6.14.2019

Investigation of Mitigation Alternatives for Harmful Algal Blooms at Ross Island Lagoon

Design Team 12

Prepared for City of Portland

Photo: Mike Houck

Table of Contents

Objective

This report analyzes three design alternatives intended to mitigate thermal stratification and harmful algal blooms (HABs) in the Ross Island Lagoon (RIL) located on the Willamette River in Portland, Oregon. The lagoon has a history of exploitative gravel mining conducted by Ross Island Gravel, resulting in a highly altered river bed. Today, the lagoon spans 130 acres with a maximum depth of 125 feet. A small entrance at the northeast end of the lagoon connects the Holgate Channel to the lagoon, and allows for tidal flows to hydraulically mix water within the lagoon. Ross Island Sand and Gravel did not assess environmental impacts when excavating, and harmful algal blooms caused by stratification from the extreme depth pose serious threats to water quality and aquatic life. Currently, multiple confined aquatic disposal (CAD) cells are buried along the inner south side of the island. The alternative designs must address these challenges and propose the costs, risks, and benefits associated with implementing the design.

Current Conditions

The current hydraulic conditions in the lagoon provide a baseline for evaluating the effectiveness of our alternatives. Water exits the lagoon at 0.1 ft/s at the northeast entrance. This velocity is not sufficient for mixing within the lagoon and mitigation of HABs. Velocities between 2.2 and 2.6 ft/s are required at the entrance of the lagoon to mix at depths between 10 and 15 feet. This mixing depth would affect the epilimnion and metalimnion layers, theoretically suppressing the cyanobacteria.

Ross Island Aerial Photo, Summer 2015. City of Portland.

Alternatives

Three design alternatives were analyzed for effectiveness in reducing the occurrence and duration of HABs within the RIL. These alternatives include the creation of a surface conveyance on the southwestern side of Ross Island to disrupt stratification through hydraulic mixing, the placement of artificial floating wetlands to inhibit the growth of HABs through multiple mechanisms, and the no-action alternative.

Surface Conveyance

The primary objective of the surface conveyance is to reduce the temperature stratification through hydraulic mixing. The surface conveyance is a rectangular concrete channel with dimensions of 50 feet wide, 50 feet deep, and 295 feet long. Adding a surface conveyance to the southwestern end of the island could draw flow into the RIL, mixing the area as water is then drawn towards the pre-existing lagoon entrance at the northeastern end of the island.

Floating Wetlands

The objective of artificial floating wetlands is to reduce optimal conditions required for the growth of HABs through utilization of several mechanisms. The floating wetlands block light penetration into the lagoon, reducing the photosynthetic activity of microorganisms. At the same time, plants uptake nutrients such as nitrogen and phosphorous that are needed for HABs to grow. An added benefit of constructing floating wetlands in the lagoon is the creation of wetland habitat. The floating wetlands would be made of recycled materials, and planted with native wetland species.

No Action

It is necessary to consider the option of taking no action to change the system. This alternative involves the analysis of current conditions and provides a baseline for the effectiveness of the other alternatives considered. The environmental costs of leaving the lagoon in its current state should be heavily weighed as the HABs threaten aquatic life.

Methods

Hydraulic Model

Our team used HEC-RAS to model the hydrological effects of adding a surface conveyance channel to the southwestern portion of the island compared to making no structural changes. The surface conveyance was represented by a box culvert spanning 50 feet with a length of 295.4 feet and a height of 50 feet. The upstream and downstream elevations were both set to 0 as to not interfere with the 2D grid cells. The loss coefficient was assumed to be 0.5 at the entrance and 1 at the exit, and the Manning's n value was assumed to be 0.03.

We examined the effects during low flows in August, mid flows in March, high flows in December, and flood flows during April. The locations of interest included the culvert exit and the lagoon entrance. We drew profile lines across these sections and calculated the average velocity for each profile line under each flow regime and treatment.

Our team analyzed our modeled flow velocities using the Richardson equation (Appendix A, Equation 1). We assumed if the Richardson number is below 0.25, the water body is expected to be mixed. Thus, we calculated the mixing depth at the culvert exits and the lagoon entrance using the modeled velocities at these locations and a Richardson number of 0.25.

ArcGIS and Mapping

The GIS specialist from our team utilized ArcGIS to map our team's selected alternative designs and find acreage of habitat affected.

Our alternatives were mapped by creating new feature classes and drawing polygons overlaid on the georeferenced aerial images of the Ross Island Lagoon from 2015. The culvert was represented with a rectangular shape with the same dimensions and location as the HEC-RAS model, and the floating wetlands were idealized using four large circular shapes. Creating these polygons allowed for analysis on the habitat area impact.

The shallow habitat impact of our alternatives was determined by comparing the area of shallow water habitat to the area of the culvert and floating wetlands polygons. The terrain file for the lagoon was imported, and the symbology was changed to clearly identify the low and high water elevations that signified the shallow water habitat boundaries. The shallow water habitat focus area was defined as within the lagoon, and between elevations of -20 and +1 feet. A shapefile and polygon were created to encompass this shallow water area. The GIS specialist overlaid the polygons for the culvert and floating wetlands to determine how much shallow water habitat area would be affected.

Alternatives Calculations

The performance and efficiency of each alternative were evaluated using criteria displayed in Table 1 in Appendix C. Project costs were estimated using RS Means data from Gordian and an array of other resources including the 2019 Oregon Prevailing Wage Rates for Public Works and a project proposal. Costs estimates include overhead and profit and a contingency of 15% was applied to the sum of all components.

Failure Modes & Effects Analysis

A failure mode analysis was completed for each alternative. For each possible failure, the severity, likelihood, and detection rate were estimated using a scaling criterion. The three values were multiplied together to find the risk priority number (RPN).

