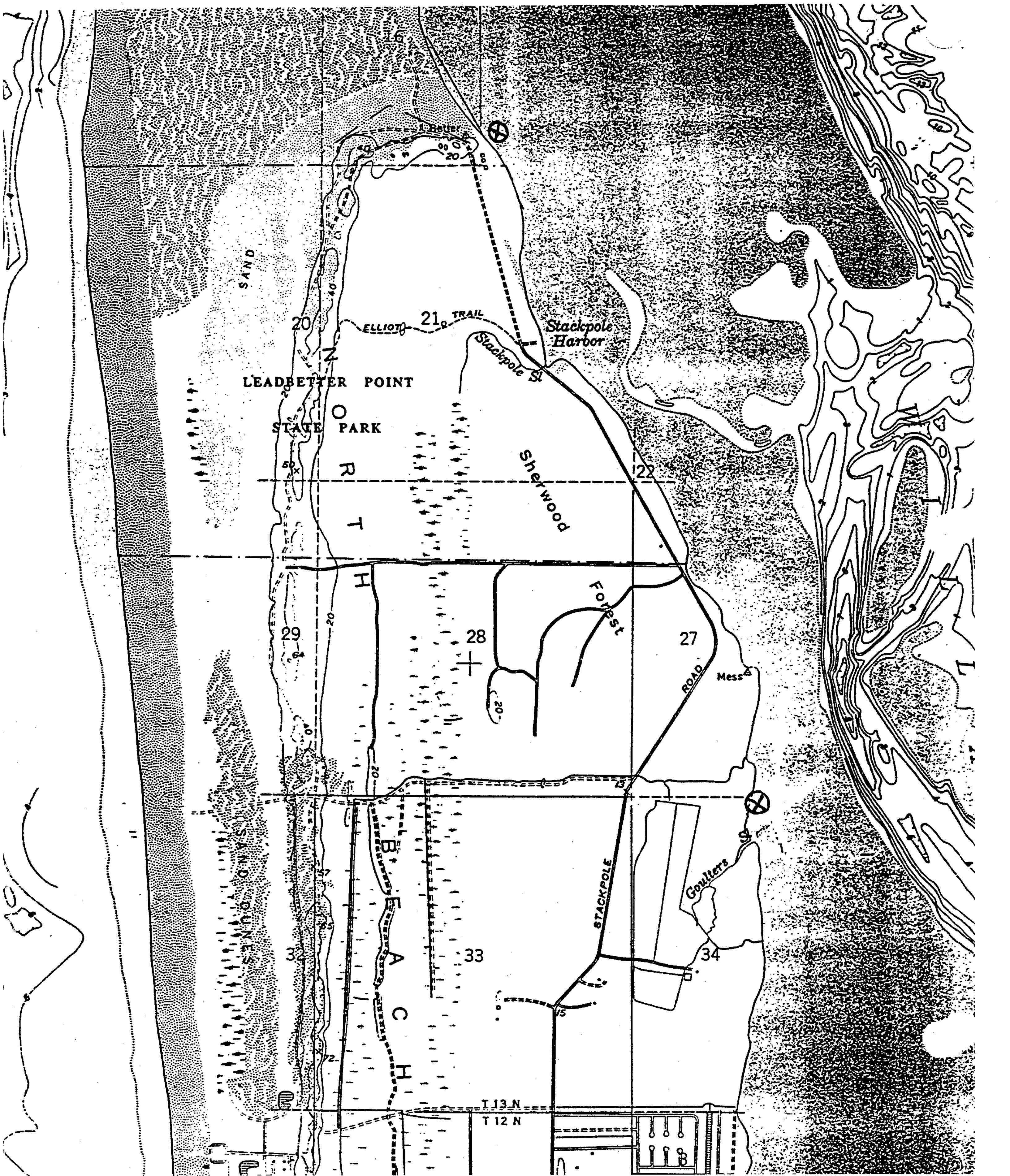


FIGURE 5.
STUDY SITE #6; DAMON POINT, GRAYS HARBOR, WA
(FROM POINT BROWN QUADRANGLE, 7.5 MINUTE SERIES, USGS)

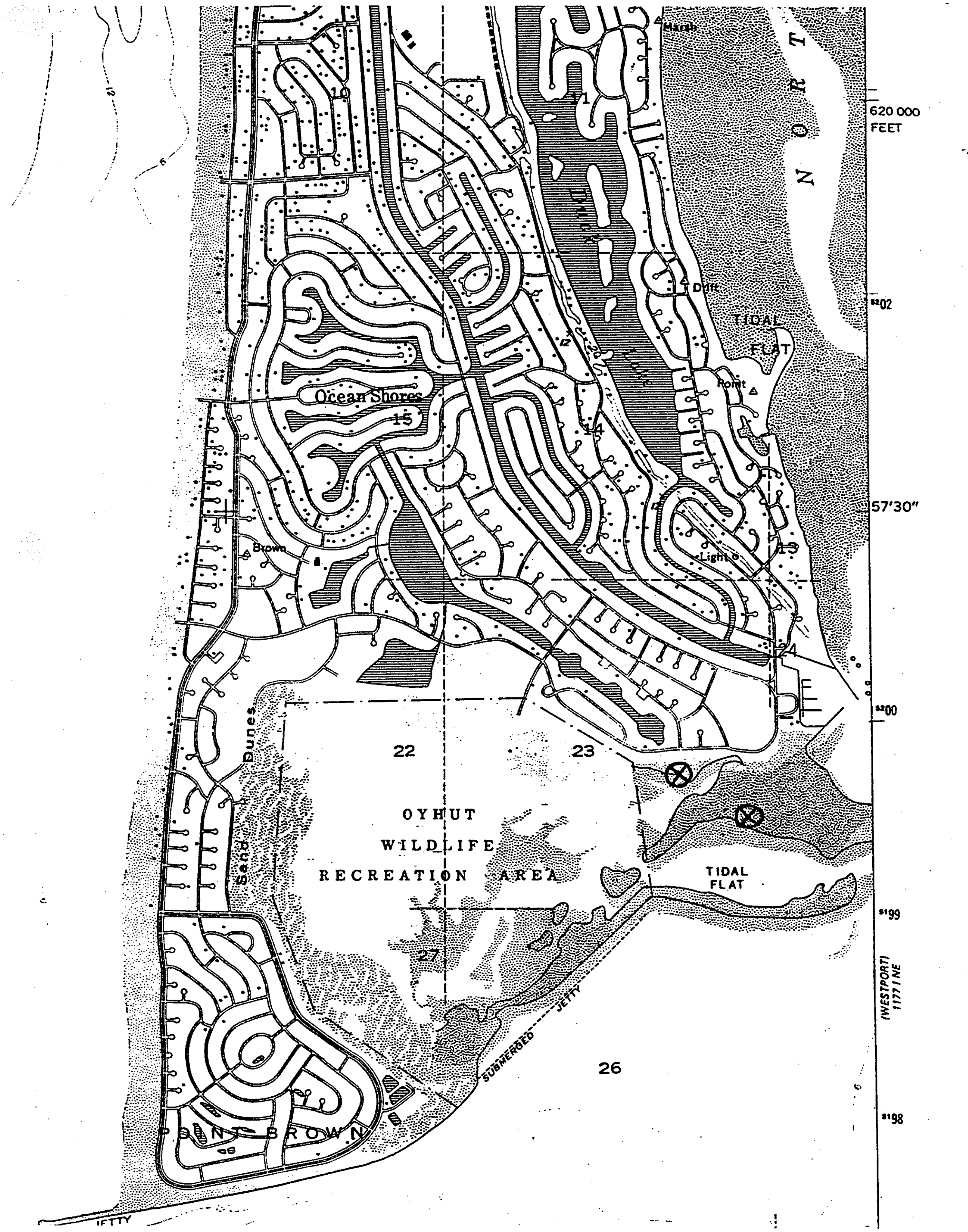


FIGURE 6.
STUDY SITES #7,8; TELEGRAPH SLOUGH & DIKE ISLAND, PADILLA BAY
(FROM LA CONNER QUADRANGLE, 7.5 MINUTE SERIES, USGS)

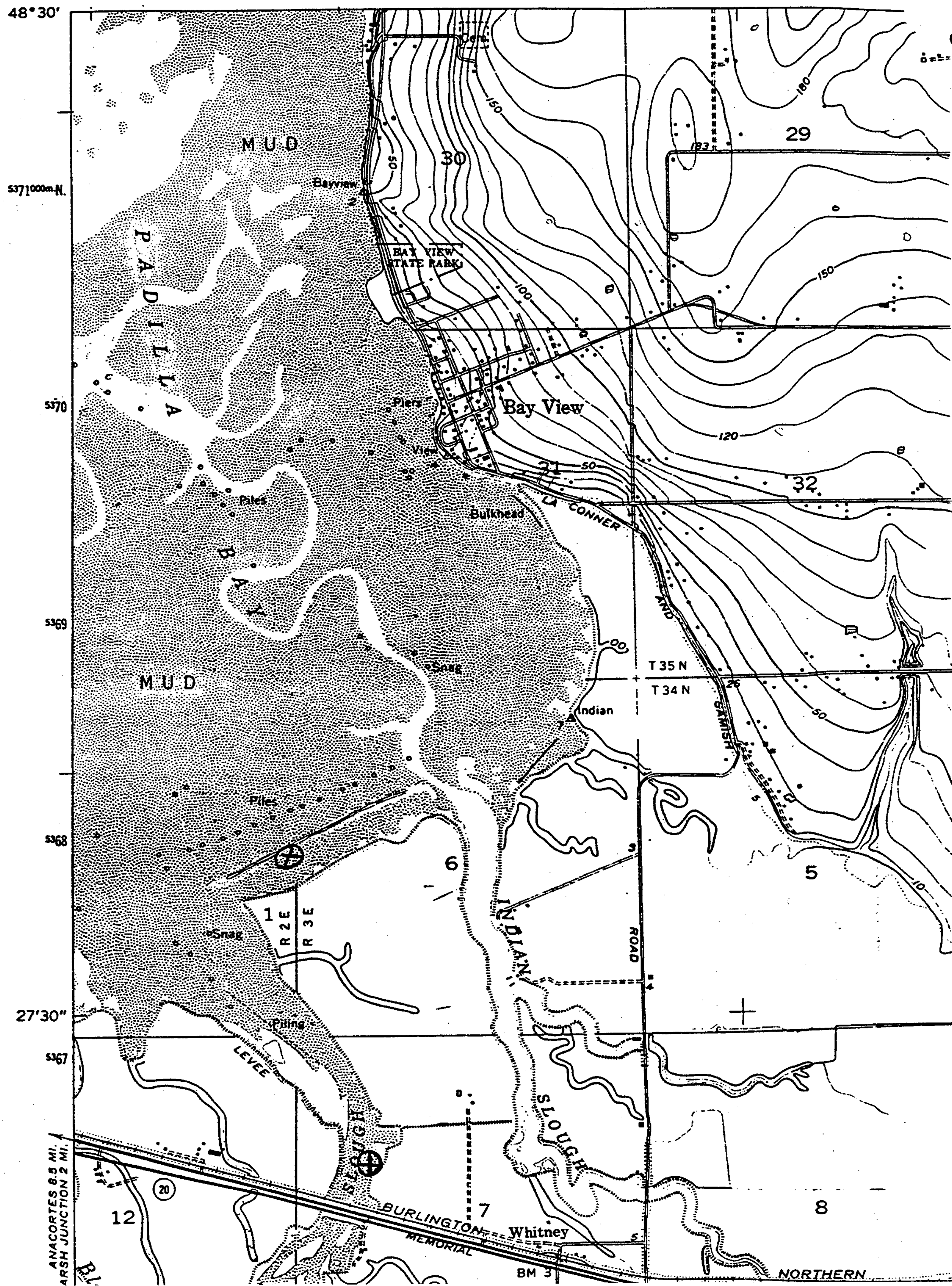
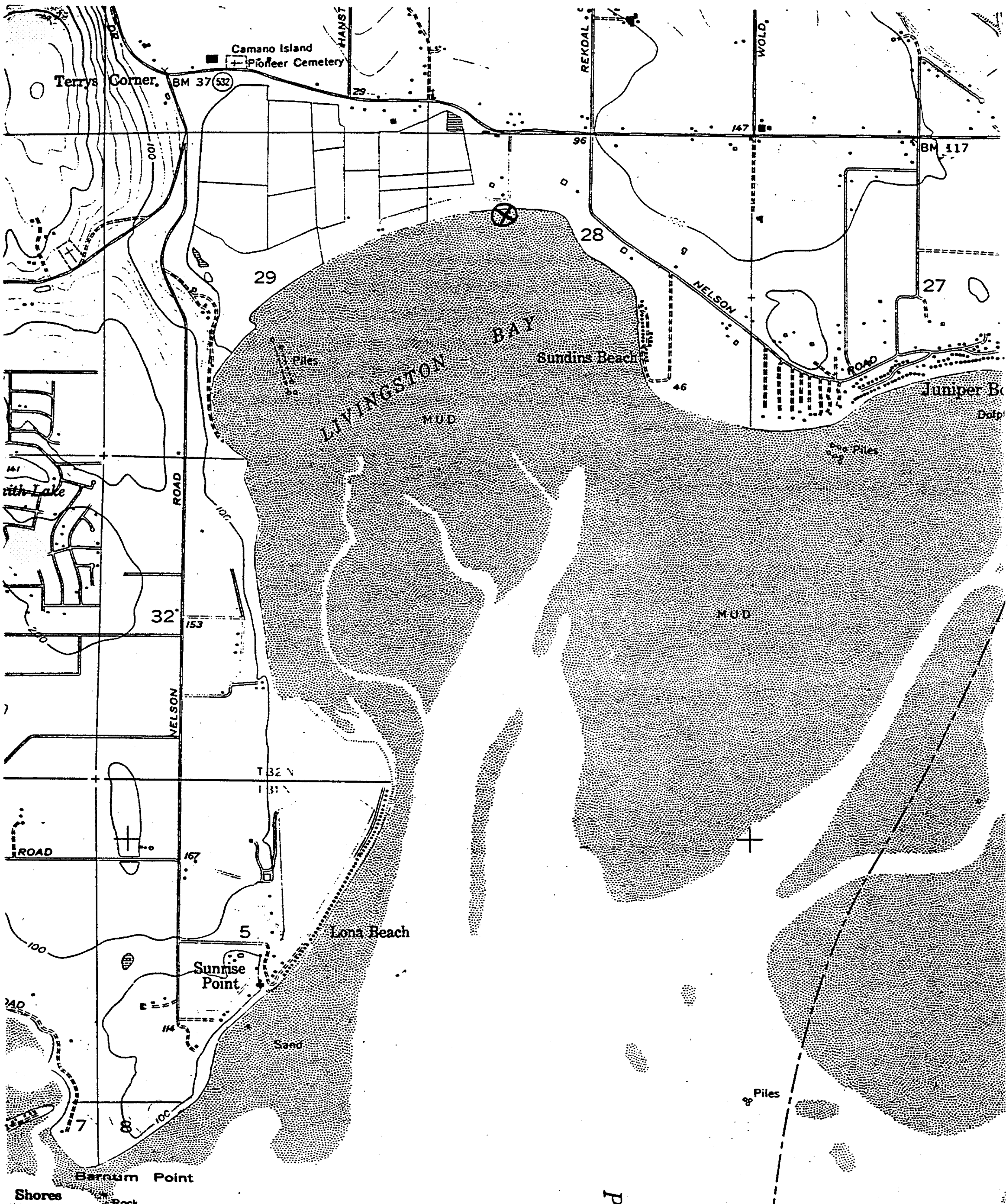


FIGURE 7.
STUDY SITE #9; LIVINGSTON BAY, WA (PORT SUSAN BAY)
(FROM JUNIPER BEACH QUADRANGLE, 7.5 MINUTE SERIES, USGS)



3.0 METHODS

Field sampling was conducted during August, 1992. Sampling sites were chosen to represent a wide variability in *Spartina* communities based on several factors, including substrate type. A total of 9 locations (including Camano Is.) were studied with a total of 16 clumps or marshes sampled. Transects were run in eight patches; see Tables 1-7. Plots were subjectively located along transect lines to represent visually diverse communities and conditions within the marsh. Plot size was 50 x 50 cm (20 x 20 in). Within each plot, visual estimates of percent cover for each species present (and bare ground if significant), stem and flower densities of *Spartina* and heights of *Spartina* culms were obtained. A pit was dug in each plot to qualitatively describe sediment profiles (in the field), measure depth of root mat and measure interstitial soil salinity and free water salinity (both salinity measurements taken at approximately 10 cm/4 in below the surface). Soil water samples were obtained by squeezing through a filtered syringe. The salinity was measured using a Goldberg T/C refractometer. Where transects were not run (eight other clumps) pits were dug, as above.

4.0 RESULTS

This report represents a general characterization of *Spartina* based on limited field characterization, observations made during the sampling period (August 1992) and review of the available literature. Sampling was of insufficient quantity to conduct statistical analysis. Accordingly, the data presented here are used to support general observations and are not meant to be used as a conclusive environmental analysis of the ecology of *Spartina*.

4.1 WILLAPA BAY

Spartina is well spread around the peripheries of Willapa Bay and up into some of the river systems that enter the Bay (within saline tidal influence). There appears to be no preference for sand or silt substrates with equal representation in both types of sediments. There can be, however, fairly dramatic differences in plant morphology (such as stem height, stem density, plant vigor, etc.) within each sediment type that does not seem to be directly correlated with any easily observable environmental parameter. We could find no relationship between salinity and observable plant morphology (stem density, stem height, plant vigor). Elevational data was not taken, however, observation of the study areas indicate that there can be significant morphological differences within areas that appear to be at the same elevation.

Soil salinities varied considerably, although soil salinities were less variable in the sandier sediments (Figures 8 and 9). This may be a function of high soil porosity which facilitates water exchange and inhibits salts concentrating in the soil. In contrast, salinities were more variable in the silty sediments, but this seemed to have negligible effects on vigor or morphology. Indeed, we could find no correlation of soil salinity with any physical characteristic, even the presence or absence of flowers.

In most of the bay, *Spartina* occurs in two geomorphic patterns. The first pattern is the most noticeable in the bay and is the round circular patches that dot the tidal flats. Some of these patches can be quite large and, judging from aerial photo inspections, can be quite old (over 40 years). This is a typical growth form of saltmarsh plants growing without competition (Caldwell, 1957). The other pattern is where several of the patches have coalesced to form monospecific marshes. Both patterns were found on sand and silt substrates.

We traced the invasion of *Spartina* patches upriver as far as we could visually observe from the roads. It is found upriver on almost all of the drainages, however, it was not observed upriver of areas influenced by saline tides. We explored some brackish areas along the Naselle River, but did not note any invasion of the *Carex lyngbyei* marshes found upriver near the town of Naselle. We also did not note invasion very far up some of the other drainages (Palix, Willapa, North, Nemah). The larger concentration of patches and marshes appeared to be centered around the river mouths and other shallow and/or protected embayments. On the east and Gulf coasts, *Spartina alterniflora* is typically limited to the lower and mid-littoral regions; this is most likely due to interspecific competition, rather than inhibitions from freshwater. However, many plants adapted to saline conditions (halophytes) are well able to tolerate freshwater conditions, and may even thrive without salt (Levitt 1972). *Spartina* could potentially spread up-river into relatively freshwater areas, but has not been observed in those areas, either in Washington state, or other areas, such as New Zealand (Bascand 1970).

We noticed areas of *Spartina* die-back scattered throughout the sample sites in areas of *Spartina* marsh on the silt substrate areas, usually away from the waterward edge. Although no measurement of anaerobiosis was taken, discussions with experts and a review of the literature indicate that die-back is usually caused by extremely reduced soil oxygen, beyond the range that *Spartina* can normally tolerate as a hydrophyte (Goodman and Williams 1966; Mendelssohn and Seneca 1980; DeLaune *et.al.* 1983; Mendelssohn and McKee 1988). It is not unreasonable to assume that some type of sulfur toxicity is responsible for the die-back areas. Die-back areas were not as common on the sandy substrates (some were noted at Oysterville), presumably because of better oxygen exchange in more porous substrates. Die-back areas were not noted on the circle patterns in the silt substrates. We speculate that this is also a function of better tidal flushing and more oxygen exchange.

Root mat depth in all sites was fairly shallow, with the greatest depth at about 77 cm (31 in) below the surface (Figures 10 and 11). We did not note the depth of live roots, instead we measured the depth of the root mat--although in most cases, it appeared that live roots were present throughout the root mat. Even dead roots do not decompose very quickly, due to the highly reduced conditions and contribute to the density of the root mat. Hemminga, *et al.* (1988) estimated that dead roots may remain undecomposed for up to 4 years. Generally, the root mat in sand substrates did not extend more than 39 cm (15.5 in) below the surface whereas the root mat in the silt substrates was larger. We found no correlations between root depth and *Spartina* geomorphic pattern, stem height, stem density or plant vigor.

Although there appeared to be a visual difference in the vigor, height, and density of plants at the seaward edges of the samples, this is not apparent from our sampling (Figures 12, 13, 14 and 15). It was our observation that the plants were more vigorous the closer they were to tidal flushing (edges of the circular patches, or the seaward sites of marshes which are generally the advancing edge). Due to the extreme variation of *Spartina* characteristics within a site and between sites, this observation gets damped out within the data. We also observed that *Spartina* was generally taller with higher stem densities in silt substrates. Again, this characteristic is not clearly visible from the data, largely due to the small number of samples that were able to be taken during the study period.

We observed no differences in the percentage of plants flowering in silty substrates as opposed to sand. Almost all areas had large populations of flowering plants spread throughout the sample sites. We also noted no difference between geomorphic patterns. The abundance of flowering plants may be related to the mild winter temperatures and warm dry summer experienced this season. According to Sayce (1988), *Spartina* patterns in Willapa vary according to the severity of the weather; milder weather instigates more flowering. In addition, abundant new plants were sprouting on the tidal flats all around the bay, indicative of increasing seed viability. It is unknown if this is a result of the warmer weather or some other factor.

Spartina usually occurred as a monospecific stand, with the exception of some community overlap at the edge of the marshes and at the edge of patches adjacent to marshes. There appears to be very little interspecific competition with the *Spartina* and native salt marsh plant species. We did notice colonization by *Salicornia virginica* in the center of some of the circular patches at Leadbetter Point (sand sediment), in the older areas of the marsh at Oysterville (also sand) and adjacent to the transect at Bay Center. We also found some buried *Spartina* culms (dead) below areas of *S. virginica* dominance, which may indicate that *Spartina* was once a dominant at the site before the colonization of *S. virginica*. We did not notice colonization by native species within the *Spartina* patches at any of the silty sediment types. Tables 1-7 illustrates the community composition of each sample site. Figure 16 is a complete species list for the study sites.

Spartina appears to be mirroring the colonization role of the native tideflat colonizer, *Triglochin maritimum*. T. *maritimum* acts as a sediment stabilizer and colonizes aggressively at a certain point, likely to be tied to some critical elevation, *S. virginica* invades and begins to dominate the center of the patches. *S. virginica* is an aggressive colonizer on stabilized sediments and will eventually become a dominant at a colonized site. We noted *S. virginica* dominance in some, but not all, of the larger circular *Spartina* patches at Leadbetter Point as well as portions of the marsh at Oysterville and the big clump at Bay Center.

The other areas of species overlap/competition occurred in limited areas at the interface with high salt marsh and *Spartina* patches and marshes. At Porter Point, what appeared to be older patches were surrounded by high salt marsh vegetation and were not as vigorous as neighboring patches further down the elevational gradient. In this case, we speculate that the *Spartina* patch was the original colonizer. Subsequent sediment deposition caused by *Spartina* colonization and the construction of a large dike to the south allowed the establishment of native salt marsh species (*Deschampsia caespitosa, Distichlis spicata, Salicornia virginica*) which appear to be excluding the continued expansion of the *Spartina* patch. This is supported by the finding of buried *Spartina* culms below areas that now support native vegetation.

We found both species of eel grass (*Zostera japonica and Z. marina*) adjacent to some of the circular patches on Leadbetter Point and at Porter Point. These areas were surrounded by tideflat with small areas of *Z. japonica* interspersed between the patches. We found a few culms of *Z. marina* close to some of the patches at Porter Point. However, it appears that tidal distribution of *Spartina* and *Z. marina* do not overlap. Although *Z. marina* and *Spartina* are found adjacent to each other in some areas, it is difficult to determine if *Spartina* colonized areas previously occupied by *Z. japonica* or if the *Spartina* colonization resulted in the accretion of sediments which provided a suitable area for colonization by *Z. japonica*.

We noted, but did not examine closely, that several areas of *Spartina* in all locations had a red tinge to the edge of the blades, which seemed unusual for plants in early August. At the time of our observation, we attributed this red tinge to some kind of salinity/anaerobic stress. However, this assumption did not correlate with our field sampling. Other possibilities may be some kind of heat stress due to the higher temperatures experienced during the summer of 1992, which could break down the proteins in the leaves (Levitt, 1972), or a viral infection of the plant. Jones (1979) noticed a viral infection on populations of *S. anglica* in Great Britain which resulted in mottled leaves (he implies this was a spotty yellowing of the leaves) and less plant vigor. The Willapa Bay populations may also have some kind of viral infection. A correlation between red tinge and plant vigor was not tested at the time of our sampling, but may be found in further investigations of the area.

4.2 GRAYS HARBOR

To date, the only known areas of *Spartina alterniflora* in Grays Harbor are two circular patches at Damon Point, on the Ocean Shores Peninsula (Refer to Figure 5). It is very likely the patches are the result of vegetative migration from Willapa Bay in the recent past. At the time of our sample, one of the sites had been mown, so we were unable to take a complete sample. However, we did observe the site prior to mowing, and can report some observations.

The two patches are located in a protected shallow embayment on the southern end of the Ocean Shores peninsula. They appear to be a relatively recent colonization, although this has not been confirmed. They are different from the Willapa sites in that both patches appear to have colonized within an existing salt marsh, although the mowed patch is a little further out on the sand flat than the undisturbed patch. The mowed patch was well mixed in a stand of *Scirpus americanus*. Both species were resprouting at the time our inspection. The undisturbed patch is within a stand of *Salicornia virginica*. This is the only observation we made where community dominance throughout the *Spartina* patch was shared with another species. Table 5 illustrates the community composition of each sample site. The undisturbed patch was flowering, although we were unable to confirm if the flowers would produce viable seed. Also, plant height at the undisturbed site was the shortest observed in the entire sample (Willapa, Grays Harbor, Padilla Bay) (Figures 17 and 18). Our observation of the mowed site during an earlier visit was that the plants were taller than at the unmowed site, but not as tall as most of the samples within Willapa Bay. Root depth was somewhat shallower, but not notably different from Willapa Bay (Figure 19).

Soil salinity was somewhat higher at these sites than most of the Willapa Bay sites (Figure 20). This finding was not unexpected as the sites are located in a protected embayment on the peninsula. Water pans at low tide in the sand flats and is likely responsible for the elevated salinity.

No other significant differences from the Willapa Bay samples were found.

4.3 PADILLA BAY

Spartina in Padilla Bay dates back to 1940. The plants were obtained by the Dike Island Gun Club from the Winnebago Nurseries in Wisconsin (Parker & Aberle 1979). The Padilla population is unique in that there has been no observations of *Spartina* flowering in the Bay. The patches in the adjacent Telegraph Slough are thought to have been the result of a vegetative propagule from the Dike Island population which landed in the slough through tidal action.

Observations and data gathered were similar to that in Willapa Bay with these differences. *Spartina* is localized without the signs of the vigorous colonization experienced in Willapa Bay. Although the stands of *Spartina* are getting larger, through vegetative spread (Riggs 1991), they have not spread beyond the original planting except for a few areas in close proximity to Dike Island. The patch pattern on Dike Island can be seen at the waterward side of *Spartina* stands, although the landward edges have coalesced into a marsh pattern. The Padilla population also appears to be more uniform in morphology.

We noted die-back in the Padilla population, similar to that found on the silty sediments in Willapa Bay. This has also been noted by Riggs (1991). In addition, we noted large areas of what appears to be a recent (this season?) die back over much of the Dike Island marsh; we did not compare the extent of die-back to the sites noted by Riggs (1991). As noted previously, we did not take any measurements of anaerobiosis, however, the die-back did seem to be related to highly anaerobic conditions (characterized by a very strong smell). We speculate that the extended periods of drought and warm weather, in 1992, may have resulted in exacerbated low oxygen conditions on a larger scale than the previously experienced localized die-back. These larger scale conditions may be reversed when a wetter, cooler weather pattern predominates.

Soil salinity, stem height and density, and depth of the root mat were not notably different from Willapa Bay populations (Figure 21, 22, 23, and 24).

Table 6 illustrates plant community composition at each sample plot.

4.4 OBSERVATIONS OF *SPARTINA ANGLICA/TOWNSENDII* - CAMANO ISLAND/LIVINGSTON BAY

No environmental sampling was done in this population due to lack of time. However, we observed that a large and vigorous population of this (these) species colonizing gravel beaches. At the time of our observations, there were abundant flowering individuals. It also appeared that many seedlings had established themselves within the past growing season. From these brief observations, it appears that *S.* anglica/townsendii has a high potential for spreading into the surrounding area.

5.0 DISCUSSION

Marshes of the Pacific northwest can be thought of as floristic islands which have developed in relative isolation from other salt marsh communities. As with most islands, introduction of an exotic species can have dramatic effects. *Spartina alterniflora* is exhibiting classic features of an introduced species in a relatively isolated habitat (Caldwell 1957; Hubbard 1965; Callaway and Josselyn 1992). *Spartina* is well known for its aggressive abilities as a colonizer (see Callaway and Josselyn 1992). Since there is little or no competition with native species, and the area is suitable to supporting *Spartina*, it has become well established in Willapa Bay.

Concern for management of *Spartina* is valid given the resource value of Willapa Bay and other estuarine environments in the Pacific Northwest. Crucial to any management scheme should be a clear understanding of the conditions that resulted in this recent episode of exponential growth, in order to determine potential future areas of spread. Of particular interest is the current relative stability of the population in Padilla Bay as opposed to Willapa Bay. Both bays have broad expanses of tidal flats which could easily host propagules. Although the population in Padilla is expanding, it is expanding at a much slower rate than the rate at which the population in Willapa is currently expanding. In addition, the Padilla population has never been known to go to seed, which is likely a contributing factor to its relatively slow spread. Several theories have been proposed which would require additional research to fully explore. Those are as follows:

1. *Spartina alterniflora* is a native dominant on the East and Gulf coasts of the United States. Coastal waters, especially during the summer, are considerably warmer than those on the West coast. In its native habitat, *Spartina* is essentially a warm water species. When it was introduced into Willapa Bay, it was introduced into a system which was considerably colder than that experienced on the East coast. These colder waters may have kept the population in check for many years (low or no seed viability, low vegetative reproductive success) until relatively recently. Large amounts of sediments have been introduced into the bay from land use practices in the surrounding area which have increased the bottom elevation of many of the small embayments around Willapa Bay. Water temperatures may be comparatively high in these areas (in relation to open ocean water) especially during the summer months. Subsequently, the warmer waters are likely to be more conducive to *Spartina* reproduction. This is supported by Sayce's (1988) observation that seed production and plant vigor increase in years with warmer weather. Padilla Bay also has extensive areas covered by shallow water, however, it lacks the numerous small embayments and shallow river mouths characteristic of Willapa Bay. Many tidal channels and embayments were lost during diking of

the estuary at the turn of the century. This theory could be tested by an examination of past changes in water temperature data from both areas (Frenkel, pers. comm., 1992).

2. *Spartina* has an interesting and well studied genetic background. Specifically, *Spartina anglica* is considered to be a fertile amphiploid of *S. townsendii*. *S. townsendii* is a infertile hybrid species which resulted from a cross between *S. alterniflora* and *S. maritimum*. *S. anglica* has been highly successful at colonizing tidal flats of coastal Great Britain. It is conceivable that the *Spartina* population in Willapa may gone through some genetic variation (amphiploidy?) during its occupancy of the bay. The recent explosion of growth may be attributed to a new, more successful variant of the parent species. The small population in Padilla Bay has not experienced this transformation and may represent the east coast parent (*S. alterniflora*) stock. Conversations with East coast experts familiar with the distribution of *S. alterniflora* indicate that the Willapa population is not limited by the same ecological parameters of the East coast variety. Specifically, it seems to have a higher tolerance to salinity and also has a broader distribution along the tidal elevational gradient. Genetic experiments (electrophoresis) could be performed to test this theory (Hackney, Thom, pers. comm., 1992) and determine if *Spartina* could spread to areas it traditionally did not.

3. Examinations of below ground productivity in newly created or newly colonized systems indicated that there is a lag time before production mirrors that of older or natural systems (Thom, pers. comm., 1992). Preliminary work indicates that plants are less likely to produce viable seed until some critical mass of below ground production is achieved (i.e., more plant energy is used to produce below-ground resources than to assure reproductive success). When that critical mass is reached, plants are more likely to go to flower and seed. The rapid increase in the number of seedlings found in Willapa Bay may be an indication of reaching critical mass in *Spartina* below-ground productivity on a grand scale, while the plants in Padilla Bay have not yet reached the critical biomass. Testing of this theory would require long term productivity studies. This type of information would also be very useful in determining the potential beneficial contributions of *Spartina* to the Willapa Bay food chain (R. Thom, C. Simenstad, pers. comm., 1992).

6.0 CONCLUSIONS

1. *Spartina alterniflora* is well established in Willapa Bay, Washington. Two substantially smaller populations are found in Padilla Bay and Grays Harbor, Washington. *S. anglica/townsendii* is well established in Livingston Harbor, Washington.

2. Distribution of *S. alterniflora* does not appear to be limited to any specific sediment type.

3. Interstitial salinity varied in all of the sample sites. There appeared to be no correlation between salinity and morphology, flowering, or distribution of *S. alterniflora*.

4. *S. alterniflora* occurs in two geomorphic patterns; a circular patch and fringing marshes where circular patches have coalesced. Both forms were found in sand and silt sediments.

5. Scattered areas of die-back were found in both Willapa and Padilla Bay. It is hypothesized that the die-back is the result of sulfur toxicity from highly anaerobic conditions.

6. Root mat depth was fairly shallow in all substrates. No correlation was found between depth of the root mat and physical characteristics.

7. An abundance of flowering plants existed in both sand and silt substrates.

8. *S. alterniflora* usually occurs in monospecific stands. There is some evidence of competition with native species. *Zostera japonica* (another exotic species) is found adjacent to some of the patches in Willapa Bay, however, a competitive relationship has yet to be determined.

9. Several areas of red tinged blades were found in Willapa during the sampling period. It is unknown if this feature is due to some, as yet, unknown environmental stress or if it is caused by a viral infection of the plant.

10. Patches in Grays Harbor showed no notable difference from Willapa Bay except that they were shorter and were found colonizing within an existing salt marsh. One site had been mowed.

11. The *S. alterniflora* population in Padilla Bay showed no notable differences **except** that there were no flowering individuals found. Comparatively large areas of recent die-back were also noted.

12. A vigorous colony of *S. anglica/townsendii* was noted at Livingston Harbor on a gravel substrate.

13. Additional research is recommended to further explore the ecology of *S. alterniflora*, specifically in regard to its exponential spread in Willapa Bay.

Bay Center (Hawk's Point)
Willapa Bay

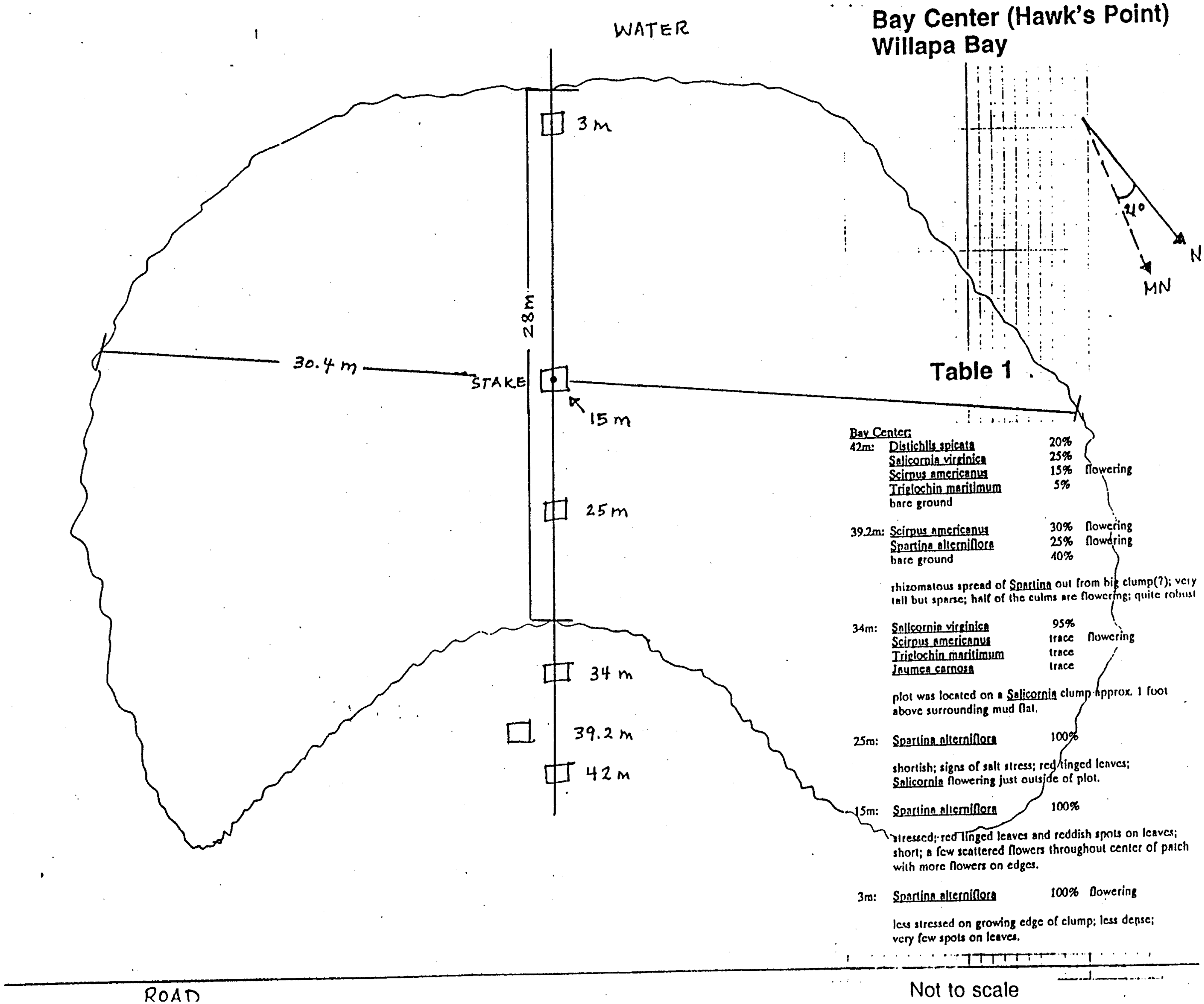


Table 1

Bay Center:			
42m:	Distichlis spicata	20%	
	Salicornia virginica	25%	
	Scirpus americanus	15%	flowering
	Triglochin maritimum	5%	
	bare ground		
39.2m:	Scirpus americanus	30%	flowering
	Spartina alterniflora	25%	flowering
	bare ground	40%	
	rhizomatous spread of Spartina out from big clump(?); very tall but sparse; half of the culms are flowering; quite robust		
34m:	Salicornia virginica	95%	
	Scirpus americanus	trace	flowering
	Triglochin maritimum	trace	
	Jaumea carnosa	trace	
	plot was located on a Salicornia clump approx. 1 foot above surrounding mud flat.		
25m:	Spartina alterniflora	100%	
	shortish; signs of salt stress; red tinged leaves; Salicornia flowering just outside of plot.		
15m:	Spartina alterniflora	100%	
	stressed; red tinged leaves and reddish spots on leaves; short; a few scattered flowers throughout center of patch with more flowers on edges.		
3m:	Spartina alterniflora	100%	flowering
	less stressed on growing edge of clump; less dense; very few spots on leaves.		

