Appendix 1: Cypress Island Net Pen Failure Engineering Review
(December 29, 2017)

Cypress Island
Net Pen Failure Engineering Review

December 29, 2017

Washington Department of Fish and Wildlife (DFW)

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Issue and revision record

Revision	Date	Originator	Checker	Approver	Description
1A	2017/12/12	JJ	NS	SP	Draft
1B	2017/12/29	JJ	NS	SP	FINAL

Document reference: 385629 | 1 | B

Information class: Standard

Certifications

This report has been prepared by Mott MacDonald under the supervision of a Professional Engineer.

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Appendix A A

Acronyms and Abbreviations

ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
BAP	Best Aquaculture Practices
ECY	Washington State Department of Ecology
FRP	Fiberglass Reinforced Plastic Grating
MLLW	Mean Lower Low Water
MHHW	Mean Higher High Water
NOAA	National Oceanographic and Atmospheric Administration
OHW	Ordinary High Water
DFW	Washington State Department of Fish and Wildlife
DNR	Washington State Department of Natural Resources

Executive Summary

Under contract with the State of Washington Department of Fish and Wildlife (DFW), Mott MacDonald reviewed information gathered following the collapse of Net Pen #2 on August 19, 2017. Net Pen #2 is owned by Cooke Aquaculture Pacific, LLC (Cooke) and is located near Cypress Island, Washington. The purpose of the work was to determine the physical cause(s) that led to the failure of the net pen structure.

The key issues considered in the review were:

- Environmental Conditions at the site;
- Mooring Analysis & System Design;
- Condition of the facility, based on salvaged components;
- Documentation including responses from Cooke, personnel Interviews, inspection and maintenance logs, and literature in the public domain.

Information provided by Cooke, until December 19, 2017, was relied upon to develop this report. However, all of the information that was reviewed has not been independently verified as of the writing of this report.

No structural analysis or mooring analysis of the net pen structure was undertaken as part of this work.

The facility near Cypress Island was first built in 1985. New net pens were installed in 2001 and these were retained through 2017. The net pens were re-positioned in 2011; they were rotated and moved to deeper water. Cooke took ownership of the facility in May 2016 and submitted a permit application in February 2017 to replace and reorient Net Pen #2.

In July 2017, there was an incident where ten anchor points on the north side of Net Pen #2 broke and anchors had dragged, causing Net Pen #2 to shift considerably. There were significant deformations on the structure resulting from this incident. Net Pen #2 was stabilized with tug assistance. Following this incident, all the broken pad eyes on the net pen and all the mooring lines to the anchors were replaced. Repairs were conducted to the net pen structure, including welding steel members to deformed float structures. An exoskeleton system of chains was installed over the floats as part of the repairs. There is no documentation of engineering analysis or design for the repairs conducted following the July 2017 incident.

On August 19, 2017, an eyewitness observed that Net Pen #2 had suffered damage on the east end (the short edge along pens 215 and 225). Cooke personnel confirmed that the first failure occurred on the east end of Net Pen #2. Following this, according to Cooke, the mooring system along the north edge (the long edge along pens 221 to 225) failed at several points. Despite efforts to stabilize the net pen over several days, the site was ultimately declared a total loss.

A review of the environmental conditions on site revealed that the summer of 2017 did not contain any large wind events. The typical wave climate in the area is unlikely to be a major contributing factor to hydrodynamic forces at the time of failure. Daily maximum flood currents on August 19 were higher than normal, but were less than the daily maximum currents measured in July. Vessel wakes were likely not a major contributor to hydrodynamic forcing affecting either the July or August incidents. Marine fouling was present and was reported to be higher than typical. The fouling observed on the salvaged nets was significantly higher than what was considered in the mooring assessment calculations reviewed. The depth of the stock nets at Net Pen #2 were larger and the openings in them were smaller than what was recommended by the manufacturer. These factors would result in a greater probability of biofouling of the nets. Therefore, Net Pen #2 was likely subject to forces larger than what was determined through analysis. Due to large currents, the forces and corresponding movements of nets may have been very high due to the higher than normal amount of fouling.

A review of the daily log reports provided by Cooke showed that the record keeping was very inconsistent. The logs show that the net pen progressively required repairs as it aged. However, there is no clear documentation of repairs and maintenance conducted on the net pen.

Upon reviewing the mooring system for Net Pen #2, the mooring arrangement on site was different from what was recommended from a mooring analysis conducted in 2015. There were fewer mooring lines than recommended. The mooring lines were arranged unevenly around the structure and did not have uniform tension in them. The connections of the mooring lines to the structure did not have the configuration recommended in the mooring analysis.

Tug operations to stabilize and reset the net pen facility following the July incident possibly exerted very high concentrated forces on the net pen structure. There is no documented procedure for the tug operations to ensure that no damage was done to the net pen structure.

Based on site visits conducted to observe salvaged components from the net pen structure, several components showed severe corrosion. It is evident that the net pen structure was not adequately protected or maintained against corrosion.

Based on the review of all the information available, the failure of the net pen likely occurred due to a combination of factors including:

- High forces imparted on the structure due to severe biofouling of the nets;
- Corrosion in the net pen structure components resulting in a reduced capacity:
- Uneven forces in the structure due to an uneven mooring arrangement different from what was recommended and which had previously resulted in anchors dragging and pad eyes breaking;
- Reduced capacity of the structural components that were likely modified without an engineering assessment (for e.g. the bent outrigger frames with new steel members welded to them, and the exoskeleton system of chains) or those which were not repaired (for e.g. hinges connecting the floats), following the July 2017 incident;
- Atypical loads imparted to the structure from the exoskeleton of chains that were installed following the July 2017 incident.

1 Introduction

This report presents the information gathered following the collapse of Net Pen #2, owned by Cooke Aquaculture Pacific, LLC (Cooke) located near Cypress Island on August 19, 2017, and the findings from review of that information. This work has been performed by Mott MacDonald under contract with the State of Washington Department of Fish and Wildlife (DFW), for use by DFW, Department of Natural Resources (DNR), and Department of Ecology (ECY).

1.1 Purpose and Scope

The purpose of the work is to determine the physical cause(s) that led to the failure of the net pen. As part of this work, the following tasks were performed:

1. Review of documents obtained from multiple sources, including eyewitness accounts from the public.
2. Review of information pertaining to the facility, obtained from various agencies including DFW, DNR, and ECY.
3. Review of the responses from Cooke to the Administrative Order Docket # 15422.
4. A metocean review of the climatic and hydrodynamic conditions on site.
5. Site visits conducted to observe the salvaged components of the failed facility.
6. Review of information obtained from the site visits.

Following the information gathering and review process, Mott MacDonald summarized the key findings to help the Incident Review Panel (IRP) assess and narrow down the potential causes that led to the failure of the facility in August 2017.

Key issues considered were:

- Environmental Conditions – Winds, Waves, Currents, Tides, Vessel Wakes.
- Mooring Analysis & System Design – Site & Framing/Cage System Specific, dynamic response, flexibility and motion, extreme conditions analysis.
- Documentation – Information obtained from the IRP by means of responses from Cooke, Personnel Interviews, Inspection and Maintenance Logs, Literature in the public domain, etc.

Figure 1.1 is an aerial photo showing the layout of the site prior to the failure of Net Pen #2.

Figure 1.1 – Site layout ***(Source – Google Earth)***

2 Document Review

The main documents reviewed by Mott MacDonald are described in Table 2.1. The key points (Keys) from each document are listed in the Comments column of the table.

Although requested, very limited design documents, drawings, or calculations for the net pen structure were made available until the time of writing this report. The following is a list of data/information that, if provided by Cooke, would have provided benefit to the assessment:

- Original design documents (including shop drawings, calculations, anchor installation requirements, etc.).
- Design documents and calculations for repairs conducted by Cooke in July 2017: Consequently, no structural analysis of the system was performed.
- Detailed documentation of the mooring configuration installed after the July 2017 incident.
- Measured currents at the facility: Exact current velocity and direction could not be determined. Currents measured nearby were relied upon to evaluate daily tidal flux.

Note: Information provided by Cooke, until December 19, 2017, was relied upon to develop this report. However, all of the information which was reviewed has not been independently verified as of the writing of this report.

Table 2.1: Document Review – Summary

No.	Description	Comments
1	Relocate Site 1 and 2 Shoreline Permit Mod Hearing Examiner Approval Nov 2009.pdf	Site located in locations with more current (relative to pre-2009 location). Repositioned pens were reinforced earlier with heavier steel that is stronger than original installation. The repositioned pens will be moored to a new mooring system. Keys: New mooring system for new location.
2	Site 2 Shift of footprint JARPA 2009.pdf	No changes will be made to the physical structure. Benthic environment varies. Silt, sand, and clay on southwest corner. Large rock, cobble, sand, and shell clutter on the northeast side. Water depth varies from 45 feet to 70 feet. Keys: Substrate material varies.
3	2009 JARPA Application for Reorientation of Deepwater Bay Fish Pen Facility (Site 2)	This contains the application materials and site plans submitted by American Gold Seafoods to move the net pen #2 into deeper waters away from the shore. Mooring line length varies. Keys: Moving net pen to deeper water.

No.	Description	Comments
4	2011 JARPA Application drawings	This contains the drawings submitted in February 2011 as part of the JARPA application for a new facility that would have been installed at the location of net pen facility #2. Keys: Location of net pen.
5	2017 JARPA. Cooke JARPA Feb2_2017_Site 2_ pen replacement project.pdf	The Deepwater Bay area has a strong tidal gyre which forms a deep-water channel running parallel to the shorelines of Deepwater Bay. The benthic environment underneath and adjacent to the net pens varies from cobble and coarse sand, to silt and shell clutter. The current condition of the existing net pen structure can be described as “used and nearing the end of serviceable life.” The existing steel net pen structure has been in service for approximately 16 years in the marine environment and is due for complete replacement. Corrosion on the metal walkway grating and substructures is beginning to accelerate. Repairing the rusted steel walkways and replacing fatigued metal components of the existing cage system structure in place is not cost effective or practical. Keys: Complex hydrodynamics, variable substrate including cobble, facility is 16 years old, corrosion present, fatigued structure noted.
6	Re-anchoring plan for anchors following anchor failure in July 2017. (Site 2 layout.pdf)	This shows the plan of the net pen facility #2 with the positions and the description of the anchors, following the events in July 2017. Keys: Anchor sizes, number/type of mooring lines on site in 2017.
7	System Farm W24 – 3,16 – Large Steel Cage System Manual as prepared by Marine Construction, Norway. (1999). (Marine Construction Cage Manual0001.pdf)	This document gives the technical data, description of the cage system, and instruction regarding assembly, installation, maintenance, transportation, and handling. This is a design manual for a steel cage system. Indicates single point fastening is not desirable. Outriggers should use 2 adjusting chain connections for each line/buoy. All moorings must be kept evenly tight over time to ensure correct and even load to the section structure. Very tight ropes/wires running lengthwise-overlapping hinges can damage poles/sockets or wires/ropes in bad weather conditions. Keys: Moorings should be kept evenly tight. Specific mooring connection recommendations.

No.	Description	Comments
8	2015 Letter to American Gold Seafoods from Marine Constructions AS. 20150310161238332.pdf	Indicates lifetime of structures (approximately 20 years if loads are moderate. Repetitive peak loads over time lead to fatigue and material failure/cracks will occur. Places to expect material fatigue is on outriggers and catamaran connections and internal members. All is subject to good corrosion protection. Assumed current is 0.5m/s (0.97 knots). System is designed for net depth of 10m (33 ft.) and mesh size of 50 mm (2in). Keys: 20-year life subject to good corrosion protection and moderate loads. Repetitive peak loads lead to fatigue. Design parameters of the nets (depth and mesh size) are different from what was on site. Nets on site had a larger depth and smaller mesh size.
9	Mooring Report for the facility prepared by Aqua Knowledge (Morenot), Norway, in April 2015, for Icicle Seafoods Inc. (Mooring report_Steel cages_Cypress Island_Site 2_April_2015.pdf)	The document describes the mooring analysis performed for the net pen facility #2 at Cypress Island. The mooring arrangement in the analysis differs from what was observed on site. Report includes mooring arrangement, forces, and assumptions. Keys: Mooring arrangement in analysis differs from on-site conditions.
10	Excel-based mooring analysis. Icicle Seafoods Deep Harbor.pdf	Mooring calculations for each 24m x 24m cage. Calculations show result from Excel sheet. Indicate rope safety margin of less than 1.0. Anchor capacity is function of anchor weight. Keys: Factor of safety is low. 25% marine fouling is assumed in the calculations.
11	Daily Inspection logs for the facility	Daily inspection logs for the facility from October 2014 to July 24, 2017. Keys: Inspection records.
12	Several photos and a video taken by Jim Davenport on 2017, August 19.	This shows the net pen facility #2 in the afternoon of August 19, 2017. Keys: Photos and timing of August incident.
13	2017 Cooke Aquaculture Pacific, LLC Fish Escape Prevention Plan Updated January 2017, 9 pages	Plan includes new technologies and materials being implemented, routine procedures and best management practices to minimize stock escape and fish escape reporting and response plan.

No.	Description	Comments
14	Norwegian Standard NS 9415.E:2009 -- Marine fish farms Requirements for site survey, risk analyses, design, dimensioning, production, installation, and operation	The standard includes site survey requirements, load and load combinations, general requirements for the main components of a marine fish farm, requirements regarding net pens, floating collars, rafts, and mooring. Keys: Site-specific mooring analysis is required.
15	Recommended Interim Guidelines for the Management of Salmon Net-Pen Culture in Puget Sound – Dec. 1986	These interim guidelines prepared for the Washington Department of Ecology are intended to provide a coordinated agency approach to management of salmon net-pens in the Puget Sound. The guidelines are for interim use until a programmatic EIS can be completed and focus on environmental protection. Guidelines include water quality, site selection, and environmental surveys.
16	Site bathymetry. PreliminaryNetPenSurveyAreas2.pdf	Approximate depths at net pen location. Depths vary across the site by ~ 10meters. Keys: Water depth at site varies.
17	NPDES Sampling Report 2002. Cypress Island Inc. Net Pens. (2002_Cypress_Sites 1to4_final_NPDES report.pdf)	Current speeds measured at Site 1, one Sept 21, 1994. Maximum current measured: 0.88 knots. Substrate materials. Keys: No currents at Site 2 were reported. Substrate material varies.
18	Current measurement stations Cypress0001.pdf	Locations of measured currents at Cypress Island net pens. Data has not been provided. Keys: Appears that currents were measured at net pen #2, but were not provided.
19	Response from Cooke Aquaculture Pacific, LLC to Administrative Order Docket # 15422 issued by the Department of Ecology.	This document contains the responses from Cooke Aquaculture to the Administrative Order issued by the Department of Ecology. Keys: Failure timeline for July and August incidents.
20	Interviews with Cooke Staff – Sky Guthrie	July 2017 incident: Anchors on north side and west failed, both mooring points and dragged anchors. Net pen facility held in place using a bridle for several (4-5) days by Millennium Star tug. Anchor reset was attempted during ebb tide. Change in mooring arrangement. August 2017 incident: Anchors on north side failed. Marine fouling: Two out of three cleaning units not in operation. Fouling on a scale of 8/10 after July.

No.	Description	Comments
21	Interviews with Cooke Staff – Tom Glaspie	July 2017 Incident: Lines didn't snap. mooring brackets yielded. Canada suggestions: "Exoskeleton grid". Would result in change to mooring arrangement.
22	Interviews with Cooke Staff – Chris Nelson	July 2017 Incident: "Strongest tides ever seen". Could mean that strongest forces rather than tidal currents if high fouling was present, causing nets to shift at an angle.
23	Interviews with Harley Marine – Luke Olson	July 2017 incident: Walkways buckled at hinges. When Millennium Star was at east end deck was pulling under water.
24	Interviews with Harley Marine – Stefan Pierie Thompson	July 2017 incident: Photos and video on phone (not yet made available). Net pen employees trying to re-set anchors.
25	Interviews with Cooke Staff – Kyle Wood	August 2017 incident: East end anchor points had come apart; the system was sliding under chains; the facility had moving approximately 500 ft. South in big sweeps.
26	Interviews with Cooke Staff – Innes Weir	July 2017 incident: The failure point in July was the pad eyes; broken pad eyes were replaced and second pad eyes were installed for each anchor so the anchor chains would be attached to 2 pad eyes rather than 1; chains were installed between the anchor lines; aanchors which were replaced initially failed during the stabilization process; chains across the walkways were installed on advice from Canada staff.
27	Interviews with Cooke Staff – Eric Brown	July 2017 incident: The anchor system was completely reset. Replaced approximately 12 anchor lines and moved several more. Cause of the incident was assumed to be anchor drag and broken pad eyes. August 2017 incident: Lines on the Northeast side broke. Lines on the slack side were tensioned by lifting anchors and dropping them. Site 2 had ongoing issues with cracks in the walkways. Square bar stock (structural steel tubing) was welded to the end cap (assume that this refers to outrigger floats) because it tried to curl under during both ebb and flood tides. The July and August incidents, both, occurred during flood tides.

3 Description of the Facility

The Cypress Island fish farm consisted of three net pens. Each net pen was made up of a moored floating structure relying upon forces imposed on the walkway floats and net systems to be resisted by a series of mooring chains and anchors. The following is a summary of the key components of the net pen #2:

3.1 Anchors

The mooring plans show that the anchors at the net pen included Danforth and Delta type drag anchors. However, salvaged components included Danforth, Delta, and Eells type anchors. These held the net pens to the seabed. The anchors are connected to the mooring lines by shackles.

In addition to the anchors in the water, the facility was attached to the shore with three connections. One connection extended from a point labeled as “Big Rock” on shore to the Northwest corner of the net pen facility. The details of this connection are not available. The line from this “Big Rock” to the connection on the net pen facility consists of a 2” studlink chain, a 1 5/8” 12 strand nylon line, and a 1 ½” surface stud link chain.

The other two connections extend from “Shore Pins” on shore to the southwest corner of the net pen facility. The details of these connections are also not available. The lines from the “Shore Pins” to the connections on the net pen facility consist of a ½” studlink chain, a 2” 8 braid nylon line, and a 1 ½” surface stud link chain. Although indicated on the plan, buoys are not listed in the description of the mooring lines.

The nylon lines are referred to as “poly” in the mooring plan for the facility.

3.2 Mooring Lines & Hardware

The mooring lines are composed of a combination of stud link anchor chain ranging in size from 1 ½” to 2”, mid line nylon rope made up of either 2” 8-braid nylon to 2 5/8” 12-braid nylon, and a surface stud link chain 1 ½” in size. The components of the mooring line are connected to each other using shackles.

A mooring layout plan from 2010 shows 22 mooring lines. However, the latest mooring plan from 2017 shows only 19 mooring lines.

3.3 Buoys and Mooring Line to Float Connections

The mooring lines connect to buoys which are approximately 5 ft. in diameter, as shown in Figure 3.1. The connection between the buoys and the walkway floats is made up of either nylon rope or stud link chain. The connection point on the floats, referred to as mooring brackets, consist of one or two pad eyes attached to a single hinge on the floats.

3.4 Predator Exclusion Nets

The predator exclusion net system makes up the outer nets, around the stock nets. The nets are made of nylon with an opening size of approximately “5in. stretch”. At the top, the predator exclusion nets are connected to the walkway floats on the outside rails. On the bottom of the nets there are steel pipes that hold them in place and prevent them from deflecting too much due to water currents. The predator exclusion nets have a “floor” that spans across the bottom of the entire net pen. These nets completely surround the inner stock nets, which contain the farmed salmon, and protect the fish from predators in the water.

3.5 Stock Nets

The stock nets form the inner nets and contain the farmed salmon. These nets are also made of nylon with an approximate opening size of "20mm stretch". The mesh size of these nets is smaller than that recommended (50mm) by the manufacturer in document # 8 in the document review summary Table 2.1. The stock nets are 79ft. wide by 45ft. deep, with a "floor" that spans across the entire bottom of each individual cage. The depth of the nets (45ft.) is greater than what was recommended (33ft.) by the manufacturer in document # 8 in the document review summary Table 2.1. At the top, these nets are attached to the walkway floats on the inner rails. There is no weight at the bottom of these nets. However, the stock nets are attached to the pipes weighing down the predator exclusion nets.

3.6 Walkway Floats

The walkway floats are composed of steel frames supported on plastic flotation tubs. The steel framing supports a grated walking surface. The floats are connected to each other by hinged connections at their ends.

The following four types of floats make up the net pen facility, and are shown in Figure 3.2:

1. Main Bridge Floats: These floats form the central walkway of the facility in the longitudinal direction and are approximately 10ft. wide. They span between the Catamaran Floats.
2. Catamaran Floats: These floats are installed at the ends of the main bridge floats along the inner edges of the net pen cells in the short axis.
3. Intermediate Floats: These floats extend beyond the catamaran floats to the Outrigger Floats. They also form the outer edges of the net pen cells in the long axis.
4. Outrigger Floats: These are the primary floats connecting to the mooring lines. They are located at the corners of each of the net pen cells.

The catamaran floats, intermediate floats, and outrigger floats are all approximately 7 ft. wide.

The floats are connected to each other by hinged connections. Typically, there are two hinges between connected floats.

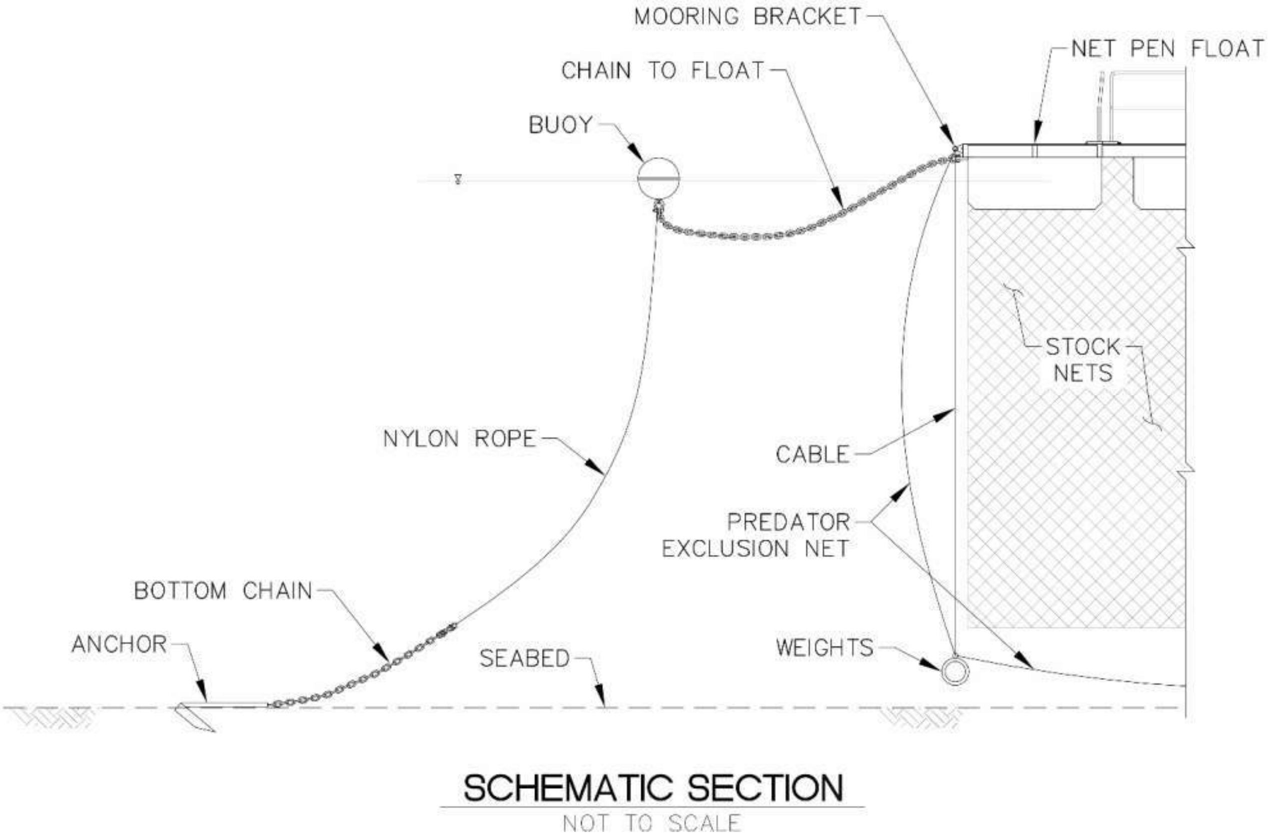

Figure 3.1 – Schematic cross-section

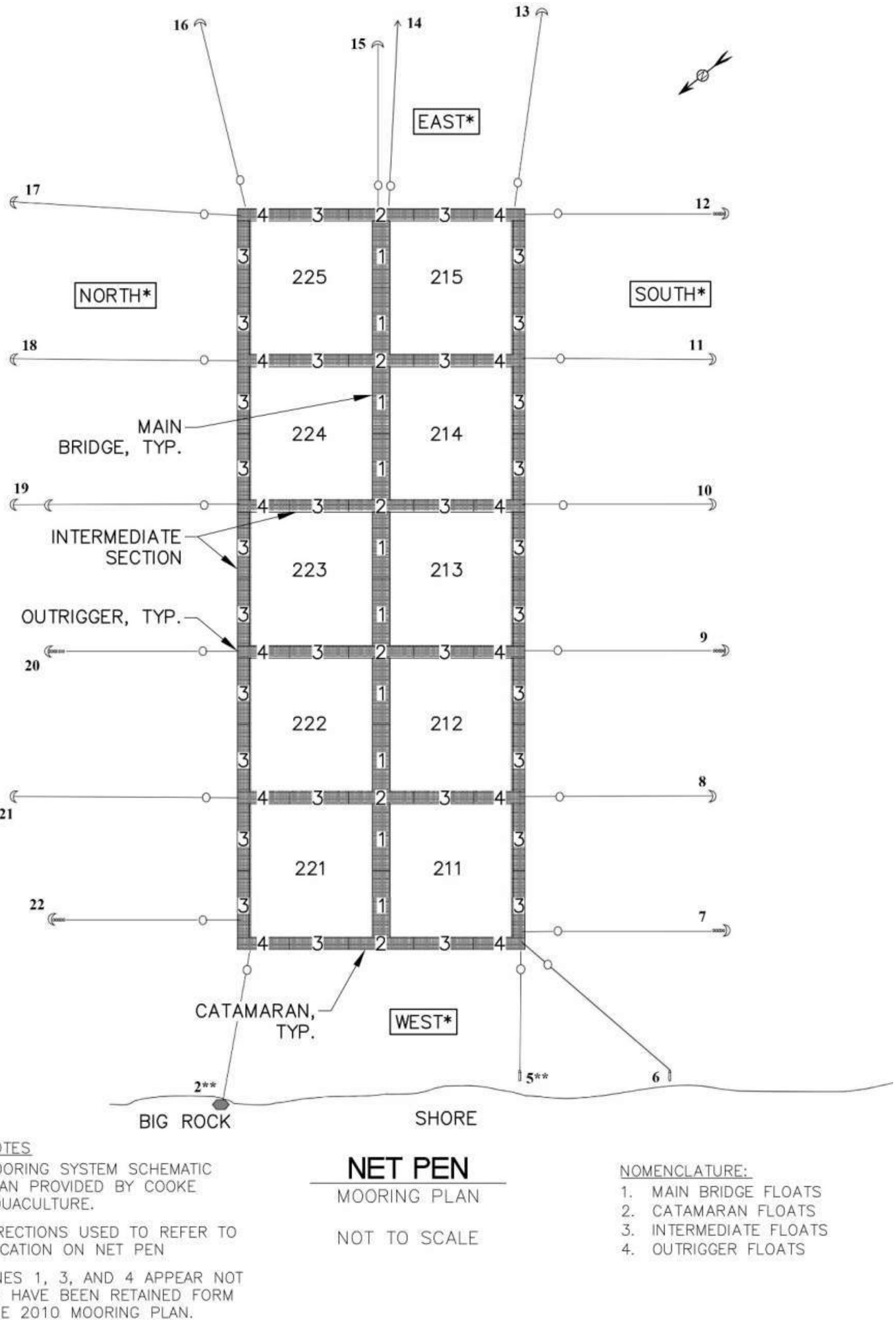

Figure 3.2 – Layout of net pen #2

4 History and Timeline of Events

This section provides a brief history of the facility and describes the events that occurred at the facility leading up to the complete collapse of Net Pen #2 in August 2017.

4.1 History of the facility

The facility was first built in 1985 (as per the JARPA application submitted by Cooke in February 2017). The original configuration of Net Pen #2 shows 15 cells in an approximately square footprint (shown in top left of Figure 4.1). The exact details of this installation are unknown. New structures were installed in 2001 (as indicated in Cooke's response to the agreed order). The new configuration of Net Pen #2 shows a more elongated rectangle with 10 square shaped cells. Each cell is larger than the individual cells in the configuration from 1985. This configuration was retained through 2017. Net Pen #2 was repositioned in 2011. It was moved offshore into deeper waters and rotated. The relocated position resulted in a location preventing the installation of a symmetrical mooring arrangement, unless the anchors were placed beyond the lease boundary.

Cooke took ownership of the facility in May 2016. In February 2017, Cooke submitted a permit application to replace and reorient Net Pen #2.

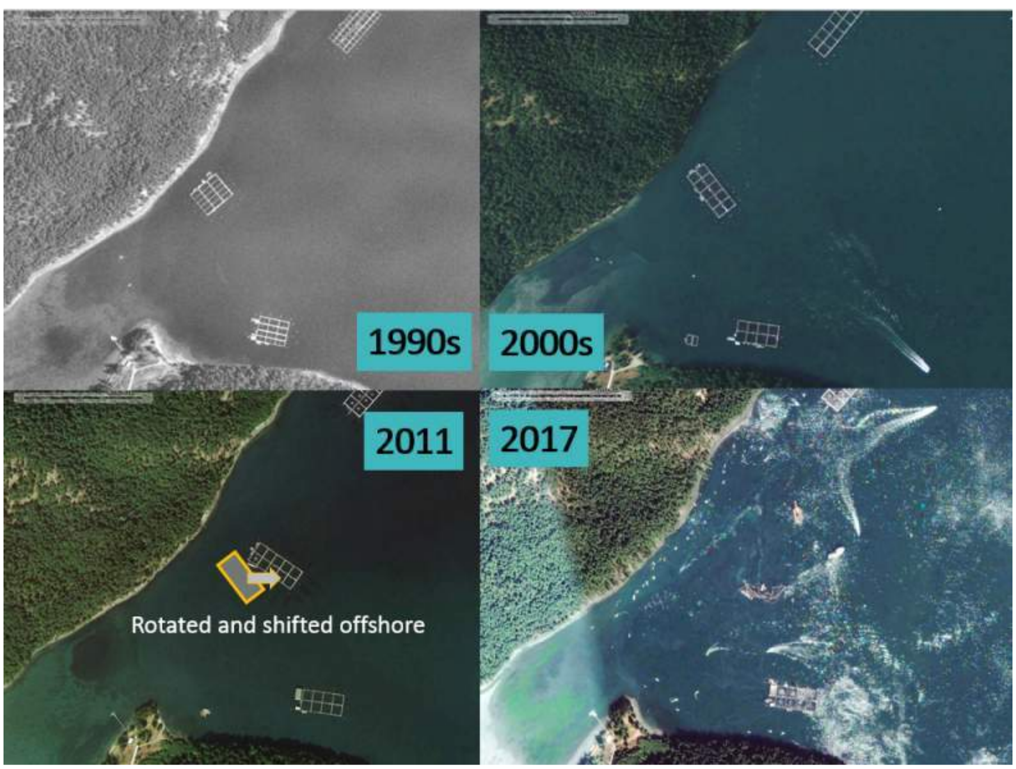

Figure 4.1 – History of facility *(Source: Google Earth)*

4.2 Incident in July 2017

Based on Cooke's response to the Administrative Order, on the evening of Monday July 24, 2017, staff at the facility reported mooring failures at Net Pen #2 (Figure 4.2). Ten anchor points on the cages (walkways) had broken and other anchors had dragged, thereby causing Net Pen #2 to shift considerably. It is unclear if the “anchor points” meant individual pad eyes or the complete mooring bracket assemblies. Tug assistance was called to stabilize Net Pen #2. The vessel Millennium Star, from Harley Marine, was involved in the operations during this time. During the operations, moorage anchors which were replaced on July 25 had broken free from the connection points on the floats, causing the net pen to shift again. Operations to stabilize the net pen continued through July 29 (Figure 4.3). During this time, the entire mooring system and anchor points had been replaced and re-tensioned. As per Cooke’s response, by July 29, the facility had been tensioned and stabilized to a “95% level”. Based on inspection by divers, there were no signs of compromised stock nets or of fish escapes.

Cooke’s entire account of the incident in July can be found in their submitted Response to Administrative Order 15422. A timeline of events and current speeds measured in the nearby Bellingham Channel are shown in Figure 4.5. Current direction and speed at the site may differ.

Based on available pictures of the repairs and the responses from Cooke (including the statements by Kyle Wood during the site visit on December 19, 2017), chains were laid across the top of the walkway decks to form an “exoskeleton” and secure the floats and connect the mooring lines. No engineering documents or calculations showing the design of the exoskeleton system were received or reviewed at the time of writing this report. Steel members were also added to the outrigger float sections to strengthen the permanently deformed floats, as shown in Figure 4.6.

