Appendix L

Pre-Installation Study Reports

Appendix L Contents

Appendix L-1

Measurement and Assessment of Underwater Noise from the OpenHydro Tidal Turbine at the EMEC Facility, Orkney

Project Title	Measurement and assessment of underwater noise from the OpenHydro tidal turbine at the EMEC facility, Orkney.
Project Number	812
Investigators	Mr S J Parvin and Mr A G Brooker
Company	Subacoustech Ltd
Report Number	812R0102
Date	6th March 2008

Summary reports are intended to provide rapid information to a limited distribution list. The data presented are not subject to the full quality approval and detailed analysis which pertains with external reports. Data used in this report may be selected to be typical, representative or indicative, or may be drawn from larger data sets which have not been fully analysed. Hence, conclusions drawn from this data should be regarded as tentative and may be amended in later reports.

Introduction

This summary report provides an overview of underwater noise measurements of the OpenHydro tidal turbine demonstrator device at the EMEC (European Marine Energy Centre) tidal test site. The measurements were undertaken between 17:00 and 19:00 on the 19th February 2008, a period approximately 1.5 to 3.5 hours after low water. Weather conditions were calm with wind speeds of 8 knots and a swell of approximately 0.3 m. The measurement period started just after slack water and tidal flow increased to between 4-5 knots towards the end of the measurement period.

The EMEC site is located in the Fall of Warness, to the west of the island of Eday in Orkney, Scotland.

Measurement Equipment

All underwater sound measurements where undertaken using a Bruel and Kjaer 8106 low noise hydrophone. These sensors are able to measure underwater sound to levels well below sea state zero noise. This is important if the recordings are to be compared with the hearing response of species of marine mammal, many of which have evolved to exploit the efficient propagation of underwater sound for communication, echolocation and detecting prey, and are therefore able to perceive sound to low sea state noise levels.

All underwater sound recordings were digitised and stored on a portable laptop computer system at a sample rate of 350, 000 samples per second. In theory this provides acoustic data to a frequency of 175 kHz. Subsequent analysis of the acoustic data was conducted over the frequency range from 1 Hz to 120 kHz. Spectral levels of noise in this report are presented over the frequency range from 1 Hz to 100 kHz

Measurements

Figure 1 presents the spectral levels of noise at the site prior to the turbine deployment, and after its removal from the sea at the conclusion of the measurements. The considerable flow of tidal water generates underwater noise due to turbulence at the surface, seabed and other boundaries. The greatest increase in noise occurs at high frequencies, above 100 Hz, and extends up to frequencies of 70 kHz in the case of the early background data, and to frequencies above 100 kHz during measurements undertaken at peak tidal flow in the evening. The spectral levels of noise are considerably above those measured by Subacoustech at other inshore coastal sites, highlighting the influence of the tidal flow on the underwater noise environment.

Figure 2 presents the spectral levels of noise during turbine operations at the site, in comparison with the measured levels of background noise. The measurements undertaken at a range of 75 m indicate an increase in noise over the frequency range from approximately 5 Hz to 10 kHz. There is a dominant noise component at a frequency of approximately 35 Hz, with acoustic energy extending to higher frequencies. The noise at this range was clearly distinguishable above the background sea noise and was similar to that from rotating machinery. The figure illustrates that at increasing range the noise diminishes. At ranges beyond 200 m, the turbine noise was difficult to identify audibly, and shows little variation in spectral levels from those of the background tidal flow in the region.

Figure 3 provides a similar summary of noise spectra measured later in the evening (approximately 3.5 hours after low water) when the tidal flow had increased. At a range of 50 m the data indicates that the turbine operation increases the underwater noise over the frequency range from approximately 1 Hz to 8 kHz. The components of man-made noise are most evident over the frequency range from 20 Hz to approximately 3 kHz. There are narrow band noise components at 32 Hz and 43 Hz. At a range of 130 m the increase in noise is still evident, but has rapidly decreased toward ambient sea noise level.

Figure 4 presents a typical time history of background underwater noise at the start of the measurement period, before the turbine had been lowered into the water. The noise during this period reached a maximum peak to peak pressure of approximately 1 Pa. The corresponding one second RMS sound pressures during this period varied from between 0.15 Pa to 0.27 Pa giving a Sound Pressure Level that varied from 103 to 109 dB re. 1 µPa.

Figure 5 presents a typical time history of underwater noise at a range of 75 m from the operational turbine. The underwater noise has increased to a maximum peak to peak pressure of approximately 7 Pa. One second RMS sound pressures measured over this period varied from 1.22 Pa to 1.43 Pa giving corresponding one second Sound Pressure Levels for the period that varied from between 122 to 123 dB re. 1 µPa.

Table 1 summarises the typical maximum, minimum and mean Sound Pressure Levels recorded at the EMEC site. Mean recorded background noise levels varied from 108 dB re. 1 µPa at the start of the measurement period to 118 dB re. 1 µPa, for measurements later in the evening. Measurements at a range of 50 m from the operational device indicate mean Sound Pressure Levels of 128 dB re. 1 µPa. The data indicates that the noise decreases with range from the turbine to mean Sound Pressure Levels of 112 dB re. 1 µPa. at a range of 270 m.

Figure 6 presents a summary of the one second, RMS Sound Pressure Levels measured during turbine operations on the 19th February 2008. The data indicates a gradual decrease in noise levels with range consistent with that from a noise source in the environment, to a range of approximately 200 m. After this, there is no further decrease in level indicating that the underwater noise from the turbine no longer influences the noise in the region. The initial fit to the data, over the ranges at which there is good signal to noise indicates a broadband Source Level noise from the turbine of 162 dB re. 1 µPa @ 1 m, with the underwater sound decaying at approximately 19 log r, where r is the range in metres. This level of noise is comparable with that for small vessel noise, and lower than that from large shipping. For example, large shipping produces source noise at levels well above 180 dB re. 1 µPa @ 1 m (Richardson *et al.* (1995)). Broadband underwater noise at levels of 162 dB re. 1 µPa @ 1 m., is comparable with that from a tug or barge, and is likely to be clearly audible and therefore act as a warning of the presence of the device to marine animals over a range of a few tens of metres.

Figure 7 presents a typical example of noise levels with range analysed in terms of the marine species. In the case shown the broadband noise data has been filtered to provide a measure of the broadband noise in comparison with the hearing threshold of the harbour porpoise (dB_{ht}). As the porpoise does not hear all of the frequency components of the turbine noise as a result of the hearing threshold for the marine species being considerably above 0 dB re. 1 µPa, the levels of noise on the dB_{ht} scale are lower than the broadband measures of noise. In this case at ranges from 75 m to 160 m the noise levels perceived by the harbour porpoise varies from approximately 86 to 73 dB_{ht}. As with human perception of sound, where levels are above 90 dB_{ht} (i.e. 90 dB(A)), the sound is loud and causes individuals to avoid the noise. In this case the 90 dB_{ht} strong avoidance range extends to a region of approximately 40 m around an individual turbine.

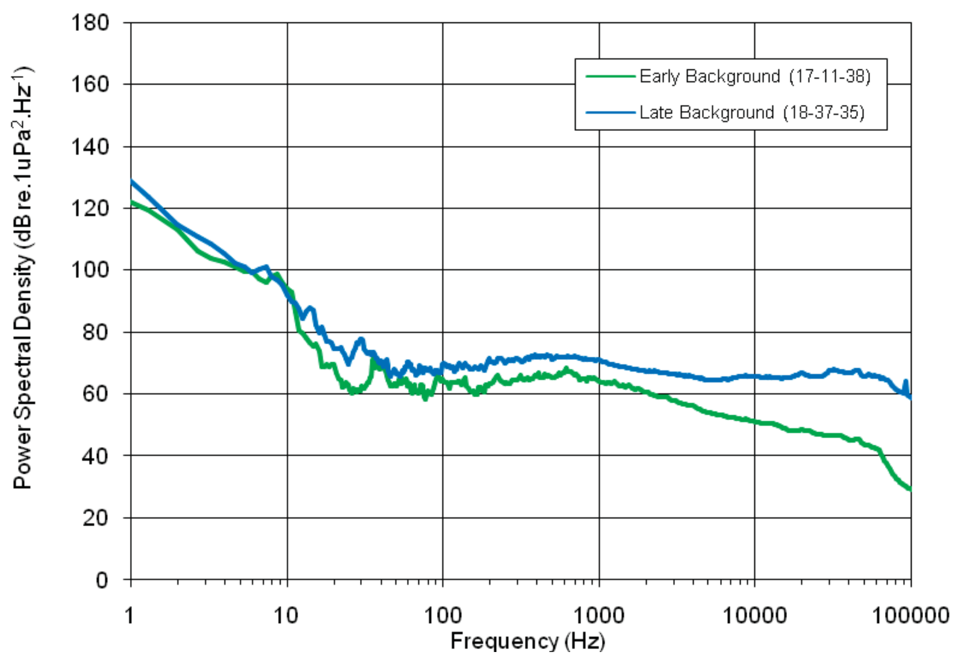


Figure 1 Comparison of spectral levels of background underwater noise at the EMEC facility, prior to, and after the conclusion of turbine operations

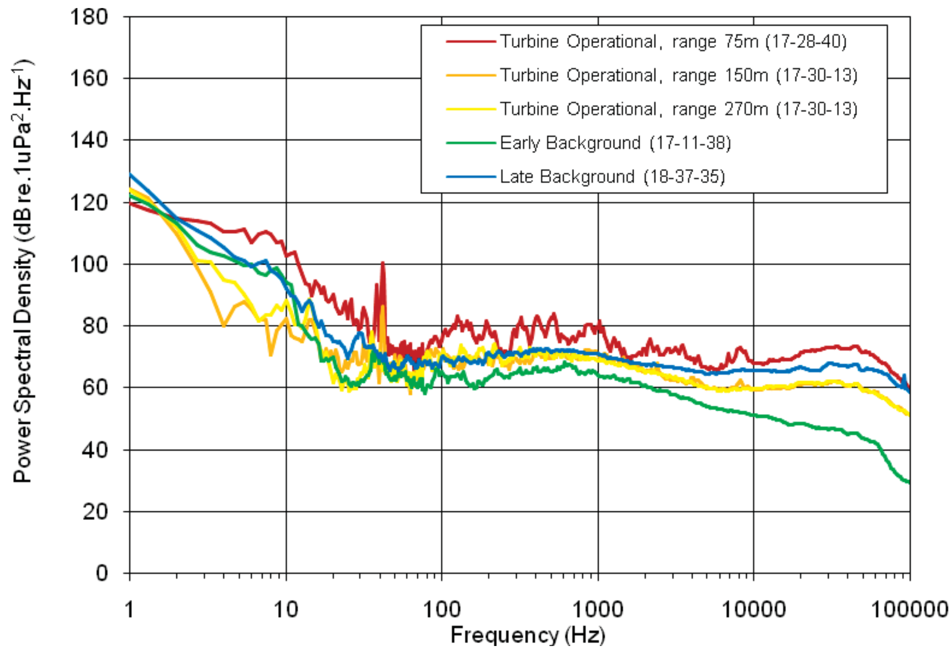


Figure 2 Comparison of spectral levels of underwater noise from the OpenHydro tidal turbine (Run 1)

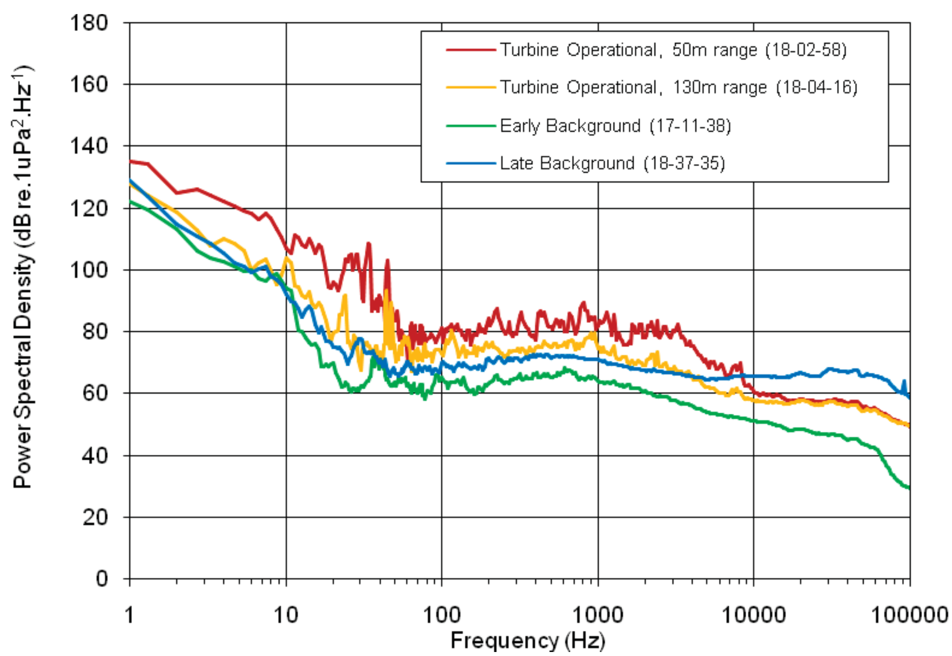


Figure 3 Comparison of spectral levels of underwater noise from the OpenHydro tidal turbine (Run 4)

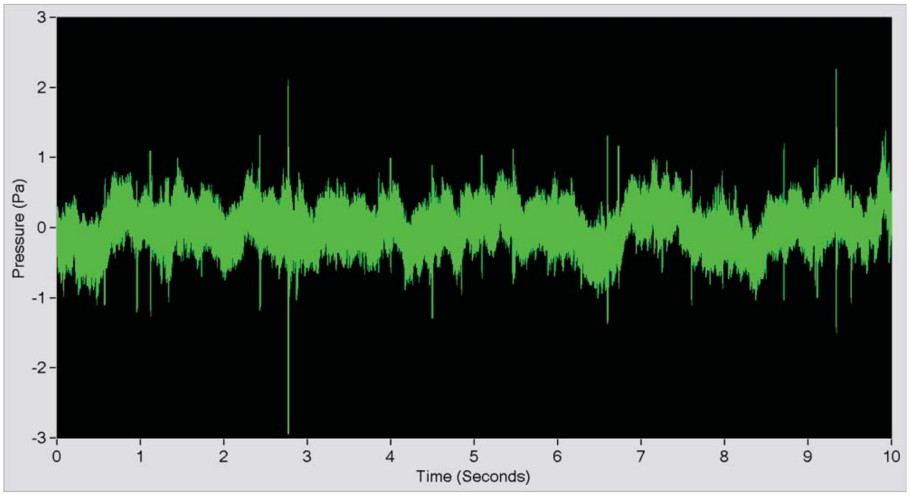


Figure 4. A typical time history of background underwater noise at the EMEC tidal energy site, Orkney (February 19th 2008, 17-09-50)

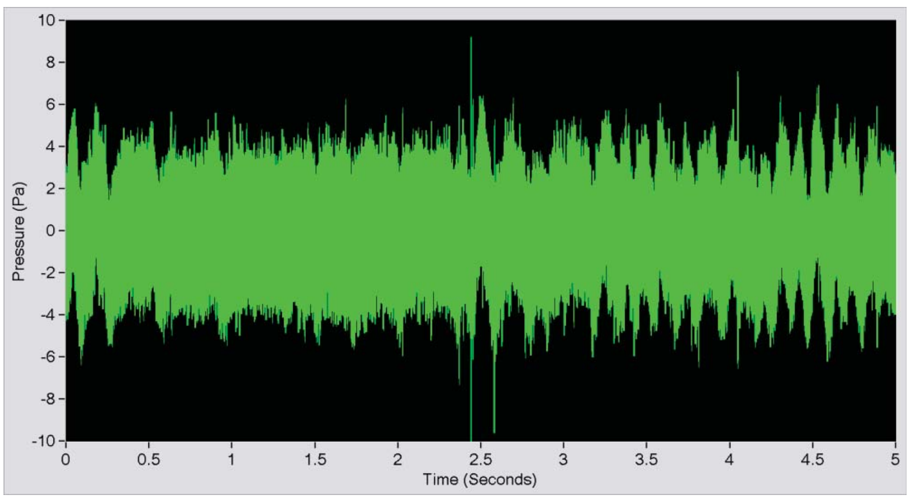


Figure 5. A typical time history of underwater noise recorded at a range of 75 m from the OpenHydro tidal turbine (February 19th 2008, 17-28-40)

		SPL (dB re. 1 µPa)		
Filename	**Condition**	**Max**	**Min**	**Mean**
17-09-50	Background at start of measurement period 1.5 hrs after low water	115	104	108
18-37-35	Background at end of measurement period 3 hrs after low water	120	116	118
18-02-58	Operational noise, 50 m from turbine	134	125	128
18-04-16	Operational noise, 130 m from turbine	117	114	116
18-04-41	Operational noise, 175 m from turbine	118	115	117
17-31-34	Operational noise, 270 m from turbine	113	111	112

Table 1 Summary of unweighted Sound Pressure Levels of underwater noise at the EMEC facility (February 19th, 2008)

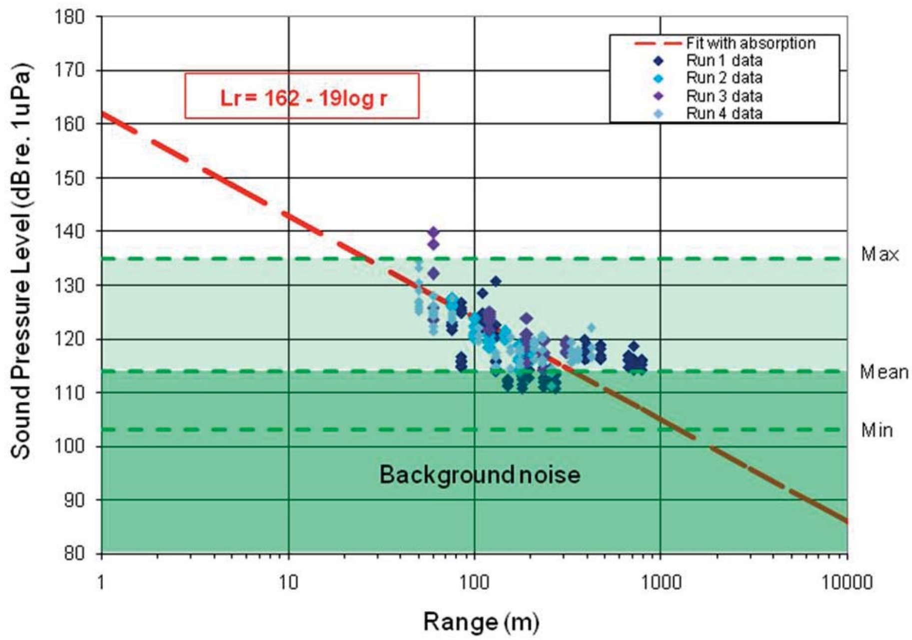


Figure 6. Summary of unweighted Sound Pressure Levels with range during OpenHydro tidal turbine operations (19th February, 2008)

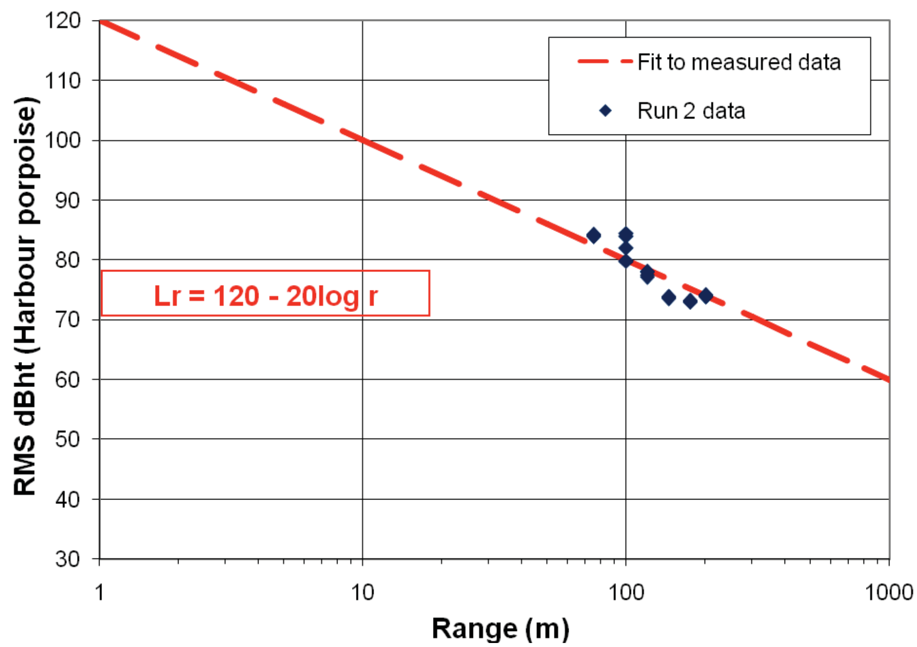


Figure 7 Measured underwater noise analysed in terms of the sound perception by the harbour porpoise.

Summary and Conclusions

1. A series of underwater noise measurements at the EMEC site on Orkney has indicated the levels and frequency components of noise during operation of the OpenHydro tidal turbine device. Measurements at ranges from 50 m to 790 m indicate broadband (1 Hz to 120 kHz) Sound Pressure Levels from 140 to 110 dB re. 1µPa respectively. The fit to the measured data indicates a Source Level noise of 162 dB re. 1 µPa @ 1 m. This is considerably below levels of noise that may cause lethal, physical injury or hearing impairment to the species of marine mammal.

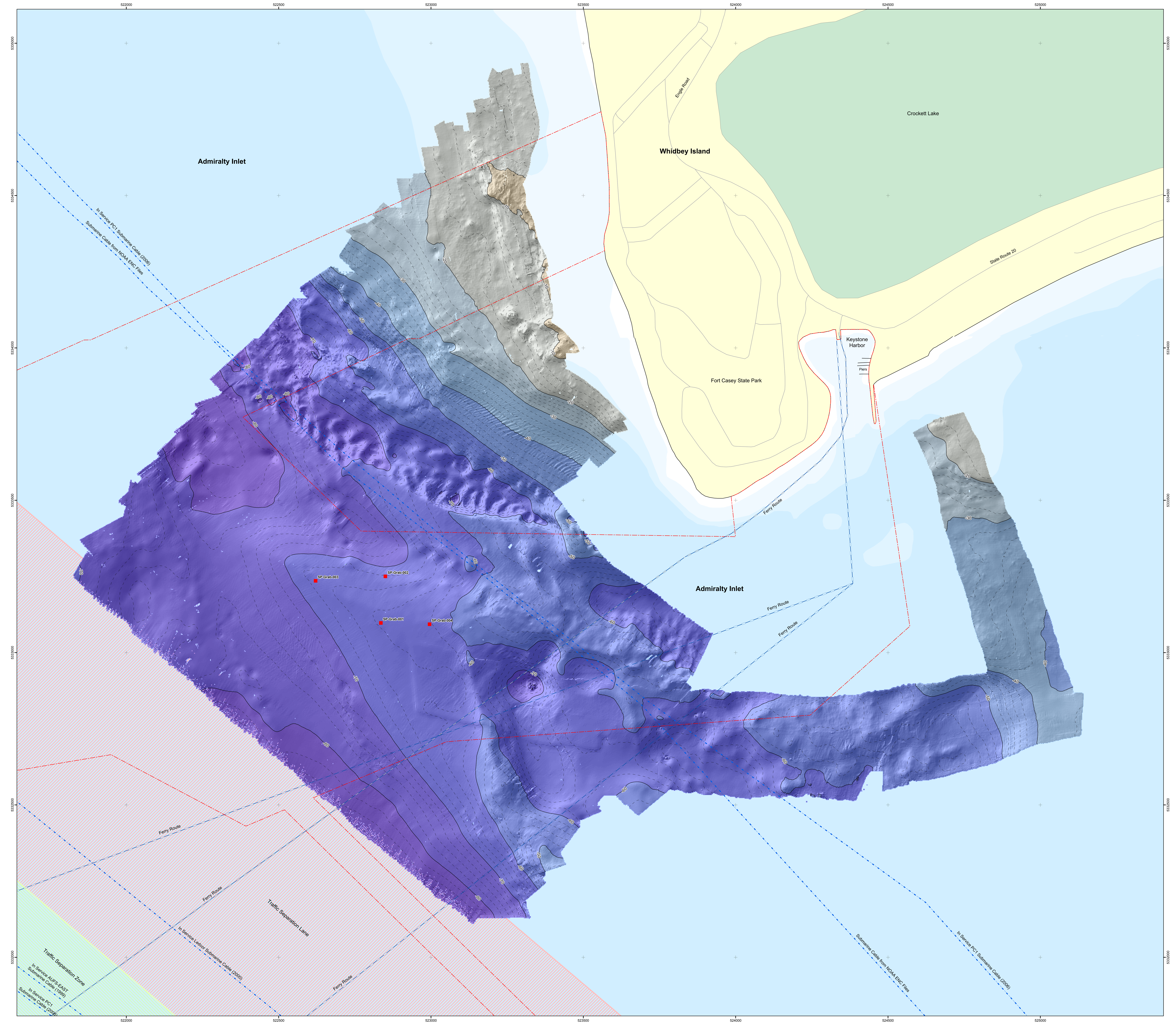
2. At ranges beyond 200 m the turbine noise was difficult to identify above the ambient tidal water flow noise. The extent of any behavioural impact to marine species due to the loudness of the noise from the turbine operation is therefore limited to this range.

3. Behavioural avoidance to the underwater sound has been assessed by comparing the measured noise with the published hearing threshold of marine species. Estimates of strong avoidance range based on a 90 dB_{ht} received level, mild avoidance based on a 75 dB_{ht} received level, and the range at which there is a low likelihood of disturbance based on a 50 dB_{ht} level are set out in the table below. The data indicates that unless fish or marine mammals are in the immediate vicinity of the turbine, behavioural disturbance is unlikely.

Species	90 dBht range	75 dBht range	50 dBht range	Range to background sea noise
Cod	< 1 m	< 1 m	5 m	200 m
Dab	< 1 m	< 1 m	2 m	200 m
Herring	< 1 m	1 m	20 m	200 m
Bottlenose Dolphin	10 m	50 m	150 m	150 m
Harbour Porpoise	30 m	150 m	250 m	250 m
Harbour seal	< 1 m	5 m	100 m	250 m

Appendix L-2

Multibeam Bathymetry Map



Legend

Cable Area- Dragging Prohibited (Refer to NOAA Chart)

Submarine Cable from NOAA ENC Files

Bathymetry

—-200— Major Contour (Contour Interval = 10 meters)

Minor Contour (Contour Interval = 2 meters)

Explorations

SP-Grab-004 Approximate Grab Sample Attempt

Bathymetry Color Scale (Elevation, Meters)

-5 to -10
-10 to -20
-20 to -30
-30 to -40
-40 to -50
-50 to -60
-60 to -70
-70 to -80
-80 to -90

Note: Colors on the map may vary slightly from colors in the legend, because the bathymetry is set to transparent. The transparency allows the 3D hillshade effect to show through. The contour lines show the actual bathymetry elevations.

Regional Bathymetry Depth Range (Meters)

0 - 5
5 - 10
> 10

Coordinate Grid: WGS 84 UTM Zone 10 North

Notes:

1) Water depths are referenced to Mean Lower Low Water (MLLW).

2) Bathymetry data were acquired by Fugro.

3) Basemap, some ferry routes, shipping channel, submarine cable locations, cable area, and regional bathymetry depth were obtained from NOAA ENC files US5WA28M and USWA16M.

4) Roads and one ferry route were obtained from ESRI Data and Maps 9.3.

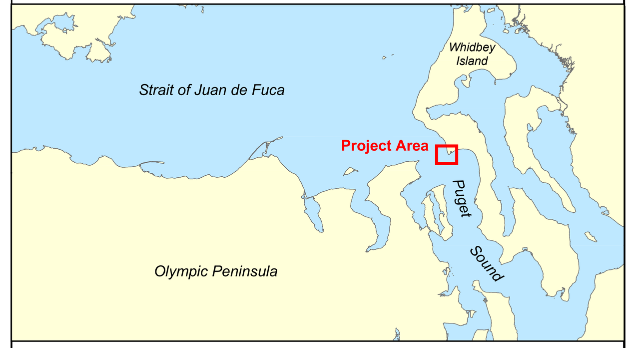
4) Map should be plotted as an E-Size Sheet.

DRAFT
PRINTED : 8-24-09

GEODETIC INFORMATION

SPHEROID:	WGS 1984
SEMI-MAJOR AXIS:	6,378,137.000
SEMI-MINOR AXIS:	6,356,752.314
INVERSE FLATTENING:	298.25722356
PROJECTION:	TRANSVERSE MERCATOR
ZONE:	10 North
LATITUDE OF ORIGIN:	0.0°
FALSE EASTING:	500000
FALSE NORTHING:	0
CENTRAL MERIDIAN:	-123
SCALE FACTOR:	0.9996

N



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SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

MULTIBEAM BATHYMETRY
Snohomish County Public Utility District
Puget Sound, Washington

SCALE : 1:4,000

100 50 0 100 200 300 Meters

NO:	DATE:	DESCRIPTION:	DRAWN:	CHKD:	APPR:
1	August 2009	Bathymetric and Geophysical Survey Site Characterization Report	SLV/CBD	SLV	PJH/CBD

JOB NUMBER: 0902J001

CHART NO.: 1

Appendix L-3

Bathymetric and Geophysical Survey Site Characterization
Admiralty Inlet Pilot Tidal Project

BATHYMETRIC AND GEOPHYSICAL SURVEY SITE CHARACTERIZATION
ADMIRALTY INLET PILOT TIDAL PROJECT

Survey Period: June 25 to 30, 2009
Report Number: 0902J001
Volume 1 of 1: Final

Prepared for:
SNOHOMISH COUNTY PUD NO. 1 (SNOPUD)

Prepared for: Snohomish County PUD No. 1
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Everett, WA 98206
Craig W. Collar, P.E.
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Client Reference: Professional Services Contract No. 53613

1	Issued as Final			E. Roach	23 September 2009
0	Issued as Draft	J. Hobson	P. Hogan	E. Roach	27 August 2009
Rev	**Description**	**Prepared**	**Checked**	**Approved**	**Date**

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APPENDICES

EXECUTIVE SUMMARY

Fugro performed a Site Survey for a proposed submarine turbine electrical generating facility and a power cable route to shore. The site area is located on the east side of Admiralty Inlet adjacent to Whidbey Island in Puget Sound. Strong tidal currents pass through this area, making it a favorable location for a submarine turbine electrical generating facility. Bathymetric and geophysical site surveys were performed. Seabed sampling with a Van Veen grab sampler was also attempted. Survey systems included multibeam bathymetry, sidescan sonar (SSS), CHIRP subbottom profiler (SBP), and magnetometer. Data processing, interpretation and analysis, and charting were subsequently performed, the results of which are described in this report.

Tectonic and glacial processes are largely responsible for shaping the physiographic setting, which consists of a north-west trending slope and channel with locally steep and irregular bathymetry. Large cobbles, gravel, and boulders cover much of the seafloor, the result of glacial outwash debris that has been scoured by strong seafloor currents since the retreat of glacial ice from the region and subsequent rise of sea level between about 13,000 and 16,000 years ago. Finer grained glacial outwash sediments may underlie the coarse, granular seafloor sediments currently covering the seafloor. Beneath the glacial outwash deposits are Eocene age strata. The thickness of the glacial deposits is unknown as no geotechnical explorations have been performed and the gravel, cobbles, and boulders on the seafloor precluded sub-seafloor penetration and seismic imaging.

Given these considerations and the potential for hard, irregular seafloor conditions, a gravity-based structure may be the best option for foundation design.

The geologic, seafloor, and subsurface conditions in the survey area suggest that, from a geoscience perspective, the design, construction, and operation of the facilities are feasible. Locally steep and irregular seafloor, strong currents, and seismicity pose the most significant geohazards to the facility. Volcanic and mass movement hazards also exist. These hazards can be mitigated through appropriate engineering design and construction practices.

1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

1.1.1 Background Project Information

The Snohomish County Public Utility District No. 1 is investigating the potential of tidal energy development in Puget Sound. The goal of their investigation is two-fold: (1) to confirm the environmental, social, technical, and economic feasibility of a tidal energy project in Puget Sound, and, if confirmed, 2) to obtain a long-term license that will allow the project(s) to operate in an economically viable and environmentally responsible manner (PAD document in http://www.snopud.com/renewables/tidalpwr/tidalpad.ashx?p=3739#).

To accomplish these goals, the District envisions a three-step process:

1. Initial investigations of the site, including:
    - Investigating the available energy resource
    - Performing targeted environmental studies
    - Assessing the commercial, recreational, and cultural uses of the waterways
    - Evaluating technologies; and
    - Investigating necessary appurtenant facilities and interconnection points.
2. The construction of a one- to five-device pilot installation to evaluate potential environmental effects from operation of the device, as well as the effectiveness of the device at generating economical electricity and the overall feasibility for the device in Puget Sound.
3. The construction of a utility-scale array which is envisioned to be built-out in stages in order to balance understanding and assessment of potential cumulative environmental effects with required cost-effectiveness of construction activities (multiple mobilizations, etc.).

Each step is dependent upon successful completion of the previous step. For example, the District would not begin construction on a utility-scale array unless the pilot project demonstrates the environmental and economic feasibility of the technology in Puget Sound. While applicable to all three steps, this investigation has been performed with a view towards the development of a pilot installation in Admiralty Inlet. Currents rush through the passage at up to nearly 6 mph, except for slack water for about 10 minutes once every 12 hours. At maximum capacity, the three turbines should supply about 1 megawatt, or enough power for about 700 homes, according to the PUD.

Fugro was contracted by SnoPUD to support the first phase of the study by performing bathymetric and geophysical site surveys for the project. Surveys included multibeam bathymetry, SSS, CHIRP SBP, and magnetometer. The surveys were completed in late June and early July 2009. Data processing was completed in late July. The complete Fugro scope of work is discussed in section 1.2 below.

1.1.2 Major Project Components

Three power-generating tidal turbines could be installed by 2011 as part of a pilot project. The demonstration turbines would be designed, built and installed by an Irish company, OpenHydro, which has installed tidal turbines off the coast of Scotland.

The 33-foot-wide turbine design selected by the PUD rotates just 10 times a minute and doesn't have exposed blade tips, which should minimize the effect on marine life. An underwater cable will connect to power lines on Whidbey Island.

It is our understanding that the turbines will be founded on a gravity-based structure, and won't require any pilings, pinnings or drilling.

1.2 SCOPE OF WORK

Fugro’s work scope consisted of Site Surveys of the turbine area and a possible cable route to shore, as well as data processing, interpretation, charting, and reporting. Both bathymetric and geophysical site surveys were performed for the project. Seabed sampling with a Van Veen grab sample was also attempted. Surveys included multibeam bathymetry, SSS, CHIRP SBP, and magnetometer. Data processing was subsequently performed. Data interpretation and analysis, charting, and reporting are the three final phases of Fugro’s work scope, as summarized below.

1.2.1 Site Characterization Report Phases and Objectives

Fugro’s scope of work was completed in six phases, including:

1. Project Definition and Planning
2. Field Surveys
3. Data Processing
4. Data Interpretation and Analysis
5. Charting
6. Reporting

1.2.2 Authorizations

The work performed in this study was authorized by Snohomish County Public Utility District under Professional Services Contract No. 53613 on June 23, 2009 with a Notice to Proceed effective June 25, 2009.

1.2.3 Key Project Personnel

Key project personnel included:

Project Manager: Eric Roach

Survey Manager: Jeff Carothers

Survey Team Leader: Eddie Stutts

Surveyors: Robert Dame, Joanna Hobson, Patrick Nissen

Data Processing: Robert Dame, Patrick Nissen, Joanna Hobson

Data Interpretation: Joanna Hobson, Stephen Varnell, Phil Hogan

GIS: Stephen Varnell, Cornelia Dean

Report Manager: Phillip Hogan

1.3 DELIVERABLES

Deliverables include charts, figures, and a (this) report. A complete list of charts, figures, and the report format is presented in the Table of Contents of this report.

2.0 SURVEY OPERATIONS

The seabed mapping survey was conducted aboard the *R/V Taku (Taku)* between June 25 and 30 at Admiralty Bay in the Straits of Juan de Fuca. High-resolution bathymetric, sub-bottom, magnetometer, bottom samples and SSS data were collected in a grid pattern specifically designed to meet the survey objectives.

2.1 HEALTH AND SAFETY

Fugro Party Chief Eddie Stutts successfully managed HSE on the *Taku*. A total of ten toolbox safety meetings were completed during this survey. There were no injuries or incidents during this phase of the project.

2.2 PERSONNEL

Personnel onboard the *Taku* during the survey operations included:

- Eddie Stutts, Party Chief, Fugro West;
- Mike Mcallister, Client Representative, Sound and Sea Technology, Inc.;
- Joanna Hobson, Sidescan Operator, Fugro Seafloor Surveys, Inc.;
- Patrick Nissen, Multibeam Operator, Fugro West; and
- Robert Dame, Sub-bottom/Magnetometer Operator, Fugro West.

2.3 DATA ACQUISITION METHODOLOGY

Data acquisition methodology and survey system configurations are provided in the following sections.

Following mobilization of the *Taku* at her Port Townsend Harbor berth, equipment initialization and system checks were performed. The vessel transited to and from the project site daily from Port Townsend beginning on June 25 and concluded survey operations on June 30. Equipment calibrations were conducted on June 25 in Admiralty Inlet.

The hydrographic and geophysical instrumentation employed for the survey included a multibeam echosounder (MBES), a sub-bottom profiler, a magnetometer, Van Veen bottom grab, and SSS system. Vessel positioning was achieved with POS/MV and the navigation software, Hypack/Hysweep. The MBES, sub-bottom, magnetometer, and SSS topside instrumentation, as well as the positioning equipment, were housed in the vessel's wheelhouse.

Survey operations consisted of traversing a pre-plotted grid of survey lines while towing the various system sensors. The SSS and magnetometer were towed astern at separate times by a winch, mounted centerline, atop the vessel's wheelhouse. The MBES transducer head was mounted on a rigid over-the-side pole along the vessel's starboard side. The sub-bottom profiler was towed concurrently with the SSS off the vessel's port quarter. All positioning, bathymetry, and sonar data were recorded digitally.

2.4 SURVEY INSTRUMENTATION

A suite of geophysical survey instrumentation was assembled onboard the *Taku* and included:

- Trimble Differential GPS Positioning System
- Reson SeaBat 8101 Multibeam Echosounder
- Klein 3000, Sidescan Sonar Towfish
- SeaSPY Marine Magnetics Cooperation, Magnetometer
- Hypack/Hysweep Navigation and Multibeam Acquisition Software
- CARIS HIPS/SIPS Bathymetric Processing Software
- EdgeTech Full Spectrum Profiler (CHIRP), Sub-Bottom Profiler
- Applied Microsystems Ltd. Smart Probe Sound Velocimeter
- Chesapeake Technologies Sonarwiz.MAP Acquisition Software
- POS/MV V-4 position and orientation system

The following section offers a detailed description of the individual systems employed during the field campaign.

2.5 POSITIONING AND NAVIGATION

A POS/MV V-4 position and orientation system measured vessel heading and dynamic motion (heave, pitch and roll). The POS/MV system uses two embedded Novatel 12-channel GPS receivers for the final position with heave, pitch and roll being generated from the inertial unit. The update rate is 10 Hertz and the system has a horizontal accuracy of 1 meter (RMS) with Differential GPS (DGPS) corrections. The system's GPS engines receive ranging information from the same satellites as the Trimble differential reference stations. These corrections are applied to the DGPS receiver's satellite data to produce a corrected and accurate position of the vessel in real-time that drives the inertial unit. This inertial position is then passed on to the MBES data collection system.

The two antennae were mounted above the wheelhouse on either aft corner. The POS/MV processor uses the GPS data, along with data supplied by gyros in the inertial measurement unit (IMU), to compute a dynamic heading alignment. This heading solution is further refined using a GPS Azimuth Measurement Subsystem (GAMS), wherein a vector is computed between the two antennae using carrier phase ambiguity resolution subroutines.

The MU was mounted on the top of the multibeam pole over the transducer. The IMU uses a series of linear accelerometers and angular rate sensors that work in tandem to determine vessel attitude solutions. All motion variables (e.g., position, velocity, heave, roll, pitch, true heading, acceleration vectors, and angular rate vectors) are output at a high rate of 10 Hertz.

Navigation and motion data originated from an Applanix POS/MV V-4 inertial motion reference system that delivers a full 6 degrees-of-freedom position and orientation solutions for marine survey vessels. The POS/MV is given Radio Technical Commission for Maritime Services (RTCM) corrections from the Trimble receiver. DGPS corrections were applied to the data.

The POS/MV together with the IMU measures true heading with roll and pitch to 0.05-degree accuracy or better under dynamic conditions in real-time, including hard turns and rapid acceleration or deceleration with a heave accuracy of 5cm or 5%. True heave was recorded and applied during post-processing.

The POS/MV controller software displayed real time accuracies of heave, pitch, roll, position and velocity for quality control purposes. The software was configured to alert the operator if the actual accuracies were outside the user-defined tolerance limits.

The vessel position information was linked to an onboard Pentium-based computer running Hypack/Hysweep navigational software. Hypack/Hysweep is a Windows navigation system designed for both surface and subsurface vehicle positioning. The helmsman's display continually updates the true vessel position, the tracklines, and distances off line and well as along line.

The Hypack/Hysweep navigation system continually shared and transmitted vessel position as well as vessel speed through a null cable to the SSS acquisition system.

2.6 MULTIBEAM ECHOSOUNDER

The *Taku* was equipped with an over-the-side mounted Reson SeaBat 8101 (240 kHz) MBES system. The Reson SeaBat 8101 is designed to meet International Hydrographic Organization (IHO) standards to measure the seafloor to a maximum depth of 320m. The Reson SeaBat 8101 system was used to collect bathymetry data from approximately 5 to 85m (16 to 279 feet) water depth during the survey

All navigation, vessel motion, and MBES data were recorded to the Hypack/Hysweep data acquisition program. This program provides the calibration, playback, editing, and binning capability of the MBES data and has sub-millisecond time tagging for all devices. In addition, the MBES, POS/MV and heave-pitch-roll sensors are all interfaced directly to the Hypack/Hysweep program, which displays and logs the combined data.

A Patch Test, or comprehensive alignment of the system, calibrated the different components of the MBES. The test was performed on June 25 in Admiralty Inlet, prior to starting field operations. The MBES calibration measures the angular mounting components of the correction sensors (roll, pitch, and yaw). Errors in these dimensions can lead to an inaccurate survey. This calibration is a data collection and processing exercise designed to document these component offsets along with the positioning system latency. The patch test calibration capability of CARIS HPIS/SIPS was used in determining the orientation of the MBES system, along with the combined delay time between the inertial system and MBES sonar, and any azimuthal misalignment. By running a defined pattern of six short survey lines, the patch test program determined the "best fit" solution for each of these items.

The Reson SeaBat 8101 measured the water depths across a wide swath that is perpendicular to the survey vessel's track, thus ensonifing a swath on the seafloor approximately 150° across track by 1.5° along track. The swath consisted of 101 individual 1.5° by 1.5° beams with a bottom detection range resolution of 1.25cm.

The 101 beams were sampled at intervals corresponding to the 1.25-cm range resolution, and the intensity data were displayed in real-time together with a read out of the detected bottom. This ability to display the raw data gave the operator an excellent quality-check facility. The 101-detected bottom samples were networked up to 40 pings per second to the acquisition system. The format was X, Y and Z relative to the acoustical center of the sonar head.

The sensor calibration factors and sensor offsets were applied during data processing together with sound velocity (derived from sound velocity profile casts as described below) and tidal corrections (from the NOAA tide gauge in Port Townsend). Absolute data accuracies from different sensors would vary due to existing environmental conditions and survey methodology like strong currents, choppy seas and layback point attachment of towed sensors.

2.6.1 Sound Velocity

Sound velocity casts were conducted so that MBES data could be corrected for sound velocity refraction. Sound velocity profile (SVP) data were acquired using AML Smart Probes, a hi-tech composite sound velocity sensor. AML Smart probes measure at a rate of eight velocity and pressure observations per second, and respond to temperature changes immediately, maximizing its ability to identify and map thermoclines, a necessity for MBES bathymetric data acquisition. The pressure sensor accuracy is 0.05%, the sampling rate is 8Hz, and the sensor range extends to 1600 meters per second (m/s).

For each cast, the probes were held at the surface for one minute to reach temperature equilibrium. The probes were then lowered at the rate of about 1 m/s to the seafloor and then raised to the surface at the same rate. HyperTerminal was used to log the depth and velocity. The frequency of casts was based on distance and time, with the limits being no more than 2km apart and approximately two to three hours apart.

2.7 SIDESCAN SONAR MAPPING

A digital, dual-frequency SSS system was employed to characterize seafloor features in the survey area. The system consisted of a Klein 3000 sonar towfish and armored tow cable that were interfaced to a data logging computer and acquisition software. Chesapeake Technology, Inc.'s SonarWiz.MAP software was utilized to provide real-time mosaics for quality control. The software also provided complete post-processing capabilities. Features include automatic gain control, time-variable gain, beam angle correction, integrated bottom tracking and a navigation editor.

During the survey, the towfish was deployed from the center stern of the *Taku* as the vessel traversed the survey grid. The length of the deployed tow cable varied with the water depth in order to keep the sonar fish at an altitude of 10 to 15% of the range setting as required to insure optimum seafloor imaging. The sonar towfish layback and position was tracked using a cable counter tow sheave.

2.8 SUBBOTTOM PROFILER

An EdgeTech full spectrum profiler (CHIRP) system was used to obtain shallow seismic reflection data to assist with characterization of shallow subsurface geologic conditions within the project area, including surficial material and faulting. The EdgeTech FS-SB system included the SB-216S towfish, the Model 3200 topside processor, EdgeTech's Discover acquisition software and an EPC 1086NT thermal printer.

The towfish was deployed and towed from the stern of the *Taku*.

The tow cable was deployed sufficiently deep so that the towfish was clear of and beneath the vessel's wake. The system was triggered at a 4 to 8 Hz pulse rate and sweep frequency range between 2 to 15 kHz. Subbottom profile record length was adjusted for water depth, and ranged from 100 to 200 miliseconds. All navigation information and SBP data were time tagged and logged to a hard drive. The reflection profiles were also simultaneously displayed on the acquisition screen for real-time data quality control.

2.9 MAGNETOMETER

A Marine Magnetics SeaSPY magnetometer was deployed from the center stern of the *Taku* at the SnoPUD site off Admiralty Point on June 30 to search for magnetic anomalies along the proposed cable route. The magnetometer was interfaced to the navigation computer through the SeaSPY communications transceiver. The total magnetic field values were logged together with time tagged navigation information at a rate of 1 Hz.

The image below (Figure 2-1) shows the expected background field for a particular area. For example, the expected field near Port Townsend, Washington is about 54,000 nano-Tesla (nT) (1nT=0.01mG).

The shape of an anomaly will vary depending on the crossing angle, the field inclination and the depth of the target.

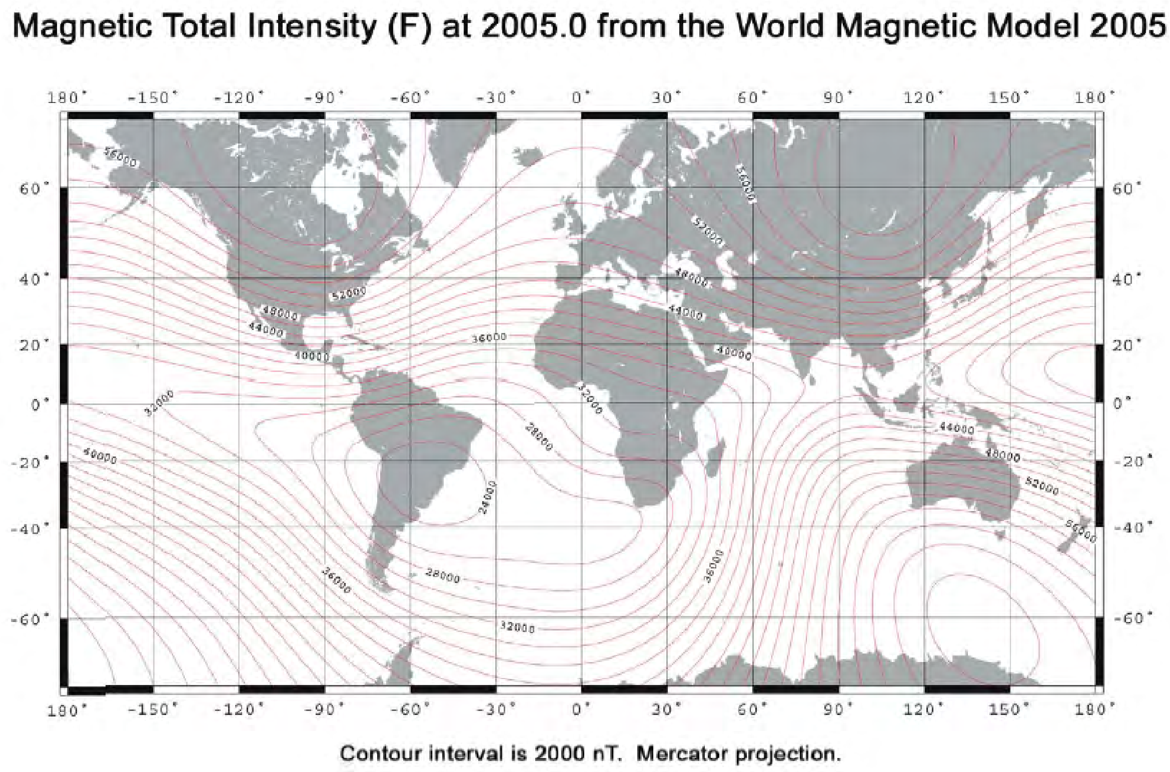


Figure 2-1: World Magnetic Model 2005 (McLean et al., 2004)

2.10 SEDIMENT SAMPLING PROGRAM

A sediment sampling program using a Van Veen grab sampler deployed off the stern of the *Taku* was conducted at the SnoPUD site on June 30. Four sample locations were planned near the proposed turbine location at a water depth of around 65m (Table 2.1). However, after multiple unsuccessful attempts at three of the sites, the fourth site was abandoned. A combination of factors, including rocky bottom type and intense current activity likely contributed to the lack of recovery.

Table 2-1. Grab Sample Locations at the SnoPUD Site

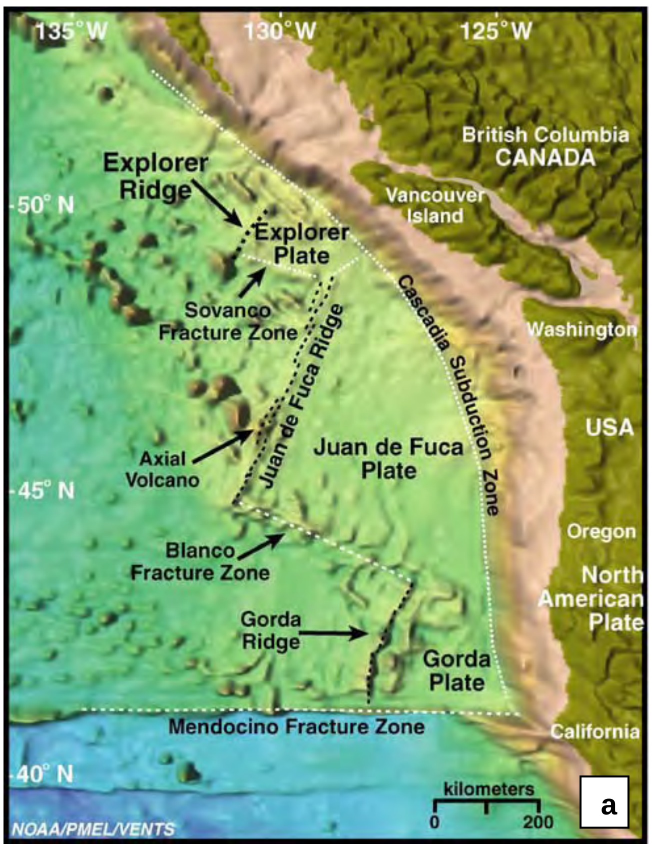
Sample	Latitude	Longitude	Water Depth (m)	Comment
SnoPUD-Grab-001	48° 09.04' N	122° 41.58' W	64	No Recovery (3 attempts)
SnoPUD-Grab-002	48° 09.13' N	122° 41.57' W	68	Not Attempted
SnoPUD-Grab-003	48° 09.12' N	122° 41.75' W	68	No Recovery (3 attempts)
SnoPUD-Grab-004	48° 09.04' N	122° 41.45' W	62	No Recovery (1 attempt)

3.0 GEOLOGIC SETTING

The following sections describe several key physiographic features, as well as geologic processes and hazards important to consider for the installation of the turbine generator and design of a submarine cable route.

3.1 REGIONAL GEOLOGY

The study area is located in the Pacific Northwest. The tectonic setting is a forarc basin located between the Cascade Volcanic Arc and the Cascadia subduction zone. In this area the Juan de Fuca plate (an oceanic tectonic plate) is being pulled and driven or "subducted" beneath the North American plate (a continental plate) [Kirby and al., 2002]. As a result of the interaction between the two plates, the continent overlying the subduction zone is actively deforming (Figure 3-1a, b). Subduction of oceanic lithosphere in the Tertiary has led to the formation of two major geologic provinces: the Coast Range/Puget Lowland on the West, and the Cascade Range in the east.



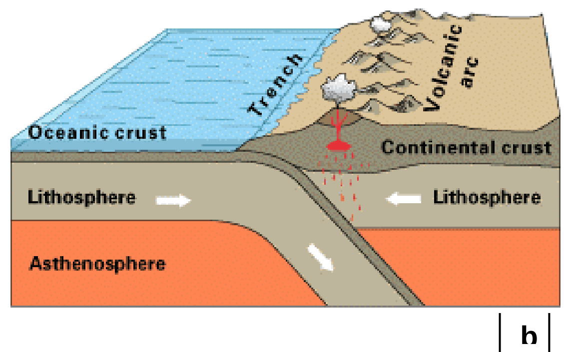


Figure 3-1:

a) Satellite imagery of the northeast Pacific Ocean and western North Pacific Plate. Explorer, Juan de Fuca, and Gorda Ridges make up the plate boundary between the Pacific Plate and the Juan de Fuca/ Explorer/ Gorda Plates. The Cascadia Subduction Zone is also highlighted, which is the area where oceanic crust is subducting beneath the North American Plate [modified from Swanson et al., 1989]

b) Deformation associated with the Cascadia Subduction Zone [from online edition of "This Dynamic Earth" http://pubs.usgs.gov/gip/dynamic/dynamic.html]

A subduction zone, in a landward to seaward direction, consists of several physiographic features. Those relevant to this project include:

- A **volcanic arc** representing a region of volcanism associated with melting of the subducting oceanic plate (Figure 3-1b). The Cascade Arc is situated in continental crust on the over-riding tectonic plate and consists of a line of active volcanoes on top of thick piles of oceanic rock and sediment scraped from the down-going plate.
- A **forearc** that extends from the Cascade Arc to the Cascadia Subduction Zone, including the project area.

3.2 GEOLOGY OF PUGET SOUND

Nestled between the Cascade and Olympic mountains in northwest Washington, the Puget Sound basin covers more than 16,000 square miles of land and water (Figure 3-2). The basin's surface area is roughly 80% land and 20% water.

3.2.1 Physiography

Puget Sound is an estuary; a semi-enclosed, glacial fjord where saltwater from the ocean is mixed with fresh water draining from the surrounding watershed. Made up of a series of underwater valleys and ridges called basins and sills, Puget Sound is deep, with an average depth of 140m. The maximum depth (285m) occurs just north of Seattle.

The Juan de Fuca Strait is a long, narrow submarine valley that originates along a northwest-southeast depression between the resistant rocks of southern Vancouver Island to the north and the Olympic Mountains to the south. The Strait is 22 to 28km wide and 100km long. A relatively shallow sill at Admiralty Inlet separates the waters of the Strait of Juan de Fuca from the waters of Puget Sound proper. The Inlet is the main entrance to Puget Sound and is defined by the United Stated Geological Survey (USGS) as a line between Point Wilson on the Olympic Peninsula and Point Partridge on Whidbey Island (Figure 3-2).

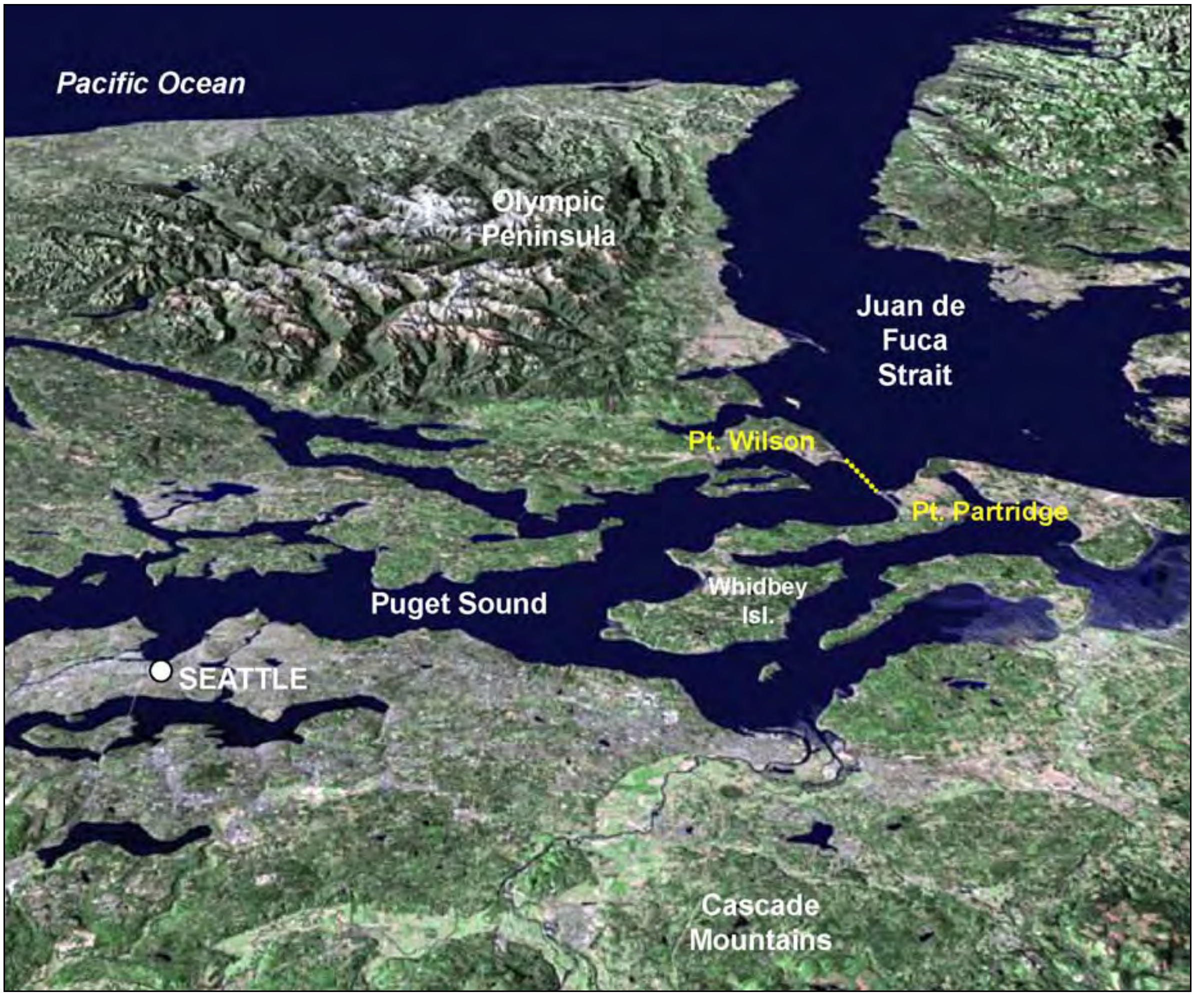


Figure 3-2: Overview of Puget Sound
[Modified from Washington Atlas of Panoramic Aerial Images; http://130.166.124.2/wa_panorama_atlas/page2/page2.html]

South of Admiralty Inlet, Puget Sound proper consists of four interconnected geomorphic basins (Figure 3-3). The largest and deepest of these, the Main Basin, extends some 100km from Admiralty Inlet to the Tacoma Narrows. Around the Tacoma Narrows, a shallow sill separates the Main Basin from the Southern Basin. To the north and east of the Main Basin (but not separated by a sill) is the Whidbey Basin. The smallest of the four basins, in terms of area, is the Hood Canal Basin on the western side of the Sound. This long, narrow channel branches from the Main Basin south of Admiralty Inlet and extends about 130km south between the Olympic Mountains and the Kitsap Peninsula.

The two-layer circulation system in the Sound is disturbed by shallow sills, a series of underwater valleys and ridges, which re-circulate water from the surface back into the depths of the basin. In particular, sills at the Tacoma Narrows and Admiralty Inlet greatly influence water movement through the basin. Mixing at the Admiralty Inlet sill draws seaward-moving surface water down into the inward-moving salty water from the Strait of Juan de Fuca.

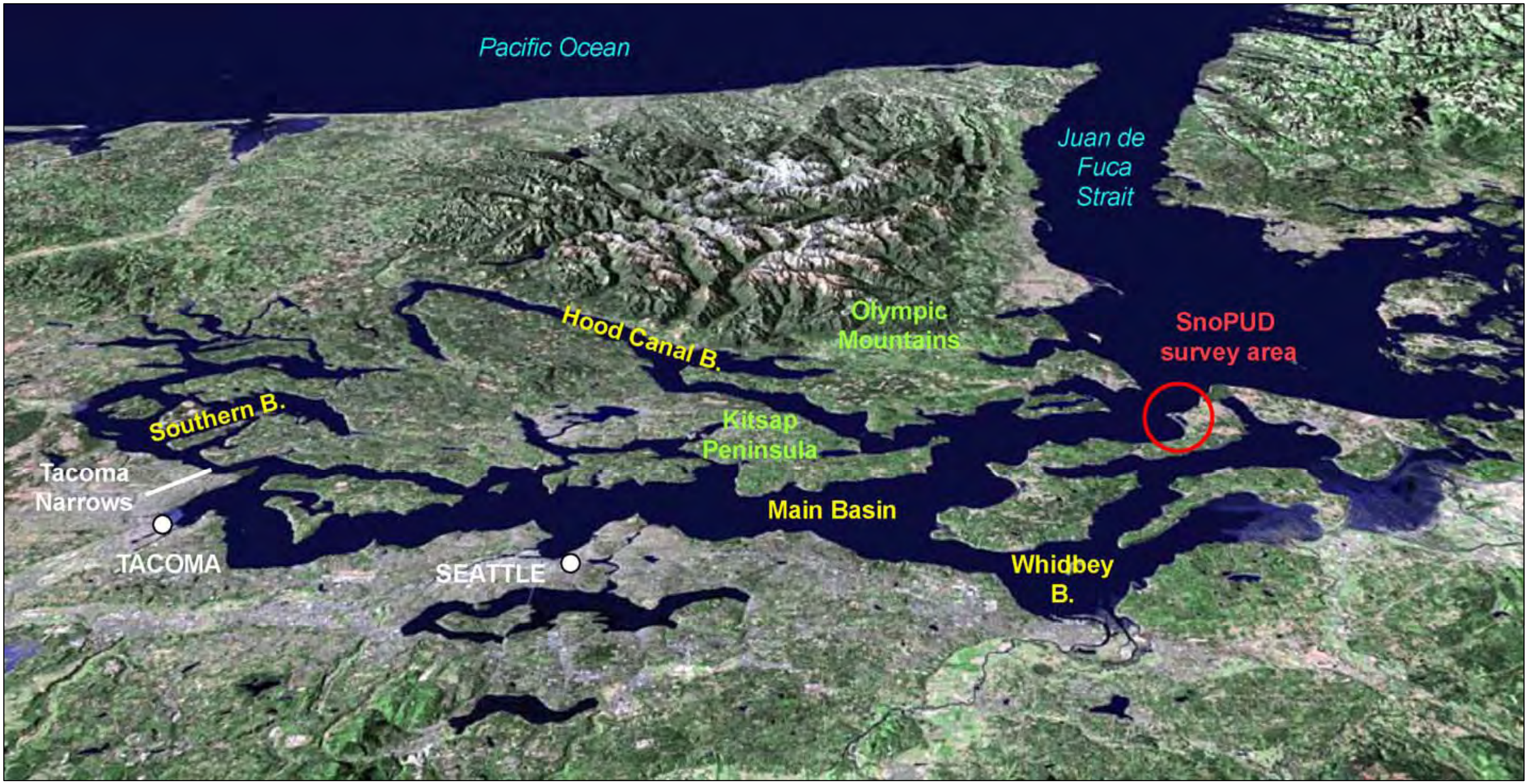


Figure 3-3: Puget Sound Basins
[modified from Washington Atlas of Panoramic Aerial Images, http://130.166.124.2/wa_panorama_atlas/page2/page2.html]

Puget Sound's circulation pattern acts as a pump to raise deep water toward the surface at the south end of the Main Basin. The water flow is also complicated by the islands, narrow passages, and changes in water depth that characterize Puget Sound. Water moves sluggishly in some of the shallow, semi-enclosed bays of the Southern Basin. Water is funneled at high speeds through passages connecting with the main system. These estuarine circulation patterns also affect the millions of tons of sediment and other materials transported to or resuspended in the Sound. However, unlike the waters that eventually move seaward, most particles are permanently trapped in the basin. In the Main Basin, only a small fraction of the particles initially present in the surface water are carried past Admiralty Inlet.

3.2.2 Structure

Structurally, the Puget Sound Lowland is controlled by east-west, north- and northwest-trending faults between the Cascade Range to the east and the Olympic Peninsula to the west (Figures 3-4 and 3-5). Oblique convergence on the Cascadia subduction zone has led to a complex array of faults of differing structural style and orientation. Active strike-slip, thrust, and oblique faults accommodate north-south convergence resulting from oblique convergence and block rotation (Johnson et al., 2004).

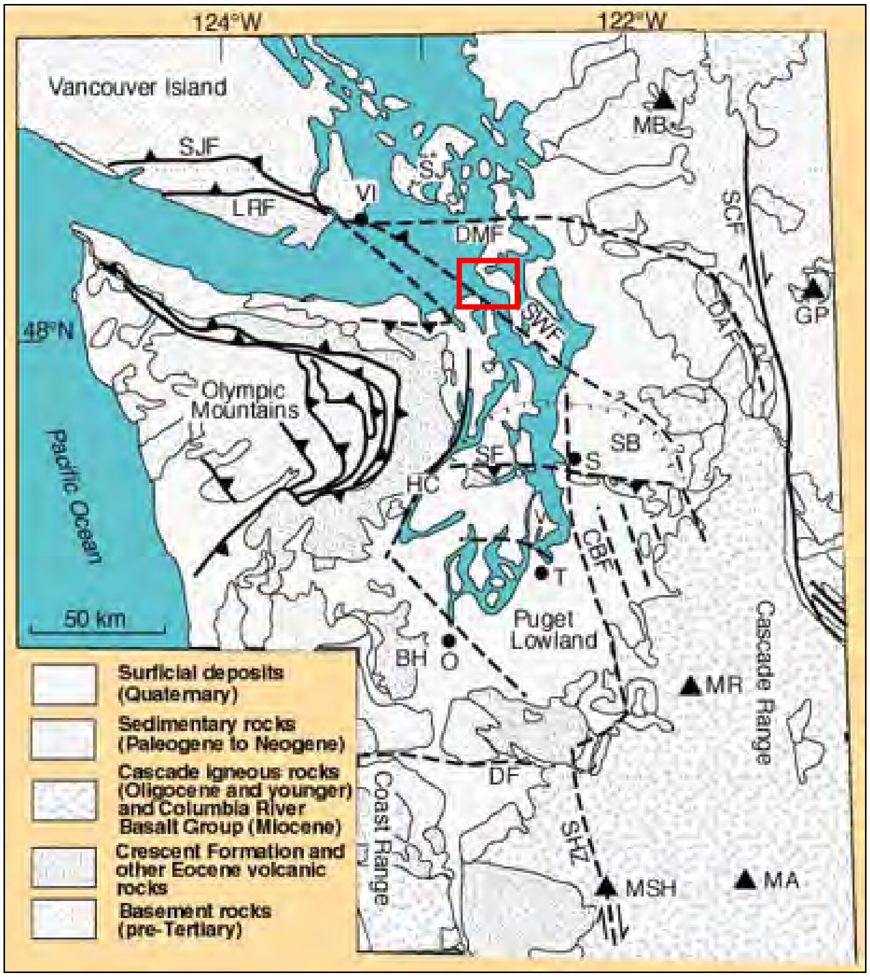


Figure 3-4: Schematic geologic map of northwestern Washington

This illustrates the Puget Lowland and flanking Cascade Mountains, Coast Range, and Olympic Mountains. Abbreviations for cities: O = Olympia; S = Seattle; T = Tacoma; VI = Victoria. Abbreviations for faults (heavy lines), modern Cascade volcanoes (triangles) and other geologic features: BH = Black Hills; CBF = Coast Range Boundary fault; DAF = Darrington fault; DF = Doty fault; DMF = Devils Mountain fault: GP = Glacier Peak; HC = Hood Canal; LRF = Leech River fault; MA = Mount Adams; MB = Mount Baker; MR = Mount Rainier; MSH = Mount Saint Helens; SB = Seattle basin; SCF = Straight Creek fault; SF = Seattle fault; SHZ = Saint Helens zone; SJ = San Juan Islands; SJF = San Juan fault; SWF = southern Whidbey Island fault. Geology from maps and compilations of Tabor and Cady (1978), Washington Public Power Supply System (1981), Gower and others (1985), Walsh and others (1987), Whetten and others (1988), Yount and Gower (1991), Tabor and others (1993), and Tabor (1994). Source: Johnson et al., 2004

The nearest mapped active faults are two splays of the South Whidby Island fault zone. The survey area is located between these two splays (Figure 3-5).

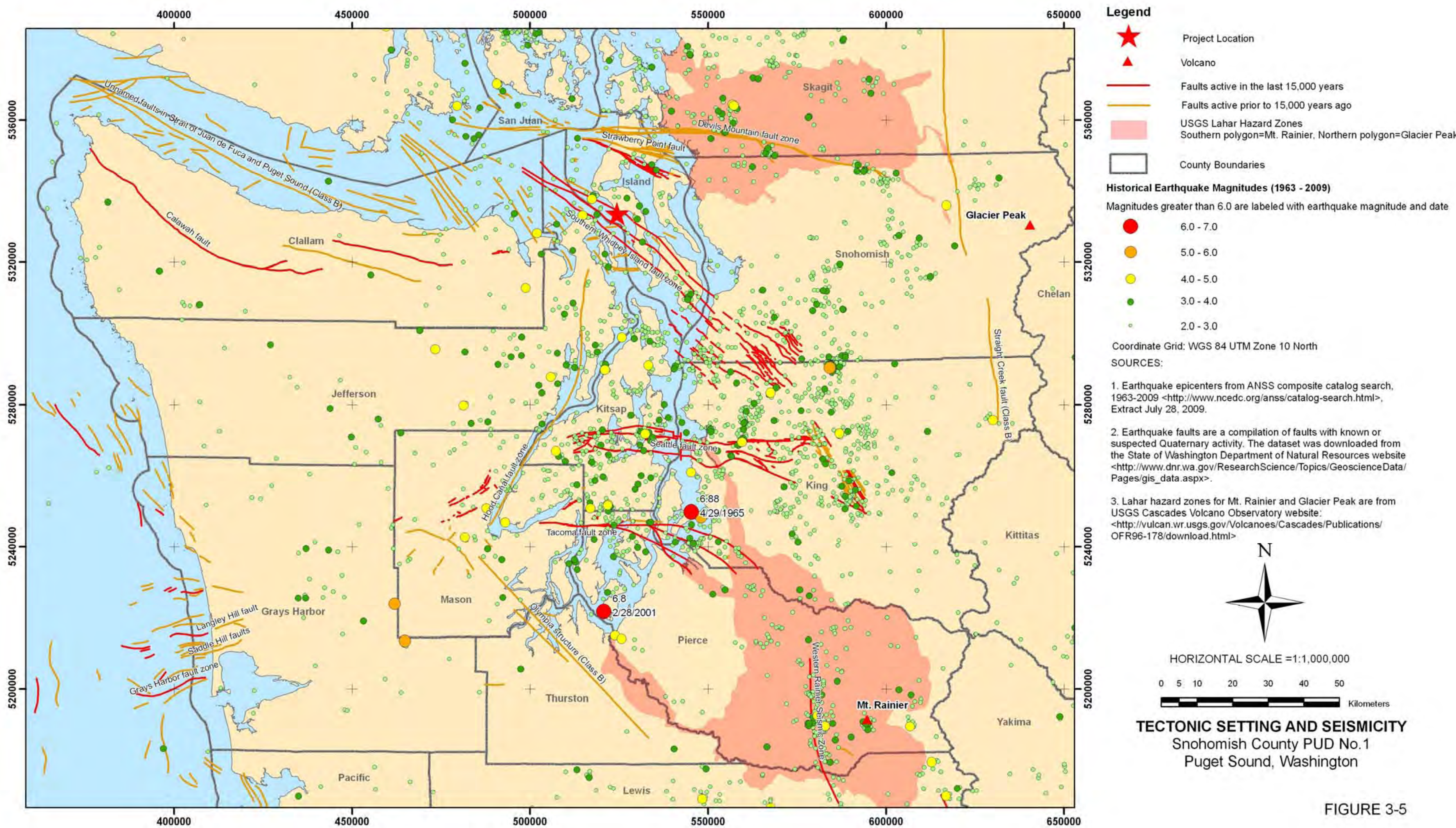

Legend
Project Location
Volcano
Faults active in the last 15,000 years
Faults active prior to 15,000 years ago
USGS Lahar Hazard Zones
Southern polygon=Mt. Rainier, Northern polygon=Glacier Peak
County Boundaries
Historical Earthquake Magnitudes (1963 - 2009)
Magnitudes greater than 6.0 are labeled with earthquake magnitude and date
6.0 - 7.0
5.0 - 6.0
4.0 - 5.0
3.0 - 4.0
2.0 - 3.0
Coordinate Grid: WGS 84 UTM Zone 10 North
SOURCES:
1. Earthquake epicenters from ANSS composite catalog search, 1963-2009 <http://www.ncedc.org/anss/catalog-search.html>, Extract July 28, 2009.
2. Earthquake faults are a compilation of faults with known or suspected Quaternary activity. The dataset was downloaded from the State of Washington Department of Natural Resources website <http://www.dnr.wa.gov/ResearchScience/Topics/GeoscienceData/Pages/gis_data.aspx>.
3. Lahar hazard zones for Mt. Rainier and Glacier Peak are from USGS Cascades Volcano Observatory website: <http://vulcan.wr.usgs.gov/Volcanoes/Cascades/Publications/OFR96-178/download.html>
N
HORIZONTAL SCALE =1:1,000,000
0 5 10 20 30 40 50
Kilometers
TECTONIC SETTING AND SEISMICITY
Snohomish County PUD No.1
Puget Sound, Washington
FIGURE 3-5
400000
450000
500000
550000
600000
650000
5360000
5320000
5280000
5240000
5200000
San Juan
Skagit
Island
Clallam
Snohomish
Glacier Peak
Chelan
Jefferson
Kitsap
King
Kittitas
Mason
Grays Harbor
Pierce
Thurston
Mt. Rainier
Yakima
Pacific
Lewis
Unnamed faults in Strait of Juan de Fuca and Puget Sound (Class B)
Devils Mountain fault zone
Strawberry Point fault
Calawah fault
Southern Whidbey Island fault zone
Straight Creek fault (Class B)
Hood Canal fault zone
Seattle fault zone
Tacoma fault zone
6.88
4/29/1965
6.8
2/28/2001
Langley Hill fault
Saddle Hill faults
Grays Harbor fault zone
Olympia Structure (Class B)
Western Rainier Seismic Zone

Figure 3-5

3.2.3 Seismicity

The region is characterized by moderate to high seismicity. Many small shallow earthquakes have been recorded in the Puget Sound area, and several moderate, shallow earthquakes have been recorded by the multistation seismograph network since 1963 (Figure 3-5). Large earthquakes, reported historically, have frequently occurred deep beneath the Puget Sound region. The most recent and best documented of these were in 2001 (the Nisqually quake, magnitude 6.8, near Olympia), in 1965 (magnitude 6.5, located between Seattle and Tacoma) and in 1949 (magnitude 7.1, near Olympia). They were roughly 65km deep and were within the oceanic (Juan de Fuca) plate where it lies beneath the continent. Figure 3.9b shows the location of these three deep earthquakes in plan view and in cross-section. The pattern of earthquake occurrence observed so far indicates that large, deep earthquakes similar to those in 2001, 1965 and 1949 are likely to occur about every 30 years.

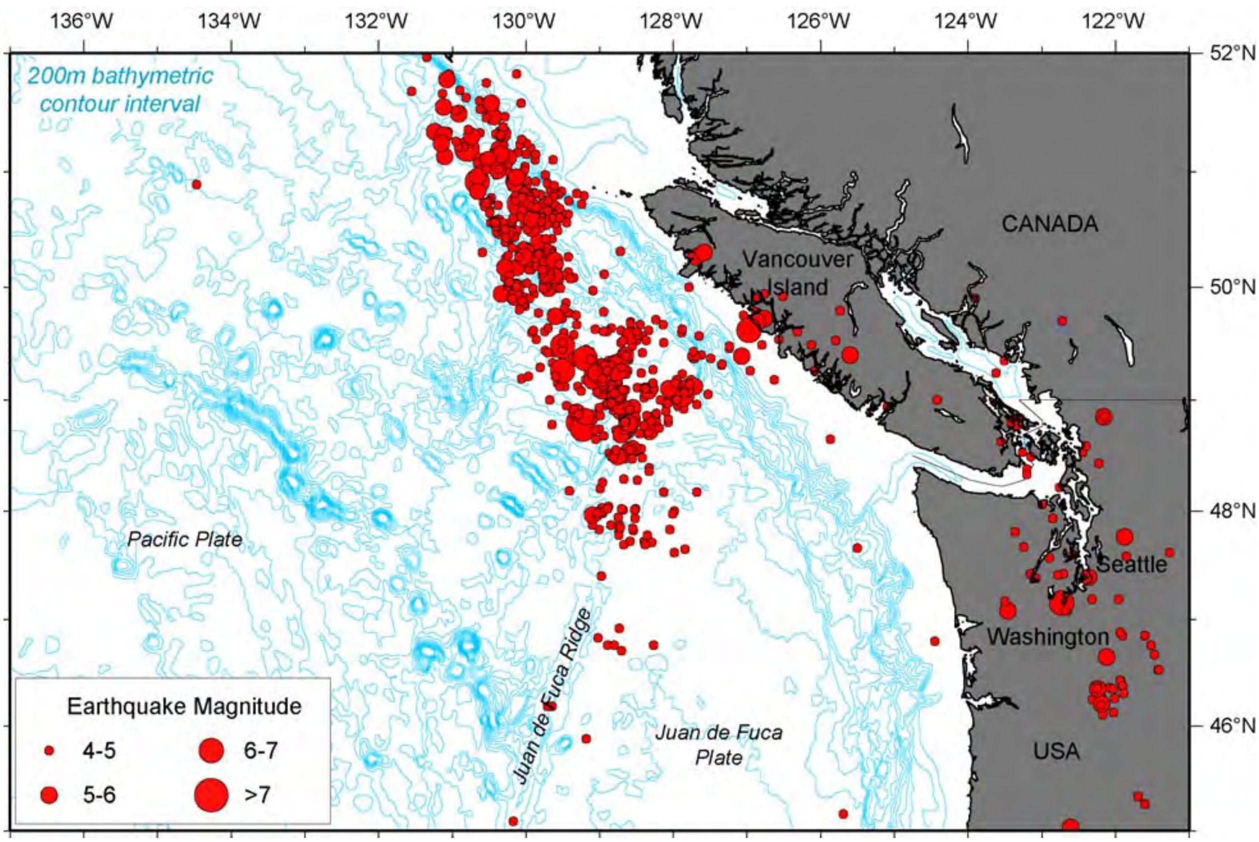
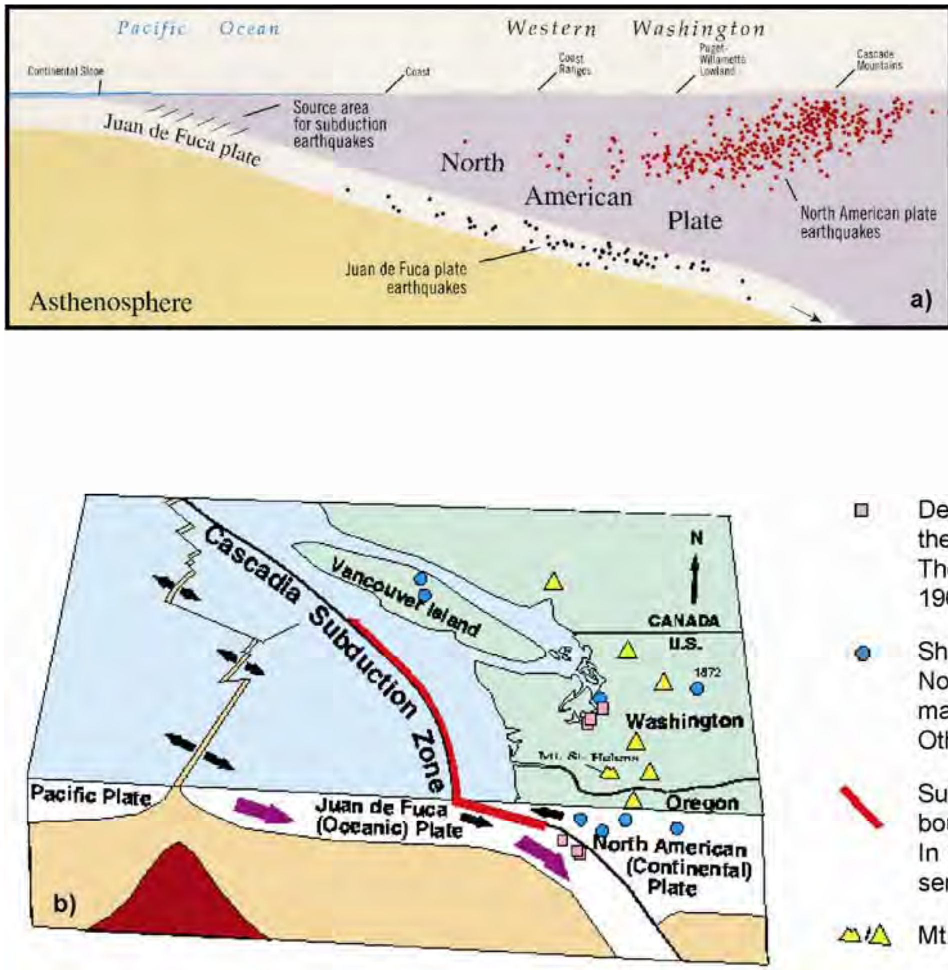


Figure 3-6: Earthquake epicenters (magnitude >4) in the Pacific Northwest (1973-2009). Compiled from the U.S. Geological Survey National Earthquake Center [www.neic.cr.usgs.gov/neis/epic/epic_rect.html]

Recent geologic findings indicate that earthquakes generated within the Cascadia subduction zone pose a significant hazard to urban areas of the Pacific Northwest, and that very large earthquakes occur every several hundred years (Atwater et al., 2005). Subduction zone earthquakes are generally thought to occur in three different parts of the subduction zone as shown in Figure 3-7a.



Cross-section of seismicity in the Cascadia subduction zone, showing the three regions where earthquakes generally occur:

1) in the deforming part of the North American plate,
2) within the down-going Juan de Fuca plate, and
3) at the contact between the two plates.

□ Deep earthquakes (40 miles below the Earth's surface) are within the subducting oceanic plate as it bends beneath the continental plate. The largest deep Northwest earthquakes known were in 1946 (M7.1), 1965 (M6.5) and 2001 (M6.8).

● Shallow earthquakes (<15 miles deep) are caused by faults in the North American Continent. The Seattle fault produced a shallow magnitude 7+ earthquake 1,100 years ago.
Other magnitude 7+ earthquakes occurred in 1872, 1918 and 1946.

Subduction earthquakes are huge quakes that occur when the boundary between the oceanic and continental plates ruptures. In 1700, the most recent Cascadia Subduction Zone earthquake sent a tsunami as far as Japan.

△/△ Mt. St. Helens and Other Cascade Volcanoes

Figure 3-7. Earthquake distribution in the Cascadia Subduction Zone.
From http://www.ess.washington.edu/SEIS/PNSN/INFO_GENERAL/platecontours.html

Geohazards associated with seismicity and surface fault rupture are discussed in Section 4.4 of this report.

3.2.4 Stratigraphy

No stratigraphic information from the project site was found in the literature. However, geologic studies have been conducted on nearby Marrowstone Island (Sinclair et al., 1994; Pessl et al., 1989). The stratigraphy exposed on Marrowstone Island consists of numerous Late Quaternary Glacial units overlying Late Eocene Sandstone units, as described below. Stratigraphic units include the following in order of increasing age:

- **Q_{vr}**, Glacial (Vashon) Recessional Drift (Pleistocene, Fraser Glaciation) - Comprising unconsolidated gravel, with sand, silt and clay. Recessional outwash, ice contact stratified drift and some ablation till deposited during and just after the retreat of the Vashon-age ice sheet. Thickness ranges from 0 to 1m.
- **Q_{vt}**, Glacial (Vashon) Till (Pleistocene, Fraser Glaciation) - Comprising sand, silt, and clay. Poorly sorted detritus deposited directly by the Vashon age ice-sheet. Silt, sand, and clay in varying proportions constitute a coherent to friable, moderately to highly dense matrix in which coarser components (pebbles, cobbles, and boulders) are firmly embedded. The till is typically massive but contains isolated lenses of sand, silt, and gravel. Thickness ranges from 0 to 30m.
- **Q_{va}**, Glacial (Vashon) Advance Outwash (Pleistocene, Fraser Glaciation) - Sand, gravel, silt, and clay deposited by meltwater flowing from the advancing ice margin of the Puget Lobe glacier of Vashon age. Moderate to well sorted, distinctly stratified, light gray to tan, medium and coarse sand and pebbly sand containing minor amounts of fine sandy silt and scattered lenses and layers of pebble/cobble gravel. Cross stratification and cut and fill structures are common. Thickness ranges from 0 to about 50m or more.
- **T_m**, Marrowstone Formation (Late Eocene) - Sandstone, mostly orange-brown to gray, friable, thin to thickly layered, blocky, contorted, and highly fractured interbedded with siltstone, mudstone, some occasional silty claystone and minor shales. Orange, calcareous sandstone concretions and concretionary lenses are common in Marrowstone Island outcrops. Clastic dikes and sills, 0.1 to 0.5m thick are exposed in the unit on the west side of Griffith Point. Thickness is about 250m.
- **T_q**, Quimper Sandstone (Late Eocene) - Sandstone, green-gray, fine to medium grained, hard, poorly sorted, massive, extensively fractured, feldspathic. Most commonly massive in character but includes some thin bedded to laminated sections and is occasionally cross bedded. Thickness is approximately 200m.
- **T_{sb}**, Scow Bay Formation (Middle Eocene) - Sandstone, light green-brown, very fine to medium grained, poorly sorted, subangular to subrounded, non-calcareous, and massive. The sandstone is interbedded with faintly bedded to massive dark gray to black siltstone. Locally contains rounded shale clasts and many round, calcareous concretions.

It is anticipated that the glacial units described above may locally be overlain by a thin veneer marine sediments, but that in most areas the glacial units have been scoured by strong tidal currents, removing fine grained sediments and leaving granular materials, cobbles, and boulders. Eocene bedrock units may be locally exposed on the seafloor and on coastal bluffs, particularly on steep slopes.

3.2.5 Depositional Environments and Glacial History

Puget Sound's striking terrain is largely the result of extensive glacial and tectonic activity. Other geologic processes, including weathering, erosion, and sedimentation, have further defined the region's landforms and physical characteristics. The shoreline environment is a complex mixture of beaches, bluffs, deltas, mudflats, and wetlands.

The geology of the Puget Sound area is essentially the result of two processes. The first is the subduction of the Juan de Fuca plate beneath the western margin of the North American Plate, as noted above. This process has been underway for millions of years and is responsible for the volcanic Cascade Mountains, the uplift of the Olympic Mountains, the mountains along western Vancouver Island and the depression of Georgia Basin and Puget Sound Lowlands. The second process shaping the regional geology was the advance and retreat of large ice sheets. The last glacial advance, known locally as the Fraser Glaciation, started about 26,000 years ago. It was associated with an ice sheet about 110km wide and 1,000m thick at the latitude of Seattle (Figure 3-8), which extended about 300km south of the Canadian border.

Figure 3-8 shows the extents and thicknesses of the Juan de Fuca and Puget Lobes during the maximum advance of the last (Fraser) glaciation based on marginal glacial deposits and ice-flow directional indicators [Porter and Swanson, 1998]. At the location of the SnoPUD site the maximum ice thickness during the Fraser Glaciation was approximately 1,200m. Based on radiocarbon dates of organic matter above and below glacial till deposits of the Fraser Glaciation, the advancing ice arrived at a site approximately 100km north of the SnoPUD site about 19,000 years ago. An ice sheet then covered the region for several thousand years before retreating to the north. The retreating ice vacated the site area about 16,000 years ago (Swanson and Caffee, 1999). From these dates, the Fraser ice sheet would have covered the SnoPUD site for about 2500 years, and the area was ice-free by 16,000 years ago.

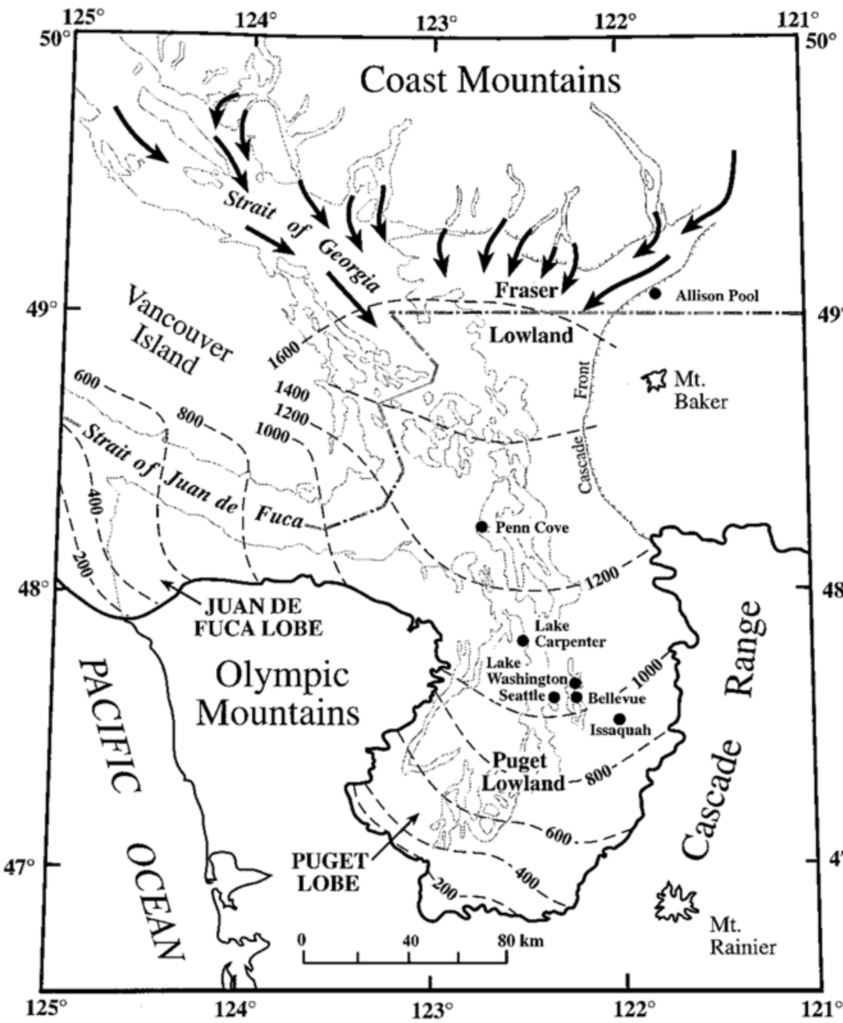


Figure 3-8. Map of Northwestern Washington and southwestern British Columbia
This figure shows the extent of the Cordilleran Ice Sheet during the maximum advance of the last (Fraser) glaciation [Porter and Swanson, 1998]. Contours (m) on the Puget Lobe are based on Thorson (1980); other contours are inferred from ice-flow directional indicators and upper ice limits in adjacent mountains. Bold arrows indicate inferred flow direction of ice moving southeast along the Strait of Georgia and issuing from fjord valleys in the Coast Mountains of British Columbia. Black dots are radiocarbon sample localities and sites discussed in Porter and Swanson (1998).

Because of the geologic processes shaping the straits of the Pacific Northwest, the passages have relatively flat seafloors with numerous narrow, deep channels. Rivers of ice flowed out of the Vancouver Island Ranges to the west and the Coast Mountains to the east, coalescing into a single glacier in the Georgia Basin. The composite glacier flowed southeastward and southward, with a finger escaping westward to the sea through the structural low of the Juan de Fuca Strait. Within the interior fjords, the glaciers cut troughs up to 365m deep in the pre-existing topography, and then mantled this new surface with glacial till and outwash deposits as the ice melted back to the north. The retreating ice sheet exposed landforms shaped by glacial processes, leaving a geomorphic record that clearly shows North-South Lineaments (Figure 3-9).

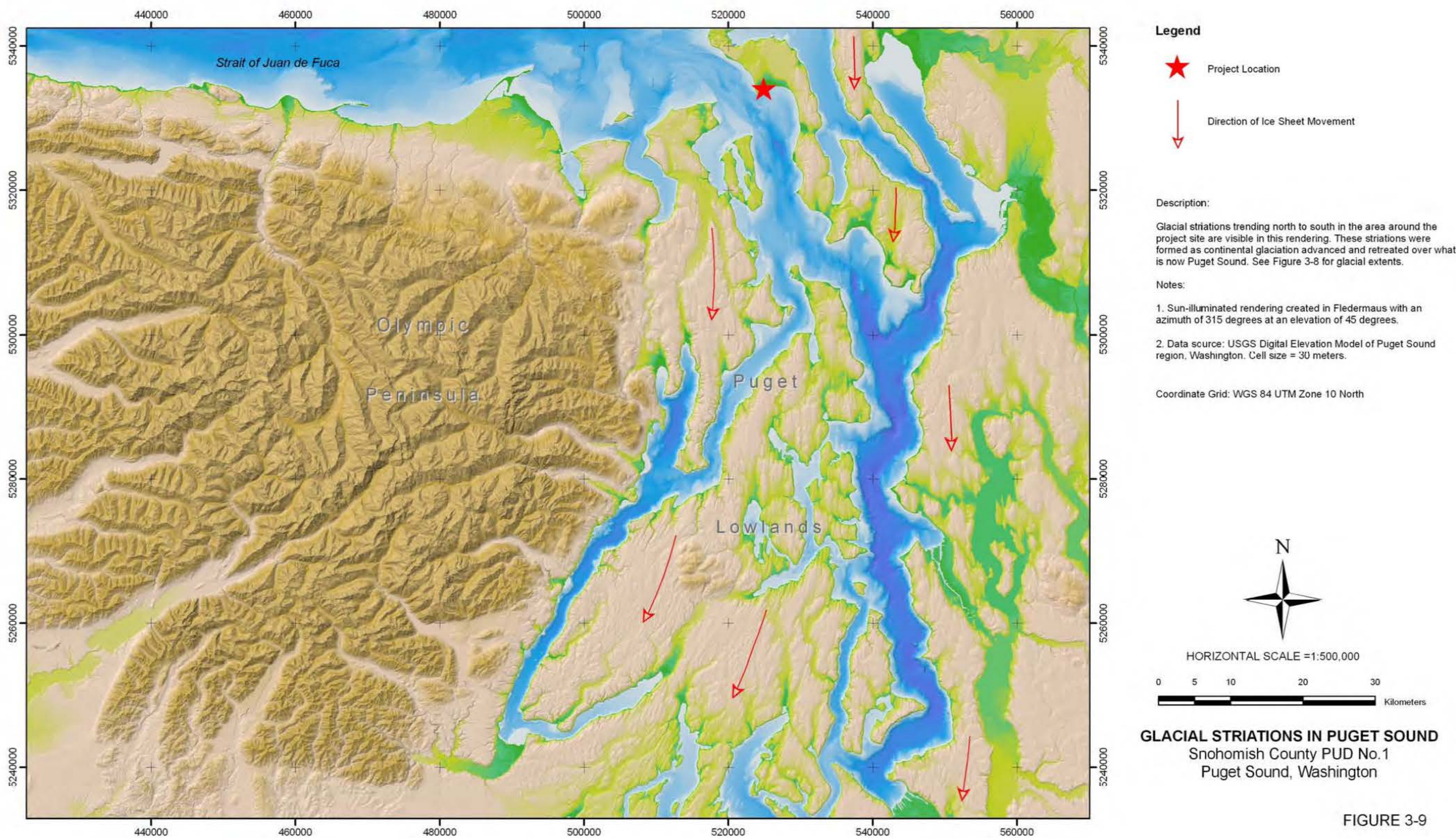

Strait of Juan de Fuca
Olympic
Peninsula
Puget
Lowlands
440000
460000
480000
500000
520000
540000
560000
5340000
5320000
5300000
5280000
5260000
5240000
Legend
Project Location
Direction of Ice Sheet Movement
Description:
Glacial striations trending north to south in the area around the project site are visible in this rendering. These striations were formed as continental glaciation advanced and retreated over what is now Puget Sound. See Figure 3-8 for glacial extents.
Notes:
1. Sun-illuminated rendering created in Fledermaus with an azimuth of 315 degrees at an elevation of 45 degrees.
2. Data source: USGS Digital Elevation Model of Puget Sound region, Washington. Cell size = 30 meters.
Coordinate Grid: WGS 84 UTM Zone 10 North
N
HORIZONTAL SCALE =1:500,000
0 5 10 20 30
Kilometers
GLACIAL STRIATIONS IN PUGET SOUND
Snohomish County PUD No.1
Puget Sound, Washington
FIGURE 3-9

Figure 3-9

As the glaciers thinned and retreated, ocean water filled the accessible troughs while land-locked troughs filled with fresh water to form large lakes. Runoff of sediment into these water bodies has covered the glacial deposits with younger post-glacial sediments. These are generally thin, ranging from a few centimeters up to a maximum of a few tens of meters in thickness. The glacial sediments have a wide range in grain size with the majority of the material being very fine sands, silts and clays, but with occasional cobbles and large boulders. The post-glacial sediments are largely fine-grained, although collapses of the steep walls of till around the coast occasionally carry gravel and boulders into the deeper water. The variations in grain size are transitional and thus do not have distinct boundaries.

3.2.6 Sediment Transport Mechanisms

Within our study area, strong currents are the primary mechanism for sediment transport. The size and physical properties of sediments are also fundamental to understanding the sedimentary mechanics by which material is transported and ultimately deposited.

As shown in Table 3-1 below, there is a direct relationship between current strength and sediment type that can be transported by currents.

Table 3-1. Relationship between Current Strength and Grain Size Moved into Suspension

Current strength (kts)	Maximum grain size moved into suspension
>1.25	Soft silty clayey sediments
>2.5	Loose to compact fine to medium sands
>3.1	All sediments

As a result of strong currents, sand-waves may be observed in parts of the Strait of Juan de Fuca. In these areas, special care should be taken during installation operations to avoid cable suspensions and to ensure proper burial. Due to the mobile nature of these features, extra armoring may also be planned to further protect the cable as it may subsequently become exposed.

In the nearshore areas of interest to this project, severe storm fronts and related storm waves may also participate in the sediment transport process. It is important to note that storm surges have been associated with slope failure that have damaged submarine cables, as observed in 1982 offshore Makaha (Hawaii) during the passage of Hurricane Iwa.

In addition, mass movement processes (such as slumps, slides, and debris flows) sometimes occur where slopes are steep and where rocks or sediments are sufficiently weak. Slumps and slides are down slope movements of large sediment blocks along discrete shear planes or only a few well-defined slippage planes, respectively [Kennett, 1982]. They generally occur where seabed gradients are great enough to cause instability and in areas associated with high sedimentation rates. Because of steep slopes and relatively high earthquake activity, slides and slumps sometimes occur along submarine slopes in the Pacific Northwest. The cable route should be designed to avoid the steepest slopes mapped during the SnoPUD survey. Designing the cable route perpendicular to the steepest parts of the slope may limit the exposure to possible mass-wasting events.

4.0 CHARACTERIZATION OF THE TURBINE SITING AREA AND CABLE ROUTE

Section 4 presents the results of the 2009 Fugro surveys for the SnoPUD Project, and is organized as follows: Section 4.1 presents an overview of site conditions. Section 4.2 focuses on data chart and data example descriptions. Section 4.3 provides site characterization information. Section 4.4 presents an evaluation of geohazards.

4.1 OVERVIEW

The site area is on the east side of Admiralty Inlet adjacent to Whidbey Island. Tectonic and glacial processes are largely responsible for shaping the physiographic setting, which consists of a north-west trending slope and channel with locally steep and irregular bathymetry. Large cobbles, gravel, and boulders cover much of the seafloor, the result of glacial outwash debris that has been scoured by strong seafloor currents since the retreat of glacial ice from the region and rise of sea level between about 13,000 and 16,000 years ago. Finer-grained glacial outwash sediments may underlie the coarse, granular seafloor sediments currently covering the seafloor. The thickness of the glacial deposits in the Survey Area is unknown. Beneath the glacial outwash deposits are Eocene age strata of the Marrowstone, Quimper, and Scow Bay Formations.

Locally steep and irregular seafloor, strong currents, and seismicity pose the most significant geohazards to the facility. Volcanic and mass movement hazards also exist. Geologic hazards can be mitigated through appropriate engineering design and construction practices.

4.2 DATA MAPS AND CHARTS

4.2.1 Trackline Map

Figure 4-1 shows a trackline of the 2009 survey from the *Taku*, as well as the location of attempted grab samples.

Safety concerns and kelp limited the survey operations to water depths greater than about 8 meters (m). Therefore, a data gap exists within the inshore zone between the end of the survey lines and the beach.

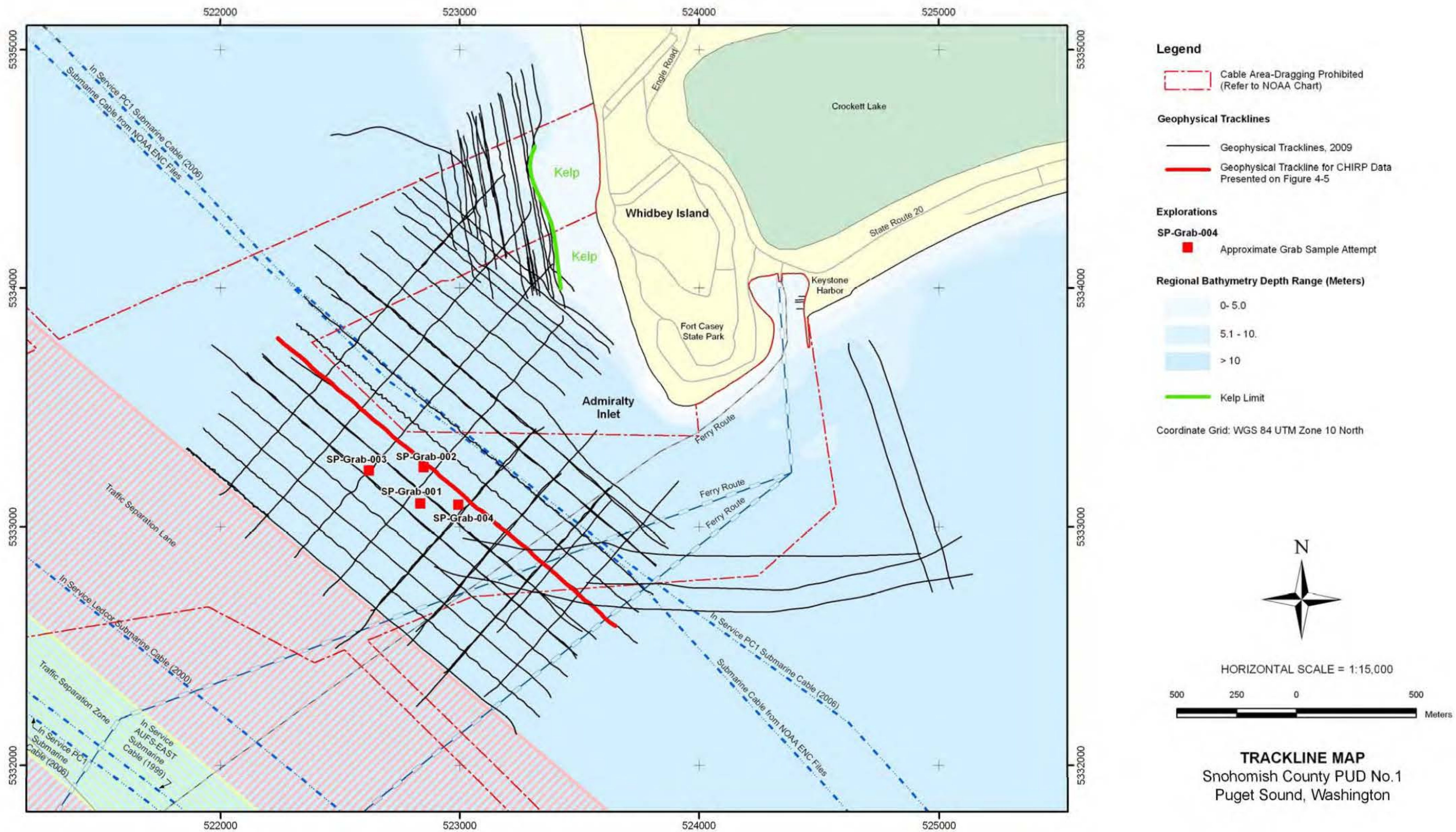

522000
523000
524000
525000
5335000
5334000
5333000
5332000
Legend
Cable Area-Dragging Prohibited (Refer to NOAA Chart)
Geophysical Tracklines
Geophysical Tracklines, 2009
Geophysical Trackline for CHIRP Data Presented on Figure 4-5
Explorations
SP-Grab-004
Approximate Grab Sample Attempt
Regional Bathymetry Depth Range (Meters)
0- 5.0
5.1 - 10.
> 10
Kelp Limit
Coordinate Grid: WGS 84 UTM Zone 10 North
In Service PC1 Submarine Cable (2006)
Submarine Cable from NOAA ENC Files
Kelp
Kelp
Whidbey Island
Crockett Lake
Engle Road
State Route 20
Keystone Harbor
Fort Casey State Park
Admiralty Inlet
Ferry Route
Ferry Route
Ferry Route
SP-Grab-003
SP-Grab-002
SP-Grab-001
SP-Grab-004
Traffic Separation Lane
In Service Ledcor Submarine Cable (2000)
Traffic Separation Zone
In Service PC1 Submarine Cable (2006)
In Service AUFS-EAST Submarine Cable (1999)
In Service PC1 Submarine Cable (2006)
Submarine Cable from NOAA ENC Files
N
HORIZONTAL SCALE = 1:15,000
500
250
0
500
Meters
TRACKLINE MAP
Snohomish County PUD No.1
Puget Sound, Washington

Figure 4-1

4.2.2 Multibeam Bathymetry Chart

Chart 1 presents the bathymetry acquired during the 2009 surveys along proposed cable route corridors and the proposed turbine area. The chart is contoured at a 2 m interval. Inshore limits of the survey were constrained by kelp in the nearshore (<8 to 10 m) zone (Chart 1). The maximum observed water depth was 86 m at the northwest portion of the area; the bathymetry shoals towards Whidby Island to the northeast. Bathymetry and seafloor conditions are described in greater detail in section 4.3.

4.2.3 Sidescan Sonar Mosaic Chart

A SSS mosaic was assembled for the SnoPUD survey area, which included the route development lines into the proposed alternate cable landing (Chart 2 and Figure 4-2).

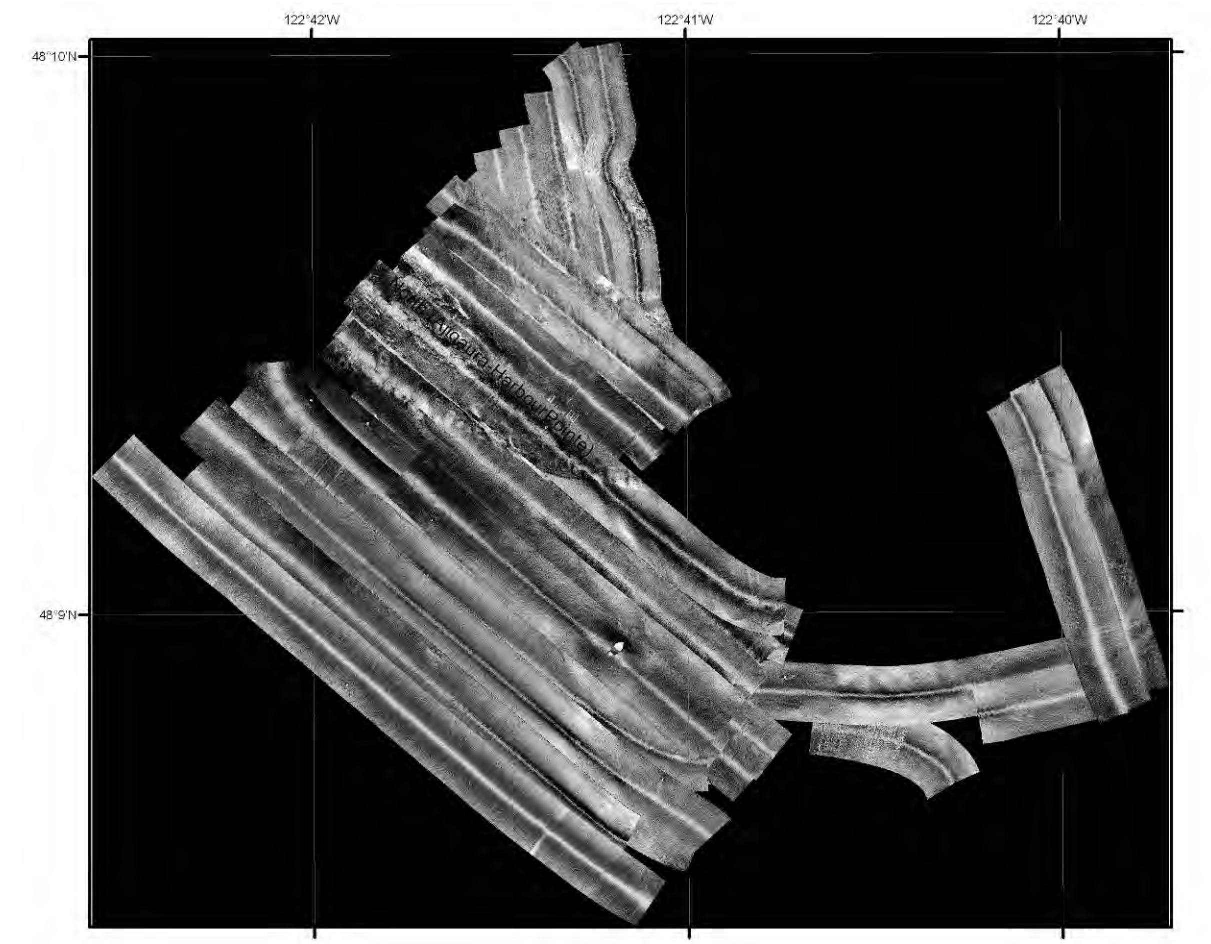


Figure 4-2: Sidescan sonar mosaic for the SnoPUD survey area

The area exhibits relatively moderate to high reflectivity from a uniform hard bottom, likely comprised primarily of cobbles and pebbles amidst frequent boulders and rocky outcrops (Figure 4-3).

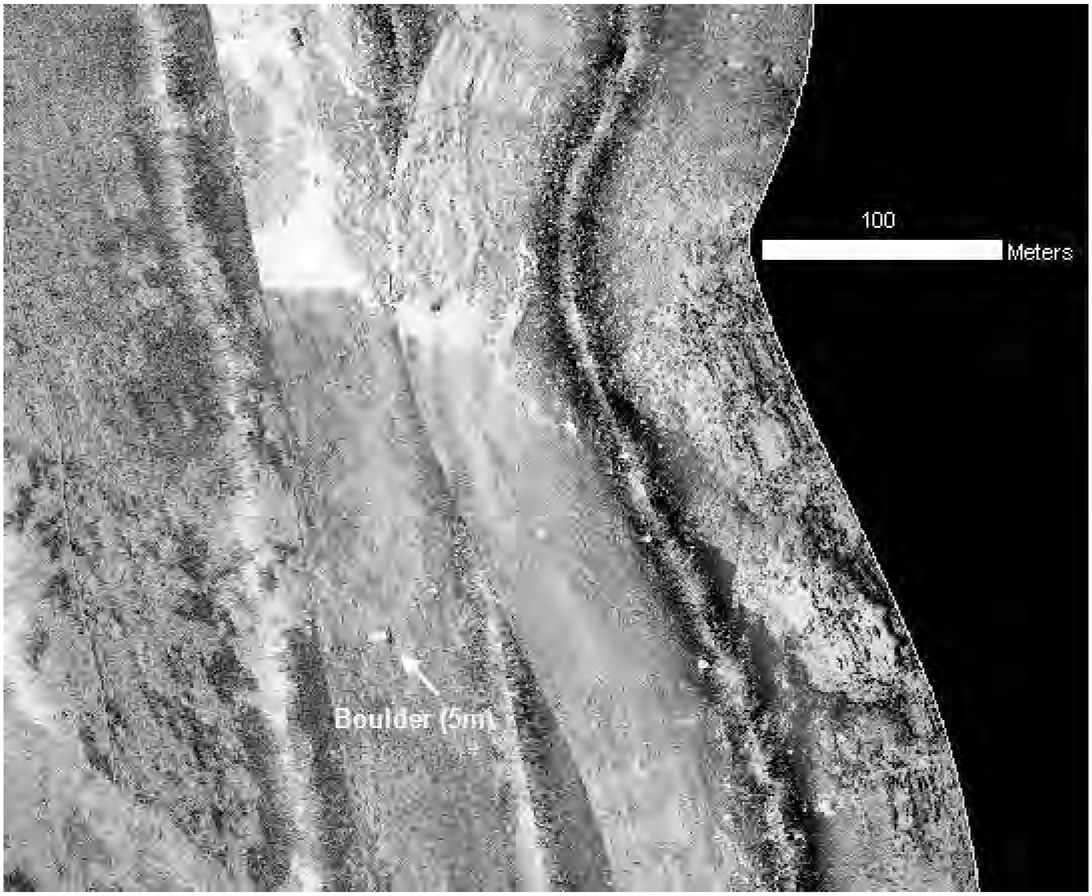


Figure 4-3: Rock outcrop located near the proposed SnoPUD cable route landing.

An area of sediment waves, or megaripples, was observed on the slope off the proposed landing site between approximately 35 and 50m water depth, which was detected in both the SSS imagery and the MBES bathymetry data. The sediment waves indicate bottom current flow through the area (Figure 4-4).

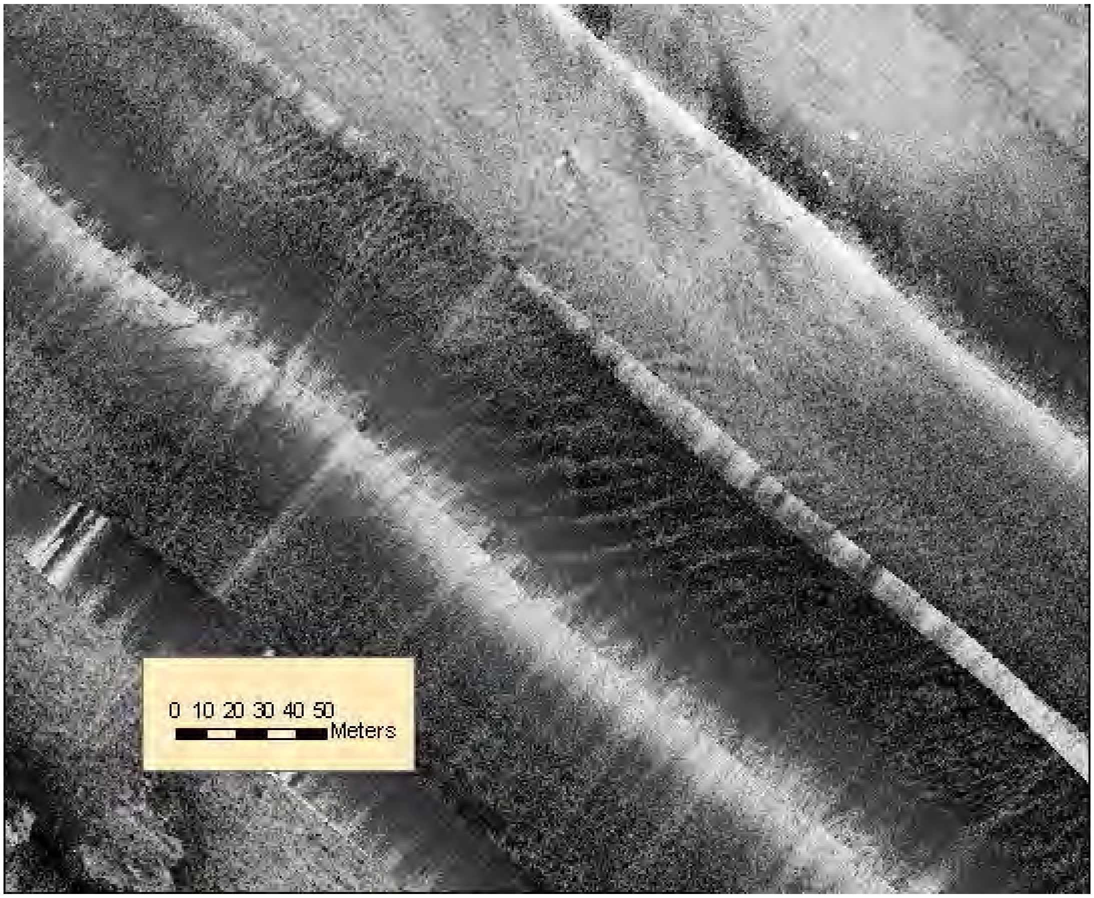


Figure 4-4: Sediment waves (megaripples) observed on the slope off the proposed cable route between 35 and 50m water depth.

Over one hundred and fifty targets were identified in the SSS data. Most of those targets are interpreted as rocks or boulders. These targets were measured in the Chesapeake SonarWiz software program and, where possible, shadows were measured to estimate the height of the target. It should be noted that not all targets have been individually identified and measured. In areas where these targets are abundant, a series of the larger targets have been tagged to estimate the approximate dimensions of targets in the area. A general comment about the size of targets was added to the area description (Table A-1 in Appendix A).

4.2.4 Seafloor Geology and Features Chart

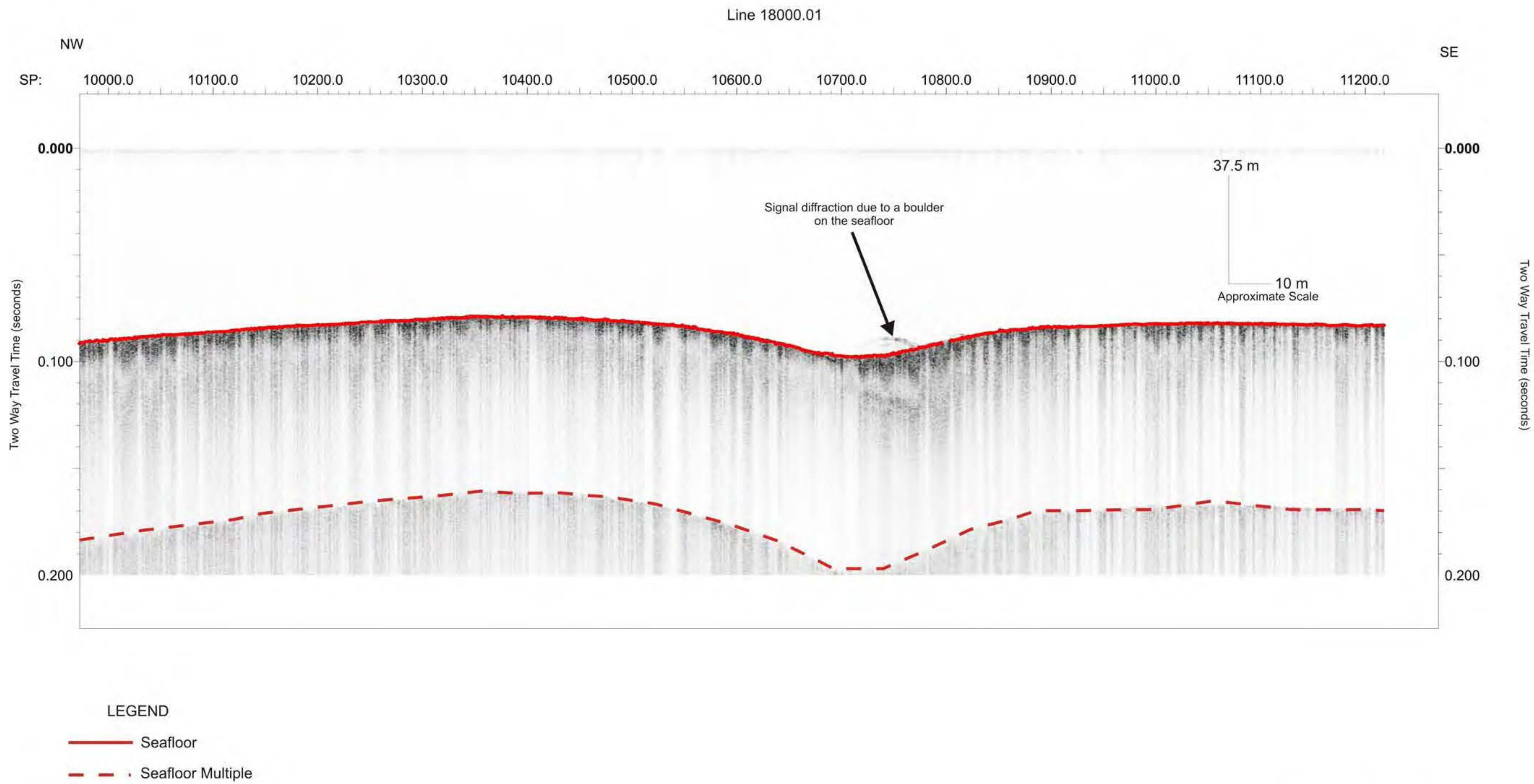
Chart 3 presents the interpreted seafloor geology and features for both the proposed cable route corridors and the proposed turbine area. As stated in section 4.2.1, inshore limits of the survey were constrained by kelp. The seafloor geology of the turbine site consists of areas characterized by ripples, cobbles and rock or glacial debris, as shown on Chart 3. Linear geologic features, ridges, and a possible slide or slump were identified in the SSS data and are also shown on the chart. These features are discussed in detail in section 4.3.1. The seafloor geology of the proposed cable route corridors is similar to the proposed turbine area, but includes an area interpreted to consist of coarse sand.

4.2.5 Geohazards and Constraints Chart

Chart 4 presents several datasets that summarize geohazards and potential constraints to the proposed project. Fault locations are from the state of Washington Department of Natural Resources. The faults are depicted as either 1) active in the last 15,000 years, or 2) active prior to 15,000 years ago. Areas of rock or glacial debris that could be constraints to project development are also shown on Chart 4. The possible slide or slump, kelp limit, and existing submarine cable routes are shown on Chart 4 (Geohazards and Constraints). Finally, a slope map is presented on the chart with areas characterized by slopes greater than 5 degrees denoted in pink. Steep, irregular slopes in these areas may result in cable spanning issues and difficulties in project construction. The data presented on this chart are discussed in greater detail in subsequent sections of the report.

4.2.6 Subbottom Data Examples

An example subbottom profile line is shown in Figure 4-5. This sample CHIRP line shows that little or no subseafloor penetration was achieved. This is because the seafloor is covered by granular materials that diffract the high-frequency energy from the CHIRP system. Strong currents have apparently removed fine grain sands, silts and clays from the seafloor, leaving coarse sands, gravels and boulders. Signal diffraction/sideswipe from a boulder is visible on Figure 4-5. Seafloor conditions are described in greater detail in Section 4.3.



SAMPLE CHIRP LINE WITH APPARENT BOULDER
Snohomish County PUD No. 1
Puget Sound, Washington

Figure 4-5

4.2.7 Magnetometer Data

The magnetometer was towed along the two development lines that were run from the SnoPUD site survey area into the alternate cable landing site located on the east side of the ferry dock on Whidbey Island. An additional line, run twice, in opposite directions, was run perpendicular to the as-laid position for the in-service PC-1 North telecommunications cable (Figure 4-6).

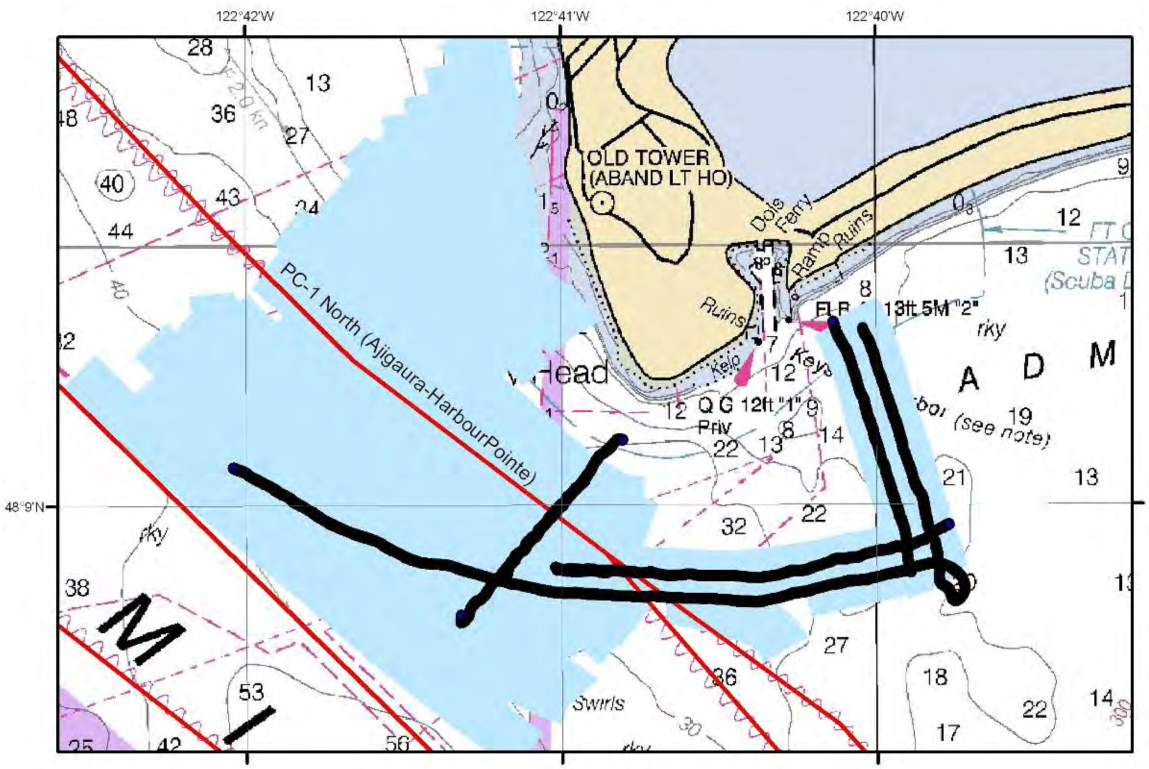


Figure 4-6: Magnetometer survey lines at the SnoPUD site (shown in black). The surveyed area is highlighted in blue, and the as-laid position for the in-service telecommunications cable, PC-1 North, is shown in red.

No significant magnetic anomalies were observed along the development route. However, a small anomaly was observed on the northeast-bound survey line run perpendicular to the in-service PC-1 cable. This anomaly occurred approximately 200m northeast of the as-laid position for the PC-1 cable; no other potential targets were observed in the SSS imagery at that location (Figure 4-7).

The position at the center of the anomaly is presented in Table 4-1. This anomaly was noted, but is not likely to represent the PC-1 cable, as the cable was detected in the SSS imagery near (within 25m) the as-laid position (Figure 4-8).

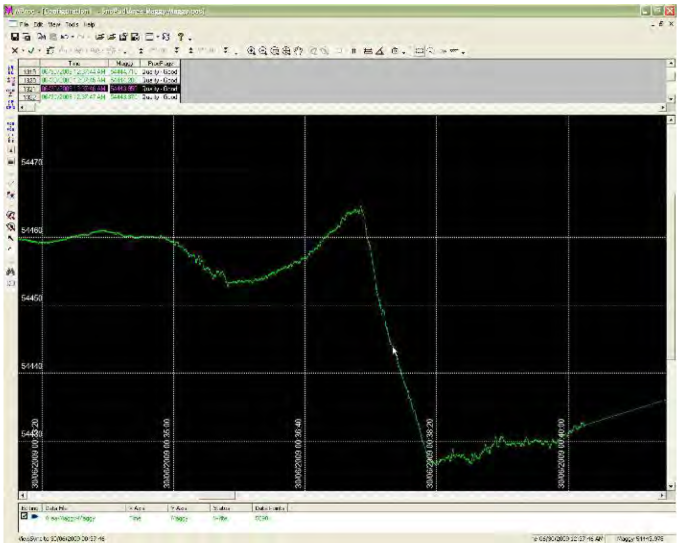


Figure 4-7: A small magnetic anomaly in the magnetic field was detected about 200m northeast of the PC-1 cable route.

Table 4-1. Coordinates for magnetic anomaly located about 200m northeast of the PC-1 cable route.

Magnetometer Contact	Easting (m)	Northing (m)	Latitude			Longitude			Magnetic Field (nT)
SP-MC-001	523654.2	5333138.7	48°	09.06'	N	122°	40.92'	W	54443.9

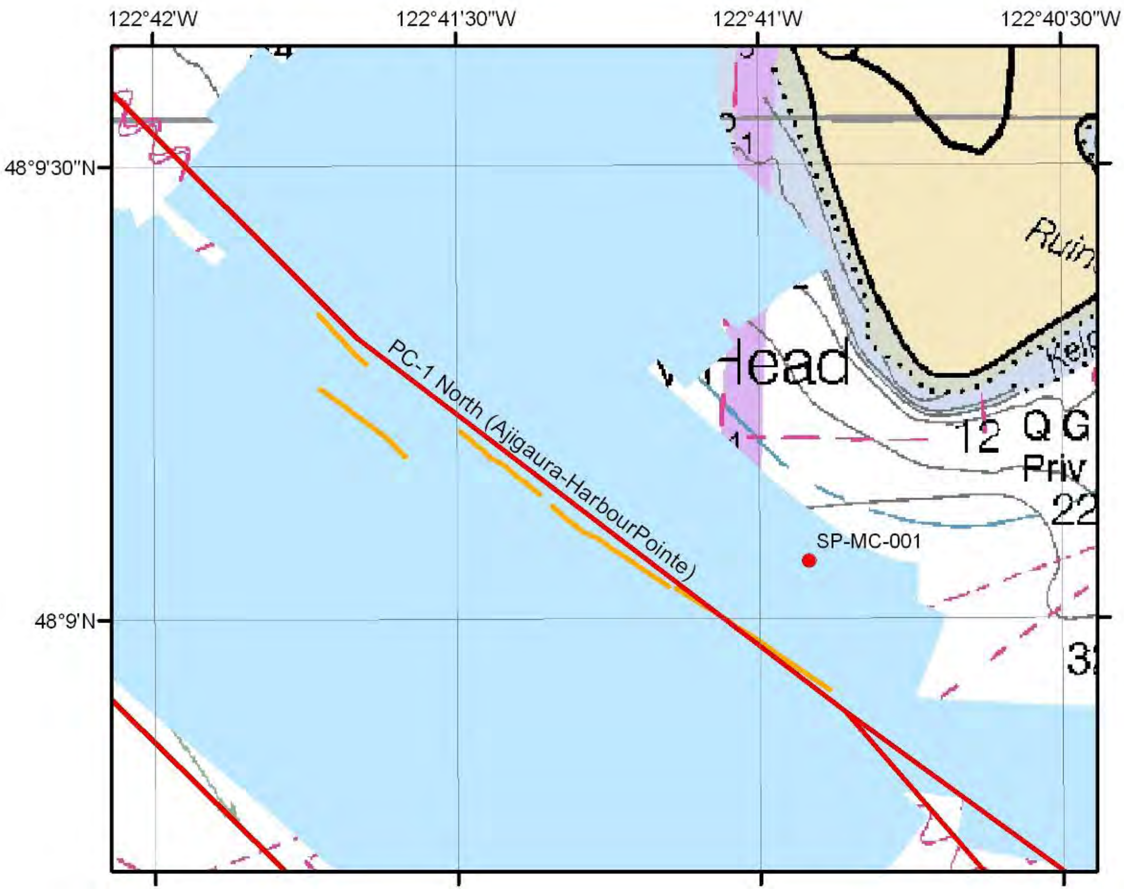


Figure 4-8: Map showing existing submarine cables in survey area. The in-service PC-1 cable, as detected in the SSS imagery is shown in orange and located very near the as-laid position (red). Note the sonar contact, SP-MC-001, north of the cable route.

4.3 TURBINE SITING AREA AND CABLE ROUTE SITE CONDITIONS

4.3.1 Bathymetry and Seafloor Features

The preferred cable route landfall is located on the northwest-facing coast of Admiralty Point on Whidbey Island. The shelf slopes gently to the west from the shore to about 20m water depth. Large rock outcrops extend out from the coast (Charts 2 and 3) while the surrounding seabed is littered with large rocks and boulders, most between 2 and 4m in size (Figure 4-9). The seabed is moderately reflective and is likely comprised primarily of cobbles and pebbles, as well as some coarse sand. Many of these larger targets have been designated on the accompanying charts, with measured dimensions, but it should be kept in mind that not all targets have been mapped.

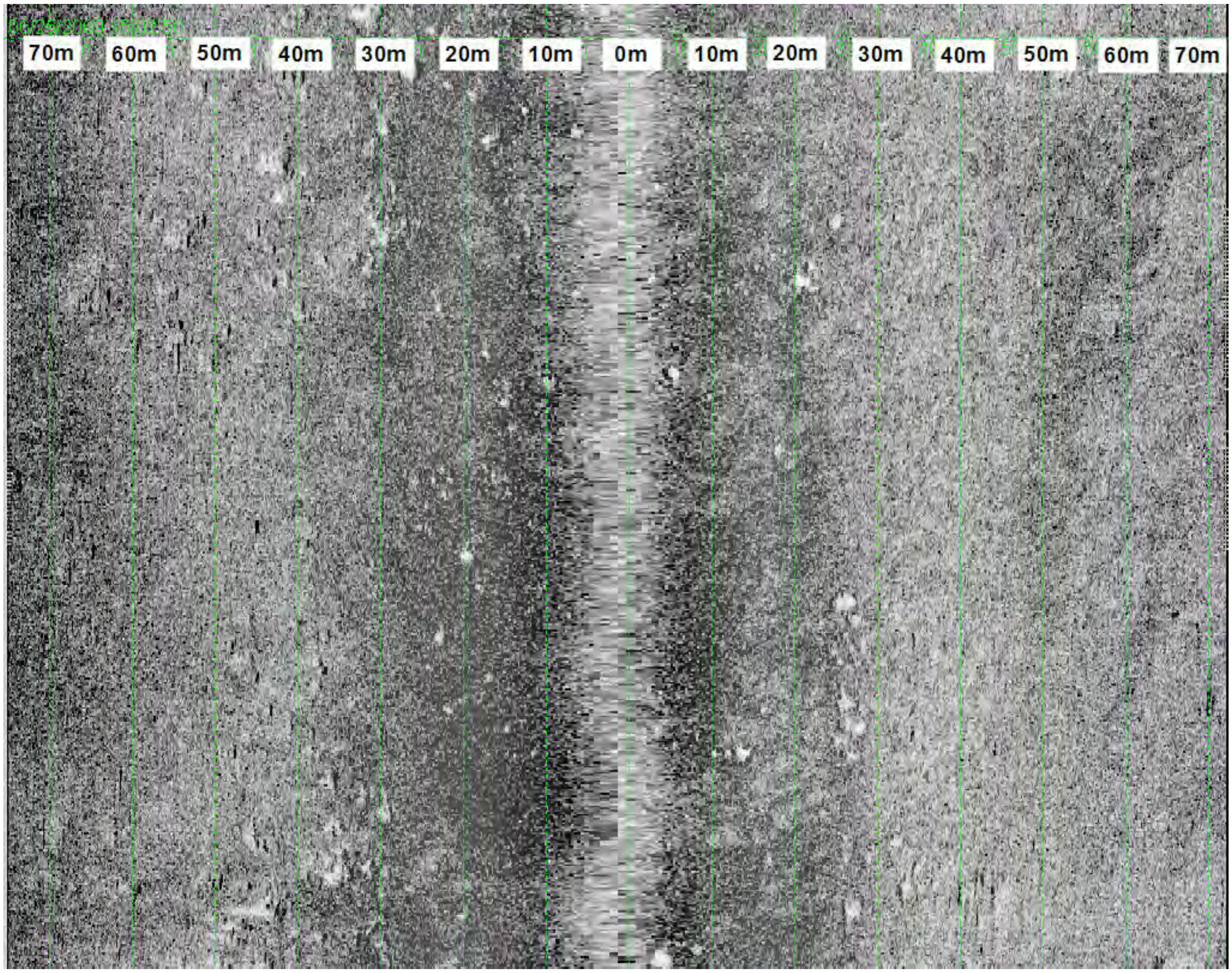


Figure 4-9. Sidescan sonar image from the northern corner of the survey area.
Shows scattered rocks and boulders (mostly 2 to 4m in size) typical of the shelf area down to approximately 40m water depth. Surrounding sediments are moderately reflective and are likely comprised of cobbles, pebbles and sand.

An area of disturbed sediments and deflected bathymetric contours is interpreted as possible shallow sliding or slumping south of the large rock outcrop in the northern corner of the survey area, between 15 and 20m water depth (Figure 4-10). Alternatively, the geomorphology of this area could be the result of glacial and glacial outwash processes.

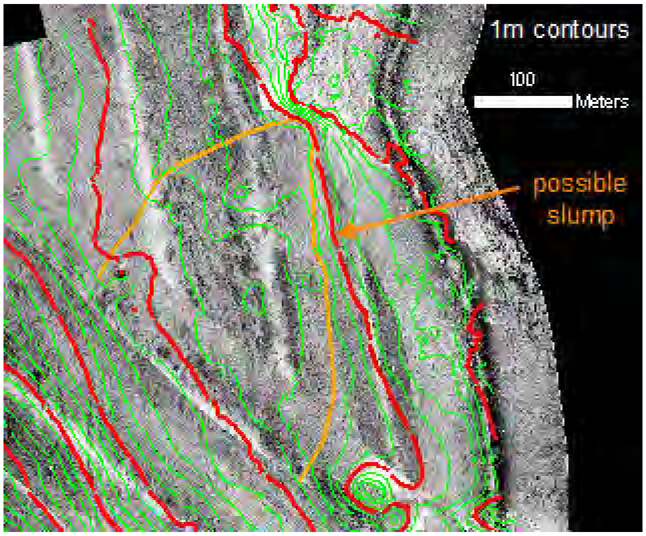


Figure 4-10: Sidescan sonar image showing disturbed sediment and deflected contours. These are interpreted as an area of possible slumping or sliding between 15 and 20m water depth.

The seabed deepens moderately to steeply between 20 and about 70m water depth towards the southwest. An area of sediment waves or megaripples is located towards the southeastern corner of the slope, between 35 and 50m water depth (Figure 4-11). The megaripples in this area have a wavelength of about 8m and are about one meter in height. Megaripples typically form in areas of oscillating water movement resulting from wave and tidal action. The presence of these features in cobbles at these depths suggests significant bottom current activity, as documented by other studies and direct observations.

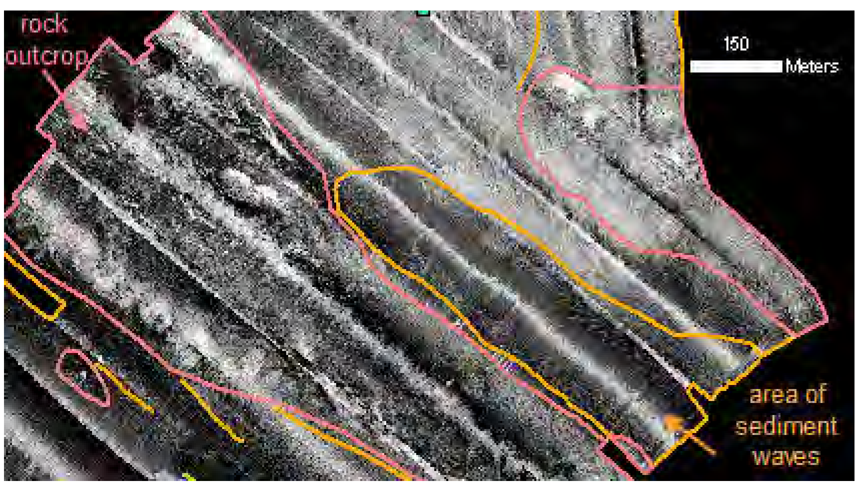


Figure 4-11: **Sidescan sonar image of inferred rock outcrop and sediment waves on the moderate slope off of the preferred landing site between 35 and 50m water depth.**

The seabed appears rockier across the survey area as the slope steepens towards the base of the slope, with large rock outcrops protruding primarily towards the western limit of the area (Figure 4-11 above). A west-trending channel extends across the survey area at the base of the slope starting at about 60m water depth. The details of this feature are best seen in the

MBES bathymetry data. The bed of this channel is very rugged and pitted with deep holes or gullies that are approximately 50m in diameter and 2 to 4m deep. The channel pinches out to the east as it abuts the slope off of Admiralty Point and deepens and widens to the west, reaching water depths of around 80m. The origin of this feature is not known but one theory is that currents flowing in through the Juan de Fuca Strait get blocked by Admiralty Point, forming swirls that scour the base of the slope. Another possibility is that the feature may be the result of glacial ice sheet recession and outwash processes (see section 3). Regardless of the origin, the channel traverses the survey area and thus will need to be crossed by the preferred cable route. Crossing as perpendicular to this feature as possible will minimize risk of damage to the cable from possible slumping or sediment movement.

A west-trending ridge crosses through the northeastern corner of the survey area and a northwest-trending ridge comes in from the southeastern corner of the survey area (Chart 1). Both ridges rise up to a minimum water depth of about 50m and drop off moderately to steeply to either side. This ridge correlates with the northwest projection of an unnamed fault located between two active splays of the Whidbey Island fault zone (Figure 3-5). In general, the seabed deepens gently towards the west and southwest except in the southwest corner of the surveyed area where the seabed shoals gently to a water depth of about 70m. Seabed sediments in the main survey area are moderately reflective and fairly uniform, indicating the same hard, cobbley seabed as on the slope towards the preferred landfall area (Chart 2). Current action has likely scoured away most of the sand and smaller pebbles, leaving primarily larger cobbles; however, for the most part, this area has considerably fewer large rocks and boulders. On the steep slopes of the ridges and on the rise in the southwestern corner of the survey area, scattered to abundant rock outcrops suggest that hard, underlying basement rock is exposed or very near the surface.

The proposed turbine location is situated on fairly flat and featureless seabed on the shoulder of the west-trending ridge near the center of the survey area, at about 64m water depth. The essentially flat seabed extends over an area about 100m in diameter. The seabed in the vicinity of the proposed turbine site is fairly uniform and moderately reflective (Figure 4-12).

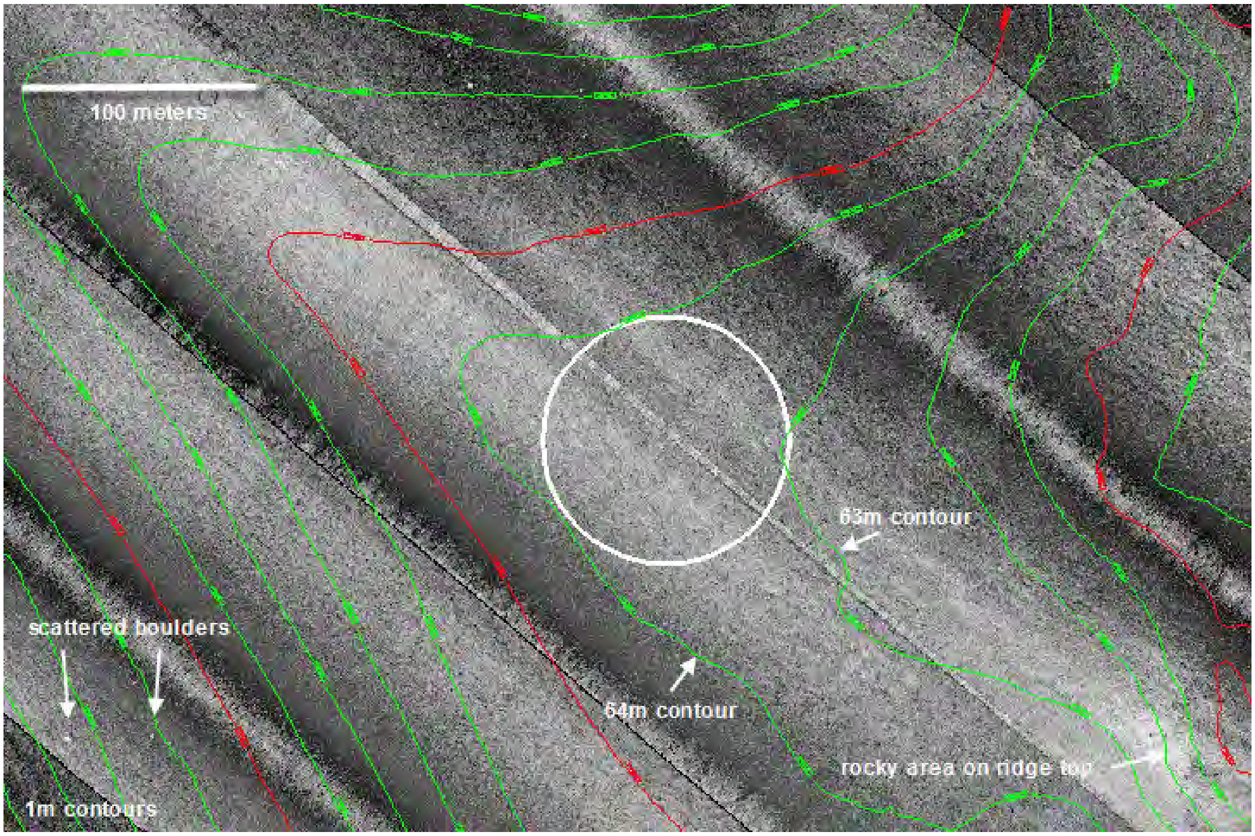


Figure 4-12. Sidescan sonar image in the vicinity of the proposed turbine location (white circle).

