



MEMO

Project name Belfast Bay Surface Water Discharge Assessment
Project no. 1690008668
Client Nordic Aquafarms
To Erik Heim (Nordic Aquafarms)
From Derek Pelletier, Richard Wenning, Kyle Fetters

At the request of Nordic Aquafarms Inc. (NAF), Ramboll reviewed two technical memoranda prepared by Ransom Consulting Engineers and Scientists (Ransom) describing near-field and far-field dispersion modeling of discharge water from NAF's proposed salmon Recirculating Aquaculture System (RAS) facility in Belfast, Maine. Ransom's Near-field Dilution of Proposed Discharge memo was dated September 27, 2018, and the Far-field Dilution of Proposed discharge memo was dated October 2, 2018. This memorandum conveys Ramboll's findings.

Date October 16, 2018

Context for this Work

NAF is proposing to construct and operate the salmon RAS facility in two phases, with the first phase expected to be operational in approximately two years. During Phase 1, the facility is anticipated to produce 15,000 metric tons of salmon per year. Five years following completion of Phase 1, salmon production is expected to double during Phase 2 operation to approximately 30,000 metric tons annually. The anticipated volume of water discharged daily to Belfast Bay during Phase 1 operations is 3.85 million gallons per day (mgd) and NAF expects for that volume to double to 7.7 mgd during Phase 2 operations.

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Water management is an important consideration for Phase 1 and 2 commercial operations. To achieve the optimal growth conditions for Atlantic salmon in their growth tanks, NAF proposes to draw ocean water from Belfast Bay and blend with a freshwater supply. A filtration system will manage water quality in the continuously circulating tanks by removing food debris and fish feces and adjusting important water quality parameters. The filtration system is designed to maintain water quality at optimal growth conditions such that the majority of the water used in the RAS can be recycled indefinitely. The RAS is not a completely closed water circulation system; some RAS fish tank water will be discharged – after filtration and treatment – in a controlled manner to Belfast Bay through an outfall located offshore from the Belfast facility.

As part of the permitting process for NAF's proposed facility, Ransom was tasked by NAF to conduct an analysis of the anticipated consequences associated with the release of water from the facility to Belfast Bay. Ransom's work addressed two important aspects – characterize the initial dispersion of discharge water in the immediate vicinity of the outfall (referred to as the near-field condition), and characterize the potential dispersion of nutrients (specifically, total nitrogen) in Belfast Bay, further away from the outfall (referred to as the far-field condition). Near-field dispersion of the discharge water was examined using the Cornell Mixing Zone Expert system (CORMIX) model. Far-field dispersion of discharge water from the outfall was examined using a combination of two-dimensional hydrodynamic modeling with the ADvanced CIRCulation Model (ADCIRC) and numerical particle tracking with the Maureparticle particle tracking model.

Focus of Ramboll's Review

Ramboll's experts in water quality modeling and US Clean Water Act compliance reviewed Ransom's two technical memoranda, focusing on evaluating the application and assumptions of the near-field and far-field models used to examine the potential influence of nitrogen¹ in the discharge water released to Belfast Bay during Phase 1 and 2 RAS operations. Ramboll focused on the following questions:

- Were the models used by Ransom the appropriate tools for their work objectives?
- Do the model assumptions appropriately reflect anticipated RAS operations?
- Were the characteristics of the Belfast Bay aquatic environment considered appropriately in the model?
- Are the model results pertaining to nitrogen applicable to the thresholds for protection of eelgrass beds and dissolved oxygen that were identified by the Maine Department of Environmental Protection (DEP)?

Ramboll did not independently replicate or validate Ransom's near-field and far-field model calculations for this review. Ramboll understands that Ransom's work was developed in consultation with Maine DEP; Ramboll did not participate in technical discussions between Ransom and Maine DEP regarding the development of model scenarios and selection of model assumptions.

Findings

1. Were the models used by Ransom the appropriate tools for their work objectives?

The ADCIRC and CORMIX models are appropriate for evaluating the questions of dispersion and transport of substances released from outfalls into an open water bay or ocean environment. Both models are commonly used to evaluate surface water discharges from outfalls.^{2,3} CORMIX is an appropriate tool to optimize outfall port design and discharge depth for rapid mixing of discharge waters with ambient surface waters. ADCIRC is an appropriate tool to examine the influence of tides and wind-driven water circulation on near shore activities that involve interaction with the marine environment.

¹ Ramboll's review focuses on total nitrogen discharges because nitrogen is typically the limiting nutrient in estuarine waters and is the primary cause of anthropogenic eutrophication and hypoxia in coastal waters (Howarth and Marino 2006).

² <http://www.cormix.info/applications.php>

³ <https://adcirc.org/>

2. *Do the model assumptions appropriately reflect anticipated RAS operations?*

The estimated discharge rates and effluent concentrations used in Ransom's modeling work are consistent with the estimates that we have been provided by NAF.

3. *Were the characteristics of the Belfast Bay aquatic environment considered appropriately in the models?*

The CORMIX model used to estimate near-field dispersion incorporated information on ambient conditions in Penobscot Bay and Belfast Bay from the available literature. Ransom acknowledges that "none of the available data to approximate ambient current conditions were collected specifically in the area of the proposed discharge in Belfast Bay." Given these constraints, Ransom's use of the closest available data is reasonable and appropriate.

