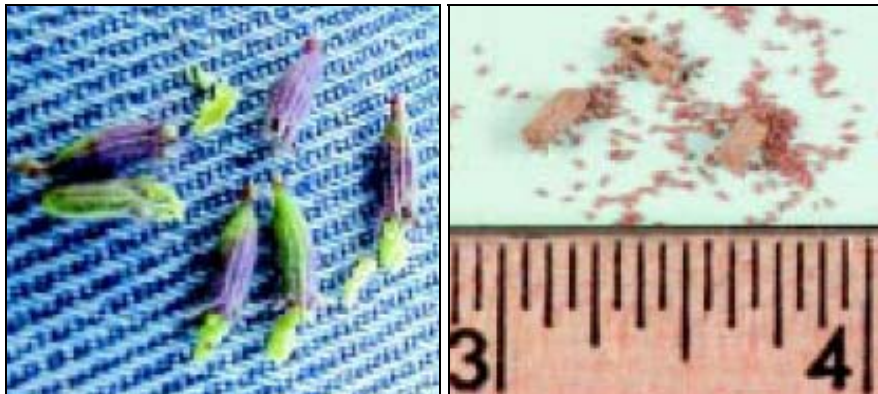


CAPITOL LAKE ALTERNATIVES ANALYSIS DREDGING AND DISPOSAL

Prepared for:



Purple loosestrife capsules (left) and seeds next to dried capsules (right)

Prepared by:



August 22, 2008

Executive Summary

Washington State Department of General Administration and the CLAMP Steering Committee are developing and understanding of the different future management alternatives for Capitol Lake. In particular, a goal of the CLAMP Steering Committee is to complete a study that evaluates the possibility of a restored estuary as an alternative to the continued management actions necessary to maintain a lake in this setting.

As one piece of this study, this report describes the costs, methods, and schedules associated with the dredging elements of the different possible future management alternatives: continued management of the lake as a lake, and restoration of the Deschutes Estuary with or without a separate reflecting pool.

The disposal sites have the most significant impacts to the project cost. Disposal sites also affect construction methods: mechanical dredging is generally most cost-effective for upland disposal or beneficial reuse, while hydraulic dredging is generally most cost-effective for offshore disposal. The most cost-effective option for material transported off-site – open-water disposal at Anderson-Ketron Island – is available only for clean material, and may not be available for the Capitol Lake sediments because of the presence of purple loosestrife seeds. The most expensive option – upland disposal at a landfill site – is certain to be available for all but the most contaminated sediments, which are not believed to be present in Capitol Lake or in Budd Inlet. Intermediate options include open-water disposal at Commencement Bay, which is more distant than Anderson-Ketron Island but which may accept materials containing purple loosestrife seeds; mine reclamation at the Lakeside Industries Central Aggregate Pit near Centralia; and (for a subset of the material) construction fill. It is likely but not certain that one of these intermediate options will be available. Chemical, biological, and physical testing (including the drainage characteristics of the sediment) will be needed to establish the available disposal sites and costs.

Dredging costs are evaluated based on the most likely dredging quantities, and with the range of possible unit costs considered. Future costs are evaluated based on a 50-year project lifetime: costs with and without escalation of construction costs, at 3.5% annually, are given. In addition, future costs are given as a net present value (NPV), using the current (2008) USACE interest rate of 4.875 percent. The NPV takes into account the time value of money. The actual dollar values can vary dramatically over a 50-year project lifetime if construction cost inflation differs from the assumed 3.5 percent.

A typical three-point construction estimate gives a low, medium, and high cost. Because the costs associated with disposal at a landfill are so much higher than other costs, this report additionally includes a worst-case cost.

For the Lake Alternative, the following cases are considered:

- Low-cost: Initial dredging with disposal at the reclamation site; Maintenance dredging with a combination of beneficial reuse as construction fill, disposal at a reclamation site, and (after 2025, when purple loosestrife is assumed to be eradicated) disposal offshore at the Anderson-Ketron Island open water disposal site.
- Medium-cost: Initial dredging with disposal offshore at Commencement Bay; Maintenance dredging with a combination of beneficial reuse as construction fill and disposal at Commencement Bay.
- High-cost: Disposal alternatives as for the medium-cost case, but costs are 30 percent higher.
- Worst-case: All disposal is to landfill.

These assumptions give the following initial and maintenance dredging costs for the Lake Alternative.

Table ES-1. Initial and Maintenance Dredging Costs for the Lake Alternative

Element	Low-Cost (\$millions)	Medium-Cost (\$millions)	High-Cost (\$millions)	Worst-Case (\$millions)
2008 Dollars (no escalation)				
Initial Dredging	\$64.8	\$79.6	\$103.5	\$120.8
Maintenance	\$101.3	\$131.1	\$170.4	\$240.2
Total Cost	\$166.1	\$210.7	\$273.9	\$361.0
Escalation at 3.5% annually with a 2015 start date				
Initial Dredging	\$82.4	\$101.3	\$131.7	\$153.6
Maintenance	\$358.6	\$467.2	\$607.3	\$863.2
Total Cost	\$441.0	\$568.5	\$739.0	\$1,016.8
Net Present Value in 2008 with interest rate 4.875%				
Initial Dredging	\$59.0	\$72.6	\$94.4	\$110.1
Maintenance	\$65.9	\$84.9	\$110.3	\$155.9
NPV of Total Cost	\$124.9	\$157.5	\$204.7	\$266.0

Two separate Estuary Restoration Alternatives have been defined. The Dual Basin alternative divides the North Basin of Capitol Lake along a north-south line, into a reflecting pool to the east and a free flowing estuary to the west. The Single Basin alternative does not provide a reflecting pool – the entire area of Capitol Lake is restored to a free flowing estuary. Costs associated with dredging for the two Estuary Restoration alternatives are similar. In the long-term, Budd Inlet must undergo more sedimentation under the Dual Basin alternative, because the available sediment storage in the eastern part of the North Basin of Capitol Lake is lost. However, the modeling work carried out by USGS suggests that this will be observed over a scale of decades or more: the difference between the sedimentation rates for the two alternatives is much smaller than the uncertainty in the sedimentation rates.

As with the Lake Alternative, four cost cases are considered for the Estuary Restoration Alternatives. The worst-case example does not include disposal at a landfill for all materials dredged in the 50-year project life, since it can be assumed that Budd Inlet – which currently contains some contamination in the form of dioxins and furans – will eventually be cleaned up. It is strongly recommended that any necessary cleanup actions occur before the estuary restoration is completed. The four cases are as follows:

- Low-cost: Initial estuary dredging and placement along Deschutes Parkway, with costs at 85 percent of the most likely estimated cost; subsequent dredging at the marinas in Budd Inlet and the Port Olympia facilities with disposal at Anderson-Ketron Island, with dredge efficiency increasing after the first cycle.
- Medium-cost: Initial estuary dredging and placement along Deschutes Parkway, with costs at the most likely estimated cost; subsequent dredging at the marinas in Budd Inlet and the Port Olympia facilities with disposal at Anderson-Ketron Island, except that 5 percent of the material is disposed of at a landfill in the first maintenance dredging cycle.
- High-cost: Initial estuary dredging and placement requires 5 percent of the material to be disposed of at a landfill, with the remainder placed along Deschutes Parkway at a cost 30

percent higher than the most likely estimated cost; subsequent dredging costs are 30 percent higher than the medium-cost case.

- Worst-case: Initial estuary dredging and placement requires 20 percent of the material to be disposed of at a landfill, with the remainder placed along Deschutes Parkway at a cost 30 percent higher than the most likely estimated cost. In the first two dredging cycles at the marinas and the Port all of the material must be transported to a landfill; in the third dredging cycle (9 years after estuary restoration) one-half of the material must be transported to a landfill; subsequent dredging costs are the same as the high-cost case.

These assumptions give the following initial and maintenance dredging costs for the Estuary Restoration Alternatives. These costs do not include effects on the marina and port operations. As with the Lake Alternative, the costs assume the most likely sedimentation rate for maintenance dredging – the cost variation results from the unit costs, not from quantities.

Table ES-2. Initial and Maintenance Dredging Costs for the Estuary Alternatives

Element	Low-Cost (\$millions)	Medium-Cost (\$millions)	High-Cost (\$millions)	Worst-Case (\$millions)
2008 Dollars (no escalation)				
Initial Dredging	\$10.2	\$12.0	\$15.0	\$26.8
Maintenance	\$47.6	\$55.9	\$72.6	\$112.0
Total Cost	\$57.8	\$67.9	\$87.6	\$138.8
Escalation at 3.5% annually with a 2015 start date				
Initial Dredging	\$13.0	\$15.3	\$19.1	\$34.1
Maintenance	\$144.9	\$170.3	\$221.4	\$282.4
Total Cost	\$157.9	\$185.6	\$240.5	\$316.5
Net Present Value in 2008 with interest rate 4.875%				
Initial Dredging	\$9.3	\$11.0	\$13.7	\$24.5
Maintenance	\$33.1	\$38.9	\$50.5	\$84.0
NPV of Total Cost	\$42.4	\$49.9	\$64.2	\$108.5

Contents

1.	Introduction	1
1.1	Background	1
1.2	Existing Conditions and Future Alternatives.....	1
2.	Dredge Material Characteristics	5
2.1	Physical and Chemical Characteristics	5
2.2	Biological Characteristics.....	6
3.	Offsite Disposal Options	9
3.1	Introduction.....	9
3.2	Open-Water Disposal	9
3.3	Landfill.....	12
3.4	Beneficial Reuse.....	13
3.5	Summary.....	14
4.	Dredging and Associated Technologies	17
4.1	Mechanical Dredges	17
4.2	Portable Hydraulic Dredges	18
4.3	Equipment Launch.....	20
4.4	Dewatering	22
4.5	Geotubes.....	23
4.6	Selection of Dredging Method.....	24
5.	Lake Dredging.....	25
5.1	Overview of Dredging Needs.....	25
5.2	Permitting and Regulatory Process.....	27
5.3	Initial Dredging Methods and Costs	29
5.4	Maintenance Dredging Methods and Costs	35
5.5	Cost Summary and Timeline.....	38
6.	Estuary Dredging: Single Basin	41
6.1	Overview of Dredging Needs.....	41
6.2	Dredge Material Disposal.....	44
6.3	Estuary Dredging Methods and Costs	45
6.4	Permitting and Regulatory Process.....	49
6.5	Cost Summary.....	50
7.	Estuary Dredging: Dual Basin.....	51
8.	Marina and Port Dredging	53
8.1	Background	53
8.2	Anticipated Dredging Needs	53
8.3	Dredge Material Characteristics.....	55
8.4	Dredge Material Disposal.....	56
8.5	Permitting and Regulatory Process.....	56
8.6	Cleanup of Budd Inlet	56
8.7	Construction and Material Handling	57
8.8	Cost Summary and Timeline.....	61
9.	References.....	63

Figures

Figure 1. Existing Conditions	2
Figure 2. Budd Inlet and Capitol Lake	3
Figure 3. Purple loosestrife (Source: flickr.com)	6
Figure 4. Purple loosestrife capsules (left) and seed next to dried capsules (right) (Source: Knezevic 2003)	7
Figure 5. Puget Sound open-water disposal sites (Source: DMMO 2008a)	10
Figure 6. Open-water disposal sites closest to Capitol Lake: Anderson-Ketron Island (left) and Commencement Bay (right).....	10
Figure 7. Nearest upland disposal sites.....	12
Figure 8. Typical derrick crane dredge with clamshell bucket (left); close-up of bucket (right) ...	17
Figure 9. Typical excavator dredge	18
Figure 10. Excavator dredge on track-mounted barge.....	18
Figure 11. Cutter head dredge (left), close-up of cutter head (right).....	19
Figure 12. Typical bucket wheel dredge.....	19
Figure 13. BNSF Railroad Trestle.....	20
Figure 14. Modular barge system in use (source: www.flexifloat.com)	21
Figure 15. Layout of modular barge system (source: www.flexifloat.com)	21
Figure 16. Potential launch sites for lake-bound equipment.....	22
Figure 17. Geotubes used in dewatering (source: Tencate)	23
Figure 18. Existing lake bathymetry, proposed dredge footprint (full yellow line), and outline of potential sediment traps (broken red line)	26
Figure 19. Published fish windows for Olympia.....	29
Figure 20. Possible rehandling layout at Marathon Park.....	31
Figure 21. Possible material transfer layout at the 4th / 5th Avenue Bridges.....	34
Figure 22. Proposed dredged bathymetry with dredge footprint (yellow line) and fill footprint (red line).....	42
Figure 23. Estuary and dredging sections	43
Figure 24. Predicted changes in the bottom elevation of the Deschutes Estuary in the first 10 years, assuming no pre-dredging.....	45
Figure 25. Diking options for the estuary placement	47
Figure 26. Anticipated erosion and deposition three years after estuary restoration: single basin (Source: USGS 2008a).	55

Tables

Table 1. Dredge areas and volumes for the lake dredging.....	25
Table 2. Daily Operations Cost – Mechanical Lake Dredging	32
Table 3. Cost of Mechanical Dredging to Landfill.....	32
Table 4. Cost of Mechanical Dredging to Reclamation Site.....	33
Table 5. Daily Operations Cost – Hydraulic Dredging	35
Table 6. Cost of Hydraulic Dredging to Commencement Bay	35
Table 7. Daily Operations Cost – Dredging Sediment Traps.....	37
Table 8. Cost of Dredging Sediment Traps.....	37
Table 9. Daily Operations Cost – Hydraulic Dredging to Anderson- Ketron Island.....	38
Table 10. Cost of Hydraulic Dredging to Anderson-Ketron Island	38
Table 11. Cost timelines for the Lake Alternative: 2008 costs, no escalation	40

Table 12. Cost timelines for the Lake Alternative: escalation at 3.5 percent annually, interest rate at 4.875 percent annually.....	40
Table 13. Dredge and Fill Quantities for Estuary Alternative	41
Table 14. Daily Operations Cost – Estuary Dredging	49
Table 15. Cost of Hydraulic Dredging for Estuary Alternative	49
Table 16. Daily Operations Costs for Marina Dredging.....	58
Table 17. Cost of Dredging at 3-Years for Marinas	59
Table 18. Daily Operations Costs for Port Dredging	60
Table 19. Cost of Dredging at 3-Years for Port Berth.....	60
Table 20. Cost timelines for the Estuary Alternative with marina and port dredging: 2008 costs, no escalation.....	62
Table 21. Cost timelines for the Estuary Alternative with marina and port dredging: escalation at 3.5 percent annually, interest rate at 4.875 percent annually	62

1. Introduction

1.1 Background

Capitol Lake was created in 1951 through the construction of the Capitol Dam, which disconnected the Deschutes River from Budd Inlet. The construction of the dam in 1951 fulfilled the 1911 vision of architects White and Wilder by providing a reflecting pool for the State Capitol Building.

Capitol Lake is increasingly unsustainable in its current configuration. Sediment from the Deschutes River and Percival Creek is filling in the lake, such that the flood storage is inadequate; environmental concerns mean that ongoing dredging of the lake is increasingly difficult and expensive. The lake is on the state list of impaired waterbodies for fecal coliform bacteria and total phosphorus. The noxious weeds purple loosestrife and eurasian milfoil are invading the lake. The need for a new lake management plan surfaced in 1996, when the State was attempting to gain permits for the construction of Heritage Park on the eastern shore of the North Basin and maintenance dredging the Middle Basin and Percival Cove.

The Capitol Lake Adaptive Management Plan (CLAMP) was developed in response to these concerns (CLAMP Steering Committee 1999). A key Management Objective in the 2002 CLAMP 10-Year Plan (CLAMP Steering Committee 2002) was to complete a study that would evaluate the possibility of a restored estuary as an alternative to the continued management actions necessary to maintain a lake in this setting.

1.2 Existing Conditions and Future Alternatives

The purpose of this report is to develop an understanding of the costs, methods, and schedules associated with the dredging elements of the different possible future management alternatives: continued management of the lake as a lake, and restoration of the Deschutes Estuary with or without a separate reflecting pool.

Figure 1 illustrates the existing condition of the lake, including the current bathymetry. The lake is divided into three main basins by the BNSF Railroad Trestle and the I-5 Bridge, as shown. Deschutes Parkway runs along the west side of the North and Middle Basins; Percival Cove is a freshwater wetland connected to the Middle Basin by a bridge under Deschutes Parkway.

Three future alternatives are considered in this report:

- Lake Dredging. This alternative would continue the lake in essentially its current configuration. An initial dredging project would remove nearly one million cubic yards of material from the lake basin; periodic future dredging within the lake would clear out several tens of thousands of annual sediment input from the Deschutes River.
- Estuary Dredging: Single Basin. This alternative would restore the Deschutes Estuary by removing the Capitol Dam. Among the actions included in the estuary restoration is a pre-dredge of the lake, to create the anticipated main estuary channel, and placement of the dredged materials to create intertidal habitat along the western shoreline, adjacent to Deschutes Parkway (Moffatt & Nichol 2007).
- Estuary Dredging: Dual Basin. This alternative would restore the Deschutes Estuary by removing the Capitol Dam. The difference between the Single Basin and Dual Basin alternatives is that a separate reflecting pool will be constructed in the eastern part of the North Basin.

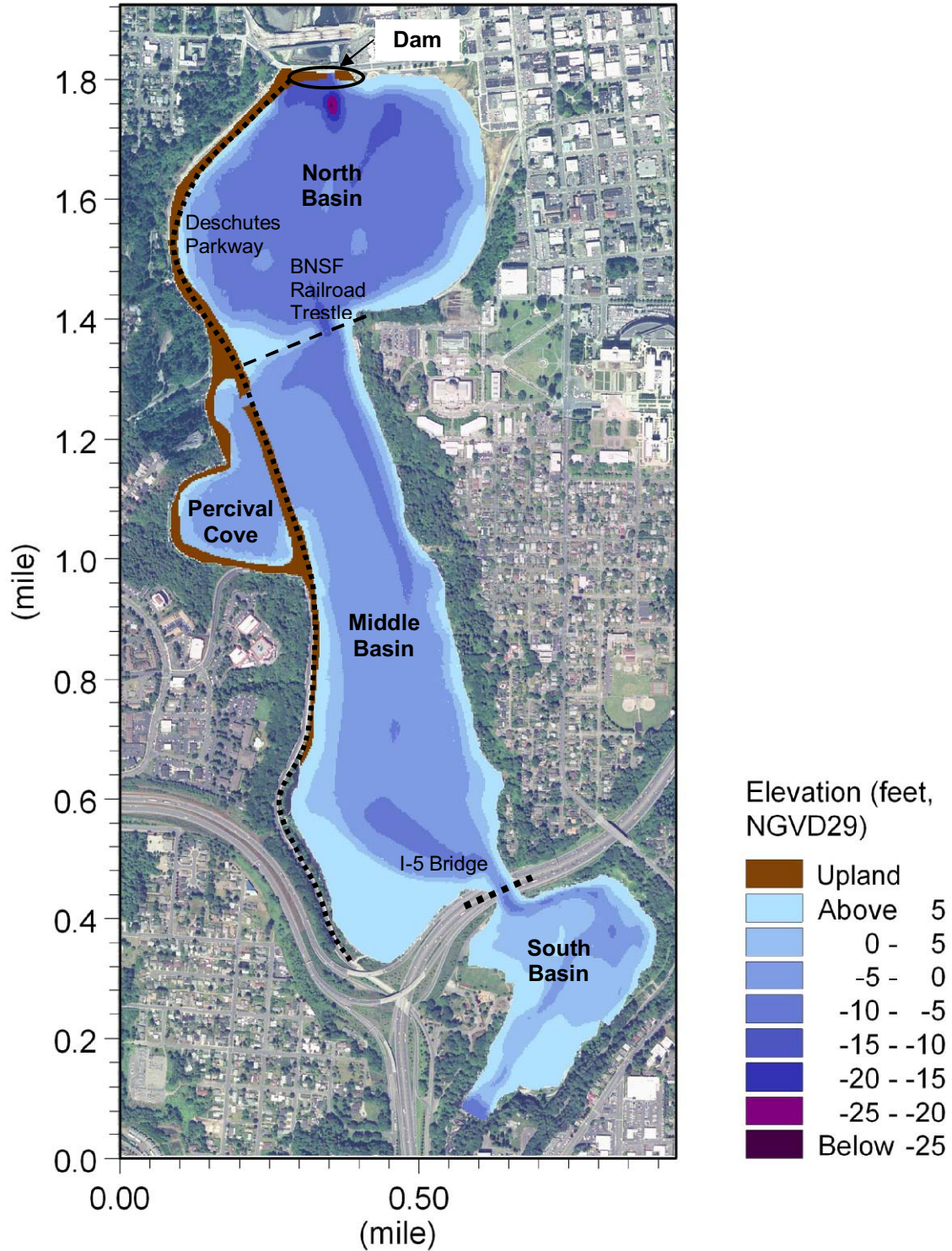


Figure 1. Existing Conditions

Under both estuary restoration alternatives, immediately after the Capitol Dam is removed, significant reworking of sediment in the existing lake basins will take place. The sediment will be transported downstream into Budd Inlet, where a significant portion will settle in the marina basins and the Port's deep draft berth in the West Bay of Budd Inlet (USGS 2006, 2008b).