The terrain along the development route to the alternate landing site to the east of the Whidbey Island Keystone ferry terminal is also rugged. The route drops down the steep east-facing slope of the northwest-trending ridge located in the southeastern corner of the survey area before climbing a west-trending ridge located along the survey route (Chart 1). The seabed continues to be moderately reflective, with rocky outcrops on the steeper slopes of the ridges (Chart 2). As the route turns north to head into the landing, some sediments of lighter reflectivity are located along the eastern edge of the corridor. This sediment patch is wispy around the edges, as though deposited by current activity and is likely to be very thin. An area of sediment waves, megaripples with a wavelength of approximately 4m and amplitude of less than 1 meter, is located just to the south (Figure 4-13). The reflectivity of the seabed sediments becomes slightly less reflective towards the landfall in less than 20m of water, suggesting the sediments may be composed of a greater percentage of pebbles and sand than cobbles.

Figure 4-13. Sidescan sonar data showing evidence of current activity along the development route on the approach to the alternate landing site.

4.3.2 Seafloor Sediments

Grab sampling operations in the SnoPUD area did not recover any samples from the seabed, so the sidescan imagery could not be directly ground-truthed. The lack of recovery is likely because the seafloor is covered by gravel, cobbles and boulders, as observed on ROV video and SSS data.

The seafloor sediments, cobbles, and boulders are believed to be of glacial origin. Glacial moraines and outwash sediments are common in the Puget Sound Area, a product of the recent geologic past (see Section 3). Glacial moraine and outwash deposits commonly include poorly sorted silt, sand, gravel, cobbles, and boulders. Given the strong currents in Admiralty Inlet, the silt and fine sand have likely been removed, leaving behind coarse sand, gravel, cobbles, and boulders.

4.3.3 Near-Seafloor Currents and Erosion

As previously mentioned, strong currents are known to occur in the area, which is why the tidal turbine project has been proposed for this area. Seafloor erosion, transport, and removal of fine grained sediments have occurred, leaving only granular sediments, cobbles, and boulders.

4.3.4 Interpreted Geotechnical Conditions

The interpreted geotechnical conditions consist of a layer of glacially-derived reworked granular sediments, cobbles, and boulders of unknown thickness overlying Eocene age bedrock. It is possible that subseafloor outwash materials include a significant fraction of fine grained sediments of the Vashon Till and Outwash materials, as has been observed in other areas.

4.4 GEOHAZARDS AND CONSTRAINTS

Major natural hazards which threaten the Pacific Northwest region are storms, floods, mass movement (rockfalls, slumps, slides, and debris flows), earthquakes, volcanic hazards, and tsunamis. Storms, landslides and floods are the most frequent causes of natural disasters and have historically caused significant casualties and property damage. However, earthquakes and volcanic eruptions have caused the most serious natural disasters. In Section 4.4 we address seismicity, tsunami, surface fault rupture, mass movement, volcanic hazards, liquefaction, and lateral spreading.

4.4.1 Seismicity

A seismic hazard is defined as the probable level of ground shaking associated with the recurrence of earthquakes. The assessment of seismic hazard is the first step in the evaluation of seismic risk, which also assesses other factors such as types of buildings and infrastructures, population density and land use. Frequent large earthquakes in remote areas result in high hazard but pose little risk, whereas moderate earthquakes in densely populated areas entail small hazard but high risk.

Subduction zones are the sites of some of the most destructive earthquakes on the planet. The maps showed in Figures 4-14 and 4-15 show seismic hazards in the Pacific Northwest region. Figure 4-14 was produced by the Global Seismic Hazard Assessment Program in 1999 [http://www.seismo.ethz.ch/GSHAP/], and assesses the likely level of short-period ground motion from earthquakes in a 50-year time window. This figure shows that areas of highest hazard occur throughout the Aleutians and southern Alaska, all of which overlie subduction zones. High hazard areas also occur along the west coast of Washington, which overlie a somewhat less-active subduction zone. Infrequent, very large subduction zone earthquakes have been documented in the region (Atwater et al., 2005). Figure 4-15 (USGS) assesses the likely level of peak ground acceleration with 2% probability of exceedance in 50 years as well [http://earthquake.usgs.gov/regional/pacnw/hazmap/]. This figure shows that areas of highest hazard are concentrated in the Puget Sound area and the Olympic Peninsula.

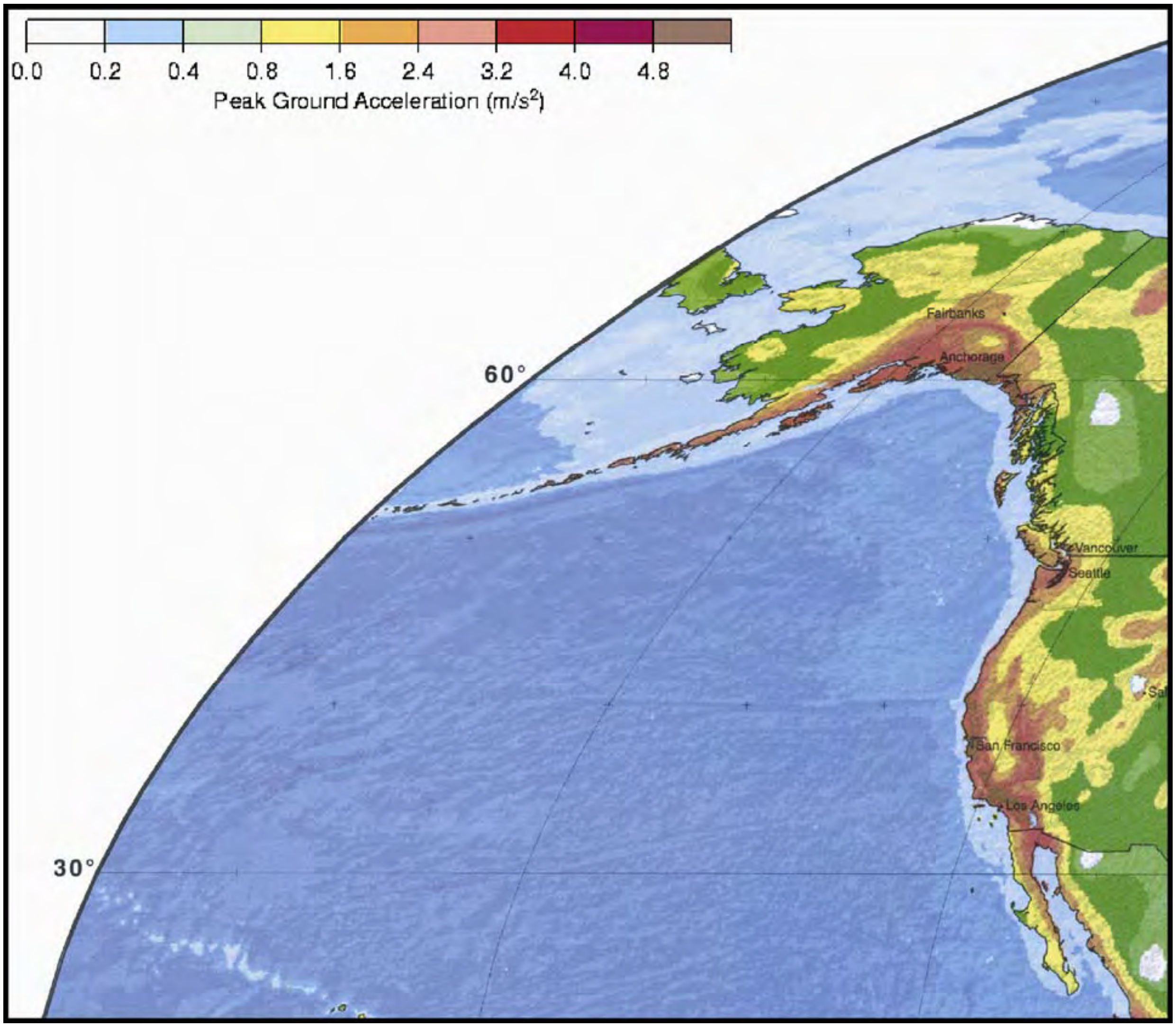


Figure 4-14: Seismic hazard map of the northeast Pacific Ocean [Global Seismic Hazard Assessment Program, 1999]. White to green corresponds to low hazard, yellow and orange correspond to moderate hazard, pink and dark pink correspond to high hazard, and red and brown correspond to very high hazard.

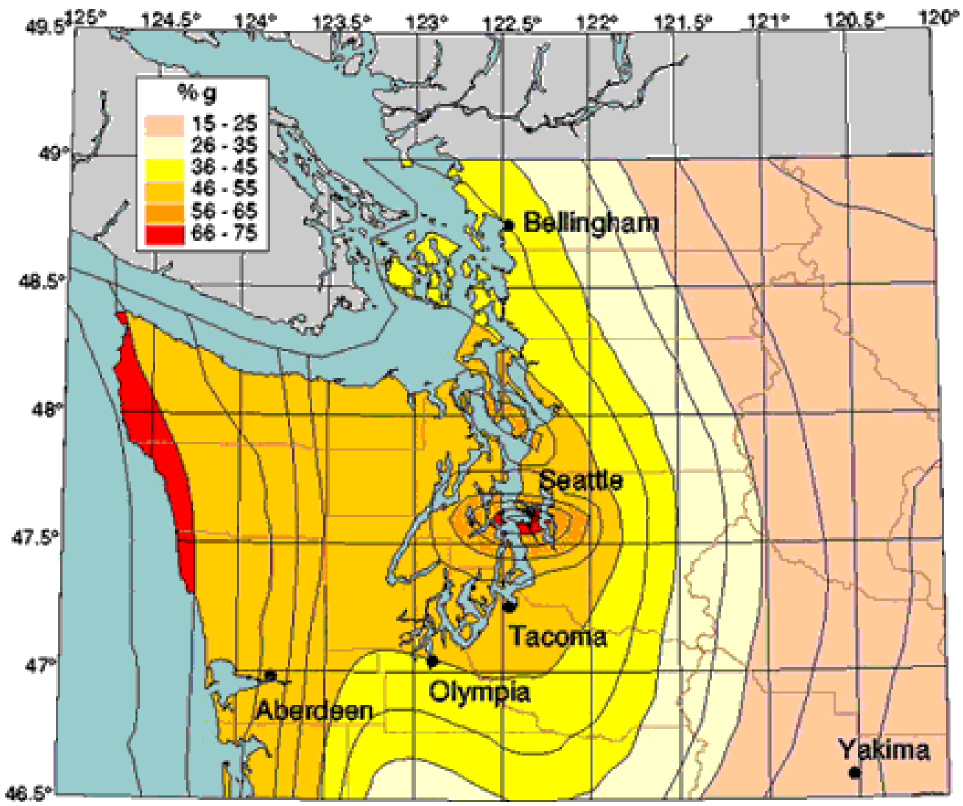


Figure 4-15. USGS Seismic hazard map of the Pacific Northwest. White to beige correspond to low hazard, yellow and orange correspond to moderate hazard, pink and dark pink correspond to high hazard, and red and brown correspond to very high hazard. [http://earthquake.usgs.gov/regional/pacnw/hazmap/]

4.4.2 Tsunami

Tsunami (from the Japanese word tsunami meaning "harbor wave") are often mistakenly called "tidal waves" when, in fact, they have nothing to do with tidal action. Rather, tsunami are seismic sea waves caused by earthquakes, submarine landslides and infrequently by eruptions of island volcanoes. During a major earthquake, the seafloor can move by several meters and an enormous amount of water is suddenly set into motion, sloshing back and forth for several hours. The result is a series of waves that race across the ocean at speeds greater than 800 km/hr. The energy and momentum of these transoceanic waves can transport them thousands of kilometers from their origin before slamming into far-distant islands or coastal areas.

There is high seismic activity along the Pacific and North American Plate boundaries and a history of Pacific-wide tsunami occurring every 10 to 20 years. In particular, the Washington coast has been largely affected by several Pacific-wide events. Therefore, although there are few historical reports of cable faulting due to a natural event in the vicinity of our study area, there are numerous damage reports for other regions along the West Coast of the U.S., suggesting that there exists the possibility of a tsunami (or earthquake) occurring during the lifetime of the facilities.

Should a tsunami originate in an area remote from the facilities, water movement would likely pose little hazard to the facilities. The greatest danger to the facilities is not from the water motion of the tsunami waves, but from the effect that earthquake-induced slumping or the large waves may have on loose sediments on the seafloor. Sediment movements due to slumping are more likely near the earthquake, although slumping due to wave action can occur along any continent and damage to shore-end installations from a tsunami is a possibility, as illustrated by the following examples.

On April 1, 1946, an earthquake occurred in the Aleutian Islands of Alaska. A Pacific-wide tsunami was triggered by the earthquake, which had a moment magnitude of 8.1, an epicenter at 52.8°N - 163.5°W and a focal depth of 25km. Before the tsunami dissipated it took the lives of more than 165 people and caused over $26 million in damage. One of the structures affected by the tsunami was the newly built Scotch Cap Lighthouse on Unimak Island, Alaska. At the lighthouse, five men lost their lives and the run-up reached 35m.

On March 28, 1964, an earthquake occurred in Prince William Sound, Alaska triggering a Pacific-wide tsunami. The earthquake had a moment magnitude of 9.2, an epicenter located at 61.1°N - 147.5°W and a depth of 23km. The earthquake, the local tsunami due to landslides and the regional tsunami were responsible for taking the lives of more than 122 people and causing over $106 million in damage. In Alaska, the death toll was 106 and there was $84 million in damage. Among Alaskan areas the run-up measurements varied from 24m at Blackstone Bay, 27m at Chenega, 9m at Valdez, and 6m at Kodiak. Outside Alaska, it took 5.4 hours for the first wave to arrive at Hilo, Hawaii, where a run-up of 3m was measured. Significant tsunami damage occurred on the west coast of Vancouver Island, particularly at Port Alberni. Another city outside Alaska that received measurable run-up was Crescent City, California, where a 4m run-up was recorded 4 hours after the tsunami was triggered. Even though the regional tsunami was very destructive the local tsunami also caused significant damage. The local tsunami was generated by landslides, which were triggered by the earthquake. At the Valdez Inlet, a large landslide triggered by the earthquake generated a tsunami that had a run-up measured at 67m in the inlet.

Because of past killer tsunamis, which have caused hundreds of deaths on the Island of Hawaii and elsewhere, the International Tsunami Information Center was created in 1965. This center issues tsunami warnings based on earthquake and wave-height information gathered from seismic and tide-gauge stations located around the Pacific Ocean basin and on Hawaii. In addition, the US West Coast/Alaska Tsunami Warning Center (WC/ATWC) was established in Palmer (Alaska) in 1967 as a direct result of the great Alaskan earthquake of 1964.

In 1982, the WC/ATWC's area of responsibility was enlarged to include the issuing of tsunami warnings to California, Oregon, Washington and British Columbia for potential tsunami-generating earthquakes occurring in their coastal areas. In 1996, the responsibility was again expanded to include all Pacific-wide tsunami sources that could affect the California, Oregon, Washington, British Columbia, and Alaska coasts.

Several federal and state agencies in the Pacific Northwest are contributing to tsunami hazard maps for local coastal communities. In our study area, the main risk of cable damage from a tsunami lies essentially at or close to the landing.

We present below the tsunami risk level based on historical records (since 1950) and data compiled by the National Geophysical Data Center (NGDC). These data show that only two (2) destructive tsunami source events have occurred in the area of the facilities (Table 4-2). The "tsunami source event" information indicates the source of the tsunami, which typically corresponds to the plate's boundaries where earthquakes are most common.

The NGDC database also provides tsunami "run-up" information, which gives the locations where tsunami effects were actually observed. It should be noted that some source events do not have run-up information; others have many locations where a run-up height was recorded. A compilation of the data available for our study areas reveals that 107 run-ups were observed in the Pacific Northwest since 1950. The tsunami run-up information is displayed in Figure 4-16.

Table 4-2. Tsunami source events in the vicinity of the cable route (1950 – 2007)

Year	Event Location	Position		Cause (*)	Earthquake Magnitude	Tsunami Run-up (m)
		Lat. (°)	Long. (°)			
1980	Washington, USA	46.20	-122.18	6	-	250
2004	Vancouver, CANADA	49.28	-128.77	1	6.6	0.05

Source: NGDC (http://www.ngdc.noaa.gov/seg/hazard/tsu_db.shtml)

(*) Cause of the tsunami

-1 = Unknown Cause
1 = Earthquake
2 = Questionable Earthquake
3 = Earthquake and Landslide
4 = Volcano and Earthquake
5 = Volcano, Earthquake, and Landslide
6 = Volcano
7 = Volcano and Landslide
8 = Landslide
9 = Meteorological
10 = Explosion
11 = Astronomical Tide

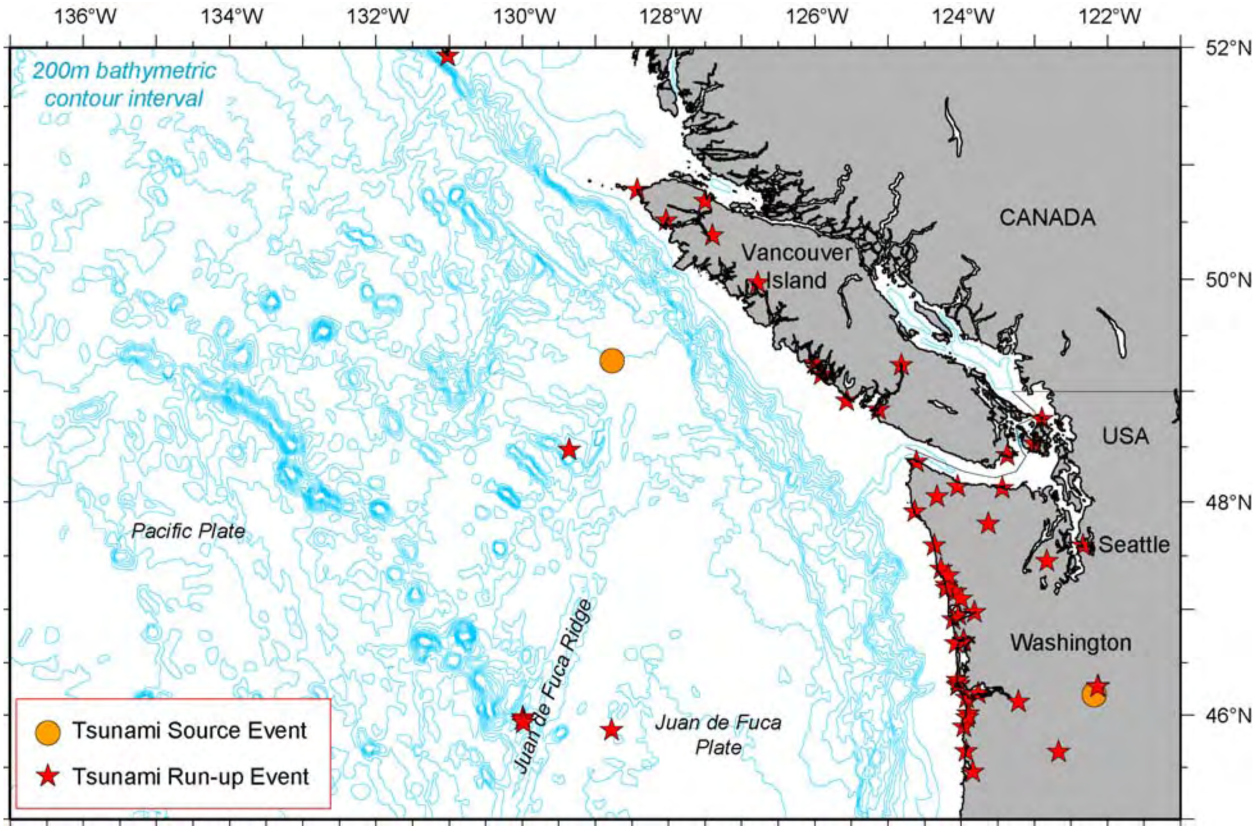


Figure 4-16. Tsunami source and run-up events in the Pacific Northwest Region.

4.4.3 Surface Faulting

As discussed in Section 3, the site is located between two mapped splays of the South Whidbey Island fault zone (Chart 4). Another short fault splay is located southeast of the survey area, and projects toward the steep slope in the northern part of the survey area (Chart 4). This splay is shown on State maps as being older than 15,000 years in age. Consequently, the hazard posed by surface fault rupture within the survey area is considered low.

4.4.4 Volcanic Activity

As with earthquakes, volcanic activity is linked to plate-tectonic processes. Most of the world's active above-sea volcanoes are located near convergent plate boundaries where subduction is occurring, particularly around the Pacific Basin. Much more volcanism, however, takes place unseen beneath the ocean, mostly along the oceanic spreading centers, such as the Juan de Fuca Ridge. Both subaerial and submarine volcanic hazards are discussed below.

Slow subduction beneath Washington has resulted in the formation of the Cascade volcanoes (Figure 3-7). Although they are historically less active than other arc volcanoes, the 1980 eruption of Mount St. Helens (in Washington State) showed their destructive ability. Subduction-zone volcanoes like Mount St. Helens typically erupt with explosive force because the magma is too stiff to allow easy escape of volcanic gases. The trapped gases expand during ascent before the pressure is suddenly released in a violent eruption. Hazards to the facilities from these volcanoes are restricted to tephra (volcanic ash) falls and lahars.

Tephra falls occur only during volcanic eruptions (Figure 4-17). They are commonly dispersed by winds over broad areas and the effects can be disruptive to cable route survey activities and cable installation activities. Clouds of fine tephra can block sunlight and greatly restrict visibility. Such clouds are commonly accompanied by frequent lightning.

Lahars (also called mudflows or debris flows) and floods commonly accompany eruptions, but can also occur during dormant periods when stability slowly declines as slopes are over-steepened by glacial erosion or as the strength of the rock is reduced due to chemical processes inside the volcano. Lahars are slurries of water and sediment (60% or more by volume) that look and behave much like flowing concrete. As they sweep down the steep sides of volcanoes, they have the strength and speed to flatten or bury everything in their paths. Lahars are restricted to valleys that originate at the volcano, but their effects can be very severe.

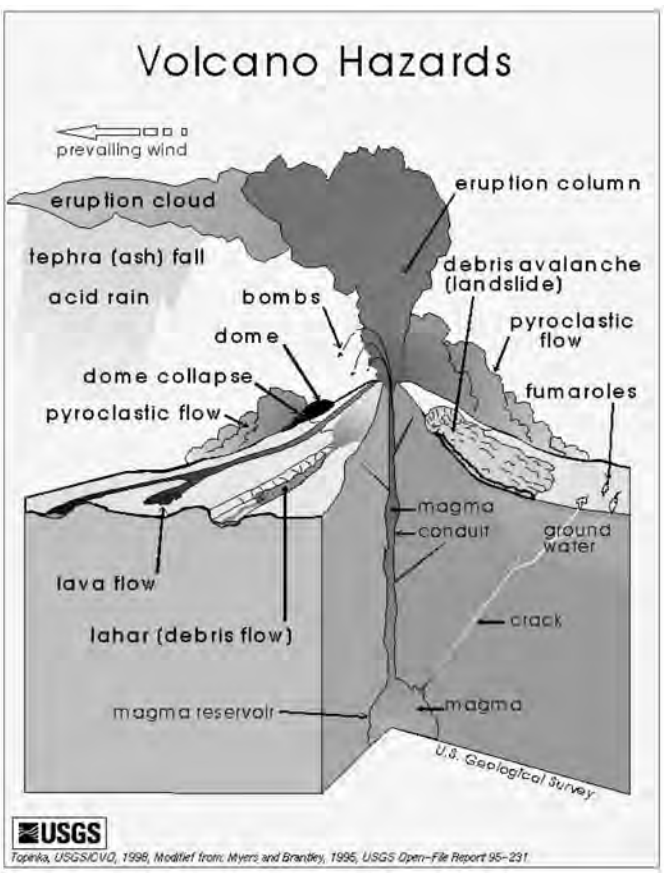


Figure 4-17. Sketch of volcano hazards associated with a Cascade-type volcano.

USGS Lahar hazard zones for the Puget Sound Region are shown on Figure 3-5. There are two large Lahar hazard zones in this region. The Mt. Rainer hazard zone includes a large area and three separate lobes that extend to Puget Sound. The Glacier Peak hazard zone is much closer to the Project Site, and also extends to the coastal area of Puget Sound. Should a Lahar occur within the project lifetime, large quantities of sediment could enter Puget Sound. Such volcaniclastic sediments have the potential to be remobilized as submarine mass gravity flows, and thus pose a hazard to the facilities.

4.4.5 Mass Movement

Mass movement processes are common on land and beneath the sea, and include rockfalls, slides, slumps, debris flows, and other forms of transport such as turbidity currents and debris flows. Mass movement is most common on slopes where soft unsolidated sediments exist, but can also occur in bedrock and stiff soils. Tectonic oversteepening, rapid sedimentation, unfavorable bedding relationships, erosion, seismicity, and other factors can facilitate mass movement. Within the survey area the most susceptible areas to mass movement are considered 1) the steep slopes between 30 and 80 m water depths (see Pink area on Chart 4), 2) shore bluffs, and 3) hyperpycnal or turbidity currents down the axis of the northwest-trending channel. Overconsolidation of glacial outwash sediments makes such deposits less susceptible to mass movement processes, however, and strong currents have removed fine grained sediments that might also be prone to failure. Storm events might result in rapid runoff of sediments from land in streams and rivers. The hazard associated with mass movement is thus considered moderate.

4.4.6 Liquefaction and Lateral Spreading

Liquefaction is the phenomenon in which saturated, cohesionless sediments temporarily lose their shear strength due to increased pore pressures during periods of dynamic loading. Liquefaction commonly occurs in granular soils with high pore pressures during strong ground shaking. The susceptibility of granular soils to liquefaction is a function of the distribution of grain sizes (gradation), soil density, cementation, total fines content, and plasticity characteristics of the fines. The resistance to liquefaction increases with increasing (a) grain size distribution, (b) soil density, (c) cementation, (d) fines content, and (e) plasticity characteristics of the fines.

Onshore, liquefaction hazard is higher in areas with granular soils (sands and silty sands), a shallow water table, and the potential for strong ground shaking. Low-lying, unconsolidated, modern beach deposits are especially susceptible to liquefaction as a result of ground shaking.

Offshore, where seabed sediments at the sediment-water interface are always saturated, hazards are higher where unconsolidated, coarser-grained sediments (sands and silty sands) predominate, and there exists the potential for strong ground shaking. For example, nearshore areas near river mouths may have higher liquefaction potential as a result of local accumulations of clean, sandy sediments of uniform grain size. Liquefaction in seabed sediments may be initiated by ground shaking, or, additionally, by variation in pore pressure caused by deep storm wave activity.

Generally speaking, clayey soils commonly deposited on continental slopes and in deeper ocean basins do not liquefy. However, such soils may be displaced by strong ground shaking. Lateral downslope displacement of submerged clay soils on slopes, while not liquefaction-induced, is similar to lateral spreading. Soil displacement and cracking may also occur at soil-type boundaries, or at the boundary between soil and rock units. These boundaries are usually apparent in high-resolution subsurface geophysical survey data.

Estimating lateral movements resulting from seismic events is highly uncertain. Bartlett and Youd (1992) present empirical procedures for estimating lateral movements. Their empirically-derived procedures for estimating lateral movements depend on earthquake magnitude, distance between the site and seismic event, thickness of liquefied layer, ground slope or ratio of free-face height to distance between free face and structure, fines content, the average particle size of the material forming the liquefied layer, and N-value. We note that Bartlett and Youd (1992) imply that lateral movements do not occur for N-values greater than about 15. An important point to note is that displacements decrease as the distance from the free face increases.

Should liquefaction occur on the beach, the low beach-front bluffs to the east of the beach may be susceptible to lateral spreading under seismic loading conditions.

The potential for lateral spreading exists, but the depth of the HDD beneath the nearshore coastal zone should preclude damage to the cable.

4.4.7 Steep Slopes, Irregular Seafloor and Hard Bottom Conditions

Numerous areas with hard-bottom or irregular seafloor conditions occur within the survey area. These are the result of glacial processes, strong currents and erosion. Large boulders, commonly referred to as glacial erratics, are found throughout the survey area. Some of these have been labeled as targets (Chart 2), while others have been zoned (Charts 3 and 4).

Steep slopes adjacent to Whidbey Island are also likely the result of glacial processes during the last Ice Age, which reached its peak between 16,000 and 20,000 years ago. As shown in Figure 3-8 and described in Section 3, at that time a large ice sheet covered Puget Sound. More than 3,000 feet of ice covered the project area. Extensive erosion occurred along the base of the ice sheet, creating long deep channels, grooves, and striations, and locally steep slopes. During deglaciation, outwash processes transported large amounts of sediment, gravel, cobbles, and boulders, creating hard bottom and irregular seafloor conditions.

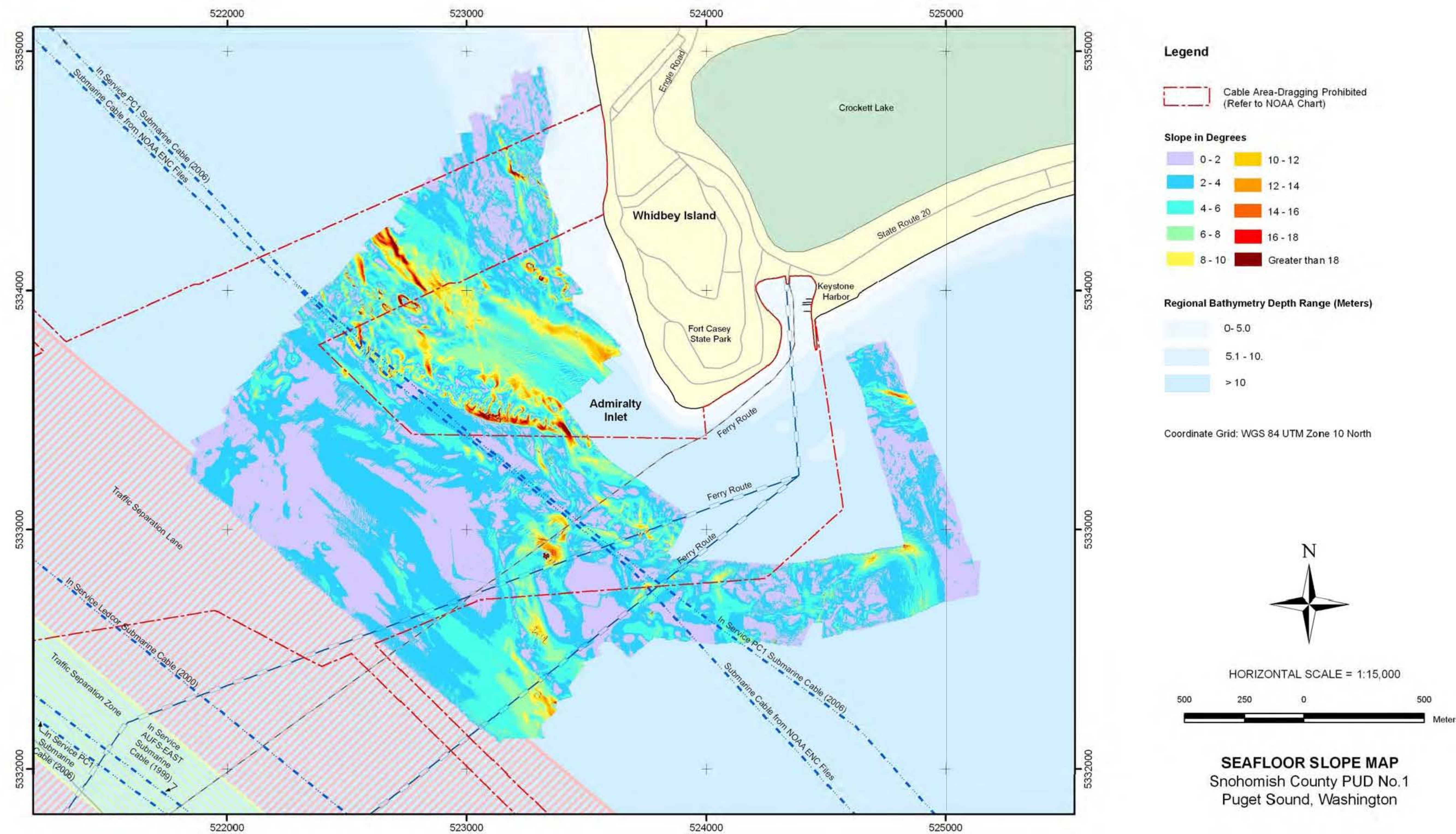

Legend
Cable Area-Dragging Prohibited (Refer to NOAA Chart)
Slope in Degrees
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
Greater than 18
Regional Bathymetry Depth Range (Meters)
0- 5.0
5.1 - 10.
> 10
Coordinate Grid: WGS 84 UTM Zone 10 North
HORIZONTAL SCALE = 1:15,000
Meters
SEAFLOOR SLOPE MAP
Snohomish County PUD No.1
Puget Sound, Washington
Crockett Lake
Whidbey Island
Engle Road
State Route 20
Keystone Harbor
Fort Casey State Park
Admiralty Inlet
Ferry Route
Traffic Separation Lane
Traffic Separation Zone
In Service PC1 Submarine Cable (2006)
Submarine Cable from NOAA ENC Files
In Service Ledcor Submarine Cable (2000)
In Service AUFS-EAST Submarine Cable (1999)

Figure 4-18

4.4.8 Man-made and Cultural Hazards

The bathymetric and geophysical surveys conducted for the SnoPUD Tidal Turbine Energy Project identified only one significant man-made or cultural seafloor hazard in the survey area. That hazard is where the submarine cable will cross an existing submarine cable or cables in a water depth of approximately 60 to 80m. The cable design and installation contractor is to address this hazard.

In addition, a Ferry Route crosses the survey area and shipping lanes exist adjacent to the survey area to the southwest (Charts 1 through 4). The Ferry Route and shipping lanes may represent cultural constraints on installation and operation of the facilities, but can be avoided or mitigated by appropriate siting.

4.4.9 Climate Change and Sea Level Rise

Climate change resulting from man's activities may result in global warming and higher sea levels during the life of the project. Global sea level rise has been a topic of controversy and contention for over twenty years. Most studies have attributed the global sea level rise to global warming, the effect of greenhouse gases due to industrial discharge of carbon dioxide, and other related emissions. These associated gases include methane, chlorofluorocarbons, nitrous oxide, and sulphur dioxide. The following sections give information on different estimates for the modeling of future sea level rise.

Accurate measurements of carbon dioxide accumulations in the atmosphere began as early as the early 1960s. Scientific evidence from several fronts has demonstrated that CO_2 levels are expected to double during the 21st century, raising the global average temperatures anywhere from 2.7º F to as much as 8.1º F, depending on the researcher. Hoffman (1984) presented a detailed estimation of sea level rise through 2100, with data gathered from oil companies, geochemical studies, atmospheric physics, and oceanography among other disciplines. He calculated a "low" scenario, a "high" scenario, and two intermediate scenarios. He estimated the following in Table 4-3:

Table 4-3. Future Scenarios for Sea Level Rise by 2100 (from Hoffman, 1984)

Scenario	Δ Rise (feet)	Δ Rise (meters)
Low	1.8	0.56
Mid-Range Low	4.8	1.44
Mid-Range High	7.0	2.16
High	11.5	3.45

Subsequent studies have estimated that during the late 1800s to late 1900s, a cumulative rise of about 0.12 m or 4.7 inches (0.4 feet) has occurred (Titus and Narayanan, 1995). Their study also collaborated the sea level rise, but showed several other studies including a 1987 National Research Council estimate which reduced the widely variable range of Hoffman's work to an upper, middle and lower bounds estimate of approximately 1.44 m (4.72 feet), 1.01 m (3.31 feet), and 0.52 m (1.71 feet), respectively.

The actual amount of future sea level rise in the facility area is probably reflected in the general eustatic (worldwide) estimates presented above. Based upon the global sea level rise estimates provided above and the estimated facility life, we do not consider sea level rise to be a hazard to the project.

5.0 CONCLUSIONS

5.1 KEY GEOSCIENCES CONSIDERATIONS

The geologic, seafloor, and subsurface conditions in the survey area suggest that, from a geoscience perspective, the design, construction, and operation of the facilities are feasible. Nevertheless there are several geologic and geotechnical considerations that may affect the design, construction and performance of the facilities.

The most significant geoscience considerations are:

- The seismic shaking and secondary earthquake effects produced by large earthquakes on nearby active faults,
- Potential secondary earthquake effects include tsunami, mass movement, liquefaction and lateral spreading,
- The region is volcanically active. The potential exists for ash and tephra to fall in the site vicinity. Lahar flows are unlikely to reach the site, but have the potential to enter Puget Sound elsewhere,
- A fault active prior to 15,000 years ago underlies the slope to the southeast of the survey area. The fault projects towards the survey area and has the potential for surface fault rupture,
- Areas of steep and irregular seafloor that include the presence of:
  - Extensive gullies and ridges located in water depths of 50 to 80m along the island slope in the central portion of the survey area,
  - Exposed cobbles and boulders on the seafloor
- The potential for infrequent, episodic turbidity current flows or other forms of mass movement down the central channel axis.

The site is favorable for a tidal powered turbine because of consistently strong currents. However, these same strong currents present challenges from a geotechnical engineering standpoint because it would be challenging and costly to perform borings into the seafloor to define subsurface soil conditions for foundation design. Given these constraints we have used our best professional judgment to speculate what conditions exist at and beneath the seafloor. Limitations of this study are presented in Section 6.

5.2 SEAFLOOR CONDITIONS FOR FACILITY SUPPORT

As observed elsewhere in the Puget Sound Region, the weight of the ice sheet likely resulted in overconsolidation of glacial debris in the Vashon Till and glacial outwash sediments. As noted previously, gravel and cobbles are locally abundant; minimal cable or turbine foundation settlement is expected in these areas. Given these conditions, a gravity-based structure may be the best option for turbine foundation design.

6.0 LIMITATIONS

6.1 DATA LIMITATIONS

6.1.1 Geophysical Data Limitations

The geophysical and bathymetric data presented in this report were acquired in accordance with the contractual scope of work. Limitations on the geophysical data acquisition systems include their physical constraints and the types of materials within the survey area. As discussed in the field reports, the MBES, SSS, and magnetometer systems have the following limitations:

- The Reson SeaBat 8101 MBES has a bottom-detection range resolution of about 0.5in.
- At the highest operating frequency, the Klein System 3000 Digital SSS can resolve features at a minimum size of about 0.3m.
- The SeaSPY magnetometer sensor has an absolute accuracy of 0.2nT and a counter sensitivity of 0.001nT.

The geologic materials within the survey area are limited by 1) the CHIRP systems' ability to image geologic surfaces, and 2) the systems' penetration depth. As noted in this report, widespread near-surface gravels, cobbles, and boulders did not allow for subseafloor penetration of the CHIRP profiling system in most areas.

The maps and figures in this report present interpretations of the geophysical and bathymetric data. Those interpretations are based, in part, on integration with other data sets and the experience and opinions of the geophysicists and marine geologists who interpreted the data.

6.1.2 Variations in Subsurface Conditions

Earth materials can vary in type, strength, and other geotechnical and physical properties between observation or exploration locations. Man's activities and/or natural earth processes (earthquakes, gas seepage, mass movement) after the time of investigation may alter site conditions. Therefore, we do not and cannot have a complete understanding of the subsurface conditions underlying the site. The conclusions and recommendations presented in this report are based on findings at the points and times of exploration only. The interpolation and extrapolation of information between and beyond points and times of observation are subject to confirmation (to the extent possible) based on conditions revealed at the time of construction of the facilities.

6.2 REPORT LIMITATIONS

6.2.1 Report Use

This draft report has been prepared for the exclusive use of Snohomish County Public Utility District (SnoPUD), and its authorized agents for specific application to the design of the proposed OpenHydro Tidal Turbine Energy Project at the specified site in the Admiralty Inlet. In our opinion, the findings, conclusions, professional opinions, and recommendations presented herein were prepared in accordance with generally accepted geophysical and geotechnical engineering practice of the project region.

Although information contained in this report may be of some use for other purposes, it may not contain sufficient information for other parties or uses. If any changes are made to the project as described in this report, the conclusions and recommendations in this report shall not be considered valid unless the changes are reviewed and the conclusions and recommendations of this report are modified or validated in writing by Fugro.

6.2.2 Confidentiality

This report and any attachments are confidential and may be privileged or otherwise protected from disclosure. The report is solely intended for the person(s) named in the cover letter. If you are not the intended recipient and do not have the permission of the intended recipient, any reading, use, disclosure, copying or distribution of all or parts of this report or associated attachments is strictly prohibited. If you are not an intended recipient, please notify the sender immediately.

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APPENDIX A
SIDESCAN SONAR TARGET LIST

Name	Description	TLength (m)	TWidth	THeight	Easting (m)	Northing (m)
Contact0001	ROCK	0.00	0.00	0.00	524978.13905	5332762.95064
Contact0002	ROCK	0.00	0.00	0.00	524969.36574	5332757.94284
Contact0003	ROCK	2.42	1.36	0.00	524946.73145	5332755.20108
Contact0004	ROCK	4.51	2.68	2.04	524847.26110	5332986.70917
Contact0005	ROCK	3.08	2.43	0.00	524844.96341	5333003.93056
Contact0006	ROCK	3.06	2.42	2.26	524833.41096	5332920.68674
Contact0007	ROCK	1.17	0.89	0.00	524741.73950	5333557.29822
Contact0008	ROCK	0.00	0.00	0.00	524692.07184	5332715.43423
Contact0009	ROCK	3.44	2.85	2.12	524218.90999	5332669.36105
Contact0010	ROCK	2.47	2.57	1.19	524165.35312	5332711.12474
Contact0011	ROCK	3.93	2.76	1.06	524101.27038	5332686.67403
Contact0012	ROCK	2.44	2.33	0.81	524081.98486	5332677.83407
Contact0013	ROCK	5.24	3.05	2.72	523905.64448	5332809.26625
Contact0014	ROCK	6.04	2.78	0.00	523883.56468	5332980.04147
Contact0015	ROCK	7.02	5.45	3.76	523876.12895	5332803.12650
Contact0016	ROCK	0.00	0.00	0.00	523860.29000	5332876.95869
Contact0017	ROCK	2.17	1.97	0.00	523860.27826	5332978.04471
Contact0018	ROCK	3.21	1.63	1.27	523820.01979	5332980.31552
Contact0019	ROCK	3.56	1.42	0.00	523808.08933	5332969.68287
Contact0020	ROCK	4.45	1.65	0.00	523798.31458	5332995.73684
Contact0021	ROCK	2.99	2.19	0.00	523790.13708	5333071.36910
Contact0022	ROCK	3.05	1.74	0.73	523765.85254	5332903.01487
Contact0023	ROCK	10.51	4.53	0.00	523755.64881	5332781.53198
Contact0024	ROCK	7.22	4.66	0.99	523749.61622	5332682.16525
Contact0025	ROCK	2.04	2.93	2.14	523738.36583	5332730.15477
Contact0026	ROCK	2.89	3.04	1.18	523737.10217	5332587.10860
Contact0027	ROCK	2.83	1.71	0.00	523733.98408	5332733.16679
Contact0028	ROCK	2.55	2.40	2.56	523727.56352	5332738.14047
Contact0029	ROCK	3.13	2.59	6.42	523708.45927	5333097.63567
Contact0030	ROCK	7.86	1.66	0.00	523701.68217	5332783.68878
Contact0031	ROCK	3.18	2.89	0.00	523683.18999	5333133.18395
Contact0032	ROCK	2.96	2.52	0.00	523646.43514	5332346.23044
Contact0033	ROCK	3.45	2.62	1.10	523644.85436	5333067.88535
Contact0034	ROCK	2.67	1.82	0.47	523624.38506	5332470.83351
Contact0035	ROCK	4.36	1.63	0.00	523612.56048	5332336.04533

Name	Description	TLength (m)	TWidth	THeight	Easting (m)	Northing (m)
Contact0036	ROCK	2.56	2.32	0.60	523603.82287	5332354.01466
Contact0037	ROCK	6.66	2.63	0.98	523544.63263	5333266.19668
Contact0038	ROCK	3.61	1.74	0.00	523523.96217	5333028.71310
Contact0039	ROCK	4.13	1.58	2.39	523519.97548	5333184.48727
Contact0040	ROCK	5.58	2.90	2.97	523519.01235	5332559.98955
Contact0041	ROCK	3.65	1.81	0.00	523506.50025	5333173.68710
Contact0042	ROCK	6.49	4.84	3.75	523467.94912	5332463.55568
Contact0043	ROCK	0.79	1.97	0.00	523451.63106	5332665.69520
Contact0044	ROCK	2.12	0.00	0.00	523442.12429	5332670.73336
Contact0045	ROCK	3.73	3.17	0.00	523420.30774	5332129.33745
Contact0046	ROCK	1.93	2.37	0.00	523414.17671	5332466.37357
Contact0047	ROCK	2.44	2.15	0.00	523403.29567	5334163.95406
Contact0048	ROCK	5.46	3.20	0.00	523399.43835	5334226.89232
Contact0049	ROCK	3.39	2.53	0.00	523393.99598	5332878.76302
Contact0050	ROCK	4.54	2.28	0.00	523391.67423	5333023.19959
Contact0051	ROCK	3.60	2.72	0.00	523378.63005	5333816.36477
Contact0052	ROCK	4.49	2.01	0.00	523371.37185	5333042.11801
Contact0053	ROCK	2.56	2.14	1.13	523365.19786	5332394.37663
Contact0054	ROCK	2.26	1.48	0.84	523361.52570	5334195.74389
Contact0055	ROCK	9.24	1.99	1.58	523358.32905	5332840.94140
Contact0056	ROCK	6.02	2.16	1.19	523351.65918	5333132.92575
Contact0057	ROCK	1.99	1.98	0.90	523346.75326	5332834.66625
Contact0058	ROCK	1.82	1.19	0.34	523341.84976	5334114.03453
Contact0059	ROCK	5.88	2.04	0.98	523341.17193	5333156.15123
Contact0060	ROCK	3.78	1.92	1.11	523336.83364	5332843.44936
Contact0061	ROCK	3.93	2.92	0.00	523325.99017	5332841.77534
Contact0062	ROCK	3.24	1.54	0.98	523320.71850	5334811.91465
Contact0063	ROCK	3.44	1.46	1.00	523315.47956	5332831.66327
Contact0064	ROCK	2.94	1.50	0.00	523309.21612	5332916.78996
Contact0065	ROCK	18.68	16.10	12.03	523305.15553	5332888.37079
Contact0066	ROCK	2.94	1.89	0.00	523303.08229	5334775.80934
Contact0067	ROCK	3.50	2.29	1.24	523303.06460	5332840.86552
Contact0068	ROCK	3.54	4.31	0.00	523289.66030	5332859.84246
Contact0069	ROCK	2.05	1.19	0.00	523282.94950	5334832.78145
Contact0070	ROCK	2.59	1.86	0.00	523280.95099	5334848.86480

Name	Description	TLength (m)	TWidth	THeight	Easting (m)	Northing (m)
Contact0071	ROCK	4.31	2.18	0.00	523280.83218	5333178.82807
Contact0072	ROCK	2.12	0.98	0.00	523273.12670	5334897.83810
Contact0073	ROCK	3.17	2.29	0.00	523268.30182	5334401.09268
Contact0074	ROCK	4.17	1.59	0.91	523267.04756	5333857.97662
Contact0075	ROCK	2.46	1.23	0.00	523260.98049	5334796.09800
Contact0076	ROCK	2.10	2.33	0.00	523260.01217	5334704.55692
Contact0077	ROCK	3.19	2.59	2.10	523258.73650	5332833.71739
Contact0078	ROCK	2.24	2.06	0.00	523253.36147	5334810.59046
Contact0079	ROCK	1.96	1.29	0.45	523246.26691	5334788.66265
Contact0080	ROCK	1.66	1.97	1.48	523215.95610	5333038.65931
Contact0081	ROCK	2.60	1.20	1.04	523214.27184	5334205.84124
Contact0082	ROCK	5.44	1.87	1.64	523207.95391	5334346.78499
Contact0083	ROCK	2.00	1.90	0.00	523204.42413	5334070.68109
Contact0084	ROCK	4.58	1.55	1.25	523193.46821	5334222.42840
Contact0085	ROCK	3.43	2.47	0.00	523186.32267	5332816.57336
Contact0086	ROCK	4.68	3.90	1.39	523179.95676	5333950.69789
Contact0087	ROCK	7.73	4.38	3.57	523168.70313	5334594.70215
Contact0088	ROCK	2.93	1.87	0.92	523167.32233	5332902.33739
Contact0089	ROCK	2.21	1.25	0.52	523166.82142	5334486.18456
Contact0090	ROCK	5.30	2.25	2.15	523160.89535	5333950.98020
Contact0091	ROCK	2.75	2.74	0.00	523151.52005	5334871.83449
Contact0092	ROCK	1.71	2.14	2.28	523147.12135	5332929.59675
Contact0093	ROCK	2.56	1.32	1.54	523146.21114	5334671.68502
Contact0094	ROCK	2.14	1.59	0.80	523141.77252	5334715.81770
Contact0095	ROCK	2.61	2.25	0.00	523118.99264	5334040.33551
Contact0096	ROCK	2.42	1.44	0.00	523114.54484	5334679.68059
Contact0097	ROCK	2.47	1.92	0.00	523093.17923	5334036.29362
Contact0098	ROCK	2.45	2.28	1.17	523077.25023	5334076.21833
Contact0099	ROCK	2.98	1.76	2.44	523072.54641	5334005.59126
Contact0100	ROCK	4.75	2.22	0.00	523068.85387	5334654.60248
Contact0101	ROCK	6.42	2.69	0.71	523058.70239	5333996.88167
Contact0102	ROCK	7.90	3.40	0.00	523038.70223	5333870.11540
Contact0103	ROCK	0.60	1.33	0.00	523037.33762	5334303.81393
Contact0104	ROCK	2.90	1.68	0.00	523031.60744	5334629.94736
Contact0105	ROCK	9.44	4.94	3.01	523010.03866	5334325.27544

Name	Description	TLength (m)	TWidth	THeight	Easting (m)	Northing (m)
Contact0106	ROCK	2.34	3.31	0.71	522941.07159	5334127.74100
Contact0107	ROCK	3.40	3.08	0.00	522931.37831	5334144.18226
Contact0108	ROCK	1.15	1.31	0.00	522904.79319	5334320.41730
Contact0109	ROCK	1.69	1.13	0.50	522893.97224	5334325.00381
Contact0110	ROCK	1.71	1.52	0.68	522881.77886	5334516.23027
Contact0111	ROCK	6.16	2.21	0.00	522878.75261	5334226.49824
Contact0112	ROCK	5.90	2.23	1.02	522878.23746	5332611.87315
Contact0113	ROCK	3.33	2.42	4.29	522877.08947	5334323.18863
Contact0114	ROCK	3.58	2.14	0.00	522857.73911	5332537.52853
Contact0115	ROCK	1.61	1.20	0.66	522817.60009	5334289.59062
Contact0116	ROCK	1.73	2.10	0.00	522811.86381	5333239.93142
Contact0117	ROCK	2.90	2.08	0.00	522804.37883	5333252.83492
Contact0118	ROCK	3.26	2.11	0.00	522779.21793	5332677.79595
Contact0119	ROCK	3.16	2.46	0.00	522755.93772	5332713.70137
Contact0120	ROCK	3.46	1.69	0.99	522739.52324	5332804.60760
Contact0121	ROCK	2.16	1.00	0.42	522732.29366	5332799.36810
Contact0122	ROCK	3.89	4.08	2.06	522730.26086	5333319.39682
Contact0123	ROCK	7.87	4.46	0.00	522726.00770	5332855.94586
Contact0124	ROCK	5.93	4.09	0.00	522721.53926	5333314.58661
Contact0125	ROCK	4.33	2.81	2.93	522713.32246	5333319.30829
Contact0126	ROCK	3.64	3.42	2.96	522706.28226	5333328.65321
Contact0127	ROCK	5.35	3.55	0.00	522706.06472	5332873.48614
Contact0128	ROCK	3.93	2.34	0.00	522698.04131	5333329.27282
Contact0129	ROCK	2.71	1.62	0.00	522682.29551	5332973.66214
Contact0130	ROCK	3.03	1.71	0.49	522680.94259	5333031.07564
Contact0131	ROCK	1.67	1.54	0.00	522679.39785	5332950.09807
Contact0132	ROCK	3.54	2.74	0.00	522675.25271	5333340.77783
Contact0133	ROCK	3.77	1.32	0.00	522670.84219	5333414.53978
Contact0134	ROCK	1.93	2.72	0.00	522670.58991	5333414.26327
Contact0135	ROCK	5.18	2.78	0.00	522669.61665	5333354.69667
Contact0136	ROCK	3.58	3.38	0.00	522659.18566	5333415.37829
Contact0137	ROCK	9.04	3.37	0.00	522620.51557	5333312.14988
Contact0138	ROCK	6.42	1.98	0.00	522602.82057	5333337.89969
Contact0139	ROCK	9.40	5.62	0.38	522596.00039	5333275.16358
Contact0140	ROCK	7.95	3.87	0.00	522586.34007	5333272.78389

Name	Description	TLength (m)	TWidth	THeight	Easting (m)	Northing (m)
Contact0141	ROCK	5.71	1.76	0.93	522499.12963	5333630.16588
Contact0142	ROCK	9.76	4.31	3.04	522494.46351	5333651.49216
Contact0143	ROCK	5.53	3.31	1.54	522409.65337	5332933.95062
Contact0144	ROCK	4.48	2.65	0.74	522399.25544	5332939.95160
Contact0145	ROCK	4.02	1.34	0.74	522370.70556	5333124.81831
Contact0146	ROCK	5.00	3.48	0.00	522368.73055	5332951.76629
Contact0147	ROCK	3.30	3.07	3.70	522349.27294	5333653.65247
Contact0148	ROCK	3.43	2.36	3.51	522348.00417	5333633.94956
Contact0149	ROCK	2.84	2.51	0.00	522339.29981	5333132.47341
Contact0150	ROCK	3.96	1.12	0.00	522331.50515	5333080.62612
Contact0151	ROCK	6.74	3.12	1.00	522329.79965	5333117.35221
Contact0152	ROCK	9.13	4.99	5.60	522313.20198	5333728.60175
Contact0153	ROCK	2.03	1.05	0.86	522282.80785	5333745.91355
Contact0154	ROCK	3.42	2.64	1.34	522248.95138	5333790.67428
Contact0155	ROCK	4.01	3.13	0.00	522208.31424	5333535.38512
Contact0156	ROCK	4.56	1.58	0.00	522198.04070	5333661.21824
Contact0157	ROCK	8.34	3.76	2.09	522195.39487	5333532.00777
Contact0158	ROCK	6.24	0.99	1.96	522190.13126	5333604.38169
Contact0159	ROCK	7.18	2.51	0.00	522175.32272	5333400.19024
Contact0160	ROCK	3.84	1.78	2.38	522155.44078	5333774.48012
Contact0161	ROCK	2.43	2.64	0.00	522151.28119	5333543.94150
Contact0162	ROCK	3.35	3.38	1.18	522147.40763	5333746.43660
Contact0163	ROCK	4.49	1.50	1.18	522142.31792	5333697.72390
Contact0164	ROCK	3.78	3.62	2.71	522126.27262	5333823.37606
Contact0165	ROCK	4.93	2.65	1.92	522124.28298	5333604.03490
Contact0166	ROCK	4.95	3.49	7.35	522090.68589	5333573.29504

APPENDIX B
SURVEY EQUIPMENT SPECIFICATIONS

Zephyr Marine
Geophysical Survey Vessel "Taku"

The survey vessel is our most important piece of equipment, as it is the platform from which we collect the geophysical data. The vessel needs to have sufficient back deck space to safely and efficiently deploy and recover the instruments. It needs to be acoustically quiet so as not to interfere with the data sensors. Finally the vessel needs to be suitable for the anticipated sea/weather conditions. We area proposing to use one vessel for this work the R/V Taku for both the shallow water and deeper water work.

VESSEL SPECIFICATIONS:

Length:	**36 Feet**
Beam:	**10.5 Feet'**
Draft:	**3.5 Feet'**
Gross Tons:	**15**
Net Tons:	**8**
Fuel Capacity:	**1,000 Gallons**
Generator:	**8 KW Northern Lights**
Cabin:	**8'x10' Electronics Lab**

SeaBat 8101

Multibeam Echosounder

- **Phase and amplitude bottom detection**
- **150° swath coverage (upgradeable to 210°)**
- **240kHz frequency**
- **Up to 600m swath width**

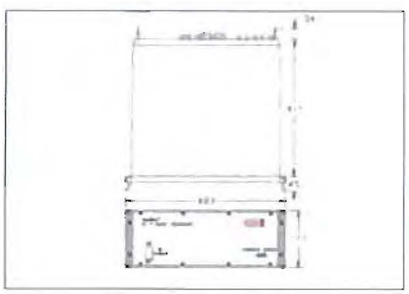
The SeaBat 8101 Multibeam Echosounder measures discrete depths, enabling complex underwater features to be mapped with precision. Dense coverage is achieved utilizing up to 4,000 soundings per second for a swath up to 600 meters in width, even as the survey vessel travels at speeds in excess of 12 knots.

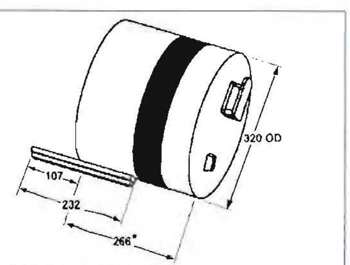
With high accuracy and a measurement rate of up to 40 profiles per second, the SeaBat 8101 enables surveys to be completed faster and in greater detail than previously realized.

The SeaBat 8101 transducer is available for operating depths of 120, 300, 1500, and 3,000 meters. Small and lightweight, it can be mounted on underwater vehicles (ROV or towed) and transported to locations where accurate measurements are required.

SeaBat 8101

Multibeam Echosounder





*Option 049: 274mm

SYSTEM PERFORMANCE		
Operating Frequency:	240kHz (nominal)	
Swath Coverage:	150°	(upgradeable to 210°)
Max Range:	300m 450m max range available with ER option	
Number of Beams:	101, beamspacing 1.5°	
Along-Track Beamwidth:	1.5° (nominal)	
Across-Track Beamwidth:	1.5° (nominal)	
Max. Update Rate:	40	
Operational Speed:	Up to 18 knots	

PROCESSOR SPECIFICATIONS		
Power Required:	100/240VAC, 47/63Hz, 100W maximum	
Data Uplink:	High-speed digital coax with fiber-optic option	
Computer Interface:	10MB Ethernet and RS232C	
Data Downlink:	Serial, 19.2k baud	
Display Video Out:	SVGA: 800 x 600;	
	Refresh Rate:	~72Hz
Graphics Colors:	Sonar Image:	256 Colors
	Other Graphics:	8-bit RGB
Input Device:	3-Button Trackball	
Dimensions (HWD):	177 x 483 x 417mm	
Mounting:	19in. rack mountable	
Temperature:	Operating:	0° to +40°C
	Storage:	-30° to +55°C
Weight:	20kg (44 lbs.)	

DISPLAY SPECIFICATIONS	
Screen Size:	14" diagonal
Display:	SVGA High-Resolution, Color Monitor
Power Consumption:	80W
Weight:	11.2kg (24.6lbs.)

SONARHEAD SPECIFICATIONS		
Power Requirements:	24VDC, 2 amps max. (Power available from Processor.)	
Operating Depth:	120m (300,1500, and 3000m available)	
Dimensions:	266 x 320mm (W / D) excluding projector	
Temperature:	Operating:	-5° to +40°C
	Storage	-30° to +55°C
Weight (aluminum):	Dry:	26.8kg (59lbs.)
	Wet:	4.8kg (10.6lbs.)
Weight (titanium):	Dry:	40kg (88lbs.)
	Wet:	18kg (39.6lbs.)

OPTIONS	
Sidescan ugrade	Mounting plate assembly
Fairings	Spares kit
Titanium housing	210° swath
Extended-Range (ER) projector	Coax to fiber optic interface unit
Increase sonar head depth rating	

For Acoustical Measurement Accuracy please refer to www.reson.com or contact sales.

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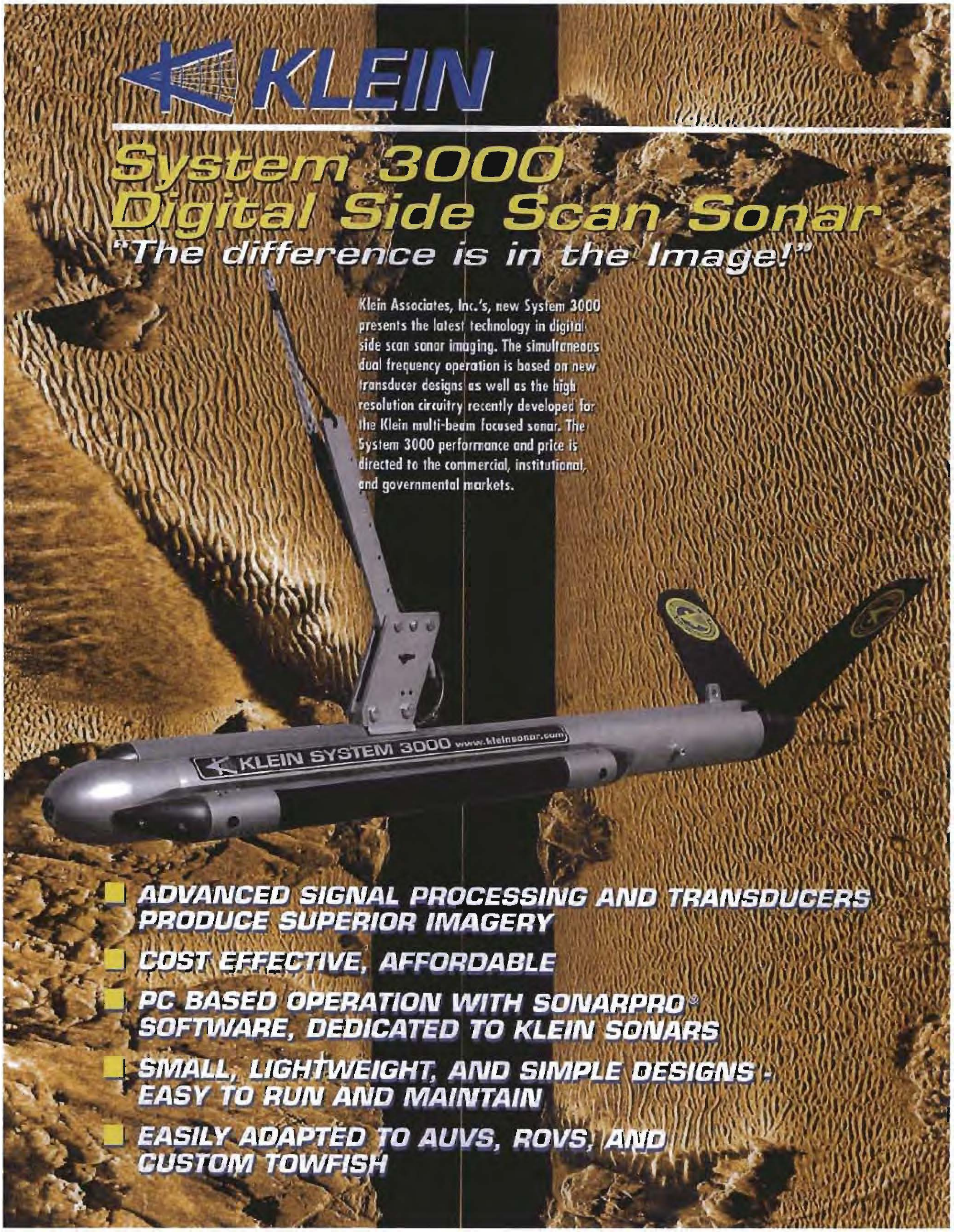
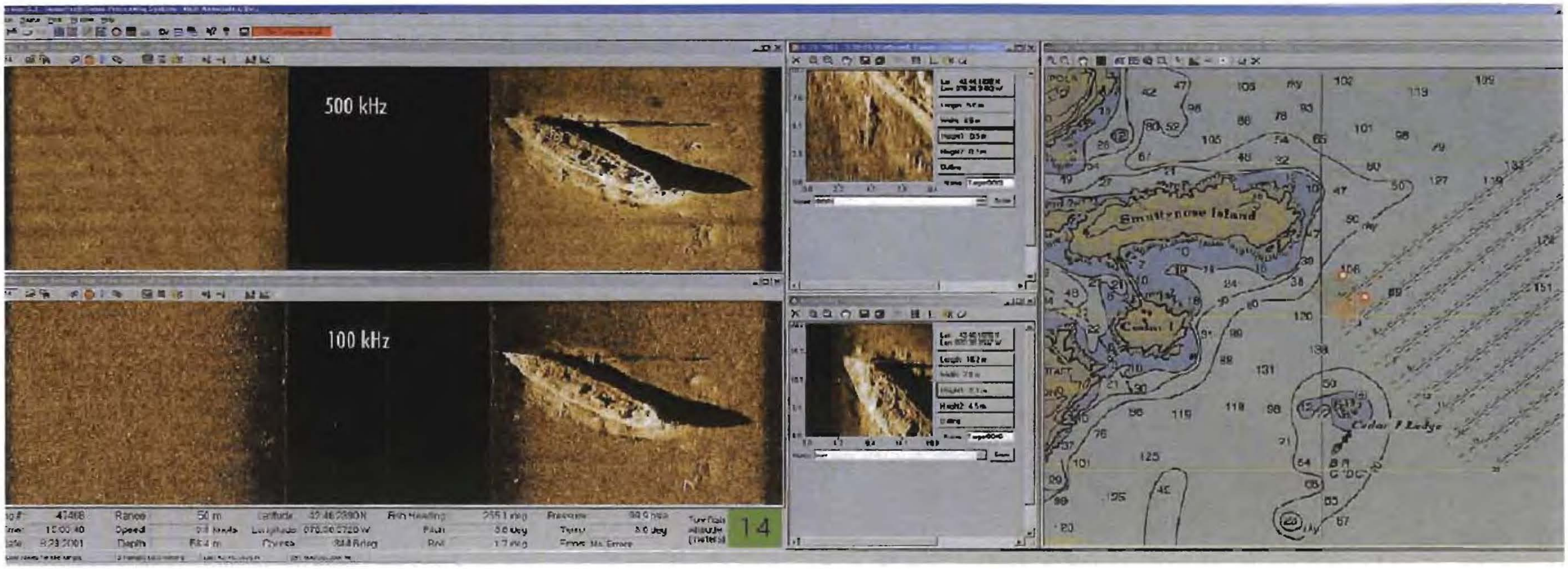
Version: 80


KLEIN
System 3000
Digital Side Scan Sonar
"The difference is in the Image!"
Klein Associates, Inc.'s, new System 3000 presents the latest technology in digital side scan sonar imaging. The simultaneous dual frequency operation is based on new transducer designs as well as the high resolution circuitry recently developed for the Klein multi-beam focused sonar. The System 3000 performance and price is directed to the commercial, institutional, and governmental markets.
KLEIN SYSTEM 3000
ADVANCED SIGNAL PROCESSING AND TRANSDUCERS PRODUCE SUPERIOR IMAGERY
COST EFFECTIVE, AFFORDABLE
PC BASED OPERATION WITH SONARPRO® SOFTWARE, DEDICATED TO KLEIN SONARS
SMALL, LIGHTWEIGHT, AND SIMPLE DESIGNS - EASY TO RUN AND MAINTAIN
EASILY ADAPTED TO AUVS, ROVS, AND CUSTOM TOWFISH

Klein System 3000



SPECIFICATIONS

Towfish

Frequencies	100 kHz (125 kHz +/- 1% act.), 500 kHz (445 kHz, +/- 1% act.)
Transmission Pulse	Tone Burst, operator selectable from 25 to 400 µsecs. **Independent pulses for each frequency**
Beams	Horizontal - 1 deg. @ 100 kHz, 0.2 deg. @ 500 kHz Vertical - 40 deg.
Beam Tilt	5, 10,15, 20, 25 degrees down, adjustable
Maximum Range	600 meters @ 100 kHz; 150 meters @ 500 kHz
Depth Rating	1,500 meters standard. options to 3km & 6km depths
Construction	Stainless Steel
Size	122 cm long, 8.9 cm diameter
Weight	29 kg in air
Standard Sensors	Roll, pitch, heading
Options	Magnetometer Interface, pressure, Acoustic Positioning Responder, and Responder Interface Kits

Transceiver Processor Unit (TPU)

Operating System	vxWorks® with custom application
Basic Hardware	19-inch rack or table mount, VME bus structure
Outputs	100 Base-Tx, Ethernet LAN
Navigation Input	NMEA 0183
Power	120 watts @ 120/240 VAC, 50/60 Hz

Klein Sonar Workstation

Base Operating System	Windows NT® & 2000® or equiv.
Sonar Software	SonarPro®
Data Storage	Internal hard drive, optional devices available
Hardware	Industrial PC with technically advanced components

Tow Cables

Klein offers a selection of coaxial, Kevlar® reinforced, lightweight cables, double armored steel cables, and interfaces to fiber optic cables. All cables come fully terminated at the towfish end.

KLEIN ASSOCIATES, INC.
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Phone: (603) 893-6131
Fax: (603) 893-8807
E-mail: mail@kleinsonar.com
web site: www.kleinsonar.com

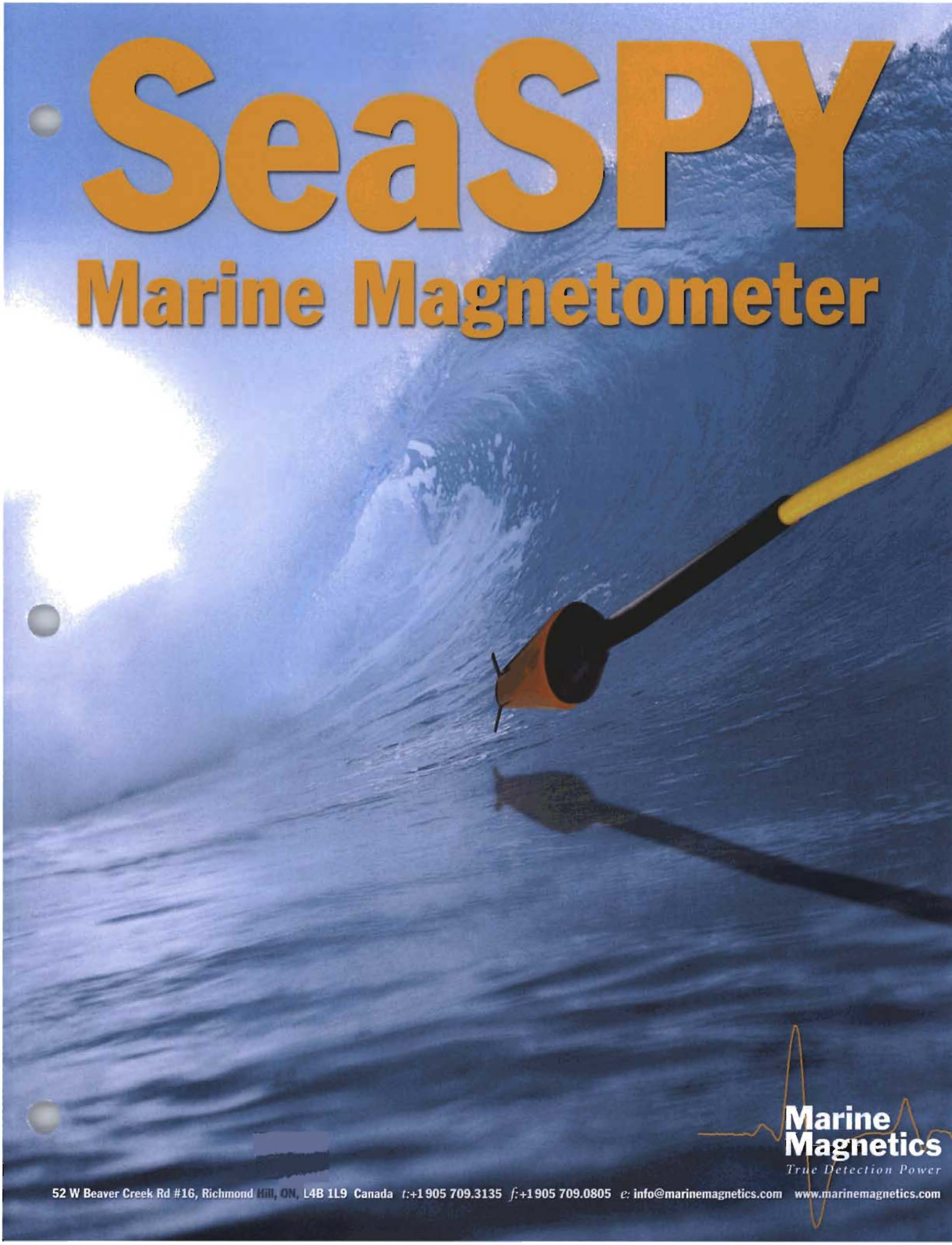
SonarPro® Software

Custom developed software by users and for users of Klein side scan sonar systems operating on Windows NT® & 2000®. Field proven for many years on Klein's Multi-Beam Focused Sonar Series 5000 Systems and adapted to the System 3000 single-beam system. SonarPro® is a modular package combining ease of use with advanced sonar features.

Basic Modules	Main Program, Data Display, Information, Target Management, Navigation, Data Recording & Playing, and Sensor Display.
Multiple Display Windows	Permits multiple windows to view different features as well as targets in real time or in playback modes. Multi-Windows for sonar channels, navigation, sensors, status monitors, targets, etc.
Survey Design	Quick & easy survey set up with ability to change parameters, set tolerances, monitor actual coverage, and store settings.
Target Management	Independent windows permitting measuration, logging, comparisons, filing, classification, positioning, time & survey target layers, and feature enhancements. Locates target in navigation window.
Sensor Window	Displays all sensors in several formats (includes some alarms) and responder set up to suit many frequencies and ping rates.
Networking	Permits multiple, real time processing workstations via a LAN including "master and slave" configurations.
"Wizards"	To help operator set up various manual and default parameters.

SeaSPY

Marine Magnetometer



Marine Magnetics
True Detection Power

52 W Beaver Creek Rd #16, Richmond Hill, ON, L4B 1L9 Canada *t:*+1 905 709.3135 *f:*+1 905 709.0805 *e:* info@marinemagnetics.com www.marinemagnetics.com

SeaSPY Overhauser Sensor

The SeaSPY Advantage

Marine Magnetics takes pride in designing and manufacturing magnetic exploration equipment that meets scientific observatory specifications. The SeaSPY magnetometer product eliminates many of the inherent problems associated with other marine magnetometers such as orientation restrictions, sensor realignment, time and temperature drift and poor absolute accuracy.

The Overhauser Effect

Marine Magnetics is the only marine magnetometer company in the world that can produce stable Overhauser sensors that do not degrade with time. Marine Magnetics' SeaSPY magnetometer measures the ambient magnetic field using a specialized branch of nuclear Magnetic Resonance technology, applied specifically to hydrogen nuclei.

Worldwide Operation With No Restrictions

The SeaSPY sensor is unique in that it is entirely omnidirectional. The amount of signal produced by the sensor is completely independent of magnetic field direction. You never have to orient your sensor, because it is already optimized to work around the World.

As a result, regardless of where you are in the World and no matter what the magnetic field strength is, your SeaSPY sensor will continue to provide a strong signal and accurate data.

Highest Absolute Accuracy

SeaSPY Overhauser sensors have the highest absolute accuracy of any magnetometer: 0.2nT

The repeatability between SeaSPY sensors is also unmatched at better than 0.01nT. This makes them ideal for gradiometer configurations, where the output of two independent sensors is compared to measure the value of magnetic gradient between them.

High Sensitivity

SeaSPY Overhauser sensors deliver high-resolution output with a noise level of 0.01nT/√Hz; counter sensitivity is 0.001nT

Maintenance Free Sensors, No Realignment and No Consumable Parts

SeaSPY Overhauser sensors are entirely maintenance free and most importantly, SeaSPY's specifications do not degrade over time. As a result, the SeaSPY sensor never has to be realigned, or recalibrated in order to meet the manufacturer's specifications at the time of shipping.

In addition, the SeaSPY sensor does not contain any parts that wear out and need to be replaced.

No Sensor Warm-Up Time

SeaSPY Overhauser sensors do not require temperature stabilization. Therefore SeaSPY will work equally as well in cold, deep water as in warm, tropical water, instantly on power-up.

Scientific Quality Instruments

Stable time: The clock used in the SeaSPY electronics module is accurate to 1ppm throughout the entire temperature range, as opposed to 100ppm found in competing magnetometer systems. As a result, no matter how much the temperature changes during a survey, the data will always be accurately time stamped, ensuring that it will always match up perfectly with diurnal correction (base station) information.

No temperature effect on accuracy: Data collected at –40°C will be identical to data recorded at +60°C

No heading error: Heading error is a detectable offset in the magnetometer output caused by changing the heading of the magnetometer within the Earth's magnetic field.

Marine Magnetics' SeaSPY magnetometer is constructed of the most nonmagnetic materials possible. As a result, the SeaSPY Overhauser sensor does not display heading error.

Therefore, no matter how the SeaSPY sensor is oriented in the Earth's magnetic field, successive survey lines taken in opposite directions will match up perfectly.

The benefits to the user are four-fold:

1. Targets will not be missed because they fall between mismatched survey lines.

2. Eliminates post processing. Competing technologies require the user to collect tie lines in order to level the data set (match-up inaccurate survey lines). This is not necessary with an accurate magnetometer like SeaSPY.

3. There will be no variation introduced in the data by slight course changes during a survey line.

4. A magnetic map of an area will look the same, regardless of in which direction the survey lines were conducted.

Digital System

SeaSPY is entirely digital. The magnetometer signal is measured inside the towfish where the signal is strongest and most immune to outside noise.

Ultra Low Power Consumption

A SeaSPY system only requires 1W standby and 3W maximum. As a result, SeaSPY can run for days directly from a 24V vehicle battery.

Standard SeaSPY Hardware

Communication Transceiver

The Communication Transceiver provides the complete interface between the customers PC and the SeaSPY towfish. One side connects to a PC serial port using an RS-232 cable, and the other plugs into one end of the deck leader cable, which in turn connects to the tow cable and towfish. In addition to conditioning the towfish power supply, the transceiver functions like a modem, providing two-way communication along the same conductors that provide power to the SeaSPY towfish.

Dimensions: 11 x 6 x 3 cm (4 x 2 x 1 inches)

Weight: 130g (0.28 lbs)

30m Deck Cable

Tow Cable

The SeaSPY tow cable is incredibly tough yet light in weight. The cable consists of one twisted pair of conductors, a Vectran strength member that is specifically woven to prevent rotational preference, water blocking and a yellow polyurethane jacket. Length to be determined by customer.

Metal Cable Reel

Included with up to 200m of cable. A wooden spool is includeu with cable amounts exceeding 200m.

SeaSPY Accessories Package

Includes: RS232 Cable, 24V AC power supply and battery clip cable.

SeaSPY Towfish

Includes:

- High sensitivity omnidirectional Overhauser sensor
- Electronics module containing all of the driving electronics, including the Larmour counter
- Depth sensor
- Leak detector
- 4 lead weights
- Custom foam lined shipping case
- aLINK Software for windows

SeaSPY OPTIONS

Drive up to 10,000m of cable with the SeaSPY Smart Transceiver

An enhanced version of the communication transceiver, the Smart Transceiver's adaptive design adjusts to suit a broad range of cable parameters, enabling it to drive up to 10,000m of cable.

Additional advantages include:

- Boosts and regulates the towfish supply voltage, to minimize voltage drop over long cables.
- Digital auto-tuning of transmission/reception frequencies.
- Diagnostic features include digital voltage and current monitoring.
- Keeps time after power off, and automatically sets the towfish time when needed.

No additional hardware has to be purchased. The Smart Transceiver is compatible with the AC power supply provided with all SeaSPY M Magnetometer Systems.

Dimensions: 12 x 6.5 x 8 cm (4.7 x 2.5 x 3 inches)

Weight: 300g (0.66 lbs)

Deep Tow Options

Marine Magnetics offers three deep tow options:

1000m SeaSPY towfish tested to 1,500psi

3000m SeaSPY towfish tested to 4,500psi

6000m SeaSPY towfish tested to 9,000psi

Side Scan Sonar Integrations

SeaSPY is compatible with a variety of industry standard Side Scan Sonar systems. The integration maintains the basic system integrity of the SeaSPY towfish and the Side Scan Sonar towfish. Each system can be run independently as well as together. For more information please see our ***SeaSPY Side Scan Sonar Integration brochure***

Altimeter

An integrated, nonmagnetic 200kHz altimeter is available for all depth options. The altimeter provides an accurate and precise (to 0.1m) towfish altitude measurement with every magnetometer reading.

SeaLINK Analogue Output

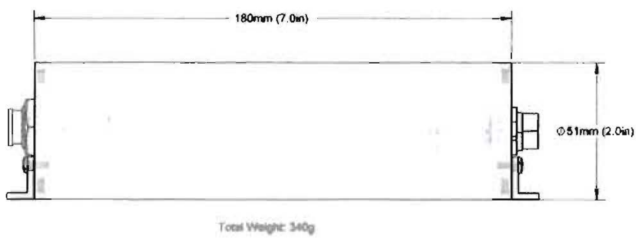
Enables SeaLINK to generate two user programmable analogue signals for output to any analogue chart recorder.

This option includes analogue output hardware for a PC, and the customer can select between a PCMCIA card, or an ISA-bus card.

OEM SeaSPY Electronics Module

SeaSPY electronics modules contain all of the driving electronics, including the Larmour counter. The module is a completely sealed, self-contained unit that is safe to handle even in dirty, or wet conditions.

All SeaSPY electronics modules are completely interchangeable, enabling a customer to swap between modules on demand. This makes them ideal for applications where multiple electronics modules are required as gradiometers or simply as spares.



SeaSPY electronics module

OEM SeaSPY Overhauser Sensor

All SeaSPY sensors are omnidirectional, maintenance free, and do not require realignment, or recalibration, and they do not contain any consumable parts, or toxic chemicals.

In addition, all SeaSPY sensors are interchangeable, and with a repeatability of 0.01nT between the sensors, they are ideal for multi-sensor applications.

Floatation Cable

SeaSPY floatation cable consists of one twisted pair of conductors, a Vectran strength member, water blocking and the addition of an extra layer of syntactic foam, coated with an orange polyurethane jacket.

Extension Cables

Marine Magnetics provides extension cables for both our standard Vectran and floatation cables.

Each extension consists of a male and female brass connector. Both connectors have the capability of bearing the full working load of the cable.

This configuration allows multiple extension cables to be connected together in series up to 1000m.

Connector –Tow cable termination kit

Marine Magnetics' proprietary screw-on underwater connector, for interface to the SeaSPY towfish, is made of a brass alloy that is entirely non-magnetic. The connector is extremely tough and can support more than one tonne of towing force. A PVC nose cone fits over the connector to protect it from side impact and to create a streamlined tow body.

This connector is used with all of the SeaSPY options, allowing the customer to swap between cables at will.

Best of all, the connector is field-serviceable with a Marine Magnetics field re-termination kit.

Tow Cable Weights

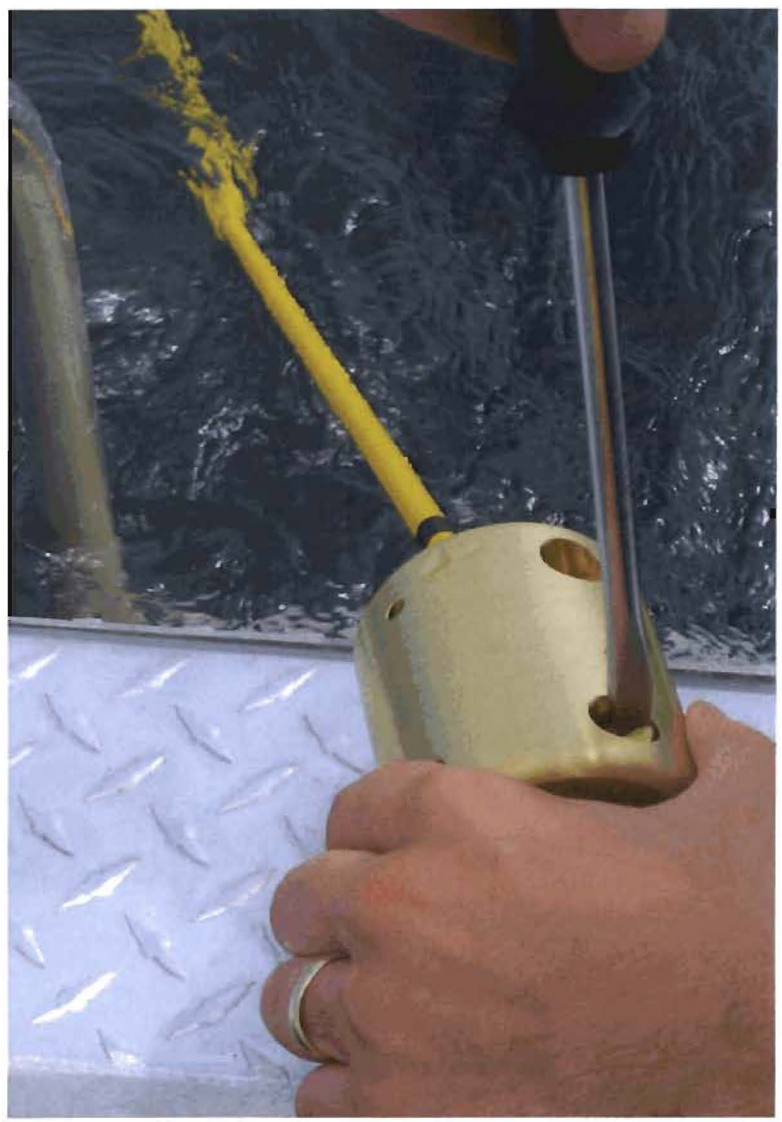
Marine Magnetics brass cable weights are an effective, yet inexpensive way of getting our SeaSPY towfish to deep depths. Placing the cable weights periodically along the length of the cable effectively counters the lift produced by tow cable drag, it also produces a very sharp drop rate that can be sustained for long cable lengths. In recent trials it has proved to be more effective than depressor wings that are costly, awkward, and large.

Each weight weighs about 6lbs in water and can be installed or removed with a screwdriver, enabling the user to remove or add weights at will.

Lead Weights

The towfish can be made buoyant in the field by removing two of the internal stabilizing lead weights.

For added versatility, the towfish can also be made heavier in the field by adding up to 4 more stabilizing lead weights inside the towfish.



Brass tow cable weight attached to MMC's cable

Gradiometer Configurations

The simplest gradiometer measures magnetic gradient in one dimension by subtracting the difference between two independent magnetic sensors. Since the Earth's magnetic field is three dimensional, up to three independent gradient directions can be measured – vertical, horizontal (across-track) and longitudinal (along-track). Marine Magnetics offers each of these gradiometer configurations with its SeaSPY magnetometer product. In addition, all SeaSPY magnetometers are compatible, enabling existing SeaSPY customers to upgrade their magnetometer to the gradiometer configuration of their choice, as they need to.

Marine Magnetics' SeaSPY sensors are highly accurate and repeatable making them ideal for gradiometers. To learn more about how gradiometers work and why accuracy and repeatability are key elements in they way perform, please see our ***Gradiometer Application Guide.***

For collection of gradient data in all three dimensions simultaneously please see our ***SeaQuest Multi-Sensor Gradiometer Platform brochure and Using SeaQuest To Track Cables and Pipelines.***

Horizontal or Vertical Transverse Gradiometer

Marine Magnetics' transverse gradiometers provide a rigid 2m structure linking the sensors, and are well suited for close-in precision surveys for small ferrous targets where short sensor separation is needed.

Applications

Cable and Pipeline Survey – A horizontal transverse gradiometer can be used to track cables, or pipelines in real time from relatively high towing altitudes. Adding a vertical gradiometer enables the user to track the cable, and it also provides accurate measurement of cable or pipeline burial depth.

Detection of Small Ferrous Targets – Short baseline gradient measurement in any direction (longitudinal, horizontal, or vertical) is useful for eliminating geological interference and diurnal variation.

Longitudinal Gradiometer

Longitudinal gradiometers provide the largest variation in available baselines, from 1.5m to 500m+. Again, Marine Magnetics' communication transceiver technology is unmatched in its ability to support extremely long distances between the two towfish. Long baselines provide superior gradient measurement sensitivity and increased detection range. Longitudinal gradiometers are also extremely hydrodynamically stable when deployed.

Applications:

Shipwreck, Search and Salvage – Medium baseline longitudinal gradient measurement can eliminate interference by geological bodies, while highlighting massive magnetic sources like steel hulls, boilers or engines. Smaller sources such as anchors or cannons will require a shorter baseline, and lower towing altitude.

Environmental Survey – Medium baseline measurement with a longitudinal gradiometer can highlight shallow magnetic sediments, while eliminating deeper geological influences. The baseline should be on the order of magnitude of the expected towing altitude.

Exploration Geophysics – Long-baseline measurement with a longitudinal gradiometer is ideal since the bodies of interest are often far from the sensor, and produce very small gradients. The baseline should be on the order of magnitude of expected depth-to-source.

Performance

Operating Zones

Al[illegible]e Accuracy
Sensor Sensitivity
Counter Sensitivity
Resolution
Dead Zone
Heading Error
Temperature Drift
Power Consumption
Timebase stability
Range
Gradient Tolerance
Sampling Range
External Trigger
Communications
Power Supply
Operating Temperature
Temperature Sensor

Towfish Dimensions

Towfish Length	124 cm (49 inches)
Towfish Diameter	12.7 cm (5 inches)
Towfish Weight in Air	16 kg (35 lbs)
Towfish Weight in Water	2 kg (4.4 lbs)

Tow Cable Dimensions

Conductors	Twisted pair
Strength Member	Vectran
Breaking Strength	2,500 kg (5,500 lbs)
Outer Diameter	1 cm (0.4 inches)
Bending Diameter	16.5 cm (6.5 inches)
Weight in Air	125 g/m (84 lb/1000 ft)
Weight in Water	44 g/m (29.5 lb/1000 ft)
Outer Jacket	Yellow Polyurethane
Cable Termination	Field Replaceable

Floatation Cable

Conductors	Twisted pair
Strength Member	Vectran
Max Working Load	2,500 kg (5,500 lbs)
Outer Diameter	1.9 cm (0.74 inches)
Bending Diameter	25 cm (10 inches)
Weight in Air	272 g/m 183 lbs/1000 ft)
Weight in Water	-20 g/m (-13.5 lbs/1000 ft)
Outer Jacket	Orange Polyurethane
Cable Termination	Field Replaceable

Other Sensors

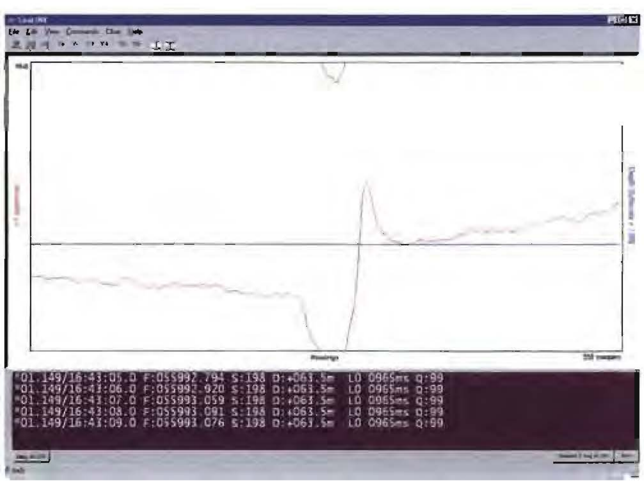
Pressure/depth sensor:
A pressure sensor is included with every SeaSPY towfish.

Altimeter:
200kHz altimeter 0-100m range, 0.1 resolution integrated into the nose of the SeaSPY towfish. Altitude is available with every mag reading.

SeaLINK Software

SeaLINK, a 32 bit application that runs under Windows 95/98/ME/NT/2000/XP is supplied as standard equipment with all SeaSPY magnetometer systems. SeaLINK provides an interactive text interface as well as a real-time plot view of data that is being collected from the magnetometer. Features include:

- real-time graphing of magnetic field trace
- display of depth trace
- bathymetry is displayed with the altimeter option
- event markers from user or serial port signal
- graph zooming and scaling
- review of stored data
- real-time graphical printing to a dot matrix printer
- audible alarms for signal quality flags



SeaLINK NMEA capability

- The ability to accept GPS NMEA data through any free COM port on the PC.
- The user will generally set the magnetometer up on COM1, and the GPS data onto COM2.
- The ability to synchronize the magnetometer clock to GPS time at the click of a button, or automatically at a periodic interval. The synchronization can be done either directly on receipt of a particular NMEA string, or very accurately via receipt of a 1PPS signal through the Ring Indicator pin of the COM port.
- The ability to tag every mag reading with a GPS coordinate, corrected for towfish layback. If the GPS data frequency is less than the magnetometer sampling rate, a coordinate will be interpolated for interim mag readings.
- GPS data can also be stored completely independently from the mag data stream
- All GPS information can be shown on-screen in real time in latitude/longitude format, or as UTM projection with user-selectable datum.

AML Smart Probe Sound Velocimeter

The **ONLY CHOICE** *for reliable measurements of sound velocity and pressure.*

Sound Velocity & Pressure Smart Sensor

The SV&P Smart Sensor is a low cost instrument designed to measure sound velocity and pressure in water. This highly adaptive sensor is ideal for integration into existing data collection platforms or OEM equipment. Connect it directly to a PC or combine it with an AML Smart View hand-held display and hand hauled profiles can be conducted in real-time. Its small size, extremely fast response time and high sampling rate make the sensor ideal for fast profiles or tow speeds.

Each sensor has internal calibration coefficients and outputs real-time data to allow a "plug and play" environment. The optional addressable features provide for daisy chaining with other sensors allowing the user to create their own system.

Sensors

SOUND VELOCITY

- Proprietary "Time of Flight" technology
- 1400 to 1550 m/s standard measuring range
- ±0.050 meters per second accuracy
- 0.015 meters per second resolution
- 145 µs response time
- Temperature compensated

PRESSURE

- Semiconductor strain gauge (temperature compensated)
- Available ranges: 0-10, 20, 50, 100, 200, 500 dbars (higher ranges available)
- ±0.05% full scale accuracy
- 0.01 dbar resolution
- 10 ms response time

Electrical

- 10 samples per second maximum
- RS-232 ASCII communications
- Optional: RS-485 or TTL
- Autobaud rates from 2,400 to 38,400 baud

Power

- 40 mA sampling current
- External 8 – 16 Vdc (12 Vdc nominal)
- Optional power configurations available upon request

Mechanical

- Weight: 575 grams in air
  180 grams in water
- Dimensions: 45.7 mm (1.80") Ø x 368 mm (14.5")
- Construction: Type 316 stainless sensor & plate, INVAR rods, acetal housing rated to 500 meters.
  Optional: Type 316 stainless steel housing rated to 4,500 meters.
  Optional: Titanium housing rated to 10,000 meters
- Connector: IMPULSE Miniature Wet Pluggable™ Series
- Environment: Operating: -20° to 50°C
  Storage: -40° to 60°C

Instrumentation THROUGH *Innovation*

APPLIED MICROSYSTEMS LTD

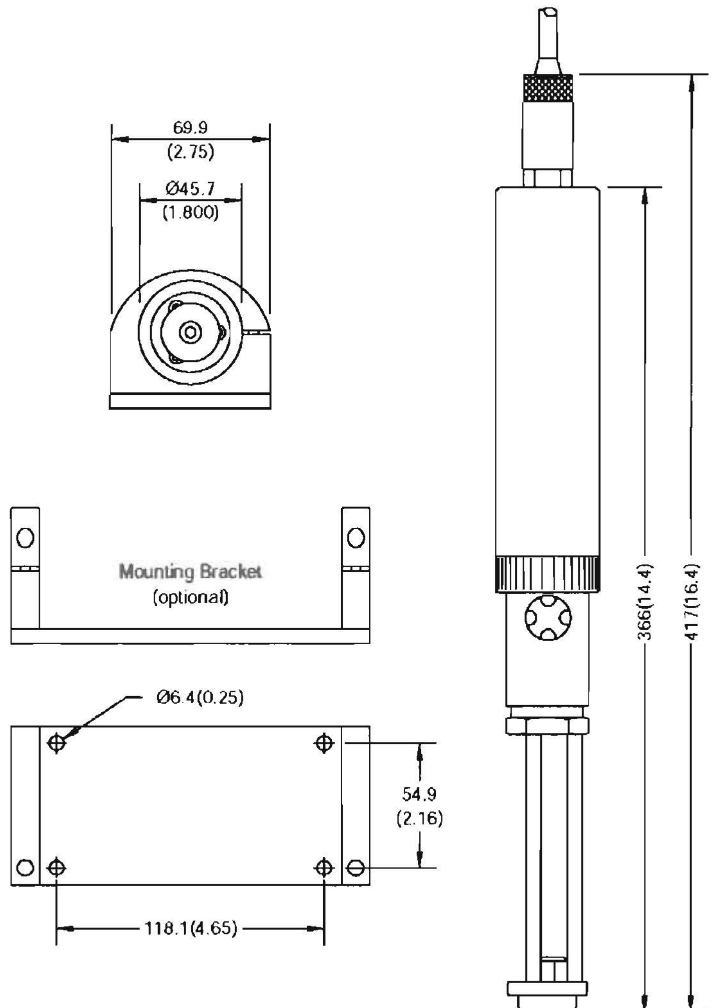
Sound Velocity & Pressure Smart Sensor

Accessories and Software

See Accessories Data Sheet for available options and software.

Smart Talk Data Logging Software is included at no charge with every sensor.

Mechanical Details:



mm(inches)

Instrumentation THROUGH Innovation

APPLIED MICROSYSTEMS LTD

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1 800 663 8721 (Canada & USA)
info@AppliedMicrosystems.com

APPLANIX POS/MV 320

POSITION & ORIENTATION SYSTEM FOR MARINE VESSELS

A proven, high accuracy GPS aided Inertial Navigation System

POS/MV is a GPS aided Inertial Navigation System (INS) that delivers full six degrees of freedom (position and orientation) solutions for marine vessels. POS/MV is now available in two specifications: POS/MV320 (accuracy to 0.01°) and 220 (accuracy to 0.05°).
With RTK aiding, POS/MV will provide position accuracy to 0.01° (320) or 0.05° (220) in all dynamics and at all latitudes. The inertial component of POS/MV ensures continuity of all data during GPS dropouts enabling continued operation in high multipath environments and under or around significant obstructions. After power-up the Inertial Measurement Unit (IMU) becomes the primary source of navigation data.

Noise and position errors from the GPS solution are not carried through to the output channel. GPS data is used only to correct the drift of the IMU. When the GPS position environment is good, the blended position from POS/MV will provide a lower noise, higher data rate solution that is available from GPS alone.

The system comprises a compact IMU, rack mountable POS/MV Computer System (PCS) and two GPS antennas. The system is controlled and monitored via a Windows® based software programme.Interfacing to a RTK GPS receiver is easily achieved using standard NMEA messages. As an option POS/MV can be supplied with an internal RTK L1/L2 receiver.

POS/MV has been designed to provide geo-referencing and motion correction data for any marine application. For the survey users, POS/MV eliminates the attitude errors associated with conventional motion sensors and gyrocompass in dynamic environments.

Rapid deployment is achieved by a dynamic self-calibration routine. When commissioned power-up to full online capability takes 3 minutes - there is no gyro spin-up time

System Attributes

- Roll & pitch accuracy to 0.05 - 0.01° in all dynamics
- True heading accuracy to 0.05 - 0.01° independent of latitude and dynamics
- Blended RTK position data to 2cm accuracy
- Complete navigation and attitude solution
- Continuity of all data during GPS dropouts
- No motion artefacts, even under the most severe conditions
- Roll & pitch accuracy to 0.05 - 0.01° in all dynamics
- True heading accuracy to 0.05 - 0.01° independent of latitude and dynamics
- Blended RTK position data to 2cm accuracy
- Complete navigation and attitude solution
- Continuity of all data during GPS dropouts
- No motion artefacts, even under the most severe conditions
- No gyro spin-up time
- Compact and reliable
- Eliminates post-processing for position errors
- Digital, analogue and ethernet interfaces
- Self-calibrating for rapid deployment
- Industry standard

Technical Specifications

PERFORMANCE	RTK	DGPS
Position	0.02 - 0.10 m CEP	0.5 - 4 m CEP
Velocity	0.03 m/s	0.03 m/s
Roll & Pitch	0.01°	0.02°
True Heading	0.01° (4m baseline) 0.02° (2m baseline)	0.01° (4m baseline) 0.02° (2m baseline)
Heave	5% of Heave Amplitude or 5 cm	
PHYSICAL		
Size	IMU	204 x 204 x 168 mm
	PCS	441 x 111 x 346 mm 2.5U, 19" rack mount
	Antenna	170Ø x 77 mm (2 off)
	Choke Ring	370Ø x 61 mm (2 off)
Weight	IMU	3.5 Kg
	PCS	7 Kg
	Antenna	0.37 Kg (2 off)
	Choke Ring	1.8 Kg (2 off)
Power	120/220 VAC, 60/50 Hz, 60W	
Temperature	IMU	-40° to +60°C
	PCS	0° to +60°C
	Antennas	-40° to +60°C
Humidity	IMU	0 to 100%
	PCS	5 to 95% RH non-condensing
	Antennas	0 to 100%
Cables	IMU	8m (standard)
	Antenna	15m (2 off, standard)
INTERFACES		
Ethernet Interface (10base-T)	Function	Operate POS/MV and record data
	Data	Position, attitude, heading, velocity, track and speed, acceleration, status & performance, raw data. All data has time and distance tags.
	UDP Ports	Display port - low rate (1Hz) data Data port - high rate (1-200Hz) data
	IP Port	Control port - used by POS/MV controller
RS232 Interfaces (D89 males)	NMEA Port	GGA, HDT, VTG, GST, ZDA, PASHR, PRDID (1-50Hz)
	High Rate Attitude Data Port	Roll, pitch, true heading and heave in all multibeam proprietary formats (1-200Hz)
Options	Internal RTK GPS receiver	
	Analogue interface (roll, pitch and heave)	
	Field support kit	

Appendix L-4

Review of Historical Information and Site-Specific Synthesis

Snohomish PUD Admiralty Inlet Pilot Project:
Marine Mammal Pre-Installation Study

REVIEW OF HISTORICAL INFORMATION
AND SITE-SPECIFIC SYNTHESIS

The Whale Museum
SMRU Ltd.
Orca Network

October 2009

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TABLE OF CONTENTS

1) INTRODUCTION

Public Utility District No. 1 of Snohomish County (Snohomish) is engaged in FERC licensing of the Admiralty Inlet Pilot Tidal Energy Project in Puget Sound, Washington. The Project involves installation of up to two Tidal In Stream Energy Conversion (TISEC) devices in Admiralty Inlet, as well as placement of a transmission cable to shore. These devices will be installed in the north-eastern portion of Admiralty Inlet, approximately 1 km west-southwest of Admiralty Head near latitude 48.149065 longitude -122.691319, in water depth of approximately 60 meters. Power generated by the project will be transmitted via a single subsea cable and connected to the grid at the Puget Sound Energy infrastructure near the Fort Casey Conference Center.

It is Snohomish's intent to 1) characterize the existing environment, including marine mammal use, within the Project vicinity; 2) evaluate the potential for the Project to substantively impact existing resources; and 3) engage in detailed post-installation monitoring of the Project to observe and assess any such impacts. This study is part of a larger marine mammal program which aims to address the first of these goals, and is intended to support the environmental analyses required for the second. These analyses will be presented in Snohomish's Draft Pilot License Application (DPLA) and subsequent Final Pilot License Application (FPLA) to FERC.

This historical review was undertaken to aid in describing Southern Resident Killer Whales (SRKW) habitat use within the Project vicinity and aid in providing data to assess encounter risk with the TISEC device(s). The Whale Museum (TWM) was contracted by SnoPUD in October 2009 to review historical data and collect new data on the usage of Admiralty Inlet by SRKW, other marine mammals, and Marbled Murrelets. This historical review will focus solely on SRKW and for the most part the sighting databases held by TWM. Additional site-specific data from a variety of other sources is also synthesized.

SRKW were listed as endangered in 2005 by the National Marine Fisheries Service (NMFS) and a recover plan finalized in 2008 (NMFS 2008). TWM has maintained sightings data on SRKW since the late 1970's, but given the smaller numbers of sightings in the early years, TWM generally only uses data from 1990 onwards for analysis purposes and refers to this later dataset as the Orca Master (OM). This database was the primary source of information in determining critical habitat for SRKW (NMFS 2008). While this dataset is not the result of a systematic study of SRKW habitat use (rather it is based on opportunistic sightings), it is the most comprehensive dataset on SRKW sightings in the inland waters of Washington State. Furthermore, Hauser et al. (2006) determined that this dataset was appropriate to use to study distribution patterns of SRKW as long as its limitations were considered. The Orca Master dataset records date, time, location within a geographic quadrant, pod ID and direction when available (see specifics below). To gather finer spatial and behavior data for SRKW usage of Admiralty Inlet to help further inform SnoPUD's FERC application, a number of other sources and datasets were also checked for finer scale location and behavior data in Admiralty Inlet. Approaches for relevant data were made to Cascadia, NOAA NWFSC, The Centre for Whale Research and Beam Reach as well as local sighting networks and local whale watching companies. Additional datasets that proved useful were provided by Orca Network, Island Adventures Whale Watching, and Puget Sound Express Cruises and are described in detail bellow. Although Orca Network sightings are included in the Orca Master dataset, any behavior or fine scale location data are not included, which explains the need to reinvestigate their original dataset for these finer details. Annual and seasonal trends in the use of Admiralty Inlet and Puget Sound waters were analyzed using only the Orca Master dataset as stipulated in Section 3 A. This dataset is also provided to NMFS on an annual basis for their own analyses, thus providing a consistent dataset for managers and researchers to use. Finer scale details from other sources amounted to 67 new sightings. These new data were used to complement the synopses of finer scale details with regard to location and behavior.

2) DATA SOURCES

A) The Whale Museum (Orca Master)

The 2008 Orca Master dataset is compiled from 5 different sources (Traxler et al. 2009). The source information for each of these five datasets are identified in Table 2.1 including a basic description of the data set, periods of coverage, locations, and numbers of records. The first data source is The Whale Museum's sighting archives. The Whale Museum has long maintained an archive of marine mammal sightings (Boran, 1980; Osborne 1991; 1999). These sightings are reported to the Museum by several channels, including the Whale Hotline (a phone recording for public sightings), Orca Network (an e-mail list service based on Whidbey Island), e-mail through the Museum's web site, eyewitness reports from affiliated researchers, Museum staff and visitors, orca web form data, and hydrophone sightings. Sightings are recorded on a data sheet and then typed into a Microsoft Access database. Sighting Archive records are identified as from a public source if the observer is not known to Museum staff; records are identified as reliable if the observer is known to be experienced or professional. Reliable opportunistic observations from whale-watch operators and naturalists, TWM staff, interns and seasonal independent researchers are also included in the sightings archive. This sighting archive contains records that The Whale Museum gathers year-round. All other dedicated sighting data sets which are incorporated in this master database are primarily centered around the six months of summer (April-September).

A new 2008 data source included in the sightings archive is the direct solicitation of sightings from various whale watch operators (in lieu of the pager system) who reliably tracked whale movements and locations throughout the summer and recorded the vital information on a form provided by TWM. Although considered to be "reliable" as far as sources goes, a special source code of "TWM-SA-WW" was assigned to these records in order to better track the number of sightings received by this method.

The second data source is the pager data previously operated by Sea Coast Expeditions and later acquired Orca Spirit Adventures Group of Victoria, B.C.

Observations of whale movements were systematically collected by members who were searching from both land and water for the whales; sometimes this also includes a paid shore observer on Mt. Douglas on Vancouver Island. As the pages were sent out, information on whale locations and pod identity were recorded by Limekiln Lighthouse interns or TWM staff/volunteers in a notebook. In some years Sea Coast Expeditions personnel kept records of the pages and sent copies of them to us at the end of the year, but this practice was discontinued in 2003. After 2003 The Whale Museum shifted to recording the pages separately in our own set of notebooks as sightings occurred throughout the summer. The notebooks and photocopies were then entered into an Excel spreadsheet. The pager data was available during the whale-watch season, May through October. As noted, this data source lasted until the 2007 whale-watch season.

The third data source is provided by Soundwatch. The Whale Museum runs the Soundwatch Boater Education program to distribute educational literature to private whale-watch boats and collect data on the vessel traffic around the whales (Koski, 2004; Koski and Osborne, 2005; Koski, 2006; Koski, 2007). Every half-hour Soundwatch personnel count boats around the whales and note the time, location, pod and direction of the orcas. This data is collected on field data sheets designed for this purpose and then is entered into a Microsoft Access database. Soundwatch data is also available during the regular whale-watch season (May-September).

The fourth source of data is Dr. Robert Otis' data set from Lime Kiln Point State Park. Since 1990 from late May until early August, Dr. Otis and his interns record data about the whales as they pass by the park in the hours between 9 a.m. and 5 p.m. This is a very important summertime control dataset that establishes a uniform observer effort and helps identify detailed pod movements in a portion of Haro Strait (Osborne et. al., 2004; Koski and Osborne, 2005).

A fifth data source derives from SPOT satellite transponders. 2008 was the first year these were used and they were placed on 3 different research vessels (Beam Reach: Marine Science and Sustainability School, Debbie Giles a graduate student researcher from the University of California, Davis, and Katherine Ayres a graduate student researcher from the University of Washington) as well as the Soundwatch and Straitwatch boater education program boats throughout the summer season. The SPOT devices record a position every 10 minutes or when the appropriate button is pushed. This data is sent via satellite link to the SPOT web site from where it was then downloaded.

Table 2.1. Orca Master Data Sources and number of records.

DATA Source	Years	Description	Location Record	Record Source Code	No. of Records
TWM Sighting Archive	1990-2008 Year-round	Sighting records reported by public and reliable observers to TWM	Locations given in descriptive terms and matched to TWM Quadrants.	TWM-SA-Pub TWM-SA-Rel TWM-SA-WW TWM-HYD-Pub TWM-HYD-Rel	5,909 6,683 751 49 <u>174</u> 13,566
Pager	1997-2007 Summers	Whale-watch pager system	Pager coordinates matched to TWM Quadrants	TWM-Pager	18,893
Soundwatch	1998-2008 Summers	Sightings observed by Soundwatch personnel recorded every half-hour on the water.	TWM Quadrant	TWM-SW	7,456
Lime Kiln Station	1991 1994-2008 Summers	Sightings by Dr. Robert Otis, Ripon College May-Aug every day from 9-5.	Lime Kiln study area is TWM Quadrant 181	TWM-Otis	1,511
SPOT data	2008 Summers	Satellite GPS tracking units used by various researchers	Actual Lat/Long tracks of boats following whales	SPOT	1,522

B) Orca Network

The Orca Network sightings are derived from citizen reports via email or telephone. The purpose of the reporting system is both for data on whale travels and for instilling public involvement in tracking the whales' movements. They are generally compiled on a daily basis and sent by email to a list of, currently, over 3500 recipients, then assembled chronologically on the Orca Network website (www.orcanetwork.org/sightings/sightings.html) and each month is then added to the archives (www.orcanetwork.org/sightings/archives.html). Queries are done by searches for place names. Place names within the study site were used to query the archives (e.g. Admiralty, Port Townsend, Keystone, Fort Casey, Point Wilson, etc.).

C) Island Adventures Whale Watching

Island Adventure Whale Watching runs out of Anacortes and maintains a web based diary or blog of whale watching trips since 2003 called the Whale Report (http://blog.island-adventures.com/). Whale reports were queried using place names within the study site (e.g. Admiralty, Port Townsend, Keystone, Fort Casey, Point Wilson, etc.). Reports with study site place names were linked with Orca Master records and additional fine scale information recorded where possible. The company was contacted in recent instances where details of time and location were difficult to discern. In these occasions the company kindly provided more details. Records not included in the Orca Master were also extracted.

D) Puget Sound Express Cruises

Observations were made during the course of whale watch tours and scheduled passenger ferry runs conducted aboard the vessels Glacier Spirit and Olympus, and were recorded by the captain in the ships log. Logs were searched visually for references to killer whale sightings at locations between Partridge Bank and Lagoon Point. Sightings were discarded if the animals were positively identified as mammal-eating (so-called "transient") killer whales at the time they were recorded. Glacier Spirit log books span the years 2004 - 2009. Glacier Spirit runs daily trips from Point Hudson to Friday Harbor from the third week of May through second week of September. From April through the second week of May and then the third week of September through October it runs 75% of the days on the same route. Olympus logs span the years 2005-2009. Olympus runs one or two trips per day from Point Hudson on 90% of the days from the third week of May through the second week of September.

3) ANALYSIS

A) Orca Master

i) Data on an annual basis:

From January 1990 through December 2008, the Orca Master dataset recorded 42,948 sightings of SRKW in the inland waters of Washington State and British Columbia (in this report the term Salish Sea will be used to denote these waters). These sightings include multiple reports of the same pod on the same day. Of these 2,532 were seen in the Puget Sound 'proper' (south of Deception Pass and Admiralty Inlet). This area is depicted in yellow in Figure 3.1. For the purposes of this report, the highlighted area will be referred to simply as Puget Sound. Of the 2,532 sightings in Puget Sound, only 196 sightings occurred in the quadrants making up the core of the study area which is defined as five nautical miles from the proposed pilot project site (approximately 1 km west-southwest of Admiralty Head near latitude 48.149065, longitude -122.691319, in water depth of approximately 60 meters). For the purpose of this report, the study area will be referred to simply as Admiralty Inlet. The quadrants that form the study area are 364, 365, 387, 388, and 389. See Figure 3.2 for depiction of study site and quadrants considered a part of the study site. See Table 3.1 for synopsis of sighting numbers.

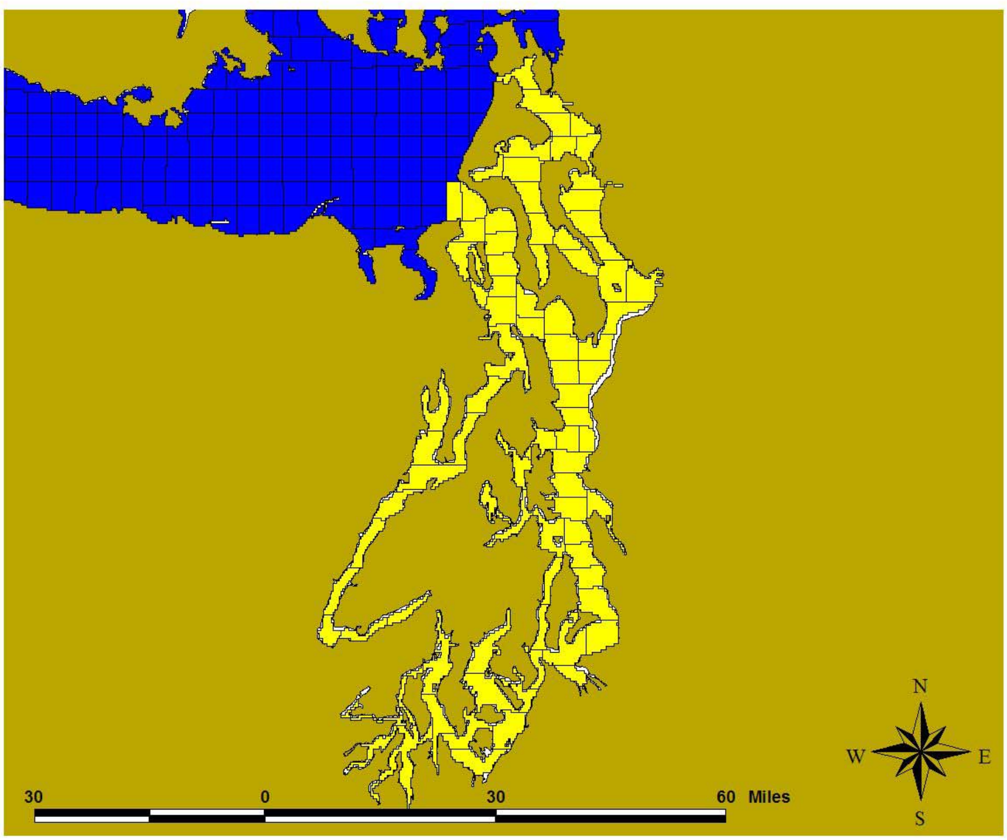

Figure 3.1. Map showing the area highlighted in yellow considered as Puget Sound for the purposes of this report.

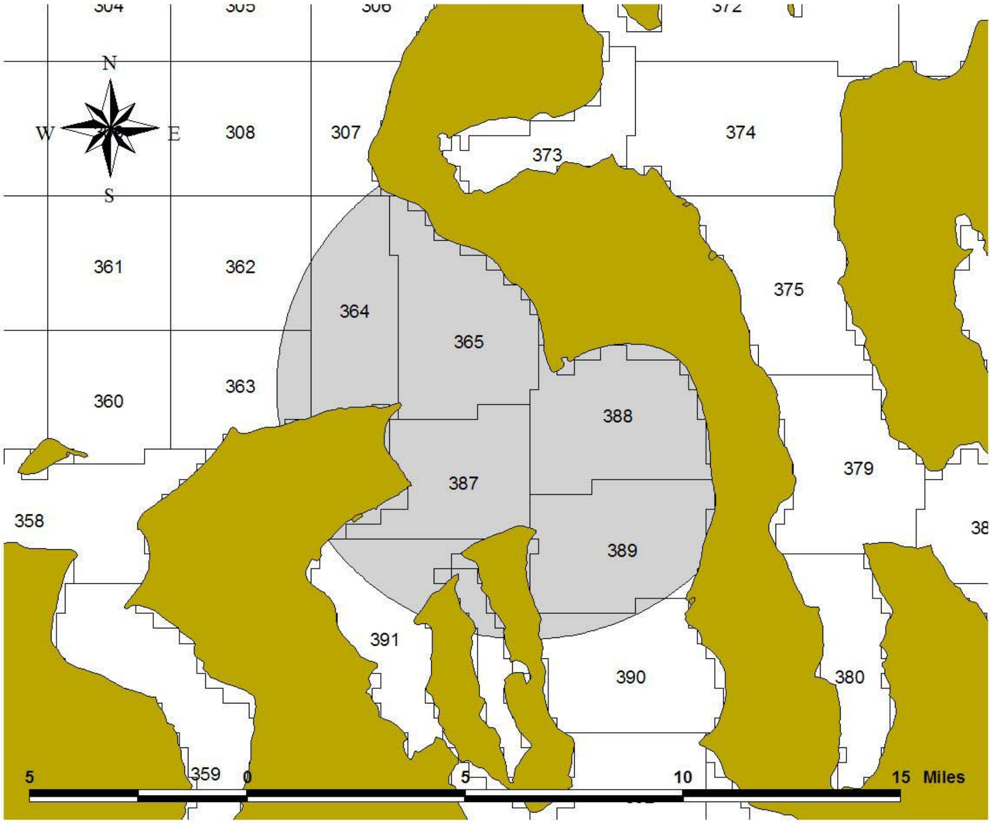

Figure 3.2. Map of study area in Admiralty Inlet showing TWM quandrants that cover the 5 nautical mile study area.

Table 3.1. Number of sighting records in TWM Orca Master dataset by region. These sightings include multiple reports of the same pod on the same day.

Location	Salish Sea	Puget Sound	Admiralty Inlet
Number of sightings	42,948	2,532	196

In terms of sightings over the years in Puget Sound, there has been both an increase in the total number of sightings over the years and the average number of sightings per day on days when whales were sighted (‘whale days’). As can be seen in figure 3.3 these two measures track each other well. In fact a regression to determine how well average sightings per whale day predicted the number of sightings in a year was significant and found that 72% of the variance in sightings per year was explained by average number of sightings per whale day ($F_{1,17} = 44.06$, $p<0.005$, $R^2 = 0.72$). The large increase in Puget Sound sighting reports is probably due to sighting contributions from Orca Network, which started in 2001 and has increased awareness and reporting by the public in the Puget Sound area. As such we conducted all further key analyses on both the time scales 1990-2008 and 2001-2008. The average number of sightings per year in

Puget Sound since 1990 was 133.26 (SD = 97.31). The average number of sightings per year in Puget Sound since 2001 was 234.63 (SD = 51.68).

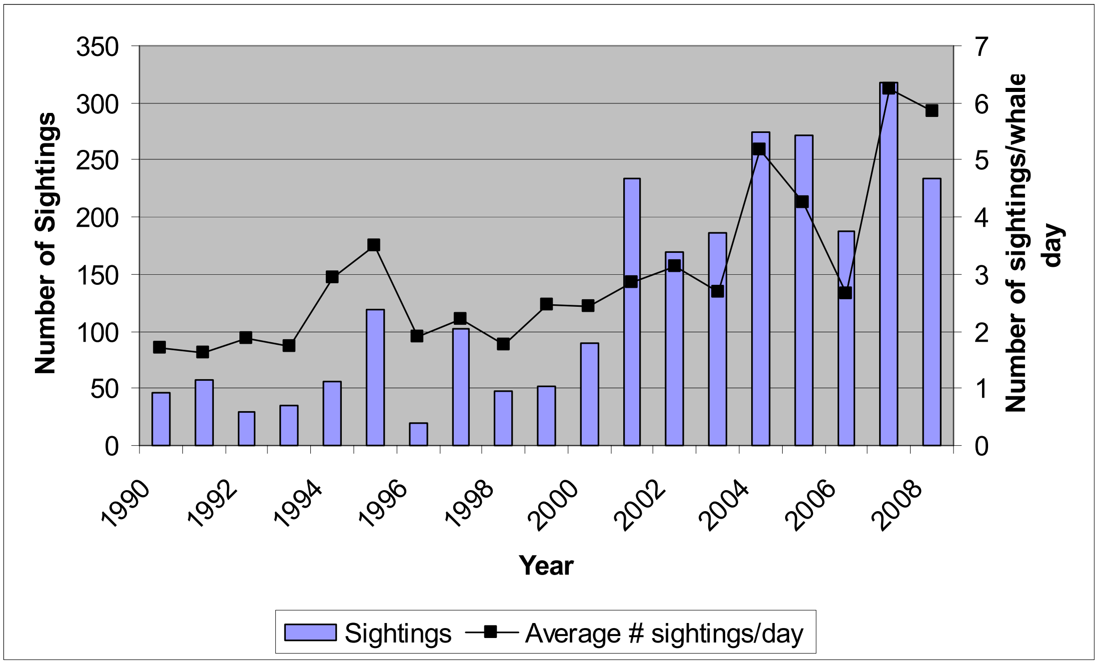

Figure 3.3. Puget Sound SRKW sightings. Number of sightings per year is depicted in the histogram, while the number of sightings per whale day is shown with the line graph. These two measures are positively correlated ($F_{1,17} = 44.06$, $p<0.005$, $R^2 = 0.72$).

While the number of sightings in the Puget Sound illuminates the fundamental quality of the dataset in that region, it is not informative about how the whales use Puget Sound. To determine habitat usage it is more appropriate to use whale days as a metric. Whale days were calculated by counting the number of days that SRKW were sighted in Puget Sound. This makes the assumption that all SRKW sighted in Puget Sound on a given day are part of the same foray into Puget Sound. This assumption will deflate the estimated number of transits if there are indeed two or more distinct groups of SRKW that are in Puget Sound on the same day. Our experience however suggests that when SRKW enter or exit Puget Sound, they typically do so on the same day. Figure 3.4 illustrates the number of days that whales were seen in Puget Sound during the years of this dataset. There is clear variation in the number of days that the SRKW used the Puget Sound habitat, but some of that variation is likely driven by the underlying dataset. That is to say, the lower number of whale days pre 2001 are likely due to an under reporting of whale sightings. From 2001 onwards, there were an average of 60.5 (SD = 13.45) whale days a year compared to an average of 26.64 (SD = 10.72) whale days for the period from 1990 through 2000. In a simple attempt to adjust for the under reporting in the early years we added the difference of the two means (33.86) to the number of whale days pre 2001 to allow for an estimate of the variance in the number of whale days had there not been under reporting (min:40, max:82, SD = 11.58). These adjusted sightings have been added to Figure 3.4 for comparison to the reported sightings. While other factors are potentially also important in this shift after 2001, it is our opinion that data from 2001 onwards should be considered as the most appropriate baseline to use for any subsequent comparisons.

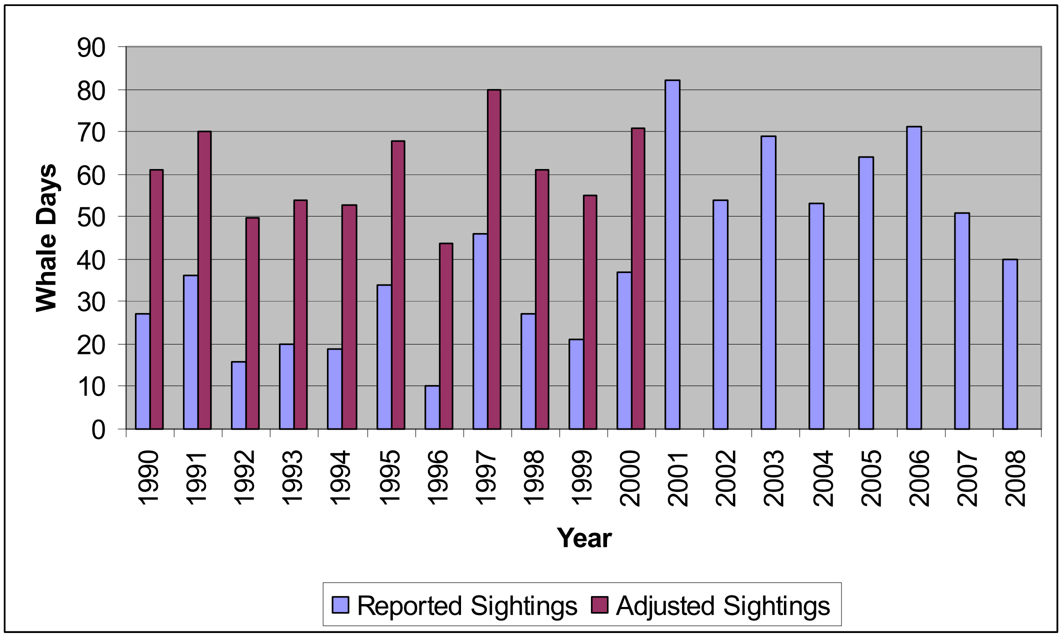

Figure 3.4. depicting the number of days whales were spotted in Puget Sound by year. Blue bars are actual reported sightings. Burgundy bars are adjusted estimates made by adding the difference in the mean number of sightings from 2001 through 2008 and the mean number of sightings from 1990 through 2000. This was done to estimate the number of whale days that might have occurred if the number of reported sightings was as high in the early years as it was in the later years. Data was grouped by calendar year (Jan. 1 through Dec. 31).

ii) Data on a seasonal basis:

In terms of seasonality, whale sightings in Puget Sound are highly seasonal, although SRKW are generally sighted in the Salish Sea in all months of the year (see http://www.whalemuseum.org/education/library/whalewatch/arrivals.html for table of pod occurrence by month starting in 1976). Seasonal trends have been investigated by number of people (e.g. Hauser et al. 2007, McCluskey 2006) and more recently by NMFS who depicted on a map the number of Orca Master sightings per quadrant by month of year, after having removed multiple sightings in the same quadrant on the same day. The SRKW spend the least amount of time in the Puget Sound during the months May through July, while spending the most amount of time in the months October through January (70% of 777 sightings, see Figure 3.5). This pattern seems very consistent in recent years, with strongest attendance in Puget Sound in November and December (Table 3.4), with 12-14 sightings/month on average. Given the length of the device deployment. it is important to determine if this seasonal pattern has changed over time. This study has undertaken two approaches to visualize and interpret the sightings data. The first was a series of histogram plots of whale days per month across the 19 years of this dataset (see Figures 3.6 & 3.7). Clearly periodicity is exhibited in the sightings data, but again with notably fewer whale days than the 19 year average in the first 10 years, and more whale days than the average in the later 9 years (2001-onwards).

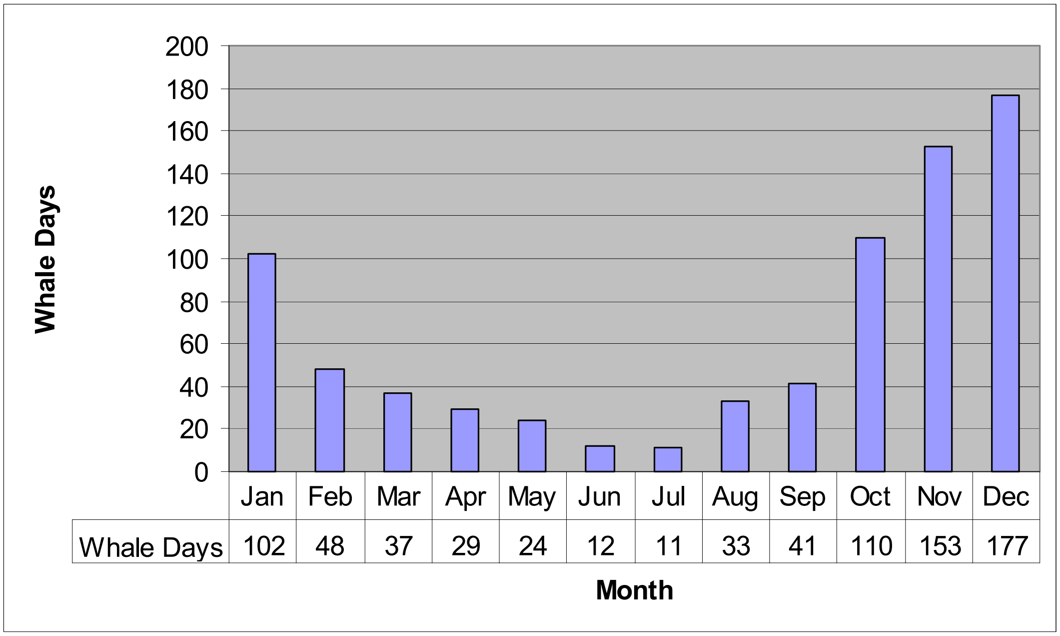

Figure 3.5. Counts of days when whales were sighted in Puget Sound from 1990 to 2008 by month. The raw numbers are also included for further information.

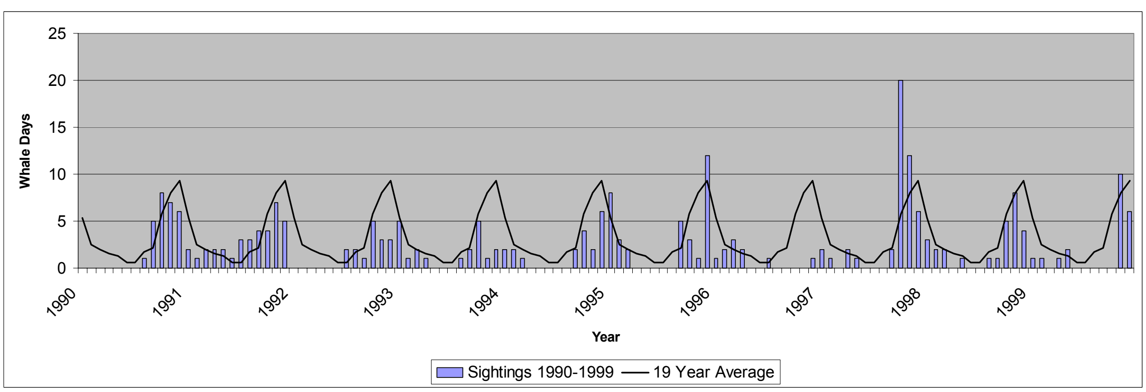

Figure 3.6. Histograms of whale days by month from 1990 - 1999. The 19 year monthly average is superimposed on the graph to allow comparison. During these years, whale days were generally lower than the 19 year average. The large spike at the end of 1997 is due to part of L pod being in Dyes Inlet for almost a month.

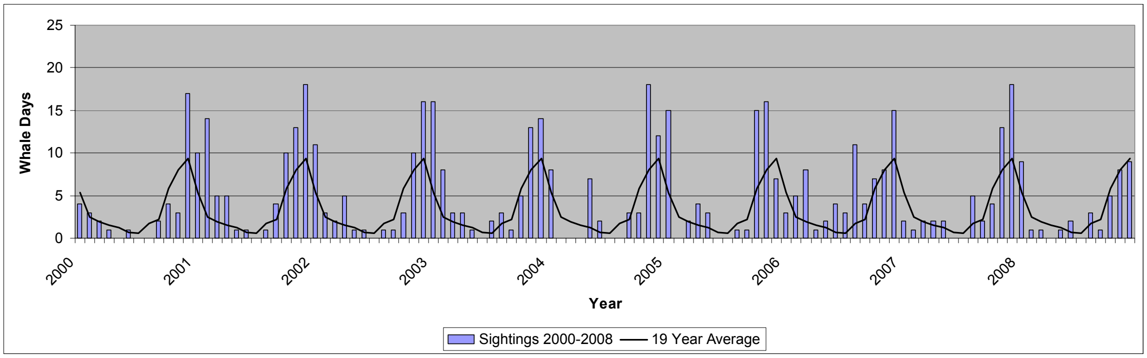

Figure 3.7. Histograms of whale days by month from 2000 - 2008. The 19 year monthly average is superimposed on the graph to allow comparison. During these years, whale days were generally higher than the 19 year average.

This change in periodicity also shows up in a wavelet analysis. Wavelet analysis has been used for a number of years to decompose time series into time-frequency space to determine cycles and the timing of those cycles in fields such as climatology (Torrence & Compo 1998; Maraun & Kurths 2004) and more recently has been applied to movement ecology to better understand periodicity in animal movements (Wittemyer et al. 2008). Figure 3.8 is a wavelet power spectrum of the sightings data. The input time series was generated from Puget Sound sightings by calculating the number of days per week there were whales sighted. This was imported into Matlab from where wavelet coherency software provided by D. Maraun and J. Laehnemann was used to generate this plot (software available at http://tocsy.agnld.uni-potsdam.de/wavelets/). The Cone of influence is the area outside of which zero padding affects the plot. Data outside this area should be ignored. The thick line surrounding the warmer colors indicates areas where values are greater than or equal to the 0.95 sample quantile of 1000 bootstrapped wavelet power spectra of a white noise null model fit to the data and are used to define areas of significant cycling. The lighter contour lines surround the 0.90 quantile areas.

Clearly visible in Figure 3.8 is the significant 1 year cycle starting at the end of 1997 and continuing until the end of the data series. This cycle corresponds to the annual movement of SRKW into Puget Sound in the Fall/Winter (specifically Oct-Jan). Although this annual cycle is evident throughout the time series, it only becomes significant at the end of 1997. It is difficult to determine if this is driven by the lower number of sightings in earlier years, although the area of significance does start well before 2001 when the number of sightings per year was reliably above 100 per year. Of note is that the start of this significant cycle coincides with the Dyes Inlet incident, when part of L pod spent around a month in Dyes Inlet during October and November of 1997. This probably explains the other 90% significant cycle in 1997-1998 at 2 cycles per year (i.e. every 0.5 years). 2005 also shows cycles at 2 and 8 times per year and seems to be driven by multiple forays into the Puget Sound divided by distinct periods of absence which are have more and less whale days per week than the average, respectively (see Figure 3.9). Therefore the data seem to exhibit a dominant cycle of once per year, with a few years where forays are broken up enough in time to exhibit cycles of 2 and 8 times per year. It is likely that these anomalous years (i.e. 2005) are driven by environmental conditions such as prey availability. See discussion below in section C for more details.

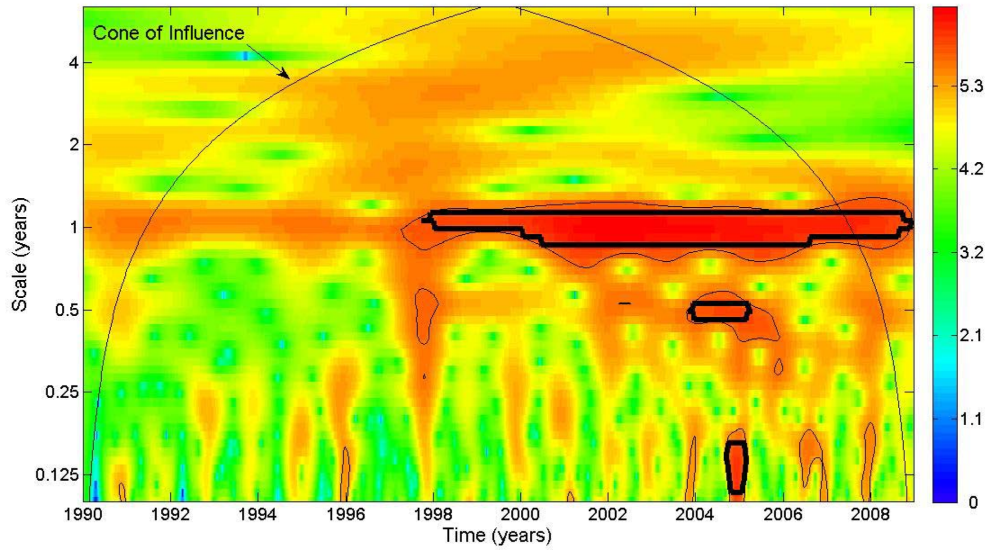

Figure 3.8. Wavelet power spectrum of the weekly whale days in Puget Sound time series using a Morelet wavelet . The cone of influence demarcates the area beyond which the plot is affected by zero padding of the data. Therefore the plot should be ignored outside of this area. Warmer colors denote higher power at that scale and time. Thick contours surround areas where the power is equal to or above the 0.95 sample quantile of 1000 bootstrapped wavelet power spectra of a white noise null model. Thinner contours surround the 0.90 sample quantile. Clearly visible is the significant 1 year cycle starting at the end of 1997.

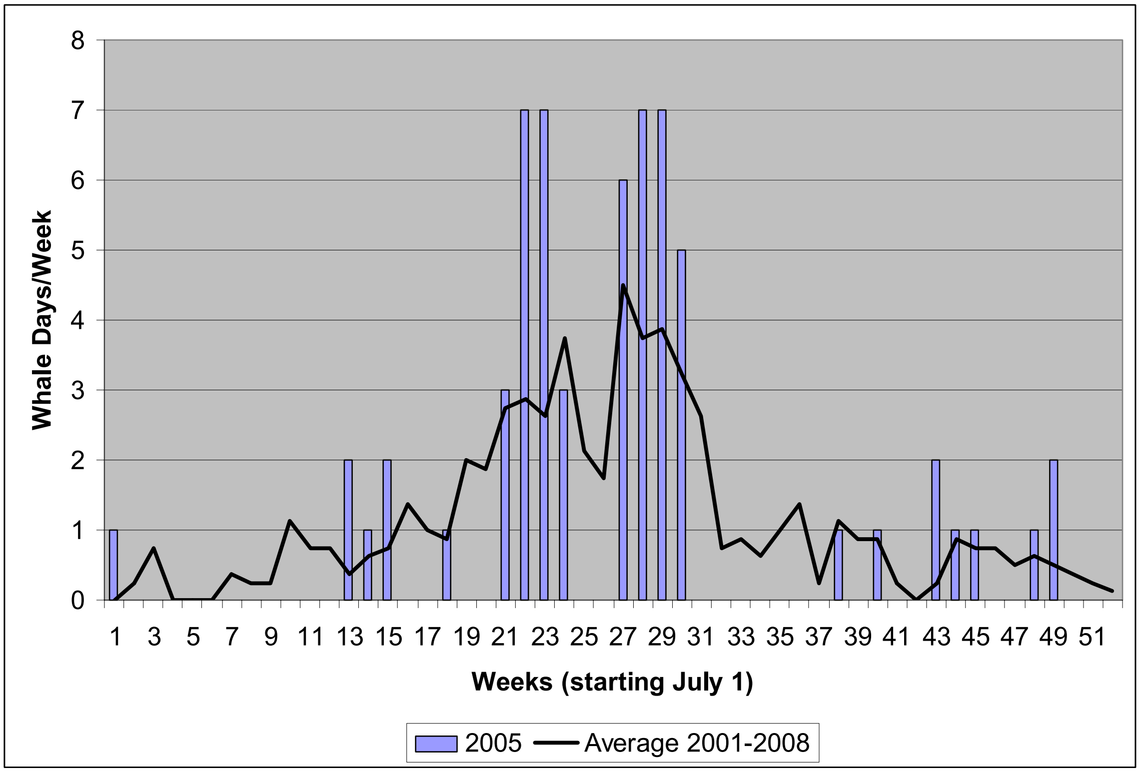

Figure 3.9. Number of Whale days per week. Week one is the first week of July. Histogram is the data from 2005 a potentially anomalous year with many cycles of forays into Puget Sound. For comparison the average number of whale days per week is also included. It is evident that during 2005 there were many distinct periods of above average whale days separated by periods of below average periods.

To summarize, SRKW usage of Puget Sound varies from year to year, but exhibits a strong annual cycle when SRKW are present during the months of October through January. Table 3.2 illustrates the number of whale days per month from 2001 on as well as the mean number of whale days per month for 2001-2008. The average number of whale days for October through January for these years is 10.44 (SD = 4.91) while the average for February through September is 2.34 (SD = 2.70).

Table 3.2. Whale days per month for the years 2001 – 2008. The average and standard deviations are given at the bottom. Although there is variation from year to year, the seasonal cycle with peaks during the months of October through January is clear.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	10	14	5	5	1	1	0	1	4	10	13	18
2002	11	3	2	5	1	1	0	1	1	3	10	16
2003	16	8	3	3	1	0	2	3	1	5	13	14
2004	8	0	0	0	7	2	0	0	3	3	18	12
2005	15	0	2	4	3	0	0	1	1	15	16	7
2006	3	5	8	1	2	4	3	11	4	7	8	15
2007	2	1	2	2	2	0	0	5	2	4	13	18
2008	9	1	1	0	1	2	0	3	1	5	8	9
Average	9.25	4.00	2.88	2.50	2.25	1.25	0.63	3.13	2.13	6.50	12.38	13.63
SD	5.01	4.90	2.53	2.07	2.05	1.39	1.19	3.56	1.36	4.14	3.58	4.03

iii) Estimates of transits through Admiralty Inlet:

As mentioned above, only 196 sightings of SRKW were reported within the Admiralty Inlet study area, but given that there were 2,532 sighting reports for all of Puget Sound (see Table 3.1), it is clear that a portion of the transit of SRKW through Admiralty Inlet was missed. One aim of this study was to assess how best to estimate the number of transits through Admiralty Inlet. This requires a number of key but necessary assumptions. The first assumption we made was that the SRKW do not enter or exit Puget Sound through Deception Pass. We made this assumption because during the whole time period we have only one report of SRKW traveling through Deception Pass (Jan. 10, 2005). By making this key assumption, the number of estimated transits through Admiralty Inlet will likely be a maximum and slightly inflated. The second assumption was that all killer whale sightings reported in Orca Master were SRKW. Every effort is made to exclude transient killer whales from the Orca Master dataset, however many sightings (67% of Puget Sound sightings) are only reported as orcas. It is likely however that the vast majority of these are actually SRKW and not transients since the later are less common in these waters, travel in smaller groups and are generally less conspicuous than SRKW. This assumption is likely to marginally inflate the estimated number of transits through Admiralty Inlet by SRKW.

Of the 2,532 sightings, there were 777 whales days in Puget Sound from 1990 to 2008 (see Figure 3.4 for annual distribution of whale days). Although as our recent field studies have shown, this will not always be the case, it is possible to assume that there will often be time delays of at least several days between one foray into Puget Sound and the next. [To avoid confusion, we use foray to mean a single episode of SRKW being in Puget Sound. For one foray to have occurred there must have been two transits through Admiralty Inlet (one entrance, one exit).] We therefore attempted to determine the appropriate time lag (in days) to use for our analysis. For each whale day we calculated the time lag in days between whale days. This meant that if the whales were sighted the following day, there would be a time lag of one day. Figure 3.10 shows the distribution of these time lags.