Figure 4.2 – Net Pen #2 in July 2017 ***(Source: Harley Marine)***

Figure 4.3 – Net Pen #2 being stabilized by Millennium Star (July 2017) (Note reduced freeboard at the floats where the two lines are applying concentrated pulling force.) ***(Source: Harley Marine and Google Earth)***

Figure 4.4 – Net Pen #2 showing the ten cages. ***(Source: Google Earth)*** **Photo is from July 25, and shows the tug, towards the top of the picture, stabilizing the net pen facility. Also appearing in the picture are the Cooke work vessels outside cages 221 and 225.**

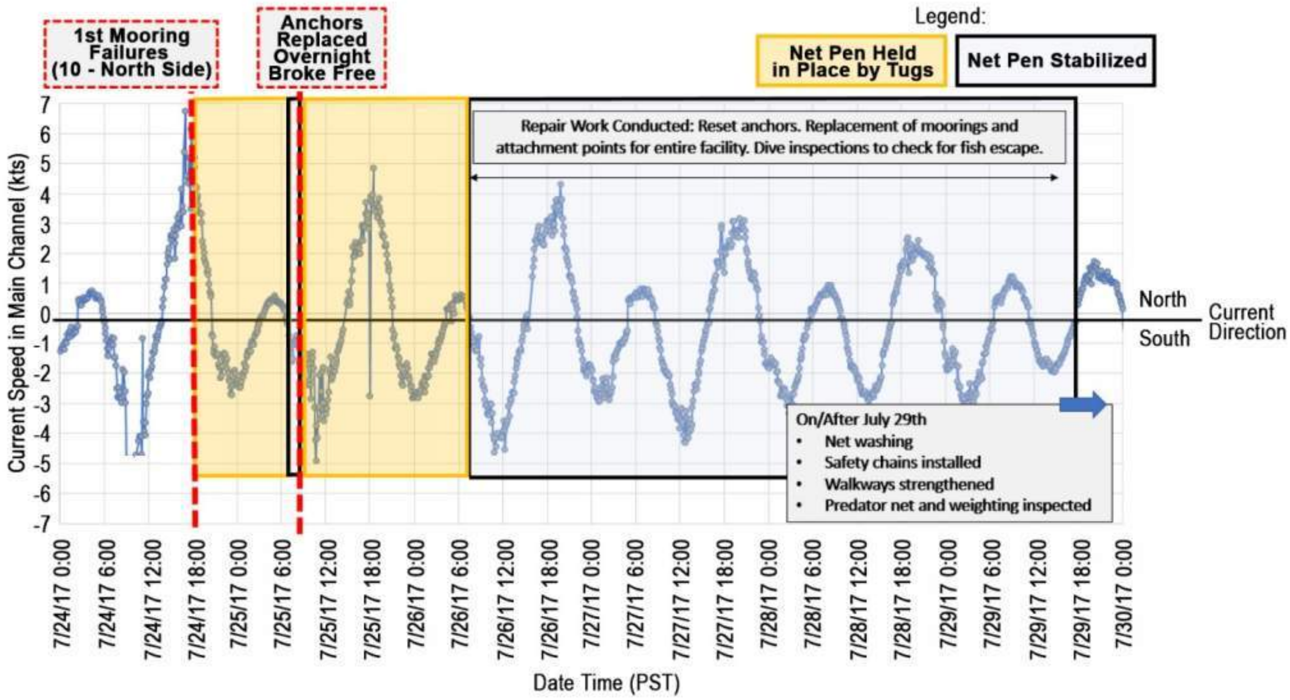

Figure 4.5 – July 2017 incident timeline and measured currents in Bellingham Channel ***(Source: Mott MacDonald)***

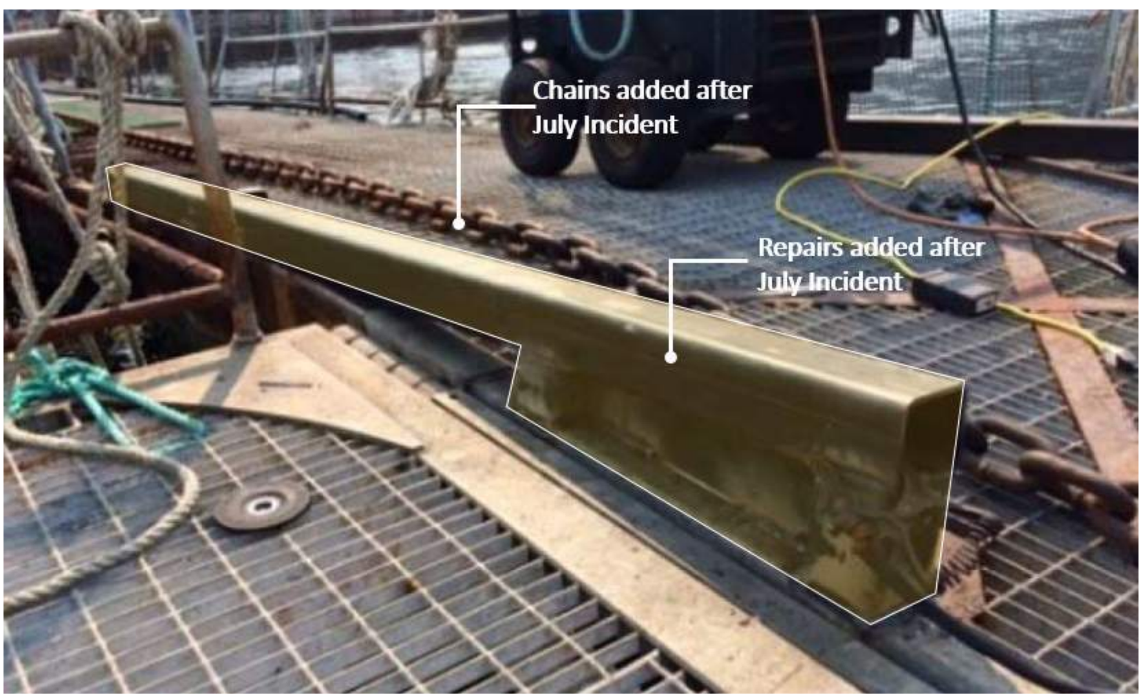

Figure 4.6 – Example of repairs to Net Pen #2 following the incident on July 24, 2017. ***(Source: Mott MacDonald)***

4.3 Incident in August 2017

To investigate the incident in August 2017, Mott MacDonald reviewed Cooke's response to the Administrative Order and the letter issued by Jill Davenport (an eyewitness to the event in August 2017) to the newspaper Anacortes American (Figure 4.7). Based on Jill Davenport's account and Cooke's response at approximately 3:30 p.m. in the afternoon of August 19, 2017, there was some unexpected activity at the net pen; the cause of which was not readily identifiable.

The eyewitness account from Jill Davenport states that a chain attached to the southeast corner buoys was dragging on the deck followed by the buoy jumping over the deck. Subsequently, the underside of the walkways of the pen on the southeast corner was visible, indicating that the walkway was listing severely. Cooke staff arrived at the pen around 4:00 p.m. and tried to contain equipment on the net pen. They also towed two floats with equipment and a storage building. A tug arrived on site at around 5:00 p.m. followed by another tug a short while later.

Figure 4.7 – Witness photo (August 19, 2017) ***(Source: Jill Davenport)***

According to Cooke, a mooring failure occurred at the site. They believe this failure coincided with the afternoon flood tide. Two anchors on the north failed, three had dragged, and one anchor on the shore side had a broken mooring bracket, broken safety chain, and a broken cleat. Cooke was trying to stabilize the net pen with tugs and staff were monitoring the situation overnight. On the morning of August 20 at approximately 6:40 a.m., another corner anchor had failed. Efforts to stabilize the net pen were hampered by tides during the day. Due to continuous movement of the structure, the walkways had become unsafe to work on. Furthermore, the conditions were too dangerous for even divers to safely enter the water and move fish from the damaged cages to adjacent cages. By this time, the fish had escaped the stock nets from two cages but were contained in the predator nets. Cooke states that the eight other cages were secure. Through August 21 and August 22, Cooke states that they attempted to secure the site, but were inhibited by strong tidal currents (currents on these dates are investigated in Section 5). The net pen continued to move and displace during this time and fish had started escaping the cages. The integrity of the pen had been severely compromised; diving operations and assessments were suspended as they were deemed to be unsafe. On August 23, the site was declared a total loss. Following this, the efforts were focused on securing the site, preventing further loss of fish, recovering the remaining fish, and salvaging the components of the collapsed pen structure (Figure 4.8).

Cooke's entire account of the August 2017 incident can be found in the response to Administrative Order 15422.

A timeline of events and current speeds measured in the nearby Bellingham Channel are shown in Figure 4.9. Current direction and speed at the net pen site may be different.

Figure 4.8 – Aerial view of Net Pen #2 on August 28, 2017 *(Source: DNR)*

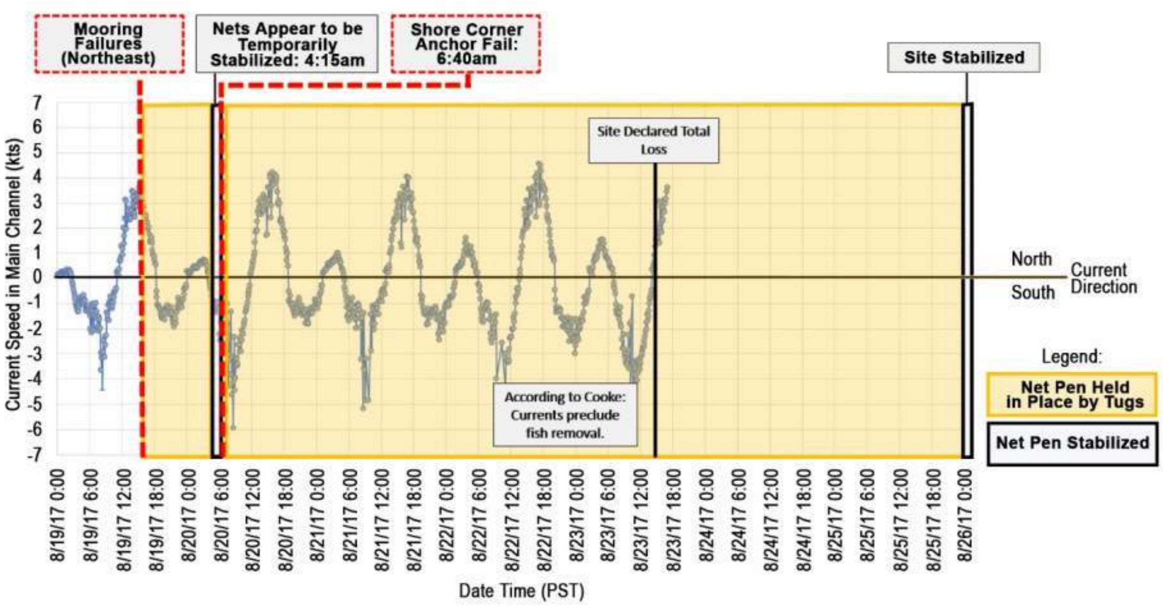

Figure 4.9 – August 2017 incident timeline and measured currents in Bellingham Channel *(Source: Mott MacDonald)*

5 Environmental Conditions

Environmental conditions in the vicinity of Net Pen #2 were investigated for the evaluation period from June to August 2017 to understand the probable causes for its failure. Environmental conditions reviewed include water depths, winds, wind-waves, water levels, currents, vessel traffic wake effect, marine fouling, and miscellaneous force considerations. Appendix A of this engineering report contains a summary of the environmental condition assessment in graphical slide format. As shown in Figure 5.1, Net Pen #2 is adjacent to the Bellingham Channel, and is approximately 400 feet from the shoreline.

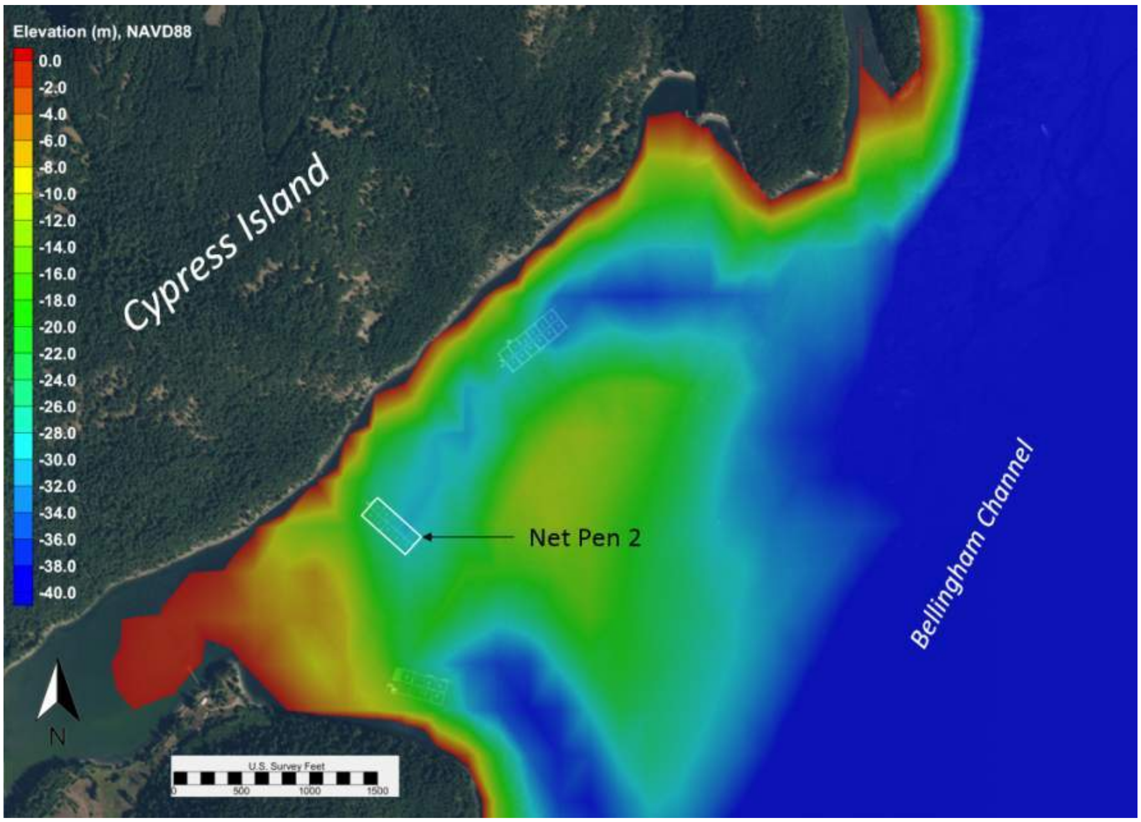

Figure 5.1 – Project site location bathymetry *(Source: NOAA Puget Sound DEM)*

5.1 Water Depths

Data Review

As shown in Figure 5.1, Net Pen #2 is located in approximately 20-30 meters (65-100 feet) of water. Net Pen #2 is located near an apparent channel, with side slopes up to 6-7 degrees.

Assessment

If equal mooring line lengths are used, the variable depths in this area could result in asymmetrical mooring line scope (or slope) i.e., anchor locations would be closer to the net pen where the water is deeper, and further from the net pen where the water depths are shallower.

5.2 Winds

Data Review

Wind in the vicinity of the facility during the evaluation period was assessed based on available data. The wind record for summer 2017 is plotted in Appendix A. The 2-year return period sustained (2-minute average) wind speed is approximately 44 mph.

Assessment

Based on review of nearby wind stations (Anacortes, Padilla Bay), the summer of 2017 did not contain any large (e.g., sustained wind over 20 mph) wind events. The 2-year storm was not exceeded during the evaluation period.

5.3 Wind Waves

The project site is not exposed to ocean swell, and therefore only wind-waves affect the site. Wind-generated waves in the vicinity of the net pen during the evaluation period were assessed based on available data. Wind-waves are generated by winds acting over a distance of water (fetch). The maximum fetch to generate wind-waves towards the project site is approximately 3.5 miles. Based on a conceptual-level empirical wave generation calculation, maximum wind generated significant wave height near the nets during summer of 2017 likely did not exceed 1.5 ft.

Assessment

Because of the short fetch length, and lack of major wind events recorded during the evaluation period, wind-waves were representative of typical conditions, and not extreme. The typical wave climate in this area is unlikely to be a major contributing factor to site hydrodynamic forcing. As per document # 8 in the document review summary Table 2.1, the manufacturer of the net pen states that cages were constructed to meet significant wave heights of up to 1m (3.3 ft.).

5.4 Water Levels

Data Review

Available predicted water levels (NOAA Station 944794) in the vicinity of the facility during the evaluation period were reviewed. Measured water level data was not available at the facility. Water levels for the months of July and August (the months in which the events at Net Pen #2 occurred) are described in the following paragraphs.

July 2017

- During the July event (July 24) the high tide occurred in the evening (~6:30 p.m. – 9:00 p.m.), and was near the elevation of mean higher high water (MHHW), as shown in Figure 5.2. The low tide on July 24 occurred near midday (~10:00 a.m. – 2:00 p.m.) and was predicted to be below mean lower low water (MLLW).

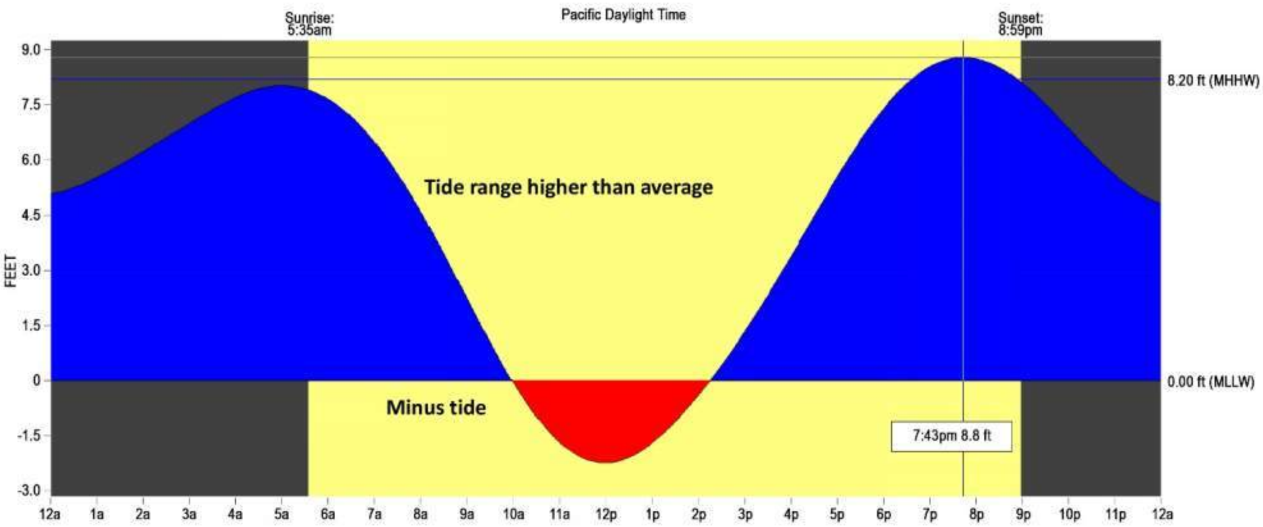

Figure 5.2 – Predicted Tides: July 24, 2017

August 2017

- During the August event (August 19), the high tide occurred in the afternoon (~4 p.m. – 6 p.m.), and was near the elevation of mean higher high water (MHHW), as shown in Figure 5.3. The low tide on August 19 occurred in the morning (~8 a.m. – 11 a.m.) and was predicted to be below mean lower low water (MLLW).

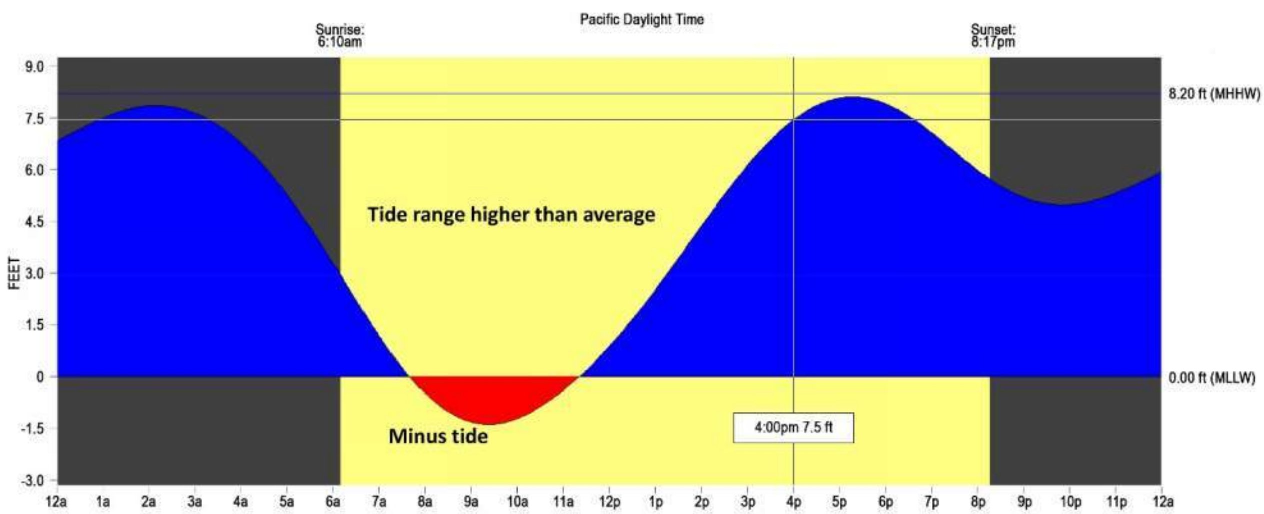

Figure 5.3 – Predicted Tides: August 19, 2017

Assessment

It is typical for tidal events with a tide range greater than normal to induce faster than average tidal currents. The tide range predicted on July 24 and August 19 were greater than average. Regional tide gauges did not measure significant differences between predicted and measured water levels during either July 24 or August 19.

5.5 Currents

Data Review

The site has complex hydrodynamics; detailed analysis or modeling of which is beyond the scope of this assessment. Available tidal current data in the vicinity of Net Pen #2 during the evaluation period (June-August 2017) were reviewed. According to Cooke (2017 JARPA. Cooke JARPA Feb2_2017_Site 2_pen replacement project.pdf), "The Deepwater Bay area has a strong tidal gyre which forms a deep-water channel running parallel to the shorelines of Deepwater Bay." The currents are reported (by Cooke) to "curve" around the cove so that flood tide currents at the facility come from the north. Cooke has consistently reported that currents associated with the flood tides affected Net Pen #2 the most. It is likely that the angle of the currents, relative to the shoreline, change daily.

Both measured and predicted currents are available from a NOAA station (PUG1740, PCT2121) located in the main channel 1.2 miles to the east. Tidal currents at this station differ in magnitude and direction from currents at the site, but give an idea of relative current magnitude as compared to other dates. The NOAA measurement tool recorded data at multiple depths; this analysis focuses on measured currents at approximately 20-ft. depth.

Although it was reported that failure events primarily occurred during flood tide, recorded daily maximum flood and ebb currents during the evaluation period (June-August) were reviewed, and are shown in Figure 5.4[1]. The July 24 event first occurred near the seasonal peak flood tide current. The August event occurred during the following set of elevated flood tide currents. However, the system did not fail during flood tide currents in June, that exceeded the currents measured in August. There is less evidence that ebb tides affected the stability of Net Pen #2.

Highlights from the review of the data from the evaluation period are given below:

June 2017

- Peak ebb current measured during the evaluation period occurred on June 26.

July 2017

- Peak flood current measured out in the channel during the evaluation period was measured on July 24.
- In the two days following July 24, the daily maximum current speed exceeded the current speed measured during the August 19 failure.

August 2017

- The solar eclipse occurred on August 21, 2017. Daily maximum flood currents on August 19 were higher than normal (85th percentile during the period reviewed), but were less than the daily maximum currents measured in July.
- The currents measured on August 19 were the greatest measured since the net pen was stabilized following the July incident.
- On August 20, 2017, the measured daily maximum flood tide current increased relative to the measured daily maximum current on August 19.
- At periods between daily maximum measured currents, the currents were often measured at less than 2 knots (lower than the seasonal average).

[1] All recorded currents were measured at the NOAA station, not at the net pen facility. Current speed and direction at the net pen facility may differ.

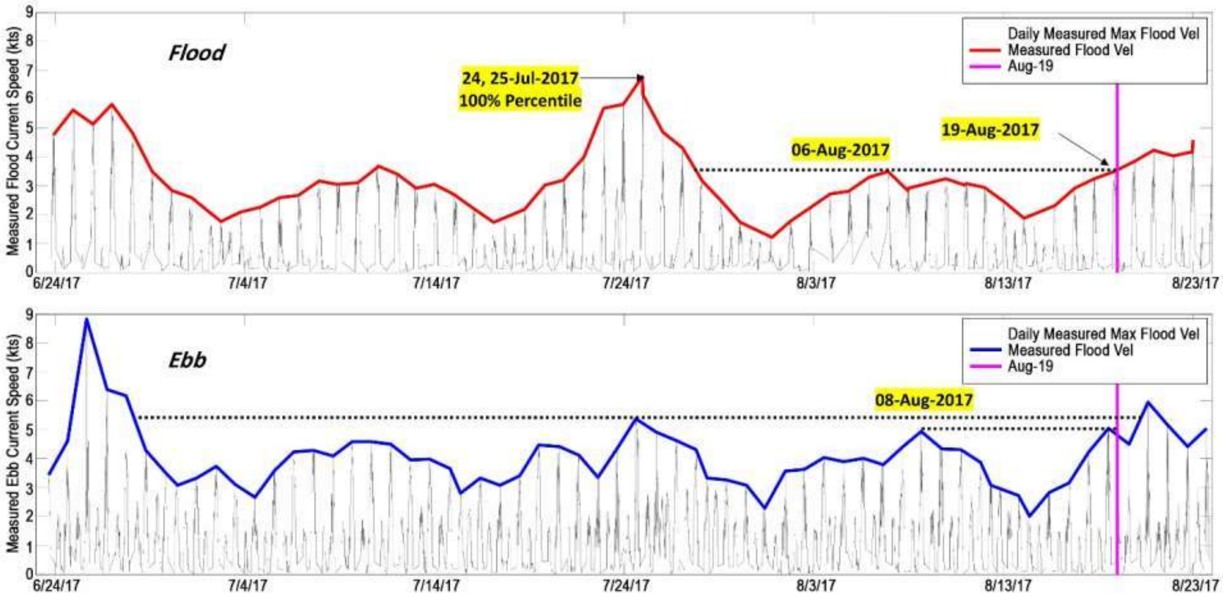

Figure 5.4 – Measured tidal currents in Bellingham Channel (20-ft. depth), June-August 2017

Pre-event Historical Data:

- Because measured currents are only available for 2017, a multi-year comparison of measured currents in this location is not possible. In lieu of measured data, a cursory comparison of predicted currents was conducted between August 2016 and August 2017. Peak flood currents on August 19, 2017 were predicted to be less than the predicted currents on August 19, 2016.
- Historical measured currents were provided for Site 1 (NPDES Sampling Report 2002. Cypress Island Inc. Net Pens, document #17), but not Net Pen #2. This document indicates current speeds of 0.45m/s (0.9 knots) maximum (ebb) on September 21, 1994. Published predicted currents in the channel on this date were 1.13 m/s (2.2 knots). Predicted ebb currents on the day of failure were 1.75 m/s (3.4 knots).

<u>Assessment</u>

It appears that the failure events coincided with seasonal and localized peak flood current events. Based on the year-to-year comparison of predicted tides from the NOAA currents station, it appears the currents are within a previously (typical) predicted range. Without measurements or a validated numerical model, it is not possible to evaluate whether the currents at the net pen site exceeded the currents used in the mooring analysis.

5.6 Vessel Traffic

<u>Data Review</u>

According to publicly available vessel tracking data (Marine Cadastre, 2017), vessel traffic in Bellingham Channel can consist of tugs, cargo vessels, research vessels, fishing vessels, pleasure craft, passenger vessels, and tankers[2]. To investigate potential unusual vessel activities and corresponding vessel wakes that could be a contributing factor to the failure,

[2] Publicly available data reviewed. 2011 AIS data shown in appendix.

vessel traffic in Bellingham Channel was reviewed. ECY provided information based on Automatic Information System (AIS) information data for July 24 and August 19[3].

Vessel wake due to the passing vessels have been estimated using empirical methods. Vessel wake heights at a specific location are dependent on the vessel displacement, speed, and distance of the vessel from the location. The vessels in Table 5.1 and Table 5.2 transited the Bellingham Channel on July 24 and August 19, and based on their size and speed, it was estimated that these selected vessels had the highest probability of creating a measurable vessel wake. Vessel location used to calculate wake propagation was based on ordinary navigable routes found in the AIS data. Vessel geometry was based on a combination of publicly available data and assumptions based on vessel type. Estimated wake wave height was estimated to be less than 1 foot for all vessels, as shown in Table 5.1 and Table 5.2.

Table 5.1 – Vessels in Vicinity of Net Pens – July 24

Vessel Name	Vessel Type	Vessel Speed	Vessel Length	Time
Jesse	Tug	14 knots	111 ft.	09:40
R/V Zoea	Aluminum Hull	20.4 knots	32 ft.	16:25
AJ	Tug	5 knots	98 ft.	19:40

Table 5.2 – Vessels in Vicinity of Net Pens – August 19

Vessel Name	Vessel Type	Vessel Speed	Vessel Length	Time
Flamingo Express	Private Vessel	21 knots	34 ft.	10:30
Island Explorer 5	Private Vessel	26 knots	91 ft.	15:50

Assessment

Wave height due to vessel traffic on July 24 and August 19 was likely less than 1 foot and typical of normal conditions. Vessels were likely not a major contributor to hydrodynamic forcing affecting either the July or August incidents.

5.7 Marine Fouling

Data Review

Observations during post-failure evaluation work indicated the marine fouling of the Cypress net pens varied. Specific fouling measurements were not undertaken. During the interviews (Interviews with Cooke Staff – Chris Nelson), fouling was described by Cooke as being an 8 on a 1 to 10 scale (1-Best, 10-Worst). Figure 5.5 shows a salvaged net on September 1.

[3] Not all vessel traffic is shown.

Figure 5.5 – Example of marine fouling found on stock nets removed from Net Pen #2 (Sept 1, 2017) ***(Source: DNR)***

Biofouling can be a serious problem in marine aquaculture, and it has a number of potential negative impacts including increased forces on aquaculture structures and reduced water exchange across nets. (Gansel *et al.*, 2014). Several studies have been conducted that report increased hydrodynamic loads due to currents with increased fouling. Increased horizontal loading on net pen support structures due to marine fouling has been reported to increase between 43% (Gansel *et al.*, 2014) and 500% (Swain and Shinjo, 2015).

In Fitridge *et al.* (2012) it was reported that fouling biomass can increase horizontal drag forces on cage netting by up to three times by common fouling hydroids and mussels. Highly deformed nets were determined to increase structural stresses on the cage at specific points with a two- to six-fold increase in horizontal forces in the cage corners.

In Gansel *et al.* (2014) the forces on all nets were measured at a flow speed of 0.1 meters per second. Swain and Shinko (2015) showed that relative increase in drag force varied, based on velocity (increasing with higher speeds). Therefore, at higher current speeds the forces due to fouling would increase. As discussed in Swain and Shinko (2015), drag force could increase up to five times (depending on current velocity) relative to a clean net after 4-5 months of biofouling growth.

Prior to the July incident, only one of three net cleaning units were operational (Interviews with Cooke Staff – Chris Nelson). In the response document from Cooke Aquaculture Pacific (Response from Cooke Aquaculture Pacific, LLC, document #19), Cooke reported that net washing was ongoing throughout the July incident, with 80% of nets washed by July 29. As per the interview with Sky Guthrie (Table 2.1 – No. 20), all available net washing equipment was brought to site on July 21st and net washing was accomplished within five days.

Assessment

Marine fouling increases hydrodynamic drag force on the net pens. Extended periods without net cleaning could result in increased forces relative to a regular cleaning schedule. Based on review of related literature, differences in hydrodynamic forces between clean and fouled nets appear to increase with faster currents. Based on review of post-failure nets, and interview accounts, it appears that marine fouling was present and was reported to be higher than typical,. The fouling observed on the salvaged nets was significantly higher than what was considered in the mooring assessment calculations available at the time of writing this report. As indicated in section 3.5, the stock nets were deeper and the mesh size of the stock nets was smaller than what was prescribed by the manufacturer. The smaller mesh size could lead to an increased probability of biofouling as the smaller holes in the nets can get occluded more easily and the greater depth of the nets would translate to a greater projected area of the net. Both these factors could lead to larger horizontal drag forces on the structure.

Due to large currents, the forces and corresponding movements of nets may have been very high due to the higher than normal amount of fouling.

5.8 Live Fish Loads

Data Review

Adult fish were present and live during failure events.

Assessment

The weight of the live fish inside the pen would not have a significant effect on the hydrodynamic forces and consequently the structural integrity of the net pen. The fish would be a part of the suspended water column within the nets.

5.9 Substrate Conditions

Data Review

Limited data on substrate was available for review. The following is a summary of information gathered:

- 2017 JARPA (2017 JARPA. Cooke JARPA Feb2_2017_Site_2_pen replacement project): Silt, sand, and clay on southwest corner. Large rock, cobble, sand, and shell clutter on the northeast side.
- 2002 NPDES Sampling (NPDES Sampling Report 2002. Cypress Island Inc. Net Pens, document #17): Video inspection described substrate as varying from muddy sand to sand with shell to sand with rock and cobble.

Assessment

Applicability of anchor type relative to sediment type and conditions is difficult to evaluate with the given information. Sediment type and depth is critical information to determine the appropriate type, installation procedure, and capacity of any installed anchor system. Anchors appear to have failed in July on the north side of the pen, where a mix of large rock, sand, cobble are reported as part of the substrate.

6 Maintenance and Repair History

6.1 Background

A review of the inspection, maintenance, and repair history, as indicated in the daily activity logs, was conducted based on the information provided by Cooke personnel as part of the response to the Agreed Order, Docket # 15422, issued by the Department of Ecology. Logs range from October 2, 2014 to July 24, 2017. At the time of writing this report, no logs were available to review for the time period between July 31, 2016 and November 1, 2016.

6.2 Summary of Daily Activity Log Reports

Cracks in the components of the facility are mentioned as far back as October 2014. In 2014, there are several reports of stress cracks on the walkway members and rusty chains. There are also reports of bent eyes (pad eyes on the mooring brackets). Most of the reported damage pertains to cages 211 and 221. These are the two adjacent cages along the short side that are closest to shore. There are no clear records or details of repairs made to these defect reports.

