Expert Report of Dr. Tobias Dewhurst

Wild Fish Conservancy v. Cooke Aquaculture Pacific, LLC

Case No. 2:17-cv-01708-JCC

June 5, 2019

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This report replaces the Expert Report of Dr. Tobias Dewhurst submitted in this matter that was dated April 10, 2019.

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1 Summary of Opinions

Based on the assessments described in this report, the opinions of the author are as follows:

- Cooke did not inspect all portions of mooring systems on an annual basis as required by section S6.F of its National Pollution Discharge Elimination System (NPDES) permits and as stipulated by the net pen manufacturers' manuals provided by Cooke. Specifically, Cooke did not annually inspect anchoring components that were below a depth of 100 feet.
- Cooke's NPDES permits required the "Identification and implementation of technology that will minimize fish escapements." However, Cooke failed to identify and implement certain critical net pen technologies necessary to prevent escapes. Specifically, conditions at each of its eight sites exceeded the maximum rated conditions specified by the net pen manufacturer. Based on Cooke's documentation that I have reviewed to date, these issues persist at many of the remaining net pen sites. Thus, the remaining net pen systems may be at risk of partial or catastrophic failure during instances of extreme environmental loading, which could result in fish escapement.
- The apparent lack of rigorous analyses of maximum current speed for each site introduced a risk of structural failure during instances of maximum current speed. This risk is a particular concern for those net pens whose configurations exceed the maximum rated conditions specified by the net pen manufacturer.
- As a result of excessive loads on the net pen system created by:
    - currents and net sizes exceeding those specified by the net pen manufacturer,
    - biofouling levels potentially exceeding design values, and
    - mooring system installations that deviate from manufacturer recommendations and were not approved by a marine engineer,

  pens and cages operated by Cooke were at risk of complete failure. One pen, Cypress Site 2, did experience a catastrophic failure.
- While achieving certainty with regard to the cause of the Cypress Site 2 failure may not have been possible, Cooke's failure to even attempt such an analysis deprives Cooke of critical information and data that it could apply to its other operations in order to reduce the risk of a similar collapse in the future. This is particularly concerning because, as with Cypress Site 2, certain remaining sites appear to be operating in conditions that exceed those specified by the net pen system manufacturers.
- Cooke avoided costs in failing to inspect all portions of mooring systems on an annual basis as required by it permits. Cooke also avoided costs in failing to identify and implement technology to minimize fish escapes.

2 Introduction

My name is Tobias Dewhurst and my work address is 2 Portland Fish Pier, Portland, Maine 04101. I have been retained as an expert familiar with the engineering of marine aquaculture structures by the law firm of Kampmeier and Knutsen to provide this report on behalf of Wild Fish

Conservancy, in the case of *Wild Fish Conservancy v. Cooke Aquaculture Pacific, LLC*, ("CAP" and "Cooke") no. 2:17–cv–01708. I expect to testify at trial regarding the subject matters set forth in this Report, if asked about these matters by the Court or by the parties' attorneys. I reserve the right to update my Report as I am able to review produced documents and as additional data become available, and as necessary if and when Cooke provides any reports from its experts. I have previously provided a declaration in this matter (ECF No. 52-2), and I incorporate that declaration herein by reference.

I am being compensated at the rate of $175/hour for my work in this matter. I have never testified as an expert at trial or by deposition in another case.

2.1 Purpose and Scope

The purpose of this report is to:

- provide opinions on whether the catastrophic failure of Cooke's Cypress 2 net pen in August 2017 is attributable in part to Cooke's failure to identify and implement appropriate technology and best/appropriate industry standards and practices;
- provide opinions on whether Cooke's operations and maintenance of its eight net pens in Puget Sound conformed to and complied with its NPDES permit requirements, including its Pollution Prevention Plan and it Fish Release Prevention and Monitoring Plan; and
- identify actions/technology (structural, engineering, best practices, or otherwise) Cooke could have implemented, or could implement in the future, to comply with its permits and provide cost estimates for those actions/technology.

2.2 Qualifications and Materials Reviewed

The author has prepared this report in the capacity of an expert familiar with the engineering of marine aquaculture structures and the technologies and practices needed to maintain such structures so as to prevent partial or catastrophic failures and other causes of pollution, including fish releases. In preparing the report, other MMC staff, including Richard Akers, PE, assisted the author by helping to identify, organize, and review relevant records, including data related to the cost estimates provided. The opinions expressed in the report are solely the author's own and are based on the author's expertise in the field of marine engineering. The author's qualifications are presented in his Curriculum Vitae at Appendix 4.

The author reviewed plans, reports, industry standards, and industry best practices in the preparation of this report. The materials reviewed do not represent an exhaustive investigation of Cooke Aquaculture Pacific's practices in the State of Washington. In addition to the author's familiarity with relevant literature, a list of records and documents the author considered in preparing this report is provided at Appendix 7. Appendix 7 contains the facts and data on which the author considered in forming his opinions. The author reserves the right to update Appendix 7 as new facts and data become available, either through discovery or otherwise.

3 Permits, Standards, and Best Practices

3.1 Facts

3.1.1 NPDES Permits

Cooke's aquaculture operations in Puget Sound are permitted under the National Pollutant Discharge Elimination System (NPDES).[1] These permits include requirements that the permittee develop, among other items:

- a Pollution Prevention Plan, and
- a Fish Release Prevention and Monitoring Plan.

These plans were updated at various intervals throughout the duration of the permits. A chronology of the applicable Pollution Prevention Plans is given in Table 1. A chronology of the applicable Fish Escape Prevention Plans is given in Table 2.

Table 1. Chronology of Pollution Prevention Plans, according to Cooke[2]

Name	Dates	Bates Number
American Gold Seafoods - NPDES Pollution Prevention Plan, Updated: January 2010	January 2010 to November 2011	To be produced.
American Gold Seafoods - NPDES Pollution Prevention Plan, Updated: November 2011	November 2011 to April 2012	To be produced.
American Gold Seafoods - NPDES Pollution Prevention Plan, Updated: April 2012	April 2012 to January 2015	COOKE_CWA_00027221 to COOKE_CWA_00027227
American Gold Seafoods - NPDES Pollution Prevention Plan, Updated: January 2015	January 2015 to April 2017	COOKE_CWA_00027228 to COOKE_CWA_00027231
Cooke Aquaculture Pacific – Pollution Prevention Plan, Updated: April 2017	April 2017 to October 2017	COOKE_CWA_00027232 to COOKE_CWA_00027234
Cooke Aquaculture Pacific – Pollution Prevention Plan, Updated: October 2017	October 2017 - Present	COOKE_CWA_00027240 – 00027243, 00027249 - 00027250

[1] COOKE_CWA_00019607.pdf
[2] 2018.08.31 - Cooke Answers to WFC 2nd Disc Reqs.pdf

Table 2. Chronology of Fish Escape Prevention Plans and Fish Escape Reporting and Response Plans, according to Cooke[3]

Name	Dates	Bates Number
Icicle Acquisition Subsidiary, LLC DBA American Gold Seafoods - Fish Escape Prevention Plans, Updated June 2009 Icicle Acquisition Subsidiary, LLC DBA American Gold Seafoods - Fish Escape Reporting and Response Plan, Updated June 2009	June 2009 to August 2012	COOKE_CWA_00027264 to 00027278
Icicle Acquisition Subsidiary, LLC DBA American Gold Seafoods - Fish Escape Prevention Plans, Reviewed August 2012 Icicle Acquisition Subsidiary, LLC DBA American Gold Seafoods - Fish Escape Reporting and Response Plan, Reviewed August 2012	August 2012 to June 2014	To be produced.
2014 Icicle Acquisition Subsidiary, LLC DBA American Gold Seafoods - Fish Escape Prevention Plans, Updated June 2014 Icicle Acquisition Subsidiary, LLC DBA American Gold Seafoods- 2014 Fish Escape Reporting and Response Plan - Updated June 2014	June 2014 to January 2017	COOKE_CWA_00027288 to 00027325
2017 Cooke Aquaculture Pacific, LLC - Fish Escape Prevention Plan, Updated January 2017	January 2017 - Present	COOKE_CWA_00027279 to 00027287

In addition to the Plans listed in Table 2, Cooke submitted an updated Fish Escape Prevention Plan in October of 2018[4].

3.1.2 Best Aquaculture Practices

Cooke's salmon operations in the state of Washington are "certified using Best Aquaculture Practices."[5] This refers to an industry standard created and maintained by the Global Aquaculture Alliance (GAA), Portsmouth, NH (formerly St. Louis, MO), called:

Aquaculture Facility Certification
Salmon Farms
Best Aquaculture Practices Certification Standards, Guidelines

GAA released versions of this standard as described in Table 9. According to these Best Aquaculture Practices (BAP), either Version 2, Rev. 2 or Issue 2, Revision 3 applied at the time

[3] 2018.08.31 - Cooke Answers to WFC 2nd Disc Reqs.pdf
[4] COOKE_CWA_00147341
[5] 30(b)(6) Cooke Aquaculture Pacific, LLC - Parsons Vol 2 eFFICIENT Transcript Package.pdf. p293.

of the Cypress Site 2 pen collapse in August, 2017. Key sections of the *Best Aquaculture Practices for Salmon – Control of Escapes* are quoted in Appendix 1.

3.1.2.1 Washington Fish Growers Association (WFGA) Code of Conduct

As part of Cooke's Best Aquaculture Practices certification, an *Aquaculture Facility Certification* Auditor Checklist[6] was created for "Icicle Acquisition Subsidiary, LLC dba American Gold Seafoods, Cypress Island Site." In this audit document there is a checklist heading entitled "1.6 Where applicable current documents shall be available to show compliance with the farm's own industry codes of practice." The auditor entered the following response to this heading:

> "Icicle Seafoods has their own Code of Practice, latest revision March 2015. A letter from Dan Swecker, president of the Washington Fish Growers Association (WFGA) states that American Gold Seafoods (Icicle) complies with WFGA Code of Conduct."

The Washington Fish Growers Association (WFGA) publishes a Code of Conduct[7] for Saltwater Salmon Net-Pen Operations, last updated in fall, 2002. This document states:

> ***"Containment of Fish Stocks***
>
> - *By law, finfish farmers in Washington must have a Washington Department of Fish and Wildlife-approved escape prevention plan that includes:*
>   - *Procedures to minimize escapes when rearing vessels, pens or cages are moved, repaired or manipulated, or during stocking or harvesting operations."*

3.1.3 Norwegian Standard 9415.E:2009

Standards Norway (Standard Norge) has published NS 9415: "Marine fish farms–Requirements for site survey, risk analyses, design, dimensioning, production, installation and operation". The stated purpose of NS 9415 is to "reduce the risk of escape as a result of technical failure and wrong use of marine fish farms." NS 9415 is referenced by BAP and is an internationally accepted industry standard. Key text from this standard is quoted in Appendix 2.

3.2 Analysis and Discussion

In this report, Cooke's various Pollution Prevention Plans and Fish Escape Prevention Plans were evaluated for their compliance with the requirements of the NPDES permits. In addition, the author referred to the Best Practices and Standards listed in Section 3.1 of this report for clarification.

Where sufficient information was available, Cooke's actions were evaluated to determine whether its implementation of technology, operations, and maintenance of its net pens in Puget Sound conform to and comply with its NPDES Permits and Plans.

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[6] COOKE_CWA_00019992, *Aquaculture Facility Certification* Auditor Checklist, Part 2 Salmon Farm Standard, Version 2, May 2015, p. 6.

[7] WFGA Code of Conduct (http://www.wfga.net/conduct.php)

4 Permit Requirements: S6 Pollution Prevention Plan

4.1 NPDES Permit Requirements for the Pollution Prevention Plan

4.1.1 Facts

Section S6 of the NPDES Permits enumerates the requirements for the Pollution Prevention Plan. Specific requirements examined in this report were that the Permittee must address the following in the plan:

- S6.B “How net cleaning will be conducted in order to minimize the discharge of accumulated solids and attached marine growth.”

- S6.F “The Permittee shall routinely, at least weekly, conduct visual inspections of exposed surface lines, shackles, and mooring points. Any defective components are to be repaired or replaced promptly. At least once per year, conduct an inspection of the main cage structure and anchoring components above and below the water line. Document any problems and maintain all components to prevent failure that could lead to fish escapements.”

  “The Permittee shall conduct inspections after any major storm event or physical accident involving the pen structures or moorings, and make any repairs necessary.”

S6.B reflects Permit requirements S5.A.9 and S5.A.10:

> S5.A.9 “The Permittee must dispose of accumulated solids and attached marine growth contained within or on the net pen in a manner which prevents to the maximum extent practical these materials from entering or reentering waters of the state.”
>
> S5.A.10 “The Permittee must not discharge accumulated solids and marine growth removed from the finfish rearing units into waters of the state without prior treatment.”

4.2 S6.B - Net Cleaning and Discharge of Marine Growth

4.2.1 Facts

4.2.1.1 <u>Cooke’s Permit Plan</u>

The Pollution Prevention Plan (PPP) submitted as Attachment B of the NPDES Permit Renewal Application Packages submitted in 2012 for all eight sites states that:

- Nets are typically pulled to the surface and changed annually.
- Fouled nets are shipped to a land based net cleaning and net repair facility for “…washing, capturing and disposing of waste materials from the cleaning process.
- Nets are dipped in a water-based copper antifouling paint at the above facility.

This PPP makes no mention of in-water net washing. NPDES permit states that no antifouling coatings are permitted. However, Section 3.8 of the PPP states that the “facilities have approval from the Department of Ecology to allow for use of the Flexgard XI net-coating product.”

Starting with the January 2015 update, Pollution Prevention Plans provided by Cooke reference in-situ rinsing of nets with pressurized seawater.

Neither the NPDES Permit nor any of the Pollution Prevention Plans specify a maximum allowable level of biofouling. However, NS 9415 specifies that farms be designed to survive up to 50% biofouling of the nets. In this standard, 50% biofouling is applied as a 50% increase in the solidity of the net. The solidity of the net is defined as its actual projected area divided by its outline area. Similarly, the manual for the Procean Ocean Catamaran Platform used at the Fort Ward, Orchard Rocks (Saltwater IV), and Clam Bay sites specifies a maximum biofouling of 50%.

4.2.1.2 Implementation by Cooke

Reviewing the daily logs for the salmon farms, there is inconsistent mention of removing nets for cleaning. In most cases the log entries refer to mechanical cleaning using an MPI, Stingray, Idema or AutoBoss in situ cleaner. The NETWASHING PRACTICES section of Attachment B does not mention in situ cleaning. There are no records of debris disposal from the in situ cleaning systems.

There were very few references to removing nets and cleaning them by raising them to the surface per the AGS Pollution Prevention Plans.