Results

ArcGIS

Analysis of habitat impact revealed that neither the culvert and floating wetlands alternatives constitute a major threat to pre-existing shallow water habitat. The culvert represents a total land area of about 0.34 acres, with about 0.03 acres coinciding with shallow water habitat. The floating wetlands have a surface area of 15.57 acres, and will remove roughly 0.3 acres of shallow water habitat. Our team concludes that the low acreage of affected habitat is mainly due to the strategic placement of our design alternatives. The mapped alternatives can be located in Figure 1 and 2 in Appendix B.

HEC-RAS

The modeled lagoon did not reach the velocities required to mix at a depth of 10 to 15 feet to eliminate HAB growth. The modeled velocities and their respective mixing depths are shown in Table 1 in Appendix B. The velocities can be spatially visualized in Figures 3 through 8 in Appendix B. There appears to be a minimal difference between the calculated mixing depths for the current lagoon structure and the addition of a southwestern channel conveyance.

Alternatives

The floating wetland is the most expensive alternative with a capital cost of approximately $28 million and maintenance cost of about $8,000. The surface conveyance alternative is expected to be cheaper, costing approximately $980,000 with higher maintenance costs of about $212,000. The no action alternative has no capital costs but is expected to have significant ecological repercussions due to HAB growth.

Failure

The largest failure risk for the south surface conveyance is bed mobilization leading to CAD cell exposure (RPN = 20). Though it is not likely to occur, this failure would cause a large impact on the environment and water quality. The largest failure for the floating wetland alternative is the failure to effectively remove the nutrients (RPN = 12) . This would leave no reason to continue to maintain and operate the wetlands. Further research of nutrient removal rates is necessary to ensure the effectiveness of a floating wetland for this design.

Discussion & Recommendation

Concerns for Local Species

It is important to consider the impact of the design alternatives on existing habitat. The creation of a large concrete surface conveyance presents multiple concerns for impact to aquatic life. One implication of the surface conveyance alternative is the removal of approximately 0.03 acres of shallow water habitat. The presence of shallow water habitat and natural debris offer refuge for anadromous salmonids, shad, and sturgeon during migration and rearing (ODFW 2005). There may be a greater impact, however, to aquatic life by altering existing hydraulic conditions due to the relatively small footprint of the structure within shallow water habitat. It is possible that the benefits associated from increased hydraulic mixing would offset the negative impacts from the footprint of the structure, and ultimately benefit aquatic wildlife. Therefore, it is difficult to define the ultimately impact from the surface conveyance alternative.

The placement of constructed floating wetlands is arguably more favorable to habitat creation than the surface conveyance, creating 15.57 acres of wetland habitat while only removing 0.3 acres of shallow water habitat. Wetland habitat is beneficial to Chinook salmon, waterfowl, and amphibians (Taft and Haig, 2003; Pearl et al., 2005; Teel et al., 2009) and conservation of wetland habitat is of considerable interest. Therefore, the placement of artificial wetlands in RIL, while likely not as beneficial to preventing HABs compared to hydraulic mixing, would boost the existing wetland habitat available to wildlife.

Final Conclusions

Our two design alternatives, the surface conveyance and floating wetlands, do not offer substantial benefits to outweigh the costs and risks associated with implementation. Our hydraulic solution was proved ineffective due to insufficient velocities and shallow mixing depths: the surface conveyance designed would not result in breaking up the stratified water layers to prevent HABs. The floating wetlands were not considered viable because of the extreme costs and inconclusive effectiveness.

The two-dimensional model created with HEC-RAS had multiple limitations. First, the model output only reports the surface velocity; our team assumed velocity remained uniform for all depths to calculate the Richardson's number for mixing depths. Furthermore, due to limitations in modeling abilities the surface conveyance was crudely represented as a box culvert. The culvert had to be extended beyond the edge of the island to produce model results, and in reality the constructed solution would be a lined conveyance, would not extend into either the channel or the lagoon, and would require extensive armoring of CAD cells. Finally, the August flow model has varying instabilities which indicates uncertainty. Risking disturbance of the CAD cells for a hydraulic solution that offers ineffective mixing is not a reasonable alternative.

Our final analysis concluded the hydraulic conveyance would cost $978,685, and the floating wetlands would cost $28,215,755. The extreme cost for the wetlands cannot be justified based on our team's limited knowledge of the effectiveness of this solution. If this option were to be submitted to permitting boards and stakeholders with our full recommendation, our team would require further investigation or testing. Key questions include requirements for percent area covered by the wetlands and time for treatment to understand how to effectively apply the floating wetlands solution.

The final recommendation is the "no-action" alternative. We cannot justify the costs and risks associated with either of our designed alternatives at this time. Our team strongly recommends Ross Island Sand & Gravel is held responsible for the full liability of this issue.

References

BIOHAVEN® FLOATING ISLAND: 5 X 5 FOOT. (2019). Retrieved June 13, 2019, from https://floatingislandswest.com/ipo500-5-x-5-ft/

Bulk, Wholesale, and Custom Seed Mixes. (2019). Retrieved June 13, 2019, from https://northwestmeadowscapes.com/pages/custom-mixes

David J. Teel, Cyndi Baker, David R. Kuligowski, Thomas A. Friesen & Barbara Shields (2009) Genetic Stock Composition of Subyearling Chinook Salmon in Seasonal Floodplain Wetlands of the Lower Willamette River, Oregon, Transactions of the American Fisheries Society, 138:1, 211-217, DOI: 10.1577/T08-084.1

Hoyle, V. (2019). *Prevailing Wage Rates for Public Works Contracts in Oregon* (United States, Bureau of Labor and Industries).

Taft, O. W., & Haig, S. M. (2003). Historical wetlands in Oregon's Willamette valley: Implications for restoration of winter waterbird habitat. *Wetlands,23*(1), 51-64. doi:10.1672/0277-5212(2003)023[0051:hwiowv]2.0.co;2

United States, Oregon Department of Fish and Wildlife. (2005). *Biology, behavior, and resources of resident and anadromous fish in the lower Willamette River: Final report of research, 2000-2004*. Oregon Dept. of Fish and Wildlife.

