Seaburst Park Master Plan

APPENDIX B
SITE BACKGROUND INFORMATION
TECHNICAL MEMORANDUM

Prepared for

City of Burien

Prepared by

Anchor Environmental, L.L.C.
1411 4th Avenue, Suite 1210
Seattle, Washington 98101

August 2002

ANCHOR
ENVIRONMENTAL, L.L.C.

TECHNICAL MEMORANDUM

SUMMARY OF BACKGROUND INFORMATION
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and

Coastal Geologic Services, Inc. • KPG • Shannon & Wilson

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PURPOSE AND SCOPE OF MEMO

Seahurst Park is a wooded 152-acre gem located on the shoreline of Puget Sound, which has provided a quiet recreational retreat for visitors for many years (Figure 1). Prior to its status as a public park beginning in 1972, Seahurst was used by the local community for shoreline recreation. When the City of Burien was incorporated in 1993, it also acquired the Seahurst Park property from King County. Since that time, the park has lacked a master plan that represents the City's vision and serves to guide investments for protection and enhancement of the park.

The City of Burien began a master planning process in January 2002 as a joint effort by the City and the Salmon Recovery Funding Board (SRFB). In 2001, the SRFB approved a bulkhead alternatives analysis looking at the shoreline along the entire park boundary. A comprehensive public involvement strategy was developed that includes a stakeholder committee of citizens, open public meetings, and input from the Park Board and City Council into the plan. The stakeholder committee represents diverse community interests including each neighborhood around the park, educational representatives (Highline School District and Environmental Science Center), natural resource groups (People for Puget Sound and WRIA 9-Watershed Planning), Park Board, and Burien Economic Development Program. Federal, State, City, and Tribal natural resource agencies that will ultimately review and issue permits for improvements in the park, have also been engaged in separate meetings to inform them of the planning efforts. All of the planning work underway needs a sound body of knowledge as a basis for decision-making.

This technical memorandum is intended to provide the City with a summary of background information about the park as a first step in developing the master plan. The memorandum is organized according to the various features of the park property as follows:

- **Park History and Facilities.** Discussion of existing park facilities and infrastructure, such as roads and utilities, park facilities, and site access.
- **Natural Physical Processes.** Discussion of both upland and coastal geologic processes, including topography, hydrology, and coastal geology. The physical processes provide the foundation upon which biological habitats at the park establish themselves.
- **Biological Processes and Habitat.** Discussion of the upland forest community, streams and wetlands, and the nearshore environment.

- **Structural Survey of Shoreline.** Condition assessment of existing shoreline protection structures.
- A list of references is included at the end of the document.

Summary of Findings

Seahurst Park presents a wonderful opportunity for the public to enjoy both a scenic, recreational, and educational resource. The parks extensive shoreline and forested hillside/bluff areas present excellent opportunities to experience and learn about the relationships between natural systems, both physical and biological, and the built environment (e.g. park facilities and surrounding urban areas). The diagram shown at left is intended to illustrate how these natural and man-made processes and features are inter-related. The diagram appears at the end of each portion the report.

Key findings that reinforce the interrelationships between natural processes and the built environment are also summarized below:

- Most of the park has been affected by varying degrees of human caused disturbance, including past logging, roads, filling, bulkheading, stormwater runoff, stream re-channelization and culverting, and surrounding urbanization. Most of the modifications evident today are the result of park development by King County in the early 1970s.
- The park contains many geologically unstable areas. The most extensive areas are located on the hillside/bluffs bordering the shoreline. Park development in all of these areas is either not recommended or limited to trails depending on the type of geologic conditions. The instability is primarily the result of seepage occurring at the sand/clay interface 130 to 150 feet above the shoreline (see Figure 5). This is a natural process that is common along Puget Sound bluffs.
- The presence or absence of bulkheads in slide prone areas directly affects the delivery of material (sediment and large woody debris) to the beach. However, it generally does not affect the inherent stability or instability of these areas because of the upslope conditions.

- The estimated volume of sediment material delivered to the beach by landslides and erosion is 21-75 tons per year. The composition of this sediment is characterized as 25 percent gravel, 45 percent sand, and 30 percent silt and clay.
- The park's beach is located at the "updrift" end of a long "drift cell" giving it limited sediment supply. The primary source of sediment supply to Puget Sound beaches and Seahurst Park is eroding bluffs and longshore transport (or littoral drift). The net drift direction is north in this location.
- The park's beaches include heavily modified and generally unmodified segments. In more unmodified segments, the beaches contain finer substrates such as sands and gravels and large woody debris is evident in the backshore. In modified segments more rock and coarser substrates are evident. Significant erosion has occurred since 1972 in these areas threatening the stability of many of the structures, perched beaches, and upland areas they protect. Repair work in the early 1990's was intended to address erosion but has not fully addressed it and much of the south gabions and perched beaches continue to be threatened.
- The further shoreline structures and armoring encroach into the intertidal zone, the less highly functioning habitat is available to juvenile salmonids, their prey, and forage fish species (sand lance and surf smelt-that spawn in these beach areas).
- While most of the parks beaches are documented spawning areas for these two forage fish species, the direct and indirect effects of bulkheading, rock armoring, and loss of overhanging forest have degraded much of this habitat.
- Extensive eelgrass beds (two species, the native Zostera marina and the non-native Zostera japonica) inhabit most of the lower intertidal and shallow subtidal zones. These are important habitats for salmon and other species.
- Much of the parks forested areas historically bordered streams and beach areas forming riparian zones. These zones of contact between terrestrial and aquatic environments perform several important ecological functions such as protecting water quality, stabilizing banks, increasing wildlife habitat diversity, nutrient inputs, and large woody debris inputs.
- The plant communities in forested areas are dominated by four native communities (Red Alder, Madronel Salal, Hemlock & Cedar, and Riparian). A fifth and much smaller community consists of non-native vegetation. The plant communities result from a combination natural and human caused disturbances (logging, geologic instability, land development), and natural site conditions (wet versus dry soils).

- The parks two streams offer limited habitat for salmonids due to their steep gradient and relatively short length.
- The park is home to a variety of reptiles, amphibians, birds and small mammals including the ensatina salamander, bald eagles, great blue herons, barred owls, and red fox, among others. A bald eagle nest is located 0.25 mile site of the park.

1 PARK HISTORY AND FACILITIES

1.1 Surrounding Land Uses and Access

Seahurst Park abuts Puget Sound to the west and is surrounded on all other sides by residential neighborhoods of the City of Burien. These neighborhoods include:

- Shorewood: North of Park
- Hurstwood: East Central (surrounded by park on three sides)
- Seahurst: South of Park

Between these neighborhoods and the park boundary are several large undeveloped areas adjacent to the park that are often mistaken for park property. These areas contain forests that are contiguous and indistinguishable from the rest of the park (see Map M-1). These undeveloped areas are predominantly located on the south side of the southern drainage (Brown Property and others) and to the east of the northern drainage. Other undeveloped, forested areas near or bordering the park include the south shoreline (Seahurst Community Club), potential North and South Basin trail linkage east of Hurstwood, and the 72-acre Salmon Creek Ravine Open Space, one block north of the park. These areas contain mature coniferous forest with a native shrub understory that serves to compliment the park aesthetically and expand it ecologically. The urban core of the City of Burien lies just a quarter mile beyond the southwest boundary of the park.

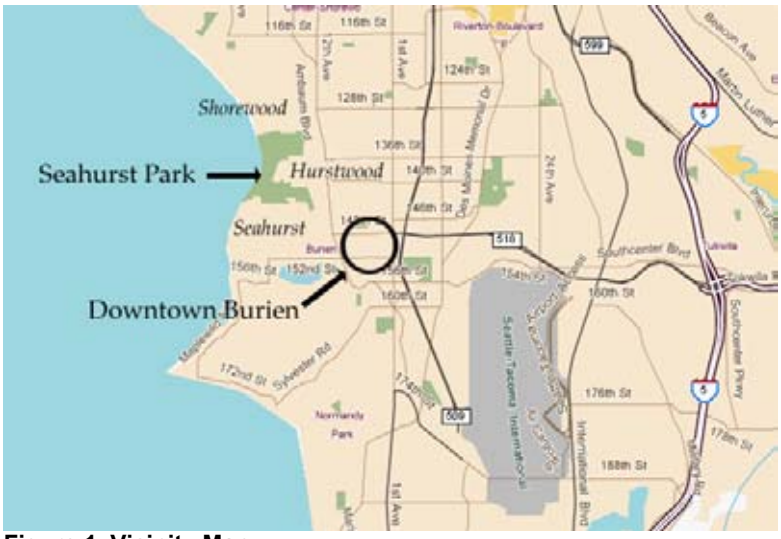


Figure 1. Vicinity Map

Visitors to the park generally access Seahurst Park by car through the main entrance road also known as Southwest Seahurst Park Drive. The park is fairly well connected to the state highway system and is relatively easy to access from State Routes 509 and 518 via the Southwest 148th Street exit to Ambaum Boulevard S.W. However, there is no signage from 148th Street or the two state highways to the park. Signs lead to the park from Ambaum

Boulevard, a major north/south thoroughfare through the city, at the Southwest 144th Street intersection. Three blocks west, 144th Street intersects with 13th Avenue Southwest, which becomes Southwest 140th Street and leads into the park. Within the park there are two parking areas on this road described below.

The park can be accessed by Metro buses via routes 135 and 136 on Ambaum Boulevard. At Southwest 136th Street (Highline Senior Center) there is a single trail leading to the park that is less than 200 yards from a bus route on Ambaum Boulevard. The park is also accessible by walking from the bus stop on Ambaum Boulevard on the sidewalk along the main entrance road described above. These park access routes are between one half to one mile from the bus route on Ambaum Boulevard to the beach.

Residents of the surrounding neighborhoods are able to access the park on foot from several small trailheads. In some cases these trails start outside the park and travel across undeveloped parcels into the park itself. Shorewood neighborhood residents use the dirt road or trails that start at 16th Avenue S.W. and Shorewood Drive at the northeast edge of the park (see Map M-2). Access from the Senior Center and Southwest 136th near Ambaum Boulevard is available via trail crossing private land before entering the park. It should be noted that the undeveloped right-of-way for 136th continues into the park. From the Hurstwood neighborhood residents can either walk in to the park along Seahurst Park Drive (the main vehicle entrance) or they can access the park's trail network from 17th Avenue S.W. Access to the park from the Seahurst neighborhood is possible by using one of the routes that connect to the park's southern drainage through undeveloped forested private property. These trails (two connected trails) access 18th Avenue Southwest and Southwest 146th Street

1.2 Site History

The park's beaches were used by Native Americans for summer clam digging and fishing (McDonald and Whitney 1997). A shell midden has also been documented in the northern portion of the park (Scott Thomas, personal communication). The site was logged in the early 20th century and the current forest is considered second growth (Macdonald & Whitney 1997). A local lumber and construction "baron" by the name of Mr. Fox built a residence near the current north picnic shelter and Marine Technology Lab in the 1930's that had a wood bulkhead with a special gate to allow "rum runners" to clandestinely off load

their contraband at night during high tides (McDonald and Whitney 1997). The alcohol was then hidden in hillside caves near the beach. The garage from this house is still located at the base of the hill and the swimming pool is beneath the north picnic shelter where it holds water for the Marine Technology Occupational Skills Center's (Marine Technology Lab's) hatchery. The residence was kept intact while the park was constructed but later removed. The south end of the park site (south/central creek basin) remained relatively undeveloped until the second half of the 20th century. The south subbasin of the creek (whose springs are described in the hillside geology section) was used as the water supply for the Seahurst neighborhood until fairly recently (Ralph Myers personal communication). Some of the infrastructure for the water supply system can still found on the Brown/Water District 85 property just south of the park boundary. Aerial photography from 1946 indicates no roads or structures in the south portion of the park. A 1965 air photo shows the completion of a road along the south creek to the delta and some fill placement along the north side of the delta (see Figures 8a & 8b and Table 2). The Hurstwood Community Club owned this portion of the site when King County purchased it for park use in the late 1960's. A 1970 aerial photo and the park construction as-built drawings show significant fill was placed at the base of the hillside and upper beach prior to park construction. It is unclear whether this material was placed by the county or Hurstwood Community Club. This photo also shows an octagonal bathhouse structure was located where the lower parking lot is currently located (Quinton Budlong 1973). This structure was probably built by the Hurstwood Community Club and was removed as part of park construction.

1.3 Park History

King County opened Ed Munro/Seahurst Park in 1975 and named it after the former County Commissioner who helped establish it (McDonald and Whitney 1997). As-built records indicate that the park was largely constructed in 1972. There was some controversy over the level of development that would be included in the park (McDonald and Whitney 1997). The current park layout includes the preservation of some natural features such as the south creek delta, that were originally proposed to be converted to more intensive uses, such as expanded shoreline parking (Wolf Bauer personal communication). There is documentation of three repair or upgrade projects by King County that occurred after park development including:

- North Concrete Bulkhead and Gabion Stabilization, 1990
- South Gabions Emergency Repair, 1991

- Water Main Replacement (central waterfront behind concrete bulkhead), 1994

All of these projects were designed by TAMS Consultants, a Seattle engineering firm (TAMS 1989; TAMS 1990; TAMS 1991; TAMS 1994). The firm's analysis of the north and south bulkhead and gabions indicated that significant erosion of the shoreline was threatening the structures and the upland fills (for park uses) which they were designed to defend. A 1989 analysis of alternatives and a response from the Washington Department of Fisheries indicate that protecting the concrete bulkhead and perched beaches with rip-rap to replace and cover the failing gabions was favored over a large beach fill in the intertidal zone (TAMS 1989, WDF 1989). It should be noted that none of the proposed alternatives proposed removing the perched beaches (or gabions that defend them) artificially created in 1972. The current conditions of these structures and the shoreline are described in the coastal geology section of this memorandum and in the shoreline protection structure assessment below. Recent efforts to further stabilize the south gabions with more riprap in the intertidal zone were strongly discouraged by the Washington Department of Fish and Wildlife (WDFW, 1999) and no further actions have been taken. In 1996, the City received a $25,000 state grant to study the feasibility of building an Environmental Science Center in the park (City of Burien, 2000). Community members formed the Environmental Science Center Foundation to help raise money for this effort and lead this planning and partnership effort.

1.4 Park Facilities and Use

With 152 acres and 0.75 mile of shoreline, Seahurst Park is the City's most heavily used park, and a regional attraction (City of Burien, 2000). Together with the adjoining Salmon Creek Ravine 1 block north of Seahurst, the combined 228-acre total park area contains 85 percent of the City's parkland (City of Burien, 2000). Seahurst Park is described as a regional park in the City's Comprehensive Park and Open Space Plan because of its size, extensive Puget Sound shoreline access, hiking trails, and picnic facilities. It is also described in regional guidebooks with close-in, but extensive hiking and walking opportunities in scenic locations (McDonald and Whitney, 1997).

A survey on the use of parks, arts, and recreation facilities that included responses from about one-half of the city's residents indicated heavy recreational use of the site and its facilities (City of Burien 2000). The attractions at Seahurst clearly include the natural

environment, the shoreline, streams, and forests. Facilities that support recreation use allow the public to access and enjoy these natural amenities. Current park facilities include:

- Paved Entrance Road and Parking (see Park Infrastructure ahead)
- Unpaved Access Road/Path (north end of site)
- Shoreline Paved and Crushed Rock Paths (approximately 4,400 linear feet)
- Hiking Trails (approximately 9,500 linear feet)
- Two Covered Picnic Shelters (north and south ends of park) (800 square feet north and 600 square feet south)
- Benches and Picnic Tables
- Children's Play Area
- Public Restroom Building (1,100 square feet)
- Marine Technology Lab (2,700 square feet)
- Former Garage/Carpenter Resident (850 square feet)

The Highline, Federal Way, Tukwila, and Tahoma school districts jointly operate the Sea-Tac Occupational Skills Center (OSC). Their vocational-technical classes use the Marine Technology Lab for their Marine Technology Program (Barbara Williams, Personal Communication). It was originally built in its current location prior to 1972 when the rest of the park was developed, and then replaced in conjunction with park construction (Quinton Budlong, 1973). The lab contains a hatchery that raises coho salmon. This facility is not open to the public and is leased from the City.

Adjoining the park on the east is the Highline Senior Center. The site is connected to the park by the SW 136th Street right-of-way (undeveloped) and an informal trail crossing private forested land. This site is owned by the Highline School District (formerly Burien Heights Elementary School), but the programs are operated by the Highline Community College (City of Burien 2000). The senior center serves the highest concentration of low income elderly in Southwest King County. Programs include social, legal, and health services for two to three thousand seniors (City of Burien 2000). Programs for local youth are also provided at this facility (Scott Thomas personal communication).

1.4.1 Park Infrastructure

1.4.1.1 Site Access and Parking Facilities

Street access to Seahurst Park is provided by 13th Avenue S.W. (see Map M-2). It consists of two lanes with a centerline. The speed limit is posted as 25 mph, with 15 mph for the steep, downhill curved sections. The condition of pavement is adequate, although there is evidence of utility trenching and repair. There are a number of existing speed bumps. There are curb and gutter facilities that drain to a system with an outfall into Puget Sound.

Pedestrian access to the park is provided by the trail system, as well as paved sidewalks along 13th Avenue beginning at 140th Street. There is a 4-foot-wide concrete sidewalk along the east side of 13th Avenue to the first curve where there is a crosswalk. On the west side there is an approximate 6-foot-wide asphalt trail that is in poor condition. From the entrance to the park to the bottom parking lot there is a 4-foot concrete/7-foot asphalt trail (11-foot total paved width) on S.W. side inside park.

The upper parking lot contains 168 parking stalls. The lower parking lot contains 25 stalls (19 regular, 5 ADA, 1 emergency), plus a bus pullout. Both sides of the lower lot have 5-foot-wide walkways consisting of 10”x14” concrete pavers; the gaps have eroded and cause a tripping hazard.

1.4.1.2 Utilities

- Underground power exists for street lights and bathroom use, presumably provided by Seattle City Light.
- Lighting along 13th Avenue is provided to the lower parking lot with shoe box lights, many of which appear broken and inoperable.
- It is assumed that Qwest provides telephone service to the Marine Technology Center. There are no public telephones in the park.
- There is a storm drain system for 13th Avenue and the parking lots that conveys drainage to an outfall discharging into Puget Sound.

- Historic roadway plans show natural gas feeding the adjacent neighborhoods, but not the park. It is presumed that Puget Sound Energy provides natural gas to the adjacent neighborhoods.
- Water service within Seahurst Park is provided by Seattle Public Utilities. The system is looped and connects with the main system located on Ambaum Blvd. Within the park, water lines consist of 6-inch cast iron and 8-inch ductile iron pipes that run north-south along the shoreline, behind (east of) the bulkhead structure. The north end of the line continues onto Standring Lane S.W.. The south end of the line turns to the east and connects to S.W. 140th Street.
- Sewer service within Seahurst Park is provided by S.W. Suburban Sewer District and also runs north-south along the shoreline behind (east of) the bulkhead concrete bulkhead structure. The upstream end of the line lies just south of S.W. 140th Street. The 8-inch asbestos concrete gravity sewer line runs west towards Puget Sound and then continues north to a lift station located at 12550 Shorewood Lane S.W.. The sewage is then pumped to the Salmon Creek Treatment Plant located at 12550 Shorewood Drive S.W..