According to the “Netwashing Practices” section in Attachment B of the NPDES PERMIT RENEWAL APPLICATION PACKAGES for all eight sites, Cooke planned to pull the fish containment nets to the surface once per year on average. As cultured fish stocks typically take 18 to 22 months in seawater to reach harvest sizes, the containment nets may be changed out 2 times during this growing period.[8]

Using the logs and other material supplied by Cooke, it is very difficult to determine whether the actual net-washing practices met or exceeded their plans. No records were found describing the effectiveness of the Stingray, MPI, Idema and AutoBoss in-situ cleaning systems.

According to the "FISH FARM SURVEY REPORT" describing the Clam Bay site, dated June 15, 2011, written by Aquaculture Risk (Management) Ltd and Sunderland Marine, for American Gold, diving by site staff for "Equipment inspection" happens “3 x weekly” in both summer and winter. Further, "Divers to report level of fouling on nets according to an established score system."

A similar survey dated July 12, 2016 says that diving at the Clam Bay site is performed “When required (see Reasons),” and for reasons lists “Mort retrieval,” Suspected damage to cage/net/moorings,” and “Cage/net/mooring inspection.”

The planned number and frequency of dives dropped off significantly between the 2011 survey and the 2016 survey.

[8] Eight references including COOKE_CWA_00054113.pdf.

4.2.2 Analysis and Discussion

Based on the logs and net cleaning and repair records, it is not possible to determine whether the nets at each site were kept free of biofouling, or even to determine the maximum percentage of fouling. It is noted in section 6.2.1 of this report that Cooke employees described significant biofouling at Cypress Site 2 during the summer of 2017.

It is noted that Cooke's operations and Pollution Prevention Plans—starting in January 2015—include the use of in-situ net washing. This is common practice in many aquaculture industries and geographical locations. However, it is noted that in-situ washing may not be consistent with the Permit's requirements that "The Permittee must dispose of accumulated solids and attached marine growth contained within or on the net pen in a manner which prevents to the maximum extent practical these materials from entering or reentering waters of the state" and "The Permittee must not discharge accumulated solids and marine growth removed from the finfish rearing units into waters of the state without prior treatment."

4.3 S6.F - Inspections and Maintenance

4.3.1 Facts

4.3.1.1 Cooke's Permit Plan

Regarding the inspection, repair, and replacement of net pen structures, the Pollution Prevention Plans from 2012 up to, but not including October 2017 state that:

1. "The Site Managers and site personnel are to routinely inspect exposed mooring components for signs of excessive wear. Any defective components are to be replaced promptly", and
2. "Below water mooring components are to be inspected and/or replaced periodically in order to maintain them in the best condition practical."

In the October 2017 update of the PPP, the plan stipulates "Weekly Visual Inspections of Exposed Surface Lines, Shackles and Mooring Points." It also stipulates "Annual Inspections of Below Water Mooring Components."

Cooke's sites in Puget Sound employed at least three different types of net pens:

- Marine Construction AS– SystemFarm
- Wavemaster Steel Cage
- Procean AS–Ocean Catamaran

The net pen system manufacturers specify the inspection requirements for their systems. Manufacturer specifications for the Marine Construction AS SystemFarm[9], the Procean AS–Ocean Catamaran[10], and the AKVA Group's Wavemaster EX-1[11] were reviewed.

The Marine Construction AS SystemFarm[12] manual specifies monthly and annual inspections. Procean AS–Ocean Catamaran manual specifies weekly, monthly, and annual inspections. For both systems, the annual inspections include items above and beyond those included in the weekly or monthly inspections. For example, the Procean AS–Ocean Catamaran annual inspection requirements include the following:

> *Once* a *year* a *thorough inspection and disinfection of the system should be carried out. If possible this should be carried out during summer months to allow* a *complete and thorough inspection of all underwater components to be checked and repaired if necessary.*
> • *Check all anchor lines for wear and tear*
> • *Check all anchor line connections and hardware*
> • *Check all anchors and anchor points*
> • *Check all can buoys and connections to* [sic]
> • *Check Predator net for wear and tear and its connection to the pred grid*
> • *…*
> • *Visually inspect all weld connections at outer beam and pontoon and main bridge and pontoon intersections.*
> • *Bolts for walkway gratings on pontoons and main walkways should be re-torqued*
> • *Check all plumbing and electrical systems*
>
> *Submerged parts of the anchoring system.*
> *Submerged parts of the anchoring system must be checked, however if the depth of these parts are to* [sic] *great for* a *diver to inspect, then it is possible to deploy an ROV (remote controlled* [sic] *operated underwater vehicle) equipped with video to perform this task. It will be necessary to stress test the lines and anchors if they are found to be slack or damaged to ensure their breaking strength and tension is sufficient. Section 3. 11*
>
> *Steel Construction*
> *Welded areas must be checked for possible cracking. Should any cracking be found then the whole system should be inspected with* a *non-destructive method preformed* [sic] *by an expert. Procean Systems Ltd. should be notified before any testing or repairs are to be carried out.*
> *The following must be checked and replaced if found necessary*
> • *Hinge bushing and bolts; maximum reduction in bushing wall before replacement is 2mm*
> • *Female hinge is to be repaired if there is an increase in hole diameter of more than 0.6mm*
> • *Shackles shall be replaced if* a *maximum reduction in metal thickness has reached 2mm*
> • *Worn out thimbles are to be replaced*
> • *All lines should be inspected for chaffing and wear. All worn or chaffed lines are to be replaced according to the anchoring plan and list of materials. Short lengths (up to 10 meters) above the water line may be replaced individually. If chaffing or wear occurs on longer lengths than 10 meters the whole line must be replaced and re-tensioned.*

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[9] 8 20150310161238332.pdf
[10] COOKE_CWA_00026357.pdf
[11] COOKE_CWA_00287357-COOKE_CWA_00287401
[12] 8 20150310161238332.pdf

• All buoys and connections to should be inspected and repaired or replaced if damaged. Contact Procean Systems Ltd. Before any repairs or changes are to be implemented to the anchoring plan.

The Marine Construction AS SystemFarm manual[13] includes the following items in the annual inspection requirements:

A. Mooring fittings
B. Chain
C. Shackle
D. Heart [Unknown definition. Possibly thimble.]
E. Rope
F. Eyelet on weight [anchor]
G. Weight [anchor], type and dimension
H. Depth
I. Distance from farm outskirts
J. Seabed condition

4.3.1.2 Implementation by Cooke

Based on documents provided by Cooke and reviewed by author to date, there were no comprehensive or thorough annual inspections being conducted at Cooke's net pens that were consistent with manufacturers' specifications. During Cooke's February 28 and March 1, 2019 deposition, Cooke[14] did not identify comprehensive annual inspection reports for any years prior to 2018, but rather pointed to ongoing, regular inspection practices at Cooke. Such practices fall within the manufacturers' specifications for more frequent (weekly or monthly) but less comprehensive inspections. Per the net pen manufacturers' specifications, they do not take the place of annual inspections required by NPDES permit section S6.F.

Mooring system diagrams and inspection reports were examined by the author. The most organized record of mooring inspections identified by the author was found in mooring diagrams provided by Cooke in the form of Excel workbooks.

These documents include mooring information and, in some cases, inspection records. Each workbook was examined and the intervals were calculated between the date the author listed as "Last Updated" and the most recent recorded inspection (When no "Last Updated" date was shown, the most recent date in the workbook was taken to be the effective date of the workbook.). These workbooks did not generally define whether an inspection included all the mooring components down to the anchor.

According to this documentation provided by Cooke, Cooke did not inspect mooring components on an annual basis. Several examples are provided below.

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[13] 8 20150310161238332.pdf

[14] The author understands that Mr. Parsons was deposed on May 24, 2019. The author reserves the right to modify this report after receiving the transcript of that deposition.

As of July 1, 2016, the "Last Inspection Date" listed for Cypress Site 1 mooring lines were as follows[15]: Anchors 1-6: January, 2014. Anchors 7-13: November, 2013. Anchors 14-22: October 2012. The components listed as being inspected in this case are "Surface hardware", "Surface Chain", "Mooring line", "Anchor Chain", and "Anchor Condition". In this case, certain anchor lines had not been inspected for three years and nine months.

As of July 1, 2016, the "Last Inspection Date" listed for Cypress Site 2 mooring lines were as follows[16]: Anchors 1-6: January, 2014. Anchors 7-13: November, 2013. Anchors 14-22: October 2012. The components listed as being inspected in this case are "Surface hardware", "Surface Chain", "Mooring line", "Anchor Chain", and "Anchor Condition". In this case, certain anchor lines had not been inspected for three years and nine months.

As of November 2017, the "Last Inspection Date" listed for Cypress Site 3 mooring lines corresponding to anchors 14-22 were October 2012. (It is noted that below water components were to be checked 11/12/2017). The components listed as being inspected in this case are "Surface hardware", "Surface Chain", "Mooring line", "Anchor Chain", and "Anchor Condition". In this case, anchor lines 14-22 had not been inspected for five years and one month.

4.3.2 Analysis and Discussion

4.3.2.1 The Need for Mooring Inspections

Mooring components are subject to corrosion, wear, fatigue, abrasion, and accidental damage. When chain contacts the seabed, sediments can be abrasive and erode the chain. For example, USCG Aid to Navigation Buoys are moored with chain connected to a heavy anchor. The USCG typically replaces the chain section near the touchdown point every one to three years due to loss of material from abrasion.[17] Furthermore, since the anchor should remain fixed while the chain moves, the connection between the bottom chain and the anchor can experience wear. For these reasons, the manufacturer of Cooke's Marine Construction AS SystemFarm[18] and Procean AS–Ocean Catamaran[19] cage systems specify annual inspections of all mooring components. The Procean AS–Ocean Catamaran manual specifically addresses the need to inspect even anchors that are deeper than 100 feet.

At several of Cooke's sites, inspection dives in 2017 showed that a number of anchors were inadequately embedded in the seafloor.[20,21] ROV inspections at the Hope Island site showed that

[15] COOKE_CWA_00018363-Site 1.xlsx
[16] COOKE_CWA_00018363-Site 2.xlsx
[17] Akers, R. Fatigue Design Methodologies Applicable to Complex Fixed and Floating offshore Wind Turbines, TAP-758, Bureau of Safety and Environmental Enforcement, p. 68. Contract E13PC00019, 2015. https://www.bsee.gov/sites/bsee.gov/files/tap-technical-assessment-program//758aa.pdf, downloaded 3/26/2019.
[18] 8 20150310161238332.pdf
[19] COOKE_CWA_00026357.pdf
[20] 2018 Mott MacDonald DW Site 3 Report.pdf, p. 26 of pdf file.
[21] 2018 Mott MacDonald DW Site 1 Report.pdf, p. 25 of pdf file.

two anchors were not embedded, or only partially embedded,[22] and inspections at the Fort Ward site showed that one anchor was not embedded, sitting on the seafloor.[23] These lines will not share loads proportionately with the other lines during instances of maximum current loading, and could result in progressive mooring failures. After drag embedment anchors for a fish farm are installed, they must either be inspected or proof-tested, pulling on the anchor horizontally until the anchor embeds and provides sufficient resistance to show that it is installed properly. Without proof-testing, the only way to detect this installation problem is through at least one visual inspection of the anchor by a deep water diver or by an ROV.

During large storms and/or high currents, a fish farm can exert extreme forces on the mooring components, possibly causing anchors to break free and be dragged across the seafloor. Ideally the anchor will re-embed, but this is not guaranteed. On August 3, 2016, workers on one of the Port Angeles farms noted that the "farm dragged anchors."[24] Following that incident the daily log for the site noted "anchors set,"[25] followed by "N end loose,"[26] "anchors pulling loose,"[27] "anchors loose,"[28] and "anchors keep pulling."[29] As with initial installation, the only ways to confirm that the anchors are set properly is through a proof test or a visual inspection by a diver or an ROV.

4.3.2.2 Compliance

Based on the records provided by Cooke related to the installation and inspection of their mooring components, it appears that Cooke did not inspect all underwater mooring components annually, as required by the NPDES permits.

Deposition testimony by Mr. James Parsons[30] indicated that sections of mooring lines deeper than 100 feet were assumed to be adequate if no problems were observed in the sections within 100 feet of the surface. The position of the anchor can be inferred from observations of the surface buoy and of line tension. However, for reasons described above (section 4.3.2.1), these observations do not indicate whether the chain on the seafloor has been excessively abraded or whether the anchor is fully embedded. Furthermore, the *ad hoc* inspections implied by Mr. Parsons do not reflect the rigorous inspections mandated by the manufacturers. For example, the manufacturers' specifications specifically require annual inspections all the way down to the anchor. In the case of the Procean systems, inspections down to the anchor are explicitly described even for anchors deeper than 100 feet. Thus, the methods described by Cooke do not constitute an inspection of all mooring components as required by the NPDES permits (section S6.F).

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[22] 2018 Mott MacDonald Hope Island Report.pdf, letter from Daniel G. Stromberg at Collins Engineers, Inc., to Mott MacDonald, "Underwater Inspection of the Hope Island," p. 2.
[23] 2018 Mott MacDonald Report Fort Ward.pdf, p. 29 of pdf file.
[24] COOKE_CWA_00074273
[25] COOKE_CWA_00074275
[26] COOKE_CWA_00074277, COOKE_CWA_00074279
[27] COOKE_CWA_00074285
[28] COOKE_CWA_00074287
[29] COOKE_CWA_00074291
[30] 30(b)(6) Cooke Aquaculture Pacific, LLC – Parsons. 103:11–19

No thorough record of repairs was provided to the author. Thus, it is not possible to determine whether Cooke complied with its Pollution Prevention Plan requirement that "Any defective components are to be replaced promptly."

4.3.2.3 Costs Avoided

The costs Cooke avoided annually by not inspecting mooring components deeper than 100 feet were estimated two ways. The first method estimated the costs to hire a contractor to inspect the moorings deeper than 100 feet.

Costs for this method were based on a quote by Collins Engineering[31] prior to their inspections with Mott MacDonald in late 2017. This method, detailed in Appendix 6, estimates that including the deep water mooring components in the annual inspections required by section S6.F of its NPDES permits would have cost Cooke $62,450 per year between 2012 and 2016. In 2017, Mott MacDonald contracted with Collins Engineers to inspect all remaining net pens and moorings after the Cypress 2 collapse. Table 15 shows that Cooke would have expended $42,250 to have the deep water moorings inspected. Similarly, Table 16 shows that the costs to inspect the deep water moorings at Cypress 1 and 3 in 2018 would have been $15,150.