A report from January 2015 states that cracks on the southern long edge of the net pen (cages 211 – 215) are getting bigger. Later reports indicate 10 cracks on the southern long edge and two cracks along the northern long edge. There is further mention of stress cracks on the net pen facility, but it is unclear if these are new cracks or existing cracks being re-recorded. No identification system is used in the reports.

The report from February 17, 2015 states that cracks in the structure remain to be fixed.

According to the report on February 19, 2015, some welding was done on the walkways.

On April 29, 2015 an eyelet (pad eye on mooring bracket) near cage 211 was replaced.

The report from October 28, 2015 shows that there is some concern about tilting in the “end cap” between 215 and 225. It is unclear what the term “end cap” refers to. There is also mention of a false CL (assumed to mean connecting line i.e., mooring line) and that it was being monitored. The report also mentions finding a “few holes”, although it is not clear what this is referring to.

The report from November 12, 2015 states that the tilting end cap between 215 and 225 is disconcerting. No specifics have been used to describe the issue.

The report from November 17, 2015 states that “the CL on 211 or 221 broke again”. The conditions listed are high tide and big current.

The report on February 2, 2016 mentions a deformed eye (pad eye on mooring bracket) at the corner of 211 or 221. According to the report on February 4, this was supposedly fixed.

The report from February 22, 2016 states that the bracket at the corner of 215 holding the box beams is bent.

Since Cooke took ownership of the facility in May 2016, the series of reports from May 2, 2016 to May 20, 2016 mentions activities consistent with a transfer in ownership. These include prepping the pens, replacing anchor lines, and moving buoys.

The report on July 1, 2016 states that the buoy between 223 and 225 is sitting low with big currents. The corner of 215 is looking old, and big currents were "popping" bad knots in the mooring lines.

There are no logs available between July 31 and November 1 of 2016.

The logs on November 4, 2016 and March 30, 2017 mention strong currents pulling on the mooring lines.

The final log is for July 24, 2017. This is the date when there was an incident at the facility which required the tug Millennium Star to stabilize the facility. However, there is no mention of any events in this log.

There are no further logs available after this date, for review, at the time of writing this report.

A separate document titled "Cypress Island – September Results" which lists observations from September 2015 states that multiple locations on sites 1 and 2 are showing structural cracks.

6.3 Assessment

The following is our assessment of the inspection, maintenance and repairs conducted at the facility:

- Inconsistent record keeping and missing logs to the time period leading up to the incidents.
- There is no clear identification of defective components.
- There is no documentation of maintenance and repairs conducted.
- There are no logs after July 24, 2017 – date of incident at the facility.
- Stress cracks were noted in the components in 2014 and 2015.
- The descriptions from the logs indicate an increasing need for repairs during the life of the facility.
- There are numerous accounts of strong currents; thus, showing the exposure of the net pen facility to repeated, larger, hydrodynamic conditions.
- Based on observations from the site visits and from the interview notes, several mooring brackets were replaced during the life of the structure and after the incident in July. These are not stated in any logs and no details are available regarding these repairs.
- Also mentioned in the interview notes is that anchors on the site were re-positioned during the August 2017 incident. However, in the daily activity logs, there is no description of a procedure for installing or re-positioning the anchors. At the time of writing this report, there is no way to verify if the anchor lines were uniformly and appropriately tensioned.

7 Site Visits and Observations

Mott MacDonald conducted four site visits following the incident in August 2017. The first visit was on September 1, 2017, the second visit was on September 26, 2017, the third visit was on November 20, 2017, and the fourth visit was on December 19, 2017. The following paragraphs summarize the observations made during these site visits:

7.1 Site Visit on September 1, 2017

The first site visit was conducted following a “stand-up meeting” held in Anacortes. This meeting served as an introductory meeting for members of the IRP and the different panelists, including Mott MacDonald. During this meeting, the general scope of the investigation and potential questions to be answered were discussed.

Following the stand-up meeting, Mott MacDonald visited the site of Net Pen #2. At the time, salvage operations were ongoing and the net pen could only be seen from afar (Figure 7.1). The components in the water were not observed closely. Some components of the facility that had been recently salvaged were on a barge near the Port of Anacortes building. This included stock nets, predator exclusion nets, walkway floats, buoys, and mooring lines.

The stock nets showed considerable marine growth on them (Figure 7.2).

There were signs of extensive corrosion on the frames for the walkway floats.

The buoys showed signs of surficial corrosion, but no major defects.

The mooring lines seemed to be in new condition. This is consistent with Cooke’s account that the mooring lines were replaced in July. Although the mooring lines were broken, it did not appear that they had failed. The breaks in the lines appear to have been because they were cut as part of the salvage operations.

Figure 7.1 – Net pen salvage *(Source: Mott MacDonald)*

Figure 7.2 – Stock Nets salvaged from Net Pen #2 *(Source: Mott MacDonald)* Note: The steam is from the dying organisms fouling the net

7.2 Site Visit on September 26, 2017

The second site visit was to the construction yard of Culbertson Marine Construction in Anacortes. The salvaged components of the net pen were stockpiled in the construction yard of Culbertson Marine Construction. However, the components were not labeled to indicate where they were in relation to the other components of the facility. At this time, a visual inspection of the components was performed.

Key observations from this site visit were:

1. The steel framework for the floats showed signs of severe corrosion (Figure 7.3).
2. Some cleats on the floats showed severe deformation, including where the bolts connecting them had failed (Figure 7.4).
3. Several pad eyes on the mooring brackets, at the connection points of the mooring lines, had either yielded or completely broken off (Figure 7.5).
4. Several hinges, connecting the floats to each other, were broken and showed signs of corrosion.

It was unclear as to which of the observed damage was a result of the primary failure, which ones were secondary failures resulting from the movement of the net pen following the primary failure, and which ones were damage resulting from salvage operations.

Figure 7.3 – Floats showing corroded framing *(Source: Mott MacDonald)*

Figure 7.4 – Bent mooring cleat on an Outrigger Float *(Source: Mott MacDonald)*

Figure 7.5 – Broken pad eyes on an Outrigger Float ***(Source: Mott MacDonald)***

Figure 7.6 – Salvaged anchors showing different anchor types (Two Danforths in front, One Eells in back) ***(Source: Mott MacDonald)***

7.3 Site Visit on November 20, 2017

The third site visit was also to the construction yard of Culbertson Marine Construction in Anacortes. The intent of this site visit was to observe the salvaged components of the net pen laid out in the arrangement when the net pen was in operation. However, the components were not entirely in their original respective positions. Also, the designated person from Cooke, who was supposed to be present at the site was not available due to a medical condition. As a result, the observations made could be linked with the components only at certain locations.

Key observations made during this site visit were:

1. The pad eyes on the mooring brackets had varying dimensions including thickness, and inner and outer diameters (see Figure 7.7).
2. The corner sections on the west side were broken (Figure 7.8).
3. The float components on the north side appeared to have sustained prior deformation as evidenced by the repair measures taken, including stiffening frames (Figure 7.10).
4. Recalling the eye-witness account and the response from Cooke staff during the interview process, Kessina Lee of ECY said that the earliest observed damage was at the ends of pens 215 and 225 which had sheared on August 19 and were held together only by the nets. This would suggest that the connections on the floats making up pens 215 and 225 might have been the first point of failure on August 19.
5. Mooring line connections to the outrigger floats were observed to be consistent with industry wide mooring practices (location of shackles, direct connection to cleats, etc.) and not consistent with the net pen manufacturer's recommendations for the mooring system.
6. Eells Anchors were salvaged, though not reported by Cooke on the mooring plan (Figure 7.11).

Figure 7.7 – Pad eyes of varying sizes on same mooring bracket *(Source: Mott MacDonald)*

Figure 7.8 – Failed Outrigger Float section ***(Source: Mott MacDonald)***

Figure 7.9 – Failed Pad Eye ***(Source: Mott MacDonald)***

Figure 7.10 – Repairs to floats following July 2017 incident (shown in yellow) Cross-bracing on the surface of the floats was installed earlier in the life of the net pen structure. ***(Source: Mott MacDonald)***

Figure 7.11 – Eells anchor ***(Source: Mott MacDonald)***

7.4 Site Visit on December 19, 2017

The fourth site visit was once again conducted at the construction yard of Culbertson Marine Construction in Anacortes. At this site visit, Kyle Wood from Cooke was present to answer questions. The main pieces of information obtained during this site visit pertained to the “exoskeleton” made up of chains and the initial failure in Net Pen #2.

During this site visit, Kyle Wood explained how the “exoskeleton” was intended to function. Chains were laid across the top of the walkway decks to secure the floats and connect the mooring lines. This network of chains was intended to hold the net pen floats together and relieve some of the forces from the anchor lines into the pad eyes on the mooring brackets. Kyle was unsure if any engineering was performed in determining the configuration of the “exoskeleton” system.

Further, Kyle Wood, mentioned that he was on site within an hour of receiving a call about the incident on August 19, 2017. He was able to observe Net Pen #2 during its early stages of failure. Kyle confirmed that the east end of Net Pen #2 (the edge along cages 215 and 225) had broken apart. The main bridge floats had broken away from the catamaran float. The outrigger and intermediate floats had also broken away from each other. This confirms that the first failure in Net Pen #2 occurred along the east edge of cells 215 and 225. Pictures taken during this site visit show that the structural framing member of the outrigger float on the northeast corner of pen 225 failed. Kyle Wood confirmed that this occurred during the failure of the net pen and not during salvage operations. The pad eyes at the corner of this outrigger float are intact; thus, indicating that an anchor point failure did not occur at this location.

Key points noted during this site visit were:

1. The “exoskeleton” system made up of chains stretched across the floats of Net Pen #2 was intended to relieve forces on the mooring brackets and hold the floats together.
2. The east end of Net Pen #2 failed first.
3. The hinges connecting the floats and the structural framing of the outrigger floats on the northeast corner of pen 225 had failed, while the pad eyes at that corner were intact.

Figure 7.12 – Broken Hinge Connection on Catamaran Float at location of Main Bridge Float *(Source: Mott MacDonald)*

Figure 7.13 – Broken Structural Framing Member on Outrigger Float *(Source: Mott MacDonald)*

Figure 7.14 – Broken Structural Framing Member at Corner of Outrigger Float – Northeast Corner of pen 225 ***(Source: Mott MacDonald)***

Figure 7.15 –Corner of Outrigger Float – Northeast Corner of pen 225 ***(Source: DNR)*** **Note intact pad eyes at the mooring brackets.**

8 Mooring System Assessment

8.1 Introduction

Floating structures require site- and facility-specific mooring analysis to ensure loads are correctly distributed to the structural elements. Cooke has provided several documents that are related to the mooring and structural system at Net Pen #2. Mott MacDonald reviewed available documents and conducted a qualitative system assessment. This section includes an abbreviated background on the floating structure, assessment of manufacturer recommendations for the net pen support structure including mooring connections, corrosion, and fatigue loading, assessment of existing mooring analyses, review and assessment of the temporary stabilization by vessels, and review and assessment of the different anchor types on site.

8.2 Background

The net pen system is a modular steel frame, cage-and-mooring type system which is custom designed to site-specific conditions. A detailed description of the system is provided in Section 3 – Description of the Facility.

8.3 Net Pen Manufacturer Recommendations

The manufacturer provided recommended structure installation, operations, maintenance, and estimated facility lifetime. This information was provided in two documents (Mooring Report for the facility prepared by Aqua Knowledge, document #9; and Excel-based mooring analysis, document #10). The recommendations were reviewed relative to on-site findings described previously in this report.

Data Review

- Mooring Point Connections: Outriggers should use two adjusting chain connections (in a hens foot (bridle) configuration) for each line/buoy.
- Use of single point fastening between buoy and mooring bracket can cause undesirable cross-diagonal forces.
- Mooring Lines: All moorings must be kept evenly tight over time to ensure correct and even load to the section structure.
- Catamarans may use a single connection point for each buoy.
- As per document # 8 in the document review summary Table 2.1, the manufacturer of the net pen states that cages were constructed to withstand currents up to 0.5m/s (0.97 knots), combined with wave heights up to 3.28 feet.
- Fatigue Loading: Repetitive peak loads over time lead to fatigue and material failure/cracks will occur. Places to expect material fatigue is on outriggers and catamaran connections and internal members.
- Facility lifetime is approximately 20 years if loads are moderate.
- Corrosion Protection: The proper functioning of the net pen is dependent on good corrosion protection.

Assessment

- Mooring Point Connections: Connections at mooring brackets observed via photos and salvage inspection do not appear consistent with recommendations. The “Hen’s Feet” (bridle) system, as shown in Figure 8.1, was not observed at net pen corners.
- Mooring Lines: Dragging anchors (as reported by Cooke and evidenced by the bathymetry), likely resulted in variable mooring line loading.
- Anchor Tensioning: To ensure uniform tension in the anchor lines, typically, a meter to measure line tension is used. Based on the interviews with Cooke personnel it is not apparent that any sort of meter or gauge was used to measure the tension in the mooring lines during anchor installation. As mentioned in Table 2.1 (line No. 27), while trying to stabilize the net pen structure during the August 2017 incident, the anchors were lifted and dropped to tension the mooring lines.
- Facility Lifetime: The structure was nearing the end of its serviceable life, which was stated as 20 years.
- Fatigue: The manufacturer noted a reduced structural capacity and/or service life if installed at locations subject to repeated peak, cyclical loading conditions. Daily exposure to ebb and flood currents and frequent wave action are present and acted upon the net pen and its support structure thereby contributing to fatigue of the structure.
- Corrosion: Corrosion appeared to be present at several key elements, which likely reduced structural capacity.
- General: There are key factors that may have contributed to shortening the facility life span, resulting in the July and August incidents: Uneven mooring lines, corrosion, fatigue loading, and mooring point connections at the mooring brackets.

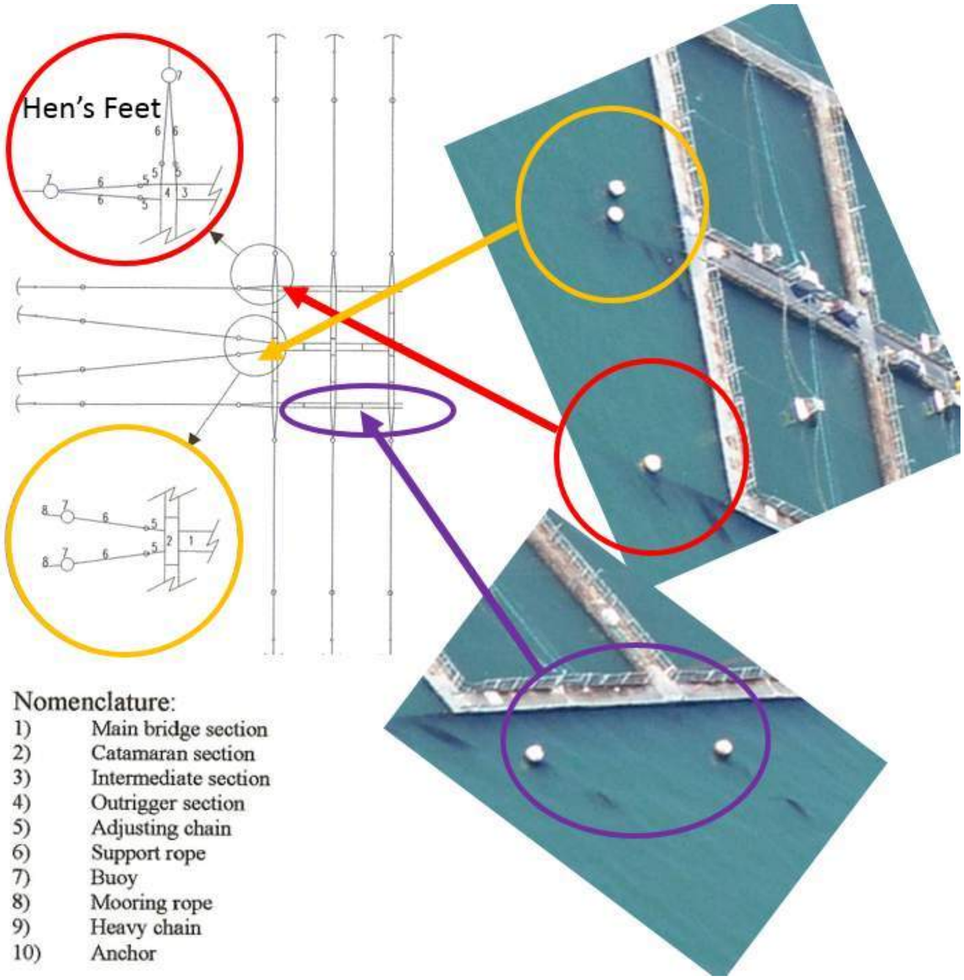

Figure 8.1 – Manufacturer recommended mooring connections and observed mooring connections (2009)

8.4 Mooring Analyses

Two mooring analyses of the Net Pen #2 system at Cypress Island were provided by Cooke. The most recent was conducted in 2015 by Aqua Knowledge. It is not known what precipitated the analysis. An Excel-based analysis was also provided in pdf format, but accompanying documentation and date were not provided. The title on the pages read "Deep Harbor – System #1", so it is unclear if this analysis was specific to Net Pen #2 or Net Pen #1.

The following documents were reviewed as part of this mooring system assessment:

- Re-anchoring plan for anchors following anchor failure in July 2017 (document #6).
- Excel-based mooring analysis (document #10).
- Mooring Report for the facility prepared by Aqua Knowledge (document #9).

8.4.1 Observed Site Conditions

The assumed configuration at Net Pen #2 is based on the document "Site 2 layout.pdf" and review of the salvaged structure, as described in Section 3.

- Anchor Type and Size:
  - Danforth: varies, 2500lb, 4,000lb, 5000lb, 6000lb, 8000lb.
  - Delta: 6000lb.
- Number of Mooring Lines: 19.
- Mooring Line Type and Length: Combination of surface chain, mooring rope, and anchor chain. The majority of the mooring points appeared to have the same length chain, and variable scope.
- Counterweight: Mooring analysis refers to counterweights, which are not found on site. It is possible that the term "counterweight" refers to the anchors.
- Marine Fouling (net):
  - Cooke Interviews: Fouling after July probably an 8/10. 2-3 is ideal.

8.4.2 Aqua Knowledge (2015) Mooring Analysis Summary

Data Review

- Maximum anchor holding force calculated to be 33 tons.
- Number of mooring lines: 22.
- Mooring Arrangement given in Figure 8.2.
- Mooring Line Type/Length:
  - Variable length top chain, mooring rope, and bottom chain with counterweights.
- Maximum mooring line force should be approximately 29.5 tons
- Environmental Forces:
  - Currents: Vary by direction, 0.83m/s (1.61 knots) (50-year max), 0.75m/s (1.46 knots) (10-year max).
  - Wind-Waves: Vary by direction: 1.6m (10-year), 1.8m (50-year).
- Marine Fouling: Not specified. Solidity[4] (including fouling) was 0.41 (2mm twine) and 0.26 (10mm twine).
- Mooring failure analysis conducted for failure of one mooring line/anchor.

Assessment

- Anchors: The maximum anchor force in the mooring assessment was calculated to be approximately 30 tons. The rated capacity of the anchors on site was not provided. Based on cursory analysis, a 6,000-lb. Danforth Anchor has a holding power of about 30,000-54,500 lbs. (15-27 tons), assuming full anchor embedment, and depending on substrate material type.
- Mooring Lines: Fewer lines observed in the 2017 mooring arrangement than used in the mooring analysis.
- Mooring Line Lengths: Mooring analysis indicates that lines should be variable length to accommodate variable depth conditions. However, at Net Pen #2 all lines are the same length, which would likely generate undesirable asymmetrical loading.
- Counterweight: Mooring analysis refers to counterweights, which are not found on site. It is possible that the term "counterweight" refers to the anchors.
- Environmental Forces:
  - Currents: Measured current data at the site were not made available for comparison to assumed current speeds in the mooring analysis.

[4] Aqua Knowledge references "solvency". It is assumed this term was used in error, and that the standard term of "solidity" was intended.

- o Waves: Waves used in the analysis appear reasonable and consistent with available analysis documents.
- Marine Fouling: Information on level of fouling in the mooring analysis is not known. Solidity is not provided with respect to fouled and un-fouled nets.

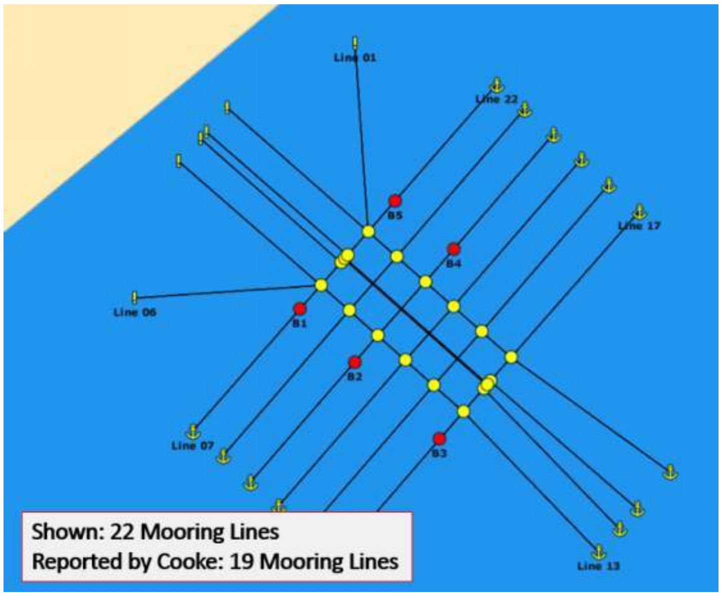

Figure 8.2 – Mooring arrangement in Aqua Knowledge Mooring Study (2015)

8.4.3 Excel Mooring Analysis (Date and Author unknown)

Data Review

- Maximum Anchor Holding Force: Approximately 33 tons. Appears to indicate 0.4 tons of downward force is required.
- Number of Mooring Lines: The analysis assumes 2 lines per steel cage. 22 total Maximum mooring line force: Approximately 33 tons.
- Mooring Line Type/Length:
    - o Type and length not specified. The analysis assumes angle of 6 degrees.
- Environmental Forces:
    - o Currents: 0.6m/sec. (1.17 knots)
    - o Wind-Waves: Not specified.
- Marine Fouling: The analysis assumes a biofouling growth factor of 25%.

Assessment

- Anchors: Anchor capacity assumptions appear uniform across the site. However, because substrate material varies, the anchor capacity will vary throughout the site. Reported anchor safety factor is low (1.1). Considering the reported variation in substrate material surrounding the site a higher factor of safety would be expected to ensure that the capacity of the anchors, during service, would exceed the possible loads that they could be subjected to.
- Mooring Lines: Fewer lines observed in the 2017 pre-failure mooring arrangement than used in the mooring analysis.

- Mooring Line Lengths: Not specified. The length of mooring lines is important to determine the capacity of the system and is dependent on the depths at the site.
- Counterweight: Mooring analysis refers to counterweights, which are not found on site. It is possible that the term “counterweight” refers to the anchors.
- Environmental Forces:
    - Currents: Measured current data at the site were not made available for comparison to assumed current speeds in the mooring analyses. Currents used in this analysis were less than in the Aqua Knowledge (2015) report.
    - Waves: Not addressed.
- Marine Fouling: Increase of drag coefficient due to observed marine growth was likely greater than assumed (25%) in analysis due to elevated levels of marine growth observed.

8.4.4 Key Findings: Mooring Analyses

- Mooring configuration and details thereof appear different than what is observed on site. No mooring analysis for the final net pen mooring configuration was provided, and therefore, may not have been conducted.
- Anchors appear to have a low factor of safety. This is corroborated by statements from Cooke that the anchors have a history of dragging.
- Dragging anchors (without proper re-setting of anchors) would likely result in asymmetrical loads (not included in the mooring analyses).
- The level of marine fouling used in the mooring analysis is either not clear, or, because little is known about the amount of fouling assumed in the mooring analysis, it is possible that the mooring analysis was not conducted with the same level of fouling that was found on site.

8.5 Temporary Vessel-Provided Stabilization

Data Review

Cooke has stated that during the July and August incidents tug boats were used to stabilize the net pens. Based on interviews, and as shown in Figure 4.3, it appears that at least once, a bridle was attached to the net pen support structure at two connection points. Therefore, the entire hydrodynamic force imparting loads on the supporting net pen structure was likely transferred to the two connection points used in the tug bridle. The tug operation during the July incident occurred during the entire period of peak ebb and flood tide currents. Information regarding manufacturer’s recommendations for net pen towing procedures were not available to review at the time of writing of this report.

Assessment

A fully operational net pen structure with pens in place is likely not designed for large concentrated loads at two connection points under typical service conditions and current velocities. Manufacturer’s typically provide recommendations on connection points and procedures for towing net pen structures. The temporary vessel stabilization actions in July, under high currents with the nets fully deployed, likely resulted in unusual loads acting on the net pen structure components. The towing of the net pen structure may have contributed to the damage to the net pen outrigger float section. Effects on the damaged structural elements may have contributed to the failure in August.

8.6 Anchors

Data Review

General: Typically, the drag anchor is sized as the "weaker link" in a mooring system to ensure that the anchor drags instead of breaking the mooring line. Anchor drag for a multi-leg mooring results in redistribution of the overstressed mooring line to neighboring mooring lines and helps the mooring survive extreme events. The factors of safety for the mooring line and drag anchor design vary depending on the type of analysis conducted (quasi-static vs. dynamic). If the anchor is overloaded at a slow enough rate, the anchor can drag, which reduces peak load (U.S. Navy). Anchors may have reduced capacity when installed on a downslope of a few degrees.

- Observed Anchor Types: Danforth, Delta, Eells.
- Type:
  - Danforth: Best suited for sand and mud substrate. A minimum depth of sand is needed to develop full capacity of the anchor. Unreliable in harder substrates such as gravel and rock. May not be reliable on sloping seafloors greater than several degrees (U.S. Navy).
  - Delta: Best suited for sand and mud substrate.
  - Eells: Stockless anchor type that was developed during World War 1 and best suited for softer sediments. In hard sediments, these hold only if they snag on an outcrop or get wedged in a crevice.
- No documentation was available at the time of writing this report to show that the mooring lines were uniformly tensioned while installing the anchors.

Assessment

The failure of mooring brackets could lead to a quick failure leading to a faster load transfer to remaining anchors. Based on review of substrate material on site (2017 JARPA. Cooke JARPA Feb2_2017_Site_2_pen replacement project), the Northeast sector of the facility contains a portion of hard rock (cobble, gravel), which may have reduced anchor capacity in this area. Additionally, the apparent tidal channel results in variable bottom side slopes in the area. Depending on the exact location of anchor installation (unknown), the anchors could have reduced capacity due to the bottom slope.

9 Key Findings

Based on our review of documentation provided by Cooke, our knowledge of the local environmental conditions, observations made during the site visits, and experience with moored floating structures the following key findings summarize our assessment:

9.1 Document Review

- Documentation of maintenance and repair was limited and facility inspection reports were sporadic.
- Limited documentation was made available on the original engineering design for the net pen facility.
- Documentation of engineering assessment of the damage to the net pen structure in July and analysis, design, or engineering documents for the subsequent repairs were not available at the time of the writing of this report.

9.2 History and Timeline and Events

- The net pen #2 was installed in 2001 and re-positioned in 2011. The age of Net Pen #2 at the time of failure was approximately 16 years.
- A substantial amount of activity to secure and modify the net pen facility occurred during and after the July 2017 event, which included a complete resetting of the anchor system, modification to the mooring brackets, and structural modification to the float system (outrigger sections). Very limited documentation of these activities or engineering thereof was made available.

9.3 Environmental Conditions Review

- Water Depths: Variable at site. Because of the apparent tidal channel near the net pen, the seafloor may slope up to 7 degrees, depending on location. The slope of the seafloor can affect the anchor holding capacity.
- Water Levels: Tide ranges on primary failure dates (July 24 and August 19) were larger than the average, which would induce larger than average tidal currents. High tide water levels in July and August were not extreme.
- Waves: No major wind-wave events occurred during June – August 2017.
- Currents: Flood currents measured in Bellingham Chanel during the July 24 failure were the fastest flood currents measured in the evaluation period of June – August 2017. The currents measured on August 19 appear to be the fastest measured since the net pen was stabilized following the July incident.
- Vessel Traffic: Vessel wake waves are unlikely to be a contributor to the failure.
- Substrate: Areas on the north and east side of the site were reported to contain cobble and gravel, which are not ideal substrate material for anchor installation, and can result in reduced anchor capacity.
- Live Fish Loads: The weight or density of the live fish in the net pen would not have a significant effect on loading or the structure.
- Contributing Forcing Mechanisms: Currents were likely the largest environmental forcing contributor to the mooring failures.

9.4 Maintenance and Repair History

- Two of three marine fouling cleaning units were not in operation leading to greater than normal fouling of the nets and consequently higher forces in the net pen structure.
- Multiple reports indicated fatigue and cracking on structural members in the years prior to 2017 thereby reducing the capacity of the structure.
- Documentation of repairs is not consistent.
- Documentation of procedures for anchor installation or replacement to ensure uniform and adequate capacity were not available to review at the time of writing this report.

9.5 Mooring System

- The mooring arrangement, as indicated on the JARPA plans, is not consistent with the recommended mooring arrangement, as described in the mooring analysis documentation. The JARPA plans show an asymmetrical arrangement, while the Best Aquaculture Practices (BAPs) and the mooring analysis both indicate a symmetrical arrangement for the mooring lines and anchors around the net pen.
- The mooring analysis for the facility and the Steel Cage System Manual (Document #7 in Table 2.1) shows a “bridle” arrangement of the mooring lines attached at two distinct points on the floats. However, the pictures show the mooring lines, including the repairs performed in July 2017, connected to the floats at a single point thereby increasing the potential for highly concentrated loads.
- Tug operations to reset the net pen facility following the July incident exerted very high concentrated forces on two outrigger sections without an engineering analysis of capacity of the net pen structure. There is no documented procedure for the tug operations to ensure that no damage was done to the net pen structure.
- Mooring system design is complex, site-specific, and a critical element to the survivability of the facility. Installed components and arrangement need to match that evaluated in the mooring analysis. Information confirming this was not available. The observed mooring arrangement did not match what was recommended or analyzed in the mooring analysis.
- Anchor type and weight were reported to vary. Anchors were reported as Danforth and Delta anchors. However, Eells anchors of unknown weights were salvaged.
- Mooring Analysis:
    - Mooring configuration and details thereof appear different than what was observed on site. No mooring analysis for the final net pen mooring configuration was provided, and therefore, may not have been conducted.
    - Anchors appear to have a low factor of safety. This is corroborated by statements from Cooke that the anchors have a history of dragging.
    - Dragging anchors (without proper re-setting of anchors) would likely result in asymmetrical loads (not included in mooring analyses).
    - The level of marine fouling used in the mooring analysis is either not clear, or, because little is known about the amount of fouling assumed in the mooring analysis, it is possible that the mooring analysis was not conducted with the same level of fouling that was found present at the site at the time of the July incident.

9.6 Engineering Design

- Mooring analysis conducted in 2015 does not match the observed conditions.
- Engineering design and shop drawings were not available. Only a manufacturer’s brochure was provided for review, along with a letter from the manufacturer (2015) listing some design criteria.

- The design parameters (net depth and mesh size) mentioned in the letter from the manufacturer differ significantly from those that were on site.
- The float structure system was approximately 16 years old and near the end of its service life.

9.7 Fatigue

- The net pen structure was subject to repeated hydrodynamic loading due to a combination of tidal current and wave action. As outlined in the letter from the manufacturer of the net pen, there is a high potential for cracking and reduced structural capacity of the net pen structure towards the end of its service life (rated by the manufacturer to be 20 years).

9.8 Corrosion

- The steel frames on the walkway floats showed signs of severe corrosion .
- Although clearly recommended by the Best Aquaculture Practices and the Steel Cage System Manual, key components at the facility were not maintained consistently to inhibit corrosion. Several key components, including the connection points of the mooring lines and hinges connecting the floats, showed signs of advanced corrosion.
- A highly corroded structural element would have a reduced capacity to resist the loads it is subjected to.

9.9 Biofouling

- There was considerable marine growth observed on the stock nets. Taking into consideration that two out of three net cleaning units were not in operation, this indicates that the stock nets were not cleaned in accordance with Cooke's regular schedule, prior to the failure of net pen #2 in August, thereby increasing hydrodynamic loading.
- As per Cooke personnel, a normal indicator of biofouling in the nets is 4 out of 10. The nets at net pen #2 were classified by Cooke personnel as 7 to 8 out of 10; almost double the biofouling that would be considered as normal.
- The severe biofouling of the nets could increase the drag force on the nets by up to a factor of 5x (depending on current speed). This would result in increased forces in the mooring system and consequently in the float structures.
- Higher than typical forces likely developed as a result of higher fouling levels.

9.10 July 2017 incident

- During the July 2017 incident, 10 mooring brackets on the north side were reported as having broken and the anchors had dragged.
- Photographs of the July 2017 incident show significant permanent deformation in the net pen components which likely resulted in permanent damage to the outriggers and other float sections.
- Following the incident in July 2017, repairs were made to the outriggers and mooring brackets that were broken or showed signs of significant damage. All mooring brackets were not replaced. All mooring lines were replaced and the anchors were reset.
- An engineering analysis of the structural framing and mooring system was not conducted for the revised configuration.
- There was a substantial amount of modification/repair to the structure and complete reinstallation of the mooring system after the incident. However, there are no engineering documents, calculations, or drawings documenting these repairs.

- There is no documentation available of the anchor capacity, orientation, and positions. The reset operations were conducted in less than ideal conditions and under tight time constraints.
- New mooring line connection system (exoskeleton) included chains installed across the floats and connection of the mooring chains to the mooring cleats, neither of which were accounted for in the mooring analysis.
- Tugs were used to hold the net pen in place for several days while anchors were being set. It is very likely that unbalanced and highly concentrated loading occurred during this time period. There is no analysis available at the time of writing this report to show that the net pen facility was designed to be towed and held in place by only two attachment points.
- The hydrodynamic forces on the entire net pen facility (with nets in place) were resisted by only two mooring points connected to the tug, as compared to 8 to 12 (along one edge of the net pen) points during normal service loading conditions.