Palix River Bridge Marsh
Willapa Bay

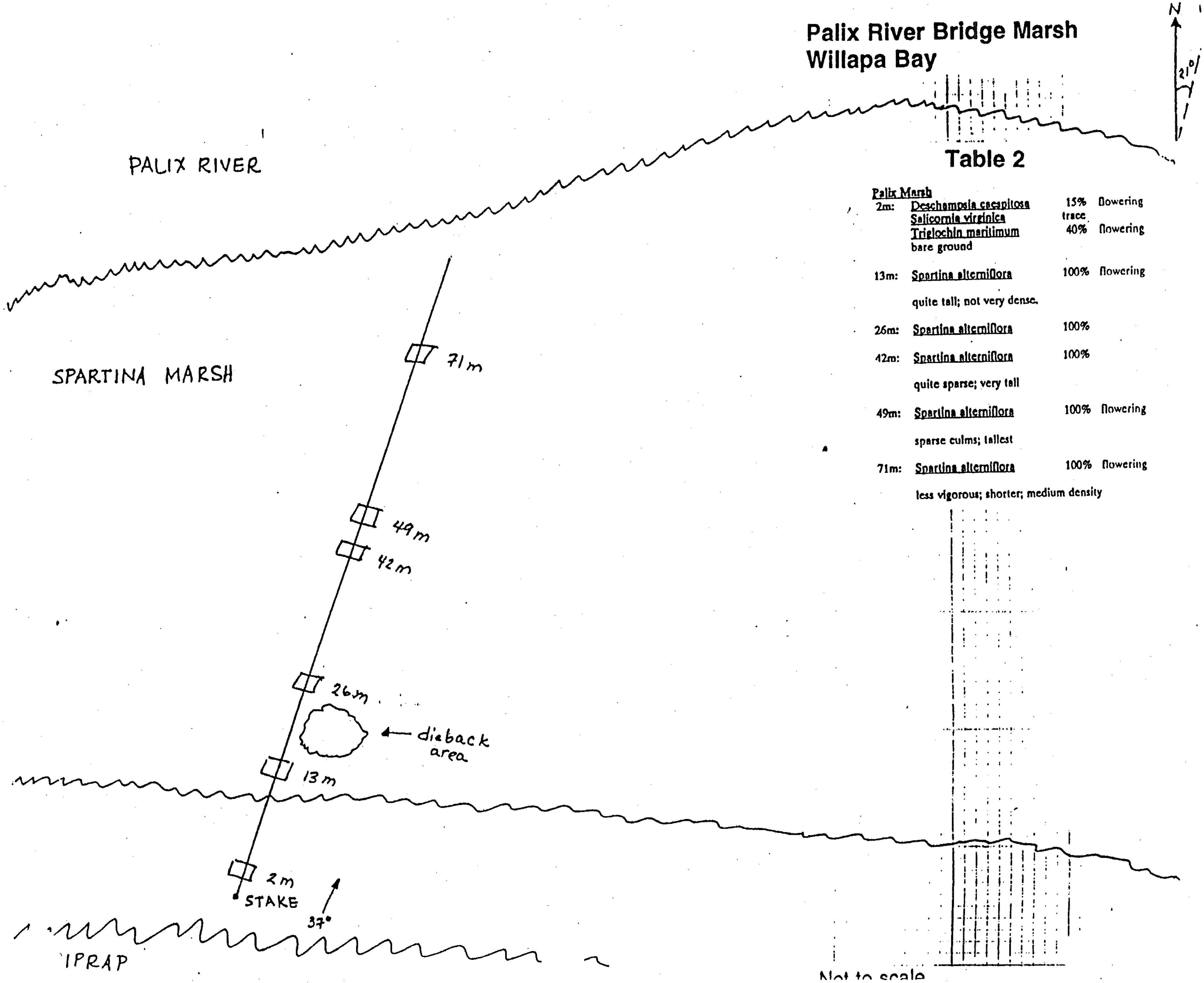


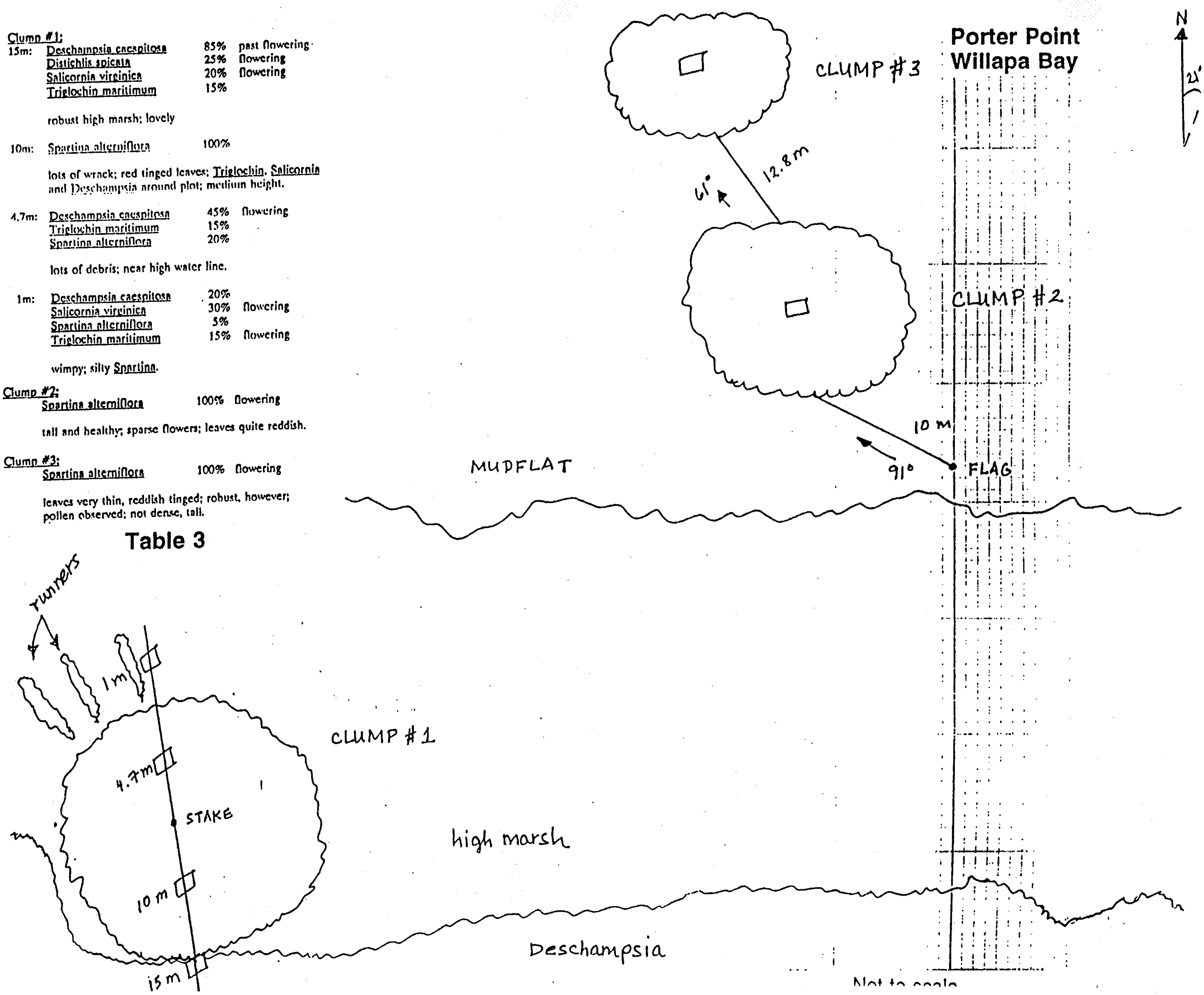
Table 2

Palix Marsh

2m:	Deschampsia caespitosa	15%	flowering
	Salicornia virginica	trace	
	Triglochin maritimum	40%	flowering
	bare ground		
13m:	Spartina alterniflora	100%	flowering
	quite tall; not very dense.		
26m:	Spartina alterniflora	100%	
42m:	Spartina alterniflora	100%	
	quite sparse; very tall		
49m:	Spartina alterniflora	100%	flowering
	sparse culms; tallest		
71m:	Spartina alterniflora	100%	flowering
	less vigorous; shorter; medium density		

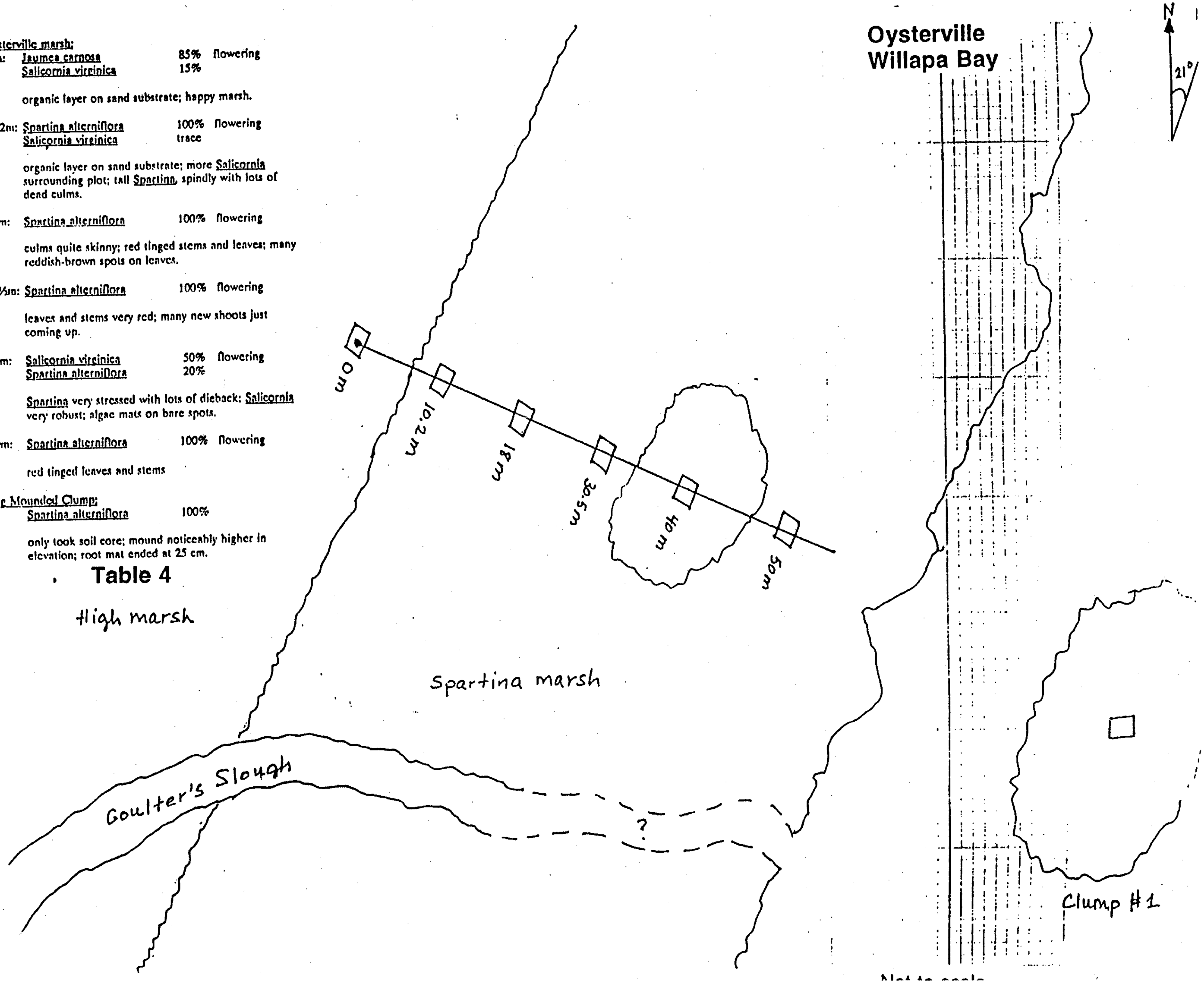
Clump #1:			
15m:	Deschampsia caespitosa	85%	past flowering
	Distichlis spicata	25%	flowering
	Salicornia virginica	20%	flowering
	Triglochin maritimum	15%	
	robust high marsh; lovely		
10m:	Spartina alterniflora	100%	
	lots of wrack; red tinged leaves; Triglochin, Salicornia and Deschampsia around plot; medium height.		
4.7m:	Deschampsia caespitosa	45%	flowering
	Triglochin maritimum	15%	
	Spartina alterniflora	20%	
	lots of debris; near high water line.		
1m:	Deschampsia caespitosa	20%	
	Salicornia virginica	30%	flowering
	Spartina alterniflora	5%	
	Triglochin maritimum	15%	flowering
	wimpy; silty Spartina.		
Clump #2:			
	Spartina alterniflora	100%	flowering
	tall and healthy; sparse flowers; leaves quite reddish.		
Clump #3:			
	Spartina alterniflora	100%	flowering
	leaves very thin, reddish tinged; robust, however; pollen observed; not dense, tall.		

Table 3



Oysterville marsh:			
0m:	Jaumea carnosa	85%	flowering
	Salicornia virginica	15%	
	organic layer on sand substrate; happy marsh.		
10.2m:	Spartina alterniflora	100%	flowering
	Salicornia virginica	trace	
	organic layer on sand substrate; more Salicornia surrounding plot; tall Spartina, spindly with lots of dead culms.		
18m:	Spartina alterniflora	100%	flowering
	culms quite skinny; red tinged stems and leaves; many reddish-brown spots on leaves.		
30½m:	Spartina alterniflora	100%	flowering
	leaves and stems very red; many new shoots just coming up.		
40m:	Salicornia virginica	50%	flowering
	Spartina alterniflora	20%	
	Spartina very stressed with lots of dieback; Salicornia very robust; algae mats on bare spots.		
50m:	Spartina alterniflora	100%	flowering
	red tinged leaves and stems		
Big Mounded Clump:			
	Spartina alterniflora	100%	
	only took soil core; mound noticeably higher in elevation; root mat ended at 25 cm.		

Table 4



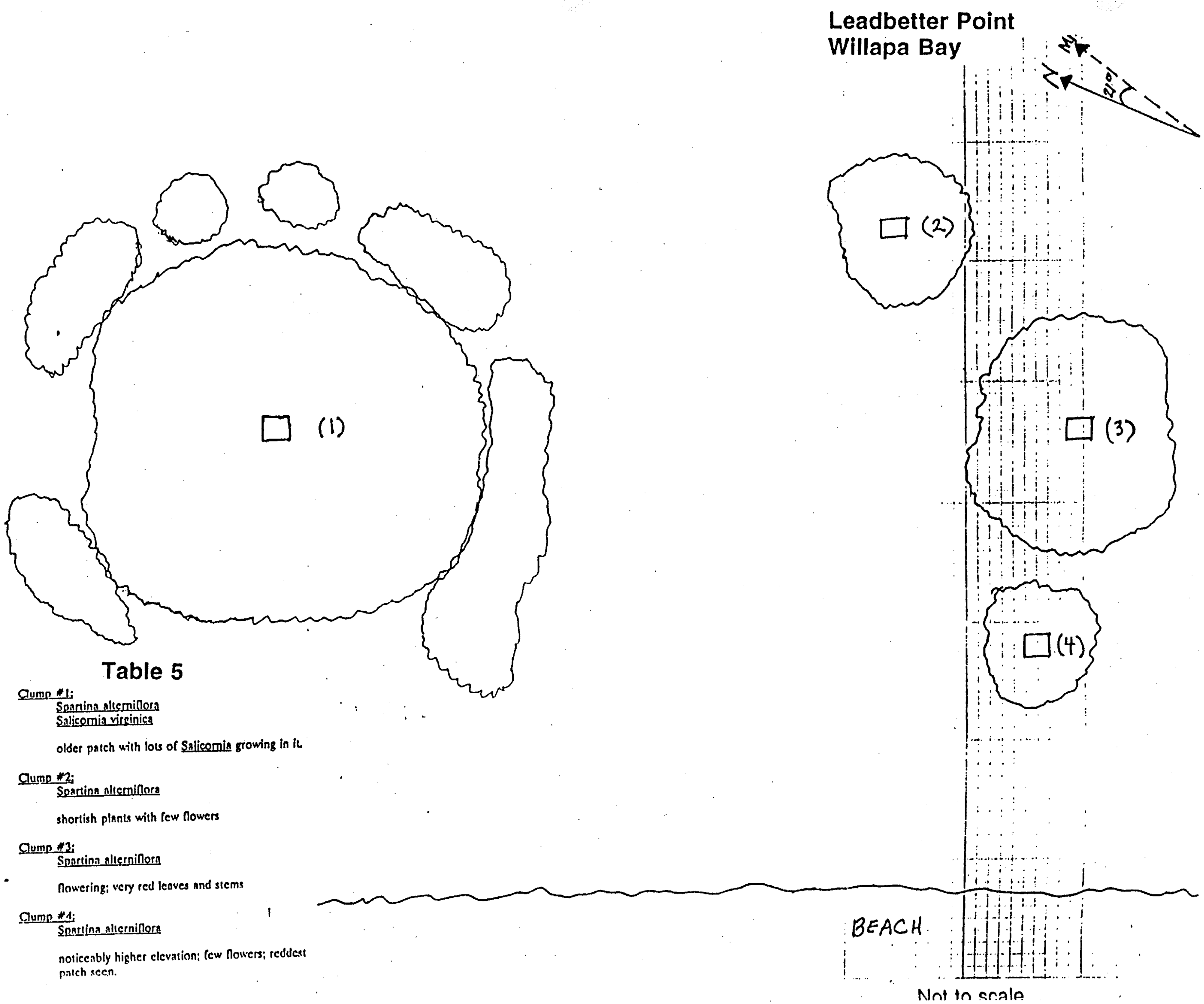


Table 5

<u>Clump #1:</u>
<u>Spartina alterniflora</u>
<u>Salicornia virginica</u>

older patch with lots of <u>Salicornia</u> growing in it.

<u>Clump #2:</u>
<u>Spartina alterniflora</u>

shortish plants with few flowers

<u>Clump #3:</u>
<u>Spartina alterniflora</u>

flowering; very red leaves and stems

<u>Clump #4:</u>
<u>Spartina alterniflora</u>

noticeably higher elevation; few flowers; reddest patch seen.

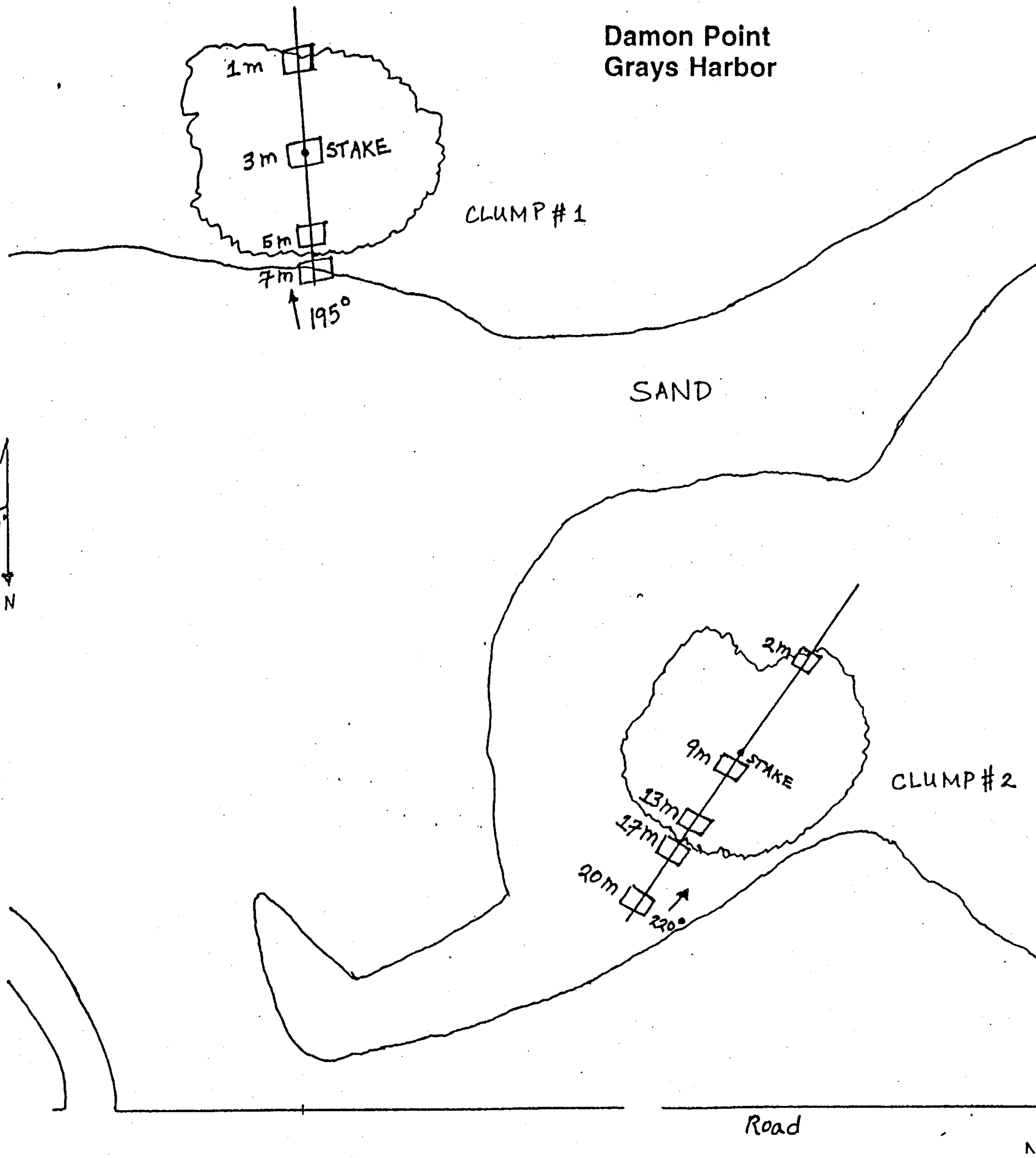


Table 6

Damon Point

Clump #1:

7m:	*Salicornia virginica*	100%	
	Triglochin maritimum	trace	
5m:	*Salicornia virginica*	50%	
	Spartina alterniflora	25%	
	bare ground	15%	
	very green and healthy *Spartina*; short; flowers around plot		
3m:	*Salicornia virginica*	100%	flowering
	Spartina alterniflora	5%	flowering
	very sparse *Spartina*, but healthy looking; not stressed; short.		
1m:	*Salicornia virginica*	85%	flowering
	Spartina alterniflora	30%	flowering
	stressed *Spartina*; reddish tinged leaves; *Salicornia* very robust.		

Clump #2:

20m:	*Distichlis spicata*	25%	flowering
	Jaumea carnosa	80%	flowering
	Salicornia virginica	10%	flowering
	Triglochin maritimum	trace	
17m:	*Distichlis spicata*	85%	flowering
	Jaumea carnosa	15%	flowering
	Salicornia virginica	25%	flowering
	Scirpus americanus	5%	flowering
	Triglochin maritimum	trace	
13m:	*Distichlis spicata*		
	Scirpus americanus		
	Spartina alterniflora		
	main part of clump was just mowed; resprouts of all plants everywhere.		
9m:	*Scirpus americanus*		
	Spartina alterniflora		
2m:	*Scirpus americanus*		
	Spartina alterniflora		

Padilla Bay
Telegraph Slough and Dike Island

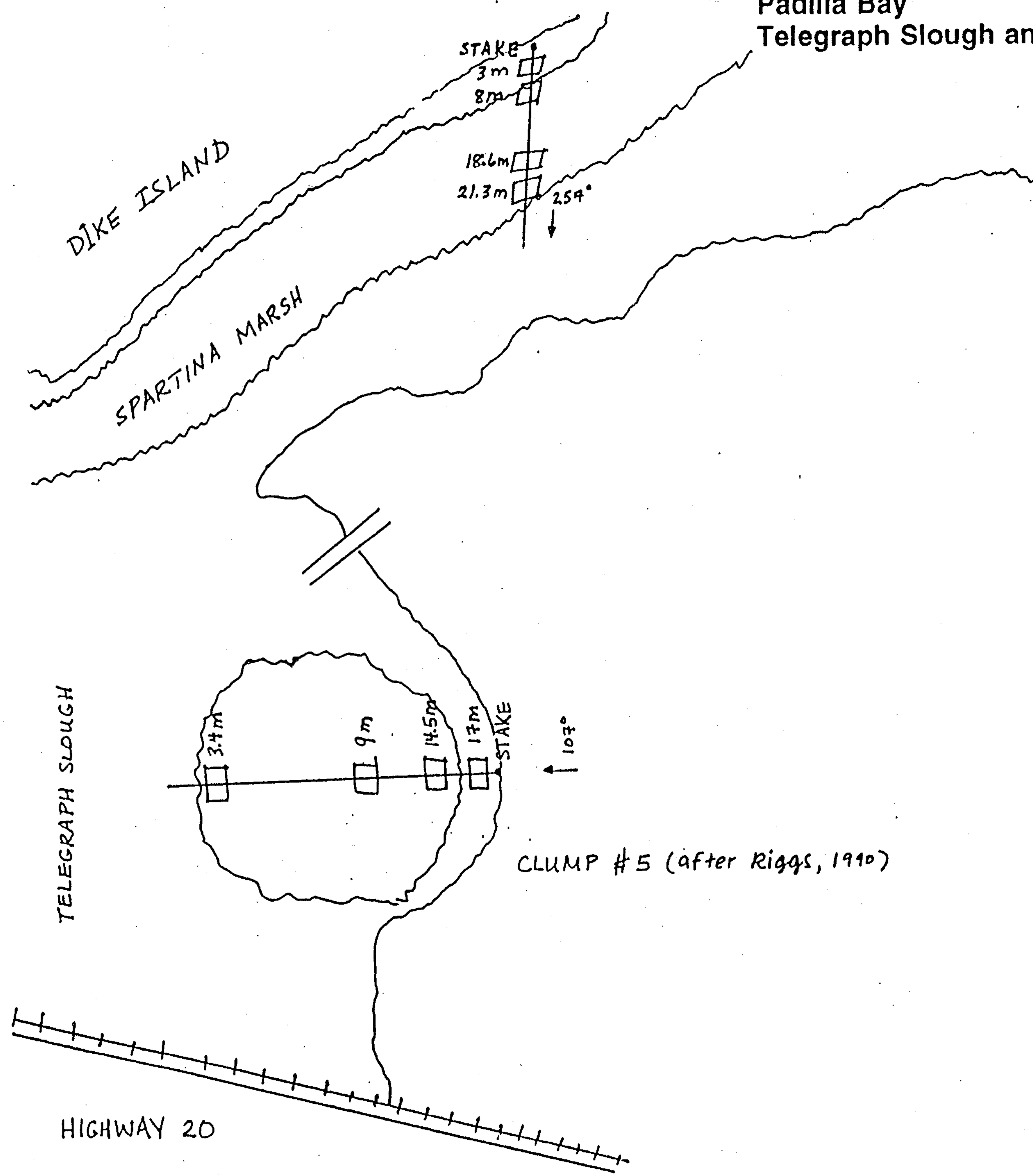


Table 7

Clump #5			
17m:	Atriplex patula	30%	flowering
	Deschampsia caespitosa	trace	
	Distichlis spicata	85%	flowering
	Salicornia virginica	20%	flowering
	happy saltmarsh		
14½m:	Salicornia virginica	5%	flowering
	Spartina alterniflora	100%	
	clump is brown (dead?) around upper edge and center; quite robust near low edge; quite dense.		
9m:	Spartina alterniflora	100%	
	healthy; very little dieback; not dense; lots of precipitated salt on leaves.		
3.4m:	Spartina alterniflora	100%	
	covered with salt; very robust; medium density.		
Dike Island			
3m:	Atriplex patula	trace	flowering
	Distichlis spicata	20%	flowering
	Salicornia virginica	100%	
	dead stalks of Spartina under other marsh plants.		
8m:	Spartina alterniflora	100%	
	lots of dead culms present; not dense.		
18.6m:	Spartina alterniflora	100%	
	plot is between dead patches; more robust; lots of salt crystals on leaves; little brown bird sitting in Spartina nearby.		
21.3m:	Spartina alterniflora		
	all dead except one culm; hard to say if it died this year or last year; very anaerobic soil.		

Not to scale

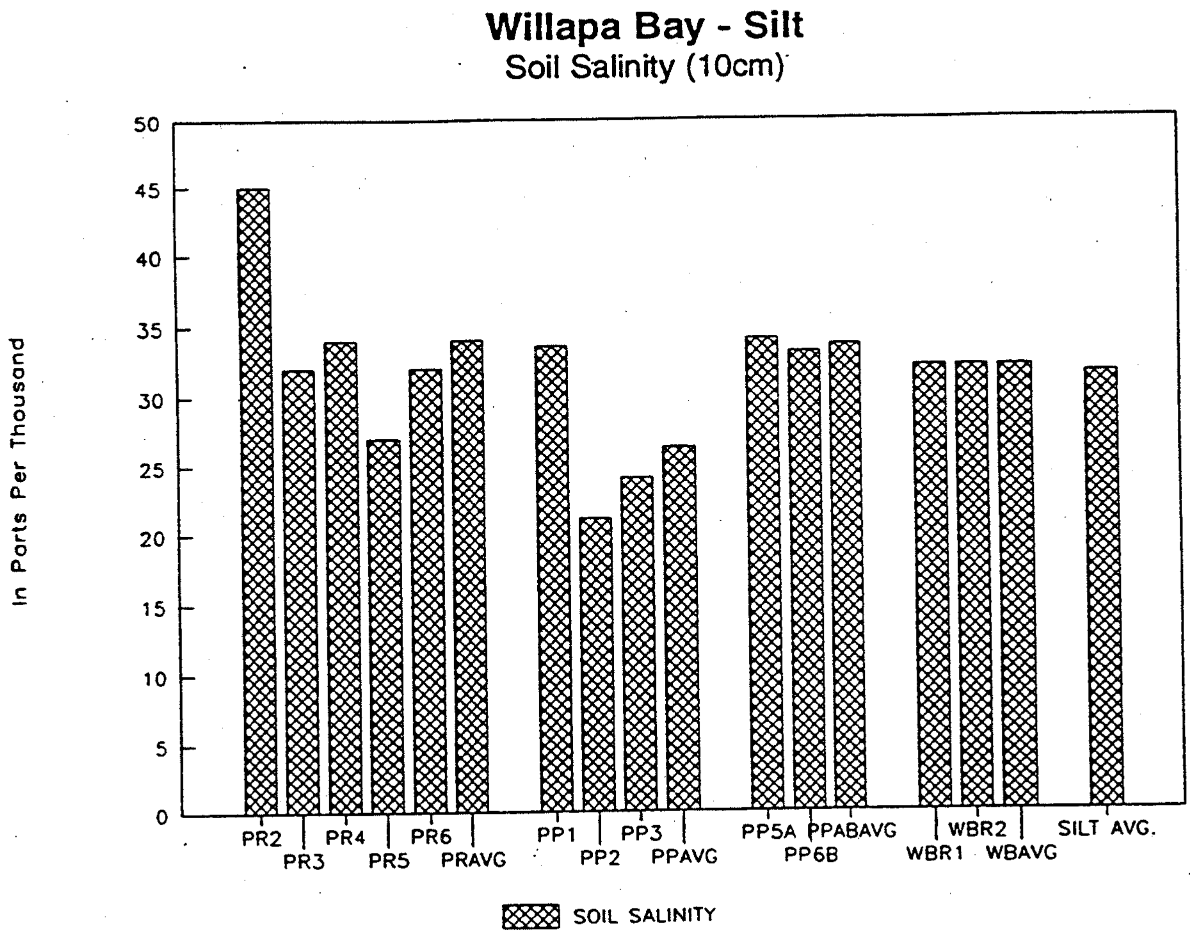

Willapa Bay - Silt
Soil Salinity (10cm)
In Parts Per Thousand
50
45
40
35
30
25
20
15
10
5
0
PR2
PR3
PR4
PR5
PR6
PRAVG
PP1
PP2
PP3
PPAVG
PP5A
PP6B
PPABAVG
WBR1
WBR2
WBAVG
SILT AVG.
SOIL SALINITY

Figure 8

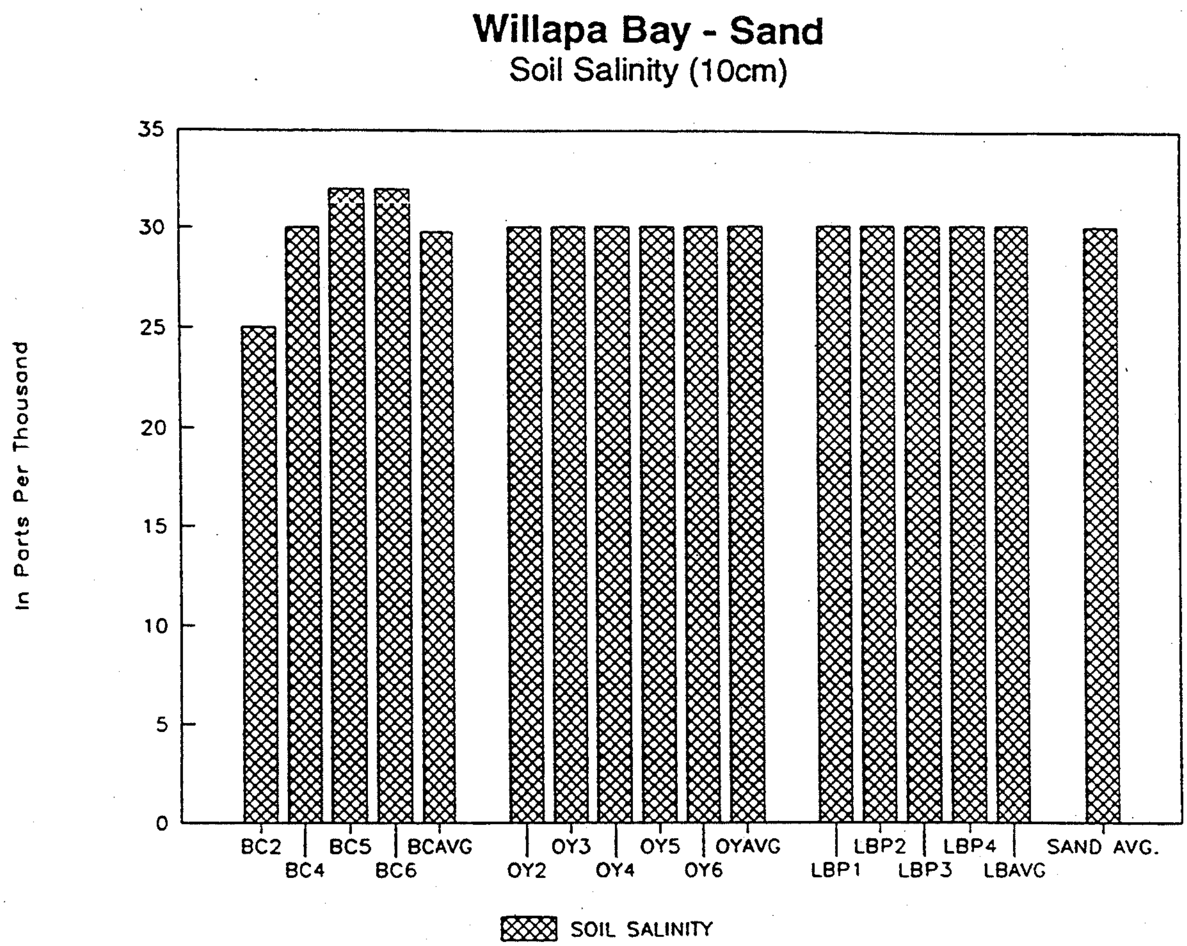

Willapa Bay - Sand
Soil Salinity (10cm)
In Parts Per Thousand
35
30
25
20
15
10
5
0
BC2
BC4
BC5
BC6
BCAVG
OY2
OY3
OY4
OY5
OY6
OYAVG
LBP1
LBP2
LBP3
LBP4
LBAVG
SAND AVG.
SOIL SALINITY

Figure 9

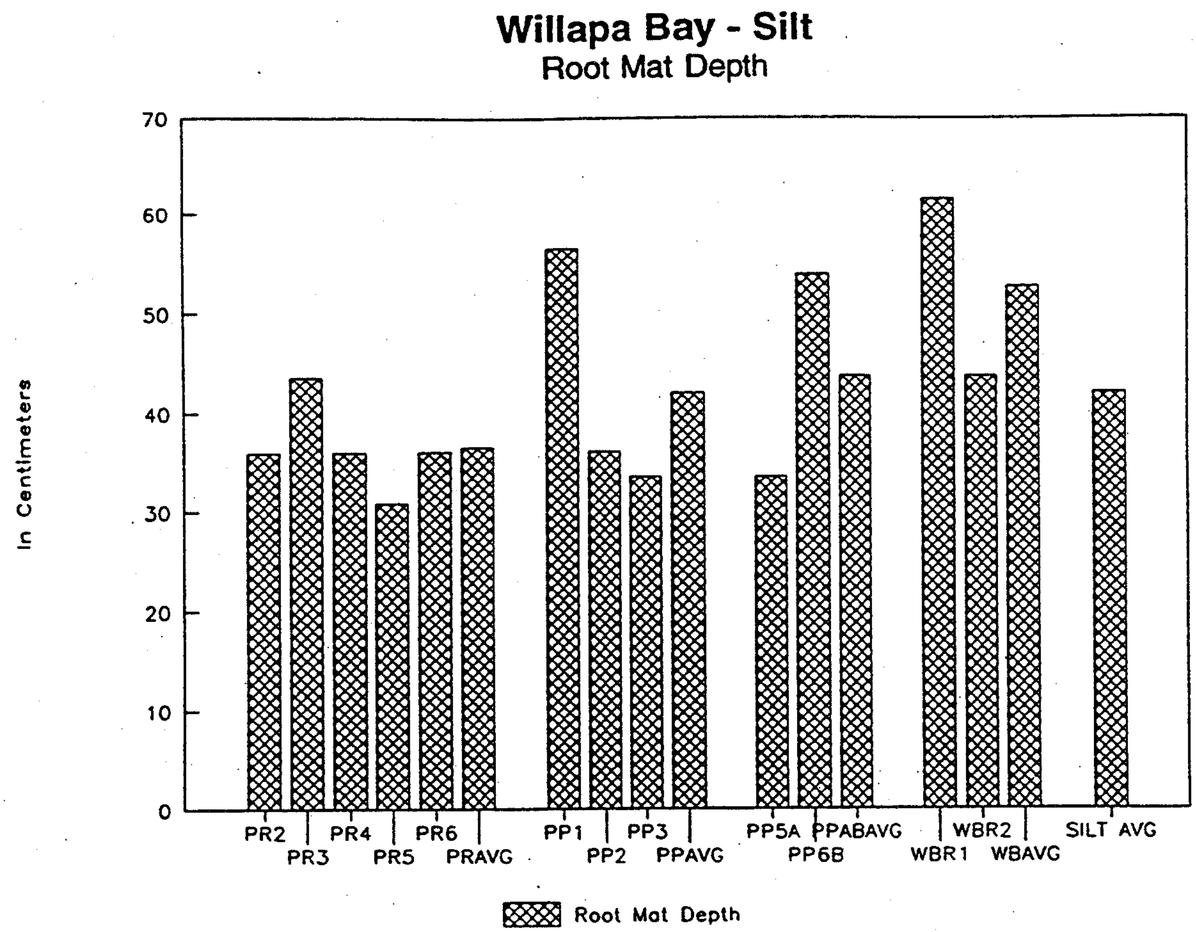
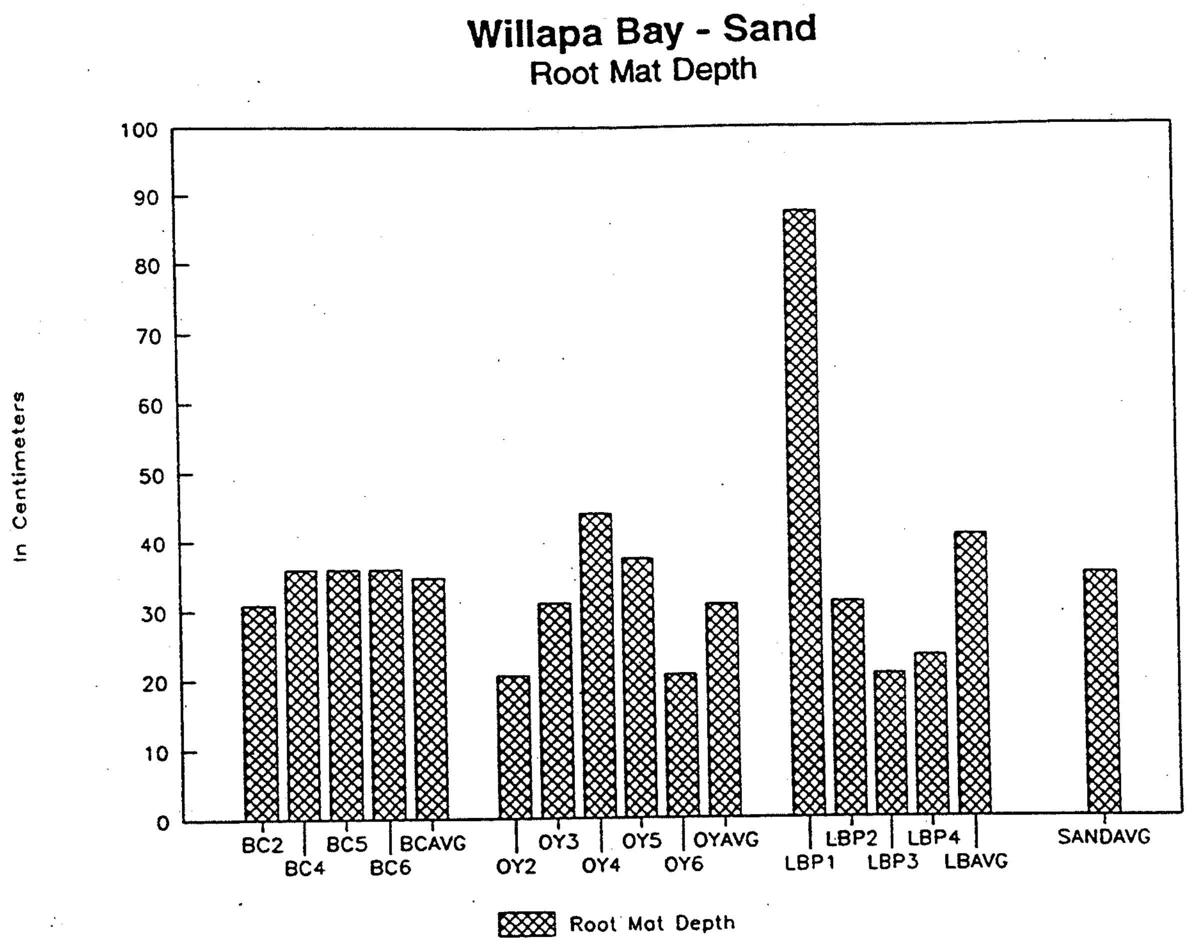
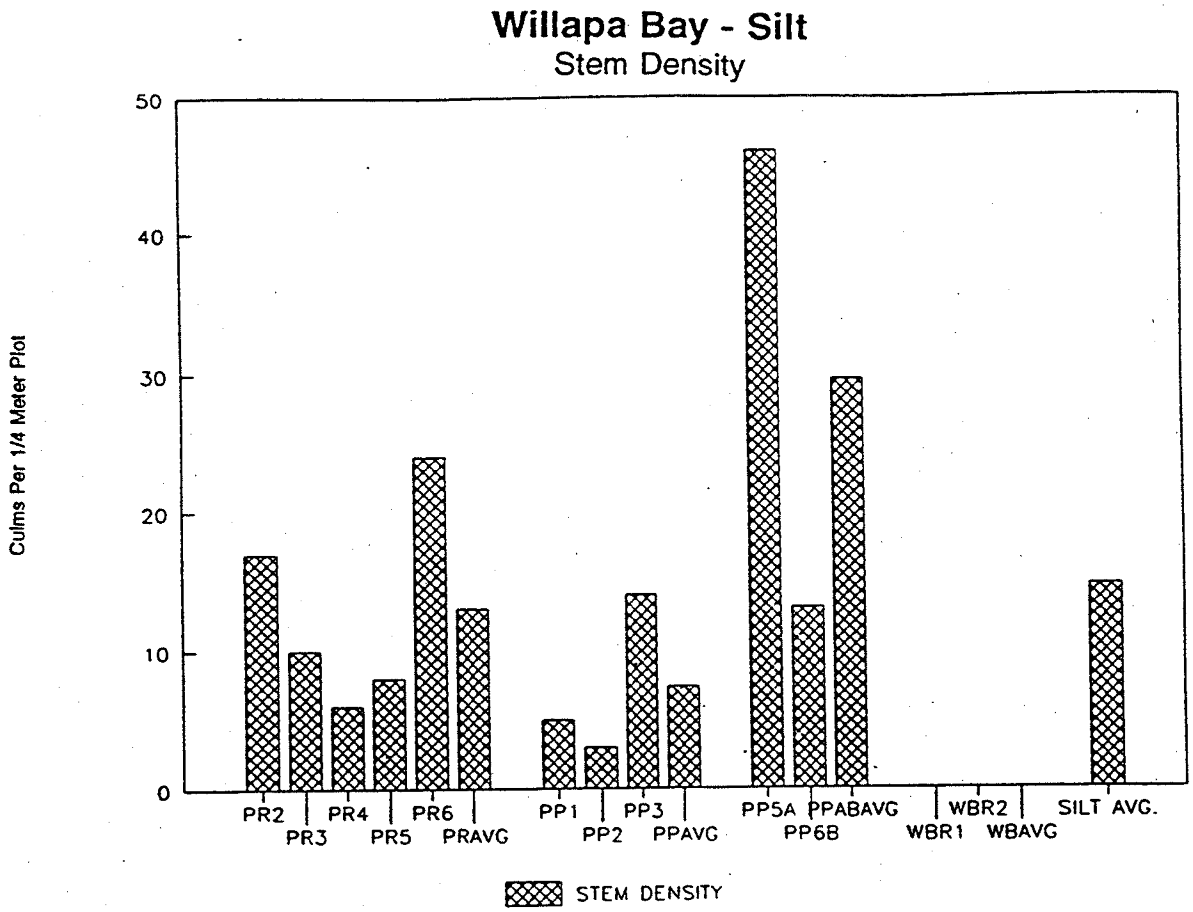