Alternatively, Cooke could have purchased its own ROV and used its own personnel and infrastructure to inspect the deep water anchors. As detailed in Appendix 6, this approach would have cost Cooke at least $23,193 each year from 2012 through 2016. In 2017, Mott MacDonald contracted with Collins Engineers to inspect all remaining net pens and moorings after the Cypress 2 collapse. Table 20 shows that Cooke would have expended $23,193 to inspect the remaining deep water moorings using its own staff. Similarly, Table 22 provides the costs to inspect the deep water moorings at Cypress 1 and 3 in 2018.

5 Permit Requirements: S7 Fish Release Prevention and Monitoring Plan

5.1 NPDES Permit Requirements for the Fish Release Prevention and Monitoring Plan

5.1.1 Facts

Section S7 of the NPDES Permits enumerates the requirements for the Fish Release Prevention and Monitoring Plan. Specific requirements include that the Plan must address "Identification and implementation of technology that will minimize fish escapements" and "Routine procedures and best management procedures used to minimize the risk of escapement from the pens during normal daily operations."

[31] Subconsultant agreement between Mott MacDonald and Collins.pdf, Table 2.

5.2 Permit Plans

5.2.1 Facts

In each Fish Escape Prevention Plans (FEPP), Cooke lists technologies it has employed to reduce the risk of fish escapement. These technologies include "improved cage structure designs"[32]. Employing cage structures that will survive the expected extreme environmental conditions is essential to preventing fish escapes. However, Cooke failed to identify and implement certain critical net pen technologies necessary to prevent escapes. Specifically, conditions at each of its eight sites exceeded the maximum rated conditions specified by the net pen manufacturer.

The FEPP submitted by Cooke from 2009 up to and including January 2017 included the following text:

- "Redundancy and over capacity shall be utilized in the moorage system. Accurate drawings and descriptions of the equipment used, dates of deployment and other relevant information shall be kept by site managers."

Cooke's compliance with its Plan to utilize "Redundancy and over capacity" in the moorage system are examined in the present chapter.

5.3 Capacity of Net Pen Systems

5.3.1 Facts

CAP's sites in Puget Sound employed at least three different types of net pens:

- Marine Construction AS– SystemFarm
- Wavemaster Steel Cage
- Procean AS–Ocean Catamaran

The manufacturer specifies the capacity of each cage with respect to environmental conditions (current speed and significant wave height) and stock net dimensions (width, length, depth, and mesh characteristics). Manufacturer specifications for the Marine Construction AS SystemFarm, the Procean AS–Ocean Catamaran, and the AKVA Group Wavemaster system are listed in Table 3.

[32] COOKE_CWA_00027279

Table 3. Manufacturer specifications for net pen capacity

	Marine Construction AS– SystemFarm[33]	**Procean AS–Ocean Catamaran 200 ton Silo Barge**[34]	**AKVA Group Wavemaster EX-1**[35]
Environment			
Current speed	0.5 m/s	0.5 m/s**	1.0 m/s
Sig. Wave Height	1m, with T_{pk}=4s	*	2.3 m
Design			
Net width	24 m	25 m***	Not specified
Net length	24 m	25 m***	Not specified
Net depth	10 m[36]	20 m**	Not specified
Net twine diameter	Not specified	Not specified	Not specified
Mesh size	50 mm[37]		Not specified
Biofouling	Not specified	50%	Not specified
Mooring tension	Not specified	1000 kg	Not specified
Inspections	Specified monthly, and annual inspection sheets.	Specified weekly, monthly, and annual inspections. Includes specific guidance on when to replace specific components.	Not specified

*If SWH exceeds 1.5 meters, variable loads must be removed from walkways.
**"If the current speed does not exceed 0.5 m/s, then depths greater than 20 meters are allowed providing an adequate engineering studies [sic] is carried out and all factor are taken into consideration."
***For E-version. This is the version shown in the drawings attached to the Procean manual in COOKE_CWA_00000014–COOKE_CWA_00000022.

The BAP standard states that there must be documentation that the farm was installed per the recommendations of a marine engineer or other accredited party.[38] (Appendix 1).

To ensure that that net pens are not operated beyond their rated capacity, the Best Aquaculture Practices standard (refer to quotations in Appendix 1) states that a meteorological and metocean study should be performed using methods in the Norwegian aquaculture standard NS 9415 (Appendix 2).

[33] 8 20150310161238332.pdf
[34] COOKE_CWA_00026357.pdf
[35] COOKE_CWA_00287359
[36] 8 20150310161238332.pdf
[37] 8 20150310161238332.pdf
[38] Aquaculture Facility Certification: Salmon Farms. Best Aquaculture Practices Certification Standards, Guidelines. 2011, p11.

According to NS 9415, current, wave, and wind conditions with 10-year return periods and 50-year return periods at the local site are to be used when establishing the capacity of the net pen system. Currents must be quantified using a set of rigorous measurements collected over a month at the salmon farm site.

The author found no evidence that rigorous current, wave and wind studies were performed at any of the sites prior to 2017. Cooke provided values for maximum current speed for each site in their permit application documents. However, no basis for these values was provided in the materials reviewed by the author.

On April 9, 2019, the author was provided materials from Dynamic Systems Analysis (DSA). The expected maximum current speeds and significant wave heights calculated by DSA for the Cypress Site 1, Hope Island, and Orchard Rocks sites are included in Table 4. Table 5 summarizes the operating conditions for the net pens at each of the eight net pen sites. Parameters which exceed the net pen manufacturer specifications given in Table 3 are shown in bold italics.

Because DSA's analysis of current speeds were only provided for three sites, the author used current measurements collected by TerraSond[39] using an Acoustic Doppler Current Profiler to estimate the maximum expected currents at each site. This data consisted of 4-minute and 5-minute averaged measurements (ensembles) of the horizontal fluid velocity at 1-meter increments (bins) throughout the water column. For the present analysis, the velocity 5 meters below the water surface was used, as per NS 9415. Current measurements were sorted into eight bins based on the current heading. For each directional bin, the peaks were fit to a two-parameter Weibull distribution and extrapolated to estimate the highest current speed that would occur during an average 50-year interval (the 50-year return period current speed). Here, peaks were defined as any observation that exceeded the mean current speed by more than three standard deviations. This rigorous requirement results in lower estimates of the maximum current than would result from other acceptable thresholds (e.g. those used by DSA). The highest 50-year current speeds from all eight directional bins is reported for each site in Table 5, along with those estimated by DSA.

39 COOKE_CWA_00242021– COOKE_CWA_00242029

Table 4. Environmental Conditions at Cooke Aquaculture Pacific's Net Pen Sites

		Maximum Expected Current				Maximum Significant Wave Heights		
Site	**Pen Type**	**Allowed by Manufacturer**	**Cooke (Permit Applications)**	**DSA* / TerraSond**	**Dewhurst***	**Allowed by Manufacturer**	**Mott-Macdonald**	**DSA***
Cypress Island #1	8-cage Marine Construction SystemFarm[40,41]	50 cm/s	45 cm/ sec[42],[43]	***176 cm/s***[44]	***132 cm/s***[45]	1m, with T_{pk}=4s	Hsig<4 ft (1.2 m)[42]	***1.47*** m[46]
Cypress Island #2	10-cage Marine Construction SystemFarm[40,47]	50 cm/s	27 cm/ sec[48]		***153 cm/s***[49]	1m, with T_{pk}=4s	Not reported	
Cypress Island #3	12-cage Wavemaster EX-140[40,50]	100 cm/s	45 cm/ sec[51]		***173 cm/s***[52]	2.3 m	Hsig<4 ft (1.2 m) [53]	
Hope Island	10-cage Wavemaster EX-1[40,54,55]	100 cm/s	96 cm/sec[56]	***164 cm/s***[57]	***114 cm/s***[58]	2.3 m	Hsig=4.5 ft (1.4 m), Tp=3 sec[55]	1.318 m[59]
Port Angeles #1	14 cage Marine Construction SystemFarm[40]	50 cm/s	15 cm/sec[60]		42 cm/s [61]	1m, with T_{pk}=4s	***Hsig=5.3 ft*** (1.6 m), Tp=4.3 sec (SE Storm)[62]	
Port Angeles #2	6 cage Marine Construction SystemFarm[40,63]	50 cm/s	15 cm/sec[60]		18 cm/s [64]	1m, with T_{pk}=4s	***Hsig=5.3ft***, (1.6 m), Tp=4.3 sec (SE Storm)[65]	
Fort Ward	12-cage Ocean Catamaran Platform, Procean[40,66]	50 cm/s	110 cm/sec[67] **125 cm/ sec[68]**		***220 cm/s***[69]	**	5 ft (1.5 m)[70]	
Orchard Rocks	Two 10-cage Procean Ocean Catamaran Platforms[40,71]	50 cm/s	110 cm/sec[67] ***115 cm/ sec***[72]	***259 cm/s***[73]	***236 cm/s*** [74]	**	***6 ft*** (1.8 m)[67]	***1.58 m***[75]
Clam Bay	10- and 12-cage Procean Ocean Catamaran Platforms[40]	50 cm/s	90 cm/sec[76] or ***110 cm/sec***[77]		***97 cm/s***[78]	**	Not reported[77]	

[42] 2018 Mott MacDonald DW Site 1 Report.pdf

*Values corresponding to a 50-year return period.

** If SWH exceeds 1.5 meters, variable loads must be removed from walkways.

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[41] 71 17-11-16 Wood Interview.docx
[42] 2018 Mott MacDonald DW Site 1 Report.pdf
[43] FACT SHEET: COOKE_CWA_00033906.pdf
[44] COOKE_CWA_00241528
[45] Cyprus S\Original\DPL8_000.000
[46] COOKE_CWA_00241528
[47] 71 17-11-16 Wood Interview.docx
[48] FACT SHEET: COOKE_CWA_00033961.pdf
[49] Average of Cyprus N\Original\DPL7_000.000 and Cyprus S\Original\DPL8_000.000
[50] 71 17-11-16 Wood Interview.docx
[51] FACT SHEET: COOKE_CWA_00034016.pdf
[52] Cyprus N\Original\DPL7_000.000
[53] 2018 Mott McDonald DW Site 3 Report.pdf
[54] 2018-2-21 Letter – COOKE_CWA_00013517.pdf
[55] 2018 Mott MacDonald Hope Island Report.pdf
[56] COOKE_CWA_00034071.pdf
[57] COOKE_CWA_00241954
[58] Average of Hope N\Original DPL5_000.000 and Hope S\Original DPL5_000.000. However, the Hope Island S ADCP deployment yielded a higher current speed and was closer to the site, so an engineering analysis should consider the higher estimated maximum current of 133 cm/s.
[59] COOKE_CWA_00241954
[60] COOKE_CWA_00034126.pdf
[61] Port Angeles W\Original\DPL10001.000
[62] 2018 Mott McDonald Port Angeles Report 1.pdf
[63] 37 CAP_DOE_0004677.pdf
[64] Port Angeles E\Original\DPL9_000.000
[65] 2018 Mott McDonald Port Angeles Report 2.pdf
[66] 71 17-11-16 Wood Interview.docx
[67] 2018 Mott MacDonald Orchard Rocks Report.pdf
[68] FACT SHEET: COOKE_CWA_00036658.pdf
[69] Bainbridge N\Original\DPL4_000.000
[70] 2018 Mott McDonald Report Fort Ward.pdf
[71] 71 17-11-16 Wood Interview.docx
[72] FACT SHEET: COOKE_CWA_00034236.pdf
[73] COOKE_CWA_00241926
[74] Bainbridge S\Original\DPL3_000.000
[75] COOKE_CWA_00241926
[76] FACT SHEET: COOKE_CWA_00033851.pdf
[77] COOKE_CWA_00013224.pdf
[78] Average of Clam Bay S\Original\DPL2_000.000 and Clam Bay N\Original\DPL1_000.000. However, the Clam Bay S ADCP deployment yielded a higher current speed and was closer to the site, so an engineering analysis should consider the higher estimated maximum current of 125 cm/s.

Table 5. Configuration of Cooke Aquaculture Pacific's Net Pens

		Allowed by Manufacturer				Implemented by Cooke					
Site	**Pen Type**	**Width**	**Length**	**Depth**	**Mesh Size**	**Width**	**Length**	**Depth**	**Twine Diam.**	**Mesh Size**	**Cage Nos.**
Cypress Island #1	8-cage Marine Construction SystemFarm[79,80]	24m[81]	24m[81]	10 m	50 mm	24m[81]	24m[81]	***15m***[81]	1.7mm[81]	***22mm***[81]	
Cypress Island #2	10-cage Marine Construction SystemFarm[40,82]	24m[81]	24m[81]	10 m	50 mm	24m[81]	24m[81]	***15m***[81]	1.7mm[81]	***22mm***[81]	
Cypress Island #3	12-cage Wavemaster EX-1[40,40,83]	24m[81]	24m[81]	Not specified	Not specified	24m[81]	24m[81]	15m[81]	1.7mm[81]	22mm[81]	
Hope Island	10-cage Wavemaster EX-1[40,84,85]	24m[86]	24m[86]	Not specified	Not specified	24m[86]	24m[86]	12m or 13m[86]	1.7mm[86]	20mm[86]	1-10
Port Angeles #1	14 cage Marine Construction SystemFarm[40]	24m or 25m[87]	24m or 25m[87]	10 m	50 mm	24m or 25m[87]	24m or 25m[87]	***12m or 15m***[87]	210/165[87]	1.5[87]	1-14
Port Angeles #2	6 cage Marine Construction SystemFarm[40,88]	24m or 25m[87]	24m or 25m[87]	10 m	50 mm	24m or 25m[87]	24m or 25m[87]	10m or **12m**	210/165 or 210/150[87]	1.25 or 1.5[87]	15-20
Fort Ward	12-cage Ocean Catamaran Platform, Procean[40,89]	25m[90]	25m[90]	20 m	Not specified	25m[90]	25m[90]	15m[90]	2.1mm[90]	20 mm[90]	
Orchard Rocks	Two 10-cage Procean Ocean Catamaran Platforms[40,91]	25m[90]	25m[90]	20 m	Not specified	25m[90]	25m[90]	15m[90]	2.1mm[90]	20 mm[90]	
Clam Bay	10- and 12-cage Procean Ocean Catamaran Platforms[40]	25m[92]	25m[93]	20 m	Not specified	25m[93]	25m[93]	15m[93]	264ply or 2.1mm[93]	20mm or 36mm[93]	

[79] COOKE_CWA_00017123.pdf
[80] 71 17-11-16 Wood Interview.docx
[81] COOKE_CWA_00000096.xlsx
[82] 71 17-11-16 Wood Interview.docx
[83] 71 17-11-16 Wood Interview.docx

[84] 2018-2-21 Letter – COOKE_CWA_00013517.pdf
[85] 2018 Mott MacDonald Hope Island Report.pdf
[86] COOKE_CWA_00000209.xlsx
[87] COOKE_CWA_00000297 (COOKE_CWA_00000277.pdf)
[88] 37 CAP_DOE_0004677.pdf
[89] 71 17-11-16 Wood Interview.docx
[90] COOKE_CWA_00000247.xlsx
[91] 71 17-11-16 Wood Interview.docx
[92] COOKE_CWA_00026379.xlsx
[93] COOKE_CWA_00026379.xlsx

5.3.2 Analysis and Discussion

5.3.2.1 Compliance

CAP's NPDES permits require the "Identification and implementation of technology that will minimize fish escapements". Furthermore, CAP's Fish Escape Prevention Plans from 2009 to 2017 provide that "Redundancy and over capacity shall be utilized in the moorage system." However, Table 4 and Table 5 show that conditions at each of its eight sites exceeded the maximum rated conditions specified by the net pen manufacturer. The loads at these sites exceed the maximum rated conditions either by exceeding the maximum current speed, significant wave height, net depth, or a combination thereof.

