POTENTIAL NEARSHORE HABITAT GAINS ANALYSIS:

BOEING CREEK DELTA

Prepared for
City of Shoreline

Prepared by
Herrera Environmental Consultants, Inc.

HERRERA

Note:
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BOEING CREEK DELTA

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EXECUTIVE SUMMARY

The City of Shoreline has halted maintenance dredging of sediment in Hidden Lake, and is proceeding with plans to remove the dam impounding the lake. These actions will restore sediment supply to the Boeing Creek delta and adjacent nearshore. As a result, the delta will begin to grow and gradually become ecologically more productive. This will improve habitat for juvenile Chinook salmon in Washington State Water Resource Inventory Area 8 (WRIA 8), and restore a habitat type that is identified in current WRIA 8 salmon recovery planning efforts as an important target for restoration. Based upon an analog delta at the mouth of Pipers Creek in Seattle, it is expected that after 50 years sediment will rebuild a delta at Boeing Creek that will have the following attributes that currently do not exist:

- More than 400 feet of intertidal channel
- Approximately 1,000 linear feet of forage fish spawning habitat in shallow nearshore areas
- Restoration of a narrow marine riparian band between the mean higher high water level and the existing railway embankment
- A more complex channel and beach environment throughout the delta

In addition to these attributes, restoration of a delta will effectively protect the railway embankment so that riprap armoring placement to repair damaged sections of the embankment is no longer necessary. Therefore, periodic habitat disturbance associated with embankment repairs can be eliminated.

INTRODUCTION

The City of Shoreline (the City) seeks to understand the potential nearshore habitat gains that could be achieved as a result of restoring sediment supply to the mouth of Boeing Creek following removal of the Hidden Lake dam. Boeing Creek is in Washington State Water Resource Inventory Area 8 (WRIA 8), and drains directly into Puget Sound. For prioritizing restoration actions associated with the Puget Sound Chinook Recovery Plan, WRIA 8 has been divided into three functional tiers. These tiers are based on watershed condition and fish habitat use, and denote priority habitat areas for Chinook salmon. Nearshore habitats associated with the Puget Sound shoreline are Tier 1, and support adult and juvenile Chinook salmon and their food base (i.e., forage fish species).

A larger, natural delta at the mouth of Boeing Creek could enhance Puget Sound's nearshore habitat for Chinook salmon, other salmonid fish species, and general fish and wildlife species. This portion of the Puget Sound shoreline is well documented as being sediment deprived because of cessation of sediment supply from eroding bluffs separated from the nearshore by the BNSF railway (Herrera 2016). In the absence of functional feeder bluffs, sediment delivery from creeks such as Boeing Creek is critical for the recovery of Chinook salmon and, therefore, should be considered high priority for restoration. In fact, Ecosystem Diagnosis and Treatment (EDT) analyses performed during creation of the Lake Washington/Cedar/Sammamish Watershed (WRIA 8) Chinook Salmon Recovery Plan (WRIA 8 Plan) identified creek mouths (along with other habitat features) as the highest priority for protection or restoration.

Boeing Creek flows through the city of Shoreline and Hidden Lake at the western edge of Shoreview Park (Figure 1). Hidden Lake is a small reservoir on Boeing Creek that has existed for extended periods of time since 1920. Farther downstream in Boeing Creek, the Seattle Golf Club owns a diversion dam spanning the creek channel, which also dates from the early 20th century. The primary means to increase sediment delivery to the mouth of Boeing Creek is to stop removing sediment trapped in Hidden Lake. The City of Shoreline has ceased sediment dredging operations in the lake, but needs to remove the dam impounding Hidden Lake to safely pass creek flows and sediment downstream of the existing dam site before the lake is filled with sediment in the coming years. There is a relatively large supply of sediment supply in the Boeing Creek basin, mostly originating upstream of Hidden Lake. Allowing that sediment to pass through the Hidden Lake area will enable it to reach Puget Sound. The Seattle Golf Club diversion dam has minimal effect on sediment supply to Puget Sound because the former pool upstream of the dam has filled with a large wedge of sediment, there is little capacity to store more sediment there, and sediment removal activities upstream of this dam have never been undertaken, and there are no plans to do so in the future.

Legend

- Hidden Lake
- Dam
- Basin
- Stream
- Park

Figure 1.
Vicinity and Site Map for Hidden Lake in Shoreline, Washington.

N

0 1,250 2,500 5,000 Feet

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K:\Projects\Y2015\15-05984-000\Project\Nearshore_Habitat_Analysis\site_vicinity.mxd (11/18/2016)

METHODS

The trajectory of nearshore habitat conditions that could be expected to evolve at the mouth of Boeing Creek following upstream dam removal(s) was hypothesized based on conceptual models for assessing restoration of Puget Sound ecosystems (Simenstad et al. 2006). The primary methods used were comparison to a reference site at the Pipers Creek mouth and delta approximately 2.5 miles south of the Boeing Creek mouth, and evaluation of historical shoreline conditions at the Boeing Creek mouth prior to construction of the existing Hidden Lake dam.