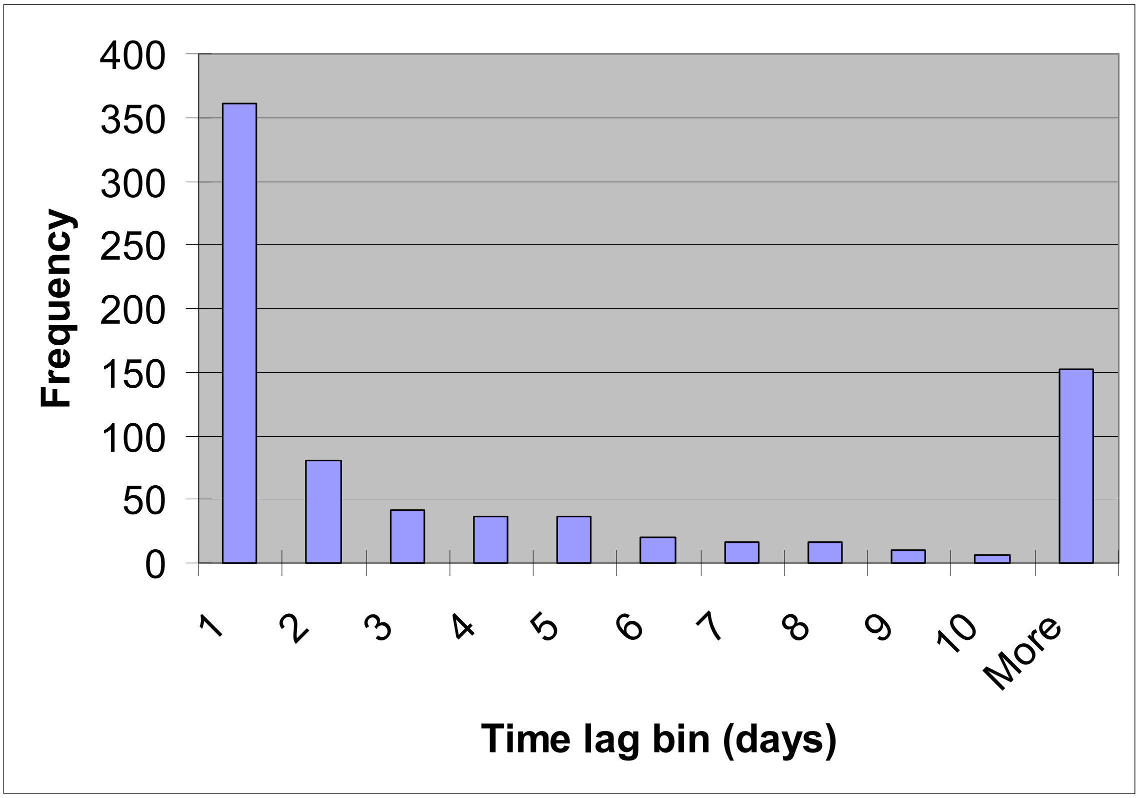

Figure 3.10. Distribution of time lags between whale days in Puget Sound from 1990 to 2008. A one day lag means that whales were sighted one day after the previous sighting (i.e. the next day).

It is clear from this analysis that it is highly likely that if whales are spotted, they were also spotted the day before. We used a log survivorship analysis to determine if there is a clear break in the data that would indicate a criteria for a separate foray into the Puget Sound? Log survivorship analysis is a common graphical technique to determine the minimum interval separating successive bouts (called the Bout Criterion Interval, Martin & Bateson 1993). Log survivorship analysis involves plotting the time interval between successive instances of a behavior (in this case whale days in Puget Sound) and the logarithm of the number of intervals greater than the corresponding time interval (Martin & Bateson 1993; Slater & Lester 1982). The point at which the slope changes dramatically is considered the BCI. Figure 3.11 is a log survivorship plot of the data from one to 20 days between sightings. The slope is stepped because we measured time since last sighting in integers (full days),however, it is evident that the slope is steepest at one day, giving way to a shallower slope beyond two days. This suggests that the split between sightings within a foray versus between forays is around two days.

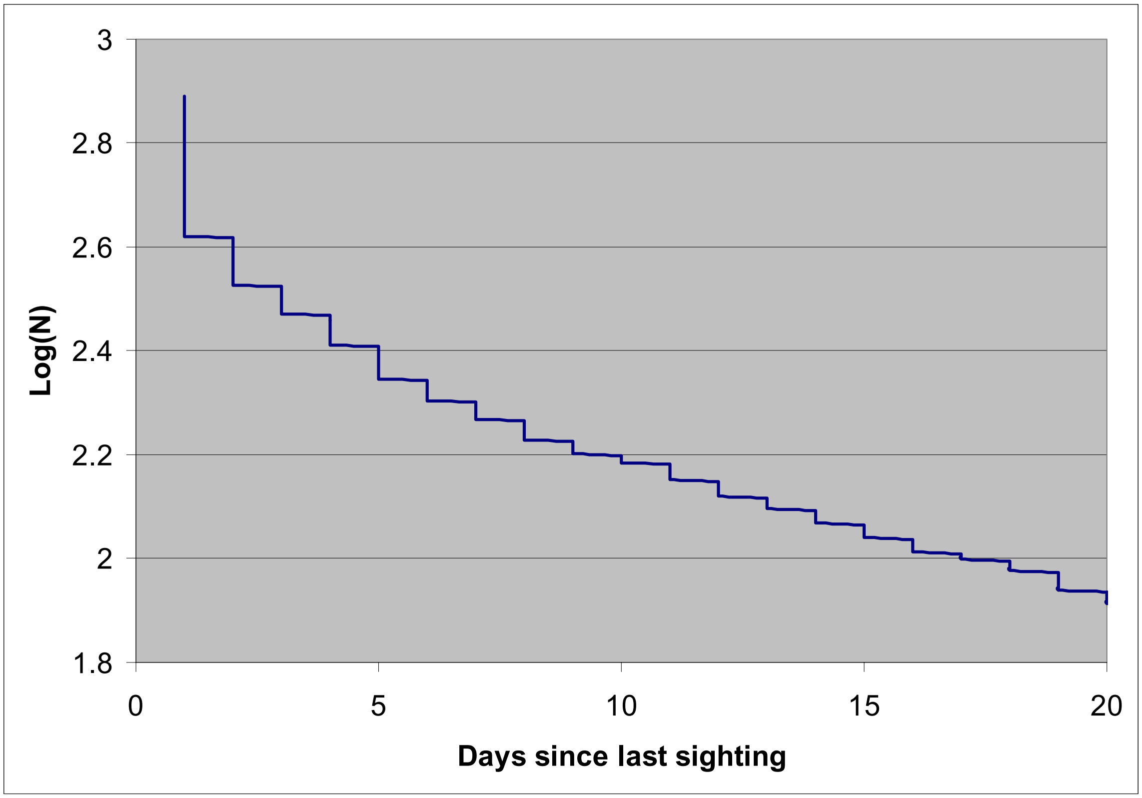

Figure 3.11. Log survivorship plot depicting days since last sighting versus the logarithm of the number of intervals greater than the corresponding day since last sighting. The dramatic change in slope around two days suggests a Bout Criterion Interval of around two meaning that any sightings two days or more apart are likely from a different foray by SRKW into the Puget Sound.

The use of two days (i.e. only one non whale day between whale days) is considered the most conservative criterion (resulting in high end estimates of the number of forays into Puget Sound by SRKW). To assess the sensitivity of this key assumption, we calculated the number of forays into Puget Sound for two to five day lag periods to give a sense of how much that would change the estimate of the number of transits (see Figure 3.12 and Table 3.3). For 2001-2008, this resulted in range from 27 (2 day lag) to 15 (5 day lag) average transits per year. Informal discussion with Dr Brad Hanson (NMFS) supported this range of lag periods as likely sufficient to assess sighting sensitivity. Since these calculations were done on an annual basis, we split the year from July 1st through June 30th rather than a calendar year in order to minimize the times when a foray into Puget Sound would get split between years (June and July have the least number of whale days in Puget Sound while December and January have many, See Figure 3.5). Since these are estimates of forays into Puget Sound, the actual transits through Admiralty Inlet will be twice the number of forays (entrances and exits). Figure 3.12 follows the trend of figure 3.4 in that whale days are lower pre 2001 than they are post 2001. A regression of the number of sightings per year versus the estimated number of one way transits into Puget Sound for that year is marginally insignificant ($F_{1,16}$ = 3.82, p = 0.069, R^2 = 0.193), but suggests that the estimates of the number of one way transits may be related to the number of sightings in that year. It appears that above approximately 100 sightings in a year this relationship disappears (see Figure 3.13).

Figure 3.12 and Table 3.3 give an estimate of the range of the number of forays into Puget Sound. The average estimated number of one way transits (assuming from 2 to 5 day lags) for the period 2001 onwards was 20.75 (SD = 6.01). Even though the BCI suggested a two day lag period for different forays, this does not leave much of a buffer for winter days when weather and visibility are poor (as suggested in communications with Dr Brad Hanson NMFS). This will diminish the chance that whales are sighted and reported. As a consequence, perhaps the most appropriate choice is the use of a 3 day lag and this would equate to 21 forays (3 day lag, average from 2001-2008, Table 3.3) into Puget Sound, and therefore 42 transits through Admiralty Inlet (rather than 54 transits for a 2 day lag). .

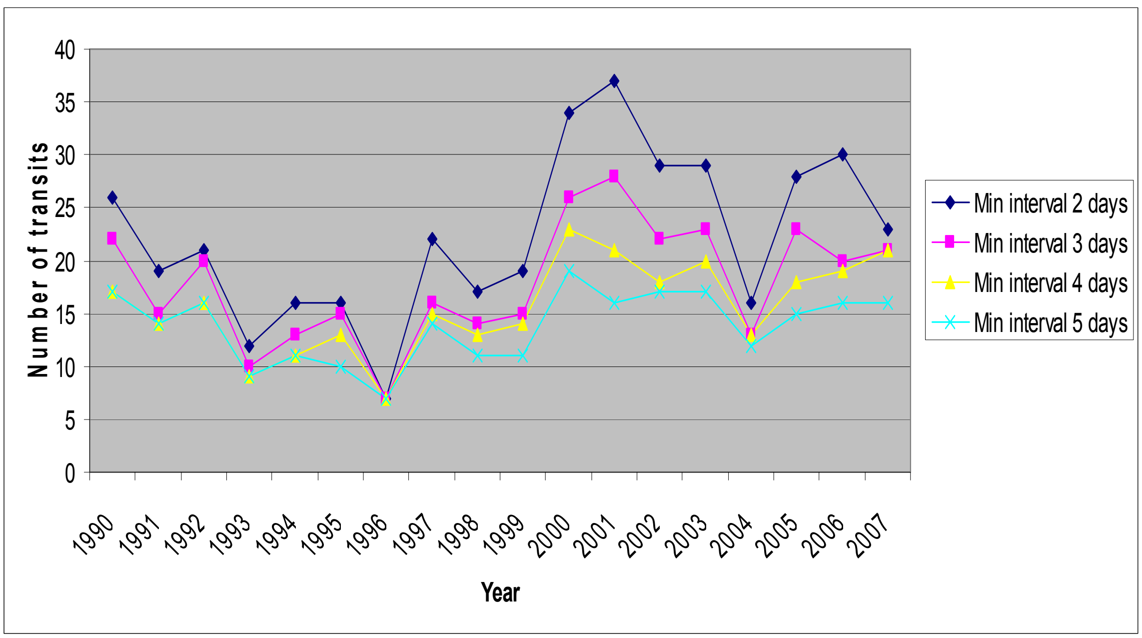

Figure 3.12. Estimates of SRKW one way transits into Puget Sound by using different interval criteria. A minimum interval of 2 days means that whales that were spotted on the second day since the previous sighting or longer were considered to be on a different foray from the previous sighting. This was the criterion suggested by the BCI in figure 3.10, but on review we also calculated the estimated number of forays for slightly higher time lags. Years in this calculation run from July 1 through June 30 so that splits between years do not occur during the peak number of forays in Puget Sound. For example, this means that the '1990' runs from July 1, 1990 through June 30, 1991.

Table 3.3. Averages and standard deviations over the periods 1990-2008 and 2001-2008 for estimates of SRKW one way transits into Puget Sound using from two to five days lag time between whale sighting days. The reason averages were calculated over different time ranges was that sightings numbers were much lower pre 2001 and thus may be depressing the estimates of the number of transits (see figure 3.3).

Year	Average 1990-2008	SD 1990-2008	Average 2001-2008	SD 2001-2008
Min interval 2 days	22.28	7.89	27.43	6.50
Min interval 3 days	17.94	5.66	21.43	4.50
Min interval 4 days	15.67	4.35	18.57	2.76
Min interval 5 days	13.78	3.34	15.57	1.72

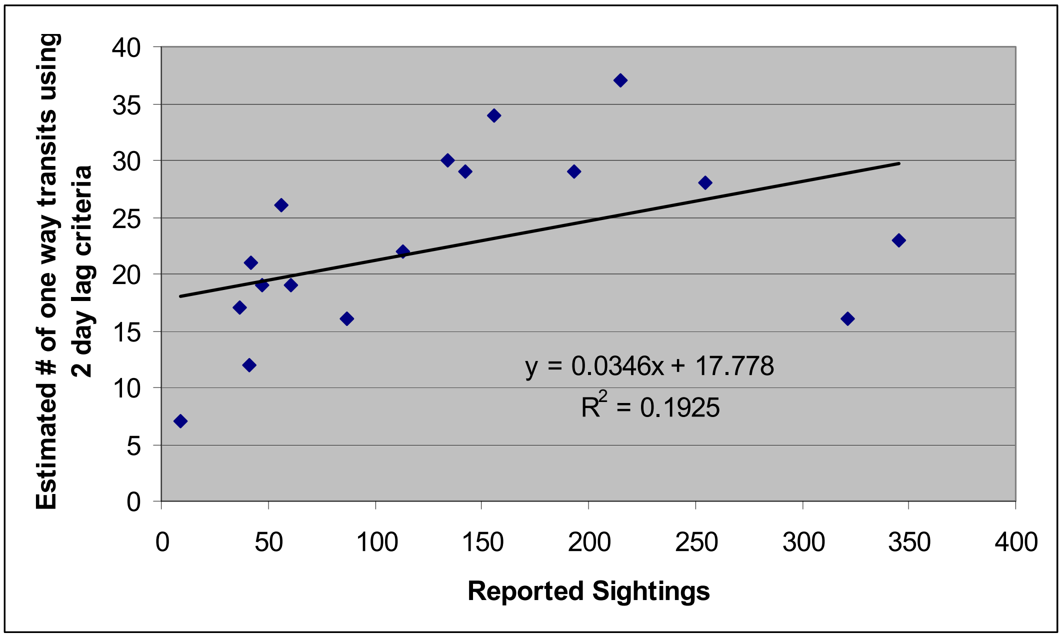

Figure 3.13. Marginally insignificant regression between the number of sightings in a year and the estimated number of one way transits into Puget Sound using a two day lag criterion ($F_{1,16}$ = 3.82, p = 0.069, R^2 = 0.193). The plot suggests that above approximately 100 sightings in a year any relationship between reported sightings and estimated number of one way transits disappears.

iv) Puget Sound usage by pod:

J pod was reported in Puget Sound more often than the other pods and spent more whale days in Puget Sound. They were followed by K pod and then L pod (see Table 3.4).

Table 3.4. Total number of sightings in Puget Sound and whale days from 1990-2008. Note, some forays into Puget Sound included more than one pod, or all three and are therefore accounted for more than once in the table.

Pod	total sightings	total whale days
J	498	184
K	405	141
L	187	98
All whales	2532	777

When pod usage is viewed by year (see Figure 3.14), there is a fair amount of variation from one year to the next. This may be partly driven by actual change in usage, but it also likely affected by reporters abilities to identify whales from different pods. For example, one reason why J pod is identified most often may be because J1 (Ruffles) is a fairly well known whale that is relatively easy to identify. Table 3.5 gives the average whale days per pod per year across the entire data set and from 2001 onward. J and K pod use Puget Sound more often that L pod.

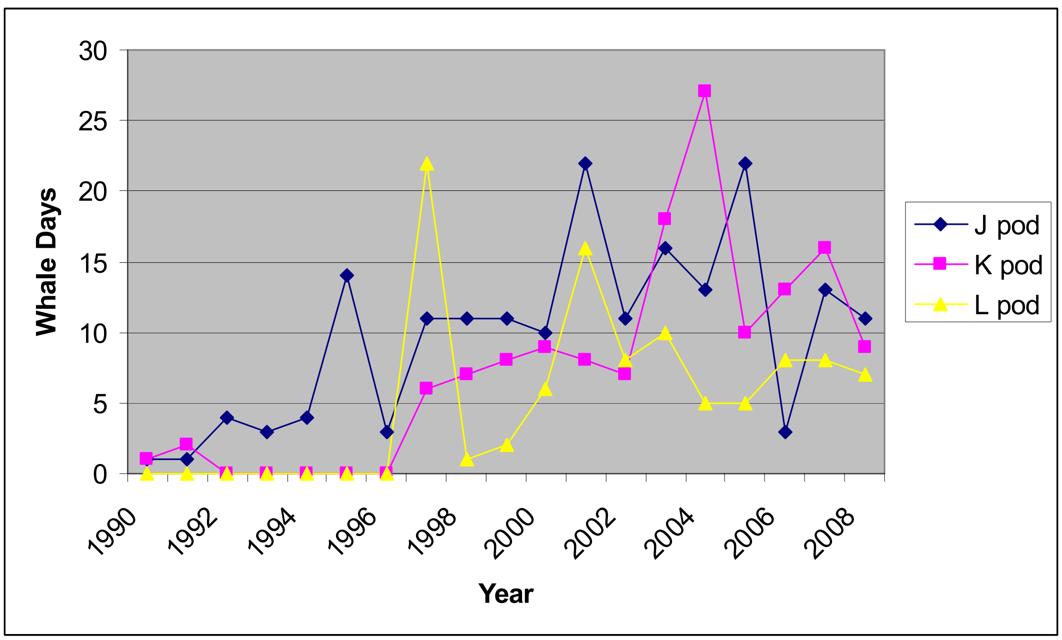

Figure 3.14. Whale days by pod across the years of the data set. Years in this case are calendar years. There is much variation across years that is likely driven both by actual variation and by reporters ability to identify pods. Most of the time though, J and K pod utilize Puget Sound more often than L pod.

Table 3.5. Average number of forays into Puget Sound per year by pod. Because of the lower sighting numbers pre 2001 we calculated averages across the entire dataset and from 2001 on.

Pod	Average 1990-2008	SD 1990-2008	Average 2001-2008	SD 2001-2008
J	9.68	6.42	13.88	6.24
K	7.42	7.31	13.50	6.70
L	5.16	6.09	8.38	3.50

v) **Number of whales per transit:**

Given an estimate of the number of forays into Puget Sound per year, and the relative use by pod we can also estimate the number of individual whales that pass through Admiralty Inlet in a given year. At the end of 2007 the SRKW population was counted as the following; J pod:25, K pod:19, L pod:43 (Center For Whale Research 2007). Although we have estimated above the number of whale days per pod, some of those days included multiple pods. In order to estimate the proportion of Puget Sound forays that involved single or multiple pods, we analyzed the Orca Master sightings that had pod identification. We grouped pods in the following way (see Table 3.6). J pod or K pod were clumped together since their population sizes are so similar (we used the mean of the two pod sizes: 22). L pod was its own grouping (43 whales). J and K involved sightings of both pods together (44 whales), while L and J or K involved a combination of L pod with J or K pod present as well (65 whales). The final grouping was all three pods, J, K and L (87 whales). We then multiplied the proportion of sightings of each of these pod groupings by 21, our estimate of the number of forays into Puget Sound per year, in order to obtain an estimate of the number of forays by grouping of whale. The estimated number of individual whale transits through Admiralty Inlet was calculated by multiplying the number of estimated forays, times two, and then times the number of whales in that grouping. The sum of all of these estimates gave us the estimated total number of individual whale transits through Admiralty Inlet per year at 1,442 (see Table 3.6).

Table 3.6. Pod groupings were used to calculate the proportion of sightings in Orca Master that reported each of these pod groupings. Because J and K pod are similar in size, we lumped them together (in the J or K grouping) and used the mean group size of 22. The estimated number of forays is based on our estimate of 21 forays per year (see Table 3.3 and text in section iii). Approximate number of whales uses population counts by The Center for Whale Research 2007. Number of whale transits is calculated by multiplying the number of forays per pod group by two (one foray = two transits), and then by the number of whales in the pod group.

Pod group	# of sightings	% of sighting by pod group	# of estimated forays	Approx # of whales	# of whale transits
J or K	514	63.14%	13.26	22	583.46
L	71	8.72%	1.83	43	157.53
J and K	113	13.88%	2.92	44	256.54
L and J or K	67	8.23%	1.73	65	224.70
JKL	49	6.02%	1.26	87	219.96
Total sighting w/Pod ID	814			Total transits	1442.19

vi) Usage of Admiralty Inlet:

One of the aims of this analysis was to attempt to provide an indication of which side SRKW might be moving. However, it is unfortunate that the quadrants that cover Admiralty Inlet tend to stretch from one side of the inlet to the other (see Figure 3.2). We felt that an indication of side use is only possible in comparing quadrant 387 (Port Townsend side north of Marrowstone island) with quadrat 388 (the bay south of Keystone). Of 106 sightings of whales in those two quandrants, 37% were seen in quadrant 388 and 63% were seen in 387. A chi-square (χ^2) test was used to confirm that SRKW were reported on the west side of the inlet more often than would be expected by chance (see Table 3.7). Section 3 B provides additional analysis using data from additional sources as to which side of Admiralty Inlet SRKW are reported as using.

Table 3.7. Number of sightings in quadrant 387 (on the west side of Admiralty Inlet. See Figure 3.2) and in quadrant 388 (on the east side of Admiralty Inlet). A χ^2 test indicated that SRKW were reported on the west side of the inlet significantly more often than expected by chance.

Quadrant	387	388	Total	χ^2	DF	p
Observed	67	39	106	7.4	1	<0.01
Expected	53	53				

We also analyzed which direction of travel Orca Master reports indicated SRKW were traveling when within the quadrants of Admiralty Inlet. Of the 196 reports of SRKW in Admiralty Inlet, 114 had direction data, with 54% heading north and 46% heading south. Based on these numbers we determined that our reports did not differ significantly from what would be expected by chance (see Table 3.8). It is obvious that if SRKW have entered Puget Sound they must also exit the same number of times. This analysis though lends credence to our assumption that SRKW do not use Deception Pass very often, and it also demonstrates that we are receiving reports of SRKW both on their south-bound and north-bound transits through Admiralty Inlet.

Table 3.8. Counts of the number of times SRKW were reported moving through Admiralty Inlet north versus south in Orca Master. A χ^2 test found no significant difference in the number of reports of SRKW moving south versus north. This is to be expected and demonstrates that we are receiving reports of SRKW moving both in and out of Puget Sound through Admiralty Inlet.

Direction	North	South	Total	χ^2	DF	p
Observed	62	52	114	0.88	1	N.S.
Expected	57	57				

B) Other data sources - Fine scale information review

In order corroborate our analyses of which side of Admiralty Inlet SRKW are reported in and to attempt an analysis of the kinds of behavior SRKW are exhibiting while in Admiralty Inlet, we used data from a number of data sources other than the Orca Master. These included the Orca Network, Island Adventures Whale Watching, and Puget Sound Express Cruises data sets. See sections 2 B, C, and D for details on these datasets. Of these additional reports, 64 have information about the location of SRKW in Admiralty Inlet. Twenty-one were reported on the east side of the inlet, while 32 were reported on the west side. The remaining 11 reports were ambiguous enough or referred to mid channel so that they were not assignable to either east of west sides of the inlet. Although there were more sightings on the west side of the inlet, this was not a significant difference (see Table 3.9). This result is different what we found using the Orca Master dataset, but may be due to small sample size.

Table 3.9. Reported location of SRKW in Admiralty Inlet using a number of datasets. Although there are more reports on the west side of the inlet, the difference is not significant.

Reported Area of Admiralty Inlet	East	West	Total	χ^2	DF	p
Observed	21	32	53	2.28	1	N.S.
expected	26.50	26.50				

Using the same combination of datasets we also analyzed reported pod behavior of SRKW in Admiralty Inlet. Some of the behavior descriptions were lengthy, while others were one word. We attempted to interpret these data into discrete behavioral categories as seemed most appropriate. If the sighting report indicated a lot of surface active behavior we categorized that sighting as ‘social’. In the one instance when milling was noted, this was considered ‘foraging’. If no behavior was given other than a direction, the behavior was classified as ‘travel’. A total of 46 sightings reported behavior. Of these 22% were classified as forage, 13% as social, and 65% travel. There was a significant difference in the number of behaviors reported, with travel being much higher than expected (see Table 3.10). Due to the small sample size (in addition to the difficulty in describing behavior from surface activity) this result should be interpreted cautiously.

Table 3.10. Behavior reports of SRKW in Admiralty Inlet from a number of data sources. While there is a significant difference between the numbers of reported behaviors, this result should be interpreted cautiously given the small sample size.

Behavior	Forage	Social	Travel	Total	χ^2	DF	p
observed	10	6	30	46	21.57	2	<0.001
expected	15.33	15.33	15.33				

C) Association of whales with other data

i) Salmon Runs:

SRKW feed almost exclusively on salmon, and recent evidence suggests that the majority of this foraging is on Chinook salmon, with Chum salmon also being taken in significant numbers (NMFS 2008). Of the two studies that have collected actual prey samples from predation events (n = 115), Chinook remains were identified in 90 of those events (78%), while Chum remains were identified in 13 events (11%) (Hanson et al. 2005, Ford & Ellis 2006). Current work by NMFS and Cascadia Research continue to find these general trends. In order to determine if SRKW presence in Puget Sound is associated with salmon abundance we ran a multiple regression analysis using whale days in the Puget Sound (see Figure 3.5) as the response variable and used the salmon sport catch in Puget Sound for Chinook and Chum as the predictors (data from S. Thiesfeld, WDFW). Whale days were log transformed to meet the assumptions of the test. The regression was marginally insignificant ($F_{2,9} = 3.73$, $p = 0.066$, $R^2 = 0.45$), however Chum catch did have a positive and more significant relationship with SRKW whale days than Chinook catch, which had a negative relationship presumably because of the Chinook peak in July and August when SRKW whale days are low. Figures 3.15 and 3.16 depict the Chum and Chinook sport catch along with whale days superimposed on the graphs by month. This visual representation corroborates the regression analysis, with Chum catch showing a much clearer association with SRKW whale days than Chinook catch does.

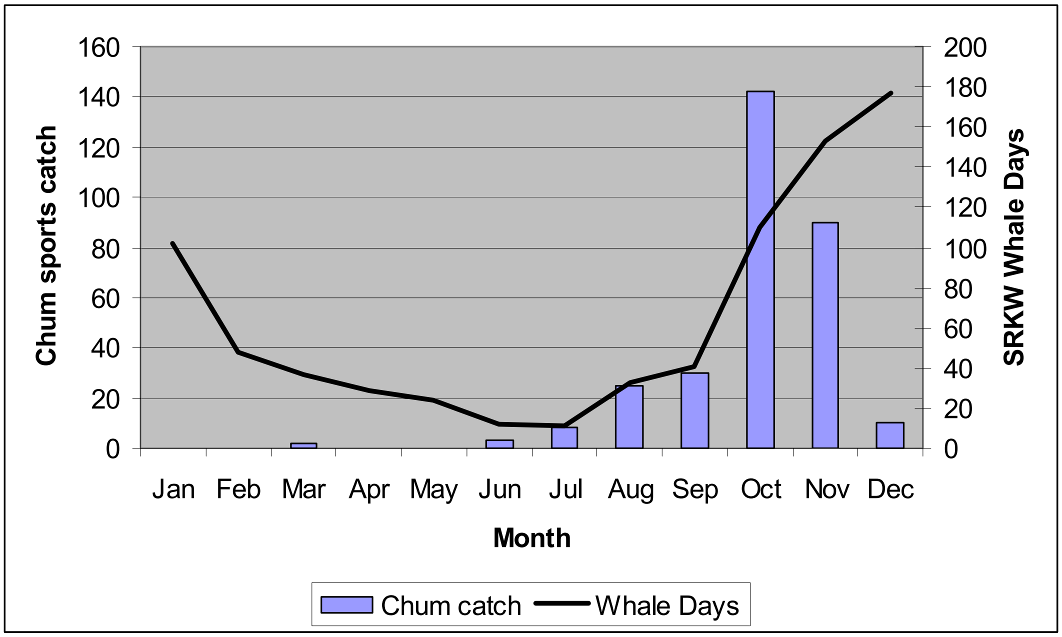

Figure 3.15. Chum sports catch by month in Puget Sound (source S. Thiesfeld, WDFW). Superimposed is a line with the number of SRKW whale days in Puget Sound (1990-2008). While the association is not perfect, there is a decent (if not significant) relationship between the two datasets.

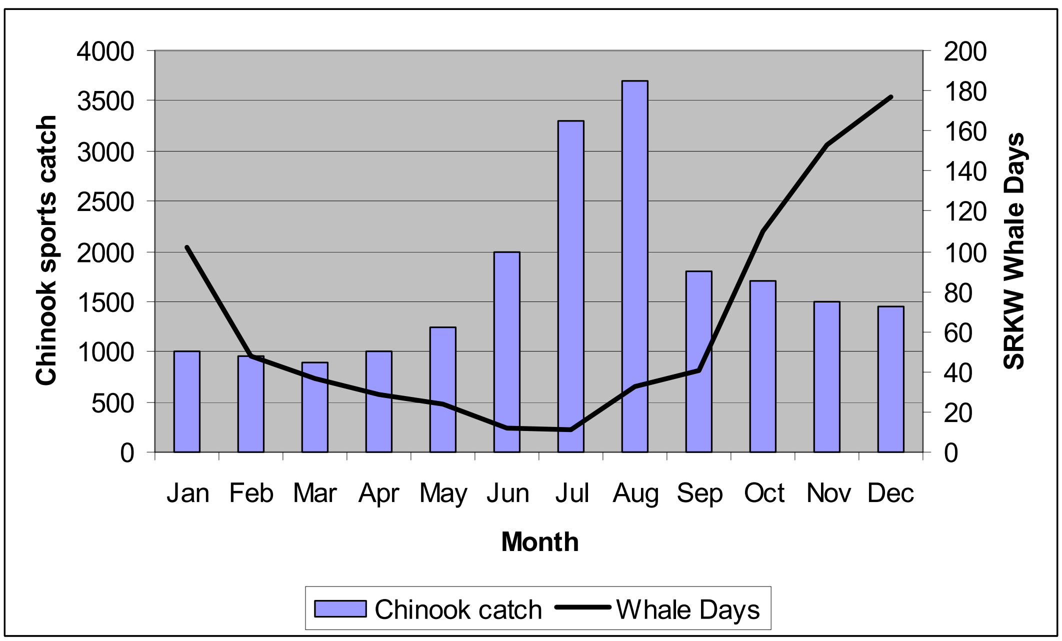

Figure 3.16. Chinook sports catch by month in Puget Sound (source S. Thiesfeld, WDFW). Superimposed is a line with the number of SRKW whale days in Puget Sound (1990-2008). If anything, the two datasets are negatively related to each other.

Two recent studies have analyzed the relationship between SRKW occurrence/survival rates and various measure of salmon abundance in different regions (Ford et al. 2005, McCluskey 2006). At broader scales the expected relationships hold, in the sense that higher abundance of prey relate to higher survival rates and occurrence. However at fine scales these relationships do not always hold and are sometimes contradictory. The problem in our opinion, with analyses at fines scales is that there is a mismatch in the scale of the analysis and the available data. In order to expect these analyses to work, there must be fine enough data on prey availability (salmon abundance is difficult to obtain on reliable temporal and spatial scales appropriate for these analyses), and those datasets need to cover the range of SRKW, which is poorly understood when they leave the Salish Sea (mostly during the winter months). In other words, the presence and absence of SRKW in Puget Sound (at least the part driven by prey availability) is affected not only by available prey in Puget Sound, but also prey availability in other parts of their range. For example the anomalous year 2005, was out of the ordinary because of higher and lower occurrence during distinct time periods (see discussion above in section 3 A ii). This was likely driven by conditions both within Puget Sound and wherever else they spent their time that year. Trying to understand their absence/presence during that time period will be incomplete without adequate knowledge of their location year round, and the conditions in the other locations they visited.

ii) Other variables:

Tidal currents have been suggested as predictors of whale direction; however results are preliminary and may be location specific. Felleman et al. (1991) found evidence that SRKW moved more often with the flood and against the ebb tides and that they were highly likely to change direction near the time of slack tide. Soucy (2006) also found that SRKW are more likely to move against an ebb tide and with the flood tide. However, this relationship changed depending on the location in which the whales were observed. Soucy (2006) also found that as current velocity increased, the SRKW were more likely to be traveling with the current. The historical data on SRKW is not sufficient to generate an accurate analysis of SRKW movements through Admiralty Inlet depending on tidal currents; however it is possible that the findings from these papers could be used as a guide for their actions in Admiralty Inlet.

Shipping traffic may also have an impact on the use of Admiralty Inlet by SRKW. The detailed observations of SRKW behavior that have been needed to determine boat effects on SRKW (see NMFS 2008 for review) would indicate that the historical dataset is too coarse to tease apart any effect that shipping may have on SRKW usage of Admiralty Inlet.

4) SYNOPSIS OF FINDINGS

For most analyses in this report we have used The Whale Museum's Orca Master dataset, the most extensive dataset on SRKW sightings in the Salish Sea. We have also gathered additional fine scale data from other sources to augment the Orca Master analyses. These datasets were not collected in a systematic manner, but are based on reports made or shared with the owners of the various datasets. The Orca Master dataset contains data from 1990-2008 and a total of 2,532 sightings of SRKW in Puget Sound and 196 in Admiralty Inlet. Because the earlier years in the Orca Master dataset had fewer sightings, these years were not included in all analyses, and the years 2001-2008 were given more weight. There were an average of 60.5 whale days per year in Puget Sound from 2001-2008, and 70% of these whale days were concentrated in the months of October through January. The seasonality of the SRKW usage of Puget Sound is likely due to the timing of Chum salmon runs in Puget Sound. We feel that an appropriate estimate of the number of transits through Admiralty Inlet is 42 per year (max 54, min 31). All three pods use Puget Sound, with J pod the most common, followed by K pod. Given reported pod associations during forays into Puget Sound we estimate a total of 1,442 animals transiting through Admiralty Inlet in a year. During these transits SRKW are more likely than expected to use the western side of Admiralty Inlet, although the eastern portion is used as well. During these transits SRKW are often traveling, but also exhibit social and foraging behavior.

5) ACKNOWLEDGEMENTS

We would like to acknowledge Erick Pearson for his help in extracting SRKW data from the ship logs of Puget Sound Express Cruises. We also thank Island Adventure Whale Watching for help with additional information on their data. We are grateful for discussions on lag time intervals with Brad Hanson, and to Brent Norberg and Lynne Barre for sharing their maps of SRKW usage of the Salish Sea by month. We would also like to acknowledge all the people who have reported whale sightings over the years. These datasets and analyses would not have been possible without your help.

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Appendix L-5

Admiralty Inlet Water Quality Survey Report:
April 2009 – February 2010

Admiralty Inlet Water Quality
Survey Report: April 2009 – February 2010

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May 29, 2010

Table of Contents

1 Introduction

Most of the exchange between Puget Sound and Strait of Juan de Fuca occurs over the Admiralty Inlet sill. The site proposed for tidal hydrokinetic turbines is at the northern end of the sill, approximately 1 km off Admiralty Head. High currents coupled with topography and bathymetry lead to intense mixing. Consequently, during periods of strong tidal currents (spring tides), water in the project area is relatively well-mixed. However, during periods of weaker tidal currents (neap tides or diurnal inequality), the water column may be somewhat stratified. The project area and local bathymetry are shown in Figure 1.1.

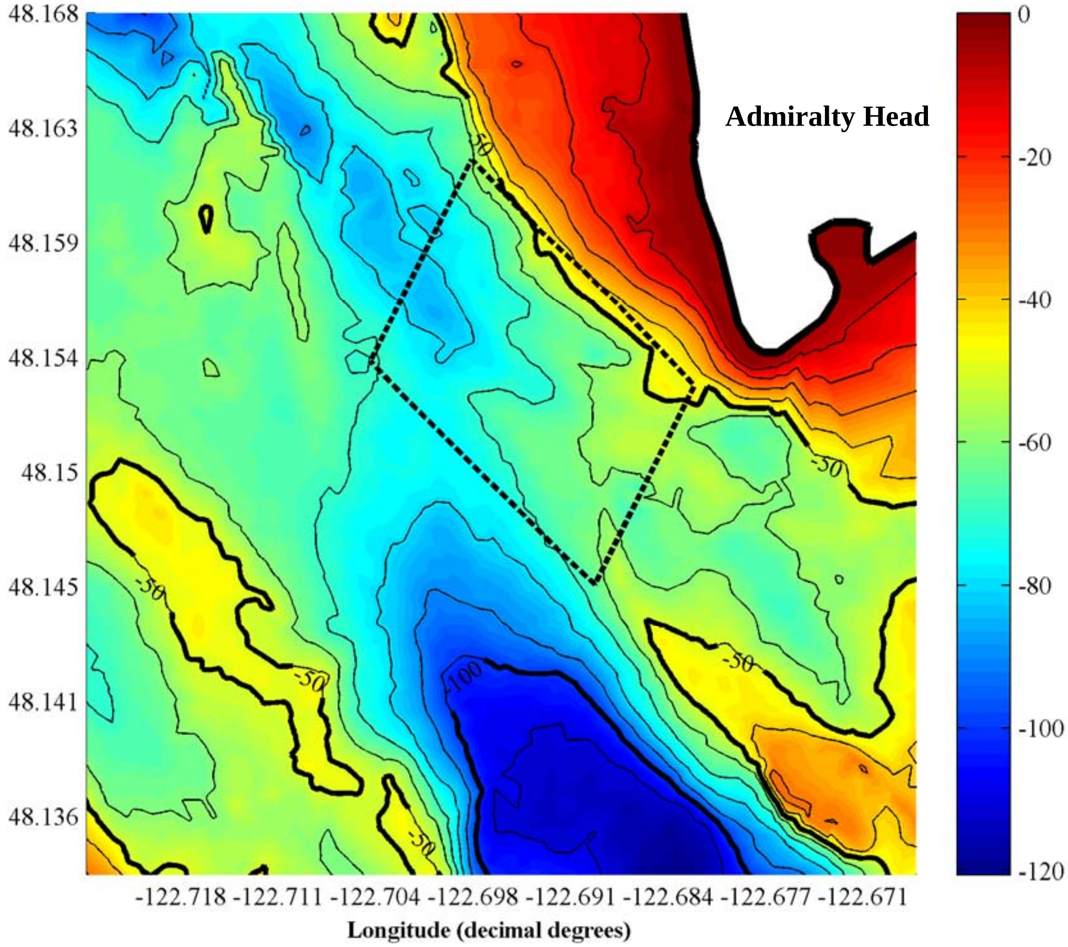

Figure 1.1 – Bathymetry in Admiralty Inlet survey area (m). Dashed lines denote extent of survey area for hydrokinetic turbine deployment.

Water quality in the project area has been assessed through shipboard surveys and seabed instrumentation.

During shipboard surveys, instrumentation and sample bottles are "cast" down through the water column. Each cast provides detailed information about the vertical structure of the water column. Repeat casts provide information about the temporal and spatial variability. Instrumentation rapidly samples a number of quantities *in-situ*. Water samples collected at discrete depths serve to (1) calibrate instrumentation (e.g., dissolved oxygen sensors) and (2) calculate properties for which there is no *in-situ* optical measurement (e.g., nutrient concentration). Shipboard surveys in the project area were carried out in April, May, August, and November of 2009 and February of 2010.

Seabed instrumentation provides a long-term record of water quality properties at a fixed location and depth. An instrumentation package which includes water quality measurements has been deployed at particular locations on the seabed from April-May, May-August, August-November 2009, and November-February 2010. Recovery and redeployment of the instrumentation package is undertaken during the shipboard surveys described above. During these deployments, efforts have been made to monitor temperature, salinity, and, recently, dissolved oxygen concentrations.

This remainder of this report is broken down into four sections. Section 2 describes the methodology applied to water quality monitoring activities. Section 3 presents the results of casts during shipboard surveys and long-term measurements by seabed instrumentation. Section 4 provides a comparison between shipboard surveys and longer term measurements collected by the UW PRISM program, as well a discussion of resolving temporal and spatial variability during shipboard surveys. Section 5 provides concluding remarks.

2 Methods

Three types of water quality are collected in the survey area:

(1) Water quality casts from the deck of a research vessel, with sensors continually measuring quantities through the water column.
(2) Water quality samples collected at discrete depths during water quality casts and processed by a shore-based marine chemistry lab.
(3) Stationary measurements collected by sensors mounted near the seabed.

2.1 Data Collection

2.1.1 Water Quality Casts

Water quality casts are conducted from the deck of the R/V Jack Robertson with a CTDO rosette (Seabird 911+) connected via conducting wire and slip-ring winch. Data is logged in real time. Sensors include:

- Temperature: SB3 (±0.0003°C)
- Conductivity: SBE 4C (±0.0003 S/m, ±0.006 PSU at 10°C and 30 db)
- Dissolved oxygen: SBE 43 (±2% of saturation)
- Turbidity: D&A OBS 3+ (greater of ±0.25 NTU or 1% of reading)
- Fluorescence: Turner SCUFA (±0.02 µg/L)
- pH: SBE 18 (±0.1 pH)

Dissolved oxygen measurements are adjusted by a linear regression between sensor measurements of dissolved oxygen and the results of wet chemistry performed on water quality samples (Section 2.1.2). The instrumentation package is allowed to equilibrate at the surface and then cast at a rate of <50 cm/s down through the water column to within 5m of the seabed. The package does not include an altimeter, so the lowest depth of the cast is chosen conservatively to avoid damaging instruments.

All data are collected and post-processed using Sea-Bird software.

2.1.2 Water Quality Samples

Water samples are collected in up to twelve 1.5L Niskin bottles mounted to the rosette and lowered from the R/V Jack Robertson by a conducting wire and slip-ring winch. All Niskin bottles remain open during the downcast of the rosette to the seabed. During the upcast, rosette is allowed to equilibrate at seabed, 30m from the surface, 10m from the surface, and 3m from the surface before Niskin bottles are closed remotely. Rosette depth is monitored by an onboard pressure sensor. Once the rosette has been recovered to the deck, samples of dissolved oxygen, total nitrogen and phosphorous, chlorophyll, total nutrients, turbidity, and salinity are prepared in accordance with procedures described in the study plan (DTA/HDR 2009). Water quality samples are transported from the research vessel to the University of Washington's marine chemistry lab where they are analyzed (http://www.ocean.washington.edu/services/techservices.html).

2.1.3 Stationary Measurement

The primary instrument for stationary measurements is a Star-Oddi DST CTD. The unit is extremely compact, measuring 15mm in diameter and 46mm in length. The compact nature of the sensor is balanced by relatively low accuracy: temperature accuracy is ± 0.1°C and salinity accuracy is ±0.75 PSU. The instrument is deployed as part of a larger equipment package at a vertical elevation of approximately 0.6m above the seabed. Temperature and salinity measurements are collected every 10 minutes.

From August 2009 – February 2010, a more robust CTDO (Seabird 16+) owned by the Washington Department of Ecology was deployed in a comparable configuration. This instrument measures temperature, salinity, and dissolved oxygen and has higher accuracy than the DST CTD. Temperature accuracy is ±0.005°C, conductivity accuracy is ±0.0005 S/m (0.007 PSU at 10°C and 30 db), and oxygen accuracy is 2% of saturation.

2.2 Study Plan Variance

There are several minor variances from the study plan described in DTA/HDR (2009), primarily in the form of additional data collection.

A survey including two water quality casts was conducted in May, 2009, in addition to planned surveys in April, August, November, and February. During the November survey, a total of nine casts (rather than the specified duplicate cast) were conducted to better quantify spatial and inter-tidal variations.

No stationary measurements were prescribed in the study plan. Two stationary instruments were deployed in the project area to obtain long-term measurements of temperature and salinity.

Not all sensors were operational for all surveys due to electrical problems or equipment availability. During the April survey, no fluorescence sensor was included in the instrument package. During the August 2009 and February 2010 cruise, there were electrical problems with one of the two dissolved oxygen sensors. On all cruises, the turbidity sensor readings remained within the instrument noise floor (i.e., not different from zero). The minimal turbidity on all cruises (< 1 NTU, too low relative to the instrument detection range of 0-4000 NTU) is consistent with visual observation of very clear conditions.

2.3 Data Quality

In general, the collected data appear to be of good quality.

Wet chemistry performed on water samples confirm the accuracy of salinity and dissolved oxygen sensors. *In-situ* fluorescence measurements vary somewhat from laboratory chlorophyll measurements at some depths. However, there are known difficulties associated with *in-situ* measurements of chlorophyll, specifically the confounding contributions of chlorophyll *a* and chlorophyll *b*.[1] Wet chemistry between duplicate casts is generally in good agreement, indicating that water samples were treated in a consistent manner both at sea and in the laboratory.

The salinity sensor on the Star-Oddi DST CTD appears to have been compromised by fouling. This conclusion is based on large disagreements between the DST and the more accurate SBE16+provided by WA DoE. The conductivity sensor also appeared visually fouled during instrument retrieval. The DST salinity measurements are, therefore, not included in this report.

[1] JGOFS Protocols—June 1994

3 Results

This section presents a summary of the data obtained through water quality sensor casts, wet chemistry on water quality samples, and long-term measurements by seabed instrumentation.

3.1 Water Quality Casts

During 2009, four surveys were undertaken in the project area, each consisting of multiple casts with varying levels of instrumentation, as summarized in Table 3.1. Figure 3.1 shows the approximate location of each cast. Most casts are conducted in the southwest corner of the survey area, which has been determined to be the most probable location for device deployment, following initial velocity and bathymetric surveys. Because of prevailing currents and winds, the survey vessel typically drifts 100-200m during a cast. During the November, 2009 survey, more casts than usual were conducted in order to better understand if cast-to-cast variation is predominantly spatial or temporal in nature.

Table 3.1 – Water quality casts and instrumentation

Survey	April 09	May 09	August 09	November 09	February 10
Dates	4/6-4/9/09	5/19-5/20/09	8/3-8/5/09	11/10-11/12/09	2/9/10 – 2/11/10
Casts	2	2	4	9	2
Temperature	✓	✓	✓	✓	✓
Conductivity	✓	✓	✓	✓	✓
Dissolved Oxygen	✓		✓	✓	✓
pH	✓		✓	✓	✓
Turbidity	✓		✓	✓	✓
Fluorescence			✓	✓	✓

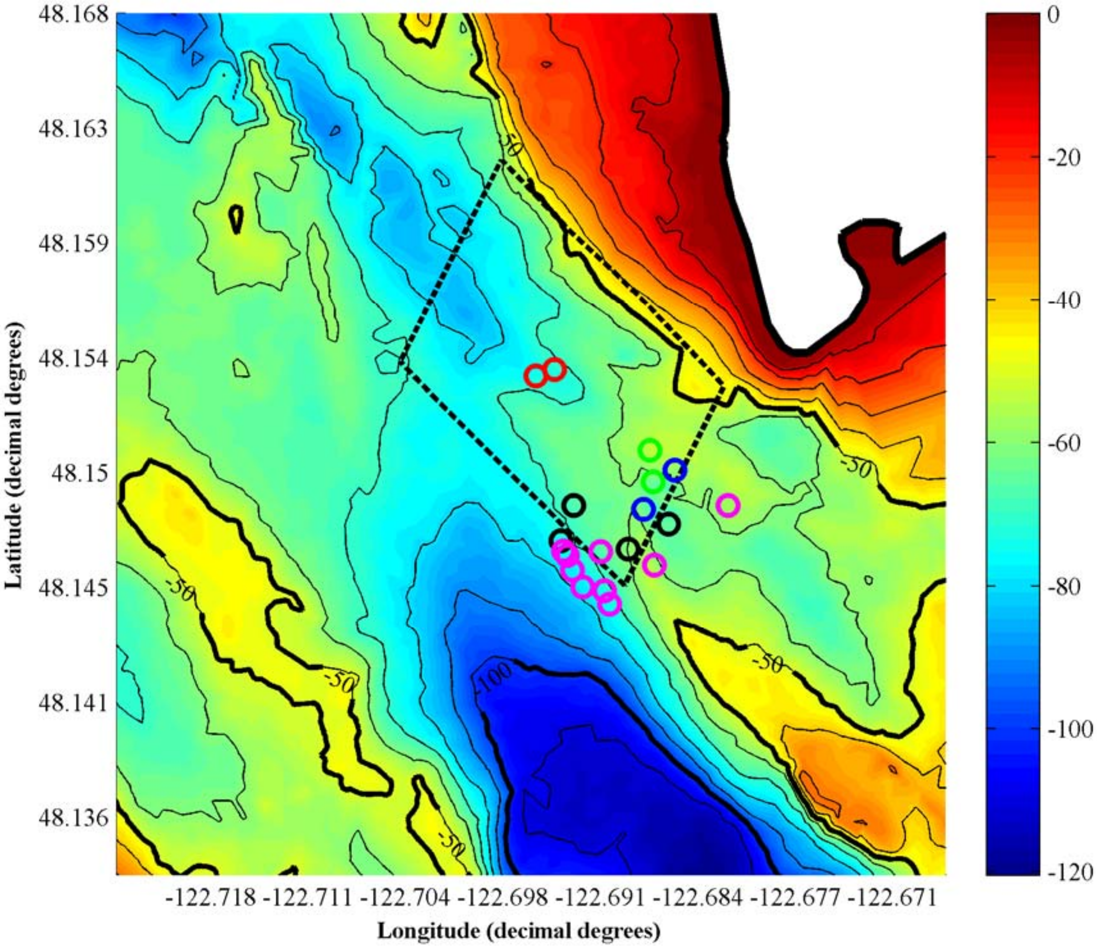

Figure 3.1 – Water quality cast locations superimposed on Admiralty Inlet bathymetry (m). blue: April 2009; red: May 2009; black: August 2009; magenta: November 2009; green: February 2010.

Figure 3.2 shows the vertical profiles for temperature, salinity, dissolved oxygen, and pH collected during all surveys. Profiles indicate both cast-to-cast and seasonal variability. As expected, the degree of stratification depends on the season, with casts from April and May considerably more stratified than casts from November and February. Seasonal patterns in temperature and salinity are representative of typical estuarine circulation and show the effects of varying levels of freshwater input to the system and solar radiation; water is less salty and warmer in the summer than in the late spring and fall. Averages for all measured quantities in the top, middle, and bottom of the water column are presented in Table 3.2.

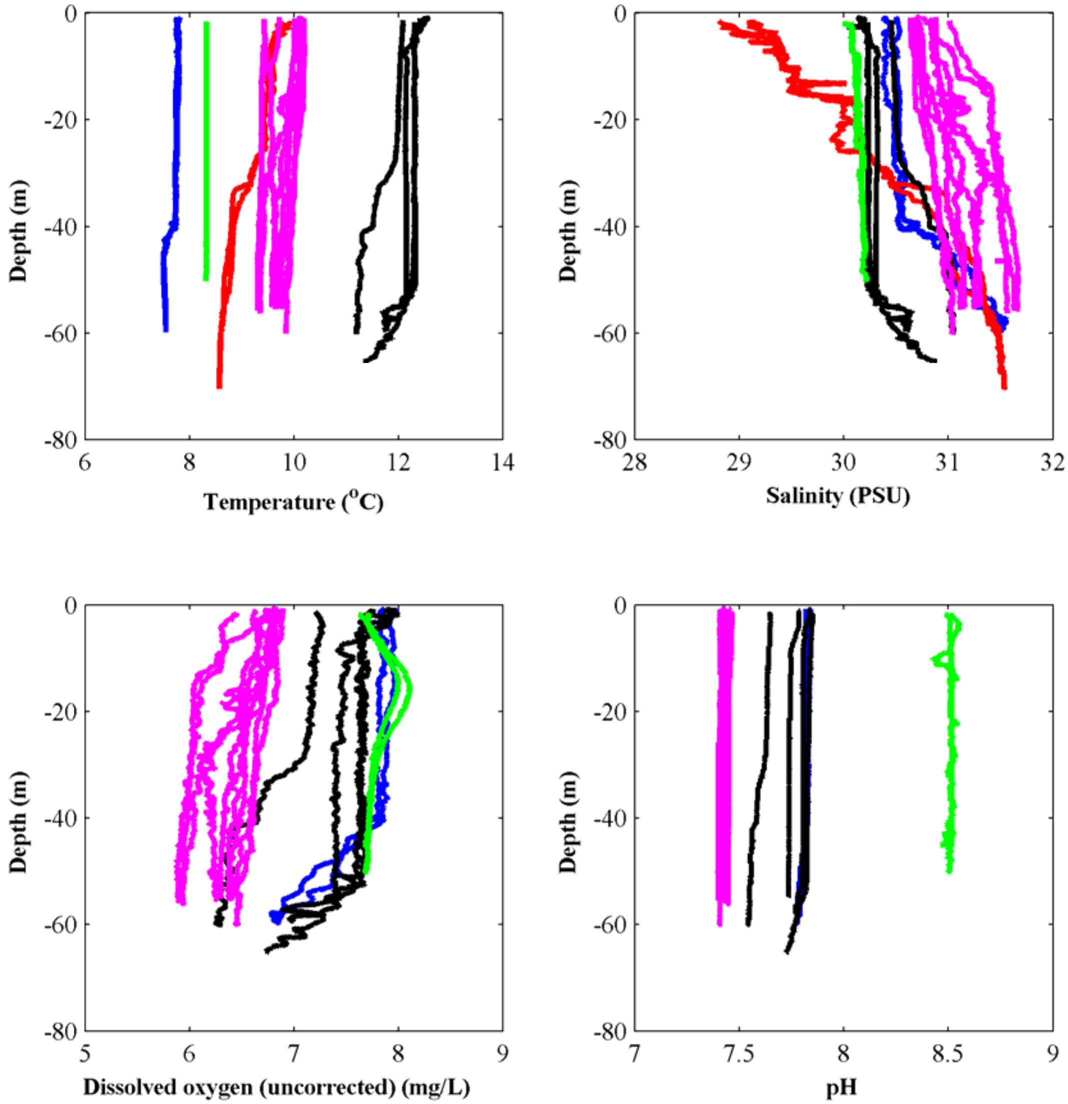

Figure 3.2 – Water quality cast data. blue: April 2009; red: May 2009; black: August 2009; magenta: November 2009; green: February 2010.

Table 3.2 – Water quality cast data (mean values)

Survey		**April**	**May**	**August**	**November**	**February**
Dates		4/6-4/9/09	5/19-5/20/09	8/3-8/5/09	11/10-11/12/09	2/9/10-2/11/10
Casts		2	2	4	9	2
Temperature (^{o}C)	0-20m	7.8	9.6	12.2	9.9	8.3
	20-40m	7.7	9.2	12.1	9.7	8.3
	>40m	7.6	8.7	11.9	9.6	8.3
Salinity (PSU)	0-20m	30.5	29.5	30.3	30.9	30.1
	20-40m	30.5	30.5	30.4	31.2	30.2
	>40m	31.1	31.3	30.5	31.3	30.2
Density (kg/m^3)	0-20m	1023.8	1022.8	1022.9	1023.8	1023.4
	20-40m	1023.9	1023.7	1023.1	1024.1	1023.6
	>40m	1024.5	1024.6	1023.4	1024.3	1023.7
Dissolved Oxygen (mg/L)[1]	0-20m	6.1	N/A	7.8	6.8	N/A
	20-40m	6.0	N/A	7.7	7.0	N/A
	>40m	5.6	N/A	7.3	7.1	N/A
pH	0-20m	7.83	N/A	7.77	7.43	8.51
	20-40m	7.82	N/A	7.75	7.42	8.52
	>40m	7.80	N/A	7.71	7.42	8.51
Fluorescence	0-20m	N/A	N/A	0.62	0.19	0.03
	20-40m	N/A	N/A	1.02	0.19	0.02
	>40m	N/A	N/A	0.94	0.19	0.02
Turbidity[2]	0-20m	N/A	N/A	N/A	N/A	N/A
	20-40m	N/A	N/A	N/A	N/A	N/A
	>40m	N/A	N/A	N/A	N/A	N/A

[1]Corrected values - sensors post-calibrated against wet chemistry results. For May, no wet chemistry performed. For Feb, dissolved oxygen wet chemistry shows QA problems and corrected values are not included.
[2]For all casts, turbidity below instrumentation noise floor

3.2 Water Quality Samples

Water quality samples were obtained at specific depths during cruises in April, August, November, and February. The location of these samples is shown in Figure 3.3. Each survey consists of a pair of casts made in rapid succession.

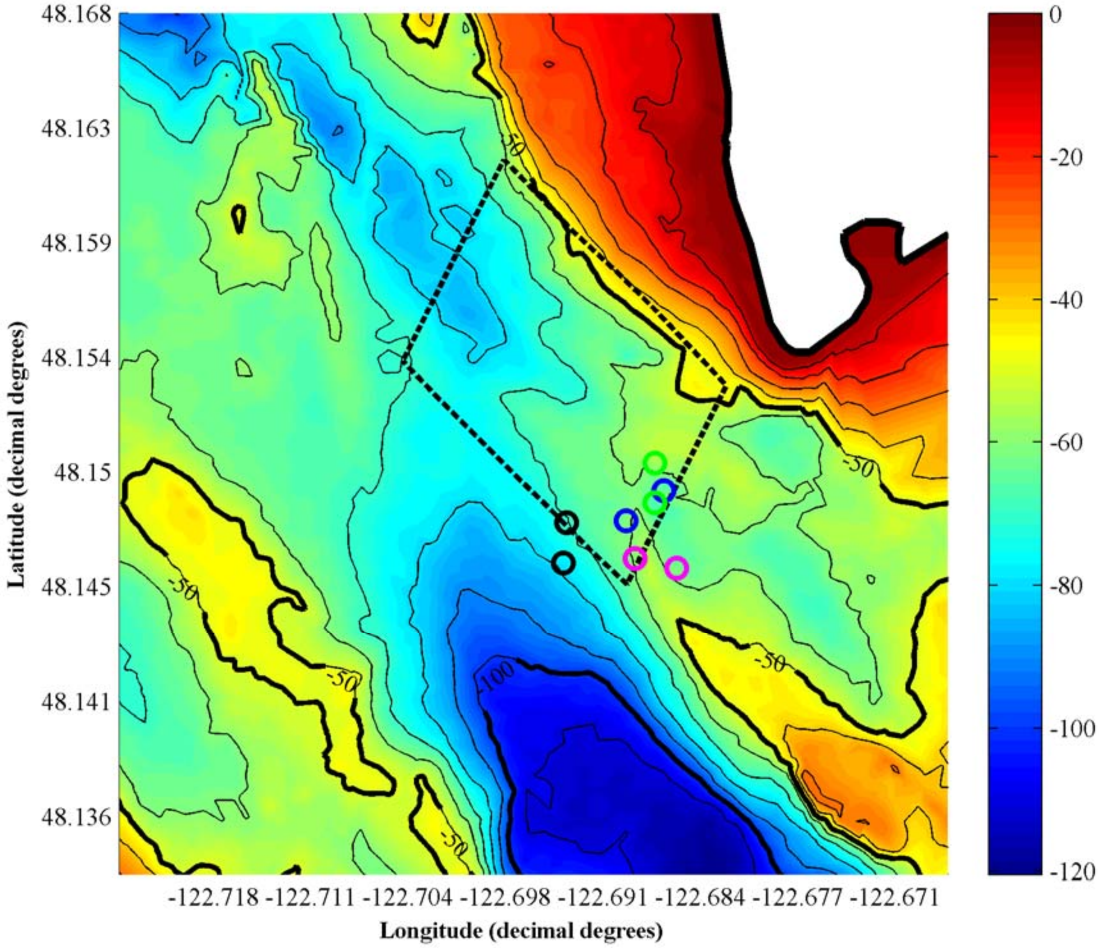

Figure 3.3 – Water quality sampling locations superimposed on Admiralty Inlet bathymetry (m). blue: April 2009; black: August 2009; magenta: November 2009; green: February 2010.

Results from wet chemistry performed on water quality samples are presented in Table 3.3 and Table 3.4.Wet chemistry indicates very low turbidity during all measurements (WHO guidelines for drinking water are < 1 NTU). Biological productivity is higher in the summer than in the spring, with higher chlorophyll levels and depleted nutrients in August.

Comparisons between *in-situ* and laboratory measurements are shown in Figure 3.4. *In-situ* salinity measurements are in close agreement with laboratory results, which is to be expected, as *in-situ* conductivity sensors are a mature technology. Agreement is poorer for dissolved oxygen measurements, reflecting on the maturity of *in-situ* dissolved oxygen sensors. Dissolved oxygen measurements in the field are typically post-calibrated against laboratory measurements using a linear slope and offset, so this lack of agreement is expected. *In-situ* chlorophyll measurements are in generally good agreement with laboratory measurements, though there is considerable, unexplained disagreement at some depths. There are known difficulties associated with *in-situ* measurements of chlorophyll *a* when chlorophyll *b* and *c* are present, which may contribute to the variations.

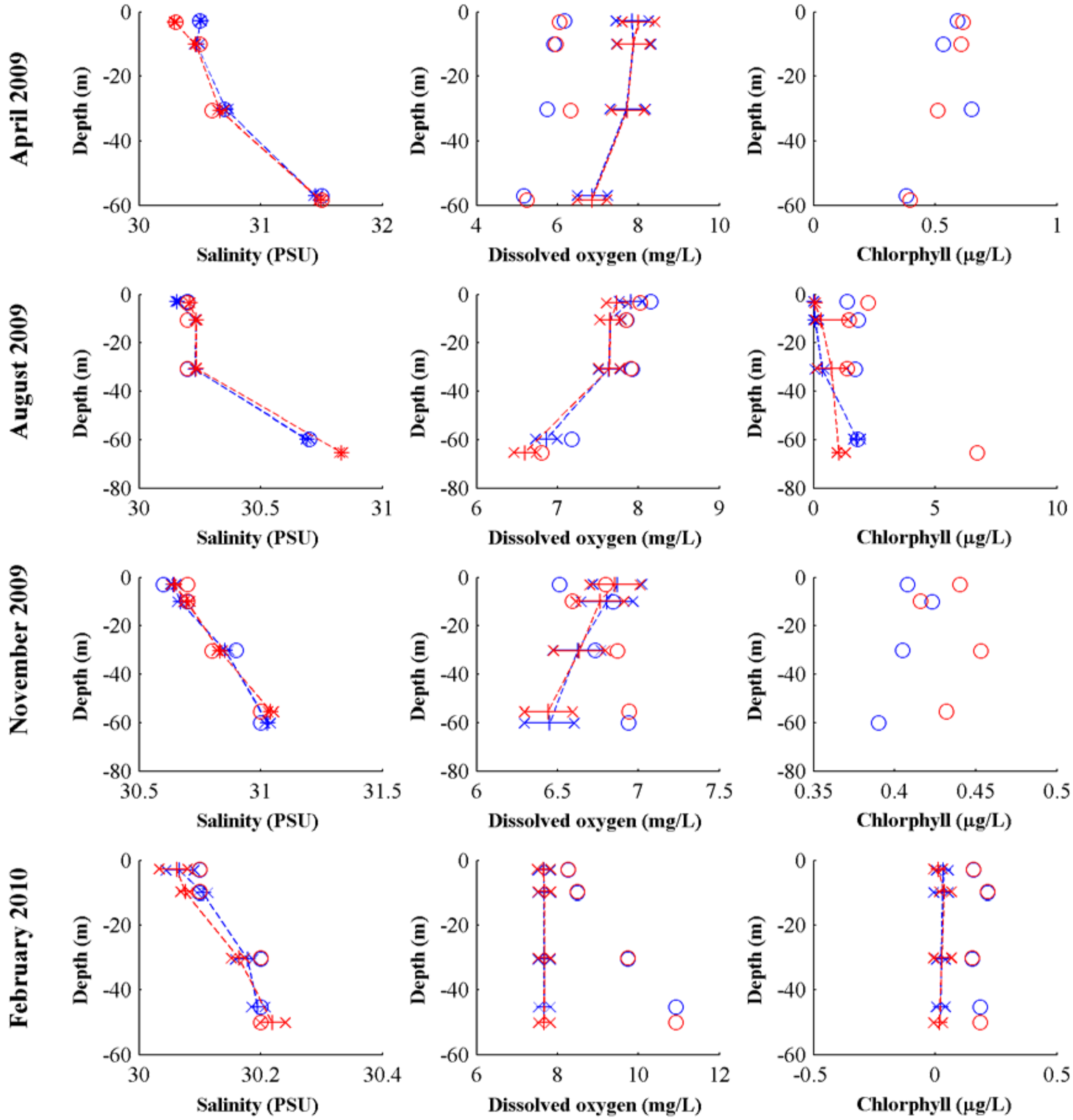

Figure 3.4 – Comparison between cast instrumentation and wet chemistry performed on water quality samples collected at specific depths. Blue denotes first cast, red denotes second cast. Circles denote wet chemistry results. Horizontal lines denote range of values measured by cast instrumentation during sample collection ± instrument accuracy.

Table 3.3 – Water quality sample results, excluding nutrients (mean values)

Survey		**April**	**August**	**November**	**February**
Date		4/7/09	8/3/09	11/11/09	2/9/10
Casts		2	2	2	2
Salinity (PSU)	Seabed	31.5	30.7	31.0	30.2
	-30m	30.7	30.2	30.9	30.2
	-10m	30.5	30.2	30.7	30.1
	Surface	30.4	30.2	30.7	30.1
Dissolved Oxygen (mg/L)	Seabed	5.2	7.0	6.9	10.9
	-30m	6.0	7.9	6.8	9.7
	-10m	5.9	7.9	6.7	8.5
	Surface	6.1	8.1	6.7	8.3
Chlorophyll (µg/L)	Seabed	0.4	4.3	0.4	0.2
	-30m	0.6	1.5	0.4	0.2
	-10m	0.6	1.7	0.4	0.2
	Surface	0.6	1.8	0.4	0.2
Turbidity (NTU)	Seabed	0.9	0.3	0.5	0.8
	-30m	0.7	0.3	0.5	1.7
	-10m	0.5	0.2	0.5	1.0
	Surface	0.6	0.3	0.5	1.1
Total Nitrogen (µM)	Seabed	46.7	28.9	39.2	36.7
	-30m	48.5	31.4	40.1	36.5
	-10m	46.7	26.3	38.1	35.2
	Surface	46.9	26.6	37.7	36.9
Total Phosphorous (µM)	Seabed	2.7	2.3	2.8	2.5
	-30m	2.7	2.4	2.8	2.4
	-10m	2.8	2.2	2.8	2.4
	Surface	2.7	2.2	2.8	2.4

Table 3.4 – Nutrient concentration results (mean values)

Survey		**April**	**August**	**November**	**February**
Date		4/7/09	8/3/09	11/11/09	2/9/09
Casts		2	2	2	2
$[PO_4]$ (μM)	Seabed	2.3	2.0	2.6	2.2
	-30m	2.3	1.9	2.6	2.2
	-10m	2.3	1.8	2.6	2.2
	Surface	2.3	1.8	2.6	2.2
$[Si(OH)_4]$ (μM)	Seabed	48.2	33.9	52.9	45.6
	-30m	50.4	26.6	53.2	45.8
	-10m	51.7	26.7	53.6	57.9
	Surface	52.2	25.7	53.7	58.0
$[NO_3]$ (μM)	Seabed	26.9	18.2	27.6	26.1
	-30m	26.1	14.8	27.5	25.8
	-10m	26.2	14.8	27.3	26.1
	Surface	26.2	14.1	27.3	26.2
$[NO_2]$ (μM)	Seabed	0.3	0.4	0.4	0.1
	-30m	0.4	0.4	0.4	0.1
	-10m	0.4	0.4	0.4	0.1
	Surface	0.4	0.4	0.4	0.1
$[NH_4]$ (μM)	Seabed	0.5	1.2	0.3	0.1
	-30m	0.6	1.2	0.2	0.6
	-10m	0.6	1.2	0.1	0.3
	Surface	0.5	1.1	0.1	0.4

3.3 Stationary Measurements

Long-term measurements of temperature and salinity are obtained from the Star-Oddi MicroCTD, positioned ~0.6m above the sea floor on the Sea Spider instrumentation platform. The instrument has been deployed within the project area since early April, 2009 and has collected data at four locations (Figure 3.5).

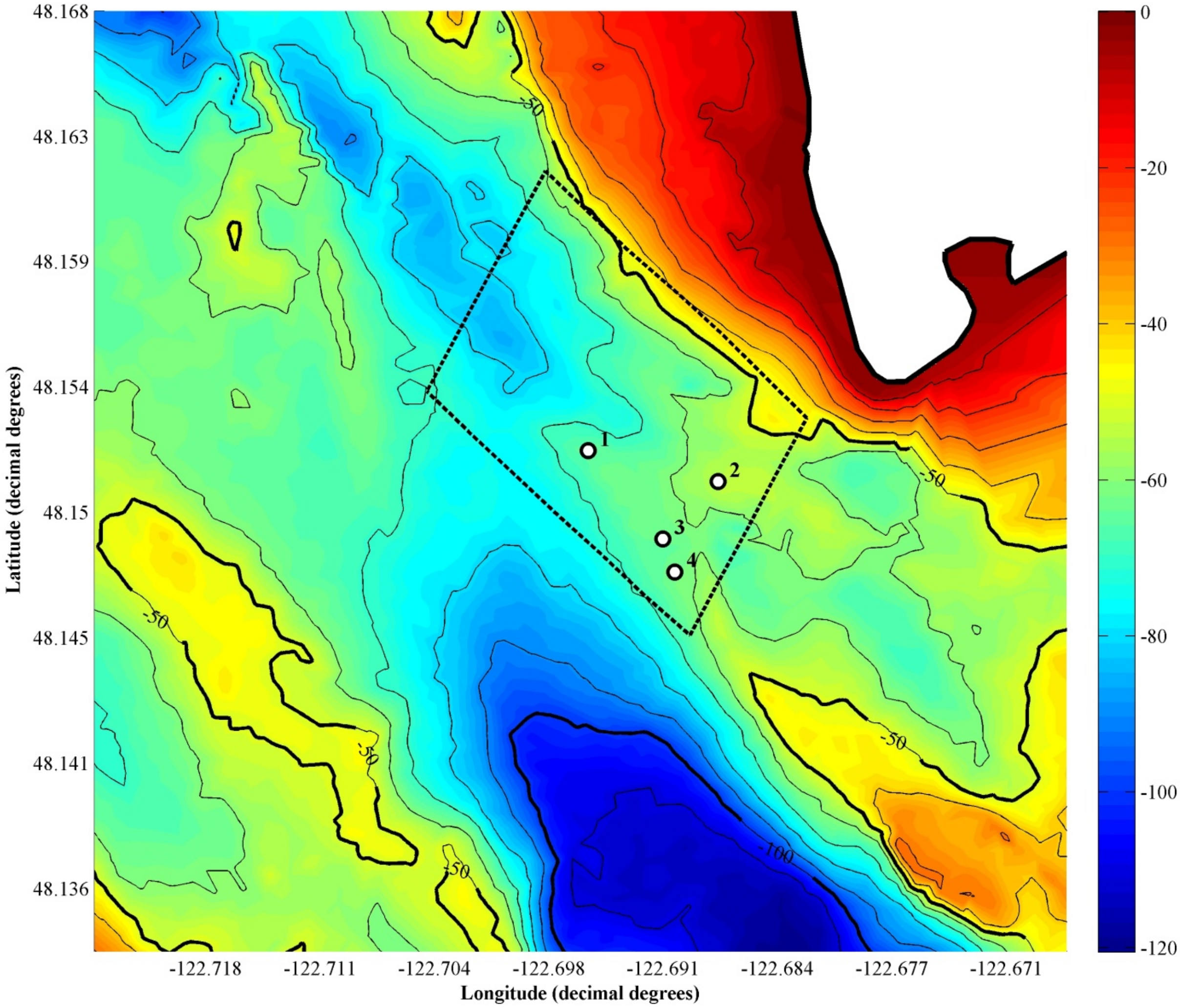

Figure 3.5 – Stationary CTD measurement locations, superimposed on Admiralty Inlet bathymetry (m). Site 1: Apr 2009-May 2009, Site 2: May 2009-Aug 2009, Site 3: Aug 2009-Nov 2009, Site 4: Nov 2009-Feb 2010.

The CTD monitors both temperature and conductivity, but the conductivity sensor has been visually fouled upon instrument retrieval in August, November, and February and the long-term data do not appear to be accurate. However, comparison to the temperature sensor inside the ADCP housing indicates that the temperature sensor on the CTD has not been similarly compromised and the long-term temperature record is presented in Figure 3.6. From April to November, the mean temperature at instrument depth varied from 8-10^{o}C, with inter-tidal variability reaching a maximum from mid-July through early September and a minimum during December.

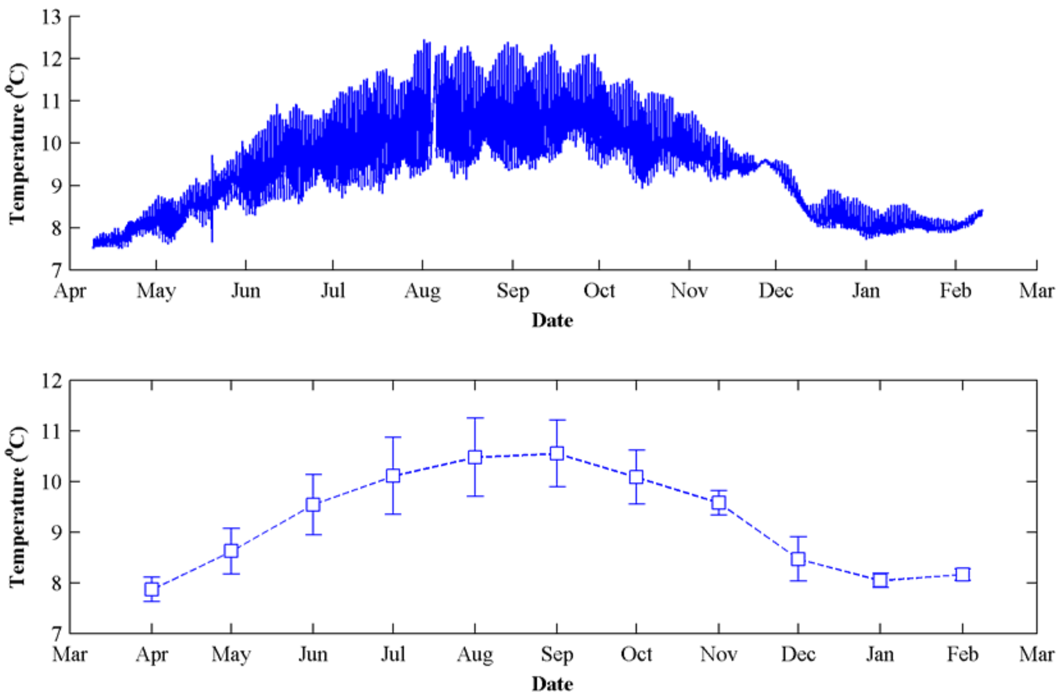

Figure 3.6 – CTD temperature. Top: 10 minute intervals. Bottom: Monthly averages with one standard deviation. Gaps in time series coincide with instrumentation recovery and redeployment.

From August 2009-February 2010, a CTDO (conductivity, temperature, depth, and dissolved oxygen) sensor owned by the Department of Ecology was concurrently deployed and data are presented in Figure 3.7. These measurements confirm that temperature, salinity, and dissolved oxygen all vary considerably with stage of the tide and season.

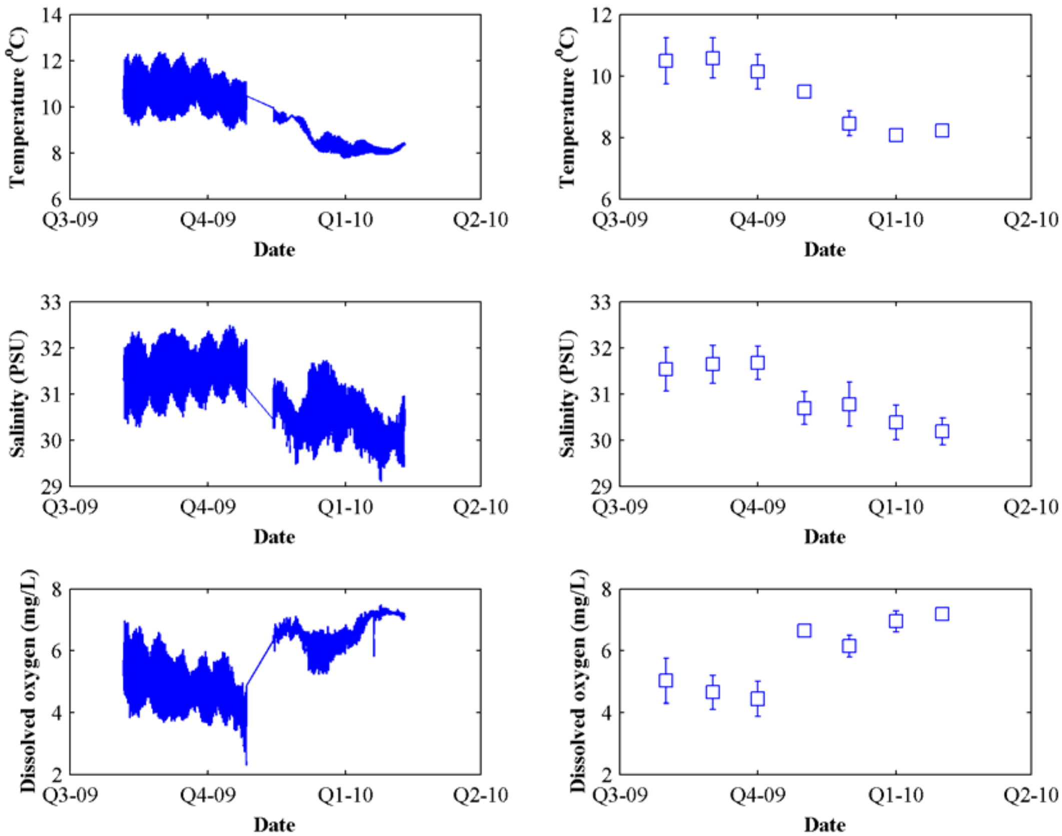

Figure 3.7 – CTDO measurements. Left: 15-30 minute sampling intervals. Right: Monthly averages with one standard deviation. Dissolved oxygen values are uncorrected and should be considered preliminary (i.e., the jump in dissolved oxygen values from the first to second deployment is likely a calibration artifact).

4 Discussion

On their own, the five research cruises present only a partial picture of water quality in the survey area. While these surveys and bottom-mounted instrumentation help to quantify temporal variations on time-scales from a tidal cycle to season, annual variability may also be significant. The University of Washington PRISM program has collected cast data at a station (P20) 18 times from 1998-2008 once or twice a year during the latter half of the year. As shown in Figure 4.1, these casts are in close proximity to the project area.

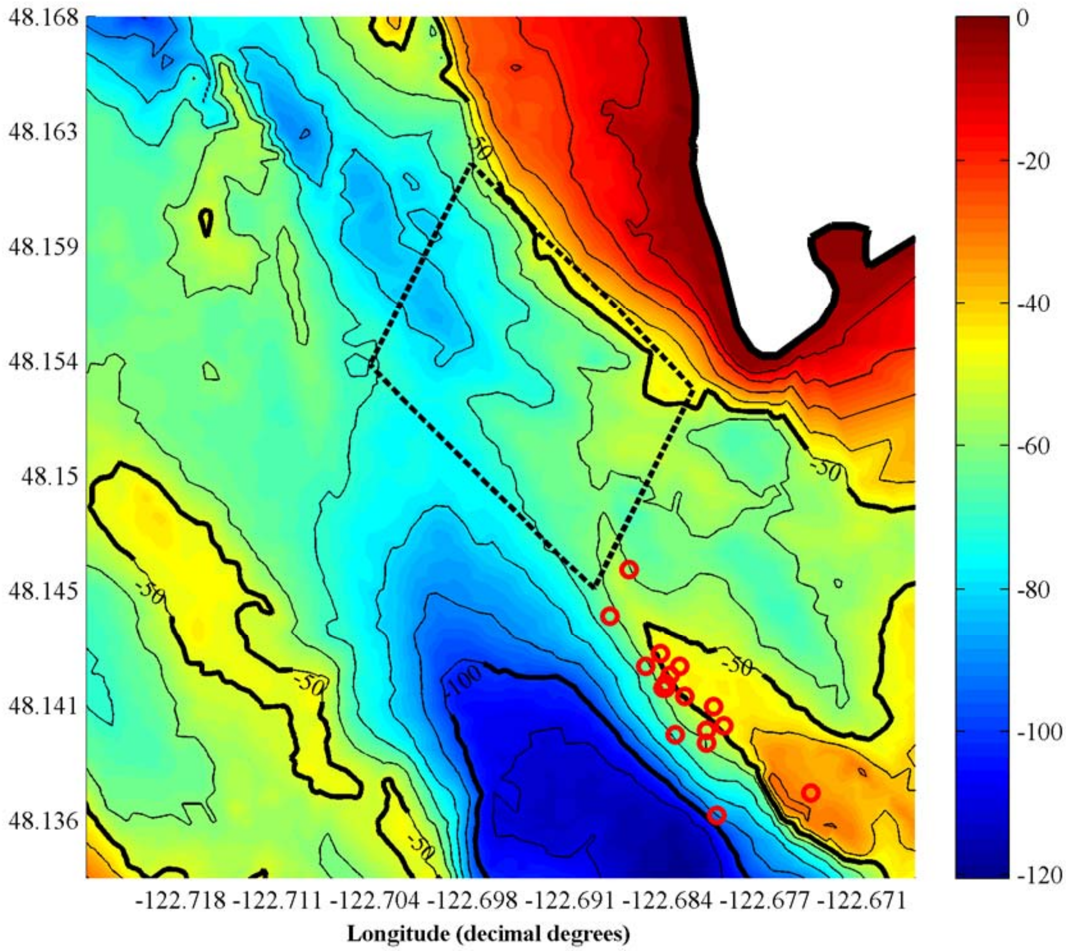

Figure 4.1 – UW PRISM station P20 casts, superimposed on Admiralty Inlet bathymetry (m) (red circles, 1998-2008).

A comparison between P20 cast data and project surveys is presented in Figure 4.2. These suggest that the variability observed within the project area is consistent with the longer-term variability observed at the P20 station. In the case of temperature, where survey casts show higher variability, it is important to note (1) P20 has never been occupied during the first six months of the year and (2) temperature shows considerable tidal variability in August, such that the measured temperature is very much dependent on the timing of a cast. This is reinforced by the temperature range shown in Figure 3.6.

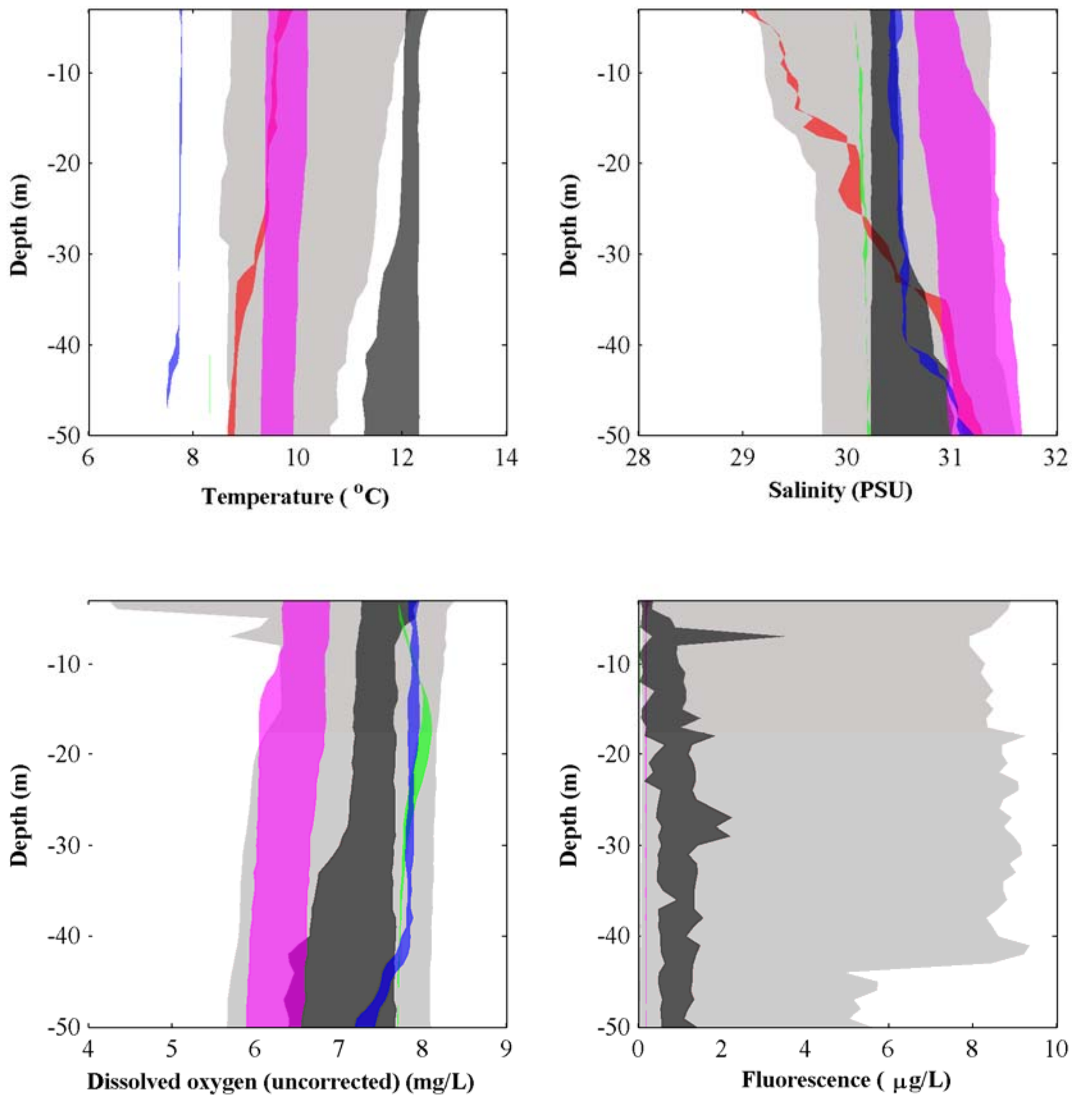

Figure 4.2 – Ranges of common measured quantities for NNMREC survey cruises overlaid on UW PRISM station P20 (light gray, N=18). (blue: April 2009, N=2; red: May 2009, N=2; dark grey: August 2009, N=3; magenta: November 2009, N=9; green: February 2010, N=2)

Variations between site P20 and the surveys off Admiralty Head do not appear to be ascribed to spatial variability. During the November survey a series of casts were conducted from near slack water through the peak of a moderate flood tide. These casts were spatial distributed on a similar length scale to P20 observations. The temporal evolution of temperature and salinity profiles is presented in Figure 4.3. These profiles suggest that the characteristics of the water column are primarily driven by the stage of the tide rather than spatial position within the project area.

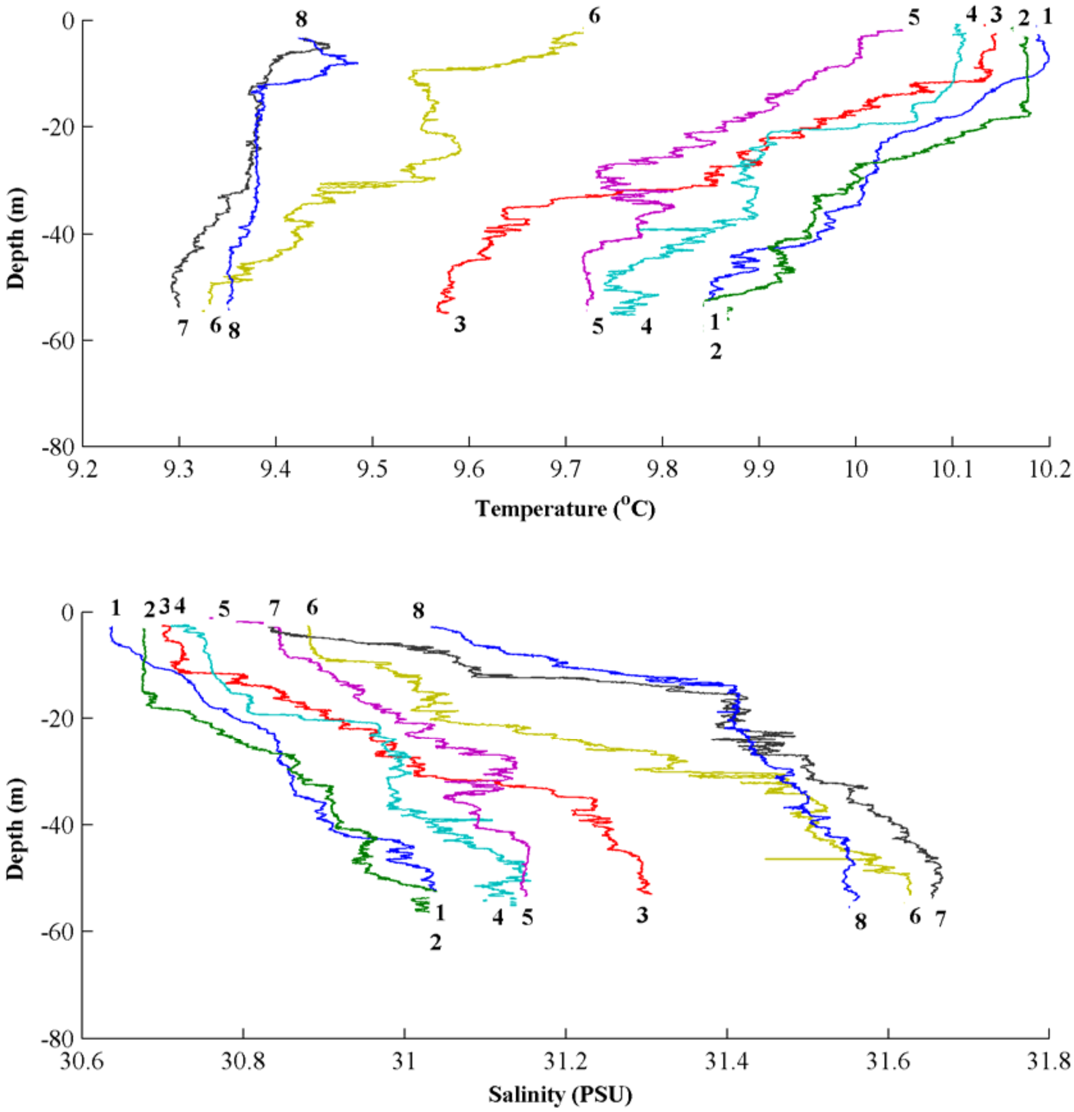

Figure 4.3 – Temperature (top) and salinity (bottom) casts from November 11, 2009. Casts are numbered sequentially from near slack water through peak flood currents.

5 Conclusions

A combination of survey cruises and bottom-mounted instrumentation have been deployed in Admiralty Inlet in the region surrounding a prospective tidal energy device deployment. Measurements and comparison to longer time series indicate significant temporal variability in water quality on tidal, seasonal, and annual time scales. Depending on the season, there may be considerable vertical variations (stratification). Horizontal spatial variability appears to play a less significant role over the length scales being considered. In order to capture this variability a combination of long-term bottom-mounted instrumentation and short-term profiling surveys are required.

6 References

Anon, HDR/DTA, Admiralty Inlet Pilot Tidal Project Water Quality Study Plan, 2009.

JGOFS Protocols—June 1994

Appendix L-6

Admiralty Inlet Hydrophone Monitoring Study
2009/2010 POD Deployments

Project Name:	Admiralty Inlet POD analysis for University of Washington SnoPUD TISEC study
Reference:	NA0509UOW

Drafted by:	Dominic Tollit and Evelyn Philpott	
Checked by:	Jim Thomson/Brian Polagye	June 17 2010
Approved by:	Kelly Macleod	June 15 2010
Date:	Submitted June 18 2010	

Admiralty Inlet Hydrophone Monitoring Study: 2009/2010 POD Deployments - Final Report June 15th 2010.

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1.0 INTRODUCTION

Public Utility District No. 1 of Snohomish County (Snohomish) is engaged in FERC licensing of the Admiralty Inlet Pilot Tidal Energy Project in Puget Sound, Washington. The Project involves installation of up to two tidal in-stream energy conversion devices in Admiralty Inlet, as well as placement of a transmission cable to shore. These devices will be installed in the north-eastern portion of Admiralty Inlet, approximately 1 km west-southwest of Admiralty Head near 48.1509°N 122.688°W, in water depth of approximately 60 meters. Power generated by the project will be transmitted via a single subsea cable and connected to the grid at the Puget Sound Energy infrastructure near the Fort Casey Conference Center.

Any potentially adverse effect of the Project on aquatic species is of concern to the Snohomish. It is Snohomish's intent to 1) characterize the existing environment, including marine mammal use, within the Project vicinity; 2) evaluate the potential for the Project to substantively impact existing resources; and 3) engage in detailed post-installation monitoring of the Project to observe and assess any such impacts. This study is part of a larger marine mammal program which aims to address the first of these goals, and is intended to support the environmental analyses required for the second. Preliminary analyses were presented in Snohomish's Draft Pilot License Application (DPLA) and this final report has been prepared to provide site characterization data to be summarised in the subsequent Final Pilot License Application (FPLA).

The deployment by the University of Washington of two project site-specific passive acoustic monitoring hydrophones aims to ensure collection of high frequency click train data from harbor porpoises (*Phocoena phocoena*), as well as other vocal marine mammals and also measurement of ambient noise levels (Bassett 2010). Both hydrophones require regular recovery from the seafloor. This report covers nearly one year of data collected in four successful deployments of the hydrophone devoted to collecting high frequency cetacean click trains (the T-POD, see www.chelonia.co.uk). It also includes complimentary data on non-porpoise click detections collected concurrently by a second updated version produced by the same manufacturer and aimed at better species resolution between cetaceans – the C-POD, which was deployed concurrently during the last three of the four deployments. Site information from a six month land based observer study (Tollit et al. 2010), as well as opportunistic sightings from voluntary sighting networks were also available for interpretation.

1.1 Passive Acoustic Monitoring (T-POD and C-POD)

Passive acoustic monitoring has become increasingly useful in studies of odontocete habitat use and behaviour, in particular when conditions are unsuitable for land-based observations or boat based sighting surveys. The T-POD incorporates a hydrophone, battery pack, memory and a hardware data-logger which detects and logs cetacean echolocation clicks. The T-POD does not record sound. Six separate scans are performed per minute and the scan settings can be adjusted to detect and log porpoise or dolphin echolocation at a range of frequencies. The T-POD works by comparing the output of two bandpass filters. The target filter is set to the frequency of the echolocation clicks of the target species, in this case porpoises, and the reference filter is set to an alternative frequency with little energy within the click. If both dolphins and porpoises are present in an area, the reference filter is set between the target frequencies of the two species, which helps to minimise the detection of porpoises in scans targeting dolphins.

Admiralty Inlet is used by and includes designated critical habitat for Southern Resident killer whales [(*Orcinus orca*, SRKW), NOAA 2008]. Their click trains are wide frequency spectrum. Occurrences are most frequent in the fall when they feed on adult chum and Chinook salmon runs (Osborne 1999, NOAA 2008). Porpoises, particularly harbor porpoises, are relatively common and can be observed in the region year-round, while other cetaceans are observed far more intermittently (Calambokidis and Baird 1994). Harbor porpoises emit narrowband high frequency clicks with a peak frequency of 128 kHz and a mean source level of 157dB re 1μPa at 1m when measured in captivity (Au et al., 1999). Although sighted far less frequently in the region, Dall's porpoise (*Phocoenoides dalli*) echolocations are also narrow band (2-10 kHz) clicks with most peak frequencies between 117 and 141 kHz (Bassett et al., 2009) and so accurate species differentiation by the T-POD is not possible. Killer whales produce highly variable clicks, lasting from 0.1-25 milliseconds and containing a narrow to broad range of frequencies that usually range from 4-18 kHz, but extend up to 50-85 kHz. Most click trains last 2-8 seconds with 2-50 clicks per second, but some exceed 10 seconds with up to 300 clicks per second. Slower click trains are probably used for navigation and orientation on more distant objects, whereas rapid click rates appear to be used for investigating objects within 10 m (Richardson et al. 1995, Au et al. 2004, NMFS 2008).

The T-POD mostly receives short segments of the trains of clicks produced by dolphins and porpoises as they scan past it. The software algorithm identifies these as click trains and assesses the probability of such trains arising by chance from other broadband sources such as shrimp, rain, propellers, etc. The T-POD records the time and duration of each detected click and allows calculation of interclick intervals (ICI). The software classifies the trains into four classes; 'Cet hi' and 'Cet lo' for click trains with very high probability of coming from cetacean, and less distinctively cetacean click trains, but still with a high probability of cetacean origin respectively. Click trains resembling "chance" trains or boat sonar are placed in 'doubtful' categories.

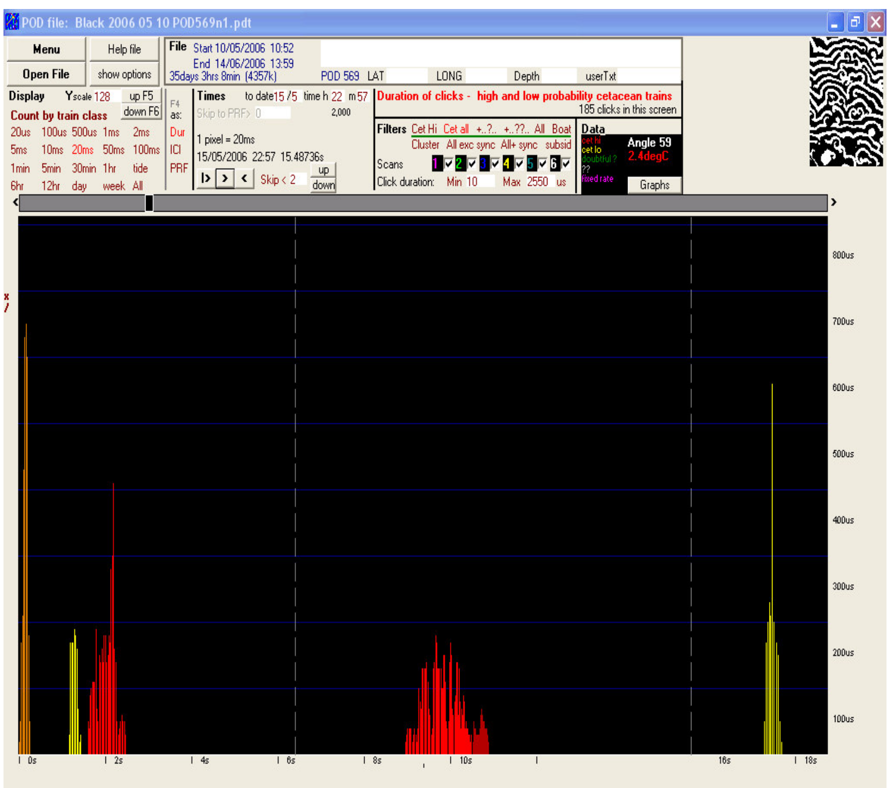

Plate 1. T-POD software screen showing high probability (red) and low probability porpoise trains. The x-axis shows time passed in seconds whilst the y-axis shows the duration in µs of each click within the train.

PODs have successfully been used to detect porpoises (Cox et al., 2001; Culik et al., 2001; Teilmann et al., 2002; Koschinski et al., 2003; Carlström, 2005; Carstensen et al., 2006; Koschinski et al., 2006), bottlenose dolphins (*Tursiops truncatus*) (Philpott et al., 2007) and finless porpoise (*Neophocaena phocoaenoides* Cuvier) (Jefferson et al., 2002). The T-POD can only detect echolocating cetaceans. Hence, cetaceans may be present in an area, but will not be detected by the T-POD unless they are echolocating. T-PODs log continuously 24 hours a day and are therefore useful for providing continuous data on porpoise activity within a radius of up to ~300m with a detection function equivalent to 100% detection within approximately a 70-100m radius (Tougaard et al., 2006). However, it is important to emphasise the limits of their utility:

• They provide data on porpoise activity (absence/presence) in a given area.

• They will only record porpoises that are actively echolocating and detection range will vary depending on the relative position of echolocating animals.

• They can not discern between harbour and Dall's porpoise.

• They do not provide a count of the number of porpoises recorded.

• They cannot on their own be used for estimating abundance of harbour porpoises.

• They can be used to compare relative frequency of occurrence between sites or through time.

In this year-long study, we investigated the acoustic activity of porpoises logged by the T-POD, as well as other delphinids logged by both the T-Pod and the new C-POD, aiming to characterize site use and investigate typical patterns. Variables under consideration included deployment location, monthly, tidal and daily (diel/diurnal) patterns, as well as the influence of current speed; a key variable given the proposed turbines do not rotate in water velocities below 0.7 m/s.

2.0 METHODS

2.1 POD deployments

The study was carried out in north-eastern area of Admiralty Inlet, the main entrance to Puget Sound in Washington State, USA. The POD deployments were carried out by Dr. Jim Thomson and Dr Brian Polagye. The T-POD was attached laterally to a sea-spider (see Plate 2), which was then lowered to the sea floor

Plate 2: Sea spider and T-POD (on right) mooring set-up

Sea spider deployments by UW to measure current have been ongoing since April 2009. The first POD (T-POD) was deployed at 9am on the May 20th 2009 (Table 1). The POD was retrieved and data downloaded on August 3rd 2009. A T-POD and a C-POD (a newer model) were redeployed on the same spider in the consequent deployments. Data contained in this report pertain to UW deployment numbers 2-5, which in this report are now termed deployment 1-4. Final recovery was on May 4th 2010. Deployments 1 and 4 were nearer shore in shallower water (51-54 m), while deployments 2 and 3 are further from shore in somewhat deeper water (61-62m), approximately 400m from deployments 1 and 4 (Table 1, Figure 1).

2.2 Data collection

The version 5 T-POD (ID no.714) was set with five scans each minute targeting 130 kHz for porpoise clicks and one scan per minute targeting dolphin clicks at 50 kHz (see Table 2). The T-POD was serviced and the data downloaded using dedicated software (TPOD.exe). T-POD software version v8.24 was used in the analysis. The C-POD (ID no. 718) software version v1.054 was used, with settings to continuous scan and high pass filter of 20 kHz.

Table 1. Sea Spider deployments to date in Admiralty Inlet (data in this report marked in bold).

UW Deployment # **(Figure 1)**	**1**	**2**	**3**	**4**	**5**	**6**
POD report deployment #		**1**	**2**	**3**	**4**	
Deployment dates	4/9/09 – 5/19/09	5/20/09 – 8/3/09	8/5/09 – 11/11/09	11/12/09 – 1/29/10	2/12/10 – 05/4/10	5/6/10 – Present
Duration (days)	40	75	97	78	82	~90
Latitude	48.1521	48.1509	48.1489	48.1477	48.1501	48.1531
Longitude	-122.695	-122.688	-122.691	-122.69	-122.686	-122.688
Deployment Depth (m)	65	54	61	62	51	~50
T-POD deployed	N	**Y**	**Y**	**Y**	**Y**	Y
C-POD deployed	N	N	**Y**	**Y**	**Y**	Y

Table 2. T-POD settings used in this study for v5 T-POD ID no 714.

Scan	**1**	**2**	**3**	**4**	**5**	**6**
Target A filter frequency (kHz)	130	130	130	130	50	130
Reference B filter frequency (kHz)	92	92	92	92	70	92
Click bandwidth	4	4	4	4	5	4
Sensitivity	16	16	16	16	9	16
Scan limit no. of clicks logged	240	240	240	240	240	240

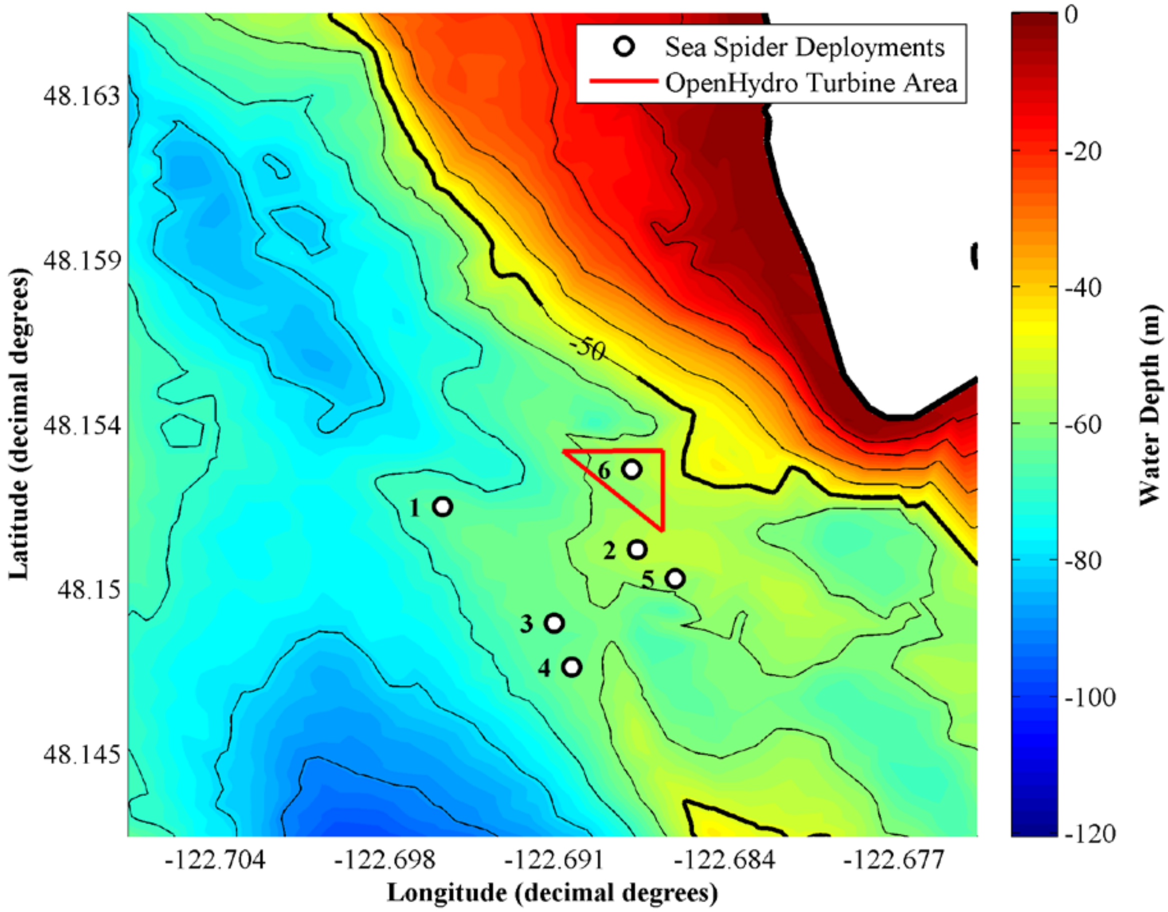

Figure 1. Sea Spider deployments by UW to date in Admiralty Inlet. Data contained in this report pertain to POD deployments at location numbers 2-5 (see Table 1).

2.3 Data processing and calculation

Raw T-POD data was assessed by a trained POD operator and analyst and considered high quality with few false negatives/positives. Typically the top two categories assigned by the T-POD software ('Cet hi' and 'Cet lo') are considered to reliably represent click trains. In this study, a large proportion of click trains were categorised as 'Cet hi'. Patterns of high and medium probability porpoise click trains ('Cet hi' and 'Cet lo') were visually compared and were found highly correlated (as per www.Chelonia.co.uk) and consequently both categories were considered valid porpoise click trains and re-categorised as 'Cet all'. 'Cet all' is used as the basic metric for comparison. The 'Cet all' category has also been used in other turbine baseline studies, and as a consequence allows some future inter-site comparison. Raw C-POD data was assessed by Dom Tollit and Dr Nick Treganza (Director of Chelonia Ltd.), particularly to assess the accuracy of instances of high probability delphinid identifications, but also to assess levels of interference by the ADCP (see below).

Porpoise detections were analysed by examining Detection Positive Minutes (DPM - the total number of minutes in a day or alternately in an hour in which porpoise clicks were detected) and Detection Positive Hours per day (DPH – the number of hours in a day in which at least one detection of clicks was detected). DPM is the most universally used metric when carrying out POD analysis, especially when presenting the data for environmental analyses (e.g., Rayment et al. 2009). We have attempted to remove the potential effect of the presence of the UW vessel in our analysis and excluded periods of non-typical boat presence from our analyses. Metrics calculated by day removed any 'incomplete' days, typically at the beginning and end of the each data collection deployment period.

Some authors also use 'encounters' to analyse the data. This method defines an acoustic 'encounter' as a series of click trains separated by a period of silence of 10 minutes (Carlstrom 2005). It is difficult to establish a set time frame to define 'encounters', but the use of a 10 minute time frame likely provide an indication of maximum encounter estimates. Some authors found that 'waiting times' (i.e., the period of time between encounters) was a useful statistic in gauging the impact of construction activities on porpoises in low density areas (Tougaard et al., 2009). However encounter rates tend to work better at low densities of animals but in high density areas encounters can run together and so can be misleading (www.chelonia.co.uk). Therefore, DPM has been used in our analyses but encounters have been summarized in this study also, to provide an alternative metric of usage. It is impossible to tell if different 'encounters' are the same animal repeatedly or many different animals.

Autocorrelation of DPM data was assessed to ensure appropriate resolution of time periods under analysis. The data used is the count of clicks in time bins that can be from 1min to 6 hours in size and uses formula derived by Chatfield (2004).

Given N observations $x_1, \ldots, x_N$, on a time series, we can form $N-1$ pairs of observations, namely, $(x_1, x_2), (x_2, x_3), \ldots, (x_{N-1}, x_N)$, where each pair of observations is separated by one time interval. Regarding the first observation in each pair as one variable, and the second observation in each pair as a second variable, then, by analogy with Equation (2.2), we can measure the correlation coefficient between adjacent observations, x_t and x_{t+1}, using the formula

$$r_1 = \frac{\sum_{t=1}^{N-1} (x_t - \bar{x}_{(1)})(x_{t+1} - \bar{x}_{(2)})}{\sqrt{\left[\sum_{t=1}^{N-1} (x_t - \bar{x}_{(1)})^2 \sum_{t=1}^{N-1} (x_{t+1} - \bar{x}_{(2)})^2\right]}} \qquad (2.3)$$

where

$$\bar{x}_{(1)} = \sum_{t=1}^{N-1} x_t/(N-1)$$

is the mean of the first observation in each of the $(N-1)$ pairs and so is the mean of the first $N-1$ observations, while

$$\bar{x}_{(2)} = \sum_{t=2}^{N} x_t/(N-1)$$

The formula, for *r1*, gives the correlation between each minute and the next one and for *r2* the correlation between each time unit and the one two time units later. The number of values in the series of lag values *r1, r2,* etc, is limited to the lower of 1000 or 20% of the number of bins. The larger bin sizes smooth the output where data is sparse, but as it reduces the number of data points the length of the autocorrelation may fall to 80% of the length of the data file. The same length of autocorrelation is used for all lag values. *r1, r2* values are plotted in a correlogram and the horizontal limits *(2/SqRt(N))* represent approximate 5% p-values and points outside them are 95% likely to indicate a real temporal correlation between values separated by that time difference. In this study autocorrelation was assessed for three deployment periods and temporal correlation was estimated as 65 minutes (deployment 2), 32 minutes (deployment 3) and 66 minutes (deployment 4). As a consequence, the use of DPM in hourly time blocks for analysis was considered the lowest and most appropriate level of resolution.

DPM per hour were used to test for effects of time of day and current speed. Time of day, sunset and sunrise times were derived[1], with the period between sunrise and sunset considered 'day'. Current speeds below and above 0.7m/s were also compared, as the proposed Open Hydro turbine does not rotate at current speeds below 0.7m/s. Current speeds were collected from a nominal hub height of 10m (mid-turbine height) and 45m (used as a near-surface depth comparison of current speed) using a current monitor (ADCP) on the same mooring[2]. Hourly averages were computed from sub-sampled 10 minute reading and used to compare against DPM per hour values.

[1] http://www.fcc.gov/mb/audio/bickel/srsstime.html
[2] http://depts.washington.edu/nnmrec/project_meas.html#ADM_082009_bottom

DPM per hour data were heavily skewed and we have therefore reported median and interquartile ranges. We applied a kernel smoother to allow visual assessment of trends. This statistical technique represents the set of irregular data points as a smooth line or surface. We also modeled expected DPM from the fit of a Generalized Linear Model (GLM) using the Log Link, and allowing for over-dispersion of the variance through a scale parameter using the Quasi-Poisson distribution. This permits the more relaxed quasi-likelihood model of an overdispersed Poisson GLM in which we make assumptions only on the mean and variance, and not on the whole distribution. Significant relationships in these overdispersed GLM models between DPM and measured covariates were assessed using Likelihood Ratio Tests.

2.4 Study plan variance

Data was collected by the T-POD in deployment 1 for the period May 20th 2009 to July 15th 2009. No data was collected between July 15th and subsequent recovery on August 3rd 2009 due to memory storage limitations or possibly loss of battery power. Complete temporal coverage was contained in datasets collected for both the T-POD and C-PODs in all other deployments.

2.5 Data Quality

On review, data quality for T-PODs was considered high. Data quality for C-PODs was considered high-moderate, given harmonic interference from the ADCP in deployments 3 and 4 (when ping rates intervals were decreased below 1s). Given the known frequency and click interval for the ADCP, filtering of C-POD data should allow an easy ‘clean up’ of the data, without the loss of cetacean click data. (It is planned for this to be carried out under SnoPUD Department of Energy’s FOA000069 funding). The automated detection and identification of delphinid clicks by the C-POD is considered by the manufacturer as a work in progress. As consequence, automated detections of high probability dolphin clicks were reassessed using raw data. For example, clicks can be filtered by any of their parameters –

- Frequency in kHz is measured over the first 10 cycles of the click (or all of it if it is shorter)
- End frequency in kHz estimated from the last zero-crossing-interval.
- Amplitude = sound pressure level = maximum peak to peak of the loudest cycle in the click = Pp-p (pressure, peak to peak)
- Duration – expressed as the number of cycles in the click.

- Envelope = two 4 bit values representing the slope from the first to the 5th wave and the first to the maximum.
- Bandwidth – a measure of bandwidth on an arbitrary scale 0-31

Dr Nick Treganza assessed all high probability dolphin click detections to provide data on reliable detections only. Many false positive which were classified incorrectly were porpoises with clicks that included a short sharp frequency drop to below 50kHz. Without such raw data user assessment, data quality from dolphin detection must considered low.

3.0 RESULTS

3.1 Overall summary

The use of a sea spider was found to be a successful method of deploying and recovering the PODs on all four occasions. This report analyses T-POD logged data over a period of 321 full days and a total of 7787 hours overall. Like the T-POD, the C-POD logged continuously across deployments 2 through 4, totalling 266 days.

The T-POD only detected porpoises and there were no detections on the 50 kHz scan channel set to detect dolphin echolocations. The C-POD detected 106 high probability dolphin detection positive minutes across the 266 days of logging, but after independent raw data review, all but 5 detections were considered false positives (Table 3).

The clicks recorded by the C-POD on October 21st, had representative features of clicks from killer whales. Concurrent behavioural and acoustic recordings over the same time period were collected during a boat-based southern resident killer whales (SRKW) focal follow and by the cabled hydrophone at Port Townsend Marine Science Center (Tollit et al. 2010). The focal follow noted an approach by SRKW as close as 275m from the project site, with notable acoustic activity. We consider this a positive validation that the C-POD can detect the clicks of SRKW. Detection was reconfirmed on December 4th 2009, when killer whale like clicks were concurrently logged on the C-POD in the same period in which SRKW calls were detected by the PTMSEC cabled hydrophone (Table 3). On three other occasions the C-POD logged non-porpoise cetacean clicks. One of these was considered potentially from killer whales. The most likely species to produce these clicks are killer whales (both resident and transient ecotypes), as well as white-sided dolphins (*Lagenorhynchus obliquidens*), which were observed at least once in Puget Sound by observers (Tollit et al. 2010). Many of the dolphin false positives were due to interference by the ADCP monitor (especially deployment 3) which was deployed concurrently on the Sea Spider. C-POD detection rates of porpoises were significantly lower that that found for the T-POD. It is clear that hydrophone sensitivity, input filters and species detection rates differ between T-PODs and the updated C-PODs. The ability to understand the level of these differences will be addressed in future DOE FOA000069 funded work.

Table 3. User-confirmed delphinid click detection information from C-POD data

Date	**Time**	**Species category**	**Comments on clicks**	**Validation information**
October 21st 2009	15:36-15:22	Killer whale	Train at 37kHz with strong rise in 5th wave	Confirmed SRKW in area
November 10th 2009	11:56-12:51	Delphinid	Short broadband bimodal pulses 33kHz and 53kHz	
November 11th 2009	12:36	Delphinid/killer whale	Component at 25kHz	SRKW sighted locally on Nov. 12th
December 4th 2009	18:51-19:12	Delphinid/killer whale		Confirmed SRKW in area
February 2nd 2010	19:01	Delphinid	Fast regular click trains at 45-75 kHz	

Porpoises were detected on the T-POD on each day of logging (see Figures 2a and 2b), averaging 129.9 ± 70.0 (Standard deviation, SD) Detection Positive Minutes (DPM) per day. In comparison, the median value was similar equalling 119 DPM per day (Interquartile range=82-174, Figure 2b). Mean DPM represents on average 9% (± 5%) of a 1440 minute day. Minimum daily detection time was 4 minutes (0.3% of time) ranging up to a maximum of 374 minutes (26.0% of time). Porpoises were present and echolocating for at least one minute in the vicinity of the T-POD on average 15.8 ± 3.8 individual hours of each day with a median of 16 hours (range 3-24). In other words, on average the two hours of clicks detected by the T-POD each day were spread across 16 different hours of the day (Figure 3). DPM per day and DPH per day both vary across the period with cycling of peaks apparent and lower values in August 2009 and April 2010. Further assessment of DPM variability was undertaken using the metric DPM per hour and statistical analysis of these apparent trends is found in section 3.2. Average number of porpoise encounters (using 10 minute silences) per day ranged between 30-48 across deployments, with values highest in deployment 1 and lowest in deployment 4 (Table 4).

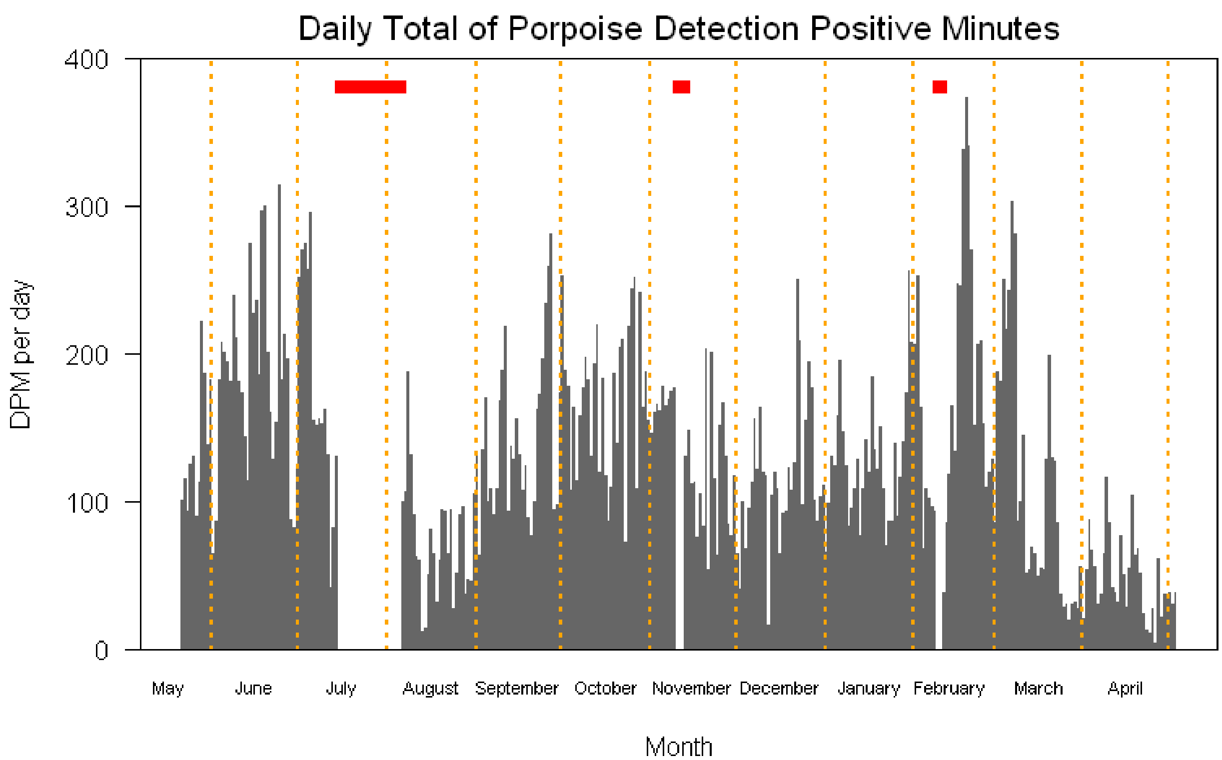

Figure 2a. Porpoise Detection Positive Minutes (DPM) per day. Red dashes denote no POD data collected or UW vessel present in study area.

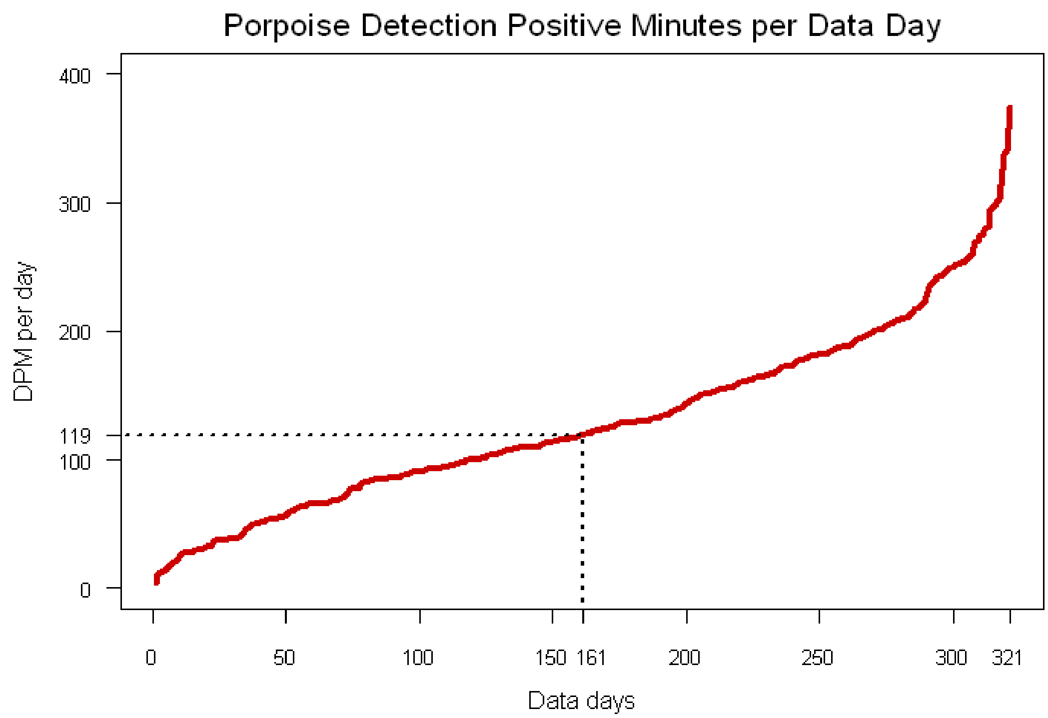

Figure 2b. Cumulative plot of porpoise Detection Positive Minutes (DPM) per data day, with arrow denoting the median value.

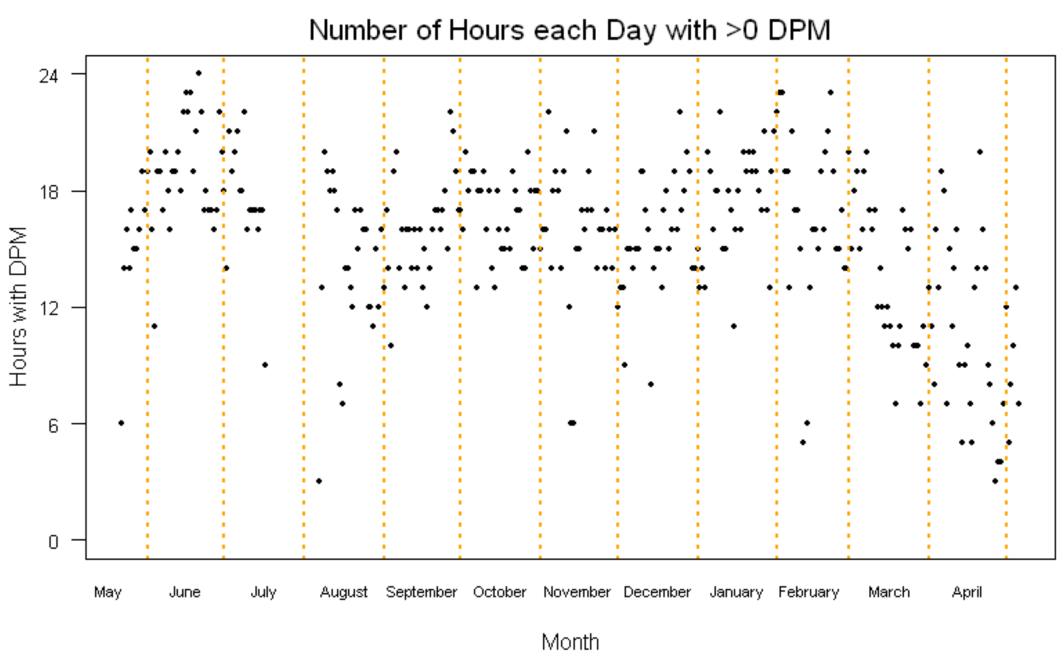

Figure 3. Porpoise Detection Positive Hours each day (or numbers of hours per day with at least one porpoise Detection Positive Minute, DPM).

Table 4. Porpoise daily encounter rate information by deployment.

Deployment Number	**Mean**	**Standard deviation**	**Median**	**Min**	**Max**
1	47.6	11.4	49	13	57
2	37.3	10.4	38	9	61
3	38.4	9.6	37	9	62
4	29.9	17.3	27	4	83

3.2 Analysis DPM per hour

Median DPM per hour over the period of the POD deployments was 2 with a 0-7 interquartile range (n=7787 hours) and a maximum of 53 minutes (Figure 4). The frequency distribution showed a strong right-handed skew. In 34.3% of hours recorded, no porpoise click trains were detected (i.e., DPM per hour = 0, n=2668, Figure 4). More non-detection hours were found during the day than during the night (see next section). In 11.2% of hours recorded (n=868), DPM per hour exceeded 15.

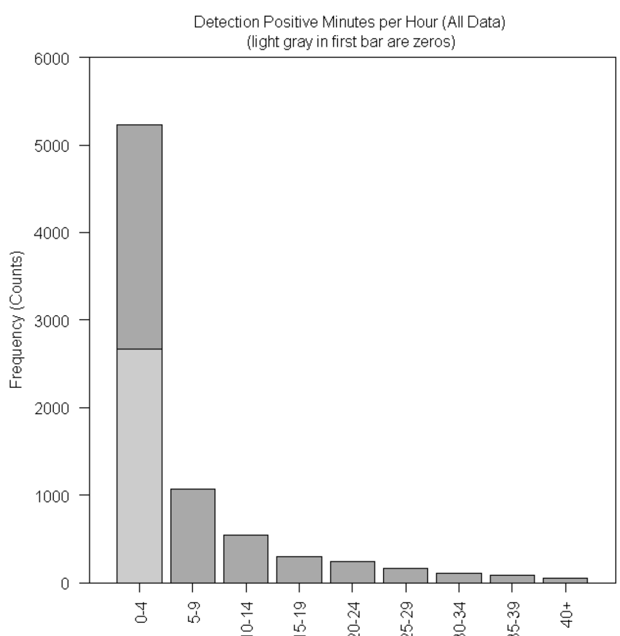

Figure 4. Frequency histogram of porpoise Detection Positive Minutes per hour overall

3.2.1 Seasonal and deployment effects on DPM per hour

Porpoise DPM per hour varied significantly across months ($X^2_{df=11}$=746.1, P<0.001, Figures 6, 7 and 8) and deployment periods ($X^2_{df=3}$=230.56, P<0.001, Figure 9). Median DPM per hour monthly values (Figure 7) were lowest in April (0), followed by August (1) and May (1). Highest median DPM values were observed in June (4), followed by January (3) and February (3). All months showed a similar right-handed skew in distribution. The fit of the overdispersed Log Linear Model highlighted monthly variability in DPM differed by 2-3 fold (Figure 8) and confirmed the trends highlighted by comparison of median values.

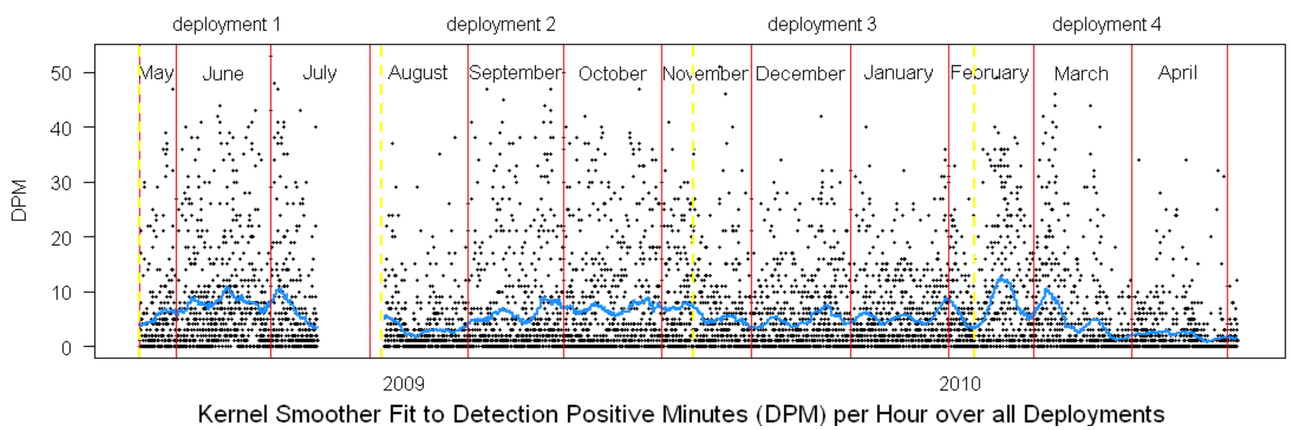

Figure 5. Trends in Detection Positive Minutes per hour by month shown using kernel smoother fit (blue line).

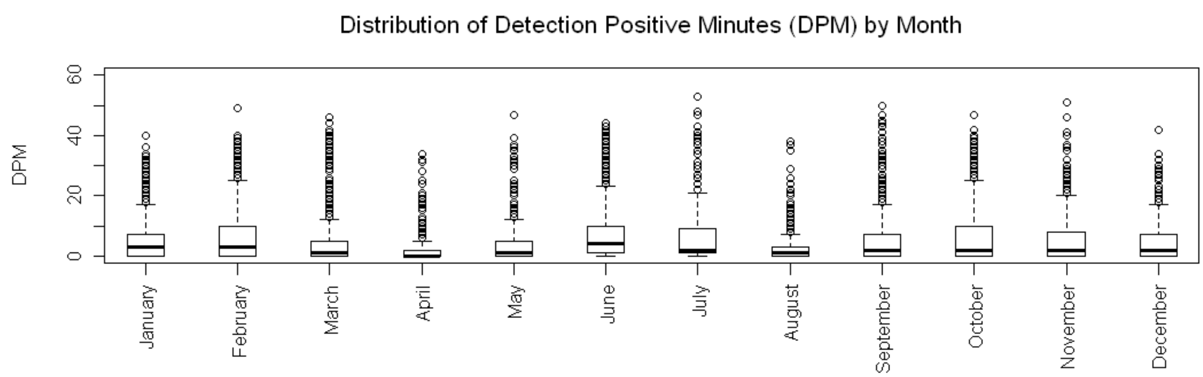

Figure 6. Overall Detection Positive Minutes per hour by month boxplot (Boxes denote IQR and circles outliers).

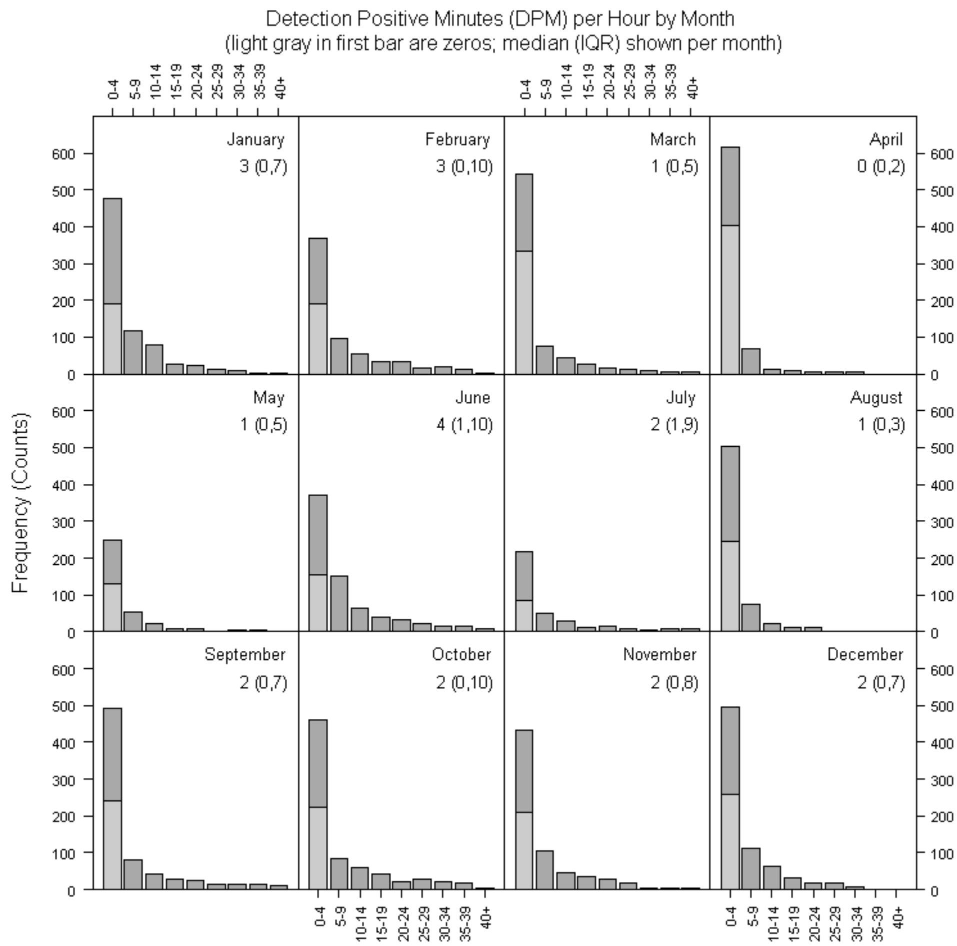

Figure 7. Detection Positive Minutes per hour by month histogram.

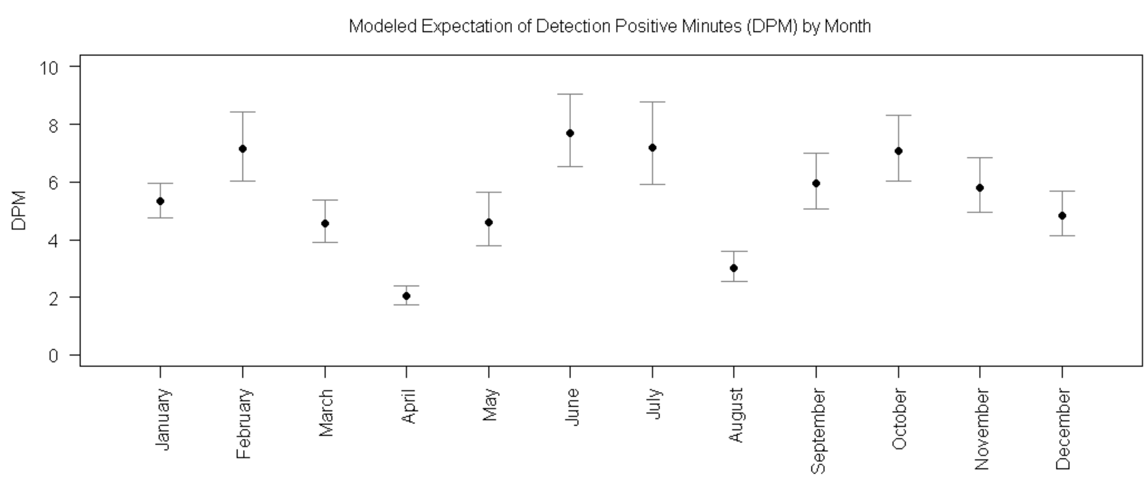

Figure 8. Overall Detection Positive Minutes per hour by month from the fit of a Generalized Linear Model. Error bars represent 95% confidence intervals.

DPM per hour was shown to be reduced in each subsequent deployment (Figure 9). Clearly, given that Sea Spider deployments varied by water depth and by location, the two variables (month and deployment) should be considered confounding variables. However, given that deployment 1 and 4 were located in close proximity, it is more likely the trends in DPM are due to seasonal effects. An additional year of POD data should clarify this picture (planned within the SnoPUD DOE FOA000069 funding).

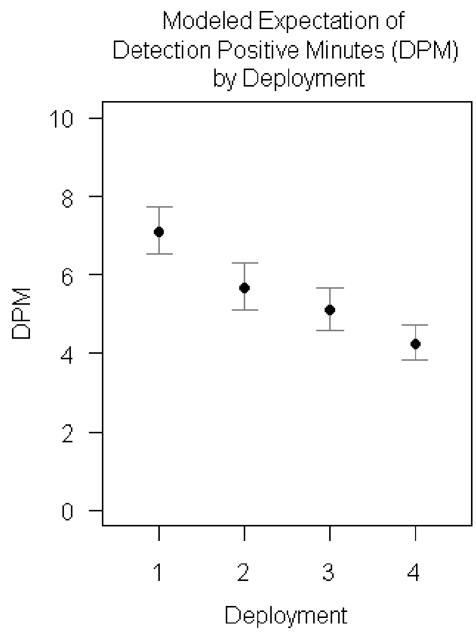

Figure 9. Overall Expected Number of Detection Positive Minutes per hour for each of the four deployments from the fit of a Generalized Linear Model. Error bars represent 95% confidence intervals.

3.2.2 Time of day effects on DPM per hour

DPM per hour showed a very strongly significant diel or daily effect ($X^2_{df=1}$=2577.2, P<0.0001, with highest rates consistently at night (median=5, IQR=1-13), notably between 22:00-3:00 hr (peaking at 00:00, midnight) and lowest rates during the day (median=1, IQR=0-2), notably between 9:00-14:00 hr (Figure 10). No DPM occurred in 49.0% of 3882 hrs of daylight, whereas no DPM occurred in 19.6% of 3905 hrs of night. The diel trend was not found to be consistent across months (Figure 11), with the time of day DPM differences least strong in months of low DPM (e.g., April/August) and stronger in months with high DPM (e.g., June/July/February/September/October). Across months the peak of DPM seemed consistently close to midnight, with troughs consistently close to midday (Figure 11).

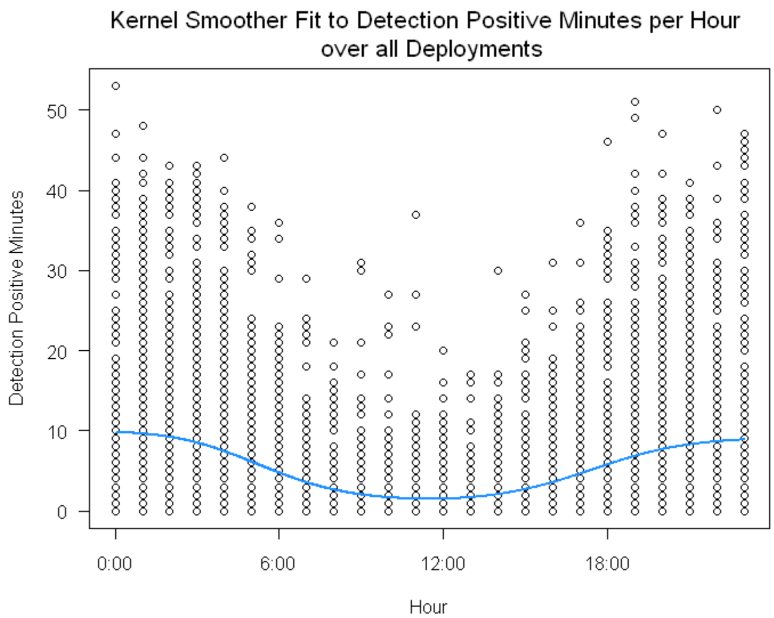

Figure 10: Overall Detection Positive Minutes per hour of day, shown with a kernel smoother.

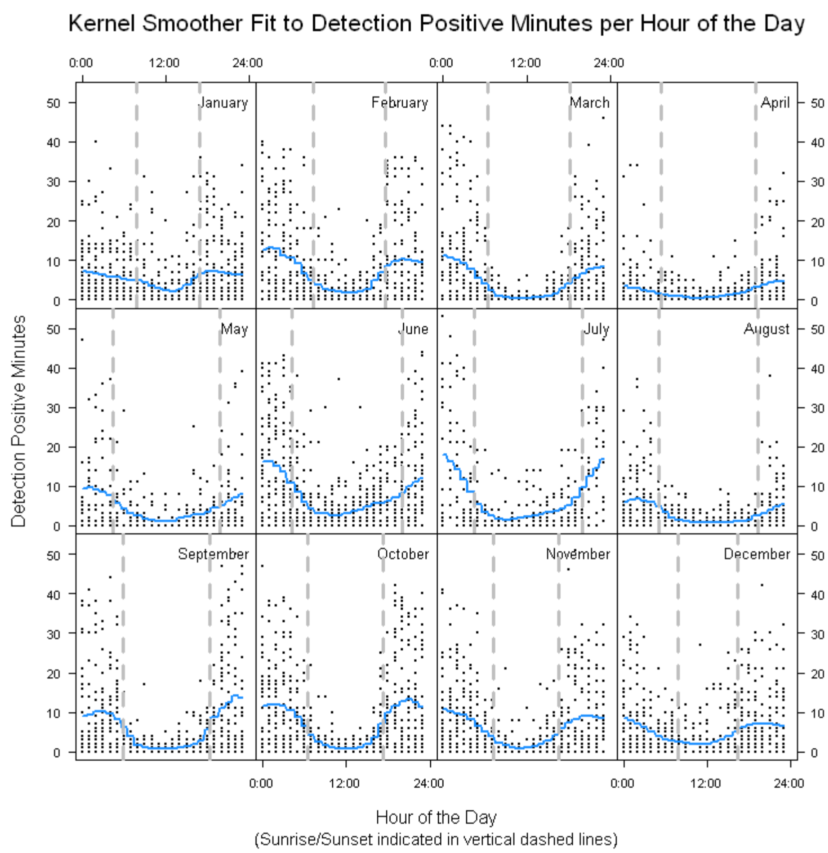

Figure 11. Detection Positive Minutes per hour by hour of the day across months with kernel smoother.

3.3 Dependence of DPM per hour on current speed

The impact of current was investigated firstly using regression analysis. Overall, it appeared there was no relationship between DPM per hour and current speed (R^2<0.001, Figure 12), nor any clear tendency to preferentially echolocate in ebb or flood currents (R^2<0.001, Figure 13).

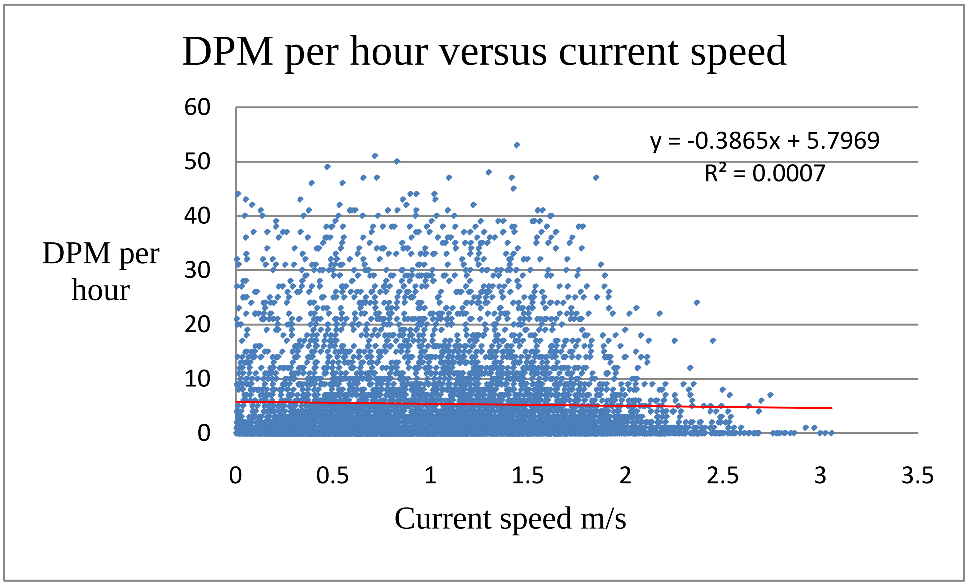

Figure 12. Linear regression of DPM per hour versus current speed.