The Cypress Island 1 net pen system used stock nets that were 50% deeper than those prescribed by the manufacturer. These nets also had a mesh size (spacing) that was less than half that specified by that manufacturer. That is, the solidity of the net panels were more than double those specified by the manufacturer. These two modifications result in the nets having an overall projected area more than 300% of that of the nets specified by the manufacturer. For a given steady current speed, the horizontal fluid drag force on a net is nominally proportional to projected area. Furthermore, the maximum expected 50-year current speed was about 2.5 times that specified by the manufacturer. Fluid drag force is generally proportional to the square of fluid speed, so a current speed of 2.5 times the rated value produces a drag force more than 6 times the drag force associated with the rated current. The combined effects of the increased drag area of the nets and the excessive current speeds result forces on the system that are far greater than those for which the structure was designed.

Similarly to Cypress Island 1, the Cypress Island 2 net pen system employed nets whose depth exceeded the maximum manufacturer-specified net depth and whose net mesh size was smaller than the minimum allowed for by the manufacturer. Furthermore, the maximum expected current at Cypress Island 2 was more than three times that specified by the manufacturer.

The author's conservative (low) estimate of the maximum expected currents at Cypress Island Site 3 were 75% higher than those allowed by the manufacturer.

The author's conservative (low) estimate of the maximum expected currents at Hope Island were 14% higher than those allowed by the manufacturer. The Port Angeles net pen systems exceeded the manufacturer's rating for net depth. Furthermore, the 50-year return period significant wave height is larger than the maximum allowable significant wave height specified by the manufacturer.

For the Fort Ward, Orchard Rocks and Clam Bay sites, the expected maximum current speeds are, respectively, 4.1, 4.2, and 2.0 times the maximum current speeds specified by the manufacturer. It is noted that the net depths at these sites are less than the maximum allowed by the manufacturer (15 m, compared to the maximum allowable depth of 20 m in currents up to 0.5 m/s). However, since the drag forces associated with the maximum expected currents at these sites will produce drag loads that are approximately 16.8, 17.6, and 4.0 times those associated with the maximum current speed specified by the manufacturer, the reduced net depth does not sufficiently offset the increased load on the net pen system due to the excessive current speeds.

Net pen systems operated under conditions that exceed the manufacturers' ratings are at risk of partial or catastrophic failure during instances of extreme environmental loading, which can result in fish escapement.

Compliance with manufacturers' specifications is necessary to ensure that net pen structures will be capable of surviving the expected extreme environmental conditions. Manufacturers' specifications and BAP guidelines require that system configurations that deviate from manufacturers' specifications must be approved by a marine engineer or by another accredited party. In the absence of a marine engineer's analysis demonstrating the safety of the system, net pen systems that do not comply with manufacturers' specifications are at risk of structural failure. The risk of failure at each of these sites was exacerbated by the apparent lack of rigorous analyses of maximum current speed for any site prior to 2017. The apparent lack of rigorous analyses of maximum current for certain remaining sites to date further exacerbates the risk of structural failure at these sites. In relation to the issues described above, Cooke failed to identify and implement technology that will minimize fish escapements at its eight Puget Sound net pen sites and failed to utilize redundancy and over-capacity in the moorage systems.

5.3.2.2 Costs Avoided

The risk of recurring or catastrophic structural failures at the sites could have been reduced by performing the rigorous analysis of 10-year and 50-year maximum current speeds as required by BAP. A budgetary estimate for the measurement and analysis work required by BAP was obtained from ASL Environmental Sciences Inc., of Victoria, B.C. The cost of this analysis for a single site—exclusive of airfare and lodging for the field technician—would be $18,284. Appendix 5 extrapolates this quote to estimate the cost of quantifying the maximum expected currents at each of seven net pen locations in three different areas (Bellingham Channel, Hope Island, and Rich Passage). Since published literature[94] suggests currents in Port Angeles are below the 0.5 m/s speed allowed by the manufacturer, a current study in Port Angeles was not included in this estimate. Using the conservative assumptions detailed in Appendix 5, quantifying the maximum expected currents at seven net pen locations would have entailed a one-time cost of at least $77,954, in 2019 USD. Since these studies were required by BAP standards, Cooke had annual opportunities back through Sept. 14, 2012 to acknowledge the need for these studies and authorize their execution.

In addition to requiring a rigorous analysis of maximum current speeds at each net pen location, manufacturers' specifications and BAP guidelines require that system configurations that deviate from manufacturers' specifications must be approved by a marine engineer or by another accredited party. Based on the author's professional experience, the simplest possible analyses of this nature require the engineering effort summarized in Table 6. These costs assume that the marine engineer has an existing numerical model of the basic net-pen system that can be adjusted to reflect the specific configuration and environmental conditions at the site in question.

Table 6. Minimum required engineering effort to assess variations on mooring configuration or net configuration. Assuming a rate of $125 for a marine engineer.

Task	Hours	Costs

[94]Ebbesmeyer, C. C., et al. "Dynamics of Port Angeles Harbor and Approaches." Prepared for the MESA (Marine Ecosystems Analysis) Puget Sound Project (1979).

Structural parameter identification	8	$1,000
Hydrodynamic parameter identification	8	$1,000
Model building and verification	8	$1,000
Model analysis	8	$1,000
Final reporting	8	$1,000
Total	**40.0**	**$5,000**

Conditions at each of Cooke's eight sites exceed the maximum rated conditions specified by the net pen manufacturer. Thus, Cooke should have conducted an engineering analysis for nine different net pen systems (Port Angeles comprises two separate cage systems), for a total one-time cost of $45,000, in 2019 USD. Since these studies were required by BAP standards, Cooke had annual opportunities back through Sept. 14, 2012 to acknowledge the need for these studies and authorize their execution.

Since the currents at Port Angeles are below the maximum speed allowed by the manufacturer, and only the estimated 50-year return period significant wave height at Port Angeles exceeds the value allowed by the manufacturer, it is possible that an engineering analysis would show that reducing the net depth to the specified sizes would allow the system to survive the maximum expected environmental conditions. For the remaining seven sites, the current speeds exceed those specified by the manufacturer by such a large margin that it is unlikely that the raft systems operated by Cooke as of 2017 could achieve the safety factors required by NS9415 or any international standard in the maximum expected environmental conditions, even if the net depths were reduced. Therefore, Cooke would have needed to upgrade its infrastructure with more robust net pen systems at Cypress Island #1, #2, and #3, Hope Island, Fort Ward, Orchard Rocks, and Clam Bay. Appendix 7 shows that the costs avoided by not upgrading to sufficiently robust net pen systems is approximately $26,440,000. Cooke had annual opportunities to incur this one-time cost between Sept. 14, 2012 and the present.

Potential costs avoided, not estimated here, include the costs of relocating net pen operations to sites with less extreme current speeds. Furthermore, the economic gains associated with the increased net sizes were not calculated in this report.

6 Cypress Island Net Pen Collapse

The purpose of this chapter is to assess whether the catastrophic failure of Cooke's Cypress 2 net pen in August 2017 is attributable in part to Cooke's failure to identify and implement appropriate technology and best/appropriate industry standards and practices. This chapter is focused on evaluating the effects of Cooke's deviations from its Permit requirements—as described in the preceding chapters—on the failure of the Cypress Site 2 net pen.

6.1.1 Chronology

6.1.1.1 Facts

A perfunctory chronology of the events leading up to the catastrophic failure is given in Table 7.

Table 7. Chronology of Events Regarding Cypress Island Site 2

Following events were extracted from source "Response to the Administrative Order issued to Cooke Aquaculture Pacific, LLC, Docket Number 15422"[95]	
7/24/17	Mooring failure at Site 2. Ten anchor points on cages had failed, other anchors dragged
7/25/17	Moorage anchors failed again, cages shifted off the permit site
7/26/17-7/29/2017	Crew worked to "...reset and replace the mooring system for the Site 2 facility." "This involved replacement of the mooring system and attachment points for the entire facility."
8/19/2017	Another mooring failure. Two anchors failed, three others dragged, one anchor had a broken pad eye, safety chain and cleat.
8/20/2017	Corner anchor failed. Staff could not reattach line. Corners of cages became submerged
8/21/2017	Some walkways started twisting
8/22/2017	Currents too high for divers
8/23/2017	Site 2 was total loss
2/9/2018	Cooke reported that all debris was removed from the sea floor.[96]

6.2 Net Cleaning

6.2.1 Facts

The July and August 2017 incidents were widely attributed by Cooke staff to excessive biofouling on the Site #2 nets. Examples are quoted below.

Cooke stated that "a slowdown in net cleaning occurred prior to the July incident because of mechanical issues related to the net cleaning equipment."[97]

The following text appears in a document entitled *Cypress Island, July 2017 results*[98] prepared by Cooke Aquaculture Pacific:

> On Monday July 24th Site 2 lost approx. 10 moorings and several anchor points drug. During the rest of the week the site was reanchored in

[95] 155 Cooke_s_Response_to_Agreed_No._Order_15422.pdf
[96] COOKE_CWA_00047613
[97] em_atlantic_salmon_cooke_investigation_response.pdf
[98] COOKE_CWA_00130821.pdf

place and feeding resumed on Saturday July 29. No stock was lost and mortality was very low. This failure was due to fouled nets and weak mooring points.

In the same document, under the heading "Cypress Island – Net hygiene:"

Cypress Island - Net hygiene

- MPI and Idema running, Stingray has been problematic, welds on the wash head continue to break.
    - New wheels arrived Monday, Aug. 7.
- Site 2 and 1 walls are washed, moving to site 3 and continuing to address floors.

The same text appears in the net hygiene section of another document entitled *Cypress Island, September 2017 results*[99].

A quotation from an August, 2017 *Production Report from Cooke Aquaculture Pacific*,[100] under the heading *Innes- Farm Sites and Marine Managers Discussion* is:

Problem- Failure and unreliability of net washing systems was a factor in both instances of Clam Bay and Site 2 breaking moorings. Both farms fell behind in keeping up with net hygiene. Increased drag during extreme tides snapped moorings.
Keeping nets clean especially during spring summer rapid fouling growth periods and hard tidal exchanges is critical.
- Are the net washers functioning at all times? No.
- What can we do to correct that problem?
Solutions:

- Have common breakdown replacement parts available on site. Keep extra 2 to 3 of each part available at each of the sites in inventory.

Action Item {to be done by Friday): Tom, Bill, Brandon write up a list of common breakdown points and issues for the MPI and the StingRay. Make a list of parts that would be needed to do on site quick repairs.

Tom, Brandon or Bill- Designate a single person to order up enough parts for each farm area to have 2 to 3 extra parts available for each machine they operate.

Site Managers- Keep parts on each site and keep an inventory of your parts. Order a new replacement part when you use one of these spare parts.

According to an interview with Matt Fitzgerald, Cooke Aquaculture Site 1 Raft Supervisor, regarding the August incident:

Nets need more cleaning in the summer. Broken net washers affected the cleaning schedule. Fouling at Site 2 was "7 out of 10", it is usually "4 out of 10"[101].

According to an interview with Sky Guthrie, Cypress Island Manager:

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[99] COOKE_CWA_00131215.pdf
[100] 115 COOKE_CWA_00130914.pdf
[101] 106 17-11-9 Fitzgerald.pdf

Fouling on a scale of 1-10, 2-3 is ideal, probably ~8 after July[102]

6.2.2 Analysis and Discussion

6.2.2.1 Compliance

No photographic or quantitative measure of the effectiveness of net cleaning between the July and August incidents was reviewed by the author. Thus, it is impossible to quantify the extent to which biofouling increased the drag on the net pens at the time of the August collapse. But the reports from Cooke staff quoted above indicate that significant levels of biofouling were present on the Cypress Site 2 nets. It is noted that Mr. Fitzgerald's comment specifically was in regard to the August incident. Thus, based on Cooke employees' observations, it is reasonable to conclude that biofouling levels could have exceeded those accounted for by the cage manufacturer, resulting in increased drag loads, leading to broken mooring attachments and dragged anchors.

6.2.2.2 Costs Avoided

Cooke's maintenance supervisor partially attributed the net washers' breakdowns to inadequate care by workers.[103] However, quantifying the cost of improved training or maintenance is beyond the scope of this report. Additionally, Cook could have replaced stock nets rather than focusing on cleaning alone. However, quantifying the economic implications of such a decision is outside the scope of this report.

6.3 Inspections and Maintenance

6.3.1 Analysis and Discussion

6.3.1.1 Compliance

It is noted that, during and after the July 2017 incident, Cooke expended significant effort inspecting and repairing components. However, prior to July 1, 2016, anchors at Cypress Site 2 went three years and nine months[104] without a documented inspection of the complete mooring system.

While no cohesive record of issues and repairs at Site 2 was reviewed by the author, it is noted that Cooke expended significant effort repairing and replacing components after the July incident. However, modifications to the net pen design and mooring plan were made without consulting a marine engineer.[105] For example, the "chain exoskeleton" installed after the July incident may have contributed to the catastrophic failure in August by applying loads to the anchor attachment points that were not accounted for in the design of those points.

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[102] 70 17-12-1 Guthrie Interview.docx
[103] 17-12-6 Clark Interview.docx
[104] COOKE_CWA_00018363-Site 2.xlsx
[105] 30(b)(6) Cooke Aquaculture Pacific, LLC - Parsons Vol 1. p207-08.

6.3.1.2 Costs Avoided

The decisions to deviate from the net pen design and mooring plan specified by the net pen manufacturer were apparently made without the evaluation or guidance from a marine engineer.[106] Based on the author's professional experience, the simplest possible analyses of this nature require the engineering effort summarized in Table 8. These costs assume that the marine engineer has an existing numerical model of the basic net-pen system that can be adjusted to reflect the specific configuration and environmental conditions at the site in question. While it is impossible to project what the outcomes of an initial engineering assessment would have been, a conservative estimate of the cost to hire a marine engineer to evaluate the effects of installing the "chain exoskeleton" in July 2017 yields an avoided cost of $10,000, in 2019 USD.