The Boeing Creek and Pipers Creek deltas were visited on the morning of October 26, 2016, during a moderately low tide (3.6 feet MLLW at 8:48 a.m. in Seattle: NOAA 2016). The visits coincided with heavy rainfall (there was more than 1 inch of rainfall in Shoreline that day: Weather Underground 2016). In addition, Herrera staff contributed observations based on extensive experience with the mouth of Pipers Creek in Carkeek Park from previous unrelated studies there, and observations of the area at the mouth of Boeing Creek during other work on the Hidden Lake dam removal project, including a visit on October 27, 2016.

Historical conditions at the mouths of Boeing Creek and Pipers Creek were assessed by examining a range of historical documents including:

- An early topographic survey of the shoreline at both Pipers and Boeing creeks (US Coast Survey 1874)
- A hydrographic (bathymetric) survey of the shoreline at both Pipers and Boeing creek deltas (US Coast Survey 1876)
- A summary of the history of the City of Shoreline (Copass 1996)
- A General Land Office survey of the mouth of Boeing Creek (General Land Office 1859)
- Aerial orthophotographs taken in 1936, 1990, 2002, 2003, and every year since 2005, except 2008 (King County 2016, Google Earth 2016)
- Oblique aerial photographs taken in 1977, 1993, 2001, and 2006 by the Washington State Department of Ecology (Washington State Department of Ecology 2016)
- Planning documents related to sedimentation in Hidden Lake and removal of the Hidden Lake dam (AltaTerra 2014, Herrera 2016)

COMPARISON OF PIPERS CREEK AND BOEING CREEK BASINS

In addition to being separated by only a few miles and being geographically similar (i.e., they have the same west aspect and each drain the western half of the isthmus that separates Puget Sound and Lake Washington), the Pipers Creek and Boeing Creek basins and their outlets to Puget Sound have several attributes in common. The Pipers Creek basin and the Boeing Creek basin are nearly identical in size—1,740 acres for Boeing Creek (Windward 2013) and 1,828 acres for Pipers Creek (Barton 2002). Both basins have comparable levels of urban and suburban development. Both creek outlets are constrained by a BNSF railway crossing, which separates the modern delta of each creek from the adjacent marine bluffs.

The most significant difference between the two creeks is that Boeing Creek has two dams in its lower reaches, both of which are located downstream of the most significant sediment sources in its drainage basin, and those dams have reduced the volume of sediment delivered to the creek mouth. The Seattle Golf Club diversion dam located approximately 2,500 feet upstream of the Boeing Creek mouth was installed in the early twentieth century. The pool that once existed on the upstream side of the 15-foot-tall dam is now completely filled with sediment. The dam impounding Hidden Lake was apparently constructed in 1920 (King County 1995). The dam failed in 1970 and was reconstructed by King County in 1996. King County's project to restore Hidden Lake in 1996 involved excavation and offsite disposal of approximately 7,500 cubic yards of sediment (King County 1995) that had filled the lake area since 1970. A year later, a major washout upstream in Boeing Creek led to Hidden Lake filling with sediment, leading to King County once again excavating the sediment to restore the lake (Windward 2013). Since 1997, King County and subsequently the City of Shoreline dredged sediment at the upstream end of the lake to maintain water storage volume in the lake. Since 2002, the City of Shoreline has dredged a total of approximately 13,000 cubic yards of sediment from the lake (AltaTerra 2014) and all of that material was hauled offsite. Thus, the artificial impoundment known as Hidden Lake has reduced sediment supply to the mouth of the creek by at least 25,000 cubic yards since 1996. Pipers Creek has never had similar restrictions on sediment transport (Barton 2002). The restriction of sediment supply from Boeing Creek to the nearshore of Puget Sound has had a profound impact on the Boeing Creek delta, as will be described below.

Another difference between the two deltas is the dominant direction of littoral drift. Littoral drift is to south at the Pipers Creek delta, while at the Boeing Creek delta it is northwards. The largest waves produced within the confines of Puget Sound are from the south (Finlayson 2006), but Pipers Creek is in the lee of Meadow Point and therefore northerlies dominate. This might imply a wave energy deficit at Pipers Creek compared to Boeing Creek, which if real would hinder delta growth at the mouth of Boeing Creek as compared to Pipers Creek. However, there are at least three pieces of geomorphic evidence indicating that if there is a wave energy deficit it does not have a significant impact on the relative ability of the Boeing Creek delta to accumulate sediment. This evidence includes:

- Finlayson (2006) demonstrated that bidirectional sediment transport is a dominant mode of transport on Puget Sound shorelines and that littoral drift is often a small fraction of the imbalance of summertime (southward) and wintertime (northward) transport.

- Pre-development delta sizes of Boeing Creek and Pipers Creek were comparable according to historical mapping as discussed in more detail below (US Coast Survey 1874 and 1876; see Figure 2 and Appendix A).

- In the early 1990s, when Boeing Creek had its sediment supply temporarily restored because Hidden Lake no longer had capacity to trap additional sediment, the delta sizes of each creek were also comparable.

