NATURAL RESOURCES

Eelgrass (*Zostera marina* L.) Abundance and Depth Distribution along the City of Bellingham Waterfront Whatcom County, Washington

Final Report to the City of Bellingham under Interagency Agreement #09-69

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WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

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by Jeffrey Gaeckle
Nearshore Habitat Program
Aquatic Resources Division

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All contributors are DNR staff unless otherwise indicated.

Contents

1 Introduction

The Nearshore Habitat Program in the Washington State Department of Natural Resources (DNR) has collected data annually since 2000 on the status of *Zostera marina* L. (eelgrass) throughout Puget Sound as part of the Submerged Vegetation Monitoring Project (SVMP). The SVMP is one component of the Puget Sound Assessment and Monitoring Program (PSAMP), a multi-agency effort to monitor key aspects of the Puget Sound environment to support resource management.

In 2008, the City of Bellingham (COB) contracted the DNR to collect baseline eelgrass area and depth distribution data at all of the SVMP sites (13 sites) along the COB marine waterfront that were not currently in the 2008 sound-wide sample plan. Three sites along the COB waterfront were already in the sample plan and scheduled to be sampled in the 2008 field season. The COB sites were selected to be sampled using the SVMP methodology to determine a baseline understanding of eelgrass area and distribution.

This report summarizes the DNR sampling methods and the eelgrass area and depth distribution results at the 16 sites along the City of Bellingham waterfront.

2 Methods

The DNR SVMP sampling methods are described in detail in Berry et al. (2003), Dowty (2005), Dowty et al. (2005), Gaeckle et al. (2007) and Gaeckle et al. (2008). The methods are summarized briefly in the following sections to provide context for the eelgrass monitoring along the COB marine shoreline.

2.1 Study Area Description

The shoreline monitored in this contract encompassed the marine waters within the Bellingham city limits and a small section of the urban growth area. The sample area ranged from the eastern edge of the Nooksack Delta (western boundary of the COB and part of the urban growth area) to the northern extent of Chuckanut Bay (Figure 2-1). To maintain methodology continuity with the existing DNR eelgrass monitoring project, the Bellingham shoreline was separated into 16 sites (Figure 2-2; Berry et al. 2003). Three of the sites were in the SVMP sample pool (1 as an annual, sound-wide site and 2 as part of the 2008 North Puget Sound Focus Area sites) and 13 sites were sampled as part of the IAA #09-69 (Figure 2-2, Table 2-1). Data from all 16 sites will be presented in this report.

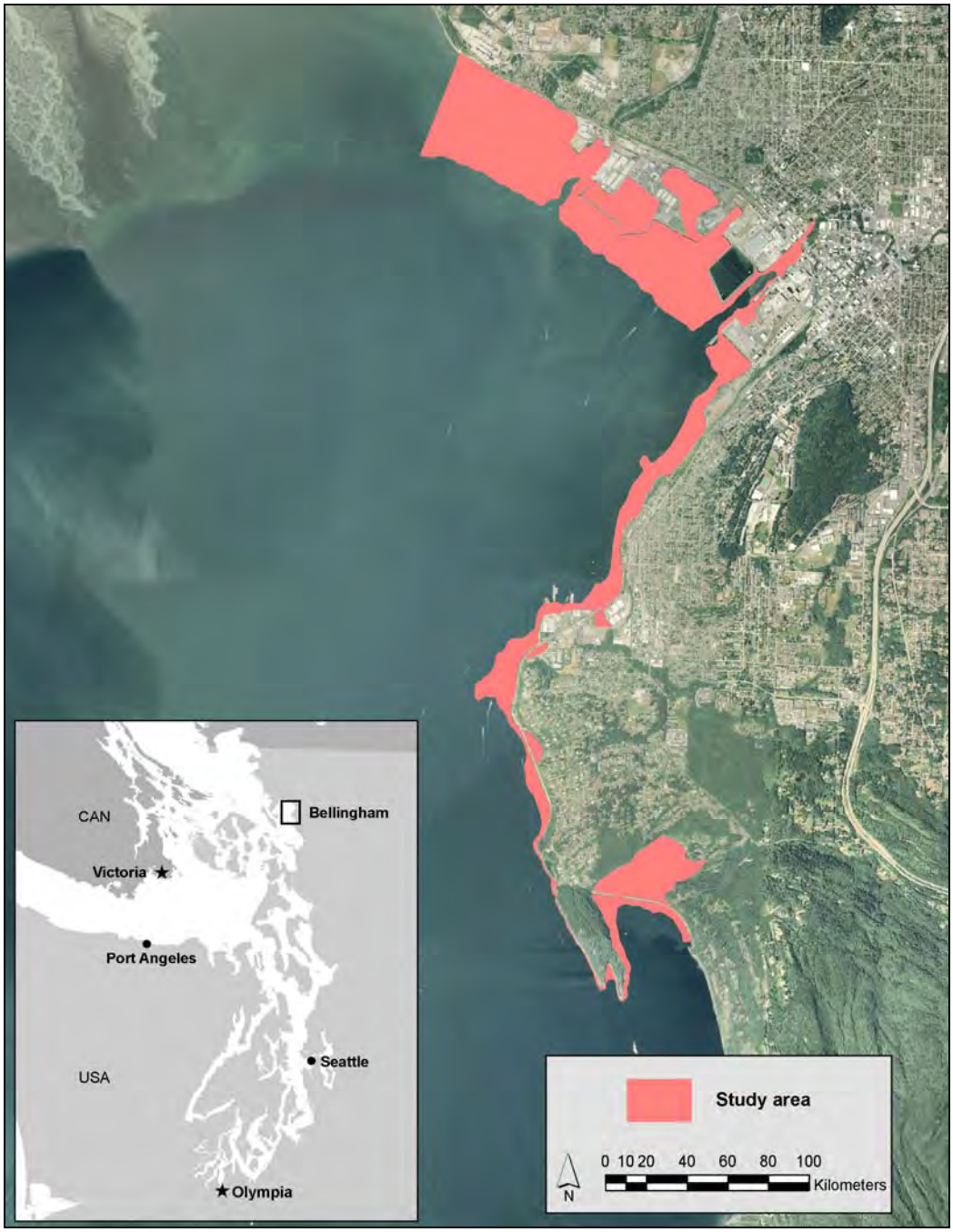


Figure 2-1. Map of the eelgrass (*Zostera marina* L.) monitoring study area for the City of Bellingham.

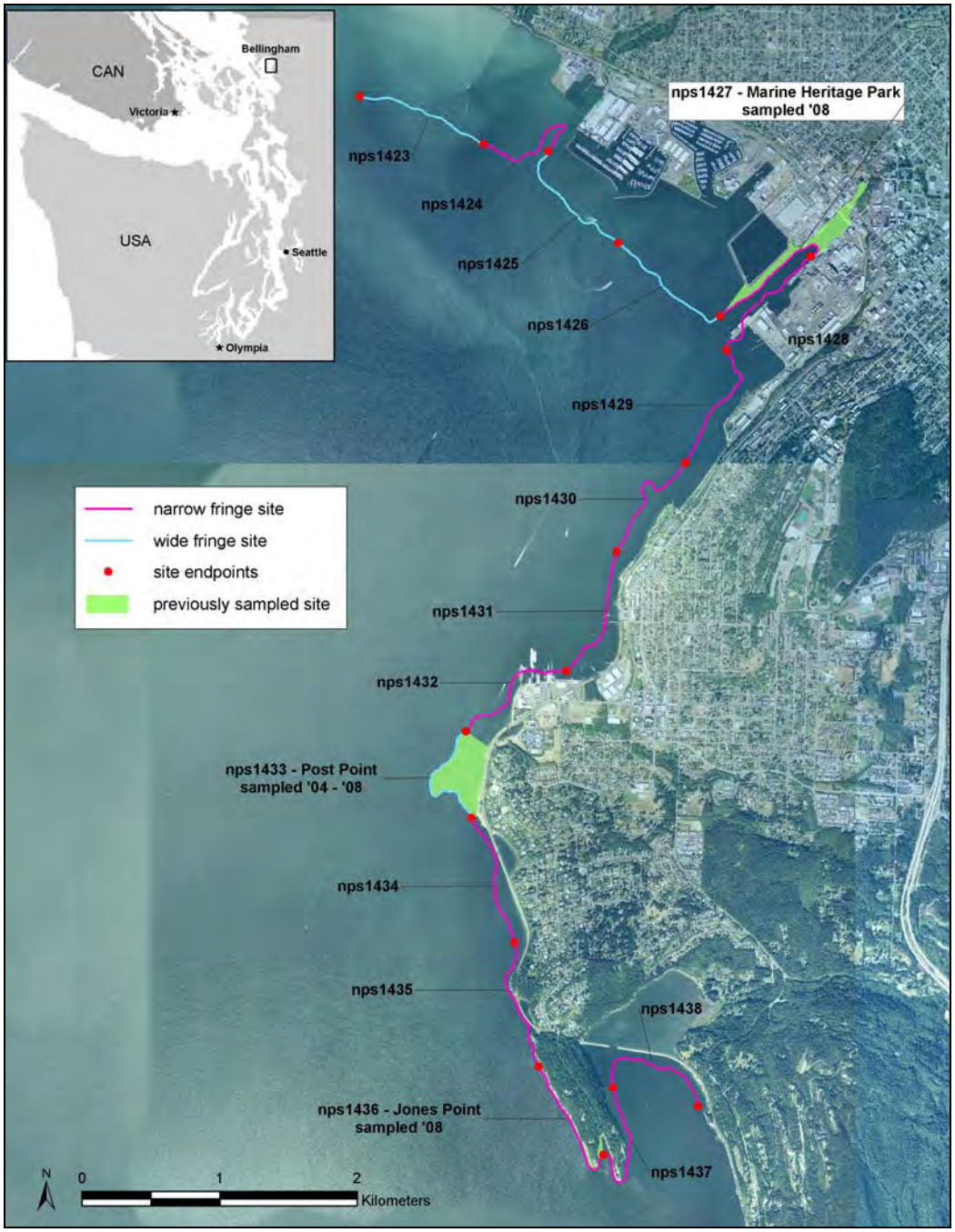


Figure 2-2. Map of the City of Bellingham marine shoreline with the 13 sites delineated for eelgrass (*Zostera marina* L.) monitoring. Three additional sites (*nps1427-Marine Heritage Park Waterway North*, *nps1433-Post Point*, and *nps1436-Clark's Point*) are shown but were sampled by the DNR as part of the 2008 SVMP annual and focus area monitoring in the North Puget Sound Region.

Table 2-1. Sites along the City of Bellingham marine shoreline that were monitored for eelgrass (*Z. marina*) abundance and depth distribution in 2008. SITE CODE indicates the region the site is located (North Puget Sound, nps) and the site number. SITE NAME refers to an adjacent geographical location. The PROJECT column lists the 16 sites monitored as part of IAA #09-69 (COB), two sites monitored for the 5-year SVMP-focus area sampling (SVMP-focus area) and one site monitored as part of the annual, SVMP sound-wide sampling (SVMP). The STRATA column indicates whether the site is a narrow fringe (fr) or wide-fringe (frw) site. The -6 m (-20 ft) bathymetry contour is < 305 m (1000 ft) from shore at narrow fringe sites and > 305 m (1000 ft) from shore at wide-fringe sites. The LAT (latitude) and LONG (longitude) columns provide the geographical center point of the sample site.

SITE CODE	SITE NAME	PROJECT	STRATA	LAT	LONG
(region site #)	(reference to an adjacent geographical location)	(COB, SVMP or SVMP-focus area)	(narrow fringe, fr; wide-fringe, frw)	(dec deg)	(dec deg)
nps1423	NW of Squalicum Creek Waterway	COB	frw	48.7585	-122.5264
nps1424	Squalicum Creek Waterway	COB	fr	48.7561	-122.5153
nps1425	Squalicum Harbor	COB	frw	48.7530	-122.5125
nps1426	N of Whatcom Creek Waterway	COB	frw	48.7473	-122.5020
nps1427	Marine Heritage Park Waterway North	SVMP-focus area	fr	48.7481	-122.4923
nps1428	Whatcom Creek Waterway	COB	fr	48.7468	-122.4927
nps1429	S of Whatcom Creek Waterway	COB	fr	48.7401	-122.4963
nps1430	Boulevard Park	COB	fr	48.7346	-122.5038
nps1431	Taylor Dock	COB	fr	48.7256	-122.5073
nps1432	Bellingham Cruise Terminal	COB	fr	48.7198	-122.5170
nps1433	Post Point, Fairhaven	SVMP	frw	48.7145	-122.5242
nps1434	S of Post Point	COB	fr	48.7081	-122.5176
nps1435	N of Clark's Point	COB	fr	48.7005	-122.5153
nps1436	Clark's Point, Chuckanut Bay	SVMP-focus area	fr	48.6926	-122.5094
nps1437	E of Clark's Point	COB	fr	48.6918	-122.5035
nps1438	Chuckanut Village	COB	fr	48.6965	-122.5013

2.2 Field Sampling

Field sampling was conducted between 3 Jul 2008 and 19 Sep 2008 from a 36-ft research vessel, *R/V Brendan D II* (Figure 2-3).

Figure 2-3. The *R/V Brendan D II* owned and operated by the Marine Resources Consultants. Eelgrass (*Z. marina*) presence and depth distribution data was collected from the *R/V Brendan D II* using underwater videography and depth sounding instrumentation.