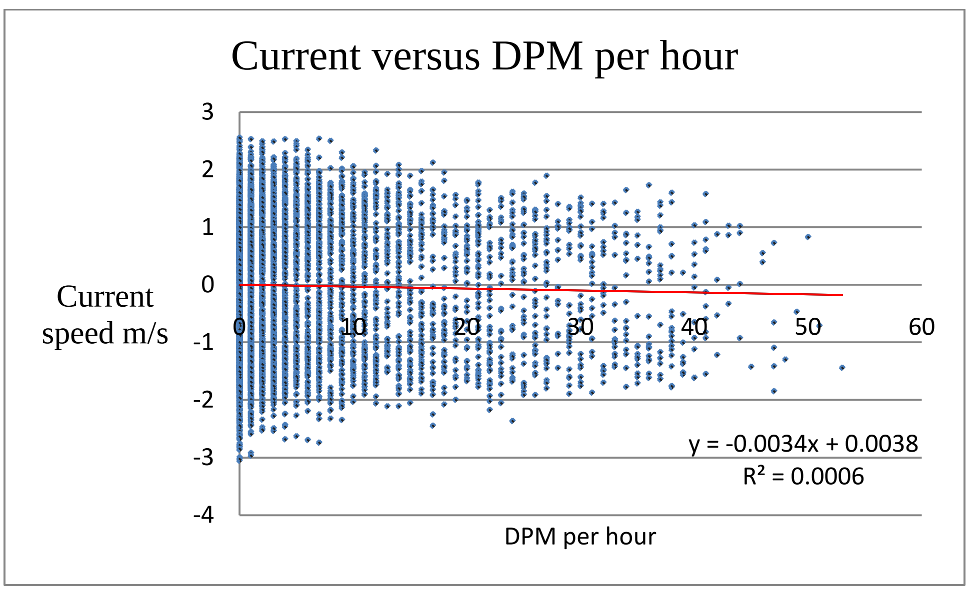

Figure 13. Linear regression of flood (+) and ebb (-) current speed versus DPM per hour.

However, given clear diel patterns and the relevance of a current speed of 0.7 m/s (current required to turn turbine), we reassessed the effect of current using the current speed cut-off ≤ / > 0.7 m/s, while controlling for night and day. Current alone was not a significant predictor ($X^2_{df=1}$=3.1, P=0.26), night and day was a highly significant predictor ($X^2_{df=1}$=2503.1, P<0.0001), as was the interaction between current and time of day ($X^2_{df=1}$=17.9, P=0.007). These results are seen in Figure 14, which highlights that DPM is significantly higher during high current velocities (>0.7m/s), but that this difference in DPM is not seen at night.

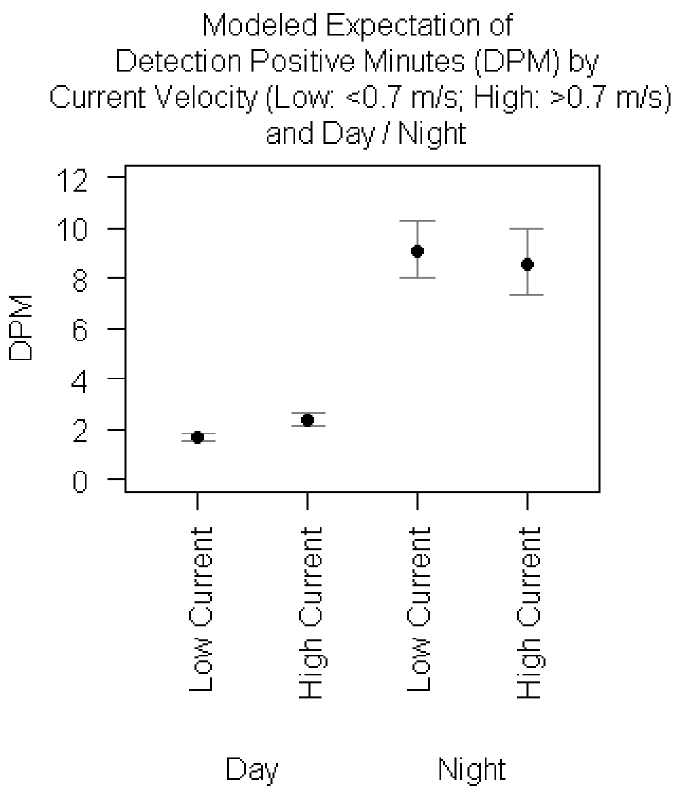

Figure 14. Detection Positive Minutes per hour by day and night and current speed cut-offs from the fit of a Generalized Linear Model. Error bars represent 95% confidence intervals.

Further assessment of temporal trends in current effects was made using the time of day for which maximum DPM was observed – midnight. Kernel smoothed data of DPM per hour clearly exhibited a bi-monthly cycling, as did current speed similarly for 10m and 45m above the seabed

(Figure 15). Direct comparison of DPM per hour (at midnight) versus 10m above seabed current speed at midnight highlighted that trends showed an inverse relationship (Figure 16). At monthly timescales, DPM appears to peak on the lower (neap) tidal velocities.

To assess the strength of this observation, we calculated sample power spectra to compare variance patterns across the kernel smoothed hourly DPM data, and across the current velocity time series. The two power spectra were compared across time frequencies for similarities in the periods where the peaks in the spectrum were found (Figure 17). Comparison of the nonzero peaks in the power spectra of DPM and current velocity (Figure 17), show a very strong correspondence. The strongest cycle in DPM is for 24hrs corresponding to the strong diel patterns exhibited by the data. This coincides with a similar peak in variance seen in the current velocity. Weaker peaks in both metrics are seen at a period of ~26 hours, which in the tidal cycles reflects that there are two high tides every ~25 hours, and these two high tides on any given day are typically not the same height. The key result that shows the importance of current velocity by way of tides on DPM, is the peak at 15 days in the DPM spectrum. This 15 day corresponds to the spring-neap tidal cycle, where ~15 days is the time between two neap tides. As the variability in currents is already captured sufficiently by the shorter frequencies (not shown in this figure is a significant peak in current velocity at 12.44 hours).

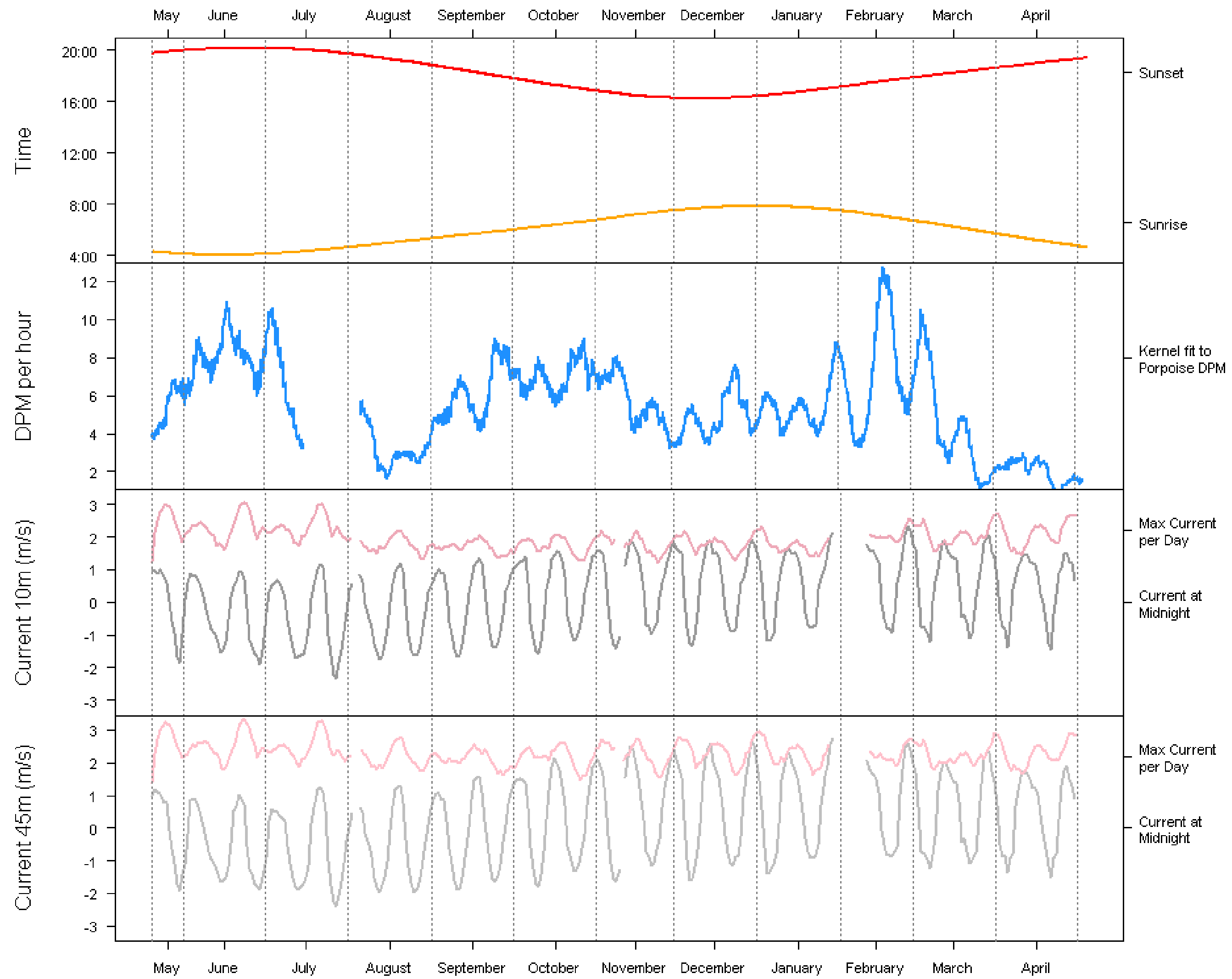

Figure 15. Study period variability in day length, smoothed DPM per hour at midnight and current (maximum and at midnight) at 10m and 45m above the seabed.

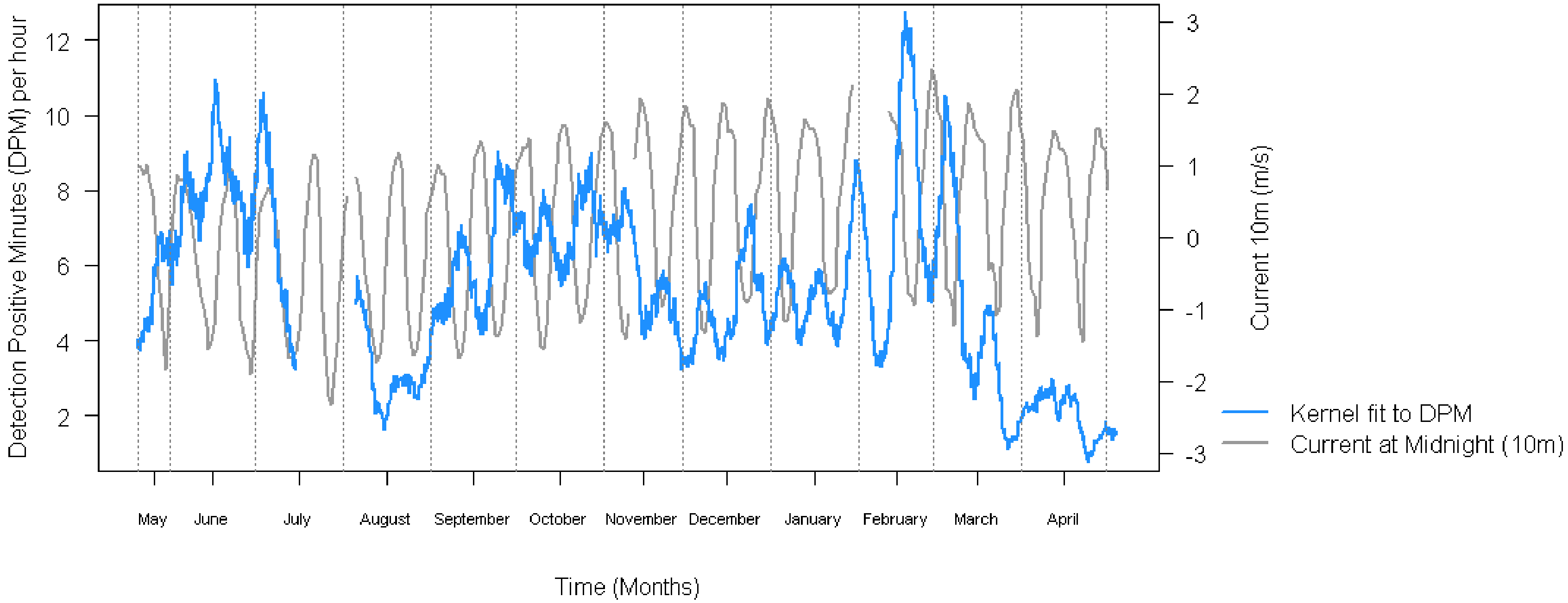

Figure 16. Study period variability in smoothed DPM per hour and current at 10m above the seabed (both values taken at midnight).

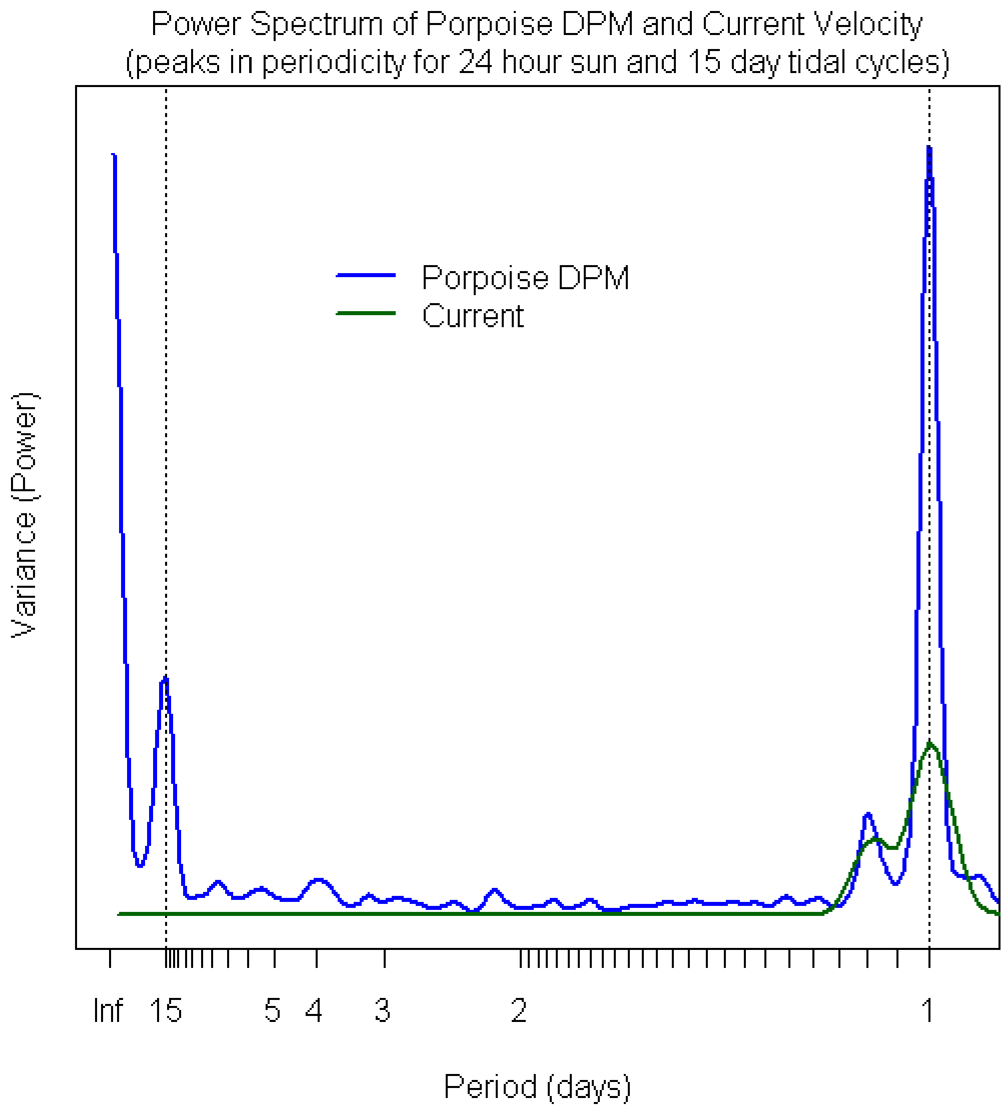

Figure 17. Power spectrum of DPM and current velocities at midnight.

Porpoise represent a key prey item of transient killer whales; and porpoise detection by transient killer whales has a strong acoustic component. Given observed decreases in porpoise click detections from a T-POD located in Admiralty during the spring of 2010 and the notable increase in transient killer whale sightings in the same period (Tollit et al. 2010), the two were plotted to highlight the possibility of some linkage. Also plotted are periods of SRKW sightings and days with periods of 3 hours or more of pile driving activity that took place at the Keystone ferry terminal (by WSDOT, Rick Huey, Pers. Comm.). We considered the results were indicative of a relationship between porpoise click detection and transient killer whale presence (Figure 18) and warrants continued data collection.

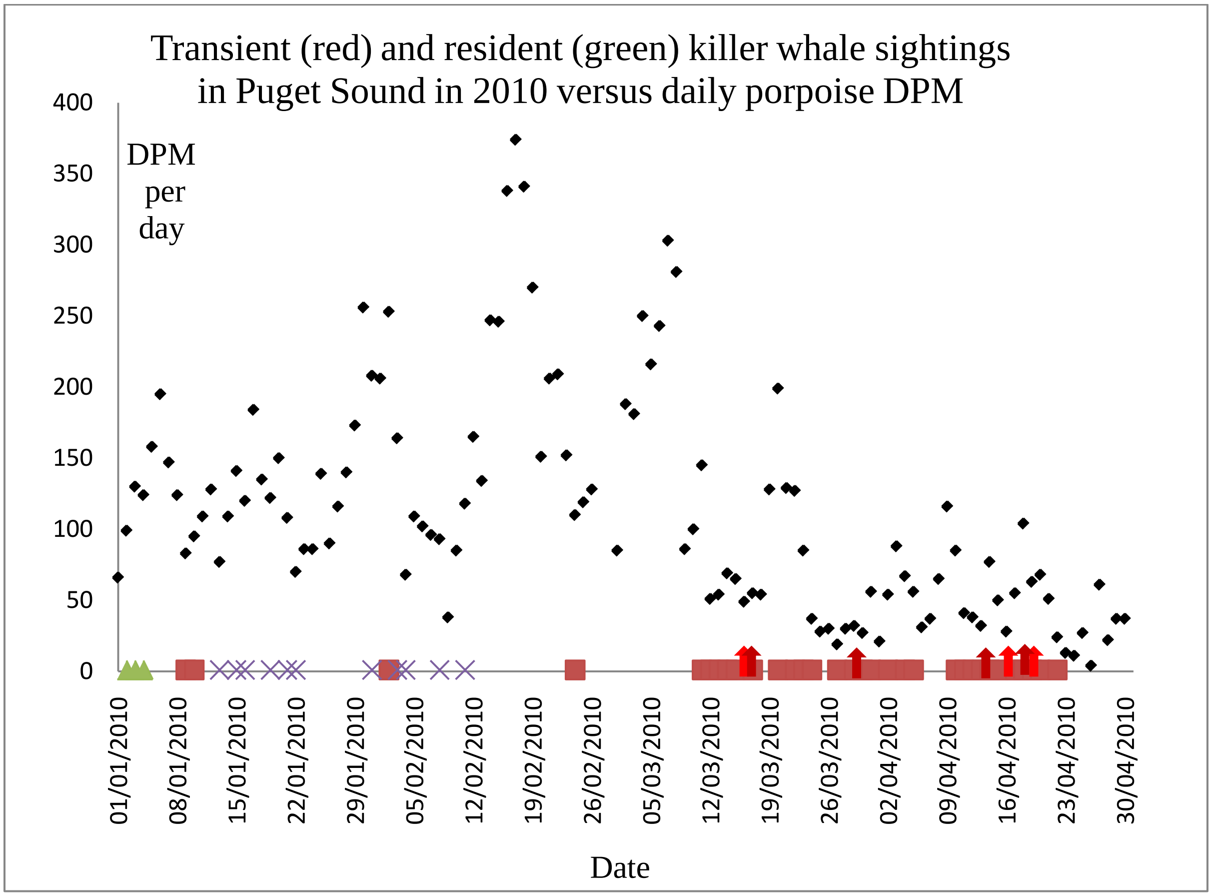

Figure 18. Porpoise daily detection positive minutes (DPM) in 2010 versus Puget Sound transient killer whale sightings in red with arrows depicting days with confirmed sightings in Admiralty Inlet. Also depicted are SRKW transit sightings (green triangles) and occasions with 3 hours or more of pile driving activity at Keystone carried out by WSDOT (cross hatches).

4.0 DISCUSSION and CONCLUSIONS

Porpoises are highly vocal animals, and wild individuals in Danish waters have been shown to produce sonar-click trains on average every 12.30 s (Akamatsu et al. 1992, 2007). T-PODs log continuously 24 hours a day and are therefore useful for providing continuous data on porpoise activity within a radius of up to ~300m (Tougaard et al. 2006). However it is important to stress, they only record porpoises that are actively echolocating and range is likely to vary depending direction of travel and to what extent clicks are produced off-axis. Despite these limitations, POD data is considered useful in comparing relative frequency of occurrence between sites, through time or after anthropogenic impact.

This study represents 321 full days (7787 hours) of data collected from a single T-POD moored at four locations in 51-62m water depth in north-eastern Admiralty Inlet, between May 20th 2009 and May 4th 2010. Only click trains from porpoises were recorded on the T-POD (i.e., no delphinid click trains were detected when scanning at a target frequency filter of 50 kHz). C-PODs were set with a high pass filter of 20 kHz and on review of raw data from 106 automated high probability ‘dolphin’ detections, the C-POD detected five instances of user-confirmed non-porpoise (dolphin) clicks. On two of these occasions, southern resident killer whale echolocation clicks were detected (as confirmed by concurrent independent boat and hydrophone observations). Other species using the area that may have been detected in the remaining three occasions of clicks detected by the C-POD include white-sided dolphins and transient killer whales. It is noted that while great care must therefore be used in interpreting dolphin detections using only automated C-POD software, the C-POD can detect killer whale clicks. Clicks were detected at higher frequencies (25-37 kHz) than typically noted, but within the normal limits (NMFS 2008). Potentially, reduction of the high pass filter to 10 kHz would improve killer whale click detection by the C-POD. Furthermore, C-PODs in close association with ADCPs may lead to false positives in cetacean detections.

Porpoises were detected by the T-POD every day of the 321 day study period, with detections logged 16 individual hours of each day and averaging 130 Detection Positive Minutes (DPM) per day, which represents on average 9% of a day. More than one third of all hours had no detectable porpoise click trains (i.e., DPM per hour = 0) and in 11.2% of hours recorded, DPM per hour exceeded 15. The median value was two minutes per hour, but a very strong influence of time of day was detected (see below). Porpoise ‘encounters’ per day ranged between 30-48 depending on deployment and using a ten minute silent time interval between click trains. Encounters (and indeed DPM rates) may represent either multiple individuals or the same individual repeatedly. Typical group sizes in daylight periods were between 2-6 in land-based observer studies in the area (Tollit et al. 2010). This study also clearly documented that between October 2009 and April 2010, all porpoise sightings in the vicinity of the Project site that were confidently confirmed to species were harbour porpoises. A probable Dall’s porpoise was detected only once during this period. On the west US coast, this species of porpoise is more commonly seen in shelf, slope and offshore waters (Morejohn 1979). The most recent abundance estimate for Dall's porpoise in the inland waters of Washington state is 900 animals (CV=0.40) (Calambokidis et al. 1997). In contrast, the estimated corrected abundance for the Inland Washington stock of harbour porpoise is 3,509 (CV=0.4) animals (Laake et al. 1997a, 1997b).

Effects of monthly and deployment locations were found significant, with monthly effects considered the more important, due to the fact deployments 1 and 4 exhibited most variation in DPM but were located in close proximity relative to deployments 3 and 4. Clear lows in monthly click detection (DPM) were observed in April and August with a clear peak observed in June. DPM per hour between night and day periods were found to be highly significant, with DPM median values during the night period five-fold than that of during the day period. Highs in DPM occurred around midnight, while lows occurred around midday. Diel patterns were strongest in months with high DPM per hour and clearly weakest in months of low DPM per month. In other words, when months with low DPM were observed, the night time increase in echolocation activity was far less apparent. Further POD studies will investigate monthly changes in prey distribution and continue to monitor the effect of transient killer whale presence. Half of all daytime hours had no DPM, whereas only 20% of night time hours had no DPM. It is uncertain whether these patterns are related to circadian rhythms, external cues (e.g., light cycles, predators), diel activity in their prey species, or to some combinations of these factors. Visual comparison of months with longer light periods per day do suggest light levels influence when night time increases in DPM are observed. Night time increases in porpoise echolocation click activity has been well documented in European studies (e.g., Calstrom 2005, Todd et al. 2009). These studies also assessed how inter-click interval varied temporally, using periods of short intervals (termed buzzes) as a confirmation of increased foraging activity. Preliminary analysis of T-POD data in this study also indicated decreased inter-click intervals at night, however, it is important to recognise that porpoises have the ability to also hunt visually in the photic zone. Reduction in clicking rates will confer an advantage due to reduced predator detection and we present some anecdotal evidence that clicking rates decrease (either due reduction in number of animals or due to reduced click activity) when predators are known to be in the region. Land-based studies that took place between October 2009 and April 2010, found that porpoises were present on average 63% of 116 days and 56% of every hour monitored (n=231 hours) (Tollit et al. 2010). This appears to back up data from the POD that detected no

DPM in 49% of all daylight hours recorded. Densities of 1-1.5 animals/km^2 are reported regionally, with selection of habitat with high current speeds noted and abundances higher in the summer months (Hall 2004).

Without taking a time of day effect into account, no relationship was found between current speed nor current speed and direction and DPM per hour. However, when time of day was considered as a factor, DPM per hour was higher during the day at current speeds above 0.7m/s than below this cut-off threshold. No current speed effect was noted at night. There was also a peak in DPM per hour every 15 days and a weaker peak at ~25 hours. These peaks are explained by the tidal cycles. The peak at 25 hours is due to the ~27 day cycle of the moon, resulting in a tidal period of 24 hours and 50 minutes. Spring tides occur every 14-15 days during full and new moons, when the sun and moon are gravitationally aligned. Neap tides occur during the first and last quarter of the moon. The geometric relationship of moon and Sun to locations on the Earth's surface results in creation of three different types of tides. Many parts of the world experience mixed tides where successive high-water and low-water stands differ appreciably. In these tides, we have a higher high water and lower high water as well as higher low water and lower low water. The tides around west coast of Canada and the United States are of this type. Our analysis provides evidence that echolocation use by porpoises in Admiralty Inlet is highest at night, especially during neap tides. The influence of tide on porpoise activity has been previously demonstrated in the Bay of Fundy (Johnston et al., 2005). This study reported a strong increase in density during the flood tide, which was not mirrored here. Gaskin and Watson (1985) reported increased densities of porpoises during neap tides in New Brunswick, Canada. In the Horns Reef area, eastern North Sea, small-scale changes in local currents reflecting upwelling driven by the interaction of the semi-diurnal tidal currents with the steep slopes of the bank are the main habitat driver of harbour porpoises. The distribution of harbour porpoises alternates between 2 upwelling cells less than 10 km large, depending on the direction of tidal currents (Skov and Thomsen, 2008). Similarly, at Morte Point in North Devon, UK porpoises are found to aggregate in an area of high tidal flow, where prey items are likely to be abundant (Goodwin, 2008). Neap tides in Admiralty Inlet may also provide improved foraging conditions due to increased availability of prey aggregations or water clarity and/or potentially reduce energetic demands during foraging trips (e.g., reduced cost of locomotion).

5.0 ACKNOWLEDGEMENTS

We would like to thank Nick Treganza, UW boat crews, Alice MacKay and Anna Hall.

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Appendix L-7

Admiralty Inlet Pilot Project Marine Mammal Pre-Installation Field Studies

Project Name:	Admiralty Inlet Pilot Project Marine Mammal Pre-Installation Field Studies Final Report to Snohomish Public Utility District
Reference:	SMRU Ltd code: NA2307SRK

Drafted by:	Dominic Tollit, Jason Wood, Scott Veirs	
Approved by	Sam Du Fresne	14 June 2010
Checked by	Douglas Mundie	5 July 2010
Date submitted	15 June 2010	
Date revisions	7 July 2010	

Admiralty Inlet Pilot Project Marine Mammal Pre-Installation Field Studies – Final Report to Snohomish Public Utility District.

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1.0 INTRODUCTION

Public Utility District No. 1 of Snohomish County (Snohomish) is engaged in Federal Energy Regulatory Commission (FERC) licensing of the Admiralty Inlet Pilot Tidal Energy Project in Puget Sound, Washington. The Project involves installation of two tidal in-stream energy conversion devices in Admiralty Inlet, as well as placement of a transmission cable to shore. These devices will be installed in the north-eastern portion of Admiralty Inlet, approximately 1 km west-southwest of Admiralty Head near latitude 48.1509 longitude -122.688, in water depth of approximately 60 meters. Power generated by the project will be transmitted via a single subsea cable and connected to the grid at the Puget Sound Energy infrastructure near the Fort Casey Conference Center.

It is Snohomish's intent to 1) characterize the existing environment, including marine mammal use, within the Project vicinity; 2) evaluate the potential for the Project to substantively impact existing resources; and 3) engage in detailed post-installation monitoring of the Project to observe and assess any such impacts. This study is part of a larger marine mammal program which aims to address the first of these goals, and is intended to support the environmental analyses required for the second. Preliminary analyses were presented in Snohomish's Draft Pilot License Application (DPLA) and this final report has been prepared to be presented in the subsequent Final Pilot License Application (FPLA).

The purpose of the scope of work described here was to collect new information to characterize the existing marine mammal use within the Project vicinity, with a focus on killer whales. The scope of work was formulated in an adaptive series of monitoring plans after discussions with Snohomish, HDR, SMRU Ltd, NNMREC, study partners and regulatory advisors. The Whale Museum was selected as the consultant to oversee the field-related project components, together with other key partners in this work (SMRU Ltd, Orca Network, Beam Reach Marine Science and Sustainability School [Beam Reach], and Port Townsend Marine Science Center, [PTMSC]). SMRU Ltd were selected to report the results of this multi-faceted collaborative project. This report aims to synthesize information from land and boat based observations, as well as passive acoustic monitoring.

2.0 STUDY OBJECTIVES

The goal of this study was to provide data on marine mammals to inform Snohomish's Final Pilot License Applications, as well as FERC and stakeholder environmental analysis of the potential effects of the Project. In line with regulatory agency recommendations, Southern Resident Killer Whales (SRKW, *Orcinus orca*) represent the main focus of the study, but information on other marine mammals was also gathered. The study area centers on the waters of northern Admiralty Inlet and was monitored both by boat and from land via a vantage point on Admiralty Head, approximately 1 km from the proposed pilot Project deployment site (see Figure 1). The field studies area encompassed a 5 nautical mile radius from the proposed pilot Project deployment site (Figure 2).

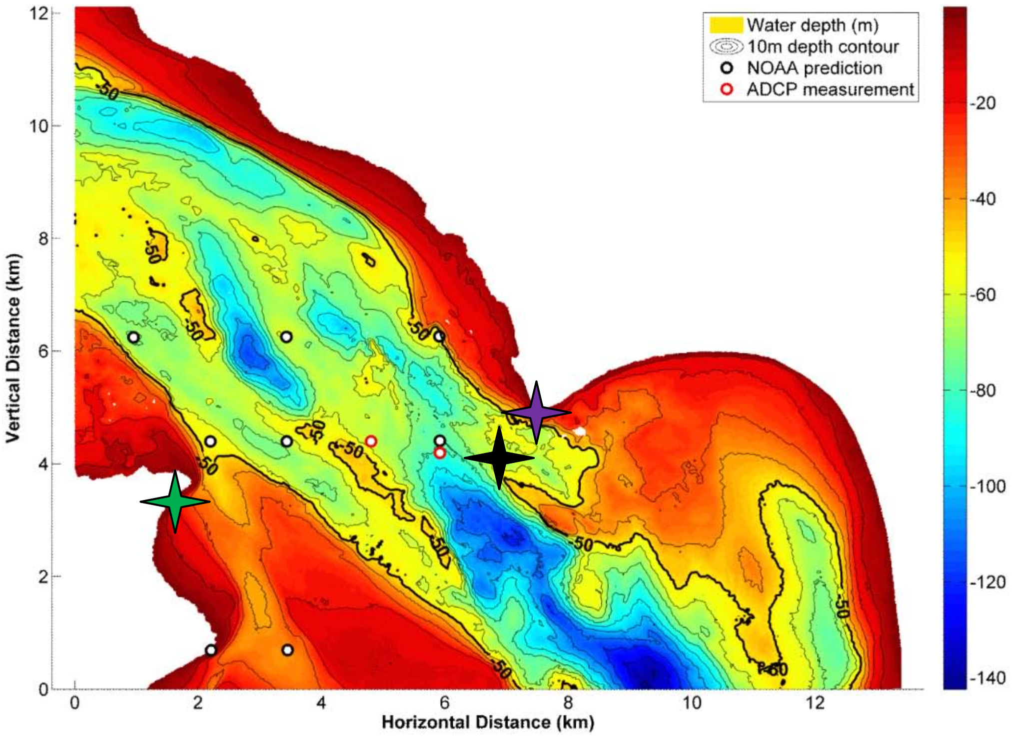


Figure 1. Bathymetric map of Admiralty Inlet showing the proposed Project site (black star) and location of the land observation site on Admiralty Head (purple star) and the site of the cabled hydrophone at Port Townsend (green star).

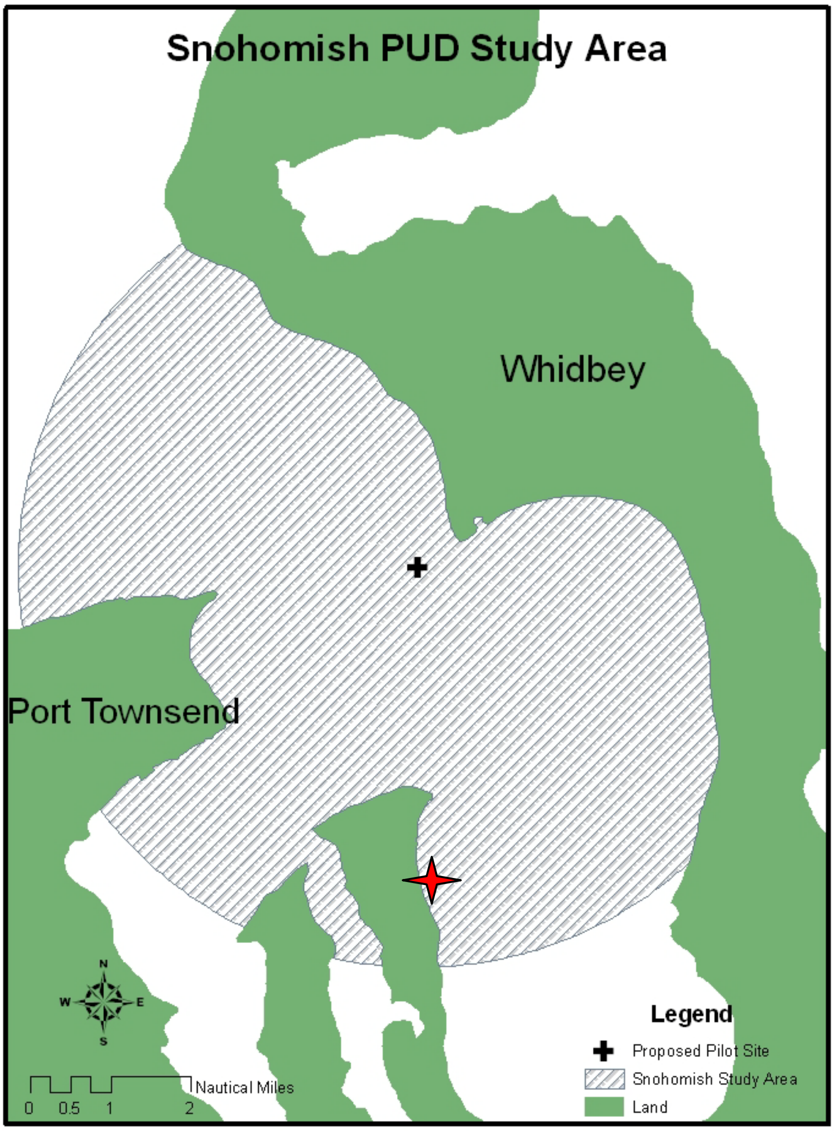


Figure 2. Map of Admiralty Inlet denoting the 5 nautical mile radius field study area and the location of the nearest pinniped haul-out located on the eastern shores of Marrowstone Island (red star).

This report details new data gathered by multi-faceted field studies between October 2, 2009 and April 30, 2010. It includes information on fine-scale habitat use by SRKW in the vicinity of the proposed Project site and additional information on key marine species in the vicinity of the proposed Project site and at the nearest local haul-out (Figure 2). This work is intended to complement and combine with results from passive acoustic monitoring (PAM) efforts from two hydrophones already mounted on the seafloor in the project area by Snohomish in partnership with the Northwest National Marine Renewable Energy Center – UW (see Bassett 2010, Tollit et al. 2010), as well as a cabled hydrophone located near Port Townsend that was deployed by Beam Reach and the Whale Museum beneath the PTMSC (Figure 1). Additionally a review of historical SRKW data sets was completed (Wood et al. 2009), which aimed to focus on information relevant to the project (i.e., transits through Admiralty Inlet). This study found that most sightings (70%) in Puget Sound occurred between October and January, but also typically occurred every month of the year. It also found that on average 42 transits past Admiralty Head have occurred annually since 2001. While field studies were therefore undertaken during the typical “peak” period of historical SRKW sightings, it is important to keep in mind that the field season covered half of one year and therefore does not claim to capture the full potential variability across seasons and years. This study does clearly show the efficacy of using sightings networks and acoustic detections in detecting most SRKW transits and a methodology for successfully monitoring SRKWs in a specified area.

2.1 Specific study objectives

2.1.1 Southern Resident killer whales

a) Describe current SRKW transit patterns through the study area. Collect new information on number of transits through the area using scheduled land observations, land and boat-based volunteers and a review of Port Townsend hydrophone PAM data. This aims to provide up-to-date information on migratory movements and complement the historical review.

b) Describe current study area habitat use by individual pods during key seasons, and whether foraging occurs in the vicinity of the Project, through the use of a fast response boat and land observations.

c) Describe vertical depth distribution of observed SRKW. Collect opportunistic dive depth information in the vicinity of the proposed installation site using a vertical hydrophone array. These data will be used to support Project risk analyses and potential-encounter estimates, but are not expected to determine if water depth influences SRKW transit routes

2.1.2 Other marine mammals and marine birds

a) Estimate presence of other species of marine mammals in the study area. Collect incidental information on marine mammal presence during boat and land observation studies, to provide supplementary data to existing data, including presence/absence, relative use levels and group sizes across species in the vicinity of the Project site.

b) Observe current usage of the nearest pinniped haul-out (Marrowstone Island: 48.078167; -122.685167) by Steller sea lions (*Eumetopias jubatus*) and harbor seals (*Phoca vitulina*). Haul-out counts are not meant to represent a systematic assessment of marine mammal populations, but rather are planned in order to take advantage of the fact that there will be a vessel in the vicinity; they are intended to supplement historical data (e.g., WDFW surveys, NMFS stock assessments) and results of other field studies (e.g., land-based observations).

c) Observe current presence of marbled murrelet (*Brachyramphus marmoratus*) in the study area. Collect incidental information on marbled murrelet presence in the vicinity of the Project site during boat-based observation studies to provide supplementary data regarding potential presence in the vicinity of the Project site. These are observations of opportunity and are not intended to represent a systematic assessment of marbled murrelet presence in the study area.

3.0 METHODS

A training day for 12 core field team members was undertaken on September 26, 2009, to confirm field study protocols and with the aim to ensure maximum consistency in field data collection through the study. A second day of safety and equipment training was also undertaken at the start of the project especially to increase team reliability in the safe and timely deployment of the vertical array. A vertical array validation study also took place on April 20 and May 5, 2010.

3.1 Enhancement of voluntary sighting networks

The enhancement of the existing volunteer sighting networks for marine mammals in Puget Sound was undertaken by notifying the 3600+ members of the Orca Network's volunteer Whale Sighting Network, ferry skippers, recreational boaters, whale watching groups, NOAA scientists, the US Navy, tug companies, and key whale researchers through email and other outreach. "Got Whales" magnets, fold-out cards, signs and decals were distributed to waterfront and marine-related businesses and volunteers, along with a news release to regional media including the Navy's "Northwest Navigator" and "Reel News" publication. Enhanced communication transfer was undertaken (using Twitter networks, automated calls, "First Alert" email list, and Blackberry phone to provide email access while out in the field). These multiple methods aimed to provide timely notice of SRKW moving in and out of Puget Sound, specifically to enable the boat and land based teams to respond in time to observe SRKW within the study area.

3.2 Scheduled land-based observation of Admiralty Inlet

Scheduled land-based observations by two trained/experienced marine mammal observers were undertaken for seven months from the lower gun emplacements on the bluffs at Fort Casey, near Admiralty Head (latitude 48.15486; longitude -122.6781). Observations were carried out to enhance chances of sighting SRKW but also to assess relative site use. The planned protocol called for ten minute period scan samples every 15 minutes undertaken for 2 hrs per day (providing 8 scan samples, Mann 1999), 5 days per week from October 2, 2009 to December 15, 2009 (10 weeks), reducing to 3 days a week thereafter. The observation period aimed to focus on those days suitable for marine mammal sighting (i.e., Beaufort Sea State 3 or less), but also where possible aimed to collect more observations when the tide was running (i.e., periods when the proposed turbine may be turning). Marine mammal sightings were recorded during scheduled observations using 7-x-50 binoculars (with internal compass and reticles to record the horizontal and vertical angle to sightings), 10-x-50 binoculars, and a spotting telescope (see Denardo et al. 2001). Observers noted species identity, location, time, and where possible direction of movement and behavior. A tripod-mounted video camera was also used to record pod (group) activity state if SRKW transits occurred on the Keystone side. Since high importance was given to listed species/whales, records of these species were collected even if sighted outside the scan periods. Binocular reticle values were recorded where possible to within 0.25 units and compass bearing recorded to within 1 degree for location estimation (Lerczak and Hobbs 1998).

Theodolite tracking has been used successfully to track and study the behavior of killer whales (Williams et al. 2002). Theodolite tracking of killer whales is a specialized skill that requires considerable set up time and good observer height. Theodolite tracking was not considered ideal for collecting data on SRKW group activity as it provides a very narrow field of view, ideally requires greater observation heights than available to us in Admiralty Inlet and importantly can only track a single animal at any one time. Yin et al. (2005) found close agreement between distances and bearing to whales obtained from binocular and theodolite fixes when measured reticles were >1. As a consequence, this study relied upon boat-based follows to collect detailed transit route (tracks) and focal group behavior information. Complimentary use of binoculars and video footage aimed to help describe the activity state (and general location) of the wider group during a Keystone side (Project site) transit. Environmental conditions (sea state, glare, sighting conditions, etc) were also recorded during land observation periods (following Laake et al. 1998).

Reticle values were converted to horizontal distance using software and protocols described by Dr Jeff Laake (National Marine Mammal Laboratory, NOAA, see http://www.afsc.noaa.gov/nmml/software/excelgeo.php). Observer height was calculated as 12.8 m and where reticle values were taken using bearings recorded as a land-sea horizon rather than a sky-sea horizon, the horizontal distance estimate was duly recalculated by using a distance to shore conversion (=retdist7X50(height, ret + if(distance to shore(km))<retdist7X50(height,0.0), distret(height,rad/ret,distance to shore), 0.0)).

It should be highlighted that there are inherent errors associated with the measuring and recording of angles to wildlife locations from land and although this approach is reported to provide a relatively good estimation of locations on the water, a short assessment of reticle location accuracy was performed on April 23’ 2010. A boat was positioned at the project site and at the three known points of the project study area triangle. Land observers took reticle and bearing readings after being informed by radio that the boat was in the selected position. Distances between each boat location and the observation site were calculated in ArcGIS v9.3.1 and compared with estimated distances as described above (Table 1). Results indicate at ranges of less than 1km, distance accuracy estimates are within 1-4%. Accuracy will quickly decline beyond this distance as noted by previous studies (Yin et al. 2005) and as highlighted by the scale of difference between, for example, reticle values of 1 (distance estimate of 1875m) versus 0.5 (distance estimate 3009m). Locations more distant from the observation site should consequently be considered of coarser resolution.

Table 1. Accuracy assessment of distance estimates based on reticle values

Location	**Latitude**	**Longitude**	**Distance (m, ArcGIS)**	**Reticle value**	**Bearing**	**Distance estimate (m)**	**Difference in m (%)**
1	48.1536	122.687	677	3.25	257	682	-5 (1%)
2	48.1514	122.687	766	3	239	738	28 (4%)
3	48.1536	122.691	969	2.5	261	976	-4 (1%)
Site	48.1509	122.688	858	2.25	239	862	7 (3%)

The estimation of geographical location (latitude and longitude) was carried out using standard trigonometry (see equations 1-4).

Equation 1

$$\text{Distance on X axis (X)} = (\mathit{Cos}(\text{RADIANS}(A\text{-}90))*B)*\text{-}1$$

Equation 2

Distance on Y axis (Y) = (Sin(RADIANS(A-270))*B

where A = compass bearing in degrees (including 17 degree correction for angle of inclination) from observer location

B = Distance estimate based on reticle calculation in meters

Equation 4

Latitude = ((((Y / x) + K_{x1})/60))+ K_x

where x = number of meters in a minute of latitude (1852m)

K_x = degrees of latitude at the observer location

K_{x1}= minutes of latitude at the observer location

Equation 4

Longitude = ((((X / y) + K_{y1})/60)*-1)- K_y

where y = number of meters in a minute of longitude at the observer's location (1237m)

K_y = degrees of longitude at the observer location

K_{y1}= minutes of longitude at the observer location

Ideally analysis of land-based surveys should be undertaken only when suitable sighting conditions exist. This report synthesized all data collected (number of sightings, proportion of days and hourly blocks sighted, relative number of species sightings, sighting location), but also assessed relative importance and area use using only data recorded when Beaufort Sea State was three or less. This data corresponds to >90% of the total sightings and is considered most representative. Land-based scan sampling methods will count the same animal(s) repeatedly (known as pseudo-replication), and lead to spatially auto-correlated data. Various sophisticated statistical procedures exist to minimize the impact of pseudo-replication (e.g., General Additive Models). In this study, the number and length of scan sampling periods varied across some observer pairs and in the first period of the study, plus scan periods without detections were not consistently timed. As a consequence, the most parsimonious method of assessing species relative importance (while minimizing the potential for pseudo-replication) was to simply pool multiple scan periods over each daily two hour survey into two 1hr blocks. Species presence and maximum species group size for each one hour block were calculated for statistical analysis.

Typically, species identification becomes harder as range increases or when the sighting is brief, resulting in this study in classifications of unknown pinniped, unknown sea lion, unknown porpoise, unknown porpoise (probable harbor porpoise, *Phocoena phocoena*), and unknown porpoise (probable Dall's porpoise, *Phocoenoides dalli*). For an overall site characterization assessment, species were grouped into both species groupings and logical functional groups based largely on family-level classification. In our detailed analysis, for practicality, we have combined sightings of harbor porpoise and the category "unknown porpoise (probable harbor porpoise)". On the three occasions that SRKW transits occurred during observational periods, whales were too distant to collect useful video footage (as hoped) and boat contact had already been confirmed. On all three occasions, observers continued to collect marine mammal scan sightings data, as well as additional location data on the SRKWs. Location data from one of 13 land-based SRKW 'fast' response was also available and has been included in location plots and data duly summarized (see also Appendix A).

In addition to providing information on relative abundance, the dataset was considered suitable to assess seasonal changes in relative abundance of the three most numerous species sighted (harbor seals, harbor porpoise and Steller sea lions). In this analysis, non-parametric tests were performed on sightings data for hourly blocks across three equal survey periods (~10 weeks). Finally, for the same key species, we undertook an exploratory spatial distribution assessment. The study area was defined and split into 8 segments based on four equal bearing segments (<170, 170-219.9, 220-269.9, >270) and distance from site (inshore [greater than reticule 7, approximately <350m from observation site), offshore [less than reticule 7, but above reticule 1.25, approximately >350m and <1350m from the observation site). Choice of the offshore segment size corresponded to an approximate area ~500m radius from the approximated proposed deployment site (reticle 2.25, ~860m, bearing 239 degrees), the approximated size of acoustic footprint (based on Log18.4 propagation loss [Bassett 2010] and no account of bottom type effects). The lower sighting location resolution, coupled with the likely lowered ability to confidently detect and easily identify key species beyond 1350m was also considered in the justification of truncating location data above reticule 1.25. The offshore segment is also in deeper water and in theory provides a good ecological comparison with the shallower nearshore area, where slope is high and fast surface currents can be observed regularly in an area that also appears favorable for seals and porpoises (D. Tollit, pers. obs). Contingency test, univariate ChiSquare tests, Kruskal Wallis and 2-sample test for equality of proportions with continuity correction were performed on 1-hour blocks and sightings data.

3.3 Boat-based surveys of SRKW

Boat-based surveys aimed to collect fine-scale study area habitat use and water depth use by SRKWs. Boat-based surveys were launched whenever the sightings network predicted a timely transit through the study area and weather, boats and crews permitted. It was estimated that a minimum of seven suitable opportunities for boat-based follows would occur in daylight hours during the full seven month study timeline. The survey boat and crew departed from either (a) Port Townsend (b) Keystone - Whidbey Island or (c) Friday Harbor, depending on where the whales were first observed and who was best equipped to launch with short notice. All boats followed 'be whale wise watching' guidelines. A safety protocol was developed and followed in order to ensure the safety of crew members during boat-based surveys.

The crew performing the boat-based SRKW surveys collected data on a focal group of animals. The data collection protocol aimed to prioritize collecting data on the group that was closest to the proposed pilot site. During these focal follows instantaneous scan samples were made every 5 minutes, or whenever the focal group changed behavioral state (Altman 1974). During scan samples a GPS waypoint was taken and the bearing and distance to the pod, pod identification, and behavioral state data were recorded. The following behavioral states were used; foraging, travelling, resting, milling and socializing (based on the Southern Resident Killer Whale Behavior Workshop report 2004, Ford 1989 and additional input from regional experts). GPS waypoints, distance and bearing measures were used to calculate SRKW transit routes in ArcGIS 9.3.1. Behavioral data was used to calculate behavioral budgets during transits of the study area. An example of the behavioral state protocols is provided in Appendix B, noting it is limited to surface observations only and often subjective.

When SRKW were near their closest point to the Project site, the crew deployed a vertical hydrophone array (similar to that used by Holt et al. 2009) to collect data on water depth usage. The hydrophone array (Lab-Core Systems, Olympia, WA) consisted of four hydrophones spaced 10 m apart and were deployed such that the shallowest hydrophone was 10 meters deep (Figure 3, Plate 1). The hydrophone array was connected to two Sound Devices 702 solid state recorders that were daisy chained together to ensure sub-sample synchronization. Recordings were made at 44,100 samples per second and 16 bit depth. Recordings were checked visually with spectrographic displays and aurally by listening to identify echolocation clicks and calls. These were used to calculate metrics such as the number of minutes with localizable calls, as well as depth of the individual that was calling. Although localizations of calls and clicks for the interim report utilized Ishmael sound analysis software, it was decided to switch to OVAL Locater software for the final report. Both programs utilize hyperbolic localization based on estimates of the time of arrival difference of the signal at each hydrophone. The OVAL Locater however has the advantage of calculating error estimates for each localization as well as allowing for the use of cross-correlations and 'hand picking' of arrival times for localizations. OVAL Locater also has the ability to utilize the time of arrivals of surface reflections to increase the accuracy of localizations. We therefore re-localized the earlier data to maintain consistency in the analysis of the data set. OVAL Locater is custom sound analysis software written by Val Veirs.

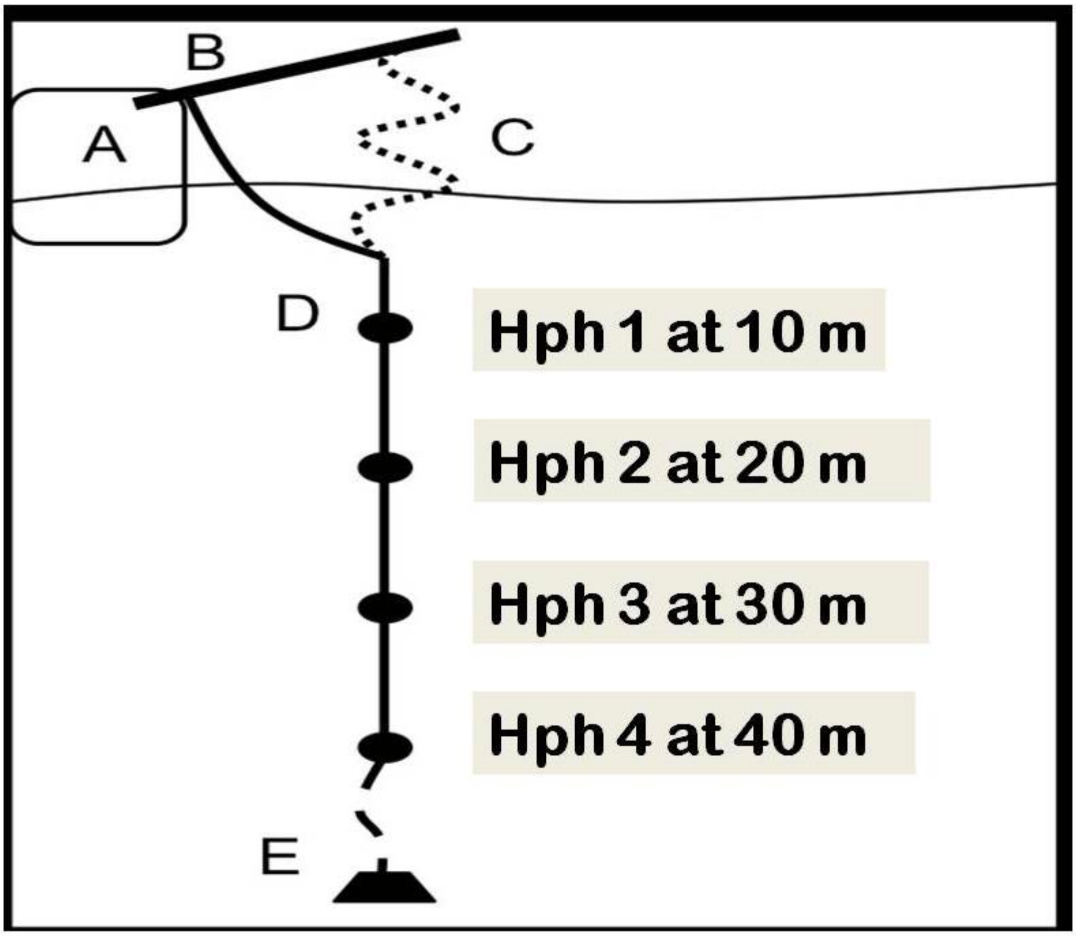


Figure 3. Vertical deployment of the hydrophone array (not to scale). A=boat, B=outrigger, C=2 m bungee cord, D=hydrophone array and E=30 lb weight.

In order to verify the accuracy of acoustic data collection and analysis methods we conducted calibration tests in Admiralty Inlet and Haro Strait. This involved two vessels: the main vessel from which the vertical array was deployed in its customary fashion; and a second vessel from which a weighted rope was deployed. At increments of 10 meters, 60W light bulbs were fastened to the rope from depths of 10 to 60 meters. An iron pipe was then slid down the rope to implode the light bulbs giving a sound source at known depths and distances from our vertical array. Distance from the main vessel and the sound source was measured with a laser range finder. Tests were conducted with distances from 100 to 500 meters. Before and during all calibration tests observers were posted to look for the presence of marine mammals. This data was localized and results compared with the known depths and distances of the light bulbs.

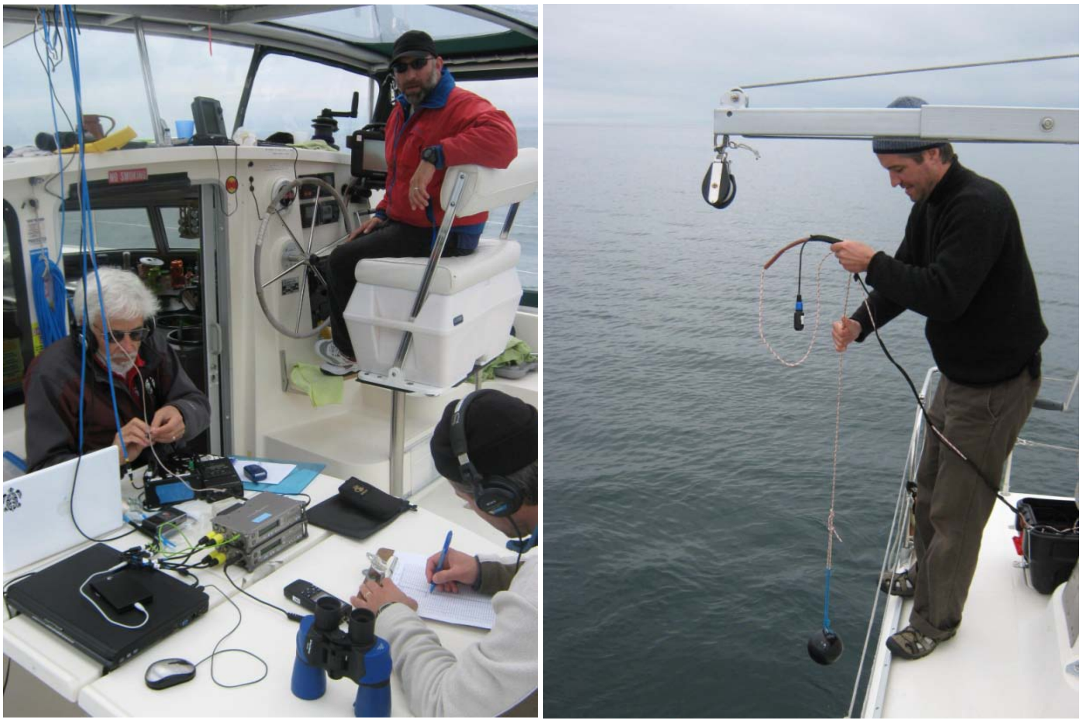


Plate 1. Vertical hydrophone array equipment in non-turbulent water..

3.4 Boat-based observations of other marine mammals and marine birds of concern

During each boat-based SRKW survey that occurred (weather and daylight permitting), observers also aimed to 1) conduct a haul-out count of harbor seals and Steller sea lions at Marrowstone Island and 2) perform a single-track sighting survey along a 2nm transect to count marbled murrelets and to collect incidental marine mammal sightings. It was planned to have surveys go through the Project site, but instead in a study plan variance, surveys were started in a randomized location within the main 5 nm study area.

Counts at haul-outs were made with 7-x-50 binoculars from a stationary boat, after a slow approach to no closer than 200 m to the haul-out. For boat sighting surveys, seven random routes were generated through the study area (using ArcGIS 9.3.1). Boat speed was maintained at 8 knots, with two trained and experienced marine mammal observers located on the bow scanning bow to port 90 degrees and bow to starboard 90 degrees to a range of 300 m using visual scans and reticle/compass embedded 7-x-50 binoculars. A GPS was used to determine start and end locations and used to ‘mark’ the boat location of each sighting. At minimum, species, group number, bearing and distance were recorded. The survey went ‘off effort’ if SRKW were spotted and a focal follow began. Little information exists on presence of marine mammals or marbled murrelet within the vicinity of Project site.

While these surveys are considered opportunistic and will not be used to quantify haul-out attendance, habitat use or population size, they do at minimum provide presence/absence information.

3.5 Port Townsend hydrophone PAM studies

The Port Townsend Marine Science Center hosts one of the five hydrophone nodes that make up the current Salish Sea Hydrophone Network which is a collaborative effort between Beam Reach, Colorado College, The Whale Museum and the various node site partners. All of these sites have cabled hydrophones that are connected to computers which stream the audio in real time to the web (www.orcasound.net). The PTMSC hydrophone is a Lab-Core-40 hydrophone with a non flat frequency response from 1-20 kHz and a peak sensitivity of 5 kHz, suitable for detecting and listening to calls of SRKW. It is positioned at a depth of about 5 meters underneath the PTMSC pier, approximately 6 km from the Project site. The hydrophone computer runs custom software that records average ambient noise levels 24/7 as well as anomalous sounds – particularly SRKW calls - using two different automated-detection algorithms. One detector triggers on sudden changes in amplitude while the other triggers on tonal sounds with durations consistent with SRKW calls. Within 5 minutes of a detection, a sound file and an associated spectrogram is stored on the hydrophone computer, uploaded to the orcasound.net server, and reported via email to an analyst for verification. The computer can also be accessed remotely for specific needs and trouble shooting.

Because we stream the audio online, the general public can also listen and detect SRKW throughout the Salish Sea in real time. Listeners are provided with a web-based spreadsheet to log any detection they make, as well as an email listserver for sharing detections and listening opportunities. There are a core group of interested listeners, mostly in the US and Europe who listen opportunistically, but often cover many hours for each node because they are situated in different time zones. These manual detections were also used in this study.

Once verified, the detections were used to help inform our land and boat responses, and were often communicated to team members and regional SRKW scientists and stewards through two private Twitter group feeds. The detection numbers and regional SRKW sightings are compared in this report to the series of transits observed during the study period. Previous experience hearing calls when SRKWs were observed passing Admiralty Head, as well as a short propagation test conducted by APL collaborators in November, 2009, confirm that this hydrophone system detects SRKW call profiles made over the Project installation site whenever the background noise level is below about 120 dB re 1 microPa. Further details regarding the automated and human detection system, as well as the Port Townsend hydrophone system, are available in the 2008-2009 Salish Sea Hydrophone Network progress report.

4.0 RESULTS

This final report aims to provide a summary of the field data collected between October 2, 2009 and April 30, 2010. During this seven month study period, we completed 116 2-hour surveys from an observation site above the Project site and 13 fast land responses which included making observations outside the study area, to provide assistance with pod identification, and supplemented transit information (see Appendix A).

An estimated 22 transits of Admiralty Inlet were made by SRKW during the study period and an overview is provided in Appendix C. We defined a transit of Admiralty Inlet as any crossing (entrance or exit) of the line connecting Admiralty Head and Point Wilson. Six transits were made in October and November and eight in December and two in early January. Transits with exits and re-entries on the same day occurred twice.

Overall, automated algorithms detected 14 (64%) of the transits acoustically, while human listeners detected 10 (45%). Network sightings information also provided incoming detections but of the 22 transits, 8 occurred too late in the evening for a response (after 19:00). Our SRKW response rate for the 14 daytime transits was 71% on land (10 fast responses) and 71% by boat. Visibility, noise levels, and killer whale position reduced the number of those 10 boat responses that resulted in successful data collection for SRKW within the study site: acoustic data was collected on 8 days (totaling 64% of daytime transits); behavioral data was collected on 7 days (totaling 57% of daytime transits). One of the boat-based responses collected data on transient killer whales (see bottom of table in Appendix C).

A total of eight pinniped haul-out counts and six boat-based study area sighting surveys were made during this study.

4.1 SRKW enhanced network sightings information

The enhanced network and communication transfer systems set up by the project were found to be successful in receiving timely reports, assessing suitable weather conditions, ensuring land and boat communication and in tracking the progress of whales into and through Admiralty Inlet and in further information gathered on pod ID and location generally.

4.2 Scheduled land-based observation of Admiralty Inlet from Fort Casey

Land observations from Fort Casey were carried out on a total of 116 days, 3-5 times a week (Figure 4). Two-hour surveys were carried out between 08:30 and 18:55. Most surveys (90%) were started between 10:00-15:00 hrs, with the remainder split evenly before and after this period. Seasonal comparisons were undertaken splitting the data into three equal periods (Figure 4). One survey was cut short to undertake a fast response for SRKW.

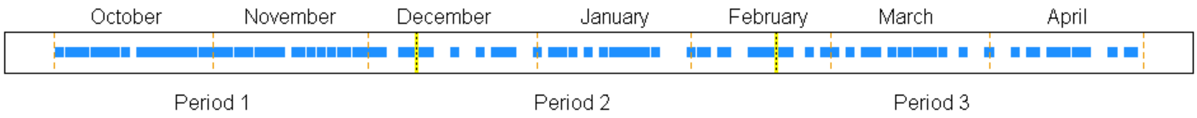


Figure 4. Land observation coverage across the study. Note coverage was decreased in mid-December. For seasonal analysis, data was split into 3 periods October 2, 2009: December 10, 2009, December 11, 2009: February 18, 2010, February 19, 2010: April 29, 2010 (dashes).

Overall, 2145 sighting locations were recorded of seven species, with marine mammals sighted on every day. 91% (1946) of sightings occurred on surveys with sea state Beaufort 3 or less. Harbor seals were observed most often, occurring on 95% of days and 49% of all sighting (Table 2, Figures 5 and 6). Harbor porpoise and Steller sea lions were the next most frequently sighted species, with harbor porpoises observed on 63% of days and representing 20% of sightings, compared with Steller sea lions with 66% and 17% respectively. California sea lions (*Zalophus californianus)* were observed on 14% of days, while Killer whales (Orca – both ecotypes) and minke whales (*Balaenoptera acutorostrata)* were seen on less than 5% of days. Dall's porpoise were probably sighted on only one day.

Locations of sightings were plotted in ArcGIS (v9.3.1) for visual interpretation. Harbor seal sightings were mainly within ~1km of the observation point (Figures 7 and 8), as were the majority of Steller sea lions and California sea lions (Figures 9 and 10). More distant sightings often could not be classified to species. In contrast, porpoise sightings were sighted further offshore, beyond 1km (Figures 11 and 12). Locations of SRKW in the project area were collected by land based observers on 3 observer days and 1 fast response day on December 6 2009 (Table 3, Figure 13). Locations depict multiple sightings of the same group, but do highlight usage across much of the inlet. Boat focal follows of SRKW were carried out on all four sighting days (section 4.3). However, based on reticle readings it was apparent that the majority of the SRKW locations on three (of four) occasions exceeded a range of 2km from the observation site. Locations closer to the observation site were noted only on October 21 2009, with one sighting at 733m. Transient killer whales (group size 1-5) were sighted 733-3591 m from the observation site, with foraging behavior described on one day (12/12/2009) at distances estimated at 2.7km. Clearly, sighting likelihood varies across species, largely dependent on animal size, group size and behavior. Maps of sighting locations show clear banding patterns. This is due to the discontinuous measurement of distance when using reticle values. All three ‘scheduled’ land observation surveys that observed SRKW had previous knowledge of local killer whale sightings and fast response surveys were ongoing and so while a survey may have been scheduled for the day, the exact timing of the observation can not be considered independent and as such we consider SRKW sighting rates inflated. Sightings of killer whales were also collected out with of 10 minute scan periods, also leading to slightly inflated sighting numbers.

Table 2. Overall summary of marine mammal sightings data and number of days sighted.

Species	**# of sightings**	**# of days sighted**
Harbor seal	1041	110
Minke whale	4	2
Orca - Resident	33	3
Orca - Transient	22	4
Pinniped - unknown	19	11
Porpoise - Harbor	429	73
Porpoise - hybrid	1	1
Porpoise - unknown	181	32
Sea lion - California	19	15
Sea lion - Steller	362	77
Sea lion - unknown	34	19
Total	*2145*	*116*

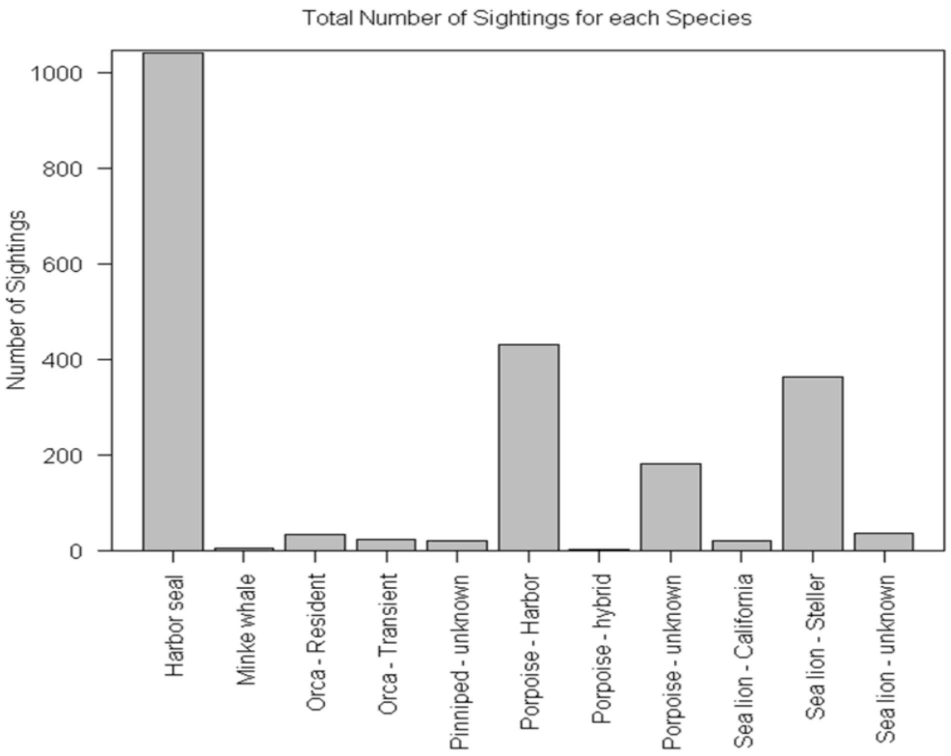


Figure 5. Overall number of sightings for each species

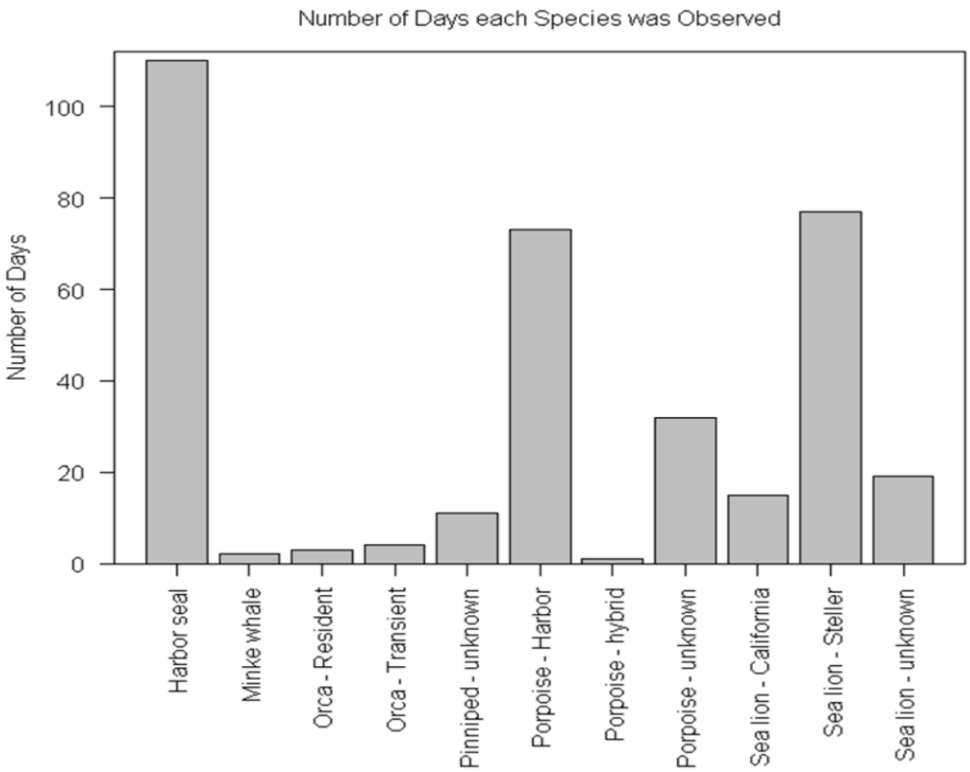


Figure 6. Overall number of days each species was sighted (n=116 survey days).

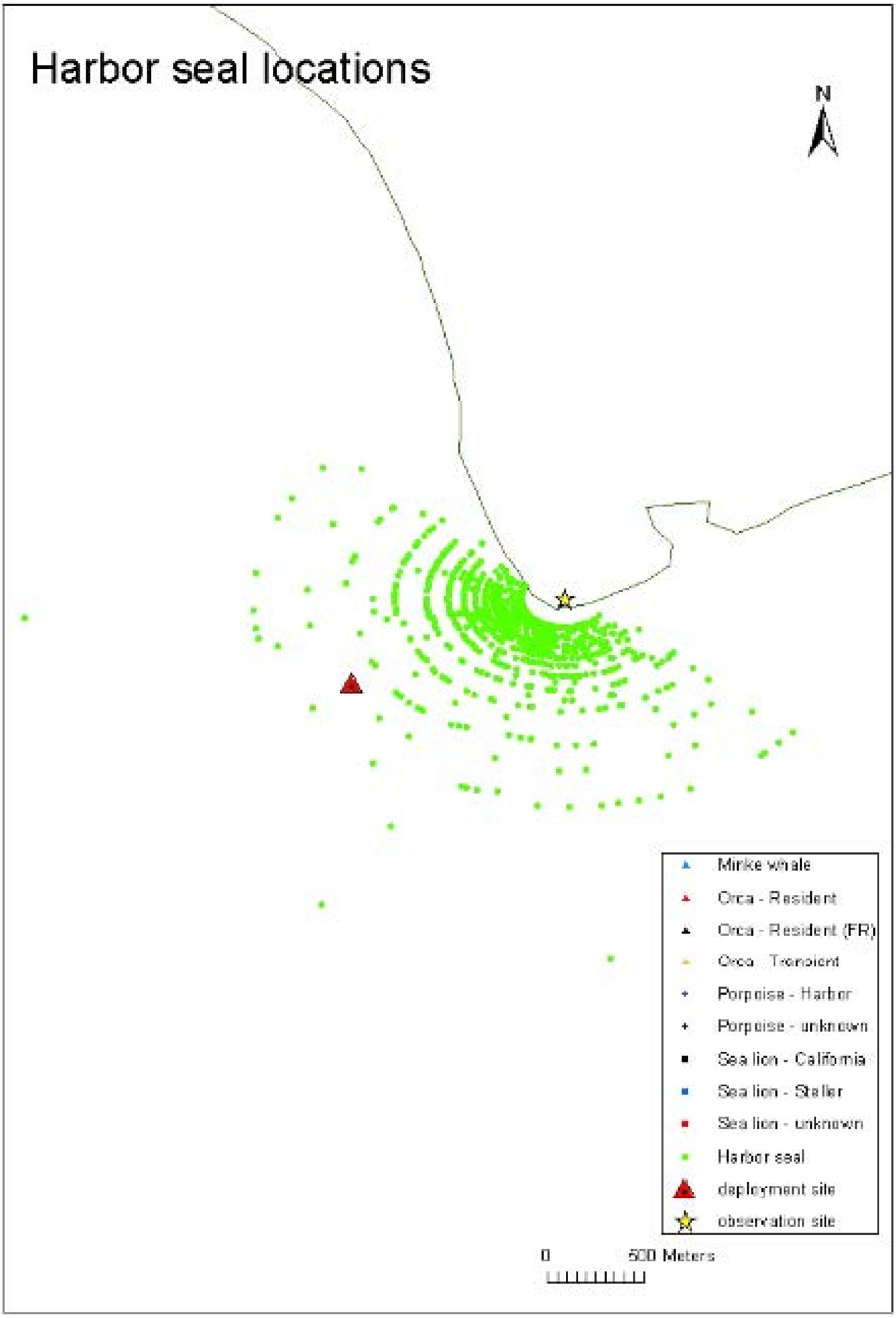


Figure 7. Harbor seal sighting locations

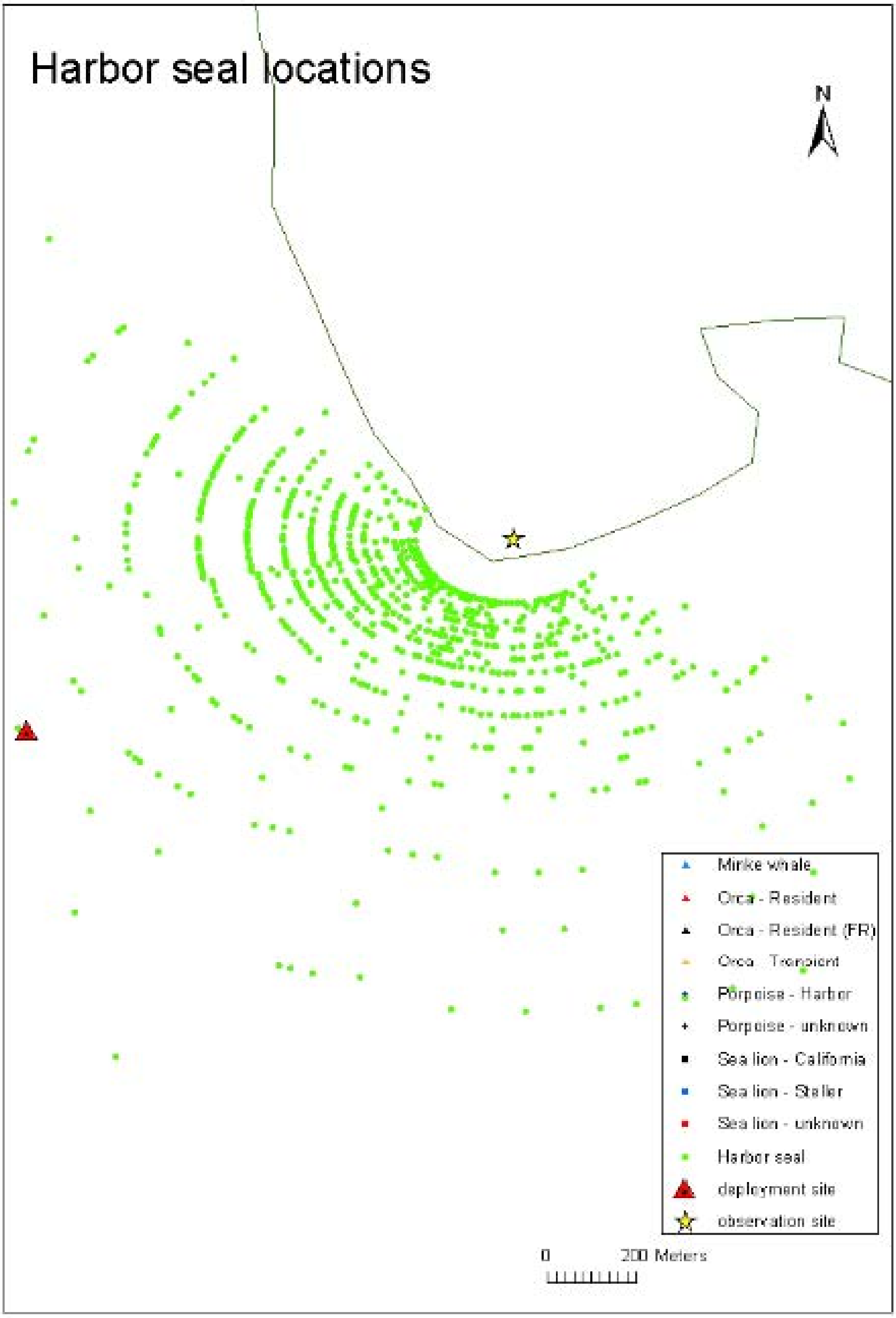


Figure 8. Harbor seal sighting locations (near site view).

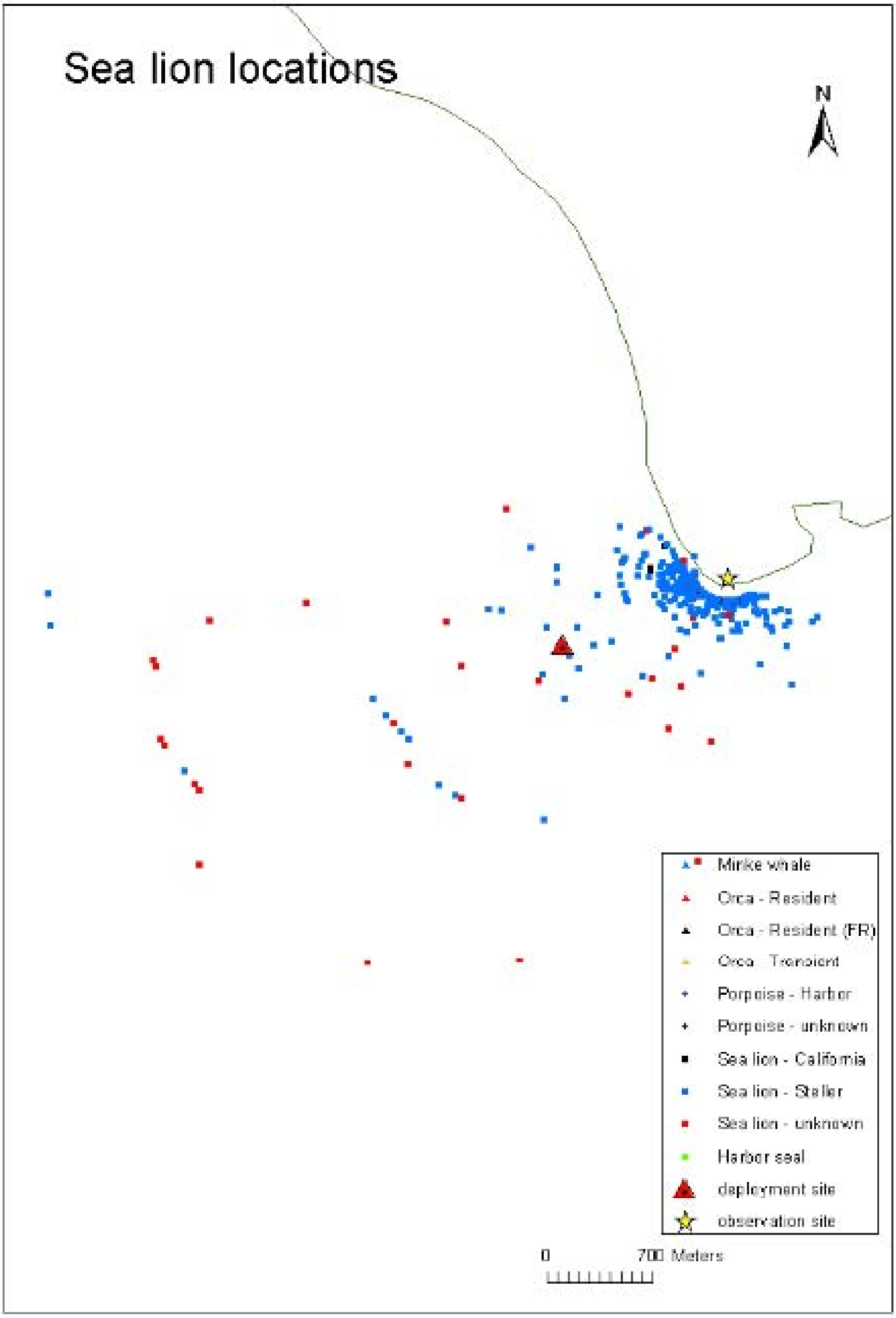


Figure 9. Sea lion sighting locations, depicting Steller sea lions, California sea lions and sea lions – unknown species.

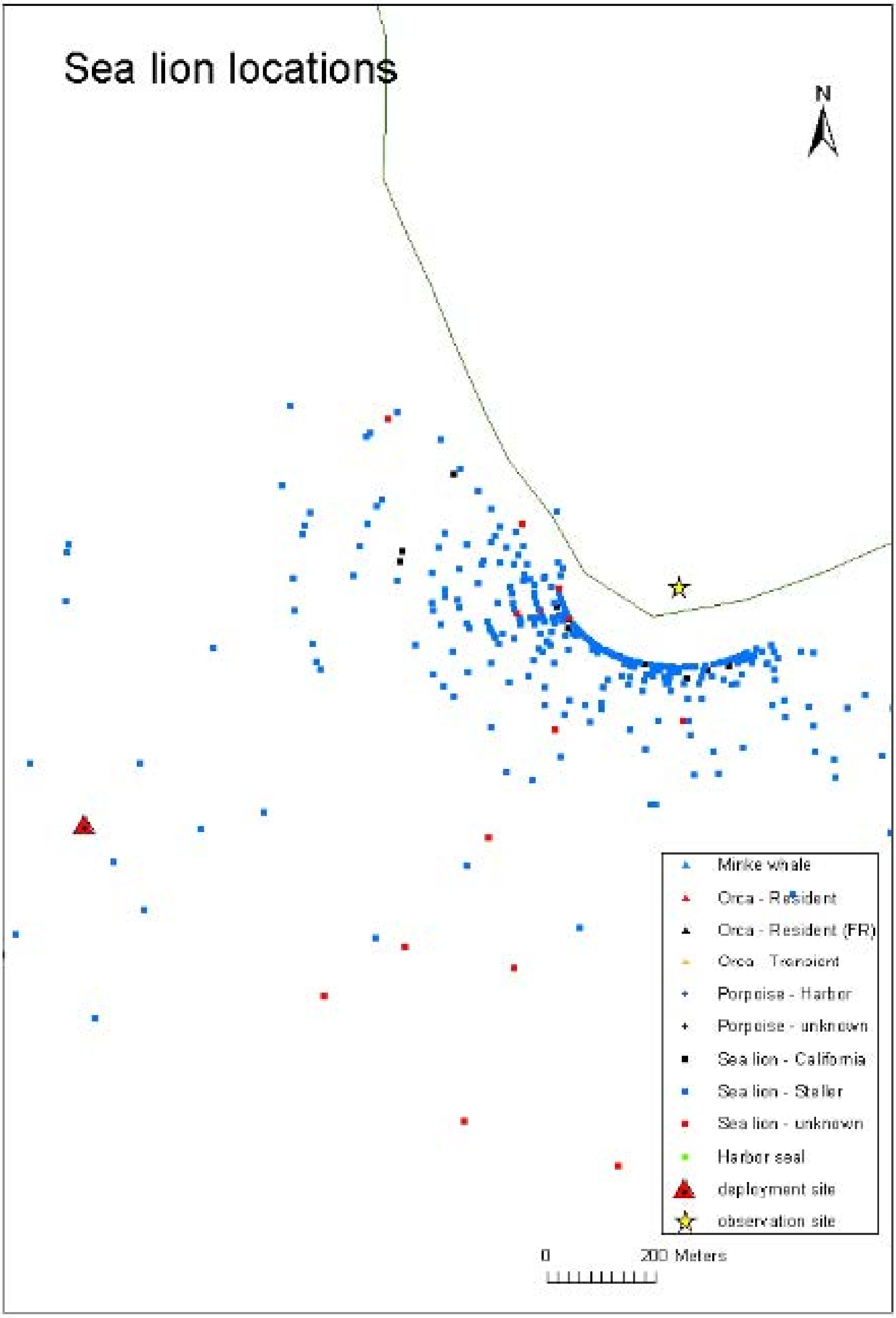


Figure 10. Sea lion sighting locations (near site view)

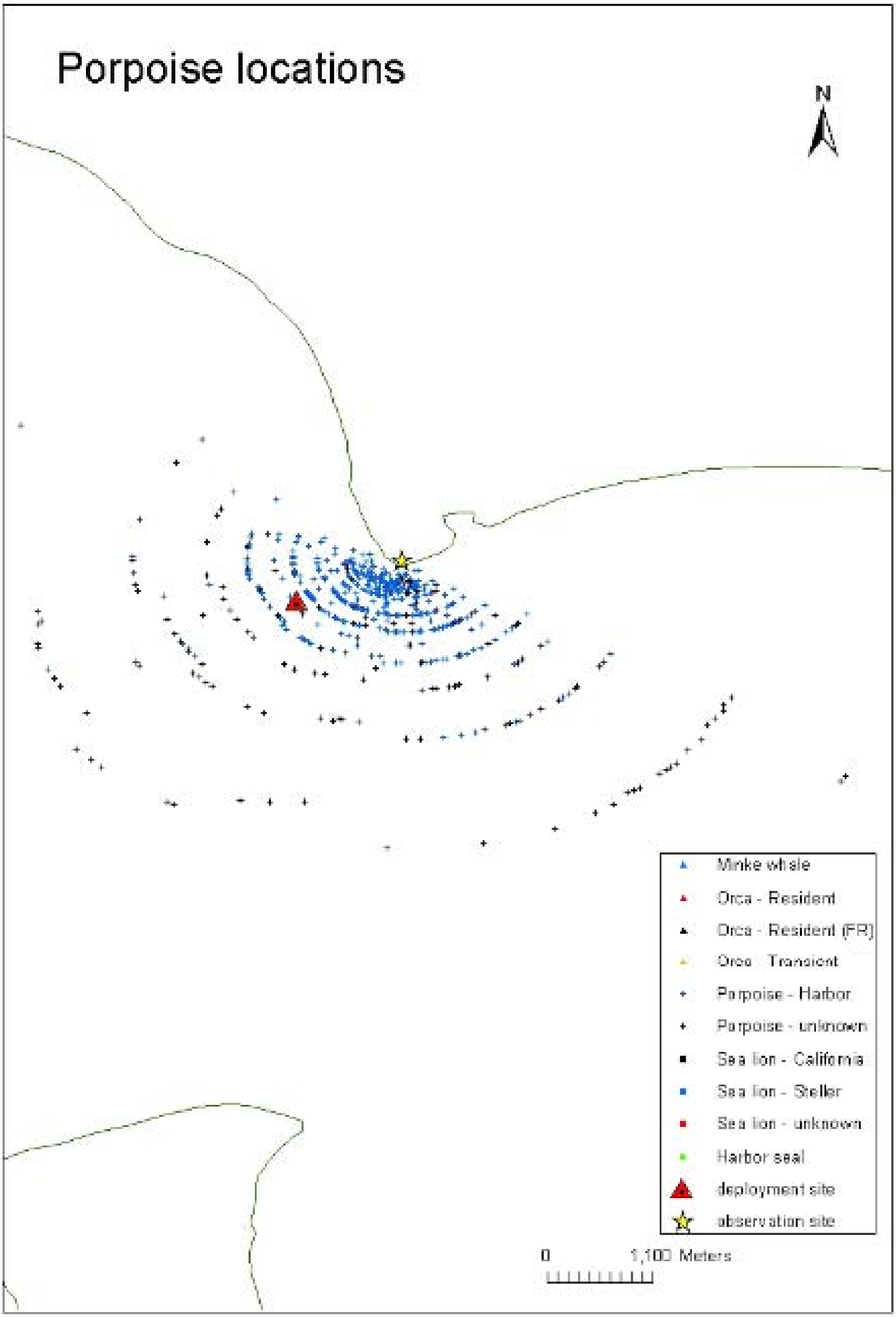


Figure 11. Porpoise sighting locations, depicting harbor porpoise and porpoise – unknown species.

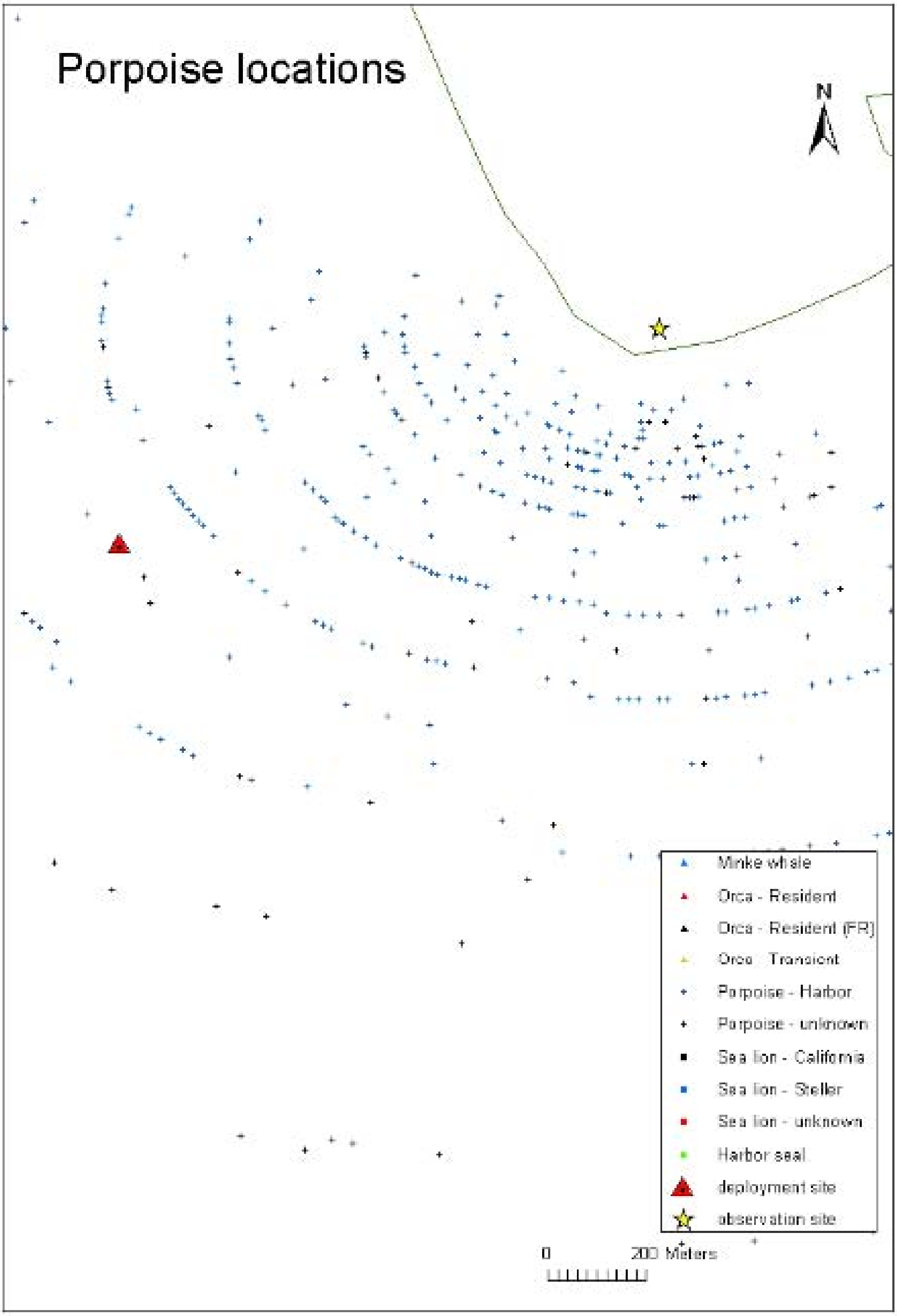


Figure 12. Porpoise sighting locations (near site view)

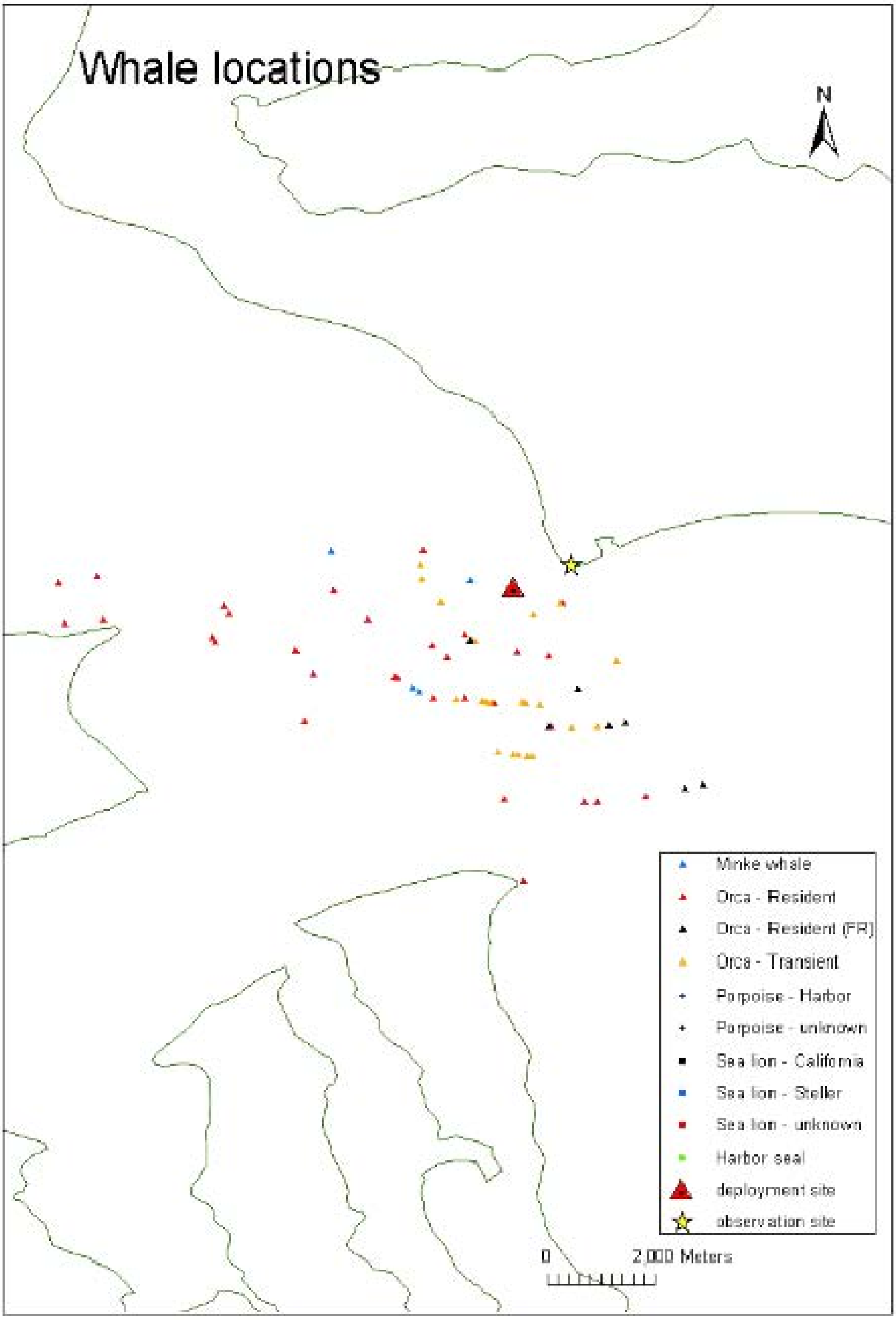


Figure 13. Killer whale and minke (blue) whale sighting locations. Included is one fast response (FR) land based survey for SRKW (red) undertaken in December 2009.

Table 3. Details of land based observations above the Project site that recorded sightings information of Southern Resident killer whales.

Date observed	Number of sightings	Min-Max range (m)	Direction of movement and comments	Max group size observed
10 October 2009	13	3009-5922	Travel SE	20
20 October 2009	13	2306-6402	Travel NW then SE, 2 spy hops	20
21 October 2009	7	733-3009	Travel NW, 4 breaches	11
6 December 2010	7	1875-4412	Fast travel S	2

Species presence in 1-hour long survey block periods (n=231) were considered as the best metric to describe relative importance. Overall, a total of 181 sightings were classified as unknown porpoises, but many of these were also recorded in the comments field as probable harbor porpoise and on one occasion a sighting of 2 probable Dall's porpoise. We have therefore provided relative importance taking into account this higher species resolution (Table 4, Figure 14), as well as collapsing the data to provide information (Table 5) at the level of logical functional groups (e.g., all porpoises combined, all sea lions combined).

Across all surveys harbor seals were observed in 85% of 1-hour blocks, 1.7 times more than Steller sea lions and harbor porpoises (50% and 49%), 13 times higher than California sea lions (7%) and 33 times higher than both killer whales ecotypes (both sighted in 2.6% of 1-hour blocks)(Table 4, Figure 15). When all identification categories of porpoises were combined, presence in all hour blocks increased to 56%, while both species of sea lion combined were present in 58% of 1-hour blocks (Table 5). Restricting our analysis to good sighting conditions had only one fairly minor effect – increasing the relative importance of harbor porpoises with an increase in sighting rate to 56% and somewhat reducing the sighting rate of Steller sea lions to 47% (Table 4, Figure 16). Group size information has been summarised, excluding hour blocks with no sightings. Median group sizes of porpoises and killer whales were highest. Harbor porpoises were observed in more than half the 1-hour block periods (interquartile range) in groups of between 2-6 individuals, while for both harbor seals and Steller sea lions, interquartile range was 1-1 (single individuals) and 1-2 respectively. Maximum group sizes were 20, 4 and 14 for these species respectively (Table 4). Southern resident killer whales were sighted in groups of up to 20 individuals in a single group. Transient killer whales were seen in smaller groups (Table 4).

Table 4. Proportion of overall hourly survey blocks each species was observed with summary group size information.

Species Group	**Proportion of the 1-hour survey blocks where species group were sighted**		**Median (IQR, Maximum) group size**
	All surveys	Sea state, Beaufort≤3	
Harbor seal	0.853	0.870	1 (1-1, 4)
Minke whale	0.009	0.011	1 (1-1, 1)
Orca - Resident	0.026	0.032	15.5 (7.25-20, 20)
Orca - Transient	0.026	0.032	4 (3-5, 5)
Pinniped - unknown	0.061	0.065	1 (1-1, 1)
Porpoise - Dalls	0.004	0.005	2 (2-2, 2)
Porpoise - Harbor	0.494	0.562	4 (2-6, 20)
Porpoise - unknown	0.160	0.189	3 (2-5, 12)
Sea lion - California	0.065	0.070	1 (1-1, 4)
Sea lion - Steller	0.498	0.465	1 (1-2, 14)
Sea lion - unknown	0.104	0.114	1 (1-1, 1)

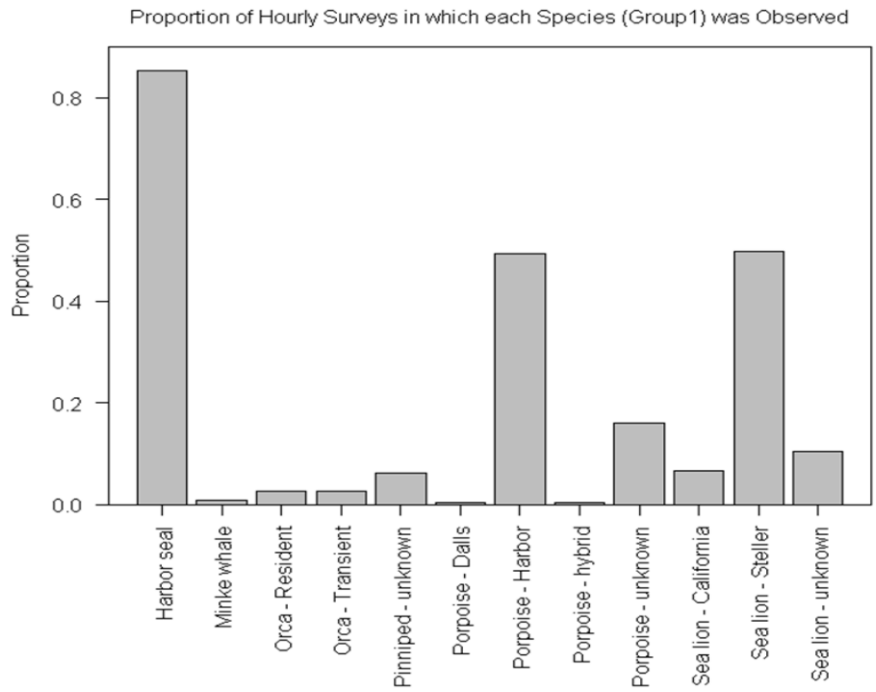


Figure 14. Proportion of all hourly survey blocks each species was observed.

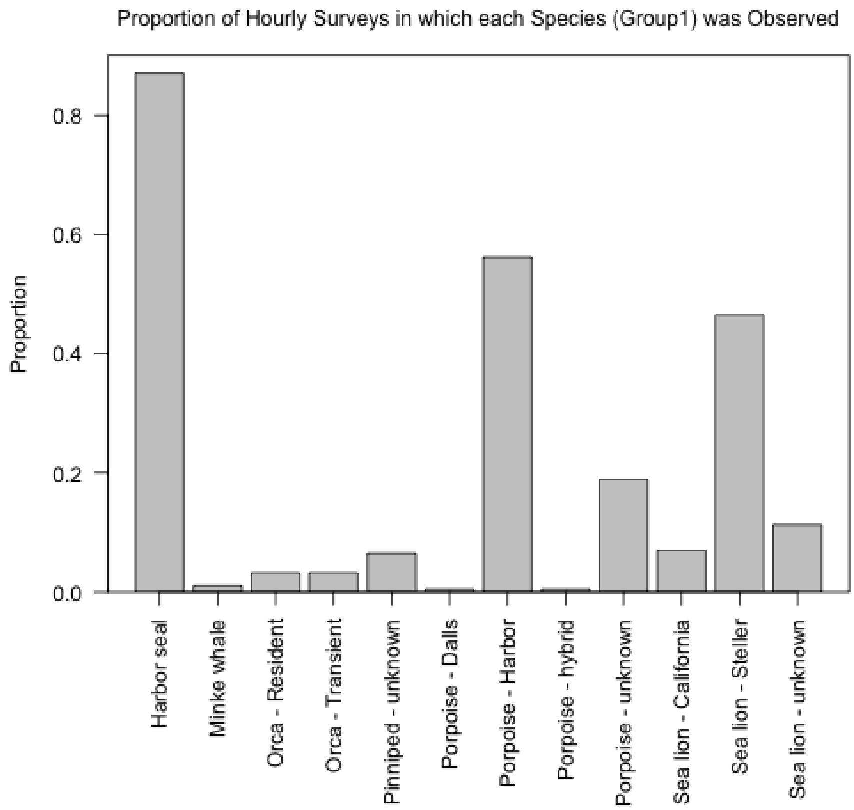


Figure 15. Proportion of hourly survey blocks each species was observed during good sighting conditions.

Table 5. Proportion of all hourly survey blocks each functional group was observed

Functional group	Proportion of the 1-hour surveys where group was sighted
Harbor seal	0.853
Minke whale	0.009
Orca - Resident	0.026
Orca - Transient	0.026
Pinniped - unknown	0.061
Porpoise	0.558
Sea lion	0.584

Further statistical analysis of sightings data concentrated on those key species considered as having sufficient data - harbor seals, harbor porpoise and Steller sea lions (see Figure 16). Seasonal variation in key species sightings (Figure 17) was assessed by comparing three equal length survey periods. Zeros were included on days when no sightings occurred. Harbor seal were sighted most frequently in period 2 (median=4) and least frequently in period 3 (median=2) (Kruskal-Wallis, H=10.4, df=2, P=0.005). Steller sea lions were sighted more often in the first period (median=2), than the second and third time period (median=0) (Kruskal-Wallis, H=35.3, df=2, P<0.0001). Porpoises showed no differences in number of sightings across time periods (Kruskal-Wallis, H=1.3, df=2, P=0.53) (Figure 17). California sea lions were mostly sighted in the second and third periods (Figure 17).

Use of the study area varied by distance from shore zone for harbor porpoise and Steller sea lions (Table 6). Harbor porpoises were more frequently observed in the offshore zone (74%), while Steller sea lions were more frequently observed in the inshore zone (71%) (Figure 18). Applying Bonferroni corrections to the marginally significant P value in this comparison for harbor seals resulted in a non-significant result. Harbour seals were seen in the inshore zone at a value of ~55% of all 1-hour blocks and sightings.

Review of the behavior/comment fields indicated groups of porpoises sometimes included calves, with porpoises observed undertaking directional travel, as well as apparent foraging activity. Sightings of harbor seals, Steller sea lions and Transient killer whales sometimes included observations of surface feeding behavioral events.

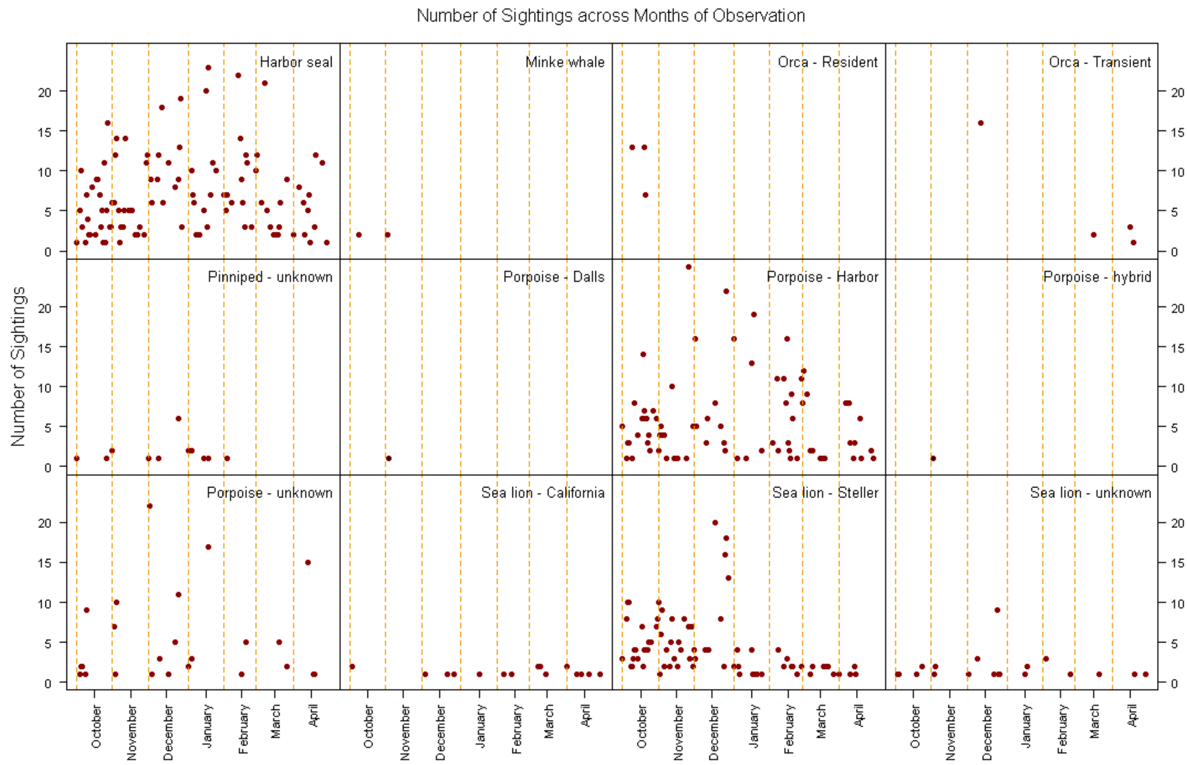


Figure 16. Number of sightings by species in each survey across the study

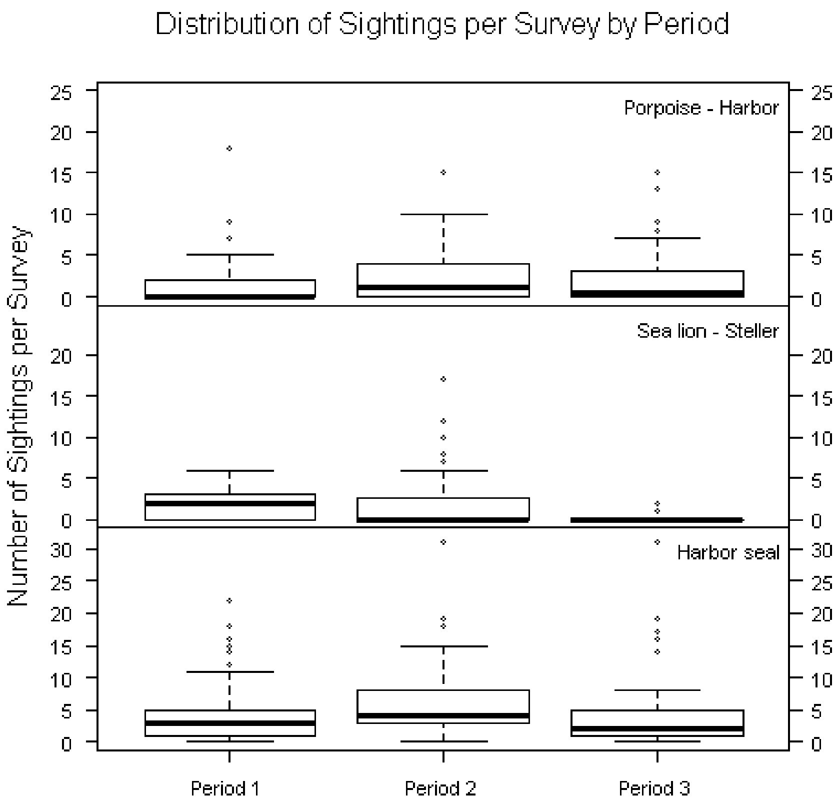


Figure 17. Boxplot distribution of key species sightings across three survey periods. Median, IQR (box) and outliers (single points) are depicted.

Table 6. Comparison of relative importance between inshore and offshore zones for good sighting conditions. 2-sample test for equality of proportions with continuity correction were performed on species presence in survey 1-hour blocks.

Species	**Inshore zone**		**Offshore zone**		**χ-squared (P)**
	# of 1hr survey blocks	# of sightings	# of 1hr survey blocks	# of sightings	
Harbor seals	143	528	118	422	5.1 (P<0.02)
Harbor porpoise	32	83	96	312	42.9 (P<0.0001)
Steller sea lions	77	223	32	49	23.2 (P<0.0001)

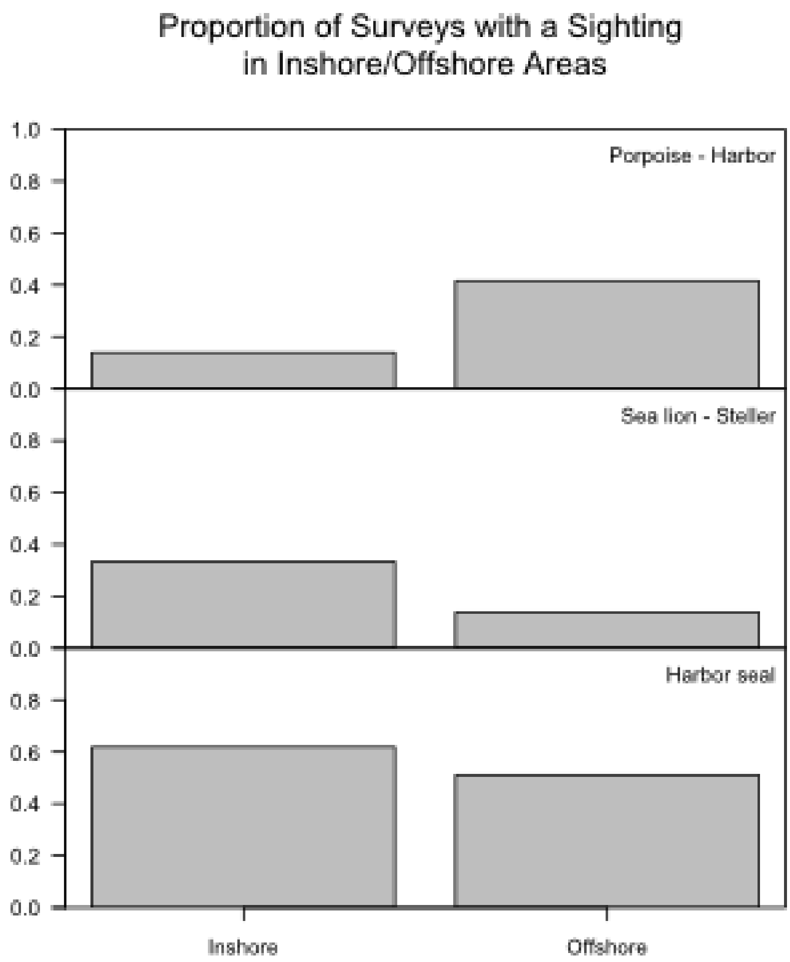


Figure 18. Relative proportional use by key species of inshore and offshore zones

A Contingency Table test indicated the proportion of hourly blocks that key species were sighted varied by compass segment category (χ-squared=24.6, df=6, P=0.0004).

Univariate ChiSquare Tests on the proportion of sightings for each key species individually confirmed all varied significantly by compass segment category (Harbor seal: χ-squared=28.3, df=3, P< 0.0001, Harbor porpoise: χ-squared=23.9, df=3, P<0.001, Steller sea lions: χ-squared=20.0 df=3, P<0.001) (Table 7, Figure 19). Generally, relative sighting rates were higher in the central two segments (170-269.9 degrees), but we note some bias may exist because 32 surveys days with high glare, all recorded times of sun glare on the water in the bearing range 103-214 degrees (thereby covering only the first two compass segments and mainly the <170 degrees sement).

Further analysis on the offshore zone alone in good sighting conditions, indicated significant differences in proportion of hourly blocks that species were sighted varied by compass segment category for only harbor seals and harbor porpoises (Table 8). Lower sighting rates were observed in the offshore compass segment <170 degrees for harbor seals, while in contrast lower sighting rates were observed in offshore compass segment >270 degrees for harbor porpoise. Steller sea lions did not vary across offshore compass segments.

Table 7. Summary of sightings and analytical 1-hour survey periods by zone and compass segment.

	All species			**Harbor seal**		
Compass segment	# of sightings	# sighting inshore zone	# sightings offshore zone	# of 1hr survey blocks	# sighting inshore zone	# sightings offshore zone
<170	373	151	171	67	78	56
170-219.9	656	339	263	122	179	105
220-269.9	790	390	306	144	251	154
>270	326	115	201	111	78	137
	Harbor porpoise			**Steller sea lion**		
Compass segment	# of 1hr survey blocks	# sighting inshore zone	# sightings offshore zone	# of 1hr survey blocks	# sighting inshore zone	# sightings offshore zone
<170	54	17	83	43	50	11
170-219.9	77	47	113	64	100	10
220-269.9	67	19	105	73	106	21
>270	28	3	32	32	33	20

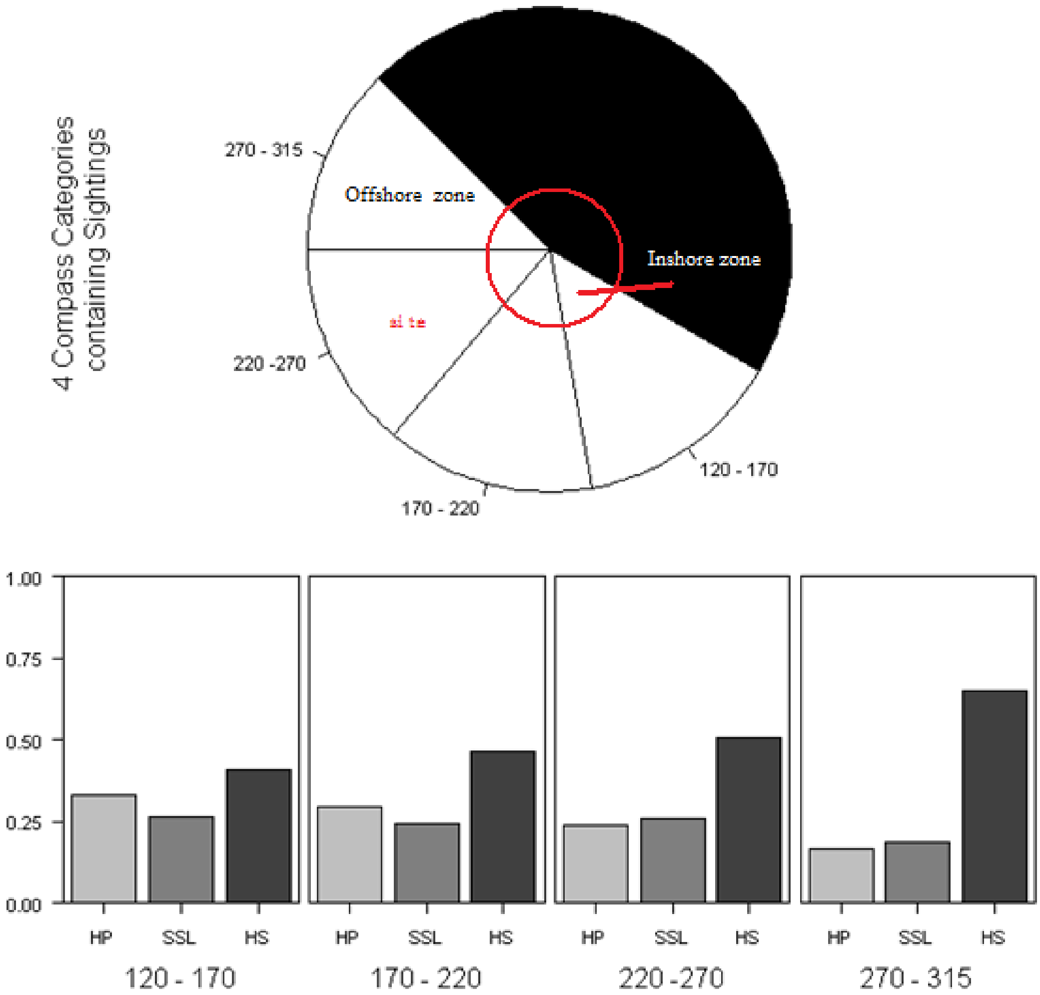


Figure 19. Proportion of total sightings of key species by compass segment category. The turbine is planned to be deployed in the third segment (220-269.9 degrees) approximately in the middle of the offshore zone. HP=harbor porpoise, SSL=Steller sea lion and HS=harbor seal. Also depicted is the relative size of the inshore zone versus offshore, with site location depicted in red.

Table 8. Comparison of relative importance in the offshore zone only by compass segment in good sighting conditions. 2-sample test for equality of proportions with continuity correction was performed on presence in survey one hour blocks.

	Harbor seal	**Harbor porpoise**	**Steller sea lion**
Compass segment	# surveys offshore zone	# surveys offshore zone	# surveys offshore zone
<170	56	81	8
170-219.9	102	108	9
220-269.9	138	98	18
>270	126	25	14
χ -Square (P)	22.1 (P<0.001)	23.1 (P<0.001)	3.6 (P=0.31) NS

4.3 Boat-based observations of SRKW

Seven boat-based follows were conducted as SRKW transited through the study area between October 2, 2009 and April 30, 2010. The Beaufort sea state was 3 or less on all days and visibility was excellent on all days except for October 20, 2009 when fog was present during part of the transit. The focal group of whales was however still clearly visible during this time. Detailed location and behavior data were collected on all of these days except for December 22, 2009 when conditions did not allow this, however acoustic data were collected during all seven responses.

Location data of the focal group of whales showed a wide use of the study area by the whales, travelling through the shipping lanes and generally west of the Project site (Figure 20). Because of the emphasis on focal groups, this map does not indicate the full extent of this habitat use by SRKW, just the use by the focal groups followed. Figures 21 through 24 depict the locations of the focal group during the seven boat responses collecting behavioural data. The arrows indicate the direction of travel.

On October 10, 2009 (Figure 21, left) J pod had already passed through the study area and we observed L pod as they entered the Puget Sound. During this time the pod was spread out in small groups travelling slowly to the south. One foraging event was noted during this 2 hour and 15 minute transit. October 20, 2009 (Figure 21, right) also involved an entrance but this time with members of all three pods. Our focal follows during this transit involved members of J and K pod. The pods were once again spread out and travelling in small groups, with some foraging behavior during the transit as well. Our longest focal follow occurred on

October 21, 2009 (Figure 22, left) when J, K and L pods started to leave Puget Sound and then turned around within the study area and headed south again. Members from all three pods were identified in the focal groups that were followed. Almost three hours of this four hour and 41 minute transit was spent travelling, while they spent just over an hour foraging and just over 30 minutes socializing. This was the only day when socializing behavior was noted and was also the day when we recorded the closest approach of the focal group to the proposed pilot site. December 6, 2009 (Figure 22, right) involved an entrance into Puget Sound of K pod. This brief focal follow documented foraging behavior from the focal group and travelling behavior by many other members of the pod. On December 7, 2009 (Figure 23, left) K pod and L87 entered the study area from the south again. The pod was spread out and travelling fast to the north. December 22, 2009 (Figure 23, right) was a challenging day when J pod was moving slowly north but was very spread out in small groups. Although the pod as a whole was moving in a northerly direction, the individual groups were changing direction often, which made it difficult to follow a focal group. As such reliable behavior data could not be collected, but good acoustic data was collected on this day. It is likely, given the constant direction changes and spread out nature of the pod that they were engaged in some foraging behavior. Our final transit occurred on January 2, 2010 (Figure 24) when J pod was entering Puget Sound. They spent most of their time travelling, but also exhibited foraging behavior on their way south. To give the full extent of all locations of SRKW that we collected we combined both boat based and land based locations on a single map (Figure 25). Boat based locations are depicted in red and are calculated from distances and bearings from the boat as it followed the focal group. The land based locations are depicted in blue and are calculated from distances and bearings from the land observation site. Combined these observations show a wide use of the study area in the main north-south corridor.

Based on opportunistic land based sightings, J, K and at least L87 were sighted multiple times during the period December 5th to December 10th. J pod was also confirmed as being sighted in the Sound on November 12th and 24th 2009, as well as January 3rd and 4th 2010.

On review of project SRKW boat responses, it was concluded a hydrophone south of the Study area would increase early detection of northward exits from the Sound and thereby improve the likelihood of increasing the number of focal follows in the future.

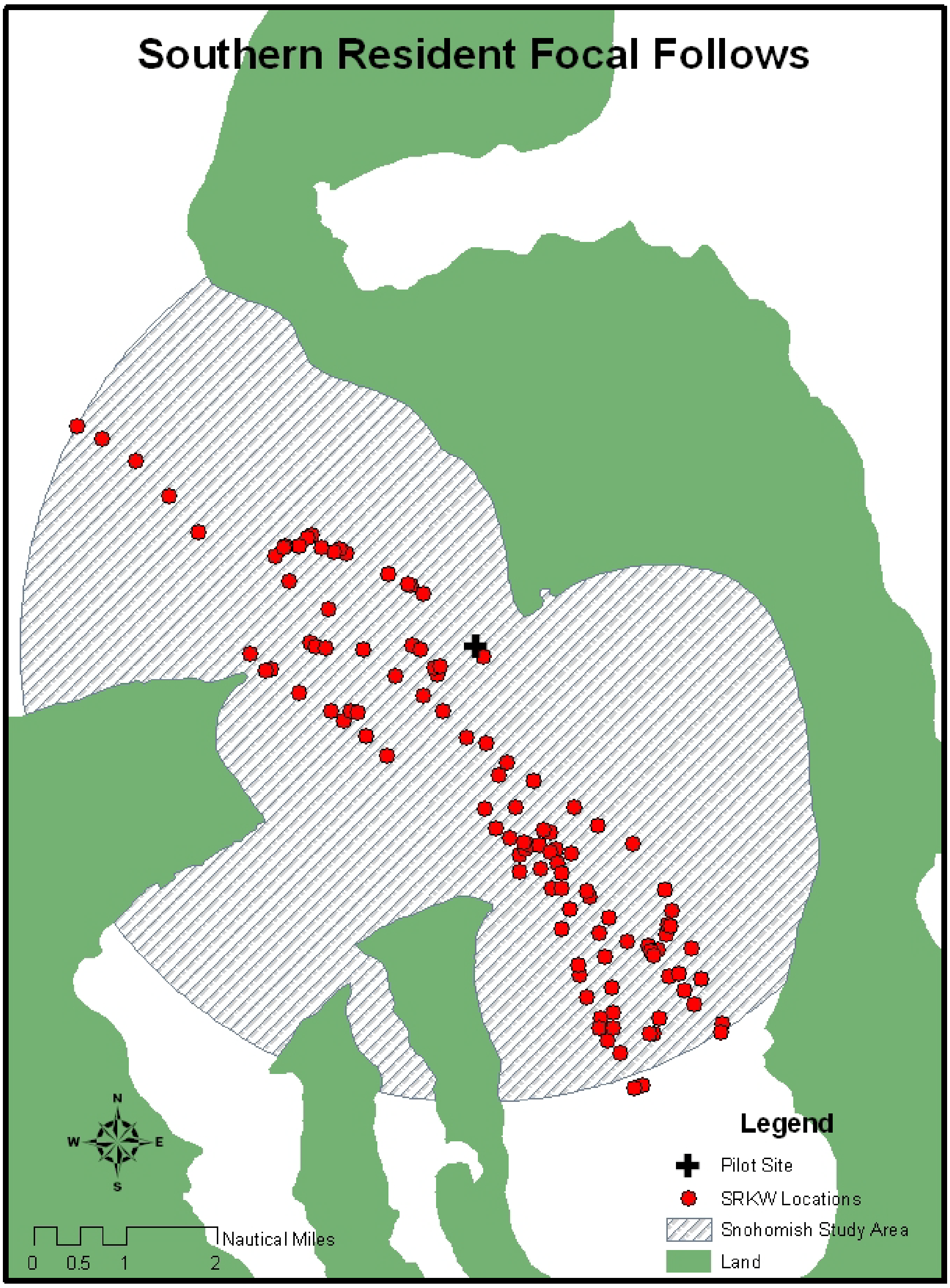


Figure 20. Calculated locations of the focal groups during the seven boat responses to SRKW transits in the study area. Locations show a wide use of the study area but cannot indicate their full use of this habitat since data were only collected for focal groups.

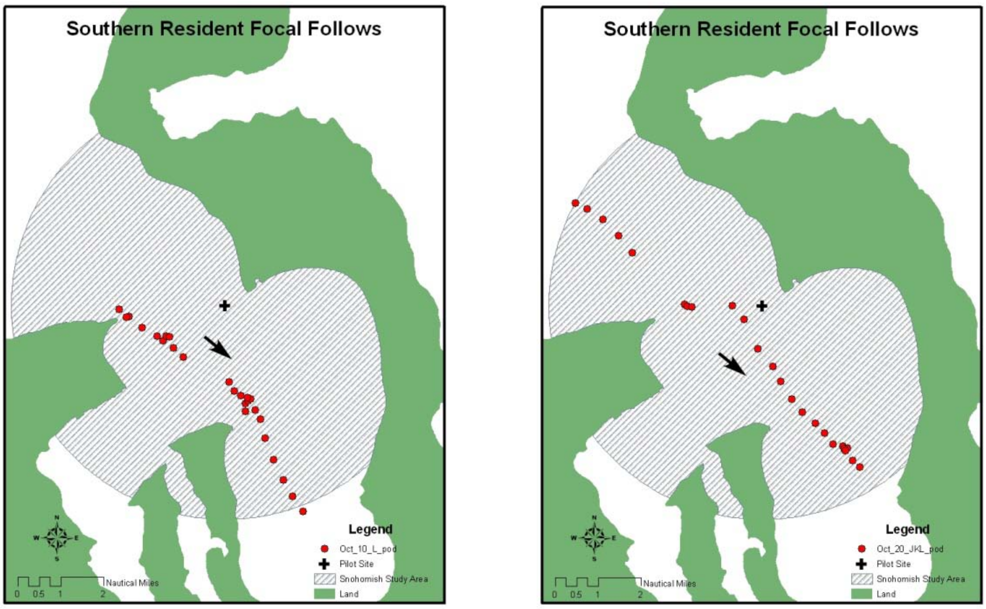


Figure 21. October 10, 2009 L pod (left) and October 20, 2009 JKL pod (right) focal whale locations. Arrows depict direction of pod movement.

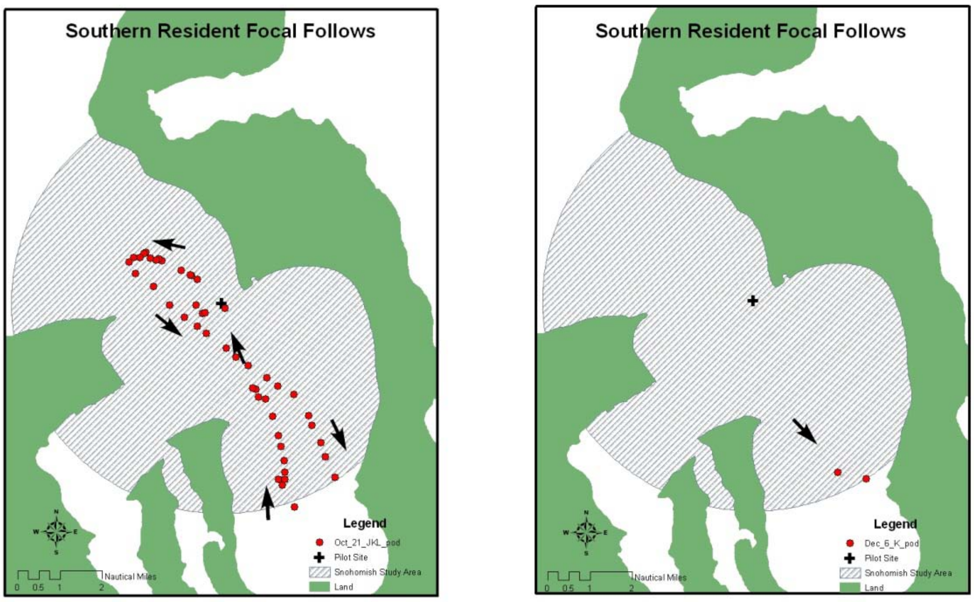


Figure 22. October 21, 2009 JKL pod (left) and December 6, 2009 K pod (right) focal whale locations. Arrows depict direction of pod movement.

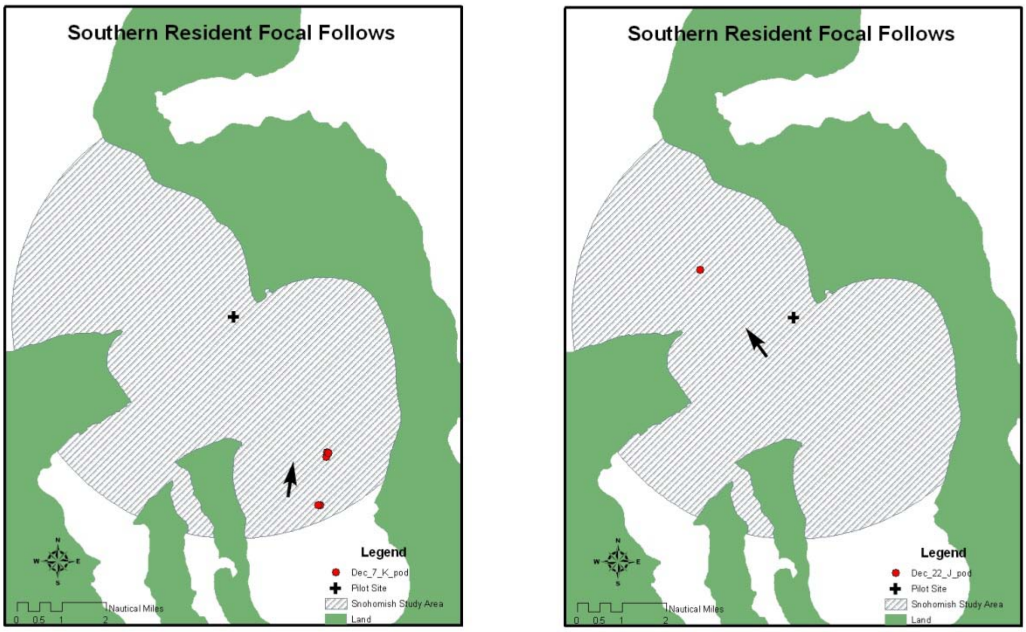


Figure 23. December 7, 2009 K pod (left) and Dec 22, 2009 J pod (right) focal whale locations. Arrows depict direction of pod movement.

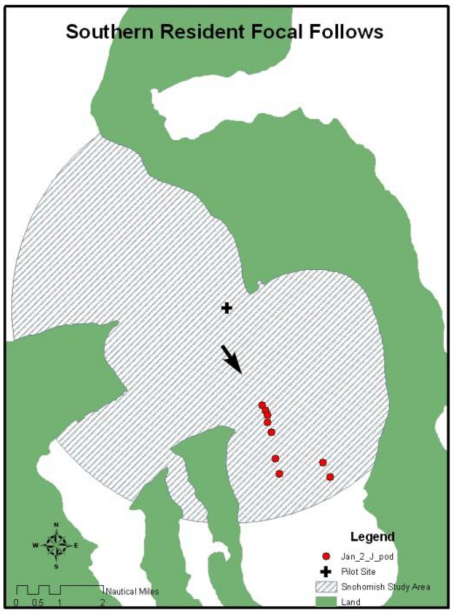


Figure 24. January 2, 2010 J pod focal whale locations. Arrows depict direction of pod movement.

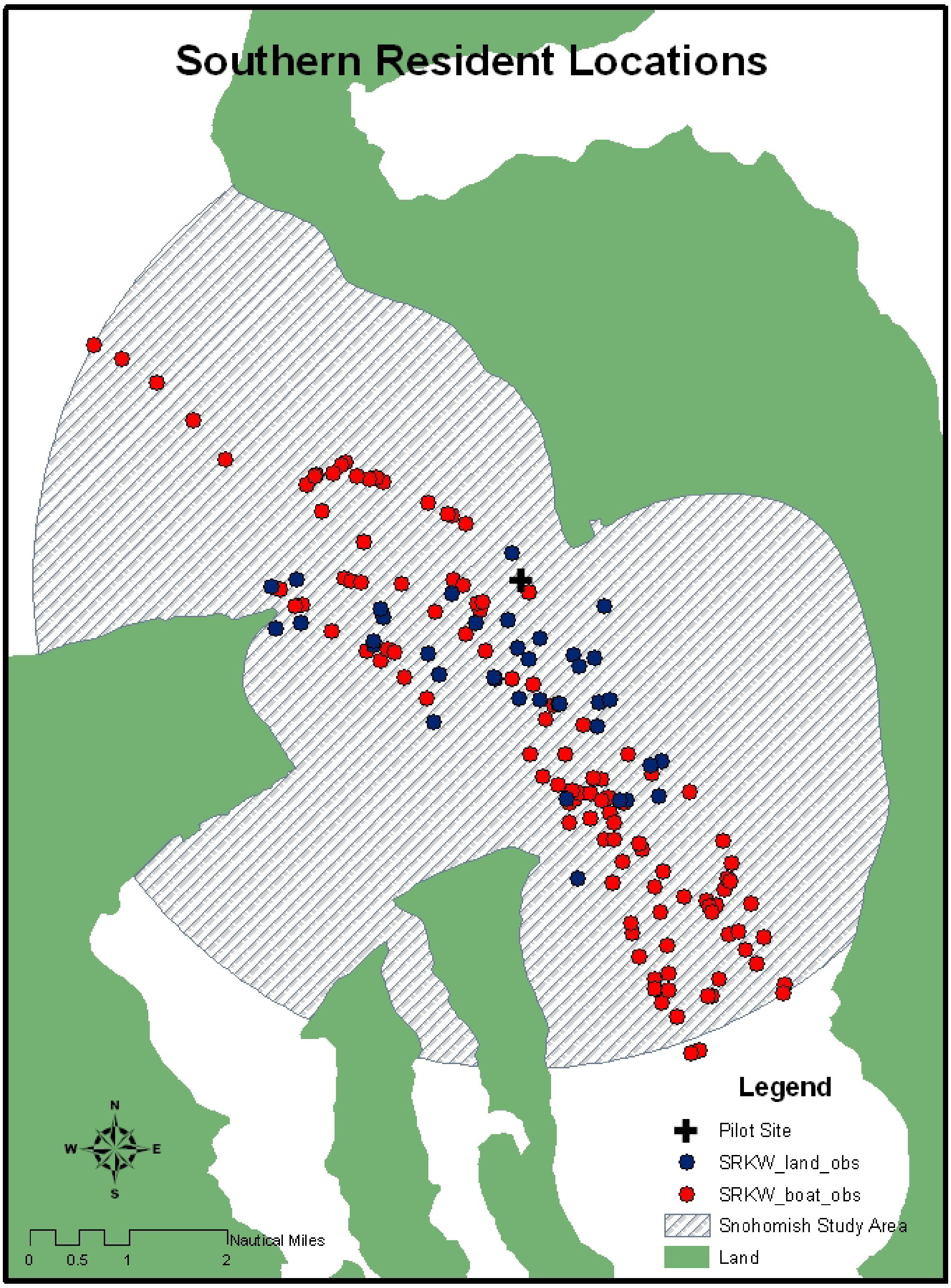


Figure 25. Map of all locations of SRKW tracked in the study area. Calculated locations of focal groups during the seven boat responses to SRKW transits are depicted in red circles. Calculated locations from land observations of SRKW transits are in blue circles. Locations show a wide use of the study area, often west and southwest of the Project site.

In total 11.5 hours of focal behaviour sampling were made across six transits. On December 22, 2009 J pod was so spread out and changed short term direction so often that it was not possible to follow a focal group for long enough to accurately record a focal group behavior state. Behavior data from that day were therefore not included in the behavior state summary provided in Table 9. Overall, the focal animals spent most of their time travelling (8:32hrs), followed by foraging (2:27hrs) and then by socializing behavior (0:34hrs) (see Table 9). All three pods were observed transiting the study area. Foraging behavior by the focal group was observed on all but one transit, across different parts of the five mile radius study area.

Table 9. Time (and percentage of time) spent by each focal group in various behavior states during the six transits during which focal group behavior could be collected.

Date	**Duration of observation**	**Forage**	**Socialize**	**Travel**	**% Forage**	**% Socialize**	**% Travel**	**Pod**
10/10/2009	2:15	0:05	0:00	2:10	4%	0%	96%	L
10/20/2009	2:19	0:32	0:00	1:47	23%	0%	77%	JKL
10/21/2009	4:41	1:10	0:34	2:57	25%	12%	63%	JKL
12/6/2009	0:12	0:12	0:00	0:00	100%	0%	0%	K
12/7/2009	0:25	0:00	0:00	0:25	0%	0%	100%	K
1/2/2010	1:41	0:28	0:00	1:13	28%	0%	72%	J
Total	**11:33**	**2:27**	**0:34**	**8:32**	**21%**	**5%**	**74%**	

4.3.1 Vertical hydrophone array deployments

The vertical array was deployed and recordings taken during all seven transits with a total recording time of 189 minutes (27% of the time spent collecting behavioral data). Of these 189 minutes, there were a total of 104 minutes with calls or clicks that were localized (55% of recording time) (Table 10). The percentage of minutes that SRKW vocalized during transits varied considerably from 92% of the time to 0 % of the time. Not all calls or clicks could be localized, but most recordings with sounds had at least one sound that was localizable, therefore the figures in Table 6 will only be a slight underestimate of the proportion of minutes the SRKW were vocalizing during transits through the study area.

Table 10. Summary of the number of minutes of acoustic recordings and minutes of recording with SRKW calls or clicks that could be localized.

Date	**Minutes of recording**	**Minutes with localizable sounds**	**% of minutes with localizable sounds**
10/10/2009	29	0	0%
10/20/2009	28	3	11%
10/21/2009	24	22	92%
12/6/2009	22	19	86%
12/7/2009	18	6	33%
12/22/2009	27	24	89%
1/2/2010	41	30	73%
Total	**189**	**104**	**55%**

OVAL Locator uses an optimization routine based on the Time Of Arrival Difference (TOAD) of signals at each hydrophone that is analogous to hyperbolic techniques for all its localizations. There are however several options for calculating the TOADs. The standard way involves running cross-correlations between each pair of hydrophones to find the time location of maximum cross-correlation. This method was used on all calls and is demonstrated in Figure 26. In addition a band-pass filter was also used on occasion to improve the cross-correlation results. On most clicks however a 'hand picking' technique was used. This technique involves locating the time of arrival of the click visually in the time series as has been used by Geophysicists for years for seismic signals. Figure 27 demonstrates this approach. The time series of all four channels are depicted with the shallowest hydrophone at the top. The horizontal axis depicts time (in this case ~45 msec) while the vertical axis depicts amplitude. The click clearly arrives at the shallowest hydrophone first, followed sequentially by the other three hydrophones. The white arrows illustrate the most obvious part of the click, which was used to hand pick the time of arrival of the signal at each hydrophone. On some clicks there was also a clear surface reflection from the click bouncing off the interface between the sea surface and the atmosphere (Figure 28). We were able to utilize this reflection as additional TOAD to increase the accuracy on clicks where this was present.

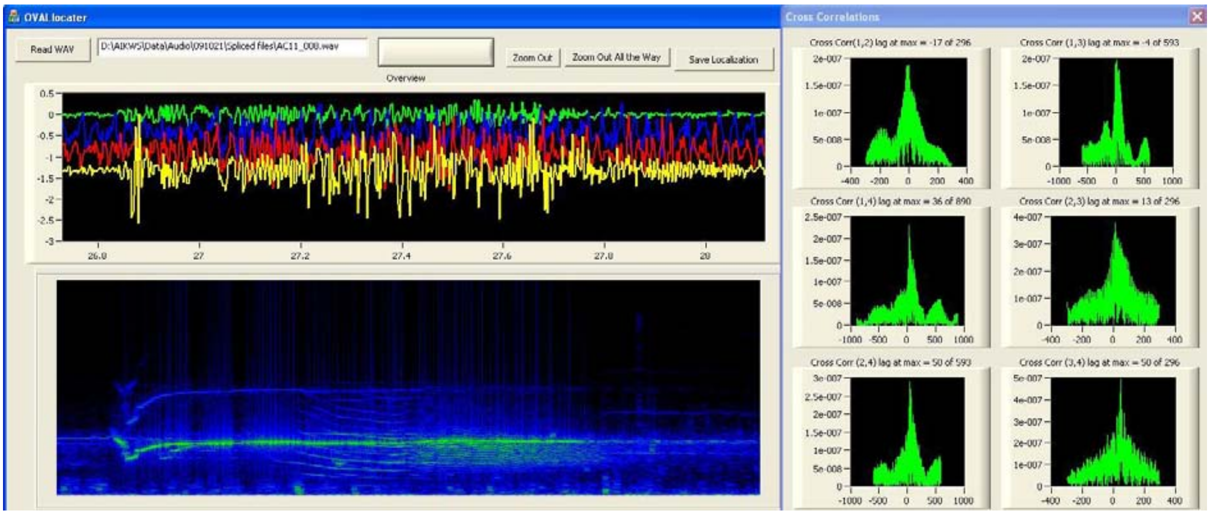


Figure 26. Output window from OVAL Locator. The time series is in the upper left window depicting the amplitude of the call across time in the 4 hydrophone channels. The spectrogram of the signal in the shallowest hydrophone is in the lower left window and depicts the frequency and amplitude change of the signal over time. The six windows on the right depict the cross-correlations of the signal between each pair of hydrophones (1vs2, 1vs3, etc.) that are used to determine the TOAD.