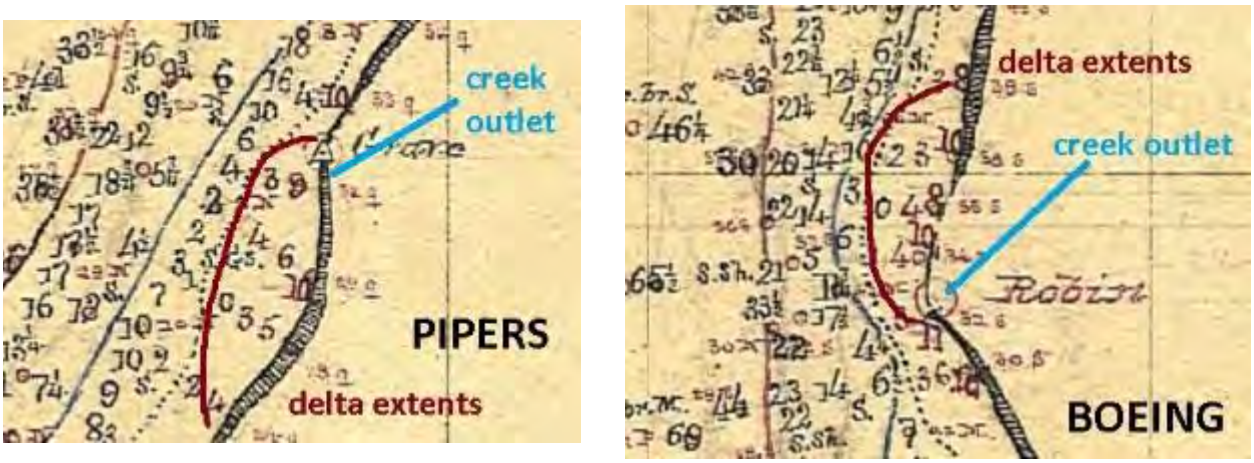


Figure 2. Comparison of Pipers Creek Delta with Boeing Creek Delta on the H-Sheet (US Coast Survey 1876) Prior to the Construction of the Railroad.

Note that the deltas are shown at the same scale.

RESULTS

Boeing Creek Delta

Historical Conditions

Predevelopment shoreline conditions at the Boeing Creek delta are recorded by a "T-sheet" (US Coast Survey 1874) and a "H-sheet" (US Coast Survey 1876). Both of these maps indicate that a large delta existed mainly to the north of the Boeing Creek mouth along the Puget Sound shoreline. Neither of the maps present any detail of the delta (e.g., the location of an intertidal channel, beach spits, etc.). These maps predate the railway that was completed in 1893 (Copass 1996). Nearshore conditions in the late 1800s were likely quite different then compared to existing conditions (and expected future conditions) because the creek outflow is now concentrated at a single location due to the railway culvert.

The oldest historical aerial photograph of the delta vicinity, taken in 1936, seems to indicate a large delta that extended both north and south of the creek outlet at that time. The railway crossing the creek mouth had existed for more than 40 years at this point in time. The first Hidden Lake dam was likely over 15 years old at that time, but the Boeing Creek basin was largely undeveloped as of 1936 and thus the lake was probably not storing much sediment as under existing conditions.

The next available aerial photograph was taken in 1977. The original Hidden Lake dam had failed 7 years earlier (AltaTerra 2014) and the lake area had reverted to wetland conditions with a flow-through creek. Some of the sediment that had been trapped in Hidden Lake up to 1970 had likely sluiced downstream, with some of it perhaps accumulating behind the Seattle Golf Club diversion dam. The full effects of sediment resupply to the delta from sources in the basin upstream of Hidden Lake to the creek mouth (with no sediment being trapped behind either dam discussed here) may not have occurred in the nearshore until several years later in the 1980s. However, in 1977 there were two well developed deltas with a moderate degree of creek flow meandering amid them.

The latest aerial photographs (those taken since 1990) show a consistent reduction of delta size, which is consistent with the large volume of sediment removal in Hidden Lake as described above. In addition, the alignment of the creek through the delta has become incrementally simplified since the 1993 aerial photograph was taken, from a meandering set of two channels to a single, straight channel.

Existing Conditions

Although as recent as 2002 the Boeing Creek channel emanating from the culvert underneath the BNSF railway had some limited meandering through intertidal areas, the channel through the delta is now extremely straight and oriented perpendicular to the shoreline. On the recent

site visit, the length of intertidal channel was measured at slightly less than 200 feet. Interpretation of these observations and analysis of the historical aerial photographs described above lead to a conclusion that the nascent delta that formed by the early 1990s has since been completely removed by wave action. This has caused the intertidal channel to be steeply sloped, conveying what limited sediment load there is in the creek into deep water.

The loss of the delta has precipitated erosion of the BNSF railway revetment. During the recent site visit considerable erosion was evident through the former delta area. In fact, one portion of the railway revetment eroded enough to prompt remedial action (i.e., riprap placement) by BNSF shortly after the site visit. It is expected that this erosion will continue and probably worsen due to sea level rise. Erosion was most prominent in areas where the delta was once broad and likely had little if any original shoreline armoring affecting it.