9.11 August 2017 incident

- Similar to what was reported in the July incident, anchors dragged on the north side of the net pen facility.
- Based on eyewitness accounts and interview notes, the mooring brackets and the connections between the floats (intermediate and outrigger floats) on the outer edges of pens 215 and 225 failed first, leading to a progressive collapse of the facility.
- Although the first point of failure cannot be definitively identified, some combination of anchors dragging, mooring brackets failing, and structural float framing members failing contributed to the collapse of the Net Pen #2 structure.

10 Conclusions

Based on the review of the information available and Mott MacDonald's assessment, the following conclusions can be drawn:

1. The net pen structure was near the end of its service life, and was exposed to cyclical loading due to currents and waves.
2. The mooring arrangement of the anchors and anchor lines was different from what was used in the mooring analysis for the structure. There were fewer lines; the anchors were not laid out symmetrically; and the forces in the mooring lines were likely not uniform. The capacity of the installed anchoring system did not match the engineered design thereby increasing its susceptibility to failures.
3. Despite the solar eclipse, tidal currents in August were of lesser intensity than those observed in June and July.
4. Adequate corrosion protection measures were not taken to protect the components of net pen #2. Several components of the structure showed signs of corrosion which likely resulted in reduced capacity.
5. The stock nets on net pen #2 were deeper and the mesh size was smaller than what was listed in the design criteria in the letter from the manufacturer. This resulted in a greater probability of the nets getting fouled with a potential for higher forces.
6. The nets on Net Pen #2 were not cleaned to maintain the typical level of fouling. This resulted in a much higher level of biofouling on the nets and increased hydrodynamic drag forces in the structure.
7. The incident in July 2017 resulted in permanent deformations of several structural components of the net pen structure including float framing sections.
8. There is no information available at the time of writing this report that towing and stabilization procedures employed during the July 2017 incident followed manufacturer's recommendations.
9. There is no documentation of the engineering analysis or design of the repairs conducted to the net pen structure following the July 2017 incident.
10. There is no documentation for the engineering analysis or design of the exoskeleton system of chains employed after the July 2017 incident. There is also no documentation showing the effects of the exoskeleton system on the net pen #2 floats or moorings.
11. The failure of the net pen likely occurred due to a combination of factors including:
    a. High forces imparted on the structure due to higher than normal biofouling of the nets;
    b. Corrosion in the net pen structure components resulting in a reduced capacity:
    c. Uneven forces in the structure due to a mooring arrangement different from what was analyzed and which had previously resulted in anchors dragging and pad eyes breaking;
    d. Reduced capacity of the structural components that were likely modified without an engineering assessment (for e.g. the bent outrigger frames with new steel members welded to them, and the exoskeleton system of chains) or those which were not repaired (for e.g. hinges connecting the floats), following the July 2017 incident
    e. Atypical loads imparted to the structure from the exoskeleton of chains that were installed following the July 2017 incident.

11 References

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Appendix A

MOTT MACDONALD

Cypress Island Net Pens

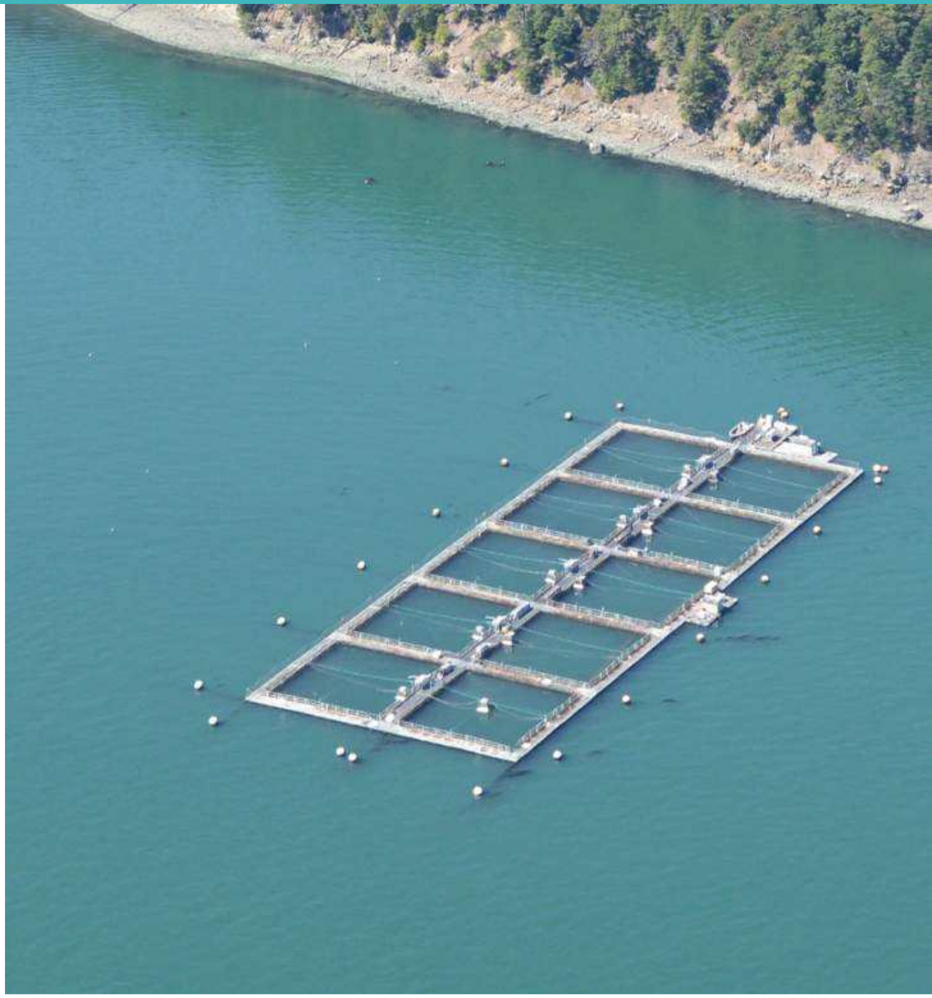
Review of:

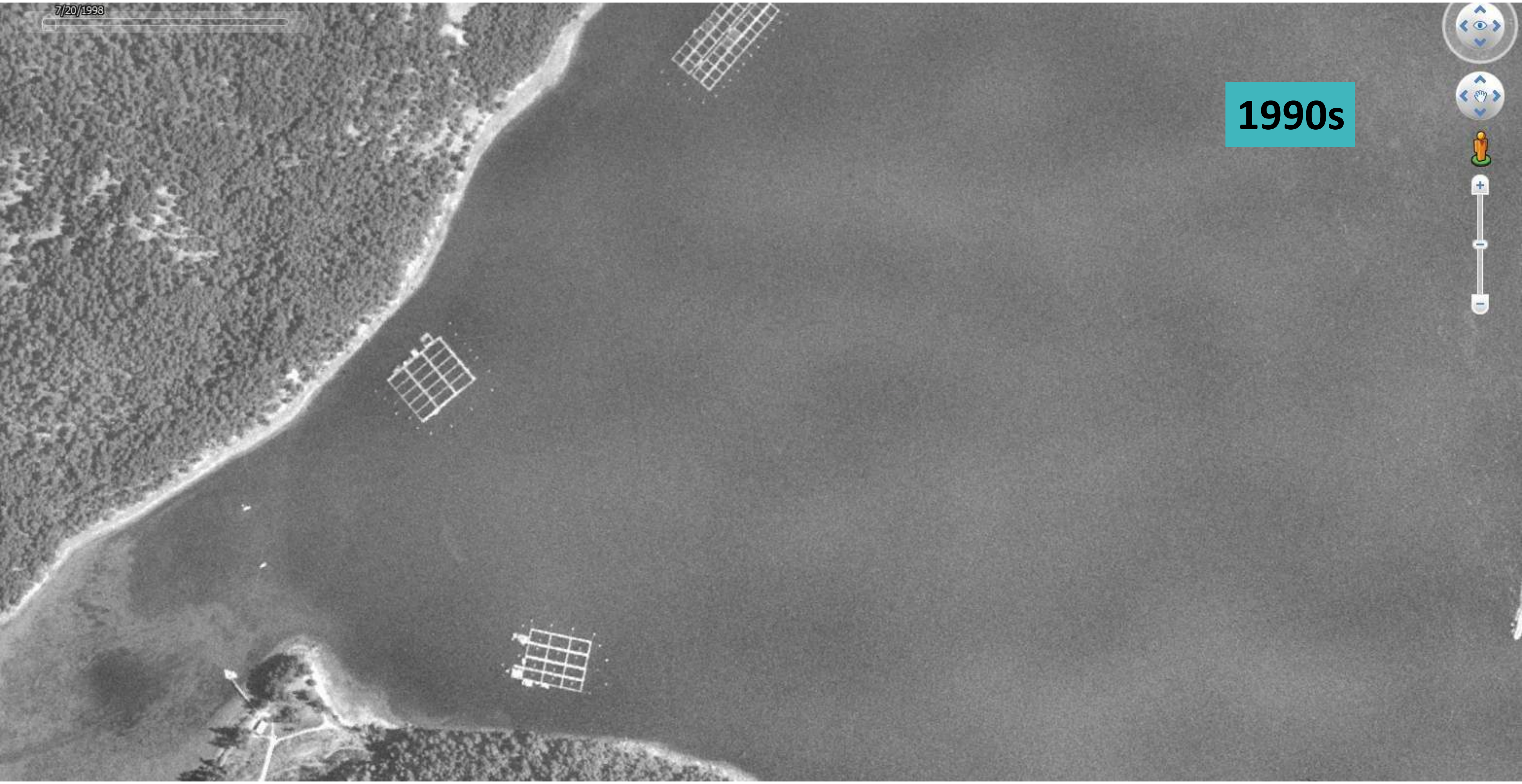
- Environmental Conditions
- Mooring Analysis

Washington Department of Fish and Wildlife

Outline

- Background/History
- Environmental Conditions Review
- Mooring Review





7/20/1998
1990s


9/10/2009
2000s


8/25/2011
2010-2011
Rotated and shifted offshore

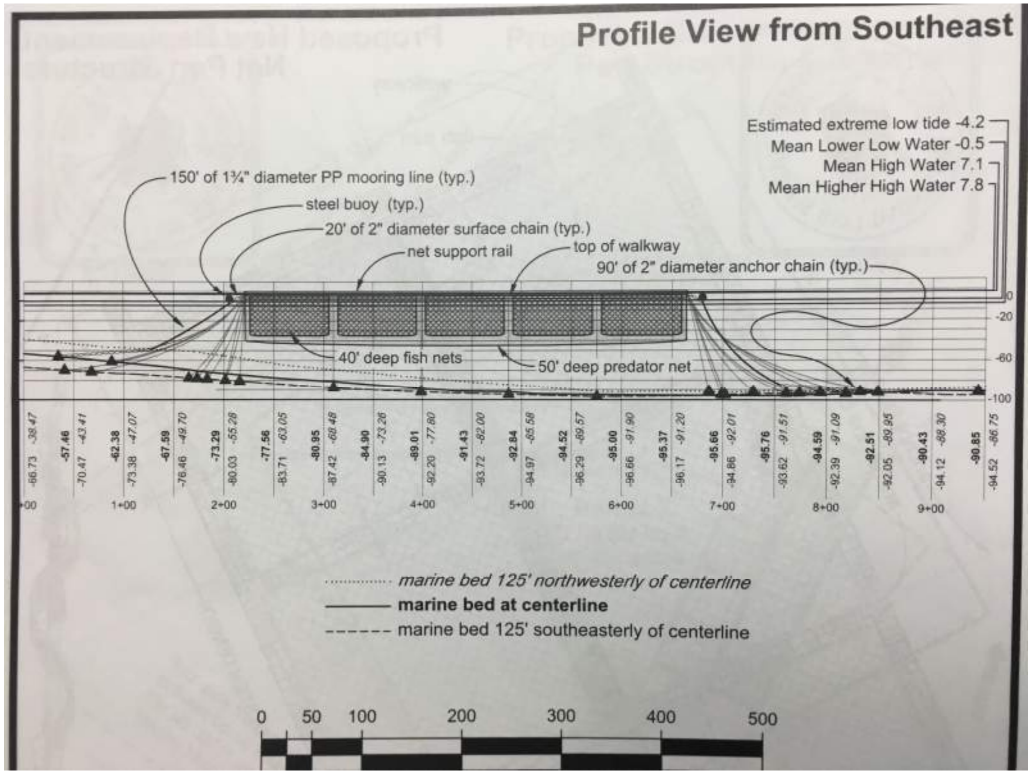

8/25/2017
2017

Timeline Summary

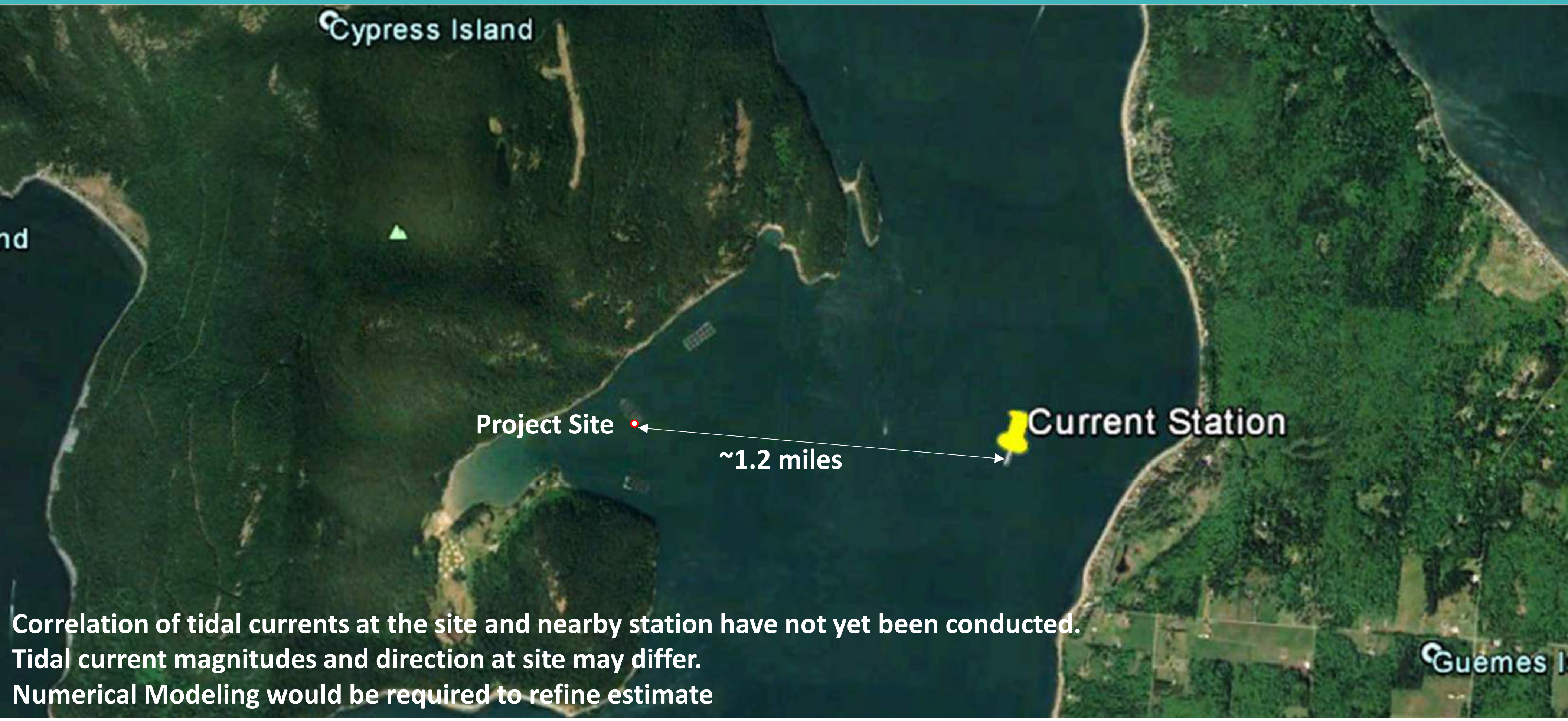
- Old Net Pen (1990s)
- New Net Pen (2000s)
- Relocated Net Pen (2010s)
- Net Pen Mooring Fail: July 24th 2017
- Net Pen repaired (anchor reset): July 24/25 2017
- Net Pen Mooring Failure: August 19th/20th 2017
- Complete Loss: August, 2017

Key Design Elements

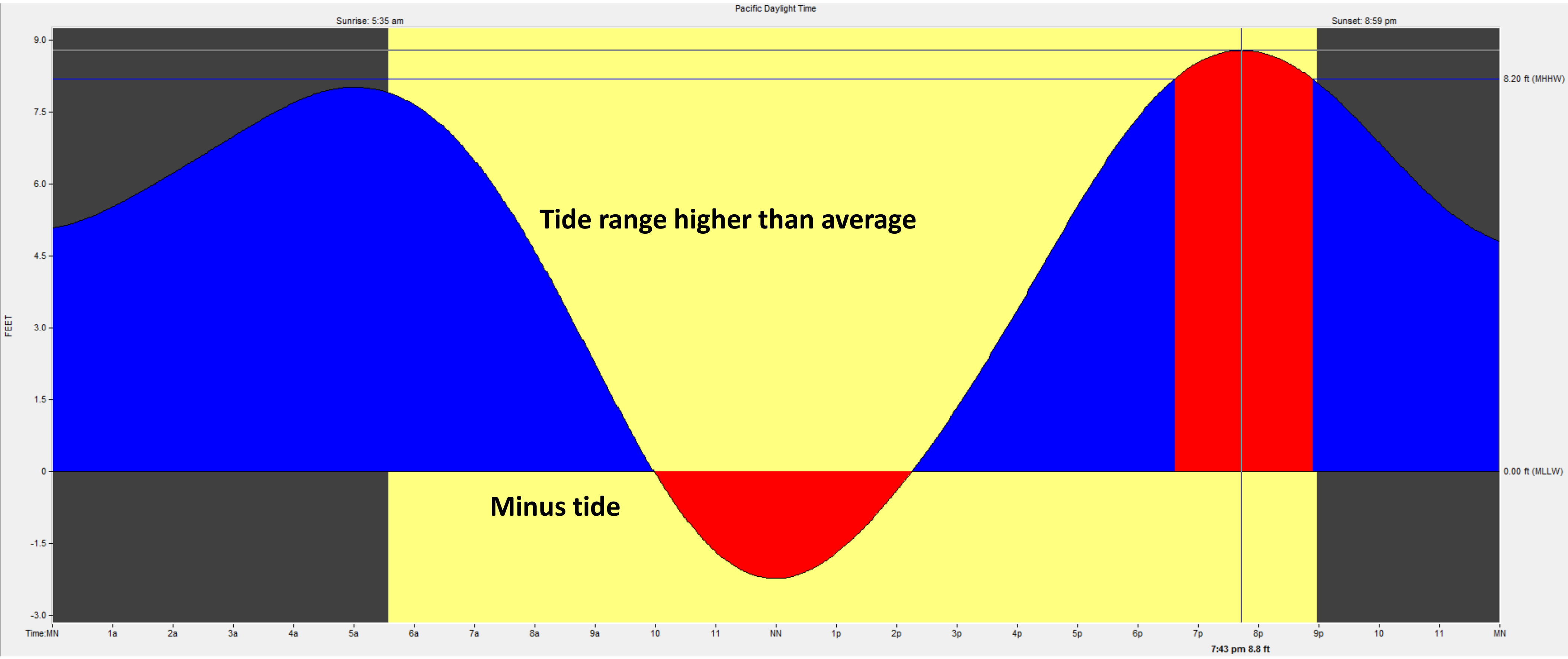
- **Environmental Conditions** – Wind, Wave, Currents, Tides, Vessel Wakes
- **Mooring Analysis & System Design** – Site & Framing/Cage System Specific, dynamic response, flexibility and motion, extreme conditions analysis
- **Stability Analysis** – Watertight pontoons, loss of mooring line, freeboard, etc.
- **Fatigue Analysis** – Considerations for fatigue due to exposure to cyclic loading conditions
- **Documentation** – sketch showing designed facility, limit conditions, working life of components, etc.
- **Inspection** – Inspection program and areas of importance, manufacturers recommendations for inspection



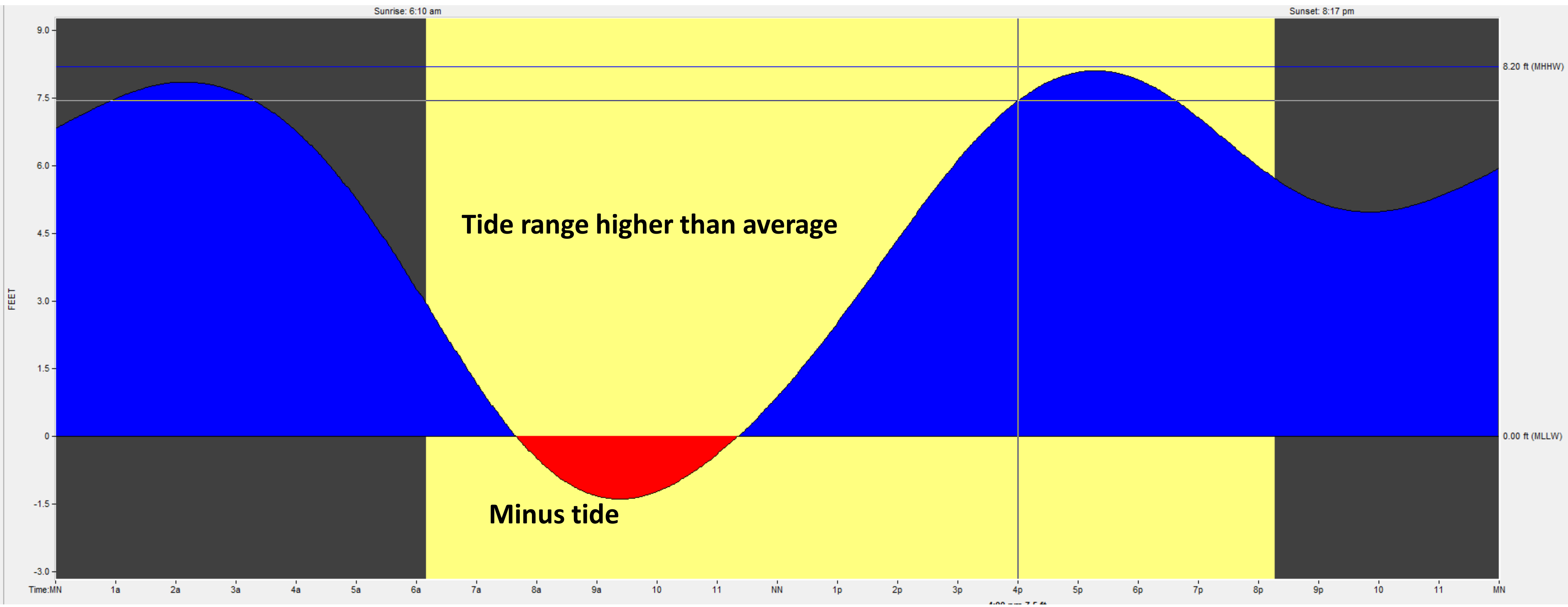
NOAA Tides Currents – Predicted & Measured



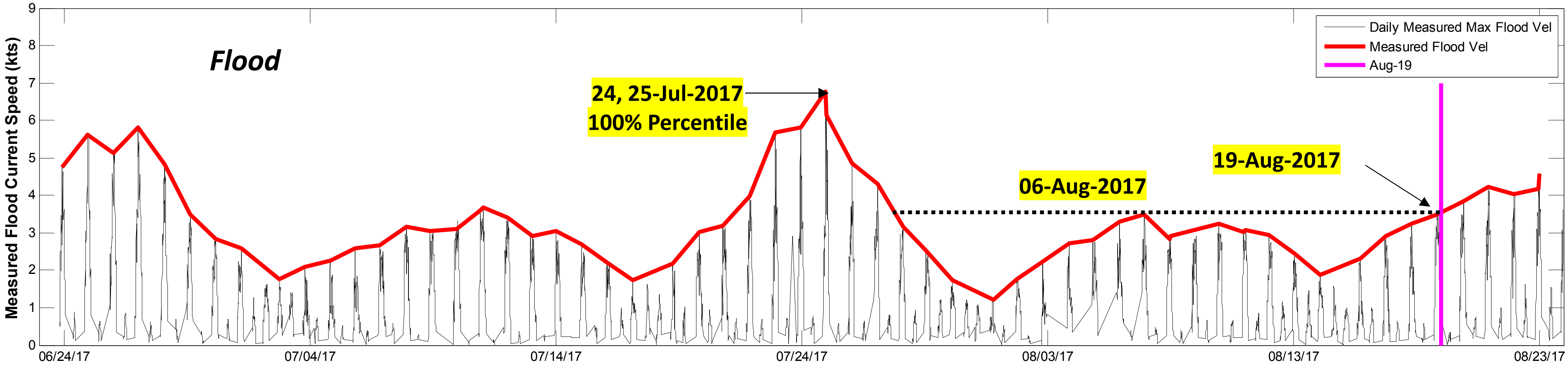
Predicted Tide Elevations – July 24th

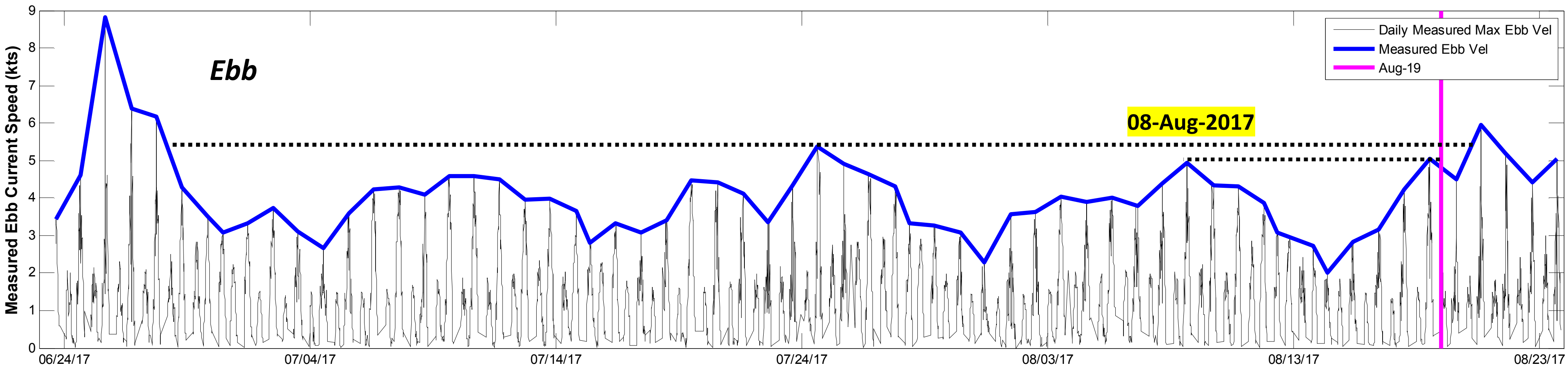


Predicted Tide Elevations – Aug 19th



Measured Currents – Summer 2017

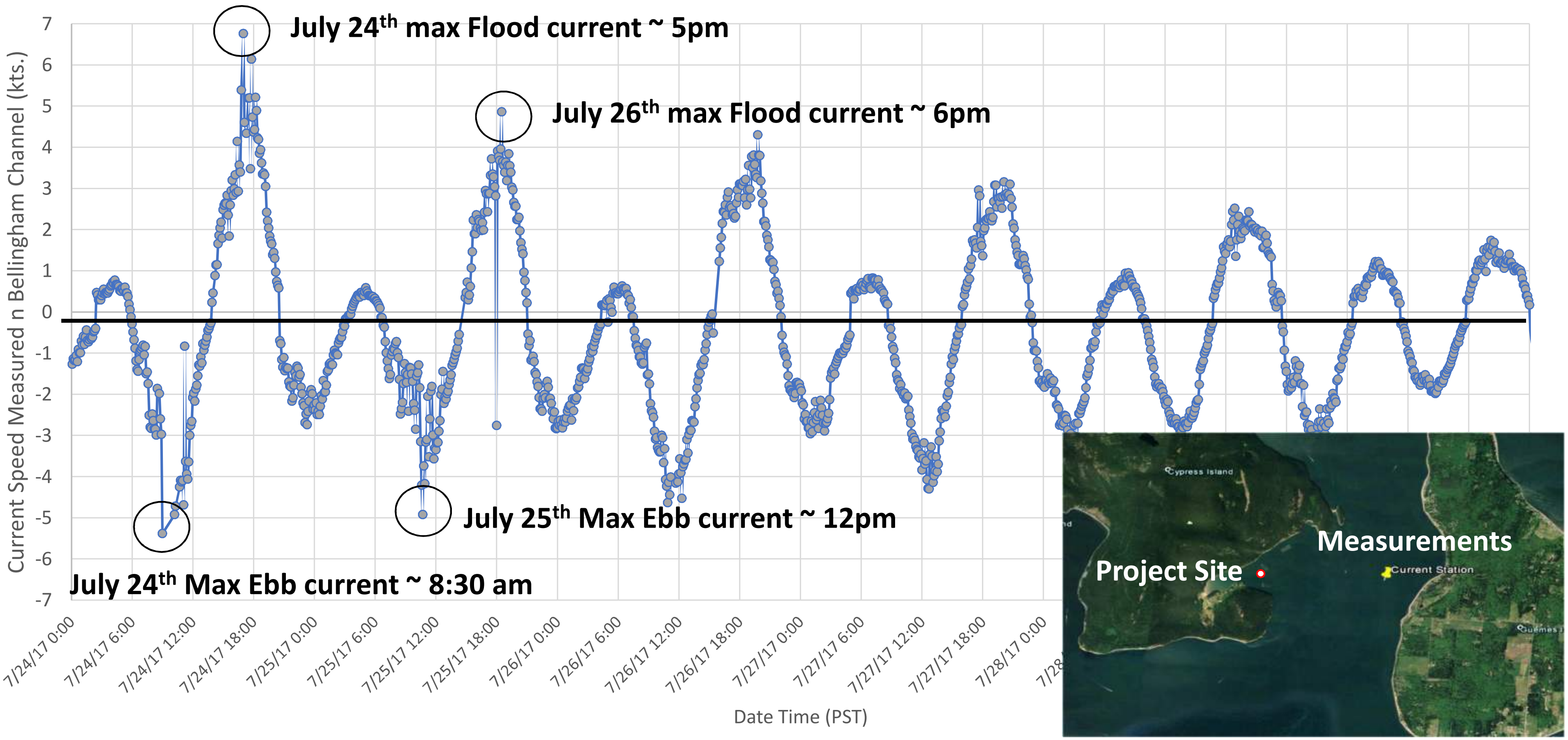




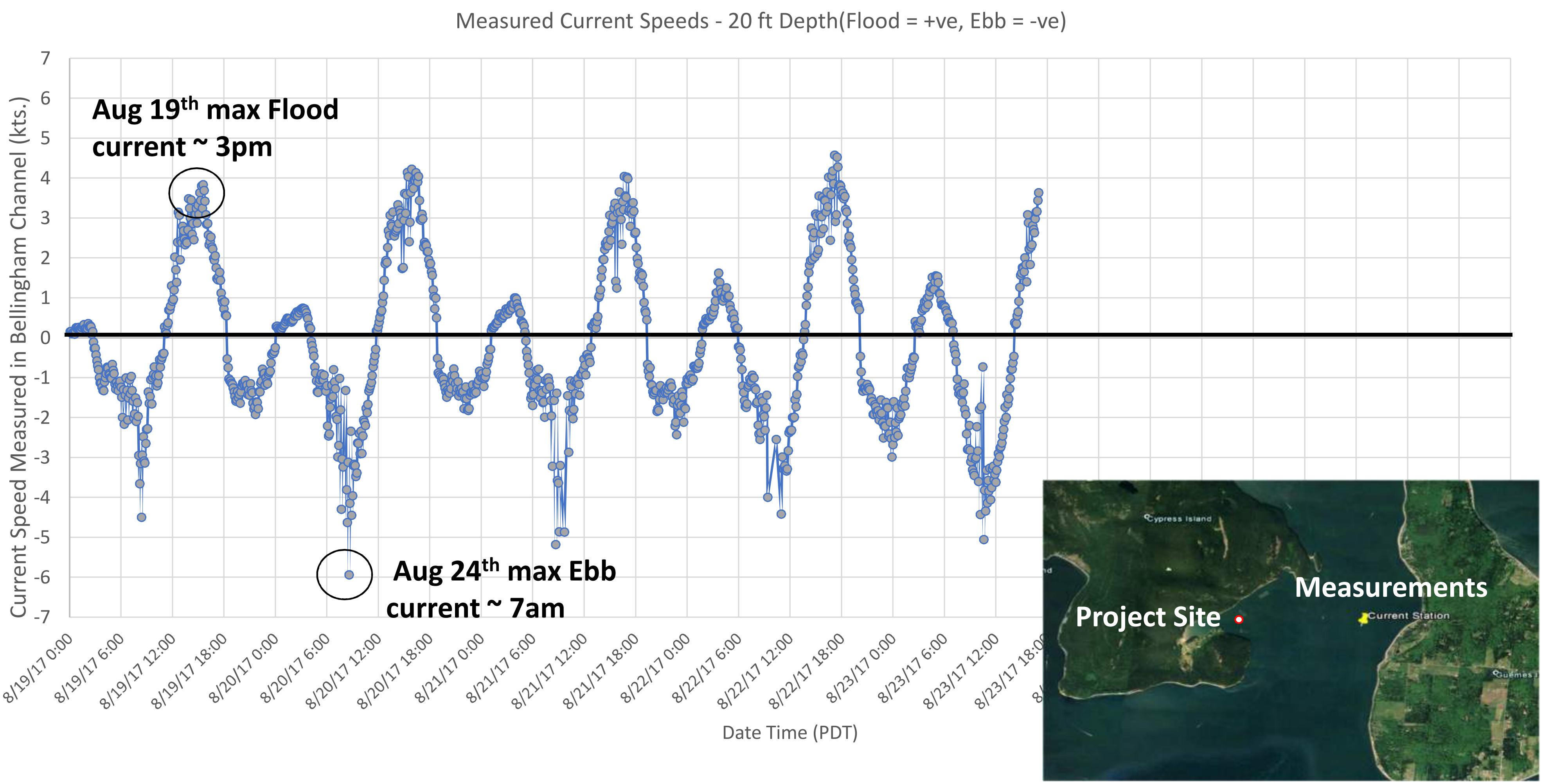
Note: Data is preliminary. Intended to represent conditions at the site relative to typical conditions only.

