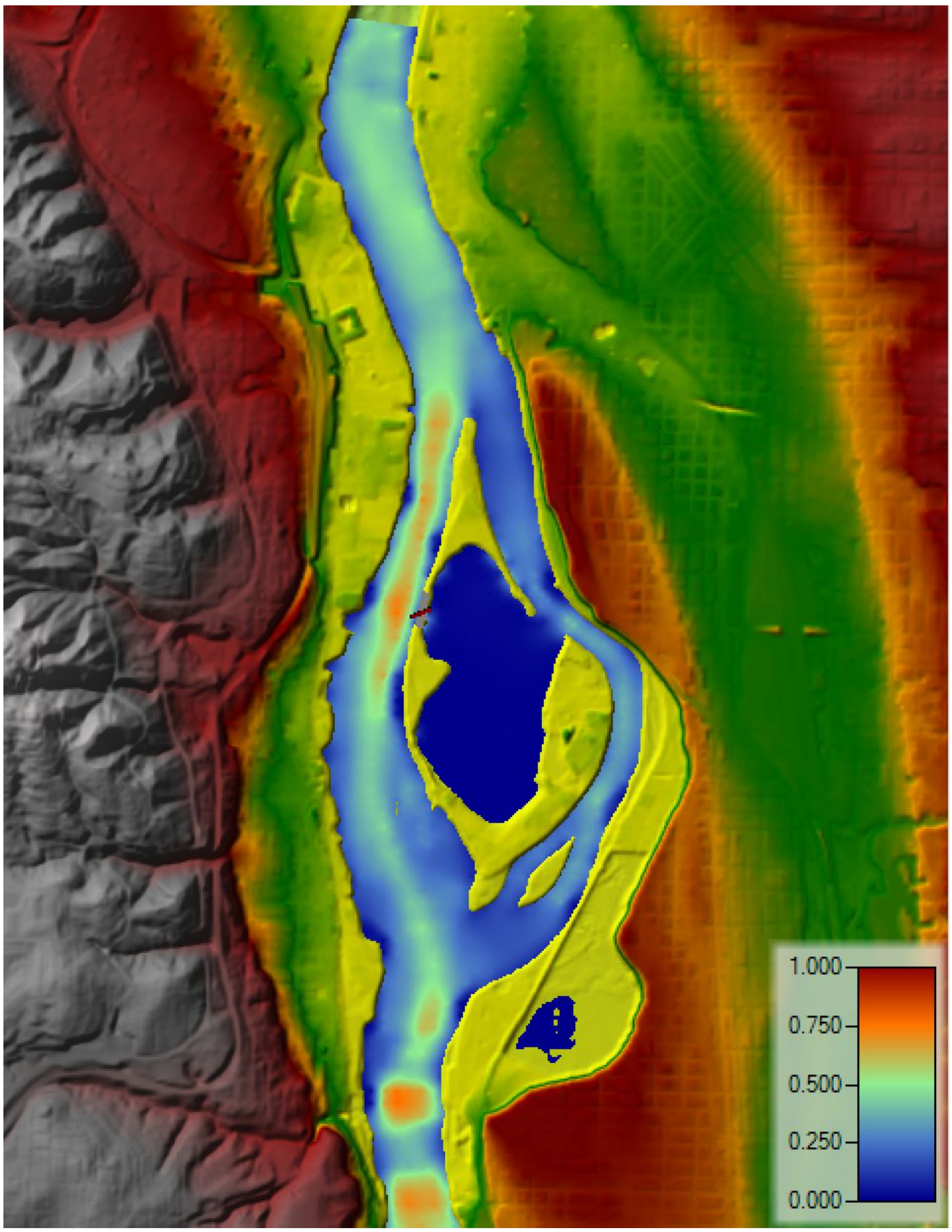
Proposed Solutions for Suppressing the Harmful Algal Bloom in the Ross Island Lagoon for the City of Portland

Design Team 9



Objective

The objective of this report is to present potential solutions to mitigate the harmful algal bloom in the Ross Island Lagoon (Note C.1).

Methods

Hydraulic Solution - Open Channel

HEC-RAS Modeler Stanton built a model within HEC-RAS following the tutorial provided by Grace Spann and Lars Larson [1]. This model uses flow data on March 25-28, 2019 from USGS and terrain data to depict current conditions within the lagoon and river [2]. The model also takes into account low and high flows with data from August 2018 and the 2019 April flood. The team decided to model the open channel with a shallow box culvert in HEC-RAS. Modeler Stanton then used the HEC-RAS Culvert Tutorial provided by Grace Spann and Lars Larson to add a box culvert on the north-west side of the lagoon in order to induce mixing within the lagoon [3]. The team tested different values of length, width, and rise of the box culvert to find the most effective combination.