1.4.2 Shoreline Protection Structures

Shoreline protection structures at the park include a concrete bulkhead, gabion revetments, riprap revetment (for toe protection) and two groins. Due to the decay of the gabion revetment in the southern part of the park, a third layer of gabion cages was added between 1990 and 1991. Additionally, a riprap revetment was placed at the toe of the gabion revetment and in front of the concrete bulkhead, replacing the gabion revetment. Figure 2 shows the different structures that exist in the park.

A two-to-three-tier gabion revetment protects the south end of the park with ramps located at two points in the revetment for access to the beach below. A riprap revetment that protects the gabion from toe erosion fronts the middle section of the gabion revetment. It is worth noting that the gabion revetment was originally built with the second layer buried in the beach, but now it is exposed and therefore requires the riprap protection at the toe.

North of the gabion revetment is a creek delta that does not have a protective structure. Continuing north of the delta is a concrete bulkhead, which is protected at the toe by a riprap revetment along most of its length. It is worth noting that a gabion revetment was originally seaward of the riprap revetment. This gabion structure does not exist anymore. Stairways are located at several points along the bulkhead to allow access to the beach below. The northern most part of the park consists of a beach protected by two groins that extend offshore. No walls or revetments exist parallel to the shore at the northernmost end of the park.

A Primer on Shoreline Structures

Gabion Revetment

A gabion revetment is a flexible structure that is generally designed to protect shorelines against erosion from currents or light wave action. Gabion revetments are formed by filling a series of wire baskets, typically shaped in the form of a 3-foot cube, with rock that typically varies from 4 to 8 inches in size. The succession of baskets creates a flexible mattress with relatively high resistance against movement.

The advantages of gabion revetments include:

- They are inexpensive and are easily built without heavy equipment.
- They are flexible and efficient, even if the foundation settles.
- They are easily repaired by adding rocks in the baskets.

The disadvantages include:

- The baskets may be opened by wave action, drift logs impacts or wire corrosion, leading to revetment failure.
- Gabion structures require periodic inspections so repairs may be made before serious damage occurs.

Riprap Revetment

Riprap revetments generally consist of a rock layer or facing with smaller rock layer beneath to act as a filter and is either dumped or precisely placed to prevent erosion, scour, or sloughing of a structure or embankment. Riprap revetments are typically built by forming a shallow excavation at the toe of the structure that suffers from erosion and filling the excavation and slope with 300 to 800 lb rock (typical), on a 1V:1.5H or 1V:2H sloping face.

The advantages of riprap revetment include:

- They can settle into the underlying soil or experience minor damage, but they do not succumb to rapid and complete failure.
- They experience less wave runup and overtopping than smooth-faced structures because of their rough surface.
- They dissipate more wave energy, producing less scour at the fronting beach than do vertical seawalls.
- They are easily maintained by the placement of additional rock.

The disadvantages include:

- Waves can displace the armor units and move them out of the structure.
- Their placement requires heavy equipment.
- If a riprap revetment is improperly designed to prevent winnowing of sediments, loss of backfill material will occur.

Vertical Concrete Bulkhead

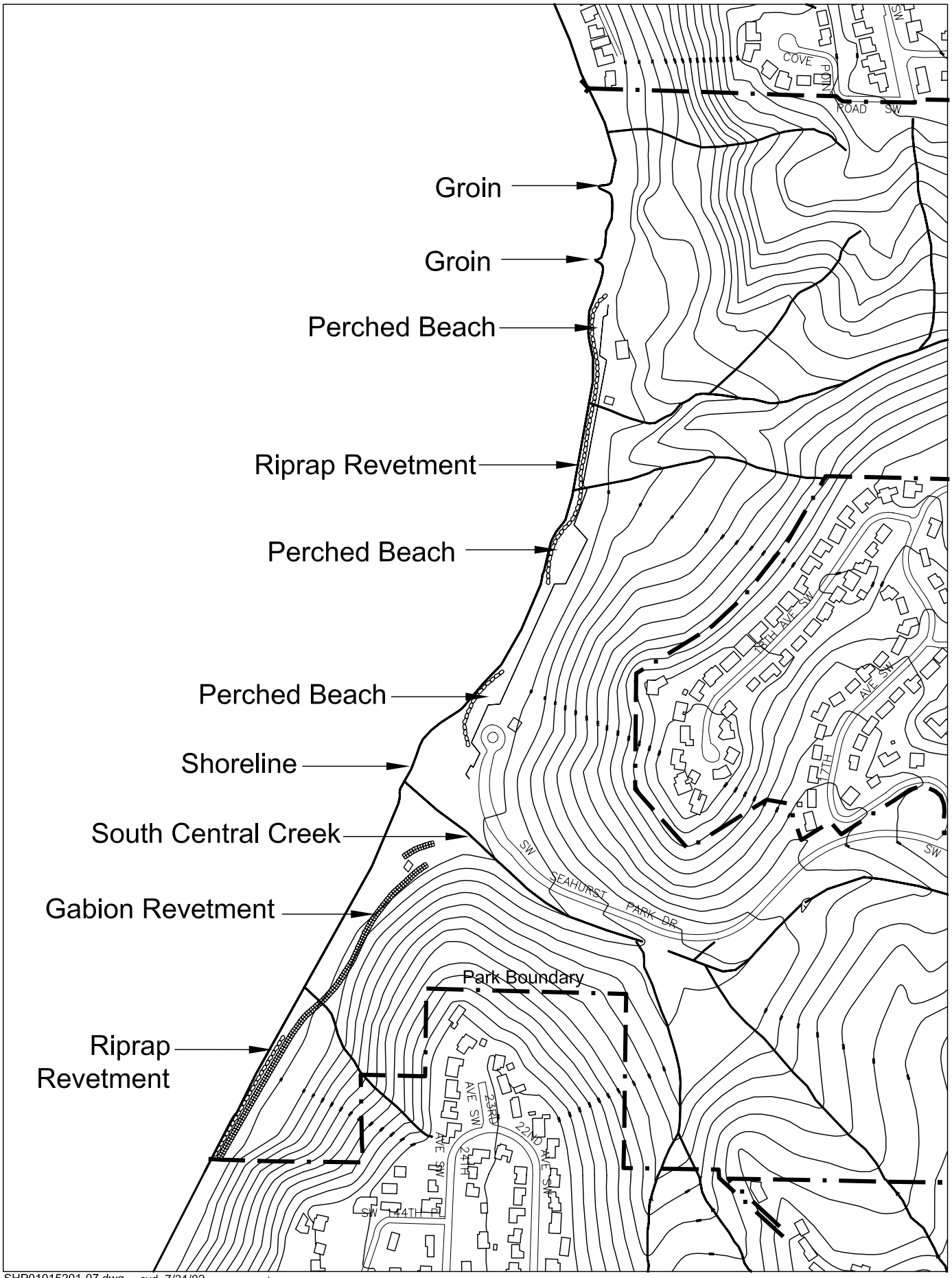
Vertical bulkheads are designed to retain fill and, while generally not exposed to severe action, they still need to be designed to resist erosion by the wave climate at the site. At Seahurst Park, the concrete bulkhead is formed from precast panels, held in place by concrete king piles or retaining columns.

The advantages of concrete bulkhead include:

- They can resist moderately strong wave action and provide a better protection than revetment.
- They are more resistant to corrosion.

The disadvantages include:

- They are potential wave reflectors that can erode a beach fronting the structure or the structure's toe.
- They can be expensive.
- Failure of a bulkhead often results in significant damage to the area behind the bulkhead.



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0 500
Scale in Feet

Figure 2
Overview of Shoreline Protection Structures
Seahurst Park Master Plan

While much of Seahurst Park is undeveloped open space, significant modifications have occurred in many areas. These modifications include past logging, roads, utilities, bulkheads and creation of uplands by filling aquatic areas. Changes to the physical environment affect and are affected by physical processes such as hillside geology. For example, much of the forested hillsides bordering the shoreline are geologically unstable. Park uses are disrupted by landslides and they can create urgent safety maintenance demands on the City.

2 NATURAL PHYSICAL PROCESSES

2.1 Upland/Hillside Geology

2.1.1 Upland Geologic Processes Relevant to Seahurst Park

Geologic conditions have a major effect on development and use of Seahurst Park. The upland (hillsides and bluffs) and coastal geologic processes at Seahurst Park are closely linked and are similar to those found at many Puget Sound shorelines. Unstable hillsides/bluffs are the major source of sediment to Puget Sound beaches. The instability in these bluffs is a function of the geologic strata and hydrologic conditions.

Steep, and often unstable, slopes characterize much of the upland area of Seahurst Park. The park features two drainage basins separated by a ridge/plateau upon which the Hurstwood neighborhood is located (see Figure 3 below and Map M-1).

Figure 3. Aerial Oblique Photo of Seahurst Park, 1993.
Source: Washington Department of Ecology 1997.

2.1.2 Site Conditions—Topography

The Seahurst Park topography is dominated by steep slopes bordering the shoreline and two drainage basins that each contain multiple, spring-fed tributaries. Elevations range from sea level along the shoreline of Puget Sound to about 425 feet at the eastern edge of the northern drainage basin (see Map M-1 and Figure 4).

Along the steep marine bluffs, the inclinations of the slopes range from about 50 to 75 percent on lower slopes to 70 to 100 percent on middle and upper slopes (see Map M-3). Where landsliding is active or till is exposed, slopes are nearly vertical. In the drainage

basins, the lower slopes are slightly flatter than the marine-facing slopes. The upper slopes range from 30 percent to 80 percent (see Map M-3).

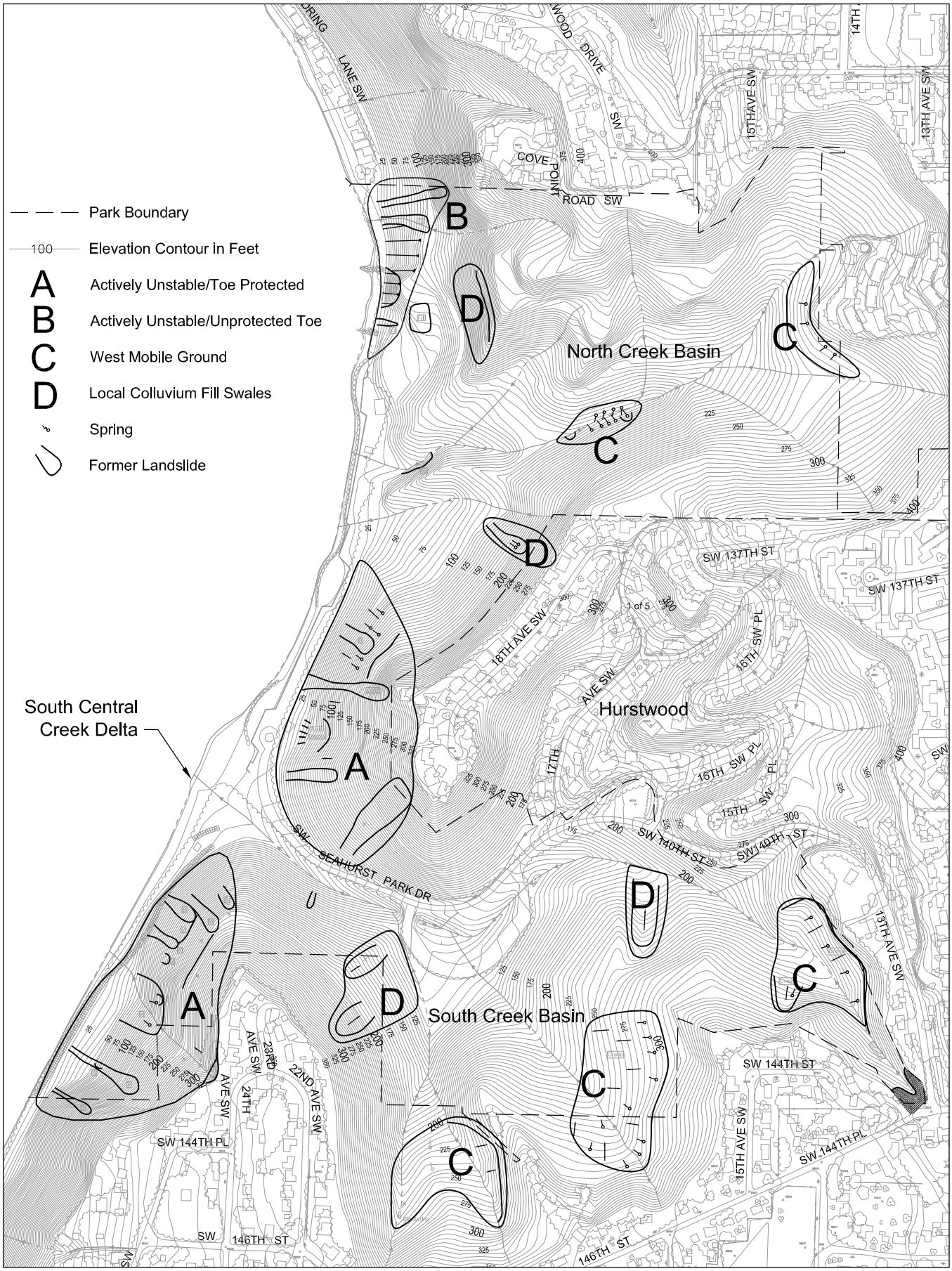
2.1.3 Site Conditions—Surface Drainage

Along the marine bluffs, springs emerging from the steep hillside coalesce and flow in very small channels 6 to 12 inches wide toward the shoreline. These springs are seasonal in some places carrying no water, in some places running downhill for a distance which infiltrates into the colluvium, and in other places reaching the shoreline, particularly in the winter and early spring. Water in these channels is locally supplemented by plastic pipes that carry stormwater runoff from residences on the plateau to the east.

Water in the two large drainage basins (north and south, for purposes of this report) is also spring-fed. However, due to multiple sources of water, there is enough water to make these streams perennial in their lower elevations. The north drainage basin contains five subbasins, each of which has minor springs that contribute to flow of the mainstem. The largest spring complexes are near elevation 275 feet in the center of the basin and along the mainstem, near elevation 150 feet, as shown on Figure 4.

The south drainage basin has five subbasins, one of which is primarily located in the Hurstwood residential area and partially culverted. This subbasin, and the subbasin that parallels S.W. 140th Street and 13th Avenue S.W. are both strongly supplemented by stormwater inflow from paved and other impervious surfaces. Stormwater flow is likely the cause of channel incision in the vicinity of elevation 310 feet that is about 300 feet downstream from the intersection of 13th Avenue S.W. and S.W. 144th Street, as shown on Figure 4. The largest spring complexes in the south drainage basin are between elevations 250 and 300 feet, as shown on Figure 4. One prolific artesian spring in a southern subbasin supplies a significant quantity to the south drainage basin.

The lower reach of the south drainage basin is significantly modified by human activity. Storm drainage pipes are located in portions of the channel and culverts are installed beneath the parking lot and road fill embankments. It is reported that the head of the delta, east of the shoreline, was revised during construction of park facilities in the early 1970's (Quinton Budlong 1973).



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0 600
Scale in Feet

Figure 4
Geologically Unstable Areas
Seahurst Park Master Plan

2.1.4 Site Conditions--Geologic

The soils at Seahurst Park are a legacy of the last glacial incursion into the Puget Lowland and preceding glacial and nonglacial intervals. These deposits are overlain locally by post-glacial deposits such as fill, creek alluvium, beach deposits and colluvium. The original geologic map for this area was completed by the U.S. Geological Survey (Waldron 1962). Recent work has resulted in an updated map, but that map has not been released for publication yet by the U.S. Geological Survey. Based on exposures observed during a reconnaissance for this project, the following geologic units were recognized, from youngest to oldest:

Holocene

13,000 years ago to present

- Fill
- Alluvium
- Beach Deposits
- Colluvium

Vashon Stade (Pleistocene)

16,000 to 13,000 years before present

- Till
- Advance outwash
- Glaciolacustrine deposit

Pre-Vashon Stade (Pleistocene)

80,000 to 16,000 years before present

- Olympia Formation
- Pre-Olympia deposits

Although not dated, the deformed clay beds and overlying sand at the northern end of the park are likely to be Olympia (last interglacial period) and/or pre-Olympia deposits. The contact with overlying Vashon glaciolacustrine deposit (Lawton Clay) is unknown, as it is covered with landslide deposits. Most of the glaciolacustrine sediment is very fine-grained glacial flour (silt and clay); however, some thin beds and lenses of sand

indicate the influence of freshets in carrying material from the margins of the basin or from gravity currents from the snout of the ice.

As the glacial ice shoaled owing to increased deposition and proximity of the glacial sediment source, the sediments became increasingly coarser. The contact between the overlying advance outwash and underlying Lawton Clay is normally transitional, consisting of interbedded silt, sand and clay. Within Seahurst Park, the elevation of this transitional zone between the sand and clay units is between 130 and 150 feet. The advance outwash is also referred to as Esperance Sand on some older geologic maps, but that terminology has been largely replaced by the more generic term advance outwash. This unit is very dense, having been overridden by about 3,000 feet of ice, and consists of fine and fine to medium sand, with varying percentages of gravel and cobbles.

Overlying the advance outwash, as it does throughout most of the Puget Lowland, is a layer of Vashon Till. The till layer is a non-sorted diamict laid down under the last glacial ice covering Puget Sound. The contact between the outwash and the till is relatively abrupt. The deposit consists of varying proportions of a very dense mixture of silt, sand, and gravel with scattered cobbles and boulders. It has the appearance of concrete and has a very low permeability. Till is locally referred to as "hardpan." It is exposed at the top of a landslide that occurred in the 1930's near the south end of the park and is indicated on the geologic map along the top of the bluff along 18th Avenue S.W. and 24th Avenue S.W. (see Figure 4).

Colluvium is a deposit that was placed by gravity. In the case of the Seahurst Park site, it consists mostly of previous landslide deposits. It exists on all of the slopes in the park, but is the thickest on the slopes that have the most active slope instability. Due to the chaotic manner of its

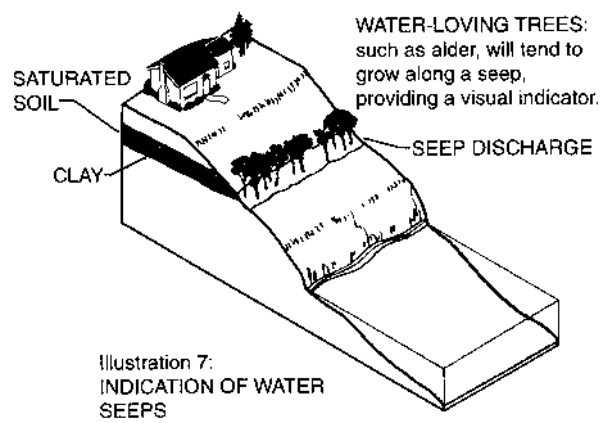


Figure 5. Typical Geologic Cross-Section
Source: Manashe. 1993.

deposition, it is a heterogeneous mixture of the soil types on and above the bench. It is loose and wet, not having been overridden by glacial ice. Beach deposits are located along the shoreline. They are reworked materials that originated on the slopes at the south of the park and from a creek delta north of the park. They are also supplemented by alluvium that is delivered to the small deltas at the marine edge of the two creek systems within the park.