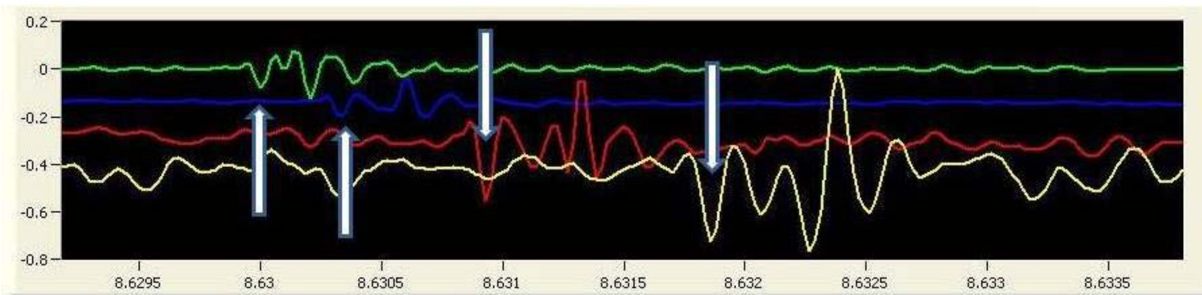


Figure 27. Time series of a click received at each hydrophone. White arrows depict the points at which the time of arrival was ‘hand-picked’ to determine the TOAD for localization. Y axis is amplitude. X axis is time in seconds.

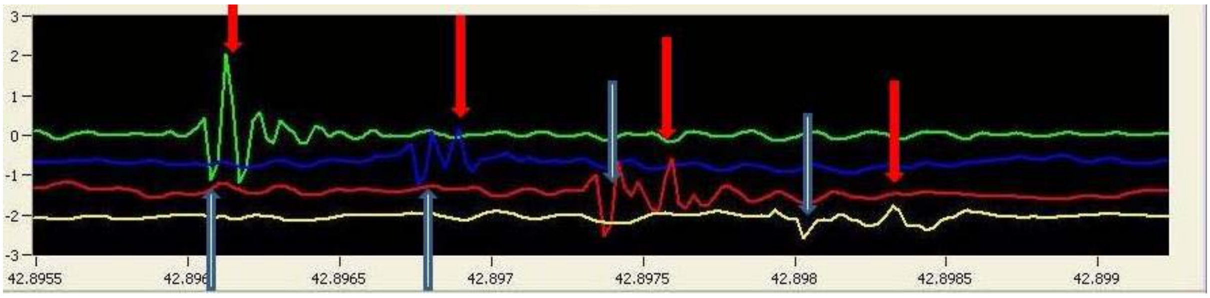


Figure 28. Time series of a click showing initial arrival followed by a surface reflection. First arrival is shown by white arrows followed by the reflection shown by red arrows. The first signal and reflection are 180° out of phase as expected, and the TOAD increase with increased depth since the reflection is from the surface.

A total of 682 calls and clicks were localized. OVAL Locator however estimates the vertical error of each localization. This is done by calculating a 20% change in the location optimization of the intersecting hyperbolic surfaces. The result is a positive and negative error in meters that is indicative of the susceptibility of the localization to slight changes in TOAD. Only localizations with errors less than 50 meters (n = 655) are included in this report. The average depth of vocalization was 24 meters (SD = 14.46) with a range from 0 to 142 meters. Table 11 lists results by behavior, vocalization type and date. Eighty percent of vocalizations were produced at 30 meters or less, however there were a number of deeper vocalizations that were also documented (Figure 29). We found there was over 90% correspondence between the behavior of the focal group and the pod in general

Table 11. Mean, standard deviation (SD), minimum, and maximum depth (m), as well as sample size across all data, behavior, vocalization type, and date. The unknown behavior listed occurred during December 22, 2009 when it was not possible to collect accurate behavior data.

		Depth (m)				
		Mean	**SD**	**Min**	**Max**	**N**
Overall	All vocalizations	24.4	14.5	0	142.6	655
Behavior	Forage	21.7	12.8	0	64.2	147
	Unknown	26.6	19.5	0	142.6	143
	Socialize	27.1	11.9	0	77.5	226
	Travel	20.6	12.6	0	69.7	139
Vocalization	Call	26.1	14.9	0	142.6	510
	Click	18.5	10.7	0	58.0	145
Date	10/20/2009	29.9	11.7	0	64.2	36
	10/21/2009	26.6	12.4	0	77.5	274
	12/6/2009	21.8	12.1	0	52.6	58
	12/7/2009	15.6	9.6	0	45.2	29
	12/22/2009	26.6	19.5	0	142.6	143
	1/2/2010	18.1	11.5	0	69.7	115

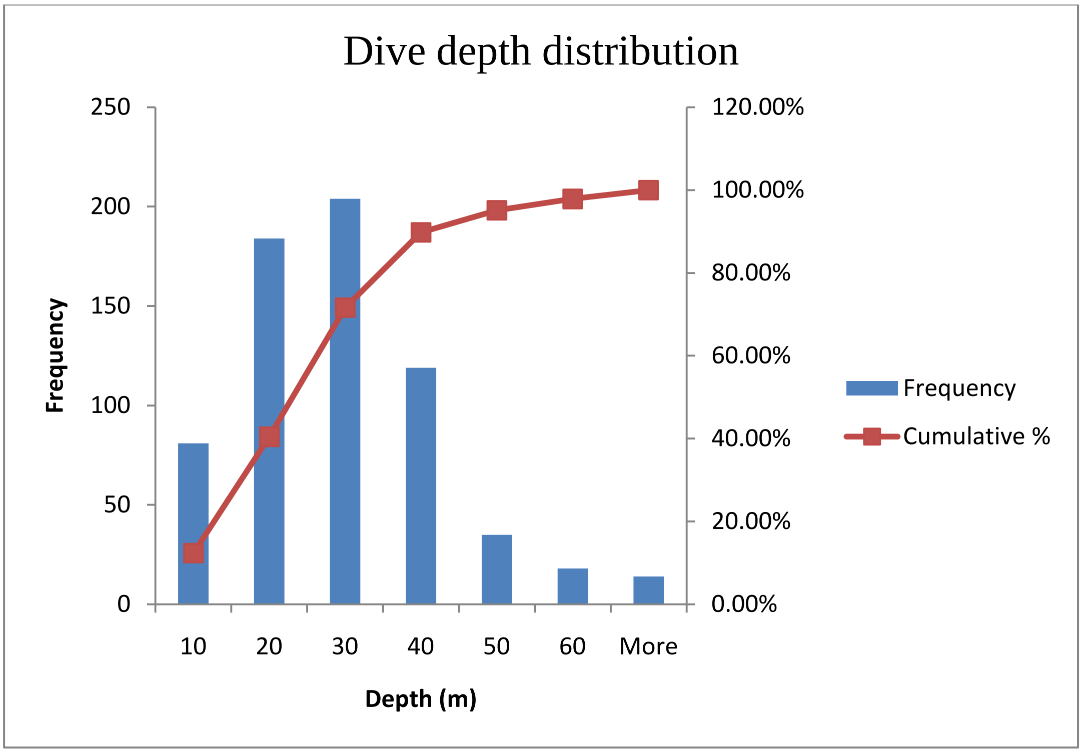


Figure 29. Histogram and cumulative distribution of the depth of the 655 localized vocalizations across 6 transits. 80% of all dives in which we recorded vocalizations are to 30 meters or less, but there were a significant number of dives to greater depths.

On October 21 2009, we collected data closest to the proposed pilot site when the focal group we were following passed within 275 meters of the pilot site. During this recording the focal group of five animals (members of both J and K pod) were recorded as foraging. The entire pod was spread out to the southwest of the focal group, actively changing directions and exhibiting similar behaviors. The majority of the recorded vocalizations were echolocation clicks. During this brief recording we localized two calls and six click episodes with localized depths from 23 to 58 meters (Table 12). All of the clicks were part of separate click trains which were localized using cross-correlation techniques across multiple clicks in the same click train.

Table 12. Estimated depth (m) of 2 calls and 6 click trains localized in the vicinity of the proposed Project site (while the behavioral state of focal group of 5 whales was considered to be foraging).

Depth (m) estimate	Vocalization category
36.4	Call
26.6	Call
23.0	Click
23.0	Click
29.0	Click
58.0	Click
26.7	Click
28.8	Click

4.3.2 Validation of vertical hydrophone array deployments

We recorded 26 light bulb implosions at distances from 113 to 475 meters and 10 to 60 meters in depth (Table 13). These implosions were clearly visible in the time series during localizations (Figure 30). These implosions were localized using both cross-correlation techniques and hand picking. As for the localized calls and clicks only localized bulb implosions with OVAL Locator error estimates of less than 50 meters were used. Hand-picked localizations were localized on average 13.4 meters (SD=10.7) deeper than the source actually was, while cross-correlation techniques localized on average 21.9 meters (SD=24.0) deeper than the source. We feel that the validation for hand-picked bulb implosions is an accurate estimate of our ability to localize clicks using hand picking techniques. However, extrapolating cross-correlation techniques on implosive sounds (the light bulbs) to tonal sounds (SRKW calls) should be done cautiously. The cross-correlation on the longer tonal calls will be more accurate than cross-correlations on the short impulsive light bulb implosions. Therefore the error estimates from light bulbs using cross-correlation should be considered and extreme upper bound for call cross-correlation.

Table 13. Counts of 26 light bulb implosions by distance between source and receiver and depth of source.

Distance (m)	Number of bulb implosions	Depth (m)	Number of bulb implosions
113	1	10	6
139	1	20	4
140	6	30	5
193	4	40	5
240	4	50	3
385	2	60	3
425	4		
470	1		
475	3		

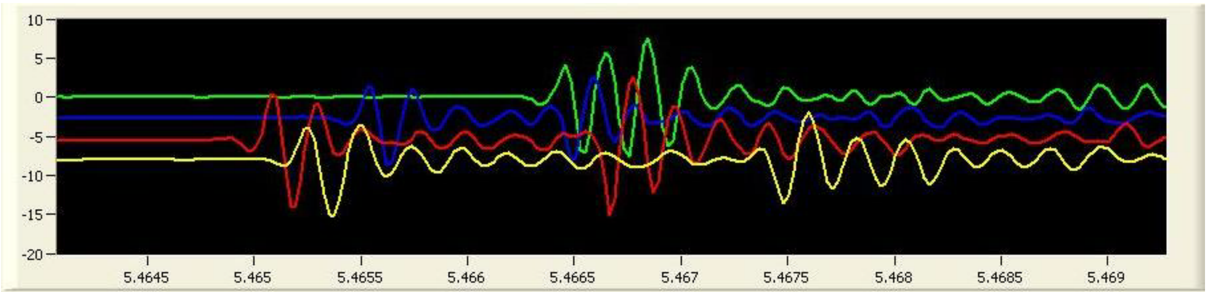


Figure 30. Time series of a light bulb implosion used to validate the localization techniques. The first time of arrival at the third hydrophone at 30 meters depth is clearly visible. There is also a clear reflection from the surface of the water.

4.4 Boat-based observations of other marine mammals and marine birds of concern

Six 2nm boat sighting surveys through the study area were completed between October and December 2009 (Table 14). All surveys were carried out in good or excellent sighting conditions. Two surveys passed within 500m of the Project site. Day length/sighting conditions did not permit sighting surveys to take place during other boat fast responses. Five harbour seals and two solitary Steller sea lions were sighted across three survey dates. Four harbour seals and five marbled murrelets were encountered on one survey which started

~7km SW of the Project area. The marbled murrelets were all observed between 11:30-11.34 as a pair and then three single individuals. Figure 31 depicts the location of these bird sightings. All were described by observers as sitting on the surface of the water.

Table 14. Details of boat sighting surveys in study area. Surveys passing within 500m of Project site are marked in italics. Start end survey locations are in Appendix D.

Date	**Start time**	**Sightings on 2nm survey**
10 October 2009	16:50	-
24 November 2009	*14:48*	*1 Steller sea lion, 1 harbor seal*
5 December 2009	12:00	-
10 December 2009	11:23	4 harbor seals, 5 marbled murrelets
12 December 2009	14:22	-
22 December 2009	*16:00*	*1 Steller sea lion*

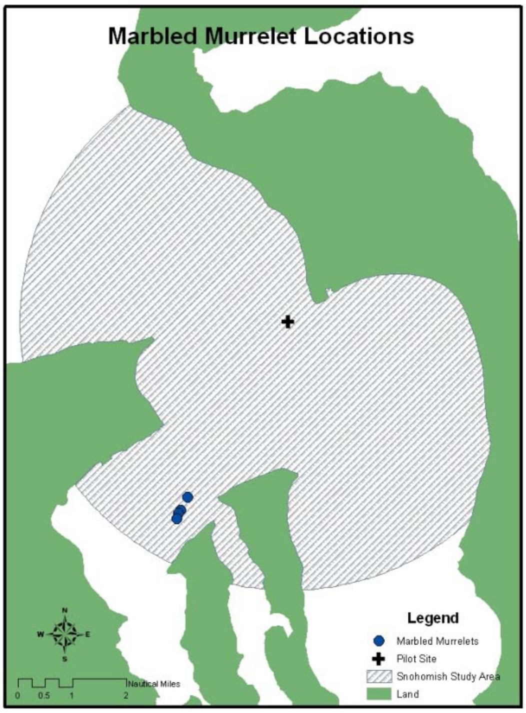


Figure 31. Location of marbeled murrelets sighted on December 10^{th} 2009 boat survey.

Eight haul-out counts were undertaken at the Marrowstone Island haul-out between October 2009 and January 2010 (Table 15). One count occurred on a vertical array deployment training day. Day length/sighting conditions did not permit haul-out counts to take place during other fast responses. Numbers of Steller sea lions varied between 0-15. A single harbor seal was hauled-out nearby on one occasion (Table 15).

Table 15. Pinniped haul-out count information.

Date	**Time**	**Steller sea lion**	**Harbor seal**
10 October 2009	16:22	3*	0
11 October 2009	18:30	1	0
24 November 2009	14:06	0	0
5 December 2009	13:08	3	0
7 December 2009	16:33	15	0
10 December 2009	11:00	10	1
12 December 2009	14:45	12*	0
2 January 2010	16:02	8	0

*Includes animals in water within 50m

Finally, we note on December 12 2009, the field team made contact with 5-6 killer whales just off Admiralty head. Animals were moving slowly in a group, in no consistent direction, with long (4-9 minutes) dives. No vocal activity was recorded. Animals became surface-active and a Steller sea lion was observed in their midst, moving slowly back and forth on the surface. Killer whales were observed striking the animal multiple times and it appeared disorientated. It is believed these animals were the T68's transients.

4.5 Opportunistic sightings information of other key marine mammals in the region

Sightings recorded by Orca Network were summarised to provide local information on less frequently observed cetacean sightings within Puget Sound over the period October 2009 – April 2010. While many sightings are highly likely to be repeats of the same animal/group, clear seasonal trends are observable. Most notably, transient killer whale sightings peak in March and April; and there is a peak in grey whale sightings in the second half of the period; with humpback sightings occurring only in February. Regionally, grey whale observations in inshore waters were considered above average and thought to relate to previous year feeding success in Alaska. Group sizes of transient killer whales were considered to be 5+ individuals on 63% of sighting occasions in March and April, with even larger groups of 12+ individuals recorded on 13% of occasions.

Table 16. Summary of Orca Network opportunistic sightings (not SRKW) in the region.

Species	**Month**	**Sightings days in Sound**
Brydes whale	Jan	1
Grey Whale	Oct	1
	Nov	2
	Dec	12
	Jan	8
	Feb	17
	March	21
	April	19
Humpback whale	Feb	6
Minke whale	Nov	1
	Feb	2
	April	3
Killer Whale - Transients	Nov	1
	March	16
	April	14
White -sided Dolphin	April	1

4.6 Port Townsend hydrophone PAM studies

Of the 22 times that SRKW transited the study area they were detected acoustically via the PTMSC hydrophone 14 times (64%) by the automated algorithm and 10 times (45%) by human listeners (Appendix C). Of these 4 extra detections, 3 occurred at night (after 19:00) when listening intensity begins to fall off and 2 occurred when most U.S. listeners would be asleep (00:30-01:30). In two cases the automated detector failed when human listeners detected calls. Overall, combining both approaches, SRKW were detected 15 times (68%).

While this is a relatively high proportion of transits, one of the key benefits of the passive acoustic monitoring is that SRKW can be detected at night and use transit times to look for diurnal and tidal patterns in how these whales use Admiralty Inlet. Figure 32 below plots all available SRKW transit times in the period against the tidal phase and magnitude at the time (derived from xtides via http://www.dairiki.org/tides for the Admiralty Inlet station).

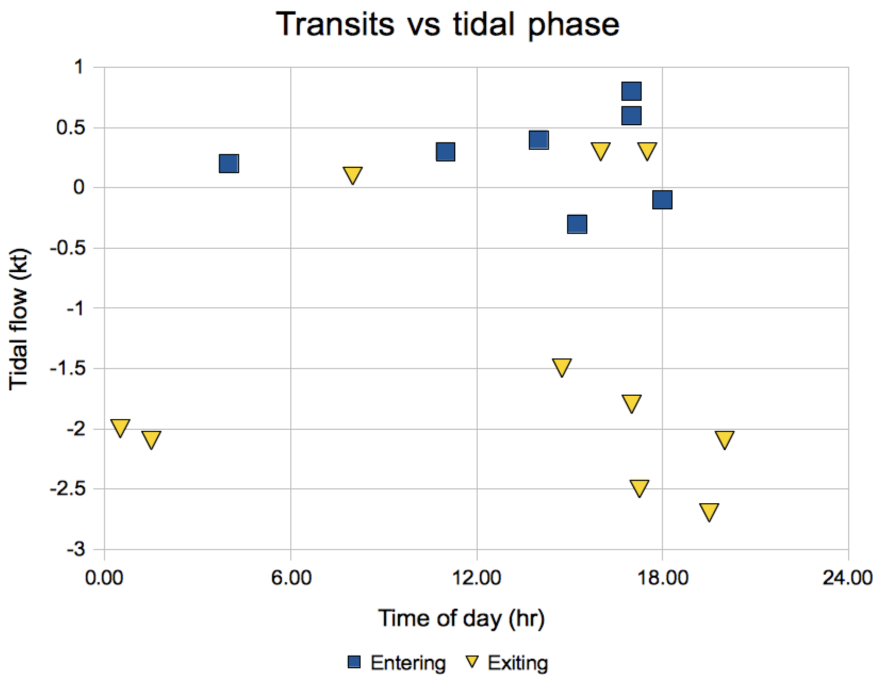
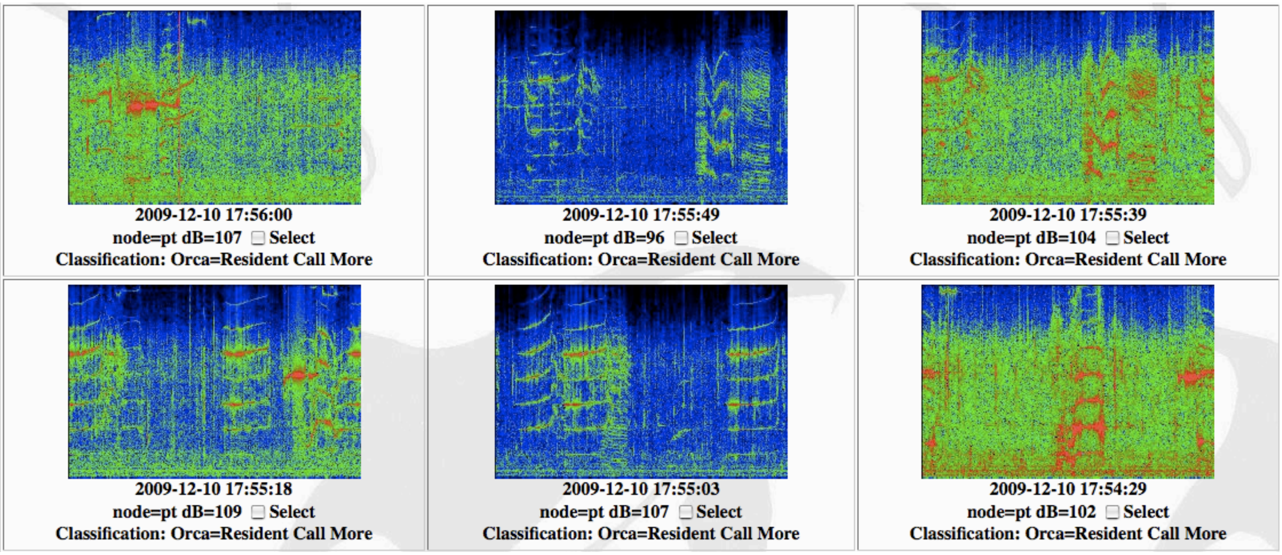


Figure 32. Timing of transits in hour of day versus the tidal flow in knots. We include only transits (10 exits; 7 entrances) for which the time of day (PDT) was unambiguous.

Visually it appears SRKW have a tendency to exit Admiralty Inlet most often on strong ebb tides, and less frequently on weak flood tides. They often entered the Inlet preferentially near slack tide. The distribution of transits over hour of day is relatively uniform for both entrances and exits, though no transits between 21:00 and 24:00 were observed.

Recordings made by the PAM system at Port Townsend during the study period were not analyzed in this study, but may prove useful if more detailed information was required on click and call rates. Recordings are publicly accessible via the Salish Sea Hydrophone Network http://www.orcasound.net/php_vv/WHO_dbViewerAnnotater_II.shtml and provide an interactive table of detections (see example Plate 2 below) where spectrograms can be viewed.



Pllate 2. Examples of SRKW spectrograms recorded by the PTMSC node.

4.7 Integrated studies

Porpoise represent a key prey item of transient killer whales; and porpoise detection by transient killer whales has a strong acoustic component. Given observed decreases in porpoise click detections from a T-POD located in Admiralty during the spring of 2010 (see Tollit et al. 2010) and the notable increase in transient killer whale sightings in the same period (Table 16), the two were plotted to highlight the possibility of some linkage. Also plotted are periods of SRKW sightings and days with periods of 3 hours or more of pile driving activity that took place at the Keystone ferry terminal (by WSDOT, Rick Huey, Pers. Comm.). We considered the results were indicative of a potential relationship between reduction in daily porpoise click detection and transient killer whale presence (Figure 33) and one that warrants continued data collection and finer scale analysis.

A ten year review of Orca Network spring SRKW sightings was collated by Beam Reach (Figure 34). The low number of SRKW sighting days in 2010 are clearly illustrated, with few sightings observed in March and April 2010. June data for 2010 has not been plotted.

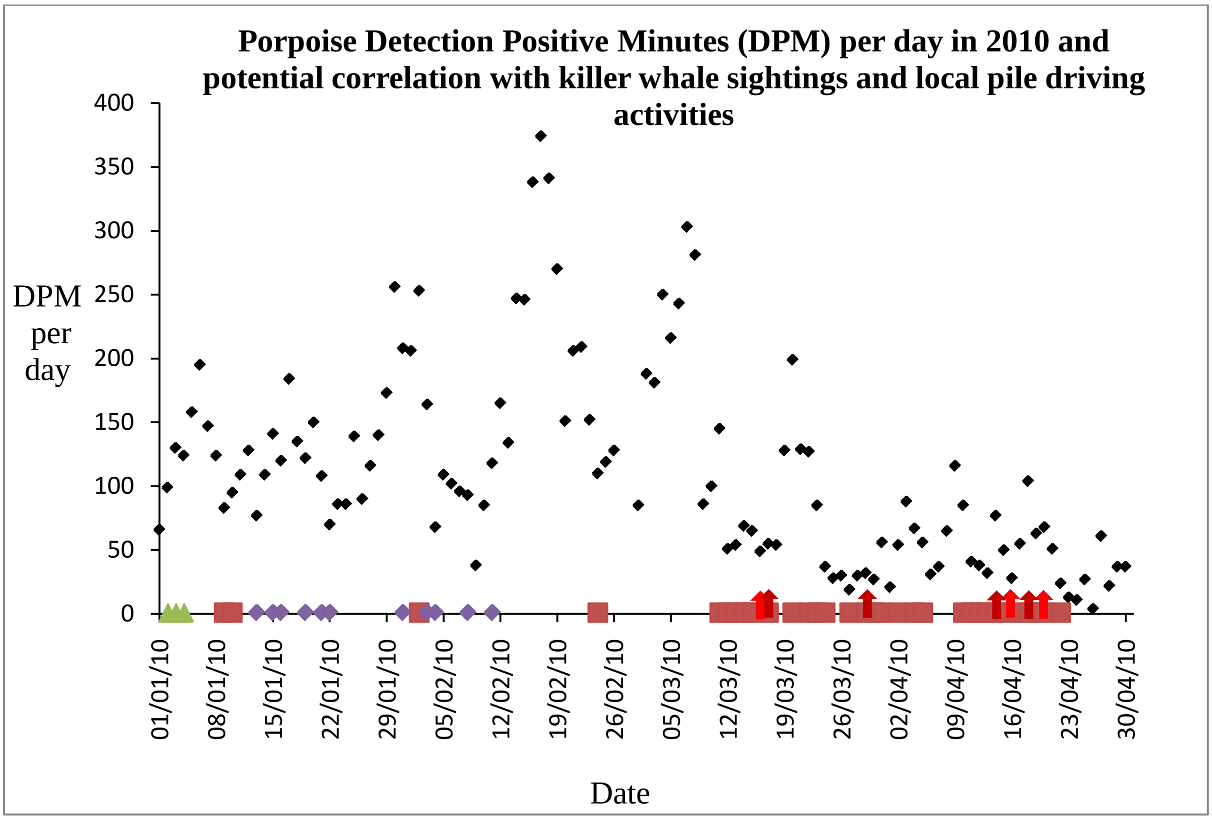


Figure 33. Porpoise daily detection positive minutes (DPM) in 2010 versus Puget Sound transient killer whale sightings in red with arrows depicting days with confirmed sightings in Admiralty Inlet. Also depicted are SRKW transit sightings (green triangles) and occasions with 3 hours or more of pile driving at Keystone carried out by WSDOT (purple diamonds).

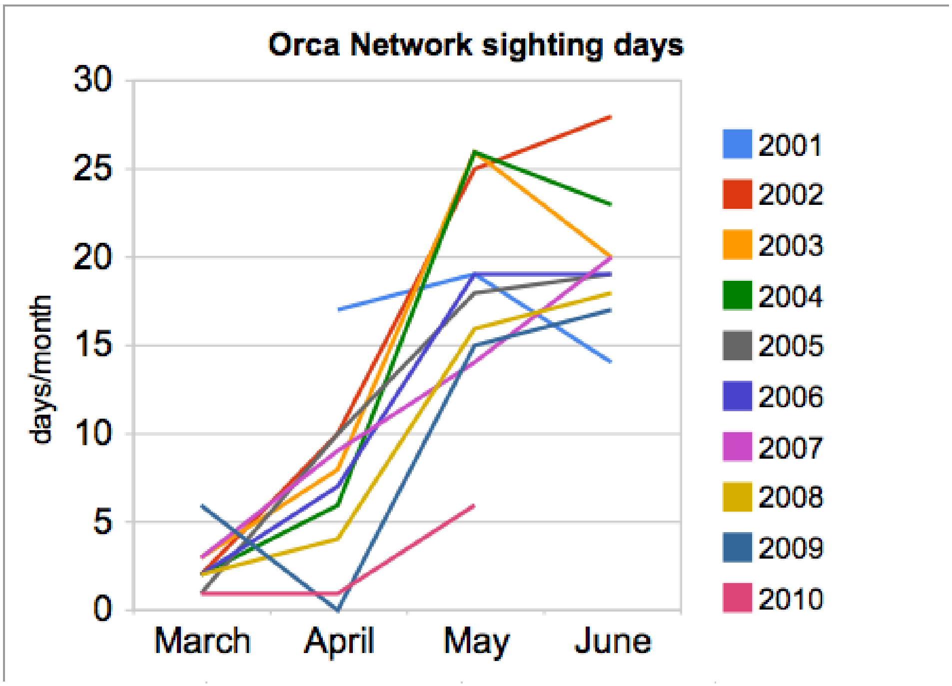


Figure 34. Spring sighting days of SRKW by year (sightings from Orca Network).

5.0 DISCUSSION

This study used opportunistic network sightings information and PAM to successfully collected new data on seven SRKW transits (of 22 estimated in total through the period) through Admiralty Inlet. In addition, a land based study overlooking the Project site collected 231 hours of marine mammal observer data across 116 days. A total of 13 fast land responses were made though the period to track killer whale movement, though no useful video footage of SRKW in the study area was collected. Six opportunistic sighting surveys and eight local haul-out counts were also completed, across a field season running from October 2 2009 to April 30 2010. We have attempted to condense the most relevant results as defined by our specific objectives, as well as put the study period into context in a regional review of integrated studies and observations. Further synthesis and interpretation of local marine mammal sightings by SMRU Ltd will continue under DOE 2009 funding to Snohomish PUD.

5.1 Southern Resident Killer Whales

<u>Objective a)</u> *Describe current SRKW transit patterns through the study area. Collect new information on number of transits through the area using scheduled land observations, land and boat-based volunteers and a review of Port Townsend hydrophone PAM data. This aims to provide up-to-date information on migratory movements and complement the historical review.* <u>Objective b)</u> *Describe current study area habitat use by individual pods, and whether foraging occurs in the vicinity of the Project, through the use of a fast response boat and land observations.*

Boat-based location data of the focal group of whales showed a wide use of the study area by the SRKW, travelling through the shipping lanes and generally west and southwest of the Project site (Figure 20). Because of the emphasis on focal groups, this map does not indicate the full extent of this habitat use by SRKW, just the use by the focal groups followed. Land based data provides a similar picture (Figure 25). All three southern resident pod matrilines were observed transiting the study area. During responses, J pod was observed on 6 occasions, K pod four times and L pod three times (only during October 2009). Additional J pod sightings were observed monthly in November through January, with K pod and L87 sighted additionally in early December. No SRKW sightings were seen in the Inlet from early January 2010 onwards. On October 21st, all three pods spent more than four hours in the study area, moving through the inlet to the north and then circling back for a double transit pass in one day. It is on this day that whales were observed foraging close (~275m) to the Project site (both by boat and land-based observers). The same approach was detected acoustically by the C-POD and by the PTMSC hydrophone. Four southward transits and two northward transits describe the remaining direction of pod movement during reponses.

In summary, during transits a total of 11.5 hours of focal sampling were conducted. During this time SRKW spent most of their time in the study area travelling (74%), however they also spent time foraging (21%) and socializing (5%). Foraging occurred on 6 of 7 focal follows across different parts of the five mile radius study area. For comparison Osborne (1986) reported foraging as the most common behavior (46%), travelling the next (27%) and then socializing (13%) during 967 hours of observations across five years (1976-1981) of all three pods. These are large differences in behavioral budgets. Osborne's (1986) data was focused on data collected around the San Juan Islands, but also included data from the Puget Sound so it is difficult to say if the differences are due to varied geographic usage, disparities in sample size, or disparities in coding of group behaviour (which can sometimes be subjective). Overall, the boat based focal follows show that SRKW utilized wide areas within the study area including the shipping lanes, most often travelling though also foraging and on one occasion observed foraging close (within a few hundred metres) of the proposed turbine site.

During land based observations both resident and transient killer whales ecotypes were observed during 3% of 1-hour survey blocks. Sightings of groups containing 2-20 SRKW were made on four days of land-based observation (including one 'fast' land response). SRKW land based sightings on October 10 and 20 2009 and December 6 2009 were recorded as generally beyond 2km from Fort Casey and >1km from the Project site, while the sightings on October 21st 2009 were again nearer to the observation site, southeast of the deployment site. The land based locations are considered less accurate than boat-based locations, but combined together these few days of observations reconfirm a wide use of the study area by SRKW mainly in the central north-south corridor (Figure 25).

Of the 22 times that SRKW transited the study area they were detected acoustically via the PTMSC hydrophone 14 times (64%) by the automated algorithm and 10 times (45%) by human listeners and overall, combining both approaches SRKW were detected 15 times (68%). Given that killer whales can remain silent for hours (often when resting and highlighted by the focal follow on October 10th 2009) and that larger noisier ships can mask distant or quieter vocalizations, acoustic monitoring detection rates of two thirds of estimated SRKW transits through Admiralty Inlet are considered high enough to be useful in future developments that may require automated advance warning systems. Although use of PAM for SRKW detection will always have some limitations, automated and human detection rates can be improved further through simple means: iterative testing and re-design of the automated triggering algorithms and global growth and education of the human listening network. The cabled hydrophone system at the Port Townsend Marine Science Center enabled detection of transits which would otherwise have gone undetected, including night time movements of SRKWs into Admiralty Inlet. If we assume our detection rate was constant throughout the study, then our in-situ PAM results suggest that SRKW vocalize at levels that are detectable from the shoreline during about half of their nighttime transits of Admiralty Inlet. The automated detectors caught half of the 8 nighttime transits, while humans only caught one. Further analysis of PAM recordings (automatically- or human-triggered) from the PTMSC hydrophone might prove useful in estimating detection ranges and describing click and call rates in the Inlet.

Based on a visual assessment of transit times, SRKW appear to exit Admiralty Inlet most often on strong ebb tides, and less frequently on weak flood tides. They enter the Inlet preferentially near slack tide. The distribution of transits over hour of day is relatively uniform for both entrances and exits, though we detected no transits between 21:00 and 24:00. A comparative review of historical trends in spring SRKW transits is detailed in section 5.2.

Objective c) *Describe vertical depth distribution of observed SRKW. Collect opportunistic dive depth information in the vicinity of the proposed installation site using a vertical hydrophone array.*

The vertical array was deployed and recordings taken during all seven transit days with a total recording time of 189 minutes (27% of the time spent collecting behavioral data). Of these 189 minutes, there were a total of 104 minutes with calls or clicks that were localized (55% of recording time). The percentage of minutes that SRKW vocalized during individual transits varied considerably from 92% of the time to 0 % of the time.

A total of 655 calls and clicks were localized at depths from the surface down to 142 meters; however 80% of the vocalizations were produced at depths of 30 meters or less, with little difference in average depth by behavior category. We note that localized calls were not always produced by the focal group of animals but potentially also by all the animals within a range thought to be of approximately one kilometer. However, given than there was over 90% correspondence between the behavior of the focal group and the pod in general, we suggest it may be reasonable to assume the focal group behavior was the same as those recorded acoustically. In comparison, Baird et al. (2003) found that on average the seven SRKW they tagged with depth recorders spent only 2.41% of their time at depths greater than 30 meters. If one assumes an even distribution of vocalization throughout depth, then the percentage of time we have documented SRKW at these depths is an order of magnitude higher than what Baird et al. reported. Differences are in part due to errors in array depth estimation (see below) but also that data sets are not easily directly comparable. We had 3 hours and 23 minutes of acoustic recording from all the whales within vocal range, while Baird et al. (2003) had 78 hours and 59 minutes of data from 7 individual whales. Clearly, location also differed across these two data sets. The depths they recorded were from whales in the eastern Juan de Fuca Strait, Haro Strait and Boundary Pass with typical bottom depths from 50 to 250 meters and with weaker tidal currents generally than Admiralty Inlet.

During the closest approach to the proposed project site (21 October 2009) while the focal group was categorized as foraging, depths from 23 to 58 meters were recorded from eight calls and clicks. Killer whale-like echolocation clicks during this transit were also recorded on the C-POD hydrophone deployed by the University of Washington (Tollit et al. 2010). Calls were also detected on multiple transits by the Loggerhead hydrophone (see Bassett 2010). This current study has shown there is great variability in the amount SRKWs vocalize when transiting through the study area (0-92% of recording time). Periods of little or no vocal activity were witnessed, most notably on October 10 2009 when the pods were described as undertaking slow (and considered resting) travel into Puget Sound.

Most acoustic localization software and the majority of published papers do not provide error estimates. We have aimed to validate our depth estimate results using implosive sound sources at known depths and incorporate error estimates into our decisions on which data to include. We estimate that our localizations were on average 13 meters deeper than the sound source for hand picked arrival times, but there was also a general trend of increasing accuracy with increasing depth. Depth estimates are therefore considered maximums. Errors for cross-correlated TOADs were more difficult to estimate since our sound source was implosive, but were no greater than 22 meters and are likely to be closer to those estimated for hand picked arrivals.

5.2 Other marine mammals and marine birds of importance

Objective a) *Estimate presence of other species of marine mammals in the study area. Collect incidental information on marine mammal presence during boat and land observation studies, to provide supplementary data to existing data, including presence/absence, relative use levels and group sizes across species in the vicinity of the Project site.*

During a seven month field study period beginning October 2 2009, at least seven species of marine mammal were recorded during 116 days of two hour long land-based observational periods at Fort Casey, providing a total of 2145 separate sighting locations. Good sighting conditions (Beaufort ≤ 3) existed for >90% of sightings and during these and indeed all surveys three species clearly dominated, making up >85% of all sightings. In good sighting conditions, harbor seals were observed in 87% of 1-hour survey analysis blocks, followed by harbor porpoise (56%) and Steller sea lions (47%). Though temporal and spatial variability was clearly documented statistically, these three species were regularly sighted throughout the whole study period and across the restricted study area (used for detailed site use analysis of these three key species and encompassing a zone radiating 1350m from the observation site. The Project site was estimated at ~850m from the observation site. Evidence of foraging activity was observed on occasions for all three key species. Interquartile ranges of group size estimates were 2-6 for harbor porpoises, 1-2 for Steller sea lions and 1-1 (single animals) for harbor seals. Overall, we consider these results indicate a subjective category of high relative use of the study area for all three species, with harbor porpoises area use considered overall most substantial, due to their consistently higher group size. Results from the specialized acoustic click detectors (PODs) appear to confirm high level of use by porpoise, with detections made on average in 16 different hours of each day and amounting to presence 9% of time on average or around two 2 hours in total (Tollit et al. 2010). We note for comparison, average boat survey densities of 1-1.5 animals/km^2 are reported regionally, with selection of habitat with high current speeds noted and abundances higher in the summer (Hall 2004). Clear diel patterns were recorded by the PODs with five times more minutes per hour of clicks detected at night compared to daylight hours. In comparison, no detections were made by PODs in 49% of all daylight hours – similar to the estimated hourly block presence values we found for porpoises during land-based observations (~56%).

Unknown porpoises and unknown sea lions were next most frequently sighted, followed by California sea lions (7%) and unknown pinnipeds. As a result, sighting frequencies for the three key species are considered lower limits. Interquartile ranges of group size were 1-1 for California sea lions, mainly in the latter part of the study period. Both resident and transient killer whales ecotypes were observed during 3% of 1-hour survey blocks, but we consider these estimates an overestimate, as timing of scheduled observation on days killer whales were sighted were not independently selected (i.e., killer whales were being tracked by fast response teams). Evidence of foraging activity was observed on one occasion for transient killer whales, with maximum group sizes of 5 observed. Minke whales were spotted on two occasions and a probable Dall's porpoise and hybrid porpoise on one occasion. These results indicate a category of low relative use of the study area for all species described above. We have assumed equal sighting likelihood across species in this assessment, but small pinnipeds and porpoises are considered less easy to sight.

Analysis of data from species with high relative use indicated clear seasonal and area use variability. Harbor seals were sighted more frequently on surveys in the middle of the study period, while Steller sea lions were sighted more frequently during first period surveys (October 2, 2009 to December 10, 2009), though a clear peak in sightings in mid-late December was noted. Harbor porpoises were sighted more frequently (74%) in the 'offshore' zone (between 350-1350m), whereas Steller sea lions were sighted more frequently (71%) in the 'inshore' zone (within 350m). Many Steller sea lions (and California sea lions) were observed very close to the shore (<150m). We have assumed equal sighting likelihood across zones for this analysis, but obviously this may introduce some small level of bias.

Generally, relative sighting rates were higher in the central two compass segments which include the zone in which the turbines are proposed to be deployed. This central tendency may, in part, reflect typical observer tendencies to cover central observation areas more effectively, but could also be partly due to sun glare on the water which occurred mainly in the southern sector (<170 degrees). Alternatively, this central area of the inlet may be a more profitable place to forage due to bio-physical factors. When only the offshore zone was considered in good sighting conditions, significant differences in sightings by compass segment were seen only for harbor seals and harbor porpoises (Table 8). Lower sighting rates were observed in the offshore compass segment <170 degrees for harbor seals, while in contrast lower sighting rates were observed in offshore compass segment >270 degrees for harbor porpoise. Thus, the segment containing the Project site showed no significant difference in sightings when compared to the other central segment or any clear evidence of being a particular marine mammal “hot-spot” within the zone. Overall, harbor seal sightings made up the clear majority of sightings in each compass segment and distance zone.

Across six 2nm opportunistic sighting surveys within the Study area between October and December 2009, sightings of harbor seal and Steller sea lions were made on three occasions, with a total of 5 harbor seals and 2 Steller sea lions observed overall. These results generally confirm land-based observer results.

<u>Objective b)</u> *Observe current usage of the nearest pinniped haul-out on Marrowstone Island by Steller sea lions (Eumetopias jubatus) and harbor seals (Phoca vitulina).*

Across eight opportunistic haul-out counts between October 2009 and early January 2010, sightings of Steller sea lions were made seven times. Numbers of Steller sea lions varied between 0-15. A single harbor seal was hauled-out nearby on one occasion.

<u>Objective c)</u> *Observe current presence of marbled murrelet in the study area.*

Across six 2nm opportunistic sighting surveys of the study area between October and December 2009, five marbled murrelets were sighted on just one occasion. The survey started ~7km SW of the Project site, on December 10 2009. A pair and three individuals were all sighted sitting on the water within a four minute interval (11:30-11:34). Sighting surveys start locations were randomized across the whole study area and not across the Project site – this is considered a study plan variance. Two surveys passed within 500m of the Project site.

5.3 Regional review and integrated studies

This study has taken place during the fall, winter and spring of 2009-2010 during a time when there have been some qualitative diversions from longer term trends. We have estimated at least 22 SKRW transits through Admiralty Inlet occurred between October and April. On two days a double transit occurred. A historical review estimated the mean number of transits for SRKW per year from July through June as 42 (min. 31, max 54) (Wood et al. 2009), with most occurring between fall and spring. Clearly there will be more transits before June and there were known transits before the study started. However the results from this year are considered at the low end of what had been estimated from the historical data set. This may be partly explained by transient killer whales being recorded in the historical data set, although every effort is made to avoid that. If we include the documented transient transits through Admiralty Inlet during this study (~10), we would be much closer to the number of transits predicted. Clearly accurate identification of ecotypes is difficult to achieve without good photographs and without doubt many network observers can not tell the difference by sight alone. The large group sizes of transients observed in spring 2010 also tend to prevent tentative ecotype classification on group size parameters.

This being said, it is clear that SRKW sightings have been low compared to long term trends during the past winter and spring. Typically, SRKW are sighted in the Salish Sea ~3 days per month in March, ~7 in April, and ~20 during May. This year they were only seen one day in March and April and only 6 days in May (Figure 33). In contrast, this spring has seen larger than usual numbers of transient killer whales and in much larger group sizes than normal. SRKW were observed rarely during the first quarter of 2010. Transits of Admiralty Inlet by SRKW stopped in early January and regional sightings of SRKW remained at near-record low levels through May, 2010. Additionally, the winter-spring transition was marked by a suite of atypical events.

First, on January 26th 2010, the oldest male southern resident whale known as J1 was twice heard calling out as he swam along the west side of San Juan Island. There was little acoustic evidence that other members his family, J pod, were nearby and visual scans by observers also suggested that J1 was separated from the rest of his pod.

Second, as detailed above sightings of SRKW through February, March, and April were patchy and infrequent. Not only were there no transits of SRKW through Admiralty Inlet during this period, but also no SRKW were observed anywhere during February. J pod was then heard (but not sighted) on March 5th 2010 at night. Shortly thereafter, around 3/11/2010, an unusual influx began of large (4-15+ member) groups of transients into Puget Sound. Also, it seemed that more grey whales were observed and were seen to also harass them this year in inland waters. In March and April, grey whales and Steller sea lions washed up on Salish Sea shorelines with surprising regularity, the latter often with evidence of blunt-force trauma. This study witnessed one predation event on a Steller sea lion within the study area. A notable drop in porpoise click detections was also observed in April by the POD hydrophones deployed in Admiralty Inlet. Pile driving operations also occurred intermittently at Keystone in late January and early February. It was not until April 30 - a record 56 days after the March 5th acoustic detection, that SRKW were again sighted in the inland waters of Washington and British Columbia.

Finally, preliminary official reports regarding the Columbia and Fraser River early run chinook salmon returns suggest one explanation for the rarity of SRKW sightings this spring. The Columbia was relatively strong and the Fraser return was considered very poor by local First Nations tribes, who voluntarily abstained from fishing for chinook from April-

June, 2010. It seems feasible the SRKWs spent proportionally more time on the outer coast where chinook populations were relatively high compared to previous years. Though they entered the Salish sea intermittently in April and May, presumably in pursuit of returning Fraser River chinook, they did so at low levels and exited again more quickly than might be expected based on past historical data. Together, perhaps these 'atypical' events best highlight the variation and complexity in how killer whales interact with their environment. Studies that involve safely tagging pod members provide one clear method to understand the wider interactions, while in addition to the methods used in this study, at finer scale, the use of faecal sampling and sonar and underwater cameras can be useful in describing behavior.

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8.0 APPENDIX

Appendix A. Fast land responses by Orca Network – summary information

DAY	MONTH	YEAR	TIME start	TIME end	VIDEO	SPECIES NAME	LOCATION	Boat follow?	TIME	Max #	ANIMAL BEHAVIOR	GROUP ACTIVITY	COMMENTS (including POD ID, key behavior info)
10	10	2009	1100	1700	no	Orca - SRs	Pt. Partridge, Ft. Ebey, to Ft. Casey	yes		30-40+			Went to Partridge Pt. & Ft. Ebey, to find the orcas from land, followed them so. to Ft. Casey State park, where we did 2 hr. scheduled obs
10	10	2009	1100	1700	no	Orca - SRs	Pt. Partridge, Ft. Ebey, to Ft. Casey	yes	1110	4-6	swimming E, then W		including 1 male, from Ft. Ebey State Park
10	10	2009	1100	1700	no	Orca - SRs	Pt. Partridge, Ft. Ebey, to Ft. Casey	yes	1129	6+	swimming S		including 3 males, N. of Pt. Partridge
10	10	2009	1100	1700	no	Orca - SRs	Pt. Partridge, Ft. Ebey, to Ft. Casey	yes	1150	30+	swimming S		at Partridge Bank - Ks & Ls?
10	10	2009	1100	1700	no		Pt. Partridge, Ft. Ebey, to Ft. Casey	yes					1230 - 1430 - See scheduled land observations from Ft. Casey State Park
10	10	2009	1100	1700	no	Orca - SRs	Pt. Partridge, Ft. Ebey, to Ft. Casey	yes	1535	10 - 15	swimming S	spread out, small groups	from Bush Pt. - orcas off S. end of Ft. Flagler
10	10	2009	1100	1700	no	Orca SRs	Pt. Partridge, Ft. Ebey, to Ft. Casey	yes	1600	10+	swimming S	more spread out groups	
10	10	2009	1100	1700	no	Orca SRs	Pt. Partridge, Ft. Ebey, to Ft.	yes	1602	10 - 15	swimming N		1st group turned & headed back NW, more

							Casey						orcas coming S from Ft. Flagler area
10	10	2009	1100	1700	no	Orca - SRs	Pt. Partridge, Ft. Ebey, to Ft. Casey	yes	1609	~6	swimming S		incl. 3 males,
10	10	2009	1100	1700	no	Orca SRs	Pt. Partridge, Ft. Ebey, to Ft. Casey	yes	1610 - 1650	30+	swimming	multidirectional	some foraging, still mainly heading S
10	10	2009	1100	1700	no	Orca - SRs	Pt. Partridge, Ft. Ebey, to Ft. Casey	yes	1655	~15	porpoising	SE, 40' from shore	Tight group made close pass by, 40' from shore, heading S fast
10	10	2009	1100	1700	no	Orca - SRs	Pt. Partridge, Ft. Ebey, to Ft. Casey	yes	1705	40+	swimming	S	All whales had passed Bush Pt., continuing S. Last report was off Skunk Bay at 1815.
10	10	2009	1100	1700	no		Pt. Partridge, Ft. Ebey, to Ft. Casey	yes					
20	10	2009	1000	1800	no	Orca - SRs	Pt. Partridge, Ft. Ebey, Ft. Casey	yes	1030 - 1420			milling	~1000, recd. word of orcas off Partridge Bank, but too fogged in to see from land. Sent 2 Email whale alerts, + recorded phone msg. updates to Whale list, coord. w/Erick on boat. Went to Pt. Partridge & Ft. Ebey to look for orcas in the afternoon.
20	10	2009	1000	1800	no	Orca - SRs	Pt. Partridge, Ft. Ebey, Ft. Casey	yes	1614 - 1814	40+			Did scheduled land observation from Ft. Casey - see data on Land Obs. sheet
20	10	2009	1000	1800	no		Pt. Partridge, Ft. Ebey, Ft. Casey	yes					
21	10	2009	1215	1830	no	Orca - SRs	Bush Pt, Ft. Casey, Lagoon Pt.	yes	1215 - 1330	30 - 40	foraging, lunging, tail-lobbing, calf	swimming, NW	920 rec. report of orcas off Edmonds. Sent out email & phone alerts,

											breaching		coord. w/boat crew. Went to Bush Pt. at 1215, found first orcas on other side of passage, crossing entrance to Hood Canal, heading NW.
21	10	2009	1215	1830	no	Orca - SRs	Bush Pt, Ft. Casey, Lagoon Pt.	yes	1345 - 1545	40+	swimming, hdg. NW	swimming, NW	Joined Jill Hein at Ft. Casey State Pk. for scheduled Land Obs, orcas off Ft. Flagler heading toward Ft. Casey when I arrived.
21	10	2009	1215	1830	no	Orca - SRs	Bush Pt, Ft. Casey, Lagoon Pt.	yes	1545 - 1700	40+	swimming, hdg NW		continued watching orcas past scheduled obs. time, from Ft. Casey.
21	10	2009	1215	1830	no	Orca - SRs	Bush Pt, Ft. Casey, Lagoon Pt.	yes	1630	40+	swimming, milling	direction changes	Orcas had nearly reached Partridge Pt, then 1 male turned back toward Pt. Wilson. Then several more, soon all had turned and were heading SE into Admiralty Inlet again.
21	10	2009	1215	1830	no	Orca - SRs	Bush Pt, Ft. Casey, Lagoon Pt.	yes	1700	40+	swimming	hdg. SE	Orcas traveling fast, SE on Pt. Townsend side.
21	10	2009	1215	1830	no	Orca - SRs	Bush Pt, Ft. Casey, Lagoon Pt.	yes	1800	40+	foraging, spyhops, tail lobs	swimming SE	Watched from Lagoon Pt, 1800 - 1830. Orcas continued south, a few direction changes, foraging, lunging, spyhops, etc.
21	10	2009	1215	1830	no	Orca SRs	Bush Pt, Ft. Casey, Lagoon Pt.	yes	1830	40+	swimming SE		whales had passed Lagoon Pt by 1830, it was getting dark. Last reports were off Bush Pt. at 7:30 - hdg. south as it

													turned dark.
12	11	2009	1335	1445	no	Orca SRs	Scatchet Head	by NOAA	1335 - 1445	20+	swimming So	spread out in small groups	Later IDs confirmed as J pod
24	11	2009	1315	1455	no	No orcas sighted	Lagoon Pt.	attempt made	1330 - 1340				
24	11	2009	1315	1455	no	No orcas sighted	Bush Pt.	attempt made	1340 - 1350				
24	11	2009	1315	1455	no	Orca - SRs	Scatchet Head	attempt made	1420 - 1455	6+	breaching, spouting	spread out, foraging, milling	Orcas were finally sighted between Pt. Wells and Shilshole Marina, and so distant we could not determine direction of travel or get further details. Other reports confirmed IDs (J pod) and direction of travel - south.
5	12	2009	1130	1240	no	Orca - SRs	S. Bush Pt	yes	1135	15+	swimming	heading north	Orcas sighted between the south end of Marrowstone Island and the entrance to Hood Canal, heading north. Several adult males were seen.
5	12	2009	1130	1240	no	Orca - SRs	Off SE Marrowstone Island	yes	1225	15+	swimming	milling, turning to head south	As the Orcas reached the SE side of Marrowstone, at around 12:25 pm, they turned and headed back south.
5	12	2009	1130	1300	no	Orca - SRs	Off entrance to Hood Canal	yes	1240	15+	swimming	continuing south	At entrance to Hood canal. Howie & Heins reached them at 1240, traveled south with them until 2 pm, left them just north of Double Bluff,

													Whidbey Island. ID photos obtained - J&K pods confirmed.
5	12	2009	1130	1300	no	Orca - SRs	S. Keystone Spit	yes	1145	2 - 4	spouts observed		Spouts were reportedly observed by Sandra & a group of birders off S. Keystone Spit. When Howie & Heins launched, around noon - Clarence Hein saw a spout between a tug & barge off Keystone, but as they scoured the area no other spouts or whales were seen - just porpoise. Erick & crew also looked in the area and never confirmed whales in this area at this time.
5	12	2009	1130	1300	no	Orca - SRs	Ft. Casey State Park	yes	1215 - 1240	2 - 6	spouts & fins observed	heading north	Sandra Pollard observed spouts & fins from Ft. Casey, just south of the PT/Keystone ferry lane.
6	12	2009	1505	1600	no	Orca - SRs	Ft. Casey State Park	yes	1505 - 1600	8+	swimming south	Orcas porpoisin g south fast	Orcas sighted between PTMSC and PT mill smokestack, heading south in the distance.
6	12	2009	1505	1600	no	Orca - SRs	Ft. Casey State Park	yes	1515	1	swimming south		
6	12	2009	1505	1600	no	Sea lion - Steller	Ft. Casey State Park	yes	1516	4	swimming, diving	tight group, then dispersed	We were there to watch the orcas, but these Stellers were right offshore, so took some photos & 1 reading on them
6	12	2009	1505	1600	no	Orca - SRs	Ft. Casey State Park	yes	1518	1	swimming	heading south fast	
6	1	2009	1505	1600	no	Orca -	Ft. Casey State	yes	1520	1	splashing	swimming	

	2					SRs	Park					south	
6	12	2009	1505	1600	no	Orca - SRs	Ft. Casey State Park	yes	1527	1 - 2	swimming	south fast	
6	12	2009	1505	1600	no	Orca - SRs	Ft. Casey State Park	yes	1530	1	swimming	south fast	
6	12	2009	1505	1600	no	Orca - SRs	Ft. Casey State Park	yes	1530	2	swimming	south Fast	
6	12	2009	1505	1600	no	Orca - SRs	Ft. Casey State Park	yes	1535	1	swimming	south fast	
6	12	2009	1630	1650	no	Orca - SRs	Lagoon Pt.	yes	1630 - 1650	3 - 5	swimming	south	swimming closer to the Whidbey side
7	12	2009	1015	1700	no	Orca - SRs	Double Bluff	yes	1255	12+	swimming	north	K pod & L87, closer to the Kitsap side
7	12	2009	1015	1700	no	Orca - SRs	Double Bluff	yes	1300	12+	swimming	north - off Pt. No Pt. Lighthous e	K pod & L87
7	12	2009	1015	1700	no	Orca - SRs	Mutiny Bay - Shoremeadow Rd.	yes	1330	12+	swimming	North - off Skunk Bay, Hansville	K pod & L 87
7	12	2009	1015	1700	no	Orca - SRs	Mutiny Bay - Shoremeadow Rd	yes	1410	12+	swimming	N - off Foulweat her bluff	K pod & L 87
7	12	2009	1015	1700	no	Orca - SRs	Bush Pt.	yes	1440	12+	swimming	N - S. of Marrowst one	K pod & L 87
7	12	2009	1015	1700	no	Orca - SRs	Bush Pt.	yes	1500	12+	swimming	off S. Marrowst one	K pod & L 87
7	12	2009	1015	1700	no	Orca - SRs	Bush Pt.	yes	1540	12+	swimming	so. of Ft. Flagler hdg N	K pod & L 87
7	12	2009	1015	1700	no	Orca - SRs	Lagoon Pt.	yes	1553	12+	swimming	N, between Lagoon Pt. & Ft Flagler,	K pod & L 87

7	12	2009	1015	1700	no	Orca - SRs	Lagoon Pt.	yes	1608	12+	swimming	some closer to whidbey foraging, hdg. N, spread out off Ft. Flagler	K pod & L 87
7	12	2009	1015	1700	no	Orca - SRs	Lagoon Pt.	yes	1620	12+	swimming	N, spread out between Admirals Cove & Ft. Flagler	K pod & L 87
8	12	2009	1000	1600	no	Orca - SRs	Double Bluff	None	1357	12+	swimming	NW off Pt. no Pt.	J & K pods, L87+?
8	12	2009	1000	1600	no	Orca - SRs	Double Bluff	None	1415	12+	swimming	NW, N. of Pt. no Pt	J & K pods, L87+?
8	12	2009	1000	1600	no	Orca - SRs	Shore Meadow Rd.	None	1440	6	swimming, foraging	South? off Foulweat her bluff	not sure of pod ID - stragglers, heading south to join J& Ks
8	12	2009	1000	1600	no	Orca - SRs	Shore Meadow Rd	None	1500	6	swimming, foraging	South? off Foulweat her bluff	not sure of pod ID - stragglers, heading south to join J& Ks
8	12	2009	1000	1600	no	Orca - SRs	Shore Meadow Rd.	None	1515	6	swimming	south, toward Hansville	not sure of pod ID - stragglers, heading south to join J& Ks
10	12	2009	830	1400	no	Orca - SRs	N. Mutiny Bay	Attempt made - SRKW turned S.	1000	12+	swimming, milling	N. of Pt. no point, possibly heading south	Pod IDd as Ks, plus likely Js
10	12	2009	830	1400	no	Orca - SRs	N. Mutiny Bay	Attempt made - SRKW turned S.	1020	12+	swimming, milling	S of Pt. No point, heading south	Pod IDd as Ks, plus likely Js
10	12	2009	830	1400	no	Orca - SRs	Admiralty Inlet	Attempt made -	1045	6	swimming, milling?	off Foulweat	Observed by Whidbey boat crew - then they

								SRKW turned S.				her Bluff	disappeared!
10	12	2009	830	1400	no	NA	Bush Pt.	Attempt made - SRKW turned S.	1200 - 1300	0			Continued looking for orcas N & S, boats came in when KWs went south.
12	12	2009	930	1530	YES	NA	Keystone boat ramp	yes	1000 - 1030	0			looked for orcas from Keystone, no sightings
12	12	2009	930	1530	YES	Orca - unknown	Ft. Casey State park	yes	10:45:00	5	milling		
12	12	2009	930	1530	YES	Orca - Transients	Ft. Casey State Park	yes	1108 - 1308				
12	12	2009	930	1530	YES	Orca - Transients	Ft. Casey State Park	yes	1310	5	off Ft. Flagler, thrashing, splashing,	swimming North	Pod had been identified as Transients by this time
12	12	2009	930	1530	YES	Orca - Transients	Ft. Casey State Park	yes	1312	5		NW of Ft. Flagler, splashing	Pod had been identified as Transients by this time
12	12	2009	930	1530	YES	Orca - Transients	Ft. Casey State Park	yes	1315 - 1324	5	milling	direction changes, swimming N& S, but generally N.	Pod had been identified as Transients by this time
12	12	2009	930	1530	YES	Orca - Transients	Ft. Casey State Park	yes	1327	5	swimming	heading S	Pod had been identified as Transients by this time
12	12	2009	930	1530	YES	Orca - Transients	Ft. Casey State Park	yes	1329	5	swimming	heading S, then N	Pod had been identified as Transients by this time
12	12	2009	930	1530	YES	Orca - Transients	Ft. Casey State Park	yes	1351	5	milling, heading N	bet. Ft.Flagler & Marrowst	Gray calf with the pod - same Transients as ID'd recently off Victoria - T36's, T68s & T137s

												one Pt.	
12	12	2009	930	1530	YES	Orca - Transients	Ft. Casey State Park	yes	1420	5	milling off Ft. Flagler		
12	12	2009	930	1530	YES	Orca - Transients	Ft. Casey State Park	yes	1515	5	milling in Pt.Townsend Bay		
18	12	2009	1020	1220	No	Orca - Transients	Ft. Casey State Park	No	1020 - 1220	4 - 7	swimming W from Pt. Wilson		We never found the orcas, but did the phone alert & worked w/Bob Whitney & Frank White to obtain their photos, identifying the pod as Transients, including T74.
22	12	2009	1340	1410	No	Orca - unknown	Ft Casey State Park	Yes - we ended scheduled obs.	1350	8+	swimming N	spread out	So. Resident orcas headed out of Puget Sound - .5 fast response phone alerts, stopped our scheduled observations when we saw distant spouts & a call to confirm orcas heading N. at Lagoon Pt, then met Roger at Keystone for boat response.
2	1	2010	1355	1645	No	Orca - SRs	Keystone boat launch area	yes	1355	6+	foraging	milling	
2	1	2010	1355	1645	No	Orca - SRs	Ft Casey State Park	yes	1405 - 1420		swimming	mainly So bound,	spread out bet. N. Marrowstone & mid-way to Lagoon Pt.
2	1	2010	1355	1645	No	Orca - SRs	Ft Casey State Park	yes	1440 - 1445	15 - 20	swimming So		all have passed Ft. Flagler; 2 - 3 adult males present
2	1	2010	1355	1645	No	Orca - SRs	Lagoon Pt.	yes	1505	20+	swimming S, tail lob	spread out	IDd as J pod
2	1	2010	1355	1645	No	Orca - SRs	Lagoon Pt	yes	1540	20+	swimming S, milling	spread out, 3	main movement continues to be

												turned N	southward
2	1	2010	1355	1645	No	Orca - SRs	Bush Pt.	yes	1615	20+	swimming S	spread out	
2	1	2010	1355	1645	No	Orca - SRs	Bush Pt	yes	1630	20+	swimming S	spread out	Trailers are approaching Foulweather Bluff
4	2	2010	915	1300	No	Orca - Transients	Marrowstone Island	No - ID'd as Transients	915	~3	swimming S		Observed & reported by Rick Huey, WSF from Marrowstone Island - orcas were mid-channel
4	2	2010	915	1300	YES	Orca - Transients	Bush Pt.	No - ID'd as Transients	1020	4	swimming S		mid-way down Marrowstone, 1 male, 2 females, 1 calf
4	2	2010	915	1300	No	Orca - Transients	Marrowstone Island	No - ID'd as Transients	1030	4 - 6	swimming S		Observed & reported by Rick Huey: heading past the Marrowstone Isl. haulout, closer to the east side of Admiralty Inlet.
4	2	2010	915	1300	YES	Orca - Transients	Bush Pt.	No - ID'd as Transients	1105	4 - 5	swimming S		past S. end of Marrowstone/Bush Pt - closer to the Whidbey Island side
4	2	2010	915	1300	YES	Orca - Transients	Bush Pt.	No - ID'd as Transients	1107	3+	swimming S		spotted more whales to the north, heading toward Bush Pt.
4	2	2010	915	1300	YES	Orca - Transients	Bush Pt.	No - ID'd as Transients	1115	6 - 7	circling	circling, foraging	just N. of Bush Pt. - this group appeared to be hunting (many porpoise & seals visible in the area)
4	2	2010	915	1300	YES	Orca - Transients	Bush Pt.	No - ID'd as Transients	1130	6+	swimming S		group from previous line passing Bush Pt.
4	2	2010	915	1300	YES	Orca - Transients	Bush Pt.	No - ID'd as Transie	1145	~6	swimming S	traveling in a resting	between Skunk Bay & Mutiny Bay

								nts				line	
4	2	2010	915	1300	YES	Orca - Transients	Bush Pt.	No - ID'd as Transients	1150	10+	swimming S	last group, off Foulweather Bluff	
4	2	2010	915	1300	YES	Orca - Transients	Bush Pt.	No - ID'd as Transients	1200	8+	swimming S	N. of Foulweather Bluff & entrance to Hood Canal	
4	2	2010	915	1300	YES	Orca - Transients	Bush Pt.	No - ID'd as Transients	1215	6+	swimming S	blows observed off Foulweather Bluff	Final count was at least 25 orcas traveling south. NOAA met up with the pod off Point No Point that afternoon, to confirm 27 Transients, photographed taking a Minke whale off Pt. No Pt. ID'd T-30's, T-86A's, T-87, T-88, T-90,T-90B, T-100's with new calf T-100E, T-101's with T-102, T-172, T-124A's with new calf T-124A4

Appendix B. Example of boat-based SRKW focal follow data sheet.

OBSERVER	RECORDER	DAY	MONTH	YEAR	WEATHER	VISIBILITY	PAGE NUMBER	ANY PICS OR VIDEO?	
TIME (Military)	MARK # (or lat long)	Number in Focal Group	DISTANCE (M)	COMPASS BEARING	FOCAL GROUP BEHAVIOR STATE	EVENTS INDICATIVE OF FORAGING (use ticks for multiple events)	POD ID/ ID NOTES	POD SPACING/ DISTANCE/ DIRECTION TO REST OF POD	POD ACTIVITY STATE

Rest: flank or non-linear orientation; directional; contact or tight distance; slow speed; high synchronicity; lack of percussive events
Travel: any orient. (oft. bunched); directional; any distance; slow, medium or fast speed (all same speed/direction); synchronous surfacing, esp. if male in matriline; no evidence of feeding
Forage: any orientation/direction/distance/speed; **lunge/chase events**. '**Victory' laps, sudden/successive dir. changes of individuals, steep dives, males away from group**.
'Play': Close physical interaction/manipulation of other whale or object (e.g. kelp).

Appendix C. Master table of southern resident killer whale transits of Admiralty Inlet during study period.

Notes:

1. Zeros indicate "no" while ones indicate "yes."
2. Grey shading indicates night-time transits when land- and boat-based responses were not possible.
3. Orange shading indicate strong evidence that SRKWs entered Puget Sound via Admiralty Inlet.
4. Pink shading indicates inferred entrances of SRKWs that were missed by both visual and acoustic detection systems.
5. We define a transit of Admiralty Inlet as any crossing (entrance or exit) of the line connecting Admiralty Head and Point Wilson.

Date	Approx. time	SRKWs exiting or entering Puget Sound?	Sounds detected by computer?	Sounds detected by human?	Boat response?	Behavior data in study area?	Acoustic data in study area?	Land response?	Land data?	Blog link
10/10/2009	11:00:00	Enter	1	0	1	1	1	1	1	http://aikws.blogspot.com/2009/10/first-entrance-in-fall-2009.html
10/11/2009										Many sightings in main basin of Puget Sound
10/12/2009	1:30:00	Exit	1	0	0	0	0	0	0	
10/20/2009	17:00:00	Enter	1	0	1	1	1	1	1	http://aikws.blogspot.com/2009/10/boat-response-day-2.html
10/21/2009	16:00:00	Quick exit	1	1	1	1	1	1	1	http://aikws.blogspot.com/2009/10/boat-response-day-3.html
10/21/2009	17:00:00	Enter	1	1	1	1	1	1	1	http://aikws.blogspot.com/2009/10/boat-response-day-3.html
10/22/2009										Many sightings in main basin of Puget Sound
10/22/2009	24:00:00	Exit (missed)	0	0	0	0	0	0	0	
11/12/2009	24:00:00	Enter (missed)	0	0	0	0	0	1	1	ON did fast land resp, but SRs were S. of study area
11/13/2009										Many sightings in main basin of Puget Sound
11/13/2009	19:30:00	Exit	1	0	0	0	0	0	0	
11/21/2009	0:00:00	Enter (missed)	0	0	0	0	0	0	0	
11/21/2009	0730-1630									Many sightings in main basin of Puget Sound
11/22/2009	0930-1500									Many sightings in main basin of Puget Sound
11/23/2009	0:30:00	Quick exit	1	0	0	0	0	0	0	
11/23/2009	0:30:00	Enter	1	0	0	0	0	0	0	
11/24/2009	14:20:00				1			1	1	ON did fast land resp. - found SRs So. of S. Whidbey, heading S.
11/24/2009	1020-1600									Many sightings in main basin of Puget Sound
11/25/2009	17:00:00	Exit	1	1	0	0	0	0	0	
12/4/2009	18:00:00	Enter	1	1	0	0	0			Likely an entrance because calls heard first at Orcasound, then Lime Kiln at dawn
12/5/2009	20:00:00	Exit	0	1	1	0	0	1	1	ON did boat response w/Hein's boat
12/6/2009	15:15:00	Enter	1	1	1	1	1	1	1	
12/7/2009	17:30:00	Quick exit	0	0	1	1	1	1	1	http://aikws.blogspot.com/2009/12/dec-7-boat-response.html
12/8/2009	4:00:00	Enter	1	0	0	0	0	1	1	
12/9/2009	0845-1600									Many sightings of J pod in main basin of Puget Sound
12/10/2009	17:15:00	Exit	1	1	1	0	0	1	1	ON did boat response w/Hein's boat
12/20/2009	?	Enter (missed)	0	0	0	0	0			
12/21/2009	1430-1625									1 sighting of 30+ orcas in south Puget Sound
12/22/2009	14:45:00	Exit	1	1	1	0	1	0	0	http://aikws.blogspot.com/2009/12/response-12-22-09.html
1/2/2010	14:00:00	Enter	0	1	1	1	1	1	1	http://aikws.blogspot.com/2010/01/january-2-2010.html
1/3/2010	1100-1600									Many sightings of J pod in main basin of Puget Sound
1/4/2010	8:00:00	Exit	0	1	0	0	0	0	0	
Totals		*22*	*14*	*10*	*11*	*7*	*8*	*12*	*12*	
Percent			*64%*	*45%*	*50%*	*32%*	*36%*	*55%*	*55%*	
Daytime totals		*14*	*11*	*10*	*10*	*8*	*9*	*10*	*10*	Total includes 12/20 entrance which may have been at night...
Percent			*79%*	*71%*	*71%*	*57%*	*64%*	*71%*	*71%*	
12/12/2009	15:00:00	Transients	0	0	1	1	1			http://aikws.blogspot.com/2009/12/t-pod-transients-in-admiralty-inlet.html
3/16/2010		Transients								
3/20/2010		Transients								
3/29/2010		Transients								
4/19/2010		Transients								

Appendix D. Start and end point latitudes and longitudes of randomised sighting surveys in the study area.

Date	Lat start	Long start	Lat end	Long end
10-Oct-09	48.14	-122.663	48.110	-122.641
24-Nov-09	48.13	-122.724	48.152	-122.686
05-Dec-09	48.112	-122.718	48.142	-122.739
10-Dec-09	48.108	-122.726	48.078	-122.750
12-Dec-09	48.102	-122.670	48.069	-122.668
22-Dec-09	48.161	-122.751	48.155	-122.686

Appendix L-8

Seafloor Substrate and Benthic Habitat Characterization of the SnoPUD Admiralty Inlet Pilot Tidal Project Turbine Site Through ROV Video Observations

Seafloor Substrate and Benthic Habitat Characterization of the SnoPUD Admiralty Inlet Pilot Tidal Project Turbine Site Through ROV Video Observations – A preliminary Report

1. Introduction

In preparation for the installation of tidal powered turbines to produce electrical energy from the northeastern part of Admiralty Inlet, offshore of Admiralty Head, a Remotely Operated Vehicle (ROV) survey was undertaken to characterize the benthic substrate and habitats of the site. This survey was undertaken at two separate times, the first during the middle of August 2010 and the second in late September 2010, in order to take advantage of tidal conditions with the least amount of exchange and velocity.

This report is based on the ROV observations made aboard the support vessel and barge using Global Diving's ROV *Seaeye Cougar-XT* and consequent video review collected during August 16 to 17 and September 29 to October 1, 2010. A separate report will be completed for the electrical transfer cable route to shore.

1.1. *Geology*

Admiralty Inlet is located in the northern Puget Sound region and is part of the Salish Sea. Geographically it lies between Admiralty Head of Widby Island and Port Townsend to the west. The region is located over the subducting Juan de Fuca Plate, the active convergent boundary between the Juan de Fuca and the North American plates, and is periodically subjected to earthquakes associated with the relative motion between the two plates.

During the Pleistocene the region was heavily glaciated with the ice sculpturing the terrain into its present landforms and depositing glacial materials as tills, moraines and outwash deposits. These deposits are today represented as coarse-grain, loosely consolidated, well-rounded, plutonic and metamorphic rocks plucked from the Cascades to the east and transported to the west by the glaciers. The coarse-grain constituents are composed of boulders or drop stones, cobbles and pebbles that melted from the ice as a heterogeneous material. Advance outwash deposits of arckosic sands and silts from the ice fronts spread out across the region during the Frazer Glaciation followed by recessional outwash deposits occurring during the Vashon Stade of the Fraser, ~15Ka. These recessional outwash materials have been deposited onto clays that were laid down along the northern edge of a fresh-water proglacial lake.

With glacial retreat and melting, sea level rise and strong tidal currents are now affecting the area where the glacial deposits have been winnowed of their fine-grain constituents leaving a coarse-grain lag in the form of a cobble, pebble and boulder pavement. Erosion of feeder banks and river input are now supplying fine-grain materials to the region.

2. Methodology

The *Seaeye Couger-XT* ROV (Fig. 1) is a moderate size (344 kg, 758.4 lbs) electric vehicle that can work at depths of 2000 m (6,562 ft) or less and obtain speeds up to 3.2 knots (nm/h [5.93 kph, 3.68 mph]). It is outfitted with two hydraulic manipulators, not used on these surveys, a pan and tilt video camera and 6000 W of lighting. For the work in August the tether was hand managed while for the work in September and October a tether management system (TMS) and an ROV garage was used to better manage the umbilical. Speed of the vehicle was kept to a knot or less for all transect runs. Stops during transects were kept at a minimum although unavoidable at certain times when bottom currents were strong or the tether was fouled. Occasional stops were made to better image a feature or organism of interest on the seafloor.

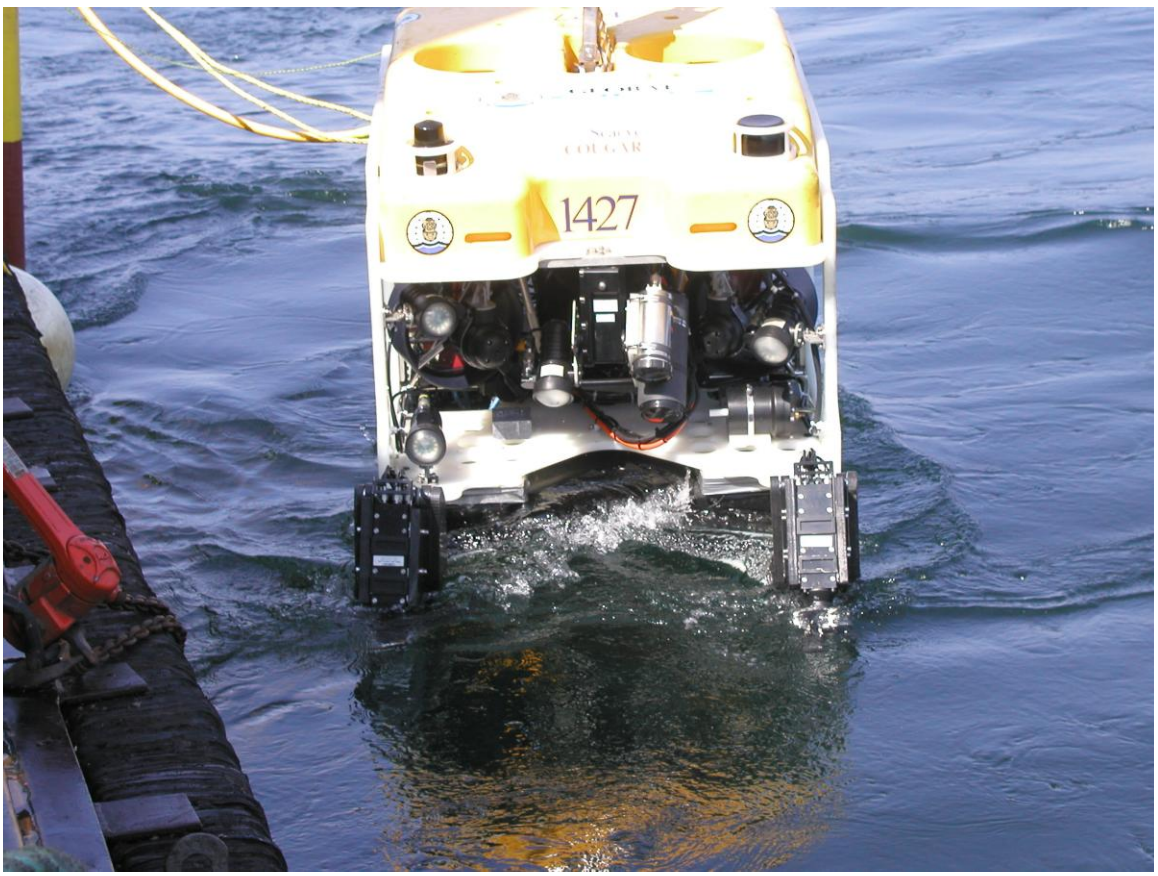

***Figure 1**. Seaeye Couger- XT ROV being lunched from a stationary barge at the SnoPUD turbine site. Lighting, camera, lasers and the two manipulators are visible. Note strong current, even though this operation is occurring at slack tide.*

The first attempt to collect ROV video at the SnoPUD tidal energy site was undertaken between August 16 and 17, 2010. Unfortunately the support vessel *Prudho Bay*, a converted LST, was too small for the tidal conditions and the anchors too light to keep the vessel in position and thus very limited observations could be done. Several transects were completed on August 18 but without onboard annotation of the video.

The second attempt to obtain video images of the seafloor within the SnoPUD tidal energy site was undertaken from aboard a large barge (Fig. 2) during the evening hours of September 29, 2010 after the barge supporting the ROV was properly anchored (see reports by McCallister, Sound and Sea Technologies). The second day of the operation, Thursday, September 30, was highly successful and the ROV performed well. However, on the third day, after the barge was positioned for the day's dives, the tether management system (TMS) aboard the ROV failed to operate and the day's dive delayed. On the fourth day the barge was re-positioned for the survey of the cable route (see Appendix I for onboard observational logs).

A total of 24 transects were observed and reported aboard the ROV support vessels. The, transects ranged in time from 3 minutes to 39 minutes with the average being about 16.5 minutes. Depth within the investigation area ranged from 55.8 m (183 ft) to 61 m (203 f), a range of 6.1 m (20 ft) with an average depth of 59 m (194 ft). All units provided in this report are given in units measured during the observations followed by conversion to metric or English system.

All video collected during the surveys were reviewed and annotated based on time and include both transects and transits to transects (all transits are labeled with a "T" prior to the line number, e.g, T-24, meaning transit to line 24). In other words, all video recorded was reviewed (see Appendix II for video review logs). Substrate and ecological conditions were observed and noted. Where possible counts of various organisms and fish were made and totaled to estimate relative percentages. A statistical analysis was not made.

The geologic and ecologic categories selected for this study include substrate type and biological organisms and assemblages observed or counted during the ROV dives. Substrate is divided into coarse-grain and fine-grain components with anomalous large-grain clasts such as boulders counted and observations of lightly encrusted or clean sediment type noted. The ecology is broken down to encrusting, attached, sessile, epifaunal, and fish types of organisms observed or counted.

2.1. Observations vs. Counts

Observations were noted when benthic characteristics changed or a particular substrate or biological assemblage dominated the seafloor for a considerable time during a transect or transit. The decision not to count such characteristics was made when it was apparent that a characteristic was ubiquitous or homogeneous throughout the investigation site. Therefore, noted observations are subjective, but when tallied can provide an estimate of relative abundances.

Figure 2. *Barge used in second attempt to collect ROV video of the SnoPUD turbine site. The ROV is housed in its garage beneath the tether management system under the launch and recovery block in the A-frame. Monitoring and control equipment is housed in the white shipping container to the left of the A-frame and one of the two green anchor winches used in positioning the barge through the four-point anchoring system is visible at left corner of the barge.*

Those characteristics selected for counting consist of distinct elements of the substrate such as boulders and those organisms that are not ubiquitous but were of significant quantity and definition to be counted such as anemones, various epifauna and fish. In this preliminary report common names of the organisms observed and counted are given – scientific names will be provided later, if possible, once expert biologists are contacted to view the organisms.

Both noted observations and counts were tallied and relative percentages of abundances are estimated for the various categories of substrate and organisms selected. Tables have been prepared and included in this report (Appendix III) to show where along a transect, or transit to a transect, various substrate type and biology occur based on time. Once a GIS project is established, spatial presentation of these conditions can be provided.

2.2. Difficulties Encountered

The investigation area, the tidal turbine site, is by necessity a highly dynamic and energetic environment subjected to strong tidal flows. Even though timing of the ROV surveys was selected to occur when tidal flow was comparatively low, the water mass at the site was always restless and very seldom was true slack experienced. Quite the contrary, strong currents often over a knot in speed were encountered and affected the smooth, trouble-free operation of the ROV. These strong current situations and the presence of occasional boulders on the seafloor prevented the ROV from flying along a transect at a constant uniform altitude resulting in the visual footprint constantly changing. Thus, the seafloor would range from out-of-focus to in-focus with the consequential varying detail and the fluctuating ability to identify benthic organisms.

Much time was spent untangling the tether when wrapped around boulders. Although moderate to large size boulders were rare they did occur in sufficient numbers to tangle the tether. These occurrences, while time consuming to remedy, often allowed for detailed inspection of the seafloor and the discovery of previously unseen organisms.

Visibility varied throughout the survey and the presence of marine snow often prevented good observation of the seafloor from much more than a meter above the bottom. The best observations were accomplished when the vehicle was either sitting on the bottom or less than 0.5 m above.

The recorded video is of less quality and resolution than the image displayed on the pilot's monitor while surveying. Therefore, it was more difficult to identify organisms using the recorded video than it was when observing the seafloor from the pilot's monitor.

2.3. Substrate Classification

Substrate as used in the context of this study follows the definition of Gary et al. (1974) where in an ecological context it is "the substance, base or nutrient (or medium) on which an organism lives and grows or the surface to which a fixed organism is attached, e.g. soil, rocks . . ."

Grain size, or clast sizes were measured using the laser scale attached to the ROV. Two red lasers spaced 10 cm (3.94 inches) apart and mounted in a parallel configuration to the camera housing provided a consistent and readable scale observable both in the pilot monitor and in the recorded video. The coarse grain size prevented any other way to obtain grain size measurement as no grab or dredge sampler would be able to collect a non-disturbed representative seafloor sample at the site. The only practical way to measure clast size is in situ observation using video.

The Wentworth Grade was modified for use in this study and is shown along with grain sizes and Phi scale in Table 1 below:

Wentworth Grade (modified)	Size Range (mm)	Size Range (cm)	Size Range (inches)	Phi Scale
Large Boulder (lgB)	>600 mm	>60 cm	26.3 inches	
Medium Boulder (mB)	400-600 mm	40-60 cm	15.8-26.3	
Small Boulder (smB)	256-400 mm	25.6-40 cm	10.1-15.8	<-8
Cobble (C)	64-256 mm	6.4-25.6 cm	2.5-10.1	-6
Pebble (P)	32-64 mm	3.2-6.4 cm	1.6-2.5	-5
Gravel (gr)	2-32 mm	0.2-3.2 cm	0.079-1.6	1 to -5
Sand - coarse (s)	0.5-2 mm	0.05-0.2 cm	0.020-0.079	0 to -1
Clay	<3.9micro m			>8

Table 1 *– Sediment grain size based on the Wentworth Scale modified for this study. Symbols in parentheses are codes used in the observational logs and tables (Appendix II and III).*

From a geologic perspective substrate is here divided into a coarse-grain component and a fine-grain component. The relative abundance of the grain sizes that represent a particular substrate type is based on the estimated percentage of grain sizes present at the time of the observation. For example, if a substrate type was comprised of three prominent clast sizes such as cobbles, pebbles and gravel where cobbles represent a third to a half of the clasts, pebbles represent less than a third and gravel is even less in abundance, then the call out for such a substrate would be C/P/gr in that order to indicate that the substrate is dominated by cobbles and pebbles with gravel being of tertiary importance. If, for example, only one constituent was present, such as cobbles, then the call out would be C/C indicating that both the primary and secondary sediment grain size are of the same clast size. Below are the sediment grain size combinations that are used to characterize the coarse –grain substrate types:

smB/C/P = small boulder/cobble/pebble
C/smB/P = cobble/small boulder/pebble
C/P/smB = cobble/pebble/small boulder
P/C/smB = pebble/cobble/small boulder
C/C = cobble/cobble (a single clast size)
C/P = cobble/pebble
P/C = pebble/cobble
lgB = large size boulder
mB = medium size boulder
smB = small size boulder

These grain size combinations are consistent with that used to describe marine benthic habitat characteristics by Lynch et al. (2004), Anderson and Yoklavich (2007), and Pacunski et al. (2008).

Below are the sediment grain size combinations that are used to characterize the fine-grain substrate types:

C/P/gr = cobble/pebble/gravel
P/C/gr = pebble/cobble/gravel
P/gr/C = pebble/gravel/cobble
gr/C/P = gravel/cobble/pebble
gr/P/C = gravel/pebble/cobble
gr/gr = gravel/gravel (single grain size)
s/s = sand/sand (single grain size)

2.4. Biology

The observed biology was divided into several different categories including the following, shown with the symbology used in the video logs and tables (see Appendices II and III):

Ubiquitous encrusting organisms – sponges, bryozoans and tubeworms (very seldom called out and no symbols (code) developed because these encrusting organisms were observed most everywhere, except in areas where lightly encrusted or clean substrate are noted. Four degrees of encrustation are noted:

1). Heavily encrusted (h/e) – approximately 80% or more of the substrate is encrusted
2). Moderately encrusted (m/e) – approximately 40-80% of substrate is encrusted
3). Lightly encrusted (l/e) – approximately less than 40% of substrate is encrusted
4). Clean – no apparent encrustation seen

Other encrusting organisms, both fauna and flora:

Barnacles
1). Single, often scattered barnacles – B
2). Clusters of barnacles – B(clust)
3). Fields of barnacles – B(lots)

Algae
1). Crinoid-like/filamentous (Cri/filiAlgae) – green feather-like stemmed algae
2). Algae – other types such as bladed algae

Attached organisms – anemones, five types based on color and patterns, and their state of feeding:

1). Purple/closed (p/c) – solid purple, no tentacles seen
2). Purple/open (p/o) – solid purple, tentacles seen
3). White/closed (w/c)- solid white or cream, no tentacles seen
4). White/open (w/o) – solid white or cream, tentacles seen
5). Stripped/closed (s/c) – pale purple with white stripes, no tentacles seen
6). Stripped/open (s/o) – pale purple with white stripes, tentacles seen
7). Pompom-like (pp) – anemone-like organism, may be a nudibranch
8). Anemone (A) – a different color (orange or yellow) or too obscure to identify color and pattern

Sessile organisms – those organisms that are fixed, sedentary or slightly mobile and consist of the following (no symbols constructed):

1). Stemmed or basket sponge – other than encrusting sponge
2). Tunicate
3). Chiton or limpid
4). Clams, living, open and closed

Primary Epifauna – mobile benthic organisms counted, including the following:

Starfish
- 1). Starfish – general five-legged, orange starfish (star)
- 2). Sun starfish – many legged sun starfish (sun)
- 3). Leather starfish – fat, leathery starfish (leath)

Urchins
- 1). Green urchin – U
- 2). Purple urchin – U(pur)

Other Epifauna
- 1). Turban snail (turb)
- 2). Hermit crab (no symbol)
- 3). Octopus (no symbol)
- 4). Crab (no symbol)
- 5). Shrimp (no symbol)

Fish – both pelagic and benthic fish counted include the following:

- 1). Ratfish (rat)
- 2). Sculpin (no symbol)

3). Lingcod (ling) – *Ophiodon elongatus*
4). Kelp greenling (kelp) – kelp cod or *Sebastes* spp.
5). Unidentified fish (UnIDfish) – generally goby-like with black and white stripes
6). Pacific sand lance (PSL) – *Ammodytes hexapterus*

3. Results

From the video observations substrate and habitat types of the SnoPUD turbine site were characterized based on the methodologies described above. The marine benthic habitat at the turbine site is primarily a cobble-pebble-boulder seafloor that provides substrate for encrusting and attached organisms (sponges, bryozoans, tube worms, anemones), as will as for various epifauna (starfish and urchins) and benthic fishes (primarily Sculpin, but some rockfish). Although probable that a considerably more diverse ecological system exists at the investigation site than is described here, the time and equipment required to comprehensively determine such a system was not practical as disturbance of the substrate would have been necessary. However, a good baseline is presented from which future observations and monitoring can be founded.

3.1. Substrate

The substrate that characterizes the SnoPUD turbine site is divided into a relative coarse-grain and fine-grain component with the coarse-grain component being the dominant one. The substrate types represented by three or less clast sizes based on how often noted from the video observations are here compared to each other. This method, although not statistically robust and somewhat subjective, is used to determine the predominant substrate types of the site.

3.1.1. Coarse-Grain Substrate Component

The coarse-grain substrate component is composed of four clast size combinations with the cobble-pebble-small boulder (C/P/smB) dominating at 57% (126 noted) followed by cobble-pebble (C/P) at 28% (62 noted), pebble-cobble (P/C) at 9%, pebble-cobble-small boulder (P/C/smB) at 4% (8 noted) and all others at 2% (4 noted) showing good observational correlations (Figs. 3 and 4). In addition, scattered boulders ranging from small to large were noted and found that the small boulders dominated (Fig. 5). See Appendices II and II for complete notations of the substrate based on the video review.

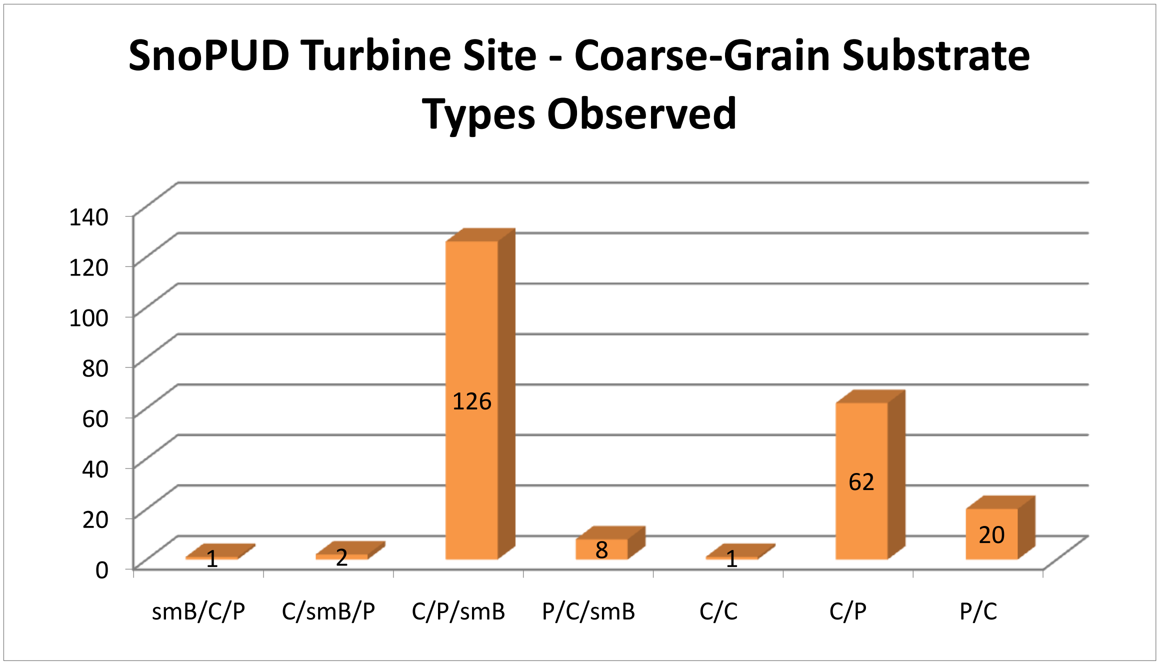

Figure 3. *Histogram of substrate types observed during the turbine site investigation. Numbers represent amount of times substrate type was observed and called out from the ROV video review.*

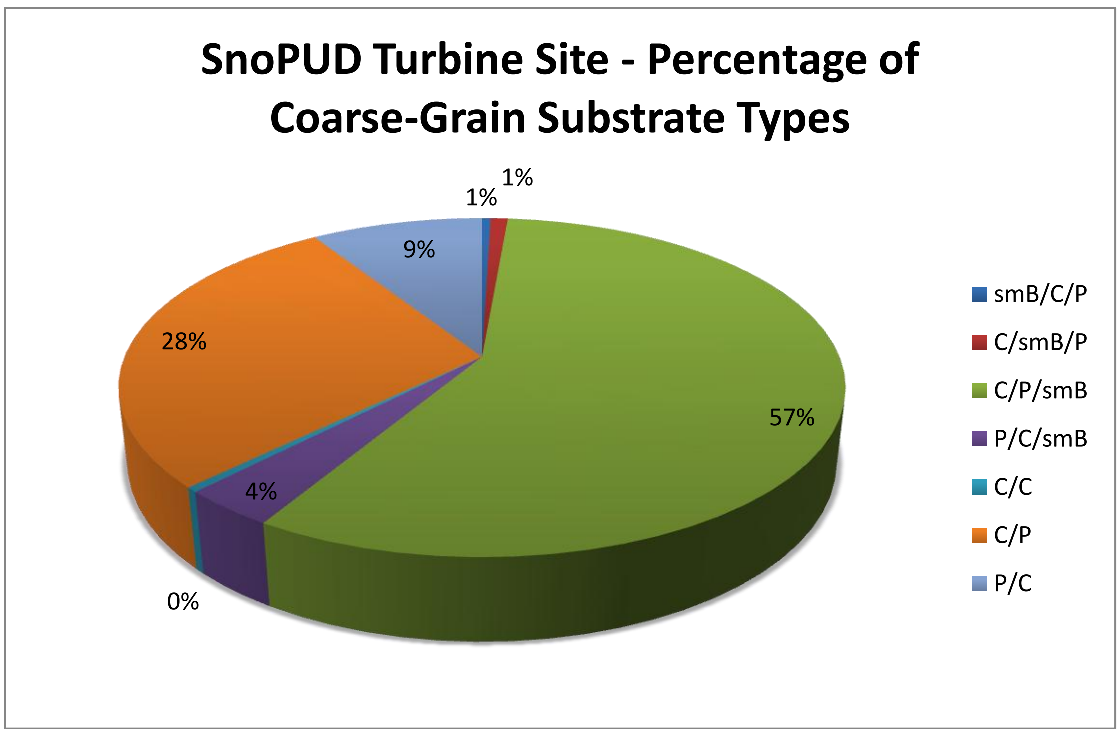

Figure 4. *Pie chart showing percentage of substrate types forming the benthic habitats of the turbine site with cobble-pebble-small boulders being the dominant form.*

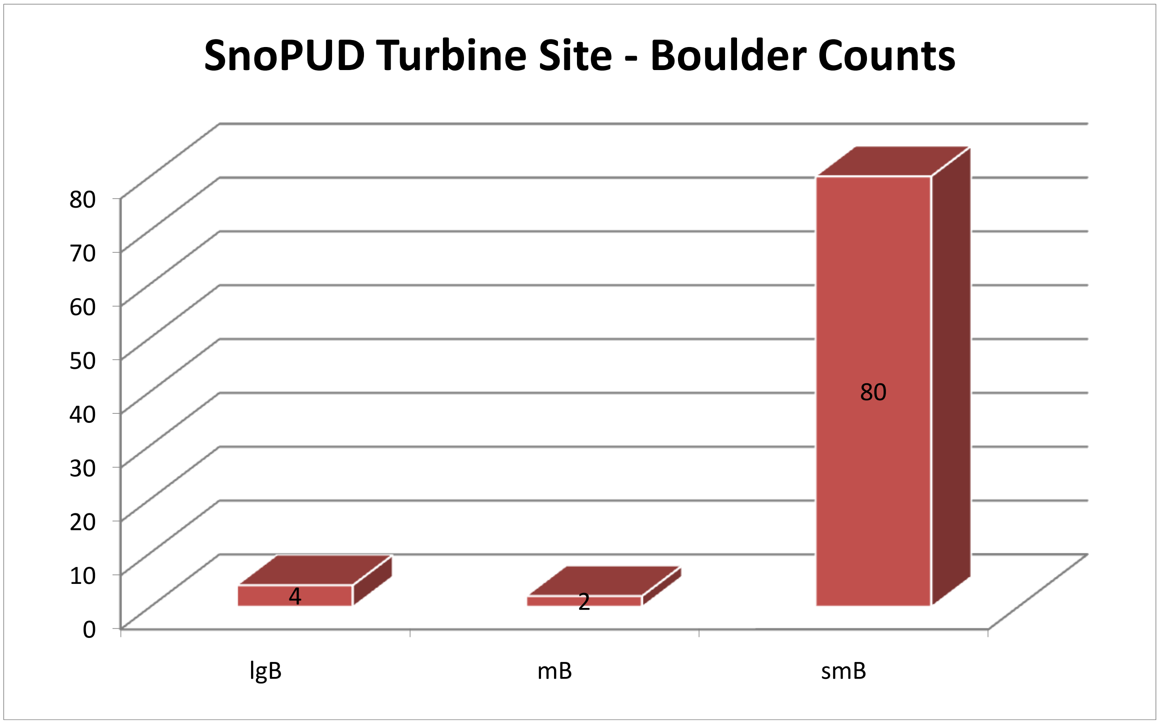

Figure 5. *Histogram showing numbers of boulder types observed in the video review. Small boulders are the most prominent of the scattered boulders observed.*

3.1.2. Fine-Grain Substrate Component

The relative fine-grain substrate is composed cobble-pebble-gravel (C/P/gr) at 34% (20 noted), pebble-cobble-gravel (P/C/gr) at 33% (19 noted), pebble-gravel-cobble (P/gr/C) at 24% (14 noted) and gravel-pebble-cobble (gr/P/C) at 9% (5 noted) with pebble-cobble-gravel and pebble-gravel-cobble being the dominant types (Figs. 6 and 7).

3.1.3. Combined Coarse-Grain and Fine-Grain Substrate Components

By combining the coarse-grain and fine-grain components it becomes apparent that the coarse-grain cobble-pebble-small boulder (C/P/smB) type is the most representative substrate of the turbine site as it represents the largest percentage grain size combinations at 45% while second most representative is cobble-pebble (C/P) at 22%, then pebble-cobble (P/C) at 7% and pebble-cobble-small boulder (P/C/smB) at 3% followed by the fine-grain constituents of cobble-pebble/gr (C/P/gr) and pebble-cobble-gravel (C/P/gr), both also at 7%, pebble-gravel-cobble at 5%, gravel-pebble-cobble at 2% and the rest at 1% or less (Fig. 8). Therefore, it can be confidently stated that the dominant substrate type at the turbine site is of a mixed cobble-pebble-small boulder and cobble-pebble clast size representing over two-thirds of the area investigated.

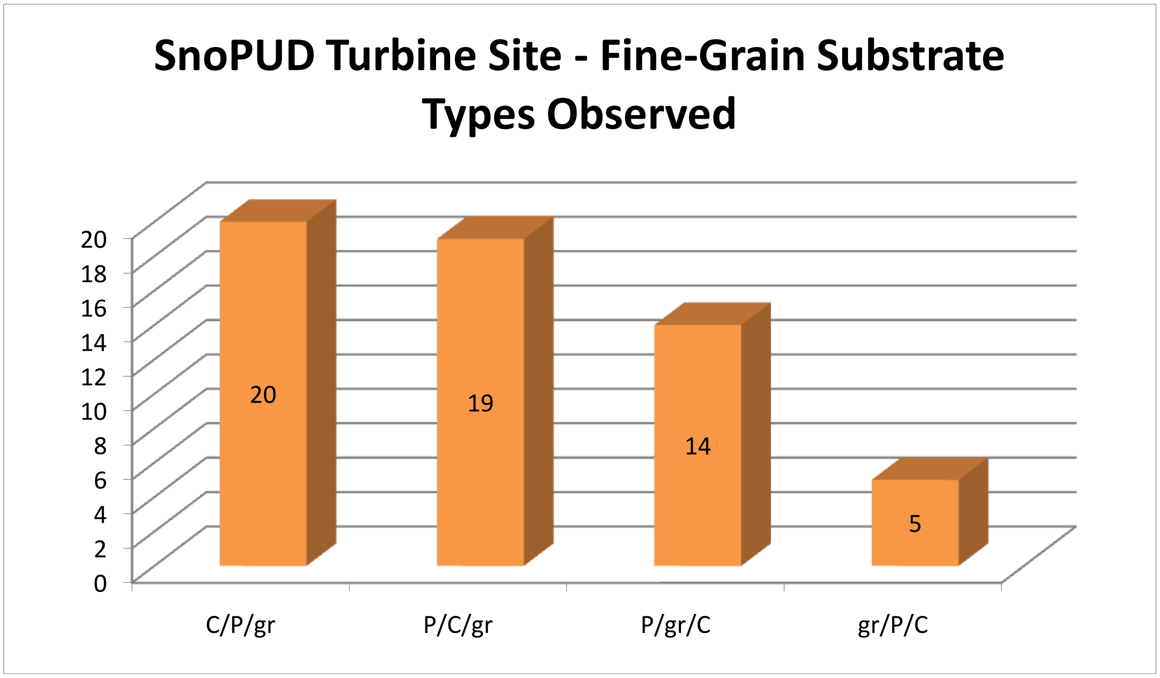

Figure 6. *Numbers of relative fine-grain substrate types noted during the video observations. Cobble-pebble-gravel and pebble-cobble gravel represent the dominant grain size.*

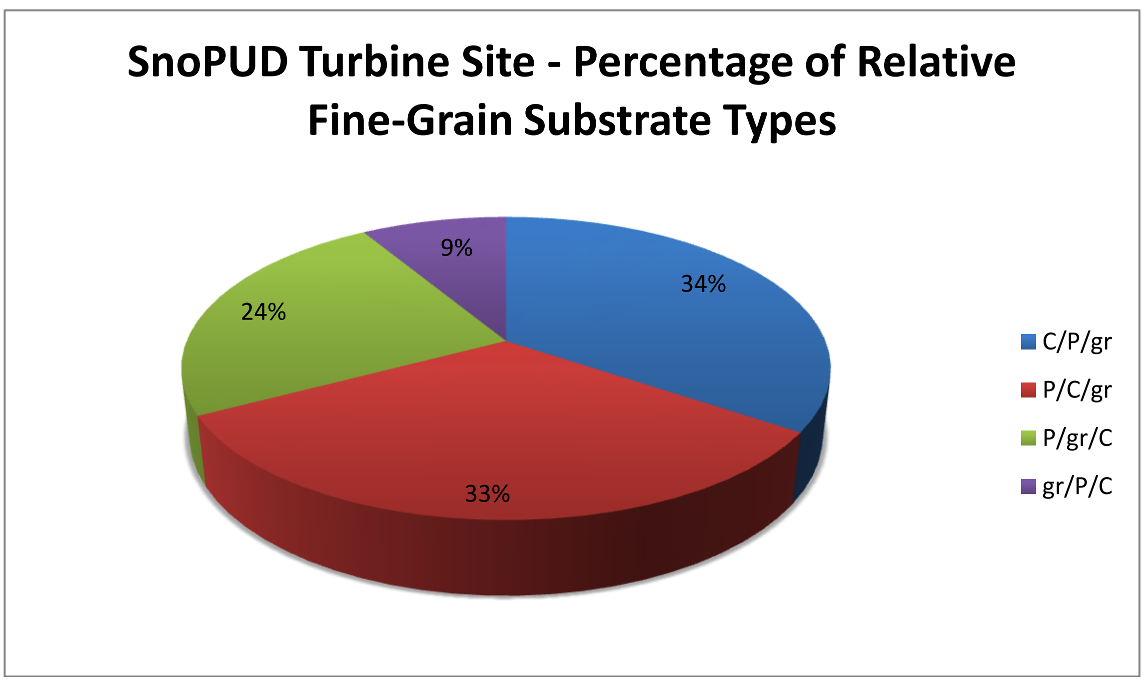

Figure 7. *Percentage of relative fine-grain sediment type observed in the video review. Cobble-pebble-gravel and pebble-cobble-gravel are equally represented and produce two-thirds of the fine-grain substrate types.*

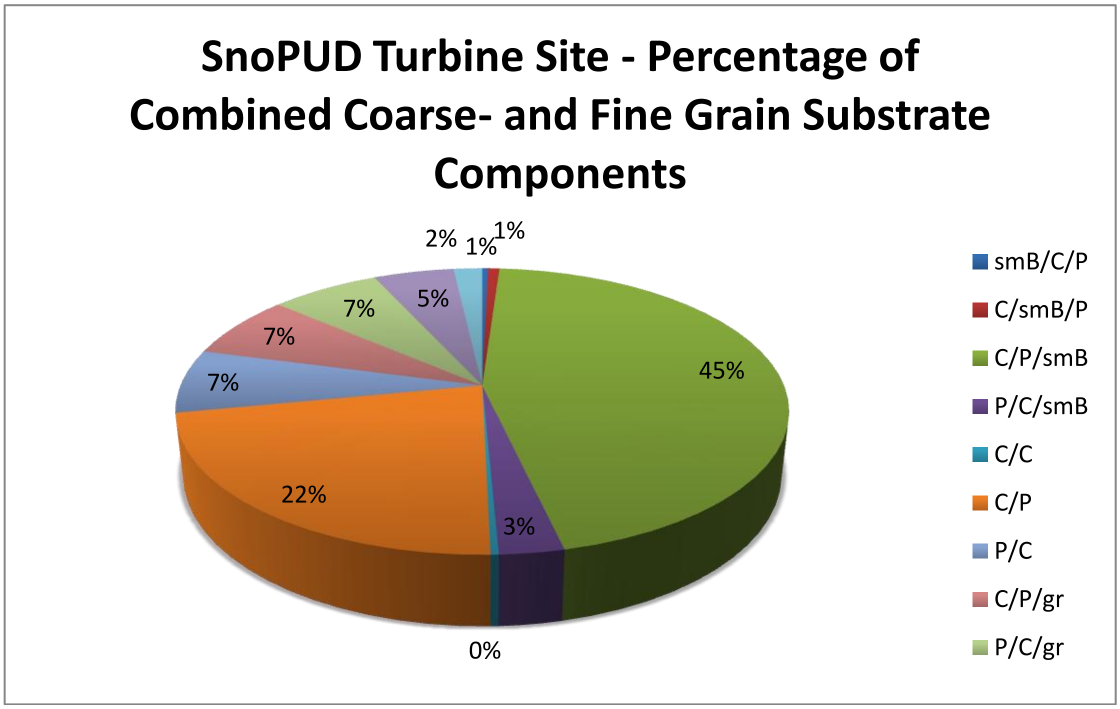

Figure 8. *Percentage of all substrate types observed from the ROV video indicating that the dominant substrate types consist of the cobble-pebble-small boulder and cobble-pebble clast sizes.*

Cobbles, pebbles and small boulders are all generally well rounded with an occasional clast being sub-rounded. These clasts are also heavily encrusted with the exception of in areas that have been noted as lightly encrusted or clean. The relatively finer-grained material such as gravel and sands that were rarely observed all generally appear clean and may represent the transport of sediment through the area. The dominant substrate is a lag deposit heavily winnowed from tidal current activity and represents a pavement where clast-to-clast contact exists and most fine-grain constituents have been removed.

The most diverse coarse-grain substrate types with varying grain sizes and patchiness exist along ROV transects 24S and 36N continued-2. For the fine-grain constituent the most diverse substrates are located along ROV transects 27S and 31S. (I cannot go further here until I see the navigation overlaid unto the bathymetry.)

3.2. *Biology*

The benthic biology of the turbine site in relation to the substrate is dominated with encrusting organisms, primarily sponge, bryozoans and tubeworms. These organisms are ubiquitous and, therefore, no attempt to count them was made. Relative cover of the substrate by these organisms was attempted by noting if an area along an ROV transect was heavily, moderately or lightly encrusted or clean. No statistical analysis was made as it was apparent that most of the substrate in the investigation site is heavily encrusted, especially on the coarser grain clasts such as boulders and cobbles. It appears that because of the strong bottom currents boulders and cobbles are the most stable, unmovable, clasts and thus are static enough for encrusting growth to occur. The finer grain constituents, small pebbles, gravel and sand are relatively easily moved by the currents and are, therefore, tumbling through the area (saltation) without being encrusted.

Other biological components, including encrusting organisms, both of fauna and flora, sessile organisms, epifauna (invertebrates), attached organisms, and fish were found in reasonable numbers to count. Selected organisms, such as anemones, starfish, urchins, and fish, were selected for counting while others, such as barnacles and algae, were noted but not comprehensively counted.

3.2.1. Selected Encrusting Organisms (Barnacles and Algae)

Barnacles and algae are prolific at the turbine site although there is patchiness to their distribution. In order to determine the amount of coverage that these organisms have they were noted in the video review in areas where they appeared to be concentrated; a direct count was not made.

Barnacles occurred as individuals, clusters and heavily concentrated in fields, lots of barnacles. Their concentrations were noted and show that at least 53% (166 notations) were made of individuals, B, while 28% (89 notations) for barnacle clusters, B(clust) and 19% for barnacle fields (59 notations), B(lots) were made (Fig. 9). This analysis basically suggests that most of the barnacles are scattered individuals while clusters and fields are less abundant (see Appendices II and III).

The algae community found at the site is composed of two basic types, a Crinoid-like or filamentous algae (Cri/filiAlgae) and bladed algae, (A). Similar to how the barnacles were assessed, algae were not counted, but notations were made where they seemed to be present in numbers that warranted mentioned (see Appendices II and III). From these notations it was found that the Crinoid-like or filamentous algae – no Crinoids are known to occur in Puget Sound – dominated the flora with 65% (106 notations) of the total and the remainder of the algae noted representing 35% (57 notations) of the total (Fig. 10).

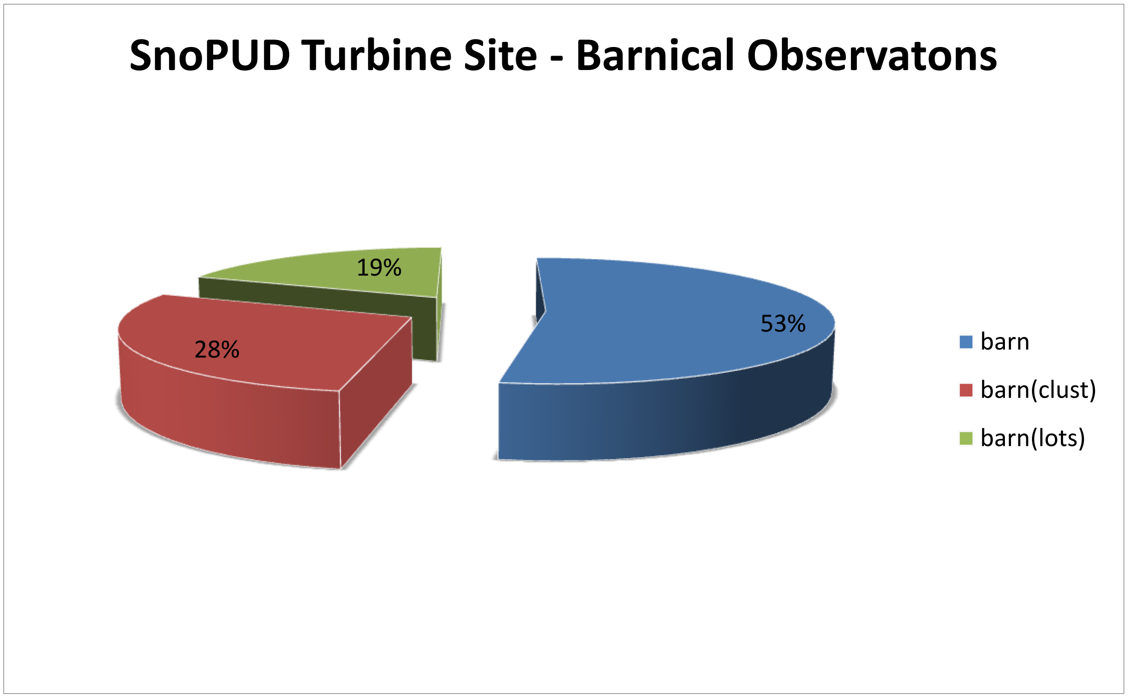

Figure 9. *Percentage of individual, barn, cluster, barn(clust) and highly concentrated or fields, barn(lots), of barnacles noted in the turbine site.*

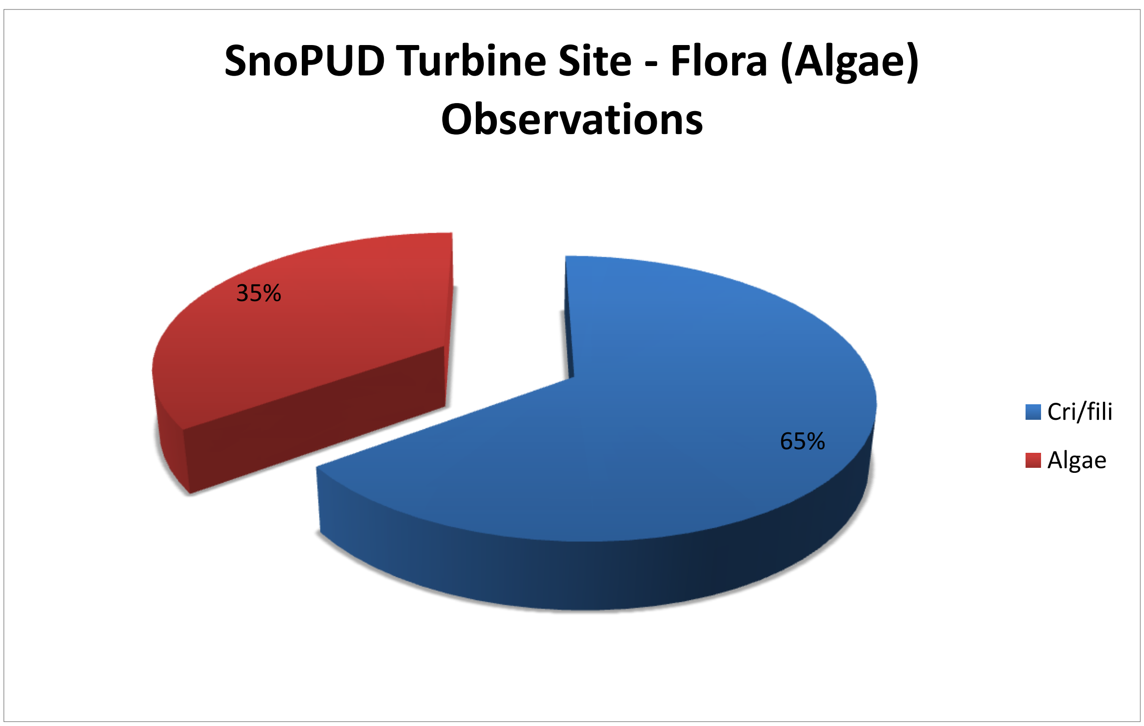

Figure 10. *Percentage of Crinoid-like or filamentous and bladed algae observed in the ROV video at the turbine site. The filamentous algae are the dominant form.*

The barnacles and algae were observed to be heavily concentrated along ROV transects 27S? (133 barnacle, 23 algae notations), 31S (251 barnacle, 17 algae notations), 36N continue (28 barnacle, 10 algae notations), and 31S (16 barnacle, 16 algae notations). Algae appeared to have a direct relationship with barnacles, as where large concentrations of barnacles occurred, such as clusters or in fields, a considerable amount of algae were attached to the barnacles (see Appendices II and III). The Crinoid-like or filamentous algae were observed attached to both barnacles and cobbles and boulders.

3.2.2 Attached Organisms (Anemones)

A variety of anemones were observed and counted in the turbine site. These organisms were relatively easy to identify and were generally solitary and thus easier to count than highly concentrated species. Three basic types were distinguished based on color and pattern (solid purple and white, and stripped white on purple) in addition to an orange or deep purple pompom-like anemone or nudibranch. Some anemones were not distinguishable enough to place into any of the above categories and, therefore, were just counted as an anemone (A). A total of 1,375 anemones were counted, a total of 1,869 if the pompom-like or nudibranch ones are included. In addition, the feeding state noted during the ROV survey indicated that most of the anemones were not feeding, but observations made during the time that tidal conditions changed from slack to flood, saw the anemones opening to feed (see Appendices II and III).

The most prolific anemones counted are the purple closed ones (p/c) at 49% (669 counts) followed by the white closed (w/c) at 23% (315 counted), purple open (p/o) at 12% (166 counted), anemones, general (A), at 9% (119 counts), stripped closed (s/c) at 6% (87 counts), white open (w/o) at 1% (15 counts) and stripped open (s/o) at >1% (4 counts), excluding the pompom-like organisms (Fig. 11).

If the pompom-like or nudibranch are included in the anemone count the purple (p/c) closed anemones still dominate at 36%, but the pompom-like or nudibranchs (pp) are found to be second in abundance at 26% followed by white closed (w/c) at 17%, purple open (p/o) at 9%, general anemones (A) at 6%, stripped closed (s/c) at 5%, white open (w/o) at 1% and stripped open (s/o) at >1% (Fig. 12).

The anemones varied in size ranging from ~4 cm to 12 cm in diameter when closed; the diameter of their stock or trunk (see Appendices II and III). The size is pretty uniform and small, probably because if larger they would provide a greater surface area to the currents and thus prone to displacement by the tidal currents.

The anemones appeared to be concentrated along specific ROV transects. The transects where these organisms were most prolific are 31S (140 counts, 183 if pp counted), 34N (99 counts, 142 if pp counted), 24S (120 counts, 160 if pp counted), and 36N continued (141 counts, 179 if pp counted).

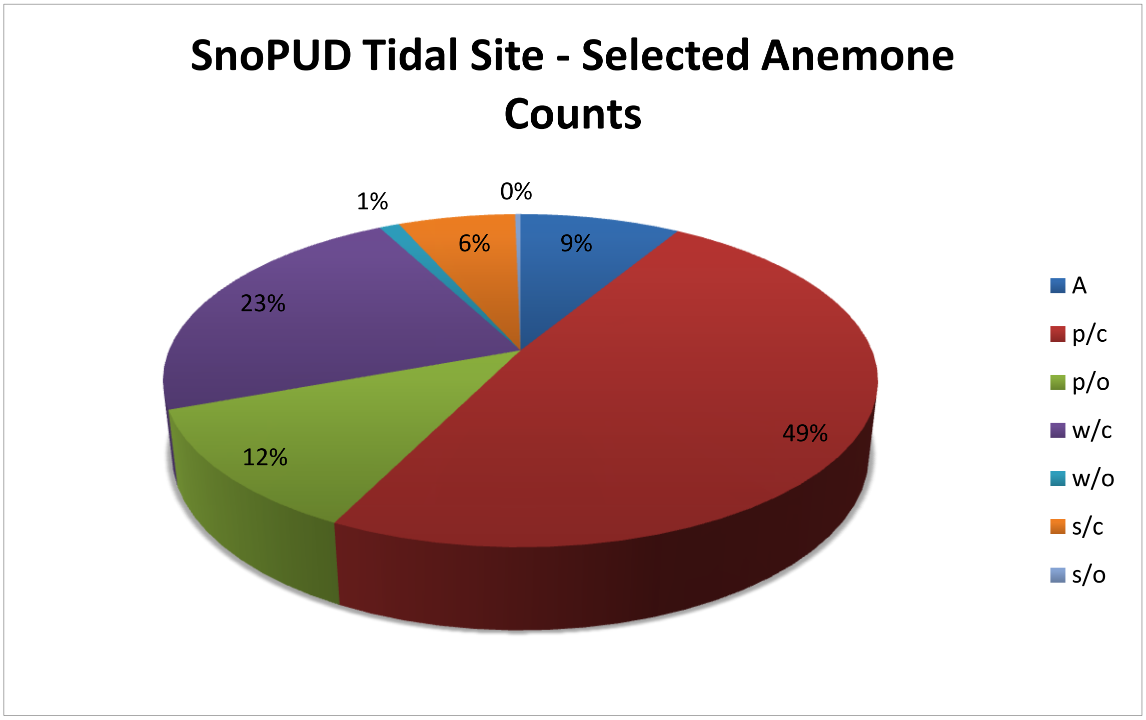

Figure 11. *Percentage of anemones counted from the ROV video. A = anemone, general, p/c = purple closed, p/o = purple open, w/c = white closed, w/o = white open, s/c = stripped closed, and s/o = stripped open anemones. The dominant type of nearly 50% is the purple closed anemone.*

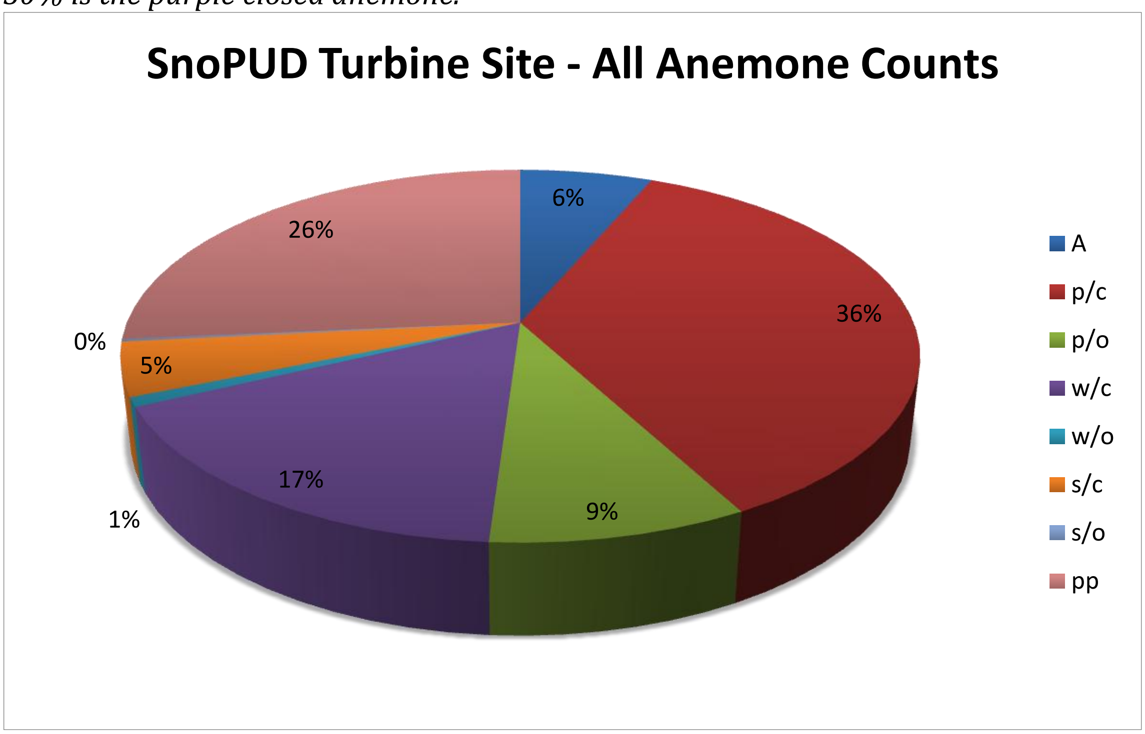

Figure 12. *Percentage of anemones counted in the ROV video including the pompom-like or nudibranch (pp) form. Purple closed anemone still out numbers all others.*

3.2.3 Sessile Organisms

Organisms included in this group are tunicate, chiton or limpid, and stemmed or basket sponge, as well as clams. Although observed in few numbers, these organisms were counted to obtain an estimate of their quantity. Chitons or limpids are the dominant organism of this group at 44% (7 counts) followed by tunicates at 37% (6 counts) and stemmed and basket sponges at 19% (3 counts) (Fig. 13).

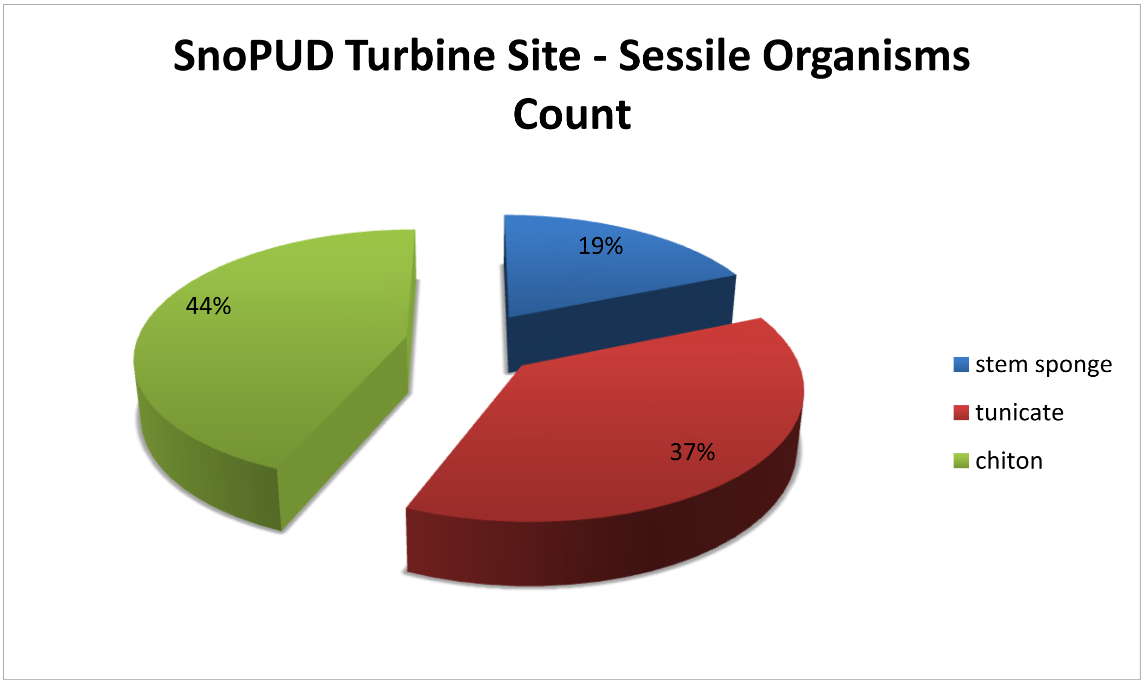

Figure 13. *Percentage of selected sessile organisms counted using the ROV video. Although small in numbers these sessile organisms provide an estimate of abundances based on what could be seen using the video.*

Clams observed in the ROV video were either partially open or closed, where 82% (23 counts) were open and 18% (5 counts) were closed (Fig. 14). If the clams are included with the other sessile organisms counted, closed clams dominate at 52%, chitons or limpids represent 16%, tunicates 14%, open clams 11%, and stemmed or basket sponges 7% of all sessile organisms counted (Fig. 15).

Open clams are the dominant species of the sessile organisms counted. These organisms were found to be most prolific along ROV transects 34N (3 counts), T-24S (4 counts), and 24S (6 counts).

For a complete run-down on the sessile organisms count see Appendices II and III.

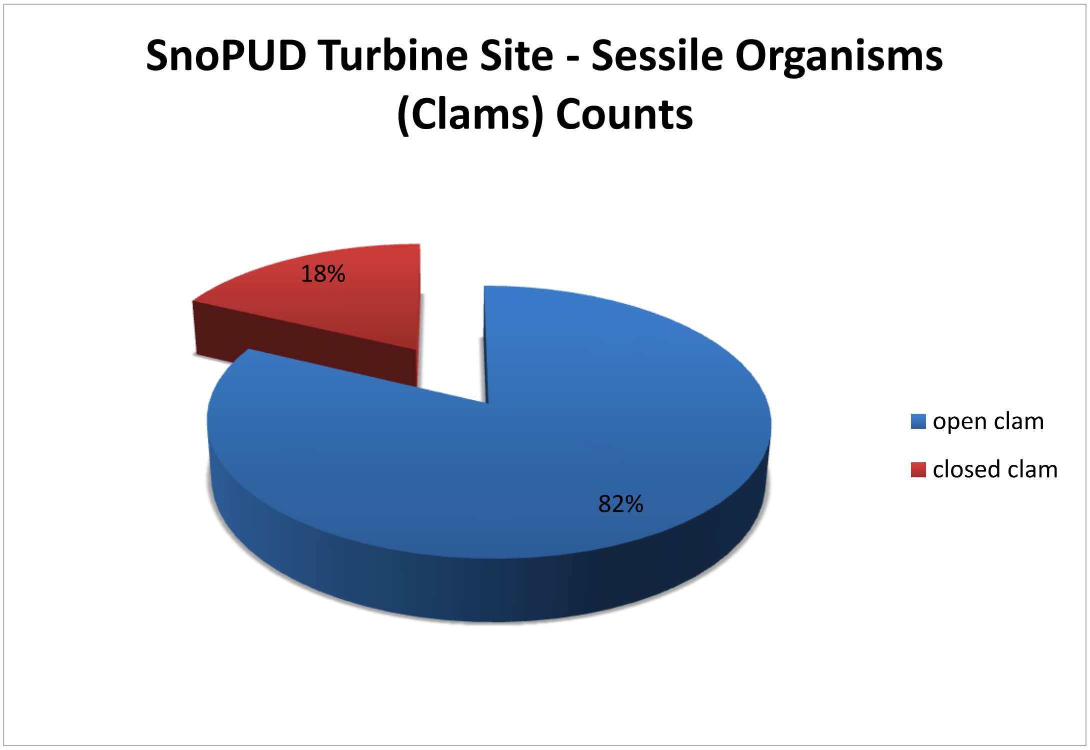

Figure 14. *Percentage of clams counted from the ROV video.*

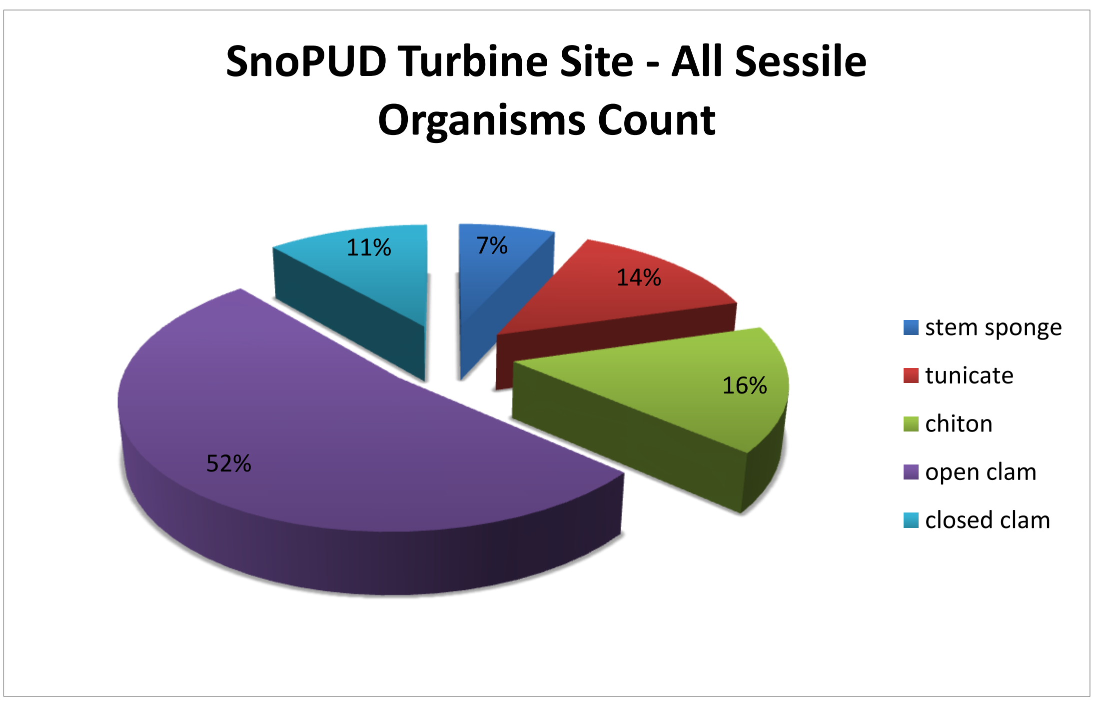

Figure 15. *Percentage of sessile organisms counted from the ROV video review including clams. Open clams dominate the group with 52%.*

3.2.4. Epifauna

The epifauna selected for counting consist of two groups, starfish and urchins. The first group, starfish, consists of three different types, general five-legged, orange starfish, sun starfish, and leather starfish. Two types of urchins were counted including green(?) urchin and purple urchin. Each group was compared independently and then combined to determine the overall relative abundance of each species.

Of the 134 starfish counted 89% (119 counts) of them were of the common type, 9% (12 counts) were sun stars, and 2% (3 counts) were leather stars (Fig. 16).

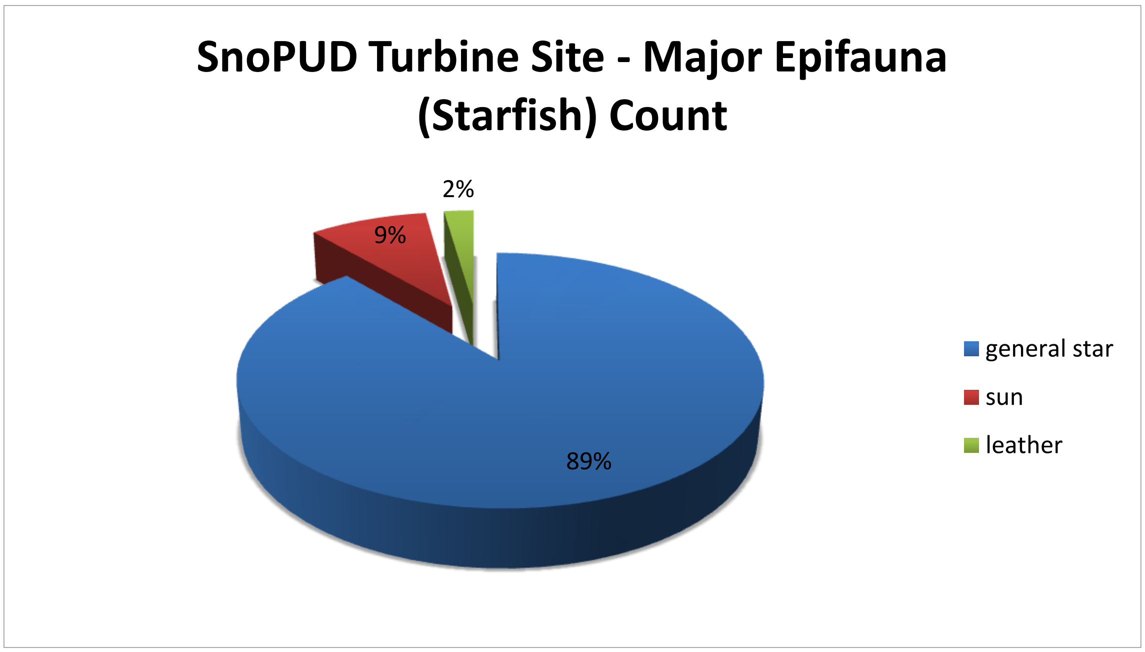

Figure 16. *Percentage of various starfish counted using the ROV video. The common general, five-legged orange starfish dominates the group with nearly 90% abundance.*

Urchins are the other epifauna group counted from the ROV video. The two types of urchins, green(?) and purple urchins, were compared to each other and it was found that the green urchin, U, represents 98% (239 counts) of the total compared to the purple urchin U(pur) or 2% (6 counts) of the total (Fig. 17).

The starfish and urchins were combined to be compared as a single group and it was found that out of a total of 242 counts the green(?) urchin comprised 63% of the group while the common starfish represents 31% with the sun star representing 3%, the purple urchin 2% and the leather star less than 1% (Fig. 18).

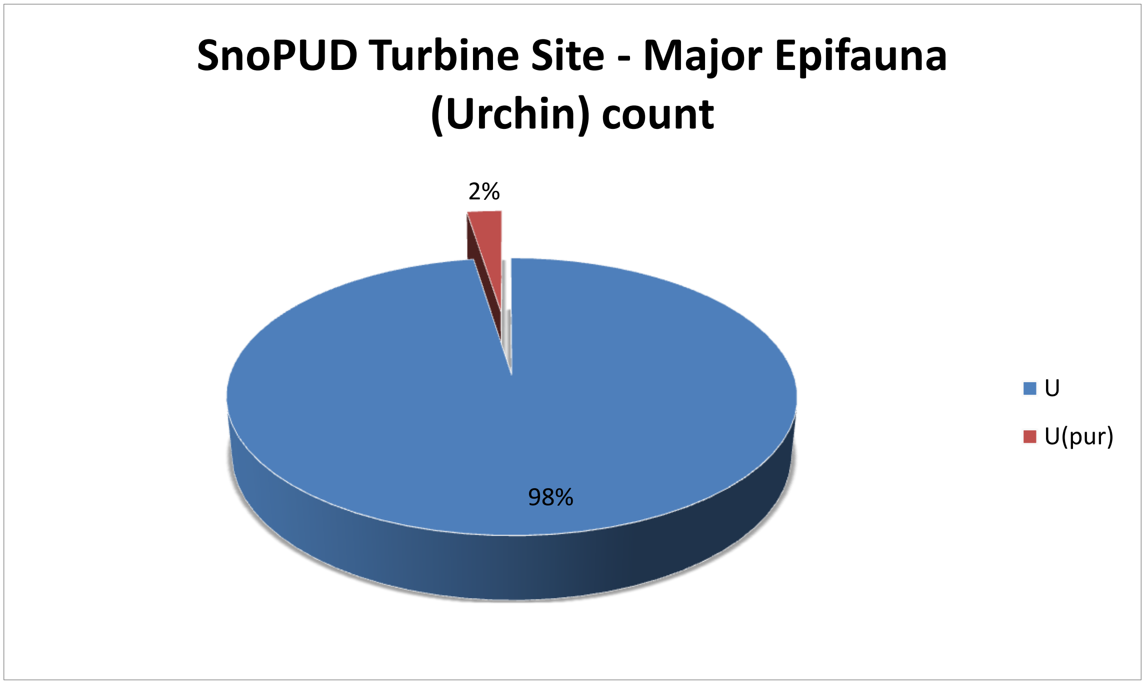

Figure 17. *Percentage of green(?), U, and purple, U(pur), urchins counted from the ROV video review.*

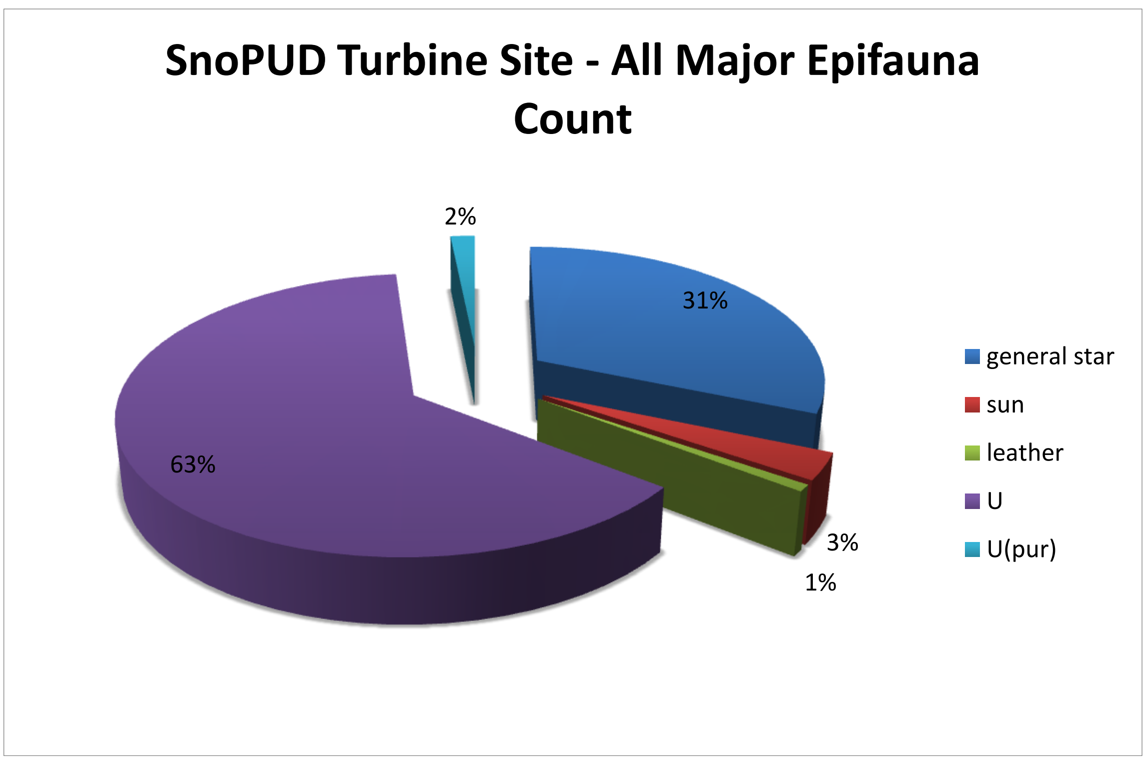

Figure 18. *Percentage of selected major epifauna counted from ROV video. The common (green?) urchin dominates the field at 63% followed by the common starfish at 31%.*

The ROV transects where this group of epifauna were found to be most concentrated in the investigation site are transects 31S (11 star, 14 urchin counts), 34N (13 star, 15 urchin counts), 24S (15 star, 24 urchin counts), 36N (11 star, 24 urchin counts), and 24S (6 star, 17 urchin counts).

Other epifauna counted, although rare, consist of turban snails (10) at 56%, shrimp (4) at 22%, hermit crab (2) at 11%, crab (1) at 5%, and an octopus (1) at 6% of the total this group (Fig. 19).

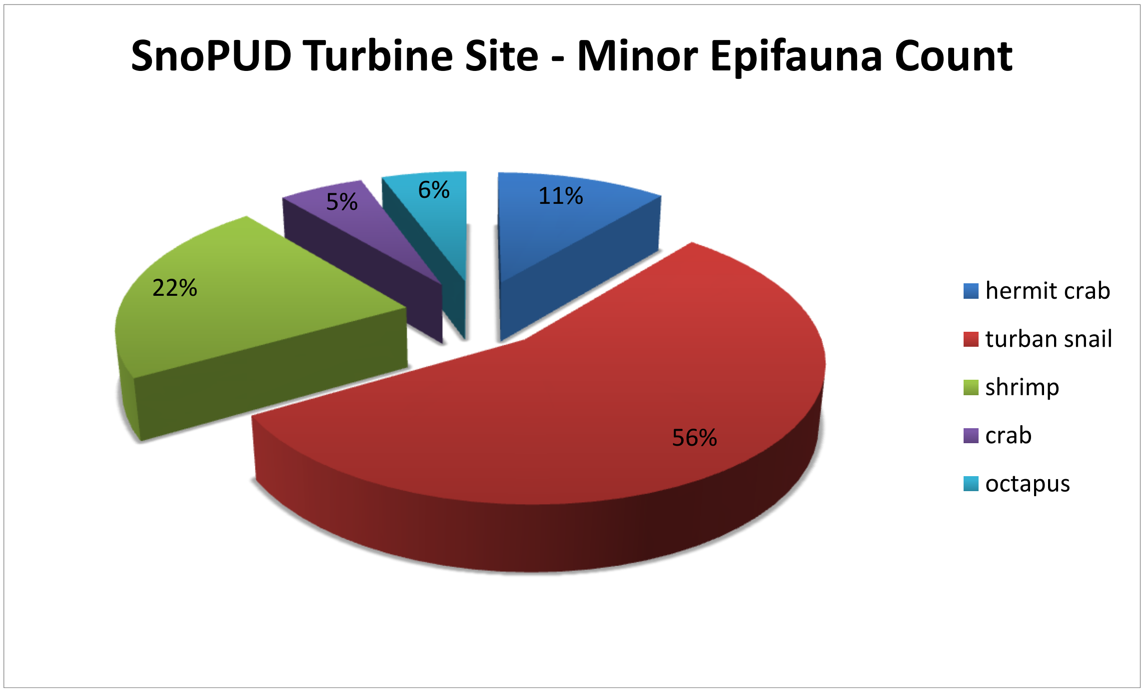

Figure 19. Percentage of rare (minor) epifauna counted in the review of the ROV video. The turban snail dominates this group at 56%.

When the major and minor epifauna are combined the common (green?) urchin dominates the field at 60%, while the general five-legged orange starfish represents 30%; these two species represent 90% of the total epifauna counted (Fig. 20). The remainder of the counted species makes up the final 10%.

Starfish were found to be most concentrated in numbers along ROV transects 31S (11), 34N (13), 24S (15), and 36N continued (11). Urchins were most concentrated in numbers along transects 27S? (14), 31S (14), 34N (15), 24S (24), 36N continued (24) and 24S continued (17). The minor epifauna were primarily concentrated along transects 16S-suspended (6), 34N (3), T-24S (4) and 24S (6). See Appendix III for complete counts.