Microbial Solution - Aeration

The team determined the depth required for aeration and researched viable solutions that both promote upwelling, can operate on a large scale, and are safe for fish populations. The Sea Pen Aeration System by aquaculture industry leader Pentair Aquatic Eco-Systems offered solutions that fulfilled our requirements for the site. The team chose the round pen system layout that contains fully adjustable diffusers for mitigation of plankton and algae populations which can be used in expansive areas such as lakes and oceans.

Hydraulic Conditions

Ross Island Lagoon is located on the Willamette River in Portland, OR. The Willamette River has velocities around 0.6ft/s in the mainstem. Ross Island Sand and Gravel mined sand and gravel from Ross Island until the lagoon reached its current depth, close to 125’. Its depth and lack of mixing lead to temperature stratification. Currently, Ross Island Lagoon suffers from a harmful algal bloom mainly caused by temperature stratification of the lagoon in that Professor Desiree Tullos cited on June 7th as an 11-meter epilimnion. These blooms include cyanobacteria in the genuses *Anabaena/Dolichospermum*, *Microcystis*, and *Aphanizomenon* which are known to cause water toxicity, and beneficial algae such as diatoms that do not cause water toxicity [4].

Alternatives

Open Channel

The open channel solution consists of a concrete rectangular channel that is 50’ wide, 10’ tall and 374’ long and placed on the north-west side of Ross Island Lagoon (Figure B.2). The team predicts that the channel will redirect flow from the main stem of the river and induce mixing within the lagoon.

Aeration

The aeration solution includes implementation of configurations of the Sea Pen Aeration System (SPA) manufactured by Pentair. Each round pen configuration consists of five 6.5’ diameter diffuser platforms that are fully adjustable at lengths up to 50’ [5]. These diffusers are able to dilute algae/plankton densities and provide controllable upwelling that is safe for fish populations.

No Action

The final alternative is no action. This will maintain current hydraulic conditions.

Alternatives Analysis

Open Channel

O.C. Benefits and Drawbacks

Use of open channels can be desirable for fitting project needs because they provide a long-term hydraulic solution to problems such as stratification. For the relatively large channel design being proposed, it was found that about 0.308 acres of wetland habitat would be lost (Figure B.1). Chinook, steelhead, and sturgeon could stand to benefit from this solution due to a slight predicted increase in D.O. levels and decrease in lagoon temperatures from mixing (Table B.1). The biggest drawback associated with this solution is uncertainty regarding its effectiveness. While flow through the channel is achieved during April flood flows and March flows, resulting outlet velocities may not be sufficient enough to induce mixing at a significant enough depth (Figure B.3). Some surface mixing may occur, however, it is unclear whether it would be enough to reduce HAB. During the August flows, no flow through the channel was achieved.

O.C. Cost Estimation

Costs associated with the construction of the open channel were estimated using *Heavy Construction Costs with RSMeans Data* [6]. Costs associated with labor, materials, dewatering, and mobilization were all taken into account (Table B.2). The total cost amounted to about $380,000 (including overhead/profit and contingency). The most costly elements to construction were gravel aggregate for soil stabilization and structural concrete, both of which were material costs. These contributed to 27% and 12% of the total cost, respectively. Cost could likely be reduced by recycling materials from the site, as well as stockpiling fill from excavation.

Aeration

Aeration Benefits and Drawbacks

Aeration provides a solution which requires little to no habitat disturbance or loss. This, along with increased D.O. levels and light mixing, makes aeration potentially beneficial for birds, amphibians, and fish (Table B.1). The suspended aerators the team chose have an extremely adjustable depth range (which can go within, as well as past the 11-meter stratified epilimnion within the lagoon). Drawbacks associated with aeration include constant required power input, filter maintenance, and limited effectiveness. In addition, aeration would be a short-term solution; stratification would be restored directly upon failure or removal, which would allow the HAB to return.

Aeration Cost Estimation

The team estimated the cost of constructing the aeration design from reviewing studies of similar projects carried out in the past. The team chose to review projects that were similar in location, objective, and characteristics of the study area. The first project which was reviewed was the Devil's Lake Aeration/Oxidation project that was carried out by the Devil's Lake Water Improvement District and was completed November 2018. The district installed 25 bottom diffusers at a depth of 21 ft spread over 50 acres. During a phone call interview on June 12th 2019 the Devil's Lake Water Improvement District Manager Josh Brainerd stated that the total cost of the project including construction, labor, and materials was approximately $150,000.