Consequently, one further dredging project must be considered:

- Dredging in the West Bay Marinas and at the Port. This is considered as part of the long-term maintenance associated with the estuary restoration alternatives.

Figure 2 shows the affected marinas and port area, as well as historical industrial uses, in Budd Inlet.



Figure 2. Budd Inlet and Capitol Lake

2. Dredge Material Characteristics

2.1 Physical and Chemical Characteristics

2.1.1 Capitol Lake

Sediments in Capitol Lake are generally a loose mixture of sand and silt, with relatively little clay (CLAMP 1999; Herrera 2000a; USGS 2008b). Sediments from samples taken at the southwest part of the lake consist of a layer of organic material over dark gray silty sands; sediments from samples taken at the northeast part of the lake consist of less organic material over olive gray silty sands and gravels. Sediment cores of the lake bottom indicate that below 15 to 20 feet of the loose silty sand material is underlying dense glacially-derived sand and gravel (CLAMP 1999). This denser material would not be affected by any of the dredging proposals considered in this document.

Within the past decade, sampling by Herrera was conducted (Herrera 2000a&b) to evaluate general sediment quality with respect to reuse of in-water materials as near-shore fill. Marine Sediment Management Standards (SMS) criteria were used for this evaluation because the criteria for freshwater sediment have not been established at this time. The data generally indicate the following:

- Benzoic acid, benzyl alcohol and phenol are present in sediment samples at three stations at concentrations that could potentially affect aquatic organisms. Additional chemical analysis would likely be required prior to approval for use as in-water fill; however, the material may be suitable for use as upland fill.
- General sediment quality at the remaining stations appears to be potentially suitable for both in-water and upland fill. The analyses reported by Herrera (2000a&b) were not sufficiently sensitive to detect all of the relevant organic compounds at concentrations that would prohibit their reuse as near-shore fill, according to the marine SMS evaluation criteria.

A recent study conducted by the Washington State Department of Ecology looked at Budd Inlet sediments to determine the extent of dioxin and furan contamination (SAIC 2008). Surface sediments from Capitol Lake were also sampled as part of this study to determine the chemical makeup of sediments that could enter Budd Inlet under the Estuary Alternative. More samples were obtained from Budd Inlet than from Capitol Lake. However, overall, Capitol Lake sediment samples had lower dioxin/furan toxicity equivalents (TEQs) (2.0 pg/g to 3.9 pg/g) than did Budd Inlet (2.9 to 60.3 pg/g TEQ, with an average of 19.1 pg/g TEQ). A picogram per gram (pg/g) is the equivalent of one part per trillion.

The 2008 SAIC report concluded that there are no direct sources of dioxins and/or furans currently located in Capitol Lake. The observed low levels of dioxins and furans in the lake may be the remnants of periodic flushing of the lake with marine waters (performed periodically since construction of the Capitol Dam in 1951) which may have introduced the dioxins to the lake sediments. They may also be the remnants from other historical industrial activities in the lake or upstream the Deschutes River.

It appears that the sediment quality in Capitol Lake is mixed but that, in terms of its chemical characteristics, most is adequate for open water and upland disposal as fill. The majority of the sediment is too fine to be suitable for structural fill. Detailed information regarding the dewatering characteristics of the sediment is not available.

2.1.2 Budd Inlet

Ecology recently conducted investigations in Budd Inlet to determine the extent and possible sources of dioxin contamination of sediments (SAIC 2008). The investigation began in the area scheduled for maintenance dredging by the Port of Olympia. Dioxins were found throughout Budd Inlet and the highest levels were observed in sediments near stormwater discharge pipes (e.g., near the outfall adjacent to the One Tree and Fiddlehead Marinas) and the Port of Olympia's shipping berths (Figure 2). Most likely, dioxin contamination has resulted from stormwater runoff, historical industrial use of shore areas (e.g., Cascade Pole) and fallout from smoke stacks.

Dioxin/furan concentrations for the Budd Inlet surface sediment samples ranged from 2.9 to 60.3 pg/g (TEQ), with a mean of 19.1 pg/g TEQ (SAIC 2008). Samples from the north end of Budd Inlet had the lowest levels and West Bay had levels closer to 19.0 pg/g TEQ (SAIC 2008). The highest concentrations in the West Bay were in the vicinity of the Hardel Mutual Plywood and Reliable Steel sites.

Some analysis was also completed for metals, semi-volatile organic compounds, and polychlorinated biphenyls (PCBs) (SAIC 2008). The most common contaminants identified, which exceeded Sediment Management Standards (SMS) were the phenols and hexachlorobenzene and were in the vicinity of the Hardel Mutual Plywood and Reliable Steel sites.

2.2 Biological Characteristics

A number of noxious weeds have been observed in or around Capitol Lake: Purple Loosestrife, Yellow Flag Iris, and Eurasian Milfoil. Without appropriate control and management, they can create monoculture conditions which can be destructive to habitat, fish and wildlife.

Purple loosestrife (*Lythrum salicaria*) is a non-native invasive weed introduced to North America in the 1800s as an ornamental and garden plant. Currently it is designated as a Class B Noxious Weed in Washington, which means that it is designated for control of existing stands and prevention of new infestations. It is under quarantine in Washington per the Washington Administrative Code (WAC) 16-752-400-415, and requires a Washington State Department of Agriculture (WSDA) permit to transport any sediment within Washington that may contain purple loosestrife seeds. This is relevant to the open water disposal of sediments as well as WSDA often comments on these types of issues to the DMMO.

Purple loosestrife is an emergent aquatic perennial and has a prolific root system. Each plant can grow up to 9 feet tall and produce up to 2 million seeds. The plant blooms pink to purple (Figure 3) from July to October.

Purple loosestrife is an especially hardy and tenacious plant. When it invades a wetland or shoreline, it can choke out native plants. It also has the potential to spread to other areas if not contained or controlled, and this is a major consideration for dredging in Capitol Lake.



Figure 3. Purple loosestrife
(Source: flickr.com)

The fruit of the plant is a small oblong capsule (Figure 4); each capsule contains up to 100 small seeds (Knezevic 2003). The tiny brown seeds are 0.4×0.2 mm in dimension (approximately equivalent to silty sand) and 0.5 to 0.6 mg in weight (USGS 2008c). The seeds of purple loosestrife can be easily moved by wind, water, animals, and birds; can germinate on bare soil with germination rates upwards of 95% (Knezevic 2003); are tolerant of marine shoreline conditions; and can lay dormant for up to 20 years.

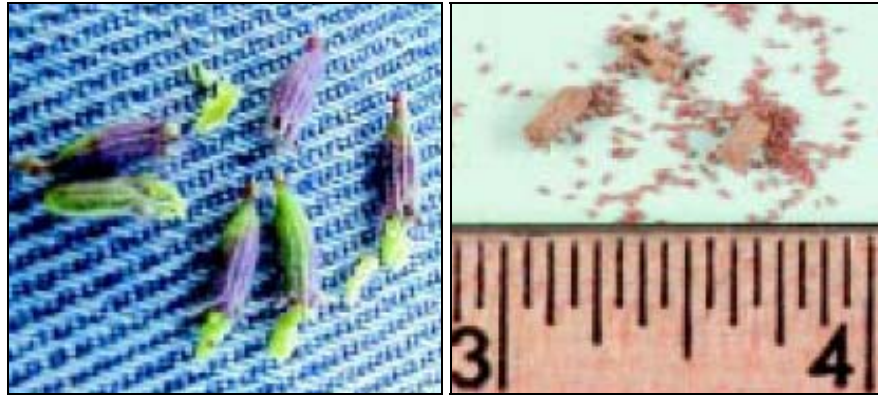


Figure 4. Purple loosestrife capsules (left) and seed next to dried capsules (right)
(Source: Knezevic 2003)

Purple loosestrife was first found in Capitol Lake in 1986 (General Administration 2002). Since this time, a lake-wide eradication program has been underway and the number of plants along the shorelines has been steadily declining. In 2000, an 80% reduction in purple loosestrife was observed (General Administration 2002). Today, fewer purple loosestrife plants can be found around Capitol Lake but they have not yet all been eradicated.

Very little purple loosestrife has been observed in Budd Inlet (Thurston County Noxious Weed Control Board [TCNWCB] 2008). A small patch is located on Port of Olympia property close to the East Bay and south of Swantown Marina (see Figure 2 for the location). No purple loosestrife is located along the shoreline of Budd Inlet's West Bay, where the Deschutes River historically discharged into Puget Sound.

3. Offsite Disposal Options

3.1 Introduction

The disposal sites and dredging methods have the most significant impacts to the project cost. One of the most cost-effective disposal options – open-water disposal – is available only for clean material, and (as described below) may not be available for the Capitol Lake sediments because of the purple loosestrife seeds. The most expensive option – upland disposal at a landfill site – is certain to be available for all but the most contaminated sediments, which are not believed to be present in Capitol Lake or in Budd Inlet. Further options include a range of potential beneficial reuse projects. At present, one such possibility – mine reclamation at the Lakeside Industries Central Aggregate Pit near Centralia – has been identified. This possibility may not be available at the time it is needed; others may become available.

In addition to the offsite disposal options described in this section, there is an onsite disposal option – placement of material dredged from one area in Capitol Lake to another area – that is available for material pre-dredged from Capitol Lake under the Estuary Restoration alternatives (Sections 6 and 7). Onsite disposal is described in Section 6.3.

3.2 Open-Water Disposal

3.2.1 Available Open-Water Disposal Sites

The Dredge Material Management Program (DMMP) is a multi-agency organization that manages dredged material in Washington and was designed to make decisions on what is considered clean and contaminated sediment in Puget Sound. The DMMP Committee includes representatives from the U.S. Army Corps of Engineers (USACE) – Seattle District (acts as lead agency), the Environmental Protection Agency (EPA) – Region 10, the Washington Department of Ecology (Ecology); and the Washington Department of Natural Resources (DNR) and includes dredged material management programs such as the Puget Sound Dredged Disposal Analysis (PSDDA) program.

Dredged material in Puget Sound that meets DMMP guidelines (material is tested using chemical, bioassay, and bioaccumulation testing methods) can be permitted for open water disposal at one of eight different sites (Figure 5). There are five non-dispersive sites (low currents, disposal material remains on site) and three dispersive sites (high currents, quick dispersal of disposal material from site).

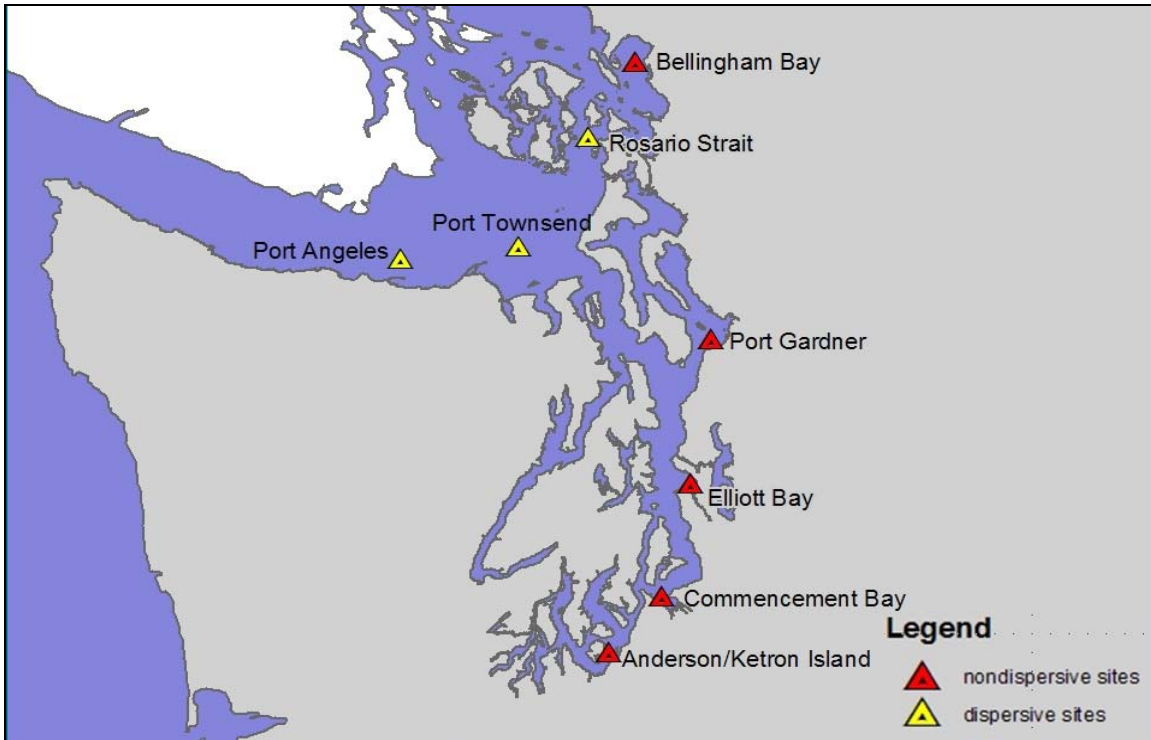


Figure 5. Puget Sound open-water disposal sites (Source: DMMO 2008a)

The two open-water disposal sites closest to Capitol Lake are Anderson-Ketron Island and Commencement Bay. The round-trip distance to the Anderson-Ketron Island disposal site is approximately 47 miles (41 nautical miles), while the round-trip distance to the Commencement Bay disposal site is 86 miles (75 nautical miles). The disposal fee at both disposal sites is \$0.45 per cubic yard.

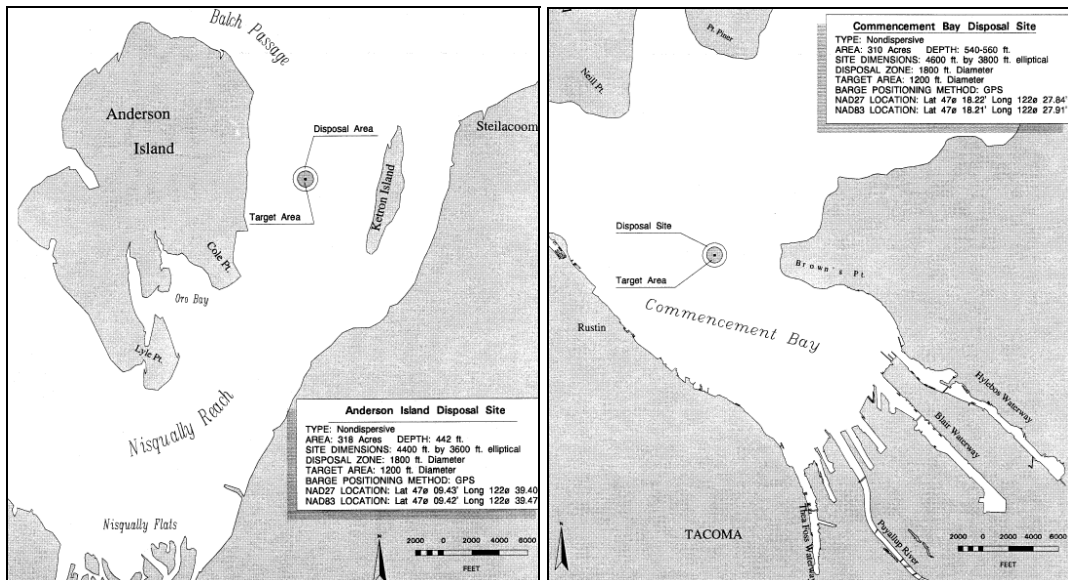


Figure 6. Open-water disposal sites closest to Capitol Lake: Anderson-Ketron Island (left) and Commencement Bay (right)

3.2.2 Current Availability for Materials Dredged from Capitol Lake

As described in Section 2.1, the material in Capitol Lake is assumed generally clean and suitable for open-water disposal, except for the presence of purple loosestrife seeds. The presence of these seeds (purple loosestrife is a Class B noxious weed in the State of Washington) has significant implications for open-water disposal, because the seeds float and because it is not known how rapidly they will be degraded in the presence of salt water.

Moffatt & Nichol representatives met with the DMMP Committee on June 5, 2008 to discuss the possibility of open-water disposal of materials dredged from Capitol Lake. The DMMP Committee stated that the closer Anderson-Ketron Island site would not be a suitable site for unconfined disposal due to its proximity to the Nisqually River delta and the very high-value wetland habitat at the Nisqually National Wildlife Refuge. The potential for purple loosestrife seeds to disperse to this wildlife refuge is too great and the U.S. Army Corps of Engineers (USACE) would not grant a permit for disposal in this area. For similar reasons, the Thurston County Noxious Weed Control Agency has indicated that unconfined beneficial reuse of the sediment in Budd Inlet – for example, in beach nourishment – would not be acceptable.

The possibility of placing the material at the Anderson-Ketron Island site encapsulated in geotubes was discussed. The DMMP Committee ruled this concept out because the USACE is required to carry out physical monitoring – that is, coring – at the site. The geotubes would either interfere with this monitoring, or they would be breached in the course of the monitoring and the purple loosestrife seeds would be released into the environment.

The DMMP Committee indicated that unconfined open water disposal at Commencement Bay may be acceptable: Commencement Bay is located in a more urbanized shoreline environment, so noxious weed control may be a lesser (although still very present) concern. Initial discussions with the Pierce County Noxious Weed Coordinator have indicated that there would be hurdles to overcome; the County would prefer not to receive any sediment that may contain purple loosestrife seeds. The Washington State Department of Agriculture would be in a position to block this proposal by refusing to grant a permit to transport the material. However, given the DMMP Committee is prepared to contemplate open-water disposal in this area, and neither Pierce County nor WSDA has ruled out the site, this should be considered a potential disposal site.

3.2.3 Future Availability for Materials Dredged from Capitol Lake

It can be anticipated that at some point in the future, the purple loosestrife and other noxious weeds in the lake will be eliminated or controlled to a level such that the seeds cease to be a concern. Consequently, it may be possible for materials dredged from Capitol Lake in the future to be disposed of at Anderson-Ketron Island.

3.2.4 Availability for Materials Dredged from the Marinas and Port

Material that may be dredged from the West Bay marinas and the Port of Olympia is not believed to contain purple loosestrife seeds; however, it may contain chemical contaminants (particularly dioxins and furans) beyond that permitted for open-water disposal. Currently, dioxins and furans in sediments have been assessed on a case-by-case basis. Dioxin levels in the sediments to be disposed of are compared to dioxin levels of sediments located in or near the disposal sites. Currently, average dioxin levels cannot exceed approximately 2.1 TEQ for the Commencement Bay disposal site or 3.6 TEQ for the Anderson-Ketron Island disposal site (DMMO 2008b).

Dioxin and furan contaminants results largely from past industrial uses. Therefore, in the near-term it is likely that a fraction of the material will not be suitable for open-water disposal at Anderson-Ketron Island. Assuming the material becomes cleaner over time as the contaminants are removed, a greater fraction should be suitable for open-water disposal in the future.

3.3 Landfill

Upland disposal at a permitted landfill facility is generally available for disposal of sediments. However, this is a relatively costly alternative.

The two landfill sites that have been identified are Rabanco's Roosevelt Regional Landfill in Klickitat County, Washington, and Waste Management's Columbia Ridge Landfill & Recycling Center near Arlington, Oregon (Figure 7). Both facilities have road (truck) and rail access. They also, indirectly, have barge access via the Columbia River: however, there would be an additional cost to haul the material from the barge dock to the land fill and this is not considered cost-effective. Recent estimates from these sites are approximately \$72 per cubic yard (\$45 per ton) for rail transport and disposal fees for Roosevelt landfill and approximately \$80 per cubic yard (\$50 per ton) for rail transport and disposal fees for Columbia Ridge landfill.