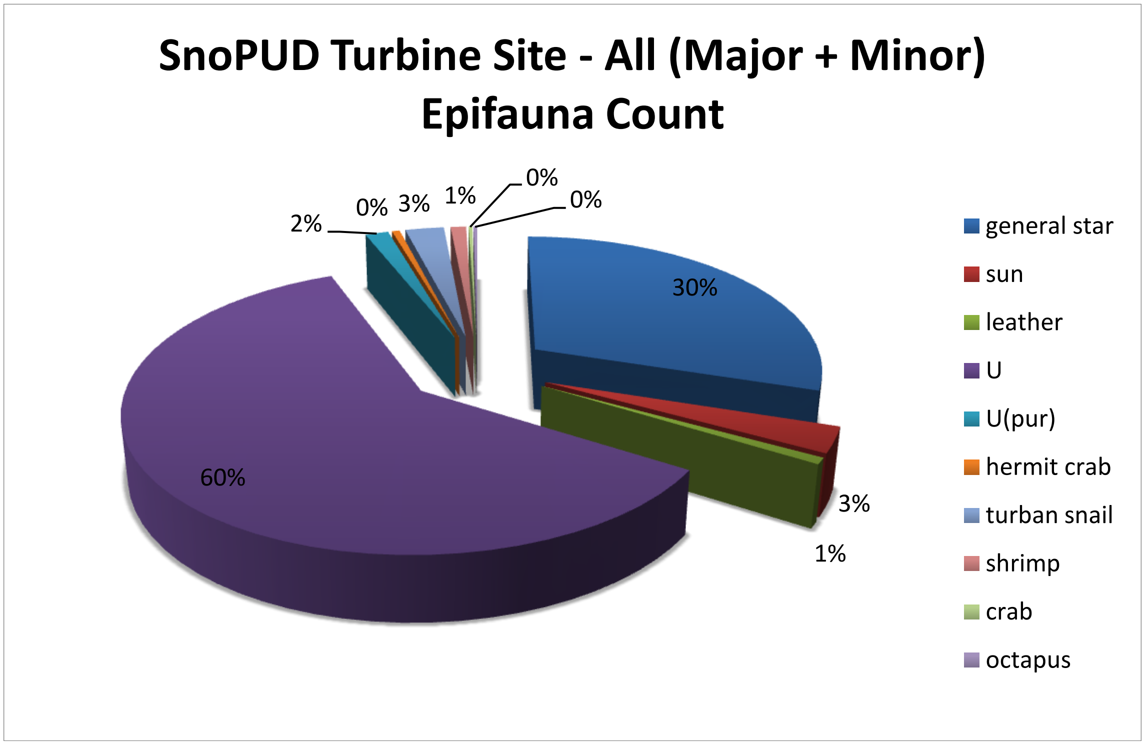

Figure 20. *Percentages of epifauna counted in the review of the ROV video. The common (green?) urchin and the common five-legged orange starfish comprise the majority of the group 90%.*

3.2.5. Fish

A total of 192 fish were counted in the ROV video review and represents a conservative estimate as many fish were seen several times but were not counted when thought to be a repeat. All fish including pelagic and benthic types were counted. Ratfish (rat) were conspicuously the most prominent representing 49% (98 counted) of the total. Sculpin is the most prominent benthic fish counted at 38% (75 counted) followed by an unidentified fish (UnIDfish), generally a black and white stripped goby-like fish, at 8% (16 counted), lingcod (ling) at 4% (7 counted), kelp cod or kelp greenling (kelp) at 1% (2 counted), and Pacific sand lance (PSL) at less than 1% (1 counted), although this identification is questionable (Fig. 21).

If ratfish is considered pelagic and not included in the count than the benthic fish would total 94, nearly half of all of the fish counted. Sculpin would then be the dominant species at 74% followed by the unidentified fish at 16%, kelp greenling at 7%, lingcod at 2%, and Pacific sand lance at 1% (Fig. 22). See Appendix II for video review log.

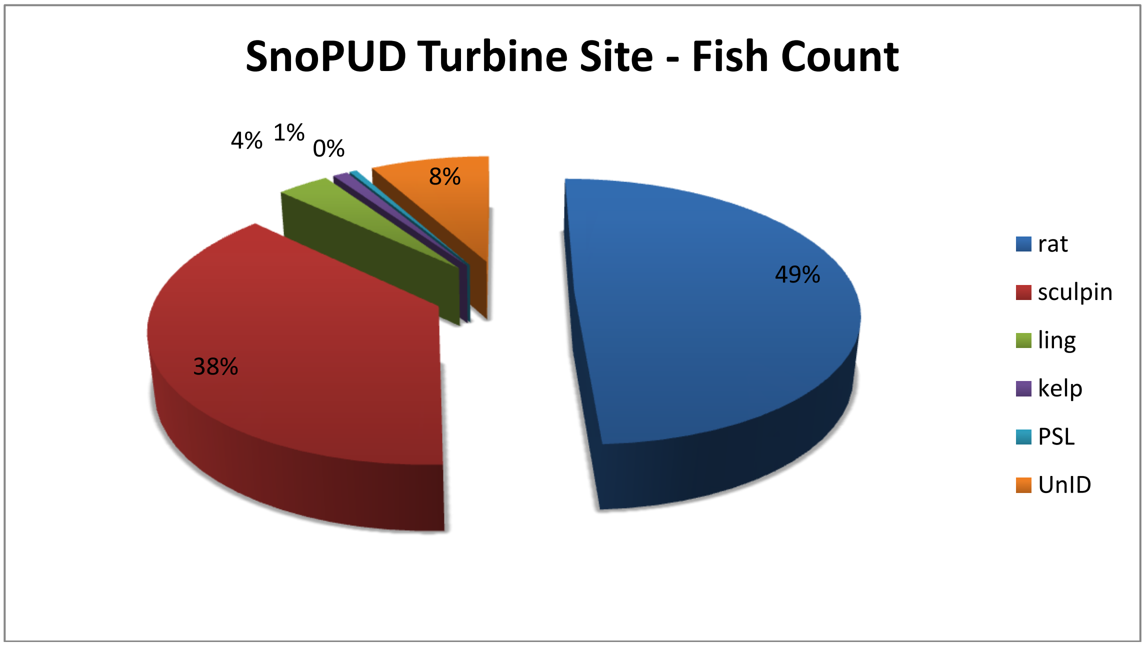

Figure 21. *Percentage of fish counted in the ROV video review. Ratfish dominate the field with almost 50% of the total.*

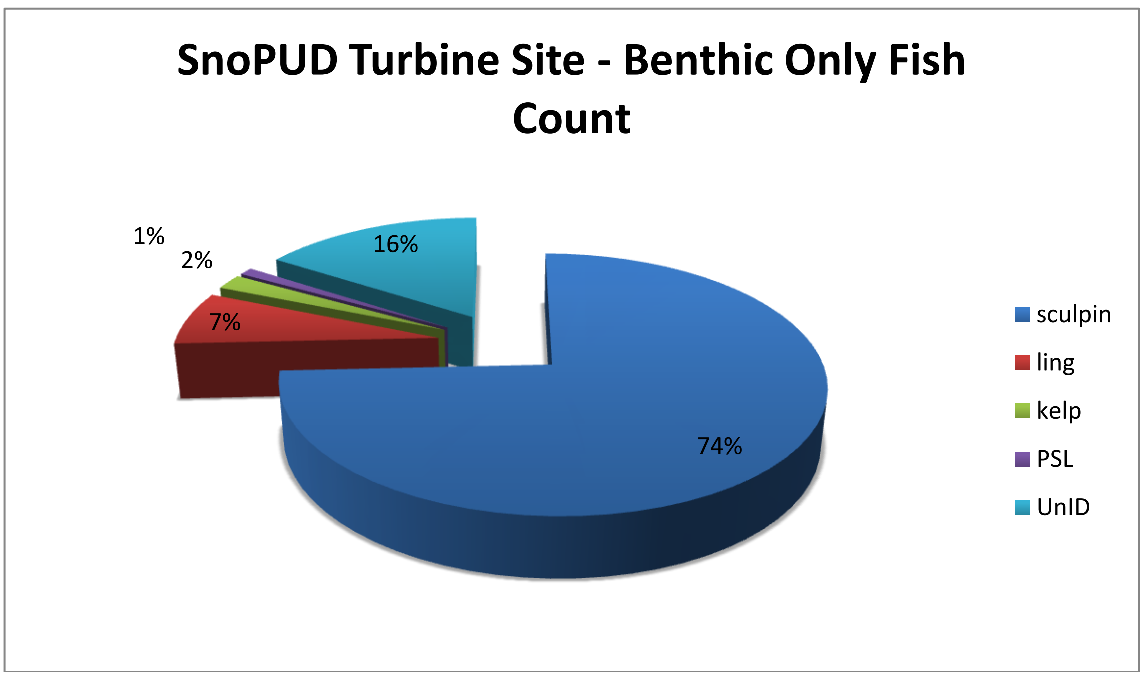

Figure 22. *Percentage of benthic fish counted in the ROV video review. Sculpin represent nearly two-thirds of all of the fish counted during the ROV survey.*

Fish also appeared to be concentrated along certain ROV transects. Ratfish were highly concentrated along transects T-14N (12), T-14N-2 (10), and 36N continued-2 (10). The benthic fish were concentrated along transects 31S (13 fish, 9 Sculpin) and 24S (9 fish, 5 Sculpin). See Appendices III for complete call out of fish.

4. Results and Recommendations

The SnoPUD turbine site is a dynamic and diverse geological and ecological area. Geomorphology and substrate types found at the site result from past glacial processes and present oceanographic conditions. Strong tidal currents winnowed the fine sediments leaving a cobble-pebble-small boulder lag pavement, heavily encrusted with sponge, bryozoans and tubeworms throughout the area. Locally, stringers of clean, fine grain sediment (gravel and sand) were observed and appear to be transiting through the site, transported by strong ebb tidal currents. A diverse and robust ecological community was observed during the ROV survey and some specific organisms were selected to be counted in order to estimate abundances.

Due to strong tidal currents, marginal visibility and irregular bottom conditions consistent elevation above the bottom and continuous even speed transiting of the ROV was not possible. Consequently, not every meter of the turbine site was video imaged. However, due to the fairly consistent substrate type and biology a good characterization of the benthic habitat was possible. A robust and comprehensive statistical analysis of the data was not attempted, but an estimate of abundances as presented here should provide a good base line for, and facilitate, future monitoring efforts.

Few biological scientific names are used in this report primarily because the quality of the recorded video was not sufficient in most cases to identify organisms at the genius or species level. However, most of the organisms observed or counted are tagged to the video logs and can be easily studied in the future to determine their lowest taxonomic level.

Substrate, although fairly consistent throughout the turbine site, is patchy in places and ranges from primarily well-rounded cobble-pebble-small boulders to well-rounded cobble-pebble pavements. The larger clasts, cobbles and boulders, are generally encrusted with sponges, bryozoans, and tubeworms (Fig. 23). The substrate is loose or unconsolidated and clasts can be moved easily with the ROV. Encrustation occurs on the exposed surfaces of the clasts, while the buried, or under surfaces, remain clean, as indicated during times substrate was disturbed by the ROV and from samples collected from an anchor. This substrate appears to attract a diverse biological community consisting of barnacles, algae, anemones and various other attaching and sessile organisms, epifauna consisting of starfish and urchins, and fish, particularly Sculpin.

There appears to be a relationship between substrate type and ecology. When comparing substrate types with biology along ROV transects it is apparent that most of the organisms observed and counted tend to be concentrated along those transects that appear to have the most diverse substrate types. For example, the most diverse substrate types were noted along transects 24S and 36N for coarse-grain clasts (cobble, pebble, and small boulder) and along 31S for the fine-grain constituents (gravel and pebble) and along these transects the substrate was heavily

Figure 23. *Small boulder and cobble recovered in flukes of anchor from barge used for the ROV operation at the turbine site. For scale pocketknife is approximately 10 cm long. Boulder and cobble are encrusted with sponge, bryozoans, and tubeworms. Note clean area on boulder where area was not exposed.*

encrusted and the largest concentrations of attached, sessile, epifaunal, and fish individuals were counted. Barnacles and algae appeared to be heavily concentrated along transects 27S(?), 31S, 24S, 36N continued and 31S continued. Most of the sessile organisms counted were found along transects 34N, T-24S, and 24S, while anemone counts were highest along transects 31S, 34N, 24S, and 36N continued. Starfish and urchins were more widespread being concentrated along transects 27S, 31S, 34N, 24S, 36N, and 24S-continued. Fish, primarily Sculpin, on the other hand, were restricted more to transects 31S, 24S, and T-34N continued.

Based on these observations and organism counts it appears that the turbine site can be characterized as a coarse-grained, cobble, pebble, boulder habitat for encrusting organisms and Sculpin, although some rockfish appear to use the habitat as well. Epifauna such as sunfish and urchins also use the habitat.

This ROV habitat characterization of the SnoPUD turbine site sets the foundation for monitoring the area during installation of the turbine and during the operational time of the unit. Based on the experience from this study it appears that it is not feasible to collect substrate samples remotely, such as using sediment grab samples or dredges. Alternatively it is recommended that in situ observations using an ROV be undertaken to measure the substrate grain size and disturbance in the same manner as has been used for this study. Also, the same biological communities selected for observation and counting for this study is recommended for any monitoring study to be done in the future. This will provide good information that can be compared with this investigation.

References:

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Gary, M., McAfee, Jr, R., and Wolf, C.L., (eds.), 1974. Glossary of Geology. American Geological Institute, Washington, D.C., 805 pp.

Lynch, T.P, Pinkard, D.R., and Bultler, J.L., 2004. Use of remotely operated vehicle as a fisheries survey tool. NOAA, ROV Operations, LaJolla, CA, 36 pp.

Pacunski, R.E., Palsson, W.A., Greene, H.G., and Gunderson, D., 2008. Conducting visual surveys with a small ROV in shallow water. In Marine Habitat Mapping Technology for Alaska, J.R. Reynolds and H. G. Greene (eds.), Alaska Sea Grant Program, University of Alaska Fairbanks, p. 109-128.

Appendix L-9

Magnetic Fields in the Vicinity of the Subsea Cable of the SnoPUD Tidal Current Turbine Installation

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MEMO

To	Craig Collar
From	Edward Spooner, PhD
Subject	**Magnetic Fields in the Vicinity of the Subsea Cable of the SnoPUD Tidal Current Turbine Installation**

To whom it may concern,

A short study has been carried out to quantify the extent of the magnetic field surrounding the subsea cable that delivers power from a pair of tidal-current turbines in the Admiralty Inlet to the shore station.

First, it is relevant to point out that it is only the cable which could produce a detectable magnetic field. Outside the turbine structure, the field will be effectively enclosed by the steel of the turbine structure. This shielding effect, combined with the disposition of windings, magnets and steel within the generator, is such that no external fields should be detectable down to levels very much lower than the natural magnetic field of the Earth. It is considered reasonable therefore to consider only the subsea cable.

<u>Theoretical Scenario – Simple Calculation:</u>
For assessing the field around the cable it is reasonable to adopt a threshold of acceptability as the Earth's natural magnetic field at mid latitudes of typically 40A/m, which is equivalent to an induction of 50μT.

The magnetic field surrounding an isolated current-carrying conductor is described by Ampere's Law, which states that the lines of magnetic field are circles centred on the conductor. The strength of the field at a distance, r, from the conductor is equal to:

current / 2πr (Amp per meter) or μ_0 x current / 2πr (Tesla)

Thus, when the tidal current is flowing at its maximum speed, the turbines will have a combined electrical output of 1000kW and this corresponds to a current of 333A at a voltage of 3kV. If this current were to flow in an isolated single-core cable, the magnetic field would exceed the Earth's field of about 40 Amp per meter everywhere within about 1.3m of the cable.

However, in practice the real cable will have at least two cores carrying the go and return current in opposite directions. The external magnetic field is the sum of the two separate fields, which are almost equal in strength and opposite in direction everywhere except close to the cable. The external field will therefore be much smaller and it will decrease more rapidly with distance. Furthermore, the steel armour wires will act to contain the field within the body of the cable and thereby reduce the external field. The combined effect of the two cores and the steel armour wires cannot be calculated simply.

<u>Cable Magnetic field Study:</u>
The cable study which was carried out to quantify the extent of the field surrounding the subsea cable uses the magnetic finite element technique in two-dimensional form with steady direct current excitation. The study examines the case of a three-core cable of the type used to connect the OpenHydro test structure at the European Marine Energy Centre

(EMEC) to the grid, adapted for use in the SnoPUD scheme. The full cable specification is appended to this memo. This cable is proposed for the purposes of this study as it represents a readily-available type of cable. However, subject to budget, availability and project procurement requirements, it may be possible to obtain a more suitable four – or six-core cable for the project in Admiralty Inlet which would result in lower external magnetic fields. Therefore the study as it is presented here represents a worst-case scenario.

For the situation displayed, the field strength is equal to the threshold value of 40A/m at a distance of 40cm from the centre of the cable. Thus it is concluded that the EM field is insignificant outside a 40cm radius from the centre of the cable.

To illustrate the point, under the conditions considered by this study, the field at the surface of the cable (cable diameter = 10cm) is about 1700 A/m. It declines rapidly as illustrated in the graph (Figure 2) that accompanies the field map (Figure 1) so that 10cm from the cable centre it is about 800A/m and at 15cm from its centre it is 200A/m. Everywhere beyond a distance of about 40cm from the cable centre the field is less than that of the Earth's natural magnetic field and so can be considered negligible.

Once again it should be noted that, if the desired four- or six-core cable type can be obtained, then the fields will be much lower.

From,

Edward Spooner, PhD
Emeritus professor of engineering Durham University UK

MEMO

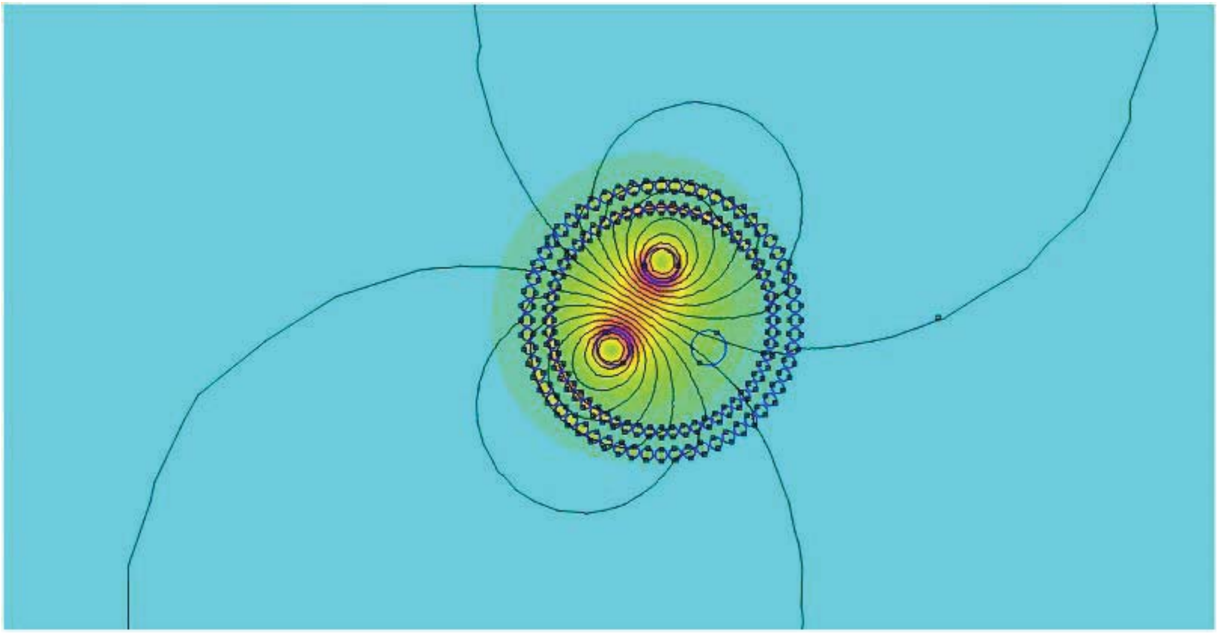

Figure 1: Magnetic Field Pattern

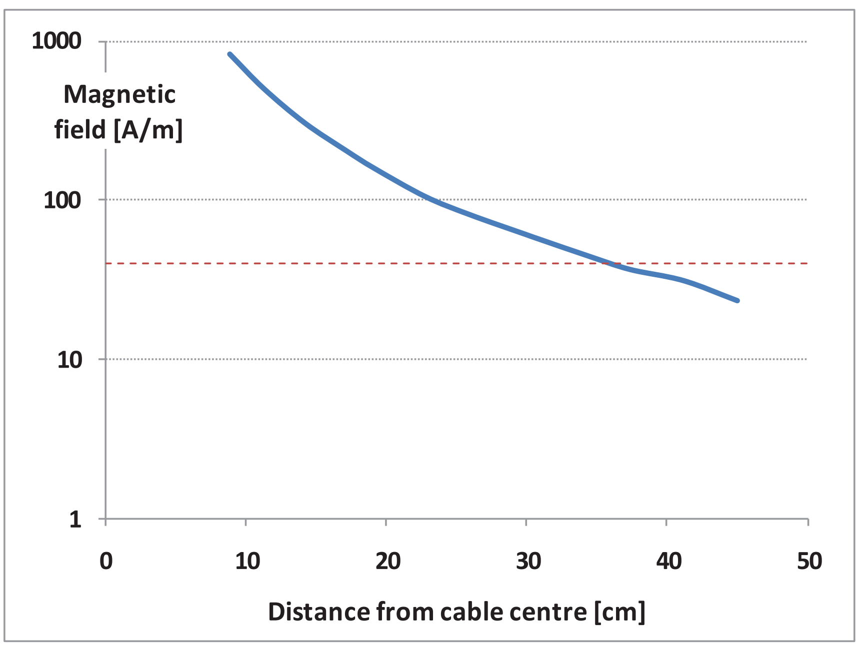

Figure 2: Magnetic field decline with distance from cable centre (Note: cable diameter = 10cm)

Appendix – EMEC Cable Specification:

SPECIFICATION FOR 11KV POLYMERIC INSULATED SUBMARINE CABLE

TABLE 1: Physical Data

Item number	Cable Component	Data
1	Conductor Cross-Section and Material	120 sqmm Cu
2	Conductor Shape	Circular
3	Number & Diameter of Strands	19 x 3.01
4	Nominal Thickness of Conductor Screen	1.0mm
5	Thickness of Insulation: a) Minimum average b) Minimum at point	4.5mm 4.1mm
6	Thickness of Insulation Screen a) Nominal b) Minimum at a point	1.0mm 0.4mm
7	Approximate Thickness of each Copper Tape	0.1mm
8	Average Thickness of Binding Tapes & Bedding	2.0mm
9	Number / diameter of Armour Wires: Inner Outer	32/6mm 40/6mm
10	Approximate Thickness of Outer Serving	3.5mm
11	Approximate Overall External diameter	98.3mm
12	Weight of Completed Cable / Metre a) Dry b) In Water	24.2 18.4
13	Minimum Coiling & Bending a) Coiling Diameter b) Bending Radius	a)6.0m b) 1.5m
14	Max. Allowable installation tension	6000kg

MEMO

SPECIFICATION FOR 11KV POLYMERIC INSULATED SUBMARINE CABLE

TABLE 2: Electrical Data

Item number	Electrical Characteristic	Data
1	Maximum DC resistance of each conductor at 20°C	0.154ohms/km
2	Maximum AC resistance of each conductor at 90°C and 50Hz	0.197 ohms/km
3	Star reactance / core at 50Hz	0.105 ohms/km
4	Star capacitance	0.31 uF/km
5	Charging current / conductor at 50 Hz	0.58 amps/km
6	Positive sequence impedance at 90°C and 50Hz	0.233 ohms/km
7	Zero sequence resistance at 20°C	0.164 ohms/km
8	Zero sequence reactance at 50Hz	0.10 ohms/km
9	Zero sequence impedance at 20°C and 50Hz	0.192 ohms/km
10	Maximum continuous current rating when buried in soil with a ground temperature of 15°C and g = 1.2.	326 Amps
11	Maximum Conductor temperature	90 deg C
12	Maximum DC resistance of pilot wires at 20°C	7.41ohm/km

Note: The current rating in (10) above is for ideal conditions. Refer to EMEC document "EMEC Eday Tidal Test Facility - Outline of Electrical infrastructure" for the as-installed rating.

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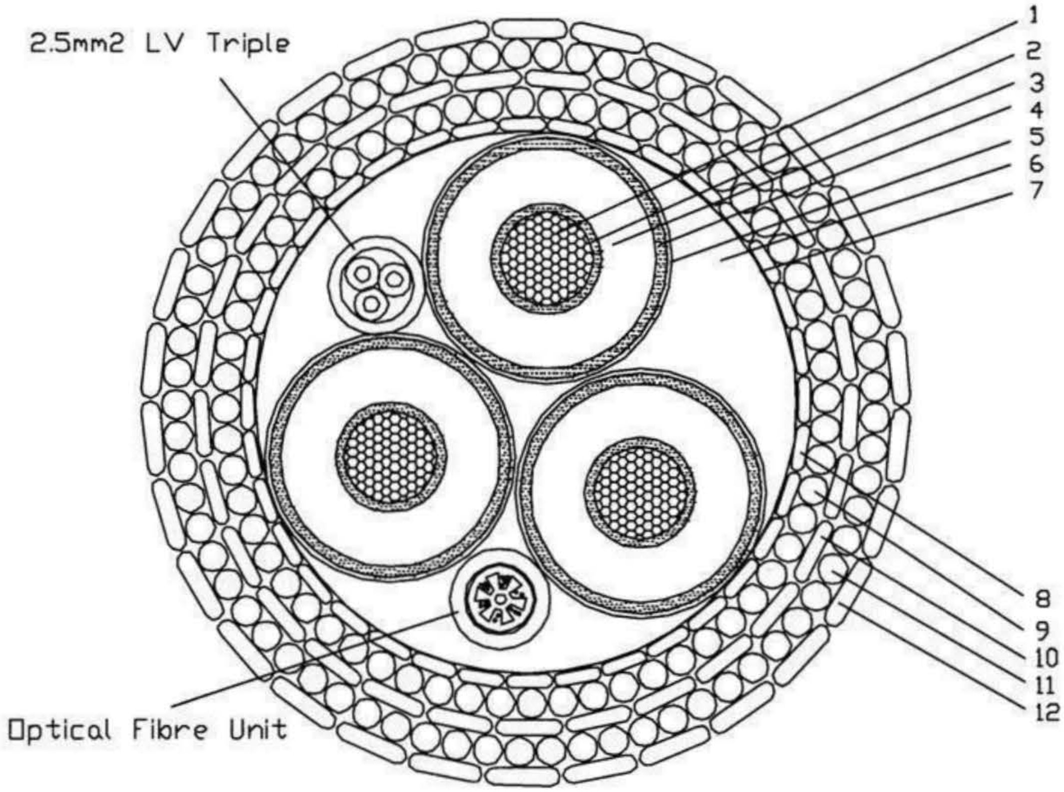
SWALEC ORKNEY T.E.P

120sqmm Cu, 6/10/(12) kV, EPR Insulated Double Wire Armoured, Submarine Cable



CABLE CONSTRUCTION

1. Water Blocked Cu Conductor
2. Extruded Semi-conducting Screen
3. EPR Insulation
4. Extruded semi-conducting Screen
5. Tinned copper tape screen
6. Polypropylene Yarn Fillers
7. Synthetic Binder Tape
8. Polypropylene Yarn Bedding
9. Galvanised Steel Wire Armour
10. Polypropylene Yarn Serving
11. Galvanised Steel Wire Armour
12. Polypropylene Yarn Serving

Dimensional Data

Nominal Diameter	98.3	mm
Cable Weight in Air	24.2	kg/m
Cable Weight in Sea Water	18.4	kg/m

Information category: **Confidential**
Author / Owner: **Edward Spooner**

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MEMO

To	Craig Collar
From	Edward Spooner, PhD
Subject	**Clarification to comments received from FERC ref:** **"*Memo: Magnetic Fields in the Vicinity of the Subsea Cable of the SnoPUD Tidal Current Turbine Installation, 20 October 2010*"**
Date	6 April 2011

To whom it may concern,

With reference to the comments received in FERC's response to the Additional Information Request, and where they relate to the above memo dated 20 October 2010, I would offer clarifications as set out below.

Preamble: Electric and Magnetic Fields

To clarify this discussion it is helpful to set out the meanings of some of the important technical terms used:

Electric potential: is measured in Volts. Energy input is required to move an electric charge to a position of higher potential. It is usual to consider the earth to have a potential of zero.

Electric field: This is the gradient of electric potential and is measured in V/m. If the electric potential varies rapidly with position then a high electric field exists. Electric fields can be established by separating electric charges, for example by processes within clouds leading to lightning, or by changing magnetic flux.

Conductivity: An electric field causes current to flow within a conducting material. Conducting materials have conductivity defined by the current density (A/m^2) resulting from an electric field of 1V/m, the unit of conductivity is Siemen/m, its inverse is resistivity measured in Ohm/m. Conductivities vary widely from zero for air to about $6x10^7$S/m for copper.

Magnetic field: This results from the nearby presence of current-carrying conductors and is measured in Amp/m. It is sometimes referred to as magnetic field intensity.

Magnetic flux: Just as an electric field causes current to flow within a conducting material, a magnetic field causes an equivalent flow through magnetically conducting materials. Magnetic flux is measured in Webers (Wb).

***Magnetic induction*:** This is the result of the presence of a magnetic field. It is equivalent to current density and in measured in Wb/m^2. This unit is given the name Tesla in the SI system.

Permeability: All materials, including a vacuum, are magnetically conducting to some extent (magnetic conductivity is called permeability). Vacuum has a permeability of 1.257×10^{-6} in SI units, {Tesla / (A/m)} most materials have permeability very nearly the same as vacuum but a few, the ferromagnetic materials, have permeabilities up to a few thousand times that of a vacuum.

MEMO

EMF: Electromotive force is the potential difference created in a conductor that surrounds a region containing a changing magnetic flux. Faraday's law gives the emf as the rate of change of magnetic flux. So if a coil with a single turn of wire is arranged on the magnetic core of a transformer and the core carries a magnetic flux that alternates at a frequency 60 cycles per second between values of plus and minus 1 Wb then a voltmeter connected between the two ends of the coil will measure a voltage alternating at 60Hz between plus and minus 377V (377 is the maximum rate of change)

Comment 1:

Our statement:

"*First, it is relevant to point out that it is it is only the cable which could produce a detectable magnetic field."*

FERC's Comment:

"this hasn't been tested"

Clarification:

The arrangement of the components within the Open-Centre Turbine generator (see Figure 1) is designed to maximise the efficiency of the dynamo effect. This is achieved through the use of the Stator Back Iron which is specified in order to focus the magnetic flux onto the generator coils, thereby also minimising any escaping magnetic flux. Our calculations show that, because of the multi-pole nature of the magnetic field, even in the absence of any shielding, the maximum magnetic field outside the generator envelope would be similar to the natural background magnetic field of the Earth. The Stator Back Iron and the steel components of the generator structure, provide sufficient shielding to ensure that the external magnetic fields produced by the generator will be much smaller than the natural background magnetic field of the Earth. Further, given our practical experience of turbine assembly and handling of magnets, we can confirm that no magnetic field is detectable outside of the turbine structure once it is fully assembled.

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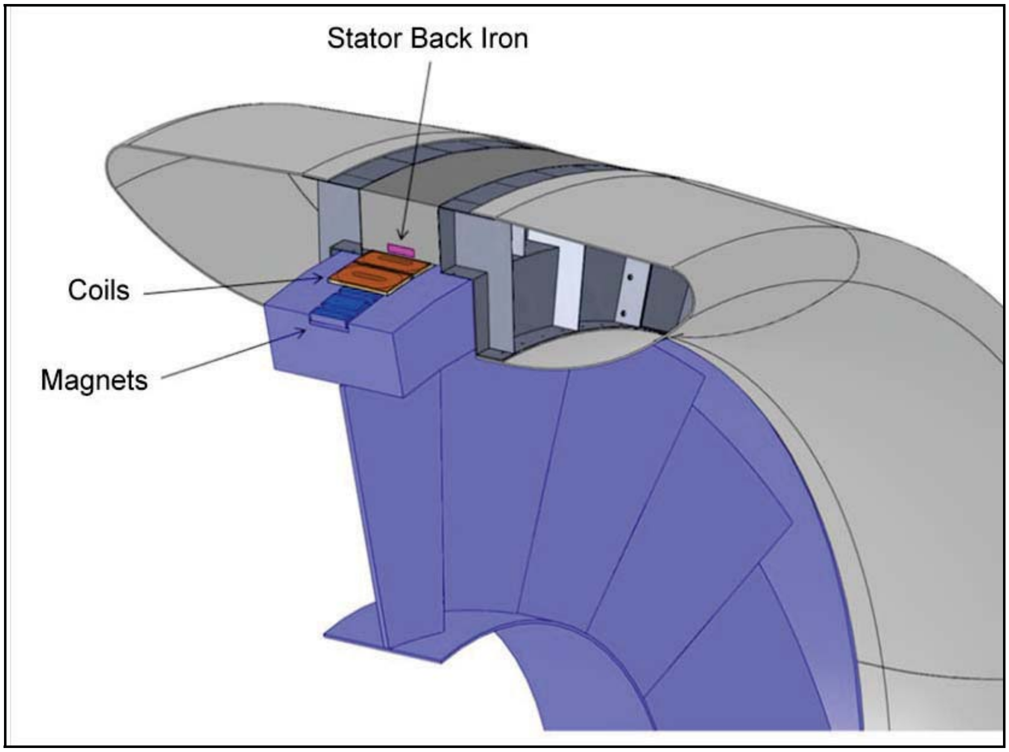

Figure 1: Open-Centre Turbine generator cut-away

Comment 2:

Our statement:

"Outside the turbine structure, the field will be effectively enclosed by the steel of the turbine structure."

FERC's Comment:

"Through conversations with Dr. Kajiura from Florida Atlantic University, NMFS does not believe that the use of a Faraday cage will be effective in the marine environment because there is essentially no way to ground the cage. Seawater is an excellent conductor, equally good as the steel material that would enclose the turbine. So the return path will not be constrained to the steel and would just as easily pass through the seawater effectively eliminating any shield effect.

NMFS is still concerned about the level of EMF that may be emitted by the two turbines considering that they are essentially two free standing magnets."

Clarification:

The FERC comment is based on a confusion between Electric and Magnetic fields. The statement concerns the Magnetic field. The reason why the Magnetic field would be shielded by the turbine structure is outlined in the Clarification to Comment 1.

The reference to the relative conductivities of steel and seawater in FERC's comment implies that a concern is held in relation to the Electric field related to current flow. This is misplaced. OpenHydro has invested heavily both time and resources in the development of the insulation system of the generator over a period of five years. It is the most crucial aspect of the machine. We are certain that no electric currents will escape from the generator into the sea water. The generator is electrically isolated from ground. In the event of an electrical fault a protection system will de-energise the system so that no ground leakage current continues to flow. This arrangement is similar to the commonplace earth leakage protector often used in domestic electrical installations.

Furthermore, the assertion that seawater is as good a conductor as steel is incorrect. Steel has a conductivity of 10^7 Siemen/metre (S/m), whereas seawater of typical salinity has a conductivity of 5S/m; i.e. the conductivity of steel is about 2 million times that of seawater and if any current were to leak from the generator then the steel of the structure would indeed provide a Faraday cage effect.

Comment 3:

Our statement:

"Thus, when the tidal current is flowing at its maximum speed, the turbines will have a combined electrical output of 1000kW and this corresponds to a current of 333A at a voltage of 3kV."

FERC's Comment:

"could the PUD provide this information in μT? It's hard to make a comparison with information provided in other reports"

Clarification:

The information presented in the section of the original memo titled: "*Theoretical Example – Simple Calculation*" is provided solely as an illustration of the principle of Ampere's Law. The values of, "*output of 1000kW*", "*current of 333A*" and "*voltage of 3kV*" do not refer to a measure of magnetic flux and therefore should not be expressed in μT, rather they refer to the operating conditions of a theoretical single core cable under the conditions described. These values are derived by the following formula:

Power (P) = Current (A) × Voltage (V) or 1,000,000W = 333A × 3000V

Using Ampere's Law:

The strength of the field at a distance, r, from the conductor is equal to:

current / 2πr (Amp per meter) or μ_0 x current / 2πr (Tesla)

Under the theoretical scenario outlined, the magnetic flux density would exceed the Earth's field of about 40 Amp per meter everywhere within about 1.3m of the cable. The Earth's field is selected as being an accepted and known standard for comparison. For reference, the value of 40 Amp per meter is equivalent to an induction of approximately 50μT.

Comment 4:

Our statement:

"If this current were to flow in an isolated single-core cable, the magnetic field would exceed the Earth's field of about 40 Amp per meter everywhere within about 1.3m of the cable."

FERC's Comment:

"how did you derive this?"

Clarification:

As outlined in the Clarification to Comment 3, this value is derived as an illustration by calculation using Ampere's Law.

Comment 5:

Our statement:

"The cable study which was carried out to quantify the extent of the field surrounding the subsea cable uses the magnetic finite element technique in two-dimensional form with steady direct current excitation."

FERC's Comment:

"NMFS has not seen the methods for this study. Please provide the study report"

Clarification:

The cable study which is referenced uses specialist software (FEMM – "Finite-Element Method Magnetics") which applies the magnetic finite element technique in two-dimensional form with steady direct current excitation. Two plots from this study are provided in Figures 1 and 2 of the original memo. These plots show the magnetic field pattern and a graph indicating the decrease in magnetic field with distance from the cable. FEMM is simple to use and is available free online. Should they choose to do so, NMFS could therefore repeat the study to confirm our calculations.

Comment 6:

Our statement:

"The study examines the case of a three-core cable of the type used to connect the OpenHydro test structure at the European Marine Energy Centre (EMEC) to the grid, adapted for use in the SnoPUD scheme."

FERC's Comment:

"Information listed above is for a single-core cable."

Clarification:

As is outlined above, the information presented in the section of the original memo titled: "*Theoretical Example – Simple Calculation*" is provided solely as an illustration of the principle of Ampere's Law and should not be taken as being indicative of the operating conditions of the turbine array and associated infrastructure.

The information presented in the section of the original memo titled: *"Cable Magnetic field Study"* relates to the study which was conducted using the above-referenced (FEMM) software to investigate the magnetic field surrounding the cable if grid connection is achieved using the proposed variable-voltage DC link to shore. The particular conditions described represent the worst case scenario and are identical to those in the previous illustration provided in the section of the original memo titled: "*Theoretical Example – Simple Calculation*", namely:

- Combined Turbine output = 1000kW
- Current in the Cable = 333A
- Voltage in the cable = 3kV

Note: if the project is connected using the proposed variable-voltage DC link to shore then only two cores within a composite 3-core armoured cable would be utilised.

Comment 7:

Our statement:

"Therefore the study as it is presented here represents a worst-case scenario."

FERC's Comment:

"Information listed above is for a single-core cable- it seems as if that would be the worst case scenario. How does the third core affect the external field?"

Clarification:

FERC has misinterpreted the statement. When referring to the worst-case scenario, the statement does not refer to the use of a single-core cable as this is a theoretical scenario only; rather the statement refers to the maximum operating conditions of the project, as outlined in the Clarification to Comment 6, namely:

- Combined Turbine output = 1000kW
- Current in the Cable = 333A
- Voltage in the cable = 3kV

The third core is not considered in the study as, under the circumstances described, it carries no current and would therefore have no appreciable effect on the magnetic field

I hope that this will serve to clarify the matter.

From,

Edward Spooner, PhD

Emeritus professor of engineering Durham University UK

MEMO

To	Craig Collar
From	Edward Spooner, PhD
Subject	**Magnetic Fields in the Vicinity of the Subsea Cable of the SnoPUD Tidal Current Turbine Installation**
Date	20 June 2011

This memo updates the study described in my memo of 20th October 2010. The earlier study concerned power delivered by direct current in subsea cables operating at 3kV. The design of the power transmission system has been reviewed in the light of new information relating to power limitations of the available grid connection and developments and it is now intended to provide a system operating with three-phase alternating current at a voltage of 6kV.

First, it remains true that only the cable could produce a detectable magnetic field. For the reasons set out in the earlier memo and the subsequent clarification of 6th April 2011.

The maximum power that the local grid connection can accept is 300kW. At times when the power available from the tides exceeds the 300kW of the grid, the power conversion system within each turbine will limit the output to 150kW. The combined maximum power corresponds to a three-phase alternating current with an rms value of 29 Amps or a peak value of 41A. The cable will resemble the example used for the earlier study. That example was rated to carry up to 250A at 11kV and so a rather smaller cable may be used for the SnoPUD project.

It is relevant to note for the non-specialist the following basic principles of three-phase AC systems: The currents in the three cores alternate but they do not rise and fall together. Each current undergoes a smooth cyclic pattern of forward and reverse. In a 60Hz system the cycle last for 16.66 milliseconds. The current in one core peaks at time 0; the current in the second core peaks at time 5.55 millisec (1/3 of the period); and the current in the third core peaks at 11.11 millisec (2/3 of the period). At any instant, the three currents add to zero and so no return current in the sea is present. The magnetic field produced by the set of three currents is a pattern of constant shape and magnitude but as the three currents change the pattern rotates.

At one particular instant the current in one of the cores is zero and the currents in the other two cores are equal and opposite and so the magnetic field pattern produced in the earlier study is a true representation of the field shape but the magnitude will be different in proportion to the current amplitude. The earlier study considered the case of 1MW at 3kV dc corresponding to 333A flowing in each core. In the revised system the corresponding case has current of 35.3A or about 11% of the current in the earlier study. Accordingly the magnetic fields are reduced in the same proportion to 11% of the earlier value.

Scaling from the graph presented in the earlier study and reproduced below, it can be seen that if a similar cable were used the magnetic field would be lower than the earth's natural field everywhere beyond about 13cm from the axis of the cable. It is likely that a smaller cable will be used for this project and the fields will be somewhat smaller than this estimate because the two cores carrying current would be closer together.

MEMO

In conclusion, it can be seen that the three-phase AC transmission system at the higher voltage and lower power leads to a considerable reduction in the strength of the magnetic field around the cable.

Edward Spooner, PhD

Emeritus professor of engineering Durham University UK

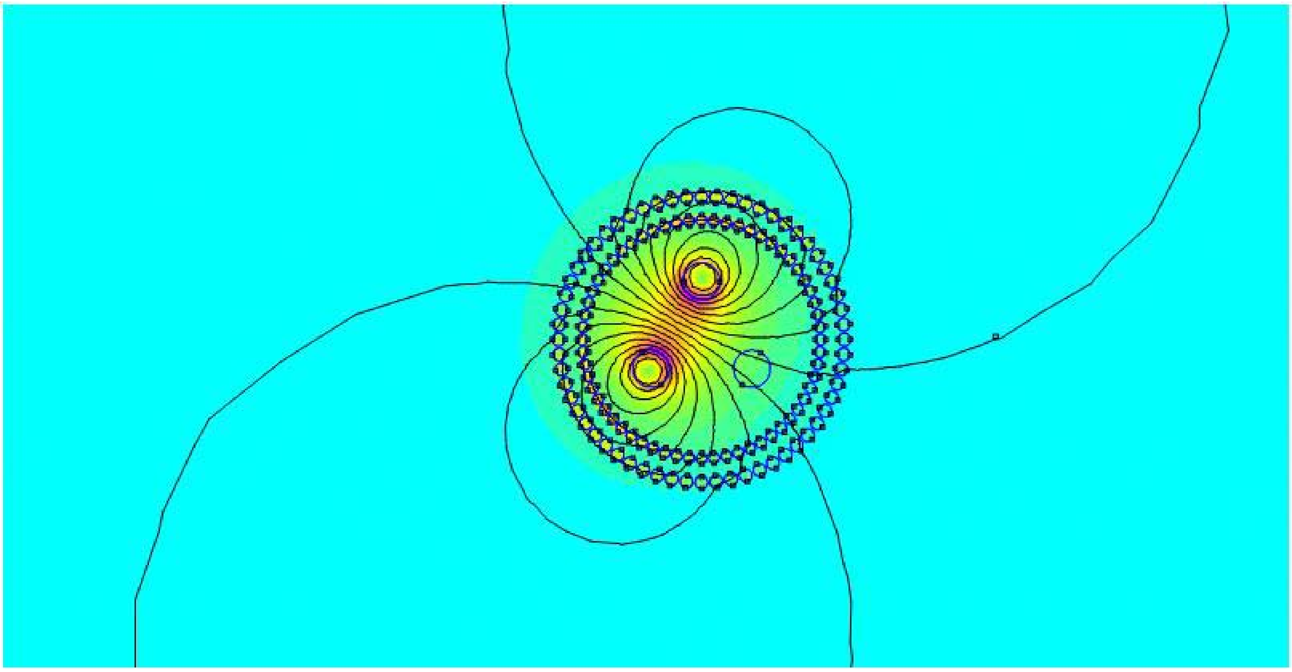

Figure 1: Magnetic Field Pattern

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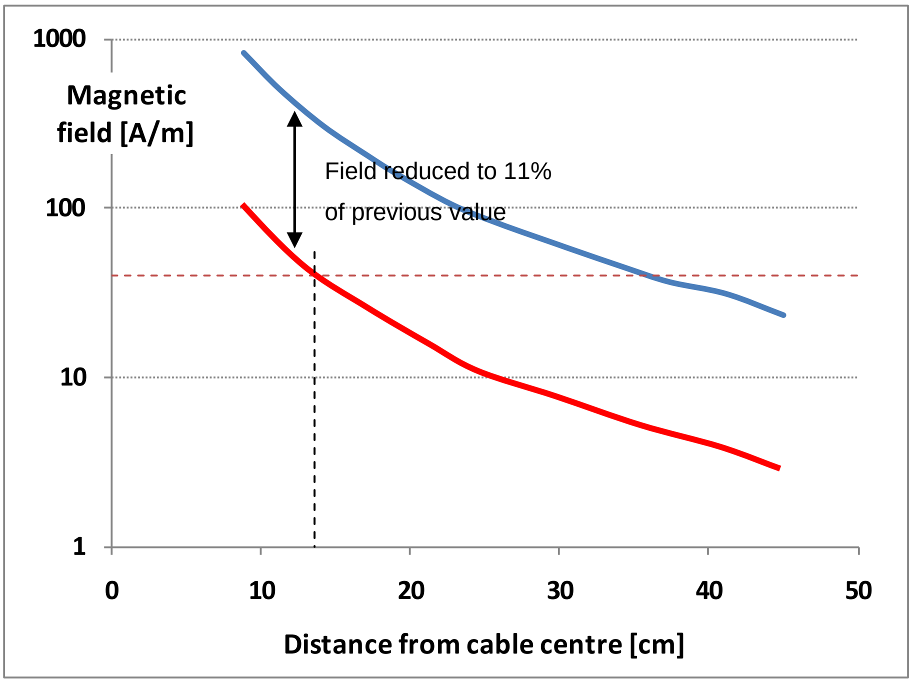

Figure 2: Magnetic field decline with distance from cable centre (Note: cable diameter = 10cm)
Original study 1MW 3kV dc ---- Blue
Revised system 150kW 6kV 3ph ac ---- Red

Appendix L-10

Habitat Characterization of the SnoPUD Turbine Site – Admiralty Head, Washington State

Habitat Characterization of the SnoPUD Turbine Site – Admiralty Head, Washington State – Final Report, June 1, 2011

H. Gary Greene
CapRock Geology

Introduction

A seafloor location identified to site a turbine for the conversion of tidal current energy into electrical power is being investigated offshore of Admiralty Head, Whidbey Island in Washington State, at the entrance to the greater Puget Sound region. This is a site of high tidal water exchanges and almost continuous strong currents, an ideal site for tidal energy conversion but a hindrance to seafloor examination. The area investigated is triangular in shape, located in water depths of approximately 90 to 200 feet, and close to land, 300 feet offshore of where the cable landfall is proposed.

Objective

The objective of this study is to map the potential marine benthic habitat types using remotely collected acoustic data and ROV video observations. Substrate type, morphology and variability were used to characterize bottom conditions and a rough census of the biology including presence of fish, epifauna, sessile and encrusting fauna and flora was undertaken.

Geology

Admiralty Inlet is located in the northern Puget Sound region and is part of the Salish Sea. Geographically it lies between Admiralty Head of Whidbey Island and Port Townsend to the west. The region is located over the subducting Juan de Fuca Plate, the active convergent boundary between the Juan de Fuca and the North American plates, and is periodically subjected to earthquakes associated with the relative motion between the two plates.

During the Pleistocene the region was heavily glaciated with the ice sculpturing the terrain into its present landforms and depositing glacial materials as tills, moraines and outwash deposits. These deposits are today represented as coarse-grain, loosely consolidated, well-rounded, plutonic and metamorphic rocks plucked from the Cascades to the east and transported to the west by the glaciers. The coarse-grain constituents are composed of boulders or drop stones, cobbles and pebbles that melted from the ice as a heterogeneous material. Advance outwash deposits of arckosic sands and silts from the ice fronts spread out across the region during the Frazer Glaciation followed by recessional outwash deposits occurring during the Vashon Stade of the Fraser, ~15Ka. These recessional outwash materials have been deposited onto clays that were laid down along the northern edge of a fresh-water proglacial lake.

With glacial retreat and melting, sea level rise, strong tidal currents are now affecting the area where the glacial deposits have been winnowed of their fine-grain constituents leaving a coarse-grain lag in the form of a cobble, pebble and boulder pavement. Erosion of feeder banks and river input are now supplying fine-grain materials to the region.

Method

The *Seaeye Cougar-XT* ROV (Fig. 1) is a moderate size (344 kg, 758.4 lbs) electric vehicle that can work at depths of 2000 m (6,562 ft) or less and obtain speeds up to 3.2 knots (nm/h [5.93 kph, 3.68 mph]). It is outfitted with two hydraulic manipulators, not used on these surveys, a pan and tilt video camera and 6000 W of lighting. For the work in August the tether was hand managed while for the work in September and October a tether management system (TMS) and an ROV garage was used to better manage the umbilical. Speed of the vehicle was kept to a knot or less for all transect runs. Stops during transects were kept at a minimum although unavoidable at certain times when bottom currents were strong or the tether was fouled. Occasional stops were made to better image a feature or organism of interest on the seafloor.

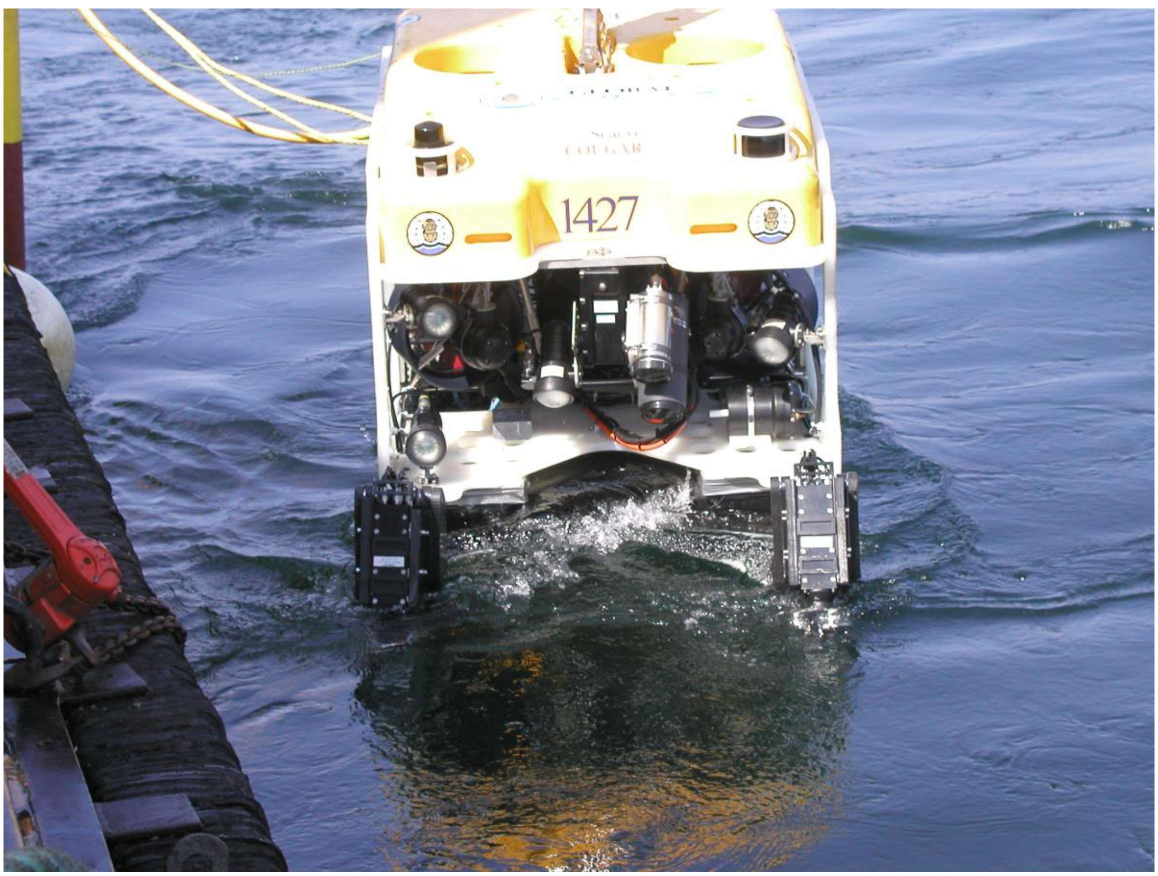

Figure 1*.* Seaeye Cougar- XT *ROV being lunched from a stationary vessel at the SnoPUD turbine site. Lighting, camera, lasers and the two manipulators are visible. Note strong current, even though this operation is occurring at slack tide.*

The first attempt to collect ROV video at the SnoPUD tidal energy site was undertaken between August 16 and 17, 2010. Unfortunately the support vessel *Prudhoe Bay* was too small for the tidal conditions and the anchors too light to keep the vessel in position and thus very limited observations could be done. Several transects were completed on August 18 but without onboard annotation of the video.

The second attempt to obtain video images of the seafloor within the SnoPUD tidal energy site was undertaken from aboard a large barge (Fig. 2) during the evening hours of September 29, 2010 after the barge supporting the ROV was properly anchored (see reports by McCallister, Sound and Sea Technologies). The second day of the operation, Thursday, September 30, was highly successful and the ROV performed well. However, on the third day, after the barge was positioned for the day's dives, the tether management system (TMS) aboard the ROV failed to operate and the day's dive delayed. On the fourth day the barge was re-positioned for the survey of the cable route (see Appendix I for onboard observational logs).

A total of 24 transects were observed and reported aboard the ROV support vessels. The, transects ranged in time from 3 minutes to 39 minutes with the average being about 16.5 minutes. Depth within the investigation area ranged from 55.8 m (183 ft) to 61 m (203 ft), a range of 6.1 m (20 ft) with an average depth of 59 m (194 ft). All units provided in this report are given in units measured during the observations followed by conversion to metric or English system.

All video collected during the surveys were reviewed and annotated based on time and include both transects and transits to transects (all transits are labeled with a "T" prior to the line number, e.g., T-24, meaning transit to line 24). In other words, all video recorded was reviewed (see Appendix II for video review logs). Substrate and ecological conditions were observed and noted. Where possible counts of various organisms and fish were made and totaled to estimate relative percentages. A statistical analysis was not made.

The geologic and ecologic categories selected for this study include substrate type and biological organisms and assemblages observed or counted during the ROV dives. Substrate is divided into coarse-grain and fine-grain components with anomalous large-grain clasts such as boulders counted and observations of lightly encrusted or clean sediment type noted. The ecology is broken down to encrusting, attached, sessile, epifaunal, and fish types of organisms observed or counted.

2.1. Observations vs. Counts

Observations were noted when benthic characteristics changed or a particular substrate or biological assemblage dominated the seafloor for a considerable time during a transect or transit. The decision not to count such characteristics was made when it was apparent that a characteristic was ubiquitous or homogeneous throughout the investigation site. Therefore, noted observations are subjective, but when tallied can provide an estimate of relative abundances.

Figure 2. *Barge used in second attempt to collect ROV video of the SnoPUD turbine site. The ROV is housed in its garage beneath the tether management system under the launch and recovery block in the A-frame. Monitoring and control equipment is housed in the white shipping container to the left of the A-frame and one of the two green anchor winches used in positioning the barge through the four-point anchoring system is visible at left corner of the barge.*

Those characteristics selected for counting consist of distinct elements of the substrate such as boulders and those organisms that are not ubiquitous but were of significant quantity and definition to be counted such as anemones, various epifauna and fish. In this preliminary report common names of the organisms observed and counted are given – scientific names will be provided later, if possible, once expert biologists are contacted to view the organisms.

Both noted observations and counts were tallied and relative percentages of abundances are estimated for the various categories of substrate and organisms selected. Tables have been prepared and included in this report (Appendix III) to show where along a transect, or transit to a transect, various substrate type and biology occur based on time. A GIS spatial presentation of the seafloor conditions and biology are presented in Plate 1, which shows the relationship of biological counts with ROV track lines. Another map (Plate 2) show the potential habitat types based on substrate interpreted from multibeam echosounder (MBES) bathymetry and backscatter and validated using the ROV.

2.2. Difficulties Encountered

The investigation area, the tidal turbine site, is by necessity a highly dynamic and energetic environment subjected to strong tidal flows. Even though timing of the ROV surveys was selected to occur when tidal flow was comparatively low, the water mass at the site was always restless and very seldom was true slack experienced. Quite the contrary, strong currents often over a knot in speed were encountered and affected the smooth, trouble-free operation of the ROV. These strong current situations and the presence of occasional boulders on the seafloor prevented the ROV from flying along a transect at a constant uniform altitude resulting in the visual footprint constantly changing. Thus, the seafloor would range from out-of-focus to in-focus with the consequential varying detail and the fluctuating ability to identify benthic organisms.

Much time was spent untangling the tether when wrapped around boulders. Although moderate to large size boulders were rare they did occur in sufficient numbers to tangle the tether. These occurrences, while time consuming to remedy, often allowed for detailed inspection of the seafloor and the discovery of previously unseen organisms.

Visibility varied throughout the survey and the presence of marine snow often prevented good observation of the seafloor from much more than a meter above the bottom. The best observations were accomplished when the vehicle was either sitting on the bottom or less than 0.5 m above.

The recorded video is of less quality and resolution than the image displayed on the pilot's monitor while surveying. Therefore, it was more difficult to identify organisms using the recorded video than it was when observing the seafloor from the pilot's monitor. The counts made of the organisms need to be considered as a minimum as it is suspected that many organisms were missed. Absolute identification of organisms was not possible due to water turbidity, excess ROV movement and at times poor quality video.

2.3. Substrate Classification

Substrate as used in the context of this study follows the definition of Gary et al. (1974) where in an ecological context it is "the substance, base or nutrient (or medium) on which an organism lives and grows or the surface to which a fixed organism is attached, e.g. soil, rocks . . ."

Grain size, or clast sizes were measured using the laser scale attached to the ROV. Two red lasers spaced 10 cm (3.94 inches) apart and mounted in a parallel configuration to the camera housing provided a consistent and readable scale observable both in the pilot monitor and in the recorded video. The coarse grain size prevented any other way to obtain grain size measurement as no grab or dredge sampler would be able to collect a non-disturbed representative seafloor sample at the site. The only practical way to measure clast size is in situ observation using video.

The Wentworth Grade was modified for use in this study and is shown along with grain sizes and Phi scale in Table 1 below:

Wentworth Grade (modified)	Size Range (mm)	Size Range (cm)	Size Range (inches)	Phi Scale
Large Boulder (lgB)	>600 mm	>60 cm	26.3 inches	
Medium Boulder (mB)	400-600 mm	40-60 cm	15.8-26.3	
Small Boulder (smB)	256-400 mm	25.6-40 cm	10.1-15.8	<-8
Cobble (C)	64-256 mm	6.4-25.6 cm	2.5-10.1	-6
Pebble (P)	32-64 mm	3.2-6.4 cm	1.6-2.5	-5
Gravel (gr)	2-32 mm	0.2-3.2 cm	0.079-1.6	1 to -5
Sand - coarse (s)	0.5-2 mm	0.05-0.2 cm	0.020-0.079	0 to -1
Clay	<3.9micro m			>8

Table 1 – *Sediment grain size based on the Wentworth Scale modified for this study. Symbols in parentheses are codes used in the observational logs and tables (Appendix II and III).*

From a geologic perspective substrate is here divided into a coarse-grain component and a fine-grain component. The relative abundance of the grain sizes that represent a particular substrate type is based on the estimated percentage of grain sizes present at the time of the observation. For example, if a substrate type was comprised of three prominent clast sizes such as cobbles, pebbles and gravel where cobbles represent a third to a half of the clasts, pebbles represent less than a third and gravel is even less in abundance, then the call out for such a substrate would be C/P/gr in that order to indicate that the substrate is dominated by cobbles and pebbles with gravel being of tertiary importance. If, for example, only one constituent was present, such as cobbles, then the call out would be C/C indicating that both the primary and secondary sediment grain size are of the same clast size.

Below are the sediment grain size combinations that are used to characterize the coarse –grain substrate types:

smB/C/P	=	small boulder/cobble/pebble
C/smB/P	=	cobble/small boulder/pebble
C/P/smB	=	cobble/pebble/small boulder
P/C/smB	=	pebble/cobble/small boulder
C/C	=	cobble/cobble (a single clast size)
C/P	=	cobble/pebble
P/C	=	pebble/cobble
lgB	=	large size boulder
mB	=	medium size boulder
smB	=	small size boulder

These grain size combinations are consistent with that used to describe marine benthic habitat characteristics by Lynch et al. (2004), Anderson and Yoklavich (2007), and Pacunski et al. (2008).

Below are the sediment grain size combinations that are used to characterize the fine-grain substrate types:

C/P/gr	=	cobble/pebble/gravel
P/C/gr	=	pebble/cobble/gravel
P/gr/C	=	pebble/gravel/cobble
gr/C/P	=	gravel/cobble/pebble
gr/P/C	=	gravel/pebble/cobble
gr/gr	=	gravel/gravel (single grain size)
s/s	=	sand/sand (single grain size)

See Plate 1 for spatial representation of the substrate types and Plate 2 for the habitat types.

2.4. Biology

The observed biology was divided into several different categories including the following, shown with the symbology used in the video logs and tables (see Appendices II and III; Plate 1):

Ubiquitous encrusting organisms – sponges, bryozoans and tubeworms (very seldom called out and no symbols (code) developed because these encrusting organisms were observed most everywhere, except in areas where lightly encrusted or clean substrate are noted. Four degrees of encrustation are noted:

1). Heavily encrusted (h/e) – approximately 80% or more of the substrate is encrusted

2). Moderately encrusted (m/e) – approximately 40-80% of substrate is encrusted
3). Lightly encrusted (l/e) – approximately less than 40% of substrate is encrusted
4). Clean – no apparent encrustation seen

Other encrusting organisms, both fauna and flora:

Barnacles
1). Single, often scattered barnacles – B
2). Clusters of barnacles – B(clust)
3). Fields of barnacles – B(lots)

Algae
1). Crinoid-like/filamentous (Cri/filiAlgae) – green feather-like stemmed organisms (positively ID as crinoids by Waldo Wakefield 2/2011)
2). Algae – other types such as bladed algae

Attached organisms – anemones, five types based on color and patterns, and their state of feeding:

1). Purple/closed (p/c) – solid purple, no tentacles seen
2). Purple/open (p/o) – solid purple, tentacles seen
3). White/closed (w/c)- solid white or cream, no tentacles seen
4). White/open (w/o) – solid white or cream, tentacles seen
5). Stripped/closed (s/c) – pale purple with white stripes, no tentacles seen
6). Stripped/open (s/o) – pale purple with white stripes, tentacles seen
7). Pompom-like (pp) – anemone-like organism, may be a nudibranch
8). Anemone (A) – a different color (orange or yellow) or too obscure to identify color and pattern

Sessile organisms – those organisms that are fixed, sedentary or slightly mobile and consist of the following (no symbols constructed):

1). Stemmed or basket sponge – other than encrusting sponge
2). Tunicate
3). Chiton or limpid
4). Clams, living, open and closed

Primary Epifauna – mobile benthic organisms counted, including the following:

Starfish

1). Starfish – general five-legged, orange starfish (star)
2). Sun starfish – many legged sun starfish (sun)
3). Leather starfish – fat, leathery starfish (leath)

Urchins

1). Green urchin – U
2). Purple urchin – U(pur)

Other Epifauna

1). Turban snail (turb)
2). Hermit crab (no symbol)
3). Octopus (no symbol)
4). Crab (no symbol)
5). Shrimp (no symbol)

Fish – both pelagic and benthic fish counted include the following:

1). Ratfish (rat)
2). Sculpin (no symbol)
3). Lingcod (ling) – *Ophiodon elongatus*
4). Kelp greenling (kelp) – kelp cod or *Sebastes* spp.
5). Unidentified fish (UnIDfish) – generally goby-like with black and white stripes
6). Pacific sand lance (PSL) – *Ammodytes hexapterus*

See Plate 1 for spatial representation of these organisms in relation to ROV track lines.

Discussion

From the video observations substrate and habitat types of the SnoPUD turbine site were characterized based on the methodologies described above. The marine benthic habitat at the turbine site is primarily a cobble-pebble-small boulder seafloor that provides substrate for encrusting and attached organisms (sponges, bryozoans, tube worms, anemones), as will as for various epifauna (starfish and urchins) and benthic fishes (primarily Sculpin, but some rockfish). Although probable that a considerably more diverse ecological system exists at the investigation site than is described here, the time and equipment required to comprehensively determine such a system was not practical as disturbance of the substrate would have been necessary. However, a good baseline is presented from which future observations and monitoring can be founded.

3.1. Substrate

The substrate that characterizes the SnoPUD turbine site is divided into a relative coarse-grain and fine-grain component with the coarse-grain component being the dominant one. The substrate types represented by three or less clast sizes based on how often noted from the video observations are here compared to each other. This method, although not statistically robust and somewhat subjective, is used to determine the predominant substrate types of the site.

3.1.1. Coarse-Grain Substrate Component

The coarse-grain substrate component is composed of four clast size combinations with the cobble-pebble-small boulder (C/P/smB) dominating at 57% (126 noted) followed by cobble-pebble (C/P) at 28% (62 noted), pebble-cobble (P/C) at 9% (20 noted), pebble-cobble-small boulder (P/C/smB) at 4% (8 noted) and all others at 2% (4 noted) showing good observational correlations (Figs. 3 and 4). In addition, scattered boulders ranging from small to large were noted and found that the small boulders dominated (Fig. 5). See Appendices II and II for complete notations of the substrate based on the video review.

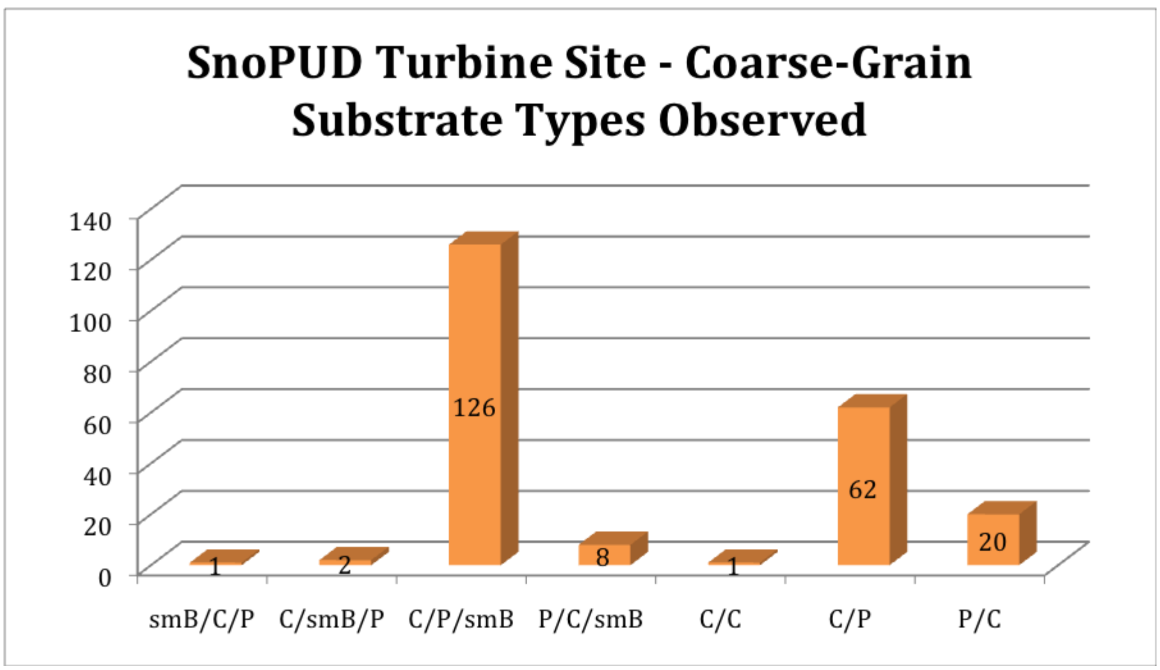

Figure 3. *Histogram of substrate types observed during the turbine site investigation. Numbers represent amount of times substrate type was observed and called out from the ROV video review.*

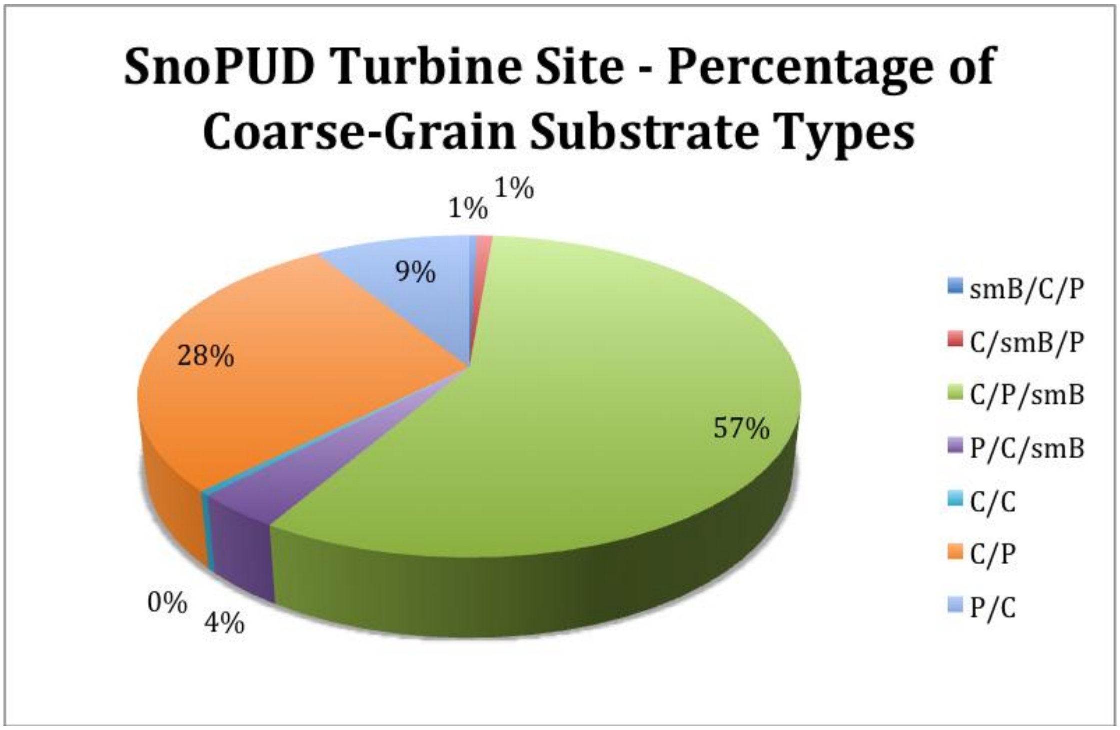

Figure 4. *Pie chart showing percentage of substrate types forming the benthic habitats of the turbine site with cobble-pebble-small boulders being the dominant form.*

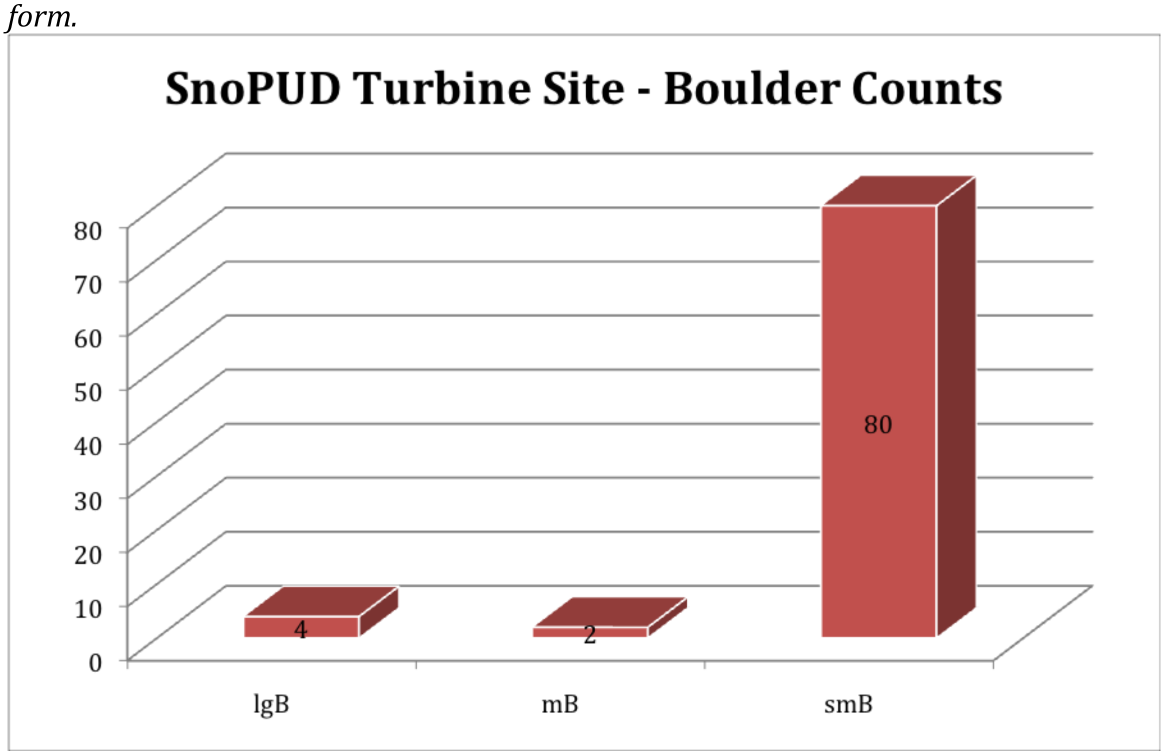

Figure 5. *Histogram showing numbers of boulder types observed in the video review. Small boulders are the most prominent of the scattered boulders observed.*

3.1.2. Fine-Grain Substrate Component

The relative fine-grain substrate is composed cobble-pebble-gravel (C/P/gr) at 34% (20 noted), pebble-cobble-gravel (P/C/gr) at 33% (19 noted), pebble-gravel-cobble (P/gr/C) at 24% (14 noted) and gravel-pebble-cobble (gr/P/C) at 9% (5 noted) with pebble-cobble-gravel and pebble-gravel-cobble being the dominant types (Figs. 6 and 7).

3.1.3. Combined Coarse-Grain and Fine-Grain Substrate Components

By combining the coarse-grain and fine-grain components it becomes apparent that the coarse-grain cobble-pebble-small boulder (C/P/smB) type is the most representative substrate of the turbine site as it represents the largest percentage grain size combinations at 45% while second most representative is cobble-pebble (C/P) at 22%, then pebble-cobble (P/C) at 7% and pebble-cobble-small boulder (P/C/smB) at 3% followed by the fine-grain constituents of cobble-pebble/gr (C/P/gr) and pebble-cobble-gravel (C/P/gr), both also at 7%, pebble-gravel-cobble at 5%, gravel-pebble-cobble at 2% and the rest at 1% or less (Fig. 8). Therefore, it can be confidently stated that the dominant substrate type at the turbine site is of a mixed cobble-pebble-small boulder and cobble-pebble clast size representing over two-thirds of the area investigated.

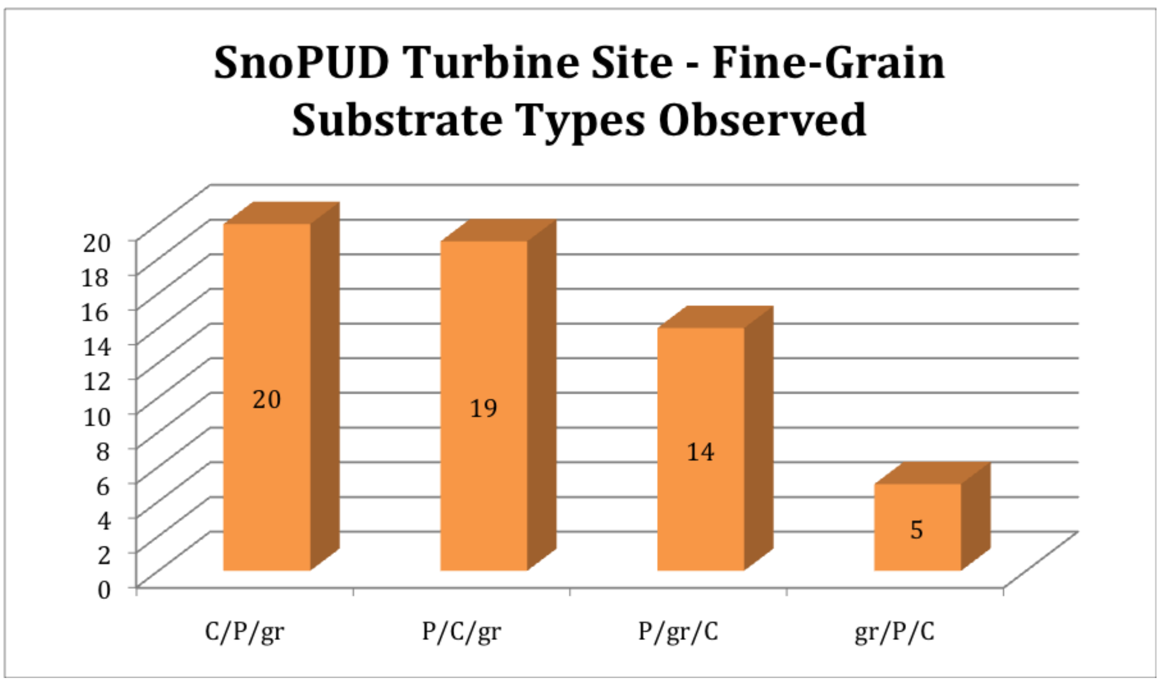

Figure 6. *Numbers of relative fine-grain substrate types noted during the video observations. Cobble-pebble-gravel and pebble-cobble gravel represent the dominant grain size.*

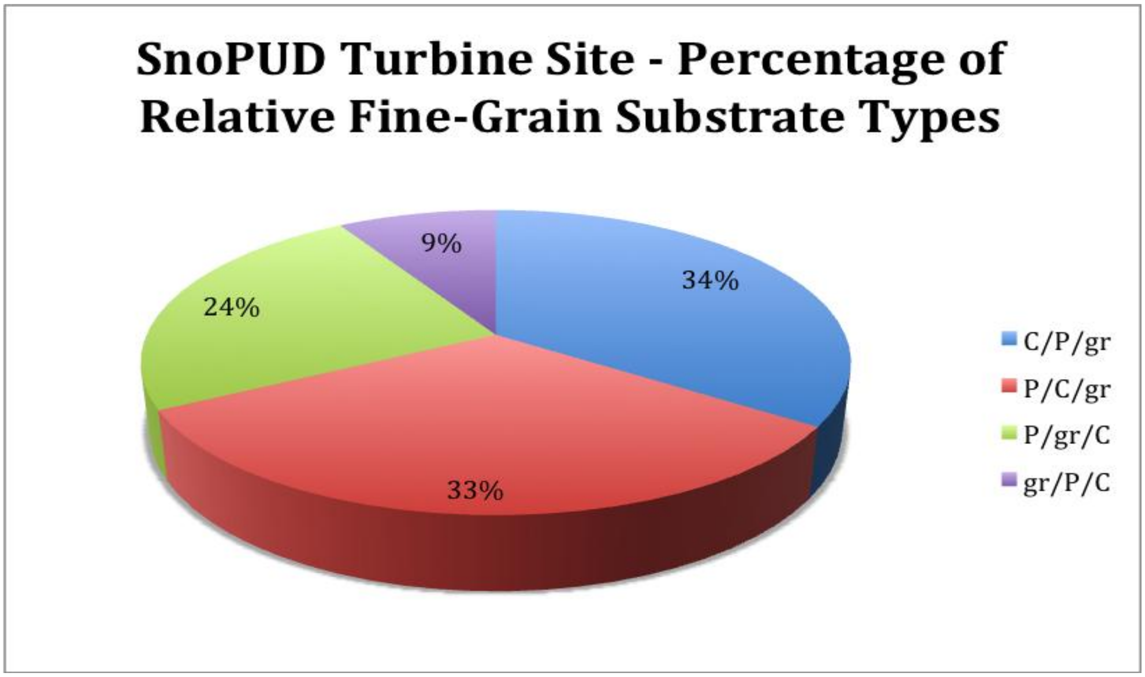

Figure 7. *Percentage of relative fine-grain sediment type observed in the video review. Cobble-pebble-gravel and pebble-cobble-gravel are equally represented and produce two-thirds of the fine-grain substrate types.*

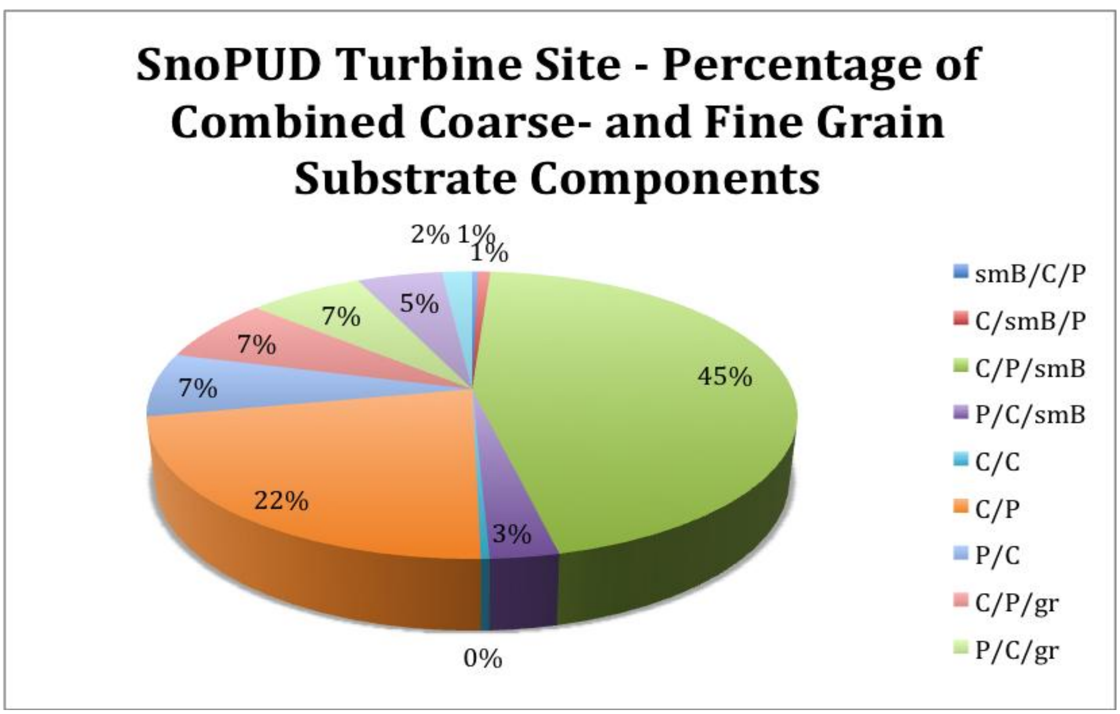

Figure 8. *Percentage of all substrate types observed from the ROV video indicating that the dominant substrate types consist of the cobble-pebble-small boulder and cobble-pebble clast sizes.*

Cobbles, pebbles and small boulders are all generally well rounded with an occasional clast being sub-rounded. These clasts are also heavily encrusted with the exception of in areas that have been noted as lightly encrusted or clean. The relatively finer-grained material such as gravel and sands that were rarely observed all generally appear clean and may represent the transport of sediment through the area (see Plate 2). The dominant substrate is a lag deposit heavily winnowed from tidal current activity and represents a pavement where clast-to-clast contact exists and most fine-grain constituents have been removed.

The most diverse coarse-grain substrate types with varying grain sizes and patchiness exist along ROV transects 24S and 36N continued-2 (see Plate 1). For the fine-grain constituent the most diverse substrates are located along ROV transects 27S and 31S. However, throughout most of the turbine area the substrate is fairly homogeneous composed of cobbles, pebbles and small boulders with locally concentrated small boulder piles and individual large boulders (see Plate 1). This is a glacial lag deposit with fine grain size (sand and gravel) winnowed by the strong bottom currents. The largest boulders appear to be concentrated in the SE corner of the mapped area. All substrate exists as a pavement winnowed by strong bottom currents. The most stable substrate exists in the SE and NW corners of the mapped area (see Plate 1).

Lightly encrusted to clean substrate was found to diagonally cross the turbine site from the east central edge to the NW corner (see Plate 2). This clean substrate is composed of finer grained clasts consisting of pebbles and gravels that may be actively transiting the site during ebb tidal flow, however, more study on this phenomenon needs to be undertaken.

3.2. *Biology*

The benthic biology of the turbine site in relation to the substrate is dominated with encrusting organisms, primarily sponge, bryozoans and tubeworms. These organisms are ubiquitous and, therefore, no attempt to count them was made. Relative cover of the substrate by these organisms was attempted by noting if an area along an ROV transect was heavily, moderately or lightly encrusted or clean. No statistical analysis was made as it was apparent that most of the substrate in the investigation site is heavily encrusted, especially on the coarser grain clasts such as boulders and cobbles. It appears that because of the strong bottom currents boulders and cobbles are the most stable, unmovable, clasts and thus are static enough for encrusting growth to occur over time. The finer grain constituents, small pebbles, gravel and sand are relatively easily moved by the currents and are, therefore, tumbling through the area (saltation) without being encrusted.

Other biological components, including encrusting organisms, both of fauna and flora, sessile organisms, epifauna (invertebrates), attached organisms, and fish were found in reasonable numbers to count. Selected organisms, such as anemones, starfish, urchins, and fish, were selected for counting while others, such as barnacles and algae, were noted but not comprehensively counted.

3.2.1. Selected Encrusting Organisms (Barnacles and Algae)

Barnacles and algae are prolific at the turbine site although there is patchiness to their distribution. In order to determine the amount of coverage that these organisms have they were noted in the video review in areas where they appeared to be concentrated; a direct count was not made.

Barnacles occurred as individuals, clusters and heavily concentrated in fields, lots of barnacles. Their concentrations were noted and show that at least 53% (166 notations) were made of individuals, B, while 28% (89 notations) for barnacle clusters, B(clust) and 19% for barnacle fields (59 notations), B(lots) were made (Fig. 9). This analysis basically suggests that most of the barnacles are scattered individuals while clusters and fields are less abundant (see Appendices II and III, Plate 1).

The algae community found at the site is composed of two basic types, a Crinoid-like or filamentous algae (Cri/filiAlgae)[1] and bladed algae, (A). Similar to how the barnacles were assessed, algae were not counted, but notations were made where they seemed to be present in large numbers that warranted mention (see Appendices II and III). From these notations it was found that the Crinoid-like or filamentous algae dominated the flora with 65% (106 notations) of the total and the remainder of the algae noted representing 35% (57 notations) of the total (Fig. 10).

Generally encrusting organisms (e.g., encrusting sponges, bryozoans, barnacles), as well as attached organisms (e.g., Crinoids, anemones) were ubiquitous in all the moderately and heavily encrusted areas, which are in all areas not mapped as clean substrate. However, where unusual concentrations of barnacles such as B(clust) and B(lots) as well as heavy concentrations of crinoids, Crinoids forests, were found they were symbolized on Plate 1 where they seemed to be concentrated in the northeastern and southwester corners of the surveyed site.

[1] These have since been identified as Crinoids by Waldo Wakefield (Wakefield, Personal Commun., 2/2011).

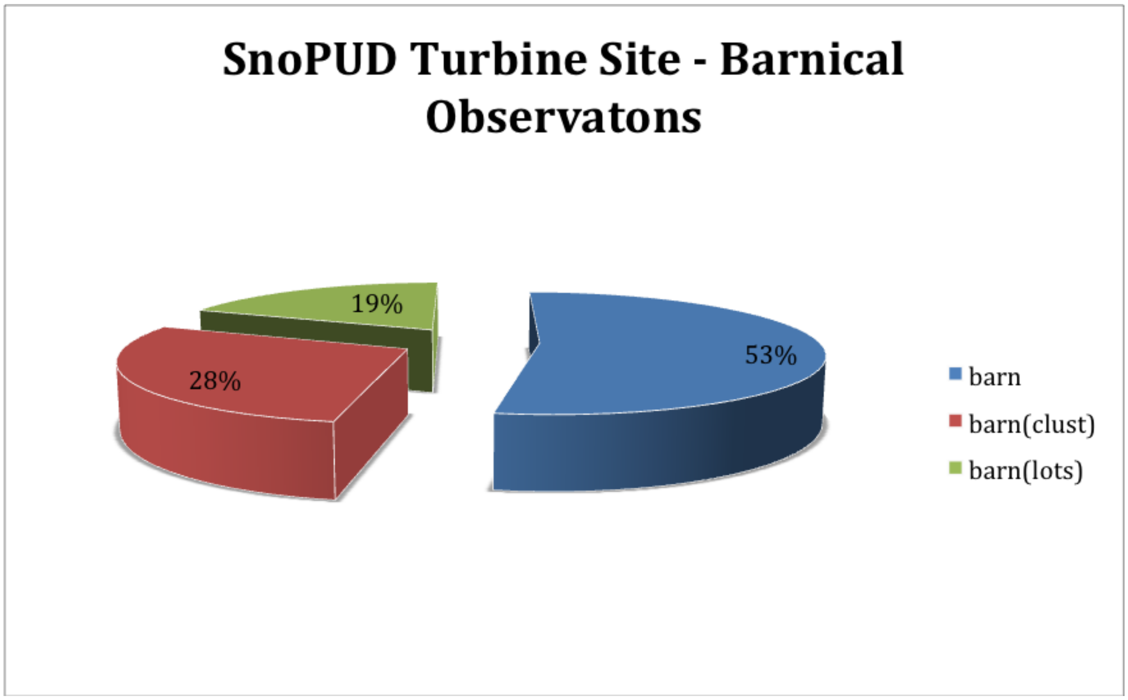

Figure 9. *Percentage of individual, barn, cluster, barn(clust) and highly concentrated or fields, barn(lots), of barnacles noted in the turbine site.*

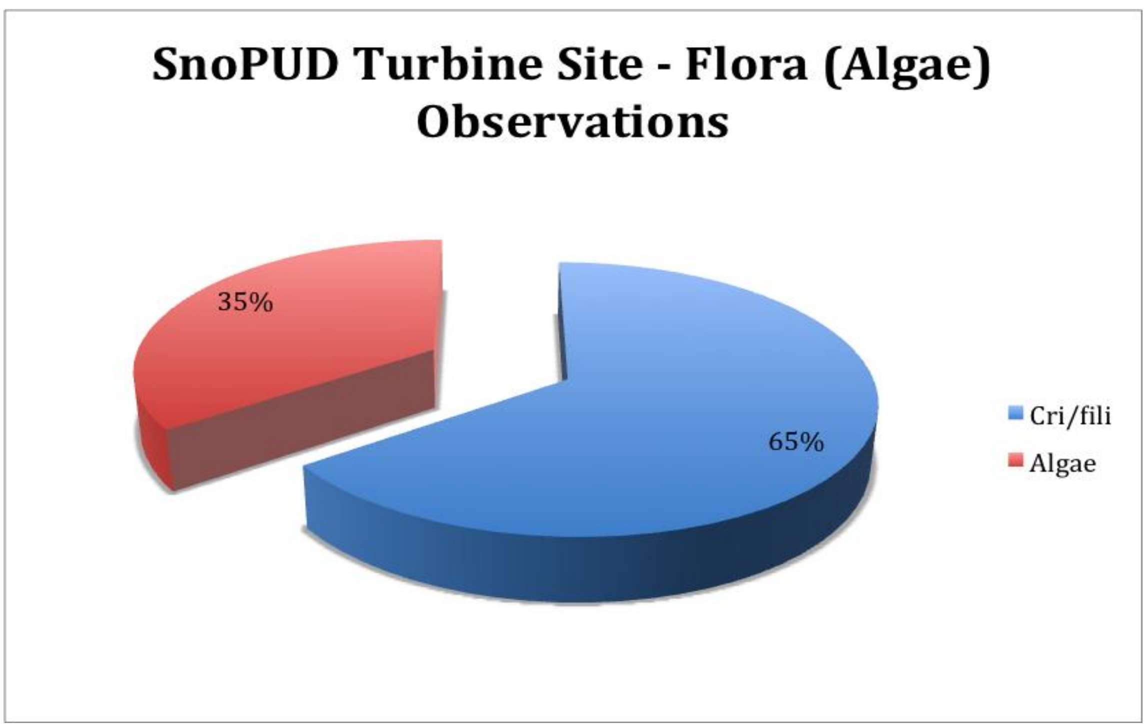

Figure 10. *Percentage of Crinoid-like or filamentous and bladed algae observed in the ROV video at the turbine site. The filamentous algae are the dominant form.*

The barnacles and algae were observed to be heavily concentrated along ROV transects 27S? (133 barnacle, 23 algae notations), 31S (251 barnacle, 17 algae notations), 36N continue (28 barnacle, 10 algae notations), and 31S (16 barnacle, 16 algae notations). Algae appeared to have a direct relationship with barnacles, as where large concentrations of barnacles occurred, such as clusters or in fields, a considerable amount of algae were attached to the barnacles (see Appendices II and III, Plate 1). The Crinoid-like or filamentous algae were observed attached to both barnacles and cobbles and boulders.

3.2.2 Attached Organisms (Anemones)

A variety of anemones were observed and counted in the turbine site. These organisms were relatively easy to identify and were generally solitary and thus easier to count than highly concentrated species. Three basic types were distinguished based on color and pattern (solid purple and white, and stripped white on purple) in addition to an orange or deep purple pompom-like anemone or nudibranch. Some anemones were not distinguishable enough to place into any of the above categories and, therefore, were just counted as an anemone (A). A total of 1,375 anemones were counted, a total of 1,869 if the pompom-like or nudibranch ones are included. In addition, the feeding state noted during the ROV survey indicated that most of the anemones were not feeding, but observations made during the time that tidal conditions changed from slack to flood, saw the anemones opening to feed (see Appendices II and III).

The most prolific anemones counted are the purple closed ones (p/c) at 49% (669 counts) followed by the white closed (w/c) at 23% (315 counted), purple open (p/o) at 12% (166 counted), anemones, general (A), at 9% (119 counts), stripped closed (s/c) at 6% (87 counts), white open (w/o) at 1% (15 counts) and stripped open (s/o) at >1% (4 counts), excluding the pompom-like organisms (Fig. 11).

If the pompom-like or nudibranch are included in the anemone count the purple (p/c) closed anemones still dominate at 36%, but the pompom-like or nudibranchs (pp) are found to be second in abundance at 26% followed by white closed (w/c) at 17%, purple open (p/o) at 9%, general anemones (A) at 6%, stripped closed (s/c) at 5%, white open (w/o) at 1% and stripped open (s/o) at >1% (Fig. 12).

The anemones varied in size ranging from ~4 cm to 12 cm in diameter when closed, the diameter of their stock or trunk (see Appendices II and III). The size is pretty uniform and small, probably because if larger they would provide a greater surface area to the currents and thus prone to displacement by the tidal currents.

The anemones appeared to be concentrated along specific ROV transects. Transects where these organisms were most prolific are 31S (140 counts, 183 if pp counted), 34N (99 counts, 142 if pp counted), 24S (120 counts, 160 if pp counted), and 36N continued (141 counts, 179 if pp counted).

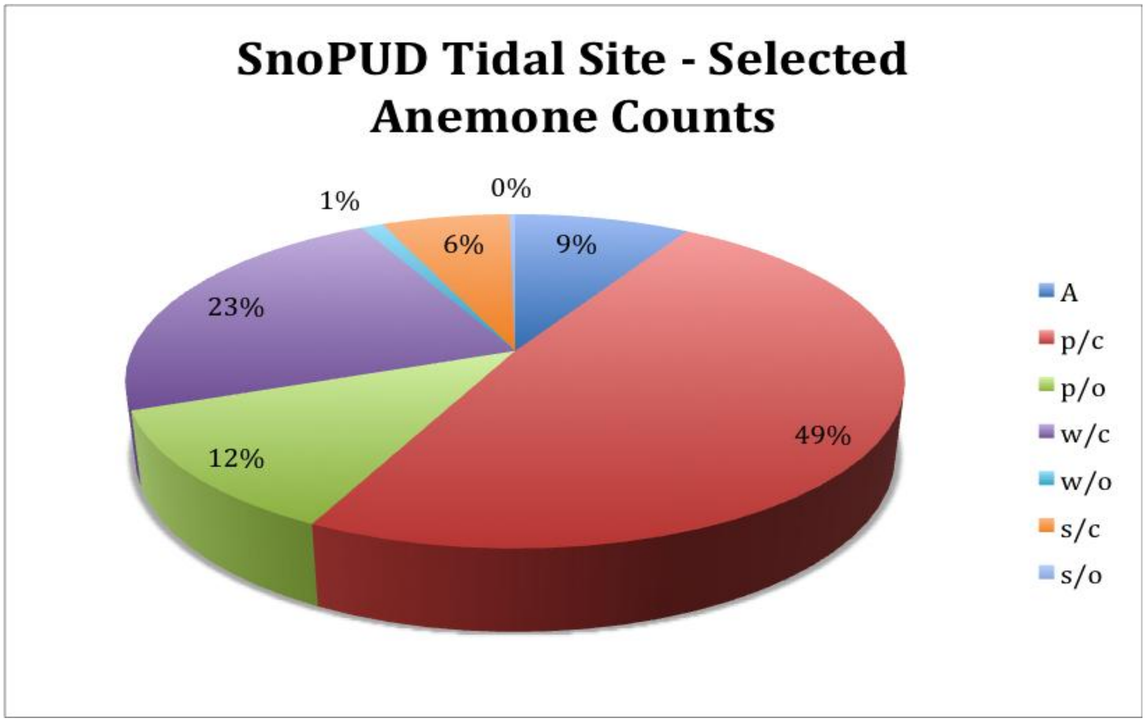

Figure 11. *Percentage of anemones counted from the ROV video. A = anemone, general, p/c = purple closed, p/o = purple open, w/c = white closed, w/o = white open, s/c = stripped closed, and s/o = stripped open anemones. The dominant type of nearly 50% is the purple closed anemone.*

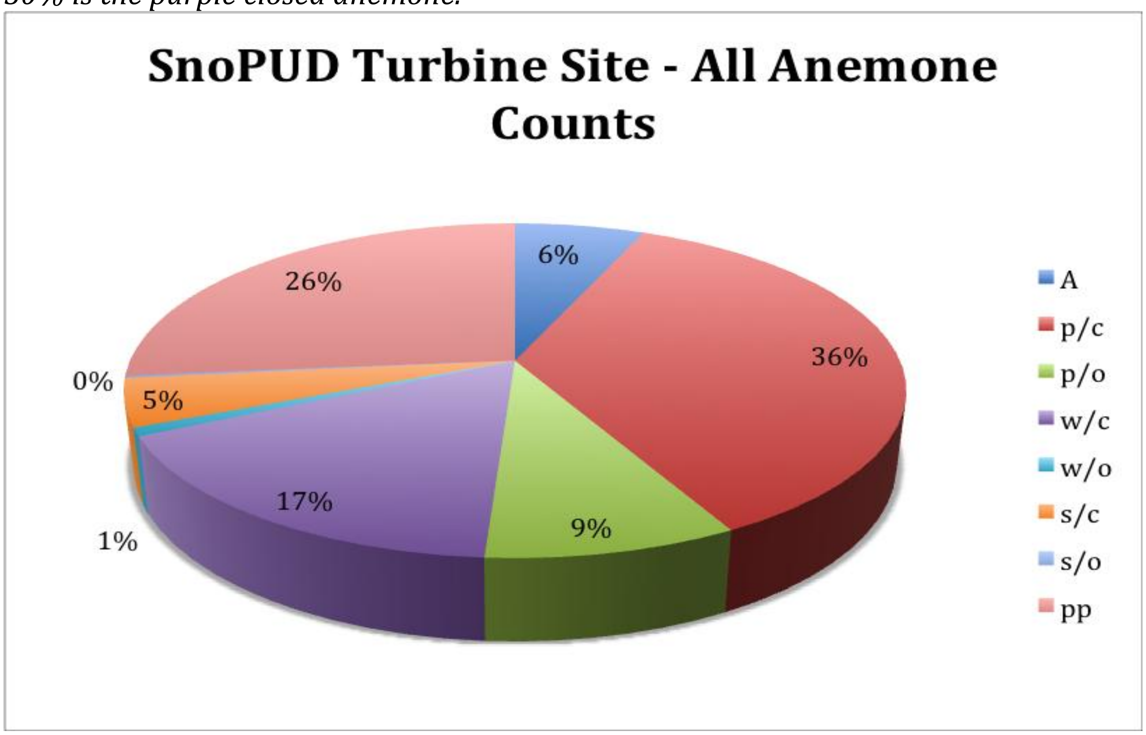

Figure 12. *Percentage of anemones counted in the ROV video including the pompom-like or nudibranch (pp) form. Purple closed anemone still out numbers all others.*

3.2.3 Sessile Organisms

Organisms included in this group are tunicate, chiton or limpid, and stemmed or basket sponge, as well as clams. Although observed in few numbers, these organisms were counted to obtain an estimate of their quantity. Chitons or limpids are the dominant organism of this group at 44% (7 counts) followed by tunicates at 37% (6 counts) and stemmed and basket sponges at 19% (3 counts) (Fig. 13).

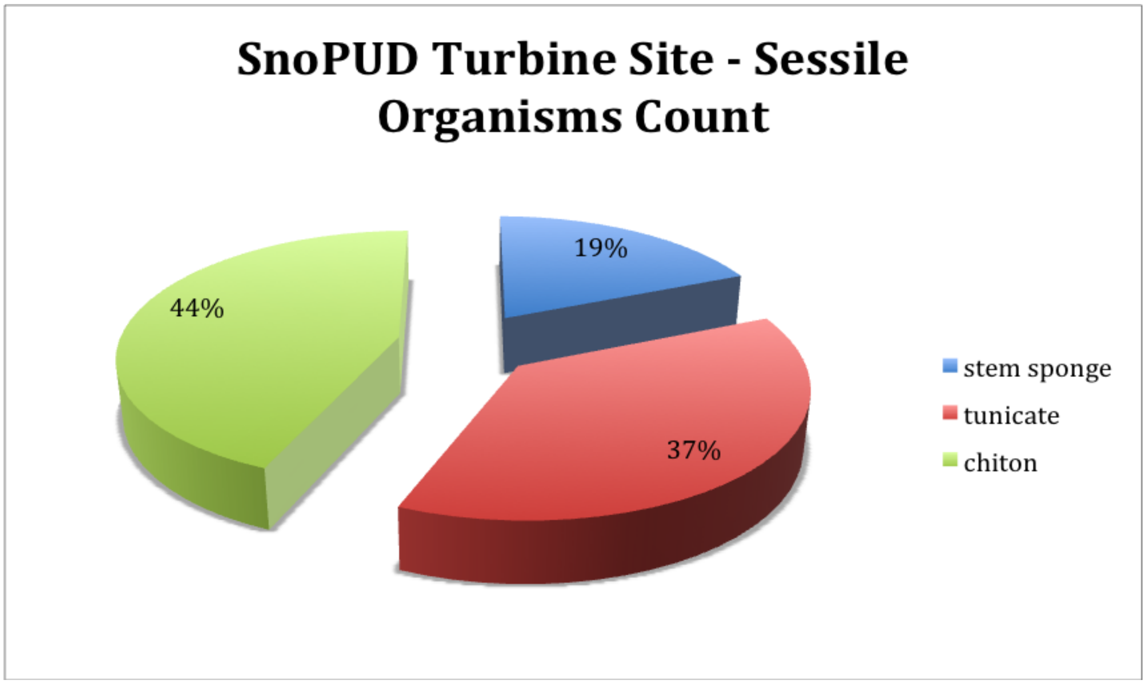

Figure 13. *Percentage of selected sessile organisms counted using the ROV video. Although small in numbers these sessile organisms provide an estimate of abundances based on what could be seen using the video.*

Clams observed in the ROV video were either partially open or closed, where 82% (23 counts) were open and 18% (5 counts) were closed (Fig. 14). If the clams are included with the other sessile organisms counted, closed clams dominate at 52%, chitons or limpids represent 16%, tunicates 14%, open clams 11%, and stemmed or basket sponges 7% of all sessile organisms counted (Fig. 15).

Open clams are the dominant species of the sessile organisms counted. These organisms were found to be most prolific along ROV transects 34N (3 counts), T-24S (4 counts), and 24S (6 counts).

For a complete run-down on the sessile organisms count see Appendices II and III.

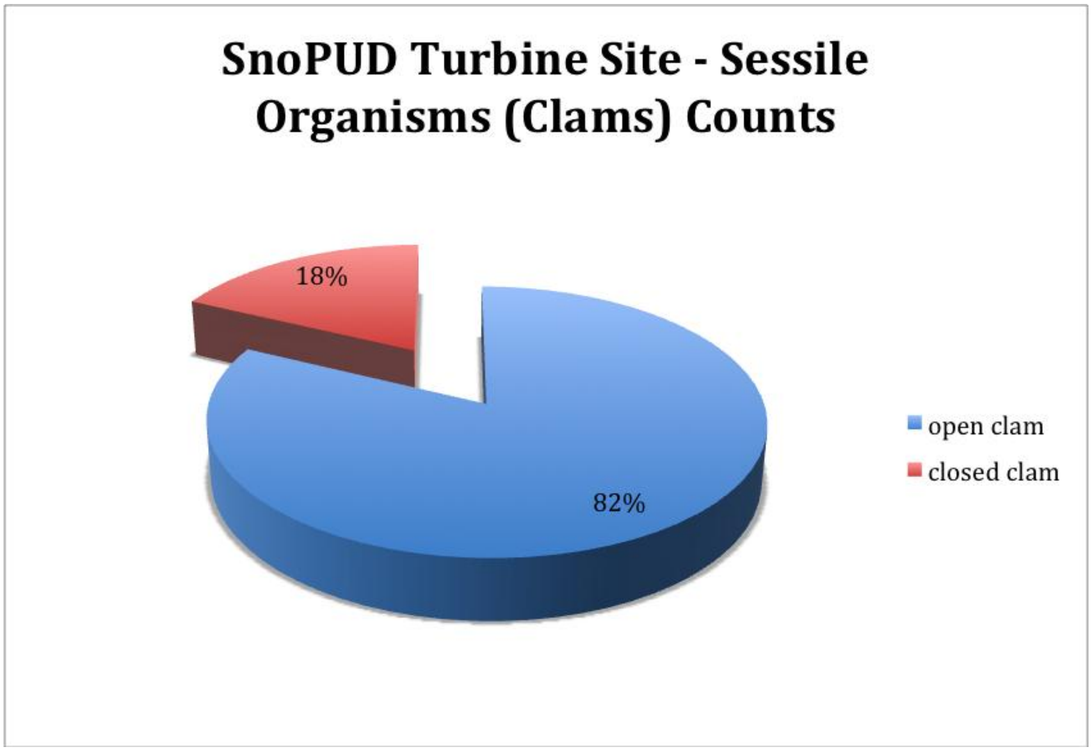

Figure 14. *Percentage of clams counted from the ROV video.*

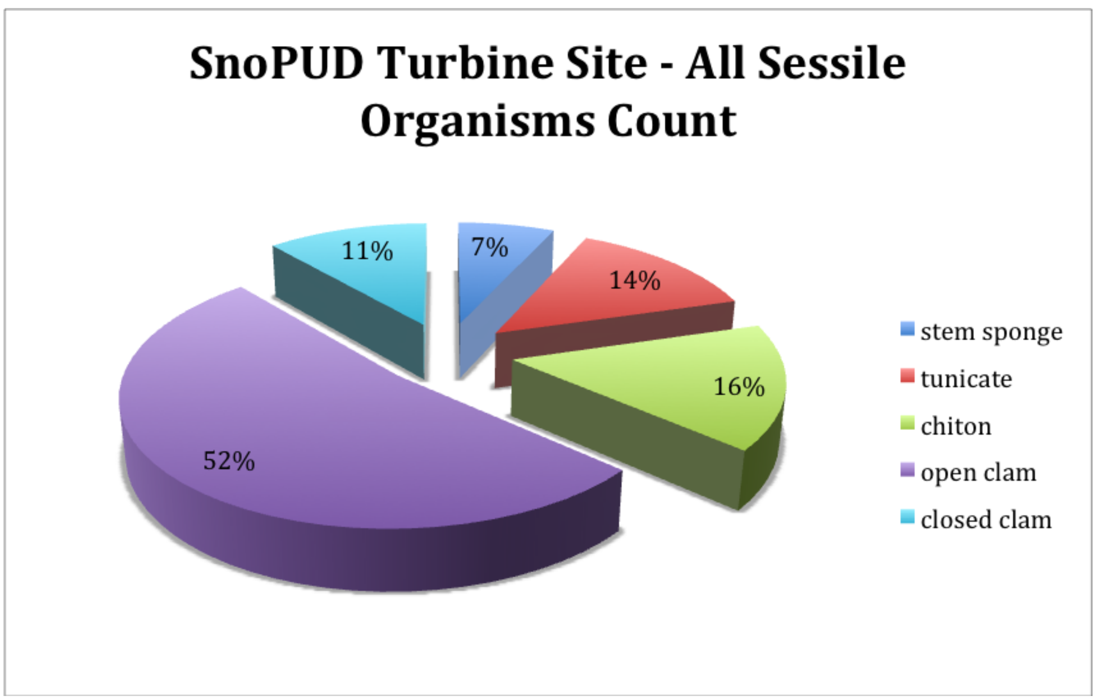

Figure 15. *Percentage of sessile organisms counted from the ROV video review including clams. Open clams dominate the group with 52%.*

3.2.4. Epifauna

The epifauna selected for counting consist of two groups, starfish and urchins. The first group, starfish, consists of three different types, general five-legged, orange starfish, sun starfish, and leather starfish. Two types of urchins were counted including green(?) urchin and purple urchin. Each group was compared independently and then combined to determine the overall relative abundance of each species (see Plate 1 for spatial distrubution).

Of the 134 starfish counted 89% (119 counts) of them were of the common type, 9% (12 counts) were sun stars, and 2% (3 counts) were leather stars (Fig. 16).

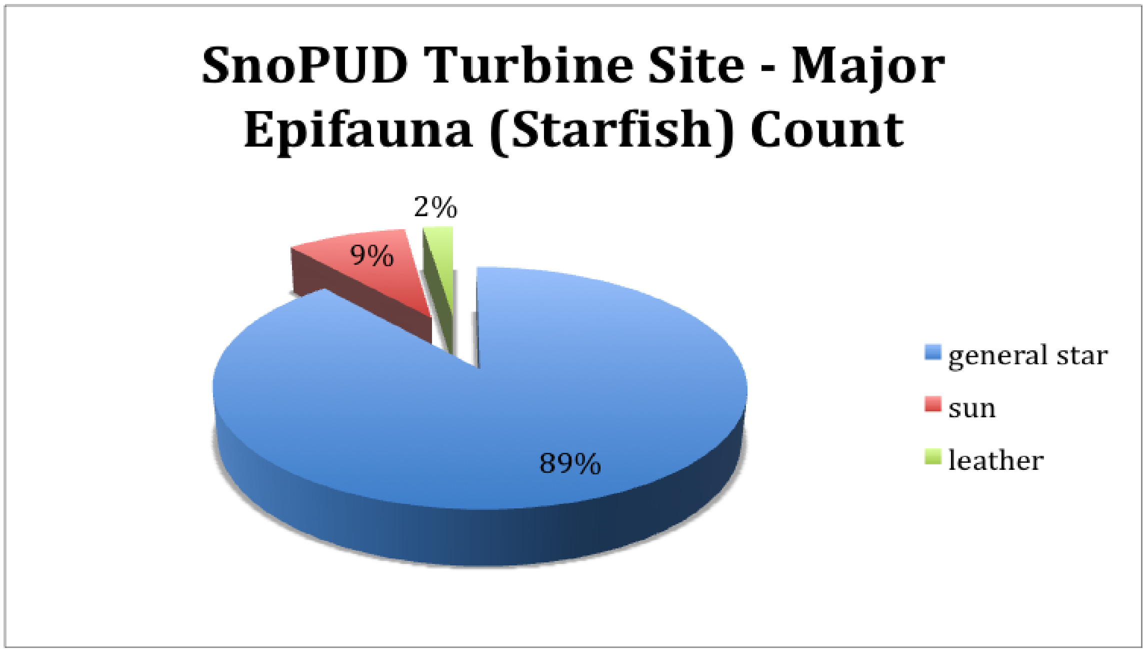

***Figure 16**. Percentage of various starfish counted using the ROV video. The common general, five-legged orange starfish dominates the group with nearly 90% abundance.*

Urchins are the other epifauna group counted from the ROV video. The two types of urchins, green(?) and purple urchins, were compared to each other and it was found that the green urchin, U, represents 98% (239 counts) of the total compared to the purple urchin U(pur) or 2% (6 counts) of the total (Fig. 17).

The starfish and urchins were combined to be compared as a single group and it was found that out of a total of 242 counts the green(?) urchin comprised 63% of the group while the common starfish represents 31% with the sun star representing 3%, the purple urchin 2% and the leather star less than 1% (Fig. 18).

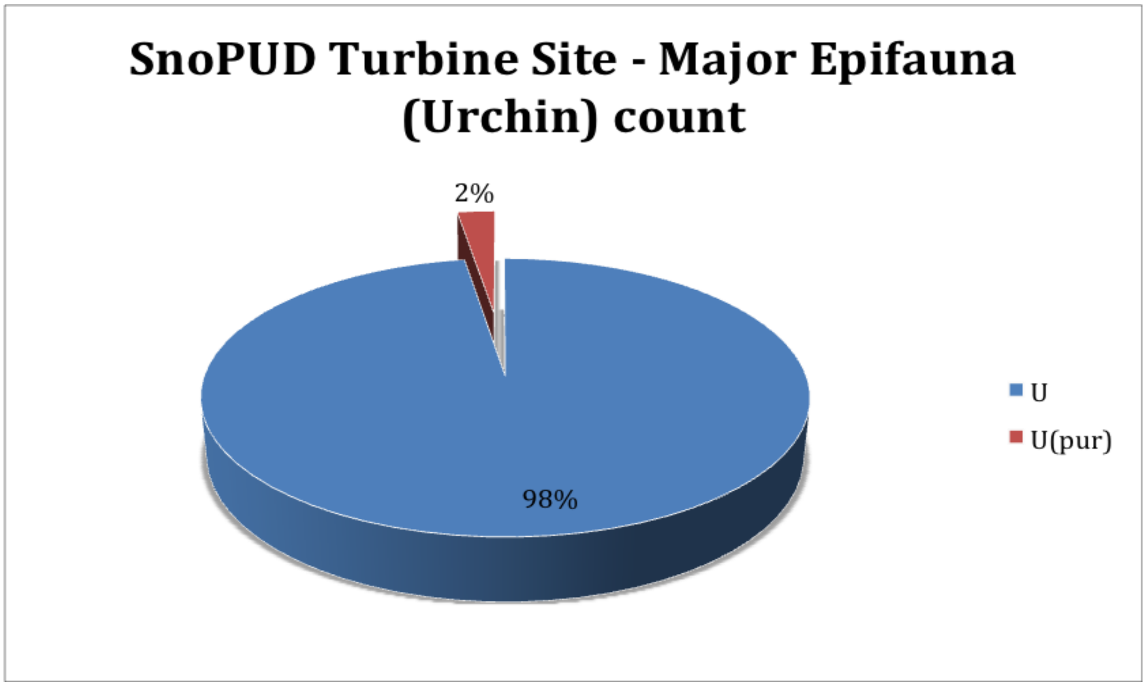

Figure 17. *Percentage of green(?), U, and purple, U(pur), urchins counted from the ROV video review.*

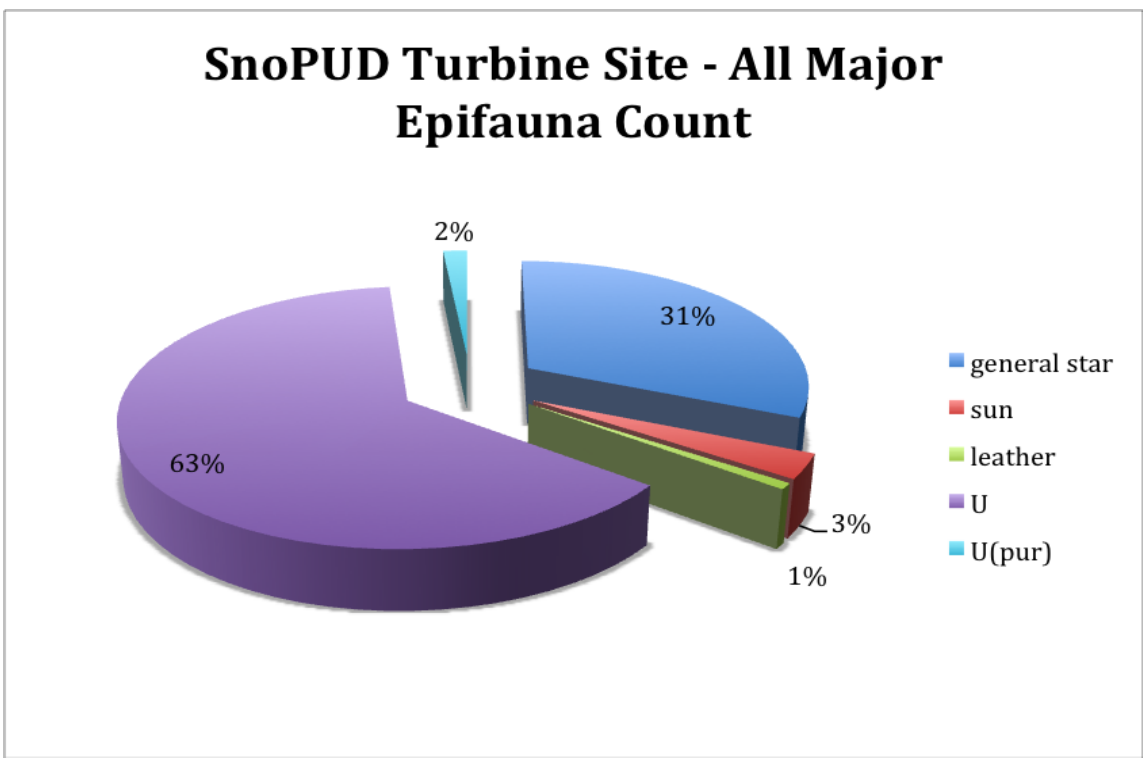

Figure 18. *Percentage of selected major epifauna counted from ROV video. The common (green?) urchin dominates the field at 63% followed by the common starfish at 31%.*

The ROV transects where this group of epifauna were found to be most concentrated in the investigation site are transects 31S (11 star, 14 urchin counts), 34N (13 star, 15 urchin counts), 24S (15 star, 24 urchin counts), 36N (11 star, 24 urchin counts), and 24S (6 star, 17 urchin counts).

Other epifauna counted, although rare, consist of turban snails (10) at 56%, shrimp (4) at 22%, hermit crab (2) at 11%, crab (1) at 5%, and an octopus (1) at 6% of the total this group (Fig. 19).

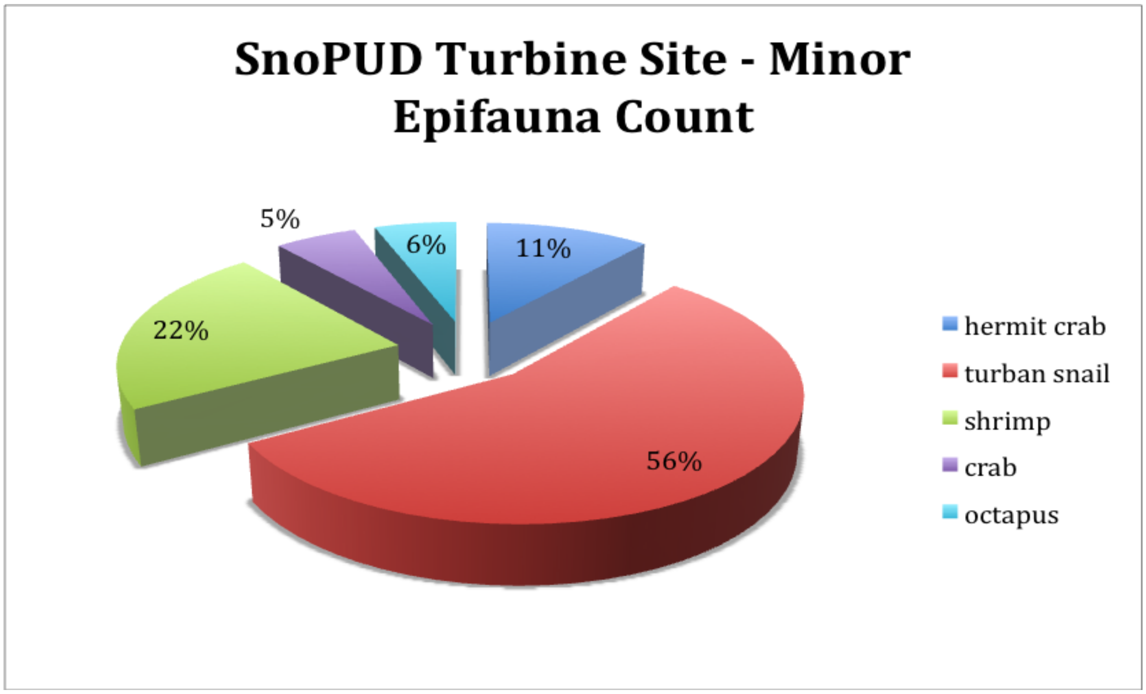

Figure 19. Percentage of rare (minor) epifauna counted in the review of the ROV video. The turban snail dominates this group at 56%.

When the major and minor epifauna are combined the common (green?) urchin dominates the field at 60%, while the general five-legged orange starfish represents 30%; these two species represent 90% of the total epifauna counted (Fig. 20). The remainder of the counted species makes up the final 10%.

Starfish were found to be most concentrated in numbers along ROV transects 31S (11), 34N (13), 24S (15), and 36N continued (11). Urchins were most concentrated in numbers along transects 27S? (14), 31S (14), 34N (15), 24S (24), 36N continued (24) and 24S continued (17). The minor epifauna were primarily concentrated along transects 16S-suspended (6), 34N (3), T-24S (4) and 24S (6). See Appendix III for complete counts (see Plate 1 for spatial distribution).

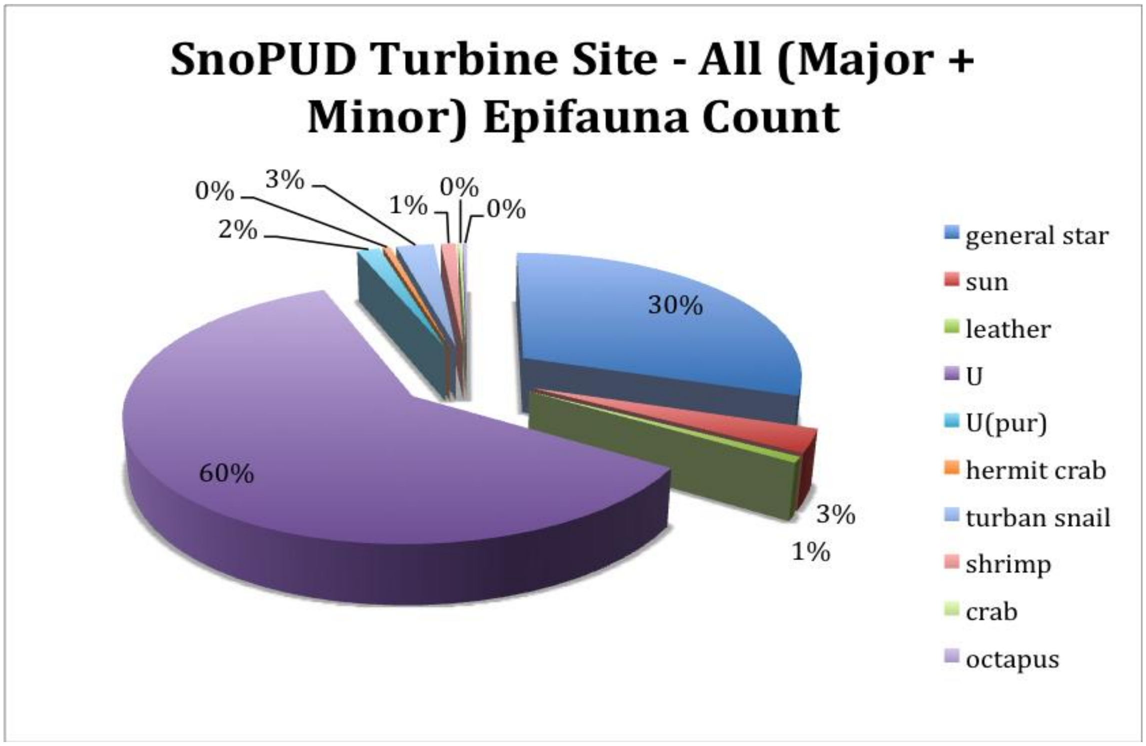

Figure 20. *Percentages of epifauna counted in the review of the ROV video. The common (green?) urchin and the common five-legged orange starfish comprise the majority of the group 90%.*

3.2.5. Fish

A total of 192 fish were counted in the ROV video review and represents a conservative estimate as many fish were seen several times but were not counted when thought to be a repeat. All fish including pelagic and benthic types were counted. Ratfish (rat) were conspicuously the most prominent representing 49% (98 counted) of the total and at times was a nuisance (some even entering the thrusters). Sculpin, ranging in size from ~5 cm to 30 cm, is the most prominent benthic fish counted at 38% (75 counted) followed by an unidentified fish (UnIDfish), generally a black and white stripped goby-like fish about 5-15 cm long, at 8% (16 counted), lingcod (ling) at 4% (7 counted), kelp cod or kelp greenling (kelp) at 1% (2 counted), and Pacific sand lance (PSL) at less than 1% (1 counted), although this identification is questionable (Fig. 21).

If ratfish is considered pelagic and not included in the count than the benthic fish would total 94, nearly half of all of the fish counted. Sculpin would then be the dominant species at 74% followed by the unidentified fish at 16%, kelp greenling at 7%, lingcod at 2%, and Pacific sand lance at 1% (Fig. 22). See Appendix II for video review log and Plate 1 for spatial distribution.

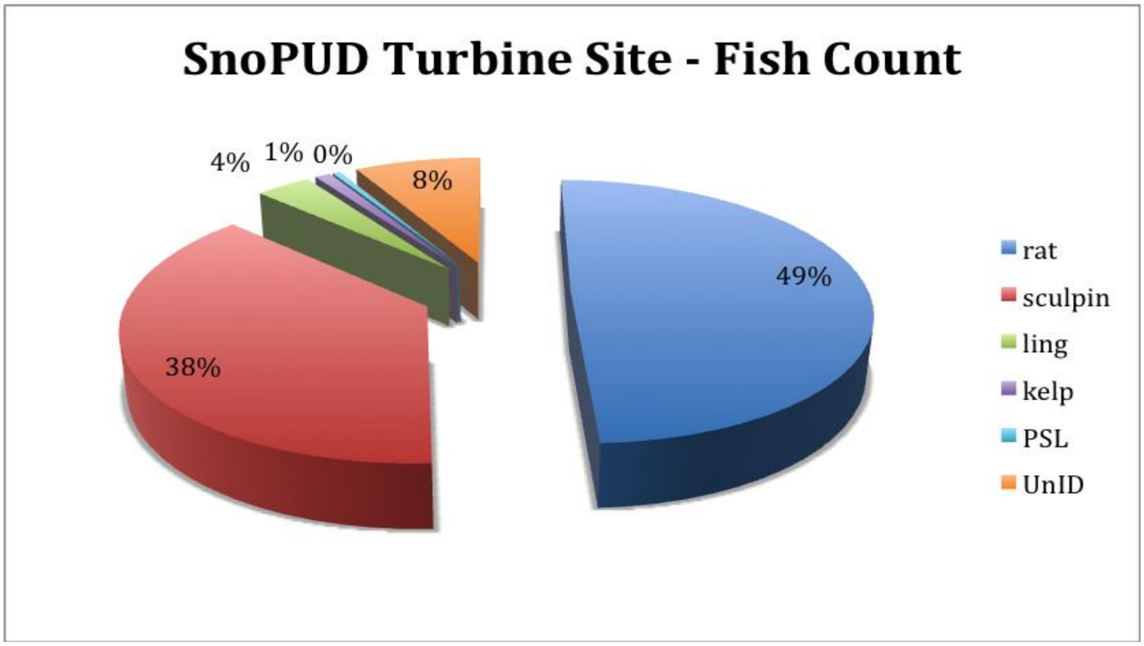

Figure 21. *Percentage of fish counted in the ROV video review. Ratfish dominate the field with almost 50% of the total.*

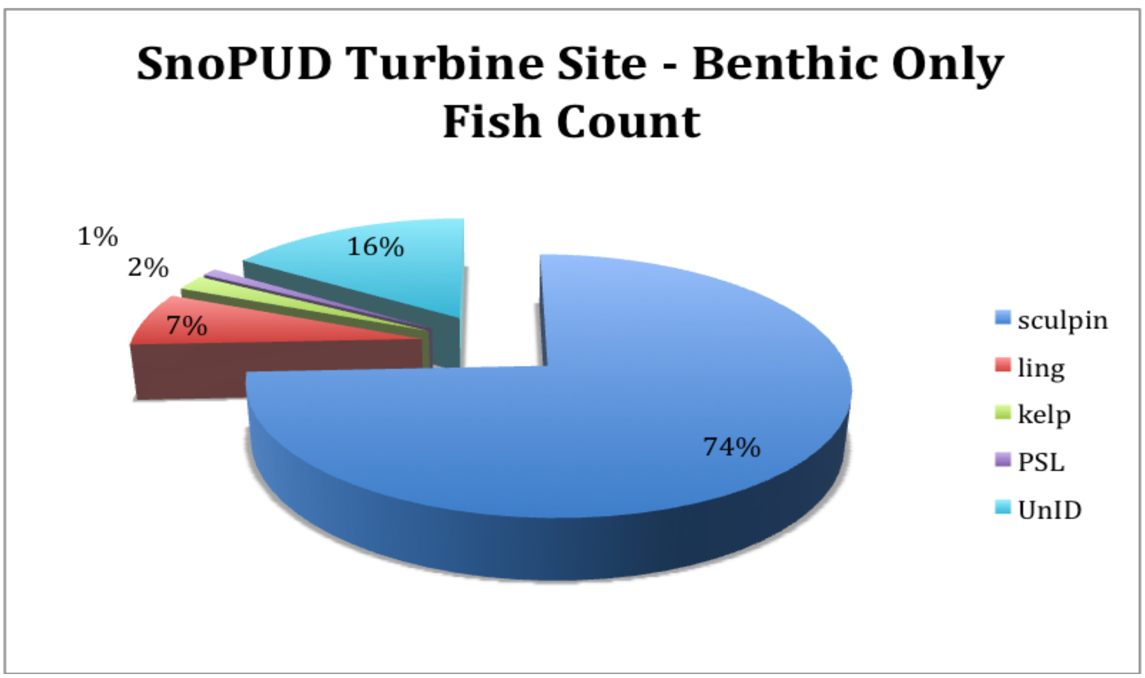

Figure 22. *Percentage of benthic fish counted in the ROV video review. Sculpin represent nearly two-thirds of all of the fish counted during the ROV survey.*

Fish also appeared to be concentrated along certain ROV transects. Ratfish were highly concentrated along transects T-14N (12), T-14N-2 (10), and 36N continued-2 (10). The benthic fish were concentrated along transects 31S (13 fish, 9 Sculpin) and 24S (9 fish, 5 Sculpin). See Appendices III for complete call out of fish and Plate 1 for their spatial distribution.

4. Results and Recommendations

The SnoPUD turbine site is a dynamic and diverse geological and ecological area. Geomorphology and substrate types found at the site result from past glacial processes and present oceanographic conditions. Strong tidal currents winnowed the fine sediments leaving a cobble-pebble-small boulder lag pavement, heavily encrusted with sponge, bryozoans and tubeworms throughout the area. Locally, stringers of clean, fine grain sediment (gravel and sand) were observed and appear to be transiting through the site, transported by strong ebb tidal currents. A diverse and robust ecological community was observed during the ROV survey and some specific organisms were selected for counting in order to estimate abundances.

Due to strong tidal currents, marginal visibility and irregular bottom conditions consistent elevation above the bottom and continuous even speed for transiting the ROV was not possible. Consequently, not every meter of the turbine site was video imaged. However, due to the fairly consistent substrate type and biology a good characterization of the benthic habitat was possible. A robust and comprehensive statistical analysis of the data was not attempted, but an estimate of abundances as presented here should provide a good base line for, and facilitate, future monitoring efforts.

Few biological scientific names are used in this report primarily because the quality of the recorded video was not sufficient in most cases to identify organisms at the genius or species level. However, most of the organisms observed or counted are tagged to the video logs and can be easily studied in the future to determine their lowest taxonomic level.

Substrate, although fairly consistent throughout the turbine site, is patchy in places and ranges from primarily well-rounded cobble-pebble-small boulders to well-rounded cobble-pebble pavements. The larger clasts, cobbles and boulders, are generally encrusted with sponges, bryozoans, and tubeworms (Fig. 23). The substrate is loose or unconsolidated and clasts can be moved easily with the ROV. Encrustation occurs on the exposed surfaces of the clasts, while the buried, or under surfaces, remain clean, as indicated during times substrate was disturbed by the ROV and from samples collected by an anchor. This substrate appears to attract a diverse biological community consisting of barnacles, algae, anemones and various other attaching and sessile organisms, epifauna consisting of starfish and urchins, and fish, particularly Sculpin.

There appears to be a relationship between substrate type and ecology. When comparing substrate types with biology along ROV transects it is apparent that most of the organisms observed and counted tend to be concentrated along those transects that appear to have the most diverse substrate types. For example, the most diverse substrate types were noted along transects 24S and 36N for coarse-grain clasts (cobble, pebble, and small boulder) and along 31S for the fine-grain constituents (gravel and pebble) and along these transects the substrate was heavily

Figure 23. *Small boulder and cobble recovered in flukes of anchor from barge used for the ROV operation at the turbine site. For scale pocketknife is approximately 10 cm long. Boulder and cobble are encrusted with sponge, bryozoans, and tubeworms. Note clean area on boulder where area was not exposed.*

encrusted and the largest concentrations of attached, sessile, epifaunal, and fish individuals were counted (Plate 1). Barnacles and algae appeared to be heavily concentrated along transects 27S(?), 31S, 24S, 36N continued and 31S continued. Most of the sessile organisms counted were found along transects 34N, T-24S, and 24S, while anemone counts were highest along transects 31S, 34N, 24S, and 36N continued (Plate 1). Starfish and urchins were more widespread being concentrated along transects 27S, 31S, 34N, 24S, 36N, and 24S-continued. Fish, primarily Sculpin, on the other hand, were restricted more to transects 31S, 24S, and T-34N continued.

Little derelict fishing gear or other anthropogenic debris with the exception of a short length of rope and crab pot rings seen on transect 26N were observed.

Most complex and diverse ecology is located in the SW corner and along the western hypotenuse of the mapped area, at sites where the substrate is coarse (e.g., large boulders). Closely spaced starfish, barnacle clusters and barnacle fields also concentrated in this corner, however the highest concentration of barnacles was found in the NE corner (Plate 1).

Based on these observations and organism counts it appears that the turbine site can be characterized as a coarse-grained, cobble, pebble, boulder habitat for encrusting organisms and Sculpin, although some rockfish appear to use the habitat as well. Epifauna such as sunfish and urchins also occupy the habitat. The proposed positions for the two tidal turbines appear to be well located in regard to the concentration of biological communities (Plate 1). The highest concentration and diversity of these communities lie in the NW and SE corner of the triangle survey area and just outside the northern and southern margin of the clean (no biological communities) dynamic substrate corridor (an active sediment migration corridor for material being transported by bottom currents) (see Plates 1 and 2).

The glacial cobble, pebble, small boulder lag is suspected to overlie a glacial clay layer as clay was observed underlying the coarse glacial lag deposit just outside of the north central boundary of the triangle turbine survey area along the cable route. The glacial lag is unconsolidated and easily moved so it is anticipated that foundation structures for the turbines can be installed with a minimum of disturbance to the substrate.

This ROV habitat characterization of the SnoPUD turbine site sets the foundation for monitoring the area during installation of the turbines and during the operational time of the units. Based on the experience from this study it appears that it is not feasible to collect substrate samples remotely, such as using sediment grab samples or dredges. Alternatively it is recommended that in situ observations using an ROV be undertaken to measure the substrate grain size and disturbance in the same manner as has been used for this study. Also, it is recommended that the same biological communities selected for observation and counting be used for future monitoring of the site. This will provide similar information that can be compared and contrasted with the results of this investigation.

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Anderson, T.J., and Yoklavich, M.M., 2006. Multiscale habitat associations of deepwater demersal fishes off central California. Fisheries Bulletin, 105, p. 168-179.

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Lynch, T.P, Pinkard, D.R., and Bultler, J.L., 2004. Use of remotely operated vehicle as a fisheries survey tool. NOAA, ROV Operations, LaJolla, CA, 36 pp.
Pacunski, R.E., Palsson, W.A., Greene, H.G., and Gunderson, D., 2008. Conducting visual surveys with a small ROV in shallow water. In Marine Habitat Mapping Technology for Alaska, J.R. Reynolds and H. G. Greene (eds.), Alaska Sea Grant Program, University of Alaska Fairbanks, p. 109-128.

Plate 1. ROV track line map of the SnoPUD tidal turbine site showing location of individual and concentrations of biological organisms and substrate types as observed from the ROV video.

Plate 2. Multibeam echosounder bathymetric image with interpreted potential benthic habitat types in the vicinity of the SnoPUD tidal turbine site offshore Admiralty Head, Whidbey Island, Washington. Habitat types based on Greene (2007).

Explanation for Plate 2:

Ih(c/p/b)_p/u	Hard unconsolidated cobble/pebble/small boulder pavement in Inland sea, moderately to heavily encrusted
Ih(b/c)i_p/u	Hard unconsolidated boulder/cobble moraine pavement in Inland sea, moderately to heavily encrusted
Ihg_p/s	Hard scour gully with sedimentary pavement in Inland sea
Ih(c/b)w(w)_u	Hard unconsolidated cobble/boulder sediment waves in Inland sea
Ihm_c/u	Hard bedrock mounds of consolidated material locally covered with sediment in Inland sea
Ime_c/u	Mixed hard consolidated bedrock locally covered with soft unconsolidated sediment in Inland sea
Ime_c/u/h	Mixed hard consolidated bedrock locally covered with soft unconsolidated sediment, hummocky, in Inland sea
Imi_p/u	Mixed hard moraine pavement locally covered with soft unconsolidated sediment in Inland sea

Imm/h_c/u/h	Mixed hard, consolidated mounds and depressions locally covered with soft unconsolidated sediment, hummocky, in Inland sea
Isb_u	Soft unconsolidated bimodal (pebble/gravel) sediment, clean or lightly encrusted, in Inland sea, dynamic, being transported

See Appendix IV for complete habitat code list (modified after Greene et al., 2007).

Appendix L-11

Geophysical Investigation for Admiralty Inlet Turbine Project

Final Report

Geophysical Investigation for Admiralty Inlet Turbine Project

Prepared for:
Snohomish PUD
Public Utility District No.1 of Snohomish County
2320 California Street

September 2011

A world of capabilities delivered locally

Golder Associates

REPORT

GEOPHYSICAL INVESTIGATION FOR ADMIRALTY INLET TURBINE PROJECT

Submitted To: Snohomish PUD
Public Utility District No. 1 of Snohomish County
2320 California Street
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September 6, 2011

Project No. 113-93037

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1.0 INTRODUCTION

This letter report summarizes the results of the geophysical investigation for the proposed Admiralty Inlet turbine project. The information presented in this report will be used by others to assist in evaluating and interpreting the geology at the turbine site and for selecting a route from shore to the site for the power cable. Further interpretation of the geology and geotechnical attributes at the site will be based on soil samples that are to be obtained in a subsequent subsurface investigation.

2.0 SURVEY OBJECTIVE

The purpose of the marine precision bathymetric and geophysical survey was to obtain information for selecting potential cable routes from shore to the turbine sites and assist in evaluating surface and subsurface geologic conditions at the turbine sites. The geophysical data are to be used as an aide to characterize seafloor material and to estimate the thickness of the sediment on the seafloor at the proposed site and along the proposed power cable corridors. This geophysical data will also be used to develop a geotechnical investigation program or an optional geophysical investigation that would include multichannel analysis of seismic waves (MASW).

3.0 INSTRUMENTATION

The geophysical data were acquired with a suite of instruments that, with the exception of the sidescan sonar, were deployed and operated simultaneously. The following is a brief discussion of the instruments and the shipboard configuration of the instruments is illustrated on Figure 1.

3.1 Navigation

The position of the survey vessel was determined using a Coda F180 inertial navigation system with differential global positioning system (DGPS) utilizing a Coast Guard beacon located at Whidbey Island. The DGPS was interfaced with the geophysical instruments including the echosounder, graphic recorders, and QPS QINSy digital acquisition systems. QPS QINSy was used to provide real-time data acquisition, quality assurance tools and data file storage during the survey. The position of the survey vessel, planned and completed tracklines and navigation parameters including speed, heading and cross-track error were displayed in real-time on multiple monitors. This made it possible for the helmsman to navigate the survey vessel along the planned survey transects.

3.2 Bathymetry

The bathymetric data were acquired with a R2 Sonic 2024 multibeam operating at the 400 kHz frequency. Vessel heading, heave, pitch and roll were recorded from an inertial navigation sensor to correct the multibeam swath bathymetry for vessel attitude. Sound velocity casts were taken at the beginning of each day and every two hours to record the speed of sound through the water column. The data was used to apply refraction corrections to the multibeam.

Bathymetric post processing was performed with Caris Hips version 7. Soundings were corrected for vessel attitude and beam refraction and cleaned of erroneous data. The final soundings were created with a data binning process that reports the average value of all soundings within a given cell. The cell center is used as the X and Y coordinate. Smaller bin sizes preserve the accuracy of the surface better but result in very large and difficult to manage datasets. A larger bin size will produce smaller datasets but may smooth the surface with undesired affects. One and two meter binned data sets were provided for this project

3.3 Datums

The horizontal datum is NAD83, UTM Zone 10, meters. The vertical datum is Mean Lower Low Water (MLLW) datum, holding the NOS Tidal Benchmark “R 257 1944” at Tide Station 9444900 in Port Townsend. Vertical positions were corrected with the GEOID09 geoid model. Post Processed Kinematic (PPK) GPS was used to refine the final horizontal and vertical vessel positioning holding Continuously Operating Reference Station (CORS) Whidbey Island 5 as the reference station. PPK positioning was applied to the multibeam only to improve the real-time DGPS vessel positioning accuracy from approximately one meter to better than 10 centimeters (cm).

3.4 Sub bottom Profiler and Seismic Reflection Systems

The need for high-resolution data in fine to medium-grained sediment and subsurface penetration in coarse-grained material required the use of two acoustic systems that had different output characteristics.

A 3.5 kilohertz (kHz) sub bottom profiler (SBP) system was used to provide high-resolution information on the thickness of fine-grained sediment. The high-resolution data were displayed in real-time on a graphic recorder, and archived on a digital acquisition system. The graphic recorder and digital acquisition system were interfaced with the navigation system to provide real-time fiducials or event marks on the archived and printed data.

A low frequency acoustic system (800 Hz to 2000 Hz) was used to acquire deeper subsurface reflection data. The data were displayed in real-time on a thermal graphic recorder and archived on a digital recorder. The display recorder and digital system were interfaced with the GPS navigation system and received an event mark, tagged to vessel position, every 30 seconds.

3.5 Survey Coverage

The bathymetric and seismic data were acquired simultaneously on a series of parallel transects (Map 1). In the turbine area, the transects were oriented NE-SW spaced at an interval of 30 feet (10 m). In the proposed cable corridor area the NS and EW transects were spaced at an interval of 150 feet (50 m).

The sidescan sonar data were acquired after completing the bathymetric and seismic survey on two transects that ran approximately down the center of the proposed cable corridor area (Map 1)

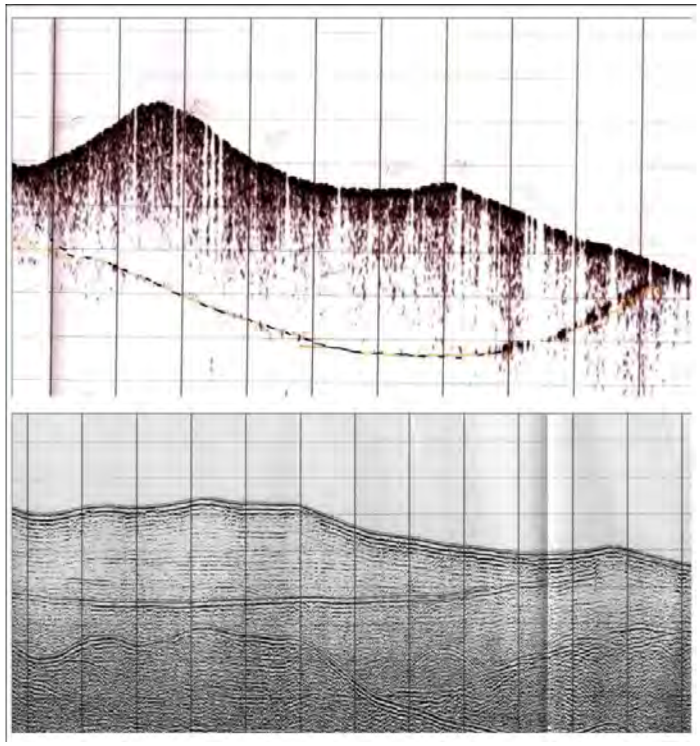
4.0 ANALYSIS OF GEOPHYSICAL DATA

The seismic reflection and subbottom field records and the processed data were analyzed to provide a qualitative classification of stratigraphy, based on seismic characteristics, and to determine the thickness of unconsolidated sediment and/or depth to an interpreted acoustically-hard material or reflector. In addition, an effort was made to identify subsurface features that suggested the presence of potential geohazards or anomalous geologic conditions such as buried channels, submarine landslides and potential faults and the presence of large boulders.