Alluvium consisting of loose sand (scattered gravel) is found along the beds of each of the creeks. The fine-grained particles are winnowed out of the deposits and carried to the shoreline, leaving behind the sand and gravel. Fill is found along most of the roadways and along the shoreline. One significant deposit, comprised of landslide deposits from various parts of the park, is located just north of the Marine Technology Center.

Two levels of groundwater are present in the park. Springs emerge where the advance outwash transitions downward into the Lawton Clay. This contact at about elevation 130 to 150 feet is ubiquitous along the shoreline bluffs (see Figure 5). In the interior drainage basins, where the geologic conditions appear to be different than they are along the shoreline, the main spring line is located between about elevations 250 and 300 feet. Most of the seepage in these springs is diffuse; however, the southernmost spring in the southern drainage basin is prolific, exhibiting artesian conditions.

2.1.5 Site Conditions—Slope Stability and Erosion

The stability of the slopes in Seahurst Park is dependent on four factors:

- Geology
- Seepage or other sources of water
- Slope inclination
- Human activity

For any particular landslide, the causes are likely to be a combination of some or all of these factors, but in different orders of importance for different landslides. Landsliding is particularly common at the contact of sand overlying a less permeable layer, such as silt or clay. At Seahurst, this condition is common where this contact is exposed on the west-facing marine bluffs. Such instability can start as a small rotational slump in the

sand above the contact or a shallow slide of colluvial soil or intact clay at or below the contact, but can also develop into a debris flow or avalanche. Such an event occurred on December 17, 2001, about 200 feet north of the park restroom. The colluvium that accumulates on the flatter slopes (below the bluffs) can also become unstable and move slowly or quickly if it becomes saturated. Where colluvium is concentrated to significant depths in natural swales, it commonly exhibits accelerated creep, typically demonstrated by jackstrawed or severely bowed trees. Such colluvium-filled swales are marginally stable.

The only recorded slope instability originating from the top of the slope was a debris flow that was generated from the steep slope west of 24th Avenue S.W. near the south end of the park. Aerial photographs taken in 1936 indicate that the debris reached the beach. Other information indicates that this area was unstable again in the 1950's, reportedly caused by stormwater that was directed toward the slope during construction activity in that area. Subsequent aerial photographs do not indicate further significant instability in this area.

Although not actively unstable at this time, there are several areas in the park where heavy seepage and loose colluvial soil have combined to create large zones of mobile soil that are creeping. Creep is the imperceptible movement of surficial soils (generally less than about 10 feet thick). The bowing of trees is one method of identifying the presence of creeping soil. In some places, these soils may be on planar slopes; whereas, in other places they may be confined in troughs, as discussed above.

In order to aid in the master planning activities of the park, four slope stability zones are roughly delineated. The zones are shown on Figure 4. They are described as follows, with their physical characteristics and other related attributes. For each zone, there are some concluding that provide recommendations on site development considerations given the slope stability issues:

A) Actively unstable, toe protected

- Actively unstable slopes protected by existing concrete bulkhead along the shoreline of Puget Sound.

- Instability caused by seepage at sand/clay contact resulting in small rotational failures in sand above the contact or debris flows in colluvium below contact.
- Commonly repeated failures at some location in troughs.
- Formerly supplied beach with fine and coarse-grained sediment, but now interrupted by concrete bulkhead.
- Removal of concrete bulkhead may result in an increase in the recurrence interval of colluvial slides, but not substantially change regression of the upper bluff line.
- Leave as-is and do not disturb, except for primitive trails that are informal.
- Mostly deciduous forest below approximately elevation 160 feet in colluvium due to recurring movement of soils and wet soil conditions. Mixed forest 160 to 200 feet. Coniferous forest, including madrona, in sand or higher slopes.

B) Actively unstable, unprotected toe

- Actively unstable slope with unprotected toe, except for groins perpendicular to the shoreline.
- Toe is being undercut by wave action, so slumping and block-calving is occurring regularly, providing mostly sand and silt to the beach.
- Evidence of an old debris flow at north edge of the park indicates other means of sediment delivery of sand to the beach.
- Very steep to precipitous slopes.
- No trails or recreational opportunities due to danger.
- Very little vegetation due to very active instability of slopes. Vegetation, where present, is mainly alder. May want to plant heavy vegetation at entrance to high bluff to discourage visitors.

C) Wet, mobile ground

- Very active creep to actively unstable slopes with widespread seepage.
- Mostly shallow soil movement, exacerbated by heavy, perennial seepage.
- Vegetation primarily deciduous, and bent and bowed due to constant shifting of soil. Cedars locally in the wet areas.
- Trails would be acceptable, but will require constant maintenance and bridges locally. No structures acceptable in this zone due to seepage and

mobile ground.

D) Local colluvial-filled swales

- Troughs filled with colluvium, exhibiting surficial signs of ground movement or recent failure.
- Trails are acceptable, but drainage should be directed away from swales. Periodic maintenance may be necessary. No structures acceptable in or at the toe of this zone due to seepage and mobile ground.

Two forms of erosion are active in Seahurst Park: along the two creeks and along the shoreline. As discussed above, channel incision is occurring near the intersection of S.W. 144th Street and 13th Avenue S.W.. The channel is deepened by 4 to 6 feet below the channel fill for a distance of 200 to 300 feet and, in some locations, is eroding into the sidewalls of the channel, causing instability of the base of the colluvial slope.

Sidewall channel erosion is also active at about elevation 50 feet and 125 feet along the edges of the mainstem of the northern drainage basin. At about 50 feet, the erosion is entraining silt and fine sand from the channel sides and clay from the channel bed. At about elevation 125 feet, sand and gravel is sloughing into the channel and being entrained by the creek waters.

Most of the park shoreline is protected by either a rock or concrete bulkhead; however, the northern 800 feet of the park is unprotected by such structures. Two rock groins are constructed in this area to help retain sand moving along the beach. About 350 linear feet of shoreline in this interval are being actively eroded by wave attack, such that sand is being regularly fed to the beach. This subject is covered in detail in subsequent sections of this memorandum.

2.1.6 Site Conditions—Contribution of Upland Instability to Coastal Sediment Supply

The landslides that occur along the slopes that border the shoreline provide sediment to the beach. Prior to the construction of the bulkheads, the delivery of sediment was not significant, except probably at the northern end of the park. Under natural conditions, the two modes of sediment delivery to the beach are from (1) debris flows from the

slopes above the beach and (2) periodic erosion of colluvium from beach-adjacent slopes that are undermined during storms. With the advent of the bulkheads, erosion of the beach slopes was eliminated and the delivery of soils from upland landslides was substantially reduced in the areas that were protected by the bulkheads.

In order to estimate a range of the amount of sediment that is supplied to the beach from unstable slopes, the landslides or old landslide scars were studied to estimate their age, their approximate return interval, and their size. This information provides an approximation of the volume of sediment that may be supplied to the beach annually by landsliding activity. The high and low estimates of colluvium entrained by erosion are based on the downhill movement of colluvium at 0.5 and 0.1 inches per year, respectively (Saunders and Young 1983).

Table 1
Approximate Sediment Supply Rates from Hillside/Bluffs (Natural Condition)

	Total Landslide Sediment Rate (Tons/Year)	Landslide Delivered Rate (Tons/Year)	Colluvium Eroded (Tons/Year)	Total Delivered Sediment (Tons/Year)
High Estimate	50	25	47	75
Low Estimate	25	12.5	9	21.5

Based on observation of the deposits in the field, and experience with landslide deposits, it is estimated that these deposits are comprised of about 25 percent gravel, 30 percent silt/clay, and 45 percent sand. This approximation is based on a natural condition. However, based on the existing condition, perhaps only 10 to 30 percent of this landslide material is currently delivered to the bulkhead-protected beach.

Understanding the upland hillside/bluff geology is key to understanding the coastal geology of Puget Sound beaches. These beaches are primarily fed by sediment that comes from the eroding bluffs described above.

2.2 Coastal Geology

2.2.1 Coastal Geologic Processes Relevant to Seahurst Park

Understanding the concept of the "Drift Cell" is critical to understanding the linkage between the unstable hillside/bluffs and the beaches of Seahurst Park and others like it on Puget Sound (see Figure 6). The drift cell concept has been employed in coastal studies to represent a sediment transport sector from source to deposition along a coast. A drift cell is defined as consisting of three components:

- A site that serves as the sediment source (erosional feature such as an unstable bluff or river mouth)
- A zone of transport, where wave energy primarily moves drift material along the shoreline
- An area of deposition that is the terminus of a drift cell.

Deposition of sediment occurs where wave energy is no longer sufficient to transport the sediment in the drift cell.

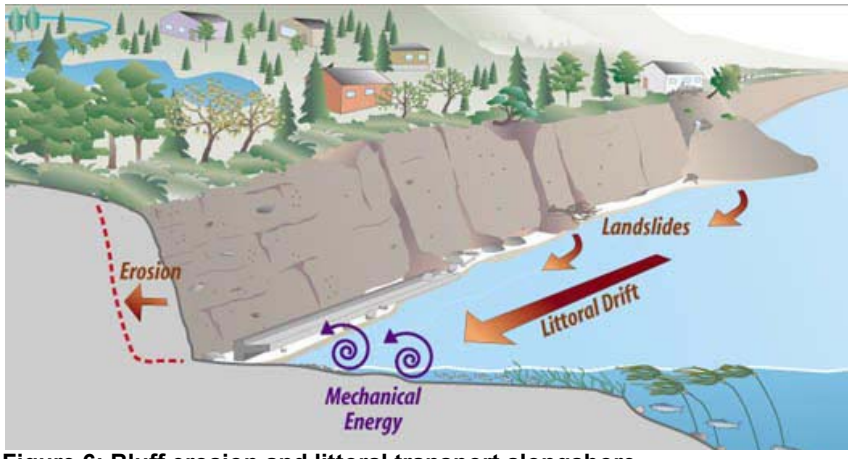


Figure 6: Bluff erosion and littoral transport alongshore.
Source: Williams, et al. 2001

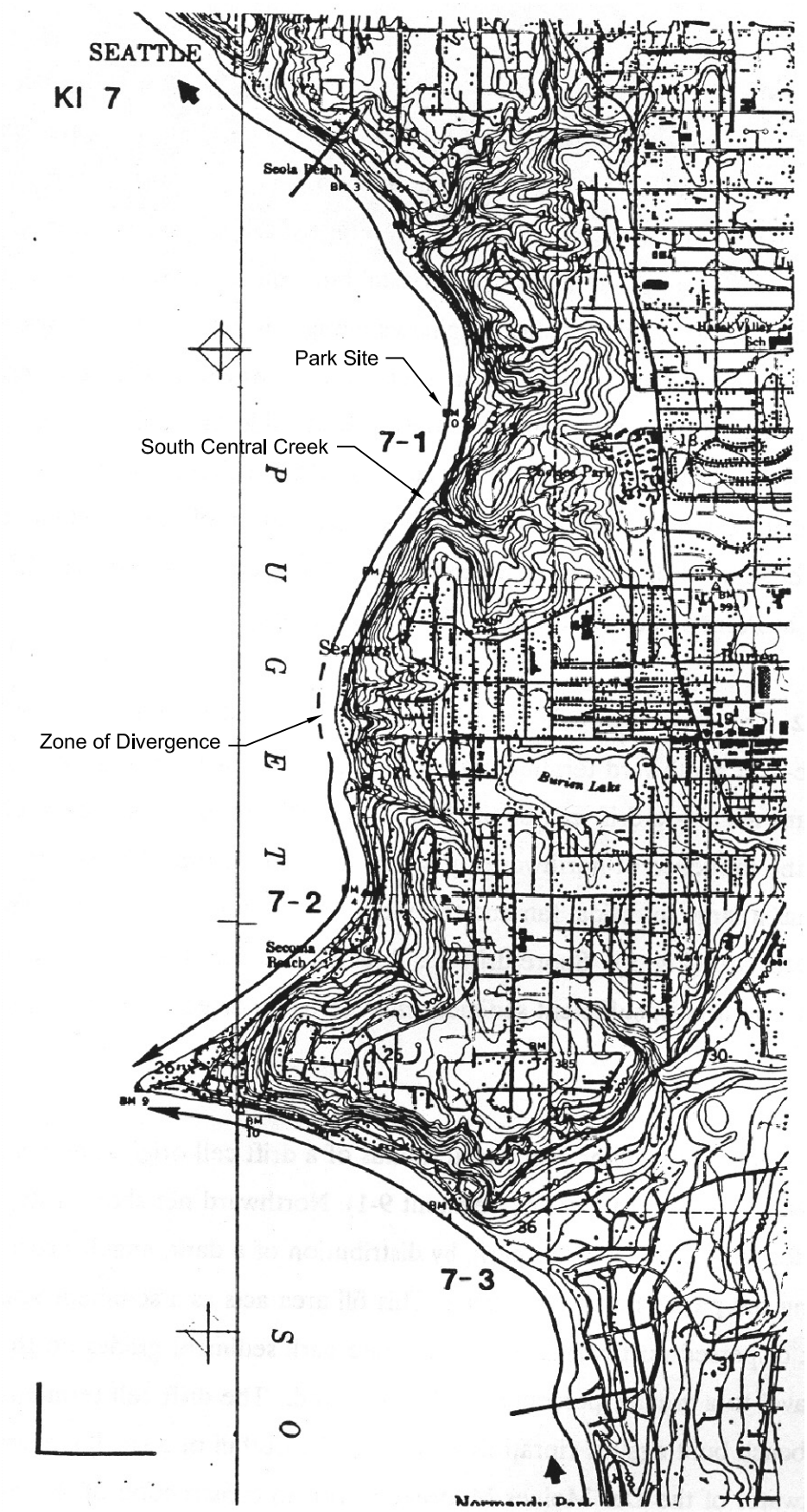
2.2.2 Site Conditions—Direction of Net Drift/Drift Cells

Net shore-drift in the south King County area was first mapped by Chrzastowski (1982). This information was first published by the Department of Ecology in 1984 and in revised form in 1991 (Schwartz and others 1991). The net shore-drift study was conducted through systematic investigations of the coast of the entire study area to identify geomorphologic and sedimentologic indicators that revealed net shore-drift

cells and drift direction. The geomorphic-derived data is the best available information on net shore-drift. (Previous drift cell mapping efforts such as the Coastal Zone Atlas of Washington relied exclusively on historic wind records (wave hindcasting). Drift directions indicated in the atlas series have commonly been proven inaccurate by extensive field reconnaissance.)

Net shore-drift in the vicinity of the Seahurst Park occurs in two net shore-drift cells (Chrzastowski, 1982) that both originate from a zone of drift divergence at the minor "point" located approximately 3,900 feet south of the mouth of the South Central creek in the park (See Figure 7, net shore-drift of the Seola Beach vicinity south to Normandy Park).

Source: Chrzastowski, 1982



Not to Scale

Map KI-7. King County: Seola Beach vicinity south to Narmandy Park.

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Figure 7

Net Shore Drift in the Vicinity of Seahurst Park

Technical Memorandum: Seahurst Background Information

Drift cell 7-1 has northward net shore-drift from this bluff, along the length of Seahurst Park, and continues all the way to Duwamish Head in Elliot Bay. Net shore-drift cell 7-2 originates from the same bluff south of the Park and extends to the distal end of Three Tree Point, which is a large cuspate spit located two miles south of Seahurst Creek (Figure 7). The relevant net shore-drift determinations from Chrastowski (1982) were reviewed for the Seahurst Park vicinity and appeared to be an accurate representation of net shore-drift.

The source of the vast majority of beach sediment along the shores of Puget Sound is erosion of unconsolidated bluffs. In the Burien area, there are several small streams that deliver sediment to the beach system, but prior to development, mass wasting and erosion of the high, unstable bluffs supplied the large majority of sediment to the beach. Bluffs in the area would be expected to experience generally moderate retreat rates. Bluff retreat is augmented in some locations by the presence of mostly-impermeable silt and clay deposits that inhibit drainage and decrease bluff stability. Once on the beach, prevailing and predominant southerly quadrant winds generally cause beach sediment to be transported northward (Map M-4).

2.2.3 Site Conditions—Exposure and Wave Climate

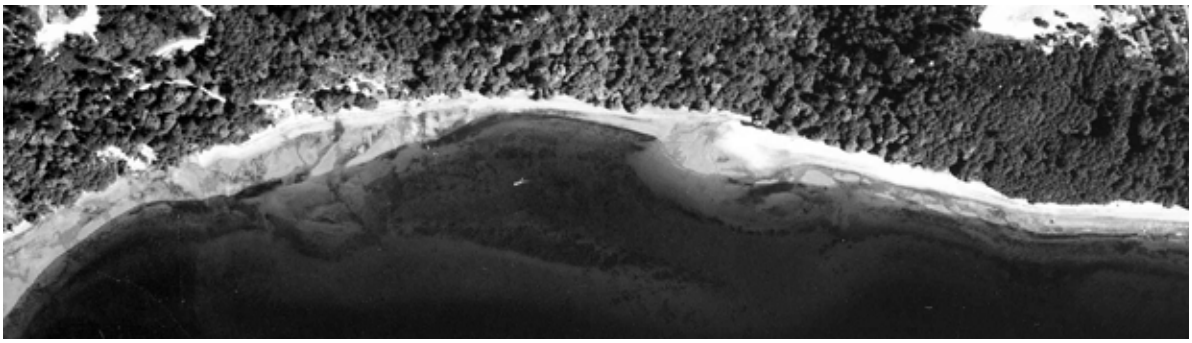
The wave climate for Seahurst Park was not quantitatively analyzed. The wave climate at the site can be generally described as moderate (TAMS 1989). Waves from the southerly quadrant are both predominant (highest velocity) and prevailing (most frequently occurring) in Central Puget Sound. The park shore is not directly exposed to southeast or south wind waves, due to the sheltering provided by Three Tree Point. The site is exposed to a southwesterly fetch (open water distance) of 4.8 miles (to the shore of the north tip of Maury Island). The northwest fetch is on the order of 12.5 miles, but the frequency of strong northwest wind waves is low and waves from this direction are not considered to be a significant factor in coastal processes.

Theoretical deepwater wave heights were computed using US Army Corps of Engineers methodology for the southwest fetch (USACE, in press). The 4.8-mile fetch from the southwest is capable of producing significant wave heights (average of the highest one-third of waves) on the order of 1.95 feet high in a sustained wind of 25 knots. A sustained 35-knot wind is capable of producing significant wave heights of 2.95 feet.

