New Submerged Diffuser for Targeted In-Water Placement of Dredged Material within the Lower Columbia Estuary

*Hans R. Moritz[1], Jarod K. Norton[1], Aaron Litzenberg[1], Max Wilson-Fey[1], Jessica Stokke[1], Travis Davidson[1], Todd Hash[1], Rachel Stolt[1], Doyle Anderson[2], Chet Thomas [2], Mark Wright [2], Neil DeRosier [2], and Jase Ousley[3]
1 US Army Corps of Engineers (USACE)-Portland District/Division, Portland, OR; 2 Port of Portland, Portland, OR; 3 US Army Corps of Engineers-Headquarters, Office of Navigation, Washington, DC
*Contact: hans.r.moritz@usace.army.mil

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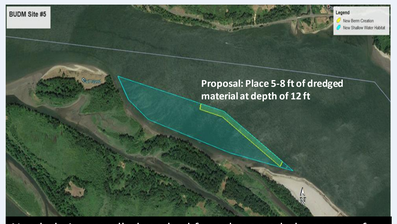
1. Motivation

Using dredged material to restore habitat within the Lower Columbia River Estuary requires precise in-water placement that does not adversely affecting the environment

Each year 70% of the 6 million cubic yards of sand dredged from the 100-mile long LCR navigation channel is placed at in-water sites within the river. This poster addresses the opportunity to improve dredged material placement within the Lower Columbia River estuary (LCRE), while sustaining the river-system & restoring emergent and shallow water habitat within the LCRE.

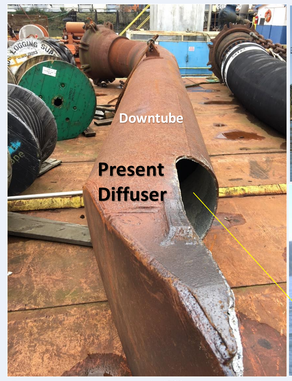
During 2018-2021, Portland District (USACE) and the Port of Portland (PoP) collaborated to design & construct a new type of submerged diffuser to allow the Port of Portland's 30-inch cutter-head dredge (*Oregon*) to discharge dredged sediment at LCRE in-water placement sites in a more controlled and environmentally acceptable manner. Prior to 2021, the cutter-head dredge *Oregon* utilized a simple discharge "diffuser" for submerged placement of dredged material at in-water placement sites. This was a crude instrument for trying to control the release of 40,000 gallons/minute (89 cfs) of dredged sand slurry. There was no energy dissipation, resulting in significant disturbance for the river bottom and highly uncertain disposition of placed dredged sediment. USACE and PoP needed a better "tool" for placing dredged material: To enable targeted "building" of in-river habitat restoration features or feeding the river's sediment budget while minimizing or avoiding adverse effect.

The poster presents the operational requirements for the new submerged diffuser leading to its design & fabrication, which included application of a computational fluid dynamics (CFD) model to refine the diffuser design. The poster summarizes results from the first operational use of the new submerged diffuser and presents lessons-learned from the new diffuser's first deployment.



Needed: A controlled method for submerged placement of dredged LCR dredged material that does not create turbidity

Submerged placement of dredged material to create the foundation for emergent habitat; while minimizing turbidity effects

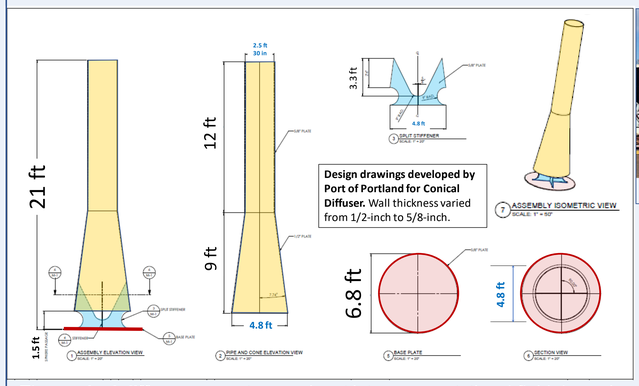


Present submerged diffuser used by the dredge *Oregon* for In-water placement
It's a 70-deg free-jet deflector with no energy dissipation.
Plume exist velocity = 16-20 ft/sec.....it's a blunt instrument

We need a better "tool" for submerged placement of dredged material within the Columbia River: One that manages energy dissipation, minimizes turbidity, enables shallow water placement (<20 ft deep), and allows controlled deposition of placed dredged material....An improved diffuser for building restoration features and feeding the river's sediment budget w/o adverse effect.