Figure 7. Nearest upland disposal sites

Material disposed of at landfills is often required to pass the “paint filter” test, which limits the water content. However, this appears not to apply to material dredged from Capitol Lake at the two landfills considered here. At Rabanco's Roosevelt site in Washington, material dredged from the Puget Sound (most likely including Capitol Lake) is exempt from water content limitations. At Waste Management's Columbia Ridge site in Oregon, non-hazardous material is exempt from water content limitations.

3.4 Beneficial Reuse

Beneficial reuse includes a wide variety of opportunities to use dredged material for a productive purpose. The objective of beneficial use of dredged material is to make the traditional placement of dredged material unnecessary or reduce the required volume of disposal. The USACE recommended categories of beneficial uses (USACE 1987) are as follows:

- Habitat restoration/enhancement (wetland, upland, island, and aquatic);
- Beach nourishment;
- Aquaculture;
- Parks and recreation (commercial and non-commercial);
- Agriculture/horticulture/forestry;
- Mine and quarry reclamation;
- Landfill cover for solid waste management;
- Shoreline stabilization;
- Industrial and commercial use;
- Material transfer (fill, levees, roads, etc.); and
- Construction material.

Some of the most plausible uses listed above were investigated in more detail by M&N. The criteria for disposal at these sites – including chemical criteria and the presence of noxious weeds – will vary from site to site.

3.4.1 Habitat Restoration or Enhancement, or Beach Nourishment

The material is not well-suited for wetland or aquatic habitat restoration / enhancement, or for beach nourishment, because of the purple loosestrife seeds. If the material were contained within a geotube, it could potentially be used in a habitat restoration / enhancement project. For example, a filled geotube could be buried under sand as part of a beach nourishment project: the geotube would provide additional protection to the area upland of the beach nourishment in the event that storm waves eroded the placed sand. At present, M&N has not identified any suitable habitat or beach nourishment projects in the south of Puget Sound. It is possible that a suitable project could be identified through the update of the Thurston County Shoreline Master Plan, which is in its early stages.

3.4.2 Mine and Quarry Reclamation

M&N has identified one quarry reclamation site: Lakeside Industries Central Aggregate Pit near Centralia. Rail access to this pit is available. The tipping fee is estimated at \$3 to \$4 per cubic yard (D. Smith, personal communication, 2008).

3.4.3 Industrial and Commercial Use/Construction and Material Transfer

Possible upland uses include using the sediments as fill for the construction of industrial and commercial upland sites. This use would be supported by the Thurston County Noxious Weed Control Board (TCNWCB) as would other alternatives where the sediment would be capped by concrete, asphalt, or other material as any purple loosestrife seeds in the sediment would not be able to germinate.

Unfortunately the majority of the sediment is of limited structural value because of its grain size characteristics – generally, structural fill should be at a minimum the size of medium sand. One possible exception is material dredged from sediment traps in the South Basin and/or the south end of the Middle Basin as part of the maintenance dredging under the Lake Alternative (Section

5.2.2). This material is anticipated to be coarser than the sandy silt and silty sand found over the majority of the lake.

M&N contacted the Washington State Department of Transportation (WSDOT) to solicit interest in the finer material, but little response has been received (T. Baker, personal communication, 2008). The material could be encapsulated in a geotube and used as a levee core: however, USACE staff were not aware of any available projects of this type (D. Weber, personal communication, 2008).

3.4.4 Capping Material for Cleanup Sites and Landfill Cover for Solid Waste Management

Budd Inlet marinas (both private and public) along with the Port and City of Olympia have discussed the need for a Budd Inlet site that could be used to dispose of their dredged sediments (General Administration 2008). If such a site was eventually considered an appropriate means of dealing with Budd Inlet sediments (currently most contain dioxins, furans, and other contaminants of concern as defined by the Environmental protection Agency [EPA] and Ecology), the Capitol lake sediments could be contained within a geotube and used as capping material. Obviously this type of use would require considerable coordination and negotiations with a number of agencies and parties, but it also has the potential to provide a realistic resolution for a number of issues faced by projects in Budd Inlet.

3.4.5 Parks and Recreation

The use of dredged material as fill for Thurston County's Department of Parks and Recreation Land was investigated in 2000 (CLAMP 2000). At that time, Parks and Recreation was willing to accept Capitol Lake material for two identified park projects (Chehalis Western Trailhead Park, Off-Road Vehicle Park) as long as the material was capped with at least six inches of soil free of purple loosestrife, and the site was revegetated.

This option is still viable although no specific projects have been identified.

3.4.6 Agriculture (Composting, Topsoil, Soil Recycling)

M&N investigated the possibility of disposal options at composting facilities. This option was originally investigated in 2000 (CLAMP 2000). As originally identified, composting is not a feasible alternative. Nearby composting facilities cannot handle the quantity of material proposed for the project (J. Burke, personal communication 2008), nor does composting generate enough heat to kill purple loosestrife seeds (R. Johnson, personal communication 2008). Due to the risk of spreading purple loosestrife seeds, composting and distribution of the dredged material to topsoil companies would not be allowed by the TCNWCB (R. Johnson, personal communication 2008). While purple loosestrife seeds could be destroyed by soil recycling, in which organics are removed from sediments by exposure to high heat (450 to 800 degrees F), TPS Technologies estimated in 2000 that it would take 3 months to sterilize 20,000 cubic yards of sediment at their Tacoma site (CLAMP 2000). This option is therefore ruled out.

3.5 Summary

The following feasible disposal sites, or potential disposal options, have been identified for the material dredged from Capitol Lake and Budd Inlet's West Bay under the Lake Management alternative.

- Open-Water Disposal:
 - Anderson-Ketron Island: This is the closer of the two open-water disposal sites. It may be available for some or all of the materials dredged from Budd Inlet's West Bay as maintenance dredging associated with the Estuary Restoration Alternatives. It may also be available for future maintenance dredging of Capitol Lake if purple loosestrife is eliminated.
 - Commencement Bay: This may be available for material dredged from Capitol Lake. Will require coordination with the Pierce County Noxious Weed coordinator and with WSDA (G. Haubrich, personal communication 2008): may require mitigation for purple loosestrife seeds.
- Upland Disposal:
 - Roosevelt, Klickitat County, WA: Disposal at a landfill is reasonably certain to be available. Hauling by railcar has been included in quoted costs.
 - Columbia Ridge, Arlington, OR: Considerations are similar to the Roosevelt site.
- Beneficial Reuse:
 - Quarry Reclamation: Lakeside Industries near Centralia appears to be available for material dredged from Capitol Lake. It would be necessary to dewater the material sufficiently that it can be spread with a bulldozer.
 - Nearshore Restoration, with placement in geotubes: This is a relatively costly option – probably no less expensive than transportation to a landfill. Additionally, no suitable site in Thurston County has been identified.
 - Construction Fill: A suitable construction site capable of accepting fill material is most likely to be identified in the future for the relatively coarse material dredged from sediment traps. Given the high costs associated with hauling material by truck, the site would need to be at 20 miles distance or less.

4. Dredging and Associated Technologies

4.1 Mechanical Dredges

Mechanical dredges remove bottom sediment through direct application of mechanical forces to dislodge the sediment at near in-place densities.

The most common mechanical dredge consists of a crane or derrick permanently mounted on a floating barge (Figure 8). Because there is no direct water access between Budd Inlet and Capitol Lake, the dredge equipment must be trucked in and assembled at the site. The need to truck the pieces of dredge equipment will require the use of smaller barges and track-mounted cranes, which limit the dredging rate and efficiency. Smaller barges will also be required for dredging within the Budd Inlet marinas, because of the limited fairway size.

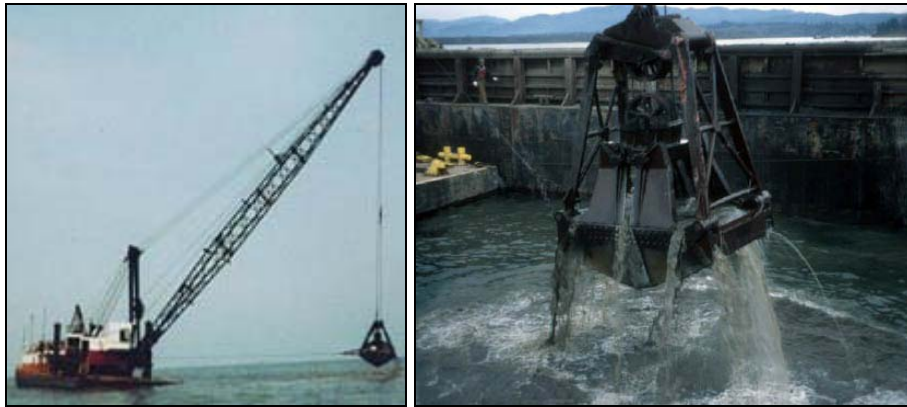


Figure 8. Typical derrick crane dredge with clamshell bucket (left); close-up of bucket (right)

Portable crane buckets, which could potentially be launched into Capitol Lake, can range in size from 1 to 3 cubic yards, while much larger buckets are available in open water. The ability to dig materials of increasing density and hardness improves with increased bucket weight, which creates the necessary force to fracture the material and break it out of the cut. Depending on crane and bucket size, the dredging rate for a single clamshell dredge varies from 75 to 200 cubic yards per hour.

Another form of mechanical dredge is the excavator mounted on a pontoon or small barge (Figure 9). An excavator on a track-mounted barge (Figure 10) is also a feasible equipment choice for dredging shallow water or marshy areas (e.g., for maintenance dredging in the South Basin of Capitol Lake). Buckets typically range in size from 1 to 7 cubic yards. Depending on crane and bucket size, anticipate dredging rates from 50 to 150 cubic yards per hour for a barge-mounted excavator.



Figure 9. Typical excavator dredge



Figure 10. Excavator dredge on track-mounted barge

All mechanically dredged material is placed onto a scow or flat-deck (haul) barge positioned alongside the dredge. The scow or barge transports the material directly to an offshore disposal site, or transports it to shore where it is offloaded onto trucks or rail and transported to an upland disposal site.

Barges and scows are sized according to their carrying capacity. Flat-deck barges are most often sized by the weight they are able to carry, while scows are most often sized by the volume. For consistency, this report describes both barges and scows in terms of the volume of sediment they are able to carry.

4.2 Portable Hydraulic Dredges

A hydraulic dredge uses a centrifugal pump to entrain the solid materials at a suction intake, and pumps the water and sediment slurry through a pipeline to a deposition area. The slurry is typically 5% to 20% solids by volume (in place). Therefore, a large quantity of water must be dealt with in this type of operation.

The size of a hydraulic dredge is indicated by the diameter of the intake/suction line to the pump. Portable hydraulic dredges, which would be needed for dredging within Capitol Lake, range in size (as determined by the suction line diameter) from 10-inches to about 16-inches. These relatively small dredges would also be suitable for dredging within the marinas.

The types of hydraulic dredges are usually classified by the cutting mechanism just ahead of the intake line to the pump. These include cutter head, bucket wheel, and auger head dredges.

The most common and most versatile hydraulic dredge is the cutter head dredge (Figure 11), which uses a rotating basket with a cutting surface ahead of the suction intake. The cutter head excavates and translates the bottom materials into the influence of the suction intake. A cutter head dredge with an intake size between 10- and 16-inches would have a production rate of 100 to about 400 cubic yards per hour, respectively. Comparable slurry flow rates are in the range of 2,000 to 8,000 gallons per minute (gpm), respectively, based on a water content of 85 percent.



Figure 11. Cutter head dredge (left), close-up of cutter head (right)

The vertical bucket wheel head (Figure 12) is a vertical rotating wheel with small buckets on the periphery of the wheel. The buckets excavate the sediment and convey it to the suction intake. Portable bucket wheel hydraulic dredges typically come in the same size range as the cutter head dredges. A bucket wheel dredge with an intake size of between 10- and 16-inches would have a similar production rate to a cutter head dredge: between 100 and 400 cubic yards per hour.



Figure 12. Typical bucket wheel dredge

Auger head dredges are rarely larger than 12-inches, rarely exceed a production rate of 100 cubic yard per hour, and are used primarily for dredging in municipal lagoons and ponds. Because of the low production rate, auger head dredges are not considered further here.

The dredged material is transported as slurry through a pipeline to a dewatering site, to a dump scow for open-water disposal, or directly to an open-water disposal site. The pipe material is usually steel (for highly abrasive sediments) or plastic (HDPE). If the material must be transported a distance greater than about 4,000 feet, a booster pump must be installed in the line. This is a common practice, but the booster pump does add cost to the project.

The discharge pipeline from the dredge can be floated on top of the water or be ballasted along the bottom. Once it reaches the shoreline, the pipeline is generally laid out on the ground (although it can be raised over obstacles such as roads or buried under them).

4.3 Equipment Launch

Since the lake is land-locked, any dredge or barge must be transported by land, assembled on-site, and placed in the lake. Furthermore, the BNSF Railroad Trestle (Figure 13) is an effective barrier to barges attempting to move between the North and Middle Basins. This limits the size, and to some extent the operations, of dredges and associated equipment.



Figure 13. BNSF Railroad Trestle

The most convenient site for access to the lake is Marathon Park. Barges and associated equipment can be launched in both the North and Middle Basins from this location (navigation between the Middle and South Basins is not problematic). Alternative equipment launch points for the Middle and South Basins are Capitol Lake Interpretive Park, at the south end of the Middle Basin, and Tumwater Historical Park adjacent to the North Basin. Capitol Lake Interpretive Park is constructed in part of previously dredged material and may include lenses of fine and soft material (Rittenhouse-Zeman and Associates 1982): the soils at this location may not be adequate to support the heavy equipment needed to launch the dredges and associated equipment. The water at Tumwater Historical Park is shallow and the channels are relatively narrow, but it appears that the equipment could be launched there.

The barges on which the dredges are mounted, and material transfer barges used with mechanical dredges (see Section 4.1), would likely be trucked to the site in segments. Several companies fabricate truckable barge segments (modules) and tugs. For example, the modular barge sections created by Robishaw Engineering, the FlexiFloat system, can be transported on a flatbed truck and assembled in place: see Figure 14 and Figure 15 for an example of this system in use. Modular barge sections come in a variety of sizes ranging in widths from 8 to 12 feet, lengths from 10 to 50 feet, depths from 4 to 7 feet, and module weights from 3 to 20 tons.

Mechanical dredges will consist of cranes or excavators mounted on a barge. Hydraulic dredges are usually equipped with an integrated barge hull. A mobile crane of at least 100-ton capacity can be used to set up the equipment at the launch site and to lift each barge module or tug unit into the lake.

Once in the lake, the modules are assembled together to form an equipment barge or a material transfer barge. For mechanical dredges, an excavator or crane is lifted, or more likely driven, onto the equipment barge and secured (chained down) to the barge deck. Since the hydraulic dredge comes with its own barge hull, a single lift can place it in the water. Containment skirts can be mounted to the decks of the material barges to help retain the dredged sediment.



Figure 14. Modular barge system in use (source: www.flexifloat.com)

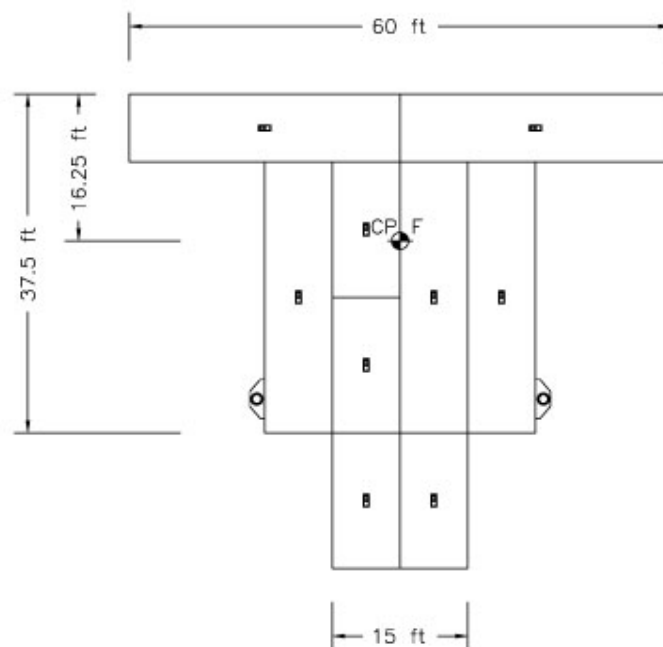


Figure 15. Layout of modular barge system (source: www.flexifloat.com)

Tugs or skiffs would be launched into the lake directly from Marathon Park or (for the Middle Basin) potentially from one of the other launch sites shown in Figure 16. While this report assumes a tug would be used, a skiff is another possibility: Skiffs have a low profile, and could potentially navigate under the BNSF Railroad Trestle if the water is relatively low. Truckable tugs range in size from 20 feet × 8 feet × 3 feet draft, 135 hp, and weighing 5 tons up to 32 feet × 14 feet × 6 feet draft, 710 hp and weighing 15 tons.

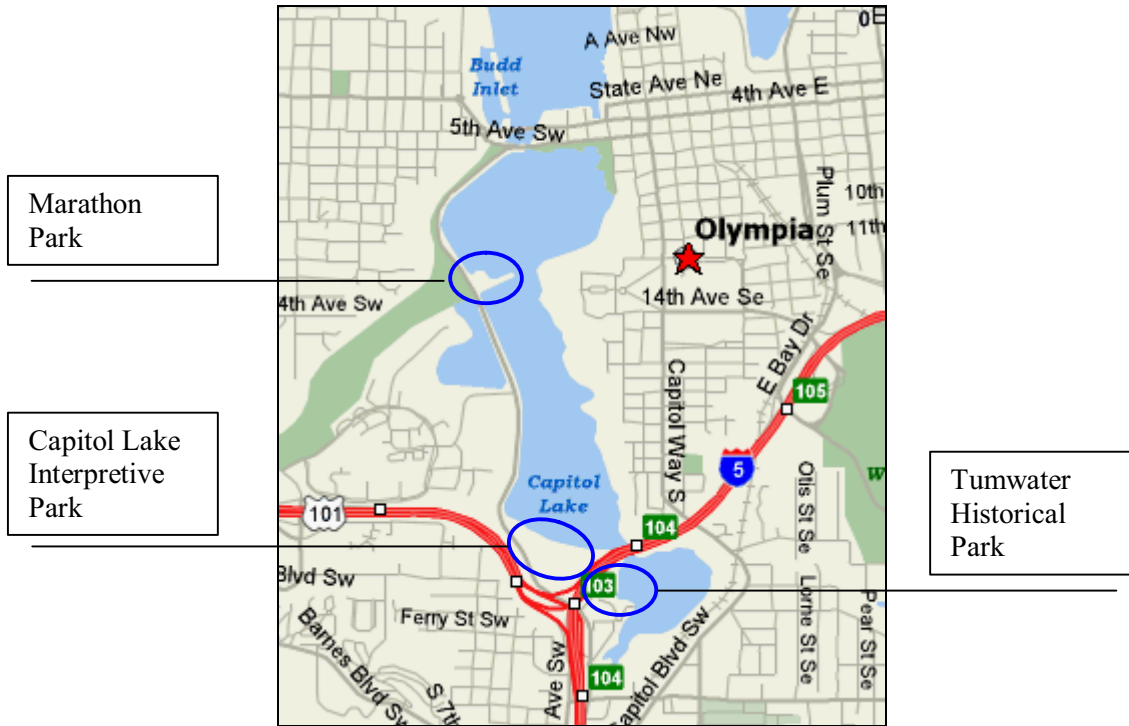


Figure 16. Potential launch sites for lake-bound equipment

4.4 Dewatering

Material that is dredged hydraulically and is destined for upland disposal must be dewatered before being placed on railcars or trucks. Dewatering of slurries reduces the amount of water in the slurry, increasing the solids concentration and making the material suitable for handling, transportation, and disposal. Dewatering of the slurry is most often performed by settling in a pond.

A settling pond can be created on any relatively flat parcel of land. The sides of a settling pond are typically constructed of local or imported soil pushed up into a perimeter dike or large stacked concrete block to form a perimeter wall. The discharge end of the slurry pipeline is allowed to empty into the pond. The end of the slurry pipeline may be moved about the pond by a wide-track or low-pressure-tired vehicle (bulldozer, front-end loader, or excavator) to spread the material out. If the pipeline discharge remains stationary, the material may be spread about by bulldozer. After the dredged sediment has settled and been dewatered, the sediment is removed from the pond for transport to the disposal facility.