No Action

No Action Benefits and Drawbacks

The "no action" solution provides no benefits outside of not being associated with any cost or habitat loss. Predicted trends associated with climate change will only decrease dormancy periods of the HAB due to favorable habitat conditions, which may lead to eutrophication and consequent dead zone within the lagoon [7]. Almost all species within the habitat would be negatively impacted by this solution, with the potential exception of large birds which rely on ample land habitat (Table B.1).

No Action Cost Estimation

There are no costs associated with the "no action" solution.

Data Gaps

There are several areas of uncertainty that were brought up while analyzing our two alternatives. One was associated with cost analysis. Aeration is being done on a large scale and the aerators the team focused on for this analysis are also not like traditional small-scale pond aerators. The team based cost estimates associated with the system upon the installation of bottom diffusers in another large body of water, instead of the suspended Pentair SeaPen model, due to insufficient available pricing information. The Pentair SeaPen model could be significantly more expensive due to its proprietary nature. Additionally, costs for reinforcement of the concrete channel alternative were not included due to uncertainty on what the project would require.

The effectiveness of the aeration system is also uncertain as the team is utilizing aeration for the purpose of mixing and not for adding oxygen to the water. In the Devil's Lake case study, the lake has other sources of mixing which includes wind mixing and some current flow throughout the lake. Since there is little flow into the system, there is possibly only wind mixing that would aid the aeration system in destratifying the water. Mixing of upper layers is the most probable outcome for the Ross Island lagoon system.

Concerning the model for the hydraulic solution, other gaps in the data used/obtained arose. The model which was tested implemented a corrugated metal box culvert, which would not be realistic under the given dimensions and conditions due to material strength along with other factors. For this reason, the cost was estimated to be that of a concrete open channel with similar dimensions. In addition, the team did not run the model for the entire summer, just low flows in August.

Recommendation

The team concluded that neither solutions are recommendable. While aeration stands to cost less, rid of less wetland habitat, and potentially benefit the most species within the immediate habitat, the effectiveness of this solution cannot be conclusively determined for the given project specifications. We do suggest, however, looking into the Pentair SeaPens more extensively, as they may be a viable option. It is also suggested that the hydraulic solution be instead modeled and potentially implemented as an open channel in order to induce mixing .

Appendix A - Works Cited

[1] G. Spann and L. Larson, "Unsteady, 2D HEC-RAS Model Tutorial ."

[2] "USGS 14211720 WILLAMETTE RIVER ...," *USGS Current Conditions* . [Online]. Available: https://waterdata.usgs.gov/usa/nwis/uv?site_no=14211720. [Accessed: 12-Jun-2019].

[3] G. Spann and L. Larson, "Unsteady, 2-D HEC-RAS Culvert Tutorial."

[4] T. Dreher, 'Genetics and drivers of cyanobacterial blooms in lakes and reservoirs', Oregon State University, 2019.

[5] Pentair Master Catalog, 39th Edition: Aeration Products. Pentair, 2017.

[6] Hale, D. (2018). Heavy construction costs: With RSMeans data (32nd ed.). Rockland, MA: Gordian.

[7] Herman, Brook, et al. "Review and Evaluation of Reservoir Management Strategies for Harmful Algal Blooms." ERDC, 28 July 2017, doi:10.21079/11681/22773.

Appendix B - Tables and Figures

TABLE 1: Likely impacts to species by alternative (Hydraulic, Non-Hydraulic, and No Action).

Alternative	Species	Project Impacts	Beneficial?	Habitat Needs/Limiting Factors
Hydraulic	steelhead	Increased flow velocities within the lagoon. Upper layers may be mixed.	Potentially	High levels of dissolved oxygen in water (cold water), refuge during spawning migration
	chinook			
	lamprey	Increased turbidity due to scour	No	Sensitivity to high turbidity
	sturgeon	Water introduced will be at channel temperature	Yes	Similar water temperatures to that in the channel
	amphibians	Increased flow velocities within lagoon	No	Relatively low flow rates