Measured Currents –July 2017

Legend:

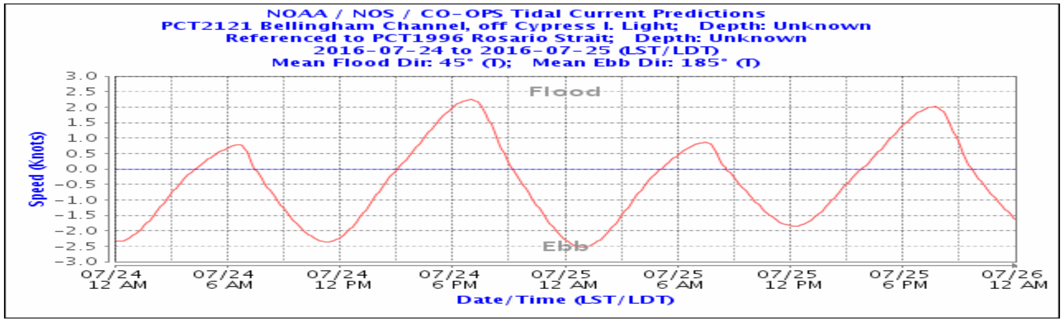


Measured Currents – August 2017

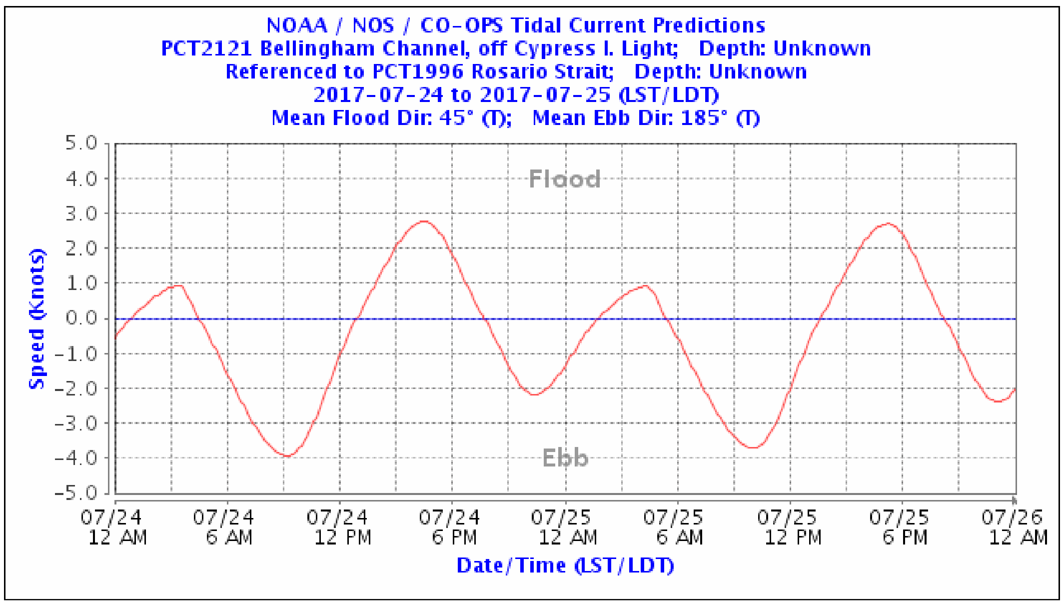


Year-to-Year Predicted Current Comparison: July

2016



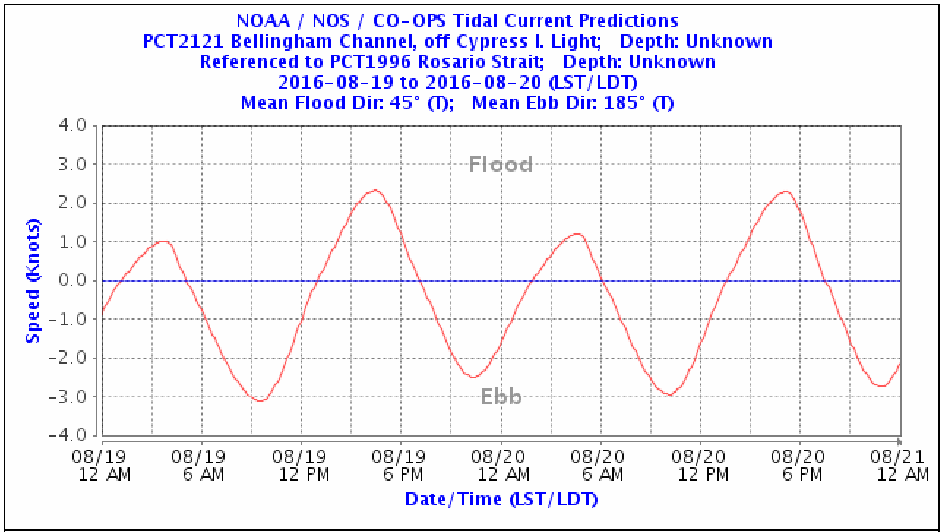
2017



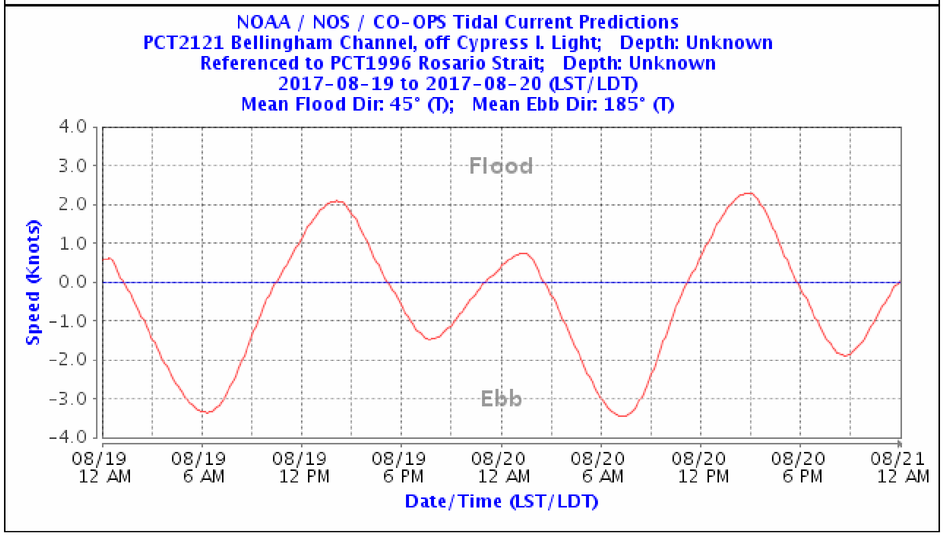
Similar predicted conditions: 2016, 2017. Slightly higher predicted in 2017.

Year-to-Year Predicted Current Comparison: August

2016



2017



Similar predicted conditions: 2016, 2017

Measured Currents At Site 1 (1994)

Year 2002 Cypress Inc. Net Pen NPDES Monitoring, Sites 1,2,3 and 4.

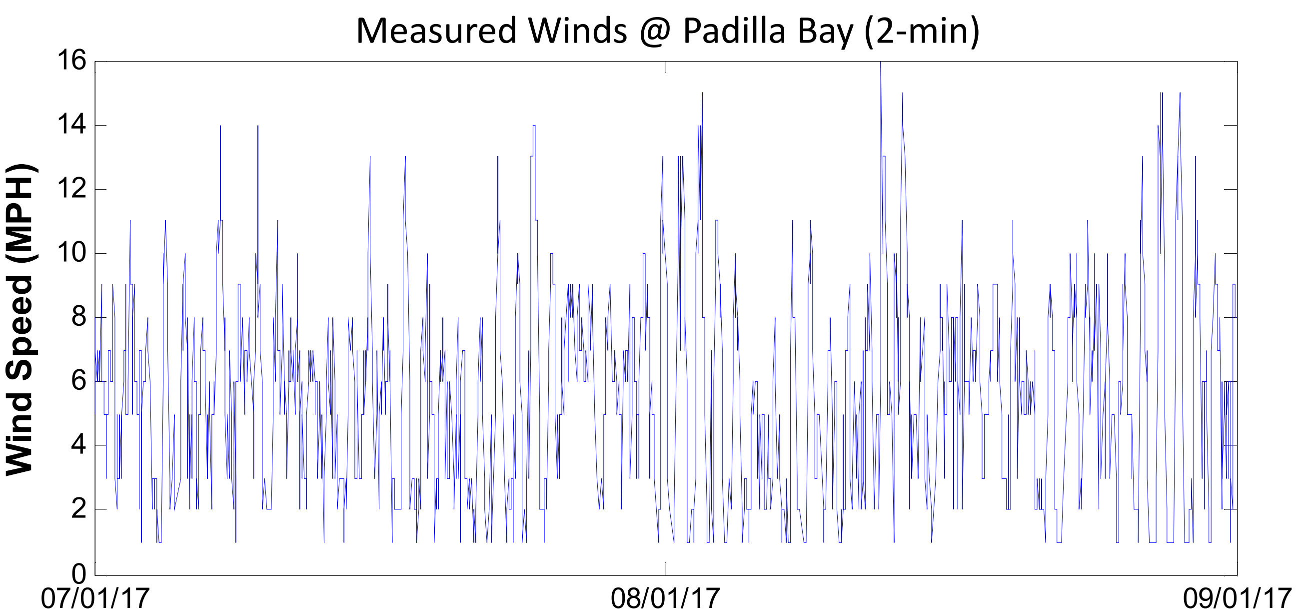
F. Average tidal velocity survey at Site 1, Deepwater Bay, September 21, 1994
Compiled 10/5/94 (Corrected 2/1/95) 2 meters depth from Rensel 1995, appendix.

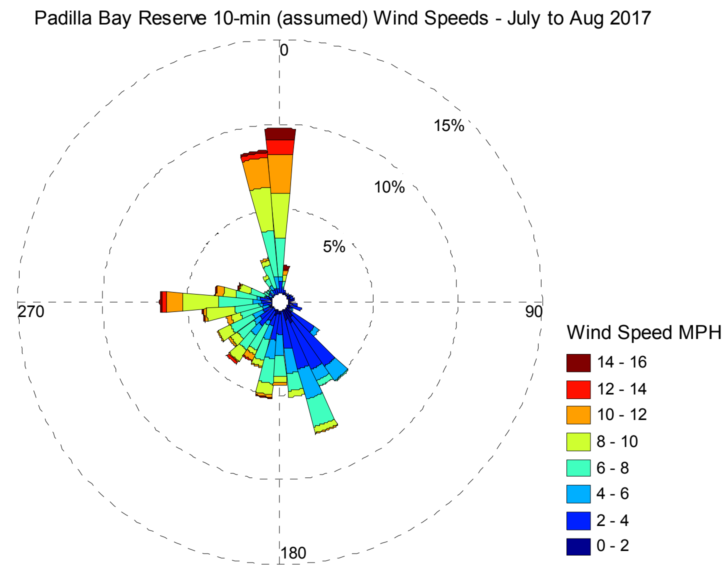
Time (24 hours)	Tidal Stage	Sampling Location	Speed cm/sec	Code	Speed knots	Magnetic Direction	Code	True Direction	Wind Dir. & speed knots
---------	---------	---------	---------	------	---------	---------	------	---------	---------
605	Ebb	W	12		0.24	243		263.5	0
630	Ebb	W	9		0.18	234		254.5	0
700	Ebb	W	6		0.12	210		230.5	0
735	Ebb	W	3	V	0.06	248		268.5	SW 1-2
800	Ebb	W	3	V	0.06	252		272.5	0
830	Ebb	W	3		0.06	235		255.5	0
900	Ebb	W	6		0.12	124		144.5	0
930	Ebb	E	30		0.59	100		120.5	0
955	Ebb	E	45		0.88	50		70.5	0
1040	Ebb	E	37		0.73	87		107.5	0
1118	Ebb	E	24		0.47	80		100.5	0
1158	Flood	E	36		0.71	102		122.5	0
1233	Flood	E	9		0.18	52		72.5	0
1303	Flood	W	9		0.18	320		340.5	0
1340	Flood	W	15		0.29	290		310.5	0
1410	Flood	W	12		0.24	273		293.5	0
1436	Flood	W	15		0.29	274		294.5	0
1506	Flood	W	24		0.47	278		298.5	0
1536	Flood	W	24		0.47	293		313.5	0
1606	Flood	W	9		0.18	165	V	185.5	0
1645	Flood	W	6		0.12	183		203.5	0
1715	Flood	W	6		0.12	320	V	340.5	0
1748	Flood	W	12		0.24	302		322.5	0
1800	Flood	W	18		0.35	312		332.5	0
Averages			15.5	cm/s	0.30	knots			
Minimum			3.0	cm/s	0.06	knots			
Maximum			45.0	cm/s	0.88	knots			

No correction factor applied as tides were very near the mean tidal range of 4.8 feet and in fact averaged out exactly 4.8 feet, the mean range for the area. Note: "Direction" of tidal flow means direction from. Sampling Location" refers to the location of the current meter relative to the pens. In all cases the meter was located at least 30 m from the cages to avoid influences of the pens Collected with a modified Magnysun meter. 5 minute averages taken at 2 m depth.

Note: Measured Currents at net pen #2 were not available.

Regional Winds (July – Aug 2017)

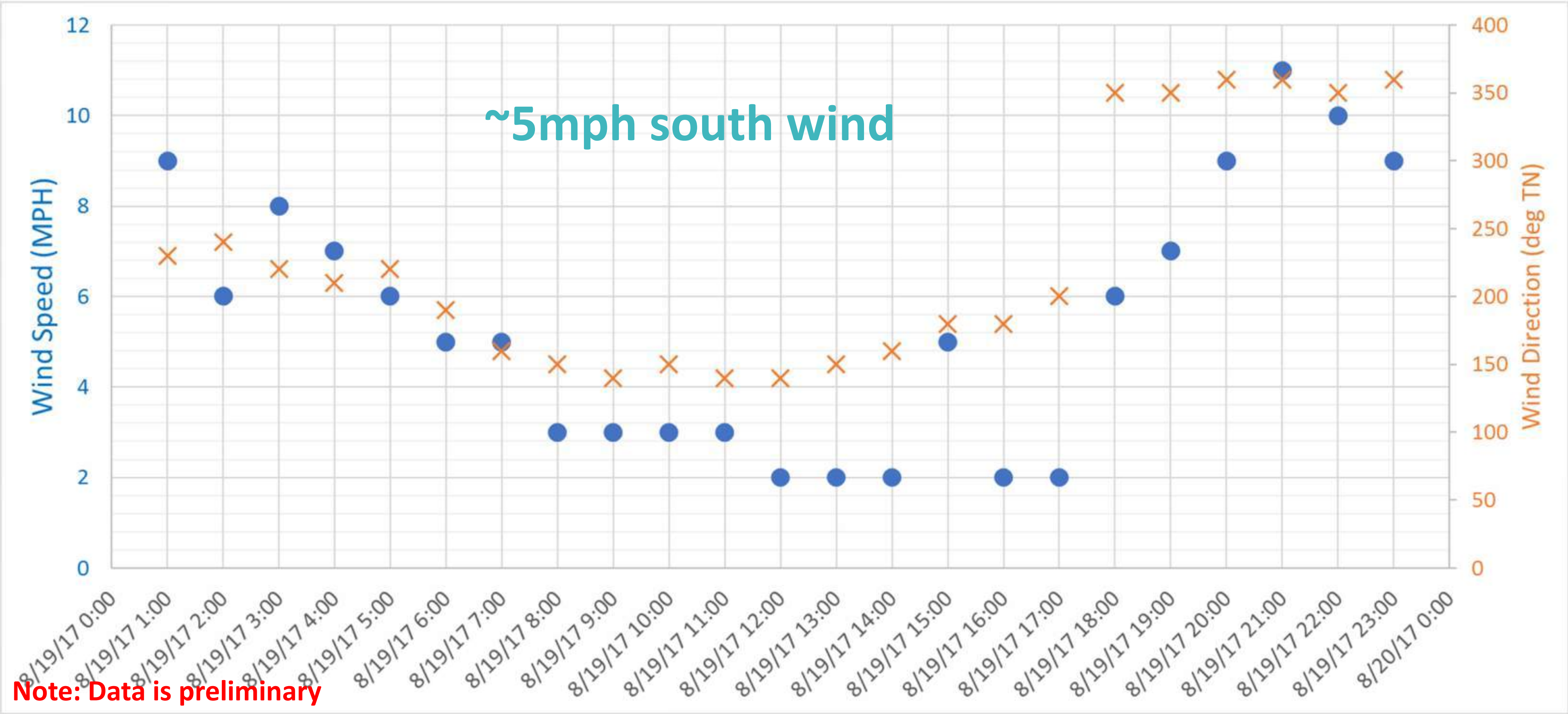




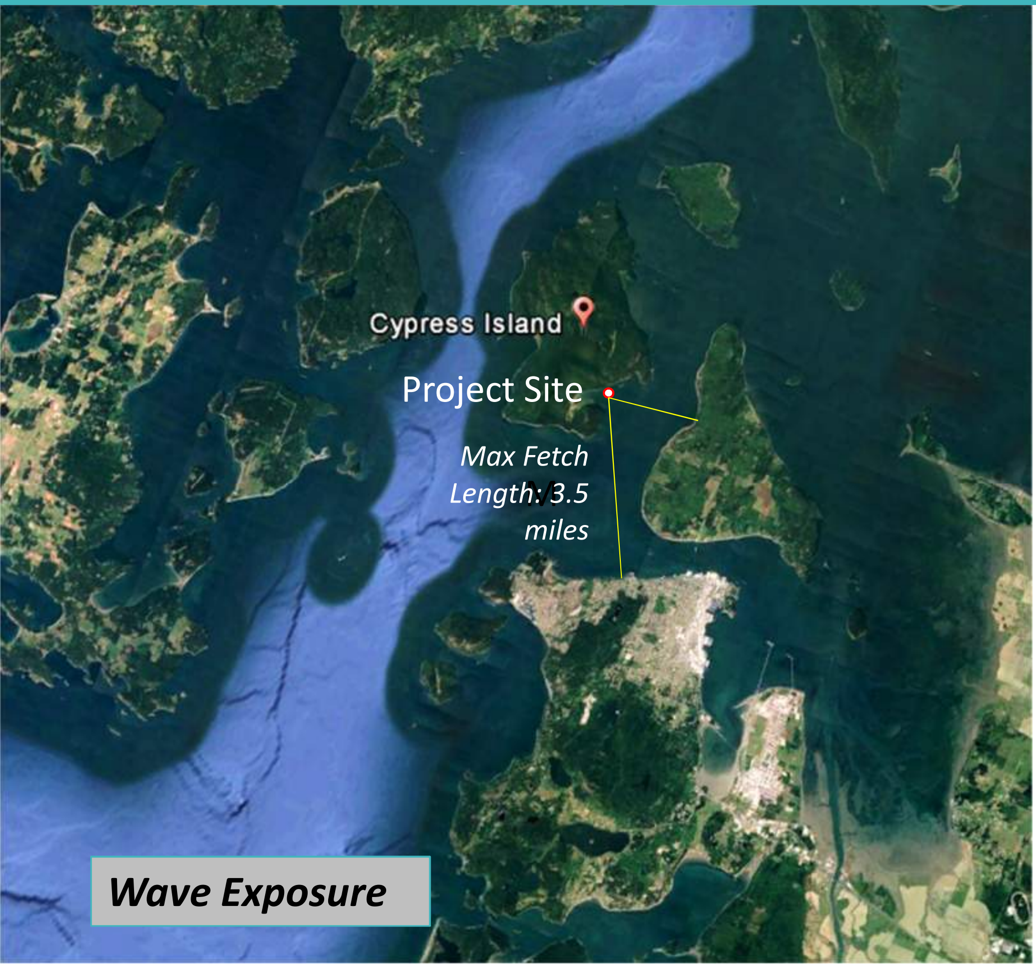
No major wind events

Note: Data is preliminary

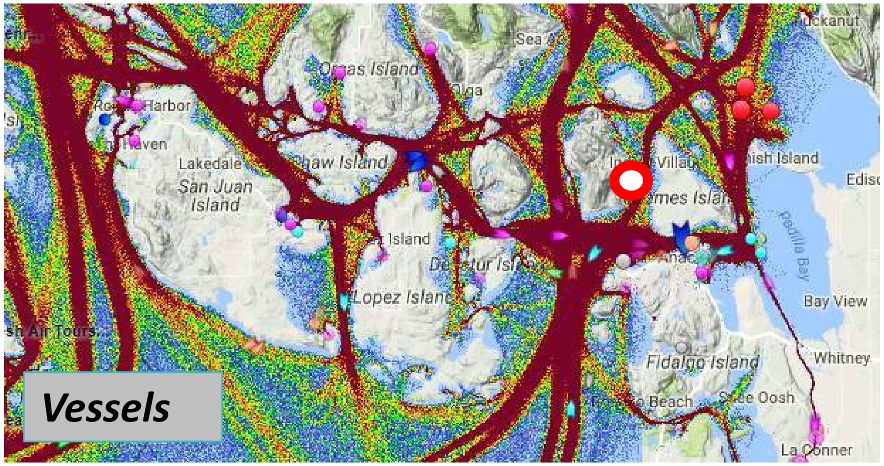
Winds: August 19th



Waves

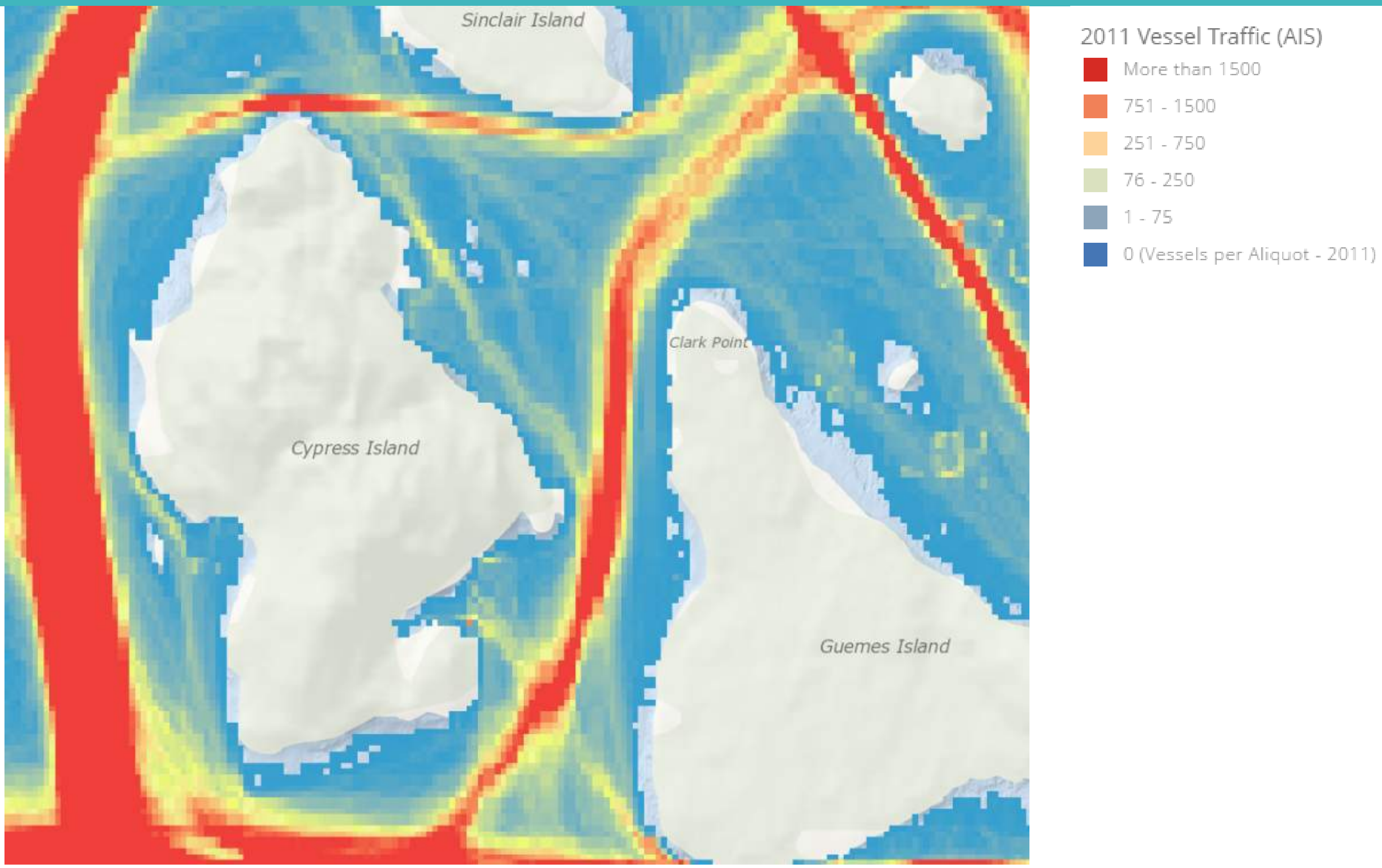


- **Moderately protected site**
- **Wind and waves - typical conditions throughout July/August**
- **Vessel Wakes**

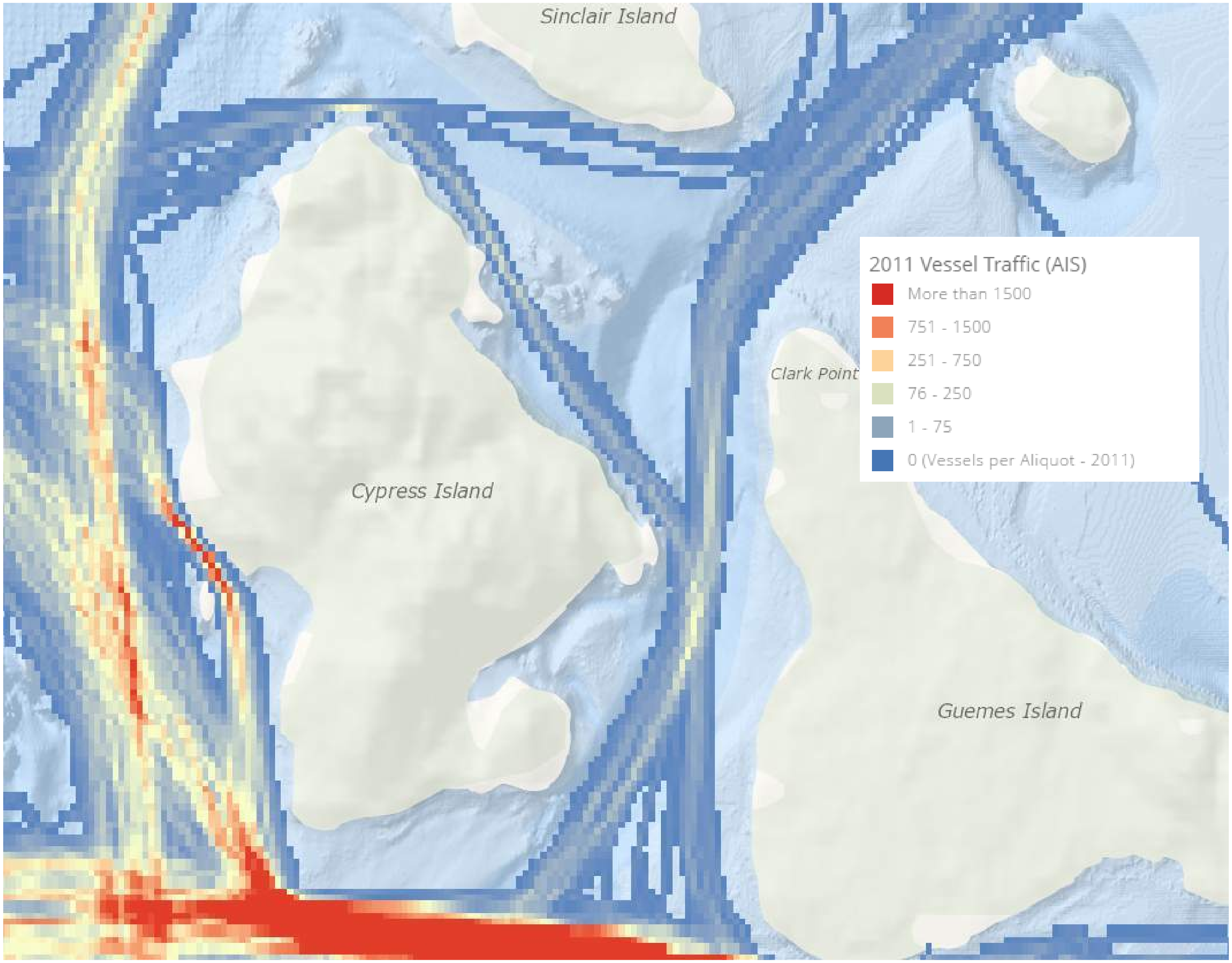


Cursory Vessel Traffic Review

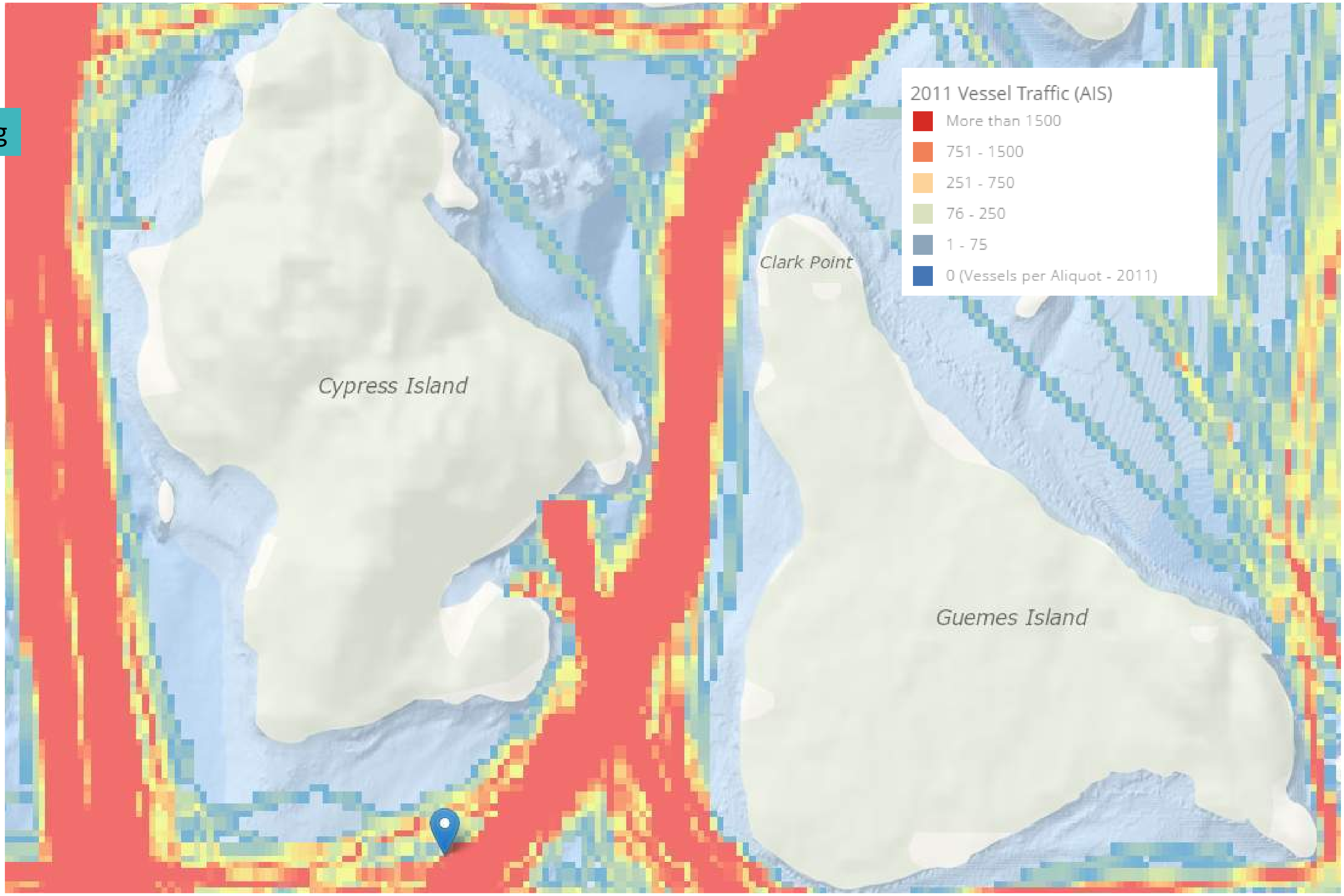
- <u>All Traffic</u>
  - Fishing
  - Cargo
  - Fishing
  - Passenger
  - Tanker
  - Pleasure
  - Tug and Towing