Shallow water breaking waves would be higher than the deep water waves, but these wave heights cannot be determined without detailed site and climate data collection and input.

2.2.4 Site Conditions—Site Coastal Geomorphic and Development History

Aerial photos (Figure 8) were reviewed and compared to document historical changes to the park shore from the time of the earliest available photos of adequate scale and tide level, which was 1946. A mirror stereoscope and a zoom transfer scope were used for this analysis. Specific findings relevant to coastal processes and development in the park area are listed in Table 2. These findings are discussed in context with coastal processes in the following section.



1946

6/29/65

8/10/70

5/31/78

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Figure 8a
Shoreline Aerial Photo History
Technical Memorandum: Seahurst Background Information

7/16/81

7/11/89

6/19/96

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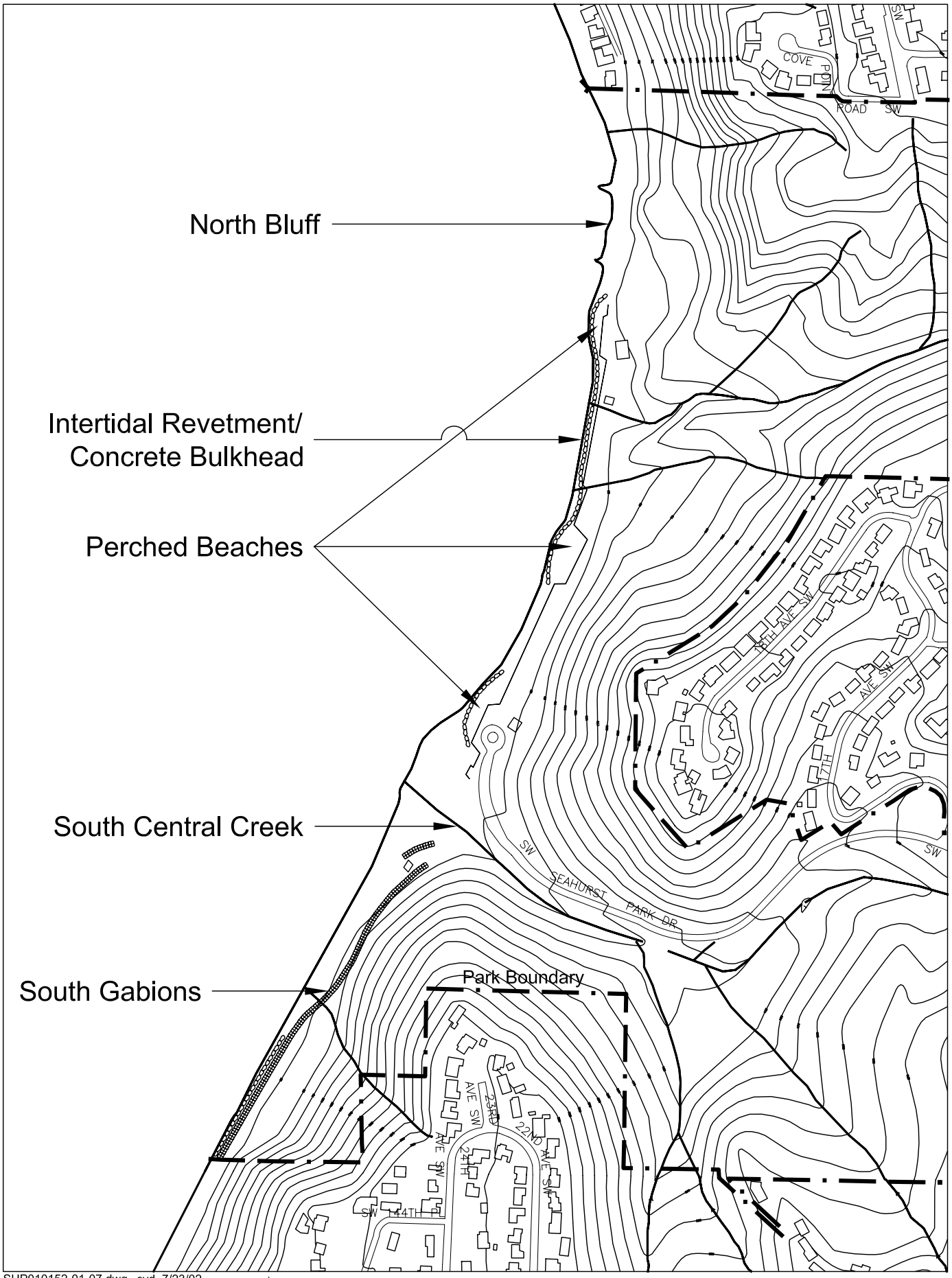
Figure 8b
Shoreline Aerial Photo History
Technical Memorandum: Seahurst Background Information

Table 2
Historical coastal geomorphology and development features at Seahurst Park, 1946-1996

Year	South Central creek mouth and Southern Park	Central Park	North Park and adjacent
1946	• Moderately large creek delta. • Creek channel crosses beach towards N. Relatively wide high tide beach at south end of park.	• Narrow high tide beach with overhanging trees. Narrower high tide beach than N and S. one deteriorated rock groin (3) N end of park.	• One large groin just N of park, likely one or several small groins. • Several buildings at beach level and possibly bulkhead. • Large clear-cut atop bluff and on bluff face to N.
1965	• Relatively large creek delta extending to west. • Wide high tide beach S of Seahurst Creek	• Revetment and fill partially visible. From 1973 as-built drawings, this feature (and fill landward) is in roughly the same location as the 1972 concrete seawall.	• Five groins present at N part and adjacent area. • Low road and houses well N of park. • Road down bluff near N end of park. • Vertical bulkhead N end park.
1970	• Fill over N side delta (with revetment). • Creek flowing N.	• Rock revetment in place and fill area (narrow to N). Beach accreting N-central area due to groins to N.	• Vertical bulkhead and four large rock groins N end park.
1978	• Majority of feeder bluff S of park bulkheaded. Gabions in S of creek. Creek flowing N along new gabions N of creek. Perched beach over portion of active delta.	• New gabion perched beaches and concrete seawalls. • Remnant of lower portion of groin S of salmon creek by Marine Technical building.	• No significant change.
1981	• Creek flowing N along new gabions N of creek. • Bar prograded W of delta. Nearshore sand bars over low tide terrace.	• No accretion waterward of perched beaches. • Erosion of perched beach immediately N of salmon creek. • VERY few drift logs on perched beach.	• No significant change.
1989	• Creek flowing WNW across beach. • Creek delta has caused accretion against gabions/rock to N. • Small ponds at ordinary high water mark (OHWM) near creek channel. • Backshore vegetation established waterward of trees on delta.	• Apparent erosion at perched beaches. • Apparent riprap failure at N end of perched beach. • Backshore vegetation becoming established.	• Groins deteriorating, likely gradually.
1996	• Creek flowing WNW across beach. • Very minor additional accretion N of delta, against perched beach.	• Additional apparent erosion of perched beaches.	• No significant change.



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0 500
Scale in Feet

Figure 9
Beach Segments
Seahurst Park Master Plan

2.2.5 Site Conditions – Beach Areas

The Seahurst Park shore was divided into five reaches based on coastal geomorphic conditions and development features that affect coastal processes. These five areas are discussed in order of the direction of net shore-drift, from south to north, in this section (see Figure 9):

- South Gabions
- South Central Creek
- Perched Beaches
- Intertidal Revetment/Concrete Bulkhead
- North Bluff

All photos included in this section were taken on March 5, 2002 unless noted otherwise.

2.2.5.1 South Gabion

The beach immediately south of the park and at the southernmost portion of the park are very similar. This reach has a consistently-oriented shore that is near linear. The beach in most of this area is the least impacted (as compared to pre-development conditions) of all the beach areas at Seahurst. The northern portion of this reach apparently had a revetment installed over the uppermost beach in the period prior to 1972, as shown on the gabion design plan sheets (Quinton Budlong 1973).

Figure 10. South End of South Gabions Area
Showing south end of area and adjacent "natural" shore south of the park, looking south.

The area south of the gabions was examined to characterize conditions of the beach and bluff in the gabion area prior to installation of shore protection.

This reach has a very narrow, near-horizontal storm berm that has overhanging

vegetation made up of predominantly red alder (*Alnus rubra*) with fewer big leaf maple trees (*Acer marcrophyllum*) (Figure 10). The natural storm berm crest is generally 7-10 feet waterward of the toe of the bank. Minor toe erosion occurred in recent years at the undefended shore. The slope of the high-tide beach, which is the relatively steeply sloping upper foreshore area that is landward of the flatter sloped low-tide terrace, was measured at 7.5:1 (H:V).

For the purposes of this report, the south end of the park is station0+00. The high-tide beach south of the park north through approximately station 3+00 (300 feet worth of the south park boundary) is a mixed beach containing gravel and sand with a fairly consistent composition alongshore (Figure 10). The sediment here consists of primarily coarse sand in the upper high-tide beach and cobble through coarse sand on the lower high-tide beach (Table 3). The composition grades into a predominantly gravel (pebble) beach at the point where the riprap fronting the gabions impinges on the upper intertidal area (approximately station 3+00) (Figure 11). The high-tide beach here also contains angular rock (quarry spalls) that apparently originated from the failed gabions, and contains little sand.

Figure 11. Central South Gabion Area

Showing riprap fronting gabions and quarry spalls on high-tide beach and low-tide terrace, looking south.

Table 3
Sediment Grain Size Analysis of high-tide beach sediment samples - Percent Frequency

Size Class	South Gabions-South Upper	South Gabions-South Lower	Perched Beach - South-Upper (landward of revetment)	Perched Beach - South-Lower (waterward of revetment)	Intertidal Revetment/ Concrete bulkheadl – Upper	Intertidal Revetment/ Concrete bulkheadl - Lower
(-) 6 phi (>64 mm) cobble	0.0%	0.0%	0.0%	0.0%	0.0%	54.4%
(-) 5 phi (32-64 mm) cobble	0.0%	6.5%	0.0%	1.6%	0.0%	12.0%
(-) 4 phi (16-32mm) pebble	5.7%	20.7%	0.7%	26.3%	5.1%	5.8%
(-) 3 phi (8-16 mm) pebble	12.3%	20.9%	0.9%	19.0%	7.9%	3.2%
(-) 2 phi (4-8 mm) pebble	5.6%	16.4%	2.0%	14.6%	10.2%	3.8%
(-) 1 phi (2-4 mm) granule	2.8%	9.5%	2.5%	9.5%	10.5%	9.6%
0 phi (1-2 mm) v. cs. sand	2.4%	5.5%	3.7%	7.2%	12.1%	8.5%
(+)1 phi (0.5-1 mm) cs. sand	54.8%	11.4%	70.4%	14.4%	36.5%	2.2%
≤(+) 2 phi (<0.5 mm) fines	16.4%	9.2%	19.7%	7.3%	17.7%	0.5%
Sum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total 1-8mm	**10.9%**	**31.4%**	**8.2%**	**31.3%**	**32.8%**	**21.9%**

2.2.5.2 South Central (Unnamed) Creek Delta

The delta of the south central creek influences coastal processes in the vicinity of the creek mouth. The sediment input of the creek should be considered to be relatively minor in perspective to the entire drift cell, but is important locally. The sediment input from the creek was likely much greater than under natural condition during the decades preceding park development as many land use alterations occurred in the creek basin (referred to as the south basin in the Geology section). These alterations are evident from review of the historical aerial photos. Land use alterations included logging and road construction (which were likely completed without much attention to drainage or minimization or disturbance); and home site development.

The south central creek delta is prograded (extended) waterward to form a very gently concave-waterward beach shape. In other words, the beach south of the delta has accreted up against the south side of the delta, and could be termed an "accretion shoreform" (Figure 12). This part of the beach is likely not accreting at this time however, due to the larger drift cell impacts (reduction in bluff sediment input).

Figure 12. South central Creek Delta Area.
Showing "Accretion beach" on the south side of delta, looking south.

The width of the active delta was reduced during installation of the pre-park revetment and park gabions and concrete bulkheads. Therefore the natural, pre-development creek meandered over a broader supratidal and intertidal area as compared to current conditions. The perched beach revetment immediately north of the creek appears to have caused some amount of accretion up against the south side of the perched beach revetment between 1978 and 1996. Interesting in habitat terms, was the presence of a series of ponds in the backshore area in the vicinity of the creek in 1989.

The beach in the delta reach has a broad backshore area containing abundant drift logs and dunegrass (Figure 12). The high-tide beach in this area is composed of sediment that is very similar to the south end of the South Gabion area, containing locally abundant coarse sand, very coarse sand, and pebble.

2.2.5.3 Perched Beaches

The area north of the south central creek delta contains three portions of a generally continuous riprap revetment (replacements of the 1972 gabion walls) that protrude waterward of the trend of the shore. The northern of these three features is located at the north end of the concrete bulkhead and is not considered part of this reach.

These areas were designed to create perched beaches at higher elevations than the natural beaches (Figure 13). The areas above the revetments were filled with coarse sand to elevation +12.5 feet mean lower low water (MLLW) upon construction (Quinton-Budlong, Inc. 1973). This is equivalent to approximately 0.9 feet above local mean higher high water (MHHW). The perched beaches had apparently eroded significantly by 1989 and it appears that 6,500 cubic yards (cy) of additional coarse sand for the perched beaches was added after 1989 to bring the beach level back up to the design level (TAMS 1989).

Figure 13. Perched Beaches (A)
Showing southern perched beach and riprap revetment fronting it, looking north.

The concrete bulkhead in this reach is located landward of the MHHW line, however the Ordinary High Water Mark (OHWM) is immediately against the bulkhead through most of this reach. The perched beach reach differs from the adjacent reach to the north in that the bulkhead is not as far waterward in the perched beach reach. The concrete bulkhead replaced an earlier filled area and some type of revetment, as this feature is shown in the As-Built drawings for the concrete wall (Quinton-Budlong Inc. 1973), and is also partially visible in the 1965 photo.

Between the southern and the central perched beaches is a long straight reach of bulkhead (Figure 14). This area has a sandy beachface that slopes up to the toe of the bulkhead, which is located above MHHW. Upon inspection of this area, it appears that the toe of the bulkhead is defended with some amount of riprap. This riprap is almost entirely buried, indicating that the beach has accreted since installation of the riprap (unless the riprap was installed as buried toe protection).

Figure 14. Perched Beaches (B)
Showing high-tide beach between the southern and central perched beaches, along straight reach of bulkhead, looking north.

Beach sediment was analyzed in the southern perched beach. The sample from the high perched beach contained 70 percent coarse sand and 20 percent finer sand (Table 3). The sediment collected from 12 feet waterward of the revetment consisted of a wide range of grain sizes from pebble through coarse sand. Sediment at the central perched beach was similar but appeared to contain relatively more gravel waterward of the central perched beach revetment.

The large "backshore area" nestled within landward projections of the bulkhead is a unique feature of the central perched beach area (Figure 15). However, Most of this area does not function as a true backshore area as the revetment keeps it partially isolated from the beachface and the vegetation is transitioning into terrestrial plant dominant.

Figure 15. Perched Beaches (C)
Showing large "backshore area" landward of the central perched beach with revetment visible to left and bulkhead to right, looking north.

The waterward and northern portion of the perched beach is eroded with drift logs present (Figure 16). The width of the riprap revetment that is exposed at the central perched beach was measured at 29 feet horizontally.

Figure 16. Perched Beaches (D)
Showing central perched beach looking south. Note wide (29 feet) exposed riprap and eroded perched beach.

2.2.5.4 Intertidal Revetment/ Concrete Bulkhead

A long reach of bulkhead is present in this northernmost section of the concrete bulkhead portion of the park. A very wide riprap revetment (generally 20 feet wide) is also present along the entire length of this reach. The revetment extends to below MHHW. The remains of one of the old large rock groins are located near the southern end of this reach (Figure 17).

A sand and gravel high-tide beach (predominantly small pebble to coarse sand; Table 2) is present waterward of the riprap in a relatively narrow band (Figure 17). The lower portion of this band (the high-tide beach) contains much more cobble and quarry spalls (54 percent; Table 3). The upper low-tide terrace also contains much angular rock (quarry spall).

The northern perched beach is within this reach. It is the most eroded of the three perched beaches in the park and contains abundant pebble, cobble and quarry spall (Figure 18). This area has apparently been overtopped by waves more frequently then the other perched beaches.

2.2.5.5 North Bluff

The north bluff reach is approximately 800 feet in length and does not have a bulkhead or any type revetment. This reach does contain several large old groins constructed of rock. This reach has a gravel and sand beach that reaches up to or very close to the toe of the bluff (Figures 19 and 20), where evidence of toe erosion is present in some areas. Sand and gravel has accreted on the south side of the groins, but the groins are somewhat deteriorated. The effectiveness of the groins in "holding" sediment has been decreased as beach sediment is passing through low points in the groin profile.

Figure 17. Intertidal Revetment/Concrete Bulkhead (A)
Showing southern end of the Intertidal Revetment/Concrete Bulkhead reach looking south. Rocks in distance are remains of old groin.

This reach is relatively more exposed to wave energy from the southwest and south. Also, the beach in this reach has been negatively impacted by the shore protection structures located south and up-drift of this area (the earlier bulkhead, the current bulkhead, and the perched beach revetments). This is due to sediment impoundment, as well as end effects (wave refraction and increased wave energy and scour) on the north side of the structures. Additionally, the deterioration of the groins has allowed time to "catch up" and erode the bluff toe that was artificially preserved for many decades.

Figure 18. Intertidal Revetment/Concrete Bulkhead (B)
Showing northern perched beach looking south.

Figure 19. North Bluff Area (A) Overview.
Looking north on 10/10/01.

Figure 20. North Bluff Area (B). *Showing upper beach and overhanging vegetation, looking north on 10/10/01.*

Understanding the physical processes of hillside/bluff geology and coastal geology is key to working with the biological habitats found in Seahurst Park. The dynamic physical processes visible at the park are the foundation upon which the biological communities develop and adapt.

3 BIOLOGICAL PROCESSES AND HABITATS

Seahurst Park contains a diverse array of habitats no longer common in King County's mainland Puget Sound shorelines. The physical processes that form these habitats have been described in the two preceding sections. The following sections cover first the nearshore habitats, and then upland forested habitats inside the park. These habitat types are described in general as to their importance and ecological function. Specifically, characteristic species within each of these habitats are identified, and site conditions at the park are described in detail based on field reconnaissance.

3.1 Nearshore Environment

3.1.1 Nearshore Habitat Processes Relevant to Seahurst Park

The nearshore zone is defined as the area between the lower limit of the photic zone - approximately minus 30 meters MLLW in Puget Sound - and the upland-aquatic interface (i.e., the riparian zone) (Williams et al. 2001). Figure 21 depicts a cross section of the nearshore zone.