The ADCIRC model used to examine far-field dispersion of discharge water appropriately characterized tidal conditions and water circulation patterns in Belfast Bay (shown in Ransom's Figures 3 and 4). The eelgrass beds located closest to the proposed outfall locations (Ransom's Figure 6) are consistent with those mapped by the Maine Department of Marine Resources based on aerial photos from 2001-2010.⁴ Finally, ambient water quality data are reportedly based on measured data recommended by Maine DEP (Ransom's Table 1). While the state of knowledge regarding the behavior of surface water in Belfast Bay and northern Penobscot Bay is limited (as acknowledged above by Ransom), the assumptions used in Ransom's modeling work are sufficiently conservative to capture reasonable and plausible worst-case aquatic conditions in the Bay.

4. *Are the model results pertaining to nitrogen applicable to the thresholds for protection of eelgrass beds and dissolved oxygen that were identified by Maine DEP?*

Ramboll finds that it is appropriate to compare ADCIRC model results describing total nitrogen to the thresholds for protection of eelgrass beds and dissolved oxygen⁵ that were identified by Maine DEP because both sets of values are representative of average conditions. Ransom calculated the estimated time averaged median concentrations of total nitrogen near the proposed outfall over the final 14 days of the model simulations. This is a reasonable and appropriate approach for calculating the central tendency of the predicted total nitrogen concentrations over time. The thresholds that Maine DEP identified to be protective of eelgrass beds and dissolved oxygen were derived from work conducted in southern New England coastal marine waters and based on average nitrogen concentrations (NHDES 2009, Benson et al. 2013). As such, the model results depicted in Figure 6 of Ransom's far-field memorandum are comparable to the threshold limits specified by Maine DEP.

The total nitrogen thresholds for the protection of eelgrass beds and dissolved oxygen conditions specified by Maine DEP as applicable to Belfast Bay are similar to the numeric thresholds used by Maine DEP to assess permits for water discharges from the City of Portland and City of South Portland wastewater treatment facilities (MEPDES Permit ME0102075 and Draft Permit ME0100633, respectively). The total nitrogen thresholds are based on environmental monitoring work conducted

⁴ <https://www.maine.gov/dmr/science-research/species/documents/6-upperpenbay.pdf>

⁵ Potential effluent impact on DO as defined by Maine DEP determined by a correlation of data from Great Bay, New Hampshire (NHDES 2009).

in Great Bay, NH, and in southern Massachusetts estuaries. Average surface water nitrogen concentrations at specific locations were correlated with eelgrass habitat metrics and dissolved oxygen conditions (NHDES 2009; Benson et al. 2013). The impacts associated with nitrogen loads in those ecosystems, however, are influenced by site-specific factors such as tidal exchange rates, freshwater flow rates, water depth, and stratification, among others. The embayments of southern Massachusetts and Great Bay, for example, are shallower and likely to have lower tidal exchange rates than in Belfast Bay. Estuaries with lower exchange rates (i.e., higher residence times) and shallow mixing depths tend to be more sensitive to total nitrogen loading than deep, well mixed estuaries (Evans and Scavia 2013). Extrapolating numeric threshold limits derived from one location to another is not an unusual regulatory approach, particularly where limits derived from examination of sensitive environmental conditions are applied to an environment with less sensitive environmental conditions. Still, while the application of nitrogen thresholds in Belfast Bay that are developed from estuaries likely to be more sensitive to total nitrogen loads is conservative (i.e., protective), there is uncertainty associated with the numeric total nitrogen threshold.

Conclusion

Ramboll finds the analyses presented in Ransom's modeling memoranda are scientifically defensible; nitrogen concentrations and dissolved oxygen conditions associated with water releases from NAF's proposed offshore outfall during salmon RAS production are predicted to have minimal impacts on dissolved oxygen conditions and eelgrass beds in Belfast Bay. While modeled results are estimates, Ransom's work is sound and reflects reasonable and plausible worst-case conditions.

Ramboll agrees with Ransom's recommendation for field data collection to generate data to validate the model results. In addition, it would be reasonable to conduct baseline monitoring of water quality and eelgrass conditions at the two eelgrass bed locations identified in the far-field dispersion memo (Figure 6)⁶. After installation and operation of the outfall, monitoring could continue periodically until the influence of the discharge water has been sufficiently characterized.

References

- Benson, J.L., D. Schlezinger and B.L. Howes. 2013. Relationship between nitrogen concentration, light, and *Zostera marina* habitat quality and survival in southeastern Massachusetts estuaries. *Journal of Environmental Management* 131: 129–137.
- Evans, M., and D. Scavia. 2013. Exploring estuarine eutrophication sensitivity to nutrient loading. *Limnology and Oceanography* 58(2): 569–578.
- Howarth, R.W., and R. Marino. 2006. Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: Evolving views over three decades. *Limnology and Oceanography* 51(1): 364–376.

⁶ Any monitoring program should also include nearby reference sites for comparison because numerous factors can influence eelgrass health.

Maine Pollutant Discharge Elimination System (MEPDES). 2017. Proposed Draft Permit Number ME0100633. <https://www.epa.gov/sites/production/files/2017-08/documents/draftme0100633permit.pdf>

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