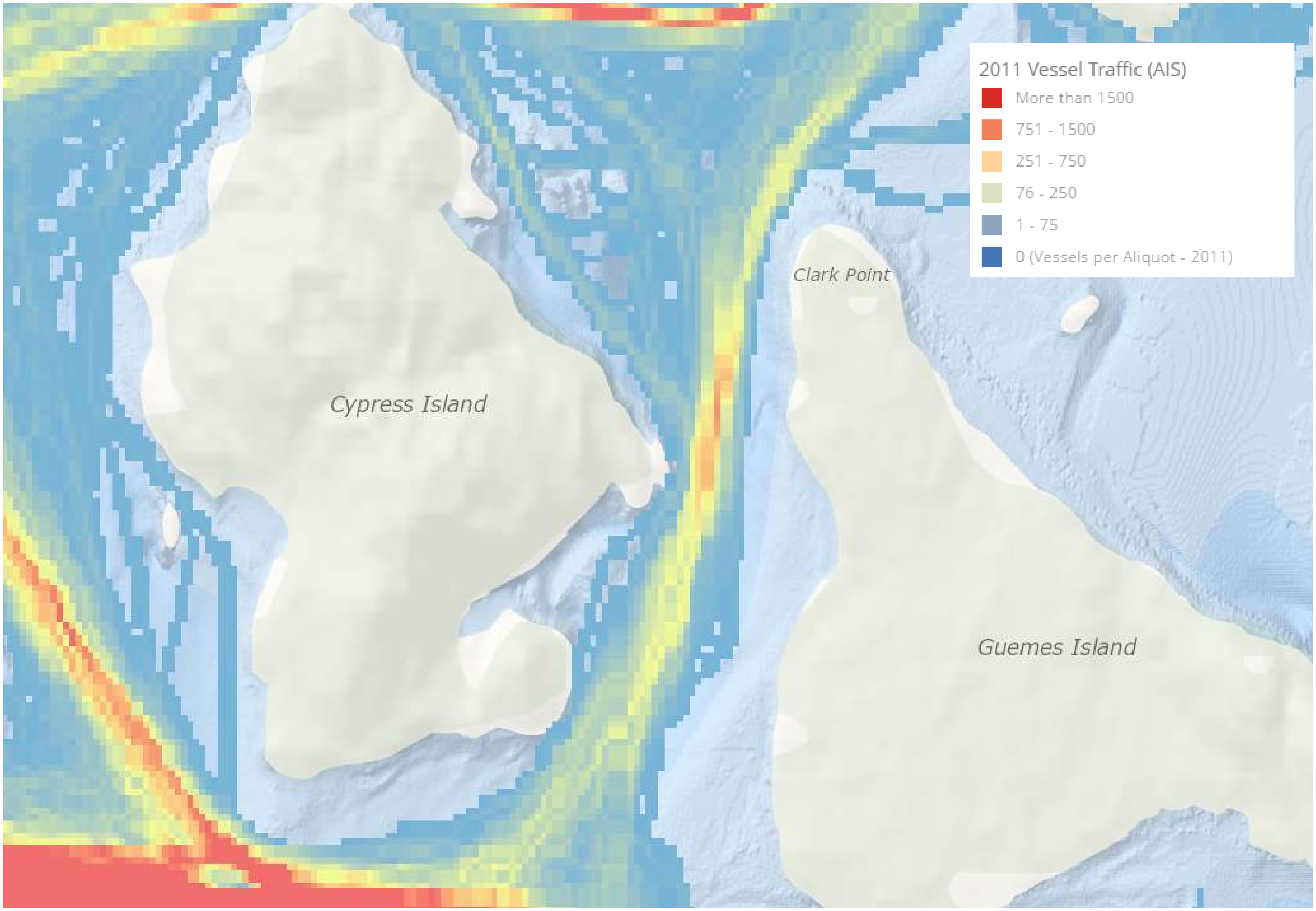
Cargo


Sinclair Island
Cypress Island
Clark Point
Guemes Island
2011 Vessel Traffic (AIS)
More than 1500
751 - 1500
251 - 750
76 - 250
1 - 75
0 (Vessels per Aliquot - 2011)

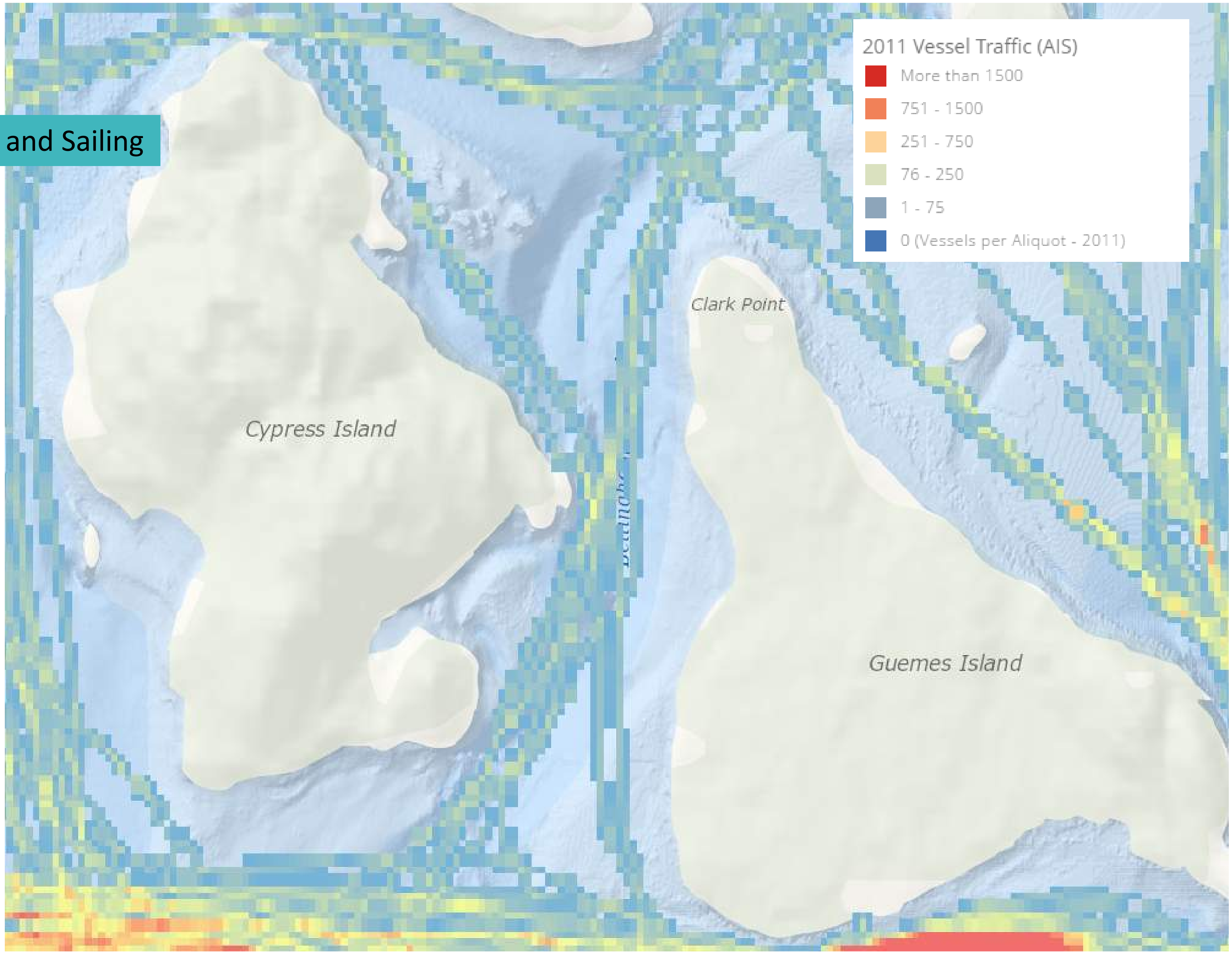
Fishing


2011 Vessel Traffic (AIS)
More than 1500
751 - 1500
251 - 750
76 - 250
1 - 75
0 (Vessels per Aliquot - 2011)
Cypress Island
Clark Point
Guemes Island

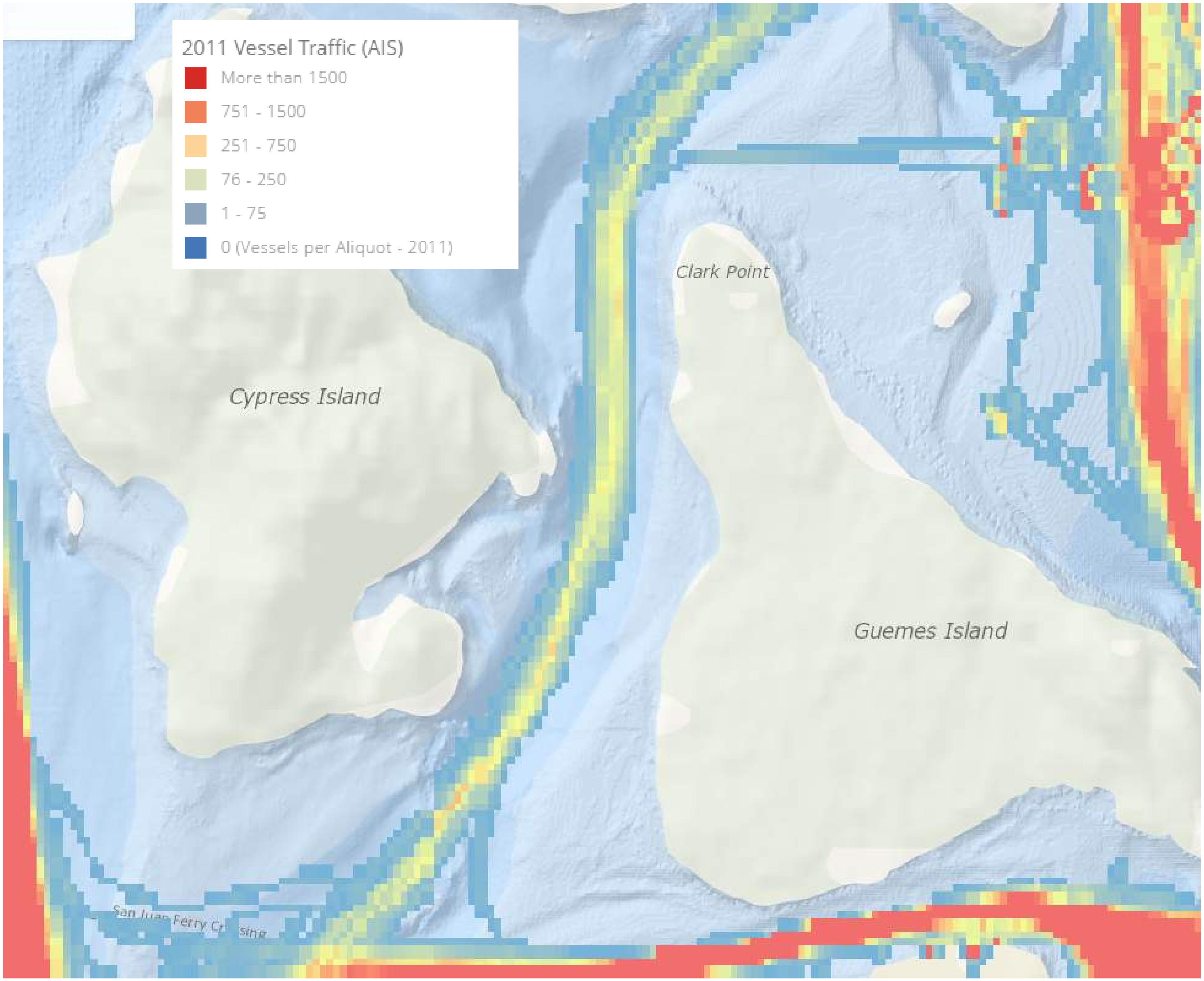
Passenger


2011 Vessel Traffic (AIS)
More than 1500
751 - 1500
251 - 750
76 - 250
1 - 75
0 (Vessels per Aliquot - 2011)
Clark Point
Cypress Island
Guemes Island

Pleasure Craft and Sailing

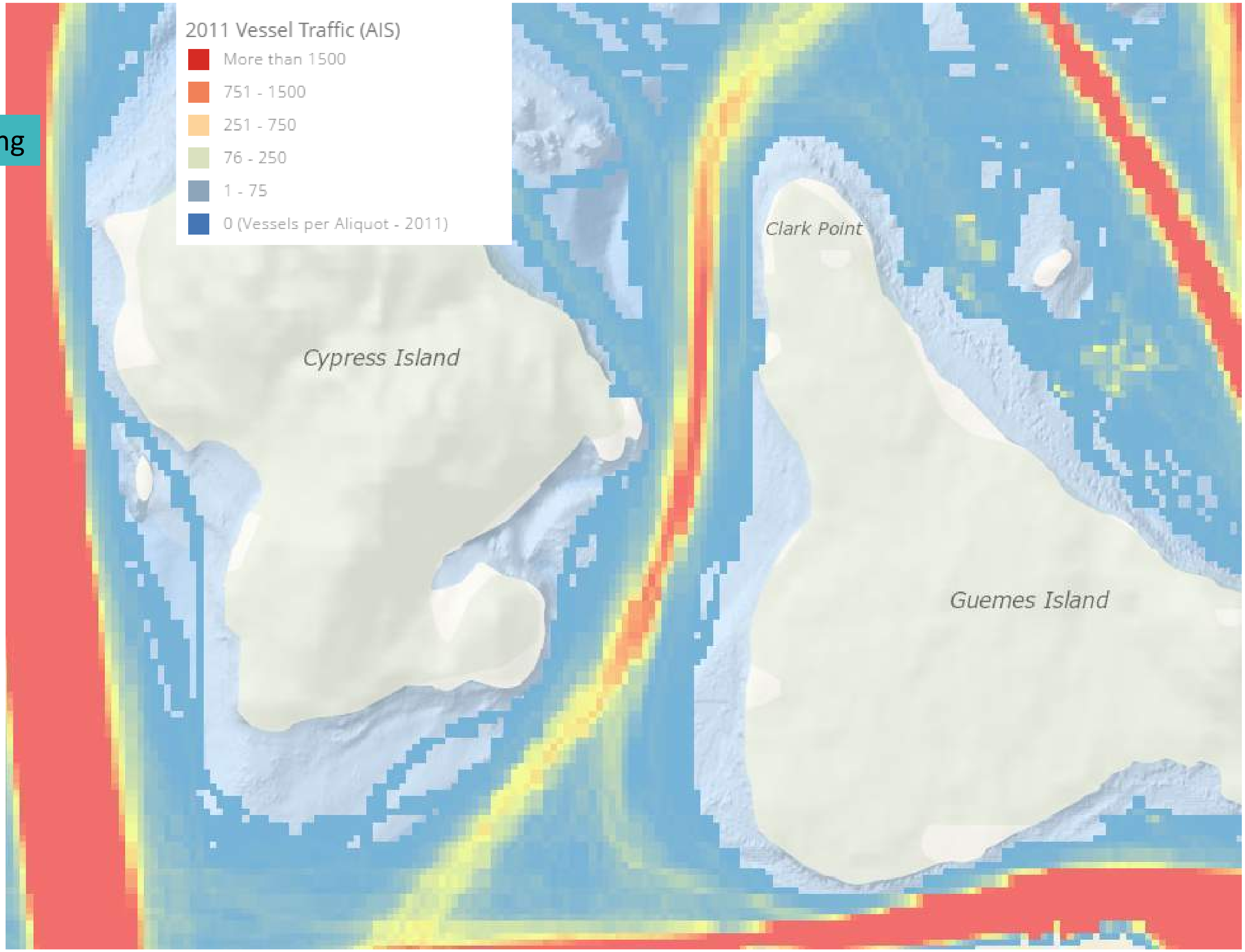


Tanker



2011 Vessel Traffic (AIS)
More than 1500
751 - 1500
251 - 750
76 - 250
1 - 75
0 (Vessels per Aliquot - 2011)
Clark Point
Cypress Island
Guemes Island

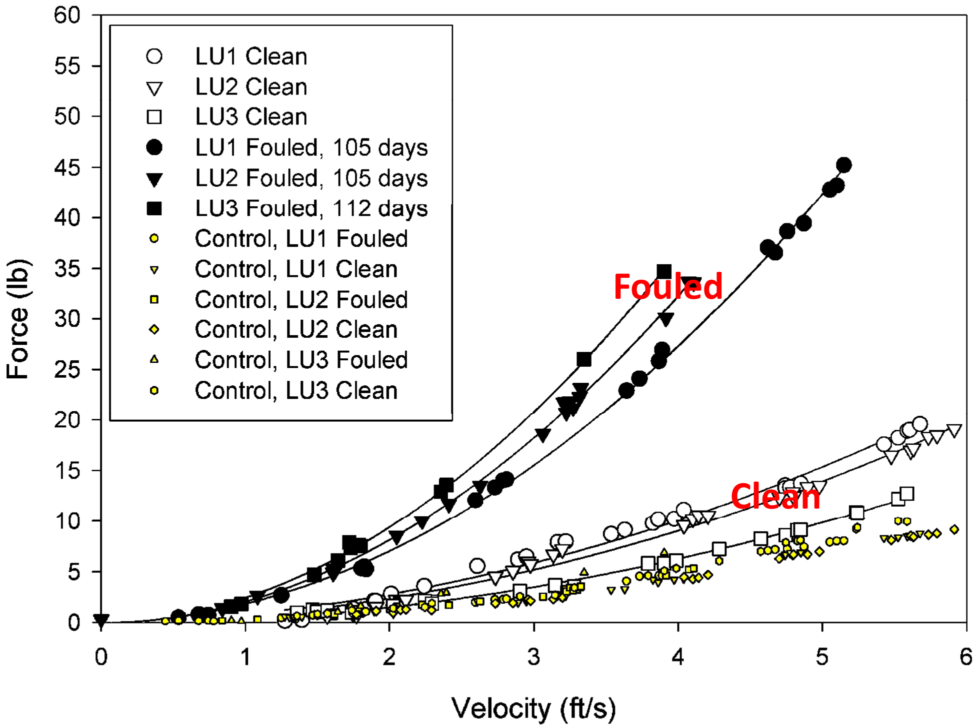
Tug and Towing



Marine Fouling

"Increase in fouling results in larger forces on the net."

Fouling can increase loads due to currents by up to 5 times



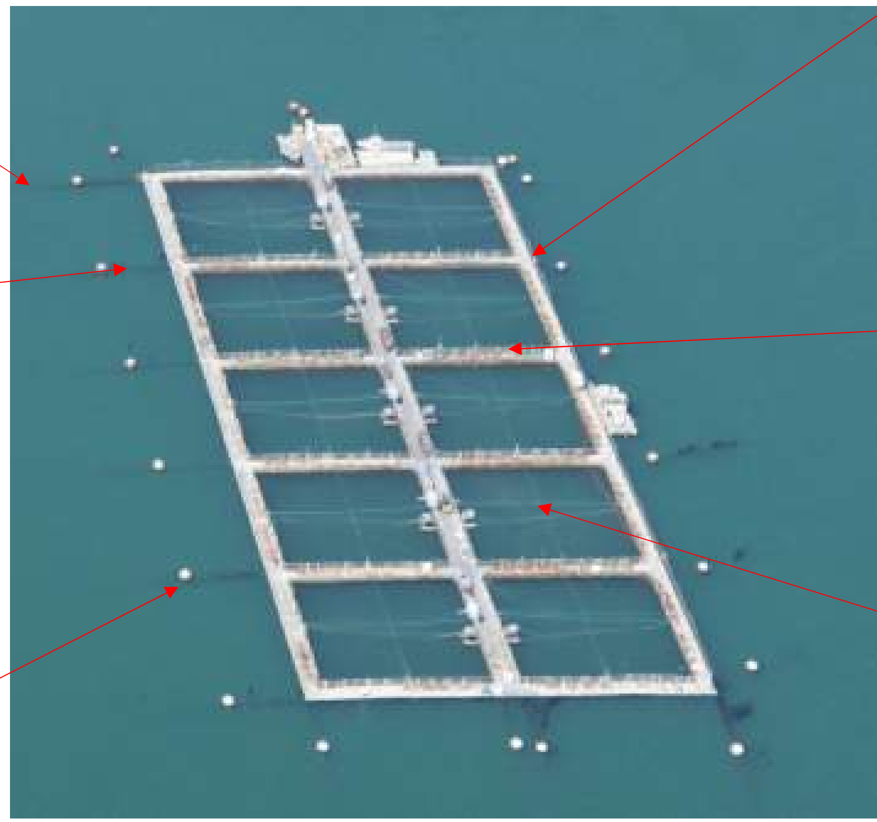
Geoffrey Swain and Nagahiko Shinjo (2014)

MAIN COMPONENTS OF THE NET PEN FACILITY
MOORING SYSTEM

ANCHOR

CHAIN AND ROPE

BUOYS



MOORING BRACKET

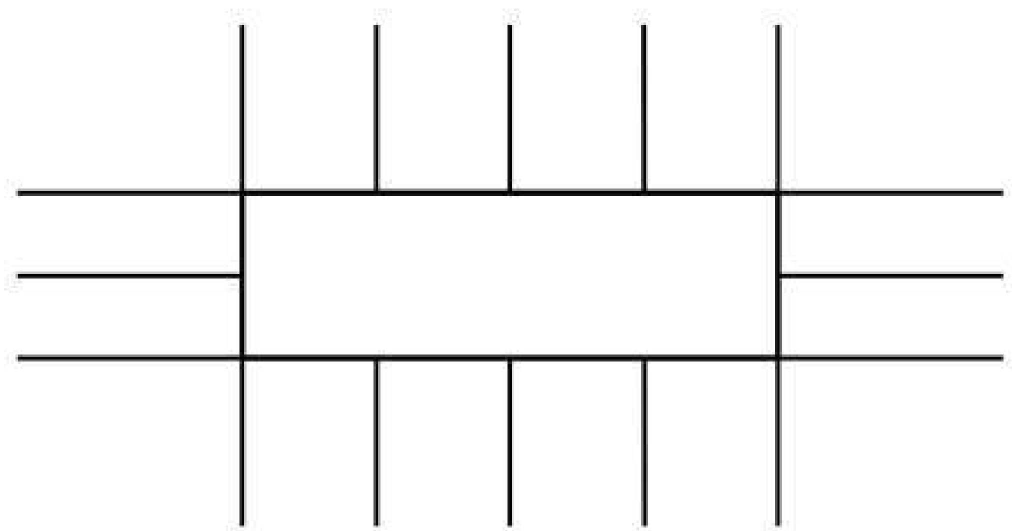
FLOATS

NETS

Mooring Review

Mooring Guidance

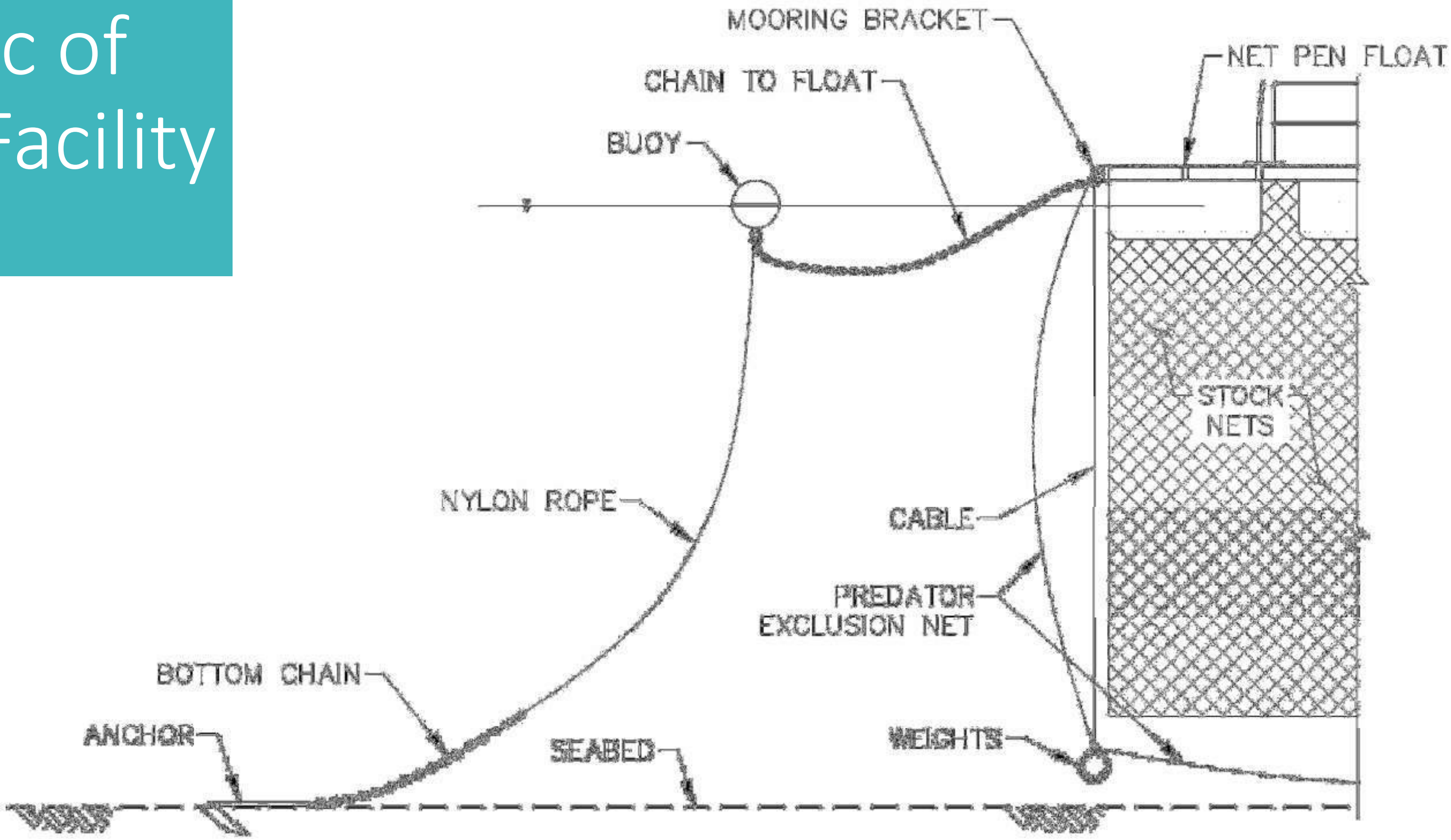
Orthogonal/Symmetrical Moorings



- Mooring design is site specific.
- Change in mooring system/layout will change distribution of loads on the mooring/anchoring system

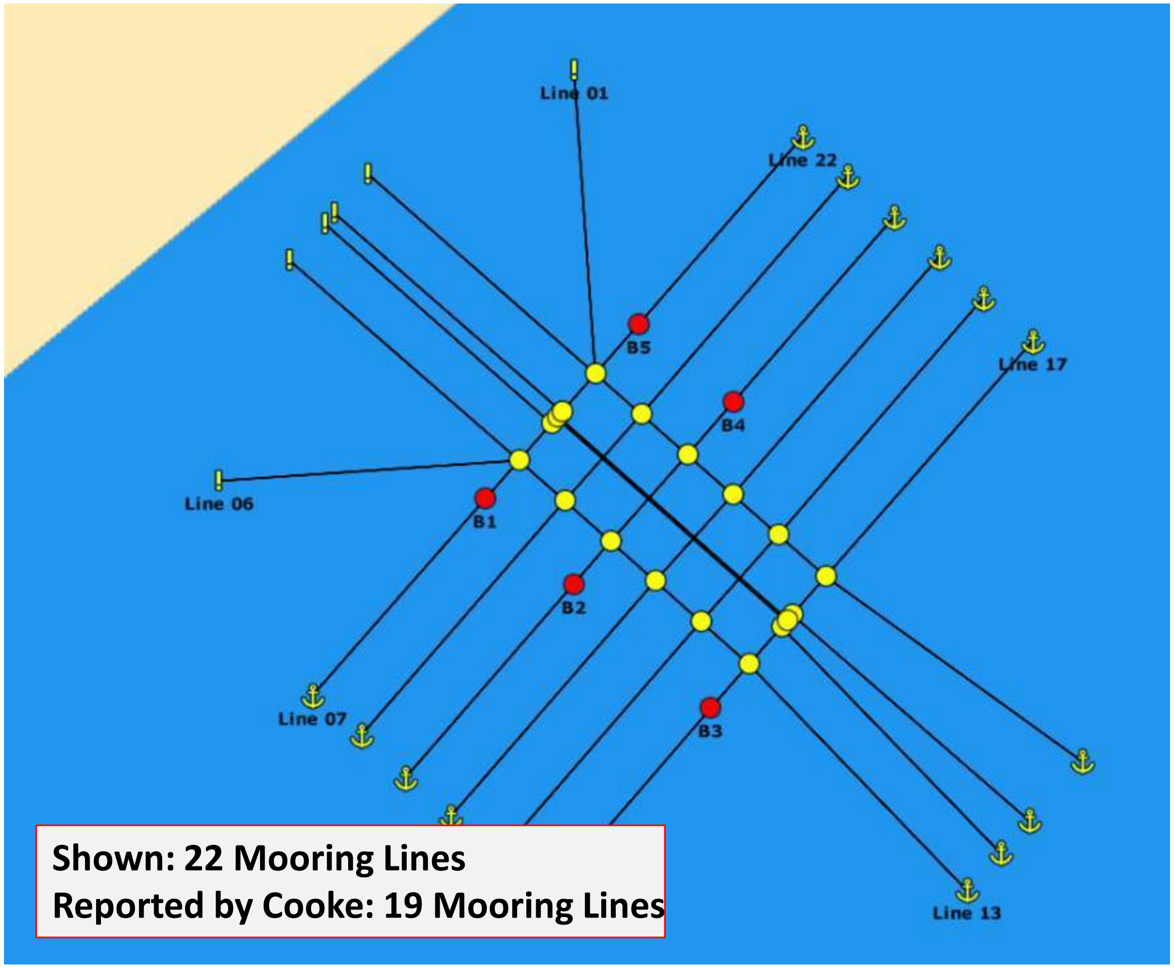
Net Pen Layout

Schematic of Net Pen Facility



SCHEMATIC SECTION
NOT TO SCALE

Mooring Analysis Review – Aquaknowledge (2015)



Shown: 22 Mooring Lines
Reported by Cooke: 19 Mooring Lines

Mooring Analysis Review – Aquaknowledge (2015)

LOAD CONDITION TABLE EXTRACTED FROM AQUAKNOWLEDGE STUDY

The combinations of environmental parameters that will be used in the analysis are shown in table 1.

Table 1 – Environmental parameters used for the eight directions

Load condition	Sector	From [°]	Wind [m/s]	Wave Hs [m]	Wave Tp [s]	Against [°]	Current [m/s] 5m	Current [m/s] 15m	Comment
		10 year wind and wave				50 year current			
1	N	0	19.5	0.34	1.59	180	0.61	0.61	Highest current
2	NE	45	31.6	1.60	3.64	225	0.83	0.83	Highest current
3	E	90	19.5	0.73	2.62	270	0.17	0.17	Highest current
4	SE	135	19.5	1.07	3.38	315	0.44	0.44	Highest current
5	S	180	21.9	1.24	3.57	0	0.28	0.28	Highest current
6	SW	225	30.5	0.73	2.18	45	0.56	0.56	Highest current
7	W	270	19.5	0.34	1.59	90	0.83	0.83	Highest current
8	NW	307	19.5	0.26	1.33	135	0.67	0.67	Highest current
		50 year wind and wave				10 year current			
9	N	0	21.6	0.39	1.65	180	0.54	0.54	Highest current
10	NE	45	35.0	1.82	3.80	225	0.74	0.74	Highest current
11	E	90	21.6	0.83	2.73	270	0.15	0.15	Highest current
12	SE	135	21.6	1.21	3.52	315	0.40	0.40	Highest current
13	S	180	24.3	1.41	3.72	0	0.25	0.25	Highest current
14	SW	225	33.8	0.83	2.28	45	0.50	0.50	Highest current
15	W	270	21.6	0.39	1.65	90	0.74	0.74	Highest current
16	NW	307	21.6	0.30	1.38	135	0.59	0.59	Highest current

Mooring Analysis Review – Aquaknowledge (2015)

FAILURE ANALYSIS TABLE EXTRACTED FROM AQUAKNOWLEDGE STUDY

Table 8 – Accident conditions and assessments

Results and assessments of the accidents conditions				
Environmental load condition:	**10**	**10**	**10**	**2**
Analysed:	Break of mooringline 18	Break of mooringline 19	Break of mooringline 20	Break of mooringline 21
Highest force appear in:	Mooringline 17	Mooringline 17	Mooringline 22	Mooringline 22
Figur:	7.3	7.4	7.5	7.6
Maximum load in establishment of capacity:	24.8	24.8	22.9	22.9
Establishment of capasity including safety factor:	85.5	85.5	79.1	79.1
Maximum load in accident condition:	30.5	30.5	31.3	31.3
Accident condition including total safety factor	61.0	61.0	62.6	62.6
Margin:	24.5	24.5	16.6	16.6
Comment:	OK	OK	OK	OK

Maximum current for eight directions have been obtained from a Excel sheet. 10 and 50 year currents are found by applying the factors 1.65 and 1.85 to the maximum current for all eight directions.