Substrate in the delta is currently dominated by gravel and cobble. Small patches of sand in the upper intertidal area were found, typically in association with recent erosion locations. The location of these sand patches adjacent to recent erosion indicated that most of the sand did not come from the creek, but rather eroded from the fine-grained railway embankment. The relatively thin extent of appropriate substrate (typically less than 1 inch deep) would likely preclude forage fish spawning. Riprap is also common in the intertidal area (see Figure 3) because of the recent repetitive protective actions by BNSF.

Figure 3. Nearshore Conditions in October 2016 Immediately North of the BNSF Railway Culvert Within the Historical Boeing Creek Delta Area.

Observed habitat conditions in the existing Boeing Creek delta are poor. Although a single adult coho salmon was observed at the culvert outlet on October 27, 2016, during the primary site visit on October 26, 2016, no other fish and only crows were encountered at the outlet of the

creek. There is minimal driftwood wrack. With the exception of a handful of trees and surrounding shrubs (e.g., Nootka rose) that likely remain from the old delta south of the culvert outlet, there is no vegetation anywhere waterward of the BNSF railway (Figure 3). The remaining trees are likely to be lost in the near future, as large scarps and exposed roots were seen adjacent to the vegetation during the recent site visit.

Pipers Creek Delta

Historical Conditions

Predevelopment shoreline conditions at the Pipers Creek delta are recorded by same the T-sheet (US Coast Survey 1874) and H-sheet (US Coast Survey 1876) as at Boeing Creek. Like at Boeing Creek, there is evidence in the bathymetric data (H-sheet) that there was a delta that extended to the south and west of the creek outlet, though as in the case of Boeing Creek, neither of these maps present detail sufficient to resolve particular features associated with the delta.

Like at the Boeing Creek delta, the railway was finished across Pipers Creek in 1893. In addition, the lower creek valley, later to be called Carkeek Park, was developed for a variety of purposes throughout the early twentieth century. These diverse purposes included the following in rough chronological order: a sawmill (on the waterward side of the railway), a fish trap (on the waterward side of the railway), rental pasturage, an informal zoo, a Civilian Conservation Corps camp, a sewer outfall (still present, though some former infrastructure has been subsequently removed), an archery field course, and ultimately the recreational day-use park and picnic areas that exist at present (Sherwood 2016). It is probable that creek and delta sediment was graded to serve these many diverse purposes. In relation to this historical land use progression it is clear that the delta first expanded due to deforestation (Sherwood 2016) and then shrank once its lower valley became developed and the creek sediment supply became actively managed (see more discussion of this below). It is difficult to imagine a sawmill being viable waterward of the railway given the size of the delta in the 1993 aerial photograph (see Figure 4).

Figure 4. Comparison of Pipers Creek and Boeing Creek Deltas in 1993 During Identical Tide Conditions.

Since establishment of the city park in 1955, a series of actions have been taken to manage the creek, often simultaneously, all of which likely had an impact on sediment delivery to the delta. Beginning in 1979, a series of log weirs was placed in the stream to store sediment related to changing streamflow hydrology due to urbanization and increased landsliding in the creek's ravine. At the time, these larger sediment volumes were thought to be causing problems for coho salmon spawning (Barton 2002). These efforts continued into the late 1990s, apparently moving in the upstream direction. It is likely that the instream weirs initially limited most of the sediment input to the lower creek reach and nearshore, not just the fine sediment responsible for suffocation of salmonid redds. In the late 1980s, the culvert under the railway was replaced to be more fish passable (Barton 2002). Although the reason for the culvert replacement was ostensibly for fish passage, the replacement also likely increased sediment input to the nearshore. Once the capacity of the instream weirs to store sediment was exceeded, the supply of sediment to the lower creek reach increased once again and the culvert beneath the railway was not an obstacle to passing that sediment through the railway crossing to the nearshore.

Interestingly, these various interventions produced a nadir in the sediment supply to the Pipers Creek delta that corresponded roughly to a recent peak in sediment supply to the Boeing Creek delta. Figure 4 illustrates a comparison of the two deltas in 1993. As can be seen in the figure, photos taken during the same low tide show that the deltas were similar in size and complexity.

Within the last 20 years, the Pipers Creek delta has been on a different trajectory than the Boeing Creek delta. Prior to 2000, the Pipers Creek delta form was relatively simple (Figure 4), like the Boeing Creek delta. The last of the City of Seattle projects that reduced sediment input to Pipers Creek in Carkeek Park were completed by the late 1990s. Since then Seattle Public Utilities has taken a more sophisticated approach to targeting fine sediments (silt and clay, often contaminated) nearer to the sources of those fine sediments farther upstream in the basin, while reducing stormwater runoff peak flows in the basin and allowing ravine-landslide-derived sediment to pass through the lower creek reach to the beach. As a result of increased coarse-grained (sand and gravel) sediment supply, a beach spit formed across the mouth of the creek. This spit eventually set the current alignment of Pipers Creek at its delta around 2006. This led to the formation of a small lagoon at the outlet of the creek. The outlet of the lagoon is to the south of a large beach spit, which protects the lagoon and makes the intertidal channel associated with Pipers Creek complex in its alignment (Figure 5).