Pearl, C. A., Adams, M. J., Leuthold, N., & Bury, R. B. (2005). Amphibian occurrence and aquatic invaders in a changing landscape: Implications for wetland mitigation in the willamette valley, Oregon, USA. *Wetlands,25*(1), 76-88. doi:10.1672/0277-5212(2005)025[0076:aoaaii]2.0.co;2

RS Means Data Free Trial from Gordian. (2011). Retrieved June 13, 2019, from https://www.rsmeans.com/

Southern Wire® 1000' 1/16" Diameter 1x7 Galvanized Aircraft Cable. (2019). Retrieved June 13, 2019, from https://www.globalindustrial.com/p/material-handling/chains-ropes-straps-connectors/rope-line-twine/1000-1-16-diameter-1x7-galvanized-aircraft-cable?infoParam.campaignId=T9F&gclid=Cj0KCQjw6IfoBRCiARIsAF6q06tJ4RxZNlPSxpw-8xnlRI3TU7dpG6isYlIUKkWt-im5if1cr2KSlccaAmhQEALw_wcB

Ware, C. (2012, October 4). Environmental Site Investigation and Related Services [Letter to City of Portland]. Portland, Oregon.

10 cu. yd. Bulk Topsoil. (2019). Retrieved June 13, 2019, from https://www.homedepot.com/p/10-cu-yd-Bulk-Topsoil-SLTS10/205325475?MERCH=REC-_-PIPHorizontal2_rr-_-205459977-_-205325475-_-N

Appendix A. Calculations

Equation 1. Richardson Equation

$$R_i = \frac{\left(\frac{g}{\rho}\right)\left(\frac{\partial\rho}{\partial y}\right)}{\left(\frac{\partial u}{\partial y}\right)^2}$$

where:
R_i = Richardson number
g = gravity (m s^{-2})
ρ = density of water (kg m^{-3})
y = depth of mixing (m)
u = velocity (m s^{-1})

Appendix B. Model Results: HEC-RAS and GIS

Table 1. HEC-RAS model results

Flow Regime	Condition	Location	Velocity		Mixing Depth	
			ft/s	m/s	ft	m
Low	Current	Lagoon Entrance	0.04	0.01	0.01	0.00
	Culvert	Lagoon Entrance	0.03	0.01	0.01	0.00
		Culvert Exit	0.07	0.02	0.03	0.01
Mid	Current	Lagoon Entrance	0.10	0.03	0.07	0.02
	Culvert	Lagoon Entrance	0.15	0.05	0.16	0.05
		Culvert Exit	0.11	0.03	0.09	0.03
High	Current	Lagoon Entrance	0.11	0.03	0.09	0.03
	Culvert	Lagoon Entrance	0.11	0.03	0.09	0.03
		Culvert Exit	0.13	0.04	0.12	0.04
Flood	Current	Lagoon Entrance	0.69	0.21	3.39	1.03
	Culvert	Lagoon Entrance	0.69	0.21	3.39	1.03
		Culvert Exit	0.24	0.07	0.41	0.13