Equipment

The *R/V Brendan D II* was equipped with an underwater video camera mounted in a "downward-looking" orientation on a weighted towfish (Figure 2-4a). Parallel lasers mounted 10 cm apart created two red dots in the video images for scaling reference. The towfish was deployed directly off the stern of the vessel using an A-frame cargo boom and hydraulic winch. The weight of the towfish positioned the camera directly beneath a DGPS antenna, ensuring that the data accurately reflected the geographic location of the camera (Figure 2-4b). Time, differential global positioning system (DGPS) data, Garmin and Biosonics depth data were acquired simultaneously during sampling. Differential corrections were received from the United States Coast Guard public DGPS network using the WSG 84 datum. Table 2-2 lists the equipment used to conduct the video sampling and acquisition of eelgrass depth data.

Figure 2-4. The *R/V Brendan D II* is equipped with a weighted towfish that contains an underwater video camera mounted in a 'downward looking' orientation, dual lasers for scaling reference, and underwater lights for night work (a). The towfish is deployed directly beneath the DGPS antenna attached to the A-frame cargo boom, ensuring accurate geographic location of the camera (b).

Table 2-2. Equipment and software used to collect underwater video and depth data in Bellingham Bay.

Equipment	Manufacturer/Model
Differential GPS	Trimble AgGPS 132 (sub-meter accuracy)
Depth Sounders	BioSonics DE 4000 system (including Dell laptop computer with Submerged Aquatic Vegetation software)
	Garmin FishFinder 250
Underwater Cameras (2)	SplashCam Deep Blue Pro Color (Ocean Systems, Inc.)
Lasers	Deep Sea Power & Light
Underwater Light	Deep Sea Power & Light RiteLite (500 watt)
Navigation Software	Hypack Max
Video Overlay Controller	Intuitive Circuits TimeFrame
DVD Recorder	Sony RDR-GX7
Digital Video Recorder	Sony DVR-TRV310 Digital8 Camcorder

Site and Sample Polygons

Prior to field sampling a site polygon is delineated for each site. The site polygon delineates the area of potential eelgrass occurrence, it encompasses the area along 1000 m (3280 ft) of the -6 m (-20 ft) bathymetry contour to the ordinary high water

mark (Figure 2-5a). A series of reconnaissance underwater video transects were completed throughout the site polygon to delineate the sample polygon (Figure 2-5b). Sample polygons include all observed eelgrass and any potential habitat where eelgrass presence could not be ruled out with a high degree of certainty (Berry et al. 2003). Random transects were selected from within the sample polygon for each site using ArcGIS software (Figure 2-5c).

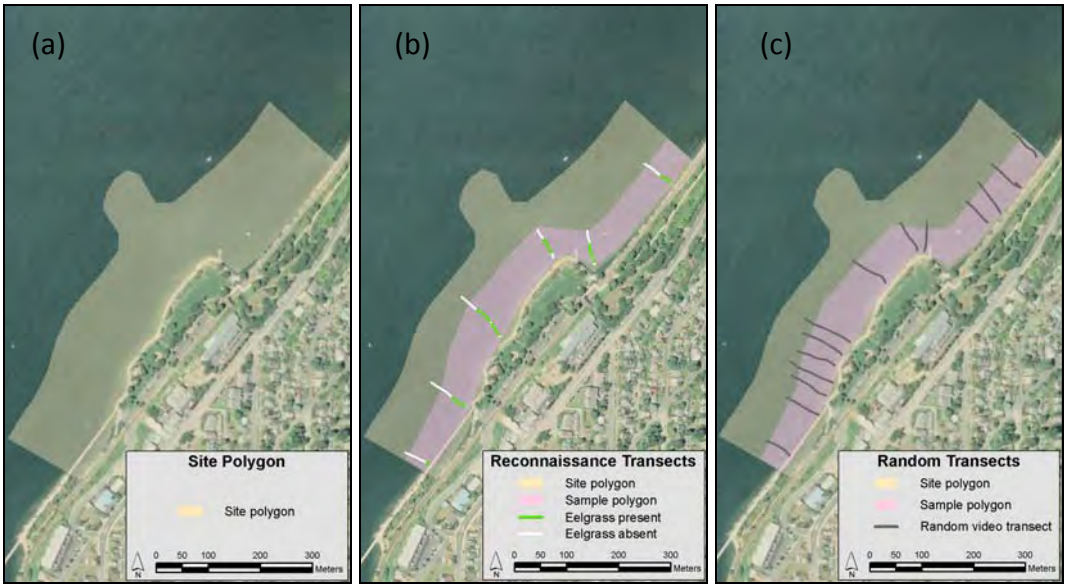


Figure 2-5. Prior to field work a site polygon, delineated as the area between the -6 m (-20 ft) bathymetry contour and the ordinary high water mark, was created using ArcGIS (a). Reconnaissance transects using underwater videography throughout the site provided the necessary data to identify a sample polygon (b). The site was then sampled with 10-20 random underwater videography transects (c).

Eelgrass video data collection

At each site, underwater videography was used to sample the presence of eelgrass along random transects in a modified line-intercept technique (Norris et al. 1997). The random transects are restricted to a sample polygon that represents the general location of eelgrass presence within a site that was delineated from reconnaissance transects. The 10 – 20 random video transects, oriented perpendicular to shore, extend beyond the shallow and deep edges of the sample area.

2.3 Video Data Processing and Analysis

The video sampling resolution is nominally one square meter and eelgrass is categorized as present or absent based on the observation of rooted shoots within the video field of view. All classification results were recorded with corresponding spatial information. The fractional cover of eelgrass along transects is used to calculate site eelgrass area. The depth at which eelgrass grows along each transect

is used to estimate mean maximum and minimum depth of eelgrass relative to Mean Lower Low Water (MLLW) within each sample polygon at each site.

All measured depths were corrected to the MLLW datum by adding the transducer offset, subtracting the predicted tidal height for the site and adding the tide prediction error (calculated using measured tide data from the National Oceanic and Atmospheric Administration website http://co-ops.nos.noaa.gov/data_res.html). These final corrected depth data were merged with eelgrass data and spatial information into a site database so the eelgrass observations had associated date/time, position and depth measurements corrected to MLLW datum.

Eelgrass area at each site was calculated using GIS software and the site database file in the following sequential steps:

1. Calculated the area within the Sample Polygon;
2. Calculated the fraction of eelgrass along each random line transect;
3. Calculated the mean fraction and associated variance;
4. Estimated the overall eelgrass area and variance at the site by extrapolating the mean fraction along random transects over the Sample Polygon area.

Every random underwater video transect that intersected eelgrass had a minimum and maximum depth observation. Minimum and maximum eelgrass depth characteristics for each site are described using descriptive statistics (i.e. means and ranges).

2.4 Side Scan Sonar

Side scan sonar data was collected at all the sites where eelgrass was previously observed using the SVMP methodology. Side scan sonar was collected by Tony Petrillo of Blue Water Engineering Services, Inc. (BWES) of Port Townsend, WA. Details of the side scan sonar survey and field notes can be found in Appendix H.

2.5 Deliverables

All underwater videography for the 16 sites, including the 3 additional sites from the SVMP sound-wide and focus area effort (*nps1427-Marine Heritage Park Waterway North*, *nps1433-Post Point*, and *nps1436-Clark's Point*), was archived on DVD. The DVD's are labeled by Site Code, sample date, and list the transect numbers recorded on each DVD for each site (Appendix I). The transect numbers in the videography data correspond to the transect numbers on each site map (Appendix G).

Appendix J contains a CD with all post-processed electronic and ArcGIS data for the sites sampled in IAA #09-69, including *nps1427-Marine Heritage Park Waterway North*, *nps1433-Post Point*, and *nps1436-Clark's Point*.

The post-processed electronic data for each site will include:

1) Pre-sampling random transect map
2) Transect notes
3) Site description
4) Transect data - provides eelgrass presence/absence, date, time stamp, position stamp, and depth data for each second of video collected at a site.
5) Post-sampling site map

The ArcGIS data will include:

1) site polygon shapefile
2) sample polygon shapefile
3) transect data shapefile

All ArcGIS data is projected in <stateplane_nad83HARN_feet_Washington_south>.

In addition, a separate folder on the data CD will include the Bellingham side scan sonar data for each site (BWES, Appendix J).

3 Results

3.1 Eelgrass Abundance along the City of Bellingham Marine Shoreline

The 16 Bellingham Bay sites were surveyed between 3 July 2008 and 19 September 2008. The average number of random videography transects per site was 14 and ranged from 12 to 18 (Table 3-1). Overall, 19.53 ± 2.29 ha of eelgrass was observed along the City of Bellingham marine shoreline (Table 3.1).

Table 3-1. Eelgrass (*Z. marina*) monitoring summary statistics from the sites sampled along the City of Bellingham marine shoreline. Data presented in acres (ac) can be found in Appendix A.

Number of sites sampled	Number of sites with eelgrass	Number of sites without eelgrass	Average Number of Transects	Average Fraction	Total eelgrass Area	Total Variance	Standard Error	95% CI Lower Limit	95% CI Upper Limit
					(ha)			(ha)	(ha)
16	12	4	14	0.4	19.53	1.36	1.17	17.24	21.81

Eelgrass was not evenly distributed throughout the Bellingham Bay marine shoreline. The greatest amount of eelgrass was observed at *nps1438-Chuckanut Village* with 3.24 ± 1.05 ha (Figure 3-1, Table 3-2). Eelgrass was not observed at three northern sites closest to the Nooksack River Delta (*nps1423-N of Squalicum Creek*, *nps1424-Squalicum Creek*, and *nps1425-Squalicum Creek Harbor*) and at one site (*nps1435-N of Clark's Point*) in the southern extent of the study area. There were two additional sites (*nps1436-Clark's Point*, and *nps1437-E of Clark's Point*) where eelgrass was observed but the patch of eelgrass was too small to properly calculate area according to DNR SVMP methodology (Table 3-2). Three other sites, *nps1427-Marine Heritage Park Waterway North*, *nps1428-Whatcom Creek Waterway*, and *nps1434-S of Post Point* all had less than 0.5 ha of eelgrass present at the site (Table 3-2).

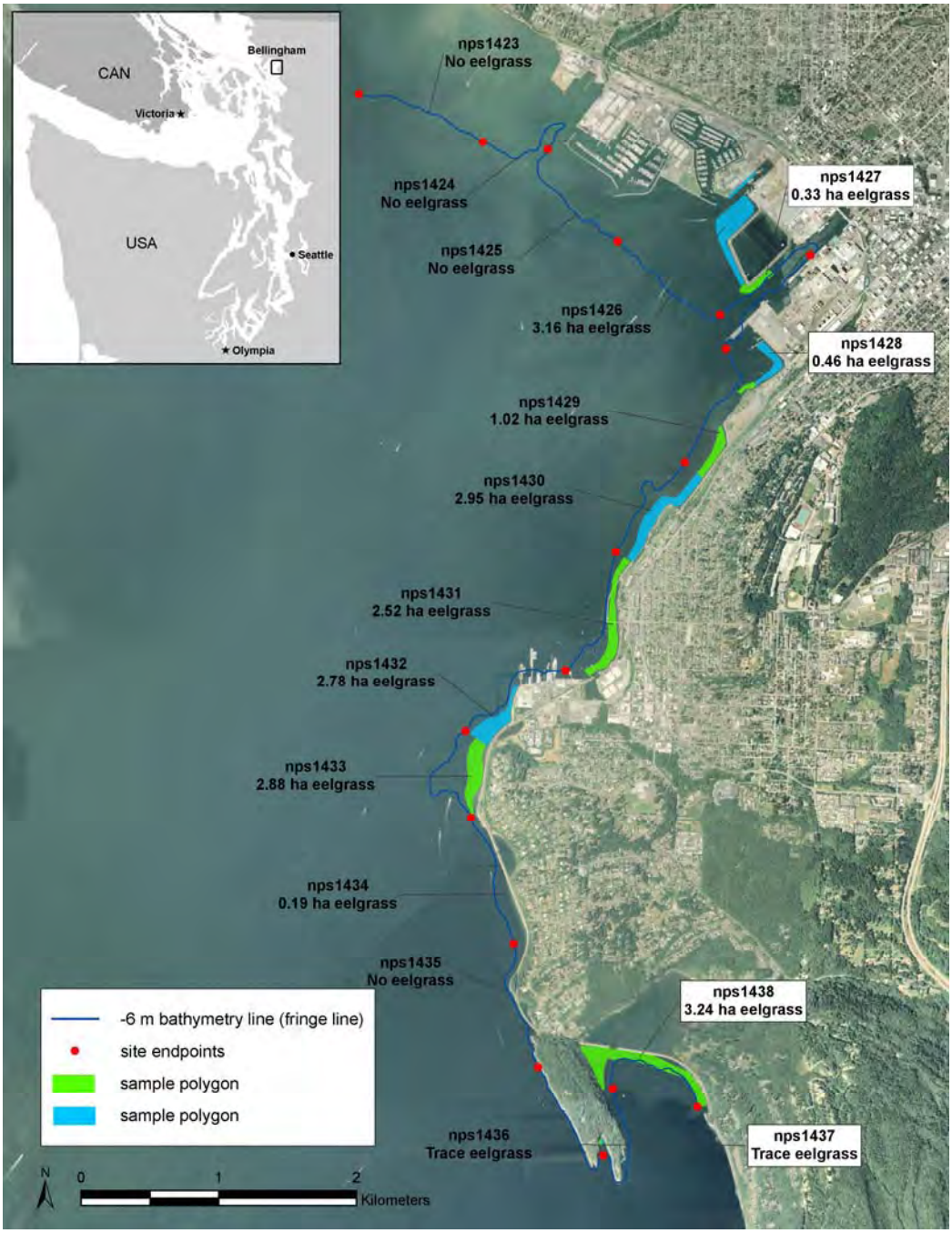


Figure 3-1. Eelgrass (*Z. marina*) area (ha) at the 16 City of Bellingham marine shoreline sites sampled in 2008. Sites are initially delineated by the -6 m bathymetry line (fringe line) and the site endpoints. The green and blue alternating sample polygons represent the general area where eelgrass was observed at each site. Data presented in acres (ac) can be found in Appendix B.