Figure 5. Aerial Photograph of Pipers Creek Delta Taken on June 27, 2016 (Google Earth 2016).

Existing Conditions

Pipers Creek exits its culvert underneath the BNSF railway into a nascent lagoon behind the southwest oriented spit that dominates the delta. Where the spits connects to the shoreline and railway embankment, a wide vegetated supratidal platform exists, with a few upland tree species (red alder and unidentified species of conifer) growing on it near the shoreline, but on the waterward side. During the recent site visit, Pipers Creek was flowing behind the spit, meandering for a length of approximately 600 feet until meeting marine waters. The surface of the spit appears to be above MHHW, but is probably submerged during the highest tides.

The substrate conditions on the delta were diverse. Gravel and small cobble were common in the Pipers Creek channel areas, while sand with minor components of gravel was common on the spit and surrounding beaches. Upper intertidal deposits were also relatively fine-grained. In total there was approximately 1,000 linear feet of habitat sufficient to support forage fish spawning in late October 2016.

Habitat conditions are reasonably good considering the highly urbanized nature of the Pipers Creek basin and the impacts to the nearshore from the railway. Near the culvert outlet, a great blue heron (*Ardea herodias*) was observed fishing (Figure 6) during the recent site visit. Where the creek meets marine waters, at least three species of birds (not including the heron found at the culvert outlet) and well over 100 individuals were observed. Vegetation transitions typical of low-gradient, undisturbed Puget Sound shorelines were found on the waterward side of the railway. There is abundant wrack interspersed with beachgrass, backed by a dense Nootka rose scrub-shrub community (Figure 7). It is interesting to note that based upon aerial photographs, the area shown in Figure 7 was largely unvegetated and intertidal in 1993.

Figure 6. Great Blue Heron Fishing at the Culvert Outlet of Pipers Creek on October 26, 2016.

Figure 7. Supratidal Vegetation Assemblage with Wrack on North Side of Pipers Creek Delta on October 26, 2016.

POTENTIAL FUTURE CONDITIONS AT BOEING CREEK DELTA

Potential future conditions at the Boeing Creek delta can be hypothesized as achieving geomorphic characteristics and ecological functions similar to those of the creek's delta that existed in the late 1970s. Simenstad et al. (2006) provide conceptual models that illustrate the expected interactions among ecosystem processes, structures and functions if a project to restore sediment supply to the mouth of Boeing Creek were implemented. The models evaluate the following progression:

restoration actions → restored processes → structural changes → functional responses.

Hence, according to these models if the Hidden Lake dam is removed (**restoration action**), the following **restored processes** would occur in lower Boeing Creek and at its delta: sediment supply, sediment dynamics, greater wave dissipation at high tide, accumulation of wood and detritus, and longer moisture retention in beach sediment. In turn, **structural changes** would also occur in the following elements: beach delta profile, sediment composition, substrate heterogeneity, backshore vegetation substrate moisture, and temperature. As a result, the following **functional responses** would be expected: reduced railway embankment erosion and thus reduced need for riprap placement, enhanced forage fish spawning habitat, improved and expanded supratidal riparian vegetation, and improved benthos and insect production.

By restoring sediment supply, the effects of dam removal on the reformation of the Boeing Creek delta would be consistent with the process-based restoration approach included in the WRIA 8 Plan. The process-based restoration approach targets the root causes of habitat degradation, is tailored to the physical and biological potential at a particular site, and is expected to adjust over time with no or minimal maintenance.

If the dam impounding Hidden Lake is removed and sediment generated upstream of the lake is thus allowed to move freely through lower Boeing Creek to its mouth, the first stage of recovery of the Boeing Creek delta will likely look similar to the (re)formation of the delta in the late 1970s through the early 1990s. However, the recovery of the delta would likely be slightly more rapid than occurred in that earlier time frame because some of the sediment discharged from the remnants of Hidden Lake beginning in the 1970s may have been stored behind the Seattle Golf Club diversion dam during this period. As described above, initial sedimentation caused the flow to split into two branches across the Boeing Creek delta, as the coarsest material (that which could not be mobilized initially by the waves) formed a wedge that split the flow into the two branches (Note: Removal of the large dams on the Elwha River on the Olympic Peninsula of Washington led to a similar occurrence at the river delta—the earliest stages of the Elwha River delta formation after dam removal included branched flow.). Once the Boeing Creek gradient across the nearshore is reduced sufficiently for fluvial processes to become comparable to wave-induced transport, the delta will change again. It is expected that without any impediment, this first stage of delta building should conclude in 10 and 20 years after increased sediment supply is restored. At the conclusion of this stage of development, it is likely that the delta will persist despite sea level rise, as the deposition in an unmodified delta will adjust to increased sea levels.