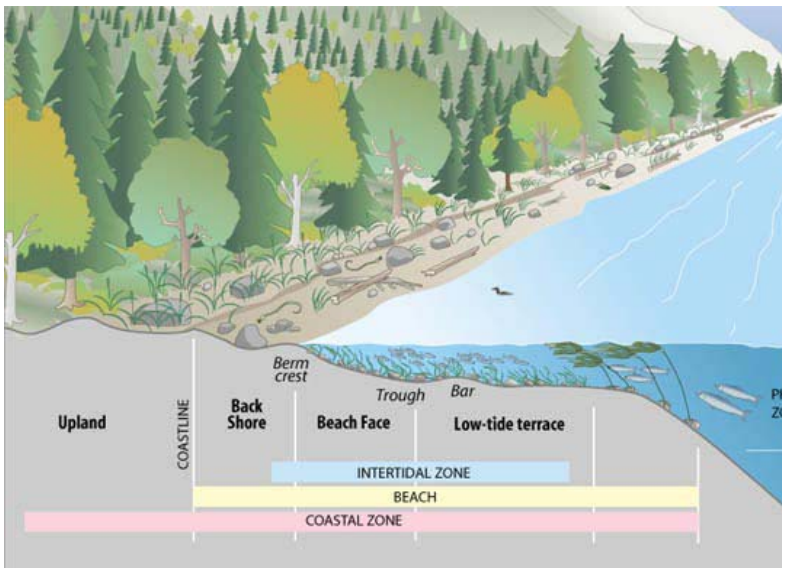


Figure 21: Typical Puget Sound Shoreline Features
(Source: Williams et al. 2001.)

The nearshore zone includes the riparian area, or supralittoral zone down to the shallow subtidal zone and to the lower limit of the photic zone. This area is the lower extent at which marine vegetation receives enough light to grow.

Ecological processes occurring in the nearshore zone create a diversity of habitat types that provide ecological functions, such as refuge and food production, important for salmonid survival (Williams et al. 2001). For example, erosion and sediment transport processes carry sediments to beaches, spits, and other coastal landforms. In addition, tides and streams contribute minerals and nutrients, shape the land, and cyclically

inundate and expose flood plain and shoreline areas. Finally, freshwater flowing into Puget Sound via rivers, streams and seeps creates complex patterns of salinity (Williams et al. 2001). Processes such as these form nearshore habitat types, including eelgrass beds, macroalgae, mudflats, and sand/cobble beaches, which all provide functions essential to salmonid survival.

3.1.1.1 Importance of nearshore habitats to salmonids

Juvenile and adult salmonids in Puget Sound rely heavily upon the nearshore environment for species survival. Nearshore habitats provide key survival functions to both juveniles and adults. Key ecological functions for juveniles include migration corridors, food production, physiological refuge (transition from freshwater to saltwater), refuge from predators, and high-energy refuge (i.e., high flows, wave action) (Mason 1970; MacDonald et al. 1987; Thorpe 1994; Levings 1994; Spence et al. 1996). Key nearshore functions for adults include migration corridors, food production, and physiological refuge.

All juvenile salmon utilize the shallow waters of estuaries and nearshore areas as migration corridors to move from their natal streams to the ocean (Williams and Thom 2001). Suitable corridors provide important predation refuge opportunities by spatially separating juvenile salmon from predators in shallow water or providing habitat structure for them to use. Juvenile salmon feed on an array of organisms found in shallow estuaries and nearshore areas. During migration, anadromous salmon must undergo a physiological transition from fresh to salt water. The estuarine environment provides a gradual transition area for juvenile salmon to adjust (Simenstad et al. 1982). As mentioned above, estuarine and nearshore habitats provide shallow water areas for juvenile salmon migrations by spatially separating them from larger predators (Williams and Thom 2001). The complex and dynamic morphology of estuarine and nearshore habitats also provide juvenile salmon refuge from high river flows and wave action (Aitken 1998).

All adult salmon use nearshore and estuarine habitats during adult spawning migrations. Returning adult salmon use nearshore habitats as foraging areas where they feed on forage fish including Pacific herring (*Clupea harengus pallasi*), surf smelt (*Hypomesus pretiosus*), and sand lance (*Ammodytes hexapterus*) (Penttila 1995; Brodeur

1990). Surf smelt and sand lance spawn in the upper intertidal zone of sand and gravel beaches. Furthermore, adult salmon tend to use nearshore and estuary areas as physiological refuge while transitioning to survival in fresh water habitats. The adults may also use estuarine habitats as holding spots until environmental conditions are conducive for entering streams or rivers (Johnson et al. 1997).

3.1.2 Site Conditions—Nearshore Habitat

Seahurst Park contains nearshore habitats important for both juvenile and adult salmonids (Map M-5). Along the shoreline of the park, the intertidal and riparian areas offer a varying degree of ecologically functioning habitat for salmonids depending upon the proximity to the two main streams that enter through the park and the shoreline armoring configuration in the area. The south central creek has created a large delta. The northerly longshore drift of sediment provides a greater amount of sandy material to the intertidal beach areas north of the stream. In general, the further the shoreline armoring in the park encroaches into the intertidal zone, the less middle and upper intertidal zone beach is available to high functioning habitat for juvenile salmonids, their prey and forage fish species (i.e., surf smelt and sand lance). The following description of habitat conditions in the park in based upon an intertidal reconnaissance survey of nearshore habitats and eelgrass occurrence conducted from land during low tide on March 4, 2002.

3.1.2.1 South Gabions

The southernmost section of the park has gabion and riprap armoring in the upper intertidal zone. This section has large gravel (1.5 to 3.0 inch diameter) throughout the middle and upper intertidal zone with small amounts of interspersed small gravel (0.1 to 0.5 inch diameter) and sand. In the low intertidal zone, the beach gradient flattens slightly and has a mixed large gravel and sand substrate. Displaced riprap boulders (6 inches and larger) are interspersed into the intertidal zone throughout much of this section (Figure 22). No vegetation, and limited barnacle cover, is observed on the large gravel substrate. A few small patches (3 feet diameter or less) of native eelgrass (*Zostera marina*) occur in the lower intertidal zone (as high as +1.8 feet MLLW). A park trail and mature trees line the riparian zone of this section. Although the trees do not overhang the intertidal zone, at low sun angles the trees will shade to the intertidal zone. These observations in the southernmost section of the park indicate that the intertidal zone offers only fair habitat for juvenile salmonids and essentially no suitable spawning areas for forage fish.

Figure 22. Southernmost Section of Park
Area has a mixed gravel and sand substrate with large riprap pieces throughout the intertidal zone

Figure 23. South of south central stream
Note the logs in upper intertidal and patchy eelgrass in lower intertidal zone

Note that Map M-5 indicates surf smelt spawning habitat exists in the portion of the shoreline. The forage fish spawning habitat data for this map comes from the Washington Department of Fish & Wildlife (WDFW). This data indicates areas where forage fish spawning has been documented but the information not updated. Therefore, WDFW makes no

distinction between highly functioning and currently degraded forage fish spawning habitats.

Figure 24. Patchy eelgrass in the low intertidal zone of the south section of the park

Further north in the southern third of the park shoreline between the intertidal positioned gabion and the south central stream delta, the gabion armoring is set back from the intertidal zone. The upper intertidal zone has numerous large logs that have created a backshore area with established beach grasses.

An area of mowed grass occurs between the backshore and the gabion. The upper and middle intertidal zone has a mix of sand and small to medium gravel (0.1 to 1.5 inches diameter) with small amounts of large gravel (Figure 23). In the low intertidal zone, the beach gradient flattens (particularly closer to the stream delta) and a sand substrate has been colonized by patches of eelgrass. Freshwater seeps in the low intertidal zone keep the low intertidal zone wet through the low tide cycle. The eelgrass patches occur as high as +2.5 feet MLLW, although most intertidal eelgrass was no higher than +1.8 feet MLLW. The patches ranged in shoreline length from 6 inches to approximately 80 feet and were comprised primarily of native eelgrass (*Z. marina*). Limited amounts of the non-native eelgrass (*Z. japonica*) were also observed in this section of the park (Figure 24). More extensive eelgrass beds were apparent in the shallow subtidal zone (0 feet to –4 feet MLLW). Trees in the riparian zone are set back from the intertidal zone and provided limited or no shade to the intertidal zone. This section of the park appears to provide good habitat for juvenile salmonids, but only limited suitable spawning areas for forage fish. The low intertidal and shallow subtidal sandy areas with eelgrass provide good substrate for production of epibenthic prey organisms for salmonids. In addition, the larger eelgrass patches can provide a refuge from predation and a migration corridor for juvenile salmonids to move through.

3.1.2.2 South Central Creek Delta

The south central stream and its delta provide additional salmonid prey production. The upper intertidal small gravel and sand substrate is suitable for forage fish spawning however, egg desiccation during incubation is likely because there were no seeps or overhanging vegetation. Observations during a recreational dive of the area reported eelgrass (*Z. marina*) further offshore (approximately –5 feet MLLW) in the south central stream delta area.

Figure 25. Riprap placed in middle intertidal zone limits the width of the beach

3.1.2.3 Perched Beaches

This section of the beach extends from the south central stream delta to the large rock slabs (greater than 6 feet diameter) in the intertidal zone occurring just off from where the stairs ascend the bulkhead and the wall turns in towards the water (see Figure 9). This section has a greater component of sand and small gravel than the south section, most likely due to the northerly transport of material from the south central stream. Two areas of middle intertidal riprap (as low as +6 feet MLLW) in the section limit the width of the middle intertidal zone and the upper intertidal areas behind the riprap do not provide good forage fish spawning habitat (Figure 25). Numerous large logs occur on the riprap and along the backshore. Beach grass occurs near the bulkhead in those areas with an established backshore. Limited amounts of barnacles, sea hair (*Enteromorpha sp*.), sea lettuce (*Ulva sp*.) and laver (*Porphyra sp*.) were found on the intertidal riprap. Tufts of a red algae (*Polysiphonia sp*.) occur on the limited gravel in the low intertidal zone. The riparian zone above the bulkhead contains mowed grass and sidewalks. Set back from the shoreline are mature trees, that likely provide little shade to the intertidal zone. No patches of eelgrass were documented in the intertidal zone of this section. There

was also no eelgrass seen in the shallow subtidal zone, although visibility was limited. This section provides good substrate for the middle and upper intertidal spawning of forage fish, although the areas of riprap in the middle intertidal zone and the lack of shading by riparian vegetation may limit forage fish utilization/production of the area.

Figure 26. North section where seawall narrows intertidal beach width and displaced riprap is interspersed throughout the low intertidal zone

3.1.2.4 Juvenile Revetment/ Concrete Bulkhead

This section includes the northern end of the bulkhead and a designed break in the bulkhead to allow a stream to drain into the intertidal zone. Behind the bulkhead is acclimation pond for hatchery releases by the Marine Technology Center that operates on site. Extensive Enteromorpha occurs at the stream mouth. Riprap occurs along the length of the concrete bulkhead (Figure 26). Near the northernmost end of the concrete bulkhead, the riprap is not directly adjacent to the bulkhead and has created a perched beach area similar to those seen in the adjacent southern beach segment. The middle and lower intertidal areas in front of the bulkhead include sand, shell fragments, and small gravel.

Figure 27. Beach north of seawall.
Area has overhanging riparian vegetation, large woody debris in the upper intertidal zone, and a mixed sand and gravel substrate.

3.1.2.5 North Bluff

North of the bulkhead, a sand and gravel beach extends throughout the middle and upper intertidal zone. Scattered amounts of displaced riprap occur in the middle and low intertidal zones throughout the north section of the park. Behind the bulkhead, the riparian zone is comprised of mowed grass, sidewalks, and the Marine Technology Building. Set back from the shoreline of the bulkhead are mature trees, that likely provide little shade to the intertidal zone. North of the bulkhead, trees in the riparian zone overhang the intertidal zone and provide a source of large woody debris to the nearshore area (Figure 27). Limited patches of eelgrass occur in the low intertidal zone just south of the Marine Technology Center and north of the northernmost groin.

These patches are a mix of *Z. marina* and *Z. japonica*. Near the Marine Technology Center, eelgrass occurs as high as approximately +2.5 feet MLLW. A patch of *Z. japonica* north of the northernmost groin occurred at approximately +4.0 feet MLLW. These eelgrass patches occur in areas with freshwater seeps that kept the areas wet throughout the low tide cycle. The north section of the park provides good habitat for salmonids north of the bulkhead and fair habitat in front of the bulkhead. The same is true for forage fish spawning areas in the section: good potential spawning areas north of the bulkhead and fair areas in front of the bulkhead. These habitat quality differences are based on the limited beach width in the bulkhead and riprap areas and the occurrence of overhanging riparian vegetation north of the bulkhead.

3.1.2.6 Site Conditions – Marine Organisms

Previous studies of the park shoreline reflect similar conditions. A baseline study of the park in 1982-83 was conducted as part of the Renton Sewage Treatment Plant Project. As part of that investigation Thom et al. (1984) reported similar substrate

conditions and subtidal eelgrass extending along most of the park shoreline except the very northern tip. A more recent study, the Washington State ShoreZone Inventory (WDNR 2001), used a helicopter survey to provide a broader look at Puget Sound and coastal shorelines and characterized the park shoreline as having both eelgrass species (*Z. marina* and *Z. japonica*) along the entire park shoreline.

3.1.2.7 Benthic infauna

The 1982-83 Seahurst Park baseline study found that the different habitat types found in the park had specific infaunal species associated with them (Thom et al. 1984). The eelgrass areas along the park were characterized by two species of polychaete worms: 1) *Mediomastus sp*. and 2) *Notomastus tenuis*, and two bivalves: 1) bent-nosed clams (*Macoma nasuta)* and 2) *M. inquinata*. The high and low cobble beach areas were characterized by gammarid amphipods (*Corophium salmonis*), oligochaete worms, native littleneck clams (*Protothaca stamina*), and the clam *M. inquinata*. The amphipods and worms are important food items for juvenile and adult salmonids (Aitken 1998). In 1996-97, a King County Beach Assessment was conducted at Seahurst Park by a group of volunteers. The assessment found the clams to be scarce and very small relative to other beaches surveyed during the same time period (King County DNR 1998). Half of the clams found were identified as *Macoma* species and approximately 20 percent were identified as native littlenecks. Other species encountered included butter (*Saxidomus giganteus*), manila (*Tapes philippinarum*), and softshell clams (*Mya arenaria*). More recently, WDFW identified the presence of geoduck clams (*Panopea generosa*) in the subtidal area along the entire length of the park (WDFW 2002).

Washington Department of Health (WDOH) Beach Health Classification for Seahurst Park shows shellfishing is not advised throughout the park.

3.1.2.8 Fish

Salmonids

Salmonids sampled in the nearshore area of Seahurst Park during 1982 and/or 1983 included chum salmon (Donnelly et al. 1984). The Marine Technology Center conducts annual beach seines in the nearshore areas of Seahurst Park and has

consistently caught coho and cutthroat, and inconsistently caught chinook (Weiss 2002a). The presence of these species indicates use of the park shoreline for migration and/or rearing purposes. A hatchery, which is part of the OSC Marine Technology Project, is run by the Highline School District and is located near the north stream. The hatchery was started in 1970 and raises coho smolts, which are released directly into Puget Sound in front of the Marine Technology Lab (Weiss 2002b). Each year, approximately 10,000 coho smolts are released and approximately 80 adults return. Additionally, the King County State of the Nearshore report (Williams et al. 2001) indicates adult and juvenile salmonid presence along the Seahurst Park shoreline. Species expected to use this area based on knowledge of species life history include chinook, chum, coho, pink, sockeye, cutthroat, steelhead, and native char (adults only). The adult and juvenile timing of each species in the nearshore environment is detailed below.

Most adult chinook salmon in the Puget Sound region return to their natal rivers to spawn in the fall, and will be found in the nearshore marine waters, including areas off Seahurst Park, at this time. Juvenile chinook are found in the nearshore from late January/early February through September. Collections with beach seines suggest that juvenile chinook are oriented to shallow water habitats located close to shore, and are most abundant in intertidal flats and shallow subtidal channels near estuarine and tidal marshes and eelgrass meadows (Williams et al. 2001).

Adult chum salmon in Washington generally return to their natal streams to spawn from October to November and will be found in nearshore waters at this time. Juvenile chum may be found in the nearshore areas, including areas of Seahurst Park, between January and July, with a peak from March to April (Williams et al. 2001). Juvenile chum tend to remain in shallow estuarine channels or other productive areas near estuarine and tidal marshes, eelgrass meadows, and over tideflats (Sibert et al. 1977).

Adult coho salmon spawn in the Puget Sound region in the winter and are expected to be in the nearshore waters during that time. Juvenile coho generally spend 18 months rearing in freshwater before moving through the estuaries and nearshore areas. Smolt outmigration timing exhibits interannual variation and can vary by

several weeks to a month (Weitkamp et al. 1995). It is assumed that they migrate through the estuary and nearshore zone rapidly. Coho smolts are much larger than chinook and chum juveniles in nearshore areas and it is thought they prefer deep, marine-influenced habitats (Emmett et al. 1991). However, they are often caught in beach seines over intertidal areas in estuaries and over eelgrass meadows and tideflats.

Adult sockeye salmon are expected to be present in the nearshore areas of Puget Sound during June through August (Gustafson et al. 1997). Juvenile sockeye use the nearshore waters, including areas off Seahurst Park, as a migratory corridor during the spring and early summer. Juvenile sockeye were caught in beach seines at Seahurst Park on June 5, 2000 (Williams et al. 2001).

Adult pink salmon return to their natal streams to spawn between mid-July and mid-August (Hard et al. 1996). Adult pinks return every other year, with most pinks in Puget Sound returning in odd years. Juvenile pinks move into estuarine and nearshore areas from March through May. Juveniles in Puget Sound rear extensively in shallow marine waters and nearshore embayments (Williams et al. 2001).

Sea run coastal cutthroat trout return to freshwater in the winter to feed, seek refuge, or spawn. Juveniles typically rear in freshwater for two to four years before moving to marine waters. Outmigration occurs from March to July, and peaks in May (Emmett et al. 1991).

In Puget Sound, two races of steelhead trout exist including winter-run and summer-run stocks. Most populations display winter-run characteristics and migrate during fall through early spring. Juveniles spend from one to four years in freshwater before migrating to marine waters typically from April through June (Busby et al. 1996).

Bull trout and Dolly Varden are two species of native char that are difficult to distinguish physically, and for management purposes are combined. Bull trout/Dolly Varden have been documented in the lower Green River and Duwamish

River (King County DNR 1998; R2 Resource Consultants 2000). Anadromous native char leave their natal rivers for marine waters as subadults; therefore, juvenile fish are not found in nearshore waters. Adult spawning occurs in Puget Sound streams peaking in September and October. Char occurrence usually coincides with surf smelt spawning beaches because they appear to favor forage fish species over salmonids as food in the nearshore environment (Williams et al. 2001). Surf smelt and sand lance spawning has been documented along Seahurst Park, therefore adult char species may forage in the nearshore waters of the park.