Table 3-2. Eelgrass (*Z. marina*) area (hectares) at the sites sampled along the City of Bellingham marine shoreline. Data presented in acres (ac) can be found in Appendix C.

Site	Date Sampled	Number of Transects	Eelgrass Fraction Along Transects	Eelgrass Area at Site	Variance	Coefficient of Variance	Estimated Eelgrass Area Confidence Interval	
							95% Lower Limit	95% Upper Limit
				(ha)			(ha)	(ha)
nps1423	16-Sep-08	0	0.00	0.00	0.00	0.00	0.00	0.00
nps1424	16-Sep-08	0	0.00	0.00	0.00	0.00	0.00	0.00
nps1425	16-Sep-08	0	0.00	0.00	0.00	0.00	0.00	0.00
nps1426	19-Sep-08	14	0.45	3.16	0.80	0.28	1.40	4.92
nps1427	03-Jul-08	11	0.21	0.33	0.01	0.28	0.15	0.51
nps1428	17-Sep-08	16	0.23	0.46	0.01	0.18	0.30	0.62
nps1429	19-Sep-08	12	0.38	1.02	0.03	0.17	0.68	1.37
nps1430	17-Sep-08	14	0.52	2.95	0.06	0.08	2.49	3.41
nps1431	19-Sep-08	13	0.49	2.52	0.05	0.09	2.06	2.98
nps1432	19-Sep-08	12	0.71	2.78	0.04	0.08	2.37	3.20
nps1433	03-Jul-08	18	0.61	2.88	0.05	0.08	2.44	3.33
nps1434	14-Sep-08	14	0.03	0.19	0.02	0.75	0.00	0.48
nps1435	15-Sep-08	0	0.00	0.00	0.00	0.00	0.00	0.00
nps1436	03-Jul-08			* tr				
nps1437	14-Sep-08			* tr				
nps1438	15-Sep-08	12	0.37	3.24	0.28	0.16	2.19	4.28

*** tr = trace eelgrass present at the site**. The site was visited and reconnaissance video transects found eelgrass present but the patch of eelgrass was too small to properly calculate eelgrass area according to the DNR Submerged Vegetation Monitoring Project protocols.

Side scan sonar was collected at all the sites where eelgrass area was estimated using the SVMP methodology. Estimates of eelgrass area from the side scan sonar data were calculated using ArcGIS and were compared to the eelgrass area estimates calculated from the underwater videography (Table 3-3). The resolution of side scan sonar differs in that it does not capture the fine scale heterogeneity (i.e. patches and gaps) of the eelgrass bed and the area estimates from side scan sonar do not have associated confidence intervals.

Table 3-3. Comparison of eelgrass (*Z. marina*) area calculated using side scan sonar and video sites along the City of Bellingham marine shoreline. Data presented in acres (ac) can be found in Appendix D.

Site	Date Sampled	Eelgrass area at Site	Eelgrass area at Site	DIFFERENCE
		(Side Scan)	(Video)	
		(ha)	(ha)	(ha)
nps1423	16-Sep-08	0.00	0.00	
nps1424	16-Sep-08	0.00	0.00	
nps1425	16-Sep-08	0.00	0.00	
nps1426	19-Sep-08	1.89	3.16	1.27
nps1427	03-Jul-08	0.34	0.33	0.01
nps1428	17-Sep-08	0.51	0.46	0.05
nps1429	19-Sep-08	0.86	1.02	0.17
nps1430	17-Sep-08	2.84	2.95	0.11
nps1431	19-Sep-08	1.81	2.52	0.71
nps1432	19-Sep-08	1.30	2.78	1.48
nps1433	03-Jul-08	1.82	2.88	1.06
nps1434	14-Sep-08	0.53	0.19	0.33
nps1435	15-Sep-08	0.00	0.00	
nps1436	03-Jul-08	* tr	* tr	
nps1437	14-Sep-08	* tr	* tr	
nps1438	15-Sep-08	3.75	3.24	0.51
TOTAL		15.65	19.53	3.88

*** tr = trace eelgrass present at the site**. The site was visited and reconnaissance video transects found eelgrass present but the patch of eelgrass was too small to properly calculate eelgrass area according to the DNR Submerged Vegetation Monitoring Project protocols.

3.2 Eelgrass Depth along the City of Bellingham Marine Shoreline

Eelgrass was found from an absolute minimum depth of -0.1 m (-0.4 ft, MLLW) to an absolute maximum depth of -4.3 m (-14.2 ft, MLLW) at the Bellingham Bay sites (Table 3-4). The mean minimum eelgrass depth at the 16 sites ranged from -0.6 m (-1.9 ft, MLLW) to -1.8 m (-5.9 ft, MLLW). While the mean maximum eelgrass depth at the 16 sites ranged from -1.9 m (-6.1 ft, MLLW) to -3.2 m (-10.5 ft, MLLW, Table 3-5).

The absolute minimum depth observed at the Bellingham Bay study sites was 1.5 m deeper than the absolute minimum depth for the North Puget Sound Region (Table 3-4, Gaeckle et al. 2008). However, the mean minimum depth falls in the

range of mean minimum depths observed in this region. A similar pattern was observed in the absolute maximum and mean maximum depths. The absolute depth at the Bellingham Bay sites was 3.7 m shallower compared to the North Puget Sound Region. Whereas the mean maximum depths observed along the COB shoreline fall within the range observed in the region (Table 3-4, Gaeckle et al. 2008).

Table 3-4. Comparison of absolute and mean minimum and maximum depths of eelgrass (*Z. marina*) observed at the City of Bellingham sites and sites sampled in the North Puget Sound Region from 2000 – 2007. Data presented in acres (ft) can be found in Appendix E.

	Minimum Depth		Maximum Depth	
Location	Absolute Depth	Range in Mean Depths	Absolute Depth	Range in Mean Depths
	(m)	(m)	(m)	(m)
COB	-0.1	-0.6 to -1.8	-4.3	-1.9 to -3.2
North Puget Sound Region	+1.4	+0.6 to -3.3	-8.4	-0.7 to -6.6

Table 3-5. Eelgrass (*Z. marina*) depth (m) at sites sampled along the City of Bellingham marine shoreline. Data presented in feet (ft) can be found in Appendix F.

	Minimum Eelgrass Depth					Maximum Eelgrass Depth				
Site	n	Absolute Depth	Mean Depth	Standard Error	95% Confidence Interval	n	Absolute Depth	Mean Depth	Standard Error	95% Confidence Interval
		(m)	(m)		(m)		(m)	(m)		(m)
nps1423	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps1424	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps1425	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps1426	9	-0.4	-1.2	0.2	0.4	9	-2.3	-2.1	0.1	0.2
nps1427	8	-0.9	-1.1	0.1	0.2	8	-2.4	-1.9	0.1	0.2
nps1428	13	-0.6	-0.9	0.0	0.1	13	-2.7	-1.9	0.1	0.2
nps1429	10	-0.8	-1.0	0.0	0.1	11	-2.8	-2.3	0.1	0.3
nps1430	10	-0.3	-0.6	0.1	0.1	14	-3.5	-2.8	0.1	0.2
nps1431	11	-0.4	-0.7	0.1	0.1	12	-3.6	-2.8	0.1	0.3
nps1432	12	-0.1	-0.6	0.2	0.3	12	-3.9	-3.0	0.2	0.4
nps1433	17	-0.1	-0.6	0.1	0.3	17	-4.3	-3.2	0.2	0.3
nps1434	4	-0.5	-1.8	0.7	1.4	4	-3.4	-2.4	0.7	1.3
nps1435	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps1436	5	-0.8	-1.1	0.1	0.7	5	-2.9	-2.5	0.1	0.3
nps1437	7	-0.7	-1.2	0.3	1.8	7	-2.7	-2.3	0.2	0.3
nps1438	5	-0.5	-0.8	0.2	0.4	8	-3.6	-3.2	0.1	0.2

-9999 = no eelgrass found at site. No eelgrass depth data available.

3.3 Challenges and Additional Notes on Bellingham Bay Sites

There were a number of challenges sampling the Bellingham Bay marine shoreline for eelgrass abundance and depth distribution. In the northern portion of the bay, *nps1426-N of Whatcom Creek Waterway* included a large portion of Squalicum Harbor. It is possible that eelgrass grows in the inner harbor basin, however, maneuvering the *R/V Brendan D II* throughout the basin was not possible. At *nps1427-Marine Heritage Park Waterway North* access to sample the entire site was limited by the Roeder Avenue Bridge. In addition, the restricted access southwest of the bridge limited the ability to use side scan sonar effectively. However, three patches of eelgrass were observed just south of the Roeder Avenue Bridge during a land based ground truthing effort in the summer of 2008 (I. Fraser, personal communication). The northeast portion of *nps1428-Whatcom Creek Waterway* did not have any eelgrass present. The absence of eelgrass in this

portion of *nps1428-Whatcom Creek Waterway* is likely due to maintenance dredging activities for marine navigation. One small area, referred to as Log Pond, along the northeast portion of *nps1428-Whatcom Creek Waterway* had a few patches of eelgrass present (transect #27, Appendix G).

There were no obstructions or challenges when sampling *nps1429-S of Whatcom Creek Waterway*. Access to capture the shallow edge of the eelgrass bed using underwater videography at the southern extent of *nps1429-Boulevard Park* was limited by Taylor Dock. A small portion of the eelgrass bed beneath and to the east of Taylor Dock was captured using side scan sonar.

Access to the shallow portion of the eelgrass bed at *nps1431-Taylor Dock* was restricted by Taylor Dock. The side scan sonar was able to capture an image of most of the bed beneath and east of the dock. Another area at the *nps1431-Taylor Dock* site that was inaccessible by the *R/V Brendan D II* was southeast of the Bellingham Bay Community Boating Center boat ramp pier. Patches of eelgrass were observed on the southeast side of the Boating Center pier in April 2008 (J. Gaeckle, personal observation).

Sampling at *nps1432-Bellingham Cruise Terminal* was difficult due to a number of obstructions from the marine shipping and cruise terminals. However, eelgrass was observed on transects 8, 9, and 10 between two of the piers. Eelgrass was absent from the video and side scan surveys in the middle of *nps1432-Bellingham Cruise Terminal* site (Appendix G). The absence of eelgrass in this portion of the site was likely due to the recent installation of the alternate outfall pipe for the Bellingham sewage treatment facility (HartCrowser 2006). There was *Zostera japonica*, dwarf eelgrass, observed at the southern end of *nps1432-Bellingham Cruise Terminal*. There is also a pocket estuary, Post Point Lagoon, beyond the train trestle at *nps1432-Bellingham Cruise Terminal* that supports 0.32 ha (0.79 ac) of eelgrass (Hoover 2005). Post Point Lagoon was not accessible to the *R/V Brendan D II* due to the railroad trestle.

Zostera japonica was also observed at *nps1433-Post Point* at a slightly higher elevation than *Z. marina*, the native eelgrass. Otherwise, there were no challenges or obstructions to note at sites *nps1433-Post Point* to *nps1426-Clark's Point*. There was very little eelgrass observed at *nps1434-S of Post Point* and no eelgrass observed at *nps1435-N of Clark's Point*. The *nps1435-N of Clark's Point* site is rocky and is very deep a short distance from shore; attributes that are not suitable for eelgrass. The rocky shoreline continues south to the next site, *nps1436-Clark's Point* where no eelgrass was found along the western side of Clark's Point. However, there was a small patch of eelgrass in the cove at the southern tip of Clark's Point. Reconnaissance transects identified eelgrass presence in the videography data but it was determined that the patch of eelgrass was too small to sample according to DNR SVMP protocols. Parts of the small eelgrass patch were captured in the videography data while sampling the adjacent site, *nps1437-E of Clark's Point*. Side scan sonar was not performed on the patch of eelgrass found in

the cove at *nps1436-Clark's Point* and *nps1437-E of Clark's Point*. There was no observed challenges at the most southern site, *nps1438-Chuckanut Village*, except for the lack of access into Mud Bay due to the railroad tracks.

A detailed description of each site and notes on the underwater videography transects can be found in each site folder on the data CD (Appendix J).

4 Discussion and Recommendations

4.1 Comparison to Historical Data

Comparison of current eelgrass abundance and distribution to historical records can provide valuable insight into changes in habitat over time and into potential restoration opportunities. In general, precise quantitative comparisons over long time periods are not possible due to differences in survey methods and data resolution. However, broad comparisons are possible, especially in the industrialized areas of Bellingham Bay, due to the detail of historical mapping and the magnitude of change that has occurred.