Once the delta is built back to the size it was in the early 1990s (similar to Pipers Creek at the same time: see Figure 4), wave forces will begin to shape the delta, as they have in the last 20 years at the Pipers Creek delta. As mentioned above, the wave environment is slightly different at Pipers Creek, but these differences are relatively minor compared to other geomorphic variables (e.g., fluvial power and sediment supply). Demonstration of this is seen in the T-sheet and H-sheet (Figure 2), which indicate similar delta sizes prior to all human development in the respective drainage basins. Because it has taken between 20 and 30 years for Pipers Creek to transition to a fully sized delta in its current configuration, it is expected that Boeing Creek will progress along a similar trajectory and at a similar rate.

Based upon comparisons to Pipers Creek, the following habitat gains are reasonable to anticipate at the mouth of Boeing Creek within 50 years of restoring sediment supply downstream of Hidden Lake:

- More than 400 feet of intertidal channel
- Approximately 1,000 feet of forage fish spawning habitat in shallow nearshore areas
- Restoration of a narrow marine riparian band between the MHHW and the railway embankment
- A more complex channel and beach environment throughout the delta
- Elimination of future railway-protection-related nearshore disturbance associated with riprap armoring placement in the vicinity of the delta.

Figure 8. Diagram Illustrating Expected Progression of Delta Formation at the Mouth of Boeing Creek.

CONCLUSION

According to the WRIA 8 Plan, the marine nearshore is important habitat for all Puget Sound juvenile Chinook salmon. Nearshore areas closer to the Ballard Locks, because of their proximity to upland fluvial environments, have higher benefit to WRIA 8 juvenile Chinook salmon as they migrate to salt water. Nearshore projects between Golden Gardens in Seattle and Boeing Creek in Shoreline are the number two priority.

The habitat gains associated with restoration of a natural delta at the mouth of Boeing Creek would enhance WRIA 8's Puget Sound nearshore habitat for Chinook salmon, other salmonids, and forage fish species. This portion of the Puget Sound shoreline is currently sediment deprived because of cessation of sediment supply from eroding bluffs separated from the nearshore by the BNSF railway. In the absence of functional feeder bluffs, sediment delivery from Boeing Creek is critical for the recovery of Chinook salmon and, therefore, should be considered high priority for restoration. Such restorative action would be consistent with the findings from the Ecosystem Diagnosis and Treatment (EDT) analyses performed during creation of the WRIA 8 Plan, which identified creek mouths (along with other habitat features) as the highest priority for protection or restoration. It would also be consistent with marine conservation strategies in the WRIA 8 Plan update currently under development. In addition, restoration of the Boeing Creek delta by restoring sediment supply would ameliorate a currently disrupted sediment process, thus supporting a physical platform for riparian vegetation, both of which are among the limiting factors listed in the WRIA 8 Plan (Chapter 3, pp. 21–23).

REFERENCES

AltaTerra. 2014. Hidden Lake Management Plan Feasibility Study. Prepared for City of Shoreline by AltaTerra Consulting LLC, Seattle, Washington.

Barton, C.M. 2002. A Sediment Budget for the Pipers Creek Watershed: Applications for Urban Stream Restoration. MS Thesis. University of Washington, Seattle.

Copass, C. 1996. Overview of Shoreline History. Prepared as a Part of the Survey and Inventory of Historic Resources in the City of Shoreline.

Finlayson, D.P. 2006. The Geomorphology of Puget Sound Beaches. PhD Thesis. University of Washington, Seattle.

General Land Office. 1859. Township No. 26 North Range No. 3 East Willamette Meridian.

Google Earth. 2016. Aerial photos of Boeing Creek and Pipers Creek delta areas. <https://earth.google.com/>.

Herrera. 2016. Alternatives Analysis: Hidden Lake Dam Removal Project. Prepared for the City of Shoreline by Herrera Environmental Consultants, Inc., Seattle, Washington.

King County. 1995. Hidden Lake Restoration. King County Surface Water Management Division.

King County. 2016. King County iMap: Interactive mapping tool. <http://www.kingcounty.gov/services/gis/Maps/imap.aspx>.

NOAA. 2016. Seattle, WA Tide Station ID: 9447130 website. <https://tidesandcurrents.noaa.gov/stationhome.html?id=9447130>.

Sherwood, D.N. 2016. Sherwood History Files. Seattle Parks and Recreation. <http://clerk.seattle.gov/~F_archives/sherwood/Carkeek.pdf>.

Simenstad, C., M. Logsdon, K. Fresh, H. Shipman, M. Dethier, and J. Newton. 2006. Conceptual model for assessing restoration of Puget Sound nearshore ecosystems. Puget Sound Nearshore Partnership Report No. 2006-03. Published by Washington Sea Grant Program, University of Washington, Seattle, Washington. <http://pugetsoundnearshore.org>.

US Coast Survey. 1874. Admiralty Inlet from Pt. Edmund to Meadow Pt., Washington Territory. Register No. 1390.

US Coast Survey. 1876. Hydrography in Admiralty Inlet from Deer Lagoon to Meadow Point, Washington Territory. Register No. 1344.

Washington State Department of Ecology. 2016. Washington Coastal Atlas. <https://fortress.wa.gov/ecy/coastalatlas/>.

Weather Underground. 2016. Meridian Park, Shoreline Washington Weather Underground Station # KWASEATT260. <https://www.wunderground.com/personal-weather-station/dashboard?ID=KWASEATT260#history/s20161026/e20161026/mdaily>.