Willapa Bay - Silt
Root Mat Depth
In Centimeters
70
60
50
40
30
20
10
0
PR2
PR3
PR4
PR5
PR6
PRAVG
PP1
PP2
PP3
PPAVG
PP5A
PP6B
PPABAVG
WBR1
WBR2
WBAVG
SILT AVG
Root Mat Depth

Figure 10



Willapa Bay - Sand
Root Mat Depth
In Centimeters
100
90
80
70
60
50
40
30
20
10
0
BC2
BC4
BC5
BC6
BCAVG
OY2
OY3
OY4
OY5
OY6
OYAVG
LBP1
LBP2
LBP3
LBP4
LBAVG
SANDAVG
Root Mat Depth

Figure 11



Willapa Bay - Silt
Stem Density
Culms Per 1/4 Meter Plot
50
40
30
20
10
0
PR2
PR3
PR4
PR5
PR6
PRAVG
PP1
PP2
PP3
PPAVG
PP5A
PP6B
PPABAVG
WBR1
WBR2
WBAVG
SILT AVG.
STEM DENSITY

Figure 12

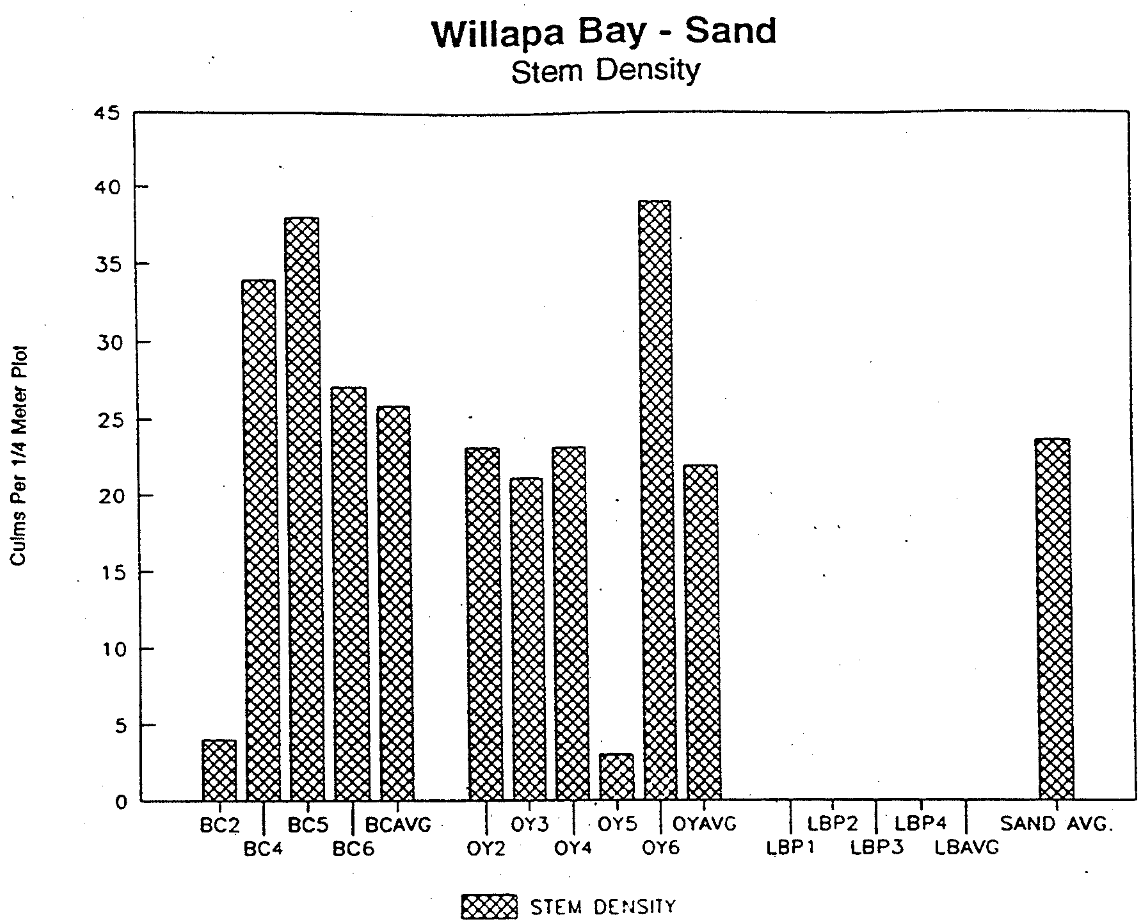
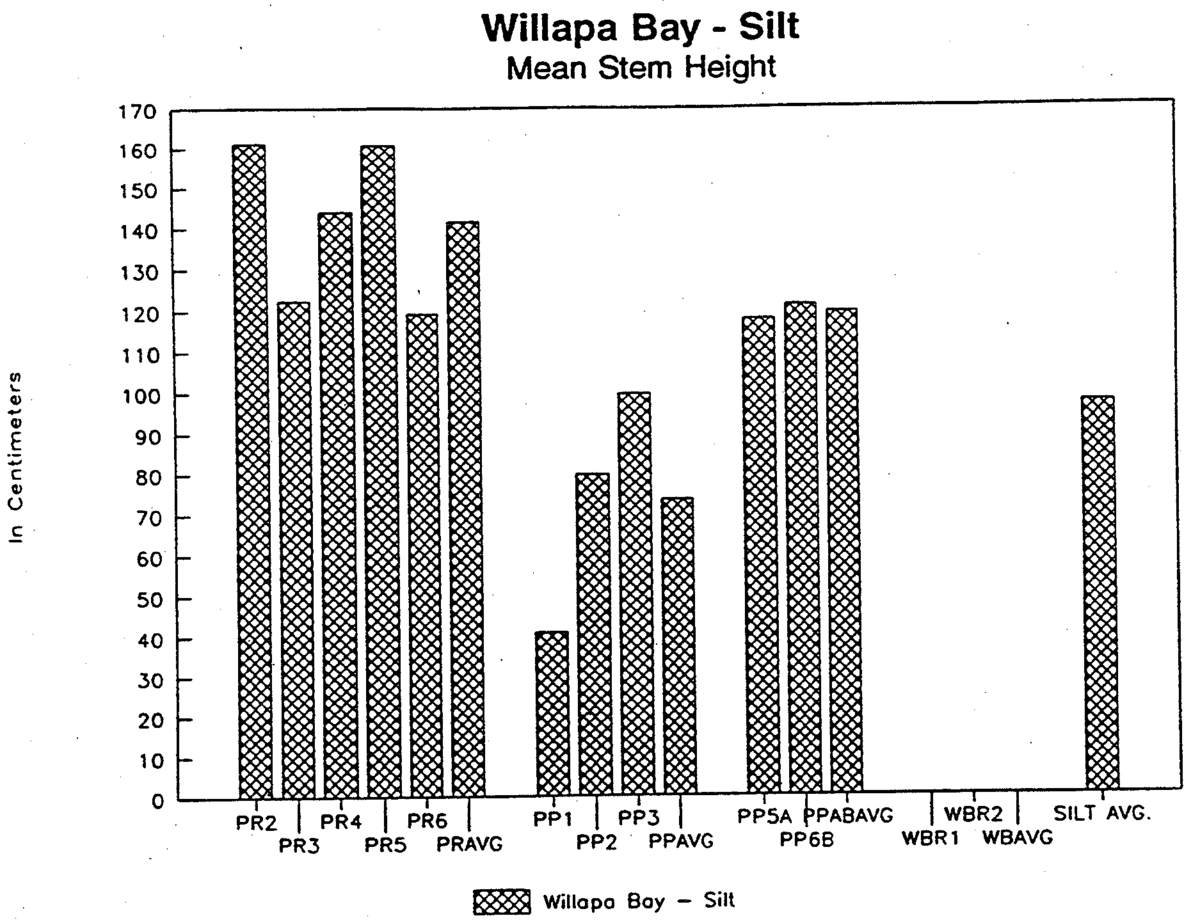

Willapa Bay - Sand
Stem Density
Culms Per 1/4 Meter Plot
45
40
35
30
25
20
15
10
5
0
BC2
BC4
BC5
BC6
BCAVG
OY2
OY3
OY4
OY5
OY6
OYAVG
LBP1
LBP2
LBP3
LBP4
LBAVG
SAND AVG.
STEM DENSITY

Figure 13



Willapa Bay - Silt
Mean Stem Height
In Centimeters
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
PR2
PR3
PR4
PR5
PR6
PRAVG
PP1
PP2
PP3
PPAVG
PP5A
PP6B
PPABAVG
WBR1
WBR2
WBAVG
SILT AVG.
Willapa Bay - Silt

Figure 14

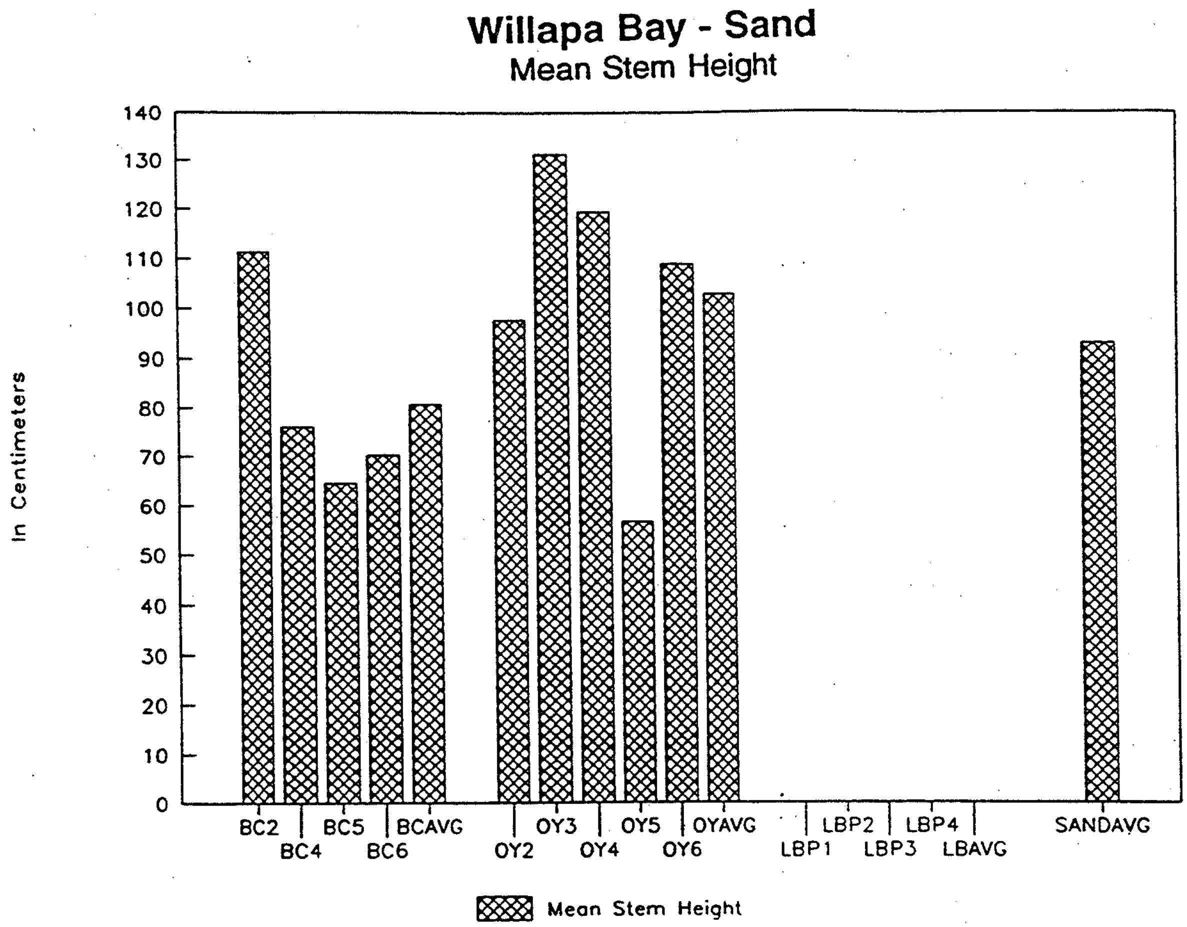

Willapa Bay - Sand
Mean Stem Height
In Centimeters
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
BC2
BC4
BC5
BC6
BCAVG
OY2
OY3
OY4
OY5
OY6
OYAVG
LBP1
LBP2
LBP3
LBP4
LBAVG
SANDAVG
Mean Stem Height

Figure 15

Figure 16: Species List

Willapa Bay

Deschampsia caespitosa (L.) Beauv.	tufted hairgrass
Distichlis spicata (L.) Greene	salt grass
Jaumea carnosa (Less.) Gray.	fleshy jaumea
Spartina alterniflora Loisel.	smooth cordgrass
Salicornia virginica L.	pickleweed
Triglochin maritimum L.	arrow grass

Grays Harbor - Damon Point

Deschampsia caespitosa (L.) Beauv.	tufted hairgrass
Distichlis spicata (L.) Greene	salt grass
Jaumea carnosa (Less.) Gray.	fleshy jaumea
Scirpus americanus Pers.	three-square bullrush
Spartina alterniflora Loisel.	smooth cordgrass
Salicornia virginica L.	pickleweed
Triglochin maritimum L.	arrow grass

Padilla Bay

Atriplex patula L.	salt bush, salt hen
Deschampsia caespitosa (L.) Beauv.	tufted hairgrass
Distichlis spicata (L.) Greene	salt grass
Spartina alterniflora Loisel.	smooth cordgrass
Salicornia virginica L.	pickleweed

Livingston Bay

Spartina townsendii H. & G. Groves/ *Spartina anglica* C.E. Hubbard	common cordgrass

Grays Harbor - Sand
Mean Stem Height

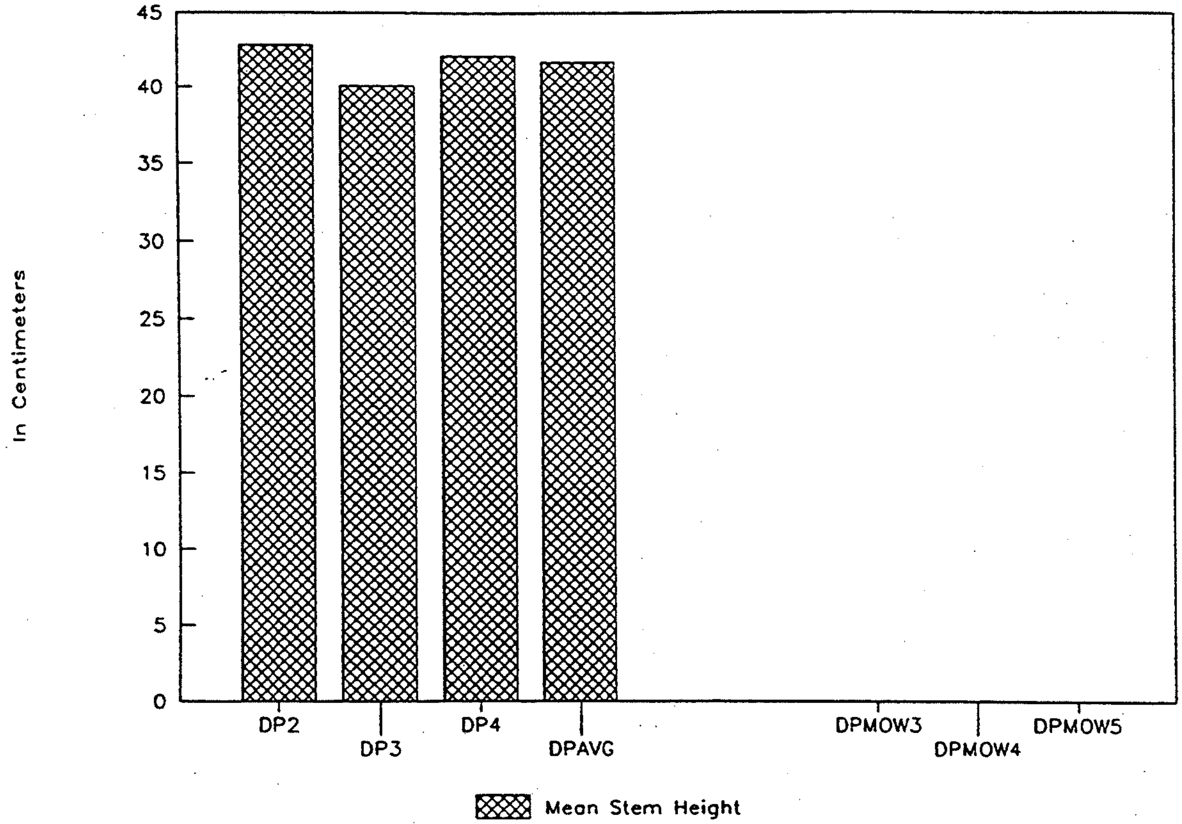


Figure 17

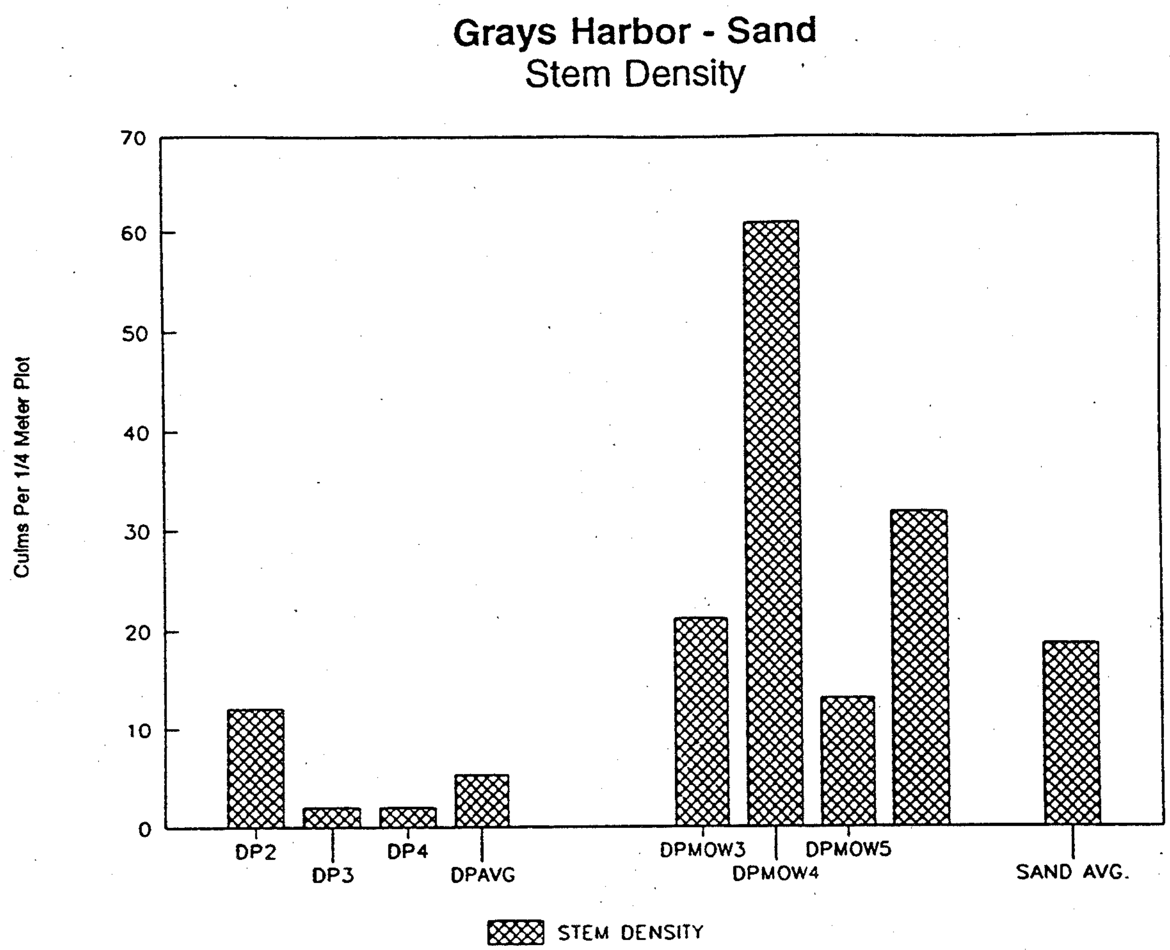

Grays Harbor - Sand
Stem Density
Culms Per 1/4 Meter Plot
70
60
50
40
30
20
10
0
DP2
DP3
DP4
DPAVG
DPMOW3
DPMOW4
DPMOW5
SAND AVG.
STEM DENSITY

Figure 18

Grays Harbor - Sand

Root Mat Depth

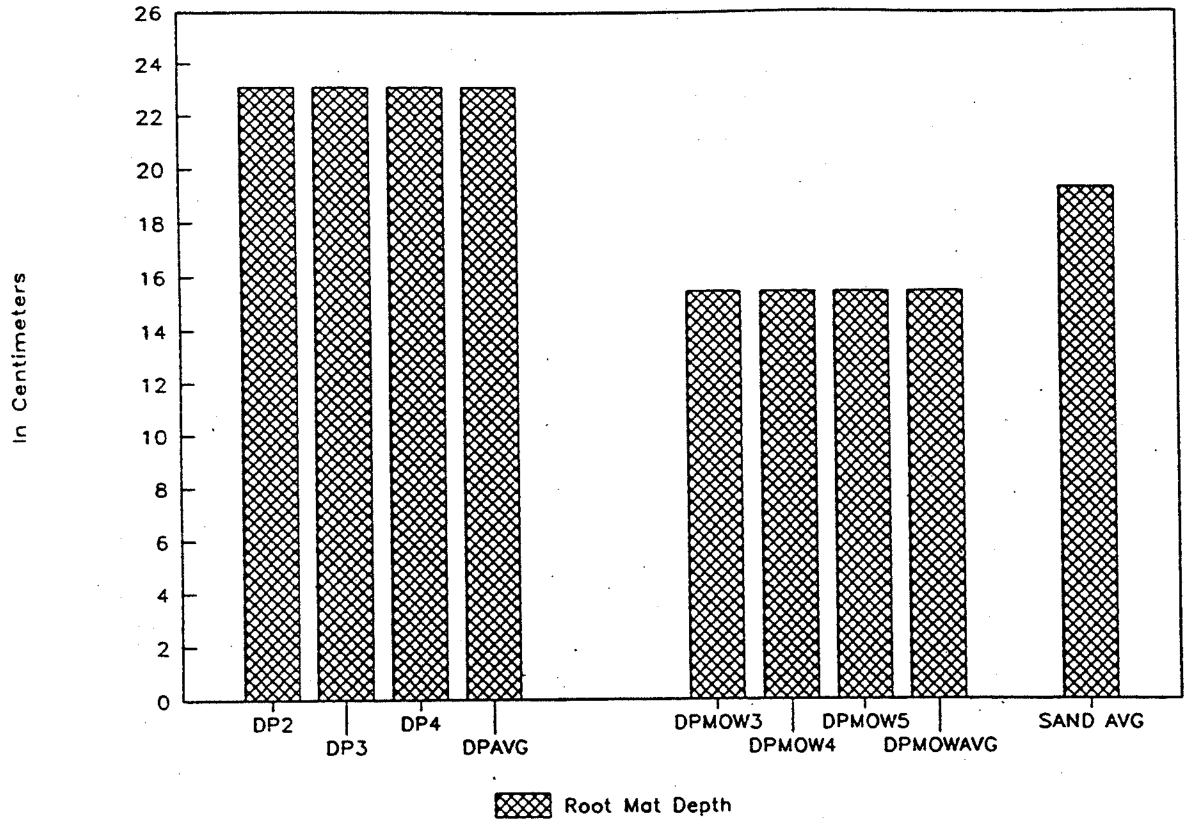
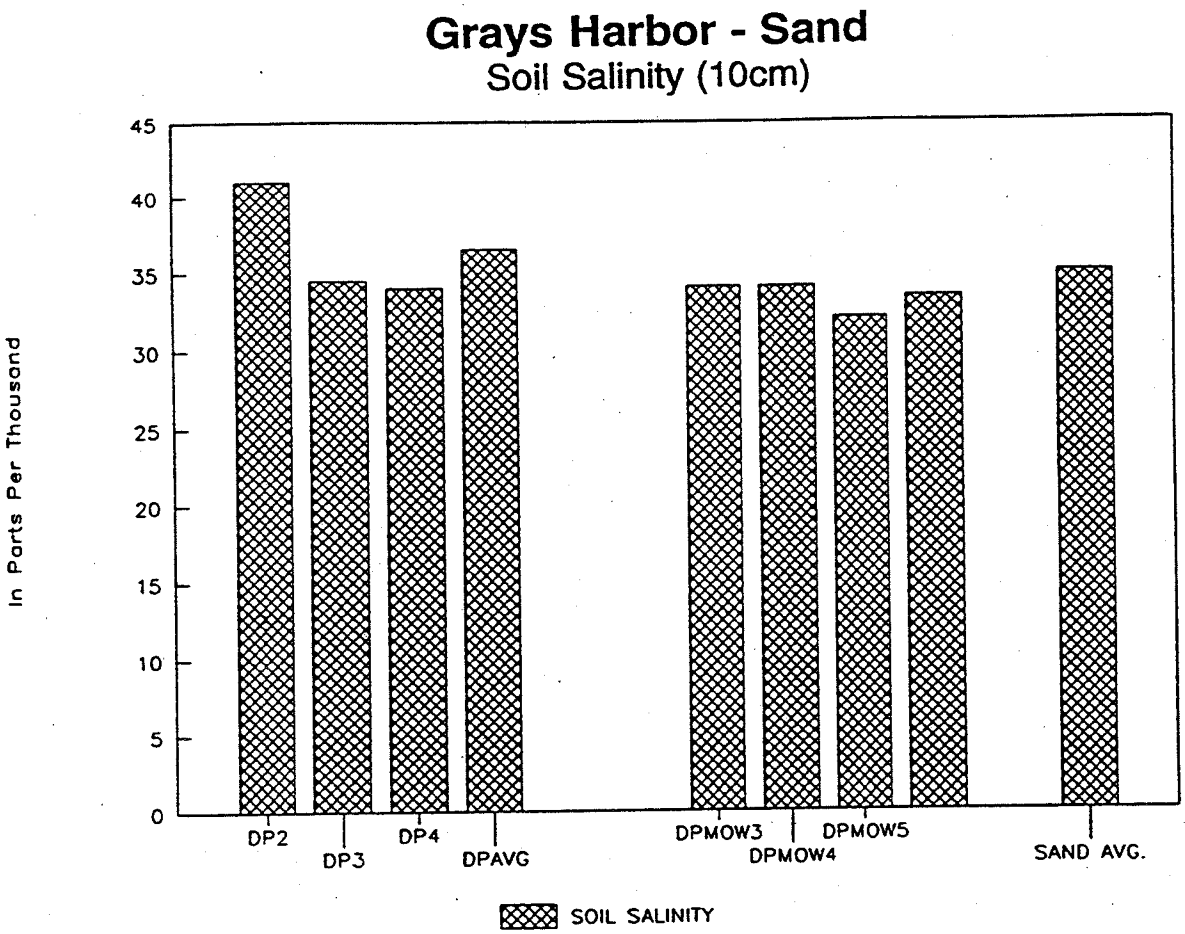


Figure 19



Grays Harbor - Sand
Soil Salinity (10cm)
45
40
35
30
25
20
15
10
5
0
In Parts Per Thousand
DP2
DP3
DP4
DPAVG
DPMOW3
DPMOW4
DPMOW5
SAND AVG.
SOIL SALINITY

Figure 20

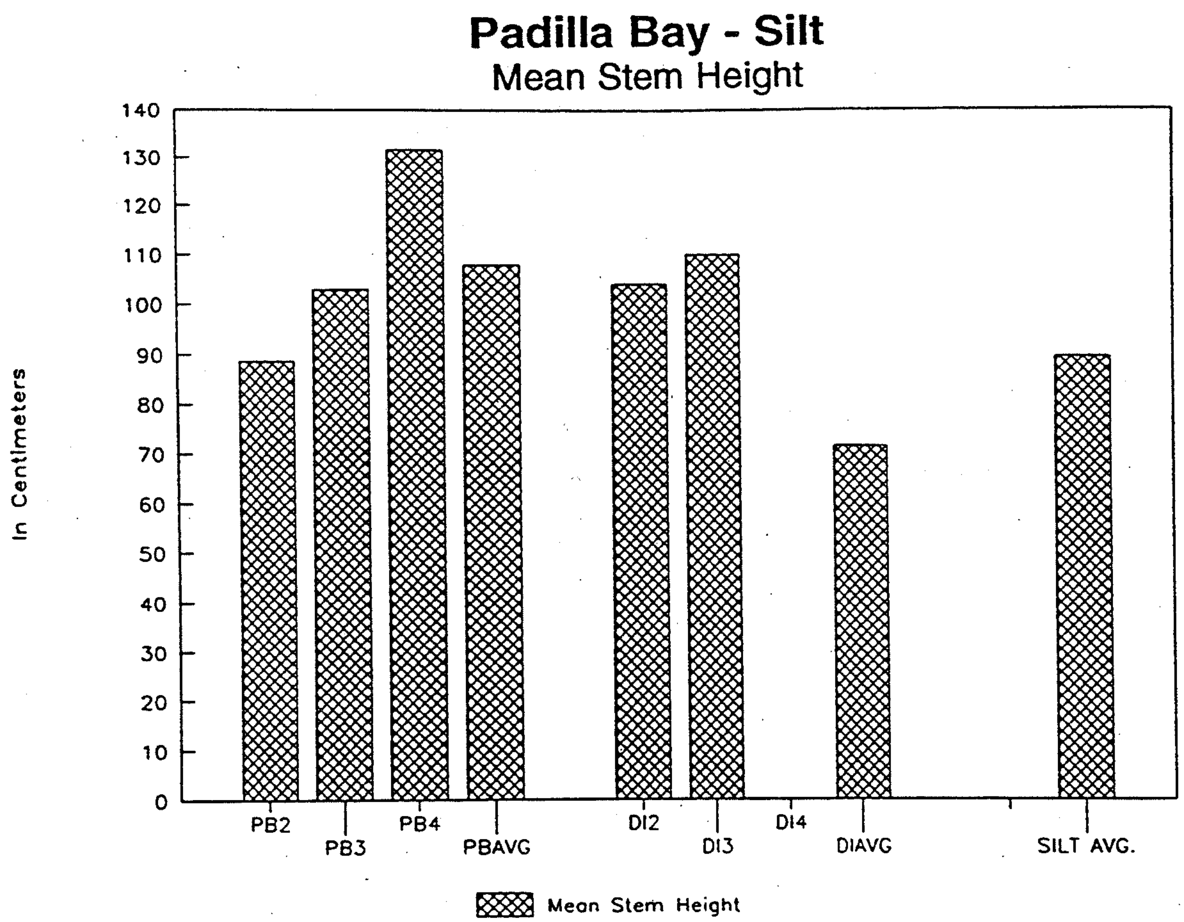

Padilla Bay - Silt
Mean Stem Height
In Centimeters
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
PB2
PB3
PB4
PBAVG
DI2
DI3
DI4
DIAVG
SILT AVG.
Mean Stem Height

Figure 21

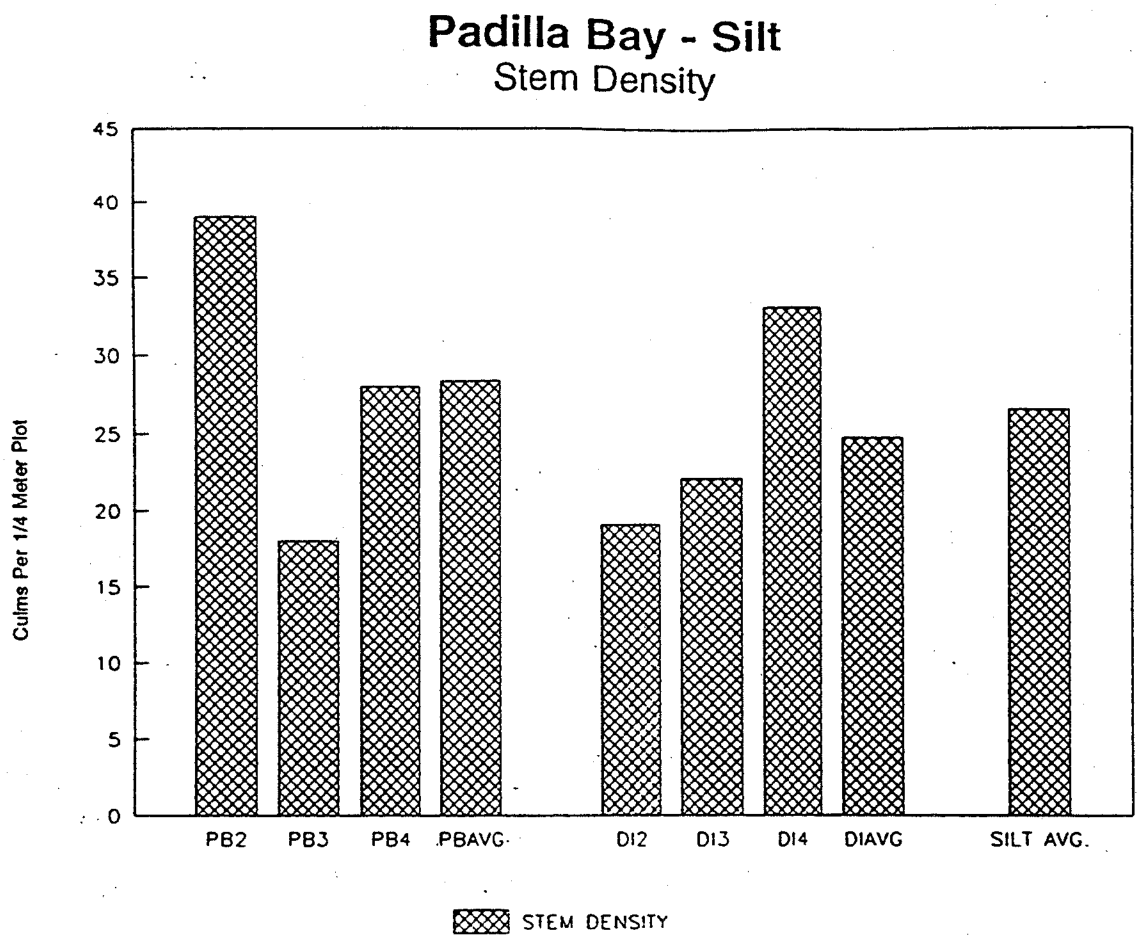

Padilla Bay - Silt
Stem Density
Culms Per 1/4 Meter Plot
45
40
35
30
25
20
15
10
5
0
PB2
PB3
PB4
PBAVG
DI2
DI3
DI4
DIAVG
SILT AVG.
STEM DENSITY