Historical information demonstrates that major eelgrass losses have occurred along the industrialized shoreline of Bellingham area. Hydrographic charts from the late 1800s delineated 48.3 ha of eelgrass at the Whatcom Creek delta (Thom and Hallum 1990). A 1965 assessment calculated 34.0 ha, a loss of 30%, of eelgrass in the same area (Thom and Hallum 1991). The present assessment of eelgrass at the Whatcom Creek delta, calculated from the combined area at *nps1426-N of Whatcom Creek Waterway*, *nps1427-Marine Heritage Park Waterway North*, and *nps1428-Whatcom Creek Waterway*, estimates that 3.95 ha remain, which represents a 92% loss relative to the late 1800s. While major losses clearly occurred, the precise estimate is uncertain due to differences in the detail of mapping, potential mis-classification of algae as eelgrass in the hydrographic charts, and changes in geographical references over time.

There was no eelgrass documented on the hydrographic charts between Whatcom Creek and Clark's Point (Thom and Hallum 1990); an area that currently has 12.34 ha of eelgrass. Other areas, particularly to the west of Bellingham towards the Nooksack Delta, also had no documented eelgrass. This historical hydrographic information is uncertain because detailed surveys could have been limited to areas where ships regularly navigate. Additionally, these beds are relatively narrow, so the features may have been too small to include on the hydrographic charts.

4.2 Observations Related to Eelgrass Distribution in Study Area

The observed pattern of eelgrass from the 2008 survey generally supports where one would expect to find eelgrass. Though the sites further west, *nps1423-NW of Squalicum Creek Waterway*, *nps1424-Squalicum Creek Waterway*, and *nps1425-Squalicum Harbor* appear to be suitable habitat, the absence of eelgrass at these sites could be related to the dynamic nature of the Nooksack delta. The SVMP sampled *flats10-Nooksack Delta East* from 2002 to 2006 and only found a few small patches of eelgrass that totaled 0.47 ha (Gaeckle et al. 2008). The habitat towards the east and south along the Bellingham shoreline has been heavily manipulated, yet some remnant populations of eelgrass remain. Further south, the rocky, bold coastline observed at *nps1435-N of Clark's Point*, *nps1436-Clark's Point*, and *nps1437-E of Clark's Point* probably limits eelgrass presence at these sites with the except of a small patch in a shallow, protected cove at the end of Clark's Point. The last site, *nps1438-Chuckanut Village*, is a small pocket estuary with the largest eelgrass bed along the Bellingham shoreline. The shallow, protected nature of pocket estuaries is often ideal habitats for eelgrass growth (e.g. Post Point Lagoon). In addition, this section of the shoreline is less developed relative to the northern part of the Bellingham shoreline.

The eelgrass in Bellingham Bay grows in a much narrower range of depths compared to the North Puget Sound Region (Figure 3-5) and Puget Sound as a whole (Gaeckle et al. 2008). And, although the videography surveys are unable to elaborate on the health of the eelgrass at a site the presence of eelgrass alone at sites where it was historically documented (Whatcom Creek Waterway) suggests the beds are persistent and self-sustaining.

4.3 Data Uses

The eelgrass abundance, distribution, and depth data presented in this report provide a baseline or benchmark to which future eelgrass surveys can be compared to assess change over time. These data also identify sensitive habitat areas for consideration in land use planning and re-development. Given the recognized ecological importance of eelgrass, planning should explicitly consider the location of the remaining eelgrass habitat in this area and its environmental requirements.

A current example of land use activities that should fully consider sensitive eelgrass habitat is the Bellingham Waterfront District re-development plan (http://www.bellinghamwaterfrontdistrict.com/index.php, http://www.bellinghamwaterfrontdistrict.com/Interactive.php). In some areas along the waterfront, eelgrass is growing adjacent to industrialized and heavily armored shoreline (e.g. Whatcom Creek Waterway, Bellingham Cruise Terminal) and is subject to potential disturbance from the activities proposed in the re-development

plan. Examples of five projects that may have deleterious impacts to eelgrass habitat include but are not limited to:

1) Proposed marina at the former Georgia-Pacific wastewater treatment facility. It is highly likely that construction activities and enhancement of the breakwater, particularly at the marina entrance, will impact the eelgrass at *nps1426-N of Whatcom Creek Waterway* and *nps1427-Marine Heritage Park Waterway North*. Furthermore, added boat traffic in this area will increase hydrodynamic energy and resuspend fine sediments which will negatively affect eelgrass (van Katwijk and Hermus 2000).
2) Pedestrian drawbridge across Whatcom Creek Waterway. Docks, piers, and walkways inhibit natural light transmission and shade eelgrass (Burdick and Short 1999). In addition, the installation of piles to support elevated marine structures can cause turbidity plumes that smother eelgrass. Although, there is no eelgrass currently beneath the proposed pedestrian drawbridge, the installation activities could impact the eelgrass at *nps1427-Marine Heritage Park Waterway North* if not properly managed and the pier will shade potential eelgrass habitat.
3) Visitor moorage along Whatcom Creek Waterway. The 2008 eelgrass surveys did not find eelgrass in this area, but there are two concerns with a moorage facility and the related impacts to eelgrass. First, the moorage structures will likely occupy or shade potential eelgrass habitat (Burdick and Short 1999). Second, increased boat traffic along the waterway will resuspend fine sediments, reduce available light and impact eelgrass (van Katwijk and Hermus 2000).
4) Proposed deepwater port. Currently, there is eelgrass to the east of the existing pier in the proposed deepwater port. Installation of a third pier and increased vessel activity in this area could impact the current eelgrass populations.
5) Overwater pedestrian walkway connecting Boulevard Park. The installation of an overwater trail connector to Boulevard Park will impact eelgrass at *nps1429-S of Whatcom Creek Waterway*. In addition, the shade created by an overwater structure will impact the eelgrass at this site (Burdick and Short 1999).

5 References

Berry, H.D., A.T. Sewell, S. Wyllie-Echeverria, B.R. Reeves, T.F. Mumford, Jr., J. Skalski, R.C. Zimmerman, and J. Archer. 2003. *Puget Sound Submerged Vegetation Monitoring Project: 2000-2002 Monitoring Report.* Nearshore Habitat Program, Washington State Department of Natural Resources. Olympia, WA. 60pp. plus appendices. Available online: http://www.dnr.wa.gov/Publications/aqr_nrsh_00_02svmp_rpt.pdf

Burdick, D.M. and F.T. Short. 1999. The effects of boat docks on eelgrass beds in coastal waters of Massachusetts. Environmental Management 23(2): 231-240.

Dowty, P. 2005. *A Study of Sampling and Analysis Methods: Submerged Vegetation Monitoring Project at Year 4.* Nearshore Habitat Program, Washington Department of Natural Resources, Olympia, Washington. 133pp. Available online: http://www.dnr.wa.gov/Publications/aqr_nrsh_samp_analysis.pdf

Dowty, P. B. Reeves, H. Berry, S. Wyllie-Echeverria, T. Mumford, A. Sewell, P. Milos and R. Wright. 2005. *Puget Sound Submerged Vegetation Monitoring Project 2003-2004 Monitoring Report*. Nearshore Habitat Program, Washington State Department of Natural Resources. Olympia, WA. 67pp. plus appendices. Available online: http://www.dnr.wa.gov/Publications/aqr_nrsh_03_04_svmp_rpt.pdf

Gaeckle, J., P. Dowty, B. Reeves, H. Berry, S. Wyllie-Echeverria, T. Mumford. 2007. *Puget Sound Submerged Vegetation Monitoring Project 2005 Monitoring Report*. Nearshore Habitat Program, Washington State Department of Natural Resources. Olympia, WA. 93pp. Available online: http://www.dnr.wa.gov/Publications/aqr_nrsh_2005_svmp_report.pdf

Gaeckle, J., P. Dowty, H. Berry, S. Wyllie-Echeverria, T. Mumford. 2008. *Puget Sound Submerged Vegetation Monitoring Project 2006-2007 Monitoring Report*. Nearshore Habitat Program, Washington State Department of Natural Resources. Olympia, WA. 89pp. Available online: http://www.dnr.wa.gov/Publications/aqr_nrsh_2006_07_svmp_report_final.pdf

HartCrowser. 2006. Post-Point Outfall Repair/Replacement Conservation Measures and Habitat Monitoring Plan, Bellingham, Washington. Prepared for City of Bellingham Department of Public Works. 10 May 2006. 12627-01-03. p. 27.

Hoover, R. 2005. Post Point Lagoon Monitoring Project – Summary Report. City of Bellingham Public Works. P. 27.

Moore, K.A. and F.T. Short 2006. *Zostera*: biology, ecology, and management. *In:* Larkum, A.W.D., R.J. Orth, and C.M. Duarte (eds). Seagrasses: Biology, Ecology and Conservation. Springer, Dordrecht. p. 361-386.

Norris, J.G., S. Wyllie-Echeverria, T. Mumford, A. Bailey and T. Turner. 1997. Estimating basal area coverage of subtidal seagrass beds using underwater videography. Aquatic Botany 58:269-287.

Puget Sound Environmental Atlas. 1987. Prepared by Evans-Hamilton, Inc. US EPA.

ShoreZone Inventory. 2001. The Washington State ShoreZone Inventory. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA.

Thom, R.M. and L. Hallum. 1990. Long-term changes in the areal extent of tidal marshes, eelgrass meadows and kelp forests of Puget Sound. Final report submitted to Region 10, Office of Puget Sound, U.S. Environmental Protection Agency. Seattle, WA. EPA 910/9-91-005. p 110.

Thom. R.M. and L. Hallum. 1991. Historical changes in the distribution of tidal marshes, eelgrass meadows and kelp forests in Puget Sound. Puget Sound Research Conference. P 302-313.

van Katwijk, M.M. and D.C.R. Hermus. 2000. Effects of water dynamics on *Zostera marina*: transplantation experiments in the intertidal Dutch Wadden Sea. Marine Ecology Progress Series 208:107-118.

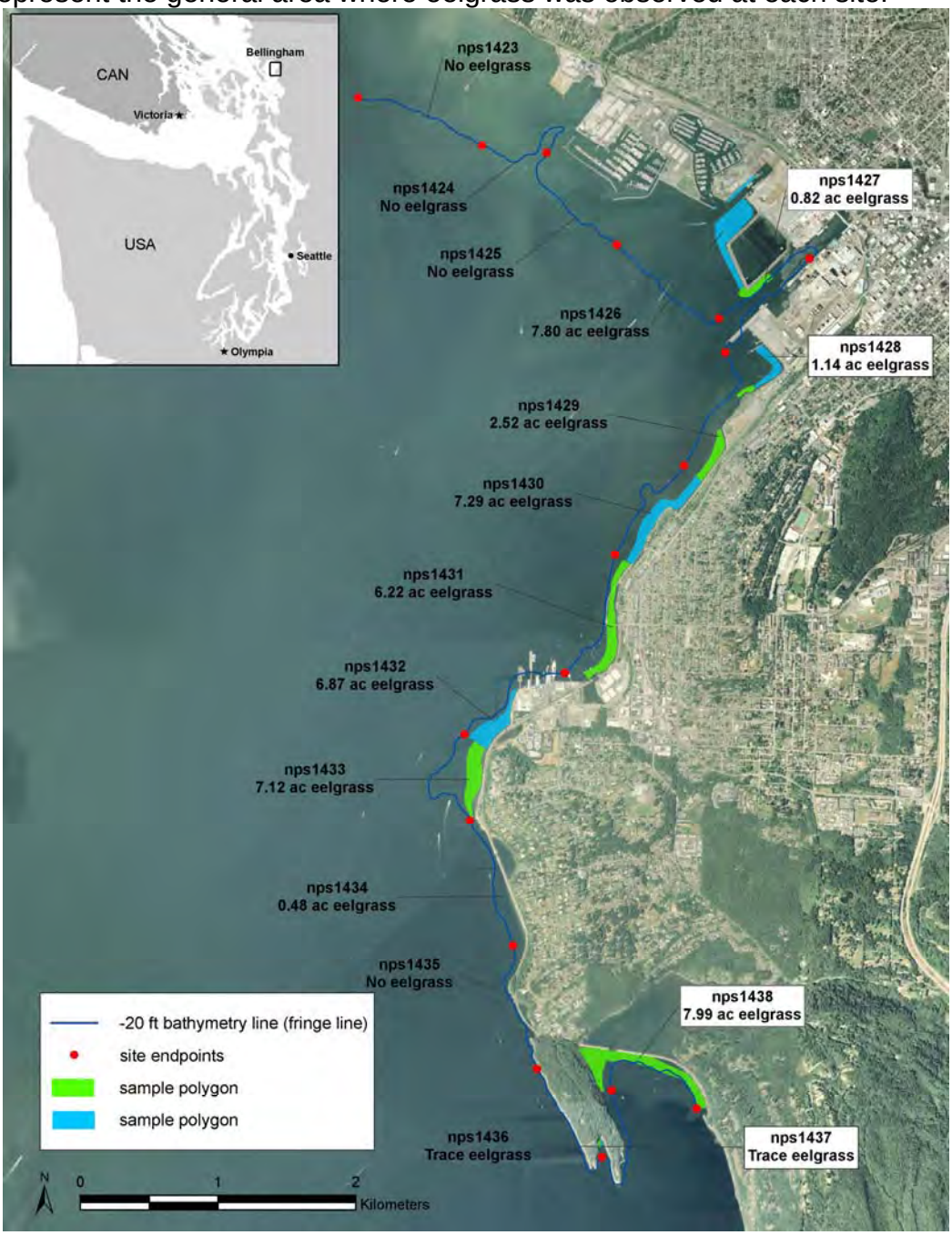
APPENDICES

Appendix A Eelgrass (*Z. marina*) Monitoring Summary Statistics at 16 Sites along the City of Bellingham Marine Shoreline

Number of sites sampled	Number of Sites with Eelgrass	Number of Sites without Eelgrass	Average Number of Transects	Average Number of Transects	Average Fraction	Total Eelgrass Area	Total Variance	Standard Error	95% CI Lower Limit	95% CI Upper Limit
						(ac)			(ac)	(ac)
16	12	4	14	13.6	0.4	48.26	8.30	1.17	45.97	50.54

Appendix B Map of the 16 Sites Sampled for Eelgrass Abundance and Depth Distribution along the City of Bellingham Marine Shoreline

Sites are initially delineated by the -20 ft bathymetry line (fringe line) and the site endpoints. The green and blue alternating sample polygons represent the general area where eelgrass was observed at each site.