Figure 1. Placement of floating wetlands at Ross Island Lagoon, Portland, OR

Figure 2. Map of culvert design at Ross Island Lagoon, Portland, OR

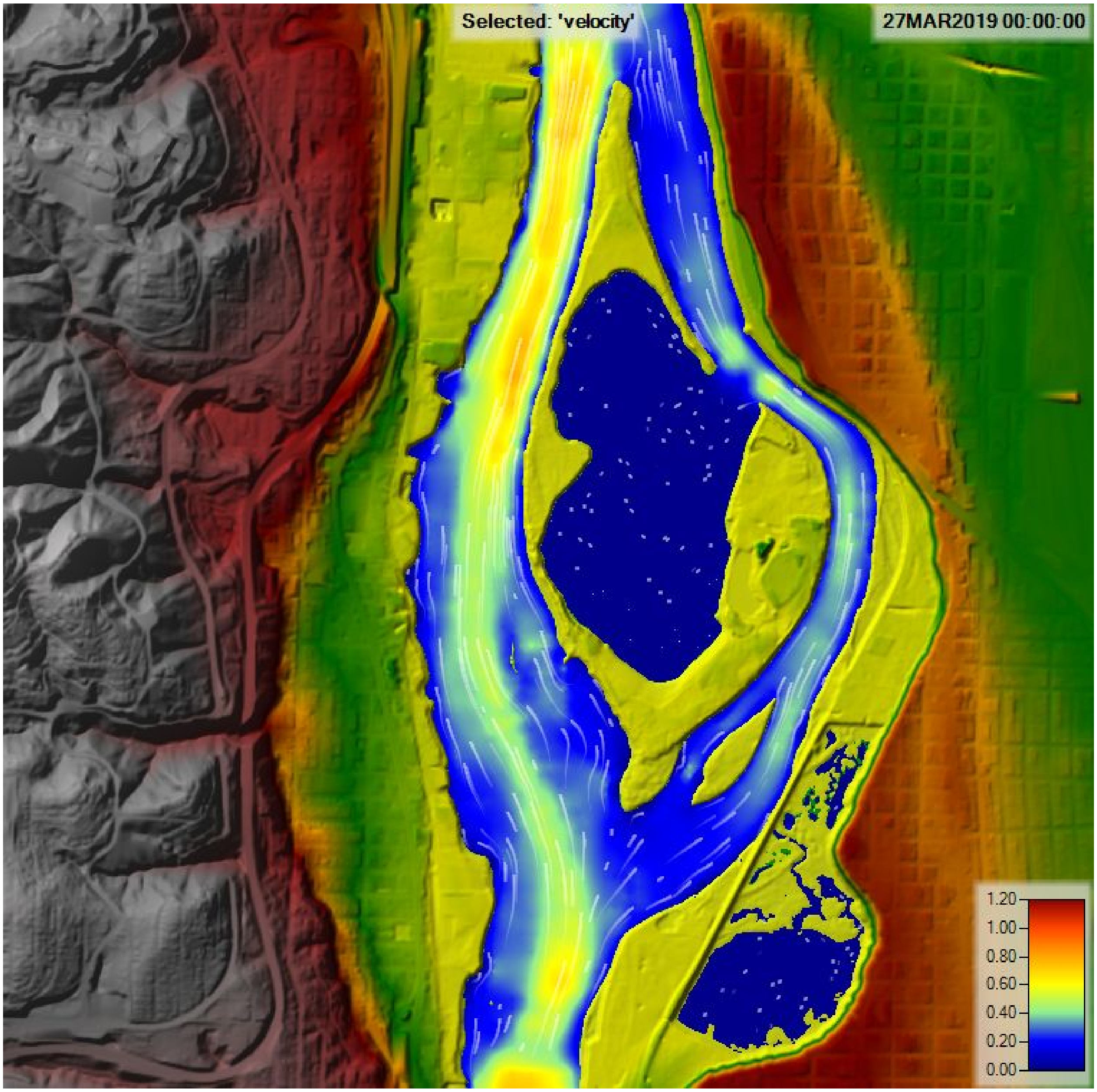

Figure 3. Current hydraulic conditions of RIL in March 2019. Velocity gradient and vector visualization displayed.

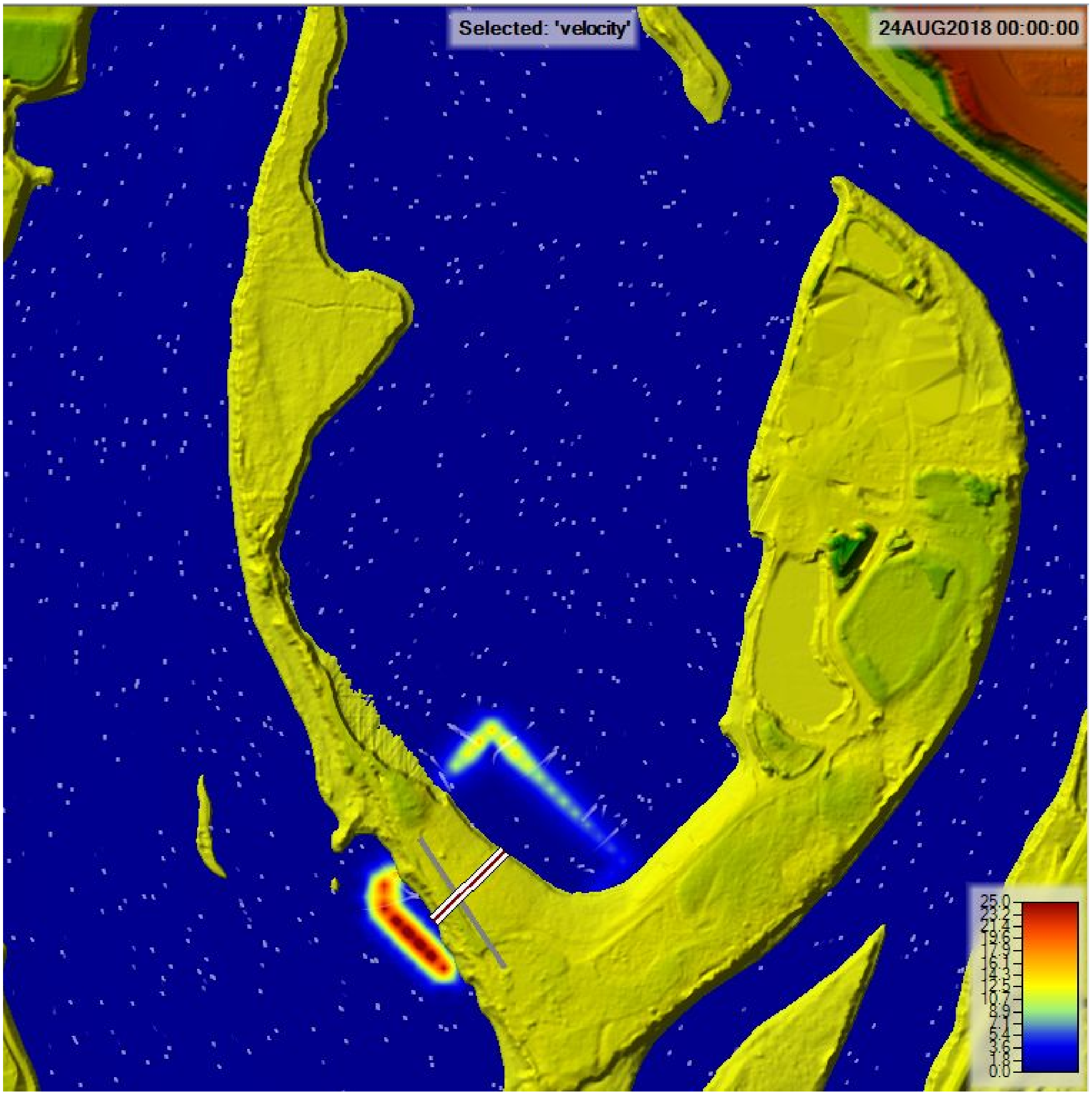

Figure 4. Low flow hydraulic conditions with culvert modeled for August 2018.