Figure 22

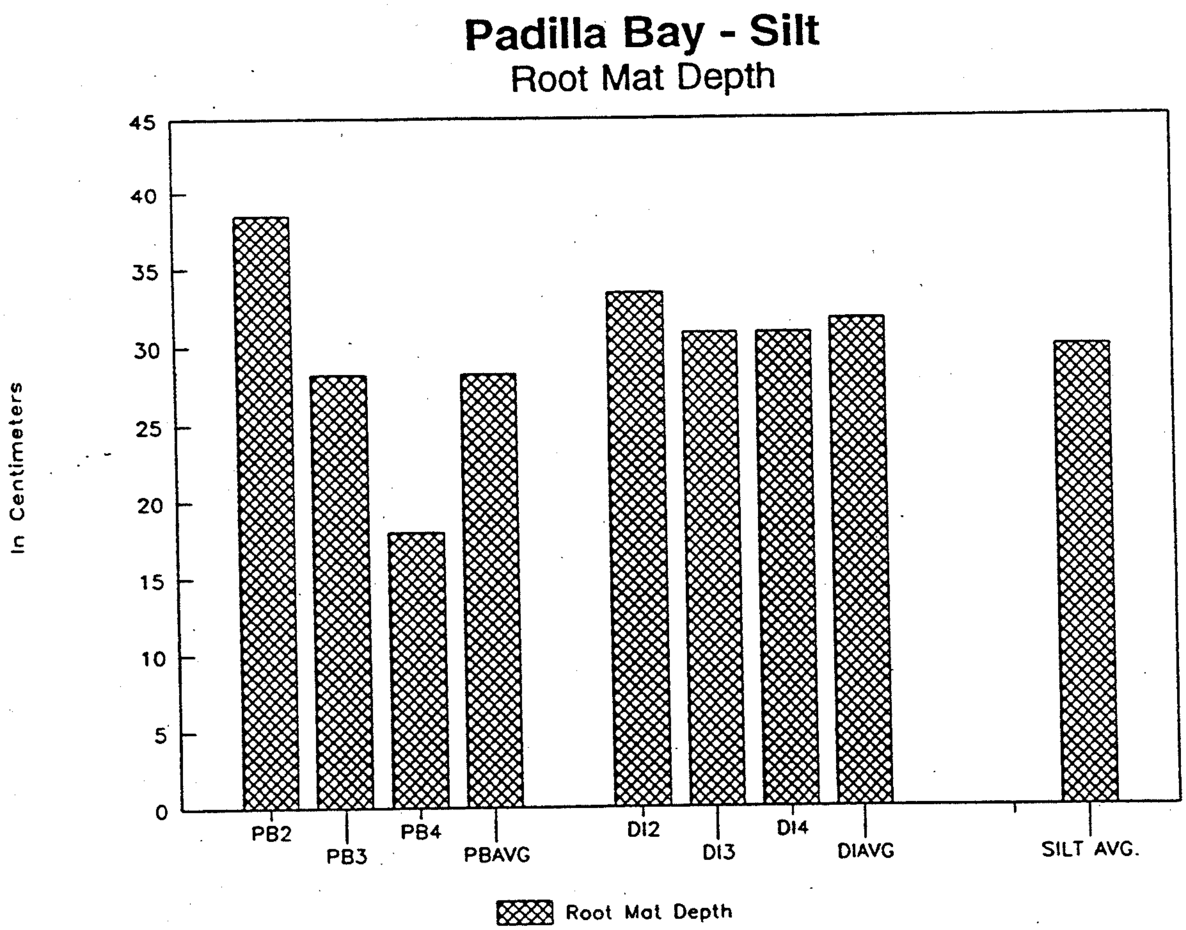

Padilla Bay - Silt
Root Mat Depth
In Centimeters
45
40
35
30
25
20
15
10
5
0
PB2
PB3
PB4
PBAVG
DI2
DI3
DI4
DIAVG
SILT AVG.
Root Mat Depth

Figure 23

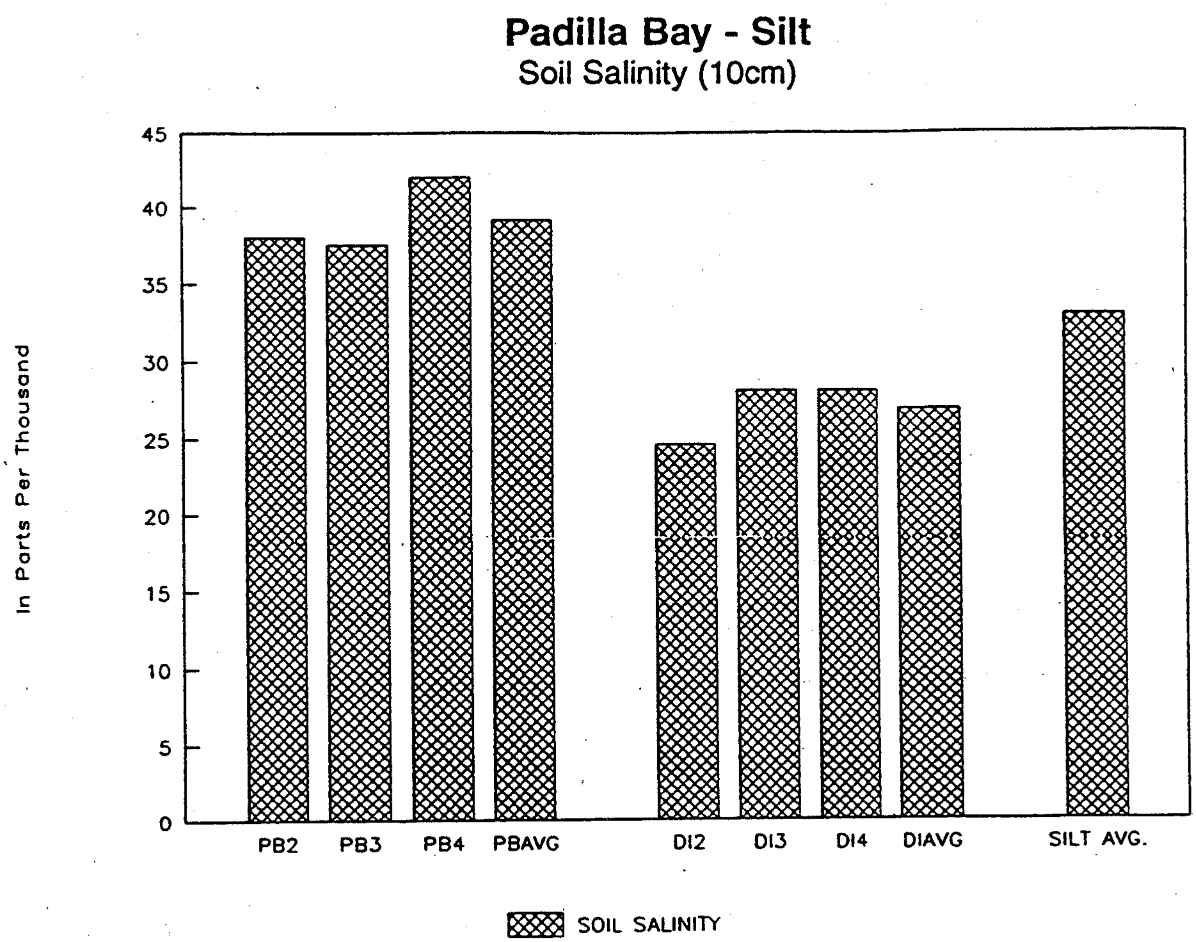

Padilla Bay - Silt
Soil Salinity (10cm)
In Parts Per Thousand
45
40
35
30
25
20
15
10
5
0
PB2
PB3
PB4
PBAVG
DI2
DI3
DI4
DIAVG
SILT AVG.
SOIL SALINITY

Figure 24

7.0 LITERATURE CITED

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CHARACTERIZATION OF INVASIVE LOOSESTRIFE SPECIES IN WASHINGTON STATE

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1.0 INTRODUCTION

The objectives of this study were to characterize the existing state of the exotic invasive loosestrife species (*Lythrum salicaria* and *L. virgatum*; *Lysimachia vulgaris* and *L. punctata*), and their associated communities, in Washington state. This report is a review of relevant scientific literature and reports from brief field surveys of the distribution of loosestrife. It is not intended to be an exhaustive characterization of purple loosestrife and should not be used as such.

Purple loosestrife (*Lythrum salicaria* & *L. virgatum*) is native to Eurasia and has become widespread in the northern and central areas of the United States and southern Canada (Stuckey 1980; Wilcox 1989; Bender 1988; Malecki & Rawinski 1985). Purple loosestrife appears to have been reintroduced time after time, both from escaped ornamentals as well as from ship ballast water (Stuckey 1980). In Washington state, purple loosestrife (*L. salicaria*) has been reported from Lake Washington (near the University of Washington campus) and Lake Sammamish from as early as 1931 (Stuckey 1980). It is now present in many areas of the state (Figure 1) including the Everett area, at the mouth of the Skagit River, Cowlitz County, Clark County and in abundance in Grant and neighboring eastern Washington counties (Battelle 1992). It is unconfirmed whether *L. virgatum* is also present in Washington state (Ebasco 1992).

Garden, or yellow, loosestrife (*Lysimachia vulgaris* and *L. punctata*) is also a native of Eurasia. It has been known to invade isolated wetland sites in the northeastern U.S. and Canada (Ebasco 1992). The method of introduction is again from escaped ornamentals. In Washington, yellow loosestrife is known only around Lake Sammamish, with unverified sightings near Lake Washington (Ebasco 1992; Weinmann, pers. comm., 1992). There is some confusion as to which species is present, or if both are present. The two are nearly indistinguishable in the field. Most of the following discussion will focus on purple loosestrife because it is far more abundant in Washington state than yellow loosestrife, and very little is known about yellow loosestrife.

2.0 BACKGROUND LITERATURE

Purple loosestrife is a tall, showy perennial herb that is found primarily in marshy areas, swamps, fens, and around ponds, lakes and river corridors, but also grows readily in wet meadows, highway corridors, and other areas with a fluctuating water table (Shamsi & Whitehead 1973; Driscoll 1992). It can tolerate prolonged periods of dryness. The plants form a dense rootball with one or more large tap roots and many finer roots (Shamsi & Whitehead 1973; Driscoll 1992). Individual plants may survive for many years, but rhizomatous spread does not occur (Shamsi & Whitehead, 1973).

The family Lythraceae, to which purple loosestrife belongs, is one of the few groups of flowering plants that have a tristyly breeding system (three different types of flowers on different plants used in reproduction). Three sizes of pollen are produced that effectively reduces overall seed production. Self-pollination does not appear to occur, and plants more than one meter apart have difficulty in setting seed (Nicholls 1987). This may be the reason that invasions seem to take 20 - 40 years before large monotypic stands arise in an area (Stuckey 1980). In plants in large stands, however, as many as 300,000 seeds can be produced per stalk (Heidorn & Anderson 1991). The seeds are very small and light (0.053 mg/1.8x10^{-6} oz.) (Keddy & Ellis 1985) and dispersed easily by wind or water. The seeds typically germinate from spring through summer (seed germination is low below 20°C/68°F), although only the spring seedlings are capable of flowering in the first season (Shamsi & Whitehead 1973). Acidic conditions (pH < 5.7) appear to inhibit germination somewhat (although some germination still occurred to about pH 4) and may inhibit growth as well (Shamsi & Whitehead 1973; Arts *et al* 1990). Seed germination is inhibited by soil particle sizes between 2 and 8 mm (0.08 and 0.32 in) in drier conditions (smaller and larger particle sizes had good germination), but seems unaffected by particle size in saturated conditions (Keddy & Constabel 1986; Shamsi & Whitehead 1973). The seeds have high viabilities (up to 92%) and may remain viable for a number of years (Cutright 1986). Flowering generally occurs from July through late September or October, with seeds ripening well before the plant dies back for the winter (Shamsi & Whitehead 1973).

Purple loosestrife competes aggressively with many wetland species and may exclude other species altogether; although some species such as *Cyperus rivularis* and *Phalaris arundinacea* compete with loosestrife successfully (Johansson & Keddy 1991). Prolonged periods of inundation prevent flowering of loosestrife (Merendino *et al* 1990). Loosestrife has trouble invading shady areas (Ebasco 1992). While purple loosestrife often forms large monotypic stands, these are frequently replaced by other species in its native range (Shamsi & Whitehead 1973). In Washington, monotypic stands occur in several areas, especially in eastern Washington, but individual plants are commonly interspersed with other wetland plants such as *Typha latifolia*, *Phalaris arundinacea*, *Phragmites australis* (Cav.) *Salix* spp. and *Scirpus* spp. (Ebasco 1992; Keddy & Ellis 1985).

Habitat values of loosestrife are not well studied. The tiny, hard seeds of purple loosestrife are likely inedible for most bird species, even in its native range. In Washington, the state

Departments of Agriculture and Wildlife (1991) indicated anecdotally that a dramatic decrease in bird populations may occur when loosestrife became dominant in an area. It also appears that small mammal usage is decreased in areas dominated by loosestrife (Carney-Hartman *et al* 1991). In its native environment, 120 species of phytophagous insects were found to be associated with purple loosestrife (Batra *et al* 1986). An experiment to determine the "food quality" of *Lythrum* determined that European corn borers utilized loosestrife fairly well, which indicates some insects may find loosestrife useful for food (McCanny *et al* 1990). No other studies were found on the utilization of loosestrife habitat by other species.

3.0 FIELD OBSERVATIONS

3.1 METHODS

Observations reported here are the result of brief field inspections conducted in late fall of 1992 in limited areas in western Washington (specifically, Lake Washington, Lake Sammamish, Sammamish River, the Sammamish Plateau, and on the Skagit River delta). Observations were recorded and compared with existing literature regarding the distribution and characteristics of purple loosestrife (*Lythrum salicaria*). Additional observations for eastern Washington were recorded by Battelle in Grant County, Washington (Appendix 1).

This report is not meant to be used as a conclusive environmental analysis of the ecology of purple loosestrife.

3.2 RESULTS

Purple loosestrife is fairly well established in the study area, but it has a rather sporadic distribution. Although monospecific stands do occur (Montlake Fill at Lake Washington, on the Skagit River delta, and other locations), it is more commonly found mixed in with established invasive marsh species such as *Typha latifolia* (cattail) *Phalaris arundinaceae* (reed canary grass) and, to a lesser extent, *Scirpus* spp. (bullrush). Species dominance was not quantitatively established in these areas, however, it appears that the purple loosestrife shared co-dominance with cattail. Even in what appeared to be an older population, the cattail persisted; the purple loosestrife appears to have become established between the individual cattail plants.

This pattern is somewhat different than the populations described by Battelle (1992) in eastern Washington where the purple loosestrife totally dominated areas previous dominated by cattails.

Perry (pers. comm. 1992) believes that the spread of purple loosestrife is much slower in western Washington than it is in eastern Washington. He attributes this to the presence of much more woody vegetation in western Washington which inhibits the successful establishment of an invasive species. The rapid expansion in eastern Washington may also be explained by the increase in new wetland habitats that have occurred since the construction of dams on the Columbia River and its tributaries prior to the 1960's. Wetlands were formed in irrigation systems and also in areas where the water table had been significantly elevated (especially around Potholes Reservoir). These newly wet areas were largely unvegetated and provided prime habitat for opportunistic species such as cattails and subsequently, purple loosestrife.

No substrate preferences were noted in the study area. Purple loosestrife was found in both organic and mineral soils. It was found in very course grained sediments (sands and gravels) as well as in very fine grained, dense materials. It appeared vigorous in all substrates. These observations are not inconsistent with similar findings in the literature (Keddy and Constabel 1986; Shamsi and Whitehead 1973).

In western Washington field observations, monospecific stands were found on the Montlake Fill, adjacent to Lake Washington and in formerly diked agricultural islands near the mouth of the Skagit River. The loosestrife near Lake Washington was apparently accidently introduced, perhaps a garden escapee. One individual plant was noted immediately after the placement of the fill (1971) colonizing a standing-water area (Ken Brunner, COE; pers. comm., 1992). The loosestrife in Skagit County could have been purposely planted or transported by hunters (Joanne Reynolds, pers. comm., 1992). As purple loosestrife is an aggressive invader in new or disturbed surfaces, the new fill surface and former agricultural lands were ideal places of establishment and loosestrife has successfully excluded colonization by other hydrophytic species.

In contrast, Battelle (1992) noted that monospecific stands in the Grant County area were not uncommon. Again, this may be a function of the circumstances of the establishment of purple loosestrife in eastern Washington.

The lack of use of loosestrife as a food source (WDA, WDW 1991) and its localized distribution, especially in western Washington, suggests that water is the main vector of propagule transport instead of wildlife or wind blown seeds. When populations become well established with significant seed banks in the soil, wildlife may contribute more significantly to the spread. The distribution of plants found within the study area could usually be traced back to a localized "parent" population along a waterbody, with densities of occurrence decreasing with distance. This is well exemplified in the Marymoor Park population. A large, established population is found on the Sammamish Lake margin adjacent to the Sammamish River outflow. Smaller populations are found downriver along both banks from this source. Plant density decreases with increasing distance from the Lake population until finally no individuals are found (around Woodinville). No purple loosestrife was noted at the mouth of the Sammamish River in Lake Washington, however, we speculate that it will only be a matter of time before purple loosestrife is introduced into the north shore of Lake Washington via this source.

The distribution of the Lake Washington/Mercer Slough population was traced along Mercer Slough. Although it was difficult to tell whether the parent population is either up or down river on Mercer Slough (established populations are found in varies places along the Slough), it appears that these populations are the source of a relatively recent invasion into the adjacent surface stormwater systems. Many small individual plants were found well distributed through the ditches in the Bellefield Business Park. Wilcox (1990) found that purple loosestrife is very effective at utilizing drainage ditches as distribution corridors. It was interesting to note that a few individuals were found in parts of the surface stormwater network of the Klahanie development up on the Sammamish plateau. It is likely that purple loosestrife will continue to spread using the surface stormwater systems in this area. This is consistent with observations made in eastern Washington, where purple loosestrife has utilized the irrigation system for distribution.

The populations of purple loosestrife observed in Skagit County are unique in Washington state, in that they are growing in a freshwater tidal system. Their proximity to Skagit Bay indicates that the plants may be exposed to brackish conditions at some times of the year (during extreme high tide events). However, at the time of observation (December) there was no salinity in the surface waters adjacent to the loosestrife areas. Field soil salinity tests (refractometer) at soil depths (10 and 20 cm/4 and 8 in) indicated no discernable residual salts.

Parts of the extensive cattail population on the delta apparently can tolerate some brackish conditions during the year (surface salinities measured between 2 and 4 parts per thousand in December). These areas, located on the bayward edges of the delta, were dominated soley by cattails. Because the site inspection occurred during winter die-back, we were unable to determine if the cattails were *Typha latifolia* or *Typha angustifolia* (both species can tolerate slightly brackish conditions and both may occur on the Skagit delta) (Weinmann, pers. comm., 1992).

We visited this site specifically to determine if the Skagit loosestrife population exhibited tolerance to brackish conditions. However, we found no loosestrife, nor any other 'freshwater' species in the bayward areas. At an abrupt vegetation break further upriver, both loosestrife and other wetland species were found within the cattail community (*Phalaris arundinaceae, Salix spp., Crataegus spp*). This suggests that the Skagit loosestrife population may have some tolerance to occasional brackish tides, but it may not be as saline tolerant as part of the existing cattail population. Further investigation would be necessary to determine the specific salinity tolerance levels of loosestrife at this site.

At the time of field observations (November and December), virtually all of the year's loosestrife population was in die-back, except for a few seedlings in the understory. Essentially every plant we observed closely had produced seed.

In most of the populations observed in western Washington, purple loosestrife was found within existing plant communities. It appears readily able to establish itself within cattail or other rooted emergent aquatic plants, as well as within small willow stands. It was also an aggressive colonizer of disturbed areas adjacent to a seed source recently (1990) flood scoured areas along the Sammamish River and Skagit River). It appears to have some difficultly becoming established in monospecific reed canarygrass stands near seed sources (Mercer Slough). Johanson and Keddy (1991) noted that reed canarygrass is a successful competitor with purple loosestrife. However, we also noted that large, relatively mature patches of purple loosestrife had established themselves within the reed canarygrass along the Sammamish River and were locally dominant.

Purple loosestrife did not appear as an understory dominant in any of the areas we observed. Indeed, it was either sparse or non-existent in the forest wetland areas adjacent to wetlands where it is well established. This is somewhat different that what was noted by Battelle (1992) in eastern Washington where purple loosestrife was found as a dominant species in the understory. It may be less tolerant of shade in the cooler, wetter climate of the western side of the Cascades. This hypothesis was illustrated at the Mercer Slough population where recent construction had created several areas of open ground beneath the I-90 overpasses. One might expect to see a rapid colonization of these sites by purple loosestrife, however, lady fern (*Athyrium felix-femina*) was the only species noted.

There were no major morphological differences found between the purple loosestrife populations observed. Tall, robust plants were found in what appeared to be the older populations while the smaller plants were thought to just be younger plants. As previously mentioned, almost every plant we observed had gone to flower and fruit, regardless of size.

3.3 DISCUSSION

Purple loosestrife populations are expanding quite rapidly in the freshwater wetlands of Washington State. Up until 1990, purple loosestrife was sold in local nurseries as an attractive garden plant. It is likely that most of the invasive populations observed today are the result of several previous "escapes" of seeds from the residential gardens. It is also likely to still be found in many gardens, and former gardens, which will continue to act as a seed source for new populations in areas currently free of purple loosestrife. In addition, the invasive populations now found in Washington's freshwater wetlands are likely to expand, using stormwater/surface water drainage systems and waterways for its main transport mechanism to suitable habitats.

Very little autecological work on purple loosestrife has been done around the country and virtually none in Washington. We are unsure of how far purple loosestrife will expand, what its limitations may be, and what the possible impacts (both positive and negative) it may have on existing wetland communities. More research is necessary to aid in a realistic management scheme for the control of purple loosestrife distribution. Suggested research topics listed include, but are not limited to, the following:

1. Genetic studies to determine if different geno- or phenotypes exist is a given study area. This would be important to understanding if purple loosestrife can be competitive in dryer or wetter conditions. Also, if biological controls are to be considered for long-term management, this information would be essential to determining the effectiveness of a particular biological control agent, over time.

2. Studies of all potential distribution mechanisms of purple loosestrife and the distribution range of a given population. This would be helpful to determine management techniques to isolate given populations from spreading.

3. Long term community dynamic studies. Purple loosestrife is acting like a invasive species in a new niche. Typically, invasive population stabilize over long periods of time and sometimes are reduced in extent. Some of the older populations should be examined for possible changes that have occurred over time. Productivity, seed production, seed

viability, and secondary productivity are all possible characterizations that would aid in long term management scenarios.

4.0 CONCLUSIONS

1. Purple loosestrife is established in sporadic populations around Washington. It acts as an invasive species in freshwater wetlands.

2. It appears to overlap the same environmental parameters as cattail and has successfully excluded cattails in eastern Washington. It can co-exist with cattail populations in western Washington. It is undetermined if purple loosestrife shares similar tolerances to salinity as does *Typha spp.*

3. Mono-specific stands occur in both eastern and western Washington, but appear to be more prevalent in eastern Washington.

4. Purple loosestrife has no observable preference for organic or mineral soils.

5. Purple loosestrife distribution appears to be heavily dependent upon water transport (waterbodies and surface and stormwater transport systems).

6. Virtually all individuals observed had gone to flower and fruit. There appeared to be very little morphological variability between different populations. Almost all observed individuals were in die-back at the time of the western Washington inspections.

7. Purple loosestrife does not appear to have a competitive advantage in understory or shady locations.

8. Reed canarygrass may or may not effectively compete with purple loosestrife. Both are aggressive colonizers of disturbed wetland habitats and it is difficult to determine which species has the competitive advantage.

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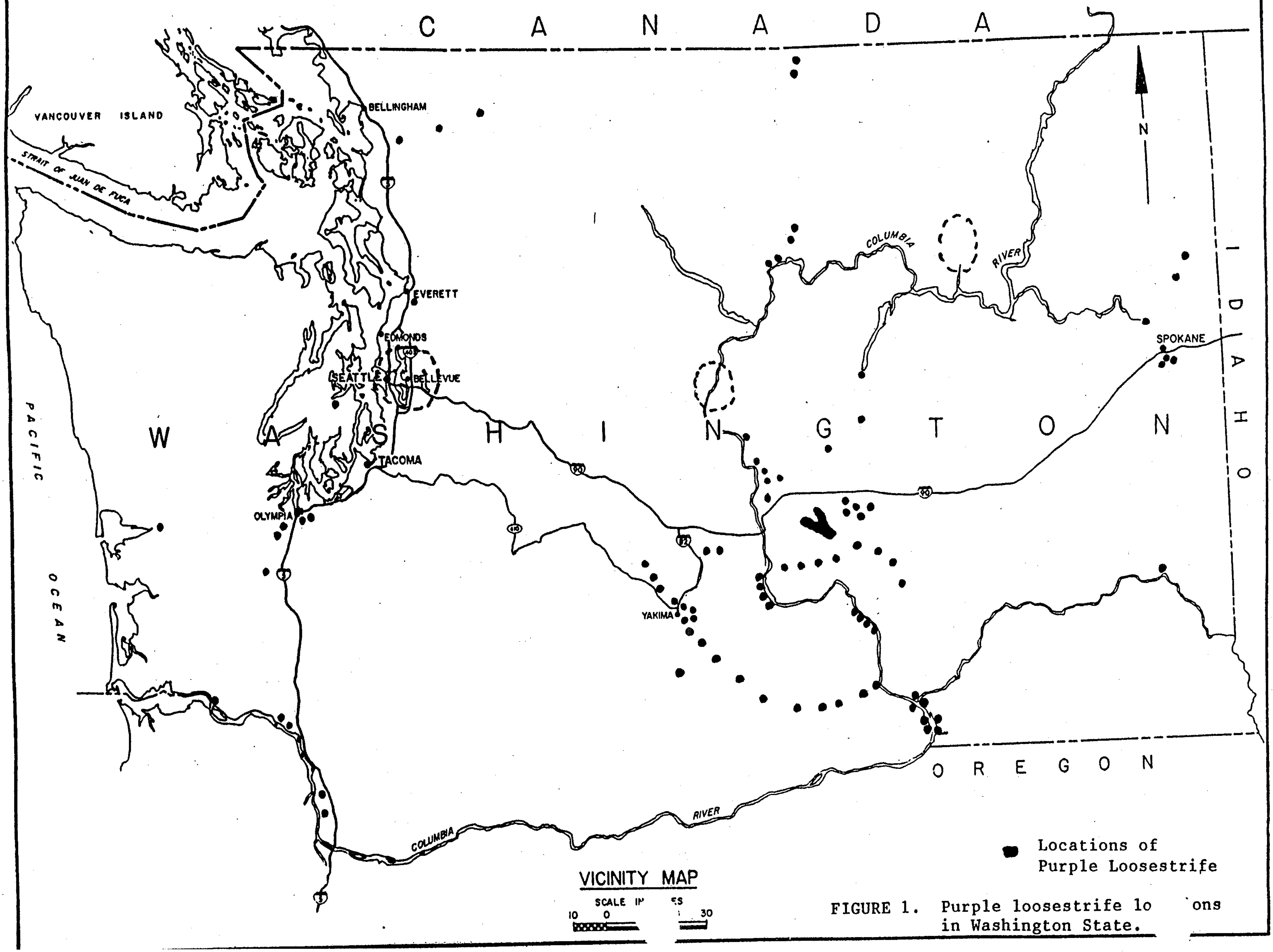

FIGURE 1. Purple loosestrife lo   ons in Washington State.

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October 15, 1992

Ms. Lauran Cole
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Dear Ms. Cole,

As you know, the State of Washington is preparing an Environmental Impact Statement (EIS) on emergent noxious weed control. Six state agencies are co-leads on the project: Departments of Agriculture, Natural Resources, Ecology, Fisheries, and Wildlife, and the State Noxious Weed Board. Ecology is acting as nominal lead and coordinating the EIS. Management and control of eight species of noxious weed plants include three species that are known as Loosestrife, e.g., Purple Loosestrife (Lythrum salicaria, L. virgatum) and Garden Loosestrife (Lysimachia vulgaris). As part of the EIS effort, I was given the task characterizing of communities in which Purple Loosestrife occurs, including a description of communities in which the species occur before invasion, a description of habitat values of these communities before and after invasion, and a description of the distribution of Purple Loosestrife in Washington State.

The work performed for this task concerns observations made in Grant County on Tuesday, September 2, 1992, and Monday, September 14, 1992. Mr. Bob Leonard, Coordinator, Noxious Weed Control Board of Grant County, talked at length with Mr. Andy Driscoll, Seattle Corps of Engineers District, and myself on Tuesday, September 22, 1992, and provided two maps of known Purple Loosestrife distribution. The first, Fig. 1, is of the known distribution throughout Grant County as of 1990, while Fig. 2 depicts the distribution throughout the State of Washington based on Mr. Leonard's experience.

On September 2, 1992, Mr. Leonard conducted Mr. Driscoll and me to several sites in Grant County where Purple Loosestrife was extremely abundant. These sites were within the Potholes region of the Columbia Basin in central Washington. The area receives a great deal of nutrient-enriched water from several wasteways that drain surrounding fertilized agricultural lands. Mr. Leonard stated that there are an estimated 5,000 to 10,000 acres of established Purple Loosestrife in Grant County. These plants are in the Potholes and the wasteways, primarily. This is actual ground cover by the plants.

In the Potholes, Mr. Leonard stated that cattails and Scirpus validus (softstem bulrush) arrived around 1962. Purple Loosestrife began to colonize around 10 years ago, e.g., 1982 to 1984.

OBSERVATIONS

The following remarks list our observations of Purple Loosestrife in the Potholes area near Moses Lake:

1. Plants flower in the second year.
2. An individual stalk from the base may live for an estimated 4 to 5 years and then die.
3. An individual plant may remain alive almost indefinitely because of repeated production of new erect branches from the root crown.
4. New erect stems are produced from budding on the root crown.
5. Purple Loosestrife appears to invade moist ground, can go upland to nearly dry soil, and can go toward the water where it will grow in water nearly 8 in. (20 cm) deep.
6. Purple Loosestrife can also invade and colonize bottom space that is already in water up to 8 in. deep.
7. Purple Loosestrife will colonize and grow on wet soil that is only seasonally wet. We saw one Pothole where the soil was dry down to an estimated 3 to 4 ft (0.9 to 1.2 m) deep, but the species had plants up to 4 ft (1.2 m) tall with abundant flowers and fruits.
8. Purple Loosestrife will invade soil that is bare of plants, but will also invade dense well-established cattail stands which are undisturbed and will increase and take them over. The same is true for Scirpus stands. We saw one location where the cattails were undisturbed, and where the Purple Loosestrife had invaded within the cattail stand and had taken over. Only scattered cattails remained. Purple Loosestrife will also invade disturbed cattails and Scirpus stands. Purple Loosestrife will also invade as a dense understory under a dense willow thicket. This was observed in the Potholes region.
9. Purple Loosestrife does not appear to grow along streams where the water is flowing or where there are regular fluctuations in water level. They appear to grow best in sloughs off streams, canals, and wasteways where the water movement is sluggish or not moving.
10. Purple Loosestrife will invade soft organic substrates that favor cattail and Scirpus (bulrush) stands, but will invade and grow well on moist soils that have a much higher amount of inorganic matter content.
11. The only requirement for Purple Loosestrife invasion is a moist soil that has an organic component. After establishment, plants will tolerate seasonally dry soils to soils that are continually inundated.

On the visit on September 2, 1992, the Purple Loosestrife was in the peak of flowering. On the visit on September 14, 1992, almost all flowers were gone. Fruits were now mature.

SPECIFIC TASKS

• Characterize the communities in which Purple Loosestrife Occurs, Including a Description of Communities in which These Species Occur Prior to Invasion.

Purple Loosestrife was observed in the following communities:

a. Palustrine Persistent Emergent Wetland

This community is made up of the cattail (Typha spp.) and softstem bulrush (Scirpus validus) marshes that the Purple Loosestrife invades. In Grant County these have been established at least since 1962, about 10 years before the invasion of Purple Loosestrife. Purple Loosestrife appears to invade on the fringes of the established marshes but can also invade within the established marsh between the plants and spread from the point of invasion. Purple Loosestrife can dominant and take over the established marsh within a 10-year period, as observed in Grant County, Washington.

b. Palustrine Aquatic Bed-Rooted Vascular Wetland

This community is made up of cattails, softstem bulrush, and occasionally the common reed (Phragmites communis) emergent in 8 in. (20 cm) of water. Often, Purple Loosestrife invades and colonizes an area with standing water to this depth that is not colonized with these wetland plants.

c. Palustrine Scrub-Shrub Wetland

In the Potholes area, Purple Loosestrife was observed as a dense understory under a dense thicket of peach-leaf willow (Salix amygdaloides), a common plant of riparian wetlands in eastern Washington.

- Describe the habitat values of the above communities before and after invasion.

The invasion of Purple Loosestrife appears to influence two major functions exhibited by wetland communities: biodiversity of plant and animal species within the community and the utility of the community as a habitat for feeding, refuging, and breeding for animals following invasion. Invasion of Purple Loosestrife results in a great reduction of space for plant growth because of the perenniality of the Loosestrife and the greatly increased density of the Loosestrife stalks. This latter aspect makes it difficult for animals to penetrate the community on the ground for feeding and nesting. This aspect would lead to decreased biodiversity of plants with the community, as well as to a decreased value of the community as a habitat for animals.

- Describe the distribution of Purple Loosestrife in Washington State.

Enclosed are two maps, both provided by Mr. Bob Leonard, Coordinator, Noxious Weed Control Board, Grant County. Both are based on his extended and vast personal knowledge of Purple Loosestrife invasion and growth in Grant County in particular, and in the State of Washington in general.

- Provide Recommendations for Research.

a. Work is needed on the phenology of Purple Loosestrife in specific areas. The species may now have the exact timing of an annual event in Western Washington as in Eastern Washington or in specific sites in Eastern Washington. Such work would be important in control technology.

b. Work is needed to discern whether the species manifests ecotypic differentiation or whether phenotypic plasticity is predominant. Again, phenologic expression as well as control strategy are important in this regard.

c. The species and or putative ecotypes should be investigated with respect to their range of tolerance and adaptive tolerances as well as their requirements of annual, seasonal, and diurnal ranges of temperature and light.

d. The requirements and effects of various nutrients on the growth and phenology of the species should be investigated. Various aspects such as seed production, seed viability, seedling success, and longevity of erect stems should be investigated with respect to nutrient availability.

e. Seed viability as well as the seed reserve in the soils at an infested site should be investigated.

MECHANICAL CONTROL OF EMERGENT NOXIOUS WEEDS

MECHANICAL CONTROL OF EMERGENT NOXIOUS WEEDS

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1.0 DEFINITION OF MECHANICAL CONTROL

"Control" of noxious weeds is defined in this document as the eradication, vegetative containment, or prevention of seed production of target species. This evaluation of the mechanical control alternative considers control of noxious emergent plant infestations by machines. Machines in this report are tools with power sources other than human that are currently used for similar applications. The machines may be used to remove all parts of a noxious plant; remove portions of a plant; or destroy without removing portions of a plant. Machines range in size from hand held to those mounted on 60 m (200 ft) barges. Various objectives of mechanical control include removing entire infestations of noxious emergent plants, weakening plants in order to discourage growth or lead to death, removing portions of plants to prevent seed production, or simply removing plant biomass temporarily to clear areas for alternative uses.

The boundaries between physical control methods and mechanical control methods are sometimes unclear. For this reason, evaluation of a few related physical methods are incorported into this report.

2.0 EVALUATION OF MECHANICAL CONTROL METHODS

Mechanical methods evaluated in this report include: dredging, digging, plowing, rotovating, crushing, mowing and harvesting. Each method is first described, and then efficacy for the target species and potential impacts are evaluated. Any method that will not control noxious emergent weeds (eradication, containment, or prevention of seed production for target species) is not further evaluated for potential impacts to the environment.

The discussion of mechanical crushing incorporates physical methods of crushing (e.g. trampling), and the discussion of mechanical mowing incorporates hand cutting with non-power tools. Material for these discussions was provided by Ebasco (1992).

3.0 DESCRIPTIONS OF MECHANICAL CONTROL METHODS

3.1 DREDGING

Dredges are typically used to remove sediment from navigable waterways to create or maintain navigation channels, boat basins and harbors. Dredging is a large scale operation that alters underwater and intertidal topography. For control of emergent noxious weeds, dredging could be used to remove entire plants, including viable roots, and any sediments accreted by the plants, in or along the edge of navigable waterways.

The three main dredge types come in all sizes, ranging from vessels of 15-60 m (50-200 ft) length to small 7.5 m (25 ft) "mini dredges," and utilize several types of dredging heads that have been developed for different sediments. The two types most likely to be effective for removing noxious emergent weeds are the **suction/pipeline dredge** and the **clam shell bucket dredge.** Although there are several types of bucket dredges, only clam shell buckets can create a relatively watertight seal. Open bucket dredges, including dragline buckets, create large amounts of turbidity and are no longer commonly used. A third dredge type, the hopper dredge, is a self contained vessel used in open water and in large channels. A hopper dredge would most likely be unable to reach typically shallow weed infested areas, and will not be evaluated further.

Suction/Pipeline Dredge Operation. For removal of noxious weeds along a navigable waterway, a suction/pipeline dredge could be maneuvered adjacent to an inundated weed bed. A pipeline dredge has a cutting head that would chew up the weeds and their root mass, then suction up most of the plant debris along with the loosened sediment/water slurry, in a ratio of one to five. A connected pipeline would transport the slurry from the dredge to a diked disposal area that acts as a settling pond, located on nearby uplands. Placement and design of a diked disposal area involves many steps requiring studies of the material to be dredged and of conditions at the disposal site (ACOE 1983). Sediment and some plant material would settle out, and floating plant fragments would be trapped at the outlet weir where effluent returns to the waterway. The depth to which the dredge cuts into the sediment and the resulting final elevation of the sediments can be controlled with a fair degree of precision.

One example of a small suction/pipeline dredge is the "mudcat". This machine is under 10.5 m (35 ft) in length and can dredge to a depth of 4.5 m (15 ft). Because of its small size, the mudcat can be operated in confined and isolated areas with shallow waters. It can remove sediments and weeds in a 2.4 m (8 ft) swath and leave the bottom flat. A retractable shield shrouds the cutterhead and entraps suspended material, thus controlling turbidity.

Clamshell Dredge Operation. The clamshell dredge is mounted on a barge that can be maneuvered in relatively shallow water. It is suspended from a crane and consists of a two sided, hinged bucket that opens, clamps down on the material to be dredged, and removes it. Clamshell buckets have a capacity that ranges from 2.3 to 19.8 m^3 (3 to 26 yd^3) and are built with seals to minimize the amount of dredged material that would escape into the water column as the bucket is pulled to the surface. Scows are typically positioned alongside the barge to receive dredged material. Once a scow is filled it is taken to an offloading facility by tug. In a weed control operation, the dredged material containing sediment, plants, and roots would be transferred to trucks for transport to an upland disposal site. No material containing plant fragments could be discharged in open water. A clamshell dredge operator can regulate the dredge depth, and return the sediment to within 15 cm (6 in) of a predetermined target elevation. The clamshell dredge can work continuously until receiving scows are full of material. Though barges and scows may work while grounded (e.g. at low tide), they can only be moved in and out of the work area at high tide levels. The clamshell dredge works well with most types of sediments except for the most cohesive consolidated sediments.

3.2 DIGGING

Digging, like dredging, removes portions of sediment from a given area. As with dredging, the purpose of this method for control of noxious weeds is to remove the entire plant with any attendant sediment buildup, returning the area as close to its pre-infestation elevation as possible. Digging machines considered here are heavy equipment vehicles: a bulldozer in combination with a front end loader and a backhoe. These machines were not originally designed to work in an aquatic environment. Their use would only be applicable for emergent noxious weed control in areas that could be approached from the upland.

For large monotypic stands of plants, a bulldozer in combination with a front-end loader could be used to remove mature plants and root structures, for disposal to an upland site. The machines would probably access infestations over temporary roads which would be removed after work was completed.

Backhoes, which are available in a variety of sizes, could also be used for control of noxious weeds by digging. Again, the material would be transported to an upland site for disposal. A unique backhoe, the "Schaff Super Hoe," has recently become available in the Northwest. It consists of a large tractor with four articulating legs with wheels and a large backhoe as a fifth leg. It is designed for all terrains and can function efficiently on steep slopes, channel banks, and along roadsides. An optional pontoon attachment can be utilized to prevent the Super Hoe from sinking into soft sediments.

Bulldozers and backhoes would be able to reach patches of weeds at the upper portions of their range where water-borne dredges could not access. After plant removal, these machines would be able to level out each disturbed area.

Possible constraints on use of any digging methods for control of noxious weeds include: (1) soft sediments that could preclude or severely limit use of machinery and construction of temporary roads for trucks; (2) difficulty in meeting water quality standards, especially for dissolved oxygen and suspended solids; (3) limited access to some areas due to tidal elevation; (4) availability of a disposal site; (5) necessity of removing plants prior to seed production; and (6) uncertainty about number of treatments needed for control.

3.3 PLOWING

The previously described mechanical control methods (dredging and digging) result in complete removal of noxious weeds along with their trapped sediments. In contrast, plowing severely damages entire plants but leaves them and their associated sediments *in situ*. A tractor and plow would turn over plants and soil to a depth relative to the size of the plow used. A plow would cut up stems and roots, expose some of the root structure, partially bury the above ground portions of the weeds and disturb the sediments, leaving mounds and furrows.

3.4 ROTOVATING

Rotovation is the process of using a large mounted machine to till up to approximately 20 cm (8 in) below the surface of bottom sediments, dislodging stems and roots of target plants. In this process the sediment is thoroughly broken up and mixed by a multibladed cutter head. Float-mounted rotovators work effectively in waters 1 to 4 m (3.3 to 13.2 ft) deep, and can extend their effectiveness in some cases to a depth of 7 m (23 ft). In water less than 1 m (3.3 m) deep, the rotovator head tends to "walk" ineffectively across the bottom, rather than digging into it.

Some plant fragments would float to the surface during rotovation, and although most rotovators do not collect floating plant pieces, some machines could be fitted with special attachments that enable collection of some fragments. Rotovators are used extensively in the freshwater environment for control of eurasian watermilfoil, *Myriophyllum spicatum*. A rotovator can cover from less than 0.4 hectare (one acre) to up to 0.8 hectares (2 acres) per day, depending on plant density, season, bottom obstructions, plant species, and weather conditions (DOE 1992).