2. Design

Initial diffuser design focused on a "stepped" concept. After PoP re-consulted with fabricator, it was determined that a simpler conical diffuser would be easier/less cost to produce.



Diffuser in final stage of fabrication, MAR 2021

The **conical diffuser** geometry was input into a computational fluid dynamics (CFD) model. CFD iterations (two-phase flow) were performed by Portland District to verify that the conical diffuser would meet performance metrics.

Nominal Dredge Aspects
Pipe diameter leading to diffuser = 30 in
Pipe fluid velocity = 16-20 f/s.
Maximum line pressure to diffuser = 120 psi
Typical dredge pumping rate of 40,000 gpm (89 cfs)
Solids content = 30% (by mass).
Slurry specific gravity = 1.23.
Expected dredging production = 25 Kcy/day

Expected Diffuser Operation
Diffuser located at 20 ft below water.
Base plate elevated 6 ft above the riverbed.
Slick clearance = 18 inches (debris passage)
Slurry encounter velocity with riverbed = 5 ft/s (max).

CFD results verified that forces acting on the base-plate can be supported by optimized 4-fin stiffener (RIGHT FIGS). Exit velocity of the dredged material plume at edge of base-plate was 8 ft/sec. At 6 ft below base-plate, the riverbed encounter velocity = 4.8 ft/sec (BELOW FIGS). Plume diameter at riverbed encounter zone = 20-30 ft. Energy dissipation within conical diffuser is superior to the stepped diffuser.

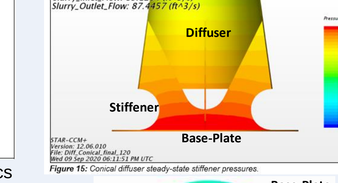


Figure 15: Conical diffuser steady-state stiffener pressures.

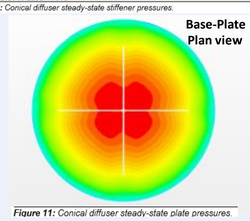


Figure 11: Conical diffuser steady-state plate pressures.

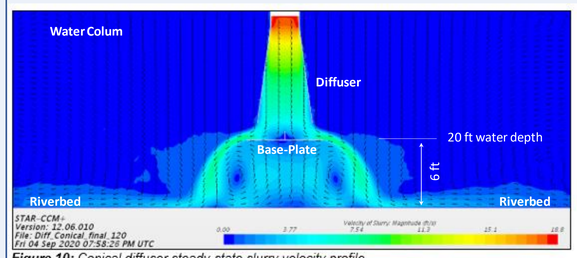


Figure 10: Conical diffuser steady-state slurry velocity profile.

CFD results indicated that energy dissipation of the plume occurs as it leaves the base plate and before it impacts the riverbed. Significant re-circulation of the dredged material plume occurs underneath the base-plate (below figs). Most of the plume's sand deposition of sand occurs within 30 ft of the diffuser.

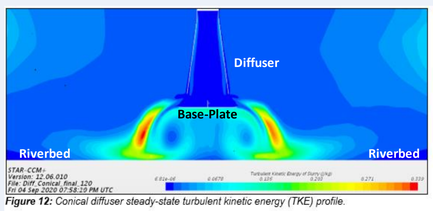


Figure 12: Conical diffuser steady-state turbulent kinetic energy (TKE) profile.