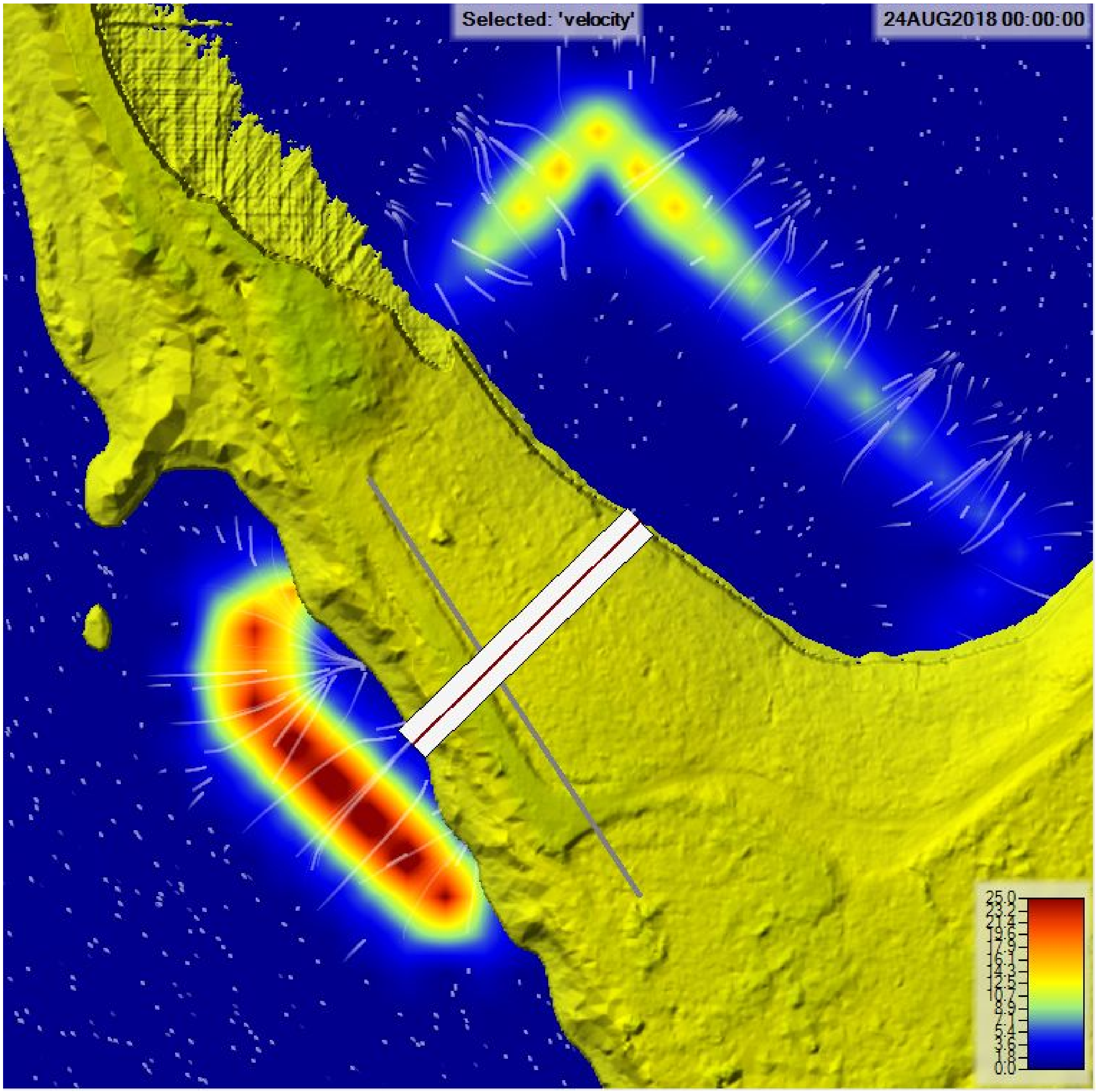

Figure 5. Low flow velocities at box culvert representing surface conveyance alternative.