3.5 CRUSHING

Crushing of noxious weeds includes trampling by foot, or mechanically crushing by tractor or all terrain vehicle. Crushing does not necessarily separate the above-ground portion of noxious weeds from their roots. This method is designed to interrupt above ground growth and seed production of noxious weeds. Repeated crushing of new shoots stresses the root systems and gradually causes plants to die. It is anticipated that this method would require repeat treatments of the same site at least two or three times during two consecutive growing seasons.

3.6 MOWING

"Mowing" involves cutting single plants or large infestations, at or near the sediment surface. In this report, mowing tools include hand-held scythes and other cutting tools with no power source other than human. Mechanical mowing utilizes machines of many different sizes and complexity, including hand-held power brush cutters, hand power mowers and weed eaters, tractor mounted mowers, and balloon-tired, articulated tractors with large arm-mounted rotary mulching cutter heads. An example of this latter machine is the "Kaiser Spyder" which is designed to work on multiple types of terrain. The Spyder can work in shallow water and on slopes, channel banks and along road sides. Optional pontoons allow the Spyder to work in soft sediment. This mower can mow at or slightly below ground level, allowing it to compensate for slight elevation changes.

The mowing method of control is not designed to save any plant material, as the harvesting (Section 3.7) method does. No attention is paid to the condition of the mowed material, except as it relates to the efficacy and efficiency of plant removal and disposal.

The range in size of mowing machines allows for treatment of a wide variety of infestations, from small individual plants and areas of interspersed native and weedy vegetation, to larger clumps, stands and marshes.

3.7 HARVESTING

Mechanical harvesting of noxious weeds is defined as the cutting and removal of the bulk of the plant prior to seed formation. Unlike the process of mowing, which is aimed at killing the plants, harvesting would not destroy the plants but encourage continued growth for additional harvests. The objective of harvesting is the economic use of plant material, but it can fulfill at least one definition of noxious weed control. By not allowing seeds to form or disperse, the harvesting method is at least partially effective in controlling the spread of noxious weeds. It would not control vegetative spread. Mechanical harvesting may use one of many machine types available, including hand-held brush cutters, tractor-mounted harvesters, and floating aquatic harvesters. These machines can access harvesting sites both from land and water, and following cutting of the plants may remove them at the same time or leave them on site for later removal. After on-site removal, the plant material would be taken to a processing location.

4.0 SPECIES OF CONCERN

These sections summarize current life history information (from Ebasco 1992) pertinent to mechanical control methods.

4.1 *SPARTINA* SPP.

Of the three species of *Spartina*, *S. altemiflora* represents the biggest infestation problem in Washington State, with *S. anglica* and *S. townsendii* a distant second and *S. patens* to date found at only one site in the state (Aberle 1990; Ebasco 1992) (Table 1). Both *S. altemiflora* and *S. anglica* inhabit similarly wide ranges in the intertidal area, whereas *S. patens* is found in the mid to upper intertidal zone (Silander 1984).

Table 1. Spartina distribution in Washington State.

LOCATION	SPECIES PRESENT
Padilla Bay	*Spartina altemiflora*
Skagit Bay	*S. anglica* *S. townsendii*
Port Susan	*S. anglica* *S. townsendii*
Deer Lagoon	*S. anglica*
Sequim Bay	*S. altemiflora*
Kala Point	*S. altemiflora*
Thorndyke Bay	*S. altemiflora*
Dosewallips River	*S. patens*
Copalis estuary	*S. altemiflora*
Grays Harbor	*S. altemiflora*
Willapa Bay	*S. altemiflora*

Spartina species are rhizomatous perennial grasses that occur in estuaries in many parts of the world. They have established themselves in several estuaries in Washington State. Recently the rate of infestation of *S. alterniflora* has increased, partly due to an increase in seed production (Sayce 1988). Before this increase, *S. alterniflora* typically only invaded new tideflats vegetatively. Lateral spread of a clone is accomplished both by vigorous underground rhizomes and by above ground roots, producing new shoots. Most likely pieces of rhizomes broken off by various means take root in new areas. Shoots grow throughout the spring and summer. In mature stands, stems can reach heights of 1.3 - 1.5 m (4 - 5 ft). *S. alterniflora* flowers in Willapa Bay from August through October and seeds are set in October (Sayce 1988). Seeds are apparently viable for less than one year (Mooring *et al.* 1971), and thus a seed bank is not developed.

Spartina is found along river mouths as well as in the intertidal areas of estuarine bays. It occurs on all types of substrates from silts to cobble (Landin 1990).

Spartina can be found in four general densities: (1) as single seedlings, (2) in separate distinct clones, or clumps, (3) as monospecific patches created by the meeting of clumps, and (4) as vast marshes, that are defined here as extensive infestations that dominate river mouths or embayments. Seedlings, clumps and patches can be found on open tide flats or interspersed with other vegetation. *Spartina* marshes abut upland marshes and shoreline.

The dense stands of *Spartina* reduce water velocity and allow suspended particles to settle out, with a resulting increase in the tideflat elevation within the infestation. Preliminary data (ACOE 1992a) indicates root mats extend from a minimum of 18 cm (7 in) to a maximum of 89 cm (35 in) beneath the substrate. It is not known, however, to what sediment depth the rhizomes remain viable.

4.2 PURPLE LOOSESTRIFE

Purple loosestrife (*Lythrum salicaria* and *L. virgatum*) occurs primarily in freshwater wetlands. It has become established in Washington State in freshwater wetlands, along stream and river banks, along the edges of ponds, reservoirs and lakes, and in ditches along right-of-ways. It can also be found in horticultural plantings (Leonard, pers. comm., 1992). Infestations have typically been found extending into the water to depths of 20-45 cm (8-18 in) (Battelle 1992; Hayes 1979). Purple loosestrife is found growing in most substrates as long as there is some organic matter present and the soil is at least seasonally ponded or saturated.

Purple loosestrife usually flowers in early summer. Seed production can continue into October, if weather permits. Purple loosestrife invades both open, unvegetated areas and native wetlands. It exhibits at least four growth forms; 1) single plants; 2) small groups of scattered plants mixed with native or naturalized vegetation (ACOE 1992); 3) small monotypic stands ranging from 10-100 feet across; and 4) large stands of several acres. Previously unvegetated areas along waterways and lake shorelines appear to be particularly prone to loosestrife invasion (Stuckey 1980; ACOE 1992) areas.

Purple loosestrife can create a tremendous seed bank within the host soil after only a few years. A single older multi-stemmed plant may produce between two and three million seeds (Thompson *et al.* 1987). These seeds may remain viable in water or soil for more than two years (Shamsi & Whitehead 1973). In addition to reproducing sexually by seed, purple loosestrife can reproduce vegetatively by resprouting from stems and rootstock fragments (Rawinski 1982). Seed germination occurs in late spring or early summer and can occur in the presence or absence of light. Successful germination usually occurs between 15 and 20 •C (59 and 68 •F) (Shamsi & Whitehead 1973).

Mature loosestrife plants have a dense, woody, fibrous root system. Most observers have described the rootstock as a tap root and lateral roots with numerous shootbuds, but there may be several main woody roots rather than a single tap root (Perry, pers. comm. 1992). The tap root, or main roots, normally only penetrate to a depth of up to 30 cm (12 in) (Parker and Burrill 1992).

4.3 GARDEN LOOSESTRIFE

Garden loosestrife species *(Lysimachia vulgaris* and *L. punctata*) are rhizomatous, herbaceous, deciduous perennials which are cultivated as ornamentals in Washington, but have escaped and are becoming invasive. Their native habitat includes freshwater marshes, river banks, wet woods, and lake shores (Tutin *et al.* 1972). In Washington they have, to date, infested moist disturbed sites such as the shorelines and associated wetlands of Lake Sammamish and Lake Washington (ACOE 1992; Gogio, pers. comm. 1992; WSNWCB undated), possibly displacing purple loosestrife (*Lythrum salicaria*). To date only small scattered patches and single plants of garden loosestrife have been confirmed in Washington (ACOE 1992; Gogio pers. comm., 1992). The life cycle begins with existing rhizomes and seeds sprouting in early spring. Flowering occurs from late spring through mid-summer and seeds disperse from late summer through fall. It is known that both species invade aggressively by rhizomes. Little or no additional information is available concerning the life histories, spreading rates, habitat values to birds and mammals, and community structure or other factors needed for complete evaluation of mechanical control strategies.

4.4 GIANT HOGWEED

Giant hogweed (*Heracleum mantegazzianum*), also known as giant cow parsnip, has been described as an herbaceous perennial, a hardy, nonwoody plant reaching heights up to 4.2 m (14 ft) (Hyypio & Cope 1982). Related to the cow parsnip (*H. lanatum*) and a member of the parsley family, giant hogweed has a large and tuberous root. The sap of the plant can cause very painful and acute skin blisters in most people (Morton 1975; Wright 1984; WSNWCB 1991). Giant hogweed was imported from Europe and is cultivated as an ornamental but has often escaped cultivation and invaded native vegetation communities. It has rapidly invaded freshwater wetlands, riparian areas, woodlands, and many drier disturbed sites in other states (Morton 1978; WSNWCB 1991; Dawr and White 1979; Hyypio & Cope 1982). It coexists with a broad diversity of plants in riparian habitats, but also has been able to form monotypic stands in disturbed sites such as landfills and roadsides, possibly as a result of its large leaves shading out competing species (Clegg and Grace 1974). Small infestations are known to occur in several Washington counties (including Clallam, Mason, Whatcom and Skagit), and several larger ones are known in King and Thurston counties (The Sequim Gazette undated; Missoulian 1981; WSNWCB 1981).

Giant hogweed does not reproduce vegetatively. Seeds are produced in the fall and dispersed by wind, water, animals and humans (Clegg and Grace 1974). Seeds and existing roots sprout in the spring, grow and flower in the summer and die back to the ground in the fall. It is thought that it takes several years for a plant to reach flowering, and that it continues to flower for several years (Morton 1978). Antieau (pers. comm., 1992) noted that giant hogweed attracts honeybees and hairy woodpeckers. Wright (1984) reported cattle and pigs eating giant hogweed with no ill effects, while Andrews (1985) and Harwood (1985) reported bad reactions to eating the plant in goats and ducklings. Little additional information is available concerning the life history, spreading rate, habitat value to birds and mammals, and community structure or other factors needed for a complete evaluation of mechanical control strategies.

4.5 INDIGO BUSH

Indigo bush (*Amorpha fruticosa*) is a perennial legume, 2-4 m (6.5-13.2 ft) tall. It is native to eastern North America and has spread west to northern Mexico, southern California and eastern Wyoming (Wilber 1975). Indigo bush typically inhabits riparian areas along rivers and streams, wetlands, and moist draws. In Washington, indigo bush has invaded native plant communities along the Columbia and Snake rivers and some of their tributaries (Johnson, pers. comm., 1992; Jolly 1988). Seeds sprout and new leaves emerge on existing plants in the spring. Flowering then occurs as the leaves reach a fully expanded condition. Indigo bush seeds become ripe at mid-summer and the fruits persist through much of the winter (Antieau, pers. comm., 1992). Seeds are dispersed by wind, water and animals. Indigo bush does not appear to spread vegetatively by roots or stems.

Indigo bush has formed dense stands along the Snake River that displace native vegetation such as willows and cattails, from the water's edge to a height on the bank of about 1.2-1.6 m (4-5 ft) (Phillips, pers. comm., 1992). It occurs naturally with many soil types, ranging from fine to coarse in texture, compacted to non-compacted, and slightly acidic to highly alkaline (pH 6.1-8.5)(Ling 1981). Mature plants form a canopy under which other riparian plant species survive. It has been noted that plants tend to be weak-wooded and relatively short lived. No additional information has been found concerning habitat value, community structure, or other factors needed for the complete evaluation of mechanical control strategies.

5.0 EFFICACY OF MECHANICAL CONTROL METHODS

5.1 DREDGING

5.1.1 EFFICACY FOR *SPARTINA*

Dredging could control and possibly eradicate some *Spartina* infestations. Unlike most control options, dredging could remove accreted sediments as well as plant material and thus approximate the pre-infestation environment. But dredging is also a large scale, costly process that would alter substantial portions of intertidal areas. Because of the large-scale nature of dredging, it would be efficacious only in large, monotypic infestations where eradication is desired. Most dredges could not reach *Spartina* where it occurs in upper intertidal areas. Where there are scattered single plants, or where clumps are small and/or interspersed with native saltmarsh vegetation, dredging would be unsuitable.

To eradicate the plant in a given area, all viable roots would have to be removed. The resulting tideflat elevation would therefore be below the existing *Spartina* root system. In some cases, this elevation may be lower than that of the surrounding unvegetated tideflats.

A **suction/pipeline dredge** could be used only when *Spartina* was inundated with water, to provide a slurry, and disposal sites would need to be within a reasonable pumping distance and not much higher than the mean higher high water line. A large suction dredge alone could pump slurry up to one mile away. Additional pipe and pumping stations could be used to pump material even further, with costs increasing with distance from the dredge site. The outlet weir of the disposal site would need to be modified to keep as much root material as possible from returning to the receiving waters. Some of the success of a suction/pipeline dredge would depend on the dredge operators' ability to vacuum in as much material as possible after disruption by the cutter head. Some fragments of *Spartina* rhizomes would escape both during dredging and from the disposal sites. These fragments could potentially reinfest the treated site or spread the infestation to uncolonized sites.

Clamshell dredge operation presents different challenges. Bucket seals do not always close completely, potentially allowing some rhizome fragments to escape and infest new areas. Some dredged material may occasionally fall off the receiving scow, also releasing rhizome fragments. Bad weather can hamper the movement of barges between the dredging site and the offloading facility. Unlike the suction/pipeline dredge, the clamshell dredge can continue operating at low tide as long as it can reach new *Spartina* areas with its crane, and until the receiving scow is full.

5.1.2 EFFICACY FOR PURPLE LOOSESTRIFE

Dredging is a large scale operation that alters subtidal and intertidal topography. Almost all dredging, even small scale, is accomplished from a water-born barge which is transported to the dredge site. However, most purple loosestrife infestations in Washington are associated with shallow or seasonally flooded wetland systems which are too shallow or otherwise inaccessible by dredgers. In areas where dredging is feasible, the dredging process would severely disturb wetland soils, and any native/naturalized flora or fauna present. Unfortunately, this type of disturbance is ideal for reinfestation by purple loosestrife (from seed banks or remnant vegetative propogules) which has an affinity for disturbed wetland habitats (Thompson 1989; Welling and Becker 1990). In addition, large numbers of seeds would be released to float to new locations and to spread the infestation.

It is highly likely that dredged material from an invested site would contain viable propogules (either seed or vegetative matter), disposal of which could serve to spread the infestation. To prevent this, dredging would have to be used in conjunction with other control methods, such as spraying of herbicides. The stands would initially be sprayed with herbicide and then the soil dredged up to remove the roots and decaying vegetation. However, the effectiveness of this option is unknown, and the disposal of dredged material, as stated above, could result in additional infestations.

The limited number of sites suitable for dredging, the adverse impacts associated with dredging, and the ineffectiveness of dredging to control the spread of purple loosestrife limits it potential for use as an effective control option. Accordingly, dredging will not be further considered as an option for purple loosestrife control in this report.

5.1.3 EFFICACY FOR GARDEN LOOSESTRIFE

Garden loosestrife is not an aquatic plant found in areas accessible to dredging. For this reason, dredging cannot control, contain or eradicate this species and will not be considered further.

5.1.4 EFFICACY FOR GIANT HOGWEED

Giant hogweed is not an aquatic plant found in areas accessible to dredging. For this reason, dredging cannot control, contain or eradicate this species and will not be considered further.

5.1.5 EFFICACY FOR INDIGO BUSH

Indigo bush is not an aquatic plant found in areas accessible to dredging. For this reason, dredging cannot control, contain or eradicate this species and will not be considered further.

5.2 DIGGING

5.2.1 EFFICACY FOR *SPARTINA*

Whereas dredging is only reasonable for weed beds approachable from navigable waterways, digging is only reasonable for weed beds approachable from the upland. Digging would remove the entire *Spartina* plant and root system. It would only be useful where *Spartina* has been present long enough to cause the buildup of sediments above the original level of the tideflats, as in Willapa Bay, Port Susan and Padilla Bay. Unlike dredging, which would be efficient only for extensive infestations, digging could be used for control of either small or large monotypic clumps. Digging would not be efficient for individual plants or areas where *Spartina* is interspersed with native salt marsh plants.

A dragline bucket can be operated at any tidal inundation, for as far as the bucket can be swung from its land-based crane. For infestations near a road or upland area, a dragline bucket could be considered to remove *Spartina* in an effort to reduce impacts on high salt marshes and other adjacent wetlands. The open bucket, however, would increase the possibility of dispersing viable rhizomes.

In most intertidal areas, work could only be accomplished when weeds were exposed during low tide. The lowest tides occur during daylight hours only from late March through August, and intertidal digging would probably need to be confined to those months. Temporary roads providing access would have to be built to access *Spartina* beds. Digging would most likely leave behind some viable roots that could be transported to another area or left to begin a new infestation. Upland disposal sites would need to be identified and secured prior to operation. Depending on the size and type of machine used, the firmness of sediments in the working area could be limiting. In some cases access for heavy machinery could also be a limiting factor.

5.2.2 EFFICACY FOR PURPLE LOOSESTRIFE

Digging would remove the entire plant and root system of the target species and would likely be most effective on large, monotypic stands of purple loosestrife. However, the use of bulldozers or backhoes would greatly disturb wetland soils in and/or around purple loosestrife stands. The major impact of this disturbance would be the germination of the dormant seed bank, with subsequent sprouting and re-establishment of the infestation. It is unlikely that digging could be used on younger areas of infestation (where the seed bank would not have built up), because younger plants typically do not form monotypic stands. In addition, as with dredging, the disposal of any dug material could spread infestations to new locations. Stem and root fragments also have a high probability of being transported to wetland environments where new infestations may occur (Leonard and McEachin, pers. comm., 1992).

The use of bulldozers for burying previously mowed or sprayed plants may be feasible. It is not known whether purple loosestrife seeds would germinate under several inches of soils. However, any unvegetated (disturbed) area would be prime location for reinfestation.

The probability of mechanical digging eliminating and prohibiting the spread of purple loosestrife is low. This, in conjunction with a high potential for exacerbating the spread of propogules by opening up more disturbed habitat, eliminates digging as a feasible option for control of purple loosestrife. Therefore, it will not be further evaluated in this report.

5.2.3 EFFICACY FOR GARDEN LOOSESTRIFE

To date there is no record or observation of large monotypic stands of garden loosestrife (*Lysimachia vulgaris* and *L. punctata*) in Washington (ACOE 1992). Since only small stands and individual plants of garden loosestrife have been noted, and because little is known about its life history, it does not appear cost efficient or environmentally sound to consider using large equipment for their control or eradication at this time.

5.2.4 EFFICACY FOR GIANT HOGWEED

As with garden loosestrife, there is no record or observation of any large monotypic stands of giant hogweed (*Heracleum mantegazzianum*) in Washington. However, since giant hogweed does pose a potential human health risk when it is handled, it is important to consider mechanical removal, i.e. small backhoe, even for small stands or patches. Wright (1984) indicates that plants can be eradicated by digging to only 10 cm deep into the sediments.

5.2.5 EFFICACY FOR INDIGO BUSH

There are relatively large stands of indigo bush (*Amorpha fruticosa*) reported on the banks of the Columbia and Snake rivers and their tributaries. This plant invades and dominates the riparian zone. It could be possible to bring in a bulldozer or a backhoe to some sites for attempts at eradication. Once uprooted, the plants would need to be removed to a separate upland disposal site.

5.3 PLOWING

5.3.1 EFFICACY FOR *SPARTINA*

Plowing could only be accomplished on *Spartina* infestations approachable from the upland, and only during low tide on firm sediments. Plowing *Spartina* meadows would result in breaking up of the plants' roots and rhizomes. After tidal flooding, rhizome fragments would be transported by tidal currents and waves to infest new areas in an estuary. In addition, viable rhizomes that remain in place could sprout and reestablish. The predicted result of plowing *Spartina* would be a decrease in seed productrion at the treated sites for one season, with a subsequent increase in vegetative spread throughout an estuary and possibly beyond.

There is no evidence that plowing could effectively control (eradicate, contain or prevent seed dispersal) of *Spartina*. Therefore, itt has not been further evaluated in this report.

5.3.2 EFFICACY FOR PURPLE LOOSESTRIFE

Plowing stands of purple loosestrife has not proven to be an effective control method, as most pieces of root stalks and stems would remain to sprout in the overturned soil. The seed bank could also easily re-establish seedlings and spread the infestation. Rendall (1988) found plowing (as well as all other mechanical control methods) ineffective for any control of purple loosestrife. The major impact of plowing would be the germination of the dormant seed bank, with subsequent sprouting and re-establishment of the infestation. Stems and roots have a high probability of being transported to wetland environments where new infestations may occur (Leonard and McEachin, pers. comm., 1992).

There is no evidence that plowing would eradicate, contain or prevent seed dispersal of purple loosestrife. Accordingly, it will not be further evaluated in this report.

5.3.3 EFFICACY FOR GARDEN LOOSESTRIFE

Garden loosestrife has not been found in large stands and thus would not presently warrant removal by plowing. . This plant is known to spread vigorously by rhizomes, and cut pieces of rhizome left *in situ* after plowing would probably encourage vigorous sprouting. For this reason, plowing would not effectively control (eradicate, contain or prevent seed dispersal) of garden loosestrife and will not be considered further.

5.3.4 EFFICACY FOR GIANT HOGWEED

Giant hogweed has not yet been found in large monotypic stands in Washington, and It often occurs mixed with native vegetation which would also be destroyed during plowing. A plow could dig deep enough (10 cm/4 in) to kill most giant hogweed plants, but would leave plant material that could pose a potential health hazard at the site. Because this species invades disturbed areas, reinfestation of the treated area would be possible unless aggressively controlled. For these reasons, use of a tractor and plow would not effectively control giant hogweed, and it will not be considered further.

5.3.5 EFFICACY FOR INDIGO BUSH

Indigo bush, a woody legume, occurs in large stands along the Columbia and Snake rivers and their tributaries. However, it is often mixed with other shrubs and trees along the banks. The area of infestation is usually a sloping bank and the weeds can grow to 4 m (13.2 ft). A tractor and plow designed to work on large areas of flat ground would not effectively control, (contain, eradicate or prevent seed dispersal) of indigo bush, and it will not be considered further.

5.4 ROTOVATING

5.4.1 EFFICACY FOR *SPARTINA*

Rotovating tills underwater bottom sediments, dislodging and cutting stems and roots of plants to about 20 cm (8 in) deep. Because viable *Spartina* roots can be found from the sediment surface to one meter (3.3 ft) or more beneath the sediment surface (ACOE 1992), underwater rotovation would cut up and dislodge some plant material capable of regeneration, and leave some in place. Plant and root fragments would float to the surface; some would remain partially trapped in tilled sediments. If the rotovator was equipped with a collector, some floating fragments could be recovered for upland disposal.

To be effective on *Spartina*, rotovation should take place early in the growing season to avoid accumulations of plant material on the cutter head, which significantly decreases machine efficiency. Winds over 12 kph (20 mph) also reduce rotovator efficiency. Operation would be limited by tidal elevation, *i.e.* rotovating could not occur during low tides.

Rotovation would decrease stem density of a *Spartina* marsh only temporarily, because remaining roots and root fragments could sprout and reestablish the infestation. Viable root fragments would continually be released to the water column during rotovation for dispersal by tides, currents, and waves. In addition, for a period of time following rotovation, tides, currents and wave action could release more root fragments before disturbed sediments reconsolidated. In all probability, rotovation could actually encourage the spread of *Spartina* throughout an estuary and beyond. Based on the above information it appears that rotovation does not control *Spartina*, and, therefore, will not be considered further.

5.4.2 EFFICACY FOR PURPLE LOOSESTRIFE

Rotovating is specifically designed to removed non-woody rooted aquatic plants and their roots from water depths of 1 to 4 m (3.3 to 13.2 ft). However, as purple loosestrife is usually found in emergent wetlands and is not considered a rooted aquatic plant, rotovating is not an option for purple loosestrife removal. Accordingly, it will not be considered further in this report

5.4.3 EFFICACY FOR GARDEN LOOSESTRIFE

Rotovators are designed to work in aquatic environments, in over one foot of water. Garden loosestrife is not a regularly inundated, non-woody plant, and thus a rotovator could not be used to control, contain or eradicate it. Hence, rotovation will not be further considered as a control method for this species.

5.4.4 EFFICACY FOR GIANT HOGWEED

Giant hogweed is not a regularly inundated, non-woody plant, and thus a rotovator could not be used to control, contain or eradicate it. Hence, rotovation will not be further considered as a control method for this species.

5.4.5 EFFICACY FOR INDIGO BUSH

Indigo bush is not a regularly inundated, non-woody plant, and thus a rotovator could not be used to control, contain or eradicate it. Hence, rotovation will not be further considered as a control method for this species.

5.5 CRUSHING

5.5.1 EFFICACY FOR *SPARTINA*

Crushing may be an effective control measure for *Spartina*, under certain conditions. Trampling by foot could be attempted on small monotypic clones or patches, even where the patches are interspersed with native vegetation. Mechanical crushing as a short term control method could be used on large monotypic marshes and on individual patches, but would not be reasonable for scattered plants or areas where *Spartina* is mixed with native vegetation.

Trampling and crushing of *Spartina* have two immediate impacts. Oxygen diffusion to the roots is interrupted by pinching off lacunae, or air passages, extending through the stem and into the roots. Oxygen supplied to the roots through these air passages allows them to survive in anaerobic soils. Trampling also pushes plants into the mud, which buries photosynthetic surfaces and further limits oxygen intake.

Trampling or crushing *Spartina* generally reduces plant vigor and, if repeated, may eventually kill plants. Turner (1988) simulated horse trampling in a *S. alterniflora* marsh in Georgia. She found that peak biomass was reduced by 20-55% following treatments. A single treatment may have little effect and may increase *Spartina* densities (Aberle 1990).

Various methods of crushing have been tried, using tractors, three-wheel all terrain vehicles, and by foot. Sayce (1988) found that crushing by foot did not provide enough pressure to be effective. However, a family in New Zealand was successful in killing a large patch of *Spartina* by repeated trampling (Aberle 1990). Tests using a tractor and an all terrain vehicle (ATV) on experimental plots of *Spartina* on a sand flat in Willapa Bay indicated that, after repeated crushings during one season, stem density decreased, new shoot initiations were reduced by two-thirds, and seed production was eliminated (Sayce, 1988). Sayce (pers. comm., 1992) reported that one clone in Willapa Bay was eradicated after crushing once by a tractor, with no regrowth appearing the following year. Other data from the southeastern United States suggest that crushing by marsh buggies over several years can virtually eradicate a *Spartina* marsh (L. Gorman, pers. comm., 1992).

Sayce (1988) indicated that crushing should be done when the growing shoots are still brittle, and seed production has not begun. In Willapa Bay, this condition generally occurs in early July. Sayce observed that compression damage from crushing was greater on sand than on mud. The larger tires needed to access *Spartina* on mud flats reduced the compression effect seen with smaller tires on sand flats (Sayce, pers. comm., 1992). Other constraints to using crushing for *Spartina* control would include: (1) trampling/crushing would not be practical in lower parts of the intertidal or on soft substrates because of difficulties in walking and using heavy equipment in these areas; (2) accessibility to *Spartina* beds would be limited by tidal elevation and inundation; (3) the number of treatments necessary to provide control is uncertain and probably variable; and (4) stormy weather, tidal inundation, and darkness during winter low tides would restrict work periods.

Crushing, especially with heavy equipment, could potentially dislodge rhizome fragments. These could float to other areas and start new colonies.

5.5.2 EFFICACY FOR PURPLE LOOSESTRIFE

Crushing/trampling involves the application of a weighted object to flatten or break the aerial shoots of plants. Crushing may be achieved by driving a vehicle over the plants or stomping them by foot. Injured plants die or experience less vigorous regrowth due to a disruption in physiological processes, especially photosynthesis and nutrient/water/ air conduction. Crushing is labor intensive and expensive, as repetitive treatments are often required to effect control.

There are no published reports of crushing being utilized against purple loosestrife. Unlike *Spartina*, purple loosestrife is very brittle and would likely break into several pieces if crushed by foot or with tracked vehicles or other large wheeled crushing devices. As stated previously, this would not kill the plant, but would likely create several times many more viable vegetative propogules than the original plant and increase the spread of seed. Root crowns of established plants are very woody and could easily survive crushing attempts. Broken stems, especially when compressed into a wet substrate, would form adventitious roots and give rise to new plants, thus increasing the infestation area. Rootstock buds would produce replacement stem growth. In addition, heavy crushing vehicles would compact the soils which could cause hydrological changes as well as future biological changes in sensitive wetland environments. Lastly, soil disturbances have repeatedly been shown to allow loosestrife seedlings to sprout from the dormant seed banks found in loosestrife infested areas (Thompson 1989).

The obvious adverse impacts of crushing purple loosestrife would be the spread of viable propagules (both seed and vegetative) beyond the impact area and also reintroduction of purple loosestrife into the impact area. This could occur in two ways: (1) crushed plant areas would be inundated during high water conditions, thereby releasing propogules to float downstream, and (2) wheels and tracks of crushing vehicles could also spread propogules to uninfested areas.

If this technique was applied against *L. salicaria*, a late July or early August treatment might be most efficacious because plant regenerative ability and seedling recruitment would be diminished during this period. Crushing would probably be most effective when done during periods when plants are under moisture stress and thus unable to compensate for aerial biomass reductions. In addition, purple loosestrife growing in flooded sites would not be amenable to human or vehicular crushing.

5.5.3 EFFICACY FOR GARDEN LOOSESTRIFE

Both species of garden loosestrife are deciduous perennials that spread aggressively by rhizomes. They inhabit moist habitats such as marshes, wet woods, and along lakeshores and river banks. No information is available on possible control methods, and crushing will not be further evaluated for this species.

5.5.4 EFFICACY FOR GIANT HOGWEED

Giant hogweed occurs in small patches or as single plants, often mixed in with native vegetation, including trees. Trampling by cattle knocks down leaves and stems and crushes the crowns of the rootstocks, preventing further growth (Morton 1978). Use of trampling as a control method may be effective in some circumstances, but has not been tested. Repeated trampling of individual young plants may eventually kill them, but effectiveness has not been shown and this method would be feasible only on a very small scale. Using large vehicles to crush giant hogweed would not be physically possible where it occurs near trees. Plant material left at the site after the crushing process would present a potential health hazard.

5.5.5 EFFICACY FOR INDIGO BUSH

Indigo bush occurs in large stands along the Columbia and Snake rivers and their tributaries in Eastern Washington. It inhabits the riparian area from water's edge to about 1.2-1.6 m (4-5 ft) above water level. Crushing vehicles could access some monotypic stands. Since no tests have been conducted it is difficult to determine what the results of attempted crushing would be on controlling indigo bush. Possible constraints on the method include: (1) necessity of crushing plants prior to seed production; (2) presence of soft soils limiting heavy machine use on the site; (3) access to the site of infestation; and (4) uncertainty about the number of treatments needed for control.

5.6 MOWING

5.6.1 EFFICACY FOR *SPARTINA*

In general, mowing must be done more than once to kill *Spartina*, although a single mowing in July, August, or September appears to reduce seed production in Willapa Bay (DNR 1992). Plants may also be weakened following a single mowing. Turner (1988) clipped plants using a weed trimmer in a *S. alterniflora* marsh in Georgia. She found that peak biomass (maximum plant biomass level at any time during the year) was reduced by 20-55% following single treatments. Conversely, increased plant vigor was found in single- and twice-mowed plots of *S. alterniflora* in Willapa Bay (DNR 1992).

Repeated mowing followed by pulling of plants eventually weakens rhizomes of *Spartina* and reduces below-ground energy reserves. Repeated hand mowing, followed by hand pulling of individual plants, was successful in eradicating a large *Spartina* clone along the southeastern shore of Long Island in Washington (Atkinson undated). Initial mowing of the 1,300 m^2 (14,000 ft^2) patch was done in August. Mowing was done using weed trimmers and was accomplished at a rate of 109 m^2/hr (1172 ft^2/hr). Subsequent mowings were done at a faster rate and, by the sixth treatment, mowing rate was approximately 434 m^2/hr (4670 ft^2/hr). In October, after six treatments, clone vigor was reduced to 10.0% or less of its original level. Four more treatments were done the following spring. The final mowing was followed by hand pulling of isolated stems. The treatments resulted in total eradication of the 1,300 m^2 (14,000 ft^2) patch. Total time invested was 64 person-hours.

Other experiments involving repeated hand mowing had sublethal results. Jim Atkinson repeatedly mowed a 60 by 41-meter (197 by 135-foot) clone of *S. alterniflora* in Willapa Bay (DNR 1992). The plot was mowed monthly from May to October 1991 and in January and March 1992. By October 1991, clone vigor had been reduced to 5% of the original level and remaining stems were located along an edge embankment. In March 1992, plants from highest elevations at the clone's center were still producing shoots.

Repeated cutting of *S. anglica* in England resulted in plants with denser growth, shorter and narrower stems, and earlier flowering than control plants (Hubbard 1970). These findings, however, were not consistent among sites.

Aberle (1990) interviewed people engaged in *Spartina* control who felt that repeated mowing would have to be at intervals of one week to one month in order to be effective. Wiegardt (pers. comm., 1992) found that a single treatment of cutting plants 15-20 cm (5.85-7.8 in) from the ground was more effective in reducing stem densities than cutting at the ground surface.

Repeated clipping or mowing may change competitive interactions among plant species in salt marshes. Scholten and Rozema (1990, cited in Gray 1991) noted differences in competitive advantages of *Spartina* versus *Puccinellia* at different elevations in a salt marsh in the Netherlands. They suggested that mowing may transform *Spartina*-dominated marshes to *Puccinellia* marsh. Scott *et al.* (1990) found that *P. maritima* colonized *S. anglica* plots and reduced *Spartina* cover following early season cuts.

Mowing must be timed to prevent scattering of mature seeds. To check resprouting of a *Spartina* clone from viable rhizomes after initial mowing, there must be repeated mow-downs of new shoots, repeated as often as necessary until cessation of new growth. Mowing should be done either at the sediment surface or just below it, in order to deny photosynthetic products that are normally received from the above-ground portion of the plant. This forces all plant resources into new shoot growth and eventually leads to death (Atkinson, pers. comm., 1992).

Mowing does not return the elevation of a treatment area to a pre-infestation level. In areas where tidal and wave energy levels are low, accumulated sediments may remain in place until recolonized by native high salt marsh species. In high energy areas, sediments may erode as the root mass decays, before recolonization takes place.

5.6.2 EFFICACY FOR PURPLE LOOSESTRIFE

Aerial biomass of purple loosestrife can be reduced by various hand cutting instruments such as rotary or sickle bar mowers, filament and blade weed-eaters, scythes, and shears, and by large mechanical instruments such as tractors with rotary mowers. Hand cutting of purple loosestrife stems can effectively prevent seed formation and deplete carbohydrate reserves within the roots (Louis-Marie 1944). However, multiple cuttings may be required to prevent *L. salicaria* from producing a seed crop. Machine cutting or hand clipping of plants requires a significant input of labor, especially if controlling large infestations.

Lythrum should be cut in the pre-bloom or early bloom stage since this is when energy reserves are lowest in the roots. The studies of Malecki and Rawinski (1985) and Haworth-Brockman *et al.* (1991) on *L. salicaria* populations in New York and Canada, respectively, have shown that subsurface, late summer clipping of established plants resulted in less vigorous growth the following year than did a midsummer cutting. The amount of moisture at a site will influence regrowth rate and, thus, affect cutting frequency. Cutting during hot weather will hasten desiccation of chopped leaves and stems and reduce the chances of vegetative reproduction from cut stems.

Previous attempts at controlling loosestrife by mowing alone have met with some failure (Malecki and Rawinski 1985). Documented negative effects of mowing loosestrife include the release of seeds from the soil seed bank when mowing disturbed the surface soil layer. The seeds, along with pieces of cut stems, were transported to new areas and became established as new infestations (Heidorn and Anderson 1991). Another negative result from mowing has been the loss of more desirable species that are mowed in conjunction with the loosestrife.

Cutting has been used to enhance the susceptibility of purple loosestrife to an herbicide application. Experiments conducted by Washington Department of Wildlife personnel have shown that glyphosate applied to the ends of *L. salicaria* stems, mowed to a height of 14 to 16 cm (5.5 to 6.3 in), effectively controlled stands of the weed (Beckstead *et al.* 1991).

Mowing of *L. salicaria* is would most effectively accomplished in sites easily reached by workers, vehicles, and boats. Plants occurring in more remote sites would be difficult to access and less amenable to mowing. The species composition and density of other vegetation at an infested site often influences its accessibility.

Current research in eastern Washington indicates that, under specific conditions, there can be temporary control of seed production without spreading the infestation (Perry, pers. comm., 1992). Those conditions are as follows: (1) the loosestrife stand is no more than three years old and should be monotypic (i.e., 95% or more dominance of the plant community); (2) the surface of the soil should be covered with the organic debris from the dieback of the first two years; (3) the soil should be firm enough to support a tractor without severe disturbance; (4) access to the site should be across areas that are not potential loosestrife habitat; (5) mowing with a rotary type mower should be during dry weather; and (6) mowing should be repeated as necessary to keep the plants from going to seed. Under these conditions, research has found that on sites of about 0.1 to 0.6 hectares (0.25 to 1.5 acres), the number of new shoots decreases, the mulching action of the rotary mower apparently lowers the viability of cut stems by making them small and damaged, and where pieces of stems do not contact bare soil with no overlying organic layer, sprouting does not occur.

5.6.3 EFFICACY FOR GARDEN LOOSESTRIFE

Both species of garden loosestrife are deciduous perennials that spread aggressively by rhizomes. They inhabit moist habitats such as marshes, wet woods, and along lakeshores and river banks. No information is available on possible control methods.

Mowing of garden loosestrife could potentially be accomplished by hand held brush cutters or rotary push mowers, since, to date, only isolated patches have been found in Washington. Repeated treatments could potentially stress the plants to the point of death, but this hypothesis has not been tested. Mowing early in the season could prevent seed production.

Possible constraints on mowing garden loosestrife include: (1) mowing prior to seed production; (2) avoiding non-target species; (3) and uncertainty about the number of treatments needed for control.

5.6.4 EFFICACY FOR GIANT HOGWEED

Mowing stimulates budding on the rootstock and does not kill the plant (Wright 1984; WSNWCB 1991). To kill the plant by cutting, it must be cut at 8-10 cm below ground level and removed (Wright 1984). Repeatedly mowing shoots and leaves, however, reduces below-ground energy reserves and may prevent seed production (Morton 1978) or eventually starve the rootstalk (WSNWCB 1991; Hyypio and Cope 1982).

A seed pool is formed in the soil, although seed survival in the field is not known (Roché undated). Following eradication of growing plants, seeds may germinate and reinfest the area.

Possible constraints on this method include: (1) mowing needs to take place before seed formation; (2) number of mowings needed for control is unknown; (3) close proximity of the infestation to human activities may pose a human health hazard; and (4) suitable safety clothing and procedures would be needed.

5.6.5 EFFICACY FOR INDIGO BUSH

Indigo bush is a tall branching woody legume and the large stands could be mowed using a large tractor-mounted mulcher like the "Kaiser Spyder". The Spyder is an all-terrain machine that could be used to approach the weeds in just about any environment. Possible constraints on this method include: (1) mowing needs to take place before seed formation; (2) site accessibility; (3) number of treatments needed for control is unknown; and (4) non-target species should be avoided.

5.7 HARVESTING

5.7.1 EFFICACY FOR *SPARTINA*

Mechanical harvesting of *Spartina* could be used as a method of inhibiting seed production in an effort to control the plant's spread. However, harvesting would not control lateral vegetative spread. As stated above, harvesting can be accomplished in three known ways: (1) via a tractor equipped with a mowing bar; (2) by hand-held brush cutters; or (3) using a floating aquatic plant harvester such as those used to harvest milfoil plants in fresh water systems. Any of these would include the cutting and removal of stems prior to seed development. A segment about 10-15 cm (4-6 in) in length would normally be left to grow a new crop. Current available information indicates that *Spartina* could be successfully harvested twice a year, about June and September (A. Wiegardt, pers. comm., 1992). The hand held or tractor/mower methods would require harvesting of the crop during low tides to prevent the clippings from floating away. The tractor/mower could be equipped with a conveyor attachment to load the clippings onto a receiving apparatus (track, wagon, etc.) at the time of mowing. After using a brush cutter, it has been demonstrated that clippings can be caught by a strategically placed containment boom such as those used to contain oil. The boom is deployed during low tide, then the flooding tide floats both the clippings and the boom. Wind, waves or tidal currents trap the very buoyant clippings against the boom as it is pulled ashore for eventual loading of the clippings onto a receiving apparatus. Nearly 100% of the clippings are captured with this method (A. Wiegardt, pers. comm., 1992).