Forage Fish

Forage fish (surf smelt, Pacific sand lance, and Pacific herring) depend on nearshore habitats for spawning and rearing and are important food sources for juvenile and adult salmonids. Surf smelt and sand lance tend to spawn on sand and gravel substrates in the upper intertidal zone. WDFW has found evidence of surf smelt and sand lance spawning along the entire Seahurst Park shoreline (Williams et al. 2001). Herring tend to spawn on intertidal and shallow subtidal eelgrass and marine algae. WDFW has not identified any herring spawning sites in the park, although there is eelgrass and marine algae present along the shoreline.

To protect forage fish species, approved work windows have been determined for activities occurring on the beaches used by these species. According to the US Army Corps of Engineers, Seahurst Park is within Tidal Reference Area 4, which has approved work windows for surf smelt between April 15 and September 30 and sand lance between March 2 and October 14.

Other fish species

As part of the Seahurst Park baseline study for the Renton Sewage Plant Project, trawl nets and beach seines were used to sample fish. The most abundant fish caught included shiner perch, English sole, and rock sole. Frequently caught species included sand lance, juvenile rockfish, chum salmon, gunnels, sculpins, and greenling (Donnelly et al. 1984).

The physical processes that connect the nearshore marine environment and the uplands have been discussed previously. The following section describes the biological connection between these two environments and the upland habitat conditions found at Seahurst Park.

3.2 Upland Forested Environment

3.2.1 Forest Plant Community Processes Relative to Seahurst Park

At Seahurst Park, much of forested environment currently and/or historically consisted of "riparian zone." Riparian zones, which occur at the interface between the terrestrial and aquatic ecosystems, consist of upland plant and forest communities. Riparian habitats are characterized by dense vegetation and provide unique functions to nearshore and freshwater stream areas including water quality enhancement, bank stability, wildlife habitat, and inputs of nutrients and large woody debris (Williams et al. 2001). These functions are discussed in detail below:

- Water Quality: Riparian vegetation buffers against pollution and sediment runoff by binding soils, retaining and absorbing contaminants, and reducing overland flow volume and velocity (Williams et al. 2001).
- Bank Stability: Vegetation reduces erosion and increases slope stability by extracting moisture through the canopy and roots and reinforcing soils through the root and stem systems (Williams et al. 2001).
- Wildlife Habitat: Wildlife species diversity and abundance is influenced by the composition and continuity of vegetation, and the proximity of riparian areas to the marine environment. For example, overhanging riparian vegetation provides shading that regulates microclimates important to intertidal invertebrate distribution (Foster et al. 1986) and surf smelt spawning (Penttila 2000). Additionally, vegetation in the riparian zone delivers organic matter and invertebrate prey to the nearshore (Simenstad and Cordell 2000), and creates complex structure that is important for fish (e.g., refuge and spawning) and wildlife (e.g., bird nesting and roosting) (Williams et al. 2001).
- Nutrient Input: Organic matter generated in riparian areas enters streams and the marine environment and contributes nutrients to the system (Williams et al. 2001).
- Large Woody Debris Input: Riparian vegetation along streams and in the nearshore zone contributes fish and wildlife habitat structure in the form of large woody debris that enters the nearshore environment through natural and human-induced erosion of banks and bluffs, erosion of wooded riverbanks with delivery through the estuary, and drift logs delivered by the tides (Williams et al. 2001).

The riparian areas of Seahurst Park are characterized by vegetation types found throughout the Puget Sound Lowlands. These vegetation types are discussed in detail in the following paragraphs.

All of the Puget Sound Lowlands and much of the rest of Washington State lies within what botanists and foresters refer to as the Western hemlock zone. The Western hemlock zone is characterized by a mild maritime climate that is wetter in winter and drier in summer. Although the forests in this region vary widely in age, condition, and species, they are comparable due to regional similarities in physiography, geology and soil types. The plant communities found in Seahurst Park are also commonly found in other undeveloped forests in the Puget Sound Lowlands. The soils of the region in general and the park in particular are deep to moderately deep with medium acidity and loamy texture.

Seahurst Park contains several plant communities common to the Western hemlock zone. The Western hemlock zone represents a wide range of geographic areas with a variety of conditions for plants. As a result, groups of species that favor a similar set of conditions are commonly found associated with one another and are sometimes called plant communities or plant associations. These communities are comprised of trees, shrubs and herbs. Each plant community becomes established in distinct areas with characteristics suitable for their survival. These characteristics at Seahurst Park developed in response to human disturbances, natural disturbances, and environmental resources (Forman and Godron 1986). Human activities (e.g., logging) and natural disturbances (e.g., land slides) alter landscape features and change the ecological characteristics of an area (Forman and Godron 1986).

3.2.2 Site Conditions – Upland Forest Communities

The plant communities at Seahurst Park are discussed in detail below and have been simplified into five groups that reflect the broad categories of growing conditions at the park (see Map M-6, names of plant communities shown on map in parentheses).

3.2.3 Site Conditions—Upland Forest Communities

3.2.3.1 Red Alder Communities (Younger Deciduous)

Forest communities of red alder (*Alnus rubra*) are dominant in much of the park. Red alder readily colonizes a site that has recently been disturbed by logging or landslide. The entire Seahurst Park site was likely colonized by red alder after the site was logged in the early 20th century. Today dense stands of red alder can be found in actively and historically unstable areas of the park, especially on the steep slopes directly above Puget Sound. The understory below these stands of red alder is commonly comprised of Nootka rose (*Rosa nutkana*), salmon berry (*Rubus spectabilis*) and sword fern (*Polystichum munitum*). Red alder trees and red alder communities tend to be short-lived and often are replaced by other more shade tolerant species as they die off. Actively geologically unstable areas in the park tend to remain in this plant community.

Figure 28. Red Alder – Big Leaf Maple Community

3.2.3.2 Madrone/Salal Community (Drier Mixed)

Along the perimeter of the park at higher elevations Pacific Madrones (*Arbutus menziesii*) are the dominant tree. They are commonly associated with a dense understory of salal (*Gautheria shallon*). Both these species are common on sandy bluffs where soils are relatively low in both moisture and nutrients. This community is best established in the northeast corner of the park, but

Figure 29. Madrone – Salal Community

occurs in many other areas above about 200 feet of elevation. Some of the individual Pacific Madrone trees appear to be more than 100 years old.

Figure 30. Western Hemlock – Western Red Cedar Community

3.2.3.3 Hemlock and Cedar Communities (Mixed Conifer and Deciduous)

Much of the park is forested with a mix of Western hemlock (*Tsuga heterophylla*), Western red cedar (*Thuja plicata*), Douglas fir (*Psuedotsuga menziesii*), big leaf maple (*Acer macrophylum*) and red alder. These forests contain some trees that have survived the clearcutting of the early 20th century as well as some that grew up in the shade of red alder communities that have since died off.

3.2.3.4 Wetland and Stream Riparian Communities (Riparian)

There is a diverse variety of small forested wetlands at Seahurst Park. Groundwater seeping to the surface on slopes in upland areas maintains small wetlands characterized by Lady and maidenhair ferns (*Athyrium filix femina, Adiantum aleuticum*) and skunk cabbage (*Lysichiton americanum*). These areas are generally under a well forested canopy of red alder, big leaf maple, Western red cedar and Western hemlock.

3.2.3.5 Non-native and Ornamental Vegetation

A fifth category found at the park is non-native and ornamental vegetation including lawns, and non-native tree and shrub species. This plant community includes maintained areas created for park use and unmaintained areas disturbed by development inside and alongside the park. This plant community is the smallest of all and limited to the central shoreline, some portions of the entrance road and stream corridor, some of the margins of the park, and undeveloped yet disturbed areas bordering the park. Map M-6 shows areas of non-native, ornamental vegetation existing along the central and north shoreline. Non-native plan colonization also occurs throughout the park at a smaller scale, and particularly in

areas disrupted by roads or other modifications. Birds also spread seeds of berry producing invasive plants such as English ivy, blackberry and holly.

3.2.4 Site Conditions—Upland Fish and Wildlife Communities

The 152 acres of park and surrounding undeveloped forested areas support populations of fish and wildlife. These species are representative of those typically found in lowland Puget Sound environments, but are limited by both natural conditions (such as stream length and gradient) and human modifications (such as urbanization of the areas surrounding the park and adjoining open space lands). The degree of fragmentation versus connectivity of wildlife habitat, in a largely urbanized setting, plays a key role in the degree species diversity occurring (Forman and Godron 1986). Another limiting factor is the size of habitat areas relative to the range needed for individual terrestrial species (particularly for larger mammals).

3.2.4.1 Fish

There are two main streams flowing into the nearshore waters of Seahurst Park. One stream enters in the north and one enters in the south central sections of the park (see Map M-1). As stated in the previous section covering geology, both of these streams flow year round (perennial streams).

The south central stream was sampled as part of the Renton Sewage Treatment Plant Project in the early 1980s. Fish caught and identified included rainbow trout, cutthroat trout, and coho salmon (Donnelly et al. 1984). Although a few adult coho were seen in this stream, WDFW does not consider it a salmon spawning stream (WDFW 2002). Factors limiting its utilization by salmon include its short length (<2 kilometers) and steep gradient. The north stream appears to provide little habitat for salmonids, except for a small acclimation pond for juvenile salmon from the Marine Technology Center hatchery operation.

3.2.4.2 Birds

In general, bird species diversity is high in riparian habitats, as these areas are important for breeding, migration, feeding, and wintering activities (Kauffman et al. 2001). Typical species that benefit from riparian habitats include galliforms (e.g.,

pheasants, grouse, ptarmigans, and quail), birds of prey (e.g., eagles, hawks, owls, and falcons), waterbirds (e.g., grebes, gulls, terns, and loons), shorebirds (e.g., stilts, sandpipers, and plovers), waders (e.g., great blue herons, cranes, and ibises), and waterfowl.

A number of different bird species have been identified in Seahurst Park. WDFW identified bald eagles in the vicinity of the park. Additionally, eagles have been seen roosting along both sides of the park. Bald eagles (*Haliaeetus leucocephalus*) typically nest in large trees near open water not in close proximity to intense human activity (Stinson et al. 2001). In 1993, WDFW identified a bald eagle nest within 0.25 miles of the southern border of the park. The United States Fish and Wildlife Service limits project construction activities from occurring within 0.5 miles (in the line of sight) and 0.25 miles (out of the line of sight) from eagle use areas during wintering (October 31-March 31) and nesting (January 1-August 15) activity periods. WDFW also identified a great blue heron rookery along the forested hillside of the north central portion of the park in 1981 (WDFW 2002). Great blue herons are typically found in freshwater, mudflat, tidal shallows, and marsh habitat types.

Other forest birds sighted in the park include barred owls, resident winter wrens, cedar waxwings, spotted towees, song sparrows, and various thrushes (McDonald and Whitney 1997). Belted kingfishers have been identified fishing in the marine waters of the park. The waters off the cobble beach harbor wintering ducks such as Barrow's, common goldeneye, and bufflehead, common loons, grebes, scoters, and gulls. The nearshore eelgrass beds attract migrating brants in the spring (McDonald and Whitney 1997).

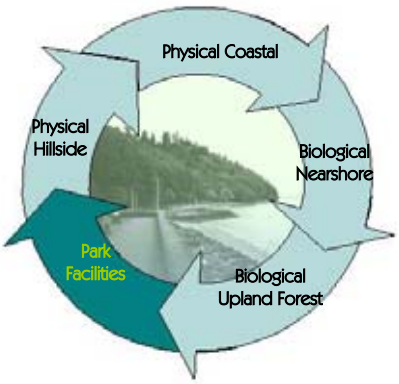
3.2.4.3 Mammals

Riparian zones are also important habitats for mammals because they have higher structural diversity compared to adjacent upland habitats, high spatial heterogeneity, and high edge-to-interior ratios offering two or more habitats in close proximity (Kauffman et al. 2001). Additionally, riparian areas provide a predictable source of water, favorable microclimates, and high plant diversity that increase structural diversity and offer a varied and abundant forage supply (Kauffman et al. 2001). Riparian areas are used by mammals for food, shelter, a source of water, and

as corridors for dispersal and movement. Mammals relying heavily upon riparian areas include bats, small mammals (e.g., voles, mice, shrews), mink, river otters, raccoon, beavers, and native ungulates (e.g., elk, deer) (Kauffman et al. 2001). While the park and other open space areas are not large enough to support large mammals such as elk and deer, many small mammals live there. Mammals sighted at Seahurst Park include a red fox family and raccoons.

3.2.4.4 Reptiles and Amphibians

Reptiles and amphibians use riparian areas for breeding, foraging, overwintering, and migration activities. These animals are sensitive to pollution and habitat loss and are good indicators of the health of aquatic systems (Kauffman et al. 2001). Reptiles and amphibians are important prey species for many carnivorous mammals and raptors, and comprise important components of riparian and aquatic food webs as detritivores, herbivores, insectivores, and carnivores (Kauffman et al. 2001). General reptile and amphibian species found in riparian areas include turtles, frogs, salamanders, and snakes. The ensatina salamander has been identified at Seahurst Park (McDonald and Whitney 1997).



The natural processes in Seahurst Park are evident in both relatively pristine, unmodified areas and those areas changed by human activity. The following section describes the specific modifications to the park shoreline and the condition of bulkhead, gabion and rock revetments. These shoreline modifications have been affected by both coastal and upland physical processes.

4 STRUCTURAL SURVEY OF SHORELINE PROTECTION STRUCTURES

4.1 General Considerations

Shoreline protection structures are typically installed to protect upland property from wave attack and loss of upland soil. Design criteria for these structures depends primarily on the amount of wave energy they are required to withstand. Structures at Seahurst Park were built to protect the trails and perched beaches and to provide viewing opportunities for visitors.

If a shoreline protection structure, such as a bulkhead or revetment, is placed on a chronically eroding shoreline, the beach will eventually disappear, until the shoreline reaches the fixed structure. Vertical structures may even compound the problem by allowing the incident wave energy to be reflected by the structure and induce further scour at the toe of the structure. Ultimately, scour and wave attack can induce failure of shoreline structures.

4.2 Failure of Shoreline Structures

Failure of shoreline structures are classified into two modes:

- Catastrophic failure: The structure fails suddenly, causing a sudden and major change in the surrounding environment.
- Progressive failure: Progressively, the structure's elements fail through time one after the other.

Failure of shoreline protection structures is generally induced by three main mechanisms:

- Toe scour: Proper design of a bulkhead or revetment calls for the structure to be supported by a toe excavated into the substrate or placed securely into the shore material. Waves breaking at the base or reflecting from the structure can cause material to be excavated from the base, undermining the structure and causing it to fail.
- Wave Impact: Storm waves can generate enormous force on shoreline protection structures. If not properly designed, the impact loads can cause rapid failure. For example, waves breaking directly against a riprap structure can cause individual stones to shift and/or become dislodged. Movement of one stone can cause others to

move and lead to failure of the structure. Waves can also transport debris, such as drift logs, that can impact the structure.

- Overtopping: During periods of high tides or exceptionally high wave energy, waves may break over the top of a structure, flooding the area behind the structure. This can cause damage by washing away the fill material behind the structure. This will then cause subsidence of the fill material and lead to disequilibrium and possible failure. In addition, wave overtopping can cause water to flow rapidly down the back of the structure, increasing pressure on the rear of the structure. A related hazard to wave overtopping is the possible destruction of upland vegetation not tolerant to salt water.

4.3 Site Conditions - Survey of Protection Structures

This survey of Seahurst Park protection structures includes the inspection of the gabion revetment, concrete bulkhead, and associated riprap revetments. The groins at the north end of the park were not fully inspected. For the purpose of this survey, the south end of the park will be used as the starting point, identified as Station 0+00. Station 1+00 is 100 feet north of the south park boundary for example.

4.3.1 Gabion Revetment

4.3.1.1 General

The gabion revetment (or Gabion) is located at the south end of the park and extends approximately 1,180 feet along the shoreline. Figure 31 provides a typical cross-section illustration of the gabion. Most of the revetment consists of two or three layers of gabion mattresses, which are separated from the upland soil by a geotextile fabric. The third layer was placed in front of (seaward of) the second layer later in time to provide additional protection from wave attack and toe scour. A riprap revetment extends approximately 10 to 15 feet seaward of the middle segment of the gabion segment (B) and protects portions of the gabion toe.