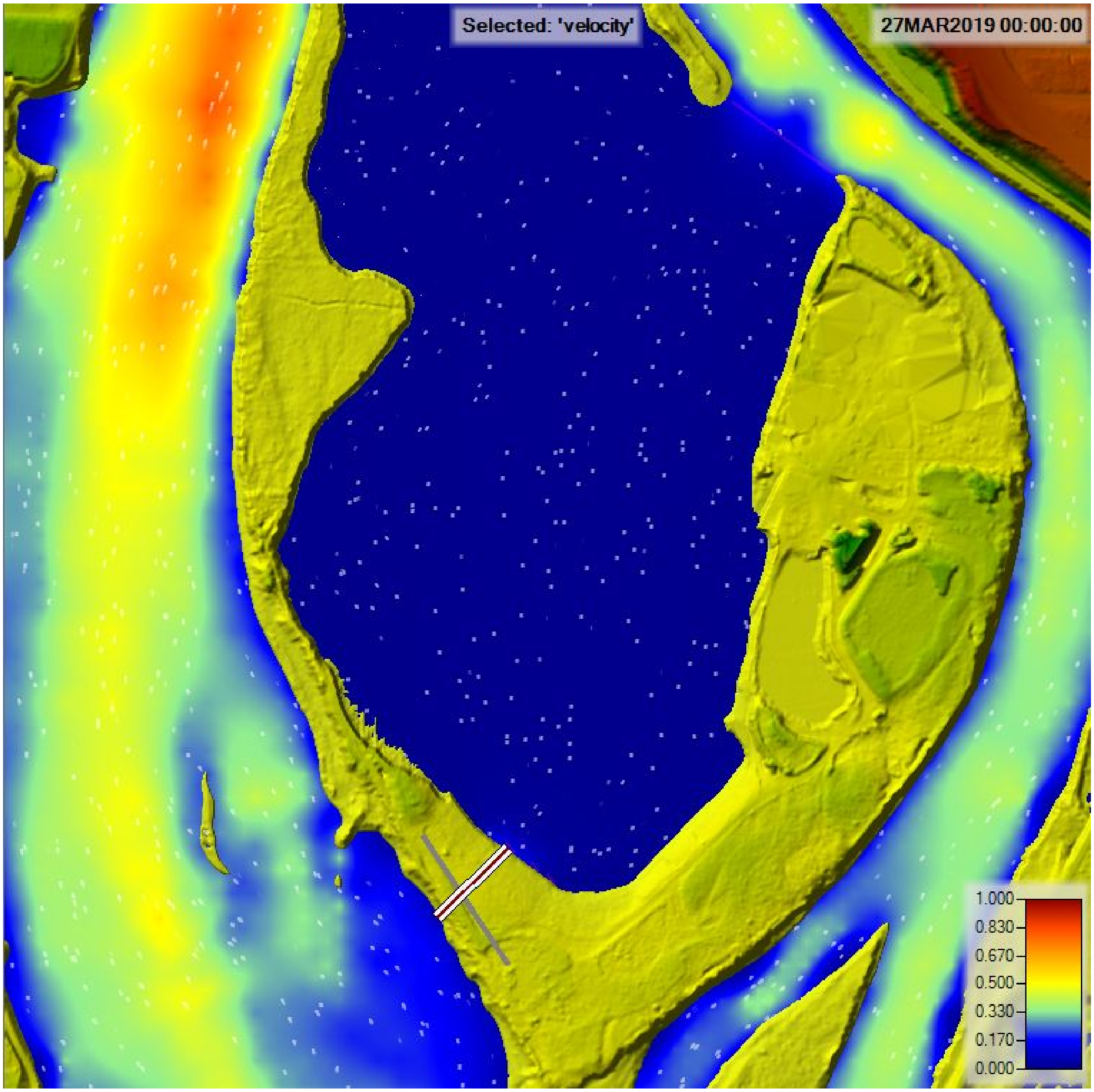

Figure 6. Mid flow hydraulic conditions with culvert modeled for March 2019.

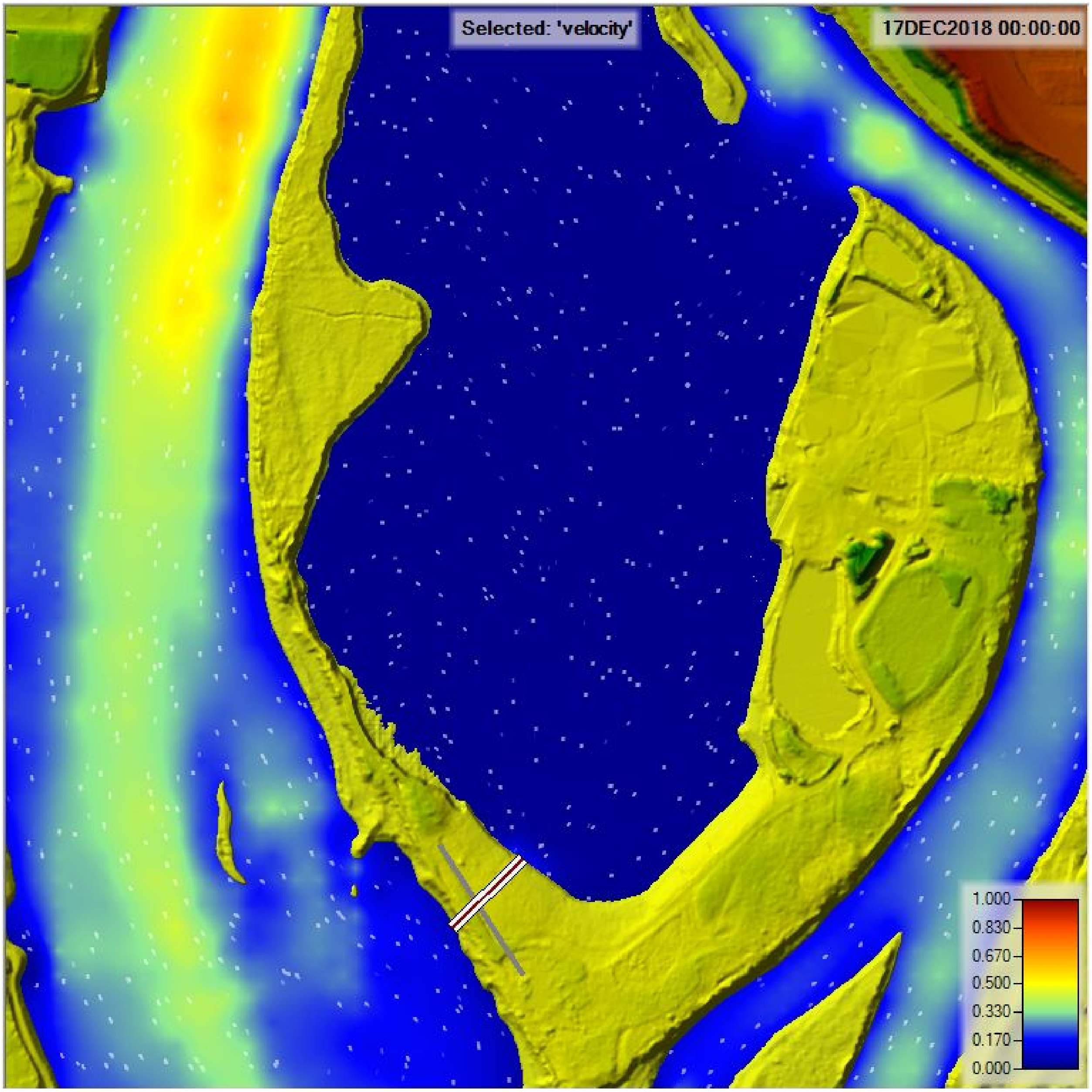

Figure 7. Mid flow hydraulic conditions with culvert modeled for December 2018.