	birds	Decreased land habitat/ potentially disturbed nesting areas	No	Habitat to nest and rest during migration
	beneficial algae	Stratification remains, shading out and competition between Anabaena and beneficial algae	No effect	Nutrients, sunlight, non-flushing velocities
Aeration	steelhead	Increased levels of oxygen, mixing	Yes	High levels of DO in water, cooler water, less toxicity from HAB
	chinook		Yes	
	lamprey	Decreased water temperatures due to mixing of cooler water	Yes	Cooler water, less toxicity from HAB
	sturgeon			
	amphibians			
	Great Blue Heron	Habitat will not be disturbed or removed, fish species benefits will increase food source	Yes	Less toxicity from HAB in fish
	Bald Eagles		Yes	
	beneficial algae	Destratification, decreased temperatures	Potentially	Nutrients, sunlight, non-flushing velocities
No Action	steelhead	Dissolved oxygen will continue to decrease	No	Cool, oxygenated water
	chinook		No	
	lamprey	Water temperature will continue to increase	No	Low/stable temperatures
	sturgeon		No	
	amphibians		No	
	Great Blue Heron	Habitat will not be disturbed or removed	Yes	Land habitat, ample shallow water habitat for foraging/hunting
	Bald Eagles		Yes	Land habitat
	beneficial algae	Stratification remains, shading out and competition between Anabaena and beneficial algae	No	Nutrients, sunlight, non-flushing velocities

TABLE 2: Cost estimates for construction of the open channel. Labor costs are derived from the base rate and do not include worker's comp., overhead, etc. Concrete costs were assumed to be validly estimated by on-site concrete pouring, rather than with precast components. Does not include other "Unit Costs" such as construction staking and layout, security, signage, overtime, taxes, insurance, performance bonds, temporary utilities, etc.

Component	Description	Unit	Price ($/unit)	Quantity	Cost	Source
Equipment						
Concrete Mixer	250HP; concrete transit mixer, 8CY rear discharge (equipment only, no labor)	week	*$1,765.00*	4	*$7,060*	RSM, www.rsmeansonline.com
Bulldozer for Soil Stabilization	Rock and sand used to stabilize soil post-excavation. Backfill, structral, sand and gravel, 200 HP dozer, 150' haul (equipment only)	LCY	*$0.86*	3740	*$3,216*	Local supplier
Compactor	Manually guided 2-drum vibratory smooth roller, 7.5 HP. Used for soil stabilization. Equipment only (no labor)	Week	*$500.00*	1	*$500*	RSM, www.rsmeansonline.com
Hydraulic Excavator 2CY	80HP; Track mounted; Equipment only (no labor)	week	*$3,095.00*	4	*$12,380*	RSM, p.541
Dump truck 12CY	Equipment only (no labor)	day	*$542.80*	7	*$3,800*	RSM, p.543
Labor/Crews						
Heavy equipment operators	For excavator operation	Hour	*$54.15*	180	*$9,747*	RSM, p.541
Heavy equipment operator	For dump truck operation	Hour	*$41.60*	35	*$1,456*	RSM, p.543
Medium equipment operator	For concrete mixer operation	Hour	*$55.10*	80	*$4,408*	(Eqmd in RSM); RSM, back
Concrete Finishers	Responsible for setting the concrete forms, ensuring they have the correct depth and pitch.	Hour	*$48.90*	200	*$9,780*	(Cefi in RSM); RSM, back page
Specialized laborer	Facilitate constructing structures, pouring concrete/asphalt, etc.	Hour	*$52.35*	200	*$10,470*	(Skwk in RSM); RSM, back page

Common building laborers	For setting up forming wall, installing HDPE lining, and cleaning out site debris.	Hour	*$39.85*	120	*$4,782*	(Clab in RSM); RSM, back page
Mobilization						
Mobilization, large equipment	Transport and activation of excavator and dump truck; up to 25 mi.; 40-ton capacity; Incl labor and equipment	Each	*$745.00*	2	*$1,490*	RSM, p.21
Demobilization	Transport and activation of excavator and dump truck; up to 25 mi.; 40-ton capacity; Incl labor and equipment	Each	*$745.00*	2	*$1,490*	RSM, p.21
Materials						
Structural Concrete	For given channel dimensions w/6" thick walls. Includes local aggregate, sand, Portland cement & water, delivered.	CY	*$91.50*	485	*$44,361*	Local supplier
Forming Wall	Job-built plywood, 8'-16', 1 use. Used for structural formation.	SCFA	*$2.08*	14960	*$31,117*	Local supplier
Rock/Sand Soil Stabilization	Rock and sand used to stabilize soil post-excavation. Aggregate, crushed bank gravel, loaded at the pit (material only)	CY	*$30.00*	3463	*$103,889*	Local supplier
Liner	30 mil. thick HDPE to prevent seepage into CAD cells	SF	*$0.41*	19180	*$7,864*	Local supplier
Rocks for Rock Armoring	Will be placed at culvert outlet for channel stabilization. Machine placed, random broken stone	LCY	*$31.50*	25	*$788*	Local supplier
Dewatering System						
Dewater construction area	Incl. pump, 20LF suction hose, 100 LF discharge hose. Attended 8 hrs/day	Day	*$577.50*	50	*$28,875*	RSM, www.rsmeansonline.com