Unfortunately, settling ponds require a relatively large area. The most convenient site for a settling pond in the vicinity of Capitol Lake is the abandoned gravel pit west of Marathon Park. Initial calculations suggest it is, at best, barely possible for this site to be sufficient to dewater hydraulically dredged material at the production rates required here. Only if the sediment characteristics are such that the material settles out and dewateres within a week to ten days – extremely unlikely given the high silt content – could the site physically handle the material. In addition, the regulatory agencies would have to allow the return of turbid water to the lake – there is not space available for a secondary settling pond on the site. This is also unlikely. Previous assessments of gravity dewatering either assumed a much lower sediment quantity, based on dredging of sediment traps rather than the entire lake (General Administration 1996), or ruled out

gravity dewatering as infeasible (CLAMP Steering Committee 2000). This report does not consider further the option of a settling pond for the treatment of hydraulically dredged material.

Additional dewatering alternatives include centrifuges, filter presses, and drying ovens. A centrifuge was tested as part of a pilot study to dewater Capitol Lake sediments in 1995 (Entranco 2000a). The centrifuge did not handle the coarser (sand-sized) fraction of the sediment well (Entranco 2000a; J. Bachmeier, personal communication, 2008). Generally, these methods are too expensive and too slow for the anticipated rate of dredging.

Some dewatering may be necessary for mechanically dredged material, depending on the requirements of the eventual disposal site. It may be adequate to dewater the sediment overnight on the material transport barge, with the supernatant (the relatively clear water remaining after the sediment settles out) pumped back into the lake. Another alternative is cement-based solidification / stabilization of the sediment. Portland cement is added to the sediment to absorb the excess water. The cement reacts with the water to chemically bind the water and dry the material (Austin 2004). This method is relatively costly (\$20 to \$30 per cubic yard). However, if the majority of the dredged material drains adequately this is an attractive alternative for the remainder.

It is critical to test the settling and dewatering characteristics of the dredged material before moving further forward with the design and environmental process.

4.5 Geotubes

Geotubes are large passive filter tubes manufactured from construction-grade geotextiles. The tubes can be manufactured in a variety of circumferences and lengths. Circumferences typically range from 7 to 90 feet, and lengths range from 10 feet to 300 feet.

The empty tubes are typically rolled out onto a flat surface. The tube is filled through inlet spouts at evenly spaced intervals along the length of the tube. The discharge pipeline can be connected to a manifold that directs the slurry to one or more inlet spouts on one or multiple tubes. The water is filtered through pores in the geotube, and the sediment (with purple loosestrife seeds) is retained within the tube. The water is channeled or pumped back into the lake. The operation continues until the tube has reached its capacity, then the tube is allowed to sit idle while the slurry water drains away the sediment consolidates. When the sediment in the tube has reached optimum consolidation, the tube is transported to the disposal site. Figure 17 illustrates geotubes in a dewatering application.



Figure 17. Geotubes used in dewatering (source: Tencate)

There are several options for handling the tubes once the sediment has been drained. If drained on a pallet, the pallet with geotube can be loaded onto a truck and hauled to a selected disposal site. The filled geotube can be hauled and placed along an eroding shoreline to form the core for a shore protection project. The filled geotube can also be hauled and placed along a river to form the core of a levee or dike. Geotubes can be filled in the hold/hull of a split-hull barge, the barge

towed to an open-water disposal site, and the geotube released into the water column to settle on the bottom.

The advantages of geotubes are the lack of moving parts (passive dewatering) and their ability to retain the purple loosestrife seeds. The main disadvantages are that the cost is relatively high (\$8 to \$60 per cubic yard for the cost of the geotubes alone), and the tubes are difficult to move once filled. To use geotubes efficiently, they need to be filled at their final resting place. Since no appropriate beneficial reuse option has been identified, this alternative is not considered further.

4.6 Selection of Dredging Method

Hydraulic dredging can be very cost-effective under certain conditions: if the dredged materials can be transported by pipeline to a nearby offshore disposal site, or if there is upland space available for gravity dewatering prior to transport to an upland disposal site. For the project alternatives considered here, neither condition holds.

Hydraulic dredging is relatively cost-effective – and is described in this report – for offshore disposal with the water and sediment slurry transported on towed scows or barges. For upland disposal, it does not appear to be feasible to dewater the slurry at the required production rates. Even if it is possible – if the slurry dewaterers more rapidly than anticipated – it appears that hydraulic dredging would be only slightly more cost-effective than mechanical dredging. Given the very significant uncertainties in the feasibility of rapidly dewatering hydraulically dredged material from Capitol Lake, this report assumes mechanical dredging for upland disposal.

5. Lake Dredging

5.1 Overview of Dredging Needs

5.1.1 Initial Dredging

Under the Lake Alternative, a significant initial dredging project will be performed to regain much of the flood storage lost over the half-century since construction of the Capitol Dam in 1951. Initial dredging is assumed to take place in the North and Middle Basins (a relatively small amount will be dredged from the South Basin: this is included with the Middle Basin for this discussion). The lake will be dredged to a uniform elevation of -7.2 feet NGVD29, which is the sill elevation of the Capitol Dam. This corresponds to a lake depth of about 13 feet during the summer months, based on the summer lake level of +6.22 feet NGVD29, consistent with the Managed Lake Alternative defined by the CLAMP Technical Work Group (CLAMP Technical Work Group 2007).

The optimal lake depth for biological purposes is a minimum of 15 feet. However, there are concerns that lowering the lake bottom below the sill elevation of the dam could increase saltwater intrusion into the lake. Additionally, dredging to a lower elevation would not increase the flood storage, since the lake cannot be drawn down below the sill elevation – the additional volume would be dead storage. Consequently, this report assumes the less costly alternative of dredging to -7.2 feet NGVD28.

No dredging will occur within 100 feet of the shoreline (taken at +10 feet NGVD29). The full yellow line in Figure 18 illustrates the outline of the proposed dredging. A relatively large part of the North Basin already is currently at an elevation below -7.2 feet NGVD, so the dredge area and volume are much smaller here compared to the Middle Basin. Table 1 gives the dredge areas and volumes for the Lake Alternative.

Table 1. Dredge areas and volumes for the lake dredging

Basin	Area (acres)	Volume (cy)
North Basin – dredge to a distance 100-feet from the shoreline	48.8	158,000
Middle Basin – dredge to a distance 100-feet from the shoreline	94.9	717,000
Total Dredge Area and Volume	143.7	875,000

5.1.2 Maintenance Dredging

The quantity of material deposited in the lake by the Deschutes River has averaged 35,000 cubic yards annually (USGS 2006). This is assumed the average quantity for future maintenance dredging.

Part of the maintenance dredging could be accomplished by constructing and maintaining sediment traps. Sediment traps are formed by excavating or dredging a depression in the bottom of a waterway. Sediment-laden runoff encounters the larger cross-sectional area created by the depression, the flow velocity decreases, and the sediment settles into the sediment trap.

In order to be effective in the long term, sediment traps require regular surveys and maintenance dredging. In the past, sediment traps have been excavated in both the South and Middle Basins of Capitol Lake. However, maintenance dredging of these traps has been haphazard at best. This report assumes that sediment traps in Capitol Lake will be re-excavated in the same general vicinity as those constructed in 1979 (General Administration 1996): see the red broken line in Figure 18. Based on a dredge depth of 4-feet below the existing lake bed (South Basin) or the

dredged lake bed at -7.2 feet NGVD29 (Middle Basin), the dredge volume for the sediment traps shown here is 55,000 cubic yards.

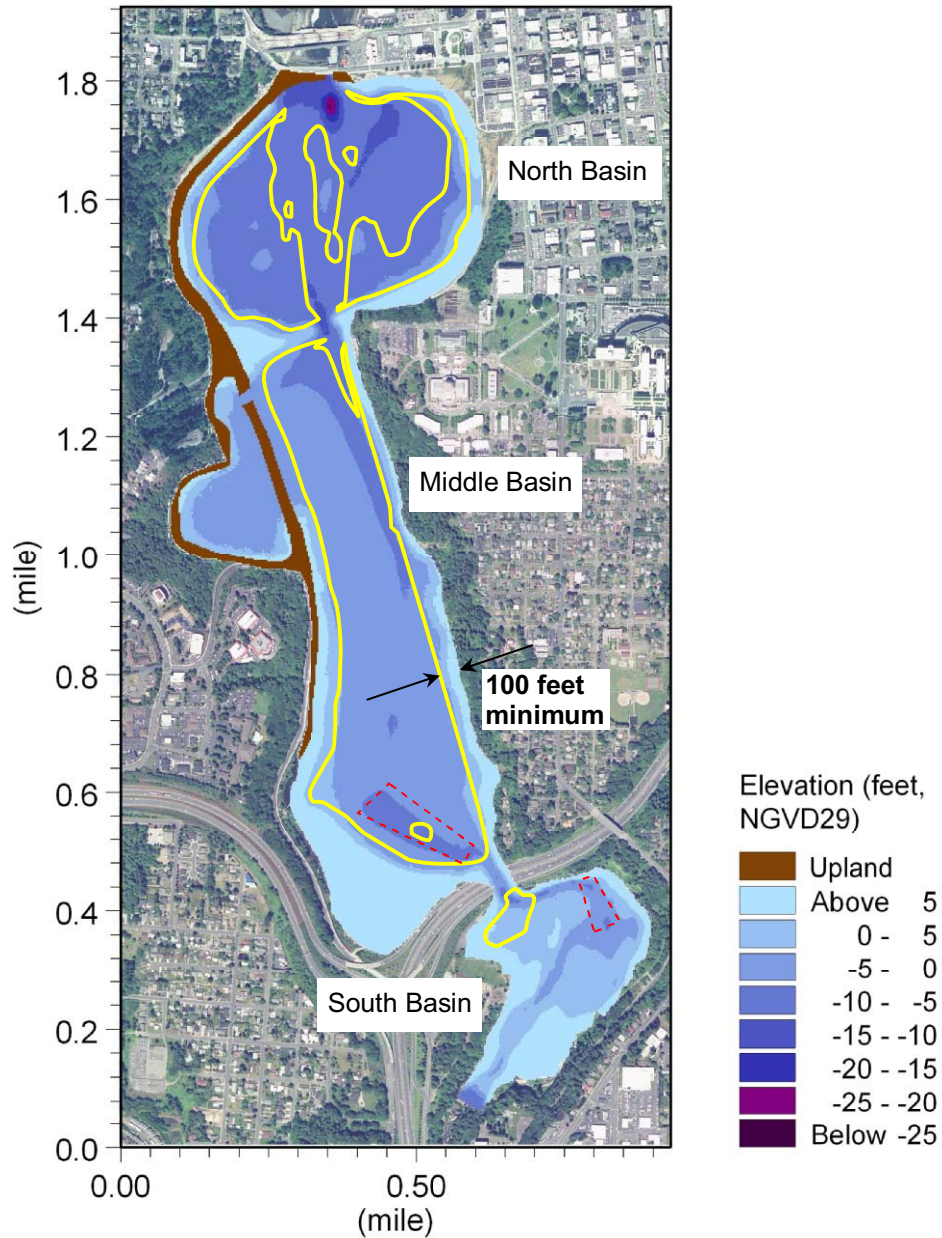


Figure 18. Existing lake bathymetry, proposed dredge footprint (full yellow line), and outline of potential sediment traps (broken red line)

Maintenance dredging of the sediment traps will be done as needed (see Section 5.1.2 for details). Since much of the finer material transported to the lake by the Deschutes River will bypass the traps, it will also be necessary to dredge the Middle and North Basins periodically.

5.2 Permitting and Regulatory Process

5.2.1 Initial Dredging

The overall impact of the Lake Dredging alternative on the environment may be considered significant even if it is considered maintenance dredging by some definitions of the term.

The following list outlines the most likely regulatory and permitting requirements that will be needed for this alternative.

Environmental Review

- National Environmental Policy Act (NEPA): Federal funds may be needed for a project of this magnitude, which would trigger specific NEPA requirements.
- State Environmental Policy Act (SEPA) Environmental Impact Statement (EIS): Required. Washington State Department of General Administration will probably be lead agency for this.

Permits and Approvals

- Washington Department of Natural Resources (DNR) Lands Lease: An aquatic lands lease, easement, or right of entry may be required. Additionally, depending on how the dredge materials are handled, a royalty may be owed to the State. Further sediment testing can be anticipated for most of the disposal options currently identified. If sediment disposal occurred at a gravel mine, a DNR Reclamation Plan would be required.
- U.S. Army Corps of Engineers (Corps) Section 10/404 Permits: These are initiated through the Joint Aquatic Resource Permit Application (JARPA). A Section 10 permit is required for work in or under navigable waters of the United States; a Section 404 Permit is required for in-water discharge of dredged or fill material. Copies of the completed JARPA will then be submitted to the Corps for Section 10/404 Permits, to Washington Department of Fish and Wildlife (WDFW) for a Hydraulic Project Approval (HPA), and to the Cities of Olympia and Tumwater for a Shoreline Substantial Development Permit.
- BE/BA, including the Essential Fish Habitat: The BE/BA is required due to federal nexus with Corps permitting. A BE/BA report with a Not Likely to Adversely Affect (NLAA) or Likely to Adversely Affect (LAA) effects determination will be needed.
- Washington Department of Ecology (Ecology) Section 401 Water Quality Certification: Required with federal permitting, triggered by the Corps.
- Ecology National Pollution Discharge Elimination System (NPDES) Stormwater Permit for Construction: Will be required.
- Washington State Department of Fish and Wildlife (WDFW) HPA: Initiated through the JARPA process. Required as activity is waterward of the Ordinary High Water Mark (OHWM).
- Washington State Department of Agriculture (WSDA) permit for transportation of sediments containing purple loosestrife (WAC) 16-752-410 – Rules Relating to Lythrum Quarantine. Permit Contact: G. Haubrich.
- City of Olympia and City of Tumwater Permits and Approvals:
 - Shoreline Substantial Development Permits: Required as project involves substantial work within 200 feet of an aquatic shoreline. Since most of the South Basin and parts

of the Middle Basin are within the City of Tumwater, a combined or parallel process would be required for the Cities of Olympia and Tumwater.

- Critical Areas Ordinance: Compliance and mitigation required to the extent project would affect designated wetlands, fish and wildlife habitat areas.
- Noise Variances: Due to in-water work window constraints (work in or along the shorelines of both fresh and marine water bodies is often only allowable for a specific time of the year), some material handling may need to be completed after 7:00 PM (WAC 173-60-040, City of Olympia Municipal Code 18.40.080, City of Tumwater Municipal Code 18.40.030, 8.08). Variances may be granted via municipal codes and WAC 173-60-080.
- Other local permits and approvals may include: Demonstrating compliance with Zoning and Comprehensive Plan; Grading Permit; Site Development Permits; Thurston County Waste Disposal and Special Use permit; and others.
- Easements (rights granted by property owners) may be required for shoreline properties along the South Capitol Neighborhood area (southeast Capitol Lake). Some of the private tidelands in this area extend further waterward than 100 feet from shore.

The time scale and process associated with federal, state, and local permitting can be anticipated to be a minimum of 4 to 5 years.

Mitigation and Monitoring Requirements

Mitigation and monitoring requirements for this alternative would be identified and defined during the environmental review phase. Conditions applied to permits and approvals are likely to include: the use of Best Management Practices during dredging; limiting dredging to specific in-water work windows; monitoring lake water quality; and (for upland disposal) covering all railcars during transportation.

Monitoring for purple loosestrife could well be required. With upland disposal, inspections of each stream crossing along the transportation route could be required for up to three years. If open-water disposal is permitted, WSDA and/or the DMMP Committee would very likely require monitoring along areas of the shoreline considered likely to be affected.

5.2.2 Maintenance Dredging

Future maintenance dredging would need to undergo a separate environmental review. A full EIS would most likely not be required if maintenance dredging were to occur at a more regular frequency than in the past. Regular maintenance dredging is often SEPA exempt or, at most, could be determined as nonsignificant (a SEPA Determination of Nonsignificance is referred to as a DNS).

Future maintenance dredging would also require in-water permits and approvals similar to those identified for the initial dredging. Additional sediment testing may be required in response to ongoing modifications to the controlling regulations.

5.2.3 Work Windows

Endangered plants, animals, and aquatic species (such as the federally listed Chinook salmon, Puget Sound steelhead, and bull trout) are the responsibility of the National Oceanic and Atmospheric Administration (NOAA) Fisheries, National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS), collectively referred to as “the Services”. The Services are charged with implementing the Endangered Species Act (ESA). The ESA requires

federal agencies, such as the US Army Corps of Engineers (USACE), to consult with the Services prior to funding, authorizing, or taking any action that might harm a listed species or degrade their habitat. Aquatic resources (such as significant salmonid habitat) are also the responsibility of the Washington Department of Fish and Wildlife (WDFW).

Figure 19 shows some of the current fish windows (timeframes where in-water work is not permitted) for the Budd Inlet/Olympia areas (WAC 220-110-271, USACE 2001, WDFW 1999). If the Services were to impose all of these fish windows, no in-water work would be allowed.

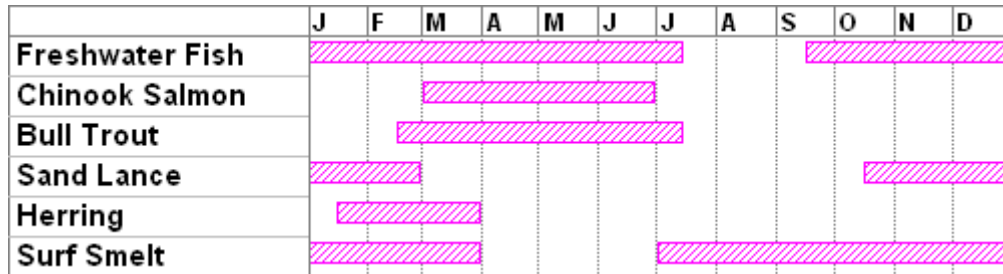


Figure 19. Published fish windows for Olympia

This report makes the preliminary assumption that only the Chinook salmon and bull trout windows will be observed, with minor restrictions at other times. That is, the report assumes that the in-water work window lasts for seven months from mid-July to mid-February each year. The rationale for this general assumption is based on the likely effects of dredging on the different species. For example, there are no known surf smelt or sand lance marine spawning beaches within a mile of Capitol Lake. As a result, these windows are unlikely to affect the construction schedule.

Fresh water work windows can be more restrictive. Work in Thurston County fresh water streams is often restricted to July through September (WDFW 1999) and chinook, coho, and steelhead all occur in Capitol Lake (ESA Adolfson 2008). Project-specific studies to identify species presence or absence, together with coordination and negotiation with the regulatory agencies, will be needed to define the exact in-water work window for this project.

5.3 Initial Dredging Methods and Costs

5.3.1 Overview

This report considers three options for the initial lake dredging:

- Mechanical dredging followed by railcar transportation to the Columbia Ridge landfill site in Arlington, OR;
- Mechanical dredging followed by railcar transportation to the Lakeside Industries quarry reclamation site near Centralia; and
- Hydraulic dredging followed by unconfined disposal at Commencement Bay.

These have very different unit costs. The reason for considering all three alternatives, rather than only the least costly, is that it is not certain that the second and third options will be available. It is very possible that it will prove impossible to obtain the necessary permits for open-water disposal at Commencement Bay, given the presence of purple loosestrife. The quarry pit may not be available by the time the project is under way. By including the most costly option of upland landfill, it is ensured that a technically feasible alternative is considered.

5.3.2 Mechanical Dredging to Landfill or Quarry Site

Mechanical dredging is assumed to consist of two portable (and lake-bound) barge-mounted cranes with clamshell buckets. It is assumed two dredges will be used, with clamshells sized at 3 cubic yards. Initially, one dredge will operate in the North Basin and one in the Middle Basin: once North Basin dredging is complete, both dredges will operate in the Middle Basin. With an average production rate for each dredge of 110 to 120 cubic yards per hour, the overall daily production rate will be 1,600 cubic yards based on an 8-hour shift with 7 hours of effective dredging. This will allow 875,000 cubic yards to be dredged in 550 working days, within four 7-month in-water work windows.

The material dredged from the lake will be loaded onto a material transfer barge which, when full, is towed to a temporary transfer dock, one each along the North Basin and Middle Basin shoreline, constructed alongside Deschutes Parkway. The material is stockpiled on the barges during each day, and loaded onto railcars (gondolas) at night. Eight barges with a 200-cubic yard capacity are able to stockpile one day's worth of dredging. Free water in the barges will be allowed to overflow back into the lake or will be pumped overboard into the lake before the barges arrive at the transfer facility.