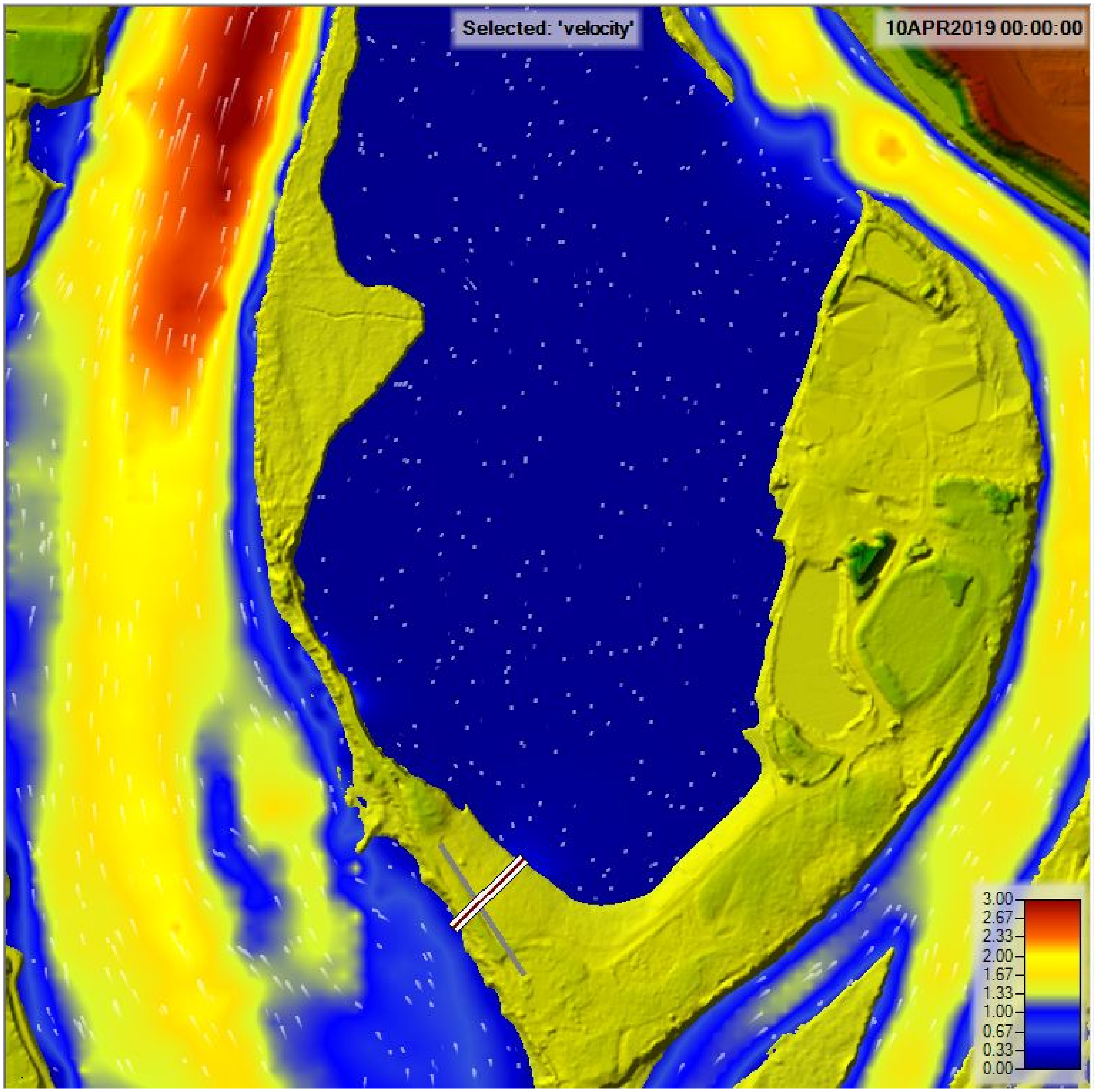

Figure 8. Flood flow hydraulic conditions with culvert modeled for April 2019.

Appendix C. Alternatives Analysis

Table 1: Analysis of Alternatives

Criteria	*Surface Conveyance*	*Floating Wetlands*	*Do nothing*
Capital cost ($)	$978,685	$28,215,755	0
O&M cost ($)	$211,692	$8404.8	0
Acres of habitat loss and creation by type – shallow water, wetland, riparian, upland (acres)	0.03 acres shallow habitat removed	15.57 acres created wetland 0.3 shallow removed	0
Expected effectiveness at controlling HAB, with justification (unknown, low, med, high)	high	low	low
Likelihood of failure during flood events (unknown, low, med, high)	med	high	unknown
Impact on base flood elevation (none, <0.6', >0.6')	none	none	none
Likely to benefit widest range of species – select all that apply, with justification (Steelhead, chinook, lamprey, birds, amphibians)	No benefit	Aquatic Insects, anadromous salmonids, shad, sturgeon, waterfowl, amphibians	No benefit
Any unintended impacts	- Reoccuring HABs not addressed	- Inhibit navigable area by watercraft	- Reoccuring HABs not addressed

Table 2: Cost Estimation for Surface Channel Conveyance

	Component	Function	Unit	Cost/Unit	Number of units	Total Cost	Source
Equipment (no labor)	Excavator 3.5 CY	Remove earth	Day	$2225	60	$133,500	A.
	Dump truck 18 CY	Transport earth off site	Day	$495	60	$29,700	B.
	Mobilization	Transport equipment on site	Day	$740	8	$5,920	C.
	Demobilization	Transport equipment off site	Day	$740	8	$5,920	D.
Labor and Project Management	Power Equipment Operator	Operate excavator	Hour	$43	480	$20,640	E.
	Power Equipment Operator	Operate Dump Truck	Hour	$43	480	$20,640	F.
	Laborer	Concrete filling	Hour	$30	480 (5 laborers)	$72,000	G.
	Project Manager	Manage Project	Hour	$32	160	$5120	H.
Dewatering	Dewatering pump	Dewatering of construction area	Day	$78	30	$2340	I.
	Cofferdam	Dewatering of construction area	Square foot	$46.85	5,000	$234,250	J.
Materials	Concrete, 94 lb bag	Create surface channel	Bag	$10.7	30,000	$321,000	K.
O&M	Concrete Maintenance	Maintenance of Channel	$/square ft/ year	$52,923	4 (20 years out, assuming maintenance every 5 years)	$211,692	L.