Appendix C Eelgrass (*Z. marina*) Area (acres) at 16 Sites along the City of Bellingham Marine Shoreline

Site	Date Sampled	Number of Transects	Eelgrass Fraction Along Transects	Eelgrass Area at Site	Variance	Coefficient of Variance	Estimated Eelgrass Area Confidence Interval	
							95% Lower Limit	95% Upper Limit
				(acres)			(acres)	(acres)
nps1423	16-Sep-08	0	0.00	0.00	0.00	0.00	0.00	0.00
nps1424	16-Sep-08	0	0.00	0.00	0.00	0.00	0.00	0.00
nps1425	16-Sep-08	0	0.00	0.00	0.00	0.00	0.00	0.00
nps1426	19-Sep-08	14	3.16	7.80	0.80	0.28	3.46	12.15
nps1427	03-Jul-08	11	0.33	0.82	0.01	0.28	0.37	1.26
nps1428	17-Sep-08	16	0.46	1.14	0.01	0.18	0.74	1.53
nps1429	19-Sep-08	12	1.02	2.52	0.03	0.17	1.68	3.38
nps1430	17-Sep-08	14	2.95	7.29	0.06	0.08	6.15	8.43
nps1431	19-Sep-08	13	2.52	6.22	0.05	0.09	5.09	7.36
nps1432	19-Sep-08	12	2.78	6.87	0.04	0.08	5.85	7.90
nps1433	03-Jul-08	18	2.88	7.12	0.05	0.08	6.02	8.22
nps1434	14-Sep-08	14	0.19	0.48	0.02	0.75	0.00	1.18
nps1435	15-Sep-08	0	0.00	0.00	0.00	0.00	0.00	0.00
nps1436	03-Jul-08			* tr				
nps1437	14-Sep-08			* tr				
nps1438	15-Sep-08	12	3.24	7.99	0.28	0.16	5.42	10.58

*** tr = trace eelgrass present at the site**. The site was visited and reconnaissance video transects found eelgrass present but the patch of eelgrass was too small to properly calculate eelgrass area according to the DNR Submerged Vegetation Monitoring Project protocols.

Appendix D Comparison of Eelgrass (*Z. marina*) Area (acres) Calculated Using Side Scan Sonar and Underwater Videography

Site	Date Sampled	Eelgrass Area at Site	Eelgrass Area at Site	DIFFERENCE
		(Side Scan)	(Video)	
		(ac)	(ac)	(ac)
nps1423	16-Sep-08	0.00	0.00	
nps1424	16-Sep-08	0.00	0.00	
nps1425	16-Sep-08	0.00	0.00	
nps1426	19-Sep-08	4.66	7.80	3.14
nps1427	03-Jul-08	0.85	0.82	0.03
nps1428	17-Sep-08	1.26	1.14	0.12
nps1429	19-Sep-08	2.12	2.52	0.41
nps1430	17-Sep-08	7.01	7.29	0.28
nps1431	19-Sep-08	4.46	6.22	1.76
nps1432	19-Sep-08	3.22	6.87	3.65
nps1433	03-Jul-08	4.49	7.12	2.63
nps1434	14-Sep-08	1.30	0.48	0.82
nps1435	15-Sep-08	0.00	0.00	
nps1436	03-Jul-08	* tr	* tr	
nps1437	14-Sep-08	* tr	* tr	
nps1438	15-Sep-08	9.26	7.99	1.26

Appendix E Comparison of Eelgrass (*Z. marina*) Depth (ft)

Comparison of absolute and mean minimum and maximum depths of eelgrass (*Z. marina*) observed at the City of Bellingham sites and sites sampled in the North Puget Sound Region from 2000 – 2007.

	Minimum Depth		Maximum Depth	
Location	Absolute Depth	Range in Mean Depths	Absolute Depth	Range in Mean Depths
	(ft)	(ft)	(ft)	(ft)
COB	-0.3	-2.0 to -5.9	-14.1	-6.2 to -10.5
North Puget Sound Region	+4.6	+2.0 to -10.8	-27.6	-2.3 to -21.6

Appendix F Eelgrass (*Z. marina*) Depth (ft)

	Minimum Eelgrass Depth					Maximum Eelgrass Depth				
Site	n	Absolute Depth	Mean Depth	Standard Error	95% Confidence Interval	n	Absolute Depth	Mean Depth	Standard Error	95% Confidence Interval
		(ft)	(ft)		(ft)		(ft)	(ft)		(ft)
nps1423	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps1424	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps1425	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps1426	9	-1.3	-4.0	0.7	1.3	9	-7.6	-6.8	0.3	0.5
nps1427	8	-2.9	-3.6	0.3	0.6	8	-7.9	-6.1	0.4	0.7
nps1428	13	-2.1	-2.9	0.1	0.2	13	-8.7	-6.3	0.4	0.8
nps1429	10	-2.7	-3.1	0.1	0.3	11	-9.2	-7.7	0.4	0.9
nps1430	10	-1.0	-1.9	0.2	0.4	14	-11.4	-9.0	0.3	0.6
nps1431	11	-1.5	-2.4	0.2	0.4	12	-12.0	-9.3	0.4	0.8
nps1432	12	-0.4	-2.0	0.5	1.0	12	-12.9	-9.9	0.7	1.4
nps1433	17	-0.5	-1.9	0.5	0.9	17	-14.2	-10.5	0.5	1.0
nps1434	4	-1.6	-5.9	2.4	4.7	4	-11.0	-8.0	2.2	4.2
nps1435	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps1436	5	-2.7	-3.6	0.4	0.7	5	-9.5	-8.0	0.4	0.9
nps1437	7	-2.4	-3.8	0.9	1.8	7	-8.7	-7.5	0.5	1.0
nps1438	5	-1.5	-2.7	0.7	1.3	8	-11.9	-10.5	0.4	0.8

-9999 = no eelgrass found at site. No eelgrass depth data available.

Appendix G Site Maps of Eelgrass (*Z. marina*) Data

Data were collected using two methods at sites along the City of Bellingham marine shoreline: SVMP videography (DNR) and side scan sonar (Tony Petrillo of Blue Water Engineering Services, Inc. (BWES) of Port Townsend, WA). The numbers listed are the associated transect numbers for each site and detailed transect information can be found in Appendix J. Maps also include eelgrass data from ShoreZone and the Puget Sound Environmental Atlas (P.S.E.A.).

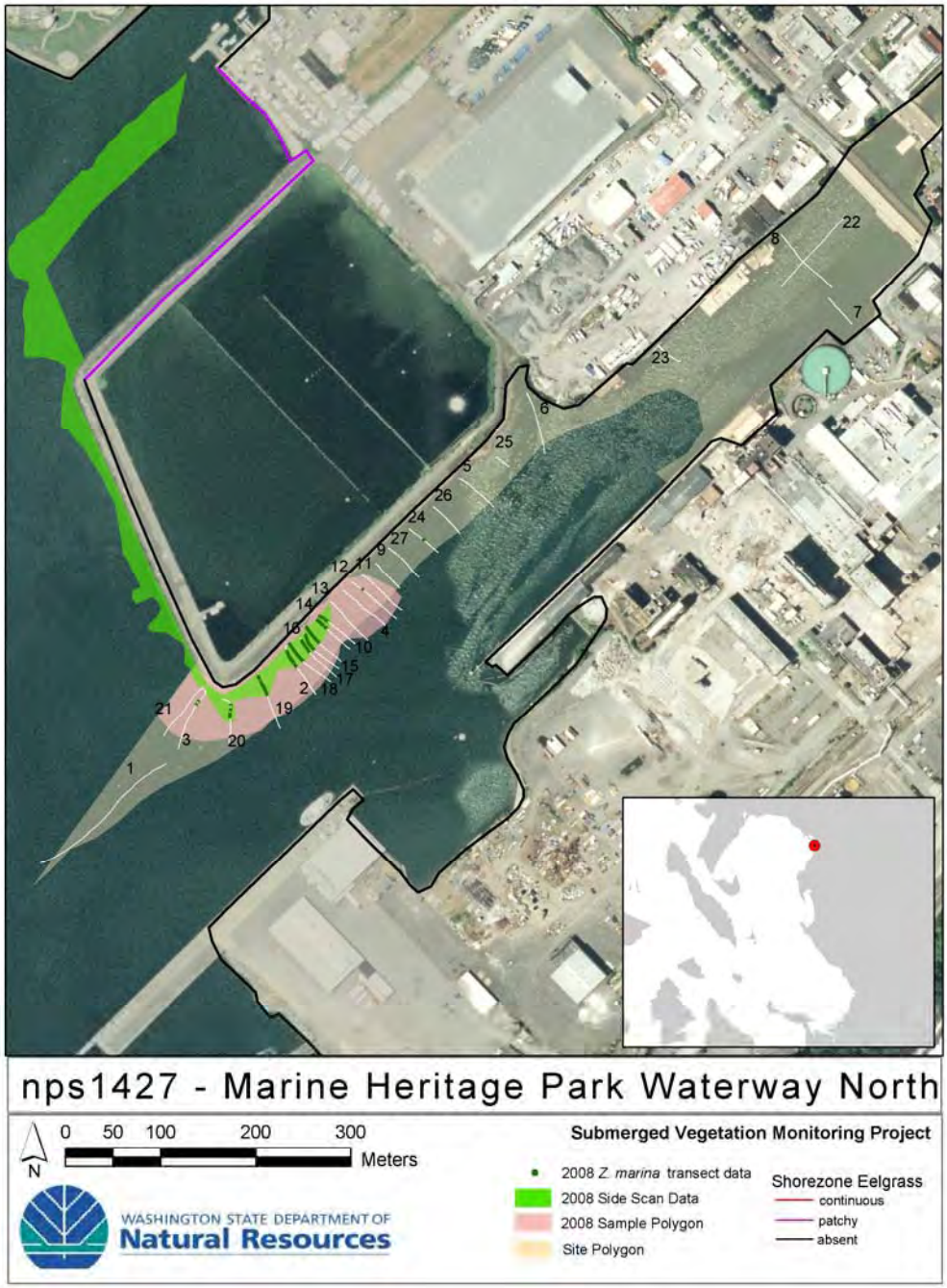
G.1 nps1423 – NW of Squalicum Creek Waterway

G.2 nps1424 – Squalicum Creek Waterway

G.3 nps1425 – Squalicum Harbor

G.4 nps1426 – N of Whatcom Creek Waterway

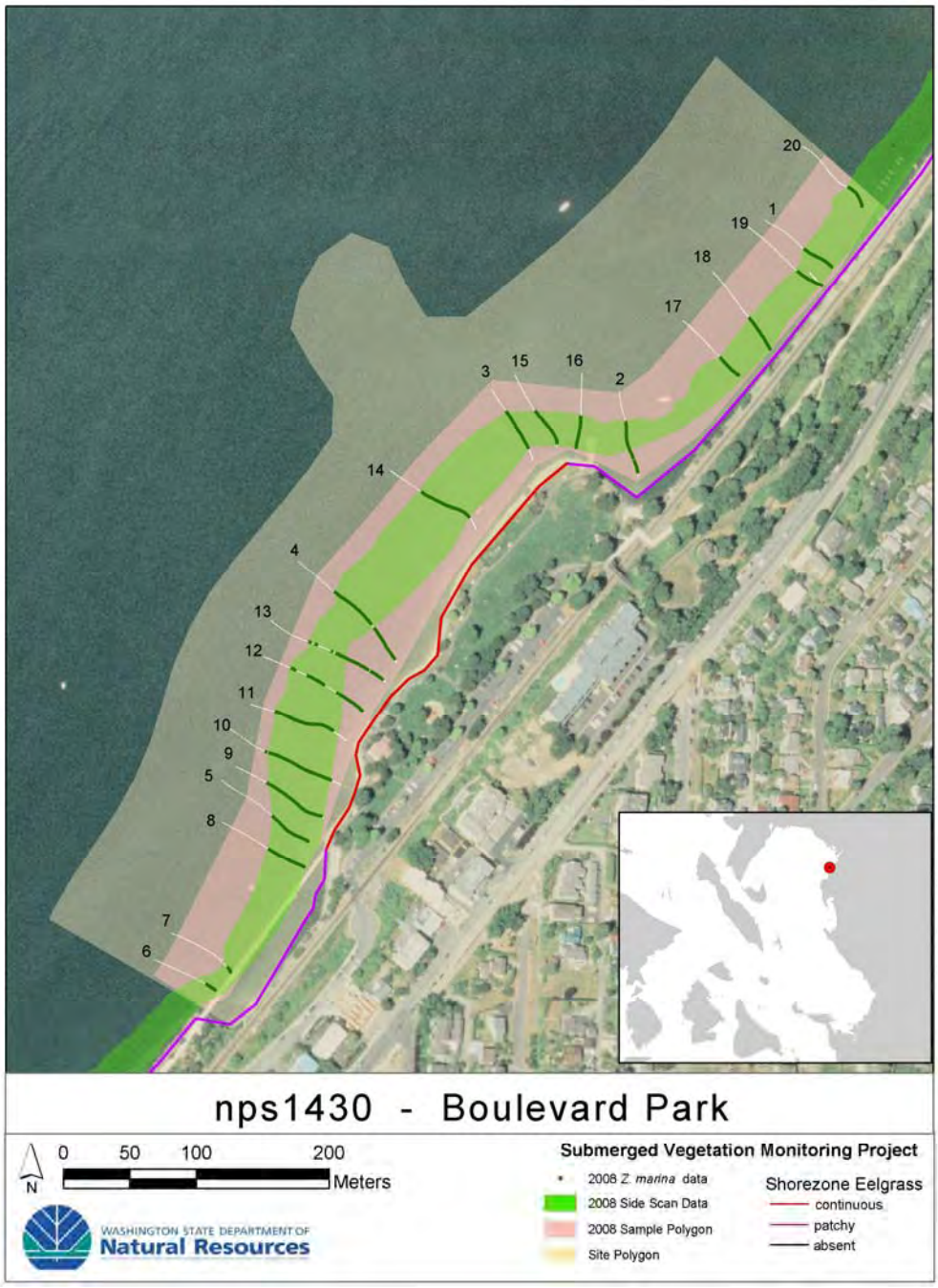
G.5 nps1427 – Marine Heritage Park Waterway North