Stratigraphic classification, based on seismic reflection data, uses the principal of seismic facies analysis. This method identifies various reflection patterns observed in the data (e.g., reflection free, uniform horizontal reflectors, discontinuous reflectors, chaotic reflectors, hyperbolic reflectors, multiple reflections etc.) and then assumes a particular pattern is characteristic of a particular type of sediment, geology or depositional environment. For example a reflector pattern (geophysical facies) on the record comprised of continuous, thin layers suggests fine-grained sediment deposited in a low energy environment such as lake or deep-water deposits. The subbottom example shown in the image below would be an example of this type of reflection pattern and interpretation. Sediments deposited in a high-energy environment, or that may be more consolidated than overlying material, usually produce very strong reflections (dark layers on the records) and the reflectors are often discontinuous. Areas of no subsurface penetration, with a dark reflection pattern, or numerous multiple reflections, represent acoustically-hard material such as bedrock or over-consolidated glacial and interglacial deposits. Large boulders produce hyperbolic reflections; upside down U shaped patterns.

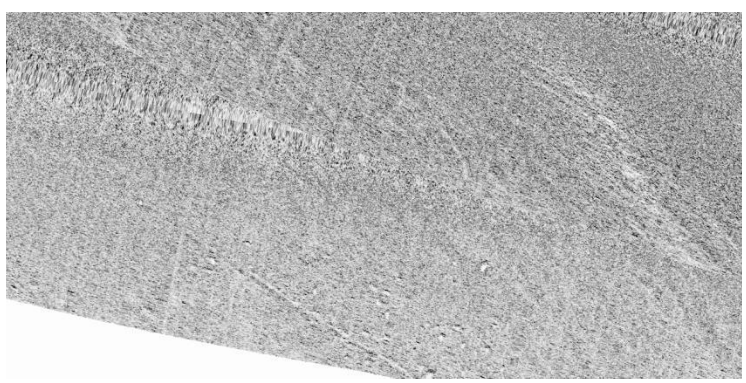
Examples of the geophysical acoustic data obtained during this survey are shown in the figure below. The upper image is from the subbottom profiler (SBP) and shows a relatively thick deposit of what is interpreted to be fine-grained sediment. It is relatively acoustically transparent. This material was probably deposited in a glacial lake or in a quiet water marine environment. Each division is 20 feet (approximately 7 m) and the deposit has a maximum thickness of 70 feet (approximately 23 m). This data example is not in the turbine area.

The lower image is from the seismic reflection system that achieved considerably more subsurface penetration than the SBP system. The fine-grained deposits discussed above can be seen on this image as well as thin, horizontally layered interbeds within the deposit. Each division is 40 feet (approximately 13 m) on this image. On the right side of the image hyperbolic reflectors can be seen suggesting the presence of boulders and possibly an over-consolidated glacial or interglacial deposit. The relative dark reflector on the left and towards the bottom of the image is a multiple reflection, or echo, of the seabed.



Example of subbottom profiler data (upper) and seismic reflection data (lower).

The sidescan sonar data were processed and the data from the two transects were combined to produce one image or a mosaic of the seabed along the proposed cable corridor.



Example of sidescan sonar mosaic. Linear feature along the bottom of the image is one of the communication cables that pass through the survey area.

5.0 INTERPRETED RESULTS

5.1 Turbine Site

The water depth in the region of the proposed turbine sites ranged from 45 to 70 m (Maps 2, 3 and 4). Based on previous studies using underwater video the bottom conditions in the area of the proposed turbine site are reported to consist of coarse-grained sediment including cobbles and boulders with interstitial clay. In addition, a number of very large boulders were observed on the multibeam bathymetric data and the sidescan sonar image as well as a section of one of the communication cables that pass through the area (Map 5). The largest of the boulders has an estimated weight of 8 million kilograms (kg) and the smaller ones are estimated to weigh approximately 45,000 to 60,000 kg (Map 3). These boulders are interpreted to be glacial erratics, dropped from the ice over 10,000 years ago. The do not appear to have settled into the seabed but do show evidence of a scour moat surrounding them.

An accurate thickness of the cobble pavement is difficult to determine but it estimated to range between 1 and 2 m. Unfortunately the gravel and cobbles on the seabed scatters the acoustic energy and therefore a distinct, continuous contact between the surficial layer and the underlying material cannot be easily identified.

In the south-west corner of the area the material on the seabed contains fine to medium-grained material, identified on the subbottom profiler data, that is up to 12 m thick (Map 6). In the remainder of the area the surficial and underlying material are interpreted to be coarse-grained and are possibly semi-consolidated (Map 7). There are also hyperbolic features and discontinuous reflectors in these underlying materials suggesting that small cobbles, gravel etc. are entrained within the deposit.

The deepest reflector mapped, 30 to 40 m below the seabed, is interpreted to be the top of over-consolidated glacial or interglacial deposits. The surface of this unit is irregular in shape, and there are numerous hyperbolic reflections indicating the presence of boulders. The seismic characteristic of this unit is typical of glacial till observed in other glacial environments.

5.2 Cable Corridor

The seabed along the proposed cable corridor ranged in depth from 2 m, at the landing site, to 60 m in the area of the turbine sites (Maps 2-4). The gradient of the seabed is approximately 1:100 going south from the landing site to the bottom of the slope. Going westward from this point to the turbine site the seabed gradient is also approximately 1:100. However, there are several changes in elevation of the seabed, such as depressions with 5 to 10 m of relief that are crossed in this direction.

The sidescan sonar data detected a number of large cobbles and boulders as well as evidence of seabed scour that are probably produced by the high currents in the area. There was no evidence of debris or cultural artifacts on the seabed with the exception of evidence for one of the communication cables near the turbine site.

The subbottom profiler (SBP) detected a surficial layer of what is interpreted to be fine to medium-grained, unconsolidated sediment along most of the corridor (Map 6). On the slope these material were generally less than 5 m in thickness. However, in one area, in deeper water, these sediments are up to 30 m in thickness in what is a relatively deep basin.

As expected the seismic reflection system was able to achieve considerably greater subsurface penetration than the SBP system. On the slope these sediment, interpreted to contain medium to coarse grained material, ranged in thickness from 5 to 30 m. No subsurface penetration could be achieved beneath this material and it appears that the underlying unit is an over consolidated glacial till.

In the area of the basin containing the fine-grained sediment mapped with the SBP the maximum sediment thickness, including fine and medium grained material is 70 m. This material is underlain by what it interpreted to be an over-consolidated glacial deposit containing large boulders.

6.0 CLOSING

We trust the foregoing is satisfactory for your current needs. If you should have any questions or comments, please contact the under signed.

Richard Sylwester, LG, LEG
Associate, Geophysicist

David P. Findley, LG, LEG
Associate, Engineering Geologist

RS/DPF/km

FIGURE

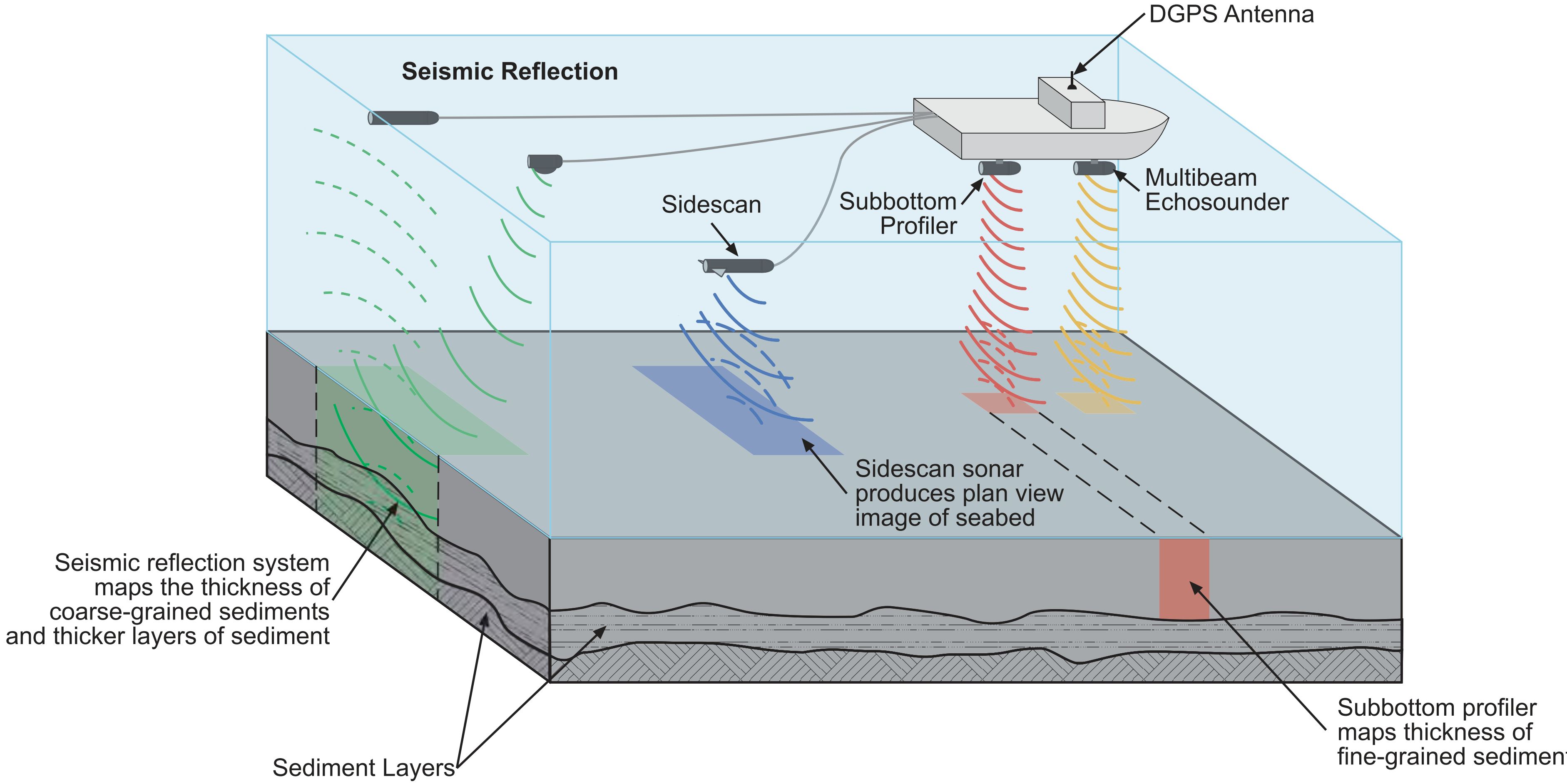
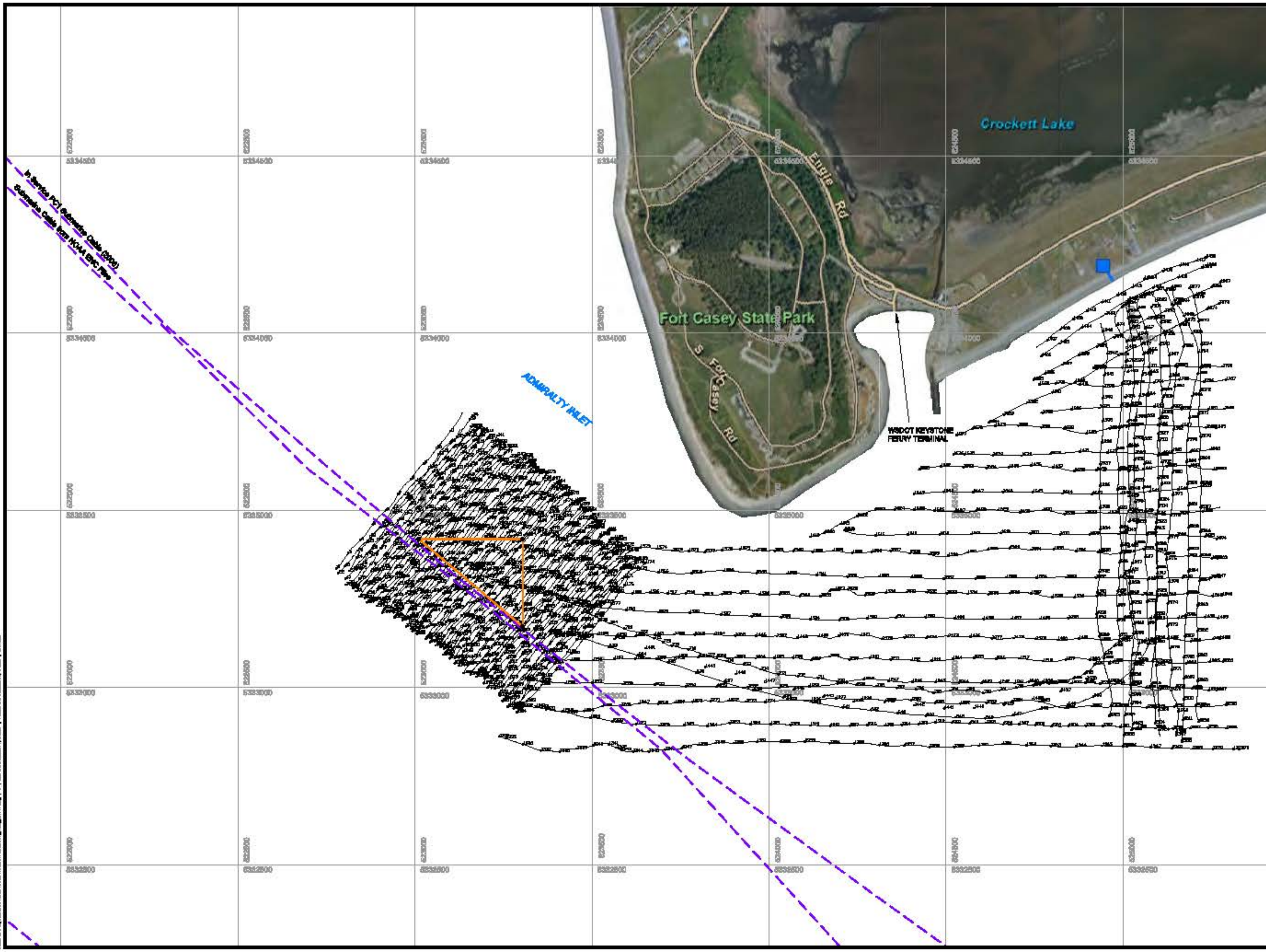


FIGURE 1
GEOPHYSICAL INSTRUMENTATION
SNOPUD/ADMIRALTY INLET TIDAL/WA

11393037100fig01_insturments.ai | Mod: 08/30/11 | AMP

Golder Associates

MAPS



KEY MAP

LEGEND

TRACK LINE AND EVENT NUMBER

PROPOSED DEPLOYMENT AREA

NOTES

1. LOCATION OR POSITIONS OF SUBMARINE CABLES BASED ON NOAA ENC.

INSTRUMENTATION

Navigation	Coda F180 Inertial System
Bathymetry	R2 Sonic 2024, 400 kHz
Sidescan Sonar	Edgetech Model 4200
Subbottom Profiler	Datasonic Model 5000
Seismic Reflection	AAE Model CSP 1500
Digital Acquisition	Sony 254 DAS

GEODETIC PARAMETERS

Horizontal Datum	NAD 83, UTM Zone 10, meters
Vertical Datum	MLLW
Tidal BM	R 257 1944, TS 944…

Golder Associates

SUBMITTED TO: SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

PROJECT: SNOPUD/ADMIRALTY INLET TURBINE/WA

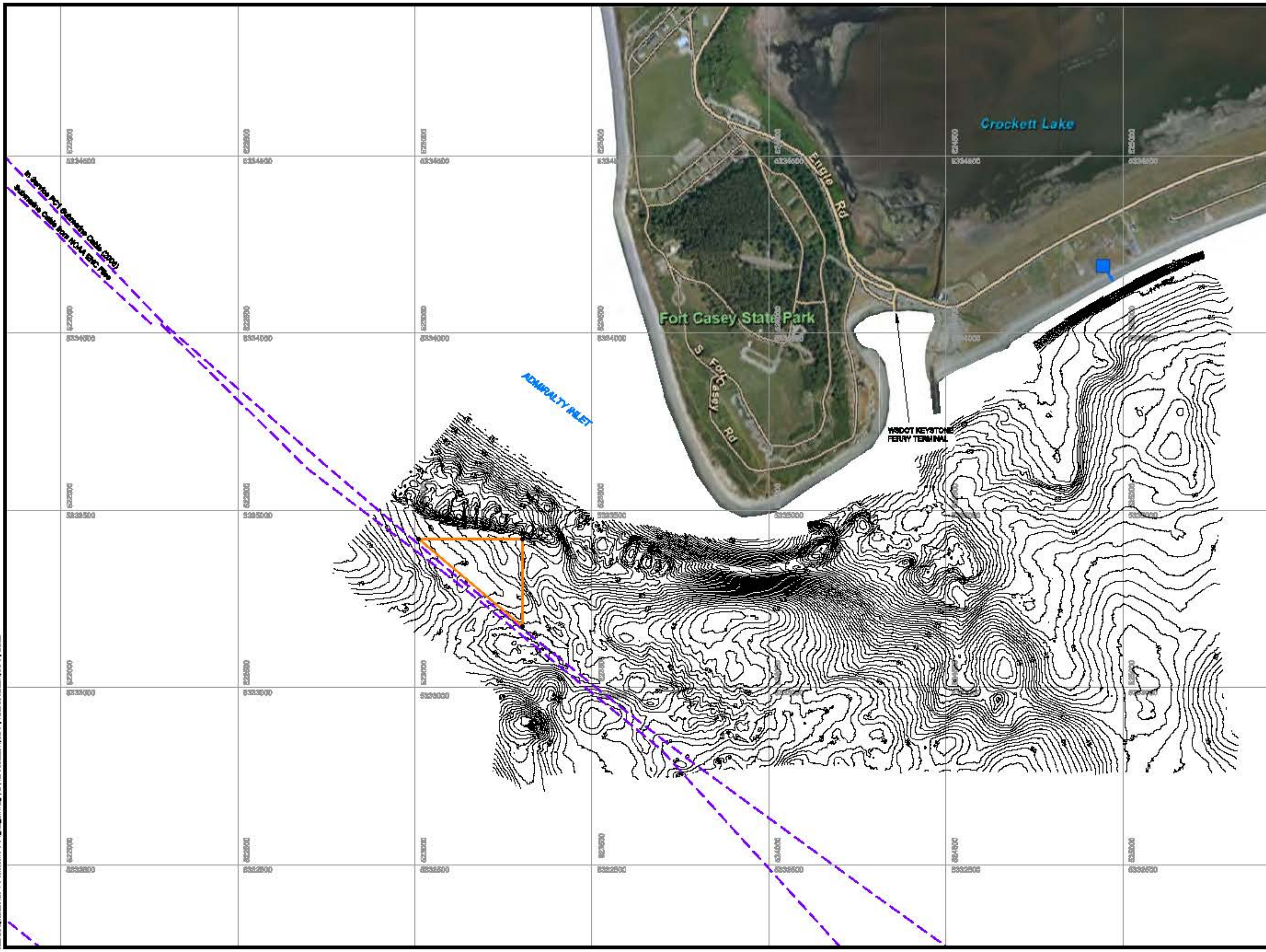
TITLE:

TRACKLINE MAP

REV	DATE	REVISION DESCRIPTION	SIGNED
1	9-1-11	FINAL	DS

PROJECT No.		113-93037
FILE No.		113-93037_100_M1r1.dwg
REV. 1	SCALE	AS SHOWN
DESIGN	DS	09-01-2011
CADD	ACF	09-01-2011
CHECK	DS	09-01-2011
REVIEW	DF	09-01-2011

MAP 1



KEY MAP

LEGEND

—20— BATHYMETRIC CONTOUR 1.0 m C.I.

PROPOSED DEPLOYMENT AREA

0 50 100 150 200 250

NOTES

1. LOCATION OR POSITIONS OF SUBMARINE CABLES BASED ON NOAA ENC.

INSTRUMENTATION

Navigation	Coda F180 Inertial System
Bathymetry	R2 Sonic 2024, 400 kHz
Sidescan Sonar	Edgetech Model 4200
Subbottom Profiler	Datasonic Model 5000
Seismic Reflection	AAE Model CSP 1500
Digital Acquisition	Sony 204 DAS

GEODETIC PARAMETERS

Horizontal Datum	NAD 83, UTM Zone 10, meters
Vertical Datum	MLLW
Tidal BM	R 257 1944, TS 9445958

Golder Associates

SUBMITTED TO:

SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

PROJECT:

SNOPUD/ADMIRALTY INLET TURBINE/WA

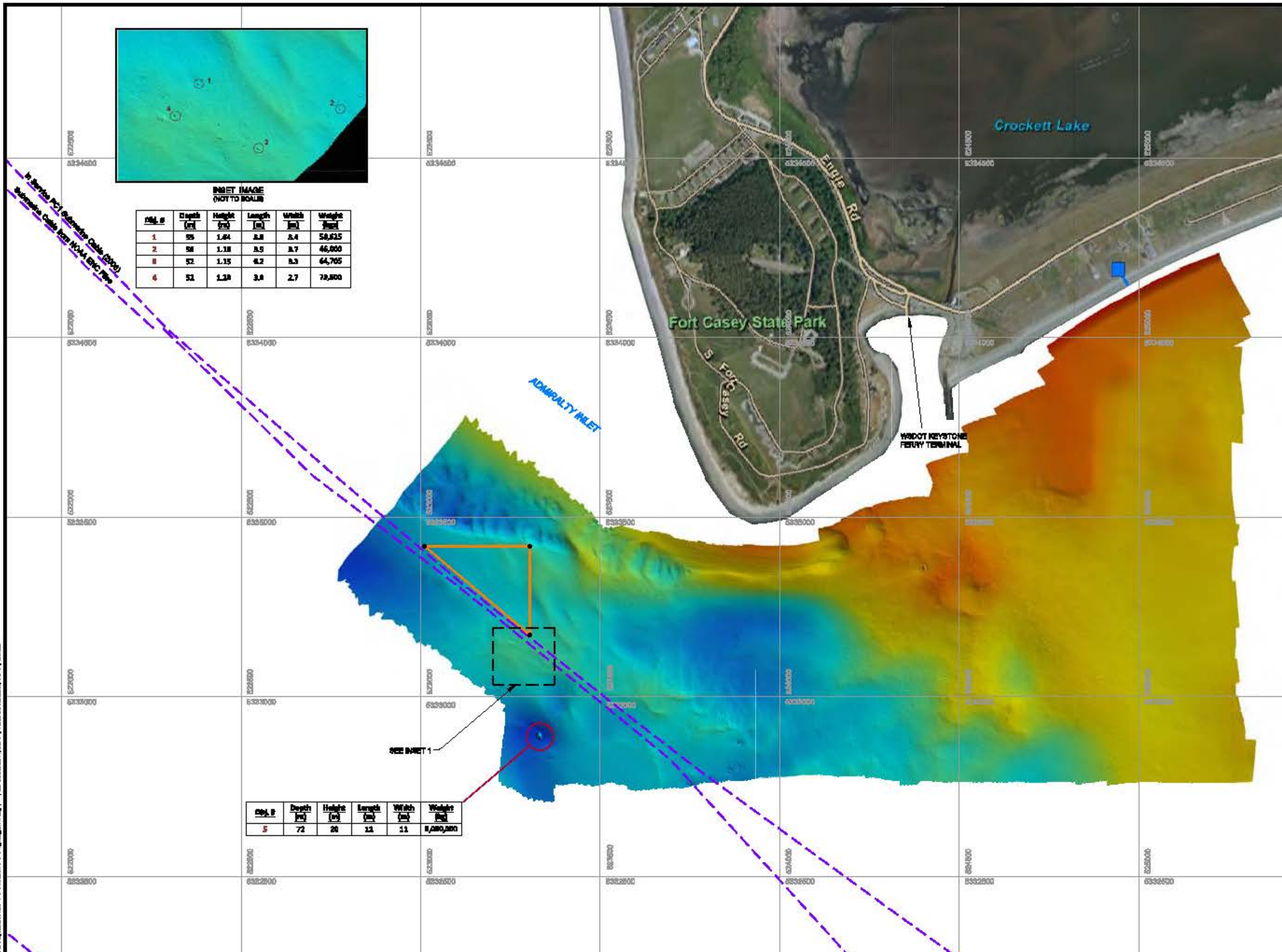
TITLE:

BATHYMETRIC CONTOURS

REV	DATE	REVISION DESCRIPTION	SIGNED
1	9-1-11	FINAL	DS

PROJECT No.		113-93037
FILE No.		113-93037_100_M1r1.dwg
REV. 1	SCALE	AS SHOWN
DESIGN	DS	09-01-2011
CADD	ACF	09-01-2011
CHECK	DS	09-01-2011
REVIEW	DF	09-01-2011

MAP 2



Obj. #	Depth (m)	Height (m)	Length (m)	Width (m)	Weight (kg)
1	55	1.64	8.8	8.4	58,625
2	58	1.18	8.9	8.7	46,000
3	52	1.15	4.2	8.3	64,705
4	51	1.28	3.8	2.7	78,800

Obj. #	Depth (m)	Height (m)	Length (m)	Width (m)	Weight (kg)
5	72	20	12	11	8,080,000

KEY MAP

LEGEND

PROPOSED DEPLOYMENT AREA

DEPTH IN METERS: 0-20, 20-40, 40-60, 60-70

NOTES

1. LOCATION OR POSITIONS OF SUBMARINE CABLES BASED ON NOAA ENC.

INSTRUMENTATION

Navigation	Coda F180 Inertial System
Bathymetry	R2 Sonic 2024, 400 kHz
Sidescan Sonar	Edgetech Model 4200
Subbottom Profiler	Datasonic Model 5000
Seismic Reflection	AAE Model CSP 1500
Digital Acquisition	Sony 204 DAS

GEODETIC PARAMETERS

Horizontal Datum	NAD 83, UTM Zone 10, meters
Vertical Datum	MLLW
Tidal BM	R 257 1944, TS 3444000

Golder Associates

SUBMITTED TO:

SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

PROJECT:

SNOPUD/ADMIRALTY INLET TURBINE/WA

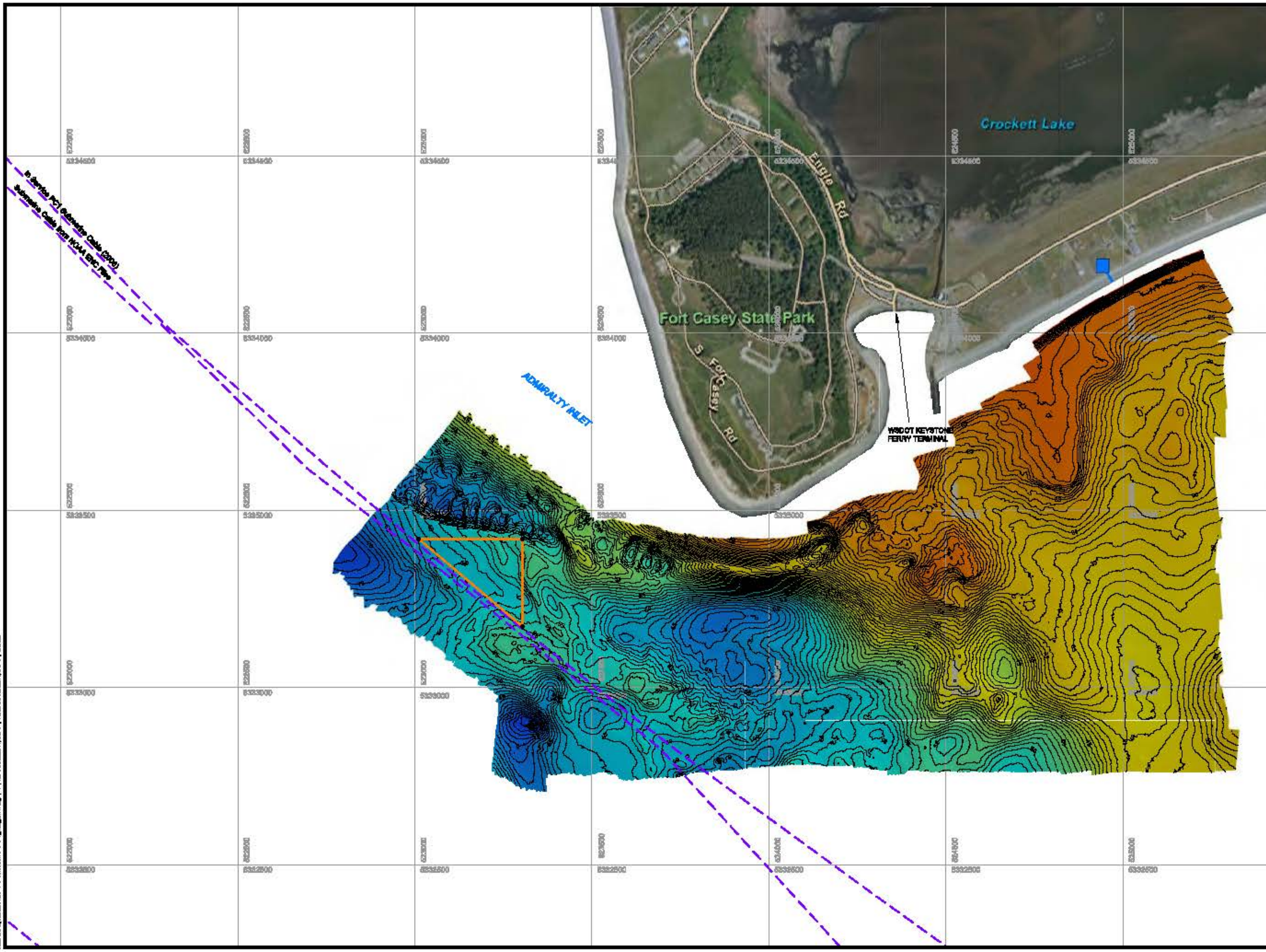
TITLE:

BATHYMETRIC IMAGE 50 cm RESOLUTION

REV	DATE	REVISION DESCRIPTION	SIGNED
1	9-1-11	FINAL	DS

PROJECT No.		113-93037
FILE No.		113-93037_100_N1r1.dwg
REV. 1	SCALE	AS SHOWN
DESIGN	DS	09-01-2011
CADD	ACF	09-01-2011
CHECK	DS	09-01-2011
REVIEW	DT	09-01-2011

MAP 3



KEY MAP

LEGEND

—20— BATHYMETRIC CONTOUR 1.0 m C.I.

PROPOSED DEPLOYMENT AREA

NOTES

1. LOCATION OR POSITIONS OF SUBMARINE CABLES BASED ON NOAA ENC.

INSTRUMENTATION

Navigation	Coda F180 Inertial System
Bathymetry	R2 Sonic 2024, 400 kHz
Sidescan Sonar	Edgetech Model 4200
Subbottom Profiler	Datasonic Model 5000
Seismic Reflection	AAE Model CSP 1500
Digital Acquisition	Sony 204 DAS

GEODETIC PARAMETERS

Horizontal Datum	NAD 83, UTM Zone 10, meters
Vertical Datum	MLLW
Tidal BM	R 257 1944, TS 9445958

Golder Associates

SUBMITTED TO:

SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

PROJECT:

SNOPUD/ADMIRALTY INLET TURBINE/WA

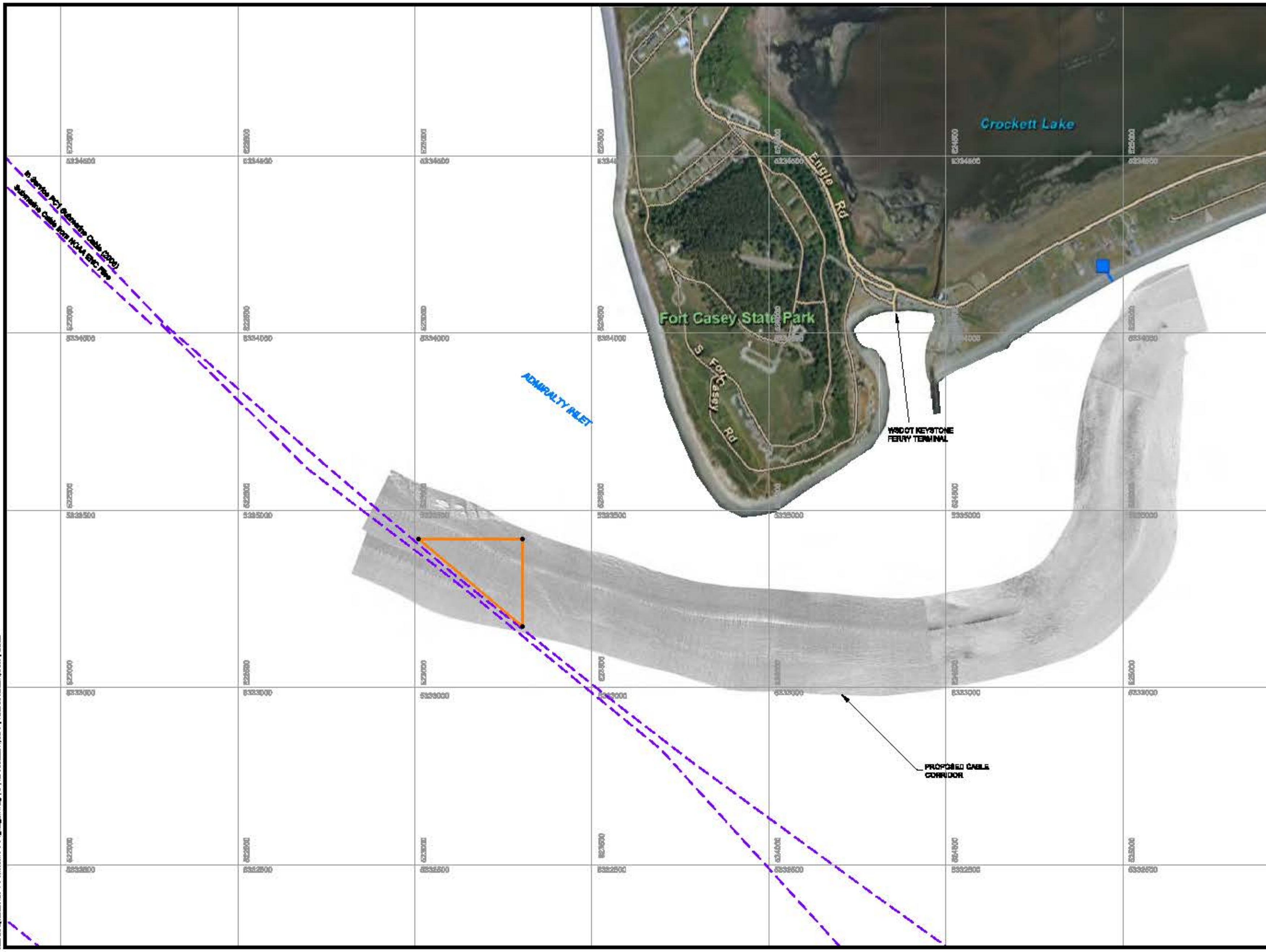
TITLE:

BATHYMETRIC IMAGE AND CONTOURS

REV	DATE	REVISION DESCRIPTION	SIGNED
1	9-1-11	FINAL	DS

PROJECT No.		113-93037	
FILE No.		113-93037_100_N1r1.dwg	
REV. 1	SCALE	AS SHOWN	
DESIGN	DS	09-01-2011	
CADD	ACF	09-01-2011	
CHECK	DS	09-01-2011	
REVIEW	DF	09-01-2011	

MAP 4



KEY MAP

LEGEND

PROPOSED DEPLOYMENT AREA

NOTES

1. LOCATION OR POSITIONS OF SUBMARINE CABLES BASED ON NOAA ENC.

INSTRUMENTATION

Navigation	Coda F180 Inertial System
Bathymetry	R2 Sonic 2024, 400 kHz
Sidescan Sonar	Edgetech Model 4200
Subbottom Profiler	Datasonic Model 5000
Seismic Reflection	AAE Model CSP 1500
Digital Acquisition	Sony 204 DAS

GEODETIC PARAMETERS

Horizontal Datum	NAD 83, UTM Zone 10, meters
Vertical Datum	MLLW
Tidal BM	R 257 1944, TS 9446969

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SUBMITTED TO:

SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

PROJECT:

SNOPUD/ADMIRALTY INLET TURBINE/WA

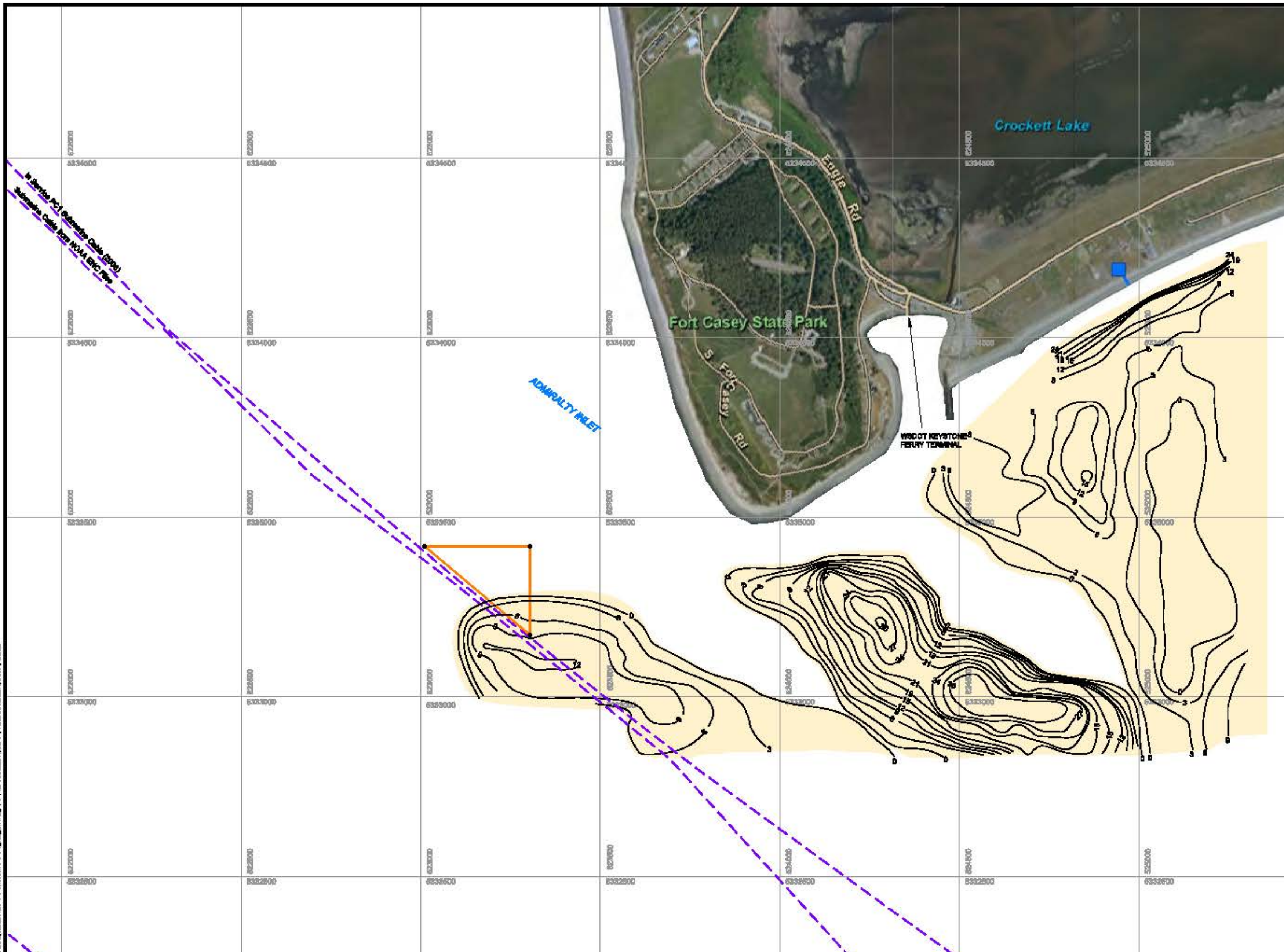
TITLE:

SIDESCAN SONAR MOSAIC

REV	DATE	REVISION DESCRIPTION	SIGNED
1	9-1-11	FINAL	DS

PROJECT No.		113-93037
FILE No.		113-93037_100_N1r1.dwg
REV. 1	SCALE	AS SHOWN
DESIGN	DS	09-01-2011
CADD	ACF	09-01-2011
CHECK	DS	09-01-2011
REVIEW	DF	09-01-2011

MAP 5



KEY MAP

LEGEND

— 12 — SEDIMENT THICKNESS CONTOUR 3m C.I.

PROPOSED DEPLOYMENT AREA

INTERPRETED STRATIGRAPHY FINE TO MEDIUM GRAINED UNCONSOLIDATED SEDIMENT

NOTES

1. LOCATION OR POSITIONS OF SUBMARINE CABLES BASED ON NOAA ENC.

INSTRUMENTATION

Navigation	Coda F180 Inertial System
Bathymetry	R2 Sonic 2024, 400 kHz
Sidescan Sonar	Edgetech Model 4200
Subbottom Profiler	Datasonics Model 5000
Seismic Reflection	AAE Model CSP 1500
Digital Acquisition	Sony 204 DAS

GEODETIC PARAMETERS

Horizontal Datum	NAD 83, UTM Zone 10, meters
Vertical Datum	MLLW
Tidal BM	R 257 1944, TS 3444880

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SUBMITTED TO:

SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

PROJECT:

SNOPUD/ADMIRALTY INLET TURBINE/WA

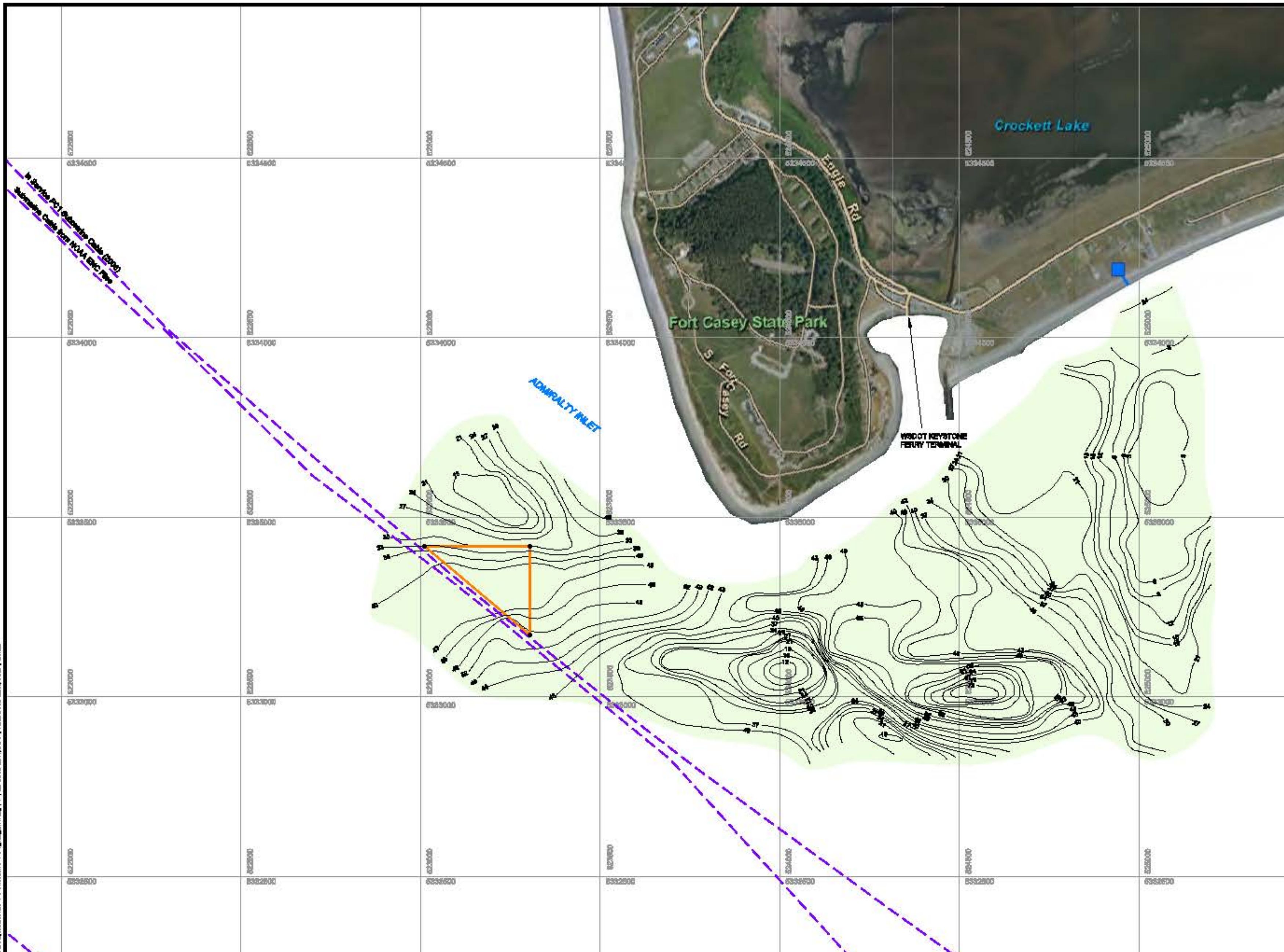
TITLE:

SUB BOTTOM PROFILER SEDIMENT ISOPACH

REV	DATE	REVISION DESCRIPTION	SIGNED
1	9-1-11	FINAL	DS

PROJECT No.		113-93037
FILE No.		113-93037_100_N1r1.dwg
REV. 1	SCALE	AS SHOWN
DESIGN	DS	09-01-2011
CADD	ACF	09-01-2011
CHECK	DS	09-01-2011
REVIEW	DT	09-01-2011

MAP 6



KEY MAP

LEGEND

—12— SEISMIC REFLECTION SEDIMENT CONTOURS 3 m C.I.

PROPOSED DEPLOYMENT AREA

INTERPRETED STRATIGRAPHY MEDIUM TO COARSE-GRAINED SEDIMENT

NOTES

1. LOCATION OR POSITIONS OF SUBMARINE CABLES BASED ON NOAA ENC.

INSTRUMENTATION

Navigation	Coda F180 Inertial System
Bathymetry	R2 Sonic 2024, 400 kHz
Sidescan Sonar	Edgetech Model 4200
Subbottom Profiler	Datasonic Model 5000
Seismic Reflection	AAE Model CSP 1500
Digital Acquisition	Sony 204 DAS

GEODETIC PARAMETERS

Horizontal Datum	NAD 83, UTM Zone 10, meters
Vertical Datum	MLLW
Tidal BM	R 257 1944, TS 9449880

Golder Associates

SUBMITTED TO:

SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

PROJECT:

SNOPUD/ADMIRALTY INLET TURBINE/WA

TITLE:

SEISMIC REFLECTION SEDIMENT ISOPACH

REV	DATE	REVISION DESCRIPTION	SIGNED
1	9-1-11	FINAL	DS

PROJECT No.		113-93037
FILE No.		113-93037_100_N1r1.dwg
REV. 1	SCALE	AS SHOWN
DESIGN	DS	09-01-2011
CADD	ACF	09-01-2011
CHECK	DS	09-01-2011
REVIEW	DF	09-01-2011

MAP 7

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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Appendix L-12

Tidal Energy Resource Characterization:
Methodology and Field Study in Admiralty Inlet, Puget Sound, US

Proceedings of the Institution of Mechanical Engineers, Part A, Journal of Power and Energy

Tidal energy resource characterization: methodology and field study in Admiralty Inlet, Puget Sound, US

--Manuscript Draft--

Manuscript Number:	JPE1401
Full Title:	Tidal energy resource characterization: methodology and field study in Admiralty Inlet, Puget Sound, US
Article Type:	Paper
Keywords:	tidal energy; hydrokinetic; resource characterization
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Corresponding Author's Institution:	University of Washington
Corresponding Author's Secondary Institution:	
First Author:	Brian Polagye
First Author Secondary Information:	
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	Jim Thomson, PhD
All Authors Secondary Information:	
Abstract:	Tidal energy resource characteristics are presented from a multi-year field study in northern Admiralty Inlet, Puget Sound, WA (USA). Measurements were conducted as part of a broader effort to characterize the physical and biological environment at this location ahead of a proposed tidal energy project. The resource is conceptually partitioned into deterministic, meteorological, and turbulent components. Metrics with implications for device performance are used to describe spatial variations in the tidal resource. The performance differences between passive and fixed yaw turbines are evaluated at these locations. Results show operationally significant variations in the tidal resource over length scales less than 100 m, likely driven by large eddies shed from a nearby headland. Finite-record length observations of tidal currents are shown to be acceptable for estimating device performance, but unsuitable for direct investigation of design loads.

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Energy Center
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University of Washington
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Seattle, WA 98195-2600
United States

Professor Chris Lawn
Queen Mary, University of London
Department of Engineering
Mile End Road
London E1 4NS
United Kingdom

Dear Professor Lawn,

Please find enclosed the contribution entitled, "Tidal energy resource characterization: methodology and field study in Admiralty Inlet, Puget Sound, US" for consideration in *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy.* This paper presents the results from a multi-year field study at a proposed tidal energy development site. A series of metrics are used to characterize the tidal resource and assess the implications for power generation. These metrics are applicable to development at any tidal energy site.

Resource characterization studies are currently undertaken in an *ad hoc* manner by industry and a more rigorous approach is required. Understanding tidal resource characteristics at proposed development sites is essential to estimate device performance and establish design loads for commercial-scale development.

Warm regards,

Brian L. Polagye

Tidal energy resource characterization: methodology and field study in Admiralty Inlet, Puget Sound, US

Polagye, B.[1] and Thomson, J.[2]

[1]Northwest National Marine Renewable Energy Center, Department of Mechanical Engineering

[2] Northwest National Marine Renewable Energy Center, Applied Physics Laboratory

University of Washington, Seattle, WA 98115

Abstract

Tidal energy resource characteristics are presented from a multi-year field study in northern Admiralty Inlet, Puget Sound, WA (USA). Measurements were conducted as part of a broader effort to characterize the physical and biological environment at this location ahead of a proposed tidal energy project. The resource is conceptually partitioned into deterministic, meteorological, and turbulent components. Metrics with implications for device performance are used to describe spatial variations in the tidal resource. The performance differences between passive and fixed yaw turbines are evaluated at these locations. Results show operationally significant variations in the tidal resource over length scales less than 100 m, likely driven by large eddies shed from a nearby headland. Finite-record length observations of tidal currents are shown to be acceptable for estimating device performance, but unsuitable for direct investigation of design loads.

Keywords: tidal energy; hydrokinetic; resource characterization

1 Introduction

The need for sustainable energy sources has driven an interest in all types of renewable energy, including tidal hydrokinetic energy, whereby the kinetic energy of strong (> 1 m/s) tidal currents is converted to electricity. The devices used to achieve this are superficially similar to wind turbines and share common physical and mechanical principles. The global tidal energy resource is relatively modest at 3.7 TW and the practically extractable resource will be several orders of magnitude lower [**1**]. Typically, economically attractive tidal energy sites are located at relative geographic constrictions (narrows or sills) and the resource is localized over length scales on the order of kilometers. In comparison, economically viable wind and wave resources are distributed over hundreds of kilometers. These limitations are offset by the first-order predictability of the tidal resource, high average resource intensity (> 1 kW m^{-2}), and the ability to leverage over forty years of experience from wind energy and offshore oil and gas exploration.

Resource characterization is an early-stage project development activity. One objective is to evaluate the power generation potential for a turbine at a particular location. Another is to establish design loads. A number of tidal first-generation turbine failures are ascribed to improper characterization of design loads.

Acoustic Doppler current profilers (ADCPs) are a standard instrument used to measure three-dimensional currents throughout the water column. ADCPs measure currents indirectly through the time dilation of backscattered acoustic pulses [**2**]. Pulses along 3 or 4 divergent beams return the velocity projection along each beam. The velocity projections are then used to reconstruct the full three-dimensional velocity field, and a coordinate transformation based on instrument orientation (heading, pitch, and roll) converts these measurements to a geographic reference frame,

$$U = u\hat{i} + v\hat{j} + w\hat{k}\,, \tag{1.1}$$

where *u*, *v*, and *w* are the north, east, and upward components of measured velocity. Because of the finite pulse length, each of these velocities includes a degree of measurement uncertainty or "Doppler noise" [**3**]. Averaging the results from multiple pulses reduces this uncertainty, providing a more accurate estimate of the mean velocity over a sampling interval. Doppler noise has a zero mean value and known standard deviation, n_{sample}. Doppler velocimeters and electromagnetic current meters, both of which measure velocity at a point, have also been used to lesser extent in resource characterization studies.

Measured currents ($\boldsymbol{U_{sample}}$) are conceptually partitioned into deterministic ($\boldsymbol{U}_{\mathbf{det}}$), meteorological ($\boldsymbol{U}_{\mathbf{met}}$), and turbulent ($\boldsymbol{U}_{\mathbf{turb}}$) components,

$$U_{\mathbf{sample}} = U_{\text{det}} + U_{\mathbf{met}} + U_{\mathbf{turb}} \pm n_{\mathbf{sample}}. \tag{1.2}$$

each of which are further subdivided. The deterministic currents include harmonic currents, described by harmonic constituents [**4**,**5**], as well as the aharmonic response to these currents induced by local topography and bathymetry. Aharmonic currents are not described by tidal constituents, but are repeatable, site-specific flow features [**6**]. Meteorological currents include wave- and wind-induced motion [**7**,**8**], residual currents associated with estuarine stratification [**9**], and storm surges [**10**]. Turbulent currents include large-scale, horizontal eddies and small-scale, isotropic turbulence [**11**]. The relative contribution of these elements to measured currents is site-specific.

This paper presents results from a multi-year tidal energy resource characterization field study in northern Admiralty Inlet, Puget Sound, WA (USA) at the site of a proposed tidal energy project. Characterization metrics are used to quantify variations in the tidal resource over a range of spatial and temporal scales. Variations in the deterministic and meteorological currents are emphasized; turbulence characteristics are described elsewhere [**11**]. The number and duration of stationary ADCP deployments at this location is more intensive than typical for site development. Consequently, these data provide insight into the variability that may be undersampled by common tidal energy siting practices. In combination with a simple turbine model, the operational significance of resource variability is evaluated and the performance of passive and fixed yaw turbines compared. This paper extends the resource metrics described in [**12**] by quantifying the error associated with their calculation from finite-length records.

2 Methodology

2.1 Field Measurements

Admiralty Inlet is a major sill at the mouth of Puget Sound. Excepting the relatively small exchange through Deception Pass, the entirety of the Puget Sound tidal prism passes through this constriction. Between Point Wilson and Admiralty Head, the channel cross-section is at a minimum and current amplitude at a maximum. ADCPs were deployed repeatedly in an upward looking configuration on ballasted fiberglass tripods (Oceanscience Sea Spiders) for periods of up to three months each. The instrument head is approximately 0.7 m above the seabed and the blanking distance is 1.0 m. Sea Spiders were lowered to the seabed and as-deployed locations recorded by DGPS. Wire angles were minimized by drifting during deployments and recovery positions were typically within 5 m of as-deployed locations (i.e., within DGPS error). Details of each deployment are given in Table 1 and locations shown in Figure 1. Site 1 is a composite record consisting of four deployments, each approximately 3 months in duration and located within a 20 m radius. Doppler noise (n_{sample}) is calculated by the manufacturer's software.

Velocity measurements were a component of studies to broadly characterize the physical and biological environment at this location prior to tidal turbine installation. Locations were selected based on shipboard ADCP surveys, power cable routing considerations for the proposed project, vessel traffic patterns, and biological characterization studies. Spatial variability in the tidal resource is assessed at three decadal length scales defined by the distance from the reference deployment at site 1:

- Macro-scale: distance greater than 1000 m (sites 2 and 3),
- Meso-scale: distance between 100 m and 1000 m (sites 4-6), and
- Micro-scale: distance less than 100 m (sites 7 and 8).

In an energetic environment, such as northern Admiralty Inlet, macro-scale variations are expected, but the magnitude of micro-scale gradients is difficult to predict *a priori*. For example, shipboard ADCP surveys of this site are able to identify meso-scale gradients, but cannot resolve micro-scale gradients [**13**].

Table 1 – Doppler profiler configuration for deployments in northern Admiralty Inlet, Puget Sound, WA

Site	Platform	Instrument	Deployment Dates (dd/mm/yy)	Duration (days)	Mean Depth (m)	Bin Size (m)	Sample Interval (s)	n_{sample} (m/s)	n_{ensemble} (m/s)
1	SS #02	Nortek Continental 470 kHz	18/08/10 - 09/08/11	356	59	2	60	0.06	0.03
2	SS #01	RDI Workhorse 300 kHz	10/11/10 - 10/02/11	92	48	1	60	0.04	0.02
3	SS #01	RDI Workhorse 300 kHz	13/02/11 - 09/05/11	85	49	1	60	0.05	0.02
4	SS #03	Nortek AWAC 600 kHz	11/02/10 - 04/05/10	82	56	1	60	0.04	0.02
5	SS #03	Nortek AWAC 600 kHz	20/05/09 - 03/08/09	75	56	1	30	0.05	0.02
6	SS #04	Nortek AWAC 1 MHz	09/05/11 - 08/06/11	30	56	1	1	0.11	0.01
7	SS #03	Nortek AWAC 600 kHz	11/05/11 - 09/08/11	90	61	1	60	0.04	0.02
8	SS #04	Nortek AWAC 1 MHz	05/07/11 - 11/08/11	37	61	1	1	0.11	0.01

Four models of Doppler profilers were used over the course of the project: RDI Workhorse (300 kHz), Nortek Continental (470 kHz), and Nortek AWAC (600 kHz and 1 MHz). All units performed well, with near-100% data return for all deployments. The instrumented Sea Spider platforms are almost neutrally buoyant (-20 kg wet weight) and are ballasted by 360 kg of lead. This was sufficient to maintain instrument stability on the cobbled seabed. During a typical deployment, each tripod generally rotated by 25-50 degrees on the seabed during the first spring tide, but once established, did not experience further rotation[1].

2.2 Data Preparation

Measured currents were evaluated to exclude low quality data from results. First, measurements in the region shadowed by the water surface are excluded. Per [**14**], this region is approximately given by

$$H(1-\cos\phi), \qquad (2.1)$$

where H is the water depth and ϕ is the angle between the ADCP transducer surface and vertical (20° for RDI, 25° for Nortek). For the deployments in Table 1, the observed shadow region varies between 4 and 6 m, consistent with (1) for water depths on the order of 60 m. Second, for

[1]One deployment with SS #01 (300 kg of lead ballast) appears to have translated approximately 100 m from the as-deployed location, based on heading and pressure sensor logs and estimated as-recovered position. This deployment is not included in Table 1 subsequent or analysis, but serves to demonstrate the marginal stability of even low-drag platforms deployed in these types of energetic environments.

measurements obtained with an RDI ADCP, bins with average correlation counts less than 60 are excluded. Nortek firmware automatically excludes measurements with comparably low correlation counts.

The sampling interval varied by deployment, ranging from 1 s to 60 s. In post-processing, all sampled velocities are converted to five minute ensembles ($\boldsymbol{U}_{\mathbf{ensemble}}$), filtering the majority of turbulent scale motion from the signal [**11**], while preserving the deterministic and meteorological components,

$$U_{\mathbf{ensemble}} = \overline{U_{\mathbf{sample}}} = \overline{U_{\mathrm{det}} + U_{\mathbf{met}} + U_{t\mathbf{urb}} \pm n_{\mathbf{sample}}} \approx U_{\mathrm{det}} + U_{\mathbf{met}} \pm n_{\mathbf{ensemble}}, \qquad (2.2)$$

where the overbar denotes a temporal mean. This also reduces ensemble Doppler noise (n_{ensemble}) by a factor of $N^{1/2}$ relative the original Doppler noise (n_{sample}), where N is the number of samples in the ensemble. Consequently, all ensembles underpinning this analysis have a standard error less than 0.03 m s^{-1}. This is at least an order of magnitude smaller than the sum of the deterministic and meteorological components over all stages of the tide.

When the vertical velocity is small, it is convenient to describe the flow field in terms of horizontal velocity (U_h)

$$U_h = \pm\sqrt{u^2 + v^2} \qquad (2.3)$$

where, by convention, flood is signed positive and ebb is signed negative. This reduces the three dimension flow field into to a one dimensional time series. Principal component analysis [**15**] is used to determine the principal axes for ebb and flood.

Surface-gravity waves, including swell from the Strait of Juan de Fuca and locally generated wind-waves, have orbital velocities that decay with depth from the water surface. Here, wave-orbital velocities are not expected to affect sub-surface current resource metrics or turbine performance, because the depths of interests are more than half a wavelength beneath the surface. Moreover, the wave orbital velocities are obscured in calculating the five-minute ensembles used for resource metrics, because the orbital velocities (nominally 2-12 s period) have a zero Eulerian average on time scales longer than several wave periods (e.g., five minutes). At shallower sites, wave orbital velocities may contribute significant variance to the sub-surface velocity field, however zero-mean is still expected for all but the shallowest sites. To confirm these assertions, site-specific wave measurements were made from August to November 2010 using a 600 kHz AWAC deployed within several hundred meters of site 1. The AWAC recorded 1 Hz bursts of surface elevation and velocity for ten minutes at the top of each hour, from which the orbital velocities at depth are calculated using the wave frequency-directional spectra and linear finite-depth theory [**8**].

Tidal estuarine systems such as Puget Sound have sub-tidal exchange flows resulting from stratification. Here, these residual currents are evaluated using a low pass filter (PL66) [**16**]. A half-amplitude period of 40 hours is used; the tidal signal is not removed by shorter half-amplitude periods.

Storm surges that appreciably alter currents are uncommon in Puget Sound and none occurred during the data collection period. Similarly, given the expected deployment depth for hydrokinetic devices (e.g., > 5 m below the surface) and prevailing water depth (60 m), the signal from wind driven currents is negligible at this location.

2.3 Resource Characterization Metrics

A representative fortnight of ADCP data is shown in

Figure **2**. The magnitude and direction of the horizontal currents vary with time and vertical position. The tidal regime in northern Admiralty Inlet is characterized as mixed, mainly semidiurnal with two ebb and flood currents of unequal magnitude each lunar day.

Resource characterization metrics are used to compare locations. Only those characteristics with clear device performance or design implications are described here; a broader set are presented in [**12**].

Four time-averaged metrics are used to describe spatial variability:

- *Mean kinetic power density* [kW m^{-2}] – the time average of kinetic power density (*K*)

  $$\overline{K} = \overline{\tfrac{1}{2}\rho\left|U_h^3\right|} \tag{2.4}$$

  where ρ is the density of seawater (nominally 1024 kg m^{-3}). The mean kinetic power density is equivalent to the mean flux of kinetic energy through a vertical plane, and this quantity is the first-order predictor of project economics [**17**].
- *Mean kinetic power asymmetry* [dimensionless] – the ratio of mean kinetic power density over all ebb currents to all flood currents, $\overline{K_{\mathrm{ebb}}}/\overline{K_{\mathrm{flood}}}$. This indicates whether power generation will be skewed towards one stage of the tide. Asymmetries may result from interactions between reflected tidal wavelengths (in an idealized embayment subjected to a single constituent harmonic forcing, peak ebb currents are slightly more intense than flood currents) or by local distortions to the harmonic currents caused by bathymetry and/or topography.
- *Peak velocity* [m s^{-1}] – the maximum horizontal velocity observed, $\max(|U_h|)$. Maximum currents are of interest for determining design loads. Here, the peak velocity associated with deterministic and meteorological currents are evaluated. Assessing the turbulent contribution to peak currents from ADCP data is problematic, even at high temporal resolution (e.g., 1 Hz), because Doppler uncertainty broadens the distribution of observed turbulence intensities, even for uniquely valued intensities [**18**]. In [**11**], a characteristic turbulent velocity fluctuation is defined, following the IEC standard for wind, however this is a statistical quantity and not equivalent to a peak turbulent velocity fluctuation.
- *Direction asymmetry* [degrees] – the asymmetry between the mean direction ($\overline{\theta}$) of ebb and flood, relative to bidirectional currents,

  $$\overline{\theta_{\mathrm{flood}}} - \overline{\theta_{\mathrm{ebb}}} - 180^{\circ}. \tag{2.5}$$

The performance of a fixed yaw turbine is degraded if the current direction and rotor plane are misaligned.

- *Direction standard deviation* [degrees] – the standard deviation of current direction relative to the principal axes (σ_θ). Around slack water, when turbines are idle, the reversing currents give rise to large, but irrelevant, direction deviations. The direction standard deviation is calculated only when the currents have fully set to ebb or flood, nominally $|U_h| \geq 0.5$ m s^{-1}. As for direction asymmetry, the performance of fixed yaw turbine is degraded if the current direction is misaligned with the rotor plane.

The *MATLAB* code to calculate these, and other metrics, is available for download at: http://depts.washington.edu/nnmrec/characterization. All measurement time series are available for download at: http://depts.washington.edu/nnmrec/project_meas.html.

2.4 Turbine Model

A simple model for the performance of a hydrokinetic turbine is used to assess the operational significance of variations in the tidal resource. The properties of an unshrouded horizontal axis tidal turbine representative of commercial prototypes are presented in Table 2. Inflow conditions over the turbine rotor are approximated by hub-height values and the device power output (P) is described as a function of horizontal velocity by

$$
\begin{aligned}
&P = 0 && |U_h \cos\gamma| < U_{\text{cut-in}} \\
&P = \tfrac{1}{2}\rho |U_h \cos\gamma|^3 \left(\frac{\pi D^2}{4}\right)\eta_p \eta_e && U_{\text{cut-in}} \leq |U_h \cos\gamma| \leq U_{\text{rated}} \\
&P = \tfrac{1}{2}\rho U_{\text{rated}}^{\;3} \left(\frac{\pi D^2}{4}\right)\eta_p \eta_e && |U_h \cos\gamma| > U_{\text{rated}}
\end{aligned}
\qquad (2.6)
$$

where γ is the angle between the current and rotor plane (γ=0 when flow is aligned with the rotor plane), D is the turbine diameter (and thus $\pi D^2/4$ is the swept area of the turbine), η_p is the performance coefficient of the rotor, η_e is the efficiency of the power train (gearbox, generator, power electronics), $U_{\text{cut-in}}$ is the speed at which the turbine begins to rotate, and U_{rated} is the speed at which maximum power is generated (beyond this point, power extraction is curtailed through active pitch control or dynamic stall). For simplicity, the performance coefficient and power train efficiency are idealized as constant over the full range of operating conditions.

A number of commercial prototype tidal turbines are fixed yaw devices [**19**, Section 2] and cannot respond to directional fluctuations. The effect of rotor misalignment is captured, to the first order, through a reduction inflow velocity by the cosγ term in (Eq. 2.6) [**20**]. For a passively yawed turbine, it is assumed that γ is always equal to zero. For a fixed yaw turbine, the alignment angle that maximizes average power generation is determined iteratively. The rated speed is chosen to yield economically viable capacity factors (e.g., 30%) in a mixed, mainly semidiurnal tidal regime [**17**]. It is assumed that energy removal will not appreciably alter inflow conditions (e.g., average power extracted by a single device is much less than the theoretical resource limit;

[21]) and that blockage effects are negligible [22] given the dissimilar magnitudes of turbine swept area (~10^2 m^2) to channel cross-sectional area (~10^5 m^2).

Table 2 – Horizontal axis turbine parameters

Parameter	**Value**
Rotor diameter (D)	25 m
Hub height	Mid-water depth (~30 m above seabed)
Performance coefficient (η_p)	50%
Power train efficiency (η_e)	90%
Cut-in speed ($U_{\text{cut-in}}$)	0.7 m s^{-1}
Rated speed (U_{rated})	2.25 m s^{-1}
Rated power	1.3 MW

2.5 Performance Characterization Metrics

Performance metrics used for this analysis include:

- *Mean power* [MW] – the time average of power output (P). This is proportional, conceptually, to project revenue.
- *Capacity factor* [%] – the ratio of average power to rated power. This is an indicator of the degree of capital utilization for a project.
- *Percentage of time operating* [%] – the percentage of time the turbine is operating (sometimes referred to as exceedence). This is helpful to understanding the persistence of environmental stressors such as dynamic effects (i.e., rotating blade), noise, and electromagnetic fields [23].

As is standard in the wind industry, rather than directly calculating power generation from an underlying time series, the data are reduced to a joint probability distribution of horizontal velocity (U_h) with direction (θ). Note that the joint probability distribution retains the relationship between velocity and direction, as opposed to independent probabilities distributions of each, and this is essential to correctly evaluate power output (Eq. 2.6). Horizontal velocity magnitude and direction discretization to 0.1 m s^{-1} and 1° result in biases of less than 1% for mean power generation estimates relative to direct calculation (not shown).

2.6 Metric Uncertainty

Metrics calculated from finite-length observations may diverge from their true values (defined as the average over an infinite observation). Generically, the convergence of a metric to its true value is given by

$$\frac{\int_0^T M(t)dt \Big/ \int_0^T dt}{\int_0^\infty M(t)dt \Big/ \int_0^\infty dt}, \qquad (2.7)$$

where $M(t)$ is the time varying metric and T is the length of observation. In shorthand, the averaging time for a metric is represented with a superscript and posited to have converged when $M^T \approx M^\infty$. Since M^∞ is not known a priori, this convergence can only be investigated in a proximate manner for a measured velocity consisting of deterministic, meteorological, and turbulent components. However, for the harmonic component, the value of a metric calculated over the tidal epoch (18.6 years) is likely to approach its true value (i.e., $M^{\text{epoch}} \approx M^{\infty}$). Because the aharmonic component is a non-linear response to the harmonic component, the deterministic currents should converge at a similar rate to the harmonic component. Further, if the meteorological currents are weak, convergence of the harmonic component may be a reasonable proxy for convergence of measured currents.

The *MATLAB T_TIDE* routine [**24**] is used to extract harmonic constituents from the horizontal velocity observations at mid-water from site 1. The Rayleigh criterion is slightly relaxed to 0.97, resulting in 60 constituents that are significant at 95% confidence level. A predicted time series over the tidal epoch is generated. Over longer time scales (days to years), the beating between constituents gives rise to decaying oscillations in the calculated metrics with periodicity,

$$T_{\text{beat}} = \frac{1}{(f_1 - f_2)}. \tag{2.8}$$

For example, the beating between the principal lunar semidiurnal constituent (M2) and principal solar semidiurnal constituent (S2) gives rise to the well-known 14.8 day neap-spring cycle. Because the modulation amplitude depends on the relative amplitude of the beating constituents, the results presented here may only be applicable to mixed, mainly semi-diurnal tidal regimes.

From the epoch prediction for horizontal velocity, a series of 185 day records are extracted at a time resolution of 15 minutes, each offset by 20 days (no constituent beating at this frequency). This yields 336 realizations of harmonic currents over the epoch. For each realization, the rate of convergence for three metrics is evaluated:

- mean kinetic power density: $\overline{K^{T}_{\text{harmonic}}} \big/ \overline{K^{\text{epoch}}_{\text{harmonic}}}$,
- maximum velocity: $\max\left(U^{T}_{h,\text{harmonic}}\right) \big/ \max\left(U^{\text{epoch}}_{h,\text{harmonic}}\right)$, and
- mean power generation: $\overline{P^{T}_{\text{harmonic}}} \big/ \overline{P^{\text{epoch}}_{\text{harmonic}}}$.

Figure 3 shows the convergence of mean power density, calculated from harmonic currents, to its epoch value. Given that the neap-spring cycle is the dominant beating between constituents at this location, it is unsurprising that the standard error decreases to 5% after two complete cycles (30 days). The standard error then continues a gradual, oscillatory decay, declining to 2% after 160 days. For the purpose of characterizing mean power density, a record length of 30 days, or longer than 70 days, provides 5% accuracy. When the temporal mean contains less than an integer number of beat periods (Eq. 2.8), the calculated metric will deviate from its true value. While all finite-length records, by definition, contain a non-integer number of constituent beat periods, as the record length increases the associated bias declines. For example, the local maximum in standard error at 38 days corresponds to a record length of 2.5 neap-spring cycles, where the relative position in the cycle is likely to bias the metric high or low. By 180 days, the neap-spring oscillations are less pronounced, as a consequence of the record encompassing more than a dozen beat periods. A synthetic tidal series containing only the M2 and S2 constituent (and, therefore, only a neap-spring beating) would have zero standard error for record lengths containing an integer number of beat frequencies.

As shown in Figure 4, the probability of observing the maximum harmonic currents over the tidal epoch within a finite observation period is low, even for observations exceeding half a year. For example, after 6 months, the probability of having observed the 95th percentile harmonic currents is less than 0.8, which is insufficient to directly inform device design. For the more typical site characterization field study lasting 30 days, the probability of having observed the 95th percentile harmonic currents is less than 0.25. This motivates statistical projections of peak velocity for device design, since direct observation is difficult.

Figure 5 shows the convergence of mean power generation, calculated from harmonic currents, to its epoch value. Convergence is qualitatively similar to mean power density, but mean power generation converges more rapidly to its epoch value than the mean power density because of the non-linear damping caused by power shed above rated speed (Eq. 2.6). The standard error decreases to within 3% of its epoch value at 30 days and to within 2% after 160 days.

3 Results

3.1 Contribution of Meteorological Currents

Analysis of AWAC wave data (August to November, 2010) indicates that surface-gravity waves in the vicinity of Admiralty Head are typically local wind-waves, with significant wave heights < 1 m and dominant periods < 4 s. According to linear finite-depth theory [**8**], the associated wave orbital velocities will decay to 0.1 m s^{-1} at depths of 5 m below the surface. Under the maximum observed wave conditions of 2.3 m significant wave height and 6.7 dominant period, the wave orbital velocities are 0.4 m s^{-1} at a depth of 5 m below the surface and 0.1 m s^{-1} at depth of 20 m below the surface. Again, these velocities are obscured (zero mean) in the five-minute ensembles, similar to the turbulent fluctuations.

Residual currents at site 1 are presented in Figure 6 and are representative of those over the study area. A classical circulation pattern is observed, with net outflow near the surface and net inflow near the seabed. There is also a seasonal variation, with relative maxima in the early summer (snow melt freshet) and the late fall (precipitation from strong storms). Because strong tidal exchanges over the Admiralty Inlet sill mix the water column, residual currents are strongest during neap tides and weakest during spring tides. At mid-water (30 m from seabed), residual currents are ubiquitously weak, with a maximum amplitude rarely exceeding 0.1 m s^{-1}. Closer to the seabed and surface, residual currents are more intense, approaching 0.4 m s^{-1}. Observations do not indicate measurable wind-driven currents or storm surge currents, consistent with expectations for this location.

The relative contribution of deterministic and meteorological currents to the measured currents, therefore, varies with depth. Over all depths, the peak deterministic (tidal) currents are nearly an order of magnitude more intense than the meteorological currents. Residual currents are significant near the surface and seabed, but not over the middle of the water column. Within 5 m of the surface, wave orbital velocities are of similar order to residual currents, but are insignificant over most of the water column.

3.2 Spatial Variability in the Tidal Resource

Spatial variability is discussed in the context of three decadal length scales defined by the distance from the reference location (site 1): micro-scale for less than 100 m separation, meso-scale for 100 m to 1000 m, and macro-scale for more than 1000 m.

Building on the analysis of metric uncertainty for the harmonic component of measured velocity (Section 2.6), the uncertainty in all resource metrics is evaluated using mid-water data from site 1. While this is a finite-length observation, the dominant periodicities are well-represented in the year-long time series. Convergence is shown in Figure 7 for power density, direction, and maximum velocity. Mean power density and power density asymmetry converge in a manner consistent with the previous analysis of the harmonic component, providing support for the assumption that the deterministic (harmonic and aharmonic) and harmonic contributions to resource metrics converge at similar rates. Direction convergence (asymmetry and variation) appears to require longer observation times. This is counterintuitive, given that there should not be a fundamental periodicity to tidal direction. However, because a flux gate compass is only accurate to a few degrees, the variations shown in Figure 7 are more likely attributable to sensor drift. The convergence of maximum velocity offers a cautionary example for resource characterization. While this metric appears to converge rapidly to its true value, analysis of harmonic currents suggests that it is unlikely for $\max\left(U_h^{1\,\text{year}}\right) \approx \max\left(U_h^{\infty}\right)$. Therefore, observed maximum velocity is likely to be lower than its true value and is reported only to demonstrate the strength of measured tidal currents at this site.

Resource characteristics for all locations are tabulated in Table 3 at mid-water depth. The observed macro-scale resource variations are expected given that site 2 is to the lee of the headland and site 3 is close to the channel center, away from the headland influence. Applying a 1 kW m^{-2} threshold for an economically attractive mean power density [**17**], sites 1 and 3 are candidates for tidal energy development, but site 2 is not, being close enough to the headland to be within the flood eddy[2]. Over meso-scale distances (Sites 4-6) and micro-scale distances (Sites 7-8), all sites have potential for development, but variations in power and direction metrics exceed metric uncertainty. The micro-scale variations are of particular interest for site development. For example, the mean power density at Site 7 is more than 10% higher than at Site 1, even though the two sites are separated by only 60 m and resource properties are evaluated at nearly the same absolute depth.

The bias in current strength towards ebb at sites 1 and 4-8 is likely to result from flow acceleration around the nearby headland and the separation that occurs in its lee [**25**]. Admiralty Head has a length (alongshore) of 5.5km and width (offshore) of 2.5km. The mean depth in the

[2] The objective of this deployment was to gather information about harbor porpoise response to passenger ferry operation. This location was never considered a likely candidate for tidal energy development and is included in this discussion to illustrate macro-scale variations in mean kinetic power density.

near-shore area is approximately 30m. On a strong ebb, horizontal currents exceed 2.5 m/s and are dominantly semi-diurnal. Per the scaling arguments presented in [**26**], these translate to length scales for frictional dissipation and the tidal excursion of 6km and 35km, respectively. For these values, eddy propagation would be expected to be similar to steady flow, with a characteristic eddy size comparable to the characteristic size of the headland.

Table 3 – Resource characteristics at sites in northern Admiralty Inlet, Puget Sound, WA

Site	Distance to Site 1 (km)	Distance from Seabed (m)	Mean kinetic power density[1] (kW m^{-2})	Mean kinetic power asymmetry	Directional asymmetry (degrees)	Directional variation (degrees)	Maximum velocity[2] (m/s)
1	-	30	1.8 ± 0.04	1.6	24	10	3.4
2	1.10	24	0.6 ± 0.02	7.8	8	12	2.5
3	2.60	24	1.4 ± 0.06	0.9	8	7	3.1
4	0.35	28	1.7 ± 0.07	1.0	27	11	3.0
5	0.23	28	2.1 ± 0.09	1.1	23	10	3.4
6	0.19	28	2.0 ± 0.10	1.2	23	9	3.3
7	0.06	31	2.0 ± 0.08	1.6	20	9	3.4
8[3]	0.07	31	2.0 ± 0.10	1.7	19	9	3.1

[1] Standard error based on analysis of harmonic velocity (Figure 3).
[2] These are likely to be understated relative to their true values for all sites given the duration of observation.
[3] Time series truncated to 30 days so that metric uncertainty is similar to other locations surveyed.

Variations with depth for a selection of sites representing macro-, meso-, and micro-scales relative to the reference site are presented in Figure 8. The vertical coordinate is normalized by the total water depth (H). In general, mean power density increases towards the surface, as would be expected assuming a no-slip condition at the seabed and a classic bottom boundary layer. For sites near the headland, the ebb power density is nearly twice that of flood near the seabed, but ebb and flood approach parity near the surface. Conversely, the direction asymmetry increases with distance from the seabed, exceeding 20 degrees for locations near the reference site. Direction variation uniformly reaches a minimum at mid-water. As for the mid-water results presented in Table 3, comparable variations are observed over micro and meso-scales at all depths.

3.3 Spatial Variability in Turbine Performance

Spatial variability in turbine performance is evaluated using the simple turbine model described in Section 2.4. The uncertainty in performance metrics are investigated in a similar manner to resource characterization metrics using the long-term data from site 1. Figure 9 shows the convergence of performance metrics at this location to their 1-year values. As with resource metrics, convergence is in general agreement with the analysis of the harmonic component. The damping in power resulting from the rated speed is apparent, with a more rapid convergence to long-term values than for the resource characteristics. Because the operating percentage is affected in a non-linear manner by the cut-in speed (rather than rated speed), this metric converges in a different manner than mean power generation.

Table 4 shows performance metrics at difference sites for devices with mid-water hub heights. Spatial variability mirrors the trends in resource characteristics. Variability on a macro-scale is pronounced, with mean power generation at sites 2 and 3 only 30% and 80% of the site 1 value.

Over meso- and micro-scales, average power generation varies by 5-10% from the reference site. This exceeds measurement uncertainty and is operationally significant in terms of cost of energy, suggesting an economic benefit to micro-siting.

Operating time for devices with economically attractive capacity factors exceeds 70% at most locations. From an ecological standpoint, the stressors associated with turbine operation would be present for the majority of time, but not continuous. The operating time is strongly dependent on the device cut-in speed.

Performance differences between passive yaw and fixed yaw turbines are also presented in Table 4. The effect of off-axis flow is a function of direction asymmetry, direction variation, and power density asymmetry (e.g., the effect of direction asymmetry is muted if there is also a large power density asymmetry between ebb and flood). For sites near the headland, the mean power generation for a fixed yaw device is 5-10% lower than for a passive yaw device. This is operationally significant, but may be economically offset by reduced device complexity. Near the seabed, the penalty for a fixed yaw device increases, with higher direction variation (σ_θ) dominating over lower direction asymmetry.

Table 4 – Turbine performance at sites in northern Admiralty Inlet, Puget Sound, WA

			Passive Yaw			Fixed Yaw		
Site	**Distance to Site 1 (km)**	**Turbine Depth (m)**	**Average power output (MW)**	**Capacity factor (%)**	**Time operating (%)**	**Average power output (MW)**	**Capacity factor (%)**	**Time operating (%)**
1	0	30	0.35	28%	72%	0.33	26%	72%
2	1.07	24	0.12	9%	36%	0.12	9%	36%
3	2.59	24	0.29	22%	66%	0.28	22%	66%
4	0.4	28	0.35	27%	76%	0.32	25%	76%
5	0.2	28	0.39	30%	73%	0.37	29%	73%
6	0.19	28	0.38	30%	76%	0.36	28%	76%
7	0.06	31	0.38	29%	74%	0.36	28%	74%
8	0.07	31	0.39	30%	75%	0.37	29%	75%

4 Discussion

This paper presents multi-year observations of tidal currents at a proposed tidal energy site in Admiralty Inlet, Puget Sound, WA (USA). Both the spatial variability in the tidal resource and the implications for device performance are evaluated. Resource and performance metrics are proposed that intuitively reduce the observational data for decision making purposes. Operationally significant variations in the tidal resource (5-10% variations in mean power generation) are identified over length scales less than 100 m (micro-scale variations). This has several consequences for resource characterization activities. First, variations on these length scales are unlikely to be resolved by shipboard surveys [**13**,**27**], though such approaches are useful for mapping larger-scale variability. Second, if numerical models are used to resolve micro-scale gradients, grid resolution should be O(10 m). The magnitude of the observed micro-scale gradients may be somewhat unique to this site given the proximity to a headland (Admiralty Head at less than < 1 km). Site developers will need to balance the beneficial resource intensification around headlands against micro-siting difficulties and ebb/flood asymmetries. Because of these asymmetries at headland sites, passive/active yaw turbines are expected to produce more power than fixed yaw turbines (5-10% at this location).

The resource metrics presented here emphasize power density over velocity. Device performance varies with the power density (velocity cubed), so mean velocity is not an inherently useful metric for tidal resource characterization. The root mean cubed velocity can be directly converted to mean power density, but can cause confusion if not carefully defined by practitioners. For mixed, mainly semidiurnal tidal energy sites, the cumulative probability density functions (CPDF) of velocity and power density are also illuminating. As shown in Figure 11, approximately 50% of the power density (and, therefore, possible power generation) occurs at velocities greater than 2 m/s. However, these velocities occur only 10% of the time.

These results also provide insight into data collection strategies informing device siting decisions, estimate performance, and determine design loads. For all performance metrics (and resource metrics related to performance) reasonable accuracy (i.e., standard error of 5%) is obtained from 30-day observations. In fact, the beating of harmonic constituents increases uncertainty in metrics calculated from data collected over marginally longer periods (i.e., 30 – 50 days). For mixed, mainly semidiurnal sites, survey periods of less than 30 days are not recommended. When the dominant velocity components are deterministic and turbulent, sampling over 30 days at a rate of 1 Hz can provide useful information about resource characteristics, device performance, and turbulent motions [**11**]. This type of data collection is within the capabilities of the current generation of Doppler profilers when equipped with GB-capacity storage cards and lithium-ion batteries. However, if the meteorological component is appreciable, longer-term data collection may be necessary to estimate device performance.

The assessment of design loads is more problematic. Specifically, the probability of observing the 90th percentile tidal epoch velocity within a 30 day period is only slightly more than 50%. Since operational lifetimes for devices are on the same order as the tidal epoch (i.e., 20 years), maximum observed currents should not be taken as a proxy for maximum expected currents over the device design lifetime. How best then to estimate design loads without resorting to extreme factors of safety? One approach is to rely on harmonic analysis to predict the deterministic component and treat turbulent and meteorological currents statistically. This is, however, problematic for three reasons. First, if the deterministic currents contain a strong aharmonic component, this will not be captured by harmonic analysis and predicted velocities may substantially under- or over-predict maximum deterministic currents. Second, accurate prediction of currents over the tidal epoch requires at least a year of data, which may be an onerous cost burden for site developers. While inference from a reference station [**5**] may overcome this difficulty, preliminary analysis of tidal elevation and current constituents from this site suggest that amplitude ratios and phase differences for currents should not be assumed, without verification, to be equivalent to those of the tidal elevation constituents. Third, conventional harmonic analysis is only suitable for predicting both magnitude and direction when currents progress through an ellipse [**5**], which is not always the case at energetic sites. Given the number of prototype tidal turbine failures ascribed to under-estimation of design loads, there remains a clear need to develop rigorous techniques for determining maximum design velocities.

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agency thereof. Their views and opinions of the authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

8 List of Figure Captions

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9 List of Notation

D	turbine diameter (m)
η_p	rotor performance coefficient
η_e	power train efficiency

H	water depth (m)
γ	angle between the current and rotor plane (degrees)
K	kinetic power density (kW m^{-2})
M	a time varying metric describing the tidal resource or device performance
n_{ensemble}	Doppler uncertainty in ensemble average currents (m s^{-1})
n_{sample}	Doppler uncertainty in measured currents (m s^{-1})
P	device power output (kW)
φ	angle between Doppler profiler transducer surface and vertical (degrees)
ρ	seawater density (kg m^{-3})
σ_θ	standard deviation of current direction (degrees)
θ	direction of current (degrees)
$U_{\mathrm{cut\text{-}in}}$	the speed at which a device begins to generate power (m s^{-1})
$\boldsymbol{U}_{\mathbf{det}}$	deterministic component of tidal currents (m s^{-1})
$\boldsymbol{U}_{\mathbf{ensemble}}$	ensemble average currents (m s^{-1})
U_h	horizontal velocity, vector sum of north and east components (m s^{-1})
$\boldsymbol{U}_{\mathbf{met}}$	meteorological component of tidal currents (m s^{-1})
U_{rated}	the speed at which maximum power is generated by a device (m s^{-1})
$\boldsymbol{U}_{\mathbf{turb}}$	turbulent component of tidal currents (m s^{-1})
$\boldsymbol{U}_{\mathbf{sample}}$	measured currents (m s^{-1})

Subscripts and superscripts

overbar	time average
ebb	ebb tidal currents (seaward direction)
flood	flood tidal currents (landward direction)
T	length of a finite observation
∞	an infinite observation
epoch	an observation over the tidal epoch (18.6 years)
harmonic	the harmonic component of the deterministic tidal current

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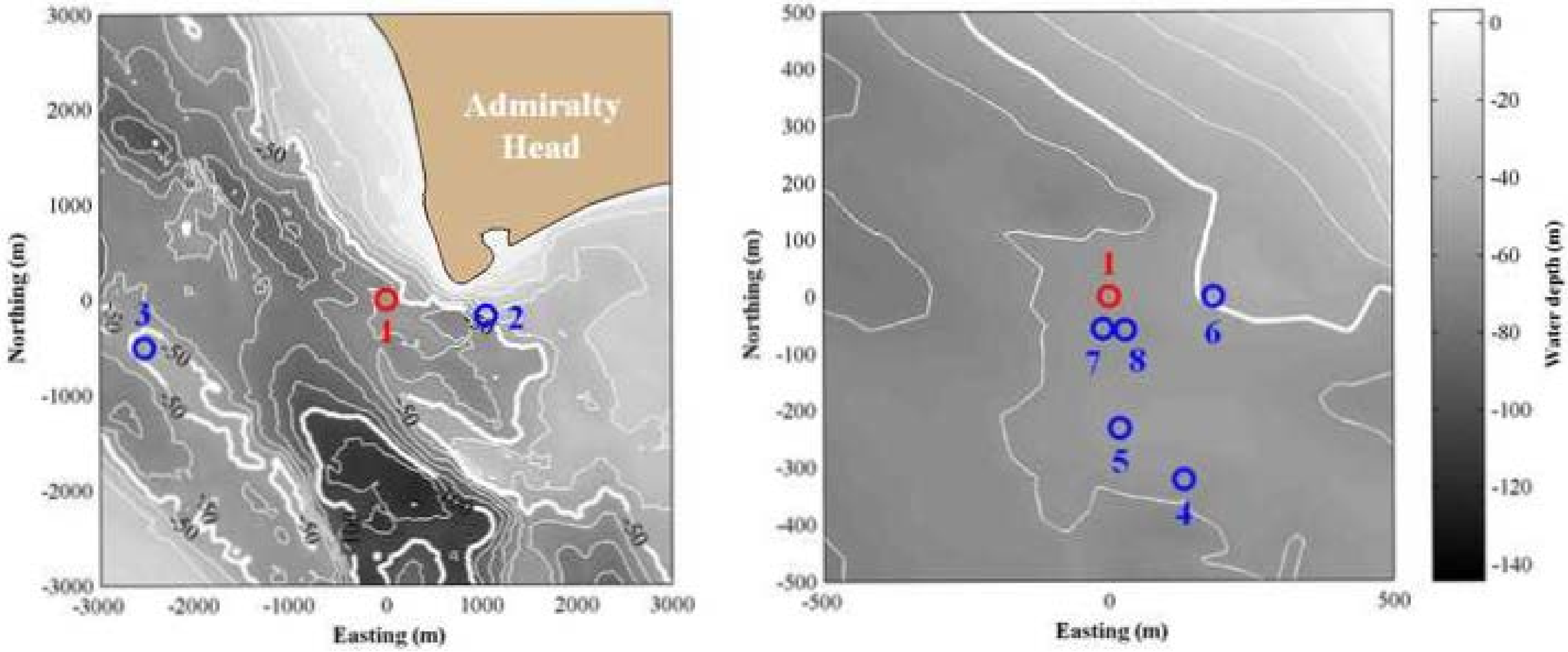

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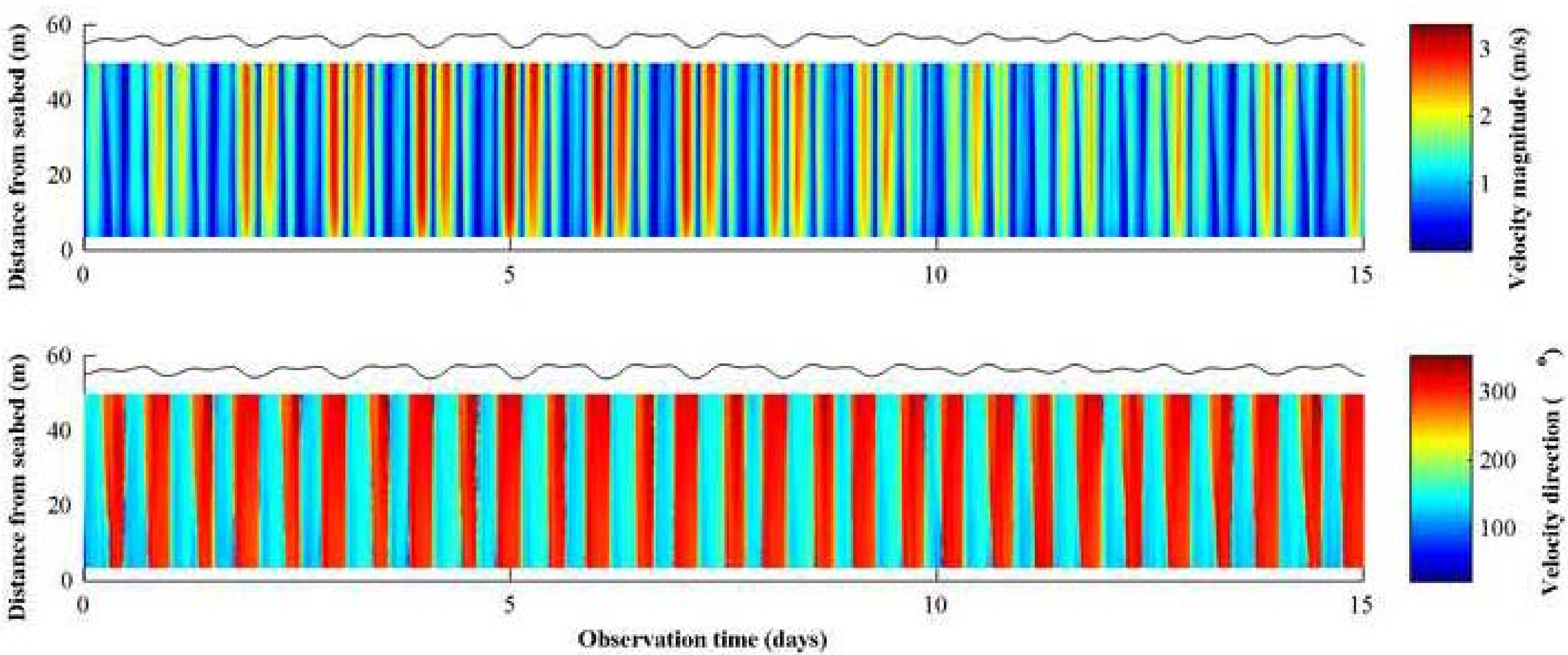

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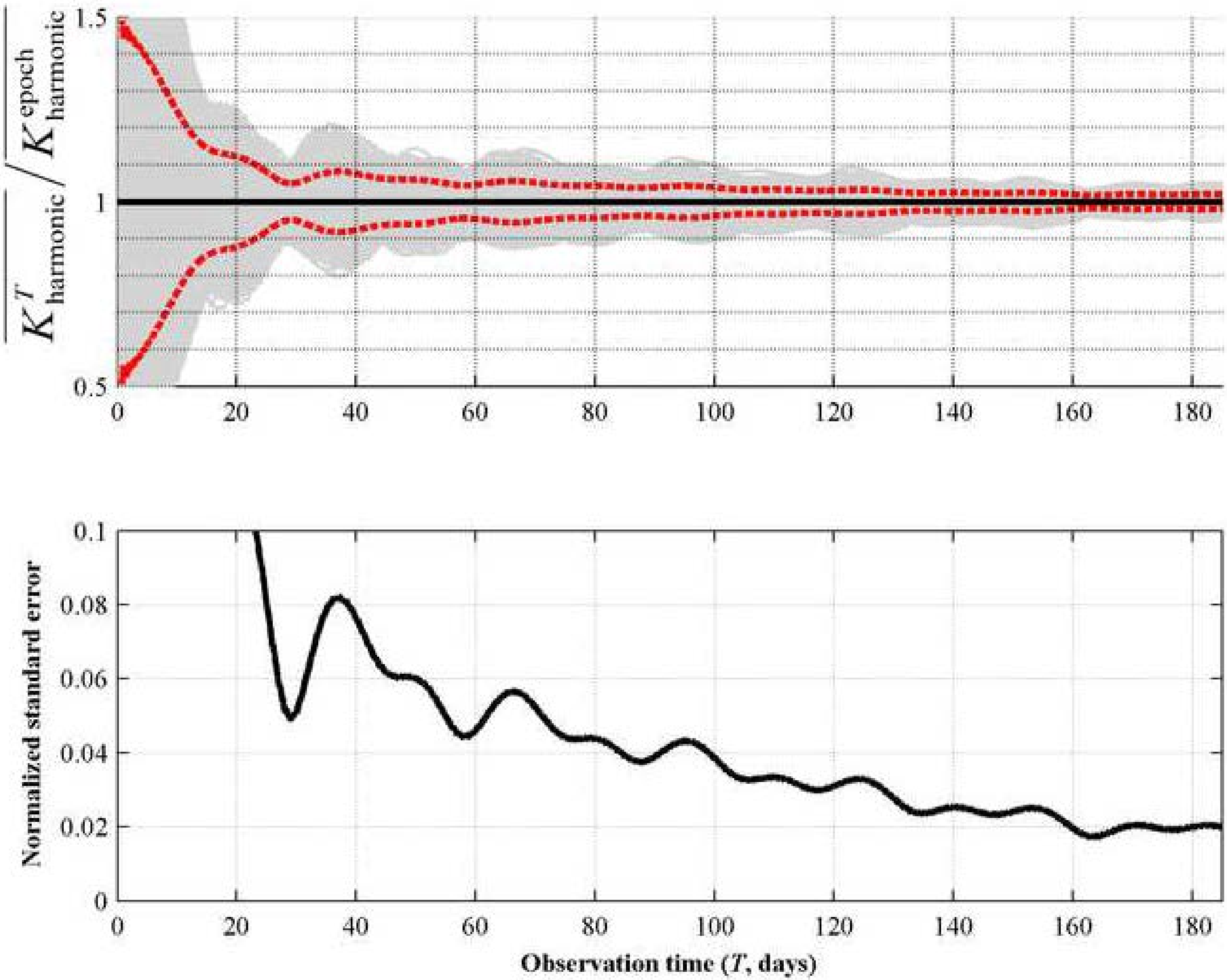

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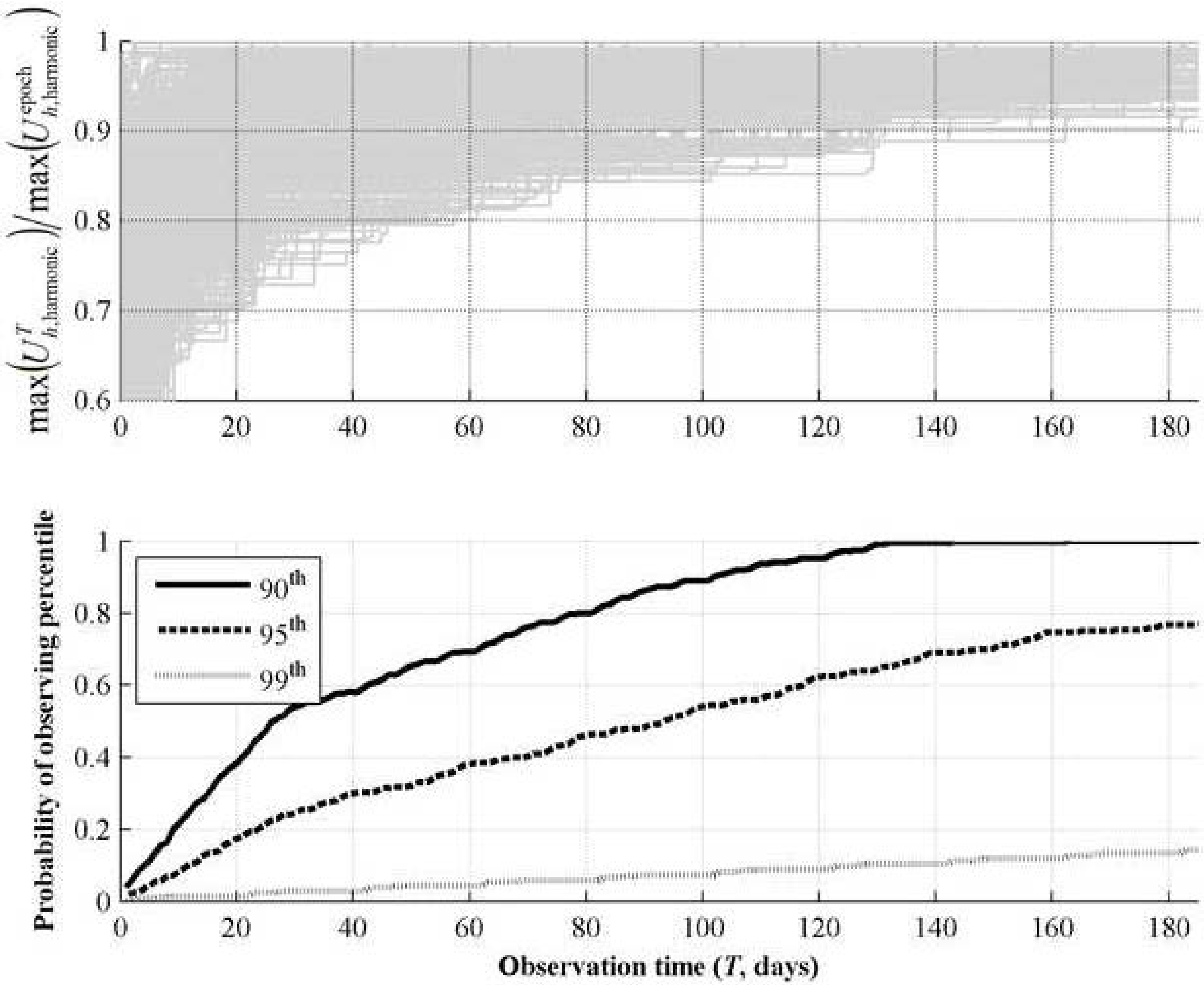

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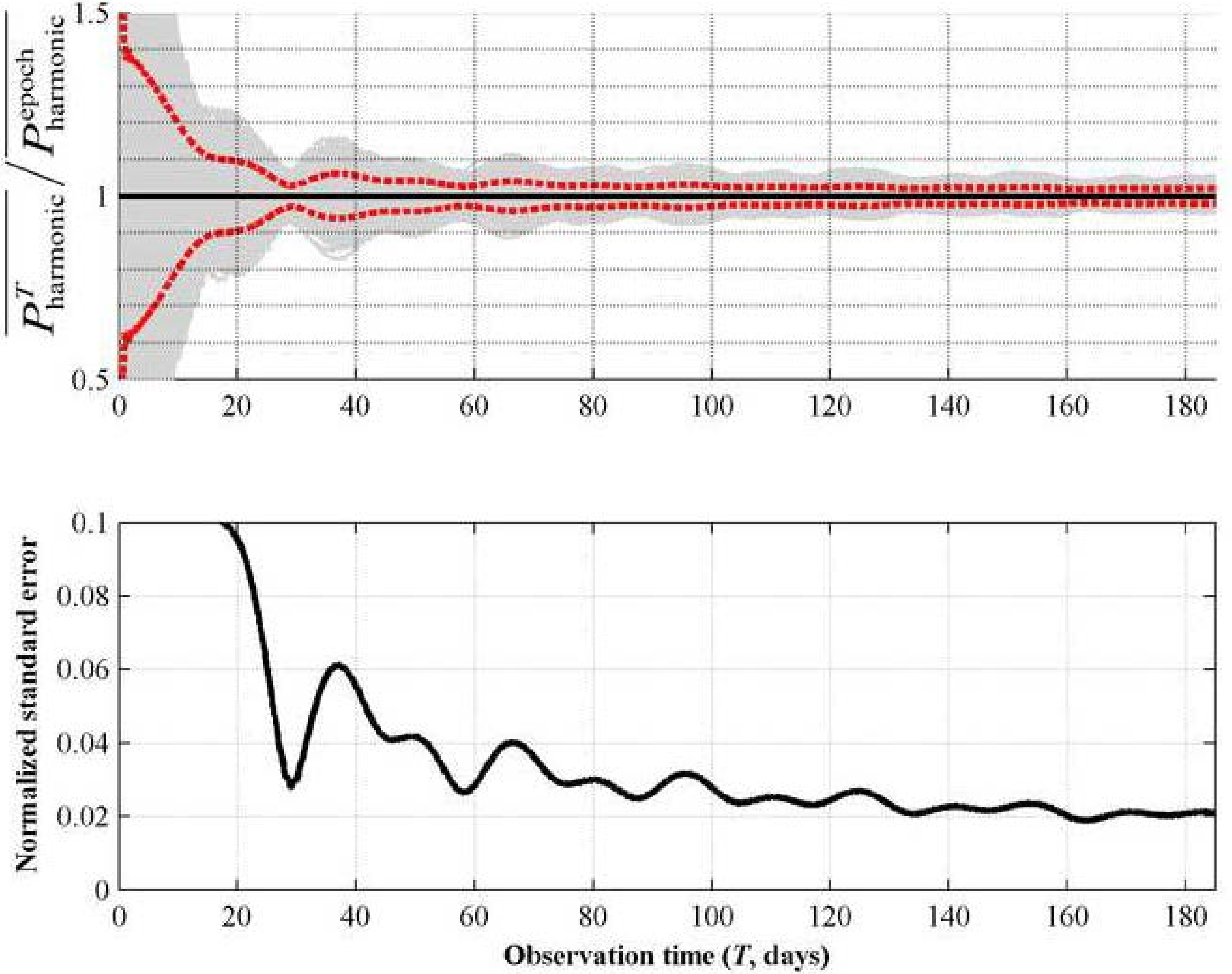

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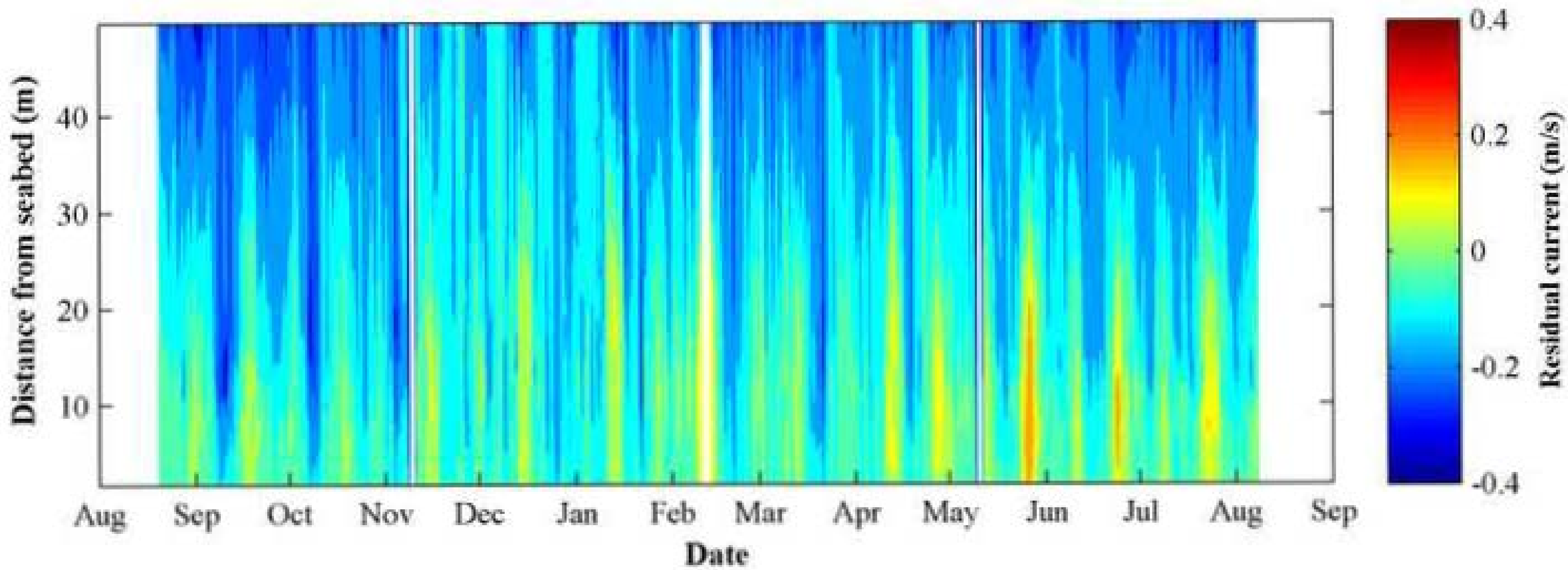

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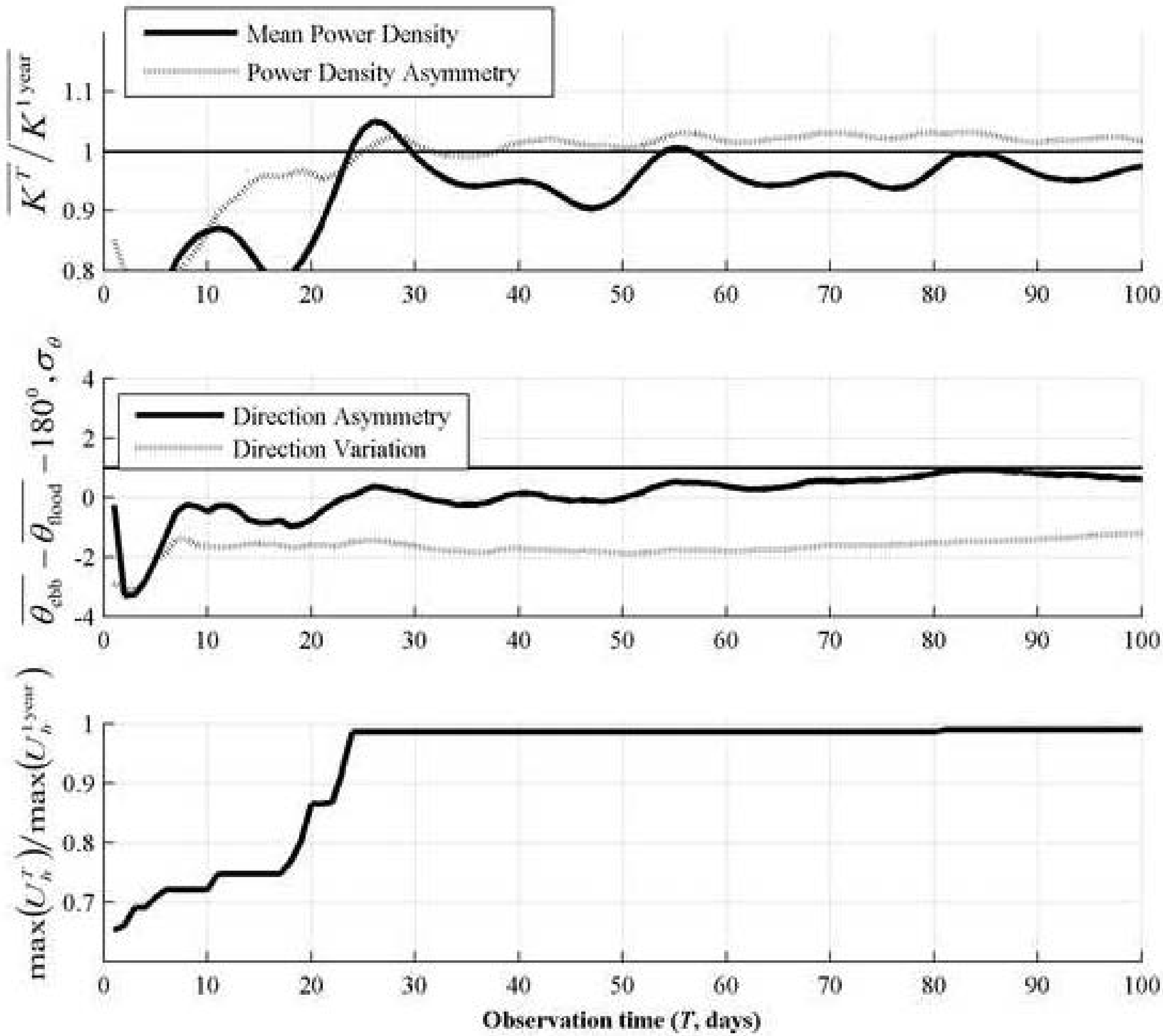

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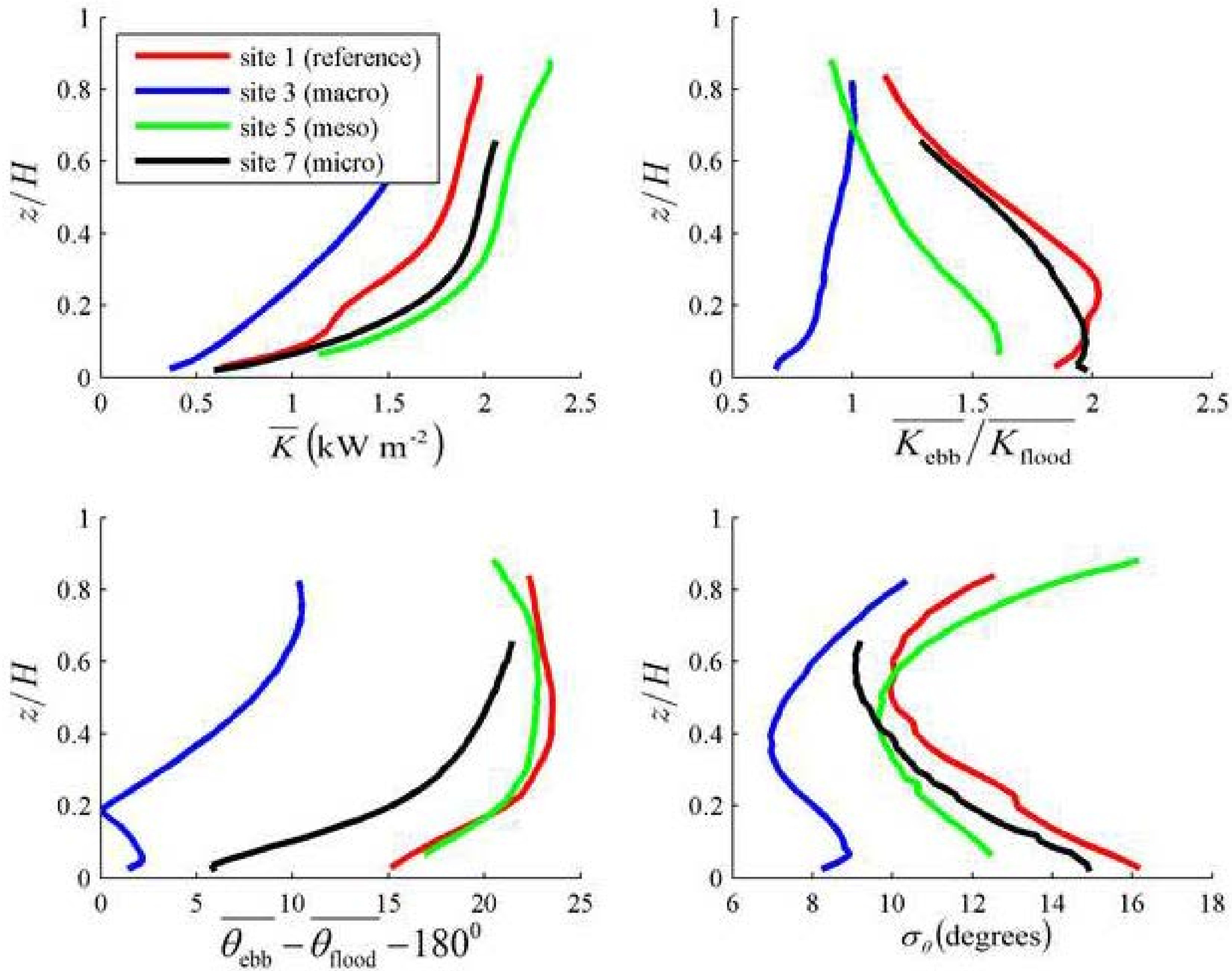

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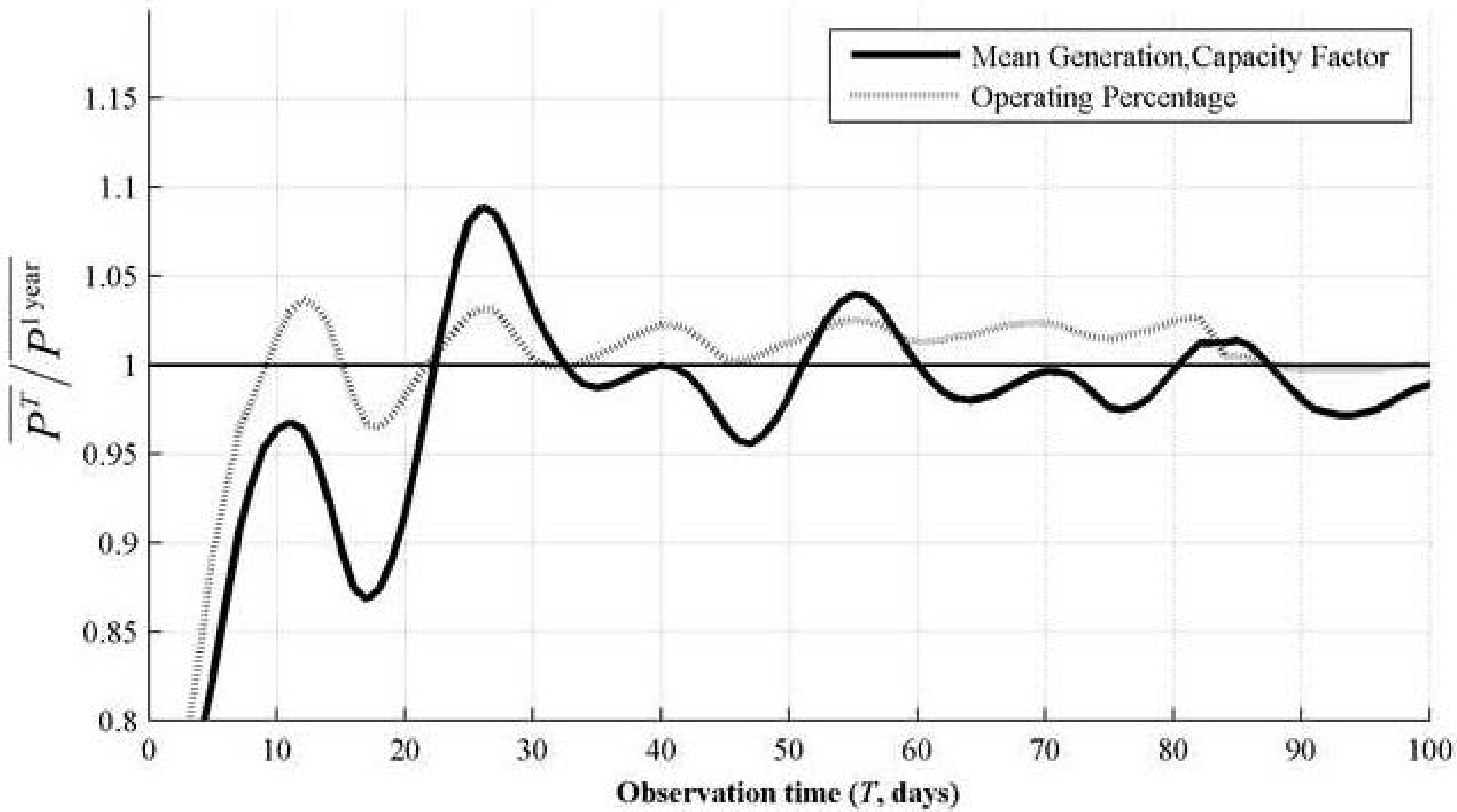

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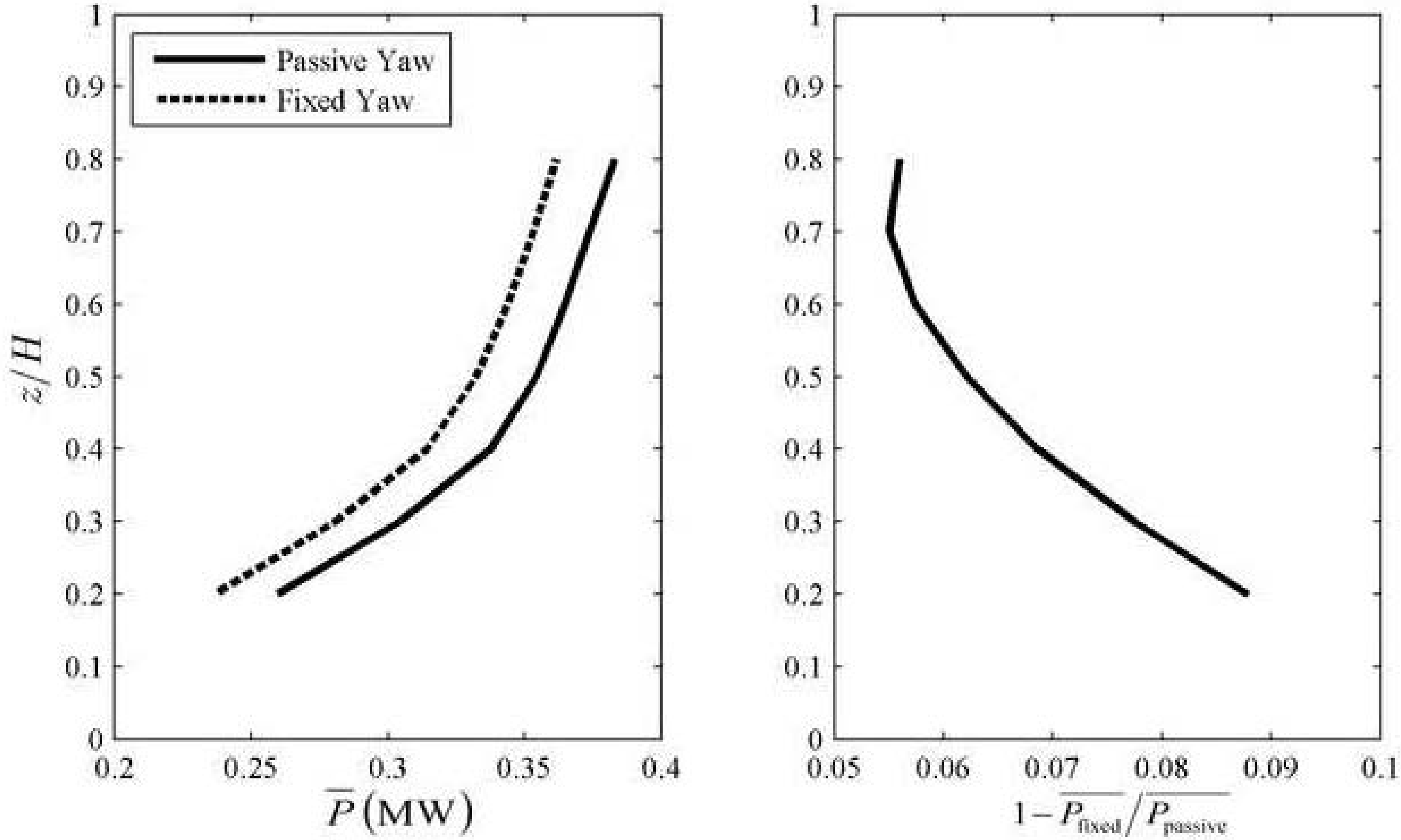

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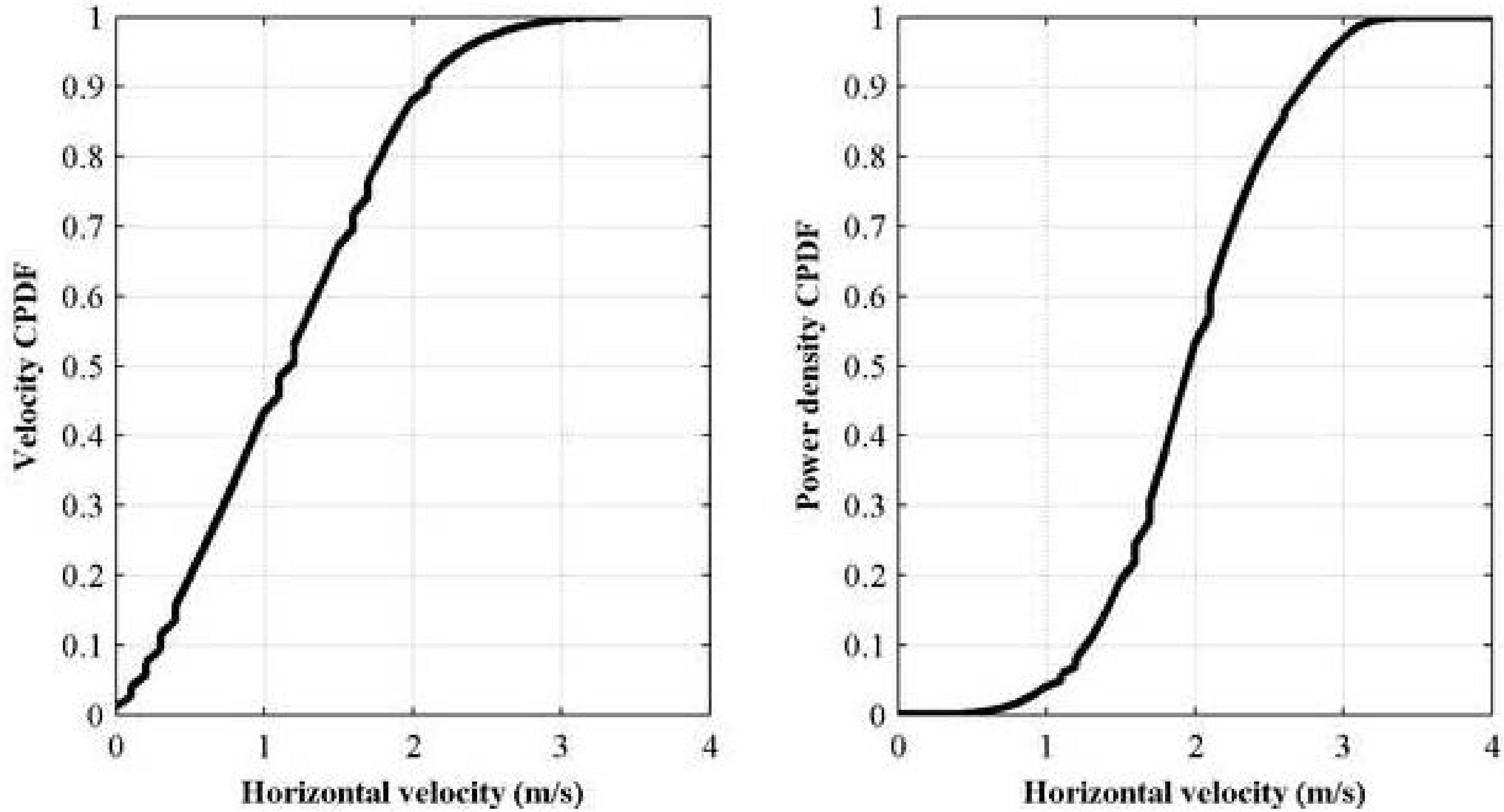

Appendix L-13

Assessment of Potential Puget Sound Marine Safety Risk Resulting from Installation of the Admiralty Inlet Tidal Energy Project

Assessment of Potential Puget Sound Marine Safety Risk Resulting from Installation of the Admiralty Inlet Tidal Energy Project

Defining a Risk Management Strategy
for
the Admiralty Inlet Tidal Energy Project

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INTRODUCTION

The Snohomish County Public Utility District (the District) Admiralty Inlet tidal energy pilot project is a short term (3 to 5 year) demonstration project intended to evaluate the technical, economic, social, and environmental viability of tidal energy generation. When installed and operating, the project will be managed by the District, with the generated electric energy entering the grid through Puget Sound Energy's Whidbey Island distribution network. The project has received approximately $13 million in funding grants, primarily from the U.S. Department of Energy.

The District and its partners propose to deploy two utility-scale tidal energy turbines in Admiralty Inlet, Puget Sound, Washington. Admiralty Inlet has been identified as one of the largest tidal hydrokinetic resources in the U.S., and was selected as the site for this project following a rigorous review of many locations in the Sound deemed to have tidal energy potential (Figure 1).

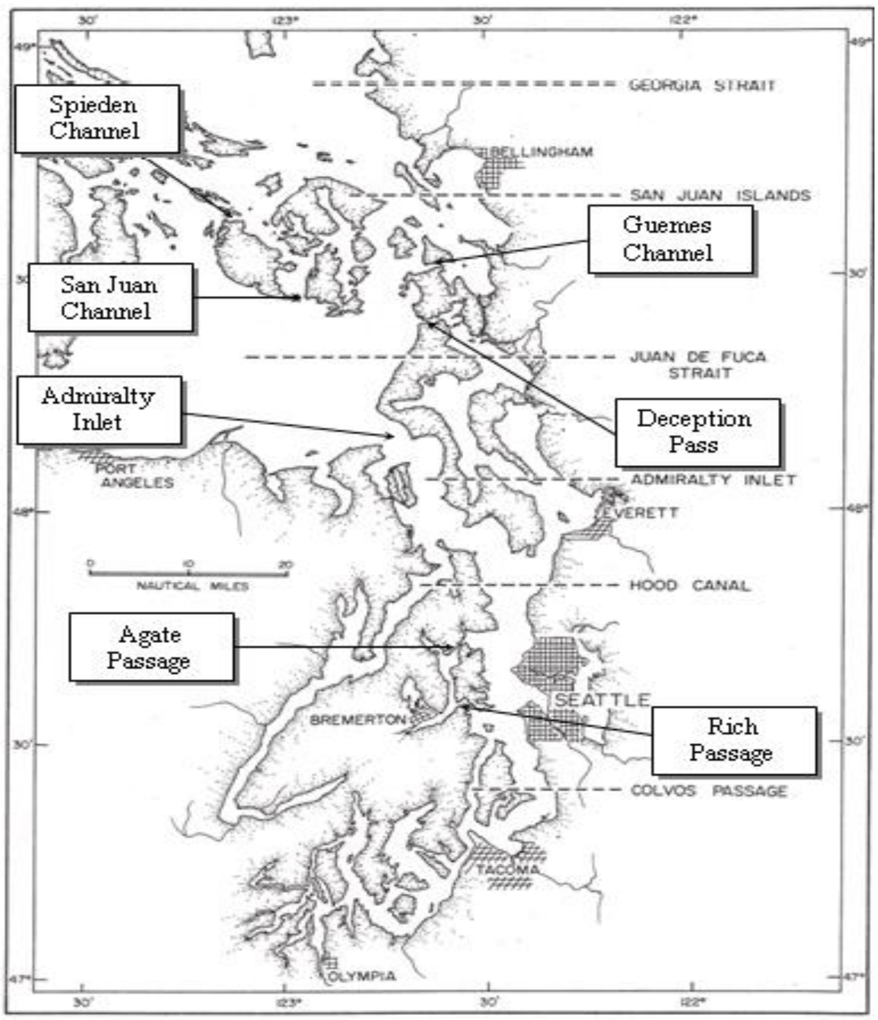

Figure 1 - Tidal Energy Sites Studied by Snohomish PUD

The site review and selection of Admiralty Inlet were conducted in 2007-2008 in partnership with the University of Washington and the Electric Power Research Institute (EPRI). The District has been actively consulting with Native American Tribal governments and with State and Federal regulatory agencies for the past two years, and filed a draft license application for the pilot project with the Federal Energy Regulatory Commission (FERC) in December, 2009. The District plans to file a Final License Application under FERC's Hydrokinetic Pilot Plant Licensing process during the first half of 2011.

Although new to the Puget Sound area, this project is not the first of its kind in the United States. The Roosevelt Island Tidal Energy (RITE) project has operated in the East River, New York City, New York with from two to six turbines under a FERC Demonstration Project license since 2006. The RITE project has recently had a Final License Application accepted by the Federal Energy Regulatory Commission for expansion to 30 turbines in preparation for megawatt-scale pilot plant operations.

The technology provider selected for the Snohomish PUD project is OpenHydro LLC, based in Ireland. This pilot project furthers the District's efforts in response to Federal and State mandates to develop renewable and sustainable power resources that will reduce dependence upon fossil fuel and curb greenhouse gas emissions. It is a multi-phase initiative that will explore the technical, environmental and economic feasibility of tidal energy.

Extensive studies, geophysical surveys, analyses and active collaboration with local, state and national agencies have already taken place to ensure that the proposed tidal energy technology is technically feasible, meets all regulatory requirements and addresses the concerns of stakeholders in accordance with FERC and Washington State environmental (SEPA) processes. To date these activities have included:

- Acoustic Doppler current profiling and tidal current modeling
- Detailed, high-resolution bathymetry, sidescan sonar measurements and geotechnical evaluation of the seabed
- Remotely operated vehicle (ROV) videography of the seabed
- Seabed habitat classification
- Water quality measurements
- Ambient noise measurements
- Multiple hydroacoustic surveys to determine the presence, location, and abundance of fish and other marine life
- Passive acoustic monitoring to detect marine mammal echolocation/vocalization
- Passive monitoring for acoustically tagged fish and marine mammals
- Southern Resident Killer Whale (SRKW) observation, tracking, and behavior assessment
- Tidal energy conversion technology assessment and selection
- Preliminary plant design and grid interconnection study
- Navigation, fishing and social considerations

The selected site is identified in Figure 2 (green stars). The timetable and scope of infrastructure installation will be determined based on the ongoing results of the permitting process. Installation is currently planned for 2013.

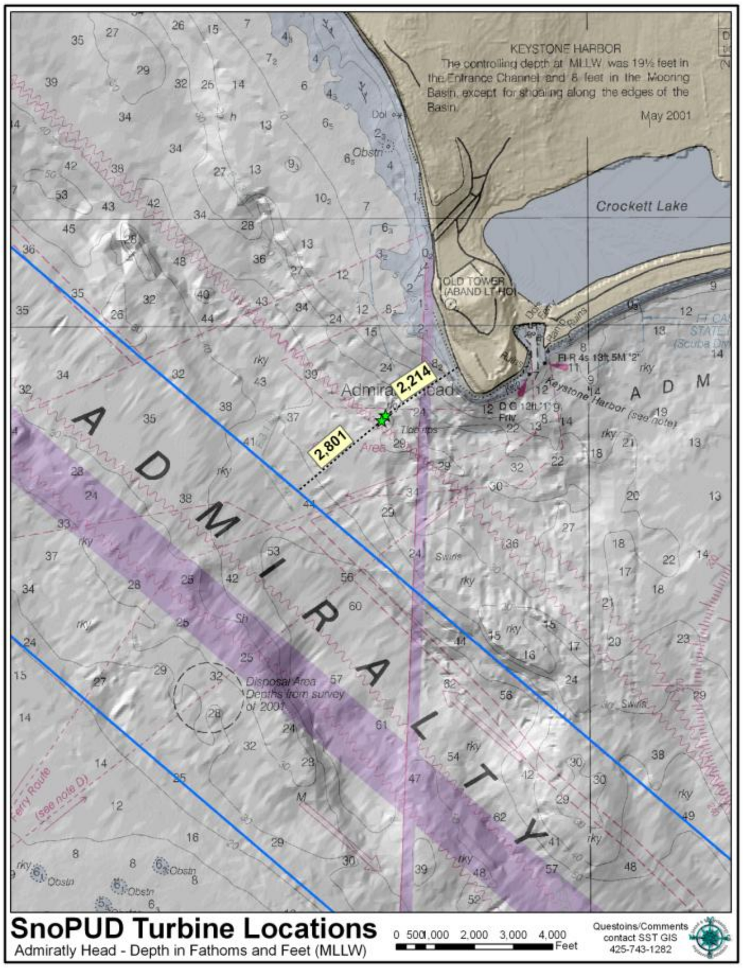

Figure 2 - Admiralty Inlet Site for Snohomish District Tidal Project. Green stars represent proposed tidal turbines

ANALYSIS OF RISK

When facing issues of human safety and risk to property in complex situations, the U.S. Armed Services routinely use an approach known as risk management. Risk management provides a systematic way to consider threats and vulnerabilities, "knowns and unknowns", and to make appropriate decisions to minimize risk. Simply put, risk management endeavors to reduce the probability of a bad outcome and the potential severity of its consequences.

In order to be effective, risk management requires the identification of the full range of possible negative outcomes and an understanding of the deficiencies of safety measures in place to deal with them. It depends on using the best data available, while taking into account that historical data cannot cover every situation. Risk management recognizes the biases in existing data and analysis methods. Most important, the identification of uncertainties with respect to the occurrence of risk is not an excuse for not advocating appropriate action to eliminate or reduce that risk.

Recognizing that the presence of the Snohomish District tidal energy project in Puget Sound may require changes in some ship transit procedures, the U.S. Coast Guard Sector Puget Sound has requested the District conduct a Risk Assessment. Specifically, the impact of the tidal power installation in Admiralty Inlet on the safety of vessel traffic movement will be examined following USCG guidelines for risk-based decision-making. Because this is the first deployment of its kind in Washington State and the Puget Sound, some of the conditions are unique to the region, and the procedure has been adapted to provide the best fit to the situation.

The risk assessment process:

- Define the activity of interest (installation of two tidal turbines in Admiralty Inlet, Puget Sound)
- Identify any significant risk-related factors with potential to affect maritime safety engendered by the pilot project
- Subdivide the risk factors into logical elements
- Determine which maritime operations lead to potential problems involving vessel safety
- Collect and organize relevant risk data for elements of the activity or system
- Display the data graphically for clarity of visualization
- Identify any safeguards that are already in place to reduce risks
- Make recommendations for further actions that may be taken within the capabilities of the marine community to further reduce or eliminate risk

Background

As part of the process of obtaining the permits and agreements necessary to deploy the hydrokinetic turbines in Admiralty Inlet, the location and depth of the chosen installation site have been reviewed in detail with the local marine community. In 2008, contact was initiated with the U.S. Coast Guard Sector Seattle (now Sector Puget Sound) and the Army Corps of Engineers Seattle Division Navigation Section, and through them, in 2009, with the Puget Sound Harbor Safety Committee (PSHSC), to introduce the pilot project to the local maritime community. District representatives were invited to several PSHSC meetings and gave presentations in 2009-2010 to both the Puget Sound maritime community at large and to smaller groups with specific concerns or interests.

The location of the tidal energy project is near, but well outside of, a regulated and International Maritime Organization established Traffic Separation Scheme (TSS) under USCG Vessel Traffic Service (VTS) control. The Admiralty Inlet passage is used by essentially all maritime traffic transiting to and from the ports of Seattle, Tacoma, Olympia, and Everett, as well as U.S. Navy facilities including Naval Station Everett, Puget Sound Naval Shipyard, and the Bangor Submarine Base.

Based upon discussions with the U.S. Coast Guard Sector Puget Sound and the U.S. Army Corps of Engineers, the District's pilot project represents an appropriate use of a commercial waterway. No anchors, pilings or surface-piercing structures will be involved with the turbine installations or power cable to shore. Both the turbines and their foundations are specifically designed to be completely removable for scheduled maintenance or other needs, as well as upon completion of the pilot project. Power generated by the turbines will be transferred to the local electrical grid via a seabed cable to Whidbey Island. The design of the OpenHydro turbine foundation, and the deployment methodology, are completely consistent with the FERC Pilot License process requirement that the project be removable or able to shut down in the event of risk to the public or environmental harm. If renewal of the license is not requested or granted, the site will be restored within the term of the pilot license.

Considering available information, Snohomish PUD anticipates that the proposed project will present no risk to either marine resources or vessel operations within Admiralty Inlet. In part, this is due to the design of the OpenHydro turbine itself: a closed-shroud, open-centered device with no exposed blade tips, running at low speed (6-14 rpm) without cavitation, with no need for oil or grease lubricants, and installed without pinning or pilings (Figure 3). Additionally, the project is of very limited scale relative to Admiralty Inlet, with minimum available depth of water for transiting ships of 43m at Lowest Astronomical Tide (Figure 4) and representing less than 0.05% of the Inlet's horizontal cross-section (Figure 5).

Figure 3 - OpenHydro turbine and seabed mount

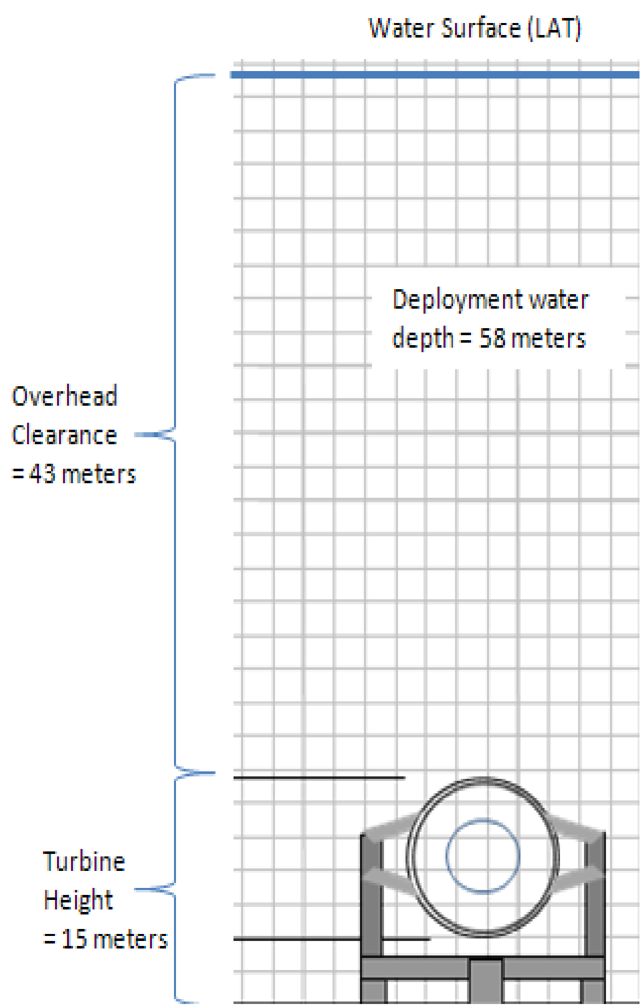

Figure 4 – Vertical cross-section of Admiralty Inlet at turbine site showing scaled size of a tidal turbine (referenced to Lowest Astronomical Tide (LAT))

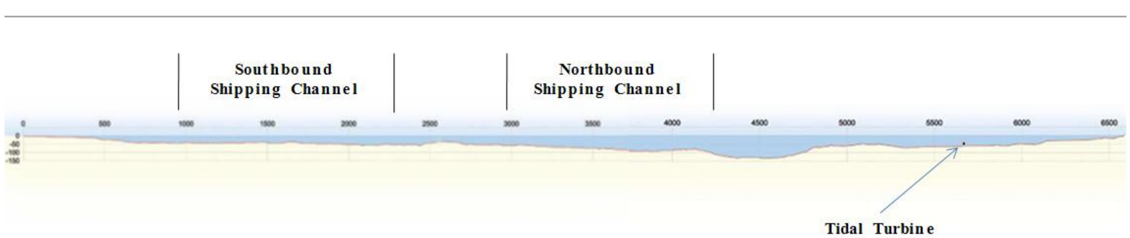

Figure 5 – Horizontal cross-section of Admiralty Inlet showing approximate scale of a tidal turbine

During the tidal energy presentations to PSHSC, the natural hazards affecting vessel operations in Puget Sound's waters were expressed in clear detail by the knowledgeable and experienced maritime community. As noted above, the Safety Committee has been briefed several times on the tidal power site selection process and the installation plans of Snohomish District. The basic concerns of the U.S. Coast Guard, the Army Corps of Engineers Seattle District Navigation Section, the Puget Sound Pilots' Association and the general membership of the PSHSC have generally been satisfied. The location and depth of the proposed Snohomish PUD turbine pilot project place it well out of the flow of ship traffic within the TSS, and below even the deepest-draft vessel's influence.

However, the Sound's strong tidal currents and the dynamics of towboat/tow response have resulted in local acceptance of a practice for tugs returning to the Puget Sound that is in opposition to normal traffic patterns as delineated by the Puget Sound Traffic Separation Scheme (TSS) as established by the International Maritime Organization (IMO). The American Waterways Organization (AWO), representing the maritime towing industry, has pointed out that these slow-moving, towing vessels utilize this route as they can more safely navigate the area outside of the main shipping channel when faster-moving deep draft vessel traffic is present in the TSS. As a result, the preferred track for many of the southbound tugs and tows is outside (east of) the northbound TSS lanes, between the traffic lanes and Whidbey Island. When following this path, the tugs often encounter the same strong tidal currents that make Admiralty Inlet an attractive site for tidal energy generation. Moving in the strong, turbulent flow further reduces the maneuverability of the vessels. AWO asserts that there is a risk to the tugs and their tows, crews, the environment, and risk to the tidal turbines as well if a southbound tow vessel meets a northbound tug and tow also using this diversionary route, and one or both of the ships is required to slow and shift its track to avoid the other. AWO believes a possibility exists that the reduced speed of the vessel could cause the towline catenary to sag deeply, resulting in the cable coming in contact with a turbine. The east-west route of the Coupeville-Port Townsend ferry crossing immediately south of Admiralty Head can also complicate inshore traffic movement near Admiralty Head and has the potential to slow the tugs if the ferry's transit is not carefully coordinated.

Risk Issues

With regards to tug and tow interaction with the proposed tidal turbine installation in Admiralty Inlet, under what circumstances does risk of entanglement of tow lines with the turbines exist? The risk assessment will endeavor to answer the following questions:

- What situations with regard to the presence of tidal turbines in Puget Sound/Admiralty Inlet create risk for a tug and tow transiting east of the TSS?
- How frequently may such hazardous situations be expected to occur?
- Are there various levels of risk depending upon specific conditions (weather, visibility, tides, density and direction of traffic, etc)?
- What is a typical catenary for a towline on a tow vessel operating at a "normal" speed?
- How great must the tug's reduction in speed be in order for the towline to sag deep enough to contact the turbines?

- Are there systems already in place capable of reducing or eliminating this risk?
- Are there constraints that would likely reduce the effectiveness of safety measures currently in place?
- Are there additional measures that can be taken to further reduce/eliminate risk?
- Are there costs associated with the implementation of these measures?

Assessment of Potential Risk

2.3.1 Initial Assumptions

This risk analysis of the Snohomish District tidal turbine installation is focused on the implications of the pilot plant installation over the three-to-five year period of the FERC license. Assumptions made as part of the assessment process include: (1) existence of a well-managed USCG Vessel Traffic Service (VTS), whose goal is to oversee movement of shipping in Puget Sound and reduce or eliminate situations that place vessels, their crews, and their cargo at risk; and (2) an alert cadre of professional mariners, operating their vessels in accordance with the International Regulations for Preventing Collisions at Sea (**COLREGS**).