Based on a similar mechanical dredging and transfer process used on the Hylebos Waterway Dredging Project for the Port of Tacoma (G. Hartman, personal communication), the sediment is likely to be dry enough to transfer directly to the railroad gondolas without dewatering, or at most with overnight dewatering on the barge. If overnight dewatering is carried out then additional barges will be needed. However, the Lakeside Industries quarry reclamation site near Centralia only accepts material capable of being reworked by bulldozer. This further limits the acceptable water content of the material. It may be necessary to dewater the mechanically dredged lake sediment for this disposal site. Additional dewatering is not necessary for the landfill sites.

An alternative dewatering method is cement-based solidification / stabilization. Portland cement is mixed on the barge using a backhoe or at the temporary dock using a blending head mounted on the end of a backhoe/excavator arm. A two to five percent volume mix of cement to sediments was used at a Port of San Diego project prior to offloading sediment from the barge (Austin 2004), and for costing purposes this report assumes a five percent mix will be needed for 30 percent of the dredged sediment. A bag test, in which sediment is held in a bag and allowed to drain freely, will be needed to determine the actual requirements.

After dewatering (if necessary), the stockpiled material is transported onto gondolas, which are stored on the north spur of the railroad track. Tacoma Rail would store empty gondolas at one of their railyards in east or south Olympia, and would bring the empties in each day to the rail spur west of Deschutes Parkway north of the railroad bridge. The gondolas would be loaded at night using a combination of excavator, trucks, and conveyor from each transfer dock. The excavator would unload the small barges into trucks (four trucks needed), the trucks would haul the material and dump it into a hopper along the rail spur, and a conveyor belt would load the material from the hopper into the railcars. The operation would most likely occur at night, with flaggers along the route or potentially with Deschutes Parkway closed to traffic for periods at night.

Approximately 2,000 feet of track remain along the rail spur, sufficient to store approximately 36 gondolas. Each gondola is able to hold 65 cubic yards of sediment, so there is storage available for 2,340 cubic yards, more than a day's worth of dredge material. The gondolas would be moved to Tacoma Rail's railyard, and eventually transported to the landfill, the Lakeside Industries quarry reclamation site near Centralia, or to another site for beneficial reuse.

Figure 20 illustrates the material handling described here.



Figure 20. Possible rehandling layout at Marathon Park

Table 2 gives an average daily cost for the operation. This daily cost provides for dredging the material; transporting the material to the temporary dock shown in Figure 20; and rehandling and hauling the material along Deschutes Parkway where it is loaded onto railcars.

Table 2. Daily Operations Cost – Mechanical Lake Dredging

Daily Operation Costs	Daily Cost per Unit	Units	Total Daily Cost
Mechanical dredge, 3 CY clamshell on barge with 200-ton crane	\$5,000	2	\$10,000
Towing tug, 210 hp	\$1,700	2	\$3,400
Tender tug, 710 hp	\$3,500	2	\$7,000
Barge, 200 CY	\$600	8	\$4,800
Excavator, truck (4), conveyor combination	\$8,200	2	\$16,400
Total daily operation cost			\$41,600

Mobilization/demobilization, rail transportation to the disposal site, and material disposal fees are in addition to this daily cost. Table 3 includes these additional costs, together with the costs for transportation to and disposal at a landfill site. The equivalent unit cost is \$138 per cubic yard.

Table 3. Cost of Mechanical Dredging to Landfill

Item	Unit	Qty	Unit Cost	Extended Cost (millions)
Mobilization/Demobilization	LS	1	\$1.3M	\$1.3
Temporary transfer docks	SF	3,000	\$200	\$0.6
Daily operation costs (Table 2)	DAY	550	\$41,600	\$22.9
Disposal, upland landfill, includes rail haul	CY	875,000	\$80	\$70.0
Construction Cost				\$94.8
Contingency (30% on operations)				\$7.4
Contingency (15% on landfill disposal)				\$10.5
WSST (8.9%)				\$8.4
Total Cost				\$121.1

Table 4 is similar to Table 3, except that it shows the costs for disposal at the reclamation site in Centralia. Disposal costs at the reclamation site are less than the disposal sites at the landfill. However, there are additional costs associated with dewatering the material sufficiently for this site. First, it is assumed the material is dewatered under gravity on the barges – requiring an additional 8 barges to stockpile the material. This increases the daily operation costs. Second, an allowance is provided for cement-based solidification. As mentioned above, physical testing of the sediments is needed to determine the extent of this solidification – both the percent admixture and the fraction of dredged sediments for which this is needed. The equivalent unit cost, assuming a five percent cement admixture for 30 percent of the material, is \$74 per cubic yard.

Table 4. Cost of Mechanical Dredging to Reclamation Site

Item	Unit	Qty	Unit Cost	Extended Cost (millions)
Mobilization/Demobilization	LS	1	\$1.3M	\$1.3
Temporary transfer docks	SF	3,000	\$200	\$0.6
Daily operation costs (Table 2 but 16 barges)	DAY	550	\$46,400	\$25.5
Cement-based solidification	CY	262,500	\$26	\$6.8
Disposal, reclamation site, includes rail haul	CY	875,000	\$14	\$12.3
Construction Cost				\$46.5
Contingency (30%)				\$14.0
WSST (8.9%)				\$4.1
Total Cost				\$64.6

5.3.3 Hydraulic Dredging to Open-Water Disposal

Hydraulic dredging will require two portable 16-inch hydraulic dredges. As with the mechanical dredging, initially one dredge will operate in each of the North Basin and Middle Basin, and the second dredge will move to the Middle Basin after the North Basin dredging is complete. With an average production rate for each dredge of 170 cubic yards per hour, the overall daily production rate will be 2,400 cubic yards based on an 8-hour shift with 7 hours of effective dredging. This will allow 875,000 cubic yards to be dredged in 365 working days. With a five-day work week, this is more than two 7-month in-water work windows. It seems likely that the work could be performed within two work windows, by increasing the shift to 10-hours, working 6 days per week, or negotiating an extended work window with the regulatory agencies.

The slurry contains a water content by volume of about 80 to 85 percent, so the volume of slurry produced will be in the range of 14,000 to 19,000 cubic yards per day. This slurry is pumped through pipelines, one for each dredge, ending at a manifold that directs the slurry into a split-hull dump scow moored at a mooring facility in the West Bay of Budd Inlet. The mooring facility is minimal, consisting of a dolphin with catwalk or similar construction: most likely the dolphins would be left in place for future use in maintenance dredging. The pipelines are routed through the earthen levee under 5th Avenue in a bored casing. Booster pumps will be needed to move the material to the mooring location.

Figure 21 illustrates the general layout of a single pipeline and scow. The main constraints on the location of the mooring are that the water be deep enough for the loaded scows, and that the mooring be out of the navigation channel. Another possibility is to moor the scow at the Port of Olympia.

The dredged material is transported by scow to the Commencement Bay open-water disposal site, a roundtrip distance of 75 nautical miles, where the material is dumped from the split-hull scow. A full 13-hour working day is estimated to make one round trip. Twelve scows holding 1,500 cubic yards would be needed to service a daily quantity of 18,000 cubic yards of slurry. This scow size is typical of equipment available in the Puget Sound region.



Figure 21. Possible material transfer layout at the 4th / 5th Avenue Bridges

Table 5 gives a daily operations cost for this alternative, while Table 6 gives a typical overall cost. The overall cost includes an allowance for monitoring and removal of purple loosestrife that may be released into the vicinity of Commencement Bay through these operations.

Table 5. Daily Operations Cost – Hydraulic Dredging

Daily Operation Costs	Daily Cost per Unit	Units	Total Daily Cost
Hydraulic dredge, 16-inch, on barge	\$5,200	2	\$10,400
Tender tug, 710 hp, 8-hour day	\$3,500	2	\$7,000
Towing tug, 1,000 hp, 13-hour day	\$9,300	12	\$111,600
Split-hull scow, 1,500 CY, 13-hour day	\$900	12	\$10,800
Booster pump	\$1,600	2	\$3,200
Total daily operation cost			\$143,000

Table 6. Cost of Hydraulic Dredging to Commencement Bay

Item	Unit	Qty	Unit Cost	Extended Cost (millions)
Mobilization/Demobilization	LS	1	\$1.3M	\$1.3
Mooring Dolphins	LS	1	\$1.6M	\$1.6
Pipeline, Booster Pumps, and Tunneling	LS	1	\$200,000	\$0.2
Daily operation costs (Table 5)	DAY	365	\$143,000	\$52.2
Disposal fee, Commencement Bay	CY	875,000	\$0.45	\$0.4
Purple loosestrife mitigation	ALL	1	\$3.0M	\$3.0
Construction Cost				\$58.7
Contingency (30%)				\$17.6
WSST (8.9%)				\$5.2
Total Cost				\$81.5

The equivalent unit cost is \$93 per cubic yard.

5.4 Maintenance Dredging Methods and Costs

5.4.1 Overview

Continued maintenance dredging in Capitol Lake is likely to involve two elements. First, the sediment traps in the southern end of the Lake can be cleaned out and regularly dredged by small mechanical dredges. This can be expected to remove much of the coarsest material transported to the Lake from Deschutes Parkway. Assuming the material is largely sand-sized, it would be more useful as construction fill or for other beneficial reuse compared to the silty sand found in much of the Lake. Additionally, by limiting the dredging to a small lake area, the environmental impacts associated with this activity are restricted.

Second, the lake as a whole must be regularly dredged. This would be carried out in a manner similar to that described for initial lake dredging in the previous section. The material resulting from this overall lake dredging will be largely the finer materials – silty sand to sandy silt with a slight admixture of clay.

Sediment traps are considered in this report because of the possibility that the unit cost of dredging and disposing of material from the traps may be less than the corresponding cost for material from the lake as a whole. The analysis below suggests that the unit costs for maintenance dredging in the dredging the sediment traps may be less than the unit costs for initial lake dredging (\$70 per cubic yard or more), but similar to the cost of hydraulic dredging with disposal at Anderson-Ketron Island (a possibility after purple loosestrife is eradicated from Capitol Lake). Therefore, even if a relatively large fraction of the sediment bypasses the traps, they may have a place in future management of the lake.

5.4.2 Sediment Traps

Much of the sediment transported into Capitol Lake will bypass the sediment traps. In the period 1991 to 1996, only 14 percent of the sediment that accumulated in the lake was deposited in the sediment trap (Entranco 1997).

The efficiency of the sediment traps could be higher than this in the future. First, the 1997 sediment volume analysis showed that 20 percent of the sediment accumulated in the channels of the North Basin. Much of this material could be collected by a new (or cleaned out) sediment trap in the North Basin. Second, the Middle Basin sediment trap has not been maintained in recent years – reducing its efficiency. A reasonable maximum trapping efficiency of 25 percent is used in this report.

The most cost-effective approach to dredging depends on the quantity and characteristics of the material that settles in the sediment traps. The material will be coarser than the typical mix of sandy silt and silty sand, which makes it much more likely to be usable as construction fill. If this is not the case, or if significant quantities of material do not settle in the traps, then it may not be worthwhile to maintain the traps. The assumed trap capacity is similar to that considered earlier by the State (General Administration 1996): approximately 55,000 cubic yards. It is assumed the traps would be cleaned out when approximately 40,000 cubic yards have settled – every four to five years based on a 25 percent trapping efficiency.

Specific disposal locations for this material have not been identified. Given the material quantities are much smaller than the 875,000 cubic yards generated by the initial lake dredging, and given that the material is likely to be suitable for construction or other beneficial reuse, it appears plausible that suitable locations will be found over the life of the project. In the long-term, it can be assumed the purple loosestrife will be eradicated, further increasing the usefulness of the material. The costs provided here assume a maximum, 20-mile radius to the beneficial reuse site.

Sediment in the traps will be mechanically dredged using a small barge-mounted crane with clamshell bucket sized at 3 cubic yards – similar to the dredging equipment used for the initial lake dredging, except only a single dredge will be used. For the South Basin, the dredge must fit under the I-5 Bridge. Since the pier spacing is approximately 80 feet (Entranco 2000b) this is not a significant limitation. The material dredged from the traps will be loaded onto a small barge which, when full, will be towed to a temporary transfer dock at the shore close to the Capitol Lake Interpretive Park and Deschutes Parkway. A front-end loader or excavator will transfer the dredged material from the barge to dump truck(s) which will haul the material to a local (within 20 mile radius) beneficial use site.

Based on a production rate of 100 to 110 cubic yards per hour over a 7-hour day, the 40,000 cubic yards in the sediment traps will be dredged in about 60 days or two and a half months. Four barges with a capacity of 200 cubic yards and a single tug are assumed to service the dredge. Based on a truck with 20 cubic yards capacity, 40 truck-trips per night will be needed. Assuming a truck can make the round trip in two hours gives 10 trucks to complete the work in an 8-hour shift.

Based on these assumptions, Table 7 and Table 8 give costs for mechanical dredging with truck haul to a beneficial reuse site.

Table 7. Daily Operations Cost – Dredging Sediment Traps

Daily Operation Costs	Daily Cost per Unit	Units	Total Daily Cost
Mechanical dredge, 3 CY clamshell on barge with 200-ton crane	\$5,000	1	\$5,000
Towing tug, 210 hp, 8-hour day	\$1,700	1	\$1,700
Barge, 200 CY	\$600	4	\$2,400
Front-end loader or excavator	\$1,600	1	\$1,600
Truck, 20 CY capacity	\$1,100	10	\$11,000
Total daily operation cost			\$21,700

Table 8. Cost of Dredging Sediment Traps

Item	Unit	Qty	Unit Cost	Extended Cost (millions)
Mobilization/Demobilization	LS	1	\$250,000	\$0.2
Temporary transfer facility	LS	1	\$150,000	\$0.2
Daily operation costs (Table 7)	DAY	60	\$21,700	\$1.3
Construction Cost				\$1.7
Contingency (30%)				\$0.5
WSST (8.9%)				\$0.1
Total Cost				\$2.3

The equivalent unit cost is \$58 per cubic yard. As is clear from the daily cost breakdown in Table 7, the cost of this dredging alternative is dramatically affected by the availability of disposal sites in the near vicinity. If a disposal site in the near vicinity can be identified, this could be a very cost-effective option for some of the future dredging. With the assumptions given here, the unit cost of dredging the sediment traps is similar to the unit cost of overall lake dredging. Consequently, the question of sediment trap effectiveness does not greatly affect the overall cost or feasibility of the lake alternative.

5.4.3 Overall Lake Dredging

It is anticipated that the finer materials (silts and clays) will bypass the sediment trap, it will be necessary to periodically dredge the entire lake. For planning purposes, we assume that the lake is dredged when about 25 percent of the lake storage generated by the initial dredging is lost – that is, about 220,000 cubic yards, based on an initial lake dredging of 875,000 cubic yards. If, as assumed above, 75 percent, or about 26,000 of the annual 35,000 cubic yards transported from the Deschutes River bypasses the sediment traps, overall lake dredging is anticipated once every eight to nine years. If a large fraction of the material settles in the sediment traps, overall lake dredging is anticipated less often.

The methods, production rates, and unit costs would be similar to that for the initial dredging. In addition, it is assumed that the mooring dolphins in Budd Inlet, used by the scows that transport the material offshore, are already in place for this case. Consequently, only some refurbishment of this mooring facility would be needed on each occasion.

Overall, the unit costs would be similar to those for the initial lake dredge, with slight differences based on different mobilization requirements. For all cases, the maintenance dredging could be carried out within a single in-water work window.

In addition, once the purple loosestrife is eradicated from Capitol Lake, it may become possible to dispose of the material at the Anderson-Ketron Island site. The round-trip distance to Anderson-Ketron Island is 41 nautical miles, compared to 75 nautical miles for Commencement Bay. This decreases the daily cost associated with the hauling tugs – the tugs can make a round-trip in less than an 8-hour day. For comparison, the round-trip to Commencement Bay takes 13 hours. Table 9 gives a daily operations cost for this alternative, while Table 10 gives a typical overall cost.

Table 9. Daily Operations Cost – Hydraulic Dredging to Anderson- Ketron Island

Daily Operation Costs	Daily Cost per Unit	Units	Total Daily Cost
Hydraulic dredge, 16-inch	\$5,200	2	\$10,400
Tender tug, 710 hp, 8-hour day	\$3,500	2	\$7,000
Towing tug, 1,000 hp, 8-hour day	\$6,200	12	\$74,400
Split-hull scow, 1,500 CY, 8-hour day	\$600	12	\$7,200
Booster pump	\$1,600	2	\$3,200
Total daily operation cost			\$102,200

Table 10. Cost of Hydraulic Dredging to Anderson-Ketron Island

Item	Unit	Qty	Unit Cost	Extended Cost (millions)
Mobilization/Demobilization	LS	1	\$700,000	\$0.7
Restore Mooring Piles	LS	1	\$200,000	\$0.2
Pipeline, Booster Pumps, and Tunneling	LS	1	\$200,000	\$0.2
Daily operation costs (Table 9)	DAY	92	\$102,200	\$9.4
Disposal fee, Anderson-Ketron Island	CY	220,000	\$0.45	\$0.1
Construction Cost				\$10.6
Contingency (30%)				\$3.2
WSST (8.9%)				\$0.9
Total Cost				\$14.7

The equivalent unit cost is \$67 per cubic yard.

5.5 Cost Summary and Timeline

The costs associated with the Lake Alternative vary dramatically, depending on whether it is necessary to transport the dredged materials – now and in the future – to a landfill site. The unit costs for maintenance dredging differ slightly from those for initial lake dredging, because of the slightly different mobilization / demobilization requirements.

The unit costs for the different disposal alternatives are as follows.

Initial Lake Dredging:

- Landfill: \$138 per cubic yard;
- Reclamation site: \$74 per cubic yard;
- Commencement Bay: \$93 per cubic yard.

Maintenance Dredging:

- Landfill: \$143 per cubic yard;
- Reclamation site: \$74 per cubic yard;
- Commencement Bay: \$91 per cubic yard;
- Construction fill (sediment traps only): \$58 per cubic yard;
- Anderson-Ketron Island (with purple loosestrife eradicated): \$67 per cubic yard.

Even if landfill disposal is not necessary, an enormous number of different scenarios can be laid out, depending on the quantity of material that settles in the sediment trap, the extent of cement admixture needed to solidify material destined for the reclamation site, whether purple loosestrife is eradicated in the project lifetime, etc. This document does not attempt to cover all these alternatives. To bound the range of potential costs, four summaries are given: three relatively optimistic cases, in which landfill disposal is not necessary, and a worst-case in which it is necessary.

The following sequence of dredging events is assumed:

- Year 0: Initial lake dredging of 875,000 cubic yards.
- All cases except the worst-case: maintenance dredging every nine years over the subsequent 50 years as follows:
 - Year 5: 45,000 cubic yards dredged from the sediment trap;
 - Year 9: 40,000 cubic yards dredged from the sediment trap;
 - Year 9: 230,000 cubic yards dredged from the lake as a whole.
- Worst-case, with all material transported to the landfill site: 210,000 cubic yards dredged every 6 years from the lake as a whole.

The following methods and disposal alternatives are assumed:

- Low-cost case:
 - Initial lake dredging: Disposal at the reclamation site;
 - Maintenance dredging for years 1 through 9: Material from sediment traps placed at a relatively close construction site, at a cost 85 percent of that shown in Table 4; material from overall lake dredging disposed of at the reclamation site.
 - Maintenance dredging for years 10 through 50: Material from sediment traps placed at a relatively close construction site, at a cost 85 percent of that shown in Table 4; material from overall lake dredging disposed of at Anderson-Ketron Island.

- Medium-cost case:
 - Initial lake dredging: Disposal at Commencement Bay;
 - Maintenance dredging: Material from sediment traps placed at a relatively close construction site, at a cost equal to that shown in Table 4; material from overall lake dredging disposed of at Commencement Bay.
- High-cost case: Disposal as for the intermediate-cost case, but costs 30 percent higher.
- Worst-case: All material is transported to a landfill site.

Table 11 gives a cost timeline for these four cases, in 2008 dollars. The costs are very similar (less than 5 percent different) if the sediment traps are eliminated.