LF = Linear Foot; SY = Square Yard, CY = Cubic yard, LB = pound, SCFA = Square Feet of Contact Area

Σ Bare Cost	*$276,695.14*
Contingency (12%)	*$33,203.42*
O & P (25%)	*$69,173.79*
TOTAL COST	***$379,072.35***

*Cost analysis is likely not inclusive of all required project components.

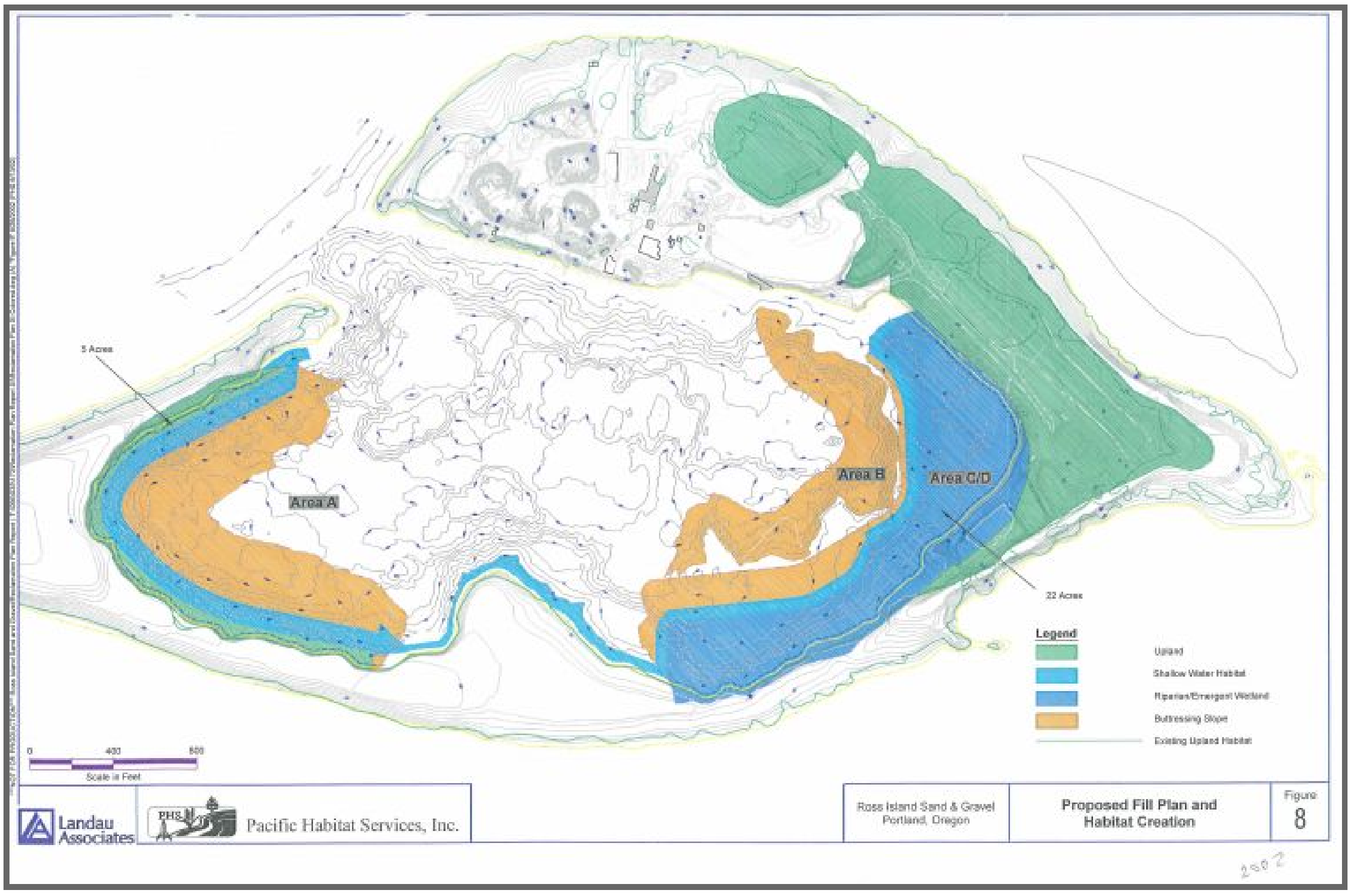


Figure 1: Overview of site location in terms of land type. Legend on the map depicts several habitats present on the site, and was used to determine which habitats/species would be impacted by the hydraulic solution.