2.3.2 Specific Risk Assessment Task

The reason for performing this risk assessment is to evaluate the possibility that an accident involving a seagoing vessel, specifically a tug with tow, could occur as a direct result of the presence in Admiralty Inlet of the Snohomish PUD tidal turbines. If, as a consequence of the deployment and operation of two marine tidal energy turbines in Admiralty Inlet, such a risk exists and cannot reasonably be abated, it could threaten lives and property of maritime operators and the environment.

This risk assessment (R/A) process is being conducted at the request of the U.S. Coast Guard, Sector Puget Sound. The USCG four-volume *"Risk Based Decision-making Guidelines,"* second edition, serves as the basis for the R/A procedures that follow. Although written primarily for internal use by USCG agencies, the document provides a straightforward approach to determination of risk in the marine environment. The R/A is being undertaken to address the likelihood of a specific situation could produce a hazard to life, the environment and/or property.

The primary circumstance that has initiated the request to conduct the R/A involves the potential for a head-on meeting situation between multiple tugs with tows and the possibility that one of the Puget Sound ferries could also become involved. Although following USCG guidelines, this R/A is not intended to meet either regulatory or legal requirements; rather, it is meant primarily to respond to stakeholder concerns.

2.3.3 Applicable Rules of the Road

COLREGS provides guidance regarding head-on situations:

Head-on Situation

(a) When two power-driven vessels are meeting on reciprocal or nearly reciprocal courses so as to involve risk of collision, each shall alter her course to starboard so that each shall pass on the port side of the other.

(b) Such a situation shall be deemed to exist when a vessel sees the other ahead or nearly ahead and by night she could see the masthead lights in line or nearly in line and/or both sidelights and by day she observes the corresponding aspect of the other vessel.

(c) When a vessel is in any doubt as to whether such a situation exists she shall assume that it does exist and act accordingly.

Objective of Risk Assessment

The possibility of occurrence of one or more unwanted outcomes separates risk-based decision making from more traditional decision making. The consideration of possible losses for any stakeholder is unique to risk-based decision making. These losses can include such things as negative impact on human safety and health, the environment, or property loss. *The overall risk for an engineered system or activity is determined by the conditions that may create risk, the types of possible losses, the frequency at which they are expected to occur, the effects they might have, and the systems and safeguards that are in place that have the capability to prevent the losses.* Although not certain, the potential losses represent hazards that must be considered in most decision-making processes.

NOTE: The purpose of risk-based decision making is to provide enough information to help someone make a more informed decision. The process focuses on organizing information for logical understanding. It does not replace the decision maker, nor does it force the decision maker into crisis-response risk assessments to gather information that is either irrelevant to the decision or obtained too late to affect it.

Resources Available for Snohomish PUD Risk Assessment

2.5.1 Availability of Data

The quality of a risk analysis is completely dependent on the availability of relevant and reliable data for the activity or system being analyzed. A very powerful resource available for the development of the Puget Sound Tidal Turbine Risk Assessment involves research in progress by the University of Washington's Northwest National Marine Renewable Energy Center (UW-NNMREC). Using statistics from the Automatic Identification System* (AIS) for vessels transiting through Admiralty Inlet, UW-NNMREC has compiled all the individual ship tracks available for calendar year 2010 (the data are approximately 82% complete). Overall, there were 92 vessels of five types (tug, research, ferry, recreational, fishing) that passed within 200 m (approximately 650 ft) of the proposed tidal turbine deployment site. Extrapolating for data lost during AIS receiver downtime yields an estimate of 113 vessels per year within a 200 m radius from the site. Several different areas are used in this analysis, as defined in **Figure 6**.

* The **Automatic Identification System** (**AIS**) is an automated tracking system used on ships and by Vessel Traffic Services (VTS) for identifying and locating vessels by electronically exchanging data with other nearby ships and VTS stations. AIS information supplements marine radar, which continues to be the primary method of collision avoidance for vessels. The International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea (SOLAS) requires AIS to be fitted aboard international voyaging ships with gross tonnage (GT) of 300 or more tons, and all passenger ships regardless of size. Information provided by AIS equipment, such as unique identification, position, course, and speed, can be displayed on a radar screen or an Electronic Chart Display and Information System (ECDIS). AIS is designed to assist traffic monitoring personnel at VTS or other maritime authorities and watchstanders aboard ship by facilitating the tracking and monitoring of vessel movements. AIS integrates a standardized VHF transceiver with a positioning system such as a GPS receiver, and with other electronic navigation sensors, such as a gyrocompass or rate-of-turn indicator.

2.5.2 Vessel Encounters

This analysis focuses on tug and tow transits that involve meeting situations moving through the District's test area. Overtaking situations should be manageable via avoidance maneuvers that do not risk either vessel approaching too close to the tidal energy site. Crossing situations in this area of the Sound nearly all involve the passenger/car ferry that operates out of Coupeville on Whidbey Island and the ferries are exceptionally accommodating about avoiding interference with other ship traffic. All tug/tow encounters with other vessels recorded by AIS within a rectangle 2 miles long (along channel direction) and 0.75 miles wide (cross channel direction) (Figure 6) centered on the turbine site are considered (Attachment 1). To be conservative, an encounter is defined as two vessels being present within the rectangular area within 15 minutes. The situation identified by AWO as having the greatest risk occurs when a southbound tug/tow carrying HAZMAT cargo meets a northbound tug/tow, similarly restricted in ability to maneuver, at maximum tidal flow. Of the seven cases of this type recorded by the AIS receiver during 2010, three also included a crossing ferry within the period of their meeting.

Figure 6 – Areas used for AIS data analysis

Green outline: 10 km radius centered on proposed project site – used to define number of vessels within "Admiralty Inlet" (Figure 8) and distance to nearest vessel by day of year and time of day (Figure 7). Blue outline: rectangular area 2 miles in length and 0.75 miles in width used to identify "head-on" events in which multiple vessels are within the general project area. Red outline: 200 m radius around the proposed turbine site used to identify the number of individual vessels passing close to the proposed project.

The AIS receiver logged **96** meeting incidents between at least one tug and tow and another vessel, with seven of those involving two tugs. Allowing for the AIS receiver's 18% down time for the year, this equates to an estimated **117** tug/tow meetings (with any vessel) yearly with approximately ten of those involving two tugs, less than one per month. Figures 7 and 8 present the results of the UW-NNMREC analysis in graphical form.

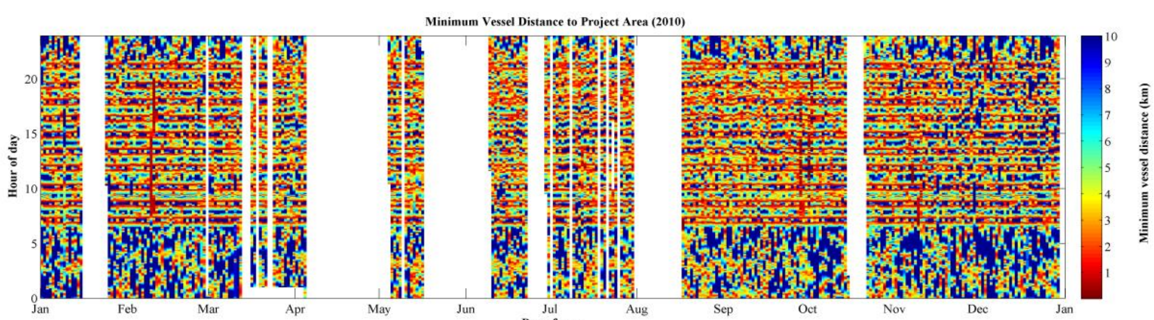

Figure 7 – Minimum vessel distance from Snohomish Utility District project site (2010 AIS data)

Figure shows the shortest distance between a vessel and the proposed project site by day of year (horizontal axis) and time of day (vertical axis). Reds represent vessels in close proximity (1 km or less) while blues represent vessels are greater distances (10 km or more). The persistent horizontal lines on the figure above are created by the 20 daily Coupeville-Port Townsend ferry transits, beginning at 0630 and ending at approximately 2230. Several red vertical lines (February, late September, October) represent day-long survey operations over the Snohomish District tidal site by UW-NNMREC and District-contracted research vessels. *Note:* Figure 7 data records vessels within ten km of the test site, and therefore includes ships operating in the northbound and southbound TSS, not just the rectangle used to identify meeting events between tugs/tows.

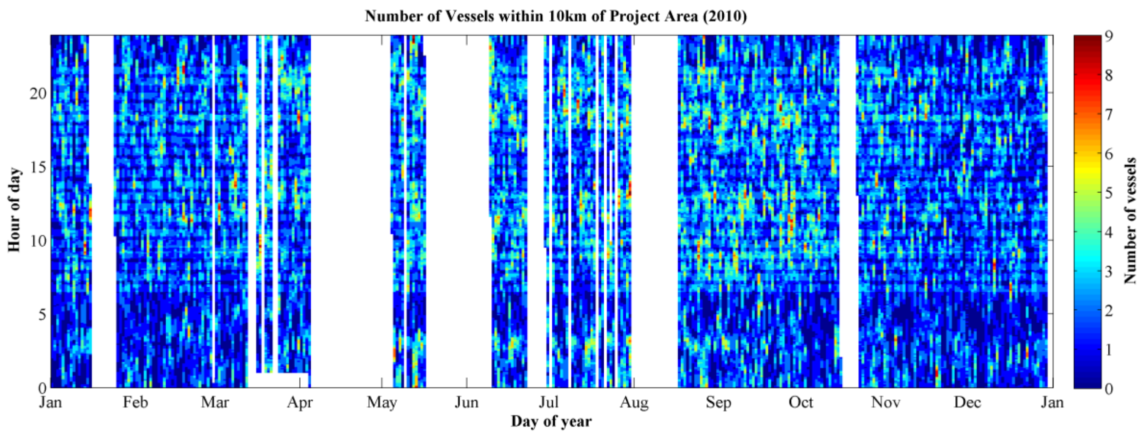

Figure 8 - Number of vessels recorded within 10km of Snohomish tidal energy site (includes all shipping transiting Admiralty Inlet in both VTS lanes)

Figure 8 shows the number of vessels within a 10 km circle centered on the test site (again, by day of year and time of day). Both southbound and northbound through Admiralty Inlet are included, as well as those operating alongshore Whidbey Island. Once again the spectrum is dominated by the ferry lines. *The take-away from this figure is that it is unusual for more than two vessels (three, counting the ferry) to be within 10km of the turbine site at any time.*

2.5.3 Applicability of Data

A preliminary review of the AIS data provided by UW-NNMREC suggests that the Snohomish pilot project will present little or no hazard to navigation safety to any other than towing vessels, because: (1) the turbines will be located about 850 m (2,800ft) outside of all shipping lanes and ferry routes; (2) there is limited traffic in the immediate vicinity of the turbine site (i.e., within a 200 m radius), and the AIS data suggest that on those occasions when multiple vessels are present within the more general area (2 mile x 0.75 mile rectangle), there should be adequate room for a safe diversion; (3) there are restrictions on commercial fishing in northern Admiralty Inlet; (4) there is no routine recreational diving within the project area; and (5) the turbines will be deployed at depths sufficient to allow overhead clearance of 43 meters (141 feet) at LAT, enough to allow for acceptable navigational clearances, even for deep draft vessels.

Tabulation of the Admiralty Inlet AIS data identifies the categories of vessel meeting situations with the highest potential to create risk. Full supporting detail is provided as Attachment (1).

2.5.4 Vessel Types

The vessel types considered for this limited analysis are tug and tow, car/passenger ferry, fishing, research and recreational. Container cargo, military, passenger liner, and tank categories were excluded from this assessment since these larger vessels transit the Sound using the TSS lanes (confirmed by analysis of AIS data). In the restricted waters of Admiralty Inlet, limits on allowable take and fishing methods confine the fishing vessel category to in-water trawlers; no bottom trawling or gillnetting is permitted in the area. The car/passenger ferry category includes all vessels whose primary function includes the transport of passengers across the water, including ferries which transport passengers with some cargo and vehicles. The tug/tow category includes all vessels whose primary function is to transport other vessel types. Recreational vessels are large privately owned vessels, often voluntarily equipped with AIS transponders. Research vessels are included because there will be occasions when either UW Applied Physics Laboratory ships or vessels hired by Snohomish District will operate in the vicinity of the test site for the purpose of monitoring or otherwise servicing the turbine installation.

Specific Activities Targeted for Risk Assessment

2.6.1 Activity of Interest

As presented by AWO, the concern with respect to the siting of the Snohomish tidal turbine pilot project is the use of the Admiralty Inlet waterway by (primarily) southbound tugs with tows returning from Alaska. The barges are reported to at times be carrying hazardous chemicals. Because of strong currents, particularly on the ebb tide, and because towing vessels are slow moving, the preferred route for these vessels is to exit the southbound TSS lane adjacent to Whidbey Island while still north of Port Townsend, Washington and move east of the traffic flow. Once outside the lanes, the tugs take a southeasterly course that carries them east of the *northbound* Puget Sound TSS lanes as they transit Admiralty Inlet southbound for Seattle. Because this diversion places the tow ships in the core of the tidal current – up to 8 knots at maximum ebb – the vessels may be slowed and significantly restricted in their ability to maneuver. In a meeting situation with an northbound tug and tow, an event that, based on analysis of AIS data, occurs slightly less than once a month, there is the potential for one or both of the vessels (and the Whidbey-Port Townsend Ferry which plies the same general vicinity) to be required to change course so as to avoid a close passage. The ferry is easily diverted, but the restricted course and speed of the towing vessels makes them more problematic. Although the occurrence is extremely low, a Risk Assessment to determine best options for management of the situation is appropriate.

2.6.2 Summary of Risk-related Factors

Based upon the AWO's concerns, the hazardous elements any or all of which potentially place tug and towing vessels at risk are:

- Head-on situation of an southbound tug with tow and an northbound tug and tow in the Admiralty Inlet channel east of the northbound TSS lane and near the proposed turbine site. Maneuverability may be further compromised by the presence of the Coupeville-Port Townsend ferry
- Presence of northbound traffic in the TSS lanes, restricting maneuvering room for diversion
- Strong currents, particularly during ebb tidal flow, further reducing both vessels' maneuverability
- Reduced visibility due to inclement weather conditions or darkness

An additional risk factor suggested by the USCG Research & Development Center is the possibility of a power failure aboard a tow vessel as it approaches the pilot project site.

2.6.3 Critical Risk Factor(s)

During a consultation meeting with the AWO and Western Tug and Barge, it was indicated that the most critical element of the risk factors listed above is the potential for a head-on meeting between two vessels restricted in their ability to maneuver. "By convention tugs have substantial slack in their tow cables and chains which would require approximately 23 meters [75 feet] of overhead clearance" (Western Tug and Barge, 2010). The ferry's maneuverability provides that vessel with the flexibility to easily avoid potential meeting and crossing hazards. Overtaking situations between tugs operating with tows are slow enough to develop that VTS monitoring and coordination should easily preclude the necessity for close passage of two vessels in the vicinity of the tidal energy pilot project site.

The complicating factors of weather and tidal currents increase risk but are not, standing alone, hazards that would likely require a vessel to change course and speed so as to pass over the tidal project test site with a tow catenary deep enough to impact the turbine installation.

PRELIMINARY HAZARD ANALYSIS

3.1Description

Preliminary hazard analysis focuses on (1) identifying apparent hazards, (2) assessing the severity of potential accidents that could occur involving the hazards, and (3) identifying safeguards for reducing the risks associated with the hazards. This technique focuses on identifying weaknesses early in the life of a system, thus saving time and money that might be required for major redesign if the hazards were discovered at a later date.

3.2Procedure for Preliminary Hazard Analysis

The steps in a preliminary hazard analysis are straightforward:

- Define the system or activity

- Assess the significance of hazards involved with conducting the activity and assign a ranking to each situation
- Use as a high-level analysis tool to identify potential problems
- Generate qualitative descriptions of the hazards
- Provide a qualitative ranking of the hazardous situations; this ranking can then be used to prioritize recommendations for reducing or eliminating hazards

3.2.1 System of interest

Installation of tidal turbines in Admiralty Inlet, Puget Sound west of Admiralty Head on Whidbey Island is the genesis for this study. The turbines will rest on the sea floor at a depth of approximately 60m. For the purpose of this risk assessment, the issue of concern involves the hazard that the turbines represent to towing vessels that are restricted in their ability to maneuver by a combination of ship traffic, speed, cargo, ocean and/or atmospheric conditions or other conditions.

3.2.2 Situations of interest and the potential severity categories

The specific situations of concern involve towing vessels that are operating east of the TSS lanes. These situations are based upon concerns identified by the American Waterways Operators (AWO).

3.2.2.1 Situation categories

- .Category I (with ferry present) and I(A) (no ferry): Head-on meeting between two towing vessels, both operating east of the TSS lanes. This situation may additionally be complicated by the routine east-west crossing of the Coupeville-Port Townsend ferry, just south of Admiralty Head
- Category II: Head-on meeting between a tow vessel and another vessel
- Category III: Crossing meeting between a towing vessel and the Coupeville-Port Townsend ferry or another vessel
- Category IV: Loss of power by a towing vessel

3.2.2.2 Safety problems

The following specific safety concerns that may arise as a result of the situations noted above all involve the tow vessel or vessels slowing, resulting in the towline catenary sagging deep enough in the water to contact a turbine:

- Allision between sagging tow cable and turbine housing, causing either stoppage of vessel in the tidal race, damage or sinking of vessel or barge, or overturning or damage to turbines, or all above
- Injury to personnel
- Damage to vessel equipment, cargo, and towline
- Damage to the environment caused by spillage of barge cargo or vessel fuel or lubricants

3.2.2.3 Potential severity
Evaluation of the situations described above yields the following prioritization relative to their likelihood of producing a bad outcome:

- Most severe: Categories I and I(A), Rank: 1 and 2. The meeting of two vessels restricted in their ability to maneuver is considered to have the greatest potential to result in reduction of speed by one or both tugs
- Less severe: Categories II and III Rank: 3 and 4
- Category IV incidents are outside the transit scenario considered for this Risk Assessment and involve statistics not available for this study. However, loss of power as the towing vessel is passing near the pilot project site could produce the same safety problems.

3.3 Hazard Review

3.3.1 Tow cable catenary and scope
Typical tow cables used in Puget Sound operations are 1-1/8 to 2 inches in diameter. With two full wraps of the cable drum run out, a representative tow catenary under power, under tow is 40-50 feet for a tow length of 800-1000 feet. Slowing the tow vessel can cause the catenary to sag significantly. When conditions require, the tow vessel operators may bring the cable in to as little as a half-wrap on the winch drum, 250-300 feet of cable out, in order to keep the towed vessel under better control. Weather can also require changes to the cable scope; in Admiralty Inlet, waves and wind can result in the tow operator increasing scope (and deepening the catenary) to allow the water to absorb some of the tow's movement.

3.3.2 Hazardous cargo
Towing vessels operating between Puget Sound and Alaska frequently carry HAZMAT as part of their loadout. Depending on the chemical nature, volume and storage of this material, environmental risk in the event of spillage may be substantial.

3.3.3 Vessel engineering systems
Failure of engines, shafts, propellers, generators and/or electrical systems could cause loss of motive power.

3.3.4 Electronic systems and navigation-related equipment
Gyrocompasses, communications gear, radar, computers, other electronics employed for system monitoring and control, accurate navigation, and tracking.

3.4 Safeguards
Safeguards will be reviewed for the above hazards in the next section (Subsection 4.5)

RISK ASSESSMENT

In order to provide the best assessment of the risk to maritime operations that might be caused by the installation of tidal turbines in Admiralty Inlet, several of the USCG's recommended techniques for risk analysis have been employed. Elements of a Checklist Analysis were presented in Section 2.0 in framing the situation and specifying potential risk elements and their predicted frequency of occurrence. A Preliminary Hazard Analysis in Section 3.0 ranked the hazardous situations in order of severity. The straightforward "What-if" Analysis allows examination of the relevant hazard questions in more detail. The results can be used to suggest potential risk management solutions, both from systems already in place and by identifying additional resources that might be available to eliminate risk. Finally, a Change Analysis, although normally intended more for short-term events, brings into focus the potential alterations to normal maritime practice caused by a new installation,; used here to look at potential impact on VTS operations.

4.1What-if Analysis

The What-if Analysis employed in this risk assessment is a brainstorming approach that uses broad, loosely structured questioning to

(1) Define the functions or events that are being evaluated, and establish the boundaries of the analysis (see Section 2.0)

(2) Postulate known or potential hazards that may result in accidents

(3) Examine the potential consequences of accidents occurring as a result of the hazard(s)

(4) Identify appropriate safeguards against these problems that already are in place

(5) Generate recommendations for preventing problems

The what-if technique has the advantage of being widely applicable for almost every type of risk assessment application, especially those characterized by relatively simple hazard scenarios. It is most often used to supplement other, more structured techniques (especially the Checklist Analysis). Assistance was provided by a broad range of experienced mariners, including former tugboat captains, research vessel officers, USCG commissioned personnel and USCG Research & Development Center analysts.

Table 1 - Analysis of Potential Hazards Attributed to Tidal Turbine Installation

Rank	Hazardous Situation	Immediate Response	Negative Consequences of Failure (“Worst-case Scenario”)	Existing Safeguards	Recommendations for Additional Measures
1	Two tugs meeting head-on, ferry crossing Southbound tug with HAZMAT cargo, Y/N	Ferry and at least one of tug/tow tandems must alter course/speed to avoid	One vessel alters course/speed over tidal turbine site; cable sags, drags over and/or snags turbine Damage to vessel, cargo, turbine, hazard to crew, to environment	1. USCG VTS tracking all units, issues early advisory to ferry and tugs 2. Tug winches in tow cable until ship is past turbine site	USCG Thirteenth District: designate a Regulated Navigation Area (RNA) above turbines to maintain area clear of traffic
1A	Two tugs meeting head-on Southbound tug with HAZMAT cargo, Y/N	Both vessels burdened; at least one of tug/tow tandems must alter course/speed to avoid	One vessel alters course/speed over tidal turbine site; cable sags, drags over and/or snags turbine Damage to vessel, cargo, turbine, hazard to crew, to environment	1. USCG VTS tracking all units, issues early advisory to ferry and tugs 2. Tug winches in tow cable until ship is past turbine site	USCG District 13: designate a Regulated Navigation Area (RNA) above turbines to maintain area clear of traffic
2	Southbound tug & tow in crossing situation with ferry Tug carries HAZMAT cargo Y/N	Ferry burdened, alters course and speed so as to avoid privileged vessel (tug)	Tug forced to slow, catenary of tow drags over and catches on turbine	USCG VTS tracking both units, issues early advisory to ferry & tug	USCG District 13: designate a Regulated Navigation Area (RNA) above turbines to maintain area clear of traffic
3	Southbound tug & tow in meeting situation w/ recreational vessel Tug with HAZMAT cargo Y/N	Recreational vessel burdened, required to take action to avoid	Tug forced to slow, catenary of tow drags over and catches on turbine	USCG VTS tracking both units, issues early advisory to ferry and tug	USCG District 13: designate a Regulated Navigation Area (RNA) above turbines to maintain area clear of traffic
* *Data not availa ble	Southbound tug & tow loses propulsion over test site Tug carries HAZMAT	*Tug issues PAN-PAN* *Contact rescue tug* *Maintain VTS communications*	Tug slows, cable catenary drags over and catches on turbine Current catches vessel, grounding	VTS broadcast Channel 16 “all call” to request any vessel capable provide assistance	Emergency generator, backup power system on tug allows crew to reel in tow cable, prevent allision Prepare to anchor

4.1.1 Hazards of Interest

The potential hazards to safe navigation resulting from the installation of Snohomish District's tidal energy project in Admiralty Inlet have been reviewed and prioritized in Section 3.0, "Preliminary Hazard Assessment."

4.1.2 Safety Problems: Consequences of Failure

Because of the presence of the tidal race off Admiralty Head, the area directly above the tidal energy test site is a challenging one from a navigational standpoint. Inadequate planning, indecisiveness in acting promptly and improper performance of avoidance maneuvers in the vicinity of the project test site, or failure of a hardware system while in transit, can end with bad results. These consequences may be caused by the following:

• One or both of meeting vessels recognize too late that they are approaching with constant bearing, decreasing range (CBDR). One or both towing vessels make an unplanned or poorly set up attempt to avoid each other, and alter course/speed such that one tug's tow line passes through tidal turbine site. The tow cable sags, drags over and/or snags a turbine; possibly resulting in damage to vessel, cargo, turbine, hazard to crew, and to the environment.

• While in transit through Admiralty Inlet, a tug and tow loses main power, goes dead in the water (DIW). If emergency generator power is not available at the tow winch and the crew is unable to recover the cable, the possibility exists that the vessel may be carried into the area of the tidal energy project and could drag the cable catenary across a turbine.

4.1.3 Environmental Consequences

The allision of a tug and tow with a seafloor obstacle such as the tidal turbines can adversely affect the environment. In particular, because many of the Seattle-bound tows returning from Alaska are reported by AWO to be carrying hazardous cargo, the potential for a spill's severity is significant in the event of a vessel collision or grounding.

• Release of HAZMAT cargo directly into the water, following allision on a turbine housing or towed vessel sinking or grounding as a result of coming in contact with a turbine

• Equipment failures occur as a direct consequence of the vessel's contact with a turbine resulting in a spill of fuel, lubricant or other chemical.

4.1.4 Economic Impacts

The improper conduct of a meeting avoidance maneuver or the failure of a vessel system can have undesirable economic impacts:

- Vessel damage or loss, loss of revenue and capacity
- Financial impact of loss of life or injury to crew
- Costs incurred in replacing damaged equipment
- Environmental restoration costs.

4.1.5 Review of Existing Safeguards

4.1.5.1 VTS

The presence of the U.S. Coast Guard's Vessel Traffic Service (VTS) in Puget Sound, having the specific duties of monitoring vessel traffic and issuing advisories where appropriate, is a very powerful safeguard against any marine transit accident. VTS effectively monitors, tracks and communicates with all commercial vessel traffic in the Sound, facilitating the secure and efficient flow of commerce and ensuring that potential incidents are not permitted to develop into hazardous situations. Recognition of a tow vessel's need for early warning of opposing traffic and an understanding of the unique hazards specific to the Admiralty Inlet operating area are critical watchstander skills needed to help prevent the hazardous situations outlined in this assessment from developing.

4.1.5.2 Reduction of Towline Scope

In the event of a necessary or unexpected reduction in speed, towing vessels have the option of taking up on the span of tow cable in the water, even to the point of bringing the towed barge or vessel alongside temporarily if required. Even in the event vessel power is lost, emergency power is normally available at the tow winch, permitting the towline to be brought in.

4.1.5.3 Anchor

As a last resort, if the vessel is adrift and no assistance is immediately available, the vessel master may make both anchors ready for letting go and prepare to anchor at closest anchorage or moor at nearest harbor of safe refuge upon direction of the Captain of the Port.

4.1.6 Recommendations for Additional Preventive Measures

4.1.6.1 Regulated Navigation Area (RNA)

Early in 2010, the suggestion of designating the tidal energy test site as a Regulated Navigation Area (RNA) as provided under 33 CFR Ch.1 Subpart B, paragraphs 165.10-165.13 (Attachment 3) was made to the Coast Guard. Figure 9, showing the proposed RNA was provided as a draft for comment, but the response was negative, both from the USCG and from members of the PSHSC. The initial draft showed a 500 x 1000 meter RNA (hatched yellow rectangle in figure), oriented along the axis of the tidal flow. In order to respond to vessel operator and USCG concerns that the proposed regulated navigation area may be too large and restrictive, a smaller zone could be designated (blue polygon), perhaps with an orientation along the tidal current axis and designed so as to only prohibit vessel operators from anchoring or other activities that would disturb the seabed or interfere with the tidal energy test site.

Designation of an RNA would provide parameters for VTS to recommend diversionary routes to vessels in potential meeting situations, and would provide clear guidance to vessel operators relative to the turbine site location. Given the presence of exceptionally high tidal currents and turbulence in this area, it does not appear to be too restrictive of normal use of the waterway.

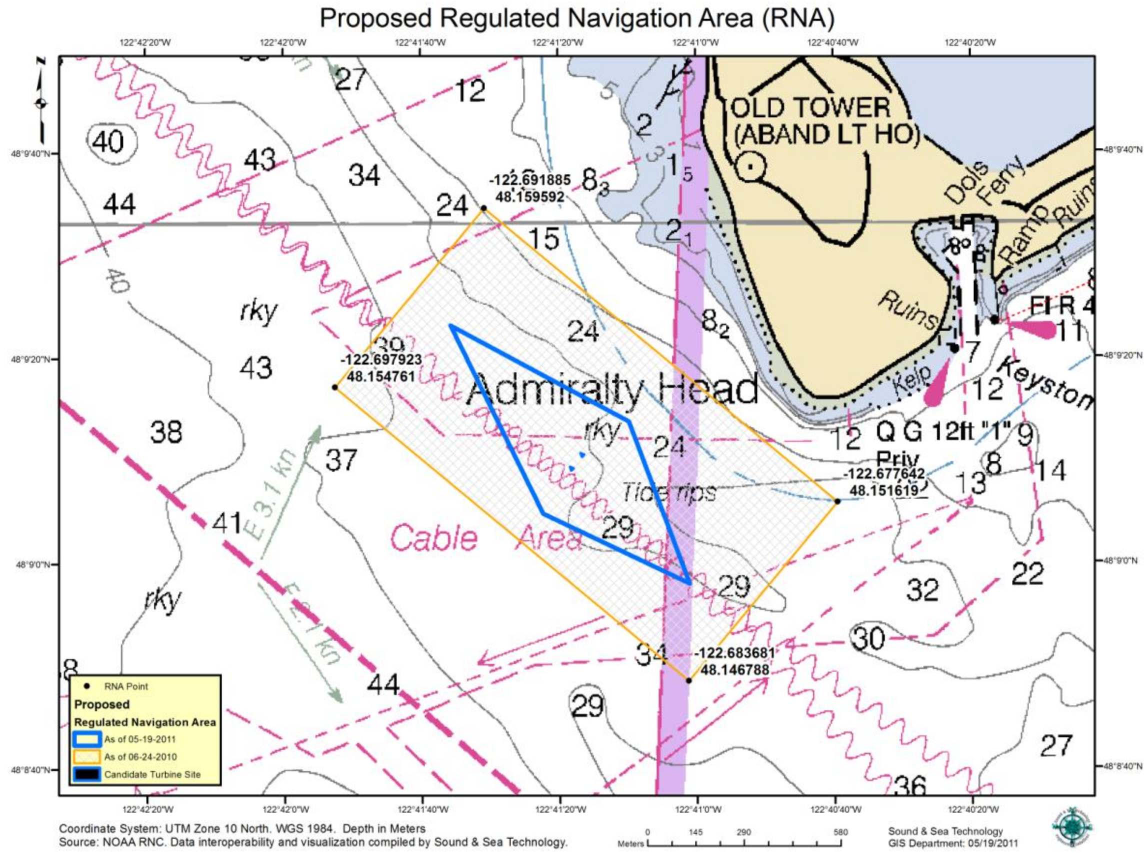

Figure 9 - Proposed Regulated Navigation Area
(initial draft – yellow rectangle; alternate draft – blue polygon)

4.1.6.2 VTS Monitoring of Tugs in Test Area

If publication of a RNA is deemed too restrictive, VTS may elect to develop an "alert zone" based on the same general restrictions outlined in Figure 9, for internal use.

4.1.6.3 Tug and tow avoidance of peak tidal flow zone

The Snohomish District project is sited directly in the peak tidal flow where turbulence is at a maximum and vessel steerage control at a minimum. It seems reasonable to suggest that shiphandling – particularly when transiting with the current – would be significantly easier and safer along a track that avoids the peak flow axis for Admiralty Inlet. A trackline farther offshore from Admiralty Head would be advantageous to reducing turbulence, particularly during the tidal ebb. One of the comments made by a towing industry representative in an early meeting to discuss AWO's concerns mentioned the turbulence in the area and its impact on vessel control.

4.2 Change Analysis

The Change Analysis assessment technique is normally applied to activities of relatively short duration and prearranged schedule, such as the Seattle Seafair or similar marine events.

However, as developed in the Recommendations section of the What-if Analysis (4.1.6), the installation of the tidal energy project may impact, to a small degree, the workload for the VTS watch. There are some features of the Change Analysis process that are useful for evaluating the impact of adjustments that may be required by VTS during the longer period (three to five years) of the District's tidal energy pilot project. Change analysis looks for possible risk impacts and identifies appropriate risk management strategies in situations where change is occurring (or has occurred). This includes situations in which system configurations are altered, operating procedures or policies are changed, new or different activities will be performed, etc.

- Change analysis systematically explores changes from "normal" operations that may occur as a result of risk introduced by (for example) the tidal turbine installation

- Change analysis is practical to implement, useful in identifying any important unresolved issues, particularly with respect to process and taskload impact

- As described by the Risk Assessment manual, change analysis is a conceptually simple tool that models how Coast Guard personnel informally think about controlling the risks associated with marine events.

The potential requirement to monitor out-of-lane tug and tow transits more closely and to pay particular attention to diversion constraints at predetermined geographical boundaries presents possible impacts to VTS operational procedures. However, as noted in Section 2.6, the frequency (based upon 2010 AIS data, Attachment 1) of tug and tow meeting events is on the order of one per month. Fewer than ten vessels per month are expected to transit within a 200 m radius of the pilot project site (Attachment 2).

4.2.1 Brief summary of technique as used here

Consistent with guidance provided in USCG's *Risk-based Decision-making Guidelines*, Snohomish PUD has conducted a variation of the Change Analysis methodology to evaluate the potential impact of the tidal turbine installation on Puget Sound VTS operations. A systematic identification of differences from current Puget Sound VTS operations associated with the pilot project installation and operation was conducted, and an effort made to identify attendant conditions that may introduce additional risks or could conceivably contribute to an accident.

The "event" of interest is the installation of two tidal turbines in Admiralty Inlet, Puget Sound, Washington for a period of from three to five years. At issue is the modification of tug and tow transit procedures and USCG VTS monitoring requirements consequent to that installation.
For comparison, the baseline situation is the existing VTS monitoring and transit procedures. The goals of the change analysis as used here are to:

- Determine any differences between the two situations, regardless of their presumed significance
- Evaluate each of the identified differences, no matter how subtle, to determine risk significance, and make recommendations for managing the associated risks

- Characterize the risk impacts (operational procedures, additional personnel requirements, administrative changes, financial) as best as possible

Table 2 - Change Analysis of Vessel Transits with Tidal Turbines in Admiralty Inlet

Change from Current VTS Operations	Potential Effects	Recommended Risk Control Strategies	
		Prevention Requirements	**Monitoring Activities**
Need for increased monitoring of tug/tow transits of Admiralty Inlet by VTS watch, particularly in the vicinity of turbine site and Coupeville-Port Townsend ferry route	Additional attention paid to new requirement takes time, may distract from watch time, alertness to risks in other areas of VTS coverage	Review VTS watch procedures and identify structure for incorporating new monitoring requirements in Admiralty Inlet outside of TSS, tracking tug & tow tandems southbound in particular.	VTS Watch Supervisors monitor tug & tow tracks on VTS during initial period following turbine installation to ensure watch procedures are adequate to meet additional requirement.
Potential increase in VTS CH16 VHF communications with tug & towing vessels and Coupeville - Port Townsend ferry in Admiralty Inlet resulting from turbine installation	Additional VTS watch communications require time and attention, may delay or interfere with other coverage responsibilities	Work with tow companies and American Waterways Organization through Puget Sound Harbor Safety Committee to ensure that tow vessel crews are aware of additional monitoring and communications by VTS while vessels are transiting Admiralty Inlet, and are prepared to take recommended diversions	VTS watchstanders maintain contact with towing vessels transiting inside VTS traffic lanes and monitor ships' tracklines for convergence with pilot project site
Increased monitoring of recreational vessels operating in vicinity of test site over turbines	Additional VTS watch voice and email/online communications require time and attention, may delay or otherwise impact coverage	Using Notice to Mariners broadcasts and web infosites to ensure widest dissemination of tidal site location to recreational users of the waterway and of the need to avoid attempts at anchoring or trolling with heavy weights in the area	Potential establishment of a Regulated Navigation Area

4.2.2 Changes to Standard VTS Procedures Due to Installation of Tidal Turbines

- Need for increased monitoring of Admiralty Inlet by USCG VTS watch, particularly in the vicinity of turbine site and Coupeville-Port Townsend ferry route: Although unlikely to occur with enough frequency to become a burden, the fact that a new requirement exists may draw some attention away from other tasking.

- Potential increase in VTS CH13 and 05A VHF communications with tug - towing vessels and Coupeville - Port Townsend ferry in Admiralty Inlet resulting from turbine installation: This projected increase in communications is seen as positive. The tow vessel operators are concerned about meeting situations and reduction of transit speed, and;

- Increased monitoring of recreational vessels using VRMS and operating in vicinity of test site over turbines: In order to ease the burden of monitoring on the VTS watch, a logical action would seem to be the designation of a Regulated Navigation Area (RNA) to publicize the need to refrain from overside operations or anchoring in the vicinity of the test site.

4.2.3 Recommended Advance Planning Strategies for VTS

- Review VTS watch procedures: Identify new monitoring requirements due to installation of sea-floor mounted turbines in Admiralty Inlet. Regularly review AIS data on ship transits east of the TSS, updating statistical information on frequency of passage, meetings and diversions required, etc. Monitor tugs with tows southbound in particular. Ensure that watchstanders take note of vessel cargo: HAZMAT on board?

- Outreach:

    - Sharing the establishment of a Regulated Navigation Area or "alert zone" and associated NOAA chart updates.

    - Establish contact with tow companies and American Waterways Organization through Puget Sound Harbor Safety Committee to ensure that tow vessel crews expect additional VTS communications while vessels are transiting Admiralty Inlet.

    - Broadcast Notice to Mariners, Local Notice to Mariners, web infosites and other venues to ensure widest dissemination of tidal energy site location and avoidance recommendations to recreational users of the waterway.

Table 3 - Potential Differences in VTS Activities Before and after Turbine Installation

1. Increased radio traffic (primarily due to need to communicate information on test site to recreational boaters; can be included in periodic information broadcasts conducted by VTS at fixed times)
2. Increased monitoring of recreational vessel traffic near the turbine site
3. Traffic operating east of TSS needs closer monitoring, particularly when more than one vessel is transiting Admiralty Inlet near the turbine site
4. Research vessel traffic to/from/around/in turbine zone (several times a year)

5. Tug and tow traffic using alternate transit route east of TSS must be closely monitored
6. Coordinated interaction required among various agencies • Coast Guard VTS • Towing industry • State ferry • Snohomish PUD

RISK MANAGEMENT

While some potential recommendations have been noted for consideration, the process of organizing and presenting the data in this risk assessment has provided substantial assurances that safety measures already in place are more than adequate to meet the challenge presented by deployment of tidal turbines in the Sound.

5.1 Selecting an Approach

A risk management strategy will aim to reliably achieve the specific objective of eliminating or reducing the possibility of collision, allision or grounding during vessel operations in Admiralty Inlet as a result of the deployment of the District's tidal energy pilot project. Suggested goals of the risk management process:

- Aim to ensure recommended safe clearance of transiting towing vessels of 200 m (660ft) from the turbine installation site
- Aim to reduce or eliminate head-on meetings between southbound and northbound tugs with tows and/or tugs with other vessels within 1 km (3900ft) of the turbine site
- Ensure VTS monitoring and early alerting of potential meetings between towing vessels and recommendations for diversion

5.2 Accident Prevention Options

5.2.1 Reduce or eliminate hazards

- VTS monitoring: Take early steps to identify potential encounters in the area east of the northbound traffic lane. Pay particular attention to those infrequent occasions when both southbound and northbound towing vessels are present
- Communications: Initiate early communications to ensure that all vessels potentially involved in meeting near the tidal energy project site are aware and prepared to take action to avoid the hazardous situation
- Prevention of initiating events: Eliminate head-on meetings between tugs with tows or with other vessels in the situations considered high-risk
- Reduce risk: Move vessels away from the turbine site using a RNA or similar restriction

5.2.2 Identify potential problems early

• Failure modes, causes, sequence of events leading to possible allision or grounding by tug and tow
• Further reduce the frequency of these problems (take steps to move vessels outside zone of turbine operation)

SUMMARY AND CONCLUSIONS

Based upon 2010 AIS tracking statistics provided as Attachment 1, the frequency of head-on meetings between two towing vessels in the area west of Admiralty Head (i.e., within area 2 miles long by 0.75 mile wide) near the proposed tidal energy test site is less than one occurrence per month. Given the presence in Puget Sound of USCG's VTS, a unit with an exceptional record of safety, it is difficult to envision a scenario in which advance coordination between VTS and towing vessels moving through the test site could not easily accomplish a safe passage with sea room to spare. Evidence from AIS tracks indicates that traffic in the northbound VTS lane east of the site (Figure 6) is easily sparse enough that in most cases a small diversion of the northbound tow vessel nearer to or even across the boundary into the lane would not be likely to cause any restriction of faster-moving commercial traffic in the system. Based on the observed one encounter each month in the area of concern, we do not believe that monitoring will cause an undue burden on VTS watchstanders.

In order to ensure safe clearance above the turbines of transiting towing vessels operating outside (east of) the northbound VTS lane in Admiralty Inlet, it seems logical to define a Regulated Navigation Area (RNA) at the tidal energy test site. The RNA would extend upstream and downstream (with the tidal current) for a distance deemed adequate by USCG and vessel operators in order to route towing vessels safely away from the possibility of cable interaction with the turbines. Other than restricting tow transits, anchoring and certain fishing procedures, the RNA would have little or no impact on use of the waterway. The tug-and-tow head-on meeting scenario has an exceptionally low probability of occurrence, particularly with monitoring by VTS and early action to follow VTS recommendations for course changes by tow vessel masters. However, the possibility of a recreational vessel trolling fishing gear into the turbine is more probable, and less likely to be detected by VTS. VHF information broadcasts by VTS at periodic intervals can also contribute significantly to public awareness and safety.

The District's tidal energy project should present little or no hazard to Puget Sound navigation safety, because: (1) the project is located about 850 meters (2,800 feet) outside of all shipping lanes and ferry routes; (2) there is limited commercial fishing in northern Admiralty Inlet; (3) there is a no routine recreational diving within the project area; and (4) the turbines will be deployed at depths sufficient to allow clearances of 43 meters (141 feet), enough to allow for acceptable navigational clearances, even for deep draft vessels.

The American Waterways Organization (AWO) filed comments on May 6, 2010, stating that they believe the proposed location of the tidal turbines "…poses a safety risk to the normal operation of tugboats and their crews, resulting in a high likelihood for an accident including crewmember injury or fatality, damage to a vessel, or environmental damage." Given that AIS statistics indicate the transit situation described by the AWO as most likely to affect vessel safety (head-on meeting, CBDR) occurs on the order of once a month, the comment that this event has a high likelihood of occurrence is probably hyperbole. The preventive measures guarding against the hazardous situations described in the earlier sections of this assessment are exceptional. USCG Puget Sound VTS is chartered to facilitate the secure and efficient transit of vessel traffic so as to assist in the prevention of collisions or groundings that could cost lives, property damage, or subject the waters of Puget Sound to environmental harm.. If tasked to place special emphasis on ensuring safe passage for towing vessels around the turbine site, particularly given the infrequency with which this occurs, it is certain that VTS watchstanders will take all measures necessary to do so.

Attachment 1 - 12-Month Record

(of all multiple-vessel transits through rectangle defined in **Figure** with multiple tug-&-tow events highlighted in red)

Month	Time Stamp	Vessel 1 Name	Vessel 2 Name	Vessel 3 Name	Vessel 1 Type	Vessel 2 Type	Vessel 3 Type
1	734141.7917	STEILACOOM 2	TRIUMPH		Ferry	Tug/Towing	
1	734141.8854	STEILACOOM 2	ALYSSA ANN		Ferry	Tug/Towing	
1	734143.4792	STEILACOOM 2	TRIUMPH		Ferry	Tug/Towing	
1	734143.5625	STEILACOOM 2	WESTERN NAVIGATOR		Ferry	Tug/Towing	
1	734146.6875	STEILACOOM 2	JOSE NARVAEZ		Ferry	Tug/Towing	
1	734148.8854	STEILACOOM 2	WASP		Ferry	Tug/Towing	
1	734152.2813	STEILACOOM 2	ANDREW FOSS		Ferry	Tug/Towing	
1	734152.4792	STEILACOOM 2	LUCY FRANCO		Ferry	Tug/Towing	
1	734162.5625	SUPERLATIVE	STEILACOOM 2		Pleasure	Ferry	
1	734164.6667	STEILACOOM 2	BILLIE H		Ferry	Tug/Towing	
1	734165.7917	STEILACOOM 2	JESSE		Ferry	Tug/Towing	
1	734166.6667	STEILACOOM 2	LUCY FRANCO		Ferry	Tug/Towing	
1	734166.8125	ANNE CARLANDER	STEILACOOM 2		Tug/Towing	Ferry	
1	734166.8333	ANNE CARLANDER	STEILACOOM 2		Tug/Towing	Ferry	
2	734174.7292	STEILACOOM 2	FALCON		Ferry	Tug/Towing	
2	734177.6875	BARENTS SEA	STEILACOOM 2		Tug/Towing	Ferry	
2	734178.4063	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734178.4271	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734178.5625	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734178.6042	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734178.625	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734179.3438	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734179.3646	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	

Month	Time Stamp	Vessel 1 Name	Vessel 2 Name	Vessel 3 Name	Vessel 1 Type	Vessel 2 Type	Vessel 3 Type
2	734179.625	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734179.6771	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734179.7292	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734179.75	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734179.7917	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734179.8125	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
2	734180.6875	PATRICIA S	STEILACOOM 2		Tug/Towing	Ferry	
2	734184.8125	STEILACOOM 2	Glitch		Ferry	?	
2	734185.8854	STEILACOOM 2	WEE HAUL		Ferry	Tug/Towing	
2	734187.8854	PACIFIC EAGLE	HARVESTOR		Tug/Towing	Fishing	
3	734200.3646	STEILACOOM 2	TRIUMPH		Ferry	Tug/Towing	
3	734200.4792	STEILACOOM 2	OCEAN RANGER		Ferry	Tug/Towing	
3	734200.5417	STEILACOOM 2	ISLAND SCOUT		Ferry	Tug/Towing	
3	734203.625	DISCOVERY BAY YTT 11	STEILACOOM 2		Military	Ferry	
3	**734205.5625**	**CAPE CAUTION**	**STEILACOOM 2**	**ISLAND STAR**	**Tug/Towing**	**Ferry**	**Tug/Towing**
3	734207.6667	STEILACOOM 2	WASP		Ferry	Tug/Towing	
3	734209.6979	STEILACOOM 2	ENTRANCE POINTS		Ferry	Tug/Towing	
3	734210.3438	STEILACOOM 2	GULFWINDS		Ferry	Tug/Towing	
3	734210.4063	STEILACOOM 2	VULCAN		Ferry	Tug/Towing	
3	734212.75	STEILACOOM 2	SEASPAN COMMANDER		Ferry	Tug/Towing	
3	734213.8438	STEILACOOM 2	#N/A		Ferry	#N/A	
3	734214.3021	STEILACOOM 2	PACIFIC MARINER 2		Ferry	Tug/Towing	
3	734214.4479	STEILACOOM 2	CHIEF		Ferry	Tug/Towing	
3	734215.3646	STEILACOOM 2	CHIEF		Ferry	Tug/Towing	
3	734218.5	STEILACOOM 2	BILLIE H		Ferry	Tug/Towing	

Month	Time Stamp	Vessel 1 Name	Vessel 2 Name	Vessel 3 Name	Vessel 1 Type	Vessel 2 Type	Vessel 3 Type
3	734221.3854	STEILACOOM 2	LINDSEY FOSS		Ferry	Tug/Towing	
3	734222.5	M Y ADVENTURE	STEILACOOM 2		Pleasure	Ferry	
3	734223.8438	STEILACOOM 2	CALEB		Ferry	Tug/Towing	
3	734227.375	WESTERN RANGER	STEILACOOM 2		Tug/Towing	Ferry	
3	734227.8333	STEILACOOM 2	CALEB		Ferry	Tug/Towing	
4	**734231.5208**	**ANNE CARLANDER**	**STEILACOOM 2**	**JOSE NARVAEZ**	**Tug/Towing**	**Ferry**	**Tug/Towing**
4	734231.8229	STEILACOOM 2	TRIUMPH		Ferry	Tug/Towing	
5	734264.2396	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
5	734264.2604	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
5	734268.7708	ANNE CARLANDER	STEILACOOM 2		Tug/Towing	Ferry	
5	734268.8438	STEILACOOM 2	CHIEF		Ferry	Tug/Towing	
5	734270.3854	STEILACOOM 2	CALEB		Ferry	Tug/Towing	
5	734270.5	STEILACOOM 2			Ferry		
5	734272.7188	STEILACOOM 2	ARCTIC DAWN		Ferry	Cargo	
5	734272.8438	STEILACOOM 2	F V PAPADO II		Ferry	Fishing	
5	734273.3229	STEILACOOM 2	BILLIE H		Ferry	Tug/Towing	
5	734274.3229	HUNTER D	STEILACOOM 2		Tug/Towing	Ferry	
6	734299.75	STEILACOOM 2	LUTHER		Ferry	Tug/Towing	
6	734300.3854	STEILACOOM 2	CHIEF		Ferry	Tug/Towing	
6	734301.3125	GOOD PARTNER	BILLIE H		Fishing	Tug/Towing	
6	734301.4375	STEILACOOM 2	FALCON		Ferry	Tug/Towing	
6	734307.6354	STEILACOOM 2	KIRSTEN H		Ferry	Tug/Towing	
6	734308.2604	STEILACOOM 2	VICTORIOUS		Ferry	Pleasure	
6	734308.5625	STEILACOOM 2	JOSE NARVAEZ		Ferry	Tug/Towing	
6	734310.5	STEILACOOM 2	REDWOOD CITY		Ferry	Tug/Towing	
6	734310.7083	STEILACOOM 2	SHANNON		Ferry	Tug/Towing	

Month	Time Stamp	Vessel 1 Name	Vessel 2 Name	Vessel 3 Name	Vessel 1 Type	Vessel 2 Type	Vessel 3 Type
7	734323.6875	STEILACOOM 2	SHANNON		Ferry	Tug/Towing	
7	**734326.7813**	**STEILACOOM 2**	**LELA JOY**	**PACIFIC STAR**	**Ferry**	**Tug/Towing**	**Tug/Towing**
7	734328.3646	STEILACOOM 2	VICTORIA CLIPPER		Ferry	Passenger Ship	
7	734328.8229	STEILACOOM 2	LINDSEY FOSS		Ferry	Tug/Towing	
7	734328.8438	ANNE CARLANDER	STEILACOOM 2		Tug/Towing	Ferry	
7	734329.3646	STEILACOOM 2	VICTORIA CLIPPER		Ferry	Passenger Ship	
7	734331.4583	STEILACOOM 2	HERCULES		Ferry	Tug/Towing	
7	734331.7188	STEILACOOM 2	SEASPAN SOVEREIGN		Ferry	Tug/Towing	
7	734332.4583	STEILACOOM 2	ISLAND STAR		Ferry	Tug/Towing	
7	734332.5	STEILACOOM 2	FALCON		Ferry	Tug/Towing	
7	734333.4479	STEILACOOM 2	PACIFIC		Ferry	Tug/Towing	
7	734333.5104	STEILACOOM 2	FALCON		Ferry	Tug/Towing	
7	734336.4375	STEILACOOM 2	FANTASIA		Ferry	Pleasure	
7	734338.6458	STEILACOOM 2	CALEB		Ferry	Tug/Towing	
7	734340.4479	STEILACOOM 2	CLIFFORD A BARNES		Ferry	Research	
7	734341.3125	ANNE CARLANDER	STEILACOOM 2		Tug/Towing	Ferry	
7	734341.3333	ANNE CARLANDER	STEILACOOM 2		Tug/Towing	Ferry	
7	734343.6979	STEILACOOM 2	VICTORIA CLIPPER 3		Ferry	Passenger Ship	
7	734345.3854	STEILACOOM 2	UNKNOWN		Ferry	?	
7	734346.4583	STEILACOOM 2	MARAUDER		Ferry	Fishing	
7	734350.4583	STEILACOOM 2	PACIFIC		Ferry	Tug/Towing	
8	734351.5208	STEILACOOM 2	HUNTER		Ferry	Tug/Towing	
8	734353.5	SUPERLATIVE	STEILACOOM 2		Pleasure	Ferry	

Month	Time Stamp	Vessel 1 Name	Vessel 2 Name	Vessel 3 Name	Vessel 1 Type	Vessel 2 Type	Vessel 3 Type
8	734354.3229	STEILACOOM 2	PACIFIC STAR		Ferry	Tug/Towing	
8	734354.4583	STEILACOOM 2	#N/A		Ferry	#N/A	
8	**734358.6979**	**STEILACOOM 2**	**RED BLUFF**	**Ferry**	**Tug/Towing**	**Passenger Ship**	
8	734359.6458	STEILACOOM 2	RED BLUFF		Ferry	Tug/Towing	
8	734361.4583	STEILACOOM 2	ALYSSA ANN		Ferry	Tug/Towing	
8	734362.4479	ANNE CARLANDER	STEILACOOM 2		Tug/Towing	Ferry	
8	734362.4688	ANNE CARLANDER	STEILACOOM 2		Tug/Towing	Ferry	
8	734362.8438	STEILACOOM 2	WESTRAC II		Ferry	Tug/Towing	
8	734365.5104	STEILACOOM 2	JENNIFER H		Ferry	Tug/Towing	
8	734367.4375	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
8	734367.4583	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
8	734367.5	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
8	734367.5521	RELISH	#N/A		? 6m x 20m	#N/A	
8	734368.2396	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
8	734368.2604	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
8	734371.4375	TORTUGA	STEILACOOM 2		Pleasure	Ferry	
8	734372.8229	STEILACOOM 2	CALEB		Ferry	Tug/Towing	
8	734375.3229	STEILACOOM 2	WESTRAC II		Ferry	Tug/Towing	
8	734375.5	STEILACOOM 2	CLIFFORD A BARNES		Ferry	Research	
8	734376.375	HUNTER D	STEILACOOM 2		Tug/Towing	Ferry	
8	734376.8438	STEILACOOM 2	BILLIE H		Ferry	Tug/Towing	
8	734378.4375	STEILACOOM 2	ISLAND SCOUT		Ferry	Tug/Towing	
9	734383.2396	STEILACOOM 2	CHIEF		Ferry	Tug/Towing	
9	734389.6563	STEILACOOM 2	CLIFFORD A BARNES		Ferry	Research	

Month	Time Stamp	Vessel 1 Name	Vessel 2 Name	Vessel 3 Name	Vessel 1 Type	Vessel 2 Type	Vessel 3 Type
9	734390.2604	HUNTER D	STEILACOOM 2		Tug/Towing	Ferry	
9	734391.4375	STEILACOOM 2	SEASPAN MONARCH		Ferry	Tug/Towing	
9	734391.4583	STEILACOOM 2	PACIFIC		Ferry	Tug/Towing	
9	734393.6979	STEILACOOM 2	ALYSSA ANN		Ferry	Tug/Towing	
9	734398.5938	DISCOVERY BAY YTT 11	STEILACOOM 2		Military	Ferry	
9	734399.5	STEILACOOM 2	PACIFIC TITAN		Ferry	Tug/Towing	
9	734399.8438	STEILACOOM 2	SHANNON		Ferry	Tug/Towing	
9	734400.75	STEILACOOM 2	CHIEF		Ferry	Tug/Towing	
9	734401.4583	NORTHERN SONG	STEILACOOM 2		Tug/Towing	Ferry	
9	734403.7708	STEILACOOM 2	CALEB		Ferry	Tug/Towing	
9	734406.5208	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
9	734407.5208	RELISH	STEILACOOM 2		? 6m x 20m	Ferry	
9	734408.7708	WESTERN RANGER	STEILACOOM 2		Tug/Towing	Ferry	
9	734409.5625	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
9	734410.3021	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
9	734410.3854	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
9	734410.4375	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
9	**734410.4583**	**CHETZEMOKA**	**STEILACOOM 2**	**ALISON S**	**Passenger Ship**	**Ferry**	**ROV Survey**
9	**734410.5**	**CHETZEMOKA**	**STEILACOOM 2**	**ALISON S**	**Passenger Ship**	**Ferry**	**ROV Survey**
9	734410.5208	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
9	734410.625	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
9	734410.6458	STEILACOOM 2	ALISON S		Ferry	ROV Survey	

Month	Time Stamp	Vessel 1 Name	Vessel 2 Name	Vessel 3 Name	Vessel 1 Type	Vessel 2 Type	Vessel 3 Type
9	734410.6875	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734413.3021	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734413.3646	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734413.4063	RELISH	ALISON S		? 6m x 20m	ROV Survey	
10	734413.4375	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734413.4583	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734413.5208	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	**734413.5417**	**CHETZEMOKA**	**STEILACOOM 2**	**ALISON S**	**Passenger Ship**	**Ferry**	**ROV Survey**
10	734413.625	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734413.6458	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734414.4375	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734414.5	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734414.5208	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734414.625	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734414.6667	ALISON S	SHANNON		ROV Survey	Tug/Towing	
10	734414.6875	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734414.7083	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734414.75	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734414.7708	STEILACOOM 2	ALISON S		Ferry	ROV Survey	
10	734414.8438	STEILACOOM 2	ANDREW FOSS		Ferry	Tug/Towing	
10	734417.8438	ALASKA TITAN	STEILACOOM 2		Tug/Towing	Ferry	
10	734420.7708	ANNE CARLANDER	STEILACOOM 2		Tug/Towing	Ferry	
10	734421.4583	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
10	734421.8854	PACIFIC	PACIFIC STAR		Tug/Towing	Tug/Towing	
10	734423.5833	STEILACOOM 2	LADY HELEN		Ferry	?	

Month	Time Stamp	Vessel 1 Name	Vessel 2 Name	Vessel 3 Name	Vessel 1 Type	Vessel 2 Type	Vessel 3 Type
10	734424.5833	STEILACOOM 2	JOSE NARVAEZ		Ferry	Tug/Towing	
10	734425.0313	ANNE CARLANDER	PACIFIC		Tug/Towing	Tug/Towing	
10	734433.8438	STEILACOOM 2	MIKE OLEARY		Ferry	Tug/Towing	
10	734434.75	BLARNEY	STEILACOOM 2		Tug/Towing	Ferry	
10	734438.5208	STEILACOOM 2	PETER M		Ferry	Tug/Towing	
10	734441.6875	STEILACOOM 2	HARVESTOR		Ferry	Fishing	
11	734443.625	STEILACOOM 2	JAMES T QUIGG		Ferry	Tug/Towing	
11	734444.7083	STEILACOOM 2	HARVESTOR		Ferry	Fishing	
11	734445.4375	STEILACOOM 2	RESPONSE		Ferry	Tug/Towing	
11	734448.3229	GULF TITAN	STEILACOOM 2		Tug/Towing	Ferry	
11	734448.5208	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734448.6875	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734448.7083	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734449.3646	STEILACOOM 2	EAGLE		Ferry	Tug/Towing	
11	734449.5417	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734449.5625	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734449.6042	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734449.6667	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734449.6875	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734449.7292	CHETZEMOKA	STEILACOOM 2		Passenger	Ferry	

					Ship		
Month	**Time Stamp**	**Vessel 1 Name**	**Vessel 2 Name**	**Vessel 3 Name**	**Vessel 1 Type**	**Vessel 2 Type**	**Vessel 3 Type**
11	734449.7917	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734450.4792	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
11	734450.5	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
11	734450.5625	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734450.6042	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734452.2813	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
11	734452.3021	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
11	734452.3438	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
11	734452.3646	R/V Jack Robertson	STEILACOOM 2		Research	Ferry	
11	734452.75	STEILACOOM 2	JESSE		Ferry	Tug/Towing	
11	734452.7917	STEILACOOM 2	AMERICAN PATRIOT		Ferry	Fishing	
11	734453.3646	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734453.4063	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734453.4792	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734453.6146	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734453.6875	STEILACOOM 2	HERCULES		Ferry	Tug/Towing	
11	734454.5417	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	
11	734456.4167	CHETZEMOKA	STEILACOOM 2		Passenger Ship	Ferry	

Month	Time Stamp	Vessel 1 Name	Vessel 2 Name	Vessel 3 Name	Vessel 1 Type	Vessel 2 Type	Vessel 3 Type
11	734456.7396	STEILACOOM 2	HARVESTOR		Ferry	Fishing	
11	**734463.7292**	**CHETZEMOKA**	**BILLIE H**	**SHANNON**	**Passenger Ship**	**Tug/Towing**	**Tug/Towing**
11	734464.75	PATRICIA S	CHETZEMOKA		Tug/Towing	Passenger Ship	
11	734465.4063	CHETZEMOKA	VICTORIA CLIPPER IV		Passenger Ship	Passenger Ship	
11	734470.7917	CHETZEMOKA	HARVESTOR		Passenger Ship	Fishing	
12	734473.75	CHETZEMOKA	ISLAND CROWN		Passenger Ship	Tug/Towing	
12	734473.8646	GULF TITAN	CHETZEMOKA		Tug/Towing	Passenger Ship	
12	734474.6042	CHETZEMOKA	ANDREW FOSS		Passenger Ship	Tug/Towing	
12	734476.6875	CHETZEMOKA	BILLIE H		Passenger Ship	Tug/Towing	
12	734476.8438	CHETZEMOKA	ISLAND CROWN		Passenger Ship	Tug/Towing	
12	734477.7292	CHETZEMOKA	HARVESTOR		Passenger Ship	Fishing	
12	734479.8854	ANNE CARLANDER	ANDREW FOSS		Tug/Towing	Tug/Towing	
12	734484.7292	CHETZEMOKA	HARVESTOR		Passenger Ship	Fishing	
12	734489.7604	CHETZEMOKA	PACIFIC STAR		Passenger Ship	Tug/Towing	
12	734492.7292	CHETZEMOKA	HERCULES		Passenger Ship	Tug/Towing	
12	734493.3646	CHETZEMOKA	ALYSSA ANN		Passenger Ship	Tug/Towing	

Month	Time Stamp	Vessel 1 Name	Vessel 2 Name	Vessel 3 Name	Vessel 1 Type	Vessel 2 Type	Vessel 3 Type
12	734493.5	CHETZEMOKA	HERCULES		Passenger Ship	Tug/Towing	
12	734493.8646	CHETZEMOKA	ANNE CARLANDER		Passenger Ship	Tug/Towing	

Attachment 2 - Vessels passing within a 200 m radius of the proposed turbine site (92 total in 2010)

Vessel MMSI	Time of Passage	Direction	Vessel Name	Vessel Type
367408890	'Apr 03 2010 12:36'	'S'	ANNE CARLANDER	Tug/Towing
303398000	'Apr 04 2010 11:45'	'S'	TAURUS	Tug/Towing
367153930	'Aug 06 2010 07:41'	'S'	STEILACOOM 2	Ferry
366980220	'Aug 11 2010 11:10'	'S'	ALYSSA ANN	Tug/Towing
367408890	'Aug 12 2010 11:19'	'S'	ANNE CARLANDER	Tug/Towing
367010430	'Aug 15 2010 12:29'	'S'	JENNIFER H	Tug/Towing
367374350	'Aug 17 2010 19:14'	'S'	R/V Jack Robertson	Research
367444560	'Aug 20 2010 09:55'	'S'	RELISH	? 6m x 20m
366751770	'Aug 21 2010 19:04'	'S'	BILLIE H	Tug/Towing
367317770	'Aug 22 2010 14:26'	'N'	ELLIS BRUSCO	Tug/Towing
366893620	'Aug 22 2010 19:46'	'N'	CALEB	Tug/Towing
366695810	'Aug 25 2010 07:53'	'S'	WESTRAC II	Tug/Towing
366866930	'Aug 31 2010 20:33'	'N'	RESPONSE	Tug/Towing
367083650	'Dec 04 2010 17:26'	'S'	HARVESTOR	Fishing
367408890	'Dec 07 2010 21:05'	'S'	ANNE CARLANDER	Tug/Towing
366866930	'Dec 11 2010 19:52'	'S'	RESPONSE	Tug/Towing
366751770	'Dec 19 2010 18:15'	'S'	BILLIE H	Tug/Towing
303442000	'Dec 21 2010 12:02'	'S'	HERCULES	Tug/Towing
367408890	'Dec 21 2010 21:03'	'S'	ANNE CARLANDER	Tug/Towing
367153930	'Feb 02 2010 13:36'	'N'	STEILACOOM 2	Ferry
366887970	'Feb 03 2010 12:09'	'S'	PROTECTOR	Tug/Towing
366980170	'Feb 04 2010 00:50'	'S'	PACIFIC	Tug/Towing
367374350	'Feb 10 2010 17:46'	'N'	R/V Jack Robertson	Research
338033478	'Feb 16 2010 12:26'	'N'	BERING	Fishing

Vessel MMSI	Time of Passage	Direction	Vessel Name	Vessel Type
316006374	'Feb 16 2010 21:29'	'N'	WEE HAUL	Tug/Towing
367083650	'Feb 18 2010 21:26'	'S'	HARVESTOR	Fishing
366972050	'Feb 24 2010 06:12'	'N'	SWINOMISH	Tug/Towing
367408890	'Feb 25 2010 04:50'	'S'	ANNE CARLANDER	Tug/Towing
367103880	'Jan 05 2010 11:26'	'S'	TRIUMPH	Tug/Towing
366751770	'Jan 26 2010 16:03'	'S'	BILLIE H	Tug/Towing
367408890	'Jan 28 2010 19:42'	'S'	ANNE CARLANDER	Tug/Towing
366751770	'Jul 01 2010 20:41'	'N'	BILLIE H	Tug/Towing
303362000	'Jul 07 2010 19:01'	'S'	PACIFIC STAR	Tug/Towing
367408890	'Jul 09 2010 20:20'	'S'	ANNE CARLANDER	Tug/Towing
366751770	'Jul 10 2010 07:07'	'S'	BILLIE H	Tug/Towing
303442000	'Jul 12 2010 10:57'	'N'	HERCULES	Tug/Towing
319193000	'Jul 12 2010 18:16'	'N'	VANGO	Pleasure
367145330	'Jul 14 2010 12:35'	'S'	FALCON	Tug/Towing
366918910	'Jul 21 2010 11:10'	'N'	CLIFFORD A BARNES	Research
367001680	'Jul 24 2010 04:07'	'S'	VULCAN	Tug/Towing
303297000	'Jul 26 2010 09:09'	'S'	UNKNOWN	?
367367880	'Jul 28 2010 10:23'	'N'	ONLINE	Pleasure
366993250	'Jul 30 2010 11:49'	'S'	REDWOOD CITY	Tug/Towing
366980170	'Jul 31 2010 11:00'	'S'	PACIFIC	Tug/Towing
367070410	'Jun 10 2010 18:06'	'N'	LUTHER	Tug/Towing
303362000	'Jun 10 2010 21:26'	'S'	PACIFIC STAR	Tug/Towing
367145330	'Jun 12 2010 02:08'	'N'	FALCON	Tug/Towing
367114810	'Jun 19 2010 06:20'	'N'	VICTORIOUS	Pleasure
366893620	'Jun 21 2010 02:53'	'N'	CALEB	Tug/Towing
366993250	'Jun 21 2010 12:01'	'N'	REDWOOD CITY	Tug/Towing

Vessel MMSI	Time of Passage	Direction	Vessel Name	Vessel Type
366740920	'Jun 21 2010 17:14'	'N'	SHANNON	Tug/Towing
366993810	'Jun 22 2010 05:44'	'N'	WASP	Tug/Towing
303362000	'Jun 24 2010 06:40'	'N'	PACIFIC STAR	Tug/Towing
367131890	'Jun 30 2010 17:50'	'N'	VAERDAL	?
367103880	'Mar 03 2010 08:59'	'S'	TRIUMPH	Tug/Towing
368631000	'Mar 08 2010 13:38'	'N'	CAPE CAUTION	Tug/Towing
366993810	'Mar 10 2010 15:57'	'N'	WASP	Tug/Towing
316005498	'Mar 15 2010 18:12'	'S'	SEASPAN COMMANDER	Tug/Towing
367408890	'Mar 18 2010 22:26'	'S'	ANNE CARLANDER	Tug/Towing
366764740	'Mar 19 2010 10:22'	'S'	CHIEF	Tug/Towing
366751770	'Mar 21 2010 11:53'	'S'	BILLIE H	Tug/Towing
303398000	'Mar 21 2010 12:51'	'S'	TAURUS	Tug/Towing
367579000	'Mar 30 2010 09:04'	'S'	WESTERN RANGER	Tug/Towing
367374350	'May 06 2010 06:10'	'N'	R/V Jack Robertson	Research
367001680	'May 06 2010 17:50'	'N'	VULCAN	Tug/Towing
367408890	'May 10 2010 18:44'	'S'	ANNE CARLANDER	Tug/Towing
0	'May 12 2010 12:04'	'N'	Glitch	?
366751770	'May 15 2010 08:07'	'S'	BILLIE H	Tug/Towing
366811310	'Nov 01 2010 15:19'	'S'	JAMES T QUIGG	Tug/Towing
366345000	'Nov 02 2010 00:40'	'N'	THOMAS G THOMPSON	UNOLS Research
367083650	'Nov 02 2010 17:08'	'S'	HARVESTOR	Fishing
366866930	'Nov 03 2010 10:34'	'N'	RESPONSE	Tug/Towing
369514000	'Nov 06 2010 07:48'	'S'	GULF TITAN	Tug/Towing
367083650	'Nov 06 2010 20:01'	'N'	HARVESTOR	Fishing
367153930	'Nov 07 2010 19:08'	'S'	STEILACOOM 2	Ferry
367374350	'Nov 08 2010 11:05'	'N'	R/V Jack Robertson	Research

Vessel MMSI	Time of Passage	Direction	Vessel Name	Vessel Type
367083650	'Nov 09 2010 21:54'	'S'	HARVESTOR	Fishing
367374350	'Nov 10 2010 07:13'	'S'	R/V Jack Robertson	Research
367083650	'Nov 23 2010 22:00'	'S'	HARVESTOR	Fishing
366994760	'Oct 02 2010 21:37'	'N'	ALISON S	ROV Survey
366757740	'Oct 27 2010 12:51'	'S'	PETER M	Tug/Towing
367313410	'Oct 29 2010 13:19'	'S'	WINDFLIGHT	Pleasure
367153930	'Sep 05 2010 18:37'	'N'	STEILACOOM 2	Ferry
366918910	'Sep 08 2010 15:54'	'N'	CLIFFORD A BARNES	Research
366623050	'Sep 09 2010 22:14'	'S'	KIRSTEN H	Tug/Towing
367103880	'Sep 10 2010 04:59'	'S'	TRIUMPH	Tug/Towing
366980220	'Sep 12 2010 16:53'	'N'	ALYSSA ANN	Tug/Towing
303442000	'Sep 17 2010 14:57'	'S'	HERCULES	Tug/Towing
366740920	'Sep 18 2010 20:29'	'N'	SHANNON	Tug/Towing
366751770	'Sep 19 2010 17:31'	'S'	BILLIE H	Tug/Towing
366893620	'Sep 22 2010 18:46'	'N'	CALEB	Tug/Towing
366994760	'Sep 29 2010 13:03'	'N'	ALISON S	ROV Survey

Attachment 3, 33 CFR Chapter 1

Subpart B—Regulated Navigation Areas

§165.10 Regulated navigation areas.

A regulated navigation area is a water area within a defined boundary for which regulations for vessels navigating within the area have been established under this part.

§165.11 Vessel operating requirements (regulations).

Each District Commander may control vessel traffic in an area which is determined to have hazardous conditions, by issuing regulations:

(a) Specifying times of vessel entry, movement, or departure to, from, within, or through ports, harbors, or other waters;

(b) Establishing vessel size, speed, draft limitations, and operating conditions; and

(c) Restricting vessel operation, in a hazardous area or under hazardous conditions, to vessels which have particular operating characteristics or capabilities which are considered necessary for safe operation under the circumstances.

§165.13 General regulations.

(a) The master of a vessel in a regulated navigation area shall operate the vessel in accordance with the regulations contained in Subpart F.

(b) No person may cause or authorize the operation of a vessel in a regulated navigation area contrary to the regulations in this part.

Appendix L-14

Intershield 300 Abrasion Resistant Aluminum Pure Epoxy
Product Report

Intershield 300

Abrasion Resistant Aluminium Pure Epoxy

PRODUCT DESCRIPTION

A light coloured, abrasion resistant, aluminium pure epoxy coating giving excellent long term anticorrosive protection and low temperature application capability.

INTENDED USES

A universal primer which can be applied directly to mechanically prepared shop primer or suitably prepared bare steel. Suitable for use with controlled cathodic protection.
For use at Newbuilding or Maintenance & Repair.

PRODUCT INFORMATION

Colour	ENA300-Bronze, ENA301-Aluminium
Finish/Sheen	Matt
Part B (Curing Agent)	ENA303
Volume Solids	60% ±2% (ISO 3233:1998)
Mix Ratio	2.50 volume(s) Part A to 1 volume(s) Part B
Typical Film Thickness	150 microns dry (250 microns wet)
Theoretical Coverage	4.00 m²/litre at 150 microns dft, allow appropriate loss factors
Method of Application	Airless Spray, Brush, Roller
Flash Point	Part A 28°C; Part B 26°C; Mixed 28°C
Induction Period	Not required

Drying Information	-5°C	5°C	25°C	35°C
Touch Dry [ISO 1517:73]	7 hrs	5 hrs	3 hrs	2 hrs
Hard Dry [ISO 9117:90]	10 hrs	8 hrs	6 hrs	3 hrs
Pot Life	6 hrs	6 hrs	150 mins	60 mins

Note See Limitations section when Intershield 300 is used as part of an Intersleek scheme.

Overcoating Data - see limitations **Substrate Temperature**

	-5°C		5°C		25°C		35°C	
Overcoated By	Min	Max	Min	Max	Min	Max	Min	Max
Interfine 691	10 hrs	3 days	8 hrs	3 days	6 hrs	3 days	3 hrs	3 days
Interfine 979	-	-	8 hrs	7 days	6 hrs	7 days	3 hrs	7 days
Intergard 263	14 hrs	14 days	9 hrs	14 days	7 hrs	14 days	4 hrs	14 days
Intergard 269	14 hrs	6 mths	9 hrs	6 mths	7 hrs	6 mths	4 hrs	3 mths
Intergard 282	14 hrs	14 days	9 hrs	14 days	7 hrs	14 days	4 hrs	14 days
Intergard 740	14 hrs	14 days	9 hrs	7 days	7 hrs	4 days	4 hrs	4 days
Intershield 300 Immersed Areas	14 hrs	14 days	9 hrs	14 days	7 hrs	14 days	4 hrs	14 days
Intershield 300 Non Immersed Areas	14 hrs	6 mths	9 hrs	6 mths	7 hrs	6 mths	4 hrs	3 mths
Intersleek 717	-	-	9 hrs	14 days	7 hrs	14 days	4 hrs	14 days
Intersleek 737	-	-	7 hrs	24 hrs	5 hrs	9 hrs	3 hrs	7 hrs
Interthane 990	14 hrs	5 days	9 hrs	5 days	7 hrs	3 days	4 hrs	2 days

Note When overcoating with Intersleek 386, refer to the Intersleek 737 data.
Intershield 300 may be overcoated with Intersleek 737 at 0°C, the minimum interval being 12 hours and the maximum 30 hours.
When overcoating with Interbond 201 or Interbond 501, refer to the Intergard 740 data.
For Intergard 740, Intergard 269 and Interthane 990 a minimum temperature of 5°C is required to achieve full cure and specified performance.
Interthane 990 may be used on boottop areas at reduced overcoating intervals. Consult International Paint.
Intershield 300 may be used at temperatures between -5°C and -20°C in certain worldwide locations. Consult International Paint for specific locations and drying / overcoating information.
Interfine 691 is currently only available in Europe.

REGULATORY DATA

VOC

386 g/lt as supplied (EPA Method 24)
318 g/kg of liquid paint as supplied. EU Solvent Emissions Directive (Council Directive 1999/13/EC)

Note: VOC values are typical and are provided for guidance purposes only. These may be subject to variation depending on factors such as differences in colour and normal manufacturing tolerances.

CERTIFICATION

When used as part of an approved scheme, this product has the following certification:

- Food Contact - Carriage of Grain (NOHA)
- Tank Coatings - Recognised Corrosion Control Coating (LR)
- Tank Coatings - B1 Classification of Ballast Tank Coatings (DNV/Marintek tested)
- Tank Coatings - Ballast Tank type approval (GL)
- Tank Coatings - NORSOK M-501, Rev 3, system 7 (Marintek)
- Fire Resistance - MSC61(67) Smoke & Toxicity (WFR)
- Fire Resistance - Surface Spread of Flame (WFR) - (IMO Resolution A653 (16))
- Fire Resistance - Marine Equipment Directive compliant
- Food Contact - FDA Compliant: Dry Foodstuffs

Consult your International Paint representative for details.

SYSTEMS AND COMPATIBILITY

Consult your International Paint representative for the system best suited for the surfaces to be protected.
When using in cargo holds, consult the Intershield 300 Cargo Hold Application Procedures.

SURFACE PREPARATIONS

Use in accordance with the standard Worldwide Marine Specifications.
All surfaces to be coated should be clean, dry and free from contamination.
High pressure fresh water wash or fresh water wash, as appropriate, and remove all oil or grease, soluble contaminants and other foreign matter in accordance with SSPC-SP1 solvent cleaning.

NEWBUILDING
Where necessary, remove weld spatter and smooth weld seams and sharp edges.
Weld seams and areas of shop primer damage or breakdown should be blast cleaned to Sa2½ (ISO 8501-1:2007) or power tooled to Pt3 (JSRA SPSS:1984).
Intact, approved, shop primers must be clean, dry and free from soluble salts and any other surface contaminants. Unapproved shop primers will require complete removal by blast cleaning to Sa2½ (ISO 8501-1:2007). In some cases sweep blasting to a defined International Paint standard (eg AS2 or AS3) may be acceptable. Consult your International Paint representative for specific recommendations.

MAJOR REFURBISHMENT
Abrasive blast clean to minimum Sa2 (ISO 8501-1:2007) or International Paint Hydroblasting Standard HB2M. If oxidation has occurred between blasting and application of Intershield 300, the surface should be reblasted to the specified visual standard.
Surface defects revealed by the blast cleaning process, should be ground, filled, or treated in the appropriate manner.

REPAIR
Consult International Paint.

OTHER
For tank coating and application of Intersleek systems, consult International Paint for the detailed coating procedures that should be followed.

Consult your International Paint representative for specific recommendations.

NOTE
For use in Marine situations in North America, the following surface preparation standards can be used:
SSPC-SP10 in place of Sa2½ (ISO 8501-1:2007)
SSPC-SP6 in place of Sa2 (ISO 8501-1:2007)
SSPC-SP11 in place of Pt3 (JSRA SPSS:1984)

APPLICATION

Mixing	Material is supplied in two containers as a unit. Always mix a complete unit in the proportions supplied. Once the unit has been mixed it must be used within the working pot life specified. (1) Agitate Base (Part A) with a power agitator. (2) Combine entire contents of Curing Agent (Part B) with Base (Part A) and mix thoroughly with power agitator.
Thinner	Use International GTA220 only in exceptional circumstances. DO NOT thin more than allowed by local environmental legislation.
Airless Spray	Recommended Tip Range 0.66-0.79 mm (26-31 thou) Total output fluid pressure at spray tip not less than 211 kg/cm² (3000 p.s.i.)
Brush	Application by brush is recommended for small areas only. Multiple coats may be required to achieve specified film thickness.
Roller	Application by roller is recommended for small areas only. Multiple coats will be required to achieve specified film thickness.
Cleaner	International GTA822/GTA220
Work Stoppages and Cleanup	Do not allow material to remain in hoses, gun or spray equipment. Thoroughly flush all equipment with International GTA822/GTA220. Once units of paint have been mixed they should not be resealed and it is advised that after prolonged stoppages work recommences with freshly mixed units. Clean all equipment immediately after use with International GTA822/GTA220. It is good working practice to periodically flush out spray equipment during the course of the working day. Frequency of cleaning will depend upon amount sprayed, temperature and elapsed time, including any delays. Do not exceed pot life limitations. All surplus materials and empty containers should be disposed of in accordance with appropriate regional regulations/legislation.
Welding	In the event welding or flame cutting is performed on metal coated with this product, dust and fumes will be emitted which will require the use of appropriate personal protective equipment and adequate local exhaust ventilation. In North America do so in accordance with instruction in ANSI/ASC Z49.1 "Safety in Welding and Cutting."
SAFETY	**All work involving the application and use of this product should be performed in compliance with all relevant national Health, Safety & Environmental standards and regulations.** **Prior to use, obtain, consult and follow the Material Safety Data Sheet for this product concerning health and safety information. Read and follow all precautionary notices on the Material Safety Data Sheet and container labels. If you do not fully understand these warnings and instructions or if you can not strictly comply with them, do not use this product. Proper ventilation and protective measures must be provided during application and drying to keep solvent vapour concentrations within safe limits and to protect against toxic or oxygen deficient hazards. Take precautions to avoid skin and eye contact (ie. gloves, goggles, face masks, barrier creams etc.) Actual safety measures are dependant on application methods and work environment.** **EMERGENCY CONTACT NUMBERS:** **USA/Canada - Medical Advisory Number 1-800-854-6813** **Europe - Contact (44) 191 4696111. For advice to Doctors & Hospitals only contact (44) 207 6359191** **R.O.W. - Contact Regional Office**

LIMITATIONS

Intershield 300 should be high pressure fresh water washed and/or solvent washed prior to overcoating, where necessary, to ensure removal of any surface contamination that has accumulated.
Suitable for use on tanker decks subject to Classification Society Regulations.
Intershield 300 may be applied at substrate temperatures down to -5°C, however consideration should be given when overcoating at low temperatures as the remainder of the system may require higher temperatures to achieve full cure.
Intershield 300 may be applied at substrate temperatures between -5°C and -20°C in certain locations worldwide (consult International Paint). However, consideration should be given when overcoating at low temperatures as the remainder of the system may require higher temperatures to achieve full cure.
When Intershield 300 is to be overcoated with Intersleek 737 or Intersleek 386 the following maximum pot lives must be observed:
+0°C - 160 minutes
+15°C - 105 minutes
+25°C - 75 minutes
+35°C - 45 minutes

Overcoating information is given for guidance only and is subject to regional variation depending upon local climate and environmental conditions. Consult your local International Paint representative for specific recommendations. Apply in good weather. Temperature of the surface to be coated must be at least 3°C above the dew point. For optimum application properties bring the material to 21-27°C, unless specifically instructed otherwise, prior to mixing and application. Unmixed material (in closed containers) should be maintained in protected storage in accordance with information given in the STORAGE Section of this data sheet. Technical and application data herein is for the purpose of establishing a general guideline of the coating application procedures. Test performance results were obtained in a controlled laboratory environment and International Paint makes no claim that the exhibited published test results, or any other tests, accurately represent results found in all field environments. As application, environmental and design factors can vary significantly, due care should be exercised in the selection, verification of performance and use of the coating.

UNIT SIZE

Unit Size	Part A		Part B	
	Vol	Pack	Vol	Pack
17.5 lt	12.5 lt	20 lt	5 lt	5 lt

For availability of other unit sizes consult International Paint

UNIT SHIPPING WEIGHT

Unit Size	Unit Weight
17.5 lt	23.4 Kg

STORAGE

Shelf Life: 12 months minimum at 25°C. Subject to re-inspection thereafter. Store in dry, shaded conditions away from sources of heat and ignition.

WORLDWIDE AVAILABILITY

Consult International Paint.

IMPORTANT NOTE

The information in this data sheet is not intended to be exhaustive; any person using the product for any purpose other than that specifically recommended in this data sheet without first obtaining written confirmation from us as to the suitability of the product for the intended purpose does so at their own risk. All advice given or statements made about the product (whether in this data sheet or otherwise) is correct to the best of our knowledge but we have no control over the quality or the condition of the substrate or the many factors affecting the use and application of the product. Therefore, unless we specifically agree in writing to do so, we do not accept any liability at all for the performance of the product or for (subject to the maximum extent permitted by law) any loss or damage arising out of the use of the product. We hereby disclaim any warranties or representations, express or implied, by operation of law or otherwise, including, without limitation, any implied warranty of merchantability or fitness for a particular purpose. All products supplied and technical advice given are subject to our Conditions of Sale. You should request a copy of this document and review it carefully. The information contained in this data sheet is liable to modification from time to time in the light of experience and our policy of continuous development. It is the user's responsibility to check with their local International Paint representative that this data sheet is current prior to using the product.

www.international-marine.com

Safety Data Sheet

ENA301

INTERSHIELD 300 ALUMINIUM PART A

Version No. 15 **Date Last Revised** 17/07/08

1. Identification of the preparation and company

Preparation/Product Name	INTERSHIELD 300 ALUMINIUM PART A
Product Code	ENA301
Reg Number	
Intended use	Anticorrosive primer For professional use only.
Application Method	See Technical Data Sheet.
Company Name	International Paint Stoneygate Lane Felling Gateshead Tyne and Wear NE10 OJY UK
Telephone No.	+44 (0)191 469 6111
Fax No.	+44 (0)191 438 3711
24 hour Emergency Telephone No.	+44 (0)191 469 6111
Official Advisory Body Telephone No.	+44 (0)870 600 6266 For Advice to Doctors & Hospitals only
Email	sds@internationalpaint.com

2. Hazard identification of the product

Flammable.
Harmful by inhalation and in contact with skin.
Irritating to eyes and skin.
May cause sensitisation by skin contact.
Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

Further information is given in section 11.

3. Composition/information on ingredients

If the product contains substances that present a health hazard within the meaning of the Dangerous Substances Directive 67/548/EC, or have occupational exposure limits detailed in EH40, these substances are listed below.

Ingredient	EINECS	Concentration	Symbol(s)	Risk phrases (*)
1,2,4-trimethylbenzene	202-436-9	1 - < 2.5	Xn,N	R10,R20,R36/37/38,R51-53
Butan-1-ol	200-751-6	2.5 - < 10	Xn	R10,R22,R37/38,R41,R67
Epoxy resin (av.mol.wt.<700)	500-033-5	25 - < 50	Xi,N	R36/38, R43, R51-53
Ethylbenzene	202-849-4	2.5 - < 10	F,Xn	R11, R20
Solvent naphtha (petroleum), light aromatic	265-199-0	2.5 - < 10	Xn,N	R51-53, R65
Xylene	215-535-7	10 - < 25	Xn	R10,R20/21,R38

* The full texts of the phrases are shown in section 16.

4. First aid measures

General

In all cases of doubt, or when symptoms persist, seek medical attention.

Never give anything by mouth to an unconscious person.

Inhalation

Remove to fresh air, keep patient warm and at rest. If breathing is irregular or stopped, give artificial respiration. If unconscious place in the recovery position and obtain immediate medical attention. Give nothing by mouth.

Eye Contact

Irrigate copiously with clean fresh water for at least 10 minutes, holding the eyelids apart and seek medical attention.

Skin Contact

Remove contaminated clothing. Wash skin thoroughly with soap and water or use a recognised skin cleanser. Do NOT use solvents or thinners.

Ingestion

If accidentally swallowed obtain immediate medical attention. Keep at rest. Do NOT induce vomiting.

5. Fire-fighting measures

Recommended extinguishing media; alcohol resistant foam, CO^2. powder, water spray.

Do not use; water jet.

Note; Fire will produce dense black smoke. Decomposition products may be hazardous to health. Avoid exposure and use breathing apparatus as appropriate.

Cool closed containers exposed to fire by spraying them with water. Do not allow run off water and contaminants from fire fighting to enter drains or water courses.

6. Accidental release measures

Remove sources of ignition, do not turn lights or unprotected electrical equipment on or off. In case of a major spill or spillage in a confined space evacuate the area and check that solvent vapour levels are below the Lower Explosive Limit before re-entering.

Ventilate the area and avoid breathing vapours. Take the personal protective measures listed in section 8.

Contain and absorb spillage with non-combustible materials e.g. sand, earth, vermiculite. Place in closed containers outside buildings and dispose of according to the Waste Regulations. (See section 13).

Clean, preferably with a detergent. Do not use solvents.

Do not allow spills to enter drains or watercourses.

If drains, sewers, streams or lakes are contaminated, inform the local water company immediately. In the case of contamination of rivers, streams or lakes the Environmental Protection Agency should also be informed.

7. Handling and storage

Handling

This coating contains solvents. Solvent vapours are heavier than air and may spread along floors. Vapours may form explosive mixtures with air. Areas of storage, preparation and application should be ventilated to prevent the creation of flammable or explosive concentrations of vapour in air and avoid vapour concentrations higher than the occupational exposure limits.

In Storage

Handle containers carefully to prevent damage and spillage.

Naked flames and smoking should not be permitted in storage areas. It is recommended that fork lift trucks and electrical equipment are protected to the appropriate standard.

In Use

Avoid skin and eye contact. Avoid inhalation of vapours and spray mists. Observe label precautions. Use personal protection as shown in section 8.

Smoking, eating and drinking should be prohibited in all preparation and application areas.

Never use pressure to empty a container; containers are not pressure vessels.

All sources of ignition (hot surfaces, sparks, open flames etc) should be excluded from areas of preparation and application. All electrical equipment (including torches) should be protected (Ex) to the appropriate standard.

The product may charge electrostatically. Always use earthing leads when pouring solvents and transferring product. Operators should wear clothing which does not generate static (at least 60% natural fibre) and antistatic footwear; floors should be of conducting type.

Activities such as sanding, burning off etc. of paint films may generate dust and/or fumes hazardous to the skin and lungs. Sanding dust may contain levels of unreacted hazardous materials which may cause irritation and sensitization; these are highest in the first 24/48 hours after application. Work in well ventilated areas. Use local exhaust ventilation and personal skin and respiratory protective equipment as appropriate.

Storage

Store in a well ventilated, dry place away from sources of heat and direct sunlight.

Store on concrete or other impervious floor, preferably with bunding to contain any spillage. Do not stack more than 3 pallets high.

Keep container tightly closed. Containers which are opened must be carefully resealed and kept upright to prevent leakage. Keep in the original container or one of the same material.

Prevent unauthorised access.

The requirements of the Highly Flammable Liquids and Liquified Petroleum Gases Regulations apply if the flashpoint is between 21°C and 32°C.

8. Exposure controls and personal protection

Engineering Measures

Provide adequate ventilation. Where reasonably practicable this should be achieved by the use of local exhaust ventilation and good general extraction. If these are not sufficient to maintain concentrations of particulates and any vapour below occupational exposure limits suitable respiratory protection must be worn.

Exposure Limits

The following workplace exposure limits have been established by the Health and Safety Executive as published in EH40.

Material	Short term (15 min. ave)		Long term (8hr TWA)		Comments
	ppm	mg/m³	ppm	mg/m³	
1,2,4-trimethylbenzene			25	125	
Butan-1-ol	50	154	-	-	+
Ethylbenzene	125	552	100	441	+
Xylene	100	441	50	220	+

For Key to entries in 'Comments' column see Section 16

Personal Protection

Respiratory Protection

If workers are exposed to concentrations above the exposure limit they must use the appropriate, certified respirators. When spraying this product use a respiratory mask with charcoal and dust filters (as filter combination A2-P2). In confined spaces use compressed air or fresh air respiratory equipment.

Eye Protection

Wear safety eyewear, e.g. safety spectacles, goggles or visors to protect against the splash of liquids. Eyewear should comply with British Standard 2092.

Hand Protection

Nitrile rubber gloves should be worn during mixing and application.

Skin Protection

Overalls which cover the body, arms and legs should be worn. Skin should not be exposed. Barrier creams may help to protect areas which are difficult to cover such as the face and neck. They should however not be applied once exposure has occurred. Petroleum jelly based types such as Vaseline should not be used. All parts of the body should be washed after contact.

9. Physical and chemical properties

Physical State	Liquid
Flash Point (deg C)	28
Viscosity (cSt)	414
Specific Gravity	1.330
Vapour Density	Heavier than air.
Lower Explosive Limit	0.8
Solubility in Water	Immiscible
R.A.Q. to ventilate to 10% of the LEL (m^3/l)	107

10. Stability and reactivity

Stable under recommended storage and handling conditions (see section 7). When exposed to high temperatures may produce hazardous decomposition products such as carbon monoxide, carbon dioxide, oxides of nitrogen and smoke.

Keep away from oxidising agents, strongly alkaline and strongly acid materials in order to avoid possible exothermic reactions.

11. Toxicological information

There are no data available on the preparation itself. The preparation has been assessed following the conventional method of the Dangerous Preparations Directive 1999/45/EC and classified for toxicological hazards accordingly. See Sections 2 and 15 for details.

Exposure to solvent vapour concentrations from the component solvents in excess of the stated occupational exposure limits may result in adverse health effects such as mucous membrane and respiratory system irritation and adverse effects on the kidneys, liver and central nervous system. Symptoms include headache, nausea, dizziness, fatigue, muscular weakness, drowsiness and in extreme cases, loss of consciousness.

Repeated or prolonged contact with the preparation may cause removal of natural fat from the skin resulting in dryness, irritation and possible non-allergic contact dermatitis. Solvents may also be absorbed through the skin. Splashes of liquid in the eyes may cause irritation and soreness with possible reversible damage.

Based on the properties of the epoxy constituents and considering toxicological data on similar preparations this preparation may be an irritant and a skin and respiratory sensitiser. Low molecular weight epoxy constituents are irritating to eyes, mucous membranes and skin. Repeated skin contact may lead to irritation and sensitisation, possibly with cross-sensitisation to other epoxies. Skin contact with the preparation and exposure to spray mist and vapour should be avoided.

Safety Data Sheet

ENA301

INTERSHIELD 300 ALUMINIUM PART A

Version No. 15 **Date Last Revised** 17/07/08

12. Ecological information

There are no data available on the product itself.

The product should not be allowed to enter drains or water courses.

The preparation has been assessed following the conventional method of the Dangerous Preparations Directive 1999/45/EC and is classified for eco-toxicological properties accordingly. See Sections 2 and 15 for details

Epoxy resin (av.mol.wt.<700) (EINECS 500-033-5)

Ecotoxicity:
LC50 96 hours fish (Leuciscus idus) 3.6mg/l
EC50 48 hours daphnia 2.8 mg/l
EC50 96 hours algae 220 mg/l

Bioaccumulation:
Bioconcentration potential is moderate (BCF between 100 and 3000 or log Pow between 3 and 5).

Mobility:
Potential for mobility to soil is high (Koc between 50 and 150)
Material is expected to cause long-term adverse effects in the aquatic environment (log Pow greater than 3.0)

Degradation:
Based on the stringent OECD test guidelines, this material can not be considered as readily biodegradable; however, these results do not necessarily mean that the material is not biodegradable under environmental conditions.

13. Disposal considerations

Do not allow into drains or water courses. Wastes and emptied containers should be disposed of in accordance with regulations made under the Control of Pollution Act and the Environmental Protection Act.

Using information provided in this data sheet advice should be obtained from the Waste Regulation Authority, whether the special waste regulations apply.

The European Waste Catalogue Classification of this product, when disposed of as waste is 08 01 11 Waste paint and varnish containing organic solvents or other dangerous substances. If mixed with other wastes this code may no longer apply and the appropriate code should be assigned. For further information contact your local waste authority.

14. Transport information

Transport only in accordance with the following regulations:

ADR/RID	UN1263 Paint, 3, III		
IMDG	Class	3	Subsidiary Class
	Proper Shipping Name	PAINT	
	UN No	1263	
	Ems	F-E,S-E	
	Packaging Group	III	
	Marine Pollutant	No	
ICAO/IATA	Shipping Name	PAINT	
	Class	3	Subsidiary Class
	UN No	1263	
	Packaging Group	III	

15. Regulatory information

In accordance with EC Directive 88/379/EEC and the Chemicals (Hazard Information and Packaging for Supply) Regulations SI /3247/1994 this product is labelled as follows:

Symbol(s)

Harmful

Dangerous for the environment

Contains;

Epoxy resin (av.mol.wt.<700)

Xylene

R. Phrases;

Flammable.
Harmful by inhalation and in contact with skin.
Irritating to eyes and skin.
May cause sensitisation by skin contact.
Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

S. Phrases;

Handle and open container with care.
Do not breathe vapour/spray.
Wear suitable protective clothing and gloves.
Use only in well-ventilated areas.

P. Phrases;

Contains epoxy constituents. See information supplied by the manufacturer.

16. Other information

FOR PROFESSIONAL USE ONLY IMPORTANT NOTE The information in this data sheet is not intended to be exhaustive and is based on the present state of our knowledge and on current laws: any person using the product for any purpose other than that specifically recommended in the technical data sheet without first obtaining written confirmation from us as to the suitability of the product for the intended purpose does so at his own risk. It is always the responsibility of the user to take all necessary steps to fulfill the demands set out in the local rules and legislation. Always read the Safety Data Sheet and the Technical Data Sheet for this product if available. All advice we give or any statement made about the product by us (whether in this data sheet or otherwise) is correct to the best of our knowledge but we have no control over the quality or the condition of the substrate or the many factors affecting the use and application of the product. Therefore, unless we specifically agree in writing otherwise, we do not accept any liability whatsoever for the performance of the product or for any loss or damage arising out of the use of the product. All products supplied and technical advice given are subject to our standard terms and conditions of sale. You should request a copy of this document and review it carefully. The information contained in this data sheet is subject to modification from time to time in the light of experience and our policy of continuous development. It is the user's responsibility to verify that this data sheet is current prior to using the product.

The information in this Health & Safety Data Sheet is required pursuant to Directive 91/155/EEC and the Chemicals (Hazard Information & Packaging for Supply) Regulations 1994.

Key to 'Comments' column in Section 8.
(+) There is a risk of absorption through unbroken skin.
(C) Capable of causing cancer and/or heritable genetic damage
(R) Suppliers recommended limit
(S) Capable of causing occupational asthma

The full text of the R phrases appearing in section 3 is:

R10 Flammable.

R11 Highly flammable.

R20 Harmful by inhalation.

R20/21 Harmful by inhalation and in contact with skin.

R22 Harmful if swallowed.

R36/37/38 Irritating to eyes, respiratory system and skin.

R36/38 Irritating to eyes and skin.

R37/38 Irritating to respiratory system and skin.

R38 Irritating to skin.

R41 Risk of serious damage to eyes.

R43 May cause sensitisation by skin contact.

R51-53 Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

R65 Harmful: May cause lung damage if swallowed.

R67 Vapours may cause drowsiness and dizziness

Safety Data Sheet

ENA303

INTERSHIELD 300 PART B

Version No. 19 **Date Last Revised** 18/07/08

1. Identification of the preparation and company

Preparation/Product Name	INTERSHIELD 300 PART B
Product Code	ENA303
Reg Number	
Intended use	See Technical Data Sheet. For professional use only.
Application Method	See Technical Data Sheet.
Company Name	International Paint Stoneygate Lane Felling Gateshead Tyne and Wear NE10 OJY UK
Telephone No.	+44 (0)191 469 6111
Fax No.	+44 (0)191 438 3711
24 hour Emergency Telephone No.	+44 (0)191 469 6111
Official Advisory Body Telephone No.	+44 (0)870 600 6266 For Advice to Doctors & Hospitals only
Email	sds@internationalpaint.com

2. Hazard identification of the product

Flammable.
Harmful by inhalation and in contact with skin.
Risk of serious damage to eyes.
Irritating to skin.

Further information is given in section 11.

Safety Data Sheet

ENA303

INTERSHIELD 300 PART B

Version No. 19 **Date Last Revised** 18/07/08

3. Composition/information on ingredients

If the product contains substances that present a health hazard within the meaning of the Dangerous Substances Directive 67/548/EC, or have occupational exposure limits detailed in EH40, these substances are listed below.

Ingredient	EINECS	Concentration	Symbol(s)	Risk phrases (*)
Butan-1-ol	200-751-6	10 - < 25	Xn	R10,R22,R37/38,R41,R67
Ethylbenzene	202-849-4	2.5 - < 10	F,Xn	R11, R20
Ethylenediamine	203-468-6	0 - < 1	C	R10, R21/22, R34, R42/43
Xylene	215-535-7	25 - < 50	Xn	R10,R20/21,R38

* The full texts of the phrases are shown in section 16.

4. First aid measures

General

In all cases of doubt, or when symptoms persist, seek medical attention.

Never give anything by mouth to an unconscious person.

Inhalation

Remove to fresh air, keep patient warm and at rest. If breathing is irregular or stopped, give artificial respiration. If unconscious place in the recovery position and obtain immediate medical attention. Give nothing by mouth.

Eye Contact

Irrigate copiously with clean fresh water for at least 10 minutes, holding the eyelids apart and seek medical attention.

Skin Contact

Remove contaminated clothing. Wash skin thoroughly with soap and water or use a recognised skin cleanser. Do NOT use solvents or thinners.

Ingestion

If accidentally swallowed obtain immediate medical attention. Keep at rest. Do NOT induce vomiting.

5. Fire-fighting measures

Recommended extinguishing media; alcohol resistant foam, CO^2. powder, water spray.

Do not use; water jet.

Note; Fire will produce dense black smoke. Decomposition products may be hazardous to health. Avoid exposure and use breathing apparatus as appropriate.

Cool closed containers exposed to fire by spraying them with water. Do not allow run off water and contaminants from fire fighting to enter drains or water courses.

6. Accidental release measures

Remove sources of ignition, do not turn lights or unprotected electrical equipment on or off. In case of a major spill or spillage in a confined space evacuate the area and check that solvent vapour levels are below the Lower Explosive Limit before re-entering.
Ventilate the area and avoid breathing vapours. Take the personal protective measures listed in section 8.

Contain and absorb spillage with non-combustible materials e.g. sand, earth, vermiculite. Place in closed containers outside buildings and dispose of according to the Waste Regulations. (See section 13).

Clean, preferably with a detergent. Do not use solvents.

Do not allow spills to enter drains or watercourses.

If drains, sewers, streams or lakes are contaminated, inform the local water company immediately. In the case of contamination of rivers, streams or lakes the Environmental Protection Agency should also be informed.

7. Handling and storage

Handling

This coating contains solvents. Solvent vapours are heavier than air and may spread along floors. Vapours may form explosive mixtures with air. Areas of storage, preparation and application should be ventilated to prevent the creation of flammable or explosive concentrations of vapour in air and avoid vapour concentrations higher than the occupational exposure limits.

In Storage

Handle containers carefully to prevent damage and spillage.

Naked flames and smoking should not be permitted in storage areas. It is recommended that fork lift trucks and electrical equipment are protected to the appropriate standard.

In Use

Avoid skin and eye contact. Avoid inhalation of vapours and spray mists. Observe label precautions. Use personal protection as shown in section 8.

Smoking, eating and drinking should be prohibited in all preparation and application areas.

Never use pressure to empty a container; containers are not pressure vessels.

All sources of ignition (hot surfaces, sparks, open flames etc) should be excluded from areas of preparation and application. All electrical equipment (including torches) should be protected (Ex) to the appropriate standard.

The product may charge electrostatically. Always use earthing leads when pouring solvents and transferring product. Operators should wear clothing which does not generate static (at least 60% natural fibre) and antistatic footwear; floors should be of conducting type.

Activities such as sanding, burning off etc. of paint films may generate dust and/or fumes hazardous to the skin and lungs. Work in well ventilated areas. Use local exhaust ventilation and personal skin and respiratory protective equipment as appropriate.

Storage

Store in a well ventilated, dry place away from sources of heat and direct sunlight.

Store on concrete or other impervious floor, preferably with bunding to contain any spillage. Do not stack more than 3 pallets high.

Keep container tightly closed. Containers which are opened must be carefully resealed and kept upright to prevent leakage. Keep in the original container or one of the same material.

Prevent unauthorised access.

The requirements of the Highly Flammable Liquids and Liquified Petroleum Gases Regulations apply if the flashpoint is between 21°C and 32°C.

8. Exposure controls and personal protection

Engineering Measures

Provide adequate ventilation. Where reasonably practicable this should be achieved by the use of local exhaust ventilation and good general extraction. If these are not sufficient to maintain concentrations of particulates and any vapour below occupational exposure limits suitable respiratory protection must be worn.

Exposure Limits

The following workplace exposure limits have been established by the Health and Safety Executive as published in EH40.

Material	Short term (15 min. ave)		Long term (8hr TWA)		Comments
	ppm	mg/m³	ppm	mg/m³	
Butan-1-ol	50	154	-	-	+
Ethylbenzene	125	552	100	441	+
Xylene	100	441	50	220	+

For Key to entries in 'Comments' column see Section 16

Personal Protection

Respiratory Protection

If workers are exposed to concentrations above the exposure limit they must use the appropriate, certified respirators. When spraying this product use a respiratory mask with charcoal and dust filters (as filter combination A2-P2). In confined spaces use compressed air or fresh air respiratory equipment.

Eye Protection

Wear safety eyewear, e.g. safety spectacles, goggles or visors to protect against the splash of liquids. Eyewear should comply with British Standard 2092.

Hand Protection

Nitrile rubber gloves should be worn during mixing and application.

Skin Protection

Overalls which cover the body, arms and legs should be worn. Skin should not be exposed. Barrier creams may help to protect areas which are difficult to cover such as the face and neck. They should however not be applied once exposure has occurred. Petroleum jelly based types such as Vaseline should not be used. All parts of the body should be washed after contact.

9. Physical and chemical properties

Physical State	Liquid
Flash Point (deg C)	26
Viscosity (cSt)	246
Specific Gravity	0.935
Vapour Density	Heavier than air.
Lower Explosive Limit	1.1
Solubility in Water	Immiscible
R.A.Q. to ventilate to 10% of the LEL (m ³/l)	115

10. Stability and reactivity

Stable under recommended storage and handling conditions (see section 7). When exposed to high temperatures may produce hazardous decomposition products such as carbon monoxide, carbon dioxide, oxides of nitrogen and smoke.

Keep away from oxidising agents, strongly alkaline and strongly acid materials in order to avoid possible exothermic reactions.

11. Toxicological information

There are no data available on the preparation itself. The preparation has been assessed following the conventional method of the Dangerous Preparations Directive 1999/45/EC and classified for toxicological hazards accordingly. See Sections 2 and 15 for details.

Exposure to solvent vapour concentrations from the component solvents in excess of the stated occupational exposure limits may result in adverse health effects such as mucous membrane and respiratory system irritation and adverse effects on the kidneys, liver and central nervous system. Symptoms include headache, nausea, dizziness, fatigue, muscular weakness, drowsiness and in extreme cases, loss of consciousness.

Repeated or prolonged contact with the preparation may cause removal of natural fat from the skin resulting in dryness, irritation and possible non-allergic contact dermatitis. Solvents may also be absorbed through the skin. Splashes of liquid in the eyes may cause irritation and soreness with possible reversible damage.

Safety Data Sheet

ENA303

INTERSHIELD 300 PART B

Version No. 19 **Date Last Revised** 18/07/08

12. Ecological information

There are no data available on the product itself.

The product should not be allowed to enter drains or water courses.
The preparation has been assessed following the conventional method of the Dangerous Preparations Directive 1999/45/EC and is not classified as dangerous for the environment

13. Disposal considerations

Do not allow into drains or water courses. Wastes and emptied containers should be disposed of in accordance with regulations made under the Control of Pollution Act and the Environmental Protection Act.

Using information provided in this data sheet advice should be obtained from the Waste Regulation Authority, whether the special waste regulations apply.

The European Waste Catalogue Classification of this product, when disposed of as waste is 08 01 11 Waste paint and varnish containing organic solvents or other dangerous substances. If mixed with other wastes this code may no longer apply and the appropriate code should be assigned. For further information contact your local waste authority.

14. Transport information

Transport only in accordance with the following regulations:

ADR/RID	UN1263 Paint, 3, III		
IMDG	Class	3	Subsidiary Class
	Proper Shipping Name	PAINT	
	UN No	1263	
	Ems	F-E,S-E	
	Packaging Group	III	
	Marine Pollutant	No	
ICAO/IATA	Shipping Name	PAINT	
	Class	3	Subsidiary Class
	UN No	1263	
	Packaging Group	III	

15. Regulatory information

In accordance with EC Directive 88/379/EEC and the Chemicals (Hazard Information and Packaging for Supply) Regulations SI /3247/1994 this product is labelled as follows:

Symbol(s)
Harmful

Contains;
Xylene

R. Phrases;
Flammable.
Harmful by inhalation and in contact with skin.
Risk of serious damage to eyes.
Irritating to skin.

S. Phrases;
Do not breathe vapour/spray.
In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
Wear suitable protective clothing, gloves and eye/face protection.
Use only in well-ventilated areas.

P. Phrases;
Contains 1,2-diaminoethane. May produce an allergic reaction.

16. Other information

The information in this Health & Safety Data Sheet is required pursuant to Directive 91/155/EEC and the Chemicals (Hazard Information & Packaging for Supply) Regulations 1994.

Key to 'Comments' column in Section 8.
(+) There is a risk of absorption through unbroken skin.
(C) Capable of causing cancer and/or heritable genetic damage
(R) Suppliers recommended limit
(S) Capable of causing occupational asthma

The full text of the R phrases appearing in section 3 is:

R10 Flammable.

R11 Highly flammable.

R20 Harmful by inhalation.

R20/21 Harmful by inhalation and in contact with skin.

R21/22 Harmful in contact with skin and if swallowed.

R22 Harmful if swallowed.

R34 Causes burns.

R37/38 Irritating to respiratory system and skin.

R38 Irritating to skin.

R41 Risk of serious damage to eyes.

R42/43 May cause sensitisation by inhalation and skin contact.

R67 Vapours may cause drowsiness and dizziness

Primocon

Primers

Conventional Underwater Primer

PRODUCT DESCRIPTION

Tar-free, quick drying conventional primer for all substrates underwater. Also suitable as a barrier/sealer coat over incompatible or unknown antifoulings.
* Primocon prevents leaching of TBT from an underlying antifouling coating provided it is applied at a minimum dry film thickness of 80 microns (minimum 2 coats by roller) & that the film remains intact.

PRODUCT INFORMATION

Colour	YPA984-Grey
Finish	Matt
Specific Gravity	1.1
Volume Solids	33%
Typical Shelf Life	2 yrs
VOC (As Supplied)	584 g/lt
Unit Size	750 ml 2.5 Lt 5 Lt

DRYING/OVERCOATING INFORMATION

Drying

	5°C	15°C	23°C	35°C
Touch Dry [ISO]	1.5hrs	1hrs	1hrs	1hrs

Overcoating
Substrate Temperature

Overcoated By	5°C Min	5°C Max	15°C Min	15°C Max	23°C Min	23°C Max	35°C Min	35°C Max
B.F.A.	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Cruiser	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Cruiser	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Cruiser Eco/Cruiser Future	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Cruiser Premium	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Cruiser UNO	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
CT Kobberstoff	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Fabi	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Fabi Eco/Waterways Future	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Fabi Skeppsmask / CT Kobber	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Interspeed	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Interspeed Aqua	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Interspeed Ultra	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Lago Racing II	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Micron	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Micron 55	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Micron 66	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Micron Eco/Micron Future	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Micron Extra	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Micron Kopervrij	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Micron Optima	24hrs	1mths	16hrs	1mths	11hrs	1mths	8hrs	1mths
Micron WQ	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Navigator	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths

Primocon	3hrs	ext	3hrs	ext	3hrs	ext	3hrs	ext
Trilux	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Trilux (S)	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Trilux 33	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Uni-Pro	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
VC Offshore	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Veridian Tie Coat	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths
Waterways (Eire Only)	6hrs	1mths	3hrs	1mths	3hrs	1mths	3hrs	1mths

Note: If maximum overcoating time has been exceeded, sand using 80-180 grade (grit) paper. Drying times refer to brush and roller application.

APPLICATION AND USE

Preparation

Wash all surfaces except STEEL with Super Cleaner.
BARE GRP: Sand using 180-220 grade (grit) paper.
BARE WOOD: Sand with 80-180 grade paper. Intertox if required. Pre-prime with Primocon thinned 10-15% with Thinners No.3 (15-20% oily woods).
PLYWOOD:: Sand with 80-180 grade paper. Intertox if required. Pre-prime with Primocon thinned 10-15% with Thinners No.3.
ALUMINIUM: Mechanically abrade using aluminium compatible paper or low pressure grit blast using aluminium oxide. Pre-prime using Etch Primer.
ZINC/GALVANISED STEEL: Pre-prime using Etch Primer.
LEAD: Rub down with an emery cloth or power wire brush. Pre-prime using Etch Primer.
STEEL: Gritblast to Sa 2½ - near white metal surface. If gritblasting is not possible, grind the metal surface with 24-36 grit abrasive discs to a uniform, clean, bright metal surface with a 50-75 microns anchor pattern. Use angle grinder on small areas. Pre-prime with Primocon thinned 10-15% with Thinners No.3.
PREVIOUSLY ANTIFOULED SURFACE:
In Good Condition: Remove loose material. Wash down with fresh water. Allow to dry.
In Poor Condition: Remove using Interstrip.

Method

If filling is required, use appropriate filler after the first coat of Primocon has been applied. Before painting, remove any dust with a dust wipe. Apply the following number of coats: GRP - 1, Wood/Plywood - 3, Aluminium/Alloy/Zinc/Galvanised Steel/Lead/Steel - 5, Barrier/Sealer coat - 1.

Hints

Mixing Stir well before use.
Thinner YTA085 Thinners No.3 GTA007.
Cleaner YTA085 Thinners No.3
Airless Spray Pressure: 211 bar. Tip Size: 2180-2680.

Some Important Points

Do not use below 5°C. Do not overcoat with 2-component products. Ambient temperature should be minimum 5°C/41°F and maximum 35°C/95°F. Product temperature should be minimum 5°C/41°F and maximum 35°C/95°F. Substrate temperature should be 3°C/5°F above dew point and maximum 35°C/95°F. Under certain application conditions it may not be possible to achieve 40 microns dry film thickness in a single coat application. For application to GRP a single coat of Primocon is suitable providing that the dry film thickness is 20 microns or above. For other substrates further coats than that stated should be applied to ensure adequate film thickness is applied for protection of the substrate. Primocon prevents leaching of TBT from an underlying antifouling dry film thickness of 80 microns (minimum of 2 coats by roller). We have studied the leaching rate of TBT from a TBT SPC antifouling (Superyacht 900) overcoated with Primocon (applied as specified) & seen that TBT leaching is prevented. The leaching rate determination method used was ASTM D5108-90 (2002) Standard Test Method for Organotin Release Rates of Antifouling Coating Systems in Sea Water.

Compatibility/Substrates

Suitable for all substrates specified.

Number of Coats

1-5 by brush depending on substrate

Coverage

(Theoretical) - 8.33 (m^2/lt)

(Practical) - 7.40 (m^2/lt) by brush

Recommended DFT	40 microns dry
Recommended WFT	120 microns wet
Application Methods	Brush, Roller, Airless Spray

TRANSPORTATION,STORAGE AND SAFETY INFORMATION

Storage

GENERAL INFORMATION:
Exposure to air and extremes of temperature should be avoided. For the full shelf life of Primocon to be realised ensure that between use the container is firmly closed and the temperature is between 5°C/40°F and 35°C/95°F. Keep out of direct sunlight.
TRANSPORTATION:
Primocon should be kept in securely closed containers during transport and storage.

Safety

GENERAL: Read the label safety section for Health and Safety Information, also available from our Technical Help Line.

DISPOSAL: Do not discard tins or pour paint into water courses, use the facilities provided. It is best to allow paints to harden before disposal.
Remainders of Primocon cannot be disposed of through the municipal waste route or dumped without permit. Disposal of remainders must be arranged for in consultation with the authorities.

IMPORTANT NOTES

The information given in this sheet is not intended to be exhaustive. Any person using the product without first making further written enquiries as to the suitability of the product for the intended purpose does so at their own risk and we can accept no responsibility for the performance of the product or for any loss or damage (other than death or personal or injury resulting from negligence) arising out of such use. The information contained in this sheet is liable to modification from time to time in the light of experience and our policy of continuous product development.

AkzoNobel

Please refer to your local representative or visit www.yachtpaint.com for further information.

Ref: 05000029
Issue Date: 17-Aug-2008
Supersedes: 28-Jan-2008

Safety Data Sheet

YPA984

PRIMOCON

Version No. 11 **Date Last Revised** 31/08/05

1. Identification of the preparation and company

Preparation/Product Name	PRIMOCON
Product Code	YPA984
HSE Number	
Intended use	See Technical Data Sheet.
Application Method	See Technical Data Sheet.
Company Name	International Paint Stoneygate Lane Felling Gateshead Tyne and Wear NE10 OJY UK
Telephone No.	+44 (0)191 469 6111
Fax No.	+44 (0)191 438 3711
24 hour Emergency Telephone No.	+44 (0)191 469 6111
Official Advisory Body Telephone No.	+44 (0)870 600 6266 For Advice to Doctors & Hospitals only

2. Composition/information on ingredients

If the product contains substances that present a health hazard within the meaning of the Dangerous Substances Directive 67/548/EC, or have occupational exposure limits detailed in EH40, these substances are listed below.

Ingredient	EINECS	Concentration	Symbol(s)	Risk phrases (*)
1,2,4-trimethylbenzene	202-436-9	10 - < 25	Xn,N	R10,R20,R36/37/38,R51-53
1,3,5-trimethylbenzene	203-604-4	2.5 - < 10	Xi,N	R10, R37, R51-53
Naphtha (petroleum), hydrodesulfurized heavy	265-185-4	2.5 - < 10	Xn,N	R51-53, R65, R66
Solvent naphtha (petroleum), light aromatic	265-199-0	25 - < 50	Xn,N	R51-53, R65

* The full texts of the phrases are shown in section 16.

Safety Data Sheet

YPA984

PRIMOCON

Version No. 11 **Date Last Revised** 31/08/05

3. Hazard identification of the product

Flammable.

Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

Further information is given in section 11.

4. First aid measures

General

In all cases of doubt, or when symptoms persist, seek medical attention.

Never give anything by mouth to an unconscious person.

Inhalation

Remove to fresh air, keep patient warm and at rest. If breathing is irregular or stopped, give artificial respiration. If unconscious place in the recovery position and obtain immediate medical attention. Give nothing by mouth.

Eye Contact

Irrigate copiously with clean fresh water for at least 10 minutes, holding the eyelids apart and seek medical attention.

Skin Contact

Remove contaminated clothing. Wash skin thoroughly with soap and water or use a recognised skin cleanser. Do NOT use solvents or thinners.

Ingestion

If accidentally swallowed obtain immediate medical attention. Keep at rest. Do NOT induce vomiting.

5. Fire-fighting measures

Recommended extinguishing media; alcohol resistant foam, CO^2. powder, water spray.

Do not use; water jet.

Note; Fire will produce dense black smoke. Decomposition products may be hazardous to health. Avoid exposure and use breathing apparatus as appropriate.

Cool closed containers exposed to fire by spraying them with water. Do not allow run off water and contaminants from fire fighting to enter drains or water courses.

6. Accidental release measures

Remove sources of ignition, do not turn lights or unprotected electrical equipment on or off. In case of a major spill or spillage in a confined space evacuate the area and check that solvent vapour levels are below the Lower Explosive Limit before re-entering.

Ventilate the area and avoid breathing vapours. Take the personal protective measures listed in section 8.

Contain and absorb spillage with non-combustible materials e.g. sand, earth, vermiculite. Place in closed containers outside buildings and dispose of according to the Waste Regulations. (See section 13).

Clean, preferably with a detergent. Do not use solvents.

Do not allow spills to enter drains or watercourses.

If drains, sewers, streams or lakes are contaminated, inform the local water company immediately. In the case of contamination of rivers, streams or lakes the Environmental Protection Agency should also be informed.

7. Handling and storage

Handling

This coating contains solvents. Solvent vapours are heavier than air and may spread along floors. Vapours may form explosive mixtures with air. Areas of storage, preparation and application should be ventilated to prevent the creation of flammable or explosive concentrations of vapour in air and avoid vapour concentrations higher than the occupational exposure limits.

In Storage

Handle containers carefully to prevent damage and spillage.

Naked flames and smoking should not be permitted in storage areas. It is recommended that fork lift trucks and electrical equipment are protected to the appropriate standard.

In Use

Avoid skin and eye contact. Avoid inhalation of vapours and spray mists. Observe label precautions. Use personal protection as shown in section 8.

Smoking, eating and drinking should be prohibited in all preparation and application areas.

Never use pressure to empty a container; containers are not pressure vessels.

All sources of ignition (hot surfaces, sparks, open flames etc) should be excluded from areas of preparation and application. All electrical equipment (including torches) should be protected (Ex) to the appropriate standard.

The product may charge electrostatically. Always use earthing leads when pouring solvents and transferring product. Operators should wear clothing which does not generate static (at least 60% natural fibre) and antistatic footwear; floors should be of conducting type.

Storage

Store in a well ventilated, dry place away from sources of heat and direct sunlight.

Store on concrete or other impervious floor, preferably with bunding to contain any spillage. Do not stack more than 3 pallets high.

Keep container tightly closed. Containers which are opened must be carefully resealed and kept upright to prevent leakage. Keep in the original container or one of the same material.

Prevent unauthorised access.

8. Exposure controls and personal protection

Engineering Measures

Provide adequate ventilation. Where reasonably practicable this should be achieved by the use of local exhaust ventilation and good general extraction. If these are not sufficient to maintain concentrations of particulates and any vapour below occupational exposure limits suitable respiratory protection must be worn.

Exposure Limits

The following workplace exposure limits have been established by the Health and Safety Executive as published in EH40.

Material	Short term (15 min. ave)		Long term (8hr time weighted average)		
	ppm	mg/m^3	ppm	mg/m^3	
1,2,4-trimethylbenzene			25	125	
1,3,5-trimethylbenzene			25	125	
Naphtha (petroleum), hydrodesulfurized heavy				600	R

(C) Capable of causing cancer and/or heritable genetic damage
(R) Suppliers recommended limit
(S) Capable of causing occupational asthma
(+) There is a risk of absorption through unbroken skin.

Personal Protection

Respiratory Protection

If workers are exposed to concentrations above the exposure limit they must use the appropriate, certified respirators. When spraying this product use a respiratory mask with charcoal and dust filters (as filter combination A2-P2). In confined spaces use compressed air or fresh air respiratory equipment.

Eye Protection

Wear safety eyewear, e.g. safety spectacles, goggles or visors to protect against the splash of liquids. Eyewear should comply with British Standard 2092.

Hand Protection

Nitrile rubber gloves should be worn during mixing and application.

Skin Protection

Overalls which cover the body, arms and legs should be worn. Skin should not be exposed. Barrier creams may help to protect areas which are difficult to cover such as the face and neck. They should however not be applied once exposure has occurred. Petroleum jelly based types such as Vaseline should not be used. All parts of the body should be washed after contact.

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9. Physical and chemical properties

Physical State	Liquid
Flash Point (deg C)	33
Viscosity (cSt)	273
Specific Gravity	1.107
Vapour Density	Heavier than air.
Lower Explosive Limit	0.8
Solubility in Water	Immiscible
R.A.Q. to ventilate to 10% of the LEL (m^3/l)	119

10. Stability and reactivity

Stable under recommended storage and handling conditions (see section 7). When exposed to high temperatures may produce hazardous decomposition products such as carbon monoxide, carbon dioxide, oxides of nitrogen and smoke.

Keep away from oxidising agents, strongly alkaline and strongly acid materials in order to avoid possible exothermic reactions.

11. Toxicological information

There are no data available on the preparation itself. The preparation has been assessed following the conventional method of the Dangerous Preparations Directive 1999/45/EC and classified for toxicological hazards accordingly. See Sections 2 and 15 for details.

Exposure to solvent vapour concentrations from the component solvents in excess of the stated occupational exposure limits may result in adverse health effects such as mucous membrane and respiratory system irritation and adverse effects on the kidneys, liver and central nervous system. Symptoms include headache, nausea, dizziness, fatigue, muscular weakness, drowsiness and in extreme cases, loss of consciousness.

Repeated or prolonged contact with the preparation may cause removal of natural fat from the skin resulting in dryness, irritation and possible non-allergic contact dermatitis. Solvents may also be absorbed through the skin. Splashes of liquid in the eyes may cause irritation and soreness with possible reversible damage.

12. Ecological information

There are no data available on the product itself.

The product should not be allowed to enter drains or water courses.
The product contains the following substances classified as dangerous for the environment.
Petroleum naphtha: Toxic to aquatic organisms, may cause long term adverse effects in the aquatic environment
Not Defined

13. Disposal considerations

Do not allow into drains or water courses. Wastes and empty containers should be disposed of in accordance with regulations made under the Control of Pollution Act and the Environmental Protection Act.

Using information provided in this data sheet advice should be obtained from the Waste Regulation Authority, whether the special waste regulations apply.

European Waste Catalogue Number
08 01 11 Waste paint and varnish containing organic solvents or other dangerous substances

14. Transport information

Transport only in accordance with the following regulations:

ADR/RID	UN1263 Paint, 3, III		
IMDG	Class	3	Subsidiary Class
	Proper Shipping Name	PAINT	
	UN No	1263	
	Ems	F-E, S-E	
	Packaging Group	III	
	Marine Pollutant	Yes	
ICAO/IATA	Shipping Name	PAINT	
	Class	3	
	UN No	1263	
	Packaging Group	III	

15. Regulatory information

In accordance with EC Directive 88/379/EEC and the Chemicals (Hazard Information and Packaging for Supply) Regulations SI /3247/1994 this product is labelled as follows:

Symbol(s)

Dangerous for the environment

Contains;

R. Phrases;

Flammable.
Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

S. Phrases;

Keep out of the reach of children.
Handle and open container with care.
Do not breathe vapour/spray.
If swallowed, seek medical advice immediately and show this container or label.
Use only in well-ventilated areas.

P. Phrases;

16. Other information

The information on this MSDS is based upon the present state of our knowledge and on current EEC and national laws.

The product should not be used for purposes other than shown in the product data sheet without first obtaining written advice.

It is always the responsibility of the user to take all necessary steps to meet the demands of applicable legislation.

The information in this Health & Safety Data Sheet is required pursuant to Directive 91/155/EEC and the Chemicals (Hazard Information & Packaging for Supply) Regulations 1994.

The full text of the R phrases appearing in section 2 is:

R10 Flammable.

R20 Harmful by inhalation.

R36/37/38 Irritating to eyes, respiratory system and skin.

R37 Irritating to respiratory system.

R51-53 Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

R65 Harmful: May cause lung damage if swallowed.

R66 Repeated exposure may cause skin dryness or cracking

Trilux 33

Antifouling

High Performance Brightly Coloured Antifouling

PRODUCT DESCRIPTION

Reformulated to give improved protection and a brighter white, Trilux 33 is a high performance brightly coloured antifouling. Formulated with Biolux Technology®, the slow polishing formula helps avoid paint build up and gives effective fouling protection for up to 18 months. Suitable for all types of construction, including aluminium, Trilux 33 now has a lower VOC content that helps reduce environmental solvent emissions.

PRODUCT INFORMATION

Colour	YBA064-White, YBA065-Navy, YBA067-Black, YBA069-Red, YBA070-Green, YBA071-Blue
Finish	Matt
Specific Gravity	1.6
Volume Solids	55%
Typical Shelf Life	2 yrs
VOC (As Supplied)	390 g/lt
Unit Size	20 Lt , 5 Lt

DRYING/OVERCOATING INFORMATION

Drying

	5℃	15℃	23℃	35℃
Touch Dry [ISO]	2hrs	1.5hrs	1.5hrs	1hrs
Immersion	24hrs	24hrs	8hrs	6hrs

Note: Maximum Immersion Time is 1 month. If maximum immersion time is exceeded, high pressure water wash or wet abrade with 180-240 grade paper prior to immersion.

Overcoating
Substrate Temperature

	5℃		15℃		23℃		35℃	
Overcoated By	Min	Max	Min	Max	Min	Max	Min	Max
Trilux 33	24hrs	ext	16hrs	ext	6hrs	ext	4hrs	ext

APPLICATION AND USE

Preparation

MAJOR REFURBISHMENT: The first coat of Trilux 33 should always be applied over a recommended primer system. The primer surface should be dry and free of all contaminants (oil, grease, salt etc) and overcoated with Trilux 33 within the overcoating interval specified for the primer.

REPAIR and UPGRADING APPROVED SYSTEMS: Degrease the surface. Clean the entire area with controlled high pressure washing (3000 psi./211 bar). Repair corroded areas with the recommended anticorrosive primer system (Primocon).
PRIMING: All preparation for bare substrates is covered on the appropriate primer datasheet.
BARE GRP: Gelshield 200 for osmosis protection, or Primocon.
STEEL/IRON: Prime with Interprotect or Primocon.
LEAD: Etch Primer followed by Interprotect or Primocon.
WOOD: Preserve, if required, with Intertox. Prime with Interprotect or Primocon.
ALUMINIUM/ALLOY: Interprotect followed by Primocon.

Method

Ensure the area is clean and dry. Apply Trilux 33 within the overcoating intervals specified by the primer. Apply an extra stripe coat in areas of high wear such as chines, rudders, sterngear and any leading edges. Note: Maximum Time to Immersion is 1 month. If coating is left for more than 1 month, the surface should be high pressure fresh water washed or wet abraded using 180-240 grade paper prior to immersion.

Hints

Mixing Stir well before use.
Thinner Thinners No.3
Thinning Thinning is not recommended. Use in exceptional circumstances only. For example,

extremes of weather.
Cleaner Thinners No.3
Airless Spray Pressure: 176-210 bar. Tip Size: 2180. - For Professional use ONLY.
Other Take care to apply all the paint calculated even if it means applying an extra coat. It is important for performance to apply the correct thickness.

Some Important Points

If Trilux 33 is exposed for any period of time, e.g. over the winter, it must be high pressure fresh water washed before being immersed. Product temperature should be minimum 5℃/41℉ and maximum 35℃/95℉. Ambient temperature should be min imum 10℃/50℉ and maximum 35°C/95℉. Substrate temperature should be 3℃/5℉ abov e dew point and maximum 35℃/95℉.

Compatibility/Substrates

Suitable for use on all substrates including suitably primed Aluminium/Alloy and Zinc-sprayed metals. Can be applied direct over most types of antifoulings, provided they are in sound condition. Prime non-antifoulings with Primocon, Intertuf 203 or Interprotect. For further details on compatibility consult International Technical Representatives.

Number of Coats

2 by airless spray, 3 by roller.

Coverage

(Practical) - 4.60 (m^2/lt) by spray, 8.3 (m^2/lt) by roller.

Recommended DFT

90 microns dry by spray, 60 microns dry by roller.

Recommended WFT

164 microns wet by spray, 109 microns by roller.

Application Methods

Airless Spray, Brush, Roller . Spray application is recommended only for Professional Applicators that have all the proper safety equipment including a full-face shield.

TRANSPORTATION,STORAGE AND SAFETY INFORMATION

Storage

GENERAL INFORMATION:
Exposure to air and extremes of temperature should be avoided. For the full shelf life of Trilux 33 to be realised ensure that between use the container is firmly closed and the temperature is between 5℃/40℉ and 35℃/95℉. Keep out of direct s unlight.
TRANSPORTATION:
Trilux 33 should be kept in securely closed containers during transport and storage.

Safety

GENERAL: Contains biocides. Antifoulings should only be wet sanded. Never dry sand or burn-off old antifoulings. Read the label safety section for Health and Safety Information, also available from our Technical Help Line.

DISPOSAL: Do not discard tins or pour paint into water courses, use the facilities provided. It is best to allow paints to harden before disposal.
Remainders of Trilux 33 cannot be disposed of through the municipal waste route or dumped without permit. Disposal of remainders must be arranged for in consultation with the authorities.

IMPORTANT NOTES

The information given in this sheet is not intended to be exhaustive. Any person using the product without first making further written enquiries as to the suitability of the product for the intended purpose does so at their own risk and we can accept no responsibility for the performance of the product or for any loss or damage (other than death or personal or injury resulting from negligence) arising out of such use. The information contained in this sheet is liable to modification from time to time in the light of experience and our policy of continuous product development.

Please refer to your local representative or visit http://www.yachtpaint.com/ for further information.

Ref: 05000376
Issue Date: 5-Nov-2009
Supersedes: 20-Apr-2009

Safety Data Sheet

YBA062

TRILUX 33 PROFESSIONAL RED

Version No. 7 **Date Last Revised** 18/06/07

1. Identification of the preparation and company

Preparation/Product Name	TRILUX 33 PROFESSIONAL RED
Product Code	YBA062
HSE Number	7478
Intended use	Antifouling
	For professional use only.
Application Method	See Technical Data Sheet.
Company Name	International Paint Stoneygate Lane Felling Gateshead Tyne and Wear NE10 OJY UK
Telephone No.	+44 (0)191 469 6111
Fax No.	+44 (0)191 438 3711
24 hour Emergency Telephone No.	+44 (0)191 469 6111
Official Advisory Body Telephone No.	+44 (0)870 600 6266 For Advice to Doctors & Hospitals only
Email	sds@internationalpaint.com

2. Hazard identification of the product

Flammable.
Harmful by inhalation and in contact with skin.
Contact with acids liberates very toxic gas.
Irritating to skin.
May cause sensitisation by skin contact.
Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

Further information is given in section 11.

Safety Data Sheet

YBA062

TRILUX 33 PROFESSIONAL RED

Version No. 7 **Date Last Revised** 18/06/07

3. Composition/information on ingredients

If the product contains substances that present a health hazard within the meaning of the Dangerous Substances Directive 67/548/EC, or have occupational exposure limits detailed in EH40, these substances are listed below.

Ingredient	EINECS	Concentration	Symbol(s)	Risk phrases (*)
Cuprous thiocyanate	214-183-1	10 - < 25	Xn	R20/21/22, R32
Ethylbenzene	202-849-4	2.5 - < 10	F,Xn	R11, R20
Rosin	232-475-7	10 - < 25	Xi	R43
Triphenyl phosphate	204-112-2	1 - < 2.5	N	R50-53
Xylene	215-535-7	25 - < 50	Xn	R10,R20/21,R38
Zinc oxide	215-222-5	10 - < 25	N	R50-53
Zinc pyrithione	236-671-3	2.5 - < 10	T,N	R22, R23, R38, R41,R50

* The full texts of the phrases are shown in section 16.

4. First aid measures

General

In all cases of doubt, or when symptoms persist, seek medical attention.

Never give anything by mouth to an unconscious person.

Inhalation

Remove to fresh air, keep patient warm and at rest. If breathing is irregular or stopped, give artificial respiration. If unconscious place in the recovery position and obtain immediate medical attention. Give nothing by mouth.

Eye Contact

Irrigate copiously with clean fresh water for at least 10 minutes, holding the eyelids apart and seek medical attention.

Skin Contact

Remove contaminated clothing. Wash skin thoroughly with soap and water or use a recognised skin cleanser. Do NOT use solvents or thinners.

Ingestion

If accidentally swallowed obtain immediate medical attention. Keep at rest. Do NOT induce vomiting.

Safety Data Sheet

YBA062

TRILUX 33 PROFESSIONAL RED

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5. Fire-fighting measures

Recommended extinguishing media; alcohol resistant foam, CO^2. powder, water spray.

Do not use; water jet.

Note; Fire will produce dense black smoke. Decomposition products may be hazardous to health. Avoid exposure and use breathing apparatus as appropriate.

Cool closed containers exposed to fire by spraying them with water. Do not allow run off water and contaminants from fire fighting to enter drains or water courses.

6. Accidental release measures

Remove sources of ignition, do not turn lights or unprotected electrical equipment on or off. In case of a major spill or spillage in a confined space evacuate the area and check that solvent vapour levels are below the Lower Explosive Limit before re-entering.

Ventilate the area and avoid breathing vapours. Take the personal protective measures listed in section 8.

Contain and absorb spillage with non-combustible materials e.g. sand, earth, vermiculite. Place in closed containers outside buildings and dispose of according to the Waste Regulations. (See section 13).

Clean, preferably with a detergent. Do not use solvents.

Do not allow spills to enter drains or watercourses.

If drains, sewers, streams or lakes are contaminated, inform the local water company immediately. In the case of contamination of rivers, streams or lakes the Environmental Protection Agency should also be informed.

7. Handling and storage

Handling

This coating contains solvents. Solvent vapours are heavier than air and may spread along floors. Vapours may form explosive mixtures with air. Areas of storage, preparation and application should be ventilated to prevent the creation of flammable or explosive concentrations of vapour in air and avoid vapour concentrations higher than the occupational exposure limits.

In Storage

Handle containers carefully to prevent damage and spillage.

Naked flames and smoking should not be permitted in storage areas. It is recommended that fork lift trucks and electrical equipment are protected to the appropriate standard.

In Use

Avoid skin and eye contact. Avoid inhalation of vapours and spray mists. Observe label precautions. Use personal protection as shown in section 8.

Smoking, eating and drinking should be prohibited in all preparation and application areas.

Never use pressure to empty a container; containers are not pressure vessels.

All sources of ignition (hot surfaces, sparks, open flames etc) should be excluded from areas of preparation and application. All electrical equipment (including torches) should be protected (Ex) to the appropriate standard.

The product may charge electrostatically. Always use earthing leads when pouring solvents and transferring product. Operators should wear clothing which does not generate static (at least 60% natural fibre) and antistatic footwear; floors should be of conducting type.

Activities such as sanding, burning off etc. of paint films may generate dust and/or fumes hazardous to the skin and lungs. Work in well ventilated areas. Use local exhaust ventilation and personal skin and respiratory protective equipment as appropriate.

Storage

Store in a well ventilated, dry place away from sources of heat and direct sunlight.

Store on concrete or other impervious floor, preferably with bunding to contain any spillage. Do not stack more than 3 pallets high.

Keep container tightly closed. Containers which are opened must be carefully resealed and kept upright to prevent leakage. Keep in the original container or one of the same material.

Prevent unauthorised access.

The requirements of the Highly Flammable Liquids and Liquified Petroleum Gases Regulations apply if the flashpoint is between 21°C and 32°C.

8. Exposure controls and personal protection

Engineering Measures

Provide adequate ventilation. Where reasonably practicable this should be achieved by the use of local exhaust ventilation and good general extraction. If these are not sufficient to maintain concentrations of particulates and any vapour below occupational exposure limits suitable respiratory protection must be worn.

Exposure Limits

The following workplace exposure limits have been established by the Health and Safety Executive as published in EH40.

Material	Short term (15 min. ave)		Long term (8hr TWA)		Comments
	ppm	mg/m³	ppm	mg/m³	
Ethylbenzene	125	552	100	441	+
Xylene	100	441	50	220	+

For Key to entries in 'Comments' column see Section 16

Personal Protection

Respiratory Protection

If workers are exposed to concentrations above the exposure limit they must use the appropriate, certified respirators. When spraying this product use a respiratory mask with charcoal and dust filters (as filter combination A2-P2). In confined spaces use compressed air or fresh air respiratory equipment.

Eye Protection

Wear safety eyewear, e.g. safety spectacles, goggles or visors to protect against the splash of liquids. Eyewear should comply with British Standard 2092.

Hand Protection

Nitrile rubber gloves should be worn during mixing and application.

Skin Protection

Overalls which cover the body, arms and legs should be worn. Skin should not be exposed. Barrier creams may help to protect areas which are difficult to cover such as the face and neck. They should however not be applied once exposure has occurred. Petroleum jelly based types such as Vaseline should not be used. All parts of the body should be washed after contact.

9. Physical and chemical properties

Physical State	Liquid
Flash Point (deg C)	23
Viscosity (cSt)	144
Specific Gravity	1.286
Vapour Density	Heavier than air.
Lower Explosive Limit	1.1
Solubility in Water	Immiscible
R.A.Q. to ventilate to 10% of the LEL (m ³/l)	111

10. Stability and reactivity

Stable under recommended storage and handling conditions (see section 7). When exposed to high temperatures may produce hazardous decomposition products such as carbon monoxide, carbon dioxide, oxides of nitrogen and smoke.

Keep away from oxidising agents, strongly alkaline and strongly acid materials in order to avoid possible exothermic reactions.

11. Toxicological information

There are no data available on the preparation itself. The preparation has been assessed following the conventional method of the Dangerous Preparations Directive 1999/45/EC and classified for toxicological hazards accordingly. See Sections 2 and 15 for details.

Exposure to solvent vapour concentrations from the component solvents in excess of the stated occupational exposure limits may result in adverse health effects such as mucous membrane and respiratory system irritation and adverse effects on the kidneys, liver and central nervous system. Symptoms include headache, nausea, dizziness, fatigue, muscular weakness, drowsiness and in extreme cases, loss of consciousness.

Repeated or prolonged contact with the preparation may cause removal of natural fat from the skin resulting in dryness, irritation and possible non-allergic contact dermatitis. Solvents may also be absorbed through the skin. Splashes of liquid in the eyes may cause irritation and soreness with possible reversible damage.

Safety Data Sheet

YBA062

TRILUX 33 PROFESSIONAL RED

Version No. 7 **Date Last Revised** 18/06/07

12. Ecological information

There are no data available on the product itself.

The product should not be allowed to enter drains or water courses.

The preparation has been assessed following the conventional method of the Dangerous Preparations Directive 1999/45/EC and is classified for eco-toxicological properties accordingly. See Sections 2 and 15 for details

Triphenyl phosphate (EINECS 204-112-2)

Ecotoxicity:
LC50 96 hours fish (Rainbow trout) 0.36 mg/l
LC50 48 hours Daphnia Magna 1.0 mg/l

Bioaccumulation:
Triphenyl phosphate exhibits low aqueous solubility and a moderate potential for bioconcentration.

Degradation:
Readily biodegradable.

Zinc oxide (EINECS 215-222-5)

Ecotoxicity

Toxicity to fish
Oncorhynchus mykiss LC50 96 hours 1 mg/l
Toxicity to daphnia
Daphnia magna EC50 48 hours 10-50 mg/l
Toxicity to algae
Desmodesmus subspicatus EC50 72 hours 10-20 mg/l

Zinc pyrithione (EINECS 236-671-3)

Ecotoxicity

Toxicity to fish
Bluegill sunfish LC50 96 hours 0.01 mg/l
Rainbow trout LC50 96 hours -3 mg/l

13. Disposal considerations

Do not allow into drains or water courses. Wastes and emptied containers should be disposed of in accordance with regulations made under the Control of Pollution Act and the Environmental Protection Act.

Using information provided in this data sheet advice should be obtained from the Waste Regulation Authority, whether the special waste regulations apply.

The European Waste Catalogue Classification of this product, when disposed of as waste is 08 01 11 Waste paint and varnish containing organic solvents or other dangerous substances. If mixed with other wastes this code may no longer apply and the appropriate code should be assigned. For further information contact your local waste authority.

14. Transport information

Transport only in accordance with the following regulations:

ADR/RID UN1263 Paint, 3, III

IMDG	Class	3	Subsidiary Class
	Proper Shipping Name	PAINT	
	UN No	1263	

	Ems	F-E,S-E
	Packaging Group	III
	Marine Pollutant	Yes
ICAO/IATA	Shipping Name	PAINT
	Class	3
	UN No	1263
	Packaging Group	III

Safety Data Sheet

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TRILUX 33 PROFESSIONAL RED

Version No. 7 **Date Last Revised** 18/06/07

15. Regulatory information

In accordance with EC Directive 88/379/EEC and the Chemicals (Hazard Information and Packaging for Supply) Regulations SI /3247/1994 this product is labelled as follows:

Symbol(s)

Harmful

Dangerous for the environment

Contains;

Rosin

Xylene

Zinc pyrithione

R. Phrases;

Flammable.

Harmful by inhalation and in contact with skin.

Contact with acids liberates very toxic gas.

Irritating to skin.

May cause sensitisation by skin contact.

Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

S. Phrases;

Do not breathe vapour/spray.

Wear suitable protective clothing and gloves.

Use only in well-ventilated areas.

P. Phrases;

DO NOT BREATHE SPRAY MIST. WEAR SUITABLE PROTECTIVE CLOTHING (COVERALLS OF A CONTRASTING COLOUR TO THE PRODUCT BEING APPLIED, UNDERNEATH A DISPOSABLE COVERALL WITH HOOD), SUITABLE GLOVES, AND IMPERVIOUS FOOTWEAR THAT PROTECTS THE LOWER LEG. WEAR SUITABLE RESPIRATORY EQUIPMENT such as air-fed respiratory protective equipment with combined protective helmet and visor when spraying. UNPROTECTED PERSONS SHOULD BE KEPT OUT OF TREATMENT AREAS. WEAR SUITABLE RESPIRATORY EQUIPMENT such as FFP3 (or an equivalent standard) when working in the vicinity of the spray plume. DISPOSE OF PROTECTIVE GLOVES after use

16. Other information

IMO Antifouling Convention (AFS/CONF/26) Compliant

Active Ingredients - Cuprous Thiocyanate CAS No. 1111-67-7, Zinc Pyrithione CAS No. 13463-41-7

The information on this MSDS is based upon the present state of our knowledge and on current EEC and national laws.

The product should not be used for purposes other than shown in the product data sheet without first obtaining written advice.

It is always the responsibility of the user to take all necessary steps to meet the demands of applicable legislation.

The information in this Health & Safety Data Sheet is required pursuant to Directive 91/155/EEC and the Chemicals (Hazard Information & Packaging for Supply) Regulations 1994.

Key to 'Comments' column in Section 8.
(+) There is a risk of absorption through unbroken skin.
(C) Capable of causing cancer and/or heritable genetic damage
(R) Suppliers recommended limit
(S) Capable of causing occupational asthma

The full text of the R phrases appearing in section 3 is:

R10 Flammable.

R11 Highly flammable.

R20 Harmful by inhalation.

R20/21 Harmful by inhalation and in contact with skin.

R20/21/22 Harmful by inhalation, in contact with skin and if swallowed.

R22 Harmful if swallowed.

R23 Toxic by inhalation.

R32 Contact with acids liberates very toxic gas.

R38 Irritating to skin.

R41 Risk of serious damage to eyes.

R43 May cause sensitisation by skin contact.

R50 Very toxic to aquatic organisms.

R50-53 Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.