Windward. 2013. Boeing Creek Basin Plan. Prepared for City of Shoreline by Windward Environmental, Inc., in association with Osborn Consulting and The Watershed Company. March.

APPENDIX A

Historical Maps and Aerial Photographs

Statute

1 ½ 1 ½ 0 1 2 3

Boeing Creek

Pipers Creek

Meadow Point

MEADOW POINT

Assistants

F. Westdahl, Aid & E.W. Dodge, Pay. Yeo.

Verified by J. Sprandel, hydr. draughtsman.
Coast Survey Office, June 25th 1877.

Approved for Registry
10 July 1877
Edward P. Lull.
Hydr. Surveyor.

Gershom Bradford
Chief of par
Gershom Bradford
Ferdinand Westd
Draughtsm

Note

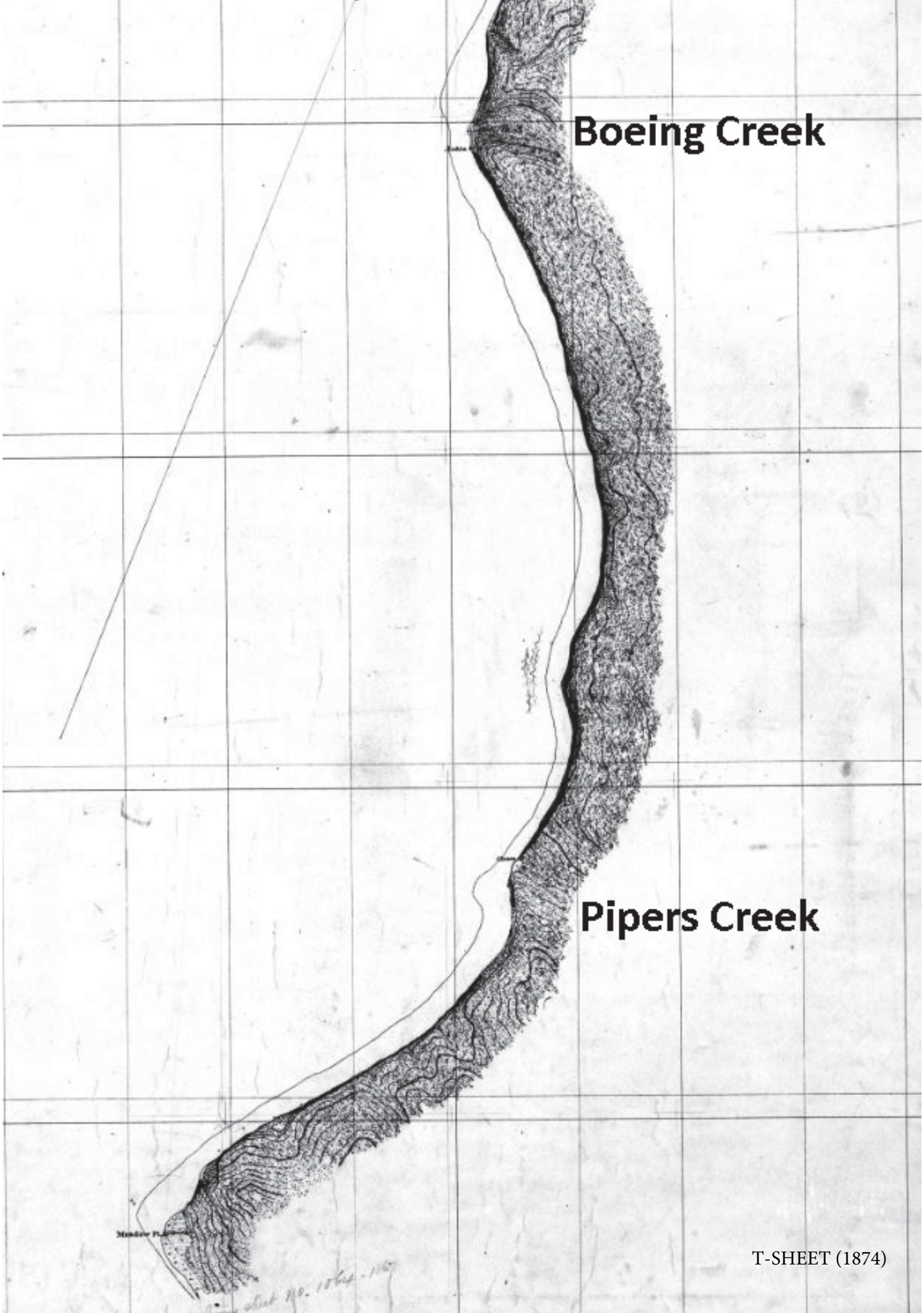
The soundings are in black, expressed in fathoms outside of 3 faths., inside that, in feet, and show the depth at the mean of the lower low ~~waters~~ of each 24 hours, the plane of reference. The curves of equal depth are represented as follows:

Low water mark, dotted line thus .....
6 foot curve in green " "
12 " " " red " " _____
18 " " " blue " " _____
25 fathom curve in purple " " _____

The heights above the plane of reference on the flats covered at high water are in red and expressed in feet. The positions of the sounding-vessel, determined by angles, are marked in red, thus ○, numbered in red in reference to the day and lettered in red in reference to the day of the month.
The sunken rocks visible at low tides are marked in red, thus *
The sunken rocks, existence doubtful, (reported but not found) are marked in red, thus ⁜
The triangulation stations are marked in black, thus △
The triangulation stations when used in surrey are marked thus ④
The stations determined by party are marked in red, thus ⊙ and lettered in same color.
Kelp is marked in black thus ~~Kelp Kelp Kelp~~
The hydrography of Deer Lagoon is protracted on a separate sheet, scale 20.000.