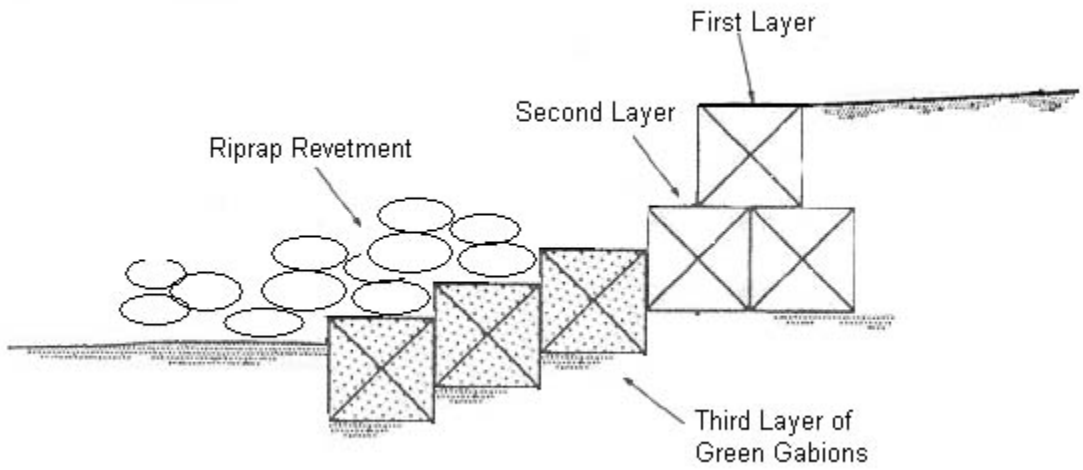
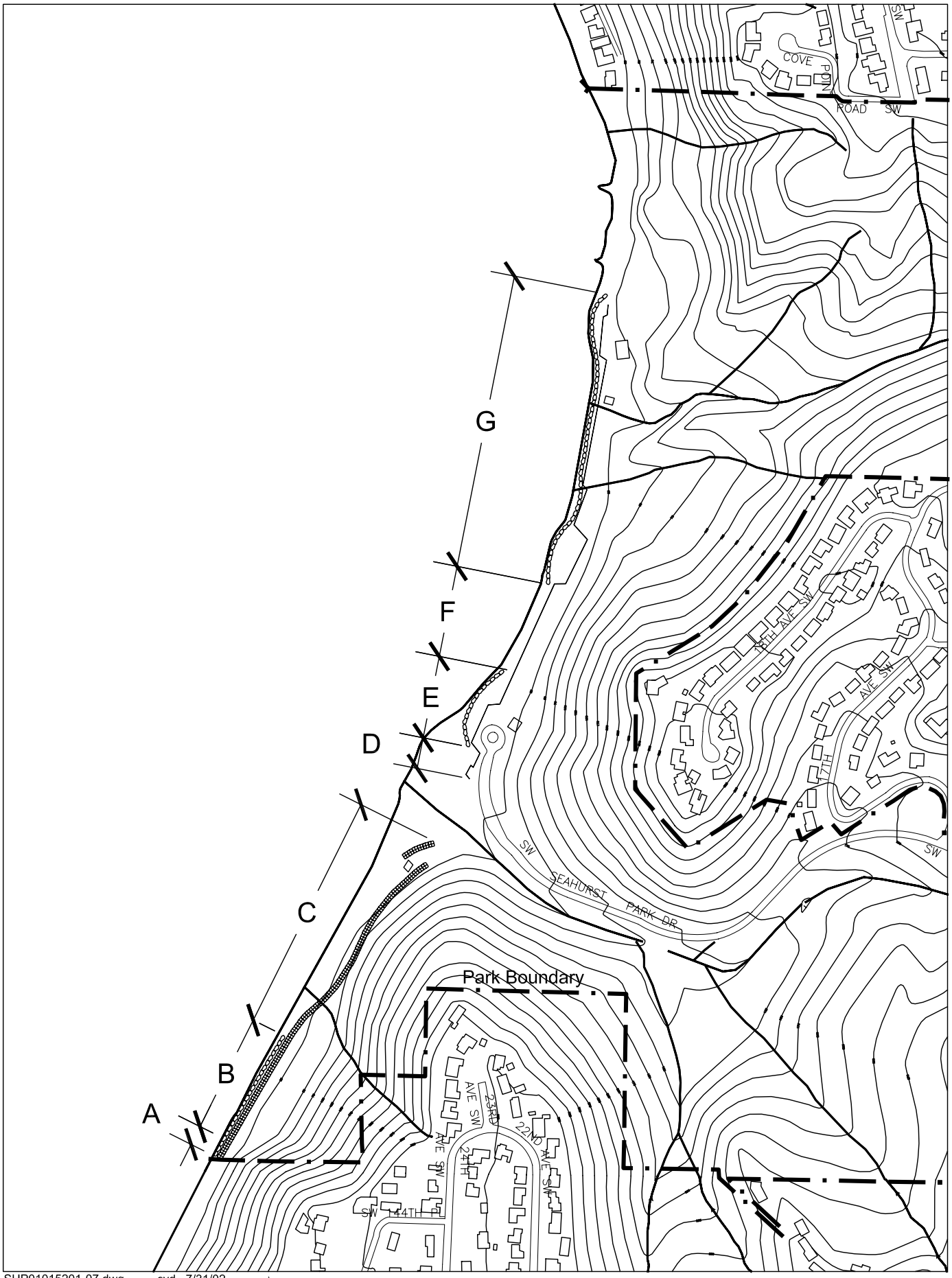


Figure 31. Typical Cross-Section of Gabion Revetment at Southern End of Seahurst Park (Segment B, on Figure 32)

In order to discuss the observed conditions of the south gabion structure, three segments have been delineated. Segment A starts at the south end of the park and extends north to Station 00+70 north. Segment B extends from Station 00+70 to Station 05+20 and Segment C extends from Station 05+20 to Station 11+80.

4.3.1.2 Segment A

Segment A is approximately 70 feet long and consists of two vertical layers of gabion revetment, as shown in Figure 33. An active stormwater culvert is located at Station 00+65. Driftwood has been deposited at the revetment toe by wave and tide activity.



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0 500
Scale in Feet

Figure 32
Shoreline Protection Structure Segments
Seahurst Park Master Plan

Figure 33: South end of the Gabion Revetment.
Driftwood is scattered along the revetment's toe; there are no signs of structural failure.

The gabion in this segment is in good condition. There is little evidence of toe scour, excessive wave impact or overtopping. This segment appears to be stable and is not in short-term danger of catastrophic failure nor exhibits progressive failure.

4.3.1.3 Segment B

Segment B is approximately 420 feet long and consists of two vertical layers of gabion. This segment extends further seaward than the other segments. Driftwood of various sizes has been deposited at the revetment toe or on the revetment by wave and tide activity. At certain locations that are suffering excessive toe scour or are damaged by floating driftwood, a third layer of gabion has been placed at the structure's toe. A riprap revetment that is approximately 5 to 7 feet wide lies at the toe of the gabion to provide toe protection. Intertidal marine organisms are present on the riprap, indicating that high tide levels inundate the riprap. During higher tides, driftwood and waves can directly impact the gabion revetment. Rocks that may have originated from the riprap itself or the gabions cages lay on the beach, indicating that the structure has been damaged by wave attack.

From Station 00+70 to 00+90, segment B consists primarily of two layers of gabion cages fronted by a riprap revetment. A third layer of gabions, which is identifiable by the green color of its cage wire, was placed at the toe of the bottom gabion layer between Station 00+90 and Station 05+50. This third layer provides additional toe protection to the primary two layers of the gabion. Above the riprap revetment at Station 03+90, there is a culvert located approximately 4 feet above the beach. A ramp that was used to access the beach from the top of the gabion elevation ends approximately 3.5 feet above the existing beach surface. This ramp is located at Station 05+10. The 3.5 foot difference in elevation gives evidence of the significant gabion structure erosion that has occurred since the construction of the park.

Approximately 30 to 40 percent of the lower two layers of the gabion cages have failed (i.e., have split open). The first open cage is at the third layer (i.e. toe layer), and is located at Station 01+40. Several other cages have failed in the third layer of gabions. The same condition is true for the second layer with the first open cage at Station 02+45. These two layers are progressively losing their rock fill and will ultimately fail to provide stability to the soil behind them. As a consequence, the upper layer seems to lose its compactness and is no longer vertical. Figure 34 shows a portion of this segment where the green cage (i.e., third layer or toe layer) gabion is open.

Figure 34. Upper Gabion.
Cages from the second layer and from third layer or green gabion cage (toe layer) are open, probably due to rocks, waves and driftwood impacts. Presence of marine organisms on the riprap shows that the rock revetment is inundated during high tide. The upper gabion is no longer vertical and leans progressively seaward.

The remains of a third layer of green gabion are still present at Station 05+50. No riprap revetment is placed in front of the structure at this location. The gabion cages are mostly empty and gabion rocks lay in front of the structure. This gives evidence of significant wave and driftwood impacts on the gabion. The failure of the gabion where there is no riprap also illustrates the effectiveness of the riprap revetment as toe protection.

From Stations 05+95 to 06+45, the upper layer of gabion has undergone catastrophic failure and the geotextile fabric filter is visible. The backfill that the gabion was supporting has eroded, as shown in Figure 35. A 50 foot-long riprap revetment was placed at the toe of the slope to protect the remaining backfill. This section of Segment B has experienced catastrophic failure and is progressively continuing to fail. A culvert is located at Station 06+70, approximately 1.4 feet above the beach surface, indicating the magnitude of beach erosion.

Figure 35: Upper Gabion Failure
The riprap at the toe of slope where the upper gabion failed completely. Due to general lack of protection at the upper slope in this location, erosion has occurred and significant erosion may occur during a future storm event.

Segment B seems to progressively be leaning seaward and appears to have lost some stability. There is evidence of toe scour and wave and driftwood impacts. This segment is undergoing progressive failure and would require maintenance to restore the stability of the structure. However, this segment does not appear to be in danger of catastrophic failure.

4.3.1.4 Segment C

Segment C starts at Station 06+75 ending at Station 11+80 and is located further landward than Segment B. Segment C consists primarily of two vertical layers of gabion revetment, which are occasionally fronted by a riprap revetment. Driftwood is scattered in front of most of the revetment.

From Station 06+90 to the end of the gabion revetment at Station 11+80, the structure is fronted by a vegetated soil from pre-park fill (Quinton Budlong, 1973), indicating that toe erosion is less significant than in previous sections. The width of the vegetated soil increases significantly in a northerly direction along this portion of

segment C. At Station 06+90, the vegetated soil is only 1-2 feet wide and shows evidence of erosion, whereas at Station 11+80, it is approximately 100 feet wide and does appear to be impacted by waves. Driftwood is scattered in front of most of the revetment on the vegetated soil, indicating that waves do overtop the vegetated surface, but rarely reach the gabion structure. Figure 36 shows the northern part of this section, where the gabions are setback and wave activity is unlikely to threaten the gabion structure.

Figure 36: Northern part of Segment C Gabion.
The presence of the vegetated soil and the location of the driftwood indicate that wave activity does not threaten this portion of the revetment, which appears to be safe from failure.

From Station 08+00 to 08+30, rocks have replaced on the gabion after a landslide occurred several years ago. However, the soil behind the wall, on the landside, is progressively settling because of differential settlement or landslide. This settling might affect the stability of the revetment.

Segment C appears to be stable and is not in short-term danger of catastrophic failure nor does it exhibit progressive failure. The vegetated soil currently provides

protection against wave attack but is subject to progressive erosion at the southern end of this segment.

4.3.2 Concrete Bulkhead

4.3.2.1 General

The concrete bulkhead starts approximately at Station 15+10 and is roughly 1,890 feet long and approximately 8 to 16 feet high (see Figure 32, Segments D, E, F, & G). A riprap revetment, which also protects two perched beaches, fronts a large portion of the bulkhead. Stairways located at various locations along the bulkhead provided access to the beach but now one is closed to the public. Between this structure and the gabion revetment is a South Central creek delta.

To discuss the stability of this structure, four segments have been defined. Segment D extends from Station 15+10 to 17+00. Segment E extends from Station 17+00 to 19+70. Segment F extends from Station 19+70 to 28+70, and Segment G ends at Station 39+00.

4.3.2.2 Segment D

Segment D of the concrete bulkhead is 195 feet long and is fronted by a wide sand beach associated with the creek delta. This portion of the structure is out of reach from significant wave action. Some driftwood and middle size rocks, probably originating from the neighboring riprap and moved by waves or tides are scattered at the structure's toe but have not apparently impacted the structure.

Cracks or damage are not visible on the bulkhead. There is little evidence of toe scour, excessive wave impact, or overtopping. This segment appears to be stable and is neither in danger of catastrophic failure nor does it exhibit progressive failure.

4.3.2.3 Segment E

Segment E is 270 feet long and is fronted by a 70-foot wide perched beach that is protected by a riprap revetment. Intertidal marine organisms are present on the lower riprap, which is at the most 6 feet above the beach surface, indicating that high tide levels partially inundate the riprap. Driftwood of various size has been deposited on the beach by wave and tide activity, indicating that the riprap is subject

to overtopping and wave attack. Almost no driftwood is scattered at the concrete bulkhead's toe. Furthermore, most of the riprap rocks are still in place, suggesting that this structure is adequately withstanding wave and driftwood impact.

Cracks or other damage are not visible on the bulkhead, and the riprap revetment appears to be stable. The perched beach is stable even though it may be affected by wave overtopping. This segment appears to be stable and is neither in short-term danger of catastrophic failure nor does it exhibit progressive failure.

4.3.2.4 Segment F

Segment F is 400 feet long and is fronted by an unprotected beach. Driftwood and small size rocks, probably moved from the neighboring riprap revetments by wave action are scattered on the beach and at the structure's toe. Parts of the bulkhead suffer from cosmetic damage due to the impacts of driftwood and rocks.

Apart from the cosmetic damage, cracks or other structural damage are not visible on this portion of the bulkhead. This segment appears to be stable and is neither in short-term danger of catastrophic failure nor does it exhibit progressive failure.

4.3.2.5 Segment G

Segment G is 1,030 feet long and is fronted by a riprap revetment. The riprap revetment was placed at the end of a perched beach between Stations 28+70 and 30+60 and between Stations 36+00 and 39+00. Between Stations 30+60 to 36+00, the riprap has been placed along the structure's toe. Three culverts are located at Stations 24+05, 25+60, and 29+60.

Driftwood and rocks are scattered throughout the perched beaches and the riprap revetment, indicating that waves frequently overtop the riprap revetment. In particular, the northern perched beach is covered with small size rocks. The remains of a failed gabion revetment and geotextile fabric can be seen in front of the existing riprap revetment. Part of the riprap revetment has failed at Station 32+70, probably due to driftwood or wave impact (Figure 37). Other locations of the riprap revetment appear to have lost some rocks but the structural stability does not appear to be

threatened. The perched beaches appear to be stable even though they may be affected by wave overtopping.

Figure 37: Segment G Revetment.
Failure of a portion of the riprap revetment that protects a perched beach in front of the concrete bulkhead.

The concrete bulkhead suffers from minor cosmetic damages, typically where the riprap meets the bulkhead's toe, as shown on Figure 38. Damage is most likely due to driftwood or rocks impacting the bulkhead. The paved trail protected by the concrete bulkhead shows signs of minor settling which is likely due to differential settlement, but this has not affected the structural stability. This segment appears to be stable and is neither in short-term danger of catastrophic failure nor does it exhibit progressive failure.

Figure 38. Segment G Revetment.
The concrete bulkhead suffers from cosmetic damage, due to rocks and driftwood impact. The bulkhead's stability is not threatened however.

4.4 Structural Conclusions

The results of the gabion revetment's structural survey reveal that most of this structure is progressively failing due to toe scour and wave and debris impacts. The southern and northern ends of the structure (i.e. Segments A and F) are stable. Segment B that is protected by riprap revetment has the greatest amount of exposure to wave action and the lower two layers of the Gabion have failed or are failing. The section of Segment B at Station 05+95 to 06+45 has lost its upper layer of Gabion and may fail during a future storm condition. However, the riprap revetment that protects the Gabion from toe protection is in decent condition and protects it effectively. This revetment is in danger of progressive failure but does not exhibit signs of catastrophic failure.

The result of the concrete bulkhead's structural survey reveals that all of this structure is safe from catastrophic or progressive failure. The three perched beaches, which are affected by wave overtopping, appear to be stable and the riprap revetment that protects them also appears to be safe from failure even though it loses some of its rocks due to wave action.

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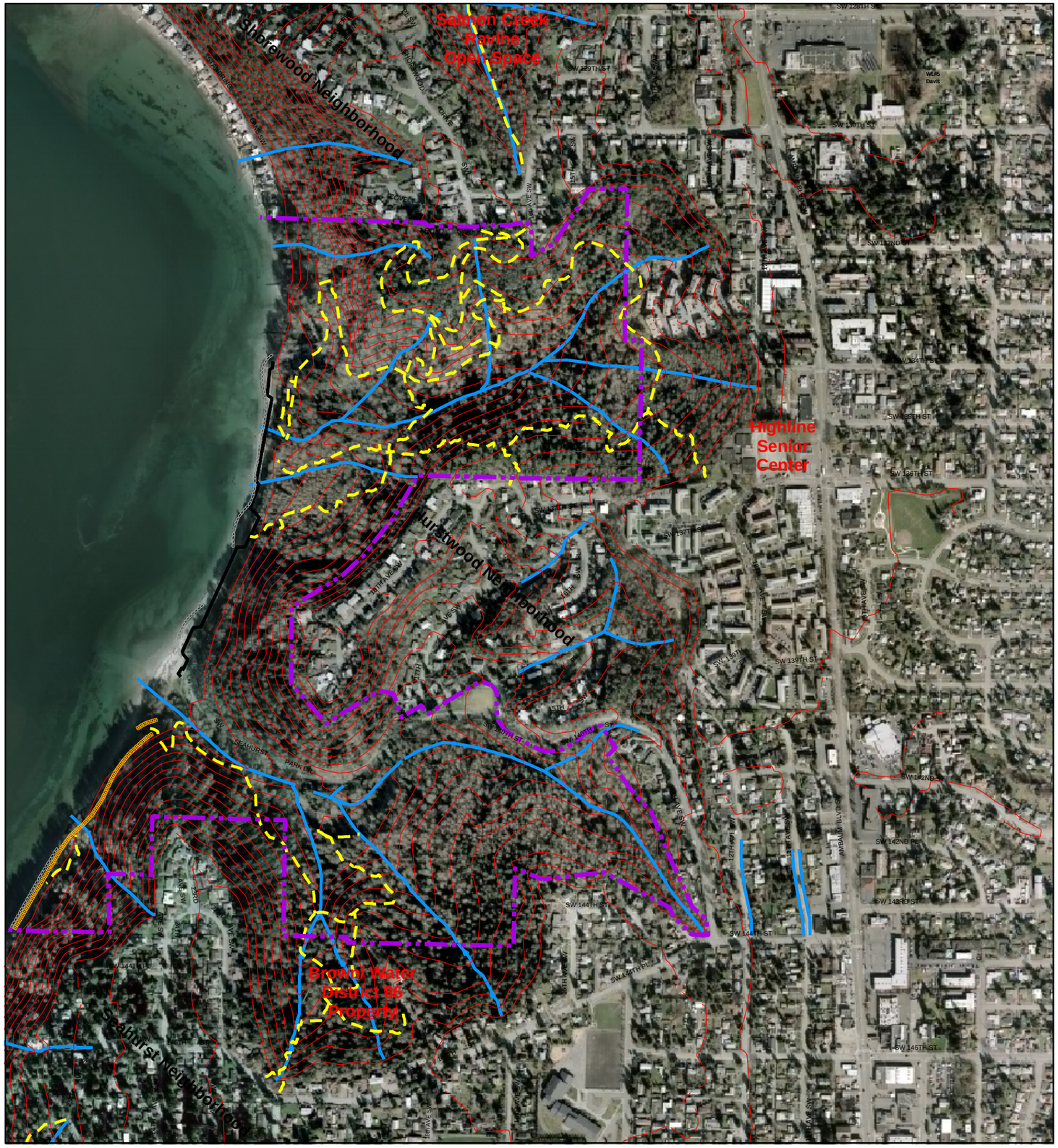


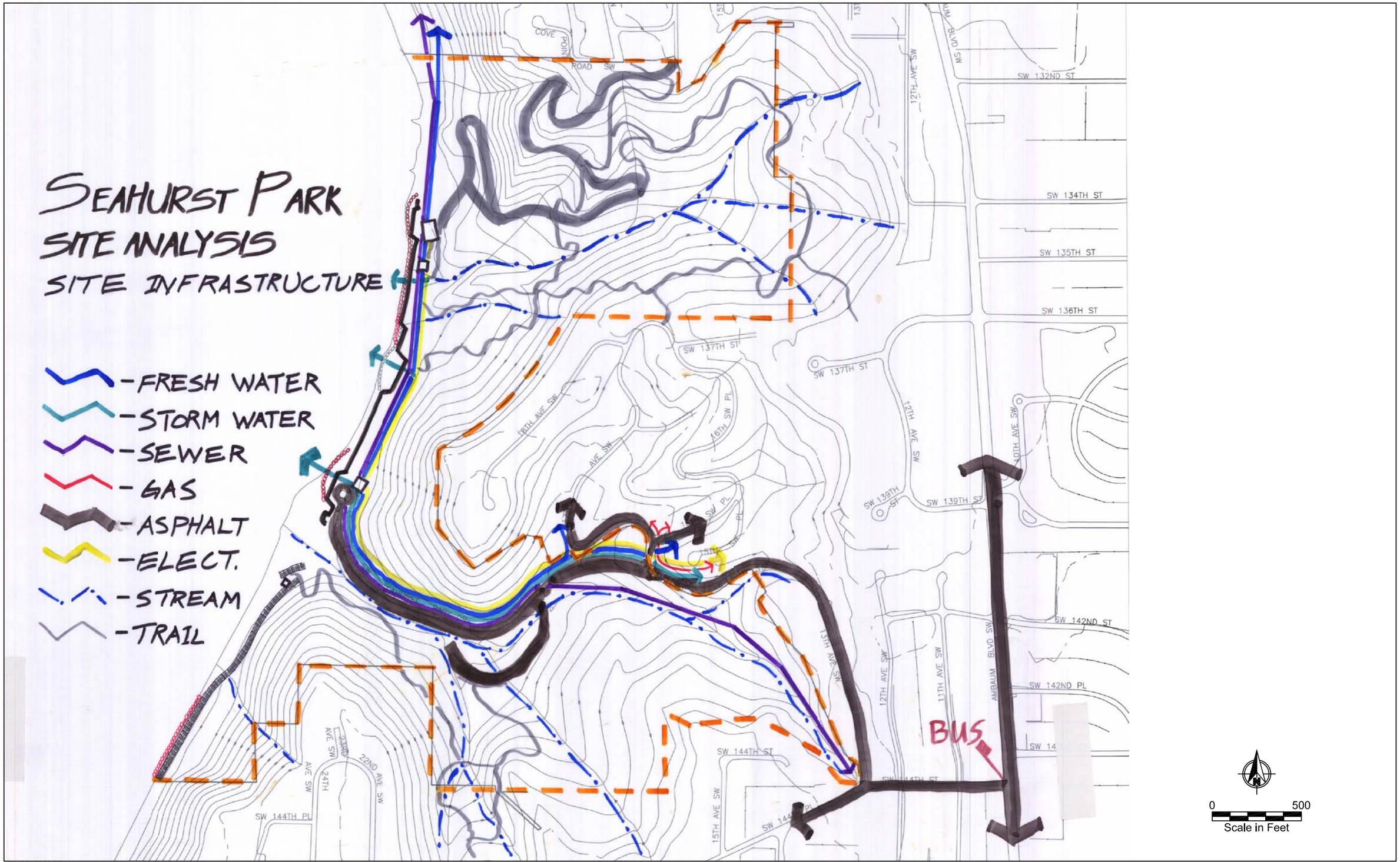
Legend

- Park Trails
- Concrete Wall
- Contour
- Stream
- Park Boundary

0 900 Feet

ANCHOR ENVIRONMENTAL, L.L.C.