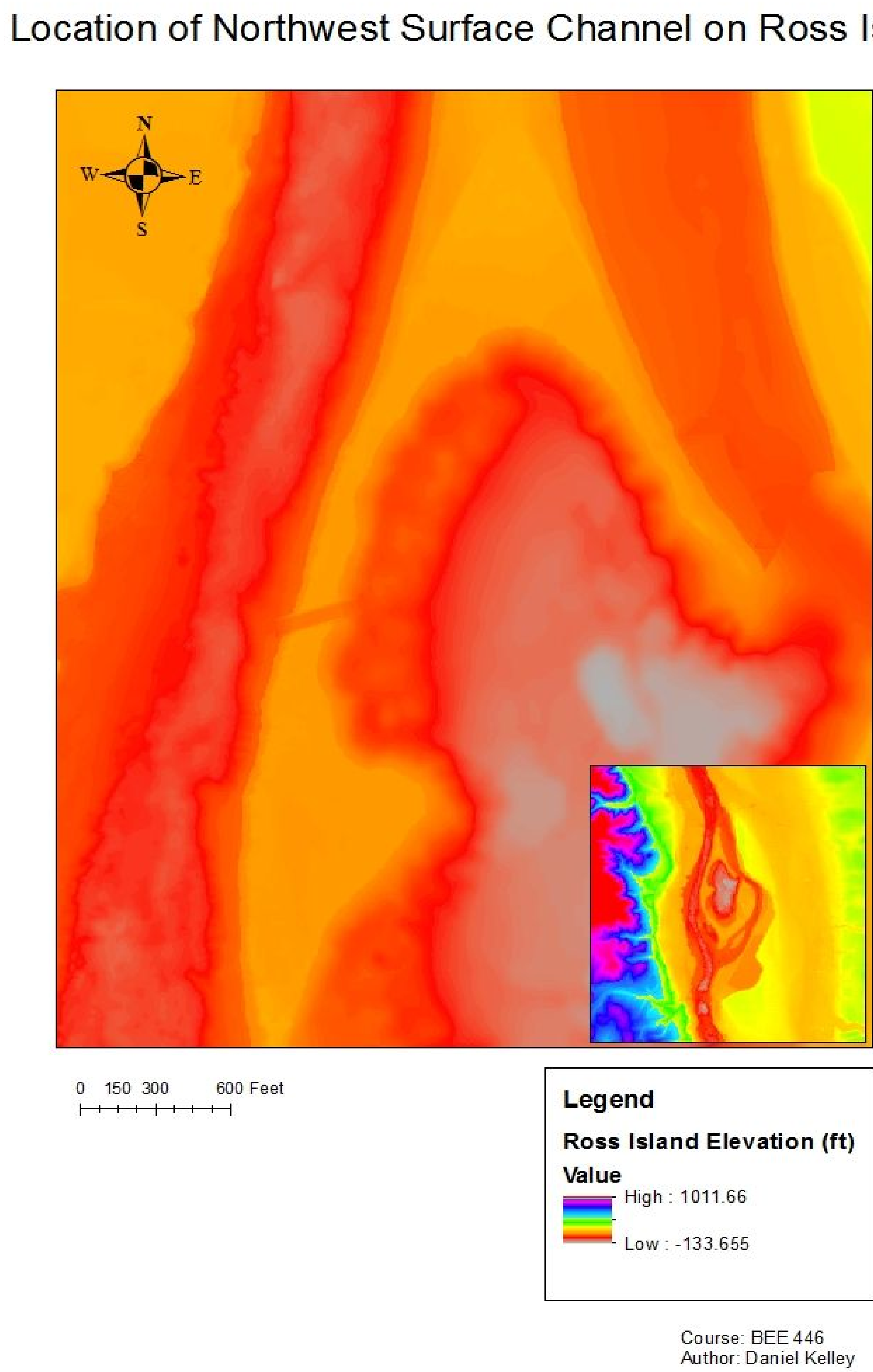


Figure 2**:** Cut of culvert made in ArcGis which was used for determining wetland habitat loss.