Both tractor/mower and hand held brush cutting methods require low tide, good land access, and a relatively firm substrate for an efficient process. On the other hand, a floating plant harvester would access a site from waterward and could be launched at most boat launches, even at some distance from the site. Once on site, this harvester can operate in water as shallow as 61 cm (24 in). The mudcat "Aquatic Plant Harvester," for example, operates using a horizontal mowing bar up to 3 m (10 ft) wide and two vertical side mowing bars. The harvester can adjust its cutting bar to a depth of 1.8 m (6 ft). Once cut, *Spartina* plants are conveyed to a hopper on the harvester and later off-loaded to a barge or returned to shore and off-loaded there. The harvester is controlled by independently operated side mounted paddle wheels. In shallow water the cutter blades occasionally hit and disrupt the bottom and the paddle wheels stir up the bottom sediments. This may release pieces of rhizomes to infest new areas.

Potential constraints with this method include: (1) inclement weather and unfavorable tidal conditions; and (2) securing a market for the plant material. If no profitable market could be found, the plant material would probably need to be disposed of at an approved upland site. Availability of such a site would be a third potential constraint.

5.7.2 EFFICACY FOR PURPLE LOOSESTRIFE

The term harvesting implies that a crop is to be harvested for some use. In contrast to *Spartina*, commercial or other public uses for loosestrife have not been developed and are not presently being pursued. Accordingly, this option has not been further evaluated in this report.

5.7.3 EFFICACY FOR GARDEN LOOSESTRIFE

Harvesting of noxious weeds would only be considered when collection of plant material has economic value. To date, garden loosestrife has no identified economic value and is not being sought for harvesting purposes at this time. Harvesting as a method for control, eradication or containment of this plant will not be further considered.

5.7.4 EFFICACY FOR GIANT HOGWEED

Giant hogweed has no identified economic value and is not presently being sought for harvesting purposes. Harvesting as a method for control, eradication or containment of this plant will not be further considered.

5.7.5 EFFICACY FOR INDIGO BUSH

Indigo bush has no identified economic value at this time and is not being sought for harvesting purposes. Harvesting as a method for control, eradication or containment of this plant will not be further considered.

6.0 IMPACTS OF DREDGING

6.1. *SPARTINA*

6.1.1. NATURAL ENVIRONMENT

6.1.1.1. EARTH

6.1.1.1.1. Soils. *Spartina* spp. inhabit silt, clay, sand, gravel, and cobble sediments. . Dredging would significantly impact sediments at the sites of removal and disposal. Both the suction/pipeline and clamshell dredges would remove the upper layer (to the depth of the root mass) of sediment in the infested intertidal area. This layer could be up to several feet thick at the water edge of the patch, tapering off towards the shoreward edge. Depressions and mounds left after dredging would be visible in the short term, but most of these irregularities in the tide flat would eventually disappear as a result of wave action and currents. Edges of dredged areas may be visible for several years. Fine sediments released during dredging would settle out at various distances from the dredging site, depending on tidal currents and wave action. Fine sediments in the return water from diked disposal sites would settle out at various distances from the point of entry into the receiving water, depending on tidal currents and wave action. These new deposits would slowly consolidate with time. In muddy areas containing silt, clay, and a high percentage of organic matter, there would be a loss of organic material to the disposal sites and release of organics into the water column. Any accumulated contaminants of concern would tend to bind more tightly to fine sediments than to coarse ones, and therefore larger concentrations would end up in disposal sites with minor releases to the water column.

6.1.1.1.2. Topography. Dredging would remove intertidal substrate and plant material to the approximate elevation of the original tide flat, or below, depending on the depth of viable roots. As indicated above, dredging would initially leave an uneven surface, but depending on tidal currents, waves and substrate composition, the surface would for the most part flatten out over time at the lower elevation. In some areas, the viable root mass of *Spartina* beds may reach well below the surrounding tide flats, and dredging would leave large depressions. These would fill in over several years through sloughing, shifting sediments and natural siltation.

6.1.1.1.3. Unique Physical Features. *Spartina* grows along the banks of channels where its thick root mass helps maintain the stability of the banks against the erosion force of waves and tidal or river currents. After *Spartina* removal, banks would become more susceptible to erosion and a constant source of fine sediments entering the water column. Unvegetated channels would also be more likely to change location due to erosion processes. In some cases, due to the depth of the root mass, dredging would eliminate a length of channel by total removal of both banks.

6.1.1.1.4. Erosion/Enlargement of Land Area (Accretion). Removing *Spartina* plants and roots would cause a temporarily unstable intertidal surface very susceptible to erosion from tidal currents and wave action. The potential for shoaling would increase.

6.1.1.1.5. Dredged Material Disposal. Disposal sites should not contain any important resources that might be impacted by the placement of dredged material. Dredged material from a suction/pipeline dredge would be pumped to a diked settling pond within about one mile of the dredging site. Typically, these sites are diked nearshore or upland disposal sites, not much higher than the extreme high tide line, so that effluent water can easily return to the bay. Soils at the diked site would be covered by the dredged material. Following disposal, the sites would be dewatered and the sediments could be planted by native upland species.

Sediments and plant material from a clam shell dredge remain consolidated and would be barged to an off-loading terminal where trucks would transport them to an upland disposal site. Again, disposal site soils would be covered by the dredged material, which could be dewatered and planted with native vegetation. Any excess water could carry some plant fragments and fine sediments into the local surface water drainage system.

6.1.1.2. WATER

6.1.1.2.1. Surface Water Movement /Quantity /Quality. Impacts of dredging on surface water movement will vary according to location and size of the area dredged. For example, a large dredging site along a river channel entering an estuary would significantly alter surface water movement by effectively widening the channel, thus reducing water velocities and increasing flood control capacity of the estuary. A dredging site along the shore of an estuary would have less impact on vater velocities, especially if large tidal channels are not present. Small dredging projects would also have less of an impact on surface water movement.

Dredging impacts on the water column normally include increased suspended solids, increased biological oxygen demand (BOD), and decreased dissolved oxygen (DO) levels. The nature, degree, and extent of sediment suspension are controlled by many factors. Chief among these are: particle size distribution, solids concentration, and composition of the dredged material; dredge type and size, discharge/cutterhead configuration, discharge rate, and solids concentrations of the slurry; and operational procedures used. Finally, characteristics of the water body in the vicinity of the operation such as salinity, temperature, wind action, wave action and water currents affect surface water impacts, causing vertical and horizontal mixing. The relative importance of the different factors would vary significantly from site to site (ACOE 1983).

A **suction/pipeline dredge** generates a level of turbidity directly related to the type and quantity of material cut that is not picked up by suction. In addition to the dredging equipment used and its mode of operation, turbidity may be caused by sloughing of material from the sides of vertical cuts and the prop wash from tenders. Based on field data observed during low current conditions, elevated levels of suspended material appear to be localized in the immediate vicinity of the dredge cutterhead. Within ten feet of the cutter, suspended solids concentrations may be as high as a few tens of parts per thousand. The pipeline dredge produces less turbidity during operation than any other dredge type (NOAA 1988).

A **clamshell dredge** causes turbidity when the bucket contacts sediment, collects a load, and is withdrawn. Some water escapes from the bucket, mainly through small openings between jaws. For this reason, some sediment resuspension always occurs during the period after the jaw is closed and before dredged material is deposited onto the receiving scow. Depending largely on water current velocities, turbidity plumes may extend down-current up to several thousand feet. Based on numerous field observations maximum concentrations of suspended solids at the surface are normally less than 0.5 parts per thousand (ppt) at the dredge site, while average water-column concentrations are generally less than 0.1 ppt.

Another impact of dredging is the release of organic matter and hydrogen sulfide (H_2S) into the water column, which results in decreased dissolved oxygen levels and elevated BOD levels. The DO levels of waters adjacent to the dredge site are normally depressed no more than about 2 parts per million (ppm). This impact may become critical in situations where receiving waters already exhibit low DO (i.e. less than 5.0 ppm) levels. Water returning from a dredged material settling pond may be low in DO, and localized short term depressions would occur in return water effluent (ACOE 1983).

Another potential dredging impact is release of sediment-bound contaminants such as heavy metals, nutrients and petroleum and chlorinated hydrocarbons that may be present with fine grained and organic components of the sediment (ACOE 1978). However, nutrient release from Willapa Bay sediments may not be a problem, as recent analysis of sediment samples from several locations in the bay has indicated that no contaminants are present in levels that would concern federal and state regulatory agencies (SAIC 1992).

6.1.1.2.2. Runoff/Absorption. Where established *Spartina* marshes exist along river channels entering an estuary, riverine runoff is hindered and upstream flooding can result. Removing *Spartina* from intertidal areas at or near river mouths would allow excess runoff to flow more freely through wider channels and over the shallows, thereby increasing the flood capacity of the estuary and decreasing the threat of upstream flooding. Removal would increase the movement of sediment into the estuary due to removal or reduction of the *Spartina* sediment trapping function.

6.1.1.2.3. Floods. As indicated above, *Spartina* removal would reduce the threat of flooding by allowing unrestricted flow of runoff into the estuary.

6.1.1.3. PLANTS AND ANIMALS

6.1.1.3.1. Habitat for, and numbers or diversity of species of plants, fish, or other wildlife.

6.1.1.3.1.1. *Primary productivity.* On a short term basis, the turbidity plume created by dredging and disposal would have the effect of reducing primary productivity in the area of the dredging. Turbidity would reduce the depth to which sunlight could penetrate, limiting the light available to phytoplankton and temporarily reducing photosynthesis. Increased suspended solids could interfere with respiration by adhering to phytoplankton cells. If significant sedimentation occurred there would be a loss of primary production by covered eelgrass (*Zostera marina or Z. japonica*), macroalgae and benthic diatoms as long as the condition persisted. Dredging would remove any eelgrass found in the immediate project area. Removal of *Spartina* itself would also cause a net long term decrease in primary productivity over present levels, but not over pre-invasion levels, except in those instances where *Spartina* had displaced native vegetation.

6.1.1.3.1.2. *Plants.* Typically, *Spartina* matures into monotypic patches and marshes, and dredging would have little to no direct impacts on other plants. Eelgrass (primarily *Zostera japonica*) is sometimes found interspersed with *Spartina* clones and would be removed during dredging. Some areas of dieback have been found in mature *Spartina* stands that have been subsequently recolonized by native upland marsh species (ACOE 1992). These native species would also be removed in a dredging operation. Indirect impacts would occur to adjacent eelgrass beds and nearby native salt marshes from the turbidity and possible sedimentation resulting from dredging. The change of the tide flat to lower elevations would potentially create habitat for new eelgrass colonization over the long term. Any viable rhizome fragments not removed by dredging could sprout new plants either in the dredged area or in a new area, thus spreading the infestation.

6.1.1.3.1.3. *Bottom dwelling organisms.* According to Atkinson (1992b) the benthic invertebrate community present in well established *Spartina* meadows in Willapa Bay does not consist of a diverse array of species and is not considered very productive compared to native salt marsh. Therefore, *Spartina* removal in areas that could be dredged would provide for better mudflat habitat for benthic colonization and more opportunity for a diverse community to become established. There could be dredging impacts to benthic organisms and eelgrass in adjacent areas caused by changes in water conditions during dredging, particularly if re-suspended sediments reach these areas. If dredging occurred near oyster beds, extended periods of turbidity or sedimentation may suppress oyster growth or temporarily interfere with respiration. This impact is not expected to be substantial. . Mobile organisms, including adult crabs, for the most part would be able to avoid these indirect impacts from dredging.

Direct effects of dredging on Dungeness crabs have been widely studied for Grays Harbor, Washington. Entrainment and mortality vary with dredge type, season, and area dredged (Armstrong *et al.* 1987). Entrainment by suction/pipeline dredge has been shown to be 20 times higher than entrainment by clamshell dredge (Stevens 1981). With upland disposal of dredged material, virtually all crabs entrained by either method would die. However, Dungeness crab use of estuarine intertidal areas on the southern Washington coast is limited to short periods during the early juvenile stages (Armstrong *et al.* 1989), and juvenile crab use of *Spartina* habitat has not been documented. If dredging did not occur during this juvenile estuarine intertidal residence window, impacts to the juveniles would be avoided.

6.1.1.3.1.4. *Fish.* On the East Coast, several fish species utilize Spartina marshes and tidal channels for habitat and cover. In Willapa Bay, studies by Allard (1991) showed utilization of *S. alterniflora* marshes by shiner surfperch (*Cymatogaster aggregata*), Pacific staghorn sculpin (*Leptocottus armatus*), surf smelt (*Hypomesus pretiosus pretiosus*), threespine stickleback (*Gasterosteus aculeatus*), northern anchovy (*Engraulis mordax*), chum salmon (*Oncorhynchus keta*) and chinook salmon (*Oncorhynchus tshawytscha*) in numbers not significantly different from utilization of open tide flats. Though fish are mobile organisms, dredging could potentially entrain any that did not escape the *Spartina* marsh during operations. A suction dredge can only be used when the plants are inundated, and entrainment of some fish would probably occur. A clamshell dredge operating during inundation would entrain fewer fish than would a suction dredge. Use of a clamshell during periods of dewatering (low tide) would entrain almost no fish.

Dredging would return the infested area to tide flats, at or below the pre-infestation elevation. When recolonization of benthic algae and fauna occurred, epibenthic predators such as sole or sturgeon, which may not be able to utilize the dense vegetation of a *Spartina* marsh, may regain previously lost habitat.

Indirect impacts of a dredging operation on fishes would be primarily due to turbidity from increased suspended solids, decreased DO, and changes in bottom topography. Turbidity plumes and depressed DO levels would be temporary, and limited to the dredging site and the site where return water from a diked disposal area reentered the estuary. This situation could result in short term interference with respiration and disorientation. In addition, release of undissociated H_2S from sediments could cause direct mortality to fish in the dredging area.

However, most fish species are able to avoid highly turbid, disturbed areas, thereby avoiding direct impacts.

Dredging-induced turbidity may have an impact on nearby fish spawning beds via increased siltation. Loss of the fine sediment trapping function of *Spartina* may allow previously trapped fine sediments to be deposited on spawning beds during and after the dredging operation. Pacific herring (*Clupea harengus pallasi*) spawns on eelgrass and macroalgae at depths between extreme high tide and 11 m (36.3 ft) deep, relative to mean higher high water (Stevenson 1962), but herring spawning has not been documented in *Spartina* marshes. In Willapa Bay, Pacific herring spawn in eelgrass beds in January and February and stay in the bay as juveniles throughout the year. Longfin smelt (*Spirinchus thaleichthys*) spawn in tributaries between October and December; and surf smelt spawn on coarse sandy beaches throughout the year. These fish are all prey species for salmonids, other predator fish, and birds, and thus represent important links in the food web of the Willapa Bay estuary. On the positive side, removal of *Spartina* by dredging may allow eelgrass beds to recolonize and expand. Restoration of mudflat and eelgrass habitat after *Spartina* removal should increase available spawning habitat for these species over present levels.

6.1.1.3.1.5. *Mammals.* Small mammals in large numbers, such as shrews, mice and voles, are known to use mature *Spartina* clones and meadows at low tide as an extension to their upland habitat, just as they have used the native marshes. Limited trapping data suggest that these mammals favor diverse native salt marshes over monotypic *Spartina* clones (Atkinson, pers. comm., 1992). Dredging would result in a reduction in habitat for these mammals over present levels until revegetation of the area. In addition, elk have been observed foraging on *S. alterniflora* in Willapa Bay (Samuelson, pers. comm., 1992), and this forage would be no longer available after removal of *Spartina*.

6.1.1.3.1.6. *Birds.* Western Washington estuaries play an important role in the maintenance of shorebirds and waterfowl throughout the year (Herman 1981, Manuwal 1979). Migrating birds depend on intertidal areas, both unvegetated and vegetated, for food. Adjacent native salt marshes, meadows, fields and beaches are used primarily for roosting, some nesting and foraging. Over 20 different species of shorebirds are known to use Washington estuaries during their migration (Herman 1981). The invasion of both *Spartina alterniflora* and *S. anglica* onto intertidal flats continues to reduce useful feeding area for shorebirds. Loss of eelgrass beds decreases food available for black brandt.

To restore important bird habitat in Skagit and Port Susan Bays, *Spartina* infested areas would need to be returned to an elevation that would support a bulrush marsh, which serves as the primary food resource for wintering snow geese. Dabbling ducks also utilize bulrush seed for a significant portion of their diet. Plants that would compose a bulrush marsh include three-square bulrush, *Scirpus americanus*, hardstem bulrush *S. acutus*, arrowgrass, *Triglochin maritima* and sedges, *Carex* spp. These are the preferred food sources for both greater and lesser snow geese as well as other waterfowl. Without these food resources, snow geese would be forced to forage to a greater extent in adjacent agricultural fields where they would be vulnerable to hunting mortality. Elimination of the bulrush marsh species by *Spartina* or by removal of *Spartina* to a depth that would not support these species would have a detrimental impact, by decreasing the waterfowl carrying capacity of the estuary. The only waterfowl which regularly utilize *Spartina* for food is the black duck *Anas rubripes*, which is rarely observed in Washington (Iten, pers. comm., 1992).

Temporary negative impacts during dredging would include noise, turbidity, presence of large equipment, boats and people. Many long term impacts of dredging should be positive, including recolonization of the tideflat by native vegetation, and benthic and epibenthic organisms, thereby restoring feeding habitat for shorebirds and waterfowl. These positive impacts may be offset if seeds and/or rhizome fragments either reestablish or spread the *Spartina* infestation.

6.1.1.3.1.7. *Fish or Wildlife Migration Routes.* Juvenile salmon emigrate through Washington estuaries primarily from January through June, and adults return from May to January. Dredging in estuaries could impact these migrations. High turbidity and low DO, even though temporary, could disorient and stress young outmigrants. However, impacts could be minor if turbidity plumes were not extensive, as juveniles are fairly adept at sensing turbid areas and avoiding them.

Depressions left by dredging could trap fish on the outgoing tide, leaving them susceptible to predation, temperature extremes and low DO. Dredging noise could impact migratory bird feeding and disrupt resting behavior in the project vicinity.

Long term positive impacts include an increase in intertidal area for fish passage along channels and an increase in production of epibenthic fish food species on restored tide flats. The resulting increase in epibenthic organisms would also benefit the large populations of migrating shorebirds and waterfowl.

6.1.2. BUILT ENVIRONMENT

6.1.2.1. LAND AND SHORELINE USE

6.1.2.1.1. Aesthetics. Dredging impacts aesthetics in a variety of ways. Noise levels increase temporarily in the project vicinity. Dredging machinery could create a negative visual image. Increased turbidity could negatively affect nearby private and public beach water quality. The public could perceive dredging of *Spartina* beds as wetland destruction and thus as a negative aesthetic impact. To the extent that the public perceived a *Spartina* marsh as more pleasing than bare mud flat, the negative aesthetic impact of removal would be long term.

6.1.2.1.2. Recreation. Dredges and tenders could be a hazard to recreational boaters. Increased turbidity and noise could impact recreational fishing and the use of private and public beaches. These would be considered short-term impacts, minor in nature. Following removal the intertidal areas would ultimately be improved for walking, bird watching, hunting, and shellfish harvesting. Shallow water boating would also be enhanced over the long term.

6.1.2.1.3. Historic and Cultural Preservation. Submerged historic or cultural sites under *Spartina* patches could be damaged by dredging. The extent of the damage would depend on operator sensitivity to this issue and the size and contents of the site. Historic or cultural sites should be identified during the design of a dredging project.

6.1.2.1.4. Agricultural/Aquacultural Crops. Oyster beds may be negatively impacted by turbidity, sedimentation, low DO, and physical grounding of barges during dredging of *Spartina* beds. Although most adult bivalves can adjust to short periods of turbidity, extended periods could cause stress in clams and oysters, and may reduce growth rates or spawning activity. Larval and juvenile oysters and clams would be much more susceptible to negative impacts of turbidity. Following dredging activities, particularly if they occurred near river mouths, sediments that would normally have been trapped by *Spartina* beds would remain suspended in the water column before settling out at some other point in the estuary. If turbidity and sedimentation remained high over oyster and clam grow-out areas, the crops would be negatively impacted over the long term. On the other hand, eradication of *Spartina* and restoration of unvegetated tide flats may provide opportunities to expand aquacultural operations.

Any economic use of *Spartina* by humans would be negatively impacted by its removal.

6.1.2.1.5. Transportation It is possible that dredging equipment could partially block some smaller navigable channels for short periods during actual dredging, but this impact is not expected to be major.

6.1.3. ECONOMIC IMPACTS

High turbidity levels or low DO levels created during a dredging project could cause negative impacts on commercial fishing and shellfishing. If heavy sedimentation or long term turbidity near commercial oyster beds is expected, oysters may need to be moved to an alternative grow out site, thus incurring the cost of rehandling. Increased turbidity may keep fish out of commercial fishing grounds for the duration of the project. If removal of *Spartina* reduced flood hazards, there would be less economic impact due to flood damage. Any potential economic value of *Spartina* would be lost with its removal.

6.1.4. CUMULATIVE IMPACTS

Dredging of *Spartina* would add incrementally to other sources of sedimentation and turbidity in a water body. Estuarine sedimentation due to upstream logging and development has increased with population and economic pressures, and dredging may exacerbate excess turbidity and sedimentation in some areas. Surface water changes would be incremental with other dredging and *Spartina* control measures, and other alterations in topography.

Though water quality degradation in each case of dredging would be short term, impacts could intensify with consecutive dredging projects, other *Spartina* control measures (mechanical, physical and chemical), and other local sources of water contamination.

Dredging would counteract negative cumulative effects of continuing spread of *Spartina* due to no -action. Control of *Spartina* could reverse trends toward increased flooding, displacement of native communities, and reduction of invertebrate, fish and wildlife habitat.

6.1.5. IMPACT MITIGATION

To mitigate potential impacts of dredging several actions could be taken, including but not limited to:

1) Installing noise controls on machinery;
2) Constraining operations to minimize turbidity;
3) Planning dredging to avoid creating large depressions;
4) Filling depressions before low tide to prevent fish stranding and mortality;
5) Placing containment booms around the dredging area to contain floating plant fragments;
6) Designing control structures to keep plant material from escaping diked disposal areas;
7) Timing dredging to avoid critical fish migration and spawning windows;
8) Preventing barges from settling on valuable eelgrass beds;
9) Limiting dredging to areas with low organic content sediments;
10) Avoiding dredging during seasons of the year when DO is typically low;
11) Mitigating negative perceptions of intertidal dredging with public education;
12) Operating, maintaining and fueling vehicles so as to minimize the likelihood of leakages or spills of oil, fuel and hydraulic fluid into intertidal areas.

7.0 IMPACTS OF DIGGING

Digging methods have been found to be feasible and effective for the control of *Spartina*, giant hogweed and indigo bush. Impacts of digging on these species is considered in this section.

7.1. *SPARTINA*

7.1.1. NATURAL ENVIRONMENT

7.1.1.1. EARTH

7.1.1.1.1. Soils. Impacts of digging on soils would be substantial, and similar to those described for dredging. Accumulated deposits of silts, clays, and organic matter would be removed, and there would be depressions and mounds of sediment visible in the short term. Over time, loose material would consolidate at the pre-*Spartina* elevation or below. Turbidity would increase during the consolidation process. Soils at disposal sites would be covered by soils and plant material from the dug area. Accessing the intertidal to remove *Spartina* would require that large machinery disturb native salt marshes and could require construction of temporary roads. The extent of impact would depend on machine size and the size of the project area. Access road construction would compact sediments and temporarily cover native soils with road bed material.

7.1.1.1.2. Topography. Digging would remove intertidal sediments and plant material to pre-invasion tideflat elevations, or lower, depending on the viable root depth. Digging machinery would smooth the surface of the disturbed substrate, and tidal forces and waves would continue to manipulate disturbed sediments until consolidation.

7.1.1.1.3. Unique Physical Features. *Spartina* grows along the banks of channels where its thick root mass helps maintain bank stability against the erosion force of waves and tidal or river currents. After *Spartina* removal, banks would become more susceptible to erosion and would be a source of fine sediments entering the estuary. Unvegetated channels would also be more likely to change location due to erosion processes. In some cases, due to the depth of the root mass, dredging would eliminate various lengths of channel by total removal of both banks.

7.1.1.1.4. Erosion/Enlargement of Land Area (Accretion). Disturbed sediments would be susceptible to the erosive forces of tidal and wave action, with erosion potential greatest along channel banks. Accretion may take place in some areas as eroded sediments are distributed throughout the estuary.

7.1.1.1.5. Material Disposal. Plant material and soils from digging would be transported to upland disposal sites. Impacts on these sites would vary depending on the types and extent of resources at the disposal site. Any excess water would carry some plant fragments and fine sediments into the local surface water drainage system.

7.1.1.2. WATER

7.1.1.2.1. Surface Water Movement /Quantity /Quality. Mechanical digging would impact surface water movement by removal of plants in areas where infestations have increased upstream flooding. Because tideflat elevation would be lowered from present levels, tidal currents could be altered. Water quality would be temporarily impacted during and after digging. Disturbed sediments would resuspend in the water column due to cyclic changes in tidal elevation. Effects would primarily be localized increases in turbidity and nutrients and slight DO depressions. Sediments containing contaminants could resuspend and be carried to other areas. Since most digging would occur only at low tide, water quality impacts would be less overall than those expected from dredging.

7.1.1.2.2. Runoff/Absorption. Where established *Spartina* marshes exist along river channels entering an estuary, riverine runoff is hindered and upstream flooding can result. Removing *Spartina* from intertidal areas at or near river mouths would allow excess runoff to flow more freely through wider channels and over the shallows, thereby increasing the flood control capacity of the estuary and decreasing the threat of upstream flooding. Removal would increase the movement of sediment into the estuary due to removal or reduction of the *Spartina* sediment trapping function.

7.1.1.2.3. Floods. *Spartina* removal by digging may allow excess runoff from rivers to flow more freely over the shallows of the estuary, possibly decreasing the threat of upstream flooding.

7.1.1.3. PLANTS AND ANIMALS

7.1.1.3.1. Habitat for, and numbers or diversity of species of plants, fish, or other wildlife.

7.1.1.3.1.1. *Primary productivity.* The primary long-term impact on estuarine primary productivity would result from the removal of *Spartina* from the estuary. However, some eelgrass (primarily *Zostera japonica*) is found interspersed with *Spartina* and may be removed during digging. In its upper range *Spartina* may be intermixed with native saltmarsh plants, which would also be removed during digging.

Phytoplankton productivity would be lowered in the short term, primarily from increased turbidity that would reduce light penetration, and from increased suspended solids that would interfere with respiration by adhering to phytoplankton cells.

7.1.1.3.1.2. *Plants.* In areas where *Spartina* has formed a monotypic stand, impacts to associated plants should be minimal. Isolated clones could be removed by digging, thus avoiding impacts to associated plants. *Eelgrass (Zostera marina* and *Z. japonica*) is able to grow among *Spartina* plants at its lower range. Native salt marsh plants such as pickleweed (*Salicornia spp.*) and salt grass (*Distichlis spicata*) have colonized areas of dieback in mature *Spartina* meadows, and are often found interspersed at the upper edge of *Spartina* stands. These plants would be removed along with *Spartina* and all associated sediments. Final elevation and substrate would determine which plants would recolonize the project area. Digging would probably leave some pieces of viable rhizomes in the disturbed sediments, which may reinfest the same area or be transported to another location.

Over the long term, the resultant lowered and unvegetated tide flat would be recolonized by benthic algae, and potentially by macroalgae and eelgrass. There may be some short term indirect impacts on eelgrass and other vegetation that is adjacent to the operation due to turbidity caused by localized increases of suspended material. Because most plant material would be removed, no large influx of excess plant material would be introduced into the estuary.

7.1.1.3.1.3. *Bottom dwelling organisms.* According to recent field observations, very few benthic organisms inhabit well established *S. alterniflora* marshes in Willapa Bay (Atkinson 1992b). No related information exists for *S. anglica* or *S. patens* marshes. Those benthic organisms present at the digging site would be removed.

Tidal action after digging would cause an increase in turbidity at the project site and in adjacent areas, which could impact nearby sessile benthic organisms, including bivalve mollusks. Mobile organisms, including crabs, for the most part would be able to avoid turbidity plumes. Though bottom-dwelling organisms typically recolonize fairly quickly, the rate of return and ultimate structure and diversity of the benthic community would depend mainly on the type of sediment that existed after digging.

Roads built to transport equipment to *Spartina* marshes would destroy any benthic resources over which they were built. If roadbed material was not completely removed, the returning benthic community may contain a different composition of species than what existed before digging.

7.1.1.3.1.4. ***Fish.*** Preliminary research indicates that both juvenile and adult fish use *S. alterniflora* clones and open tideflats equally in Willapa Bay (Allard 1991), and thus long-term impacts from *S. alterniflora* removal on those fish populations should not be substantial. No information is available for fish use of other *Spartina* species or in other locations. There would be some short-term impacts due to localized increases in turbidity, decreases in D.O., and trapping of fish in depressions left by machinery. These impacts could affect salmon smolts, juvenile herring, smelt, and other resident fish and prey species that utilize shallow tide flats.

Digging impacts would be less substantial than dredging impacts. Digging would be done only when low tides uncovered intertidal areas. Digging operations could be more selective than dredging operations, due to the advantage of visual inspection and to the smaller scale of most equipment.

Turbidity associated with digging could impact nearby fish spawning beds due to increased suspended solids and siltation. Loss of the fine sediment trapping function of *Spartina* could allow substantial quantities of previously trapped fine sediments to be deposited on spawning beds following the digging operation. Pacific herring (*Clupea harengus pallasi*) spawns on eelgrass and macroalgae at depths between extreme high tide and 11 m (33 ft) deep (relative to mean lower low water, MLLW) (Stevenson 1962), but spawning has not been documented in *Spartina* marshes. In Willapa Bay, Pacific herring spawn in eelgrass beds in January and February and reside in the bay as juveniles throughout the year. Longfin smelt (*Spirinchus thaleichthys*) spawn in tributaries between October and December; and surf smelt spawn on coarse sandy beaches throughout the year. These fish are all prey species for salmonids and thus represent an important link in the food chain of the Willapa Bay estuary. On the positive side, removal of *Spartina* by digging may allow eelgrass beds to recolonize the newly exposed, unvegetated tideflats. Restoration of mudflat and eelgrass habitat after *Spartina* removal could increase available spawning habitat for herring and smelt over present levels.

7.1.1.3.1.5. ***Mammals.*** Small mammals such as shrews, moles, mice and voles are known to use mature *Spartina* clones and meadows at low tide as an extension to their upland habitat, just as they have used native marshes. In addition, elk have been observed foraging on *S. alterniflora* in Willapa Bay (Samuelson, pers. comm., 1992). Mammal habitat usage of *Spartina* beds would be decreased by digging in proportion to the amount of *Spartina* habitat removed. Digging would lower the tideflat below *Spartina* elevation, which would prevent colonization by high marsh species that could replace lost *Spartina* habitat.

7.1.1.3.1.6. ***Birds.*** Coastal estuaries are extremely important temporary or permanent habitats for shorebirds and waterfowl. Noise from digging would impact feeding, roosting, and nesting of nearby birds. However, following removal of *Spartina* plants and associated sediment, colonization of intertidal mudflats by epifauna and infauna, marsh vegetation, and/or eelgrass, would provide shorebirds and waterfowl with productive intertidal area that would provide important feeding, resting, and rearing habitat, similar to that available before infestation. Over 20 different species of shorebirds are known to use Washington estuaries during their migration (Herman 1981). The invasion of both *Spartina alterniflora* and *S. anglica* onto intertidal flats continues to reduce useful feeding area for shorebirds. Loss of eelgrass beds decreases the food available for black brandt.

Spartina infested areas in Skagit and Port Susan Bays would need to be returned to an elevation that would support a bulrush marsh, which serves as the primary food resource for wintering snow geese. Dabbling ducks also utilize bulrush seed for a significant portion of their diet. Plants that would compose a bulrush marsh include three-square bulrush, *Scirpus americanus*, hardstem bulrush *S. acutus*, arrowgrass, *Triglochin maritimum* and sedges, *Carex* spp. These are the preferred food sources for both greater and lesser snow geese as well as other waterfowl. Without these food resources, snow geese would be forced to forage to a greater extent in adjacent agricultural fields where they would be vulnerable to hunting mortality. Elimination of the bulrush marsh species by *Spartina* or by removal of *Spartina* to a depth that would not support these species would have a detrimental impact, by decreasing the waterfowl carrying capacity of the estuary. The only waterfowl which regularly utilize *Spartina* for food is the black duck *Anas rubripes*, which is rarely observed in Washington (Iten, pers. comm., 1992).

Short term negative impacts during digging would include noise, some turbidity, and presence of large equipment. Many long term impacts of digging may be positive, including revegetation of the tideflat and recolonization by benthic and epibenthic organisms, thereby restoring feeding habitat for shorebirds and waterfowl. These positive impacts may be offset if seeds and/or rhizome fragments either reestablish or spread the *Spartina* infestation.

7.1.1.3.1.7. ***Fish or Wildlife Migration Routes.*** Juvenile salmon emigrate through Washington estuaries primarily from January through June, and adults return from May to January. *Spartina* marsh digging could impact these migrations. Elevated turbidity, depressed DO and increased levels undissociated H_2S could disorient and greatly stress young outmigrants. Depressions left by digging could trap fish on outgoing tides, leaving them susceptible to predation, temperature extremes and low DO. Migrating birds could be disturbed by machinery noise, and feeding could be impacted by increased turbidity.

Long-term impacts include an increase in intertidal area for fish passage along channels and an increase in production of epibenthic fish food species on restored tide flats. The resulting increase in epibenthic organisms would also benefit the large populations of migrating shorebirds and waterfowl.

7.1.2. BUILT ENVIRONMENT

7.1.2.1. LAND AND SHORELINE USE

7.1.2.1.1. Aesthetics. Digging operations would have some impacts on aesthetics, in and around the work area. Noise levels would increase temporarily in the project vicinity and the presence of large machinery may create a negative image to many. Removal of *Spartina* could be perceived by some as destruction of a valuable wetland. Another aesthetic impact would be temporarily decreased water clarity due to increased suspended solids resulting from digging.

7.1.2.1.2. Recreation. Digging operations would increase noise and turbidity levels which could impact recreational activities such as boating, fishing, and sightseeing. However, following *Spartina* removal project intertidal areas could be available for bird watching, hunting, and shellfish harvesting. Shallow water boating would also be enhanced over the long-term.

7.1.2.1.3. Historic and Cultural Preservation. Submerged historic or cultural sites under *Spartina* patches could be damaged by digging operations. The extent of the damage would depend on operator sensitivity to this issue and the size and contents of the site. Known historic or cultural sites would need to be identified before design of a digging project.

7.1.2.1.4. Agricultural/Aquacultural Crops. Oyster and clam beds may be impacted by increased turbidity, sedimentation, and depressed DO levels. Following digging activities, particularly near river mouths, sediments that would normally have been trapped by *Spartina* beds would remain suspended in the water column before settling out at some other point in the estuary. However, these impacts would be minor and short term, and would vary with factors such as proximity of the digging site, direction of water currents, and type of soils disturbed. Impacted oyster and clam beds could require reconstruction and reseeding.

Long-term impacts would be the loss of *Spartina* for any economic use by humans. On the other hand, eradication of *Spartina* and restoration of tide flats to approximate pre-invasion conditions may provide opportunities to expand clam and oyster aquaculture.

7.1.2.1.5. Transportation. It is not expected that digging of *Spartina* would impact local transportation to any significant degree.

7.1.3. ECONOMIC IMPACTS

Depending on where and when digging takes place, there could be impacts on commercial and recreational fishing from increased turbidity or low DO levels. Heavy sedimentation or long-term turbidity near commercial oyster beds could necessitate transfer of oysters, at least temporarily, to an alternative grow out site, thus incurring substantial rehandling costs. In addition, costs would be incurred by any necessary reconstruction and reseeding of oyster and clam beds. Increased turbidity could temporarily prevent fish from frequenting known commercial fishing grounds for the duration of any project. If *Spartina* removal reduced flood hazards, there would be a positive economic impact in upstream areas. Any potential economic value of *Spartina* would be lost with its removal.

7.1.4. CUMULATIVE IMPACTS

Digging of *Spartina* would add incrementally to other sources of sedimentation and turbidity in an estuary. Estuarine sedimentation due to upstream logging and development has increased with population and economic pressures, and digging may temporarily exacerbate excess turbidity and sedimentation in some areas. The incremental additions would be short-term impacts and would not be considered a significant contribution to long-term cumulative impacts resulting from other sources of sedimentation.

Water quality degradation from each case of digging would in itself be short term and minor, but impacts from all sources would accumulate. Other incremental additions would result from consecutive digging projects, other *Spartina* control measures (mechanical, physical and chemical), and other local sources of water turbidity and contamination. Impacts of road building and heavy machinery on wetland vegetation would contribute to long term impacts on statewide wetland resources.

Digging would counteract negative cumulative effects of continuing spread of *Spartina* due to no action. Control of *Spartina* could reverse trends toward increased flooding, displacement of native communities, and reduction of invertebrate, fish and wildlife habitat.

7.1.5. IMPACT MITIGATION

To mitigate potential impacts of digging on *Spartina* several actions could be taken, including but not limited to:

1) Installing noise controls on machinery;
2) Constraining operations to minimize turbidity;
3) Planning digging to avoid creating large depressions;
4) Smoothing the surface of disturbed sediments at low tide;
5) Operating, maintaining and fueling vehicles so as to minimize the likelihood of leakages or spills of oil, fuel and hydraulic fluid into intertidal areas;
6) Refraining from disturbing adjacent areas that will not be removed;
7) Timing digging to avoid critical fish migration and spawning periods;
8) Avoiding areas of eelgrass and other native vegetation;
9) Testing sediments for contaminants before digging to avoid release of contaminants at levels of concern into the water column;
10) Backfilling depressions with appropriate sediment hauled by trucks that could also be used to transport material to upland disposal sites;
11) Replanting backfilled areas with appropriate native vegetation;
12) Mitigating negative perceptions of intertidal digging with public education.

7.2. GIANT HOGWEED

7.2.1. NATURAL ENVIRONMENT

Soils would be compacted, disturbed or removed during digging. The extent of this impact would depend on the size of a given infestation and the digging technique used. Since digging would be shallow (approximately 10 cm/4 in) for control of this species, soil disruption would be comparatively minimal. Following removal of the plants and topsoil there would be an increased potential for erosion, depending on the location of the site and the type of soils present. If the site was near a water body, any shoreline soils disturbance and accompanying runoff could cause a limited short term increase in turbidity, and short-term DO depression. Most giant hogweed infestations presently in Washington are in complex vegetation communities, and non-target plants would be destroyed during mechanical digging methods. Wildlife in the area would be disturbed in the short term by the presence of machines and associated noise.

7.2.2. BUILT ENVIRONMENT

There would be an increase in noise levels during the operation, which would have a varying human impact depending on the proximity to the noise source. There would be a loss of any perceived ornamental values of giant hogweed, but also a decrease in the health risk posed by the plants. Digging-induced turbidity in an adjacent water body would cause short term localized impacts on aesthetics and recreation.

7.2.3. IMPACT MITIGATION

To mitigate potential impacts of digging on giant hogweed several actions could be taken, including but not limited to:

1) Installing noise controls on machinery.
2) Reducing erosion potential by installing erosion control measures and replacing lost soils.
3) Replanting disturbed sites with native vegetation.
4) Timing work to avoid wildlife critical life history stages.
5) Operating, maintaining and fueling vehicles so as to minimize the likelihood of leakages or spills of oil, fuel and hydraulic fluid into wetland areas.
6) Refraining from disturbing adjacent areas that will not be removed.
7) Mitigating negative perceptions of wetland digging with public education.

7.3. INDIGO BUSH

7.3.1. NATURAL ENVIRONMENT

Soils in the riparian environment where indigo bush is found would be compacted, disturbed or removed by digging. The extent of impact on soils would vary with the size of the particular infestation. There could be localized increases in turbidity and depressions in DO in adjacent waterways following plant removal. Some non-target native plants would be probably be removed with indigo bush. Wildlife use of indigo bush is unknown, and therefore specific impacts of removing this species cannot be predicted. However, any species utilizing this habitat as feeding, resting, reproductive or rearing habitat would be substantively affected at least until new vegetation was established in denuded areas. Wildlife in the project area would be disturbed in the short term by the temporary increase in noise and presence of the large machines.

7.3.2. BUILT ENVIRONMENT

There would be an increase in noise levels during the activity, but most areas presently infested in Washington State are not heavily inhabited by humans, and thus, this impact would be minimal. Removal of infestations near recreation sites would temporarily reduce the recreational value of a site.

7.3.3. IMPACT MITIGATION

To mitigate potential impacts of digging on indigo bush several actions could be taken, including but not limited to:

1) Installinging noise controls on machinery;
2) Reducing erosion potential by installing erosion control measures and replacing lost soils;
3) Replanting disturbed sites with native riparian vegetation;
4) Timing work to avoid wildlife critical life history stages;
5) Operating, maintaining and fueling vehicles so as to minimize the likelihood of leakages or spills of oil, fuel and hydraulic fluid into wetland areas;
6) Refraining from disturbing adjacent areas that will not be removed;
7) Mitigating negative perceptions of wetland digging with public education.