Table 11. Cost timelines for the Lake Alternative: 2008 costs, no escalation

Year(s)	Low-Cost (\$millions) ¹	Medium-Cost (\$millions)	High-Cost (\$millions)	Worst-Case (\$millions) ²
0	\$64.8	\$79.6	\$103.5	\$120.8
1-9	\$21.1	\$25.7	\$33.4	\$30.0
10-18	\$19.5	\$25.7	\$33.4	\$60.1
19-27	\$19.5	\$25.7	\$33.4	\$30.0
28-36	\$19.5	\$25.7	\$33.4	\$60.1
37-45	\$19.5	\$25.7	\$33.4	\$30.0
46-50 ³	\$2.2	\$2.6	\$3.4	\$30.0
Total Cost	\$166.1	\$210.7	\$273.9	\$361.0

1. Costs decrease for the low-cost scenario after year 9, because it is assumed purple loosestrife is eradicated.
2. The worst-case scenario assumes a dredging event every 6 years; therefore the costs are not the same for each nine-year period.
3. Costs for this period are less because only a single cycle of dredging in the sediment trap occurs in this five-year period.

Finally, Table 13 gives the cost timelines assuming initial construction in 2015 and escalation of construction costs at 3.5 percent annually. The Net Present Value (NPV) of the total project cost is also given, based on the 2008 Federal interest rate of 4.875 percent.

Table 12. Cost timelines for the Lake Alternative: escalation at 3.5 percent annually, interest rate at 4.875 percent annually

Year(s)	Low-Cost (\$millions)	Medium-Cost (\$millions)	High-Cost (\$millions)	Worst-Case (\$millions)
2015	\$82.4	\$101.3	\$131.7	\$153.6
2016-2024	\$36.1	\$44.0	\$57.2	\$47.0
2025-2033	\$45.4	\$59.9	\$77.9	\$128.7
2034-2042	\$61.9	\$81.7	\$106.2	\$87.2
2043-2051	\$84.4	\$111.3	\$144.7	\$239.1
2052-2060	\$115.0	\$151.7	\$197.2	\$162.0
2061-2065	\$15.8	\$18.5	\$24.1	\$199.1
Total Cost	\$441.0	\$568.5	\$739.0	\$1,016.8
NPV of Total Cost	\$124.9	\$157.5	\$204.7	\$266.0

Note: Numbers may not sum exactly due to rounding.

6. Estuary Dredging: Single Basin

6.1 Overview of Dredging Needs

Under the estuary restoration scenario, Capitol Lake will be dredged before the establishment of tidal flow. Material will be dredged from those areas of the lake due to become the main channel of the restored estuary, and will be placed along Deschutes Parkway to provide intertidal habitat. In addition to the habitat benefits, this will decrease the quantity of navigation dredging required at the marinas in the south end of Budd Inlet and at the Port of Olympia in the years immediately following reintroduction of tidal flow into Capitol Lake.

Figure 22 illustrates the proposed bathymetry after the dredge and fill has occurred, together with the outlines of the dredge and fill areas. Sections across the initial and dredged/filled bathymetry are shown in Figure 23, and dredge and fill quantities are shown in Table 13.

Table 13. Dredge and Fill Quantities for Estuary Alternative

Basin	Area (acres)	Volume (cy)
North Basin – dredge in channel	8.0	42,000
Middle Basin – dredge in channel and shoulders	40.8	352,000
Total Dredge Volume	48.8	394,000
North Basin – place along Deschutes Parkway	25.0	182,000
Middle Basin – place along Deschutes Parkway	30.4	212,000
Total Fill Volume	55.4	394,000

The proposed balanced dredge and fill plan is based on the predicted evolution of the Deschutes Estuary. Figure 24 illustrates the changes in the bathymetry of the lake in the first ten years after removal of the dam and restoration of tidal flow into the estuary, under the assumption that no pre-dredging or material placement takes place (USGS 2008a). The changes in bathymetry can be summarized as follows:

- A more definite main channel is formed through the North and Middle Basins;
- Deposition occurs on both sides of the main channel in the North Basin;
- The shoreline is generally stable or slightly erosional along the west shore of the Middle Basin, adjacent to Deschutes Parkway.

The total dredge and fill volume proposed here is greater than the 180,000 to 360,000 cubic yards assumed in the initial exploration of the proposed pre-dredging (Moffatt & Nichol 2007). This is largely because the previous work was based on the bathymetry three years post-restoration, rather than ten years post-restoration as used here.

A relatively large quantity of sediment – more than needed for protection of Deschutes Parkway – is placed on the west side of the North Basin. The reason for this is to maintain balanced cut and fill quantities, while placing sediment in stable or generally accretional areas. If more material were placed along the longer shoreline of the Middle Basin, much of the additional material would be placed in an erosional area, based on the USGS modeling results.

The east side of the North Basin remains untouched as a deposition area for the future evolution of the estuary – allowing some of the 35,000 annual cubic yards of sediment carried by the Deschutes River to stay within the estuary rather than entering the marina basins in Budd Inlet.

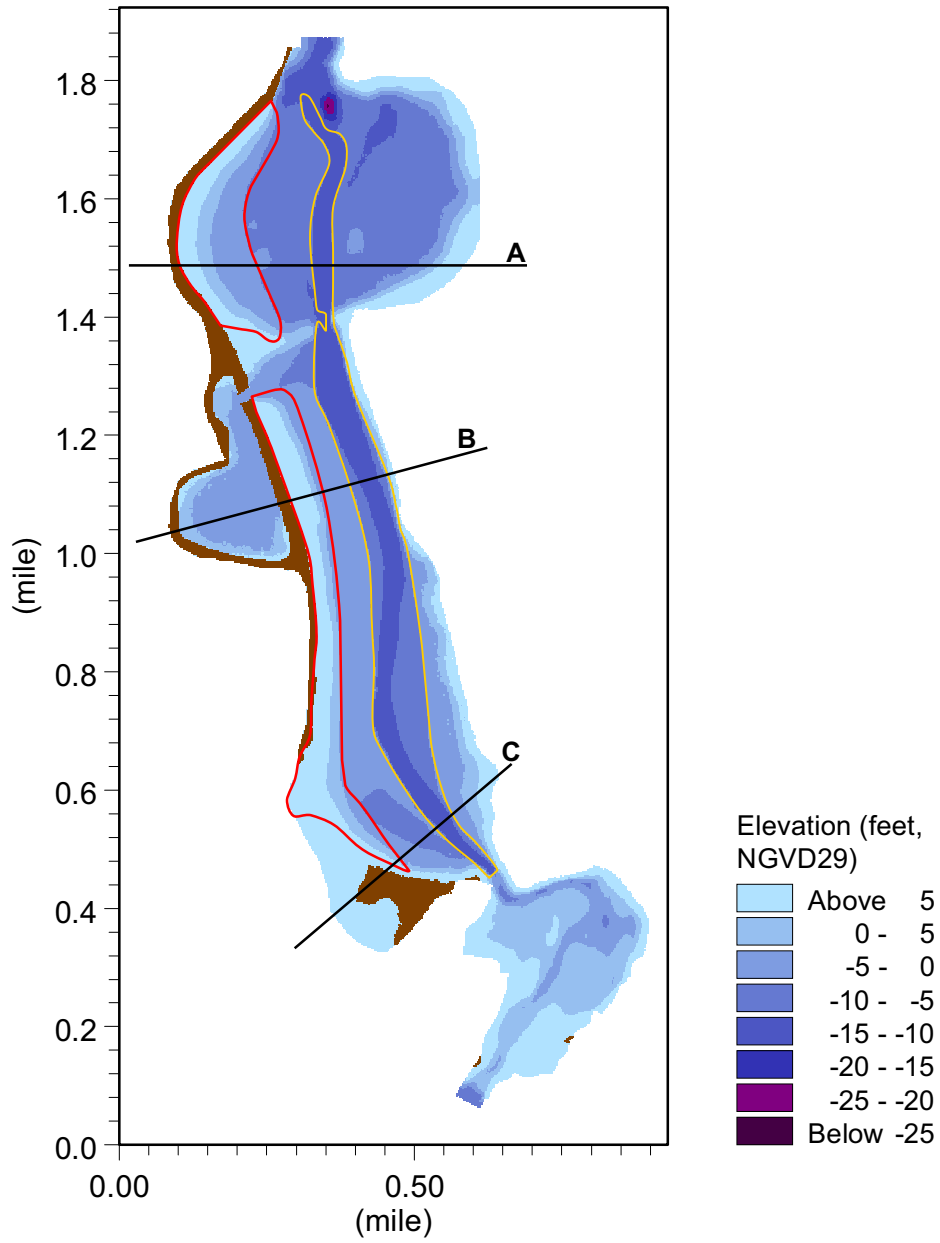
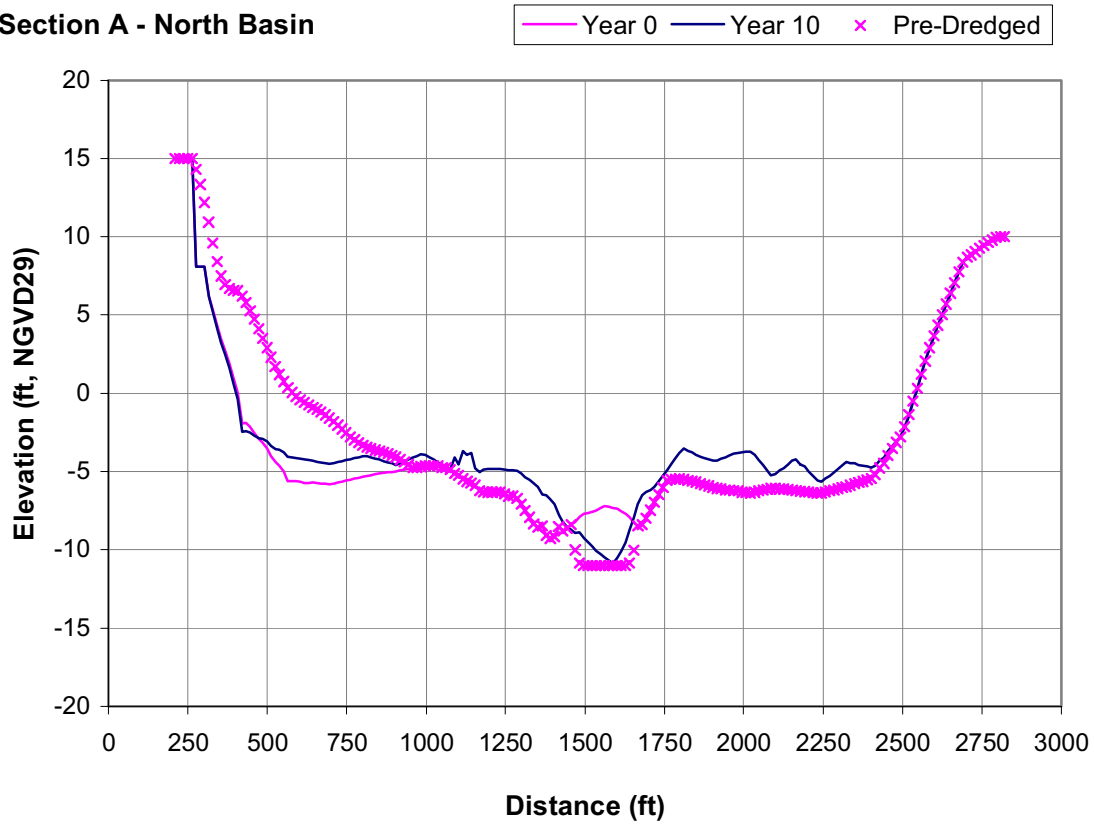


Figure 22. Proposed dredged bathymetry with dredge footprint (yellow line) and fill footprint (red line)

Section A - North Basin



**Section B - Middle Basin
at Causeway**

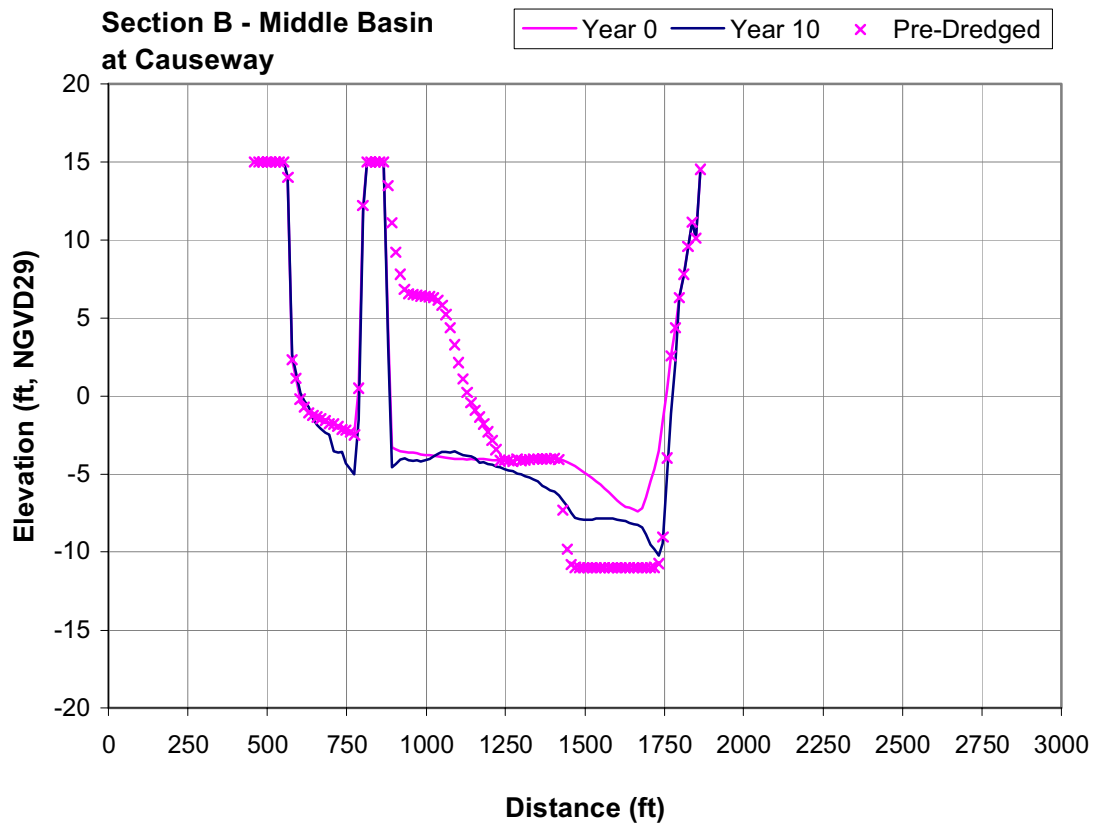


Figure 23. Estuary and dredging sections

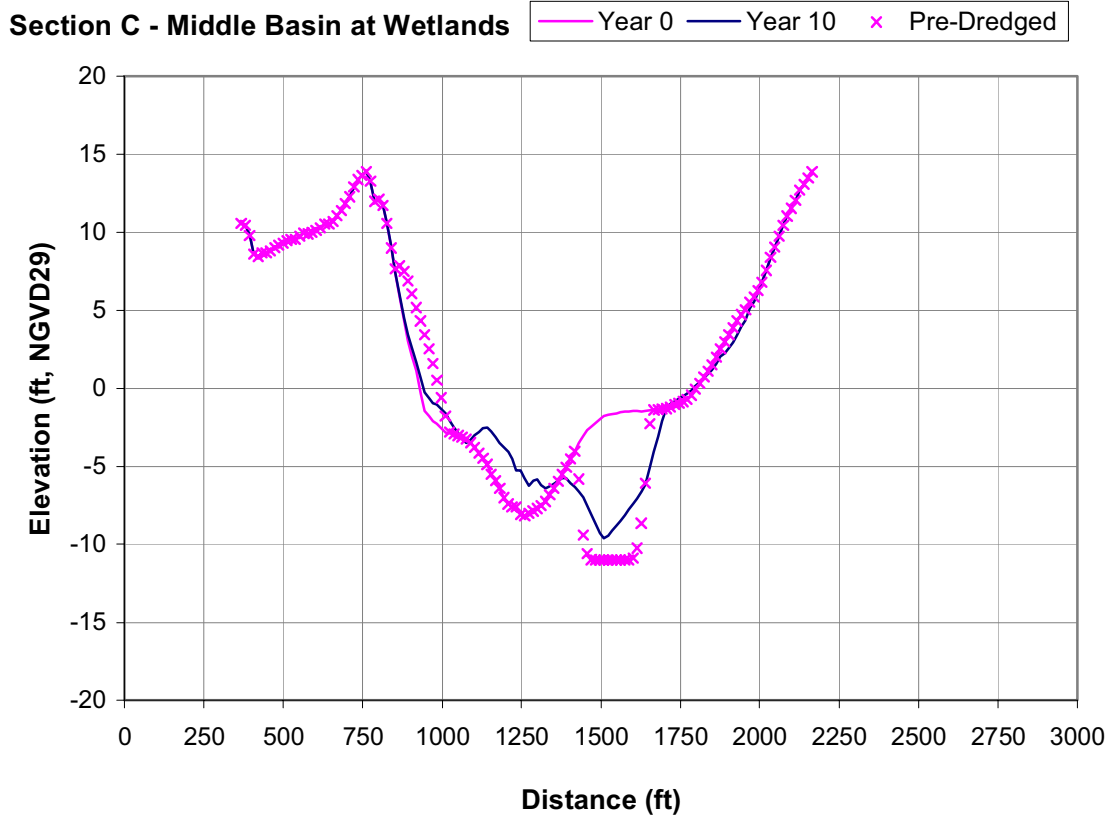


Figure 23 (continued). Estuary and dredging sections

An alternative approach would be to decrease the quantity of material placed on the west side of the North Basin, and to remove some of the material from the lake entirely. For example, modeling and analysis during final design might show that a relatively stable estuary configuration could be attained only if the initial pre-dredging and placement include a net export of material – or that the quantity of material deposited in the marina basins in Budd Inlet would be greatly reduced by exporting material at this stage. If it is possible to dispose of material from Capitol Lake to Commencement Bay, and if further investigations of the material in Budd Inlet shows that only landfill disposal can be permitted for this material, it would almost certainly be cost-effective to remove material from the lake during the initial construction. In this case, because the estuary dredging would be performed before removal of the Capitol Dam, the considerations and methods would be the same as for the lake dredging.

6.2 Dredge Material Disposal

Dredge material disposal is not a significant consideration for the estuary dredging alternative, since the material dredged from the main channel is placed along the west shoreline of the lake. Thurston County’s noxious weeds coordinator has indicated that it will be acceptable for sediment potentially containing purple loosestrife seeds to be moved within the lake footprint (R. Johnson, personal communication, 2008).

If some of the material were to be exported from the lake at the initial pre-dredging phase, the disposal alternatives and considerations would be the same as for the lake dredging alternative. However, at this time there is no reason to consider offsite disposal at the landfill sites.