Mooring Analysis Review – Icicle Seafoods (Excel)

Icicle Seafoods
Deep Harbor - system #1

force on 24m x 24m square cage	**actual**		**NS 9415**	**design**
Angle from longitudinal (degrees)	0		50 year return period	1
measured velocity cm/sec	60		cm/sec	60
Velocity knot	1.2		knot	1.2
ft/sec	2.0		ft/sec	2.0
longitudinal component (cm/sec)	60.0			
longitudinal component (ft/sec)	1.97			
Cd	0.3			
Biofouling growth factor (assumed)	25%			
Design coefficient of drag	0.375			

	Fd	Actual tons on cage	Fd	Design tons on cage
	5,628	2.8	5,628	2.8

sea water density slugs/ft3: 2

	ft	m
width	79	24
depth	49	15

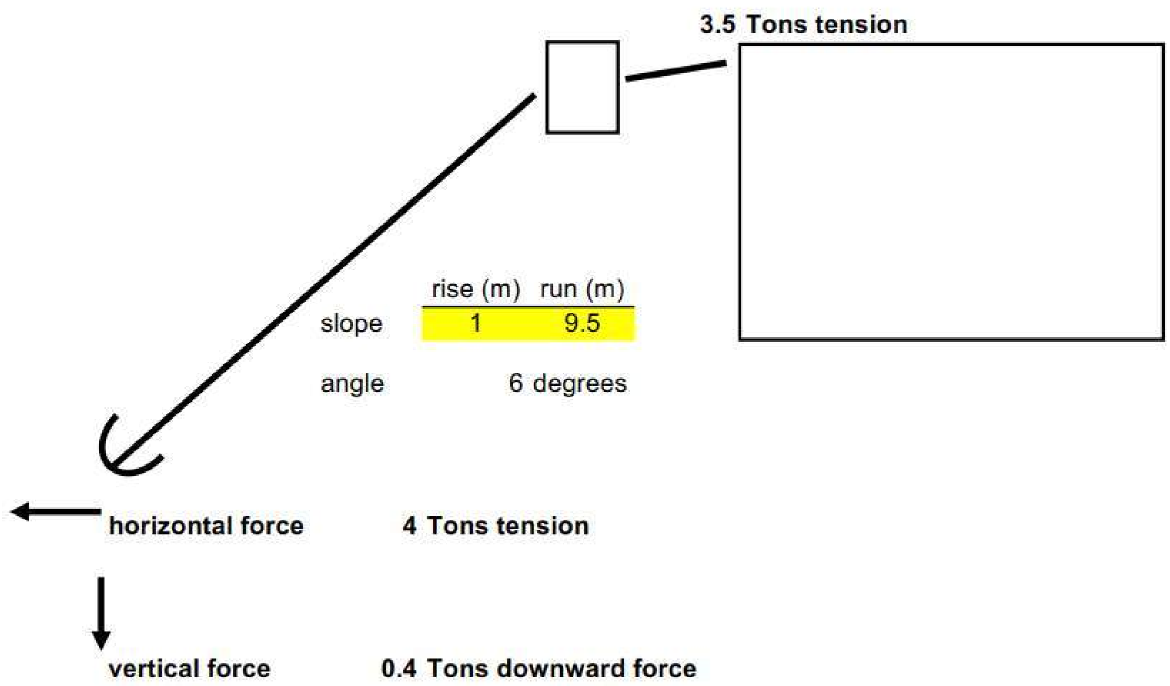
velocity reduction %	cage #	Fd	tons on cage
0%	1		2.8
15%	2		2.0
30%	3		1.4
45%	4		0.9

total force on system		
	tons	7.1
	tonnes	6.3

Mooring Analysis Review – Icicle Seafoods (Excel)

force on 24m x 24m square cage

number of anchor lines 2



Mooring Analysis Review – Icicle Seafoods (Excel)

Site #2

anchor #	scope	buoy depth %	buoy flotation (tons)	anchor tension (tons)	NS 9415 1.85 50 year force	NS9415 mooring load factor	design mooring force	anchor safety margin	chain (tons) 1-1/2" stud link	NS9415 chain material factor	chain safety factor	rope	diameter	breaking strength (lbs)	NS9415 rope material factor	design rope force (tons)	rope capacity (tons)	rope safety factor	NS9415 load factor rope break	NS9415 rope break force (tons)	NS9415 rope material factor rope break	rope breaking capacity (tons)	rope breaking safety factor
1	8	0.5	0.2	1.6	5	1.6	8.8	1.1	91.5	2.0	5.2	8 strand poly	2"	70000	3	9	12	1.3	1.0		1.5	23	
2	8	0	0.2	1.6	5	1.6	8.8	1.1	91.5	2.0	5.2	8 strand poly	2"	70000	3	9	12	1.3	1.0		1.5	12	
3	8	0	0.2	1.6	5	1.6	8.8	1.1	91.5	2.0	5.2	8 strand poly	2"	70000	3	9	12	1.3	1.0	11	1.5	12	1.1
4	8	0	0.2	1.6	5	1.6	8.8	1.1	91.5	2.0	5.2	8 strand poly	2"	70000	3	9	12	1.3	1.0		1.5	12	
5	8	0	0.2	1.6	5	1.6	8.8	1.1	91.5	2.0	5.2	8 strand poly	2"	70000	3	9	12	1.3	1.0		1.5	12	
6	8	0	0.2	1.6	5	1.6	8.8	1.1	91.5	2.0	5.2	8 strand poly	2"	70000	3	9	12	1.3	1.0		1.5	12	
7	8	0.5	0.6	4.8	16	1.6	26.3	1.5	91.5	2.0	1.7	8 strand poly	2"	70000	3	26	12	0.4	1.0		1.5	12	
8	8	0.5	0.6	4.8	16	1.6	26.3	1.9	91.5	2.0	1.7	8 strand poly	2"	70000	3	26	12	0.4	1.0		1.5	12	
9	9	0.5	0.6	5.4	18	1.6	29.6	2.7	91.5	2.0	1.5	8 strand poly	2"	70000	3	30	12	0.4	1.0	37	1.5	12	0.3
10	9	0.5	0.6	5.4	18	1.6	29.6	1.7	91.5	2.0	1.5	8 strand poly	2"	70000	3	30	12	0.4	1.0		1.5	12	
11	10	0.5	0.6	6.0	21	1.6	32.9	1.5	91.5	2.0	1.4	8 strand poly	2"	70000	3	33	12	0.4	1.0		1.5	12	
12	10	0.5	0.6	6.0	21	1.6	32.9	1.1	91.5	2.0	1.4	8 strand poly	2"	70000	3	33	12	0.4	1.0		1.5	12	
13	6	0.5	0.6	3.6	12	1.6	19.7	1.3	91.5	2.0	2.3	8 strand poly	2"	70000	3	20	12	0.6	1.0		1.5	12	
14	6	0.5	0.6	3.6	12	1.6	19.7	1.5	91.5	2.0	2.3	8 strand poly	2"	70000	3	20	12	0.6	1.0	25	1.5	12	0.5
15	6	0.5	0.6	3.6	12	1.6	19.7	2.5	91.5	2.0	2.3	8 strand poly	2"	70000	3	20	12	0.6	1.0		1.5	12	
16	6	0.5	0.6	3.6	12	1.6	19.7	2.5	91.5	2.0	2.3	8 strand poly	2"	70000	3	20	12	0.6	1.0		1.5	12	
17	4	0.5	0.6	2.4	8	1.6	13.1	3.8	91.5	2.0	3.5	8 strand poly	2"	70000	3	13	12	0.9	1.0		1.5	12	
18	4	0.5	0.6	2.4	8	1.6	13.1	3.8	91.5	2.0	3.5	8 strand poly	2"	70000	3	13	12	0.9	1.0		1.5	12	
19	4	0.5	0.6	2.4	8	1.6	13.1	6.1	91.5	2.0	3.5	8 strand poly	2"	70000	3	13	12	0.9	1.0		1.5	12	
20	4	0.5	0.6	2.4	8	1.6	13.1	3.8	91.5	2.0	3.5	8 strand poly	2"	70000	3	13	12	0.9	1.0		1.5	12	
21	4	0.5	0.6	2.4	8	1.6	13.1	3.0	91.5	2.0	3.5	8 strand poly	2"	70000	3	13	12	0.9	1.0		1.5	12	
22	4	0.5	0.6	2.4	8	1.6	13.1	3.0	91.5	2.0	3.5	8 strand poly	2"	70000	3	13	12	0.9	1.0		1.5	12	

Mooring Connections to Net Pen– Recommendations from Manufacturer

All moorings must be kept evenly tight over time. A periodic check once a month of the moorings is recommended. In period with high sea state and/or strong current, such check must be done more frequently. To perform such a check, it is easily done by a person with mooring experience to step on the hen foot chains to feel that the moorings are evenly tight. The force, to which each mooring is tightened to, shall be approx. 300 kg.

5.2. *Periodic maintenance*

Every month perform a visual inspection on the plant. In general pay attention to corrosion on all steel Construction. If any corrosion is found, take the necessary preventive actions to stop further corrosion. In particular pay attention to:

5.2.1. Monthly

5.2.1.1. Mooring

Check that moorings are evenly tight. If necessary, adjust the stretch of the relevant adjusting chain.

5.2.1.2. Hinges

Look for no damage on the bolts and nylon cones and that they are tight. See that the bolts do not rotate.

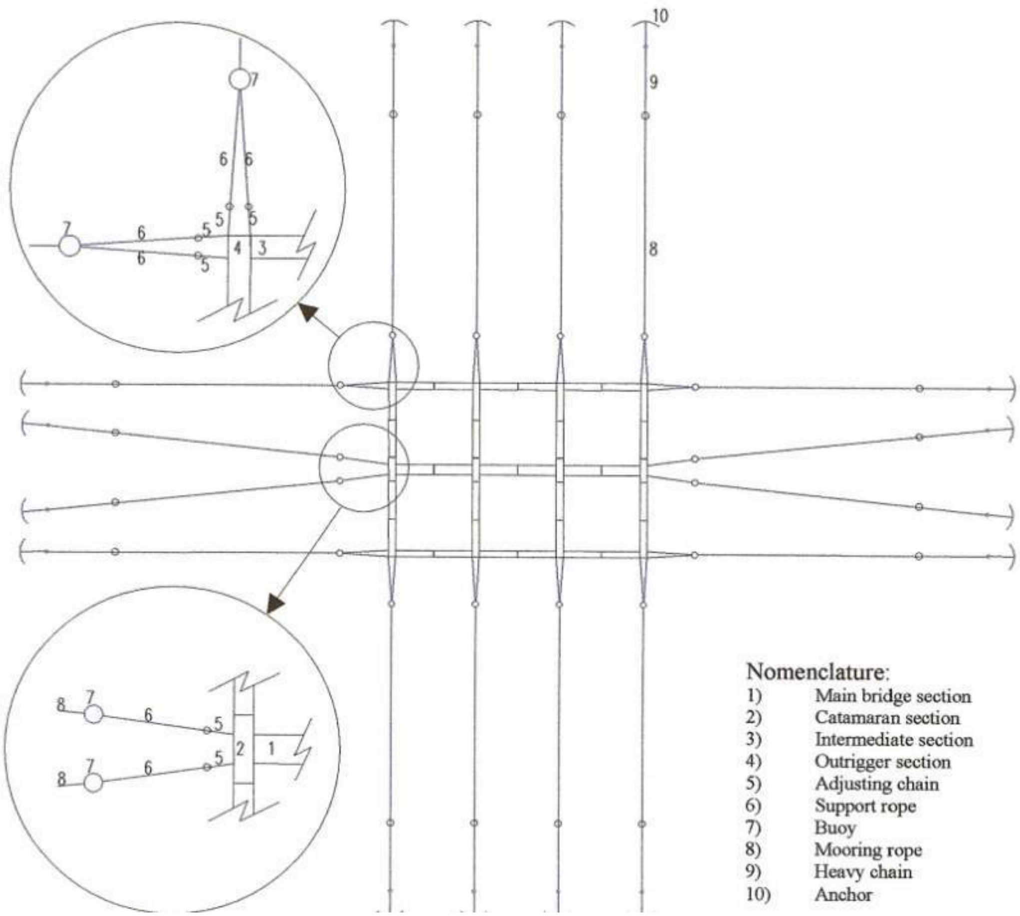
5.2.1.3. Net poles

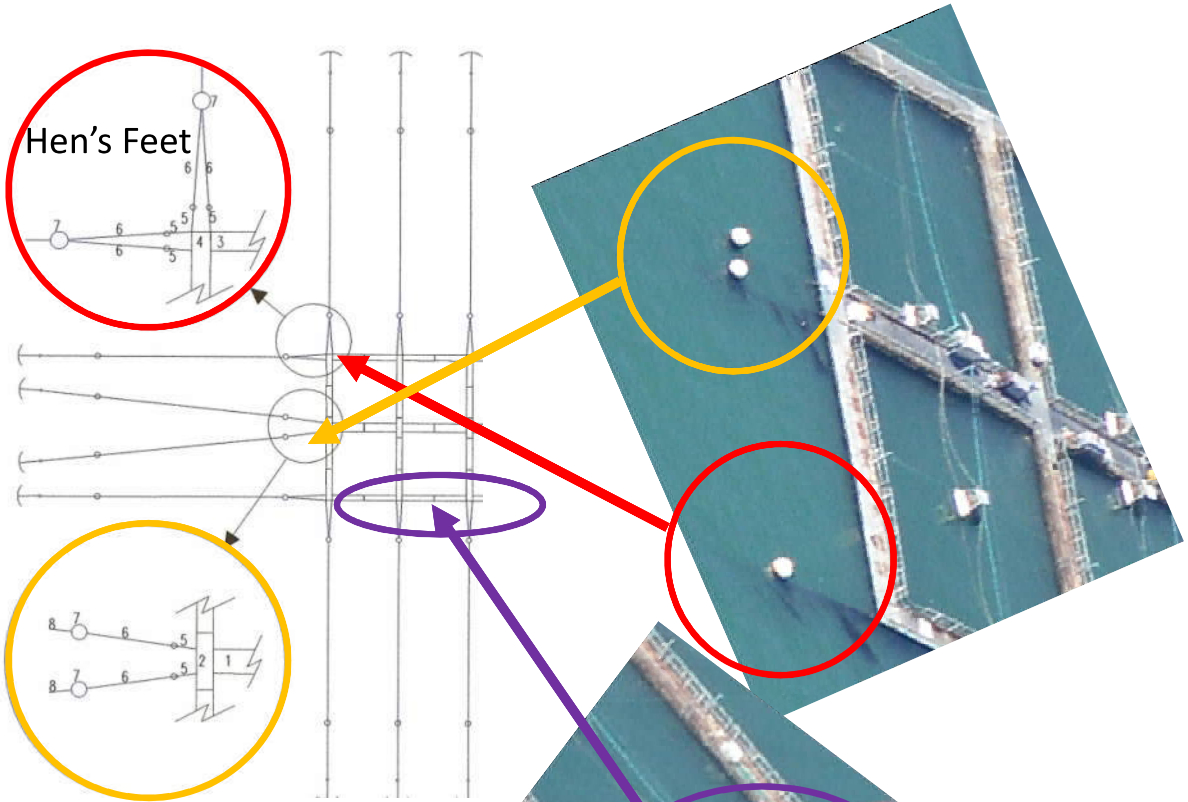
Check that the ropes or wires are not to tight to allow movement with sections. Look for deformation or bending. If any, replace.

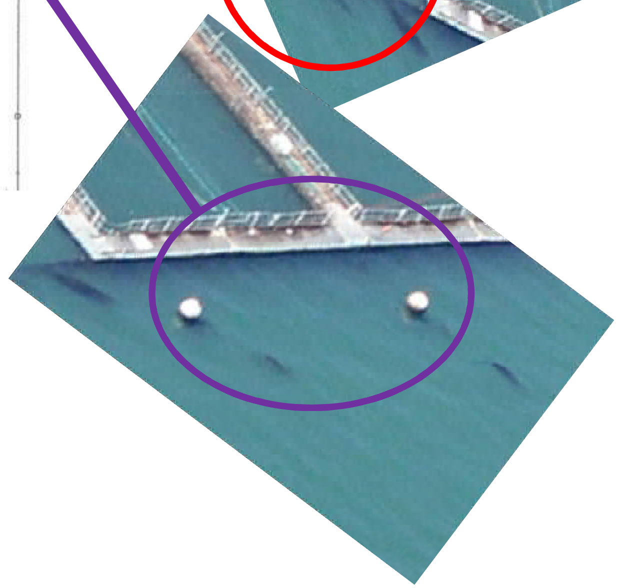
5.2.1.4. Walkways

For safety reason, check that the gangways are free of any extraneous matter.
Check that the grating is free of damage.

Mooring Connections to Net Pen– Recommendations from Manufacturer







Nomenclature:

1) Main bridge section
2) Catamaran section
3) Intermediate section
4) Outrigger section
5) Adjusting chain
6) Support rope
7) Buoy
8) Mooring rope
9) Heavy chain
10) Anchor

Appendix 2: Atlantic Salmon Cypress Island Net Pen Break Response Timeline

Atlantic Salmon Cypress Island Net Pen Break Response Timeline

ECY NPDES Waste Discharge Permit – WA-003157-7
DFW Aquatic Farm Registration – 8218-03
DNR Aquatic Lands Lease Cypress Island – DNR Aquatic Lease 20-B12517

Historical Context

1983-1986 – The three Cypress Island net pen structures were initially permitted and installed

- **1985** – Lease with Cypress Salmon, Inc. – 20-012034 Commencement Date
- **1987** – Lease with Cypress Salmon, Inc. – 20-012330 | Lease with Scan Am Fish Farms – 20-012517
- **1991** – Net Pen Advisory Workgroup (industry, state and local regulators, tribes, and environmental groups) developed model NPDES permit.
- **1996** – Amendment allowing for three leases listed above to be combined into one lease under 20-A12517 | 12 individual Marine Salmon Net Pen NPDES permits issued by ECY

1997-2006 – Lease with Scan Am Fish Farms – 20-A12517 – Sites 1, 2, and 3 – Skagit County Auditor Recording No. 9702040004

- **1999** – Lease with American Gold Seafoods – 20-B12517 – Skagit County Auditor Recording No. 200801240076.
- **2001** – 2001 U.S. Army Corps permit – authorization for replacement of Site 2 net pens.
- **2002** – Presumptive cage structure replacement, Site 2 - Coastal Zone Atlas image from 6/12/2002 shows that Site 2 structure had been replaced since 1999. | NPDES permit renewals issued.
- **2005** – Notice of and consent to assignment of lease to American Gold Seafoods, LLC – consent signed by DNR 4/18/2006.
- **2007** – Cypress Island Aquatic Reserve Management Plan completed. | NPDES permit renewals for remaining eight privately-owned sites.

2008-2023 – Lease with American Gold Seafoods – 20-B12517 – Skagit County Auditor Recording No. 200801240076

- **2008** – Washington Fish and Wildlife Aquatic Farm Registration. Notice of and consent to assignment of lease to Icicle Acquisition Subsidiary, LLC.
- **2012** – NPDES permit renewal applications received; permits administratively extended.
- **06/2014** – Fin Fish Aquaculture Plan of Operation
- **2016** – Fish Transport Application/Permit Received by DFW | 9/16 – DNR Aquatics staff visited net pens; contract compliance evaluation filed | 5/24/16 – Notice of and consent to assignment of lease to Cooke Aquaculture Pacific signed by DNR
- **2017** – Application to replace/reconfigure net pens – JARPA by letter dated 2/2/2017 (received by DNR 2/10/2017); Cooke provides memo dated 6/28/2017 to DNR addressing consistency with 2007 Cypress Island Aquatic Reserve management plan.
  - Fish Escape Prevention and Response Plan Updated and Received by ECY. | Fish Transport Application/Permit Received by DFW.
  - 4/17 – NPDES permit renewal applications received.
  - DNR receives notification from U.S. Army Corps of Engineers (USACE) dated 6/20/2017; DNR submits comment letter dated 6/30/2017
  - 07/26/17 – Kevin Bright notified ECY and DNR of mooring point failures that occurred at net pen #2 on 7/24.
  - 07/27/17 – Kevin Bright notified ECY and DNR site secure and back in position, anchors being tensioned, and no fish escapement.

Pen Break Response

Atlantic Salmon Pen Break

Saturday 08/19/2017

Film and photographs of the structural compromise of net pen array #2 captured by a member of the public while crabbing in the area – 15:30. ECY notified of incident at net pen #2.

Individual Agency Response

Date	DNR	ECY	DFW
Sunday 08/20/2017 Total number of fish extracted to-date * 3,098	Cooke leaves multiple voicemails notifying DNR of net pen #2 structure failure and salmon escapement.	Cooke notifies ECY Water Quality Program that strong tides and currents caused some damage to net pen #2. Cooke later notifies ECY that conditions worsened and at least 4-5k fish escaped.	Cooke notifies DFW that extreme tides damaged net pen #2. Cooke later notifies DFW that the situation escalated, and estimated 4-5k fish escaped.
Monday 08/21/2017 Total number of fish extracted to-date 5,166	Land Manager Sean Carlson relays information to DNR management upon arriving at work and listening to voicemails.	Cooke sends an Accidental Fish Escape Report for net pen #2. Cook notes that fish at the site had not received mediations since July 2016.	DFW receives Incidental Fish Escapement Report from Cooke. DFW works with NOAA and NWIFC to issue emergency fishery permits.
Tuesday 08/22/2017 Total number of fish extracted to-date 5,166	DNR and ECY work with Cooke to arrange a joint site visit on 8/23.	ECY and DNR work with Cooke to arrange a joint site visit on 8/23. ECY and NOAA confirm that tides and currents were not exceptionally strong, thus ruling out he eclipse as a cause for the failure of net pen #2.	DFW sends news release encouraging sport anglers to help recover Atlantic salmon. Authorizes retention and sale ofAtlantic salmon taken in Puget Sound commercial salmon fisheries.
Wednesday 08/23/2017 Total number of fish extracted to-date 5,166	ECY and DNR photograph and video failed net pen #2.	ECY and DNR photograph and video failed net pen #2.	
Thursday 08/24/2017 Rec. and Fishing Vessels Present 100+ Total number of fish extracted to-date 5,166			News release asking anglers to report catches on website. Authorization for Atlantic salmon fishing by Treaty Tribes using beach seine and gillnet gear in Deepwater Bay, 8/24-8/28.

* All figures represent fish extracted from net pen cages, as reported by Cooke.

Unified Incident Command

Friday 08/25/2017

Rec. and Fishing Vessels Present: 80+

Total number of fish extracted to-date: 5,166

Directors of ECY and DFW, as well as DNR CPL sign a Delegation of Authority and Memorandum of Authority to emplace a Unified Incident Command to address the pen break.

After a safety briefing, Cooke and Global personnel began the removal of floating lines, and the establishment of more anchors to secure and re-position the structure. The Foss tug also attached a tow line to the structure to add stability.

Gov. Jay Inslee and Public Lands Commissioner Hilary Franz announce the state will not issue any new leases or permits for commercial marine Atlantic salmon net pens until a full review of the incident takes place.

DFW reduces minimum size required for the all citizen's gillnet fisheries from 7 inch to 5 inch in Bellingham and Samish bays to increase fishing pressure on Atlantic salmon.

DNR sends notice of lease defaults to Cooke through certified mail.

Saturday 08/26/2017

Rec. and Fishing Vessels Present: 70+

Total number of fish extracted to-date: 67,266

Unified Incident Commanders from ECY, DFW, and DNR set up an Incident Command Post at the Port of Anacortes

The crane barge arrives at net pen #2.

ECY identifies decomposed fish carcasses as detrimental to water quality.

DFW issues Temporary FIsh Buyers License to Cooke.

Sunday 08/27/2017

Rec. and Fishing Vessels Present: 50+

Total number of fish extracted to-date: 118,978

Cooke requests an exclusion zone perimeter around net pen array #2. United States Coast Guard collaboratively drafts a safety zone plan that respects tribal fishing efforts.

Decomposed fish carcasses identified by ECY as a water quality concern.

UIC begins holding regular conference call briefings for government stakeholders and for tribal stakeholders.

Monday 08/28/2017

Rec. and Fishing Vessels Present: 50+

Total number of fish extracted to-date: 121,478

USCG implements a temporary safety zone in collaboration with UIC LEOs to ensure safety of all parties on the water without impeding tribal fishing efforts.

Conducted UAV flight to obtain photography of net pen #2 and immediate surroundings.

A single limited sample taken early in the day by Cooke showed results within water quality standards.

Tribal meeting held at Swinomish Casino. Subsequent tribal Meeting with Cooke.

DFW authorizes Treaty Indian and all citizen's fisheries targeting Atlantic salmon using beach seine and gillnet in waters around Cypress Island and select other locations, 8/28-9/4.

Tuesday 08/29/2017

Rec. and Fishing Vessels Present: 40-60

Number of cage nets removed to-date: 3

Total number of fish extracted to-date: 141,288

Safety zone persists, enforced by USCG and supported by DNR law enforcement.

UIC makes a formal request to Cooke and salvage contractor to document, to the extent safe and possible, the condition of the net pen and mooring system as it is removed from the water in Deepwater Bay.

Cooke takes water quality readings inside and outside the net pen array near the start of work this morning. The readings are within standards.

Daily update calls begin for all levels of government and tribal governments.

Wednesday 08/30/2017

Rec. and Fishing Vessels Present: 15-20

Number of cage nets removed to-date: 4

Total number of fish extracted to-date: 141,888

Safety zone persists, enforced by USCG and supported by DNR law enforcement.

UIC begins the process for standing up an Investigation branch.

Cooke provides ECY a copy of their water quality plan developed in consultation with ECY. Water quality testing occurs during the day and Cooke reports no adverse results.

After receiving a request from Cooke supported by the UIC, the US Army Corps clears the way for removal of the net pen structure.

G.I. James, from Lummi Nation, joins UIC for the day

The Samish Indian Nation brings forward above-mentioned film and photographs of net pen array #2 structural failure of 08/19/17.

Thursday 08/31/2017

Rec. and Fishing Vessels Present: 5-10

Number of cage nets removed to-date: 5

Total number of fish extracted to-date: 141,888

Safety zone persists, enforced by USCG and supported by DNR law enforcement.

UIC posts video and photos capturing initial net pen failure, taken by a citizen recreating in Deepwater Bay.

Lummi Nation declares a state of emergency, and begins to assemble a response team.

Nets and structural pieces of net pen array #2 are cut and prepared for removal. Barge crane non-operational late in the day.

Friday 09/01/2017

Rec. and Fishing Vessels Present: 5-10

Number of cage nets removed to-date: 7

Total number of fish extracted to-date: 142,013

Number confirmed recaptured fish to-date: 1,248

Safety zone persists, enforced by USCG and supported by DNR law enforcement.

The M/V Harvestor carries dead fish from the net pen to Anacortes to unload to trucks headed for a digester in Lynden.

Investigation and Review Board meets to discuss plans and needs. The team photographs nets and other structural pieces of the net pen.

Saturday 09/02/2017

Rec. and Fishing Vessels Present: 15-20

Number of cage nets removed to-date: 9

Total number of fish extracted to-date: 142,263

Number confirmed recaptured fish to-date: 1,351

Safety zone persists, enforced by USCG and supported by DNR law enforcement.

Lisa Cook ERT Coordinator on-site as a part of the Lummi Nation investigation team.

To date, seven nets, walkway sections, floats, and cage equipment have been offloaded at Curtis Wharf in Anacortes.

A potential trespassing event occurs during the night of Saturday/Sunday at net pen #3.

Cooke removes two nets, outriggers, walkways, a feed hopper and two anchors.

Sunday 09/03/2017

Rec. and Fishing Vessels Present: 10-15

Number of cage nets removed to-date: 10

Total number of fish extracted to-date: 144,813

Number confirmed recaptured fish to-date: 1,750

Safety zone persists, enforced by USCG and supported by DFW and DNR law enforcement. USCG cutter returns to Seattle.

UIC Brendan Brokes (DFW) and Ben Starkhouse of Lummi Nation board a small plane to scout marine fishing areas for Atlantic salmon surface activity – none observed.

Cooke crews continue to deconstruct damaged net pen array. The final net pen net is removed.

Monday 09/04/2017

Rec. and Fishing Vessels Present: 5-10

Number of cage nets removed to-date: 10

Total number of fish extracted to-date: 145,063

Number confirmed recaptured fish to-date: 1,750

Safety zone persists, enforced by USCG and supported by DNR law enforcement.

Cooke reports final count on fish extracted to be 145,851 (later revised downward to 145,063).

Cooke crews continue to deconstruct damaged net pen array two. Outside walkways are removed from two of the pens as well as one half and one full outrigger.

Transfer to Single Incident Command

Tuesday 09/05/2017

Rec. and Fishing Vessels Present: 0-5

Number of cage nets removed to-date: 10

Total number of fish extracted to-date: 145,063

Number confirmed recaptured fish to-date: 1,750

Safety zone persists, enforced by USCG and supported by DNR law enforcement.

ECY, DFW, and DNR transition joint incident management from Unified Incident Command to a DNR single unit Incident Command structure. Dennis Clark begins to serve as the Local Unit Incident Commander.

Salvage crew begins to secure the predator net for removal, removes most of the remaining outriggers, and begins to remove the safety bridle and anchor from the site.

Fraser River Panel agrees to allow Treaty Tribes and all citizen's fisheries using beach seine and gillnet in the waters around Cypress Island, Fidalgo Head, and Lummi Island to extend through 9/12, and add embayments around the southern poritons of San Juan and Loez Islands, Burrows Bay, and Birch Bay targeting Atlantic salmon.

Wednesday 09/06/2017

Rec. and Fishing Vessels Present: 0-5

Number of cage nets removed to-date: 10

Total number of fish extracted to-date: 145,063

Number confirmed recaptured fish to-date: 1,750

Safety zone duration ends.

Salvage crew continues to dismantle net pen #2.

DNR staff conduct photographic/video inspection of walkways and floats from net pen #2 that had landed in Anacortes on 9/1.

Thursday 09/07/2017

Rec. and Fishing Vessels Present

0-5

Number of cage nets removed to-date

10

Total number of fish extracted to-date

145,063

Number confirmed recaptured fish to-date

52,717

Version: 01/22/2018

DFW reports 26 Atlantic salmon stomachs as negative for contents.

DNR gathers bathymetric data using multi-beam sonar, data to help identify bottom debris, remaining anchors, and signs of anchor drag. Cooke requests data.

Gov. Jay Inslee, Public Lands Commissioner, DFW Director Jim Unsworth, and Ecology Director Maia Bellon met with Tribes in Everett to discuss the incident.

Appendix 3: Weight of Stock Nets Landed in Anacortes Following Salvage in September 2017 (Prepared by DNR for Investigation and Review Panel)

Order of "pick"	Date of Landing	Net #	Weight in pounds	Notes
1	9/1/2017	223	28,000	
2	9/1/2017	unknown	38,000	
3	9/1/2017	225	26,000	
4	9/1/2017		28,000	
5	9/1/2017		29,000	
6	9/1/2017		100	Presumed to be part of a net
7	9/1/2017		23,000	
8	9/1/2017		13,000	Presumed to be part of a net
9	9/1/2017		23,000	
10	9/8/2017		16,000	Reported in video 00942.MTS
11	9/8/2017		20,500	Reported in video 00944.MTS and 00949.MTS
12	9/8/2017		22,500	Reported in video 00949.MTS as ranging from 22,000 to 23,000
	Total		267,100	
	Average weight/net		26,710	
	Subtract net weight, dry and new, gross weight at factory		3,620	12/21/17 provided by John Wolfe, Orrick, by email to Dennis Clark
	Weight of marine growth, debris, absorbed water		23,090	
	Subtract debris and absorbed water (assumed figure)		1,000	
	Weight of marine growth (biofouling), average per stock net		**22,090**	**Importance of figure is not weight per se but rather increase in drag and thus loading on cage system including moorings**

Notes

1) Weight was reported by operator of Culbertson Marine crane; state staff observed reported amounts being noted on paper by worker on dock

2) Nets when weighed at landing included the net itself, marine growth on the net, added lines for lifting support, and debris from the net pen structure (most frequently these were metal railings and bird exclusion nets)

Appendix 4: Salmon Mortality Counts from Video Collected by Global Dive & Salvage's Fish Extraction at Cooke Aquaculture's Atlantic Salmon Net Pens in Deepwater Bay (Cypress Island, WA)

Developed by the Washington Department of Fish and Wildlife – Marine Fish Science Unit January 19, 2018, version 2.0

Qualifications

The Washington Department of Fish and Wildlife's Marine Fish Science Unit utilizes a small remotely operated vehicle (ROV) to visually assess bottomfish distributions, abundances, and habitats throughout Washington State inland marine waters. Following the completion of field surveys, video recordings of ROV transects are analyzed in a laboratory setting by trained reviewers using an established protocol. The current reviewers, Amanda Phillips and Andrea Hennings, have conducted video review for 4 years and 6.5 years, respectively, and have significant experience in correctly identifying and precisely enumerating Puget Sound fishes and invertebrates from a variety of survey methodologies (e.g., ROV, dive, drop-camera) and video formats (e.g., Hi-8 tape, digital) collected under widely varying environmental conditions.

Methods

Two batches of videos were provided to Marine Fish Science Unit video review staff. The first batch were collected by Global Dive & Salvage's commercial divers during net pen removal operations at the Cooke Aquaculture Atlantic Salmon farm in Deepwater Bay (Cypress Island, WA). These videos were reviewed by Amanda Phillips (AMP) and Andrea Hennings (ARH) at the WDFW Mill Creek annex office. The reviewers split the videos and each watched their designated group of videos one time through to familiarize themselves with the content and characterize the video as Mortality Assessment, Mortality Removal, and/or Net Pen Removal. Additionally, they recorded relevant audio commentary and referenced Global Dive and Salvage's dive logs for the net pen removal project for other pertinent information.

Reviewers then watched the videos designated as Mortality Removal a second time through to obtain counts of Atlantic Salmon (*Salmo salar*) suctioned out of the net pen per 30-second of video time; record when the diver was actively suctioning the salmon from the net pen; and record the times when the vacuum pump was turned on and off. All fish counted were dead, located inside the net pens, and therefore assumed to be Atlantic Salmon that originated from the Cooke Aquaculture facility. The count per 30-seconds (hereafter referred to as a count per segment) were taken when the diver was actively suctioning salmon, the end of the vacuum was generally in view, and the visibility around the end of the vacuum was high enough to assess when a fish was entering the vacuum. Each salmon was counted as it entered the terminal end of the vacuum pump. Counts were obtained using a mechanical tally counter – a device that advances count by one per user-click and is commonly used to enumerate objects of interest with higher precision than finger-counting and/or recording counts on paper. The speed at which the video played during review was left up to the reviewer's preference in order to improve visibility of each salmon entering the vacuum.

Once the reviewers reviewed their group of videos, they switched and counted the segments established by the other reviewer in the same manner. If the counts differed by 5, each reviewer recounted that segment once more and the resulting new counts were kept.