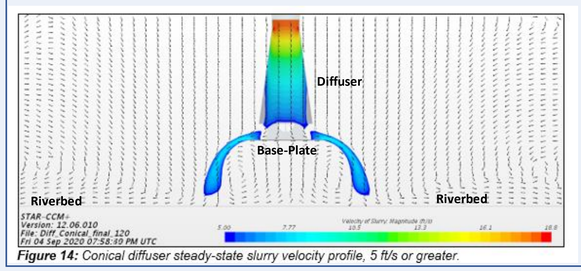


Figure 14: Conical diffuser steady-state slurry velocity profile, 5 ft/s or greater.

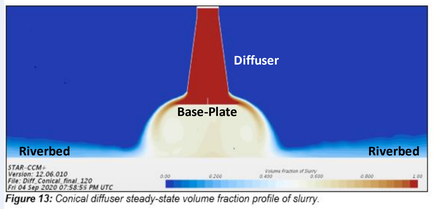
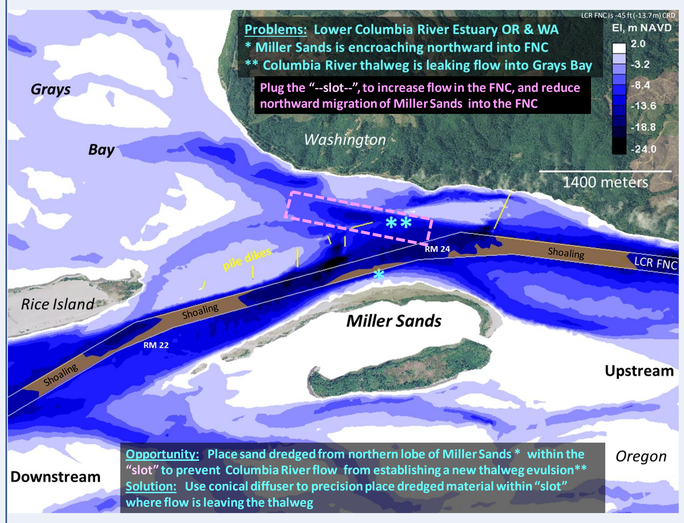


Figure 13: Conical diffuser steady-state volume fraction profile of slurry.

3. Implementation

First use of the conical submerged diffuser, was within the lower estuary (RM 24) during Aug-Oct 2021 where sand was dredged from a large cut-line shoal encroaching the LCR FNC.

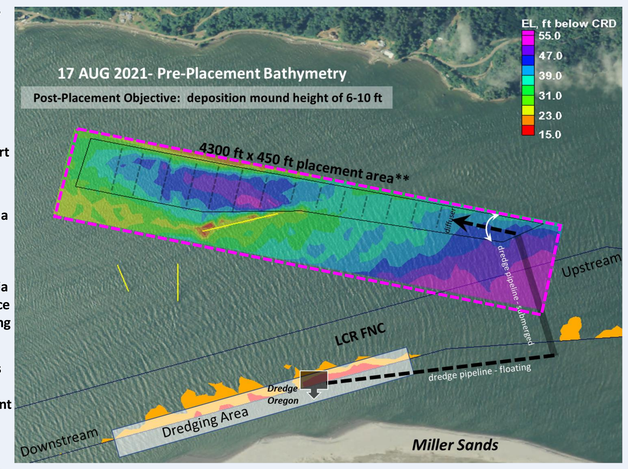
The conical diffuser was used to place 400 Kcy of dredged sand within a tidal channel evulsion to re-direct river flow from the evulsion & back toward the river's thalweg: Stabilize the river thalweg and reduce FNC shoaling.