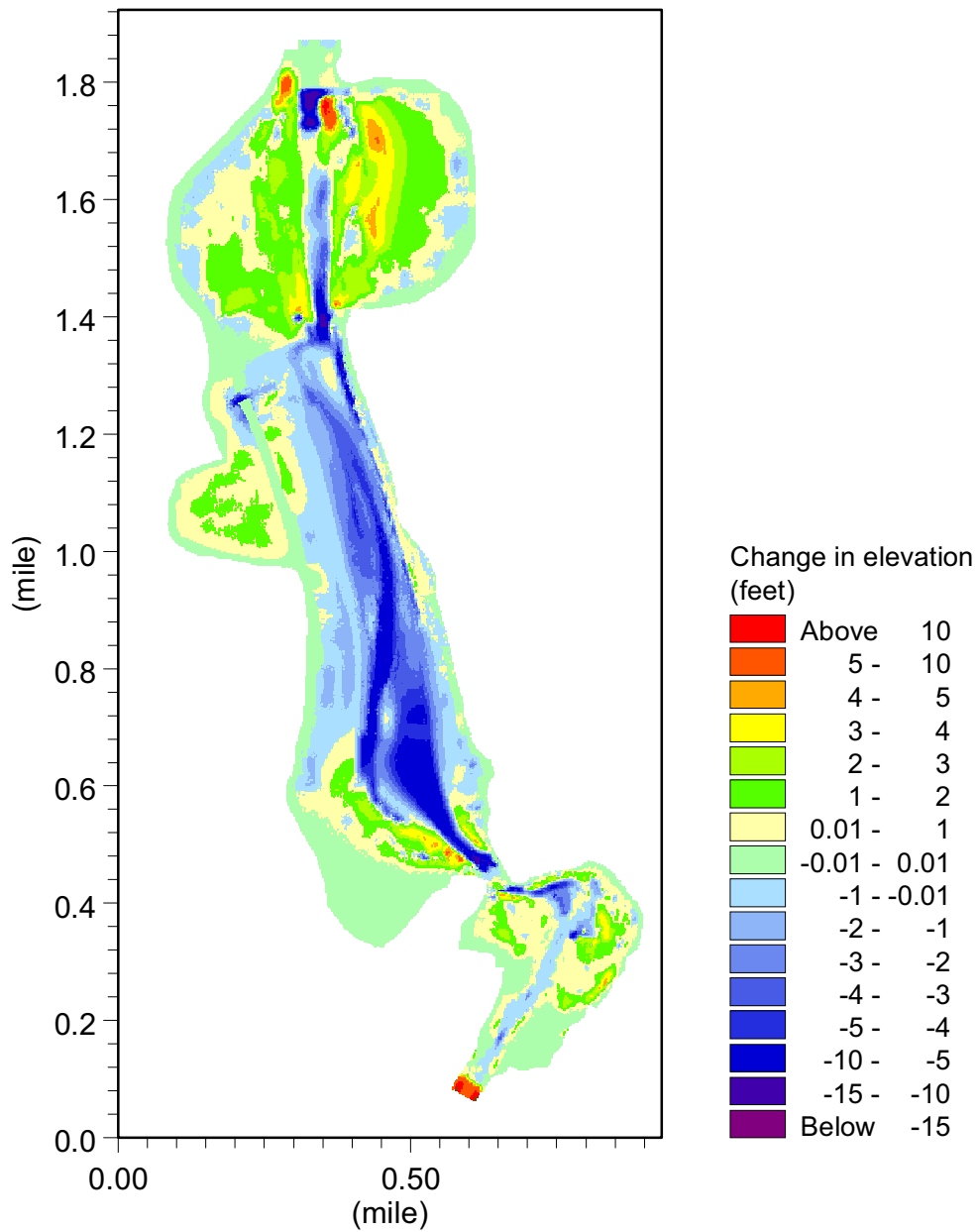


Figure 24. Predicted changes in the bottom elevation of the Deschutes Estuary in the first 10 years, assuming no pre-dredging

6.3 Estuary Dredging Methods and Costs

6.3.1 Overview

The most cost-effective method for the estuary dredging appears to be hydraulic. With mechanical dredging, it would be necessary to rehandle the dredged materials, because a large

fraction of the materials are dredged from the Middle Basin but placed in the North Basin and navigation between the two basins is blocked by the BNSF Railroad Trestle.

With hydraulic dredging, the slurry containing dredged sediment would be pumped from the dredge footprint into the footprint of the fill areas (Figure 22). A barrier would be constructed along the outer perimeter of the fill area to contain the slurry, allowing the sediment to settle out.

6.3.2 Containment Dike / Barrier

One possibility for this barrier is a dike constructed from ecology blocks. Prior to dredging, the lake water level would be lowered to the toe of the proposed fill – about -5 feet relative to NGVD29, or approximately 2 feet above Mean Lower Low Water (MLLW).

Up to 9,000 lineal feet of stacked-block dike will be needed along the shoreline of Capitol Lake. The blocks are 2.5 feet × 2.5 feet × 5 feet long and weigh approximately 4,300 pounds each. The blocks would be stacked two to three high to form a diked area, or settling pond, to receive dredged sediments. Multiple subcells could be laid out to allow more control over the settlement of the sediments. Assuming an excavator can set a single stack of three blocks per hour, for a total distance of 40 feet per day, it could take as much as 225 days (11 months) for one excavator to dike the designated perimeter of the lake. Most likely, two excavators with low-pressure wide-tracks, one working in each lake basin, would start a few weeks ahead of dredging to set dike blocks, with further block setting done concurrently with dredging after that. A geotextile layer with gravel is required as a foundation to minimize the sinking of the blocks in the soft lake bed. A biodegradable material could potentially be used in place of the geotextile.

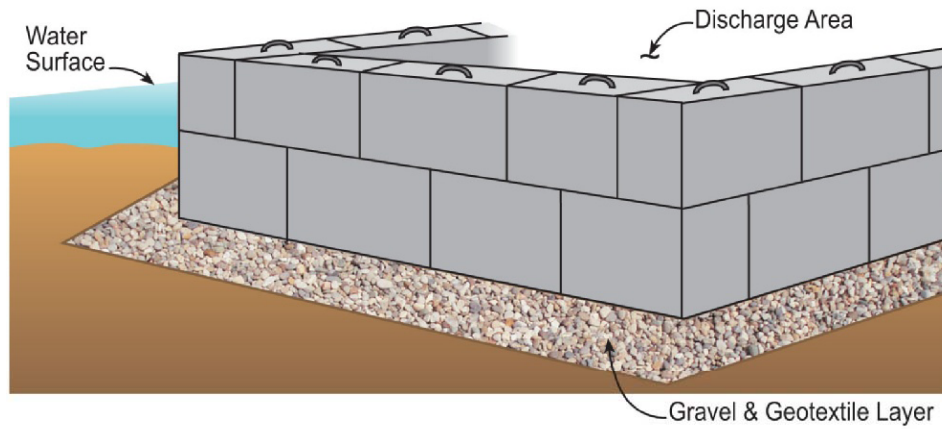
A wide-track bulldozer or excavator will spread the slurry material as it settles out, pulling the materials to the higher parts of the shoreline. Most, but probably not all, of the blocks can be removed for reuse once settling is complete.

A potential problem with this approach is the low bearing capacity of the lake sediments: it is possible that the sediments are so soft that the ecology blocks would sink deeply into the lake bottom. An alternative possibility is to use suspended steel plates or silt curtains to contain the dredge slurry. In this case, it would not be necessary to draw down the lake.

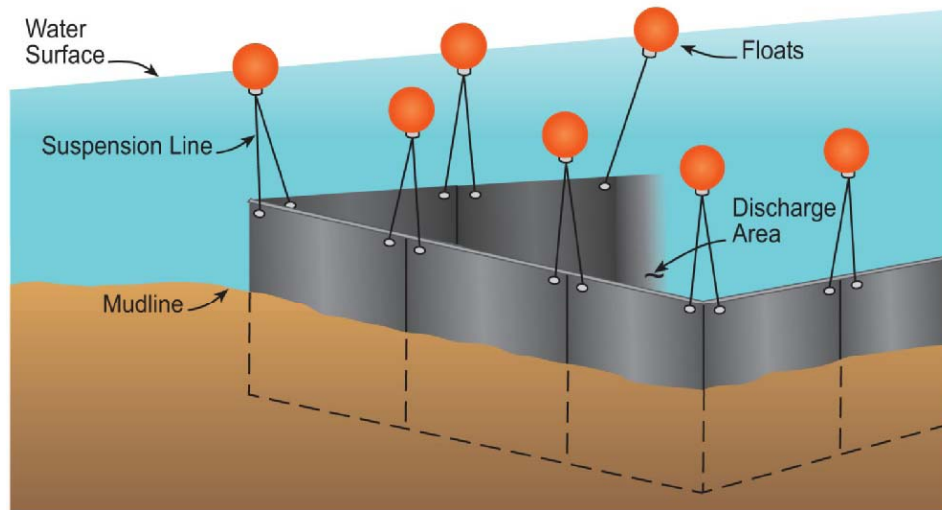
- The suspended steel plate dike consists of steel plates (similar to those that contractors use to cover street trenches) set in a line along the perimeter of the slurry discharge area. The steel plates are suspended from surface floats. The plates and chains are sized so that the lower half of the plate penetrates the soft mud. The suspended upper half of the plate forms the dike to hold the slurry mud in place.
- The silt curtain is an impermeable plastic or fabric sheet suspended in the water column from floats, with a chain attached to the lower edge as a weight. The silt curtain is deployed along the perimeter of the slurry discharge area. The curtain height would be designed so that the chain weight would penetrate into the soft lake bottom a foot or two. Gaps or meshed panels spaced along the upper edge would allow dredge water to return to the lake.

The different diking options are illustrated conceptually in Figure 25. These illustrations assume the slurry discharge area is divided into multiple subcells: this may not be necessary.

ECOLOGY BLOCKS DIKE



SUSPENDED PLATE DIKE



SILT CURTAIN DIKE

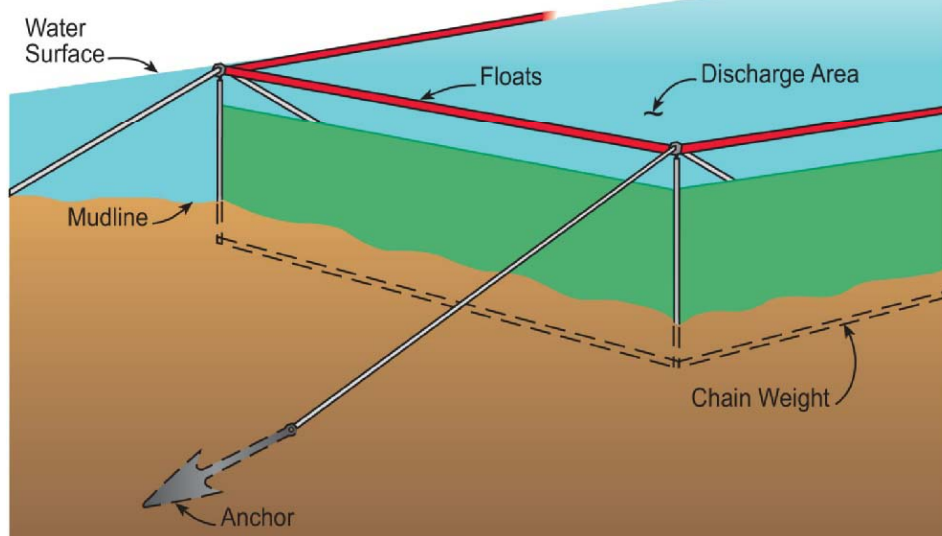


Figure 25. Diking options for the estuary placement

6.3.3 Flocculent

Because the lake sediments are fine, it may take a considerable time for them to settle out of the slurry. To increase the settlement rate, it may be necessary to add a flocculent. One potential flocculent is alum (aluminum sulfate).

Alum is used in water treatment plants to clarify drinking water and remove suspended solids in the water. When alum is mixed with water, aluminum hydroxide is created which then binds with suspended solids precipitating them out (Sutherland 1999). Alum is also used in lakes as a nutrient inactivation product, to reduce the amount of the nutrient phosphorus in the water (Cooke et al. 1993; Welch and Cooke 1999). Alum treatment has been used in several Washington state lakes including Green Lake, Campbell Lake, and Pattison Lake (Herrera 2003).

The toxicity of flocculants such as alum is dependent on pH (Sutherland 1999). In the past it has been assumed that as long as a pH of 6.0 or above was maintained, impacts to aquatic life would be avoided (Cooke et al. 1993). However, further research on the topic may be necessary to verify if this is still the case as more recent studies are beginning to show that other environmental factors may affect aluminum toxicity (Sutherland 1999), especially in fish. Other cationic and anionic polymer flocculants are available, but all flocculants would need to be tested specifically with Capitol Lake sediments for dosage, effectiveness, and toxicity.

The selected flocculent would be pumped into the discharge pipeline about 200 feet from the end of the pipe. The flocculent would mix with the slurry and cause the finer sediments to group together and settle out faster behind the containment dike. The cost of adding flocculent is dependent on the injection or dosing rate which cannot be known without batch testing on actual Capitol Lake sediment slurries.

The use of a flocculent would most likely require a permit from the Department of Ecology. Monitoring and water testing before, during, and after the use of the flocculent may be required for parameters such as pH, alkalinity, and dissolved aluminum.

6.3.4 Sequencing, Schedule, and Costs

Two portable hydraulic dredges (each 16-inch) will be launched into Capitol Lake, one each into the North and Middle Basins.

The discharge pipeline from each dredge will go to the settling pond in its respective lake basin. The settling pond in the North Basin will also need to receive sediment from the Middle Basin. When the middle settling pond is full, the pipeline from the Middle Basin dredge will be rerouted under the BNSF Railroad Trestle to the settling pond in the North Basin. Similarly, after dredging is complete in the North Basin, the dredge will be moved to the Middle Basin.

If the water in the lake is drawn down before the equipment is launched, the launch method will be slightly different from that proposed for the Lake Alternative. One possibility is for the contractor simply to launch before the lake is drawn down – this would tie up the equipment for a week or two while the lake is drawn down. Another possibility would be for the contractor to place metal mats on the shoreline adjacent to the launch site. The dredge would be placed on the mat to avoid sinking into the soft sediments. The dredge would then work its way into the main channel, dredging as it goes.

With an average production rate for each dredge of 170 cubic yards per hour, the overall daily production rate will be 2,400 cubic yards based on an 8-hour shift with 7 hours of effective dredging. This will allow 394,000 cubic yards to be dredged in 165 working days. With a 5-day work week, this is a single in-water work window. However, given the dike building must precede the dredging, it can be expected that a second in-water work window will be needed.

Table 14. Daily Operations Cost – Estuary Dredging

Daily Operation Costs	Daily Cost per Unit	Units	Total Daily Cost
Hydraulic dredge, 16-inch	\$5,200	2	\$10,400
Tender tug, 710 hp	\$3,500	2	\$7,000
Booster pump	\$1,600	2	\$3,200
Bulldozer to smooth settling areas	\$2,200	2	\$4,400
Total daily operation cost – dredging			\$25,000
Excavators	\$3,000	2	\$6,000
Dike foundation mat	\$800	1	\$800
Sacrificial Ecology Blocks	\$200	8	\$1,600
Total daily operation cost – diking			\$8,400

Table 15. Cost of Hydraulic Dredging for Estuary Alternative

Item	Unit	Qty	Unit Cost	Extended Cost (millions)
Mobilization/Demobilization	LS	1	\$0.5M	\$1.3
Pipelines and Booster Pumps	LS	1	\$200,000	\$0.2
Flocculent Treatment (per CY sediment)	CY	394,000	\$5	\$2.0
Daily operation costs (Table 14) – diking	DAY	115	\$8,400	\$1.0
Daily operation costs (Table 14) – dredging	DAY	165	\$25,000	\$4.1
Construction Cost				\$8.6
Contingency (30%)				\$2.6
WSST (8.9%)				\$0.8
Total Cost				\$12.0

The equivalent unit cost is \$30 per cubic yard.

6.4 Permitting and Regulatory Process

The overall impact of this estuary alternative on the environment is anticipated to be positive as the lake will be restored to its natural and historic condition. This suggests that the regulatory agencies will generally be supportive of the project.

The environmental review phase and permitting requirements for this alternative would be similar to that listed for the Lake Dredging Alternative except for the following elements.

- Thurston County Noxious Weed Control Board (TCNWCB) would not be as concerned with the spread of purple loosestrife for this option (R. Johnson, personal communication 2008) as most of the sediments would be contained in the modified estuary.
- The restoration of the Deschutes Estuary would create significant marine shoreline habitat in Budd Inlet for ESA listed species. This improved habitat may be of benefit to GA and other surrounding Budd Inlet facilities in that this credit could be used as mitigation for other Budd Inlet projects, providing a benefit to the local area.

The application of estuary creation for ESA credits in Washington State is very new. Once an estuary has been restored or constructed, mitigation credits can be sold to interested parties or

entities based on agreements negotiated with the federal and state agencies (S. Miller, personal communication 2008). The Port of Everett began selling ESA credits as of June 24, 2008. In the case of Capitol Lake, GA could share or trade mitigation credits to other Budd Inlet entities (Port, City, County, private marinas and other waterfront businesses, etc.).

Maintenance dredging under the estuary alternatives will be in the marinas and port berth of Budd Inlet, rather than within the estuary basin. This ongoing dredging is considered in Section 8.

6.5 Cost Summary

The cost associated with estuary dredging for the single basin scenario is approximately \$12.0 million in 2008 dollars, or \$31 per cubic yard. A more detailed timeline, including this cost and potential variations, is given in Section 8.8, together with the ongoing maintenance dredging in Budd Inlet.

7. Estuary Dredging: Dual Basin

The Dual Basin estuary restoration alternative is similar to the Single Basin alternative, except that a separate reflecting pool will be constructed in the eastern part of the North Basin.

Estuary dredging for the dual basin alternative is essentially identical to that for the Single Basin alternative. The proposed pre-dredging scheme (Figure 22) does not overlap the proposed reflecting pool. Consequently, no changes to the estuary pre-dredging and placement are needed for the Dual Basin alternative.

Because the east side of the North Basin is unavailable for sediment storage under the Dual Basin alternative, it can be expected that more sediment will eventually be transported in the marinas and the Port of Olympia's berth under the Dual Basin alternative compared to the Single Basin alternative. Numerical modeling of hydrodynamics and sediment transport (USGS 2008a) shows only a slight increase in sedimentation over the first three years for the Dual Basin alternative: it can be concluded that the decrease in sediment storage will become apparent only over the long-term. Although the effects of this decrease in storage have not been well quantified, the possibility of moving a portion of the dredged material off-site should be considered seriously for the Dual Basin alternative.

8. Marina and Port Dredging

8.1 Background

The marinas and transient docks in West Bay, from south to north, include the Olympia Yacht Club, Percival Landing, Martin Marina, One Tree Island Marina, Fiddlehead Marina, and the Port of Olympia recreational docks, all on the east side of Budd Inlet's West Bay; and West Bay Marina on the west side of Budd Inlet (Figure 2). The history of maintenance dredging in this area, and the concerns of the marina owners and operators, as well as the Port of Olympia, were discussed at a recent meeting called by General Administration (General Administration 2008) and in a telephone conversation with the owner of the Fiddlehead Marina (Wubbena, personal communication 2008).

This document refers to the Olympia Yacht Club, Percival Landing, Martin Marina, One Tree Island Marina, and the Fiddlehead Marina as "the marinas." Since (as described below) it is anticipated that dredging in West Bay Marina will not be significantly increased by the estuary restoration, this marina is not considered further.

The marinas have not required significant maintenance dredging over the past few decades. Martin Marina, One Tree Island Marina, and Fiddlehead Marina were dredged at various times in the 1980s, in the course of reconfiguration and expansion. Slow ongoing sedimentation has occurred near the shorelines, such that dredging is now becoming desirable in many areas – generally, for the first time in twenty years. Sedimentation has been relatively rapid at the southwestern corner of the Olympia Yacht Club (J. Lengenfelder, personal communication 2008). Percival Landing (City of Olympia) is currently considering dredging approximately 4,500 cubic yards of sediment from under their docks in the next several years. This is part of a major enhancement of the public areas of West Bay. More information on this project will be available in September 2008.

In a similar vein, the Port of Olympia wishes to dredge its West Bay berths 2 and 3, last dredged in 1979 (Port of Olympia 2006). The Corps maintains the channel into the Port of Olympia at -40 feet MLLW. The Corps last dredged 106,000 cubic yards from the channel in spring 2007, with the material going to Anderson-Ketron Island disposal site.

The main concerns of the marina operators are:

- How often would West Bay marinas need to conduct maintenance dredging in the future?
- What is the cost-benefit of each alternative for this project? Specifically, how would the two Estuary Alternatives impact the marinas, City facilities (Percival Landing and shoreline parks), and the Port's terminals?

This report only attempts a partial answer to these questions. Specifically, the report does not address costs associated with impacts to marina operations during dredging – e.g., the need to relocate boats while their slips are being dredged.

8.2 Anticipated Dredging Needs

On average, the Deschutes River delivers 35,000 cubic yards of sediment annually to Capitol Lake (USGS 2006). This material will eventually make its way through the estuary and will settle out in Budd Inlet. This deposition of material will have an impact on the future maintenance dredging needs of the various marinas and the Port facilities.

In the short term (three years after restoration) and the medium term (up to 15 years) the sedimentation rate in the marinas and the Port facilities will be greater than 35,000 cubic yards

per year. Even with the recommended pre-dredging of the main estuary channel, a significant fraction of the sediment stored in Capitol Lake will be swept into Budd Inlet as the estuary bathymetry evolves. Recent estimates of deposition within Budd Inlet (USGS 2008a) are as follows:

- Within three years of estuary restoration: 90,000 cubic yards at the Port of Olympia's West Bay Berth and 70,000 cubic yards at the marinas. This assumes that the pre-dredging described in Sections 6 and 7 does take place: otherwise the 3-year dredging approximately doubles.
- Between three and ten years after estuary restoration: 35,000 to 40,000 cubic yards per year at the Port of Olympia, and about 20,000 cubic yards per year at the marinas.
- In the long term (beyond the 10 year maximum modeling horizon of the USGS): this document assumes that the sedimentation rate will drop to 15,000 cubic yards per year each in the Port of Olympia and at the marinas.