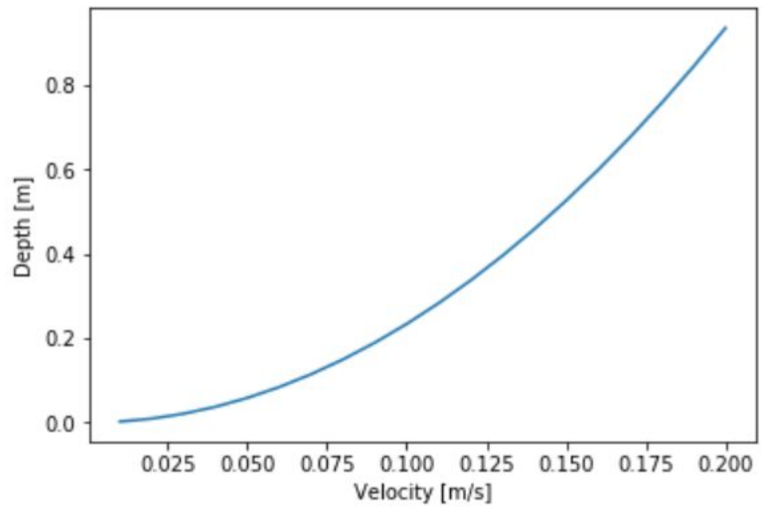


Figure 3: Mixing depth in Ross Island Lagoon as a function of velocity using Richardson Number during March, 2019 flows with a culvert.

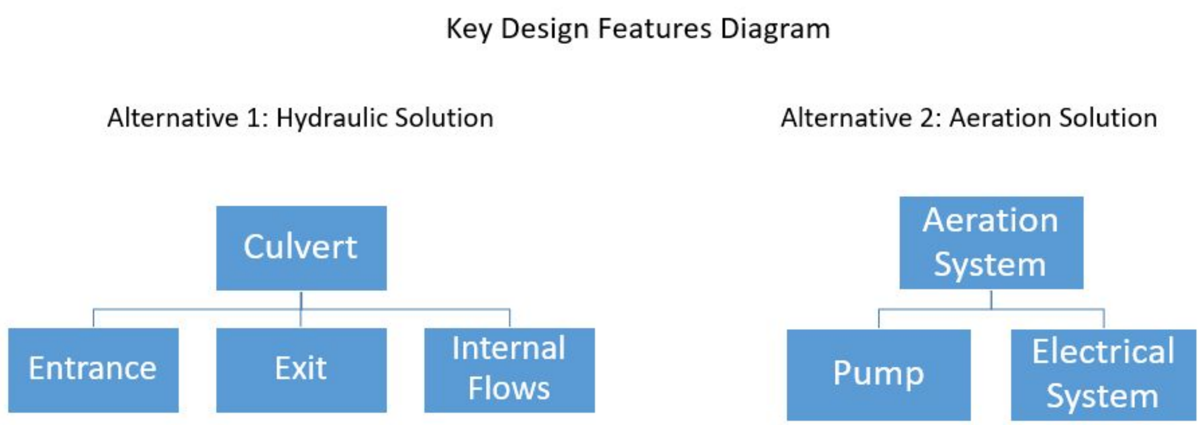


***Figure 4*:** Key design features of the alternatives analyzed

TABLE 3: FMEA results for hydraulic and non-hydraulic alternatives

FMEA

Process/Product Name: Harmful Algal Bloom Suppressant System

Prepared By: Shea Binder, Daniel Kelley, Mia Palmer, Sydney Stanton

Responsible:

FMEA Date (Orig.): May 29th, 2019

Alternative	Process Step	Potential Failure Mode	Potential Failure Effects	SEVERITY (1 - 5)	Potential Causes	LIKELIHOOD (1 - 7)	Current Controls	DETECTION (1 - 5)	RPN (S * L * D)	Action Recommended	Resp.
	What is the process or feature under investigation?	In what ways could the process or feature go wrong?	What is the impact if this failure is not prevented?		What causes the process or feature to go wrong? (how could it occur?)		What controls exist that either prevent or detect the failure?			What are the recommended actions for reducing the occurrence of the cause or improving detection?	Who is responsible for making sure the actions are completed?
1	*Culvert entrance*	*Creation of headwater pool which leads to high velocities, overtopping, debris blockage*	*catastrophic failure of culvert*	*3*	*When the culvert is smaller than the natural stream, extremely high flood flows*	*4*	*Modeling culvert at high flowrates in HEC-RAS, observing river flowrates once implemented*	*2*	*24*	*Sizing the culvert correctly*	*Engineers and Ross Island*
1	*Culvert exit*	*Scouring and erosion of Ross Island Lagoon bank material*	*Creation of perched culvert, fish passage barrier*	*4*	*when the culvert exit is not sized correctly in reference to the downstream*	*4*	*Modeling culvert at high flowrates in HEC-RAS, observing river flowrates once implemented, visual detection by Ross Island Gravel*	*3*	*48*	*Reinforcing the exit of the culvert with large boulders, preventing a perched culvert*	*Engineer, Ross Island*
1	*Internal culvert flow rates*	*High flows created by constriction of culvert*	*Fish and organism mortality*	*3*	*Culvert is sized incorrectly for flood events with long return periods*	*2*	*monitoring velocities in the culvert, modeling culvert sizes in HEC-RAS before implementing*	*3*	*18*	*Modeling culvert in HEC-RAS before implementation, monitoring velocities in culvert*	*Engineers and Ross Island*
2	*Aeration system*	*Aeration inadvertently disrupting the habitat and food source of other organisms*	*Destruction to the habitat of benefical algae and diatoms*	*3*	*Aeration is harmful to benefitial algae and diatoms*	*3*	*Monitor beneficial algae and diatom concentrations along with harmful algae*	*3*	*27*	*Monitoring algae and diatom levels regularly*	*Engineers and Ross Island*
2	*Pump*	*Pump failure*	*Destratification would not be acheived and HAB would occur*	*3*	*Seal failure (water seepage to motor), overheating due to head loss due to clogging*	*4*	*Regular maintenance of diffuser orifices*	*2*	*24*	*Regular maintenance of diffuser orifices, monitoring for water temperature as a proxy for mixing*	*Engineers and Ross Island*
2	*Aeration system*	*Aeration does not promote destratitification*	*Destratification would not be acheived and HAB would occur*	*3*	*Mixing power is not sufficient*	*4*	*Design aeration specifically for mixing hypolimnon and hyperlimnon*	*3*	*36*	*Monitoring for water temperature as a proxy for mixing*	*Engineers and Ross Island*
2	*Electrical system*	*Power failure*	*Destratification would not be acheived and HAB would occur*	*3*	*Overheating due to head loss due to clogging*	*4*	*Regular maintenance of diffuser orifices*	*2*	*24*	*Regular maintenance of diffuser orifices, monitoring for water temperature as a proxy for mixing*	*Engineers and Ross Island*

Appendix C - Additional Project Notes

Note C.1. Project Need

The Ross Island Lagoon has been listed by the Oregon Department of Environmental Quality as impaired for “aquatic weeds (harmful algal blooms).” The need that has been established for this project is thus the reduction of both the frequency and duration of these blooms within the lagoon while maintaining the protection of CAD cells and condition of existing habitat. The purpose of this analysis is to identify multiple feasible solutions to the problem at hand, both hydraulic and non-hydraulic (specifically through the movement of pre-existing land to form a culvert and aeration), to promote destratification while keeping associated costs as low as possible.

Note C.2. Failure Modes Analysis

The team used a failure mode effects analysis spreadsheet that uses severity, likelihood, and the ability for current process controls to detect the failure mode of interest before the next process. The processes analyzed are attached in Appendix B as a key features diagram.

The full FMEA results are shown in Table 3 attached in Appendix B. The PFMAs that have the highest RPNs are culvert exit failure at an RPN of 48 and aeration system failure at an RPN of 36. The culvert exit failure that produces scour could erode the lagoon bank and destroy emergent wetland and shallow water habitat. This failure mode was ranked with the critical severity, high likelihood and moderate detectability. The team is confident in this ranking as it represents the worst possible outcome of all the failure modes analyzed. The aeration system failure to produce stratification would not allow for treating for the HAB. The aeration system failure was ranked with marginal severity, high likelihood, and moderate detectability. The team is not as confident in this ranking as the measurement used to monitor mixing would be temperature which may not provide accurate determinations of mixing, reducing detectability. This would still produce an RPN of 48 if this uncertainty in the relationship between observed temperature and actual mixing are taken into account.

These RPNs show that the alternative with the lower risk is the non-hydraulic alternative. From a risk perspective the severity of the risk of the damage to habitat by the hydraulic solution causes it to be less favorable.