Map M-1
Park Air Photo and Topographic Map
Seahurst Park Master Plan



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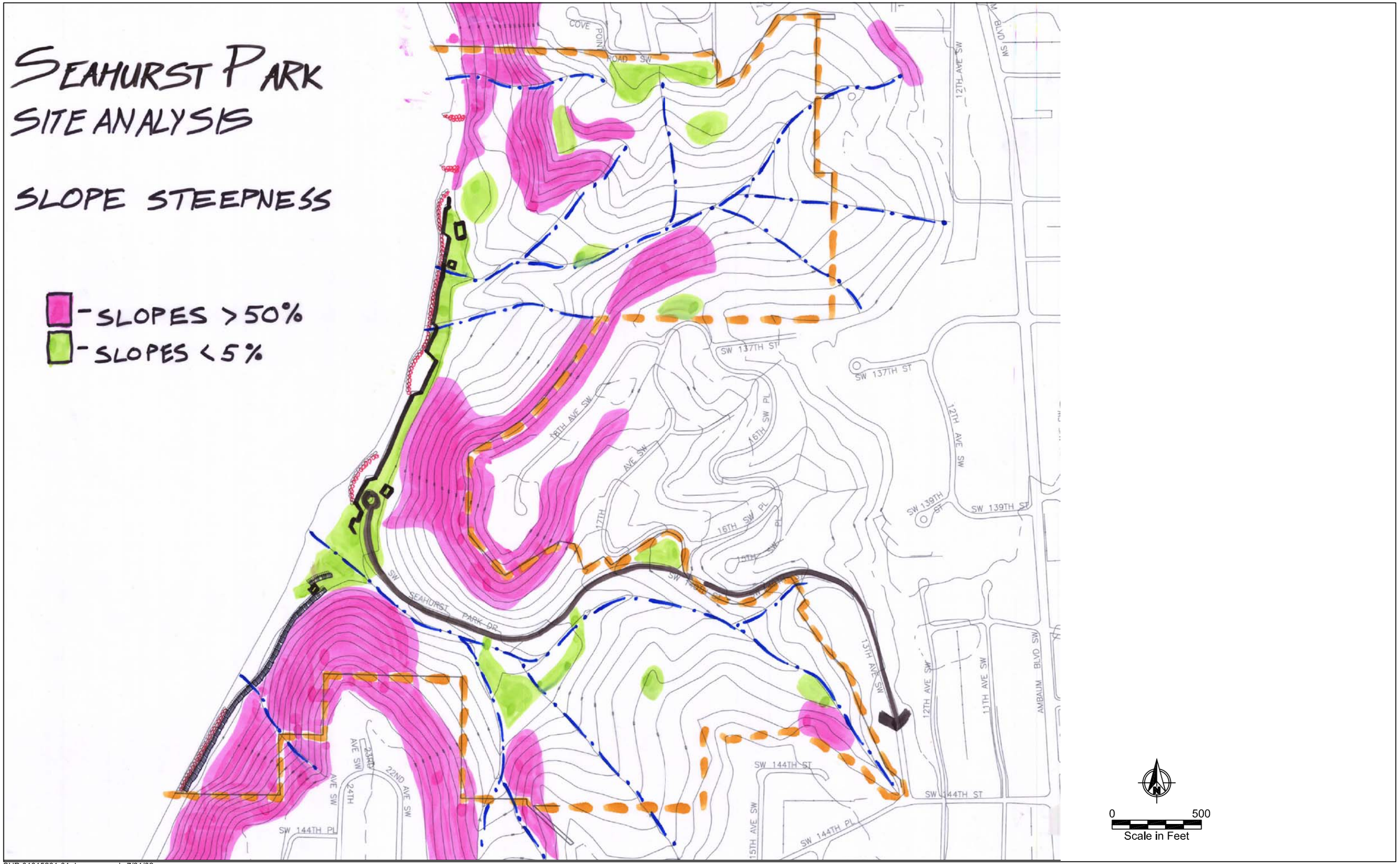
ANCHOR ENVIRONMENTAL, L.L.C.

Map M-2
Park Infrastructure
Seahurst Park Master Plan



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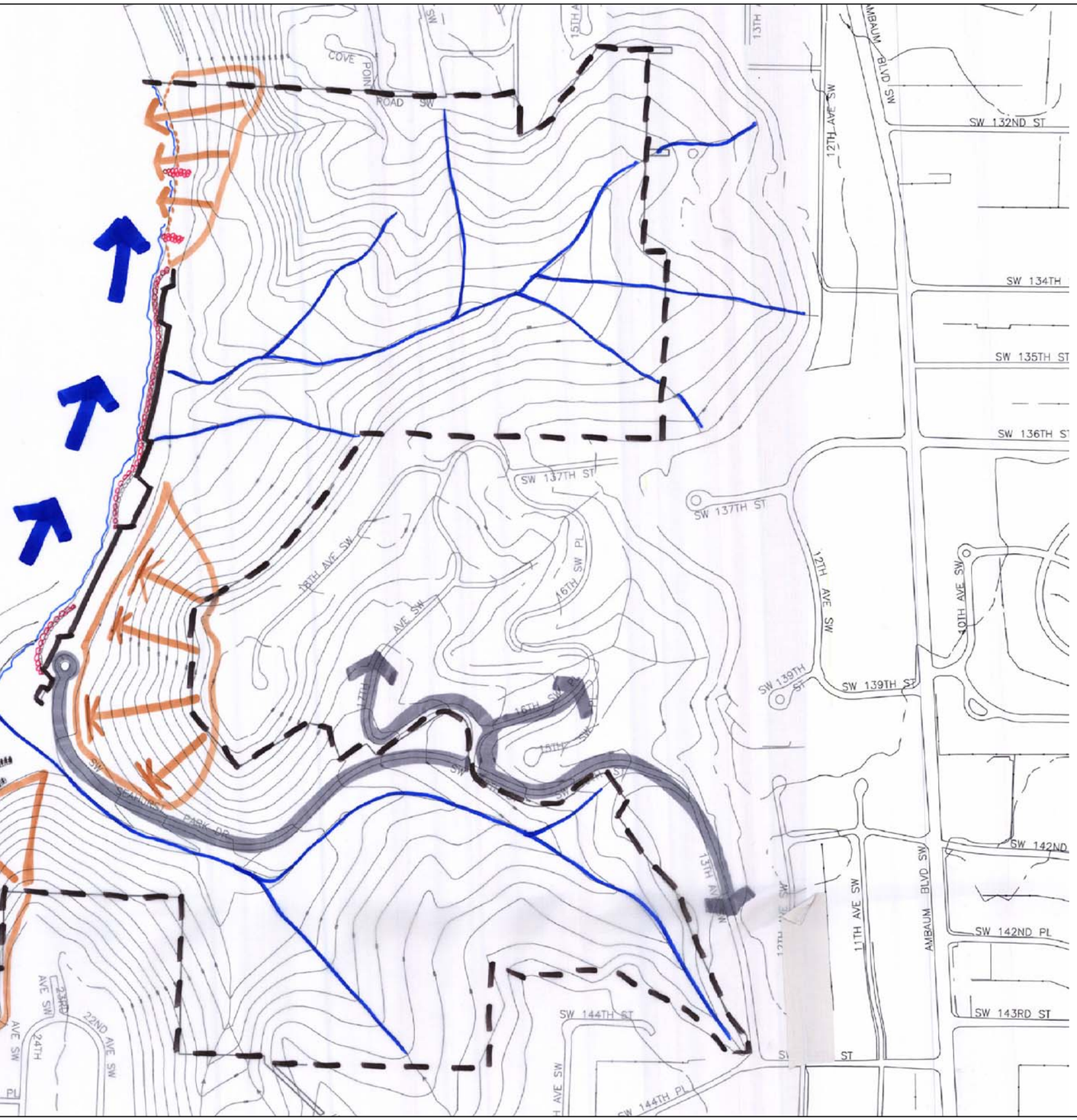
ANCHOR ENVIRONMENTAL, L.L.C.

Map M-3
Slope Steepness
Seahurst Park Master Plan

SEAHURST PARK SITE ANALYSIS

COASTAL PROCESS

- NET SHORE DRIFT
- EROSION



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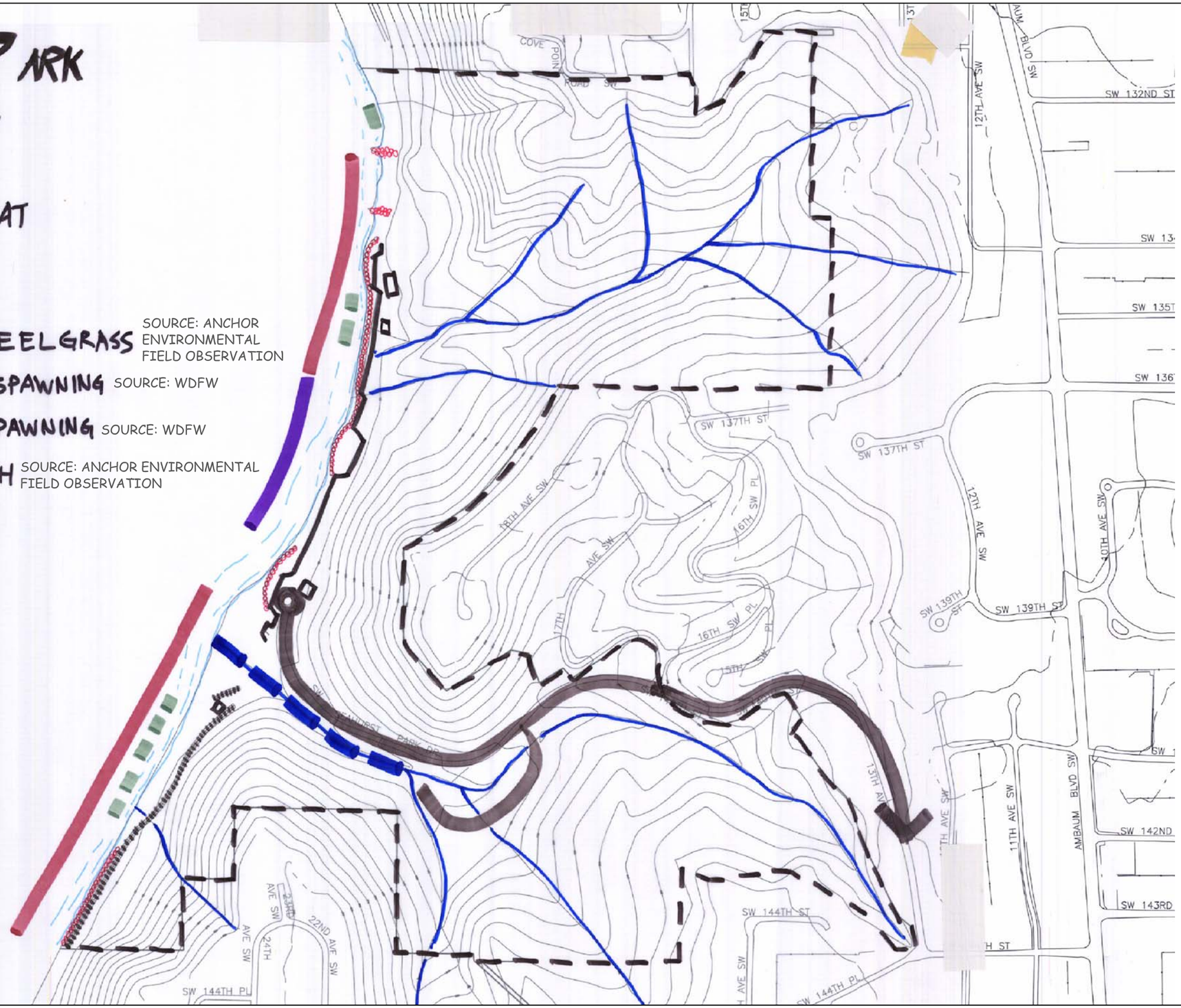
ANCHOR ENVIRONMENTAL, L.L.C.

Map M-4
Coastal Process
Seahurst Park Master Plan

SEAHURST PARK
SITE ANALYSIS

NEARSHORE HABITAT

- INTERTIDAL EELGRASS — SOURCE: ANCHOR ENVIRONMENTAL FIELD OBSERVATION
- SURF SMELT SPAWNING — SOURCE: WDFW
- SANDLANCE SPAWNING — SOURCE: WDFW
- JUVENILE FISH — SOURCE: ANCHOR ENVIRONMENTAL FIELD OBSERVATION



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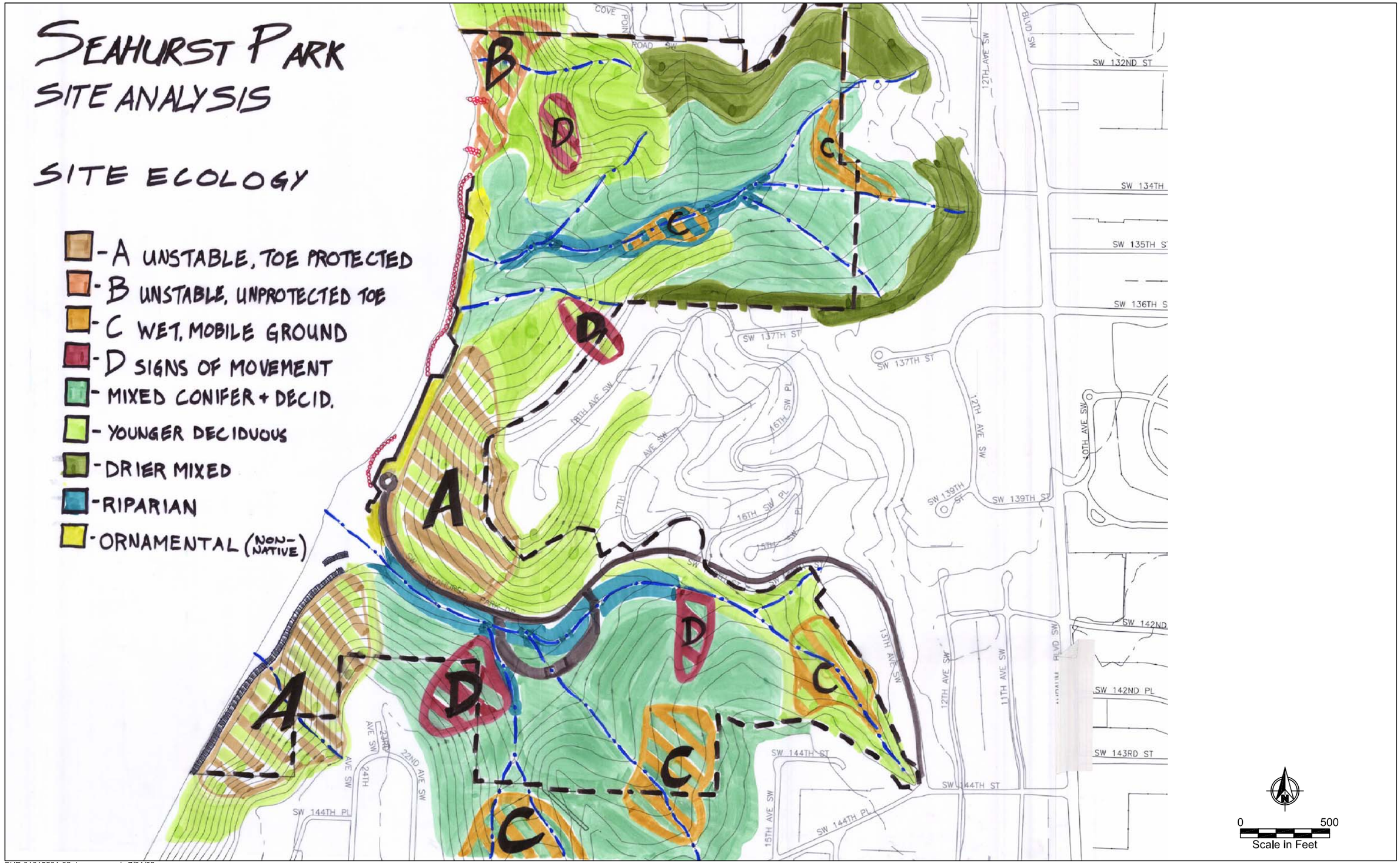
ANCHOR ENVIRONMENTAL, L.L.C.

Map M-5
Nearshore Habitat
Seahurst Park Master Plan



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ANCHOR ENVIRONMENTAL, L.L.C.

Map M-6
Site Ecology (Upland Vegetation and Geology)
Seahurst Park Master Plan