Following the review of the Global Dive footage and completion of a first draft of this report, a second batch of videos consisting of two DNR-collected videos were provided to the reviewers that corresponded to the previously reviewed dive videos. These videos were collected topside on the M/V Harvestor where the dead salmon suctioned with the vacuum pump were landed on a dewatering table and passed along a chute to the vessel's fish hold. This video footage was not provided to the reviewers prior to conducting counts on the dive videos to avoid any risk of biasing the dive data. For these two topside videos, counts were taken as fish passed out of the bottom of the viewing screen within 30-second video segments, starting at the beginning of each video and ending when the vacuum pump was audibly heard turning off and no more fish landed on the dewatering table. As with the dive footage, both reviewers completed independent counts on each video.

Results

Global Dive and Salvage dive logs indicate their divers were active at the net pen site from August 25, 2017 to September 6, 2017. The dive logs and associated videos show that salmon mortality removal took place between August 26, 2017 and August 30, 2017 over the course of 12 dives (updated from 11 dives since the first draft of this document to account for confirmation of a single video that was not provided to reviewers – see note below in discussion), with no mortality removal via vacuum pump taking place on August 29. See the accompanying Excel spreadsheet for details of each dive video, including tabs for individual dives where mortality removal took place that list the counts per segment, the breakdown of the time the pump was on, and the amount of time the diver was actively suctioning salmon. The time the pump was on and the time the diver was actively suctioning were determined visually (i.e., when particulate or salmon stopped moving into the vacuum pump) and through listening to the accompanying audio.

Of the 11 provided dive videos designated as Mortality Removal, two dives (Dives 7 and 25) had low visibility due to frequent camera movement and high levels of flocculence from removal activities that resulted in no counts being taken. For the remaining nine dive videos, salmon mortality removal counts per segment varied from a maximum of 66 (Segment 32.1, ARH) and a minimum of 8 (Segment 5.2, ARH). The mean count per segment for Amanda Phillips was 27.4 and for Andrea Hennings was 28.7. Following the segment count cross checks, only two of the 27 segments counted differed by more than 5 fish suctioned (Segments 5.5 and 10.3).

Despite various levels of decay, no dead fish were observed nor vacuumed that were of a different size or body morphology than that of a salmon. Decay also increased the likelihood of fish breaking apart during suctioning – this resulted in pieces of fish being suctioned. These pieces were considered one fish if the reviewer was unable to see the entire body enter the vacuum. Other fish species observed alive in the nets that were not vacuumed included Pacific Sandlance (*Ammodytes personatus*), juveniles of the family Gadidae, juveniles of the order Pleuronectiformes, and potentially other small-bodied (<10 cm adult length) species.

The DNR-collected topside videos of mortality removals were collected on August 29, 2017 by Dennis Clark. The videos were filmed in bright sunlight from the high vantage of the M/V Harvestor wheelhouse, providing a clear line of sight to fish passing over the dewatering table. On both videos, salmon were seen being delivered to the dewatering table from the vacuum pump where a deckhand used a plastic scoop shovel to move the fish along the dewatering table chute. A second deckhand, noted on audio in the first video (00856) as a fish counter, is located next to the chute as the fish pass by. A third deckhand is located near the terminal end of the chute to ensure the fish continue to move into the fish hold. The video 00856 is 2 minutes, 20 seconds and corresponds to a 22-minute mortality removal dive noted in the dive logs as having been completed between Dives 31 and 32 (hereafter referred to as the unnumbered dive). As noted in the first draft of this report, diver video was either not collected or not provided for this dive. Both reviewers counted 45 salmon passing along the dewatering table chute into the fish hold during this video. The second video (00857) is 7 minutes, 25 seconds and corresponds to the approximately 7-minute period during Dive 32 when the vacuum pump was on, as noted on the audio for both this video and the dive video. Amanda Phillips and Andrea Hennings counted 240 and 239 salmon, respectively, passing along the dewatering table into the fish hold during this video. Counts between reviewers did not differ enough after the first review to warrant recounts.

Discussion

Of the dives where mortality removals took place, a number of factors influenced the number of segments available to count, as well as the actual counts within each segment for all videos. The three major factors influencing these countable segments and the individual counts were: 1) the camera angle, which was often moving as the diver's head scanned around the net; 2) the reduced visibility due to debris and flocculence in the water; and 3) the diver moving the end of the vacuum to clear obstructions or to move to another location, which resulted in times where no fish were suctioned. Most of the counted segments were also subject to the first two issues, but only those where the reviewer felt the reduced visibility, for whatever reason, was minimal were included in this analysis. Often, each reviewer would over count during these times of reduced visibility to ensure the counts weren't biased low. Overall, diver time spent suctioning fish versus the relative amounts of time completing other tasks (e.g., keeping lines out of the vacuum, moving the vacuum to a different vantage point) while the vacuum pump was on appeared similar across all videos.

Counts were variable between segments and generally highest when the end of the hose was next to a large pile of fish with no potential obstructions in the vicinity (e.g., lines, torn netting). This was often at the beginning of vacuuming operations, though could be at any point the diver encountered a new pile. Count precision was notably low between the reviewers for Segments 5.5 and 10.3, where counts were higher than the average. This was likely due to a high number of fish entering the vacuum at once and increased uncertainty as to how many fish were captured that were obscured from view. Note that while the cross count checks between reviewers were not blind, bias was likely low due to the use of tally counters.

The state of decay played a part in the overestimation of fish counts per segment as well. The highest count per segment, the single segment for Dive 32, is likely an overestimation due to the high level of decay and increased likelihood of counting partial fish entering the vacuum, rather than a whole fish.

Additionally, the vacuum would occasionally lose suction due to issues with the pump or when the vacuum became so filled with fish a blockage would occur. This often resulted in a few fish backwashing out of the vacuum. These fish were usually recounted as they were suctioned back into the vacuum to ensure the counts were overestimates.

As noted above, the divers often moved the terminal end of the vacuum, which reduced the number of segments available to count. This was due to the awkward nature of holding the long vacuum hose and positioning it in a way that continuously suctioned fish. Reviewers note that the divers often spent quite a bit of time maneuvering the vacuum, and as a result, no fish were suctioned during these periods. These small but frequent gaps in diver suctioning time were not noted or captured in the final calculation, and as a result, diver suctioning time is an overestimate.

Dive logs indicate one video of mortality removal was not provided to the reviewers, or simply not recorded. Following the mortality assessment on Dive 31, the dive logs note Simon Cleasby entered the water for 22 minutes to “suck out morts.” However, this video was not received by the review staff. By coincidence, DNR staff collected video 00856 showing the vacuum pump on and suctioning salmon during the time Global’s dive logs indicate the unnumbered mortality removal dive took place. Although the video lasts only about two minutes and ends when the vacuum pump is turned off, narration by DNR staff notes the vacuum pump was on for a total of approximately 7 minutes. Due to the length of the DNR video and the missing dive video, reviewers are unable to independently determine the length of time the vacuum pump was on for this dive.

The second DNR-collected topside video (00857) correlates with Dive 32 and shows the vacuum pump on for approximately 7 minutes, 20 seconds. The dive video shows this is the only time the pump was on for this dive, though it was calculated on the dive video as being on for 7 minutes, 8 seconds - 12 seconds shorter than indicated on the topside video. Because the time the pump was on during the dive video was assessed through both audio and visual cues, the reviewers suggest this discrepancy was likely due to a lag between the time the pump was turned on at the surface and when suction was reached at the diver’s end. The reviewers believe the pump on time as calculated from the diver video is a more realistic amount of time on which to base any calculations, though the difference between the two measurements is nominal.

The DNR topside videos were of much higher clarity due to bright sunlight and the salmon being spread out along the dewatering table, rather than the often poor visibility in the dive videos where clumps of fish were suctioned at once and individuals might have been obscured entering the vacuum pump. On video 00856, the camera operator pans away from the dewatering table two times for a total of 28 seconds to assess the vessel surroundings. During this time, it is unclear whether fish are being transported down the dewatering table to the fish hold. On video 00857, the camera operator zooms in on a deckhand over the course of 7 seconds, during which time the dewatering table is briefly not visible. Based on the camera angle and speed at which the camera pans back to the table, the reviewers assume no fish counts were missed during this time. Due to the topside video being of better quality and capturing the entire time the vacuum pump was on for Dive 32, the reviewers believe this video could be used to accurately account for the number of fish suctioned from net pen 25 during Dive 32, rather than use any estimates derived from the associated dive video. However, the individual segments from the dive and topside videos should not be directly compared due to the difference in how and when fish were counted. Dive video counts per segment were often dependent on fish density in front of the vacuum, while topside counts per segment were dependent upon both the density of fish delivered to the dewatering table and the speed at which the deckhands moved them along the table.

The audio on video 00856 indicates one of the deckhands is responsible for counting fish (video time 0:00:47). While the audio does not indicate how the deckhand was counting fish or for what purpose, the reviewers note he appears to be using a mechanical tally counter (as seen on video 00857 at video time 0:05:44), though with a different method than the reviewers used to count fish from both the dive and topside videos. For example, when the camera zooms in on the counting deckhand and dewatering table on video 00857 at video time 0:03:47, he can be seen depressing the clicker on the tally counter once as 8 salmon move past him on the dewatering table chute. This difference in tally counter methods, plus the video reviewer's ability to slow down and replay video, may result in different counts between those collected by the deckhand and the video reviewers.

Finally, the videos reviewed contained more than just mortality assessments and removals. Net pen assessments and removal operations were also captured, including video of large holes in the net where the substrate below the net could be seen. Dead salmon were seen through these holes on the substrate in at least one video. See the Excel spreadsheet for more details.

<u>Summary</u>

The reviewers feel that a conservative estimate of the number of dead Atlantic Salmon removed from net pens via vacuum suctioning by Global Dive and Salvage's divers can be made using the following metrics from the accompanying spreadsheet:

- Total Time Pump On, as calculated to the second from the 11 mortality removal dive videos
- Total Time Unnamed Dive, as calculated to the minute from the Global dive logs
- Maximum Count per Second, as captured by reviewer Andrea Hennings

Using other data like Total Time Diver Suctioning and Mean Count per Second would still likely be conservative estimates, although less so than the calculation listed above.

The availability of video 00857 provides the opportunity to compare the estimate of salmon suctioned (as calculated from a dive video) to what was counted on the vessel deck for the duration of time the vacuum pump was on (as seen from the topside). The calculation that should be considered would compare the product of Total Time Pump On and Maximum Count per Second for Dive 32 with the total count of fish suctioned for the entirety of the video 00857 for the same dive. Reviewers feel the counts from video 00857 are more accurate and that the maximum count (240, AMP) could be used in lieu of any estimates derived from the associated dive video.

Video Date	Dive #	Video Name	Video Duration	Time Diver Left Surface	General Video Contents	Reviewer 1	Review 1 Date	Reviewer 2	Review 2 Date
8/26/2017	2	8-26-17 - Simon Cleasby - Pen 14 video 1	0:09:01	8:29	Pen unknown - audio at beginning of Dive 3 indicates this is not pen 14. Dead (few) and live (few) salmon present. Large hole in bottom of net at 0:03:40.	AMP	1/5/2018	N/A	N/A
8/26/2017	3	8-26-17 - Simon Cleasby - Pen 14 video 2	0:58:12	8:47	**Pen 14.** Mortality assessment. Dead (many) and live (few) salmon present. Diver surfaces at 0:06:28, with remaining video a recording of dock.	AMP	1/5/2018	N/A	N/A
8/26/2017	4	8-26-17 - Simon Cleasby - Pen 14 video 3	0:17:07	9:46	**Pen 14.** Mortality removal.	AMP	1/5/2018	ARH	1/10/2018
8/26/2017	5	8-26-17 - Dan Gilchrist - Pen 14	0:45:14	10:13	**Pen 14**. Mortality removal. Live salmon present (noted on audio).	AMP	1/8/2018	ARH	1/10/2018
8/26/2017	6	8-26-17 - Chris Schauer - Pen 12	0:32:08	11:49	**Pen 12.** Mortality removal. Live salmon present.	AMP	1/8/2018	ARH	1/10/2018
8/26/2017	7	8-26-17 - Cale Hoffman - Pen 21 mort recovery	0:23:21	13:46	**Pen 21.** Mortality removal. Live salmon present.	AMP	1/8/2018	ARH	1/10/2018
8/26/2017	8*	8-26-17 - Ben Swan - Pen 21 mort recovery	0:14:37	14:50	**Pen 21.** Mortality removal.	AMP	1/8/2018	ARH	1/10/2018
8/27/2017	8*	8-27-17 - Brent Seymour - Pen 11	0:28:02	7:26	**Pen 11.** Mortality assessment. Diver was supposed to be vacuuming, but hose was too short. Dead (many) and live (some) salmon present.	AMP	1/8/2018	N/A	N/A
8/27/2017	9	8-27-17 - Brent Seymour - Mort Recovery	0:28:02	8:22	Pen unknown - likely Pen 11. Mortality removal. Live salmon present.	AMP	1/9/2018	ARH	1/10/2018
8/27/2017	10	8-27-17 - Simon Cleasby - Mort Recovery	0:47:37	9:00	**Pen 11.** Mortality removal. Live salmon present.	ARH	1/8/2018	AMP	1/9/2018
8/27/2017	11	8-27-17 - Dan Gilchrist - Pen 12	0:48:05	10:27	**Pen 12.** Mortality removal. Live salmon present.	ARH	1/8/2018	AMP	1/11/2018
8/27/2017	12	8-27-17 - Chris Schauer - Pen 22	0:07:31	11:37	**Pen 22.** Mortality assessment. No salmon.	ARH	1/8/2018	N/A	N/A
8/27/2017	13	8-27-17 - Chris Schauer - ROV Recovery	0:07:22	12:04	**Pen 24.** ROV recovery. Dead (many) and live salmon present.	ARH	1/8/2018	N/A	N/A
8/27/2017	14	8-27-17 - Chris Schauer - Pen 24 mort recovery	0:29:33	13:06	**Pen 24.** Mortality removal.	ARH	1/8/2018	AMP	1/11/2018
8/27/2017	15	8-27-17 - Cale Hoffman - Pen 25	0:06:09	14:10	**Pen 25.** Mortality assessment.	ARH	1/8/2018	N/A	N/A
8/28/2017	17	8-28-17 - Simon Cleasby - Pen 11 net recovery	0:16:44	7:36	**Pen 11**. Net pen assessment. Dead and live salmon present.	ARH	1/8/2018	N/A	N/A
8/28/2017	18	8-28-17 - Simon Cleasby - Pen 11 video 2	0:10:42	8:02	**Pen 11.** Net pen assessment. Live salmon present.	ARH	1/8/2018	N/A	N/A
8/28/2017	19	8-28-17 - Simon Cleasby - Pen 11 video 3	0:10:03	9:14	**Pen 11.** Net pen removal.	ARH	1/8/2018	N/A	N/A
8/28/2017	20	8-27-17 - Dan Gilchrist - Pen 11	0:15:09	9:50	Pen unknown - likely pen 11**.** Net pen removal. Date in video file name is not correct - dive logs indicate this was 8/28/2017.	ARH	1/8/2018	N/A	N/A
8/28/2017	24	8-28-17 - Chris Schauer - Pen 11 video 2	0:17:50	12:42	**Pen 11.** Net pen removal. Live salmon (many) present. Diver was supposed to be vacuuming, but was prevented by excess netting.	ARH	1/8/2018	N/A	N/A
8/28/2017	25	8-28-17 - Chris Schauer - Pen 11 mort removal	0:09:16	13:43	**Pen 11.** Mortality removal. Live salmon (many) present. New metal end piece on vacuum added since previous video. Unable to count morts due to poor video quality.	ARH	1/8/2018	AMP	1/11/2018
8/29/2017	26	8-29-17 - Cale Hoffman - Pen 11 net removal	0:36:09	7:24	**Pen 11.** Net pen removal. Dead salmon (few) in predator net. Live salmon present.	ARH	1/5/2018	N/A	N/A
8/29/2017	27	8-29-17 - Ben Swan - Pen 24 net removal	0:15:28	11:16	**Pen 24.** Net pen removal. Live salmon present.	ARH	1/5/2018	N/A	N/A
8/29/2017	28	8-29-17 - Ben Swan - Pen 24	0:31:12	12:08	**Pen 24**. Net pen removal. Fewer than 15 dead salmon in net pen material being retrieved at beginning of video.	ARH	1/5/2018	N/A	N/A
8/30/2017	29	8-30-17 - Brent Seymour - Video 02	0:39:11	8:00	Pen unknown. Net pen removal. No salmon.	ARH	1/5/2018	N/A	N/A
8/30/2017	30	8-30-17 - Brent Seymour - Burning	2:06:09	9:21	Pen unknown. Net pen removal. Dead salmon at end of video is beginning of mortality assessment from next video.	ARH	1/5/2018	N/A	N/A
8/30/2017	31	8-30-17 - Simon Cleasby - Pen 25	0:06:30	11:32	**Pen 25.** Mortality assessment.	ARH	1/5/2018	N/A	N/A
8/30/2017	32**	8-30-17 - Dan Gilchrist - Pen 25	0:32:51	13:02	**Pen 25**. Mortality and net pen removal. Diver appears to remove almost all dead salmon from pen before transitioning to net pen and walkway removal. Live salmon (many) present.	ARH	1/5/2018	AMP	1/11/2018
8/31/2017	34	8-31-17 - Cale Hoffman - Video 2	0:07:00	8:50	**Pen 22**. Mortality assessment. Diver audio indicates approximately 40 dead salmon in pen. No dive number listed on logs, but they indicate this is the second of three consecutive dives by Cale Hoffman following dive 34. Left as dive 34.	ARH	1/5/2018	N/A	N/A
8/31/2017	34	8-31-17 - Cale Hoffman - Pen 12 net removal	0:28:08	9:15	**Pen 12**. Net pen removal. One dead fish (possible salmon) in predator net. No dive number listed on logs, but they indicate this is the third of three consecutive dives by Cale Hoffman following dive 34. Left as dive 34.	ARH	1/5/2018	N/A	N/A
8/31/2017	35	8-31-17 - Ben Swan - Walkway removal	0:46:40	12:43	Pen unknown. Net pen removal. Diver disassembling walkways, removing predator net. No salmon.	ARH	1/5/2018	N/A	N/A
9/2/2017	41	9-02-17 Cale Hoffman	0:15:35	7:40	Pen unknown. Net pen removal. Diver cutting pen lines. Audio indicates this diver would be going back in the water, but no following video provided. No salmon.	ARH	1/5/2018	N/A	N/A
9/2/2017		9-02-17 Chris Schauer	1:56:58		Pen unknown. Net pen removal. Diver disassembling walkways over the course of three dives. One dead salmon in predator net. No dive log entry for these dives apparent, though may be dive 42 and diver Chris Hume - not Chris Schauer as indicated.	ARH	1/5/2018	N/A	N/A
9/3/2017	45	9-03-17 Chris Schauer	0:14:08	8:31	Pen unknown. Net pen removal. Diver removing nets. Audio indicates last net pen to be removed. No salmon. This video cuts off approximately 25 minutes early.	ARH	1/5/2018	N/A	N/A

* Dive logs use dive 8 twice

Dive #	Video Name	Total Time Pump On	Total Time Diver Suctioning	Segment	Start time	End time	AMP Counts	ARH Counts
4	8-26-17 - Simon Cleasby - Pen 14 video 3	0:10:46	0:10:46					
				4.1	0:02:12	0:02:42	29	30
				4.2	0:13:27	0:13:57	26	23
				4.3	0:14:30	0:15:00	18	21
5	8-26-17 - Dan Gilchrist - Pen 14	0:39:33	0:38:23					
				5.1	0:02:07	0:02:37	40	44
				5.2	0:02:42	0:03:12	11	8
				5.3	0:06:02	0:06:32	34	36
				5.4	0:14:15	0:14:45	22	26
				5.5	0:18:55	0:19:25	45	60
				5.6	0:22:05	0:22:35	18	17
				5.7	0:28:14	0:28:44	29	30
				5.8	0:29:45	0:30:15	11	12
				5.9	0:35:27	0:35:57	11	11
6	8-26-17 - Chris Schauer - Pen 12	0:24:59	0:24:59					
				6.1	0:04:10	0:04:40	15	15
				6.2	0:16:45	0:17:15	23	25
7	8-26-17 - Cale Hoffman - Pen 21 mort recovery	0:27:20	0:20:53					
						None		
8	8-26-17 - Ben Swan - Pen 21 mort recovery	0:15:45	0:14:55					
				8.1	0:14:59	0:15:29	28	27
9	8-27-17 - Brent Seymour - Mort Recovery	0:23:28	0:23:28					
				9.1	0:12:39	0:13:09	21	22
				9.2	0:14:36	0:15:06	15	14
				9.3	0:15:08	0:15:38	49	50
10	8-27-17 - Simon Cleasby - Mort Recovery	0:41:40	0:41:55					
				10.1	0:07:00	0:07:30	16	18
				10.2	0:08:29	0:08:59	39	37
				10.3	0:30:58	0:31:28	42	51
				10.4	0:38:15	0:38:45	14	14
11	8-27-17 - Dan Gilchrist - Pen 12	0:37:35	0:36:30					
				11.1	0:07:55	0:08:25	30	30
				11.2	0:33:22	0:33:52	12	11
				11.3	0:33:58	0:34:28	30	30
14	8-27-17 - Chris Schauer - Pen 24 mort recovery	0:24:45	0:24:45					
				14.1	0:10:02	0:10:32	46	47
25	8-28-17 - Chris Schauer - Pen 11 mort removal	0:06:46	0:06:36					
						None		
32*	8-30-17 - Dan Gilchrist - Pen 25	0:07:08	0:06:25					
				32.1	0:01:57	0:02:27	65	66

* Dive logs indicate this dive was preceeded by a 22-minute dive by Simon Cleasby to remove fish from the pen in which dive 32 took place. This correlates with video 00856, collected by D

Video Date	Dive #	Video Name	Video Duration	General Video Contents	Reviewer 1	Review 1 Date	Reviewer 2	Review 2 Date
8/30/2017	See content notes	856	0:02:20	**Pen 25.** This video captures topside footage of salmon removal vessel, *M/V Harvestor* , the dewatering table, and the dead salmon being removed via vacuum pump. It shows the last two minutes of mortality removal from the 22-minute dive (no associated dive log #) completed by Simon Cleasby for which diver video is missing.	AMP	1/17/2018	ARH	1/17/2018
8/30/2017	32	857	0:07:25	**Pen 25.** This video captures topside footage of salmon removal vessel, *M/V Harvestor* , the dewatering table, and the dead salmon being removed via vacuum pump. It shows the approximately 7 minute period (as determined by the topside audio and associated dive footage) where the vacuum pump was on and suctioning fish.	AMP	1/17/2018	ARH	1/17/2018

Date	8/26/2017
Dive #	6
Pen #	12
Video Name	8-26-17 - Chris Schauer - Pen 12
Video Duration	0:32:08
Time Diver Suctioning	0:24:59
Time Pump On	0:24:59
General Notes	Diver asks to have pump shut off briefly during operations.

Video Time	Event	Comments
0:03:15	Pump suction on	
0:03:15	Diver starts suctioning	
0:13:45	Pump suction off	
0:15:36	Pump suction on	
0:30:05	Diver stops suctioning	
0:30:05	Pump suction off	Audio doesn't indicate when p

Segment	Start time	End time	Length	AMP	ARH
6.1	0:04:10	0:04:40	0:00:30	15	15
6.2	0:16:45	0:17:15	0:00:30	23	25

ump is turned off, so used time diver actively stops suctioning.

Date	8/26/2017
Dive #	4
Pen #	14
Video Name	8-26-17 - Simon Cleasby - Pen 14 video 3
Video Duration	0:17:07
Time Diver Suctioning	0:10:46
Time Pump On	0:10:46
General Notes	Vacuum pump loses suction at least once dur

Video Time	**Event**
0:02:09	Pump suction on
0:02:09	Diver starts suctioning
0:04:00	Pump suction off
0:05:50	Pump suction on
0:14:45	Diver ends suctioning
0:14:45	Pump suction off

ing video.

Comments	Segment	Start time	End time
	4.1	0:02:12	0:02:42
	4.2	0:13:27	0:13:57
Noted on audio; pump likely off since about 0:02:50	4.3	0:14:30	0:15:00

Length	AMP	ARH
0:00:30	29	30
0:00:30	26	23
0:00:30	18	21

Date	8/26/2017
Dive #	5
Pen #	14
Video Name	8-26-17 - Dan Gilchrist - Pen 14
Video Duration	0:45:14
Time Diver Suctioning	0:38:23
Time Pump On	0:39:33
General Notes	None

Video Time	**Event**	**Comments**
0:02:07	Pump suction on	
0:02:07	Diver end suctioning	
0:40:30	Diver starts suctioning	
0:41:40	Pump suction off	Diver estimates ~ 50 fish remain in net

Segment	Start time	End time	Length	AMP	ARH
5.1	0:02:07	0:02:37	0:00:30	40	44
5.2	0:02:42	0:03:12	0:00:30	11	8
5.3	0:06:02	0:06:32	0:00:30	34	36
5.4	0:14:15	0:14:45	0:00:30	22	26
5.5	0:18:55	0:19:25	0:00:30	45	60
5.6	0:22:05	0:22:35	0:00:30	18	17
5.7	0:28:14	0:28:44	0:00:30	29	30
5.8	0:29:45	0:30:15	0:00:30	11	12
5.9	0:35:27	0:35:57	0:00:30	11	11

Date	8/26/2017
Dive #	7
Pen #	21
Video Name	8-26-17 - Cale Hoffman - Pen 21 mort recovery
Video Duration	0:23:21
Time Diver Suctioning	0:20:53
Time Pump On	0:27:20
General Notes	No counts for this video. Diver spends a lot of time managing vacuum

Video Time	Event	Comments
0:01:55	Pump suction on	
0:01:55	Diver starts suctioning	
0:11:30	Diver stops suctioning	Diver leaves vacu
0:13:32	Diver starts suctioniong	
0:18:55	Diver stops suctioning	Tying a line on vac
0:21:55	Diver starts suctioning	
0:25:20	Diver stops suctioning	
0:26:45	Pump suction off	
0:32:00	Pump suction on	
0:32:00	Diver starts suctioning	
0:34:30	Diver stops suctioning	
0:34:30	Pump suction off	

and keeping debris out of the way. No diver light and high levels of flocculence results in low visibility.

Segment	Start time	End time	Length	AMP
None				

ım to scout

cuum with suction on but not near fish pile; one fish suctioned during this time

Date	8/26/2017
Dive #	8
Pen #	21
Diver	8-26-17 - Ben Swan - Pen 21 mort recovery
Video Duration	0:23:21
Time Diver Suctioning	0:14:55
Time Pump On	0:15:45
General Notes	Diver notes that he only gets 5-10 seconds of good suction before the vacuum is fillec

Video Time	**Event**	**Comments**
0:02:30	Pump suction on	
0:02:30	Diver starts suctioning	
0:17:00	Diver stops suctioning	
0:17:20	Pump suction off	
0:19:35	Pump suction on	
0:19:35	Diver starts suctioning	
0:20:00	Diver stops suctioning	
0:20:30	Pump suction off	

l and it shoots backward, every time he attempts to vacuum fish from the pile, due to blocked suction. Large hc

Segment	Start time	End time	Length	AMP	ARH
8.1	0:14:59	0:15:29	0:00:30	28	27

ɔles in both net pen and predator net (indicated on audio) at 0:17:41.

Date	8/27/2017
Dive #	9
Pen #	21
Video Name	8-27-17 - Brent Seymour - Mort Recovery
Video Duration	0:28:02
Time Diver Suctioning	0:23:28
Time Pump On	0:23:28
General Notes	None

Video Time	Event	Comments
0:04:15	Pump suction on	
0:04:15	Diver starts suctioning	
0:27:43	Diver stops suctioning	
0:27:43	Pump suction off	Audio indicates pump is being

Segment	Start time	End time	Length	AMP	ARH
9.1	0:12:39	0:13:09	0:00:30	21	22
9.2	0:14:36	0:15:06	0:00:30	15	14
9.3	0:15:08	0:15:38	0:00:30	49	50

turned off at an earlier point, but visually still has suction. Used time diver actively stops suctioning.

Date	8/27/2017
Dive #	10
Pen #	11
Video Name	8-27-17 - Simon Cleasby - Mort Recovery
Video Duration	0:47:37
Time Diver Suctioning	0:41:40
Time Pump On	0:41:55
General Notes	None

Video Time	**Event**	**Comments**
0:03:20	Pump suction on	
0:03:20	Diver starts suctioning	
0:45:00	Diver stops suctioning	
0:45:15	Pump suction off	

Segment	Start time	End time	Length	AMP	ARH
10.1	0:07:00	0:07:30	0:00:30	16	18
10.2	0:08:29	0:08:59	0:00:30	39	37
10.3	0:30:58	0:31:28	0:00:30	42	51
10.4	0:38:15	0:38:45	0:00:30	14	14

Date	8/27/2017
Dive #	11
Pen #	12
Video Name	8-27-17 - Dan Gilchrist - Pen 12
Video Duration	0:48:05
Time Diver Suctioning	0:36:30
Time Pump On	0:37:35
General Notes	This is the second mortality recovery from this net. Some fish remain following remova

Video Time	Event	Comments	Segment	Start time
0:07:55	Pump suction on		11.1	0:07:55
0:07:55	Diver starts suctioning		11.2	0:33:22
0:44:25	Diver stops suctioning		11.3	0:33:58
0:45:30	Pump suction off			

l due to barriers in net (e.g., grate, feeding hopper).

End time	Length	ARH	AMP
0:08:25	0:00:30	30	30
0:33:52	0:00:30	12	11
0:34:28	0:00:30	30	30

Date	8/27/2017
Dive #	14
Pen #	24
Video Name	8-27-17 - Chris Schauer - Pen 24 mort recovery
Video Duration	0:29:33
Time Diver Suctioning	0:24:45
Time Pump On	0:24:45
General Notes	None

Video Time	Event	Comments
0:01:45	Pump suction on	
0:01:45	Diver starts suctioning	
0:26:30	Diver stops suctioning	
0:26:30	Pump suction off	

Segment	Start time	End time	Length	AMP	ARH
14.1	0:10:02	0:10:32	0:00:30	46	47

Date	8/28/2017
Dive #	25
Pen #	11
Video Name	8-28-17 - Chris Schauer - Pen 11 mort removal
Video Duration	0:09:16
Time Diver Suctioning	0:06:36
Time Pump On	0:06:46
General Notes	Did not take any counts due to poor video quality. Fish often backw

Video Time	Event	Comments
0:01:09	Pump suction on	
0:01:09	Diver starts suctioning	
0:07:45	Diver stops suctioning	
0:07:55	Pump suction off	

vash out of vacuum and diver pans away frequently.

Segment	Start time	End time	Length	AMP	ARH
None					

Date	8/30/2017
Dive #	32
Pen #	25
Video Name	8-30-17 - Dan Gilchrist - Pen 25
Video Duration	0:32:51
Time Diver Suctioning	0:06:25
Time Pump On	0:07:08
General Notes	The majority of these fish lack skin and were prone to breaking apart when disturbed. O

Video Time	Event	Comments	Segment
0:01:55	Pump suction on		32.1
0:01:55	Diver starts suctioning		
0:08:20	Diver stops suctioning		
0:09:03	Pump suction off		

nly counted a single 30-second segment due to poor camera angle and visibility. Video after 0:09:03 is net remo

Start time	End time	Length	AMP	ARH
0:01:57	0:02:27	0:00:30	65	66

Date	8/30/2017
Video Name	00856.MTS
Video Duration	0:02:20
Time Pump On	N/A
General Notes	Audio at beginning of video indicates the current time is 12:45 a

Segment	Start time	End time	Length	AMP	ARH
1	0:00:00	0:00:30	0:00:30	15	15
2	0:00:30	0:01:00	0:00:30	24	24
3	0:01:00	0:01:30	0:00:30	4	4
4	0:01:30	0:02:00	0:00:30	2	2
5	0:02:00	0:02:20	0:00:20	0	0
		Total count fish suctione		45	45

nd diver is suctioning fish from pen 25. Audio further notes that the vacuum pump was on from 12:40 to 12:47. W

Comments
Audio indicates fish are from pen 25, fish start arriving on deck table at 0:00:09
Camera pans away from dewatering table from 0:00:58 to 0:01:05 (beginning of next segment)
Camera pans away from dewatering table from 0:01:18 to 0:01:39 (beginning of next segment)
Camera pans back to dewatering table at 0:01:39
No fish, pump off at 0:02:10 - audio notes pump was on from 12:40 to 12:47

Vhen camera pans away from dewatering table, no fish are visible or counted.

Date 8/30/2017
Video Name 00857.MTS
Video Duration 0:07:25
General Notes Audio at the beginning of the video indicates the vacuum pump was on sta

Segment	Start time	End time	Length	AMP	ARH
1	0:00:00	0:00:30	0:00:30	0	0
2	0:00:30	0:01:00	0:00:30	8	8
3	0:01:00	0:01:30	0:00:30	75	78
4	0:01:30	0:02:00	0:00:30	68	67
5	0:02:00	0:02:30	0:00:30	39	36
6	0:02:30	0:03:00	0:00:30	11	11
7	0:03:00	0:03:30	0:00:30	6	6
8	0:03:30	0:04:00	0:00:30	9	9
9	0:04:00	0:04:30	0:00:30	1	1
10	0:04:30	0:05:00	0:00:30	1	1
11	0:05:00	0:05:30	0:00:30	5	5
12	0:05:30	0:06:00	0:00:30	7	7
13	0:06:00	0:06:30	0:00:30	4	4
14	0:06:30	0:07:00	0:00:30	3	3
15	0:07:00	0:07:25	0:00:25	3	3
		Total count fish suctioned		240	239

rting at 13:05 - this is presumably also the video start time, though it is not stated explicitly. Audio indicates pump

Comments
Audio indicates pump is on at segment start (13:05)
Camera zooms in on deckhand - any fish on dewatering table would not be visible from approximately 0:03:50 to
Camera still zoomed in though fish path on dewatering table is visible
Camera zooms back out at 0:05:06, back in on deckhand and part of dewatering table at 0:05:16, and back out aga
Pump off at 0:07:20

is off at 13:13.

0:03:57

ain at 0:05:42 (next segment)