G.6 nps1428 – Whatcom Creek Waterway

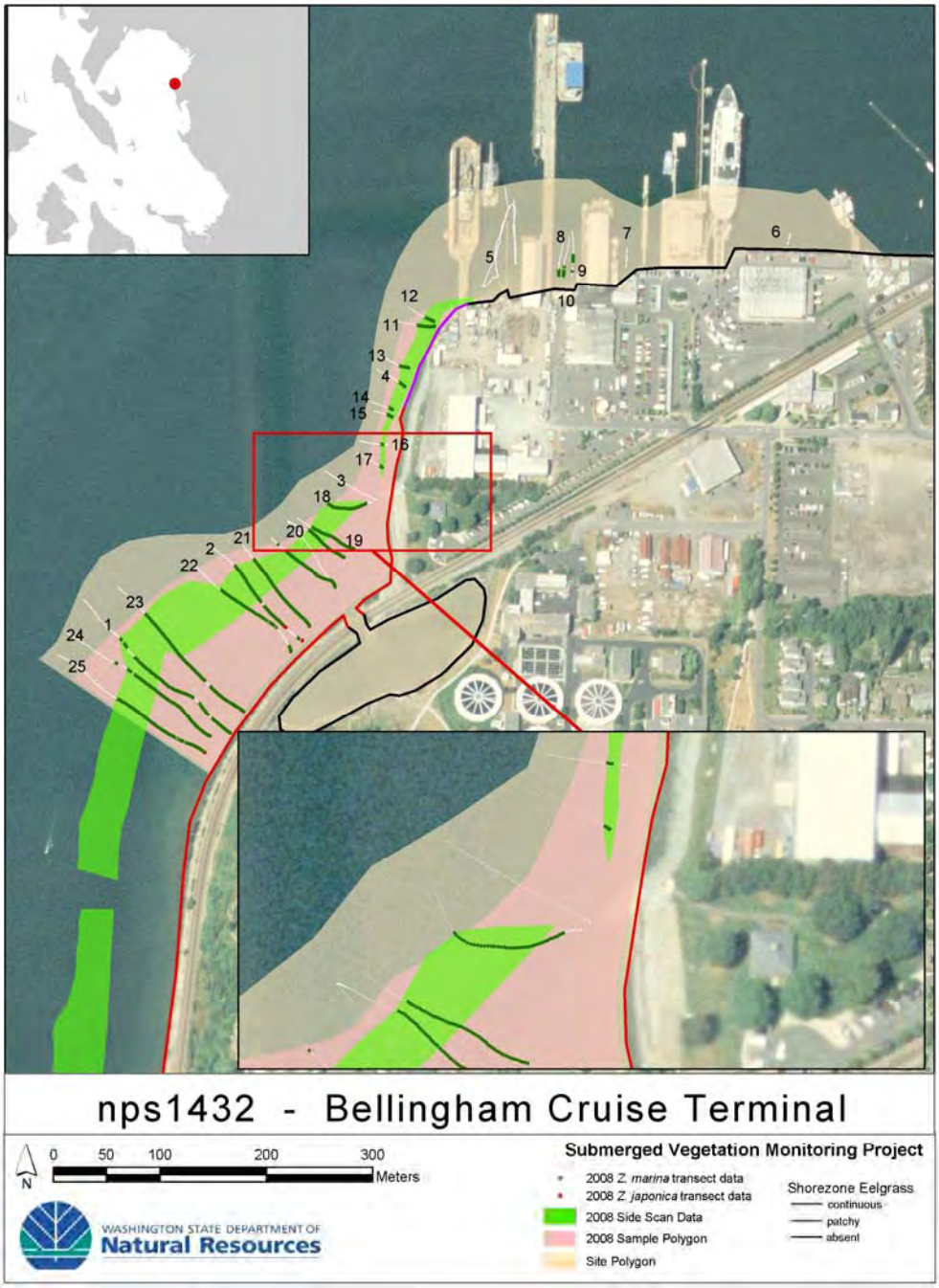
G.7 nps1429 – S of Whatcom Creek Waterway

G.8 nps1430 – Boulevard Park

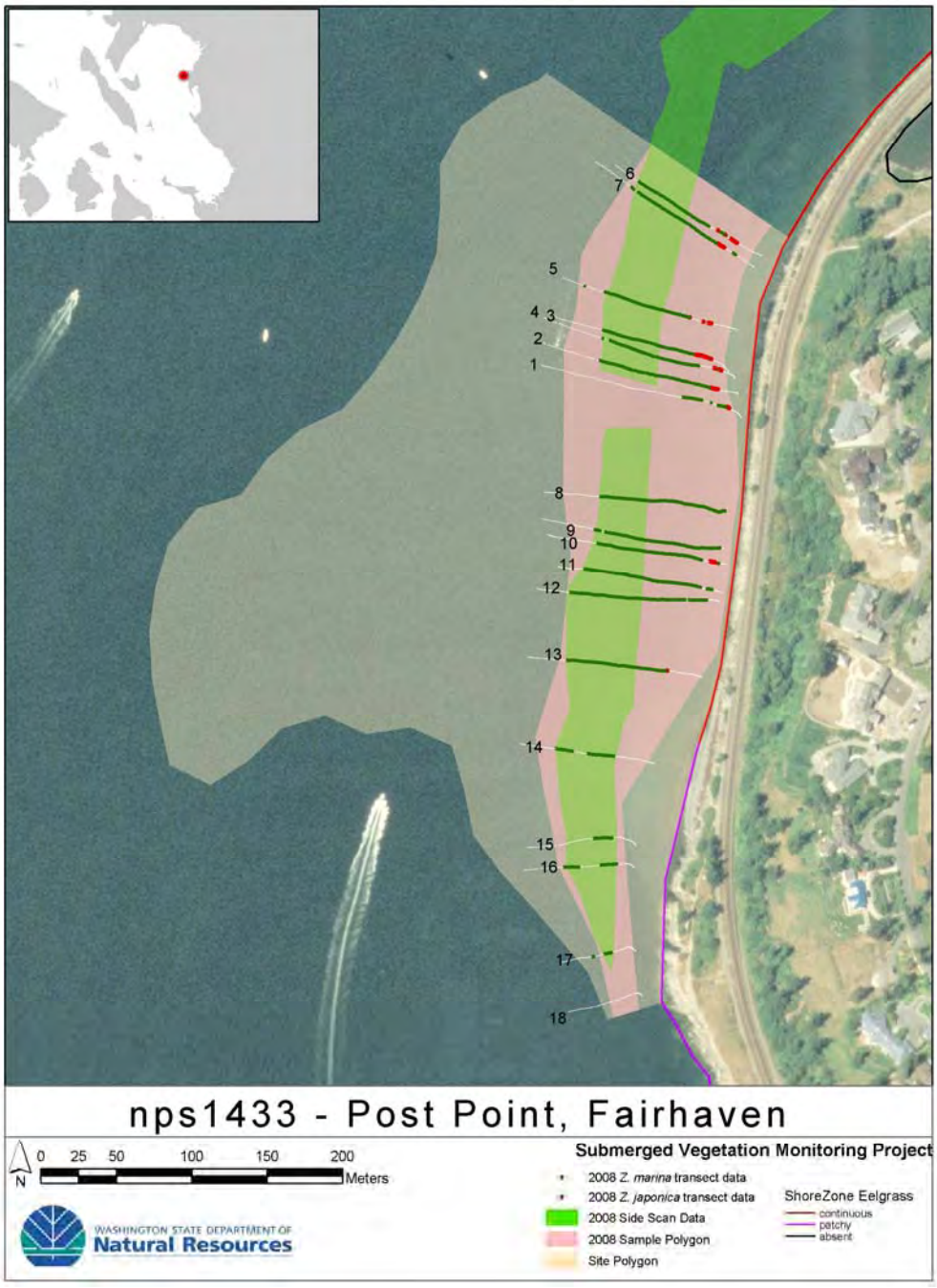


G.9 nps1431 – Taylor Dock

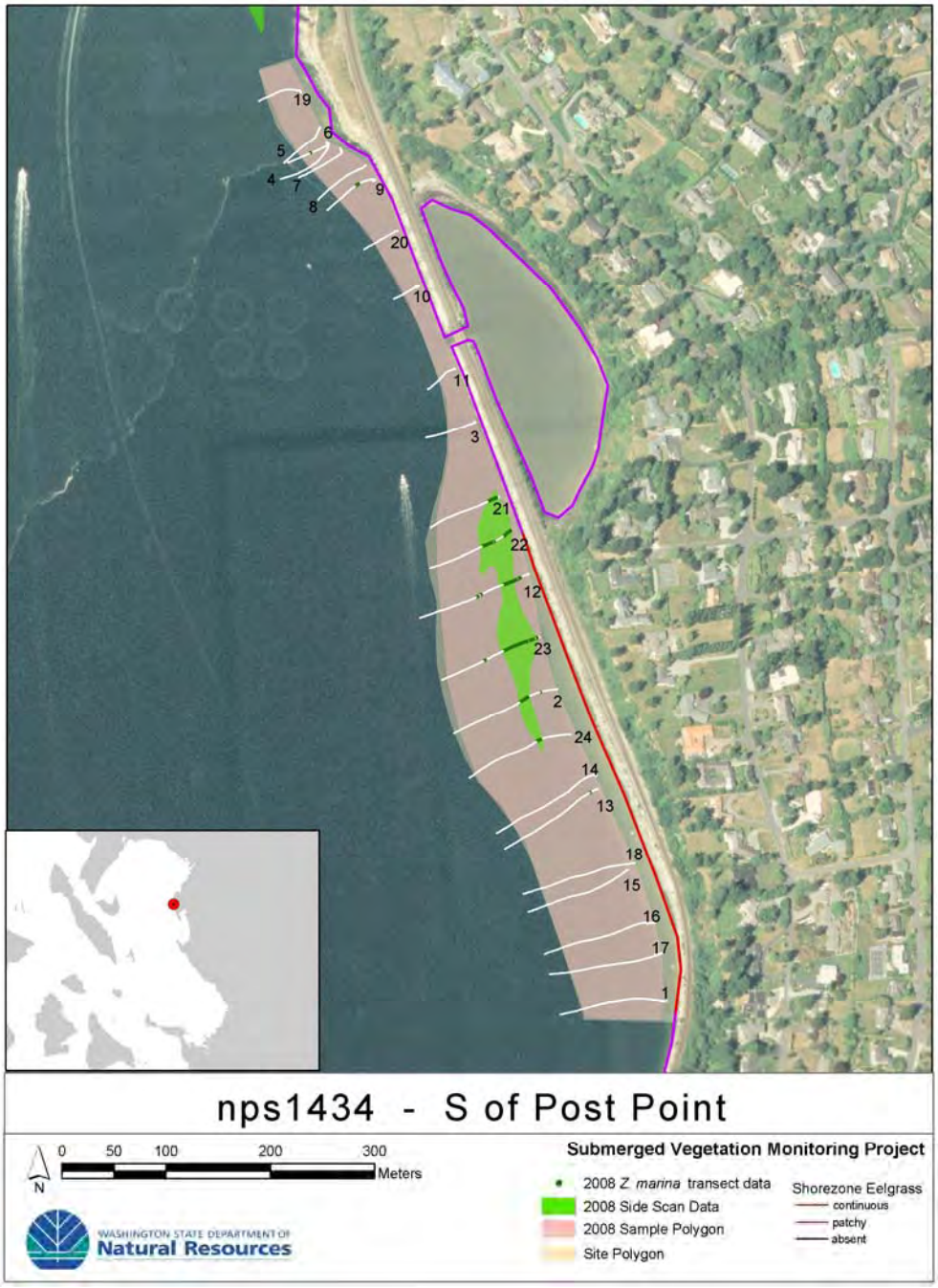
G.10 nps1432 – Bellingham Cruise Terminal