8.0 IMPACTS OF PLOWING

In the analysis of efficacy, plowing has not been found to be effective or feasible for control of any of the species considered in this report.

9.0 IMPACTS OF ROTOVATING

Rotovating has not been found to be effective or feasible for control of any of the species considered in this report.

10.0 IMPACTS OF CRUSHING

Impacts of crushing are analyzed in this report for *Spartina*, purple loosestrife, giant hogweed and indigo bush.

10.1 *SPARTINA*

10.1.1 NATURAL ENVIRONMENT

10.1.1.1 EARTH

10.1.1.1.1 Soil. *Spartina* spp. occur on silt, clay, sand and gravel substrates. Dense *Spartina* root masses create a firm bed even in very soft substrates, and trampling or driving a wide tracked or wheeled vehicle over *Spartina* beds therefore does not usually mix or disturb the soils to a great degree. However, some compaction would undoubtedly occur. The degree of compaction and disturbance would depend on the substrate type, the trampling or crushing method, the weight of any vehicle used, and the tire or tread type. Some resuspension of soils would occur and cause short term localized increases in turbidity and decreases in DO levels. Crushing is best suited for areas where *Spartina* plants grow in large meadows rather than in separate clumps interspersed with open mud.

10.1.1.1.2 Topography. The crushing method would minimally modify soil surface features from pressure.

10.1.1.1.3 Unique Physical Features. Tidal channels are a unique physical feature of *Spartina* meadows, with extensive root masses stabilizing the banks of these channels. Mechanical crushing of *Spartina* plants could cause less stability of these channel banks and subsequent erosion. In instances where channel banks are several feet high, crushing vehicles would be unable to drive along bank edges.

10.1.1.1.4 Erosion/Enlargement of Land Area (Accretion). As a result of mechanical crushing there would be minor erosion where the sediments would be disturbed by vehicles. Along channel banks, erosion would take place as the root mass slowly disintegrated due to stress caused by repeated crushing of plant stems. Bank disintegration would result in channel shifting and resultant turbidity and sediment deposition in non-*Spartina* areas.

10.1.1.2 WATER

10.1.1.2.1 Surface water movement /quantity /quality. Mechanical crushing of *Spartina* beds would result only in a minor impact on surface water movement, as discussed previously with tidal channel modifications. Minor quantities of fine sediment would be resuspended, leading to short-term, localized increases in turbidity and depressions in DO. Turbidity levels would vary depending on the crushing technique used and on the characteristics of the *Spartina* meadows and tidal channels. Nutrient levels may be elevated and dissolved oxygen levels may be decreased from decaying vegetation.

10.1.1.2.2 Runoff/Absorption. Mechanical crushing of *Spartina* beds should not significantly impact runoff or absorption. After *Spartina* plants have been successfully removed by this method runoff from rivers would flow unhindered into the estuary. Removing *Spartina* from tideflats along river mouths would allow excess runoff to flow unhindered over the shallows and thereby decrease the threat of up-river flooding. On the other hand, increased water velocities over the tide flats may cause erosion of the flats, where *Spartina* had previously functioned as a sediment trap.

10.1.1.2.3 Floods. Removal of *Spartina* from river mouths could reduce upstream flooding by allowing unrestricted flow of runoff through the estuary.

10.1.1.3 PLANTS AND ANIMALS

10.1.1.3.1 Habitat for, and numbers or diversity of species of plants, fish, or other wildlife.

10.1.1.3.1.1 *Primary productivity.* Mechanical crushing would temporarily decrease estuarine primary productivity, because with repeated crushing runs *Spartina* would be destroyed. Impacts to eelgrass from crushing, or indirectly due to increases in turbidity, would also reduce primary productivity in the short term. However, eelgrass, native salt marsh plants and benthic algae would colonize the unvegetated tide flats, thereby restoring some primary productivity. Crushing would not cause significant increases in turbidity and would therefore not be expected to significantly affect phytoplankton productivity.

10.1.1.3.1.2 *Plants.* Although *Spartina* meadows are frequently monotypic, they occasionally include eelgrass and patches of other native salt marsh plants such as pickleweed (*Salicornia* spp.) and salt grass (*Distichlis spicata*). Eelgrass would normally be destroyed by mechanical crushing. However, Sayce (1988) found that crushing does not appear to severely harm the dominant native plants of the lower salt marsh, *Salicornia virginica, Jaumea carnosa* or *Distichlis spicata* var. *borialis.*

10.1.1.3.1.3 *Bottom dwelling organisms.* Soil compaction and trampling may kill infauna and other non-target biota, that could include threatened and endangered (TES) species. Infauna and epifauna populations may be temporarily affected by minor changes in sedimentation and erosion caused by soil disturbance. However, according to Atkinson (1992b) the benthic invertebrate community is not well developed in established Willapa Bay *Spartina* meadows.

If a crushing operation eventually eradicated *Spartina* and its associated community, and the project area reverted to pre-infestation conditions, a new macrofaunal and meiofaunal community would become established. Evidence of rapid colonization by some invertebrates has been found in instances of surface removal of *Spartina* by mowing, where shore birds were observed feeding on benthic and shallow infaunal organisms within one month after treatment (Atkinson 1992a).

10.1.1.3.1.4 *Fish.* Fish populations may be temporarily diminished or displaced during trampling or crushing but would reoccupy habitats once disturbance ceased and mudflats or native vegetation were re-established.

Juvenile and adult fish of many species, including silver surf perch, sculpin, surf smelt and threespined stickleback, utilize *Spartina* beds and unvegetated tide flats in equal numbers and with a similar composition of species (Allard 1991). Therefore, if *Spartina* is eradicated as a result of crushing, it appears that significant habitat depletion would not occur in a given estuary after stabilization of the treatment area and colonization by benthos and macroalgae. High marsh species such as *Salicornia virginica, Distichilis spicata* and *Triglochin maritimum* would expand into the bare *Spartina* beds and create more native marsh habitat for fish. It is not known whether this vegetated habitat is more or less desirable than *Spartina* as upper intertidal fish habitat. There is no literature indicating that any of these fish species utilize *Spartina* beds for spawning.

Juvenile salmonids are thought to utilize the *Spartina* beds for feeding and rearing habitat during high tides to the same extent as they use the tideflats. Crushing activity would be conducted during low tide and therefore would not directly impact fish use. Crushed *Spartina* stems do not significantly affect dissolved oxygen and water turbidity is not significantly increased by mechanical crushing. Some crushing vehicles leave shallow depressions in the exposed surface and these depressions could potentially trap fish during low tides, making them vulnerable to temperature extremes and bird predation.

10.1.1.3.1.5 *Mammals.* *Spartina* marshes and native marshes are utilized by small mammals such as shrews and voles during low tide as an extension to their usual upland habitat. Limited trapping data from Willapa Bay indicates that monotypic *Spartina* meadows are not utilized by small mammals to the same extent as diverse native marshes (Atkinson 1992b). Crushing of *Spartina* would result in a reduction of habitat for small mammals now utilizing these meadows.

10.1.1.3.1.6 *Birds.* All estuaries are extremely important to shorebirds and waterfowl. The spread of *Spartina* marshes is reducing the area of mudflat habitat available to shorebirds and waterfowl. The noise and disturbance of mechanical crushing activity would temporarily disturb feeding, resting and nesting activities of shorebirds and waterfowl to an unknown, but probably not significant, extent. *Spartina* containment would prevent further habitat reduction for shorebirds and waterfowl, and eradication would increase their desirable habitat over present levels. Because crushing would not remove extensive *Spartina* root masses, treated areas would not immediately return to pre-infestation elevation or habitat value, but may in the long term.

10.1.1.3.1.7 *Fish or Wildlife Migration Routes.* Crushing activities would not be expected to significantly impact juvenile salmonid outmigration routes or returning adult salmonid migratory routes. Migrating birds could be disturbed by the presence and noise of crushing vehicles. All adverse impacts could be minimal or non-existent if crushing activities were scheduled to avoid important fish and bird migratory seasons.

10.1.1.3.1.8 *Trophic Interactions.* A temporary increase in *Spartina* detritus would enhance decomposer populations.

10.1.1.3.1.9 *Human Health.* Sustained stomping activities may adversely affect some individuals. Blisters, foot, ankle and leg sprains/strains, falls, fatigue, and other job site injuries could occur. Accidents involving crushing machinery could debilitate workers.

10.1.2 BUILT ENVIRONMENT

Effects of crushing/trampling treatments on sediments/soils, water quality, aesthetics, and cultural resources of the built environment would be similar to those occurring in the natural environment.

10.1.2.1 LAND AND SHORELINE USE

10.1.2.1.1 Air Quality. Minor emissions would be generated by tractors or other machinery. Such emissions would not be expected to significantly impact air quality.

10.1.2.1.2 Aesthetics. Mechanical crushing would impact work area aesthetics because of the intrusion of large vehicles into a natural setting. Impacts would include visual, auditory, and psychological aspects. Duration of these impacts would be several days to several weeks, the latter due to recurring crushing intervals several weeks apart. To eradicate a *Spartina* bed, crushing may be necessary three to four times per growing season and for more than one year. Further study would be necessary to determine how frequently crushing would have to occur to be an effective treatment method. Many *Spartina* meadows are located some distance from human dwellings, so the visual and audible impacts would not be as great as if the activities were proximate to homes or heavily used recreation areas. The process of crushing and the resulting flattened *Spartina* stems will give the perception to the public that a natural marsh is being destroyed which may be aesthetically distressing to many.

10.1.2.1.3 Recreation. Trampling/crushing treatments would have minor impacts on area recreation. Access to beaches and mudflats may be temporarily restricted. Eradication of *Spartina* would create more area for swimming, boating, and other water sports. Noise from the use of tractors or mechanized vehicles could discourage recreational use and annoy local inhabitants. Crushing activities would negatively impact sightseeing and bird watching when machinery was present in the project area, estimated to be a few days at a time at a given site during the growing season.

10.1.2.1.4 Historic and Cultural Preservation. Control measures could potentially disturb or destroy unidentified cultural resources by trampling, using heavy equipment, or changing erosion patterns.

10.1.2.1.5 Agricultural/Aquacultural Crops. Crushing/trampling treatments in agricultural and aquacultural environments would produce effects on sediment/soil stability, soil chemistry, and water quality similar to those occurring in natural environments.

Minimal short-term impacts on aquacultural operations, including oyster beds, would be expected from crushing, due to minimal turbidity. Shellfish cultivation may be improved by eradication of *Spartina* infestations. An important impact would be the eradication of any *Spartina* patches used for agricultural purposes.

10.1.3 ECONOMIC IMPACTS

Mechanical crushing of *Spartina* beds would not interfere with any major economic activity, such as commercial fishing or shellfishing. No indirect adverse impacts on local economies would be expected.

10.1.4 CUMULATIVE IMPACTS

In the short term, crushing would contribute to impacts from past and present estuary projects or ongoing operations. Trampling/crushing extensive *Spartina* colonies may significantly impact local populations of non-target biota, especially threatened and endangered species (if present). Noise from heavy equipment may impact recreation and wildlife use. Sediment dynamics would be altered, with positive or negative effects. Extensive soil compaction may adversely affect infauna populations. Repeated treatments could result in substantial disturbance of the habitat due to soil compaction and increases in water turbidity.

In the long term, control of *Spartina* would have a positive impact on the overall health of the estuary.

10.1.5 IMPACT MITIGATION

Potential negative impacts caused by crushing/trampling include *Spartina* dispersal to new sites, adverse changes in sediment dynamics, loss of non-target species including threatened and endangered species, temporary degradation of water quality, temporary loss of habitat, soil compaction, adverse impacts to human health, loss of cultural resources, and destabilization of shorelines protecting built environments. Before initiating control measures, surveys should be done in the vicinity of each particular project area to determine potential impacts on its affected resources, built environments, and aquacultural and agricultural practices.

Some steps to mitigate potential impacts of crushing *Spartina* include, but are not limited to:

1) Installing noise abatement equipment on crushing vehicles;
2) Constraining operations to minimize turbidity;
3) Carefully selecting vehicle type, including weight and tread pattern best suited for a particular substrate;
4) Operating vehicles in a careful and methodical manner;
5) Operating, maintaining and fueling vehicles so as to minimize the likelihood of leakages or spills of oil, fuel and hydraulic fluid into water bodies;
6) Avoiding disturbance of adjacent vegetation;
7) Training personnel involved in implementing control methods in appropriate safety procedures;

8) Inspecting the treatment site for propagules throughout the tidal cycle;
9) Scheduling crushing treatments to minimize noise disturbance to wildlife, tourists, and recreationists;
10) Timing crushing operations to avoid critical bird nesting and migrating seasons;
11) Replanting bare areas left in salt marshes after eradication of *Spartina* with native vegetation;
12) Conducting cultural resource investigations in any project area;
13) Scheduling operations to avoid interference with sensitive or critical fish and wildlife life history periods.
14) Mitigating negative aesthetic perceptions of crushing with public education.

10.2 PURPLE LOOSESTRIFE

10.2.1 NATURAL ENVIRONMENT

10.2.1.1 EARTH

10.2.1.1.1 Soil. Crushing/trampling operations would substantially disturb the integrity of wetland soils. Sediments uplifted during the trampling process may enter adjacent waterbodies and temporarily increase turbidity. These sediments could be contaminated with metals, pesticides or other undesirable toxicants from historical or existing uses. Re-suspension of sediments containing high levels of nutrients could trigger phytoplankton blooms.

10.2.1.1.2 Topography. Soil surface features would be modified by the pressures from crushing equipment and human feet.

10.2.1.2 WATER

10.2.1.2.1 Surface water movement /quantity /quality. Crushing/trampling activities may cause sediment and nutrient infusion of surface waters. Temporary increases in turbidity and phytoplankton populations could occur. Surface water flow patterns could be altered by soil compaction and topography rearrangement associated with this form of control.

10.2.1.3 PLANTS AND ANIMALS

10.2.1.3.1 Habitat for, and numbers or diversity of species of plants, fish, or other wildlife. Substantial non-target plant and animal mortality is anticipated if this method is used indiscriminately in diversified *Lythrum* plant communities. Non-target vegetation would also be subject to debilitation or destruction. Damage to some plant species, especially those with poor regenerative capabilities, could be significant. Some animals that feed, hide, or nest in target site vegetation could be displaced or destroyed. Those animals with limited mobility are at greatest risk since they could not avoid plant crushing devices. Included would be many invertebrates, amphibians, reptiles, and immature birds and mammals. Any of the European insects purposely introduced for the biological control of *L. salicaria* would be highly susceptible to injury. However, crushing/trampling could be a selective control if applied to monospecific stands of purple loosestrife.

The amount of animal habitat rendered unusable by crushing/trampling is a function of purple loosestrife and non-target vegetation densities and occurrence frequencies within the control area. Benthic organisms should not be seriously impacted if plant breakage operations are directed against plants rooted in wet but not flooded soils. Fish are also not expected to be harmed. Wildlife will suffer most from habitat alterations. Animals may be forced to vacate the habitat while the control method is being implemented. Living and feeding site availability may be reduced for some species. Repopulation of affected sites will depend upon the invasive and reproductive characteristics of affected biota and the frequency of disturbance imposed upon the habitat by vegetation flattening procedures.

10.2.1.3.2 Trophic Interactions. Purple loosestrife biomass will be diminished following trampling/crushing. This influx of organic matter will be processed by detritivores and nutrients will be released into the soil for plant and animal utilization. These nutrients may accelerate seedling and vegetative regrowth of *Lythrum* and other plant species found at the control site.

10.2.1.3.3 Human Health. Sustained stomping activities may adversely affect some individuals. Blisters, foot, ankle and leg sprains/strains, falls, arthropod bites and stings, fatigue, and other job site injuries could occur. Accidents involving crushing machinery could possibly debilitate some workers.

10.2.2 BUILT ENVIRONMENT

Impacts on soil sedimentation, stability, and chemistry, water quality and movement, and aesthetic, recreation, and cultural resources resulting from the deployment of trampling/crushing in built environments would be similar to those witnessed in natural environments. Control of *L salicaria* by trampling or crushing should not impede maintenance activities normally practiced in the built environment.

10.2.2.1 LAND AND SHORELINE USE

10.2.2.1.1 Air Quality. Human trampling of plants will not affect air quality. Pollutant emissions from internal combustion engines of crushing machinery should only have a slight, transient, and localized effect on air quality.

10.2.2.1.2 Aesthetics. Areas subjected to vegetation flattening may be aesthetically offensive to some viewers. Certain wetland plants and animals may become more visible once the height of *L. salicaria* is reduced.

10.2.2.1.3 Recreation. Crushing large infestations of purple loosestrife should generally improve most forms of recreation undertaken in a wetland environment. Reducing plant stature will increase exposure of some birds and mammals to hunters. Angler access to streams, rivers, and lakes would also be improved.

10.2.2.1.4 Historic and Cultural Preservation. Trampling or crushing could potentially disturb or destroy unidentified cultural resources on or near the soil surface.

10.2.2.1.5 Agricultural/Aquacultural Crops. The impacts of trampling/crushing on soil stability, sedimentation, and chemistry, in an agricultural environment, would parallel those encountered in the natural environment. In addition, irrigation ditchbank integrity could be compromised by the repetitive utilization of this control method.

The control of purple loosestrife in cultivated crop and wetland pasture sites by trampling/crushing would have negligible impacts on surface and groundwater quality. Control of loosestrife in and along irrigation canals and ditches will improve water flow and decrease water losses attributable to evapotranspiration.

Selective use of the trampling/crushing method would eliminate or reduce *L. salicaria* competition with desired crop or forage plants and, thus, promote yield increases of the affected agricultural commodity. Beekeepers dependent upon purple loosestrife for late summer bee pasturage, may experience reduced honey production if the plant is prevented from flowering by employing this technique.

10.2.3 CUMULATIVE IMPACTS

An adverse cumulative effect of trampling/crushing would be an alteration of surface water flow or storage capacity resulting from repetitive, human- or machine-induced compaction of wetland soils. A beneficial cumulative effect would result from the on-site re-establishment of desirable vegetation.

10.2.4 IMPACT MITIGATION

In sites where purple loosestrife grows amongst desirable plants and where trampling/crushing would be utilized, a survey of each proposed treatment site should be conducted to determine habitat values of possible impacted plant and animal species and the consequences of their debilitation or destruction. In addition, cultural resource surveys should be completed. Survey results would dictate appropriate mitigation measures to be taken and may include the preservation of essential wildlife plants or replacement of damaged flora. This method of control should only be considered for use when purple loosestrife occurs in monospecific stands. This would minimize injury to non-target plant associates.

To mitigate the spread of loosestrife within treatment sites, all broken stems should be collected, removed from the sites, and properly disposed. Crushing equipment and footwear should be cleaned to remove attached stem fragments and/or seeds before exiting work sites to prevent dispersal. Crushing equipment operators should be thoroughly trained in its safe use to reduce the possibility of serious job site accidents.

10.3 GIANT HOGWEED

Environmental impacts to natural, agricultural, and built environments due to crushing giant hogweed would be negligible.

10.3.1 NATURAL ENVIRONMENT

Soils would be compacted due to weight of humans and/or crushing machines. Soils would be slightly disturbed where giant hogweed is found in wet soils. Water quality and air quality may be locally affected due to rotting vegetation. Plant debris may be toxic to some organisms. Giant hogweed infestations are few in number in Washington and removing them would probably not noticeably affect wildlife. The noise of crushing vehicles would temporarily impact any wildlife in neighboring areas. Once the weeds were removed, an area could be returned to native habitat.

Giant hogweed produces contact dermatitis in susceptible individuals (Camm *et al.* 1976), resulting in photodermatis, which sensitizes the skin to ultraviolet light (Wright 1984). Human trampling would be dangerous, and the use of a crushing vehicle would pose a health hazard to the machinery operator, bystanders and people cleaning up plant cuttings.

10.3.2 BUILT ENVIRONMENT

Aesthetics would be temporarily diminished from habitat disturbance. There would be a temporary increase in noise during crushing. People and pets should be kept from the site until plant material is removed or allowed to dry.

10.3.3 IMPACT MITIGATION

Seed dispersal should be minimized by crushing plants before seeds have matured. Plants should be disposed of in a manner that would prevent plant dispersal and adverse impacts to air and water quality.

Workers should be properly clothed and should take measures to avoid contact dermatitis from exposure to giant hogweed. Sap should be washed off skin with soap and water as soon as possible.

10.4 INDIGO BUSH

10.4.1 NATURAL ENVIRONMENT

Soils would be compacted and disturbed. The extent of impact on soils would vary according to type of soil present, crushing method used, and topography of the site. Wildlife in the area would be impacted by the increase in noise and the presence of any large vehicles.

10.4.2 BUILT ENVIRONMENT

There would be an increase in noise levels, but human habitation near infestations is minimal and the impacts would not be severe. Crushing activity could disturb nearby recreational use. Work should be scheduled to avoid heavy recreational use times.

10.4.3 IMPACT MITIGATION

Potential impacts of crushing indigo bush could be mitigated by some of the following actions:

1) Installing noise controls on crushing machinery;
2) Refraining from disturbing adjacent vegetation;
3) After eradication, replanting disturbed sites with native vegetation;
4) Timing work to avoid wildlife critical life history stages for wildlife;
5) Operating, maintaining and fueling vehicles so as to minimize the likelihood of leakages or spills of oil, fuel and hydraulic fluid into wetland areas;
6) Using forums, signs and other public education tools to combat negative aesthetic perceptions of crushing operations.

11.0 IMPACTS OF MOWING

Mowing is considered feasible to some extent for control of all species considered in this report.

11.1 *SPARTINA*

11.1.1 NATURAL ENVIRONMENT

11.1.1.1 EARTH

11.1.1.1.1 Soil. *Spartina* spp. occur on silt, clay, sand and gravel substrates. Dense *Spartina* root masses create a firm bed even in very soft substrates, and driving a wheeled mowing vehicle over *Spartina* beds therefore does not usually mix or disturb the soils to a great degree. However, some compaction and disturbance would undoubtedly occur, even from human activity. The degree of compaction and disturbance would depend on the substrate type, the weight of the person or vehicle used, and tire or tread types. Cutting/mulching blades would occasionally cut below the sediment surface, causing short term soil disturbances. This soil will resuspend during high tide, causing some increase in turbidity. This impact can be mitigated somewhat by mower head settings and by care in use of the machinery.

Spartina plants killed by repeated mowing have intact (though dead) root and rhizome systems that decompose slowly. The decomposing roots and rhizomes continue to anchor sediments, especially in areas with weak or moderate tidal flows. However, erosion is more pronounced on slopes and along margins of stream banks and tidal channels. After removal by repeated mowing of a *S. anglica* stand in New Zealand, significant movement of sediment occurred, especially along channel and creek banks, which collapsed and widened (Gillespie *et al.* 1990). In a *S. anglica* marsh in Great Britain, where *Spartina* was dying back and being eroded, Gray (1991) noted higher, possibly enhanced sediment accretion rates in higher tidal zones. He attributed these findings to increased mobilization of sediments in the lower zones and indicated that a steepening of the marsh profile was an inevitable consequence of the changing sediment dynamics.

11.1.1.1.2 Topography. The mowing procedure would not cause changes in topography. However, mowing does not remove the *Spartina* root mass, which may remain intact for several years. Sediments trapped by *Spartina* may slowly erode over time, depending on soil type, localized water currents, and decomposition rate of the root mass. Atkinson (1992a) found rapid colonization of the mowed area by native marsh species, which would prevent erosion of accumulated sediments and keep the area from returning to pre-infestation elevations.

11.1.1.1.3 Unique Physical Features. Tidal channels are a unique physical feature of *Spartina* meadows, with extensive root masses stabilizing the banks of these channels. Mechanical mowing of *Spartina* plants could cause instability of these channel banks. In instances where channel banks are several feet high, mowing vehicles would be unable to drive along bank edges. *Spartina* roots would decay after mowing where exposed to oxygen along tidal channel banks. Thus, mowing would impact tidal channels by causing gradual bank erosion, making them less permanent features.

11.1.1.1.4 Erosion/Enlargement of Land Area (Accretion). Mowing activities would cause some soil disturbance, resulting in minor erosion of surface sediments. Along channel banks erosion would take place as the root mass slowly disintegrated. As banks deteriorated, erosion would continue. Bank disintegration would result in channel shifting and resultant sediment deposition in other areas.

11.1.1.2 WATER

11.1.1.2.1 Surface Water Movement /Quantity/Quality. Mowing *Spartina* would have some effect on water movement. With no *Spartina* growth in the summer after mowing, water movement would be the same as it is in the winter after *Spartina*'s annual dieback. Mowing would disturb some surface sediments that could become resuspended during subsequent tidal cycles, thus temporarily impacting water quality. Plant litter would float with the first incoming tide and be transported by wind and tides throughout an estuary.

Increased nutrient and/or decreased dissolved oxygen levels from litter decomposition may occur in areas subjected to little water exchange. These conditions, however, may be similar to those following annual dormancy periods in *Spartina* stands, when above-ground portions typically die. Oil and fuel from hand-operated motorized equipment used in cutting operations may enter waterbodies.

11.1.1.2.2 Runoff/Absorption. The mowing of *Spartina* would not directly impact runoff or absorption. Where *Spartina* meadows have infested river outlets, it is possible that high river runoff in the spring would not be hindered as it is in the presence of *Spartina*.

11.1.1.2.3 **Floods.** Although unreported, removal of *Spartina* from the banks of river mouths may reduce upstream flooding by allowing unrestricted water flow into and through the estuary.

11.1.1.3 PLANTS AND ANIMALS

11.1.1.3.1 Habitat for and numbers or diversity of species of plants, fish, or other wildlife.

11.1.1.3.1.1 ***Primary productivity.*** The component of primary production contributed by *Spartina* plants would be impacted by mowing. Because *Spartina* stands are generally monotypic, few other types of primary productivity would be impacted. In those instances where other plants exist, mowing would remove them also. Eelgrass and native salt marsh plants may recolonize after the *Spartina* has been destroyed thereby restoring some primary productivity (Atkinson, pers. comm., 1992). Mowing would also cause some turbidity due to the mowing blades cutting into the substrate. This may cause some reduction in phytoplankton productivity on a temporary basis.

11.1.1.3.1.2 ***Plants.*** Because *Spartina* frequently grows in monotypic stands there would typically be little or no impact on other plant species. In some older beds there are some dieback areas containing other salt marsh species such as pickleweed (*Salicornia spp.*) and salt grass (*Distichlis spicata*), which would be mowed. Other non-target plants, including TES species, could be impacted. There are some locations where *Spartina* competes with native salt marsh plants along the upper edge of its range, and also with eelgrass along the lower edge of its range. Removal of *Spartina* would reduce the level of primary productivity in an estuary and the subsequent yearly release of nutrients through breakdown of the plant matter. This reduction would probably be lessened by a combination of increases in productivity by eelgrass, native salt marsh species, algae and benthic diatoms invading the old *Spartina* habitat. Large wheeled mowing machines would have a varying impact on upper salt marsh plants and some upland vegetation at access locations. The number of times needed for access, wheel pressure, and sediment firmness would determine the extent of such impacts on a site by site basis.

11.1.1.3.1.3 ***Bottom dwelling organisms.*** Because mowing occurs near or below the sediment surface, it would have a direct impact on benthic epifauna and infauna, including any TES species present. Based on preliminary studies, however, there does not appear be a substantial population of benthic organisms such as shellfish, amphipods and polychaete species established in mature *S. alterniflora* marshes in Willapa Bay (Atkinson 1992b).

Invertebrates in *Spartina* marshes would be injured and/or destroyed upon direct contact with wheels and blades of mowing machines, especially when the blades cut into and slightly under the surface of the substrate. The necessity for repeated mowing over a full growing season would extend the impact over a long time period. According to A. Weigart (pers. comm. 1992), cut *Spartina* stems would most likely disperse on the first high tide. Mowed stems may float in a clump to other areas of marsh or tide flat during high tide. Then, as the tide receded, litter may cover and thus stress invertebrate animals found in these areas until decomposition and dispersal were complete. If the mowing action mulched stems into pieces, those may disperse and decompose more quickly than whole stems, but they may also be dispersed even further into native marsh areas, potentially creating a problem by covering native salt marsh plants. Decomposition of mulched material could increase suspended solids and lower dissolved oxygen levels on a localized basis, which might stress small fish and invertebrates inhabiting adjacent intertidal areas.

Soil compaction may kill infauna. Infauna and epifauna populations would be temporarily affected by changes in sedimentation and erosion, both within the area treated and at lower elevations. Sediment transported away from the site could smother infauna and epifauna.

11.1.1.3.1.4 ***Fish.*** On the East Coast, several fish species utilize *Spartina* marshes and tidal channels for habitat and cover. Studies by Allard (1991) showed utilization of *S. alterniflora* marshes in Willapa Bay by shiner surfperch (*Cymatogaster aggregata*), staghorn sculpin (*Leptocottus armatus*), surf smelt (*Hypomesus pretiosus pretiosus*), threespine stickleback (*Gasterosteus aculeatus*), northern anchovy (*Engraulis mordax*), chum salmon (*Oncorhynchus keta*) and chinook salmon (*Oncorhynchus tshawytscha*) in numbers not significantly different from utilization of open tide flats. Mowing *Spartina* may not affect the quantity of habitat for these species. Epibenthic predators such as sole or sturgeon, which may not be able to utilize the dense vegetation of a *Spartina* marsh, may regain habitat by removal of *Spartina* by mowing. However, undegraded root masses and the associated accumulated sediment are left behind in the mowing process, and may be revegetated with higher elevation vegetation before eroding back to reinfestation levels. Tide flat elevation and habitat similar to pre-infestation levels may never recur. In areas associated with active tidal flushing, fine sediments accumulated by *Spartina* may begin to erode immediately after mowing (Wiegardt, pers. comm. 1992), and root masses exposed to aerobic conditions will decay much more quickly than root masses found in highly anaerobic areas.

Mowing could cause some temporary increases in turbidity which may have a minimal impact on nearby fish spawning beds. Loss of the fine sediment trapping function of *Spartina* may allow previously trapped fine sediments to be deposited on spawning beds after mowing. Pacific herring (*Clupea harengus pallasi*) spawns on eelgrass and macroalgae at depths between extreme high tide and 11 m (33 ft) deep, relative to mean higher high water (Stevenson 1962), but herring spawning has not been documented in *Spartina* marshes. Mowed areas in the upper intertidal may be recolonized by native high marsh species, making those areas unusable for spawning fish.

11.1.1.3.1.5 *Mammals.* Mowing of *Spartina* would result in a reduction of habitat for small mammals until native vegetation recolonizes the area. *Spartina* marshes are utilized by small mammals such as shrews, voles, moles and mice during low tide as an extension to their usual upland habit just as they use native marshes. In addition, elk have been observed foraging on *S. alterniflora* in Willapa Bay (C. Samuelson, pers. comm., 1992), and this forage would be no longer available after removal of *Spartina*.

11.1.1.3.1.6 *Birds.* Washington estuaries are heavily utilized by migratory and year round shorebirds and waterfowl. Although their use of *Spartina* marshes seems very limited (Millard and Evans 1984) the activity of mowing would impact any nearby feeding, nesting or resting. The impact would vary with the type and number of mower(s) used. One hand held brush cutter would have less of an impact than several used on the same site. A large machine could have less noise impact than several small brush cutters. Another impact variable would be the length of time of the mowing activity. A hand-held cutter used on a small site for a few hours would have little impact when compared to a large machine or several hand held machines working for days or weeks on a large marsh. It has been suggested that the expanding infestation of *Spartina* is reducing the available habitat and this is actually causing a reduction in numbers of migratory and resident shorebird populations that can be supported in Willapa Bay, Padilla Bay and Grays Harbor (Goss-Custard and Moser 1988). Therefore, there may be a long term positive impact on the shorebird and migratory waterfowl populations as their habitat expands.

Mowing *Spartina* may not restore some important bird habitat in Skagit and Port Susan Bays, unless the resulting elevation could support a native bulrush marsh. Plants that would compose a bulrush marsh include three-square bulrush, *Scirpus americanus*, hardstem bulrush *S. acutus*, arrowgrass, *Triglochin martimum* and sedges, *Carex* spp. These are the preferred food sources for both greater and lesser snow geese as well as other waterfowl. Dabbling ducks also utilize bulrush seed for a significant portion of their diet. Without these food resources, snow geese would be forced to forage to a greater extent in adjacent agricultural fields where they would be vulnerable to hunting mortality. The only waterfowl which regularly utilize *Spartina* for food is the black duck *Anas rubripes*, which is rarely observed in Washington (Iten, pers. comm., 1992).

11.1.1.3.1.7 ***Fish or Wildlife Migration Routes.*** Migrating fish are thought to utilize the *Spartina* marshes during high tides to the same extent that they use the tide flats. Because mowing would be conducted at low tide, it is not expected to directly impact fish migration. Mowing would disturb sediments enough to create some short term increases in local turbidity which could stress emigrating juvenile salmon. Also, the larger machines could leave light depressions which could trap small fish. The level of these impacts would vary with the type of sediment and size and operation of machines used. Noise from mowing and vehicle presence would probably disturb migrating waterfowl and shorebirds depending on how loud it was and how long it lasted. The birds' feeding, resting, and nesting activities could be disrupted. A positive impact of the control would be the long term restoration of lost bird habitat and reestablishment of native salt marshes, eelgrass beds and native benthic and epibenthic communities.

11.1.1.3.2 Trophic Interactions. Eradication by repeated mowing would initially leave dead root and rhizome systems intact. In general, salt marsh species annually produce roots and rhizomes that equal or exceed above-ground production (Hemminga *et al.* 1988). Decay of killed *S. anglica* rhizomes and roots took 2.0-3.9 years when they were buried in soil at the sites from which they were taken. Decay took place in three phases: rapid biomass loss of the litter, active microbial decomposition, and slow decay of microbe-resistant materials. This study used experimental plots placed in living stands of *Spartina*. Thus, decay rates may vary for stands killed by mowing, which, until recolonization, lack living roots.

11.1.1.3.3 Potential for Spread of *Spartina* to Unaffected Areas. Mowing and cutting may contribute to the spread of *Spartina*. It is spread by dispersal of seed, rhizome fragments, and entire plants. Cut rhizomes may float to new sites and establish new colonies. It is essential that pulled plants and cut stems be disposed of away from estuarine habitats to prevent vegetative regrowth and/or seed dissemination. Seeds or rhizome fragments may inadvertently be redistributed within the treatment site or transported to new sites in mud attached to the footwear and clothing of workers, on cutting tools, or on vehicles and boats entering the treatment area. *Spartina alterniflora* and *S. anglica* seeds overwinter but do not persist to the following year and, therefore, do not form long-lived seed banks (Sayce 1990; Hartman 1988).

11.1.1.3.4 Human Health. Mowing requires the use of various nonmotorized or motorized equipment, such as weed trimmers. Workers could be injured by contact with the cutting surfaces of tools or by flying debris. Gas powered motors of weedeaters or push mowers may explode or catch fire. The possibility of worker injury is heightened as the size of the work crew increases and as the crew's work is performed in concentrated areas.

Workers walking on soft substrates may use "mudluks," which attach to boots to increase surface area contact with the substrate. These are made from tire innertubes attached to a support. They require the user to walk with legs spread more widely than customary and may stress leg joints after prolonged use. Workers may become stuck in deep, soft sediments if improperly equipped and be exposed to cold temperatures or incoming tides. When temperatures and humidities are high, workers may experience increased fatigue, heat exhaustion or stroke, and heart or respiratory problems. Certain individuals may experience allergic reactions upon contact with pollen produced by *Spartina* or other plants in the habitat.

11.1.2 BUILT ENVIRONMENT

11.1.2.1 LAND AND SHORELINE USE

11.1.2.1.1 Aesthetics. The mowing process would impact the aesthetics of the area because of the intrusion of noisy machines into a quiet, natural setting. The impact would vary with the length of the operation, frequency, and proximity to homes, recreation areas and view points. Manual removal or cutting may have either a positive or negative impact on aesthetics, depending upon the attitude of the observer. *Spartina* clumps or larger colonies would be replaced by mud patches, which would temporarily have uneven, possibly unattractive surfaces. The patches would either blend in with continuous mud flats or contrast with vegetated marshes. The visual appeal of sites currently infested with *Spartina* would be increased for those people who prefer appearances of natural settings. Increased *Spartina* litter floating on the water or washed ashore may diminish aesthetic quality.

11.1.2.1.2 Recreation. Access to, use of, or quality of recreation sites would not be permanently impacted, although access to beaches and mudflats may be temporarily restricted. Beach areas would ultimately be improved for walking, bird watching, hunting, and shellfish harvesting. In areas where *Spartina* colonies have accreted sediments to the extent that boating is curtailed, *Spartina* removal may eventually result in the reestablishment of boating areas. Floating debris may become tangled in fishing nets or outboard motor propellers.

11.1.2.1.3 Historic and Cultural Preservation. Subsidence has submerged archeological sites in some areas. Some of these areas may currently be vegetated with *Spartina*. Mowing control measures could potentially disturb or destroy unidentified cultural resources on or near the soil surface. The extent of the damage would depend on operator sensitivity to this issue and the size and contents of the site. Historic or cultural sites should be identified during the design of a dredging project.

11.1.2.1.4 Agricultural/Aquacultural Crops. Total eradication of *Spartina* populations would eliminate potential agricultural uses of the plants in Washington. Spartina is grazed by livestock in parts of the world (Doody 1990). *S. x townsendii*, and probably other species as well, have potential for cropping as silage (Hubbard and Ranwell 1966). In England, *S. anglica* has been studied for use in methane generation or production of gases, tars, or char (Scott *et al.* 1990). It has also been used as packing for shipping oysters and, locally, for making paper. In Willapa Bay, Andrew Wiegardt (pers. comm., 1992) has been experimenting with producing hand-made paper from *S. alterniflora*. Aerial portions of plants are harvested with a line trimmer, shredded, and boiled to produce a pulp suspension. Tests conducted by Georgia Pacific showed that pulp content and fiber quality of *S. alterniflora* are comparable to or better than most wood pulp (Wiegardt, pers. comm., 1992). Other potential products include mats for erosion control, room dividers, flooring, and baskets (Wiegardt, pers. comm., 1992; Stiles undated).

Any increased turbidity caused by mowing could impact adjacent oyster or clam beds. The extent of the impact would vary with the nature of the sediment and type of mowing activity and therefore the potential levels of turbidity. Sandy sediments would not release as much fine material as silt and clay sediments. A large mower would tend to disturb the sediments more than the hand held cutters. Sediment redeposition on oyster or clam beds may have detrimental effects. Way (1987) reported a case in which oyster beds were smothered by sediments that may have come from mudbanks of recently eradicated *Spartina*. Other effects would be similar to those occurring in the natural environment.

Spartina colonies used for grazing, sources of paper fiber, or other agricultural purposes would be harmed by control measures. In addition, *Spartina* has detrimental effects on oyster and clam beds because of accretion of fine sediments and formation of dense root mats. Therefore, removal of *Spartina* could increase available habitat for aquaculture. However, mowed stems and leaves that are washed out to open water may foul fishing nets.

11.1.2.2 TRANSPORTATION

There are no anticipated impacts on transportation systems from mowing activities.

11.1.2.3 MAINTENANCE PRACTICES

Mowing *Spartina* typically should not adversely impact maintenance practices in built environments. If *Spartina* is providing beach stabilization, alternative shoreline stabilization measures would be required upon its removal. Practices could be incorporated into existing maintenance and beautification programs to help prevent *Spartina* establishment or spread.

11.1.3 ECONOMIC IMPACTS

The mowing activity could impact the oyster and clamming industries due to the potential of increased turbidity levels slowing down oyster growth. Commercial fishing could also be slightly affected by increased turbidity levels. Other nearby land based economic activity would not be impacted by the mowing activity.

11.1.4 CUMULATIVE IMPACTS

Significant cumulative effects of mowing extensive *Spartina* colonies in bays or enclosed waterways include negative impacts to non-target biota, especially TES species (if present), whose populations may suffer long-term declines. Recreation and tourism could be impacted due to floating litter, noise from motorized mowing devices, and exclusion from areas undergoing control treatments. Sediment dynamics may be altered, with positive or negative affects. Repeated entry by workers and repeated pulling or digging treatments could produce substantial habitat disturbance and lead to increases in water turbidity and soil compaction.

Positive cumulative effects of controlling *Spartina* by hand pulling and/or cutting would occur from the on-site reestablishment of desirable habitats. Wildlife habitat, scenic vistas, and recreational opportunities would be benefitted by site rehabilitation.