Table 8. Minimum required engineering effort to assess variations on mooring configuration or net configuration. Assuming a rate of $125 for a marine engineer.

Task	Hours	Costs
1. Hydro-/structural dynamic model		
Structural parameter identification	8	$1,000
Hydrodynamic parameter identification	8	$1,000
Model building and verification	8	$1,000
Model analysis	8	$1,000
2. Finite element model of mooring attachment subject to loads from mooring and "exoskeleton"		
Geometry and material property identification	8	$1,000
Model building and verification	24	$3,000
Model analysis	8	$1,000
Final reporting	8	$1,000
Total	**80.0**	**$10,000**

6.4 Capacity of Net Pet Systems

6.4.1 Facts

Table 3 and Table 5 show that the nets on the Cypress Island Site 2 pen were 50% deeper than those allowed by the net pen manufacturer and had a mesh size less than half that specified. As described in 5.3.2, these two modifications result an overall increase in the fluid drag force of 300%. Furthermore, the system was operated in a location with expected extreme currents three times those allowed by the cage system manufacturer. Thus, rather than identifying and implementing "technology that will minimize fish escapements" as required by condition S7.1 of

[106] 30(b)(6) Cooke Aquaculture Pacific, LLC - Parsons Vol 1. p207-08.

its NPDES permit, Cooke increased the risk of fish escapements by increasing the risk of structural failure.

Furthermore, the mooring system differs from that recommended by the manufacturer. The mooring design at the time of the structural failure in July, 2017, is described in a document, “COOKE_CWA_00018363-Site 2.xlsx”. After the failure in July, 2017, the revised mooring system is described in “COOKE_CWA_00018184.xlsx”. The latter document was in effect at the time of the complete pen collapse in August, 2017. It differs significantly from the layout specified in the SystemFarm manual.

The Best Aquaculture Practices (BAP) standard states that there must be documentation that the farm was installed per the recommendations of a marine engineer or other accredited party[107]. Two analyses of the Cypress Site 2 system were reviewed by the author. The first is in the form of an Excel workbook[108] and a corresponding PDF[109]. These have no author or date listed. They do not report the assumptions or calculations that were used to generate the results. These documents report “rope safety factors” of 0.3 to 1.3 for the various anchor lines analyzed for Cypress Site 2. The second analysis of the Cypress Site 2 system is summarized in a report from a Norwegian company, Aqua Knowledge, dated April 16, 2015[110]. This analysis reports the safety margins for the mooring lines are “OK.” It should be noted, however, that this report details the stock nets included in the analysis, but makes no mention of including a predator net. Furthermore, the mooring configuration differs from what was present at Cypress Site 2 before the August collapse. Both of the analyses show 22 anchors at Cypress Site 2. However, the mooring diagram provided by Cooke update 8/3/2017 shows only 20 anchor lines at Site 2.[111] Neither of these analyses report safety factors for the structural components of the raft (e.g. mooring points).

6.4.2 Analysis and Discussion

6.4.2.1 <u>Compliance</u>

The Cypress Island 2 net pen system used stock nets that were 50% deeper than those prescribed by the manufacturer. These nets also had a mesh size that was less than half that specified by that manufacturer. These two modifications result in the nets having an overall projected area more than 300% of that of the nets specified by the manufacturer. For a given steady current speed, the horizontal fluid drag force on a net is nominally proportional to projected area. Furthermore, the fluid drag is nominally proportional to fluid speed squared. Since the system was operated in a location with expected extreme currents three times those allowed by the cage system manufacturer, the total drag loads under an extreme current event could be as high as 27 times those allowed by the manufacturer in the design process.

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107 Aquaculture Facility Certification: Salmon Farms. Best Aquaculture Practices Certification Standards, Guidelines. 2011, p11.
108 COOKE_CWA_00017135.xls
109 20 Icicle_Seafoods_Deep_Harbor.pdf
110 COOKE_CWA_00013573.pdf
111 COOKE_CWA_00018184.xlsx

Given the discrepancies between the manufacturer's specifications and the configuration of the net pen system, the system required the analysis of a marine engineer or other accredited party[112]. Two analyses were reviewed. The analysis in COOKE_CWA_00017135.xls appears to be based on observations of how far various mooring buoys submerged when their mooring lines were under tension. This spreadsheet shows "rope safety factors" from 0.3 to 1.3 for the various anchor lines analyzed for Cypress Site 2 when incorporating load factors and material factors similar to those prescribed in NS9415. Safety factors lower than 1.0 indicate failure. The report by Aqua Knowledge concluded that the safety margins in the mooring lines were "OK". This analysis lists the correct dimensions of the stock nets that were used, but makes no mention of a predator net. The basis of the current speeds used in this analysis is not stated.

A subset of daily logs for Cypress Site 2 related to structural concerns were reviewed by the author. The logs do not provide a clear record of structural issues. However, the apparent repeated breaking or bending of anchor attachment points[113,114,115, 116] and the occurrence of cracks in the steel structure[117,118] are consistent with a net pen system that was being operated under loads that were higher than those for which it was designed. These excessive drag forces would be due to oversized nets with a fine mesh and current speeds significantly higher than those allowed by the manufacturer.

6.4.3 Costs avoided

Performing a rigorous study of the maximum currents at Site 2 would have informed Cooke whether the Marine Construction SystemFarm pen technology was sufficiently robust as to prevent fish escapes due to structural failure at the site. As described in Section 5.3.2.2, this study, conducted only for Cypress Site 2, would have cost Cooke over $18,284.

In addition to performing a rigorous study of the maximum current speeds at the site, Cooke should have used the net size specified by the net pen manufacturer. The economic losses associated with using this smaller net size are outside of the scope of this report.

6.5 Summary: Cypress Island Net Pen Collapse

As a result of excessive loads on the Cypress Site 2 net pen system created by:

- Currents, net sizes, and net solidity exceeding those specified by the net pen manufacturer,
- biofouling levels potentially exceeding design values, and
- mooring system installations and repairs that deviated from manufacturer recommendations and were not approved by a marine engineer,

[112] Aquaculture Facility Certification: Salmon Farms. Best Aquaculture Practices Certification Standards, Guidelines. 2011, p11.
[113] 20160222_ShackleAt15CornerBendInBracketsHoldingBoxBeams.pdf
[114] 20160202_CockeyedPadeyeAt21Corner.pdf
[115] 20150212_AnchorsLookGoodAnchorPointStillNeedFix.pdf
[116] 20141125_8StressCracks211AnchorEyeStillNeedsFix.pdf
[117] 20141002_8CracksTeensSide1Crack221.222Outside.pdf
[118] 20150116_AnchorsLookGood8CracksPlus1.pdf

the Cypress Site 2 net pen system was at risk of partial or catastrophic failure when subjected to the expected extreme tidal currents. Thus, these factors likely contributed to the partial and catastrophic failures that occurred when the system was subjected to these tidal currents in the summer of 2017.

7 Recommendations

In order to avoid or mitigate the risk of failure under future extreme environmental loading events at Cooke's net pens, to better respond to partial or total failures if they occur, and for Cooke to comply with its NPDES permits, the author makes the following recommendations, to the extent they are consistent with Cooke's NPDES permits:

- Cooke should complete rigorous current speed analyses at all sites and adjust net pen engineering and siting if necessary.
- Cooke should bring all net pen sites within the maximum rated conditions specified by the net pen manufacturer, including but not limited to maximum current speed, significant wave height, and net dimensions. Alternatively, net pen systems that deviate from manufacturers' specifications should be evaluated and approved by a marine engineer according to industry standards. This engineering analysis must consider the structural integrity of the mooring system and the net pen structure.
- Cooke should ensure that engineering analysis takes into account the actual dimensions, mesh size, and twine diameter of all nets on each net pen system when determining whether sites are within maximum rated conditions.
- Mooring systems and net pen cage structures should be shown to include "redundancy and over capacity" as stated in Cooke's Fish Escape Prevention Plans and as required by industry standards.
- Maximum biofouling on nets should not exceed levels accounted for in the design of the net pen structure and mooring system.
- Cooke should develop a Standard Operating Procedure for future partial or total failures of net pens that, at a minimum, requires consultation with a marine engineer and an attempt to identify the cause(s) of the failure.
- Cooke should inspect all portions of mooring systems on an annual basis as required by NPDES permits, including visual inspections via dive teams or via ROV of all anchoring components below 100 feet in depth.
- Cooke should conduct thorough "annual" inspections of the full main cage structures that are not part of daily, weekly, or monthly inspections and prioritize necessary maintenance identified through these inspections.

Appendix 1 Best Aquaculture Practices for Salmon – Control of Escapes

The Global Aquaculture Alliance (GAA), Portsmouth, NH (formerly St. Louis, MO) creates and maintains an industry standard called:

Aquaculture Facility Certification
Salmon Farms
Best Aquaculture Practices Certification Standards, Guidelines

GAA released versions of this standard as described in Table 9. According to these standards, either Version 2, Rev. 2 or Issue 2, Revision 3 applied at the time of the Cypress Site 2 pen collapse in August, 2017.

The current version of the BAP Salmon Farm Standards is Issue 2, Revision 3 October 2016. The standard is available from:

Global Aquaculture Alliance
Best Aquaculture Practices
85 New Hampshire Avenue, Suite 200
Portsmouth, NH 03801 USA

Table 9. Versions of *Aquaculture Facility Certification, Salmon Farms, Best Aquaculture Practices*

Release Date	Version Designation (in document)	Applicability
6/2011	Initial Release	(open ended)
5/2015	Version 2 – Rev 2, May 2015	Replaces Initial Release, valid until October 15, 2017
10/2016	Issue 2 – Revision 3	October 2016 Onward

An excerpt from this document follows. The only change between the text in the three versions of the standard is the omission of the word "that" in the third bullet item of the May 2015 version as compared to the earlier version.

6. Environment

Control of Escapes

Salmon farms shall take all practical steps to prevent escapes and minimize possible adverse effects on aquatic wildlife if escapes occur.

...

Implementation

...

Escape Prevention

- A classification of the farm site based on expected wave heights and currents based on local estimates of 10- and 50-year maximum wind speeds and directions using the method proposed in NS9415 or equivalent.

- A report from a qualified marine engineer or accredited third-party that confirms the farm structure design and installation are appropriate, given the 10- and 50-year site conditions estimated in the site classification
- Documents that show ~~that~~ the farm's moorings were installed according to the manufacturer's and/or marine engineer's specifications.

  ...

- Procedures that require the main surface components of the system to be inspected by qualified inspectors at least annually and repaired or replaced as needed. The sub-surface components must be inspected and replaced, as needed, at least every two years or between each crop cycle, whichever is shorter. Equipment shall be replaced as needed.
- Net inventory management procedures that track the ages of all nets on the farm or in storage, and provide strength tests on all nets between crops or every two years, whichever period is shorter. Nets shall be retired when their strength is below levels specified in local regulations or, where there are none, below the manufacturer's or supplier's recommendations.
- Cage inspection procedures that ensure all operational nets are surface checked for holes at least weekly and checked sub-surface at least every four weeks. Nets and cage superstructure shall be checked for holes and other indications of structural damage after risk events such as storms or big tides.

  ...

- A training program for all staff, which shall be part of their initial training, on all procedures in the Fish Health Containment Plan.

Standards

...

6.3 The applicant shall provide documents to show that all staff members have received training in the Fish Containment Plan, which shall be verifiable by training certificates in employees' files and verified at audit by a subset of interviews.

Appendix 2 NS 9415

The following text is quoted from Norwegian Standard NS 9415.E:2009 entitled *Marine fish farms, Requirements for site survey, risk analyses, design, dimensioning, production, installation and operation*.

5 Site surveys

...

5.2 Determination of velocity of current

5.2.1 General

Either para. 5.2.2, 5.2.3. or 5.2.4. shall be used in determining current velocities.

Measurements shall be done at a minimum of two levels, 5 m and 15 m respectively below sea level, where topography allows.

Measurements shall be undertaken at a place at the site which is expected to have the highest current velocities and shall be representative of the areas where the fish farm is to be located. The measurement site shall be indicated and justified. Logging of current shall take place at least every 10 minutes and form the basis for the dimensioning current velocity at the site. Previous measurements which are logged every 30 minutes can be used when current data is to be collated for a complete year.

Measurement of current velocity entails registration of both time, velocity and direction during the whole of the measurement period. Current measurements shall take place in accordance with NS 9425-1 and/or NS 9425-2, dependent on the bottom depth of the site and exposure.

Which critical current components contribute to the total current overview shall be assessed and documented:

- tidewater current;
- wind-induced surface current;
- outbreak from the coastal current;
- spring flood because of snow and ice melting.

Quality assessment of measurement data of current measurements shall be performed, and include:

- credibility;
- factors during the measurement period that can have affected the measurements.

5.2.2 Measurements of current for one year and use of long-term statistics

...

5.2.3 Measurement of current for one month

...

5.2.4 Use of previous current measurements

...