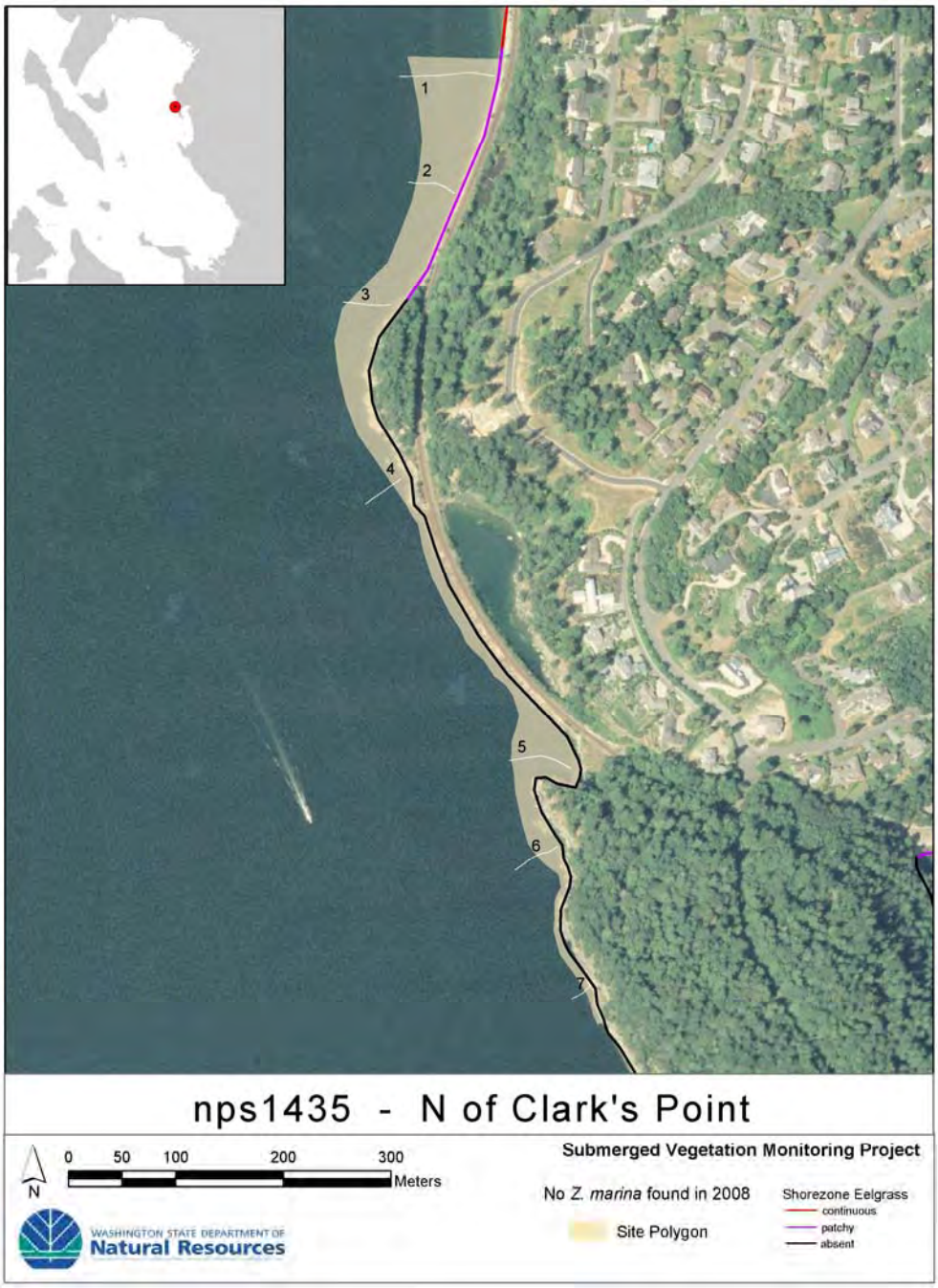
G.11 nps1433 – Post Point



G.12 nps1434 – S of Post Point



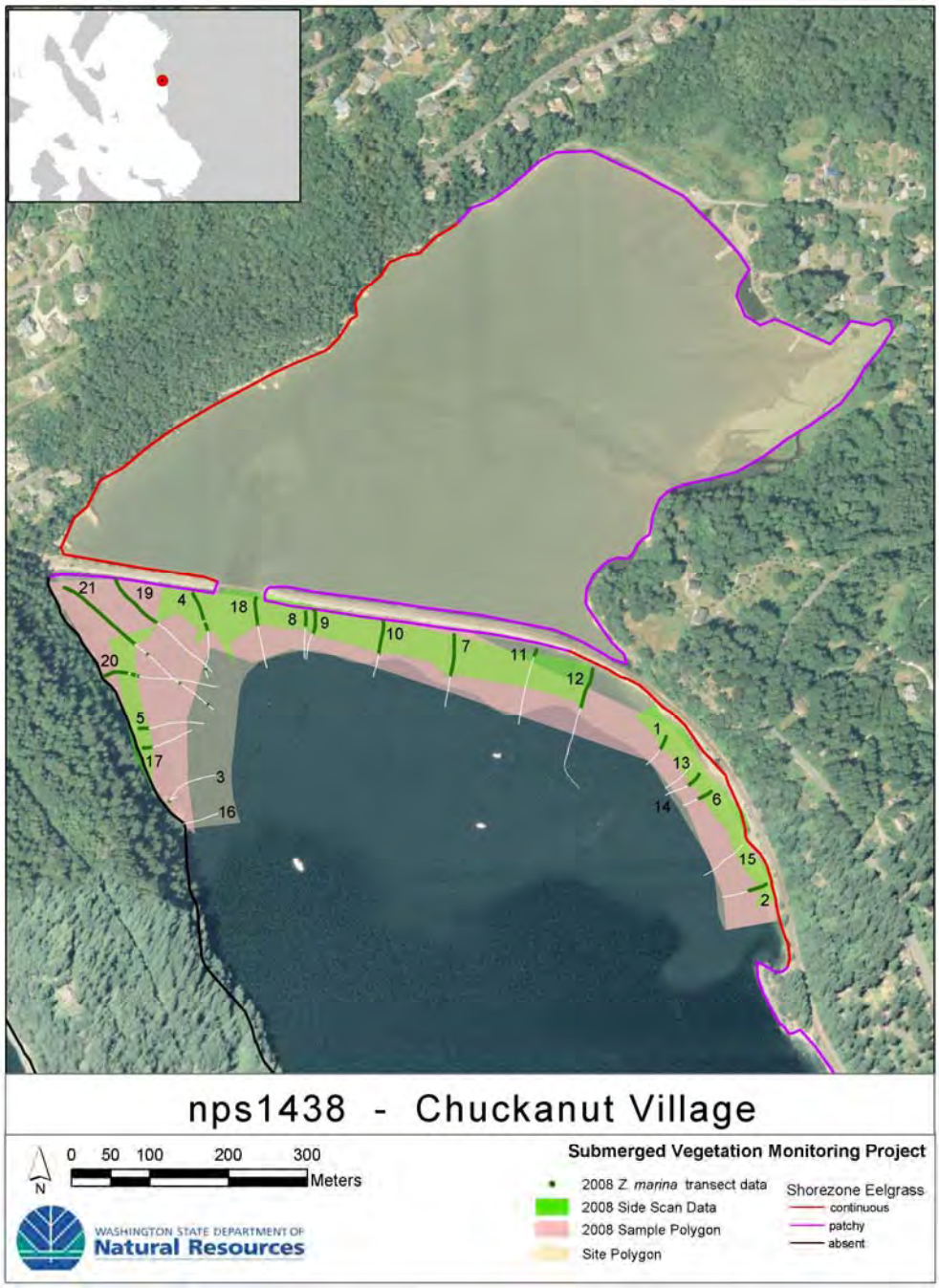
G.13 nps1435 – N of Clark's Point



G.14 nps1436 – Clark's Point, Chuckanut Bay

G.15 nps1437 – E of Clark's Point

G.16 nps1438 – Chuckanut Village



Appendix H Side Scan Sonar Data

Contents of Appendix H were provided by Tony Petrillo of Blue Water Engineering Services, Inc. (BWES) of Port Townsend, WA.

H.1 Side Scan Sonar Survey

The side scan sonar data acquisition was conducted by Tony Petrillo of Blue Water Engineering Services, Inc. (BWES) of Port Townsend, WA. The side scan sonar and navigation systems were mobilized on the Brendan D II. Field operations to acquire data were conducted on Friday, 29 August at the Vashon Island site and Thursday, 18 September at the Bellingham site.

The side scan sonar survey data was acquired using an analog side scan sonar system (SSS), a digital side scan data acquisition and processing (SSSDAS) system, a differential GPS (DGPS), and a navigation and hydrographic software system (HYPACK). The side scan sonar was a Geoacoustics Dual Frequency system. It consisted of a topside electronics processing unit, a tow cable and a submersible sonar tow fish. The SSSDAS was a Chesapeake Technologies hardware-software package. It consisted of a desktop computer fitted with a dual channel analog-to-digital (A-D) conversion board and ran both data acquisition and post-processing software. Vessel positioning was done using a DGPS and a laptop running HYPACK hydrographic software. The DGPS data was split so that both the HYPACK and the SSSDAS software were receiving the data at the same time. The survey vessel was guided by pre-programmed survey track line data on HYPACK and was displayed on a monitor for the helmsman.

Side scan sonar detects images using acoustic pulses. The tow fish is fitted with a sonar transducer on the left and right (port and starboard) sides of the unit. Each transducer simultaneously transmits an acoustic pulse at set intervals depending upon the port and starboard channel transmit distance in meters. The SSS could be set to fire at a high or low frequency (nominally, 100 or 500 kHz) depending upon the quality of image displayed in real time. As a starting point, we used 100 meters per channel at 500 kHz. The plan was to make a single pass with the SSS along the shoreline where eelgrass was previously detected by Marine Resources Consultants (NORRIS) surveys. Based upon previous experience, SSS survey is best conducted parallel with the bathymetric contour when possible. Surveying along a bathymetric contour interval means that one channel faced upslope and one channel faced down slope. Due to the physics of the sonar pulse upslope images resolve more detail than down slope images. Thus, the survey track lines were planned based on the sonar “looking” upslope towards known patches of eelgrass.

The track lines for the survey were pre-planned based on the recent video-sonar mapping done by NORRIS.

During survey, the SSS tow fish was deployed over the port side of the vessel directly below the DGPS antenna. Thus, there was no offset or layback. Because the tow fish was deployed over the port side, all track lines were run with the port side of the survey vessel facing shore. Thus, the SSS tow fish was always facing upslope. Track lines were laid out based upon an assumed offset of about 100 ft to the deep side of existing eelgrass beds. All track lines were run at between 2 and 3 knots.

During the survey, the helmsman would align the survey vessel at the start of the track line. Once aligned, the HYPACK data acquisition was started, and then the SSSDAS was started. At the end of each track line, the SSSDAS was terminated and then HYPACK was ended. The acquired HYPACK navigation data was used in post-processing to confirm that there were no shifts in the position of the vessel track between the navigation and the side scan vessel track. The data from each system were stored separately on each respective computer. At the end of each survey data the raw data were stored on separate media so that there were 2 copies of all data.

The SSS was set at high or low frequency depending upon data quality for local site conditions. It was always set for 100 meters per channel

Post-Processing and Analysis

HYPACK Analysis

To confirm that there were no gross errors in the navigation data, they HYPACK track line data was reviewed line by line using the HYPACK post-processing software. Once completed, that data was forwarded to Sound GIS in the form of northings and eastings in Washington state plane coordinates–south zone (NAD 83/91). The units were US survey feet.

SSS Analysis

The raw digital SSS data acquired and saved by the SSSDAS were stored in a proprietary format with an XTF extension. All the SSS data were imported into the Sonar Wiz processing program (SONARWIZ) for an initial pass through the software. After the first pass, the navigation data were reviewed for errors. This is essentially the same data as the HYPACK data. Next, the bottom tracking data was reviewed and edited. This data shows the raw SSS data including the water column. A detailed discussion of the physics of SSS analysis is beyond the scope of this report. Suffice it to say that this process allows the user to “remove” the water column from the SSS data to make the data look more like a scale-corrected plan view photograph of the sea bed. Once this process was completed, all the SSS data was processed for a second pass and then review for errors. This process was iterative until all errors were corrected.

The final products of this analysis were 2 files for each track line. The primary file was a JPG file of the side scan image for each track line. An ancillary file was a JGW (world) file which provided positioning information for the JPG file in GIS.

Digitizing

Digitizing of the side scan images was done in GIS as a collaborative effort between Exa Data and Mapping and BWES personnel. The GIS system had the capability of displaying the SSS images and the NORRIS eelgrass data simultaneously. The SSS data was displayed on the GIS screen and reviewed relative to the NORRIS data. Once SSS eelgrass images were identified on the screen relative to the NORRIS data a polygon was digitized around the eelgrass patches.