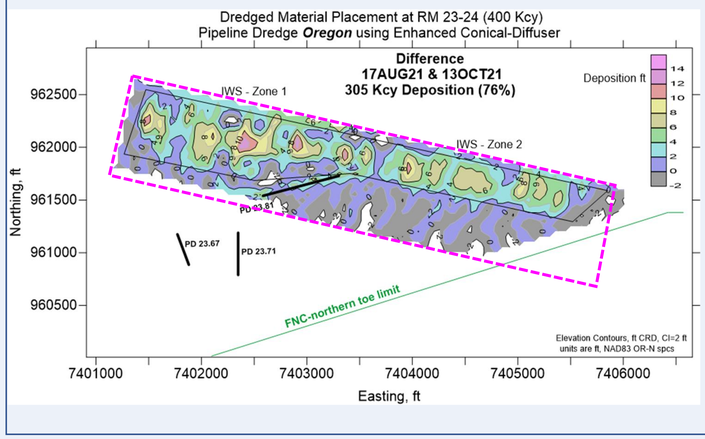


During Aug to Oct 2021, 550 Kcy of advance maintenance dredging was performed by the Port of Portland cutterhead dredge Oregon along Miller Sands to remove a northward migrating part of the shoal*.

400 Kcy of sand was precision-placed within a 4300 ft x 450 ft area** using a submerged diffuser: To maintain flow within the Columbia River thalweg and reduce future FNC shoaling along Miller Sands.

The conical diffuser was used to control the lateral and vertical extent of dredged sand placed within the site**. The diffuser barge moved across the site at 80-150 ft/hr to achieve a target deposition of 8-12 ft within the site.

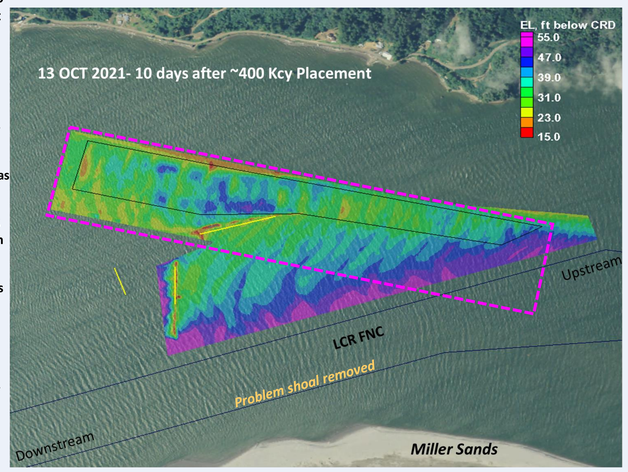




Left graphic shows deposition within the site** 10 days after placement. The black-line indicates zone of controlled placement. 76% of the material was retained within the placement-zone, with most of the other 34% being contained within the site**.

Right bottom graphic is riverbed after placement. Compare top right and bottom right figures. Note the infill within the "slot", meeting the objective.

7 months later (APR 21), 70% of placed material remained within the "slot".



4. Operational Summary

post-placement OCT 21

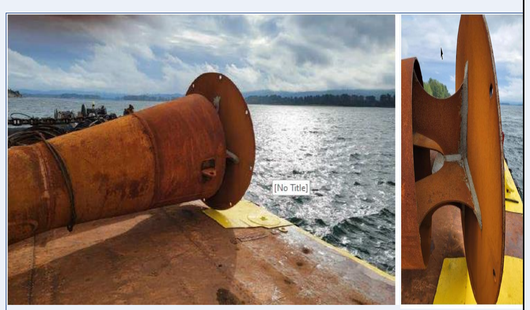
* New conical diffuser was successful for first use during the 2021 LCR dredging season without adverse effects on dredging operations, and within an energetic area of estuary.

* Diffuser was located at 20 ft below river surface, with placement in total water depth of 35-55 ft depth. Tide range was 8 ft, and currents were 1-4 ft/sec.

* Discharge pipe sections of 120-240 ft were added/removed as diffuser barged moved through placement site at 80-150 ft/hr.

* Diffuser passed 400,000 cy of dredged sand without clogging and without wear. Diffuser maintenance will be minimal.

* No turbidity was observed at or near the point of diffuser discharge.



Close-up view of diffuser plate and stiffener vanes, post-placement OCT 21