Appendix 3 NPDES Permits

Site	Primary Permit	Renewal Application Package, Salmonid NPDES Discharge Application	Permit, Fact Sheet
Clam Bay	WA-003152-6	(Original) COOKE_CWA_00052126.pdf (Modified) COOKE_CWA_00030411.pdf COOKE_CWA_00052170.pdf	COOKE_CWA_00030478.pdf COOKE_CWA_00033851.pdf
Cypress Site 1: Deepwater Bay	WA-003156-9	COOKE_CWA_00034878.pdf COOKE_CWA_00054113.pdf	COOKE_CWA_00054233.pdf COOKE_CWA_00033906.pdf
Cypress Site 2: Deepwater Bay	WA-003157-7	COOKE_CWA_00034906.pdf COOKE_CWA_00054769.pdf	COOKE_CWA_00019607.pdf COOKE_CWA_00033961.pdf
Cypress Site 3: Deepwater Bay	WA-003158-5	COOKE_CWA_00034934.pdf COOKE_CWA_00055402.pdf	COOKE_CWA_00055523.pdf COOKE_CWA_00034016.pdf
Fort Ward, Saltwater II	WA-003153-4	COOKE_CWA_00036683.pdf COOKE_CWA_00052786.pdf	COOKE_CWA_00036658.pdf COOKE_CWA_00036658.pdf
Site 4 - Hope Island	WA-003159-3	COOKE_CWA_00034992.pdf COOKE_CWA_00056049.pdf	COOKE_CWA_00056165.pdf COOKE_CWA_00034071.pdf
Orchard Rocks, Saltwater IV	WA-003154-2	COOKE_CWA_00035020.pdf COOKE_CWA_00053432.pdf	COOKE_CWA_00053496.pdf COOKE_CWA_00034236.pdf
Port Angeles, Ediz Hook Site	WA-004089-4	COOKE_CWA_00035047.pdf COOKE_CWA_00056681.pdf	COOKE_CWA_00056738.pdf COOKE_CWA_00034126.pdf

A3.1 MARINE/FRESHWATER SALMONID NET-PEN NPDES WASTE DISCHARGE PERMIT APPLICATION CURRENT SPEEDS

Text common to all of the *Marine/Freshwater Salmonid Net-Pen NPDES Waste Discharge Permit Application Forms*, Section B. Background Information:

Table 10. Current Information provided in Permit Renewal Application Packages

Site	Direction of dominant current from the net-pen(s)	Est. mean current (midway between net-pen bottom and sea floor, cm/sec)	Max. current (midway between net-pen bottom and sea floor, cm/sec)
Clam Bay	West	15	90
Site 1, Deepwater Bay	West	25	45
Site 2, Deepwater Bay	South	25	35
Site 3, Deepwater Bay	South	35	65

Site	Direction of dominant current from the net-pen(s)	Est. mean current (midway between net-pen bottom and sea floor, cm/sec)	Max. current (midway between net-pen bottom and sea floor, cm/sec)
Fort Ward, Saltwater II	West	40	125
Site 4 – Hope Island	North	35	95
Orchard Rocks – Saltwater IV	West	35	115
Port Angeles – Ediz Hook	West	5	20

Appendix 4 Tobias Dewhurst—CV

Tobias Dewhurst

Hydrodynamics Engineer
Maine Marine Composites

SPECIALIZATIONS

Wave-structure Interaction | Hydrodynamics | Marine Renewable Energy | Aquaculture
Numerical Modeling | Wave/tow Tank Testing | Field Experiments| Data Analysis, Visualization

A4.1 Experience

Maine Marine Composites *Project Engineer* September 2016–Present

Secured and managed commercial consulting projects and federally funded research projects in the design and analysis of ocean systems. Industries include marine renewable energy (wave, tidal, and floating offshore wind), aquaculture, lifting and construction applications, and various novel systems exposed to waves and currents.

University of New Hampshire December 2016

Doctor of Philosophy, Mechanical Engineering
Dissertation: *Dynamics of a Submersible Mussel Raft System*
Master of Science, Ocean Engineering May 2013
Thesis: *Muskeget Channel Tidal Energy Test Facility*

Cedarville University December 2009

Bachelor of Science, Mechanical Engineering
Minors in Math, International Business (courses at Dublin Business School, Ireland)

A4.2 PEER REVIEWED PUBLICATIONS

Dewhurst, T., Hallowell, S.T., & Newell, C.R., 2019. *Dynamics of an Array of Submersible Mussel Rafts in Waves and Current.* Proc. of the 38th Conf. on Ocean, Offshore and Arctic Engineering, Glasgow. Accepted.

Simulation of an Axisymmetric, Pneumatic-PTO WEC in Operational and Survival Conditions for Model-Based Design, 2018. Dewhurst, T., MacNicoll, M, Akers, R. *Marine Energy Tech. Symposium Proc.*

Testing and Modelling the RTI F2 QD WEC (2017). Rohrer, J., Weise, N., Dewhurst, T., MacNicoll, M,. EWTEC 2017.

Dynamics of Submersible Mussel Rafts in Waves and Current. Wang, X., Swift, M. R., Dewhurst, T., Tsukrov, I., Celikkol, B., and Newell, C. 2015 China Ocean Engineering Journal, 29(3).

Dynamics of a Floating Platform Mounting a Hydrokinetic Turbine. Dewhurst, T., Swift, M. R., Wosnik, M., Baldwin, K., DeCew, J., & Rowell, M. 2013. Marine Technology Soc. Journal, 47(4).

Dewhurst T; Swift MR; Baldwin K; Wosnik M (2016) Design of a Mooring System for an Inertia Tube Wave Energy Converter. *Marine Energy Tech. Symposium Proc.*

Swift MR; Baldwin K; Bezerra, CAD; Dewhurst T; Sullivan, C (2016) A Student Designed and Built Wave Energy. *Marine Energy Tech. Symposium Proc.*

Dewhurst T; Rowell M; DeCew J; Baldwin K; Swift MR; Wosnik M (2012) Turbulent inflow and wake of a marine hydrokinetic turbine, including effects of wave motion. *Bull. Amer. Phys. Soc.*, Vol.57. No.17, p.146

A4.3 CONFERENCE PRESENTATIONS AND PUBLICATIONS (Selected)

World Aquaculture Society Annual Meeting 2019
Dynamic Finite Element Modeling of a Macroalgae Longline Segment
Engineering Analysis of a Mooring Grid for an Array of Submersible Mussel Rafts
Spatial Extrapolation of Design Wave Conditions from a National Data Buoy Center Platform to a Local Aquaculture Site using Short-Term Measurements

Milford Aquaculture Seminar/Northeast Aquaculture Conference 2019
Analysis of an Array of Submersible Mussel Rafts in Storm Conditions
Design Considerations for a Kelp Longline Exposed to Waves and Currents
An instrument for measuring in-situ tensions in mooring system aquaculture gear

MTS/IEEE OCEANS 2018
A Design of Experiments based approach to engineering a robust mooring system for a submerged ADCP
Wave-to-Wire Modeling and Simulation of a Wave Energy Converter for Off-Grid and Micro-Grid Applications

World Aquaculture Society Annual Meeting 2018
Hydrodynamic characteristics of macroalgae grown on a long-line aquaculture system from physical model tests.

National Shellfisheries Association Annual Meeting 2017
Evaluation of a Submersible Mussel Raft for Use in Semi-Exposed Sites: Field Study
Evaluation of a Submers. Mussel Raft for Use in Semi-Exposed Sites: Numerical Modeling

Milford Aquaculture Seminar/Northeast Aquaculture Conference 2017
Evaluation of a Submersible Mussel Raft for Use in Semi-Exposed Sites

National Shellfisheries Association Annual Meeting 2014
Dynamics of a Submersible Mussel Raft in Waves and Current

Marine Renewable Energy Technical Conference 2013
Dynamics of a Surface Platform for Testing Hydrokinetic Turbines

UNH Graduate Research Conference 2013
Design Alternatives for the Muskeget Channel Tidal Energy Test Site

Global Marine Renewable Energy Conference 2011
Muskeget Channel Tidal Energy Test Site

A4.4 HONORS

Joan and James Leitzel Award for Excellence in STEM Education and Outreach April 2015
UNH Dissertation Year Fellowship 2015-16
Best Presentation—UNH Marine School Graduate Research Symposium April 2015
Muhammad Yunus New Hampshire Social Business September 2013
Innovation Challenge—3rd place

Outstanding Mechanical Engineering Senior in Design May 2009

Daniel Award for Scholarship and Character May 2009

NAIA Scholar Athlete December 2008

A4.5 TEACHING

ME 526 – Mechanics of Materials, TA 2013
Teaching one recitation class per week, grading, one-on-one help, review sessions
ME 747 – Experimental Measurement and Modeling of Complex Systems, TA 2012
Helping design and run lab experiments, grading, one-on-one help
OE 810 – Ocean Measurements Lab, Guest Lecturer 2012

A4.6 PROFESSIONAL OUTREACH ACTIVITIES

Technical Advisory Group US Shadow Committee for IEC TS 62600-2:2016 Marine energy - Wave, tidal and other water current converters - Part 2: Design requirements for marine energy systems.

Reviewer: Aquaculture Engineering 2017–present

Reviewer: Marine Energy Technology Symposium 2018

Fishermen's Forum. *Technical Strategies for Anchoring Floating Aquaculture Structures* 2019

North Hampton Middle School Buoy Project 2013-present

Designed curriculum with science and math teachers around the physics of buoys, culminating in students testing their models in the UNH wave tank. Included real-time, interactive internet broadcast of wave energy/aquaculture experiments.

College Success Foundation Higher Education Readiness Opportunity Program 2013
Designed and gave short, simple wave tank demonstrations and lessons on buoy dynamics to groups of at-risk, college-bound teenagers.

University of New Hampshire Engineering Camp 2013

Appendix 5 Cost of Metocean Study to Establish Extreme Current Speeds.

A budgetary estimate for quantifying the maximum expected currents at each net pen location as required by BAP was obtained from ASL Environmental Sciences Inc., of Victoria, B.C. The cost of this analysis for a single site—exclusive of airfare and lodging for the field technician—would be $18,284 (Table 11). That quote was extrapolated to estimate the cost of quantifying the maximum expected currents at each of seven net pen locations in three different geographical areas (Bellingham Channel, Hope Island, and Rich Passage). Since published literature[119] suggests currents in Port Angeles are below the 0.5 m/s speed allowed by the manufacturer, a current study in Port Angeles was not included in this estimate. To be conservative in this extrapolation, the following assumptions were used:

- All seven locations would be measured simultaneously.
- Time and materials required for management, equipment mobilization, and data processing would be the same as those required for a single deployment. (In reality, these costs will increase with the larger scope.)
- Instruments for a single geographical area (e.g. Bellingham Channel, Hope Island, or Rich Passage) would be deployed in a single day. Similarly, all instruments for a geographical area would be recovered in a single day.
- Equipment and operational costs would not increase for net pens in deeper locations.
- No professional liability insurance would be need.
- No weather days would be included.
- Cooke would supply a vessel and a field technician to assist ASL at no cost.
- Shipping instruments, flights, hotels, and meals were not included.

Using these conservative assumptions, Table 12 shows that quantifying the maximum expected currents at seven net pen locations would have cost a minimum of $77,954.

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[119] Ebbesmeyer, C. C., et al. "Dynamics of Port Angeles Harbor and Approaches." Prepared for the MESA (Marine Ecosystems Analysis) Puget Sound Project (1979).

Table 11. Quote from ASL for quantifying maximum expected currents at a single net pen location.

Twenty and fifty year return currents at ~ 6 m and 16 m depth at the outer edge of a tidal channel in water depths of 25-30 m. For a client in Washington State.							
File:	P1474						
Date:	February-28-2019						
ASL Environmental Sciences Inc.							
All Prices in USD							
Item		units	$/unit	#	cost ($)	Type	Date (MMM-YY)
1	Base						
1.1	Management						
	Program Planning / Management / HSE / Personnel Mobilization						
	Rick [redacted]	day	875	1	875		
	Jerem[redacted]	day	607	1	607		
	Kea[redacted]	day	684	1	684		
	Communications (L.D. Telephone, fax, courier)				250		
	Handling on Direct Expenses		10%		25		
		Sub-Total Task 1.1			2,441	Cost Plus	Aug-19
1.2	Mobilize Equipment						
	Jerem[redacted]	day	607	1	607		
		Sub-Total Task 1.2			607	Cost Plus	Aug-19
1.3	Equipment Lease and Consumables for 38 days (Assumes 30 day deployment, and 3 days transit to and from the field)						
	TELEDYNE RDI 600 kHz WH Sentinel ADCP - 200 m	unit	2,480	1	2,480		
	Lease of mooring, releases and equipment for field operations	unit	2,558	1	2,558		
	40% Discount if ASL provides field and data services	unit	2,015	1	-2,015		
	Consumables (batteries)	unit	600	1	600		
	Consumables (mooring)	unit	750	1	750		
	Insurance	unit	4,201	1	4,201		
	Handling on Direct Expenses		10%		420		
		Sub-Total Task 1.3			8,994	Cost Plus	Aug-19
1.4	Field Work (Trip 1 - Deployment)						
	Travel and Field Time						
	Jerem[redacted]	day	607	3	1,821		
		Sub-Total Task 1.4			1,821	Cost Plus	Aug-19
1.6	Field Work (Trip 2 - Recovery)						
	Travel and Field Time						
	Jerem[redacted]	day	607	3	1,821		
		Sub-Total Task 1.6			1,821	Cost Plus	Aug-19
1.8	Data Processing and a Brief Quality Report (Currents Measurements and the 20 and 50 year return inteval currents at 2 selected depths)						
	Jerem[redacted]	day	607	3	1,821		
	Rick[redacted]	day	875	0.5	437		
	Kea[redacted]	day	684	0.5	342		
		Sub-Total Task 1.8			2,600	Cost Plus	Aug-19
		Total Task 1			18,284		
Notes							
1	All pricing is based on ASL fixed rates and estimates for third parties.						
2	Part of the program planning is to design an appropriate mooring for the site and application.						
	Details learned during this phase may impact the equipment which is required or the						
	consumables required to build the mooring.						
3	Assumes no professional liability insurance is needed. If needed, it is available.						
4	Number of days for lease and labour are estimates. Actual time will be charged.						
5	Number of days for field work are estimates only. Due to unforeseen events like weather delays, the actual time may be more.						
6	The lease cost of 2 single point current meters was ~ $1000 less than the lease cost of the ADCP which provides						
	measurements over the full water column. Use of an ADCP also allows currents which track the sea-surface to be obtained rather						
	than a fixed depth which a point current meter provides.						
7	If the client uses ASL to do the field work and data analysis, a 40% discount will be provided on the lease rates.						
8	If the client chooses to complete the work themselves and just lease the equipment,						
	an additional mobilization fee to prepare the equipment will be incurred.						
9	If the client chooses to lease the equipment and do the work themselves, they must sign a lease agreement						
	in which they agree to be responsible for damage or loss of the equipment. Insurance should be obtained for this scenario.						
10	Vessel costs have not been included. ASL can arrange a vessel if desired. Vessel costs as well as costs to						
	find the vessel and make arrangements will be passed on to the client.						
11	Pricing assumes the client has found an anchor locally which will satisfy the mooring requirements which are developed.						
12	Shipping to the site, flights, hotels and other third party costs associated with the field work have not been provided here.						
13	The use of one field tech assumes a competent field tech to assist with the field operations will be provided by the client.						
14	All third party expenses will be charged a handling fee.						

Table 12. Quote from ASL for quantifying maximum expected currents at seven net pen locations in three geographical areas. Inputs adjusted relative to the original quote are indicated in *underlined italics.*

ASL Environmental Sciences Inc.