Table 3: Cost Estimation for Artificial Floating Wetlands

	Component	Function	Unit	Cost/Unit	Number of units	Total Cost	Source
Materials	Floating Base Structure	Provide base structure for media and plants	25 square feet	$879	$27,129.2	$24,416,251.2	M.
	Soil Media	Media for plants	10 cu. yards	$320	300	$96,000	N.
	Slough Sedge Seeds	Plant of choice	lb	$210	100	$21000	O.
	Anchor cable	Anchor structure	1000’	$21.75	4	$87	P.
Labor	Planting and assembly	Assemble the soil within the base and plant seeds.	Hour	$17.51	120	$2101.2	Q.
O&M	Plant and structure maintenance	Maintain plant health and structural integrity	Hour	$17.51	480	$8404.8	R.

A. RS Means 2011
B. RS Means 2011
C. RS Means 2011
D. RS Means 2011
E. Hoyle, V. (2019).
F. Hoyle, V. (2019).
G. Hoyle, V. (2019).
H. (Ware 2012)
I. RS Means 2011
J. RS Means 2011
K. RS Means 2011
L. RS Means 2011
M. BIOHAVEN® FLOATING ISLAND: 5 X 5 FOOT. (2019). Retrieved June 13, 2019, from https://floatingislandswest.com/ipo500-5-x-5-ft/
N. 10 cu. yd. Bulk Topsoil. (2019). Retrieved June 13, 2019, from https://www.homedepot.com/p/10-cu-yd-Bulk-Topsoil-SLTS10/205325475?MERCH=REC-_-PIPHorizontal2_rr-_-205459977-_-205325475-_-N
O. Bulk, Wholesale,and Custom Seed Mixes. (2019). Retrieved June 13, 2019, from https://northwestmeadowscapes.com/pages/custom-mixes
P. Southern Wire® 1000' 1/16" Diameter 1x7 Galvanized Aircraft Cable. (2019). Retrieved June 13, 2019, from https://www.globalindustrial.com/p/material-handling/chains-ropes-straps-connectors/rope-line-twine/1000-1-16-diameter-1x7-galvanized-aircraft-cable?infoParam.campaignId=T9F&gclid=Cj0KCQjw6IfoBRCiARIsAF6q06tJ4RxZNlPSxpw-8xnlRI3TU7dpG6isYlIUKkWt-im5if1cr2KSlccaAmhQEALw_wcB
Q.(Ware 2012)
R. (Ware 2012)

Appendix D. Failure Modes Analysis Matrix

Table 1. Potential Failure Modes Analysis for Ross Island Lagoon design alternatives

FMEA

Process/Product Name: Potential Failure Mode Analysis for Ross Island, Portland, OR — Prepared By: Austin Cuenca

Responsible: Austin Cuenca — FMEA Date (Orig.): 14-Jun

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
	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?
1	*Entrance Gate*	*Mechanism Failure*	*Compromised flow, channel does not allow water through*	1	*Neglecting maintenance*	3	*Regular maintenance and monitoring*	1	3	*Regular maintenance and monitoring*
1	*Inflow Armoring*	*High flows lead to bed mobilization*	*Compromised bed stability and entrace gate structure*	3	*High flows, inadequate design*	3	*Factor of safety during design, periodic analysis*	2	18	*Use factor of safety during calculations, periodically analyze site*
1	*Channel Bed Armoring*	*High flows lead to bed mobilization*	*Compromised structure of surface channel may lead to bed erosion and exposed CAD cells*	5	*High flows, inadequate design*	1	*Factor of safety during design, periodic analysis*	2	10	*Use factor of safety during calculations, periodically analyze site*
1	*Outflow Armoring*	*High flows lead to bed mobilization*	*Compromised outlfow site may lead to erosion and disturbance of wetland habitat*	2	*High flows, inadequate design*	2	*Factor of safety during design, periodic analysis*	1	4	*Use factor of safety during calculations, periodically analyze site*
1	*Wetland Replacement*	*Wetland failure (plants die, partial/complete loss of vegetation)*	*Loss of created wetland habitat*	3	*Contribution to nutrients in lagoon, ineffective treatment*	2	*Ensure wetland is well established, proper maitenance and monitoring*	1	6	*Regular maitenance and monitoring*
2	*Bed Material*	*Irregular water flows cause bed material to exit structure into water*	*Soil entering water, causing need for heavy maitenance and reconstruction of wetland*	3	*Extreme winds causing large waves, damage to structure (ie. hit by a boat/barge), Irregular flow patterns*	1	*Ensure proper anchoring during construction, use of a buffer zone to marine vehicles*	1	3	*Ensure there is little tipping possibility in floating wetland design*
2	*Planting Surface*	*Planting surface become uninhabitable to plants*	*Wetland vegetation partial/complete failure*	2	*Inadequate design, improper installation, damage to structure (ie. hit by boat/barge)*	1	*Proper installation, use of a buffer zone to marine vehicles*	1	2	*Ensure design is properly protected*
2	*Anchoring Mechanisms*	*Anchor failure*	*Loss of floating wetlands, float down river*	4	*Inadequate design, improper installation, damage to structure (ie. hit by boat/barge)*	1	*Proper installation, use of a buffer zone to marine vehicles*	3	12	*Regular monitoring, use of buffer zone to marine vehicles*
2	*Operation and Maintenance*	*Wetland vegetation dies during operation*	*Loss of vegetation, replanting/heavy maintenance needed, nutrients contributed to lagoon*	2	*Neglect of regular maintenance and monitoring*	2	*Regular maintenance and monitoring, ensuring vegetation is healthy*	2	8	*Employ regular maintenance and monitoring schedule*
2	*Control of HAB*	*Inability to effectively remove nutrients to prevent HABs*	*Harmful algal blooms continue to impact river ecosystem*	2	*Unable to uptake enough nutrients to treat HABs, does not block enough light*	7	*Regular monitoring of blooms and water quality*	1	14	*Increase surface area of wetlands, increase density of plants, consistent water sampling*
2	*Storage for Winter*	*Wetland freezes and vegetation dies*	*Loss of vegetation to floating wetlands, would need to replace partially/completely*	2	*Improper winter storage, extreme weather*	2	*Ensuring proper winter storage, prepare for extreme weather*	2	8	*Ensure proper winter storage, employ semi regular maintenance and monitoring schedule*