11.1.5 IMPACT MITIGATION

To mitigate potential impacts of mowing several actions could be taken, including but not limited to:

1) Installing noise controls on machinery;
2) Constraining operations to minimize turbidity;
3) Avoiding impacting adjacent native vegetation with trampling or cutting;
4) Timing mowing to avoid periods of peak bird migration;
5) Timing mowing to avoid heavy public use periods, including holidays and weekends;
6) Avoiding mowing during critical bivalve early life history stages (larval and early juvenile), when increased turbidity may hinder feeding and retard growth;
7) Examining each site for TES species before mowing; enhance habitats to encourage TES species, if these occur in the vicinity;
8) Cleaning footwear and vehicles befor leaving site, to avoid spread of infestation;
9) Wearing mudluks on soft sediments to minimize soil disturbance;
10) Inspecting for and remove propagules during different times in the tidal cycle; contain all floating propagules with containment booms;
11) Mitigating negative perceptions of mowing with public education programs and signs;
12) Operating, maintaining and fueling vehicles so as to minimize the likelihood of leakages or spills of oil, fuel and hydraulic fluid into intertidal areas.

11.2 PURPLE LOOSESTRIFE

11.2.1 NATURAL ENVIRONMENT

11.2.1.1 EARTH

11.2.1.1.1 Soil. Removal of solid stands by hand mowing may cause small, short-term increases in surface erosion, particularly along stream banks and shorelines, until vegetation reoccupied treatment sites. In flowing water habitats, plant removal may also decrease sedimentation rates. Mechanical mowing would impact soils to varying degrees, depending on the type of machine used, the type of soil, and the hydrologic regime. Any type of heavy machinery would compact the soil, but the degree of adverse impacts would vary. Organic soils are likely to suffer the most damage from compaction. Compaction of organic soils may also change the hydrologic regime from saturated to flooded or ponded. Changes in the hydrologic regime has been shown to change species composition in organic soil systems (Fred Weinmann, pers. comm., 1992). Other, more dense, soils types would be more likely to support the weight of machinery without extensive compaction. Each affected soil would have to be evaluated separately prior to mowing for a full review of potential adverse impacts.

11.2.1.1.2 Topography. Mowing is not expected to alter the topography except in those systems which are vulnerable to extensive soil compaction.

11.2.1.1.3 Erosion/enlargement of Land Area (Accretion). Mowing would uncover soils normally protected by vegetation. These soils would then be exposed to erosive forces (rain, wind). However, it is not expected that these impacts would be extensive, as the root structure of loosestrife would provide some protection from major erosion. In addition, mowing is more likely to occur during the spring and summer months, when damaging storm events are less likely to occur (R. Leonard, pers. comm., 1992).

11.2.1.2 WATER

11.2.1.2.1 Surface water Movement /Quantity /Quality. Hand cutting has a low potential for adverse impacts on water resources. In some habitats, a localized, short-term increase of surface water turbidity may occur upon uprooting the plants. Increased nutrient and/or decreased dissolved oxygen levels would not develop if the excised plant biomass is removed from the treatment area. Plant removal would also increase surface water volume since evapotranspiration rates would be reduced. Oil and fuel from motorized hand-held equipment (e.g., weedeaters) used in cutting operations could enter waterbodies.

Adverse effects from mowing on surface water characteristics would be dependent upon the time of year of the mowing and the location of the affected environment. If mowed sites are located in or closely adjacent to water bodies, then increases in turbidity (from surface disturbance), suspended particulate matter (plant parts), biological oxygen demand, and the release of decomposition by-products of the materials (nutrients, etc.) would all have localized temporary negative effects on water quality. However, these are likely to be of short duration and of minimal long term impact, unless the receiving water is already severely stressed.

11.2.1.2.2 Floods. Flow rates in streams, rivers, and irrigation waterways and current patterns in ponds and lakes would be increased by the physical removal of purple loosestrife. The removal of above ground plant matter would reduce the ability of the remaining vegetation to slow flood waters. This may be of critical importance to large systems that are in or adjacent to floodways. However, impacts are likely to be very localized and of minimal import.

11.2.1.3 PLANTS AND ANIMALS

11.2.1.3.1 Habitat for, and numbers or diversity of species of plants, fish, or other wildlife. The plant community structure for purple loosestrife varies, dependent upon the age of the plants and their location. Although there is little information for monospecific stands, the habitat value is considered minimal due to its density and the lack of use of the plant as a food source by consumers (Perry, pers. comm.,1992). Preliminary observations indicate that where loosestrife grows next to wetlands with a mixture of native plants there is a significant decrease in the number and diversity of birds using purple loosestrife when compared to the native vegetation (Leonard, pers. comm., 1992). The habitat value of loosestrife in a more varied plant community is unknown, but likely similar to monospecific stands.

Mowing of loosestrife may have a positive impact by controlling its spread into more productive systems, and by opening up habitat for colonization by more valuable species. However, colonization of more beneficial species could not occur until the loosestrife was completely eradicated, as it is such a competitive colonizer.

Potential impacts on other plants or animals could not be determined due to lack of information.

11.2.2 BUILT ENVIRONMENT

11.2.2.1 LAND AND SHORELINE USE

Mowing is likely to have a negative temporary aesthetic impact due to the noise of any machinery and the removal of vegetation from wetland systems. The impact would vary with the length of the operation, number of mowing events, and its proximity to homes, recreation areas and view points. Mowing may also distress members of the public who may view it as destruction of wetland resources.

11.2.3 ECONOMIC IMPACTS

It is anticipated that there would be no economic impacts from mowing purple loosestrife.

11.2.4 CUMULATIVE IMPACTS

Adverse environmental impacts are likely to be short term in duration, relatively minor, limited in extent, and mitigated by best management practices and careful consideration of the impact site. Long term results would be the reduction in the spread of loosestrife and restoration of wetlands to more beneficial habitats.

11.2.5 IMPACT MITIGATION

These impacts may be mitigated by noise controls, timing of the activity around heavy public use periods, public information and education programs, and informational signs at the site.

11.3 GARDEN LOOSESTRIFE

11.3.1 NATURAL ENVIRONMENT

Where garden loosestrife occurs in wet areas, soils would be slightly disturbed during mowing. Since infestations in Washington are presently small and few in number there would probably not be any direct negative impacts on wildlife. Eradication of garden loosestrife would create an opportunity for native plants to recolonize or be replanted and thus enhance the local habitat. There would be a temporary impact on wildlife in the area due to the increase in noise.

11.3.2 BUILT ENVIRONMENT

There would be a temporary increase in noise during mowing. This may take place more than once since repeated treatments may be necessary.

11.3.3 IMPACT MITIGATION

To minimize noise impacts, mowing should take place only during normal working hours. The noise impact on wildlife could be mitigated by using noise controls and avoiding critical life history periods.

11.4 GIANT HOGWEED

Environmental impacts to natural, agricultural, and built environments due to giant hogweed control measures would be negligible.

11.4.1 NATURAL ENVIRONMENT

Soils may be compacted due to increased foot traffic. Soils would be slightly disturbed where giant hogweed is found in wet soils. Water quality may be affected if plants are improperly disposed of and air quality may be locally affected due to odors from rotting vegetation. Plant debris may be toxic to some organisms. Giant hogweed infestations are few in number in Washington and removing them would probably not noticeably affect wildlife. The noise of mowing would temporarily impact any wildlife in neighboring areas. Once the weeds were removed, an area could be returned to native habitat.

Giant hogweed produces contact dermatitis in susceptible individuals (Camm *et al.* 1976), resulting in photodermatis, which sensitizes the skin to ultraviolet light (Wright 1984). Dermatitis (strimmer dermatitis) associated with use of weed wackers on vegetation that included giant hogweed has been reported (Reynolds *et al.* 1991). The use of a brush cutter, push mower or tractor mounted mower would pose a health hazard to the machinery operator, bystanders and people cleaning up plant cuttings. Hospital stays have resulted from mowing giant hogweed (Reynolds *et al* 1991).

Cutting back the plant after seeds have matured could result in seed dispersal (Hyypio and Cope 1982). Improper disposal of plants may spread infestations.

11.4.2 BUILT ENVIRONMENT

Aesthetics would be temporarily diminished from habitat disturbance. There would be a temporary increase in noise during mowing. Any people near the site should be moved away to avoid being hit by flying pieces of giant hogweed. People and pets should be kept from the site until plant material is removed or allowed to dry.

11.4.3 IMPACT MITIGATION

Seed dispersal should be minimized by cutting plants before seeds have matured. Plants should be disposed of in a manner that would prevent plant dispersal and adverse impacts to air and water quality.

Workers should be properly clothed and should take measures to avoid contact dermatitis from exposure to giant hogweed. Sap should be washed off skin with soap and water as soon as possible.

11.5 INDIGO BUSH

11.5.1 NATURAL ENVIRONMENT

Soils would be disturbed by the large vehicles necessary for mowing indigo bush. The extent of this impact would vary with the type of soil and slope of the terrain. Wildlife use of indigo bush stands has not been documented and therefore direct impacts are unknown. Increased noise associated with mowing would disturb any nearby wildlife.

11.5.2 BUILT ENVIRONMENT

There would be an increase in noise during mowing activity but few people inhabit areas currently infested in Washington and this impact would be minimal. Mowing noise could disturb people in the area for recreational purposes.

11.5.3 IMPACT MITIGATION

Noise controls are advised as well as scheduling work to avoid critical life history stages for wildlife. Replanting the sites with native plants would have a positive impact by restoring native habitat lost to indigo bush. Seed dispersal should be minimized by cutting plants before seeds have matured. Plants should be disposed of in a manner that would prevent plant dispersal and adverse impacts to air and water quality. Work should avoid heavy recreational use periods.

12.0 IMPACTS OF HARVESTING

In the analysis of efficacy, harvesting was considered a feasible control method only for *Spartina,* and thus harvesting impacts are evaluated only for *Spartina* species.

12.1 *SPARTINA*

12.1.1 NATURAL ENVIRONMENT

12.1.1.1 EARTH

12.1.1.1.1 Soil. *Spartina* spp. occur on silt, clay, sand and gravel substrates. The *Spartina* root mass helps form a firm substrate even when sediment is soft. Using a tractor/mower would impact the sediments through compaction and disturbance, and resultant increase in localized turbidity. The use of hand held brush cutters would impact soils less, because workers would walk on mats of clippings. An aquatic plant harvester would disturb sediments if the cutter blades hit bottom, and in shallow water the paddle wheels would stir up bottom sediments.

12.1.1.1.2 Topography. The harvesting process itself would not be expected to result in any significant changes in project area topography. *Spartina* would continue to trap sediments during periods of growth, and harvested beds would accrete enough sediment to continue spreading vegetatively. Changes in topography in this case would parallel those expected under the no action alternative.

12.1.1.1.3 Unique Physical Features. Mature *Spartina* marshes have well established tidal channels, as the *Spartina* root mass stabilizes channel banks. Harvesting *Spartina* would not impact the channel stability, because the root mass and some above ground stem remains.

12.1.1.1.4 Erosion/enlargement of Land Area (Accretion). Because harvesting is designed to leave the entire root mass and some stem intact, only minor and short-term erosion is expected to occur.

12.1.1.2 WATER

12.1.1.2.1 Surface water Movement /Quantity /Quality. Harvesting *Spartina* would have only a minor, short-term effect on water movement. Water movement patterns are affected by *Spartina* marshes, which slow down water movement. Because, with harvesting, the plants would not be allowed to remain at full height during the second half of the growing season, water movement would be comparable to water movement during winter and spring, before annual growth begins. Water quality is not expected to be significantly impacted by the harvesting of *Spartina*. Only localized short-term increases in turbidity is expected.

12.1.1.2.2 Runoff/Absorption. Harvesting of *Spartina* is not expected to have any significant impacts on local runoff or absorption functions.

12.1.1.2.3 Floods. Harvesting of *Spartina* is not expected to have any substantive impacts on project area flood potential or events.

12.1.1.3 PLANTS AND ANIMALS

12.1.1.3.1 **Habitat for, and numbers or diversity of species of plants, fish, or other wildlife.**

12.1.1.3.1.1 ***Primary productivity.*** The harvesting of *Spartina* would immediately remove the products of primary production from the local nutrient cycle, with potentially negative results. On the other hand, Marinuci (1982) stated that *Spartina* acts as a nutrient sink, and its importance to overall primary production of an estuary can, in general, be very low. If harvesting was successful, *Spartina* plants would become more vigorous and primary productivity would increase. As in crop farming, there could be a loss of nutrients from the overall system over the long term.

12.1.1.3.1.2 ***Plants.*** Large, accessible monotypic *Spartina* marshes would typically be chosen for harvesting, primarily for economic reasons. However, the aquatic weed harvester could harvest even small new clones of *Spartina*, which would minimize impacts on other plant species. Other salt marsh plants that inhabit dieback areas in the *Spartina* marshes are typically much shorter and would probably not be substantially impacted by the harvesting process. However, more substantive impacts would occur to higher marsh plants and upland plants where access to *Spartina* is only available over undisturbed vegetation. Also, because *Spartina* grows vegetatively via rhizomes, harvested marshes would continue to slowly invade new tide flats unless other control measures were put in place.

12.1.1.3.1.3 ***Bottom dwelling organisms.*** Harvesting of *Spartina* would have only minor impacts on bottom dwelling organisms. Of the three harvesting methods, the tractor/mower would be most damaging due to crushing effects of the wheels. Continuous harvesting at a rate of two harvests per year would probably not allow full reestablishment of a benthic community between harvests. Estuary-wide, the impacts could be considered relatively minor as there appear to be relatively few benthic organisms that inhabit west coast *Spartina* marshes (Atkinson, pers. comm.). Further study on habitat value of *Spartina* for native benthic organisms is needed to clarify these impacts.

12.1.1.3.1.4 ***Fish.*** Harvesting would be expected to have only minimal impacts on fish habitat and/or behavior. Tire depressions from the tractor/mower, if sufficiently deep, could cause small fish to be trapped at low tide, leaving them vulnerable to predation. Even with slight alterations of habitat from harvesting, available data suggests many species of resident fish utilize unvegetated mud flat as much as *Spartina* marshes and therefore, depending on the species, would not be significantly impacted by the harvesting process. There is a potential for an aquatic harvester to kill small fish that get caught in the plants being harvested.

12.1.1.3.1.5 ***Mammals.*** *Spartina* marshes are utilized by small mammals such as shrews, voles, moles and mice at low tide as an extension to their usual habitat, just as they use native marshes. Harvesting would temporarily reduce available cover until the grass grows back. Repeated harvesting may not allow recuperation of the benthic community, on which the mammals feed, and thus a harvested *Spartina* bed would not support the number of small mammals supported in a mature *Spartina* or native marsh. This impact would probably not substantially reduce numbers of small mammals since the marsh is not their primary habitat.

12.1.1.3.1.6 ***Birds.*** Washington estuaries infested with *Spartina* are heavily utilized by migratory and resident shorebirds and waterfowl. There are indications that invading *Spartina* is reducing prime habitat for these birds, namely the open tideflats. The process of harvesting would slow the spread of *Spartina* by reducing seed production, but it would not restore substantial areas of lost bird habitat. Harvesting activities would temporarily impact birds because of noise level increases and general corruption in the treatment area. After harvesting and before the plants have regrown, the cut marshes might be suitable feeding habitat for great blue herons and other waterfowl.

12.1.1.3.1.7 ***Fish or Wildlife Migration Routes.*** It is not anticipated that harvesting would have any significant impacts on fish or waterfowl migration routes. Because harvesting would occur only once or twice a year, it could be timed to avoid critical juvenile salmonid downstream migratory periods. Similarly with birds, sensitive shore bird or waterfowl migratory periods should be avoided. With little or no impact of soils or water quality, the only disturbance would be a temporary increase in noise levels.

12.1.2 BUILT ENVIRONMENT

12.1.2.1 LAND AND SHORELINE USE

12.1.2.1.1 Aesthetics. Harvesting would negatively impact area aesthetics due to noise intrusion into natural settings. Because the process would only occur once or twice per year, these impacts would be minimal. Harvesting could be seen by people as the degradation of a natural wetland, and public information and education would probably be essential to explaining the program.

12.1.2.1.2 Recreation. Harvesting is not expected to impact recreation except for short-term distractions during sightseeing and bird watching.

12.1.2.1.3 Historic and Cultural Preservation. Harvesting could potentially disturb or destroy unidentified cultural resources by changing erosion patterns, but this effect is not expected to be significant.

12.1.2.1.4 Agricultural/Aquacultural Crops. Harvesting of *Spartina* would not take place in areas currently under agricultural/aquacultural cultivation. This control method would produce an agricultural/aquacultural product in its own right. *Spartina* has been successfully used to make a pulp that can be made into paper.

The slight turbidity caused by harvesting could impact adjacent oyster or clam beds.

12.1.2.2 TRANSPORTATION

There would be no substantive, long-term impacts on transportation, as the increased traffic due to trucks hauling the crop to a processor would be only incremental, and minor, in nature.

12.1.3 ECONOMIC IMPACTS

Harvesting would beneficially impact, to a small degree, the economy of any project area. The extent of impacts would depend on the size and frequency of the harvesting operation, and location of the processing plant. Currently, efforts are underway in Pacific County to develop markets for *Spartina* pulp for specialty papers, and to begin a demonstration project to determine its potential as an ingredient in basic paper (A. Wiegardt, pers.comm).

12.1.4 CUMULATIVE IMPACTS

Because most of the potential impacts of harvesting *Spartina* are minor, there would be no major contribution to cumulative impacts in any project area, except for short-term increases in noise and human intrusion into natural systems and settings.

12.1.5 IMPACT MITIGATION

To mitigate potential impacts of harvesting *Spartina* several actions could be taken, including but not limited to:

1) Installing noise controls on machinery;
2) Constraining operations to minimize turbidity;
3) Avoiding impacting adjacent native vegetation;
4) Timing harvesting to avoid periods of peak bird migration;
5) Timing harvesting to avoid heavy public use periods, including holidays and weekends;
6) Cleaning vehicles befor leaving site, to avoid spread of infestation;
7) Containing all floating propagules with containment booms;
8) Mitigating negative perceptions of harvesting with public education programs and signs;
9) Operating, maintaining and fueling vehicles so as to minimize the likelihood of leakages or spills of oil, fuel and hydraulic fluid into intertidal areas.

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REQUIRED FEDERAL AUTHORITIES FOR EMERGENT NOXIOUS WEED CONTROL

REQUIRED FEDERAL AUTHORITIES FOR EMERGENT NOXIOUS WEED CONTROL

TABLE OF CONTENTS

1.0 Introduction

This section presents specific Federal authorities, regulations, and policies that would need to be followed with implementation of an emergent noxious plant management plan involving physical, mechanical and/or biological control methods. Application to the Corps of Engineers is required for any state or local agency planning control of emergent noxious weeds.

2.0 Section 10 of the Rivers and Harbors Act of March 3, 1899, (33 U.S.C. 403) and Section 404 of the Clean Water Act (33 U.S.C. 1344).

2.1 Agency with authority: Army Corps of Engineers

2.2 Authority. Section 10 generally requires a Corps of Engineers permit for structures and/or work in or affecting navigable waters of the United States (Reference 33 CFR 322.3). For non-tidally influenced navigable waters, Corps jurisdiction extends to the Ordinary High Water (OHW) mark (33 CFR 329.11). This includes the construction of any structure in or over any navigable water of the United States, the excavating from or depositing of material in such waters, or the accomplishment of any other work affecting the course, location, condition, or capacity of such waters. The Corps' decision whether to issue a permit is based on an evaluation of the probable impacts, including cumulative impacts, of the proposed activity and its intended use on the public interest. That decision will reflect the national concern for both protection and utilization of important resources. The benefit which reasonably may be expected to accrue from the proposal must be balanced against its reasonably foreseeable detriments. The Corps considers three general criteria in the evaluation of every application: (1) the relative extent of the public and private need for the proposed structure or work; (2) where there are unresolved conflicts as to resource use, the practicability of using reasonable alternative locations and methods to accomplish the objective of the proposed structure or work; and (3) the extent and permanence of the beneficial and/or detrimental effects which the proposed structure or work is likely to have on the public and private uses to which the area is suited.

Section 404 generally requires a Corps of Engineers permit for the discharge of dredged or fill material into waters of the United States, including adjacent wetlands. The selection and use of disposal sites will be in accordance with guidelines developed by the Environmental Protection

Agency (EPA) in conjunction with the Secretary of the Army. The Corps' decision whether to issue a permit is based on an evaluation of the probable impacts on the public interest as stated above for Section 10, as well as on application of the guidelines promulgated by EPA, otherwise referred to as the Section 404(b)(1) guidelines (40 CFR, Part 230). Discharge of dredged or fill material in jurisdictional wetlands is especially important under this Act. Corps of Engineer regulations state that wetlands constitute a productive and valuable public resource, the unnecessary alteration or destruction of which should be discouraged as contrary to the public interest. These regulations further state that (1) wetlands perform several functions important to the public interest, (2) although a particular alteration of a wetland may constitute a minor change, the cumulative effect of numerous piecemeal changes can result in a major impairment of wetland resources, and (3) no permit will be granted which involves the alteration of wetlands identified as important unless the Corps concludes based on the very extensive and complex 404(b)(1) evaluation that the benefits of the proposed alteration outweigh the damage to the wetlands resource. Section 404 of the Clean Water Act requires the Corps to evaluate the proposed discharge of dredged material into waters of the United States, including adjacent wetlands, in accordance with the Section 404(b)(1) guidelines. These guidelines require that the following four conditions be met before a Section 404 permit may be issued:

(1) There is no other practicable alternative that would have less adverse impact on the aquatic environment;

(2) The disposal, after consideration of dispersion and dilution, will not cause or contribute to violations of applicable water quality standards; will not violate any applicable toxic effluent standards; nor will it jeopardize the continued existence of threatened or endangered species; nor will it violate any requirement to protect marine sanctuaries;

(3) The disposal will not cause or contribute to significant degradation of waters of the United States; and

(4) All appropriate and practicable steps have been taken to minimize potential adverse impacts of the discharge on the aquatic environment (Reference 40 CFR 230.10).

2.3 Application to Physical and Mechanical Control Methods for *Spartina* spp.

2.3.1 Dredging. Since dredging would occur in navigable waters of the United States, including adjacent wetlands, a standard individual permit would be required in accordance with

Section 10. Nationwide Permit No. 19, Minor Dredging, for dredging of less than 25 cubic yards as part of a single and complete project would not apply since the activity would occur in wetlands.

As long as the dredged material was not placed in waters of the U.S. or adjacent wetlands, the activity would not be subject to Section 404 and its 404(b)(1) evaluation.

2.3.2 Digging/Excavation. A standard individual permit per Section 10 would be required. As with dredging, excavation of quantities less than 25 cubic yards would not fall under Nationwide Permit No. 19. If the excavated material were placed in waters of the U.S. and/or its adjacent wetlands, the project would be under the jurisdiction of Section 404 and a 404(b)(1) evaluation would be required.

2.3.3 Mowing. The actual cutting process is exempt from Section 10, however, placement of markers (stakes, piling, et cetera) to delineate project boundaries would require Section 10 permit. If the project was minor in nature, only a Letter of Permission would be required. If substantive, the project could require a standard individual permit per Section 10. This method would not fall under Section 404.

2.3.4 Diking and Flooding. Construction of dikes to control *Spartina* would require a Corps permit under authority of Section 10, if any work was performed in a navigable waterway, and under authority of Section 404 if dredged or fill material was placed in a water of the United States or adjacent wetlands. This would require a rigorous evaluation per Section 404 (b)(1) of the Clean Water Act. A Corps 404 permit would not be required for any diking material placed on uplands adjacent to or surrounding a *Spartina* marsh.

2.3.5 Bottom barriers. Utilization of bottom barriers composed of fabric or plastic materials to cover *Spartina* marshes for extended periods of time would require a Corps of Engineers permit under Section 10 if the barriers would be anchored by stakes or other structures in navigable waters below the OHW line. If the utilization of anchoring structures is considered minor, only a Letter of Permission will be required. Section 404 would likely not apply as this method would not appear to involve placement of dredged or fill material to fulfill its purpose.

2.4 Application to Physical and Mechanical Control Methods for Noxious Emergent Freshwater Weeds.

2.4.1 Hand Cutting. Cutting the various freshwater plants at ground level utilizing any hand-held implement would require a permit if the cutting occurred below the ordinary high water mark (OHW) in certain large lakes and if markers were placed to delineate project boundaries. Lakes in Washington in which Section 10 jurisdiction applies are: Lake Washington, Lake Chelan, Lake Sammamish, Lake Union, Drano Lake (Skamania County), and Vancouver Lake. This method is currently not considered under the jurisdiction of Section 404 of the CWA.

2.4.2 Digging/Excavating. Scraping or excavation of noxious emergent plants would require a permit under Section 10 if the action occurred below the OHW mark in certain lakes (see **Hand Cutting** above) or if markers were placed to delineate project boundaries. If the action was conducted in a wetland and soil was removed, this would be considered "land clearing" and would be under the jurisdiction of Section 404 of CWA. The type of 404 permit would be determined by the size of the work. If the work extended over an area less than two acres, it would likely qualify under Nationwide Permit (NWP) No. 26 (NWP 26 appears as Appendix X). An excavation project over two acres of wetlands would require a standard individual permit under the Section 404 jurisdiction. Any scraping or excavation in upland areas would require no Corps of Engineers permit. A 404 permit would also be required if a temporary access road was constructed to the project site, using fill material placed on jurisdictional wetlands.

2.4.3 Dewatering. This method involves lowering water levels in an area infested with emergent noxious weeds.. This would likely be accomplished by discharging extra quantities of water through or by existing dams or other water control structures. This would not require a Corps permit under either Section 10 or Section 404, unless markers were placed below the ordinary high water line to delineate project boundaries, which would require a Section 10 permit, probably in the form of a Letter of Permission.

2.4.4 Burning. This method would only require a Corps permit under Section 10 if stakes or other marking structures were placed to delineate project boundaries and these markers were placed below the ordinary high water line. Presuming this action would be considered a minor action by the Corps, only a Letter of Permission would be required.

2.4.5 Bottom barriers. Utilization of bottom barriers composed of fabric or plastic materials to cover noxious weeds for extended periods of time would require a Corps of Engineers permit under Section 10 if the barriers would be anchored by stakes or other structures in areas below the ordinary high water line. If the utilization of anchoring structures is considered minor, only a Letter of Permission will be required. Section 404 would probably not apply as this method would not normally involve placement of dredged or fill material in a water of the United States or any adjacent wetlands.

2.5 Application to Biological Control Methods for *Spartina*. A permit would be required under Section 10 if markers (stakes, pilings, et cetera) were used to delineate project boundaries below the OHW line. This action would probably not require a permit under the authority Section 404, provided no dredged or fill material were placed in wetlands adjacent to waters of the United States for such activities as temporary road access.

2.6 Application to Biological Control Methods for Freshwater Noxious Emergent Plants. See Paragraph E. above.

3.0 Coastal Zone Management Act (CZMA) of 1972 (Public Law 92-583) as amended

3.1 Agency with authority: NOAA, delegated to Washington State (any agency).

3.2 Authority. The Coastal Zone Management Act as amended requires that applicants for federal permits for activities directly affecting a state's coastal zone to comply to the maximum extent practicable with the enforceable policies of approved state coastal zone management programs. The Act also requires any non-federal applicant for a federal permit to conduct an activity affecting land or water uses in the state's coastal zone to furnish a certification that the proposed activity will comply with the state's coastal zone management program. In Washington, the basis for coastal zone management is the Washington State Shoreline Management Act of 1971 and the local Shoreline Master Program (SMP). The CZMA declares a "national interest in the effective management, beneficial use, protection, and development of the coastal zone. Important ecological, cultural, historic, and aesthetic values in the coastal zone which are essential to the well-being of all citizens are being irretrievably damaged or lost." The Act requires a planning process for the protection of public coastal areas of environmental, recreational, historical, aesthetic, ecological, or cultural value.

3.3 Application to Mechanical Control Methods. Any selected mechanical control methods would need to be fully consistent with the state CZM program.

3.4 Application to Biological Control Methods. See 3.2 above.

4.0 Endangered Species Act of 1973, as Amended, 16 U.S.C. 1531 *et. seq.*

4.1 Agency with authority: Army Corps of Engineers, U.S. Fish and Wildlife Service, National Marine Fisheries Service.

4.2 Authority. The Endangered Species Act (ESA) declares the intention of the Congress to conserve threatened and endangered species and the ecosystems on which those species depend. The act requires that federal agencies (the Corps of Engineers in the case of a permit application to the Corps), in consultation with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, use their authorities in furtherance of its purposes by carrying out programs for the conservation of endangered or threatened species, and by taking such action necessary to insure that any action authorized, funded, or carried out by the Agency is not likely to jeopardize the continued existence of such endangered or threatened species or result in the destruction or adverse modification of habitat of such species which is determined by the Secretary of the Interior or Commerce, as appropriate, to be critical (33 CFR 320.3(i)).

4.3 Application to Physical and Mechanical Control Methods. All projects involving mechanical control methods that would require a Corps of Engineers permit under Section 10 or Section 404 are subject to the Endangered Species Act. Required coordination between Federal agencies will determine if any endangered or threatened species or their critical habitat are present in the project areas. If so, the Corps of Engineers will be required to prepare a biological assessment that evaluates if the control methods in that area would have significant impacts.

4.4 Application to Biological Control Methods. See 4.2 above.

5.0 The National Historic Preservation Act of 1966 (16 U.S.C. 470)

5.1 Agencies with authority: Advisory Council on Historic Preservation; U.S. Department of the Interior, National Park Service.

5.2 Authority. This act created the Advisory Council on Historic Preservation to advise the President and Congress on matters involving historic preservation. In performing its function, the Council is authorized to review and comment upon activities licensed by the Federal Government which will have an effect upon properties listed in, or eligible for listing in, the National Register of Historic Places or eligible for such listing. The concern of Congress for the preservation of significant historical sites is also expressed in the Preservation of Historical and Archeological Data Act of 1974 (16 U.S.C. 469 et seq.). By this Act, whenever a federally licensed project, activity, or program alters any terrain such that significant historical or archeological data is threatened, the Secretary of the Interior may take action necessary to recover and preserve the data prior to the commencement of the project.

This act requires early coordination with the Advisory Council on Historic Preservation, appropriate State historic preservation officers, the National Park Service, Indian Tribes, and other appropriate groups with cultural resources expertise.

5.3 Application to Mechanical Control Methods. If any mechanical control project is deemed to have an effect on any properties listed in the NRHP, or may alter any terrain such that significant historical or archeological data is threatened, appropriate steps will be necessary to coordinate with the Advisory Council on Historic Preservation, the SHPO, Indian Tribes, and other agencies with cultural resources expertise/jurisdiction as appropriate, so that a program for recovery and preservation of materials is established.

5.4 Application to Biological Control Methods. Not applicable.

6.0 Federal Plant Pest Act of 1957, as amended (7 U.S.C. 150 *et seq.*).

6.1 Agency with authority: U.S. Department of Agriculture

6.2 Authority. No plant pest from a foreign country shall be moved into or through the United States, or interstate, unless such movement is authorized under general or specific permit from the Secretary of Agriculture and is made in accordance with such conditions as the Secretary may prescribe in the permit and in such regulations as he may promulgate under this section to prevent the dissemination into the United States, or interstate, of plant pests. The Secretary of Agriculture may refuse to issue a permit for the movement of any plant pest when, in his opinion, such movement would involve a danger of dissemination of such pests.

6.3 Application to Mechanical Control Methods. Not applicable.

6.4 Application to Biological Control Methods. Any shipment of a control agent (plant pest) must be authorized by permit from the Secretary of Agriculture. Typically, after overseas research has earmarked a specific control agent, a request is made to the U. S. Department of Agriculture, Plant Protection and Quarantine (PPQ), Animal Plant Health Inspection Service (APHIS) Technical Advisory Group (TAG) on Biological Control of Weeds to have the agent introduced into a quarantine facility. If approval is received, the agents are shipped to a U.S. quarantine facility where intensive host specificity testing is conducted and studies are performed to determine other key preferences factors of the agent. If the agent is specific to only the target plant, a petition to release the agent is requested from the USDA-APHIS-PPQ. If the agent is approved for release, the Washington State Department of Agriculture (WSDA) will issue a release permit.

7.0 Federal Noxious Weed Act of 1974, Public Law 93-629 (7 U.S.C. 2801 *et seq.*)

7.1 Agency with Authority: U. S. Department of Agriculture

7.2 Authority: No person shall knowingly move any noxious weed, identified in a regulation promulgated by the Secretary, into or through the United States or interstate, unless such movement is authorized under general or specific permit from the Secretary of Agriculture (or other person to whom authority may be delegated to act in their stead) and is made in accordance with such conditions as the Secretary may prescribe in the permit and in such regulations as he may promulgate under this Act to prevent the dissemination into the United States, or interstate, of such noxious weeds. The Secretary may refuse to issue a permit for the movement of any such noxious weed when, in his opinion, such movement would involve a danger of dissemination of such noxious-weeds into the United States or interstate.

7.3 Application to Mechanical Control Methods. Not applicable.

7.4 Application to Biological Control Methods. Any selected method that could involve transfer of any noxious weeds, in whole or part, interstate, for whatever reason, would require a permit from the Department of Agriculture.

8.0 The National Environmental Policy Act (NEPA) of 1969, as Amended (42 U.S.C. 4321 to 4370c)

8.1 Agency with Authority: Any Federal agency with jurisdiction could qualify as responsible Federal agency under NEPA.

8.2 Authority: The National Environmental Policy Act requires the use of a systematic interdisciplinary approach in decision-making which may have an impact on the human environment. NEPA is our basic national charter for protection of the environment. The purposes of NEPA are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality. NEPA requires an environmental impact statement for major Federal actions that significantly affect the quality of the human environment. A Corps of Engineers Section 10 or Section 404 permit for certain proposals may be considered as significant and trigger the requirement for an environmental impact statement (EIS). The EIS is prepared prior to any permit decision and contains the following elements:

(1) The environmental impact of the proposed action,

(2) Any adverse environmental effects which cannot be avoided should the proposal be implemented,

(3) Alternatives to the proposed action,

(4) The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

(5) Any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented (42 U.S.C. 4332).

The information generated in the NEPA process is intended to assist public officials in making decisions that are based on an understanding of environmental consequences, and in taking actions that protect, restore, and enhance the environment.

8.3 Applications to Mechanical Control Methods. Generally, for any proposed mechanical control action on Federal lands, Tribal lands, or requiring a Corps of Engineers permit application, an environmental assessment (EA) shall be prepared by the responsible Federal agency. The EA will determine if the project requires an environmental impact statement (EIS), i.e. if the project is determined to be a major Federal action that would significantly affect the quality of the human environment and/or would be highly controversial. If it is determined that the project does not require preparation of an EIS, a Finding of No Significant Impact (FONSI) is prepared (40 CFR 1500).

8.4 Applications to Biological Control Methods. Generally, for any proposed biological control action on Federal lands, Tribal lands, or requiring a Corps of Engineers permit application, an environmental assessment (EA) shall be prepared by the responsible Federal agency. The EA will determine if the project requires an environmental impact statement (EIS), i.e. if the project is determined to be a major Federal action that would significantly affect the quality of the human environment and/or would be highly controversial. If it is determined that the project does not require preparation of an EIS, a Finding of No Significant Impact (FONSI) is prepared.

TRIBAL RIGHTS AND CULTURAL RESOURCES

TRIBAL RIGHTS AND CULTURAL RESOURCES

1.0 INTRODUCTION

The objective of this report is to provide Washington State agencies with background information with which to make regulatory decisions on control of emergent noxious weeds -- those presently invading and those that emerge in the future. Because localized information will be specific to every situation, this report outlines processes, rather than specifics, for approaching tribal and cultural resource concerns.

2.0 AMERICAN INDIAN CONCERNS

There are twenty-six federally recognized Indian tribes in the state of Washington. In recognition that each tribe has an independent relationship with each other and the state, most tribes signed a Centennial Accord with the state of Washington in August 1989. The principles of the Centennial Accord provide that each agency of the state will initiate a procedure and establish a documented plan for implementation procedures with Indian tribes.

When plant control efforts are proposed, affected tribal lands should be identified from a map of Washington reservation lands. If Indian tribal lands are affected by any proposed action or alternative, then it is essential to consult with the affected tribes. Consultation includes:

1. formal written notification to tribal government describing the program;

2. if requested, a meeting and/or presentation to tribal governments to describe program objectives and discuss problems and their possible solutions;

3. resolution of issues documented in the form of a tribal resolution, letter from tribal government, or negotiation of a memorandum of agreement between the tribe and the agency.

Issues of concern to Indians should be addressed for any proposed action contained in the EIS, including the no-action alternative. Such issues might vary widely, and could range from loss of habitat for traditionally used native plants if noxious species remain uncontrolled, to adverse effects on fish or shellfish habitat if unwanted plants are controlled through chemical or mechanical means.

Anticipated concerns might include the following:

1. How does this program affect tribal lands or the quality of habitat at Usual and Accustomed (U&A) fishing sites? If tribal lands could be affected by any means of control, then tribal consultation should occur.

If the control program does not affect tribal lands or a U&A fishing site, then primary jurisdiction lies with the landowner or land-managing agency. Only those tribes with ceded lands within the affected project area would need to be contacted. Normally this would be done by written notification to the affected tribal government. Comments received from an Indian tribe in this case would be treated as other comments from interested parties. Religious sacred sites (such as vision quest sites) or traditional use sites (root digging grounds) might fall into this category. However, if Indian burial sites or petroglyph sites are affected, these are protected by state law regardless of ownership (Title 27 RCW, 27.44 Indian Graves and Records; and WAC 25-48-070, Notification to Indian Tribes) and require consultation.

2. Does the program limit or restrict access to U&A fishing sites guaranteed by treaty? Consultation with tribal governments should occur (as described above) with the goal of establishing a mutually satisfactory scheduling "window" for access to U&A fishing sites. Examples of hazards to U&A fishing could included timing of plant control activities, residual effects of chemical control on the fishery, or entanglement of fish nets on mechanically removed plants within the fishery.

3. Will aquatic plants be affected that are important to the practice of traditional cultural activities? Many Indian groups within the state still rely upon native plants for herbal or medicinal cures, traditional religious practices and the production of cultural arts and crafts. Just how the program will affect the habitats of specific native plants of special importance to individual tribal groups can only be determined through consultation with individual tribal governments and their culture committees. Many Indian groups assert that they have the right to gather roots, berries, and medicinal herbs on lands that they ceded to the Government. Examples of Indian uses of native plants may be found in Erna Gunther's Ethnobotany of Western Washington (1941).

4. An unresolved issue rests with claimed Indian rights to half of the state's shellfish harvest. Possible effects of noxious weed control in areas where commercially important shellfish beds exist could become an important Indian issue according to decisions the courts make on this issue.

For the present time, since *Spartina* is invading both Padilla and Willapa Bays, it would be appropriate to consult with the Shoalwater and Swinomish Indian tribal governments (because there is potential for effects on Indian interests at both locations). Consultation should focus on two things:

1. What effects would *Spartina* likely have on native plants and shoreline habitat on Indian lands in those locations?

2. What effects would there be on native plants and fish habitat if chemical or mechanical means of control are implemented? **Only consultation** will identify specifically what needs to be protected.

3.0 CULTURAL RESOURCE CONCERNS

Cultural resources include archeological objects and sites, historic buildings, industrial or residential dumps, and Indian traditional cultural sites that are at least 100 years old.

Cultural resources coordination follows an entirely different line of coordination and a different process for consultation than does Indian coordination. The procedure would follow these steps:

1. Identify Resources. Sites selected for treatment under the emergent noxious weed control program (exact map locations) need to be surveyed for the existence of archeological or historic sites that could be affected by control measures. . Normally, this is determined by conducting an archeological survey of project lands.

An archeological survey is a technical study conducted by a professional archeologist that physically and systemmatically examines a geographic area for the existence of cultural sites. If found, such sites are described and recorded on forms submitted to the SHPO for the state inventory. In addition, the archeologist makes a recommendation regarding National Register eligibility. A formal determination, however, must be made by the landowner or land manager, in consultation with the SHPO. A simple records check of the state inventory at the SHPO is not sufficient evidence for absence of cultural resource sites, since the area in question may never have been surveyed and recorded. Archeological surveys should be done at locations where specific aquatic plant control measures would be implemented.

2. Evaluate Resources. Archeological or historical sites would need to be professionally evaluated for their National Register eligibility in consultation with the State Historic Preservation Office (SHPO) in Olympia, Washington. SHPO routinely requires information based on an archeological survey report. Sites meeting the Criteria of Eligibility for the National Register of Historic Places are regarded as "significant" sites and need to be addressed in any Environmental Assessments (EA) or Environmental Impact Statement (EIS) documents. Sites that do not meet these criteria need not be further considered, but concurrence from SHPO is required.

3. Coordinate Plans for Impacted Resources. If the effects upon significant (National Register eligible) cultural sites appeared to be adverse, plans for data recovery or mitigation would need to be coordinated. In the worst case, this would mean avoidance of the site or recovery of the attributes that make it significant. Any plans for data recovery or mitigation would need to be reviewed by the SHPO and comments sought from interested parties, including Indian tribes, concerning appropriate treatment and curation. Data recovery work on state or private lands requires a permit issued by the SHPO under Chapter 25-48 WAC.