All Prices in USD

Item	units		$/unit	#	cost ($)	Type
1	Base					
1.1	Management					
	Program Planning / Management / HSE / Personnel Mobilization					
	Managing Physical Oceanographer	day	875	1	875	
	Technician	day	607	1	607	
	Sr. Physical Oceanographer	day	684	1	684	
	Communications (L.D. Telephone, fax, courier)				250	
	Handling on Direct Expenses		10%		242	
		Sub-Total Task 1.1				$2,658
1.2	Mobilize Equipment					
	Technician	day	607	1	607	
		Sub-Total Task 1.2				$607
1.3	Equipment Lease and Consumables for 36 days (Assumes 30 day deployment, and 3 days transit to and from the field)					
	TELEDYNE RDI 600 kHz WH Sentinel ADCP - 200 m	unit	2,480	*7*	17,360	
	Lease of mooring, releases and equipment for field operations	unit	2,558	*7*	17,906	
	40% Discount if ASL provides field and data services	unit	-2,015	*7*	-14,105	
	Consumables (batteries)	unit	600	*7*	4,200	
	Consumables (mooring)	unit	750	*7*	5,250	
	Insurance	unit	4,201	*7*	29,407	
	Handling on Direct Expenses		10%		6,002	
		Sub-Total Task 1.3				$66,020
1.4	Field Work (Trip 1 - Deployment)					
	Travel and Field Time					
	Technician	day	607	*5*	3,035	
		Sub-Total Task 1.4				$3,035
1.5	Field Work (Trip 2 - Recovery)					
Travel and Field Time						
	Technician	day	607	*5*	3,035	
	Sub-Total Task 1.5					$3,035
1.6	Data Processing and a Brief Quality Report (Currents Measurements and the 20 and 50 year return interval currents at 2 selected depths)					
	Technician	day	607	3	1,821	
	Managing Physical Oceanographer	day	875	0.5	437	
	Sr. Physical Oceanographer	day	684	0.5	342	
		Sub-Total Task 1.6				$2,600
		Total Task 1				**$77,954**

ASL Environmental Sciences Inc.

All Prices in USD

Item	units		$/unit	#	cost ($)	
1	Base					
1.1	Management					
	Program Planning / Management / HSE / Personnel Mobilization					
	Managing Physical Oceanographer	day	875	1	875	
	Technician	day	607	1	607	
	Sr. Physical Oceanographer	day	684	1	684	
	Communications (L.D. Telephone, fax, courier)				250	
	Handling on Direct Expenses		10%		242	
		Sub-Total Task 1.1				$2658
1.2	Mobilize Equipment					
	Technician	day	607	1	607	
		Sub-Total Task 1.2				$607
1.3	Equipment Lease and Consumables for 36 days (Assumes 30 day deployment, and 3 days transit to and from the field)					
	TELEDYNE RDI 600 kHz WH Sentinel ADCP - 200 m	unit	2,480	8	19,840	
	Lease of mooring, releases and equipment for field operations	unit	2,558	8	20,464	
	40% Discount if ASL provides field and data services	unit	-2,015	8	-16,120	
	Consumables (batteries)	unit	600	8	4,800	
	Consumables (mooring)	unit	750	8	6,000	
	Insurance	unit	4,201	8	33,608	
	Handling on Direct Expenses		10%		6,859	
		Sub-Total Task 1.3				$75,451
1.4	Field Work (Trip 1 - Deployment)					
	Travel and Field Time					
	Technician	day	607	6	3,642	
		Sub-Total Task 1.4				$3,642
1.5	Field Work (Trip 2 - Recovery)					
Travel and Field Time						
	Technician	day	607	6	3,642	
	Sub-Total Task 1.5					$3,642
1.6	Data Processing and a Brief Quality Report (Currents Measurements and the 20 and 50 year return interval currents at 2 selected depths)					
	Technician	day	607	3	1,821	
	Managing Physical Oceanographer	day	875	0.5	437	
	Sr. Physical Oceanographer	day	684	0.5	342	
		Sub-Total Task 1.6				$2,600
		Total Task 1				**$88,606**

Appendix 6 Annual Cost of Inspecting Mooring Systems Deeper than 100 Feet.

Goals of Inspections:

- Confirm that anchor(s) are embedded properly
  - Anchors may not have been installed correctly
  - Storms can cause anchors to drag, possibly not re-embed
- Confirm that, to the extent visible, anchors are in good condition
  - No damage from debris, other lines dragging against anchors
  - No damage from scouring
- Confirm that anchor shackles are in good condition
- Confirm that chain on the seafloor shows limited corrosion or abrasion, especially at chain touchdown points
- Confirm that rope (when used) and thimbles are intact and not abraded.

A remote-operated vehicle (ROV) can be used to inspect anchors. These are self-propelled systems with a camera, connected to the surface through an umbilical wire. The operator at the surface drives the ROV along the mooring line to the anchor, making the same visual inspection that a diver would perform. Use of an ROV generally requires a support boat and an ROV team of at least two people.

Cooke Aquaculture Pacific fish farms are clustered in four distinct areas. Instead of requiring mobilization/demobilization work for each fish farm, these tasks can be combined into four tasks instead of eight.

A6.1 Costs of ROV Inspections using Outside Contractors

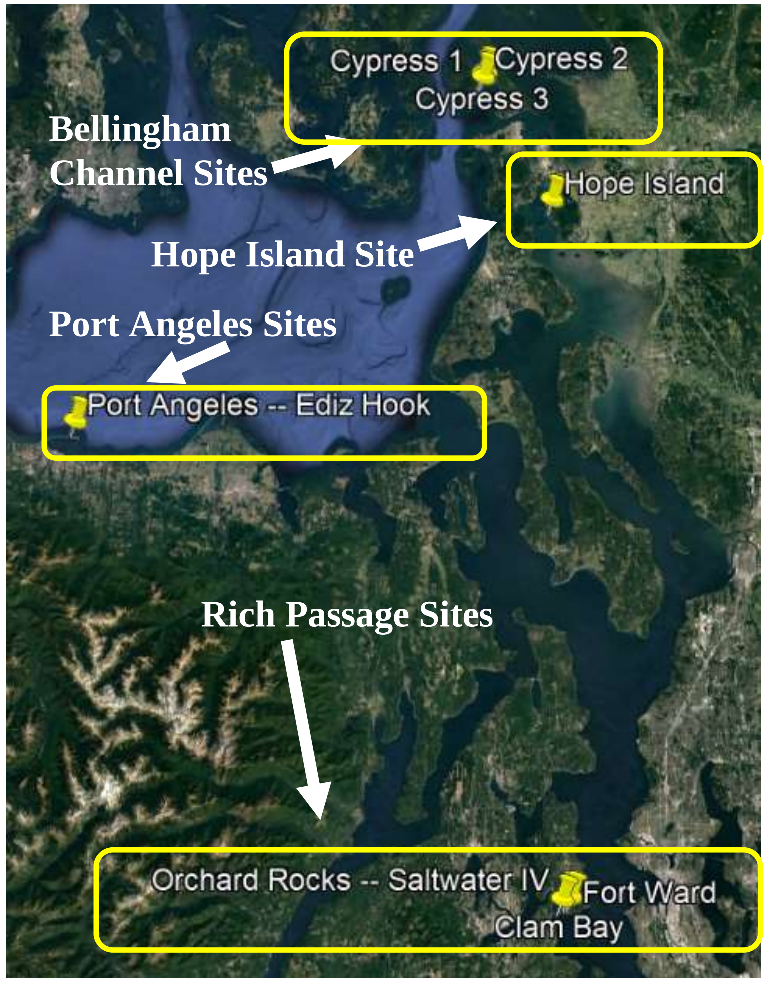

Figure 1. Locations of Cooke Aquaculture Pacific fish farms. Farms are clustered in four areas.

The annual cost for hiring a contractor to inspect anchors deeper than 100 feet was estimated based on a quote by Collins Engineering[121] ("Collins") prior to their inspections with Mott MacDonald in late 2017. This budget estimated the time and cost to inspect moorings and structures at Hope Island, Port Angeles 1 and 2, Fort Ward, Orchard Rocks, and Cypress Island Site 1 and 3. Collins' estimates were based on the assumption that only three of these sites included anchors deeper than 100 feet[122]. (Clam Bay and Cypress Site 2 were not included. And Collins was apparently unaware at the time of providing the estimate that Orchard Rocks South and Cypress Site 1 had anchors deeper than 100 feet.) Collins estimated that the three sites with anchors deeper than 100 feet would require 6 days of ROV surveys. They also estimated that each of the seven sites would require one day of post-processing and report writing. Thus, it is assumed here that each site with anchors deeper than 100 feet required two days of ROV surveying and one day of post-processing and report writing. To be conservative, it was assumed that sites with less than 10 anchors deeper than 100 feet required only one day of ROV surveying and half a day of reporting.

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[121] Subconsultant agreement between Mott MacDonald and Collins.pdf, Table 2.
[122]Subconsultant agreement between Mott MacDonald and Collins.pdf, Table 1.

Table 13. Cost of ROV Contracted Inspection Services per day as quoted by Collins Engineers, Inc.

Activity	Day Rate
Mobilization	-
ROV Survey Operations	$3,200
Reports	$3,700
Travel and lodging	(not included)

Assumptions in the following cost analyses are as follows:

- The number of anchors and depths for each fish farm were derived from an Excel workbook provided by Cooke Aquaculture Pacific.[123]
- The last mooring diagram created by Cooke shows 16 anchors at the Cypress 2 site.[124] Although the anchor depths were undocumented, Global Diving and Salvage[125] found at least one anchor deeper than 100 feet. For this analysis 15 anchors were assumed to be in shallow water (< 100 foot depth) and one anchor in deep water.
- Mooring diagrams from Cooke were reviewed for evidence of inspection or replacement of deep water mooring components. These Excel workbooks included some inspection dates and some dates of key maintenance or replacement activities. However, none of the materials reviewed suggested any inspection which would have offset the need for an ROV inspection at any of the sites for any of the years considered in this report.
- All values are in 2017 USD.
- This estimate does not include any of the following:
    - Explicit costs for mobilization including assembling, calibrating equipment, fueling, and transporting the ROV,
    - Weather days
    - Travel and lodging for contractors

Table 14 shows the annual costs Cooke would have incurred to comply with the mandated annual inspections of mooring components by contracting an ROV survey service annually between 2012 and 2016. In 2017, Mott MacDonald contracted with Collins Engineers to inspect all remaining net pens and moorings after the Cypress 2 collapse. Table 15 provides the costs Cooke would have expended to have the deep water moorings inspected. Similarly, Table 16 provides the costs to inspect the deep water moorings at Cypress 1 and 3 in 2018.

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[123] Kyl Wood, Cooke Aquaculture Pacific, "anchor depths.xlsx", created 9/11/2018.
[124] COOKE_CWA_00018184.xlsx, updated 8/3/2017.
[125] COOKE_CWA_00047601-COOKE_CWA_00049032.pdf , Global Diving and Salvage, *Cypress Island Debris Recovery Project*.

Table 14. Costs avoided by not inspecting anchors deeper than 100 feet annually from 2012–2016

Mob. Group	Site	# Deep Anchors	ROV survey (Days)	Post-Proc and Reports (Days)	
1	Hope Island	0	0	0	
2	Cypress 1	5	1	0.5	
2	Cypress 2	1	1	0.5	
2	Cypress 3	10	2	1	
3	Port Angeles Main	23	2	1	
3	PA Secondary	13	2	1	
4	Clam Bay North	5	1	0.5	
4	Clam Bay South	10	2	1	
4	Orchard Rocks North		0	0	
4	Orchard Rocks South	3	1	1	
4	Fort Ward	0	0	0	
	Days		12 days	6.5 days	
	Rate per day		$3,200	$3,700	**Total**
	Cost		$38,400	$24,050	**$62,450**

Table 15. Costs avoided by not inspecting anchors deeper than 100 feet in 2017

Mob. Group	Site	# Deep Anchors	ROV survey (Days)	Post-Proc and Reports (Days)	
1	Port Angeles Main	23	2	1	
1	PA Secondary	13	2	1	
2	Clam Bay North	5	1	0.5	
2	Clam Bay South	10	2	1	
2	Orchard Rocks North		0	0	
2	Orchard Rocks South	3	1	1	
	Days		8 days	4.5 days	
	Rate per day		$3,200	$3,700	
	Cost		$25,600	$16,650	**$42,250**

Table 16. Costs avoided by not inspecting anchors deeper than 100 feet annually in 2018

Mob. Group	Site	# Deep Anchors	ROV survey (Days)	Post-Proc and Reports (Days)	
1	Cypress 1	5	1	0.5	
1	Cypress 3	10	2	1	
	Days		3 days	1.5 days	
	Rate per day		$3,200	$3,700	
	Cost		$9,600	$5,550	**$15,150**

A6.2 Costs for ROV Inspections using Cooke Aquaculture Pacific Staff

A6.2.1 Cost of Labor

ROV operators and boat support staff will be experienced, trusted employees. The US Bureau of Labor Statistics (BLS) does not offer information on pay rates for ROV operators. Based on skill levels and working environments, equivalent occupations are commercial divers and surveyors who work with sophisticated measuring equipment in the field. Averaging the 2017 hourly rates for these occupations in Washington State (Table 17) yields $32.14 per hour. According to the BLS[126] these rates would be unchanged during the following year.

Table 17. Labor Rates in Washington State

Occupation	2017 Mean Hourly Rate in Washington	Source
Commercial Divers	$25.80	https://www.bls.gov/oes/2017/may/oes499092.htm
Surveyor	$38.48	https://www.bls.gov/oes/current/oes171022.htm

[126]BLS, "Real average hourly earnings unchanged from June 2017 to June 2018," https://www.bls.gov/opub/ted/2018/real-average-hourly-earnings-unchanged-from-june-2017-to-june-2018.htm, July 17, 2018.

The BLS states that: "Wages and salaries averaged $23.85 per hour worked and accounted for 70.0 percent of these costs, while benefit costs averaged $10.20 and accounted for 30.0 percent."[127] Based on this, the total hourly rate for ROV operators and crew is $45.91 per hour.

An ROV dive team would consist of a boat driver and an ROV operator. As they would have equivalent skill levels, the hourly rate for labor on the ROV support boat would be $91.83. With the exception of documentation tasks, all activities are assumed to require the same two-person team, the boat and the ROV itself.

A6.2.2 Cost of Boat and ROV

An ideal support vessel for the ROV would be robust as it will be out in open water. It would include a partially enclosed space for the ROV control so that the operator can read the screen on a sunny day. The boat would be designed so that it is relatively simple to load and unload, with a relatively open arrangement to hold equipment, an enclosed cabin and a bow ramp for easy mobilization. Such a boat, e.g. a Munson 24-32 Sport, can cost up to $191,000[128]. However, for the sake of being conservative in the present analysis, a simple 17' Boston Whaler *Montauk* (2016) was assumed. Using the calculations in Table 18 a rate of $28.67/hour was obtained for the support boat.

There are a number of industrial quality, inspection class ROVs on the market. The device has to have bright underwater illumination, good maneuverability, and enough thrust to operate in moderate currents. The device has to be rugged and reliable to handle frequent use and handling in challenging wave and current conditions. As this is a precision device, maintenance and support services must be available domestically.