H-SHEET (1876)

Register No 1344.



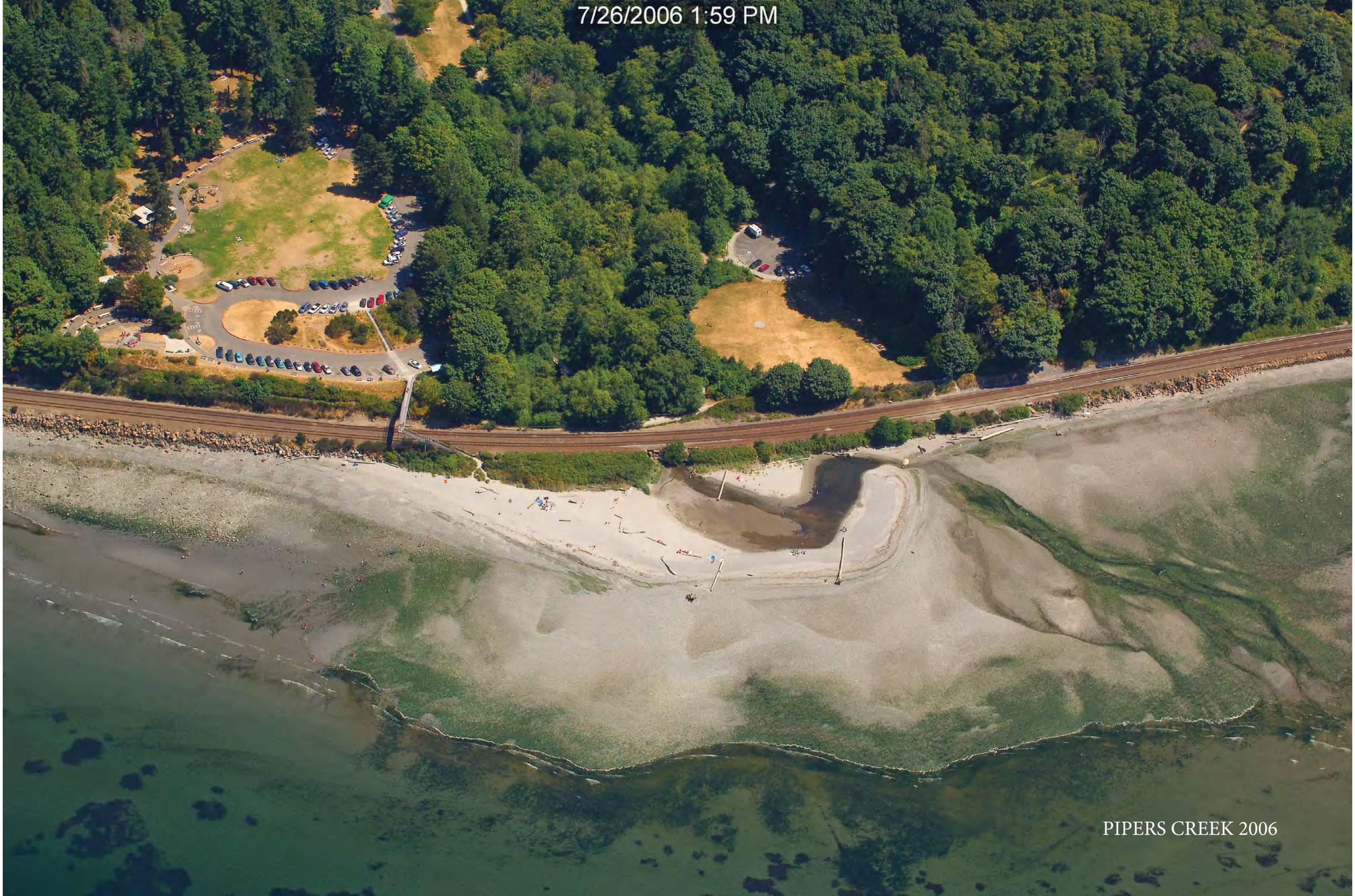
T-SHEET (1874)

PIPERS CREEK 1936

PIPERS CREEK 1977

PIPERS CREEK 1993


000925_124246
PIPERS CREEK 2001



PIPERS CREEK 2006

BOEING CREEK 1936

BOEING CREEK 1977

BOEING CREEK 1993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BOEING CREEK 2001

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BOEING CREEK 2006