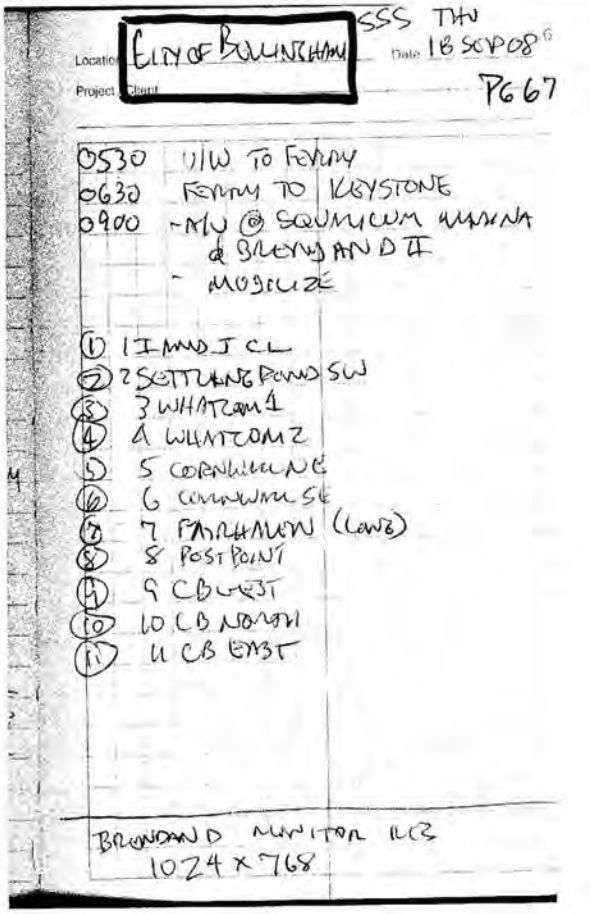
H.2 Side Scan Field Notes.

BLUE WATER ENGR.
SUCS, INC.

LOG BOOK

29 JUL 2008 -
25 OCT 2008

360 385-2680

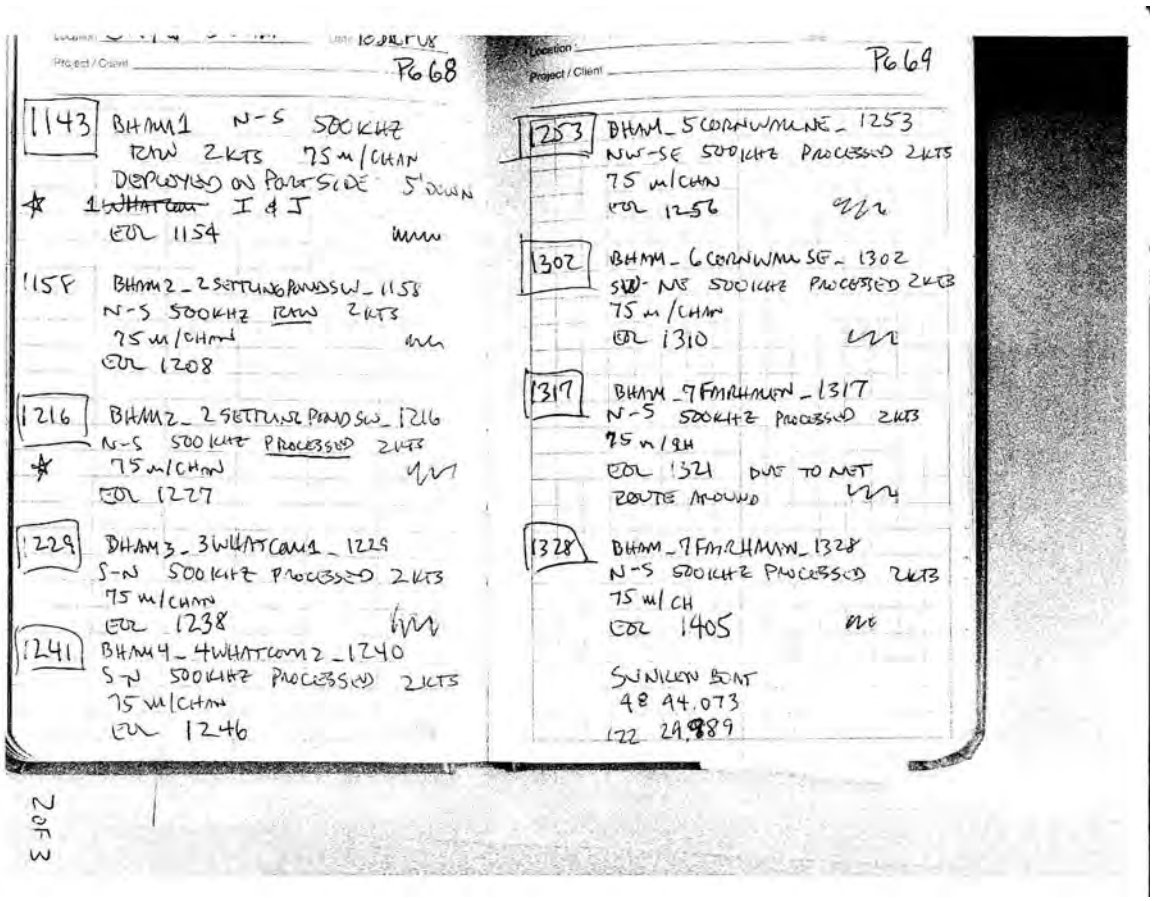

SSS THN
Location CITY OF BELLINGHAM Date 18 SEP 08
Project Client PG 67

0530 U/W TO FERRY
0630 FERRY TO KEYSTONE
0900 - M/V @ SQUALICUM MARINA
& BELLINGHAND II
- MOBILIZE

1 I-MND J CL
2 SETTLING POND SW
3 WHATCOM 1
4 WHATCOM 2
5 CORNWALL NE
6 CORNWALL SE
7 FAIRHAVEN (LOW)
8 POST POINT
9 CB WEST
10 CB NORTH
11 CB EAST

BRANDAND MUNITION ILCS
1024 x 768

1 OF 3



Project / Client _____ Pg 68

1143 BHMM1 N-S 500KHZ
RAW 2KTS 75 m/CHAN
DEPLOYED ON PORT SIDE 5' DOWN
★ ~~1 SWHATCOM~~ I & J
EOL 1154

1158 BHMM2_2SETTLINGPONDSW_1158
N-S 500KHZ RAW 2KTS
75 m/CHAN
EOL 1208

1216 BHMM2_2SETTLINGPONDSW_1216
N-S 500KHZ PROCESSED 2KTS
★ 75 m/CHAN
EOL 1227

1229 BHMM3_3WHATCOM1_1229
S-N 500KHZ PROCESSED 2KTS
75 m/CHAN
EOL 1238

1241 BHMM4_4WHATCOM2_1240
S-N 500KHZ PROCESSED 2KTS
75 m/CHAN
EOL 1246

Location: _____
Project / Client _____ Pg 69

1253 BHMM_5CORNWMLNE_1253
NW-SE 500KHZ PROCESSED 2KTS
75 m/CHAN
EOL 1256

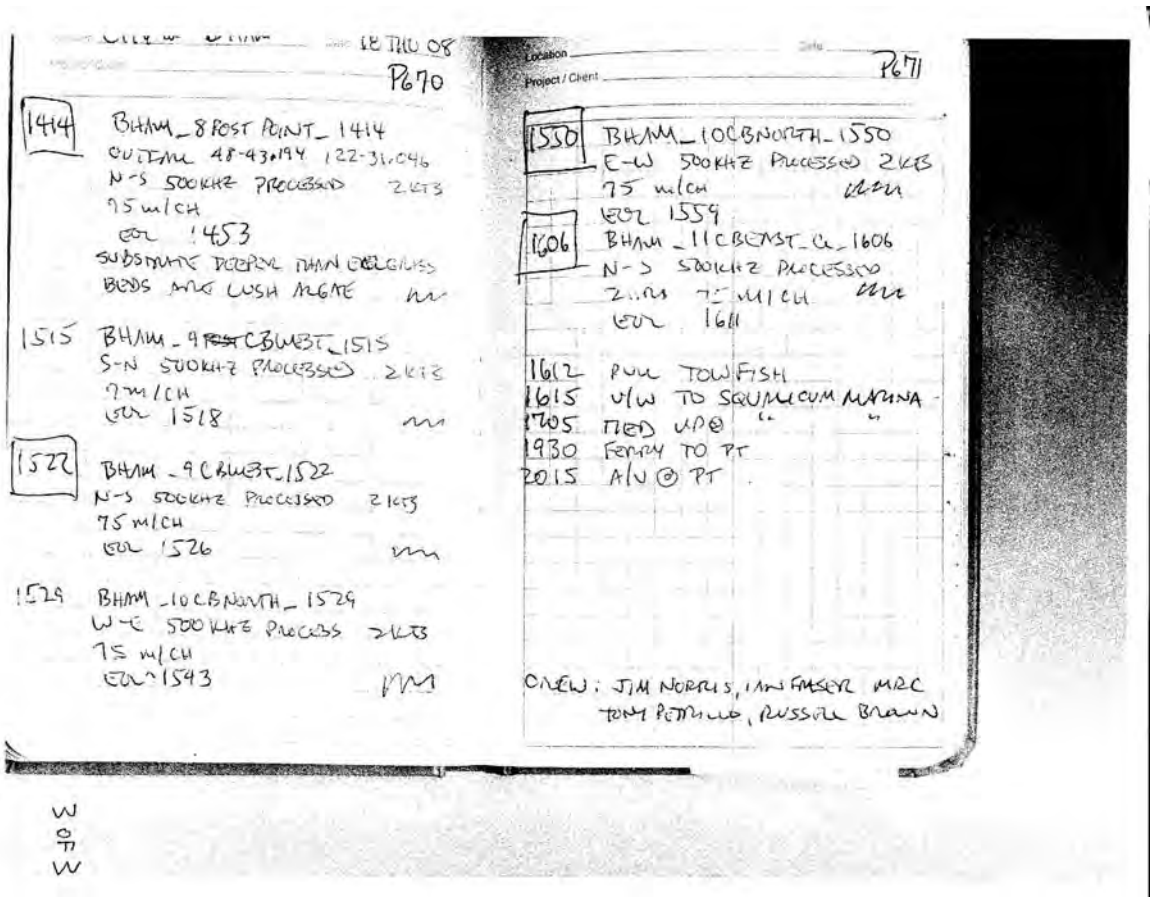
1302 BHMM_6CORNWMLSE_1302
SW-NE 500KHZ PROCESSED 2KTS
75 m/CHAN
EOL 1310

1317 BHMM_7FMRHMLN_1317
N-S 500KHZ PROCESSED 2KTS
75 m/CH
EOL 1321 DUE TO NET
ROUTE AROUND

1328 BHMM_7FMRHMLN_1328
N-S 500KHZ PROCESSED 2KTS
75 m/CH
EOL 1405

SUNKEN BOAT
48 44.073
122 29.889

2 OF 3



P670

1414 BHAM_8 POST POINT_1414
OUTFALL 48-43.194 122-31.046
N-S 500KHZ PROCESSED 2KTS
75 m/CH
EOL 1453
SUBSTRATE DEEPER THAN OBSERVED
BEDS MUD LUSH ALGAE

1515 BHAM_9 ~~POST~~ CBWEST_1515
S-N 500KHZ PROCESSED 2KTS
75 m/CH
EOL 1518

1522 BHAM_9CBWEST_1522
N-S 500KHZ PROCESSED 2KTS
75 m/CH
EOL 1526

1529 BHAM_10CBNORTH_1529
W-E 500KHZ PROCESS 2KTS
75 m/CH
EOL 1543

P671

1550 BHAM_10CBNORTH_1550
E-W 500KHZ PROCESSED 2KTS
75 m/CH
EOL 1559

1606 BHAM_11CBWEST_CL_1606
N-S 500KHZ PROCESSED
2KTS 75 M/CH
EOL 1611

1612 PULL TOW FISH
1615 U/W TO SQUALICUM MARINA
1705 TIED UP @ "
1930 FERRY TO PT
2015 A/N @ PT

CREW: JIM NORRIS, IAN FRASER MRC
TOM PETRILLO, RUSSELL BROWN

W
of
W

Appendix I Underwater Videography Data (DVD).

Appendix J Site Data (CD)

City of Bellingham Eelgrass Monitoring Project (IAA 09-69)

Bellingham Bay folder:

Sidescan_eelgrass_2008 – Interpretations of cumulative Bellingham Bay eelgrass presence using side scan images and post-processed video data. Side scan data collection and interpretation was performed by Tony Petrillo of Blue Water Engineering Services, Inc. (BWES) of Port Townsend, WA.

Bellingham_Bay_eelgrass_database_2008 – MS Access Database of videography data. Included in the data base are:

1. Two tables
    a. *2008sites*: table consists of site level results.
    b. *2008transects*: table consists of transect levels results by site.
2. One query
    a. *qry_site_samp_convert_to_metric_08*: Converts sites table input units from feet to meters and hectares.
3. Two reports
    a. *2008 Bellingham Bay Area Estimates*: Site-level area results in hectares.
    b. *2008 Bellingham Bay Depth Estimates*: Site-level depth results in hectares

Individual site folders (nps1423 - nps1438):

These folders contain post-processed electronic and ArcGIS site-specific data. Within each site folder are three additional folders:

ArcGIS data:

Included are site-level GIS polygons, sample polygons (when *Z. marina* is present) and video transect data.

Electronic site data:

Contents of this folder are as follows:

1. Pre-sampling random transect map *(transects.pdf)*
2. Post-sampling random transect map *(2008_field_transect_map.pdf)*
3. Post-sampling site map *(ortho.pdf)*
4. Transect notes *(2008 Transect Notes.xls)*
5. Site description *(2008 Site Description.xls)*
6. Raw, post-processed transect data *(TD.csv)*
7. Area and depth estimates *(Zm_area_depth.xls)*

Side Scan Sonar Polygon:

All sites have a PDF with side scan and SVMP transect data overlaid. Sites with *Z. marina* present have a GIS shapefile of side scan interpretations

(*2008_SideScan_Polygon.shp)* and site-level area calculations in the attribute table.

All ArcGIS information projected in: NAD 1983 HARN State Plane Washington South FIPS 4602 Feet.