Table 18. Cost of ROV Support Boat

ROV Support Boat		
17' Boston Whaler MONTAUK[129] 170/CC (2016)	$28,667	List Price
Assuming 5 year depreciation	$5,733	per year
Assuming 400 hours/year	$14.33	per hour
Insurance, Docking		
50% of hourly rate	$7.17	
Maintenance		
50% of hourly rate	$7.17	
	$28.67	total per hour

Table 19 lists two ROV packages suitable for this application. The DTX2 package from DeepTrekker can operate up to 305 m (1000 ft.) deep. The DTX2 package includes cases and a

[127] BLS, "EMPLOYER COSTS FOR EMPLOYEE COMPENSATION –DECEMBER 2018," https://www.bls.gov/news.release/pdf/ecec.pdf, USDL-19-0449, March 19, 2019
[128] https://www.munsonboats.com/series24-MVCKAT.php. Retrieved 4/2/2019
[129] https://www.nadaguides.com/Boats/2016/Boston-Whaler-Inc/MONTAUK-170-CC_/32063531/Specs. Retrieved 4/2/2019

150 m (492 ft) tether. The SeaOtter-2 from JW Fishers can operate at a depth of 500 feet and includes a 250-foot tether. Both the DTX2 and the SeaOtter-2 have metal housings for durability.

Table 19. Cost of Remote-Operated Vehicles

Model: DeepTrekker DTX2 Package[130]			Model: JW Fishers SeaOtter-ROV[131]		
Includes umbilical, cases	$26,999	List	Includes umbilical, cases	$19,940	List
Assuming 5 year deprec.	$5,400	per yr	Assuming 5 year deprec.	$3,988	per yr
Assuming 400 hours/year	$13.50	per hr	Assuming 400 hours/year	$9.97	per hr
Insurance, Spare Parts			Insurance, Spare Parts		
50% of hourly rate	$6.75		50% of hourly rate	$4.99	
Maintenance and Service			Maintenance and Service		
50% of hourly rate	$6.75		50% of hourly rate	$4.99	
Total cost per hour	$27.00		Total cost per hour	$19.94	

ROVs require periodic maintenance and have a limited life. In this analysis it is assumed that the life of an industrial inspection ROV is 5 years. To be conservative, it was assumed that the ROV would be regularly used for other tasks and actively operated for 400 hours per year. The costs for insurance, spare parts and maintenance/service were assumed to equal the hourly costs of the device itself. Averaging the costs of the two representative ROV systems results in a cost of $23.47 per hour.

Table 20 is an estimate of the costs of using CAP staff and equipment to perform anchor and mooring inspections of anchors more than 100 feet deep. Two hours per site is allotted for perfunctory reporting of observations. Some factors not included in these estimates are:

- Staff training
- Staff land transportation
- Loss of equipment use due to maintenance and repair activities

In 2017, Mott MacDonald contracted with Collins Engineers to inspect all remaining net pens and moorings after the Cypress 2 collapse. Table 21 provides the costs Cooke would have expended to inspect the remaining deep water moorings. Similarly, Table 22 provides the costs to inspect the deep water moorings at Cypress 1 and 3 in 2018.

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[130] DTX2 Package, Deep Trekker, https://www.deeptrekker.com/product/dtx2-rov/, retrieved 03/22/2019
[131] SeaOtter-2 ROVER- Underwater Video System, JW Fishers Mfg Inc., https://www.gsaadvantage.gov/advantage/catalog/product_detail.do?gsin=11000017496642, retrieved 03/22/2019.

Table 20. Estimated annual cost of ROV inspections using CAP staff, only anchors deeper than 100 feet from 2012–2016

Mob. Group	Site	# Deep Anchors	Mobilization/ Demobilization	Anchor Inspections (Days)	Anchor Inspections (Hours)	Transit to/ from site (hours)	Post-Proc. and Report
1	Hope Island	0		0	0	0	0
2	Cypress 1	5	12	1	8	2	2
2	Cypress 2	1		1	8	2	2
2	Cypress 3	10		2	16	4	2
3	Port Angeles Main	23	12	2	16	4	2
3	PA Secondary	13		2	16	4	2
4	Clam Bay North	5	12	1	8	2	2
4	Clam Bay South	10		2	16	4	2
4	Orchard Rocks North	0		0	0		
4	Orchard Rocks South	3		1	8	2	2
4	Fort Ward	0		0	0		
	Hours		36 hours	12 days	96 hours	24 hours	16 hours
	Cost		$5,183		$13,821	$3,455	$735

Total Annual Cost **$23,193**

Table 21. Estimated annual cost of ROV inspections using CAP staff, only anchors deeper than 100 feet in 2017.

Mob. Group	Site	# Deep Anchors	Mobilization/ Demobilization	Anchor Inspections (Days)	Anchor Inspections (Hours)	Transit to/ from site (hours)	Post-Proc. and Report
1	Port Angeles Main	23	12	2	16	4	2
1	PA Secondary	13		2	16	4	2
2	Clam Bay North	5	12	1	8	2	2
2	Clam Bay South	10		2	16	4	2
2	Orchard Rocks North			0	0		
2	Orchard Rocks South	3		1	8	2	2
	Hours		24 hours	8 days	64 hours	16 hours	10 hours
	Cost		$3,455		$9,214	$2,303	$459

Total Annual Cost **$15,432**

Table 22. Estimated annual cost of ROV inspections using CAP staff, only anchors deeper than 100 feet in 2018.

Mob. Group	Site	# Deep Anchors	Mobilization/ Demobilization	Anchor Inspections (Days)	Anchor Inspections (Hours)	Transit to/ from site (hours)	Post-Proc. and Report
1	Cypress 1	5	12	1	8	2	2
1	Cypress 3	10		2	16	4	2
	Hours		12 hours	3 days	24 hours	6 hours	4 hours
	Cost		$1,728		$3,455	$864	$184

Total Annual Cost **$6,230**

Appendix 7 Cost of Upgrading Net Pen Systems

Cost estimates for 25m-by-25m square steel cages designed for high-energy sites were obtained from the AKVA group. According to the personal communication with the AKVA group, their WaveMaster EX-2 cage system is design to withstand currents up to at least 190 cm/sec. This is the highest allowable current speed of any steel cage known to the author. This estimate gives the cost per cage (i.e. one 25m-by-25m bay in a net pen system) at $130,000 CAD. Using the CAD to USD exchange rate for Jan. 1, 2013[132], this is equivalent to $130,000 in 2013 USD. The costs of stock nets, predator nets, and aviary nets were not included in this analysis because Cooke incurred these costs while operating its cages. The cost of the purchasing and installing a mooring system similar to those in use by Cooke between 2012 and 2017 was taken to be $150,000[133]. This cost was multiplied by 20% to account for the increased capacity recommended by DSA[134]. Summing these costs results in an estimated cost of $310,000 per cage.

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[132] https://www.xe.com/currencycharts/?from=USD&to=CAD&view=10Y. Accessed 6/3/2019

[133] http://www.soyaquaalliance.com/wp-content/uploads/2014/02/07-Alan-Cook-2014-Finance-Roundtable-Salmon-Netpen-Production.pdf. Accessed 6/3/2019

[134] DSA/COOKE_CWA_00241926.pdf

Product: Wavemaster EX 2 Cage System	Wavemaster 25m x 25 m - EX2 Cage system in a 6 x 2 Configuration			AKVA GROUP
Date: 30-05-2019	Page: 2 of 6	Rev: Rev. 1.0	Drawn up by: BB	

Maine Marine Composites

Attn. Mr. Richard Akers

Below is our budget offer of Wavemaster EX 2 Cages

1. Description: 12 cages 25x25 meter EX-2 Design

Product Description

Number of sets	: 1 (one) set.
Number of Cages	: 12 (eight) units. 6 by 2 arrangement.
Dimensions	: 25 by 25 meters.
Main Beam Dimensions	: 200 x 70 x 6 mm
Main Walkways	: 2.3 m wide.
Perimeter Walkways	: 2.0 m wide.
Head End Walkways	: 2.0 m wide.
Stabilizers	: Included are 04 pcs of stabilizing (flappers) for leading edges of pen system (prevents twisting)
Hinges	: 2 hinge points with 1¾" inch stainless steel hinge pins and Technygen plastic bushing.
Decking	: 25 x 5mm Steel Grating.
Floats	: Super Jumbo Rotational Molded Polyethylene foam filled floats.
Handrails	: 1¼" inside perimeter steel handrails – 1 meter height with welded net hook pointed up and down.
Corrosion Protection	: Hot Dipped Galvanizing.

2. Pricing- Wavemaster Steel Cage System

(12) 25 m x 25 m Wavemaster cages as indicated in above section 1.0 Description.

COMPONENT	QTY		PRICE (CAD)
STEEL	1	$	1.070.000
FLOATS (CANADA)	1	$	300.000
STEEL FREIGHT (CHILE)	1	$	130.000
FLOATS FREIGHT (VANCOUVER)	1	$	60.000
TOTAL	**12**	**$**	**1.560.000**
TOTAL PER CAGE		**$**	**130.000**

Components are CIF Vancouver, BC.

Figure 2. Budget Estimate for a WaveMaster EX-2.

The $2,700,000 that Cooke expended in purchasing and installing new cages at Clam Bay was subtracted from the total cost of acquiring more robust cages, since these costs would have been displaced by the cost of the more robust cage system.

Table 23. Costs to Upgrade Net Pens to More Robust Technology

Upgrade the cage system at Cypress Island #1 (8 cages)	$2,480,000	One time cost. Annual opportunities between Sept. 14 2012 and the present
Upgrade the cage system at Cypress Island #2 (10-cages)	$3,100,000	One time cost. Annual opportunities between Sept. 14 2012 and the present
Upgrade the cage system at Cypress Island #3 (12 cages)	$3,720,000	One time cost. Annual opportunities between Sept. 14 2012 and the present
Upgrade the cage system at Hope Island (10 cages)	$3,100,000	One time cost. Annual opportunities between Sept. 14 2012 and the present
Upgrade the cage system at Fort Ward (12 cages)	$3,720,000	One time cost. Annual opportunities between Sept. 14 2012 and the present
Upgrade the cage system at Orchard Rocks (20 cages)	$6,200,000	One time cost. Annual opportunities between Sept. 14 2012 and the present
Upgrade the 12 cage system at Clam Bay	$3,720,000	One time cost. Annual opportunities between Sept. 14 2012 and the present
Select a more robust 10 cage system at Clam Bay than the one installed in 2013/14	$400,000	Jan. 1 2014. Difference between actual cost and estimate of cost for a sufficiently robust system

APPENDIX 7 List of Records Considered

In addition to drawing upon his knowledge and expertise, and a general review of relevant literature in the field, Dr. Dewhurst considered the records listed below or portions thereof in forming the opinions expressed in his report. Pursuant to the parties' Rule 26(a) agreement, the Conservancy will produce the expert's file within two weeks of disclosure of this report or one week before the expert's deposition, whichever is sooner.

- Cooke NPDES Permits, fact sheets, and permit applications
- Cooke's Pollution Prevention Plans, Fish Escape Prevention Plans, Plans of Operations, Spill Prevention, Control, and Response Plans, and Annual Accidental Fish Release Reports
- Portions of reports prepared by Mott MacDonald for each of Cooke's net pens, and records cited therein, and related invoices and contracts
- The Washington agency report regarding the collapse, dated January 30, 2018, and records cited therein
- Notes from Washington agency interviews of Cooke employees and contractors taken after the August 2017 Cypress Site 2 collapse
- Cooke's response to the January 30, 2018 Washington agency report regarding the collapse and records cited therein
- Global Diving and Salvage Report on the Cypress Island Debris Recovery Project, dated December 2017-February 2018, and related invoice
- Photos and videos of the Cypress Site 2 structure after the collapse
- Communications between Cooke and Washington agencies since the collapse, including records related to administrative enforcement and lease termination
- Manufacturer specifications for cages installed at the net pen sites
- Records related to Cooke's Best Aquaculture Practice certification
- Mooring diagrams for the net pens
- Discovery requests and responses in the litigation
- Records related to the July 2017 incident at Cypress Site 2
- Daily Logs for the net pens
- Spreadsheet related to Cooke's 2018 anchor inspections
- Deposition testimony of Jim Parsons, Cooke's designated Federal Rule of Civil Procedure 30(b)(6) witness
- Records exchanged between Dynamic Systems Analysis, Ltd. and Cooke, including but not limited to proposals, bids, emails, and reports
- Surveys conducted of the net pens, including pontoon surveys and Risk Management Surveys
- Cooke's briefing in this litigation
- Cooke Management Meeting Notes
- Norwegian Standard 9415:E:2009, *Marine fish farms, Requirements for site survey, risk analyses, design, dimensioning, production, installation and operation*
- The Washington Fish Growers Association Code of Conduct for Saltwater Salmon Net-Pen

Operations (Fall 2002)

- Akers, R. Fatigue Design Methodologies Applicable to Complex Fixed and Floating offshore Wind Turbines, TAP-758, Bureau of Safety and Environmental Enforcement, p. 68. Contract E13PC00019, 2015. https://www.bsee.gov/sites/bsee.gov/files/tap-technical-assessment-program//758aa.pdf, downloaded 3/26/2019
- Ebbesmeyer, C. C., et al. "Dynamics of Port Angeles Harbor and Approaches." Prepared for the MESA (Marine Ecosystems Analysis) Puget Sound Project (1979)
- Quotes from ASL for quantifying maximum expected currents at net pen locations
- BLS, “Real average hourly earnings unchanged from June 2017 to June 2018,” https://www.bls.gov/opub/ted/2018/real-average-hourly-earnings-unchanged-from-june-2017-to-june-2018.htm, July 17, 2018
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- Munson, 24-32 Sport, https://www.munsonboats.com/series24-MVCKAT.php. Retrieved 4/2/2019
- NADA Guides, 2016 Boston Whaler Inc Montauk 170/CC(*) Specs, https://www.nadaguides.com/Boats/2016/Boston-Whaler-Inc/MONTAUK-170-CC_/32063531/Specs. Retrieved 4/2/2019
- DTX2 Package, Deep Trekker, https://www.deeptrekker.com/product/dtx2-rov/, retrieved 03/22/2019
- SeaOtter-2 ROVER- Underwater Video System, JW Fishers Mfg Inc., https://www.gsaadvantage.gov/advantage/catalog/product_detail.do?gsin=11000017496642, retrieved 03/22/2019.
- https://www.xe.com/currencycharts/?from=USD&to=CAD&view=10Y. Accessed 6/3/2019
- http://www.soyaquaalliance.com/wp-content/uploads/2014/02/07-Alan-Cook-2014-Finance-Roundtable-Salmon-Netpen-Production.pdf. Accessed 6/3/2019
- Records produced by Cooke in this litigation related to the costs of purchasing, replacing, and/or maintaining net pens and parts
- Current data and related files from Cooke current study in late 2017/early 2018