Figure 26 illustrates the pattern of sedimentation predicted by USGS 2008a after three years. Based on these modeling results, we make the following plausible assumptions regarding dredging in the marinas and at the Ports:

- After 3 years:
 - 35,000 cubic yards at the Olympia Yacht Club;
 - 35,000 cubic yards collectively at the other West Bay marinas;
 - 90,000 cubic yards at the Port of Olympia.
- After 6, 9, 12, 15, and 18 years:
 - 30,000 cubic yards at the Olympia Yacht Club;
 - 30,000 cubic yards collectively at the other West Bay marinas;
 - 120,000 cubic yards at the Port of Olympia.
- Every 6 years subsequently:
 - 45,000 cubic yards at the Olympia Yacht Club;
 - 45,000 cubic yards collectively at the other West Bay marinas;
 - 90,000 cubic yards at the Port of Olympia.

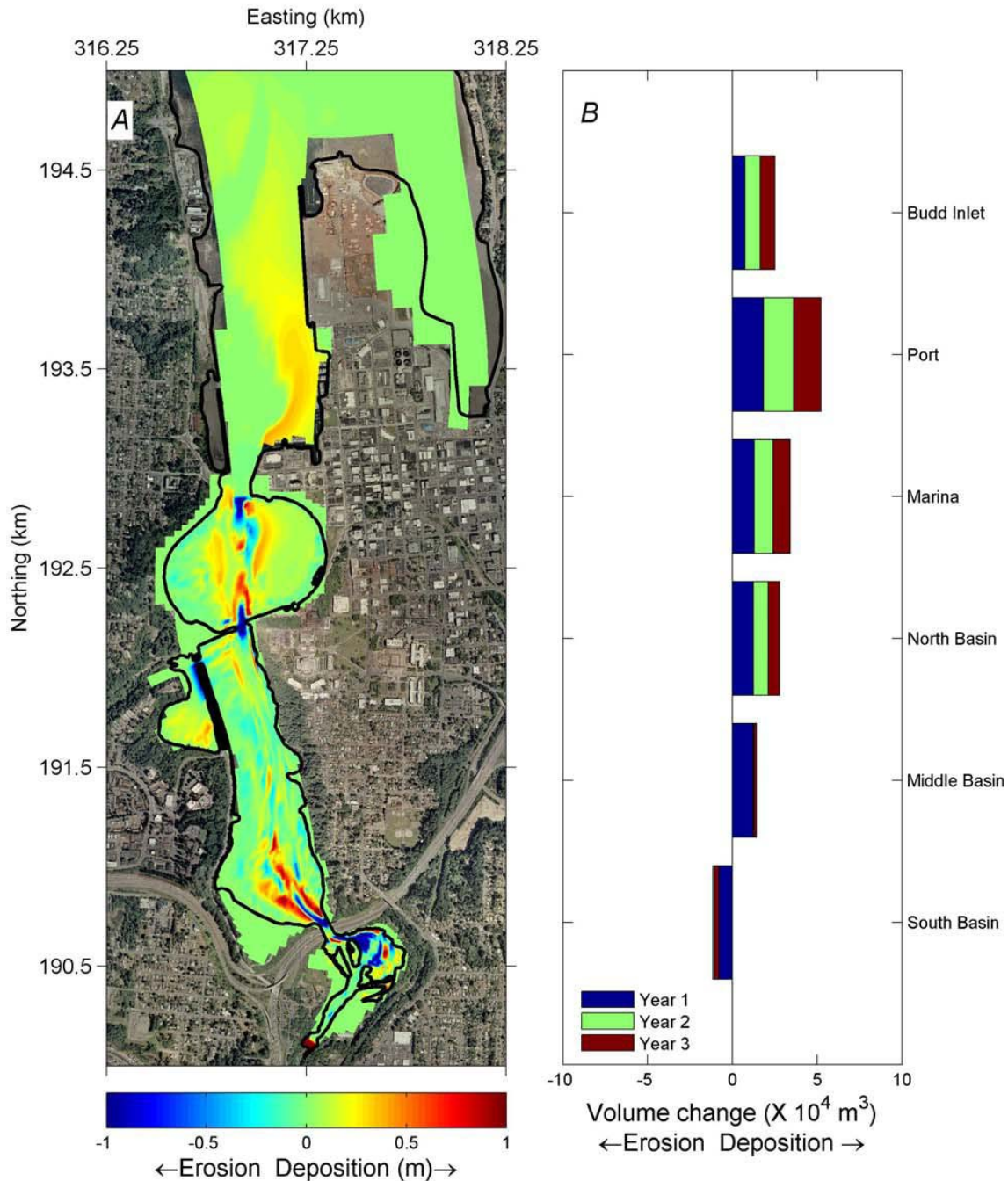


Figure 26. Anticipated erosion and deposition three years after estuary restoration: single basin (Source: USGS 2008a).

8.3 Dredge Material Characteristics

Sediments in Capitol Lake are sandy silt with purple loosestrife seeds intermixed. The sediments that have been dredged in the past from the marinas in Budd Inlet are of a sandy silt, with some dioxin contamination – at least some of these materials are likely to have dioxin levels beyond that permitted for open water disposal. Sediments dredged from the deep channel of Budd Inlet in 2007 were suitable for disposal at Anderson-Ketron Island.

Material dredged from the Fiddlehead Marina in the past has been contaminated with organic materials, believed to be due to a combined sewer overflow discharge pipe on the site (Wubbena 2008).

8.4 Dredge Material Disposal

The dredge material disposal options are determined by the sediment characteristics.

- Clean sediments (sufficiently low levels of dioxins, furans, and other chemical contaminants and without purple loosestrife seeds) may go to the Anderson-Ketron Island disposal site.
- Clean (uncontaminated) sediments, but containing purple loosestrife seeds, could potentially be transported to the Commencement Bay open water disposal site. Since the seeds would already be within Budd Inlet at this stage, it is possible that such material could be used for nearshore restoration or beneficial reuse within Budd Inlet, or even to Anderson-Ketron Island. This material could also go to the Centralia reclamation site.
- If contaminated, the sediments must go to either Rabanco's Roosevelt Landfill or Waste Management's Columbia Ridge Landfill.

At the recent meeting called by General Administration (General Administration 2008) to discuss dredging in Budd Inlet, one other possibility was discussed: to use sediments as fill to extend the Port peninsula further north. It is possible that the improvement in open-water habitat introduced by an estuary restoration project could be considered adequate mitigation for landfill.

8.5 Permitting and Regulatory Process

Any increased sedimentation in Budd Inlet resulting from the removal of the Capitol Lake dam would need to be explained in the project EIS for the Estuary Dredging alternatives.

Any future maintenance dredging for each West Bay facility would also need to undergo separate environmental review prior to being completed; however, a full EIS would most likely not be required. Maintenance dredging is often SEPA exempt or, at most, could be determined as nonsignificant.

Future maintenance dredging for any of these facilities would also require all of the necessary in-water permits and approvals similar to those identified for the Lake Dredging alternative in Section 5.2.

If resolution to Ecology's concerns over how to deal with the dioxin/furans in Budd Inlet have not yet been identified or decided upon by the time some of these facilities need to complete maintenance dredging, permitting may require more extensive sediment testing than normally required and the disposal of sediments may also be more difficult and expensive.

8.6 Cleanup of Budd Inlet

Currently Ecology is conducting a harbor-wide investigation of the sediments in Budd Inlet, with specific interest in dioxin/furan levels. Additional sampling in much of Puget Sound is scheduled to occur in 2008 to assist Ecology in determining what cleanup levels, if any, for dioxins/furans is required within Puget Sound.

Both the Port of Olympia, as part of the permitting for their berth dredging project, and the City of Olympia are currently negotiating cleanup agreements with the Department of Ecology. The City is negotiating a cleanup agreement which relates only to the west side of Budd Inlet's West

Bay (D. Hanna, personal communication 2008). It is likely that cleanup will be needed for some or all of the marinas concerned in Budd Inlet.

If contaminated materials are not removed from Budd Inlet before the estuary restoration, these sediments would be intermingled with sediment from the estuary. Because separating these two types of sediments would be difficult, this intermingled sediment could well be unsuitable for open-water disposal in its entirety – and could be required to go to more expensive disposal sites. If, however, a cleanup plan was identified and completed prior to the need for maintenance dredging, any sediment deposited from Capitol Lake may be suitable for open-water disposal, which could result in an overall cost saving. Close coordination with the City, Port, the many marina operators, USACE, Ecology, and the other regulatory agencies involved with the many dredging projects planned for Budd Inlet would be of significant value to all involved and could result in the most cost effective and practical solution for the area.

Because the eventual need for cleanup is independent of the estuary restoration project, the costs of cleanup are not included in this report. However, those costs could be substantial. For example, if 100,000 cubic yards must be removed from Budd Inlet at a unit cost of \$140 per cubic yard (similar to upland disposal of the lake sediment), the cost would be \$14 million.

8.7 Construction and Material Handling

8.7.1 Marinas

The uncovered moorage at the West Bay marinas will be dredged mechanically. The first step will be to relocate the boats in each section, so the dredge can access the slips. The boats could potentially be moved to the transient moorage at Percival Landing; in the short term to Swantown Marina; or they could be rafted.

The uncovered marina fairways are typically not more than 40 feet wide. Allowing for close maneuvering, this limits the beam of mechanical dredge equipment, and attendant dump barges, to about 30 feet. Mechanical dredges on barges of this size have track-mounted lattice boom cranes in the 100- to 200-ton capacity with buckets in the 1 to 3 cubic yard size range. A typical production rate for a 3-cubic yard dredge is 115 cubic yards per hour. Given the narrow maneuvering, a more likely production rate is 100 cubic yards per hour. Based on an 8-hour shift with 6 hours of effective dredging per day, the likely dredging rate will be on the order of 600 cubic yards per day.

The operation might proceed as follows:

- After mobilization to the site, the mechanical dredge, consisting of a barge-mounted crane with a clam shell bucket, will drop the bucket to the bottom;
- The bucket will scoop up sediment;
- The crane will bring the bucket to the surface and swing the bucket over the uncovered (and empty) docks, and deposit the sediment in the attendant dump barge;
- As each barge is filled, it will be moored temporarily and the second barge brought into service;
- At the end of the day, the full barges will be towed to the open-water disposal site at Anderson-Ketron Island.

Covered moorage at the Olympia Yacht Club will require a combination of mechanical and hydraulic dredging equipment. The fairways can be dredged using a mechanical dredge in the same way as the uncovered moorages just described. However, a hydraulic dredge will be needed

in and under the covered moorage. The reason is that hydraulic dredges have a lower profile, which allows them to get under the roofline. The crane on a mechanical dredge effectively rules this out.

A small (no larger than 12-inches) hydraulic dredge with cutterhead or augerhead will be used in and under the covered moorage. The dredging rate for the hydraulic dredge will most likely be on the order of 400 cubic yards per day, due to the constant moving between boathouses and the potential for debris to clog the pump. It can be expected that the first dredging event will be the slowest and most costly, since debris has built up over the years.

As with the mechanical dredges, the vessels will be relocated from the boathouses in order to provide the hydraulic dredge access to the moorage. The main difference in the operation is that the hydraulic dredge generates a slurry, which has a greater volume than the material generated by the mechanical dredge. With a water content by volume of between 80 and 85 percent, the quantity of slurry produced will be between 2,000 and 2,700 cubic yards per day.

Six to eight scow-loads or barge-loads, each of 500 cubic yards, will be generated and towed to Anderson-Ketron Island daily while the hydraulic dredge is operating in parallel with the mechanical dredge; two will be generated once only the mechanical dredge is in operation. A relatively large tug will be used and will tow two of the 500 cubic yard barges or scows to the disposal site. A smaller tug is used to move the scows between the marina and the towing tugs.

After the first three years, it is assumed that 10,000 cubic yards will be dredged mechanically from the fairways and uncovered areas in the Yacht Club; 35,000 cubic yards will be dredged mechanically from the other marinas; and 25,000 cubic yards will be dredged hydraulically from the covered moorages in the Yacht Club. Based on the production rates of 600 cubic yards per day and 400 cubic yards per day for mechanical and hydraulic dredging respectively, this would take 75 days for mechanical and 63 days for hydraulic dredging. The costs are broken out in Table 16 and Table 17. The costs for mobilization and demobilization are much less for dredging in Budd Inlet compared to the lake-bound dredging alternatives considered previously, because it is not necessary to launch large equipment in the lake.

Table 16. Daily Operations Costs for Marina Dredging

Daily Operation Costs	Daily Cost per Unit	Units	Total Daily Cost
Hydraulic dredge, 12-inch, on barge	\$3,800	1	\$3,800
Mechanical dredge, 3 CY clamshell on barge with 200-ton crane	\$5,000	1	\$5,000
Towing tug, 1,000 hp, 8-hour day	\$6,200	3	\$18,600
Tender tug, 300 hp, 8-hour day	\$3,500	2	\$7,000
Scow, 500 CY	\$600	6	\$3,600
Total daily operation cost – two dredges			\$38,000
Mechanical dredge, 3 CY clamshell on barge with 200-ton crane	\$5,000	1	\$5,000
Towing tug, 1,000 hp, 8-hour day	\$6,200	1	\$6,200
Tender tug, 300 hp	\$3,500	2	\$7,000
Scow, 500 CY	\$600	2	\$1,200
Total daily operation cost – one dredge			\$19,400

Table 17. Cost of Dredging at 3-Years for Marinas

Item	Unit	Qty	Unit Cost	Extended Cost (millions)
Mobilization/Demobilization	LS	1	\$100,000	\$0.1
Daily operation costs, 2 dredges (Table 16)	DAY	63	\$38,000	\$2.4
Daily operation costs, 1 dredge (Table 16)	DAY	12	\$19,400	\$0.2
Disposal fee, Anderson-Ketron Island	CY	70,000	\$0.45	< \$0.1
Construction Cost				\$2.8
Contingency (30%)				\$0.8
WSST (8.9%)				\$0.2
Total Cost				\$3.8

The unit cost averaged over hydraulic and mechanical dredging is \$55 per cubic yard. The hydraulically dredged material is relatively expensive, at about \$67 per cubic yard. This is due to the low production rate, which results from the confined operations within the covered moorings and the potential for debris in the sediment that may clog the intakes. In addition, the large amount of slurry produced increases the disposal costs. This unit cost may decrease after the first dredging event, in that the quantity of debris will be lower. The cost for the mechanically dredged material is approximately \$48 per cubic yard.

8.7.2 Port

The main channel leading to the docks at the Port of Olympia will continue to be maintained by the U.S. Army Corps of Engineers; this report assumes the additional dredging associated with the estuary restoration will occur in the Port's berth. It is anticipated any such dredging will be done using mechanical dredge equipment (barge-mounted derrick crane with a clam shell bucket). Dredged material will be placed on material barges/scows and, if clean, towed to either Anderson-Ketron Island or Commencement Bay for disposal. If contaminated, the material will be brought to the dock and transferred to railcars for hauling and dumping at either the Roosevelt or Columbia Ridge landfills.

The Port docks, which are open-faced docks, can use larger mechanical dredge equipment than the marinas. A large barge-mounted derrick crane with clamshell bucket up to 15 cubic yards is feasible at the Port. This means that dredging rates will be on the order of 2,500 to 3,000 cubic yards per day.

To dredge the 90,000 cubic yards of sediments at the Port after the first three years at a dredge rate of 2,500 cubic yards per day means allowing 36 days to complete the dredging. To keep up with the dredging rate of up to 2,500 cubic yards per day, two dump scows will be needed. One scow will be loading while the second one is being towed and dumped. A single tug can make one round-trip to Anderson-Ketron Island in an 8-hour working day.

Table 18. Daily Operations Costs for Port Dredging

Daily Operation Costs	Daily Cost per Unit	Units	Total Daily Cost
Mechanical dredge, 15 CY clamshell on barge with 200-ton crane	\$5,000	1	\$5,000
Towing tug, 1,000 hp, 8-hour day	\$6,500	2	\$13,000
Split-hull scow, 1,500 CY, 8-hour day	\$1,000	2	\$2,000
Total daily operation cost – one dredge			\$20,000

Table 19. Cost of Dredging at 3-Years for Port Berth

Item	Unit	Qty	Unit Cost	Extended Cost (millions)
Mobilization/Demobilization	LS	1	\$100,000	\$0.1
Daily operation costs (Table 18)	DAY	36	\$20,500	\$0.7
Disposal fee, Anderson-Ketron Island	CY	90,000	\$0.45	< \$0.1
Construction Cost				\$0.9
Contingency (30%)				\$0.2
WSST (8.9%)				\$0.1
Total Cost				\$1.2

The unit cost is \$13 per cubic yard – divided approximately equally between dredging and disposal.

8.7.3 Contaminated Materials

If any of the sediments are contaminated, that portion of the dredging will need to go upland to a landfill. One possibility would be for the mechanically dredged sediments to be brought to dock at the Port and transferred to railcars for hauling and dumping at either the Roosevelt or Columbia Ridge landfills. Barges containing the contaminated materials will be towed the short distance to the Port dock and unloaded with a front-end loader, excavator, or crane and clamshell. If this is expected to be a regular occurrence, it would be useful to lay new rail trackage at the Port so that the sediment can be transferred directly from the barges to the railcars without additional rehandling.

Unless they can be moved, the covered moorage areas – including the Yacht Club – will have to be dredged using hydraulic dredging equipment. The hydraulically dredged material would be pumped to a settling basin at the Percival Cove gravel pit, or potentially at the Port, for dewatering. After dewatering, the sediment may be loaded onto railcars for hauling to a landfill for final disposal.

Costs are anticipated to be approximately \$100 to \$120 per cubic yard for mechanically dredged material at the Port, and \$150 per cubic yard for the combination of mechanically and hydraulically dredged material at the Olympia Yacht Club. Given the quantities of contaminated material are not known, the methods and schedules are not given here.

8.8 Cost Summary and Timeline

As with the Lake Alternative, four cost timelines are considered. The dredging quantities are as given in Section 8.2. The timelines are based on the following unit costs:

- Estuary pre-dredging: basic cost is \$23 per cubic yard; it is possible that some material will be transported to a landfill site at a cost of \$136 per cubic yard, similar to the lake dredging alternative.
- Marina and Yacht Club dredging: \$60 per cubic yard based on offsite disposal at Anderson-Ketron Island, \$150 per cubic yard for any material transported to a landfill site.
- Port dredging: \$11 per cubic yard based on offsite disposal at Anderson-Ketron Island, \$120 per cubic yard for any material transported to a landfill site.

The dredging scenarios are as follows:

- Low-cost:
 - Initial estuary dredging and placement along Deschutes Parkway, with costs at 85 percent of those given above (see also Table 15);
 - Initial maintenance dredging at 3 years with disposal at Anderson-Ketron Island;
 - Subsequent maintenance dredging with disposal at Anderson-Ketron Island, with costs at 85 percent of those given above.
- Medium-cost:
 - Initial estuary dredging and placement along Deschutes Parkway, with costs as given above;
 - Initial maintenance dredging at 3 years with 95 percent of the material disposed at disposal at Anderson-Ketron Island and 5 percent at a landfill site;
 - Subsequent maintenance dredging with disposal at Anderson-Ketron Island, with costs as given above.
- High-cost:
 - Initial estuary dredging with 95 percent of the material placed along Deschutes Parkway, with costs 30 percent higher than given above; 5 percent of the material disposed at a landfill site;
 - Maintenance dredging costs 30 percent higher than the medium-cost case.
- Worst-case:
 - Initial estuary dredging with 80 percent of the material placed along Deschutes Parkway, with costs 30 percent higher than given above; 20 percent of the material disposed at a landfill site;
 - Maintenance dredging in years 3 and 6 require disposal at a landfill site;
 - Maintenance dredging in year 9 requires disposal at a landfill site for 50 percent of the material, and as the high-cost case for the other 50 percent;
 - Subsequent maintenance dredging as the high-cost case.

Table 20 gives the costs for these four alternatives, in 2008 dollars (no escalation).

Table 20. Cost timelines for the Estuary Alternative with marina and port dredging: 2008 costs, no escalation

Year(s) ¹	Low-Cost (\$millions)	Medium-Cost (\$millions)	High-Cost (\$millions)	Worst-Case (\$millions)
0	\$10.2	\$12.0	\$15.0	\$26.8
1-9	\$13.3	\$15.6	\$20.2	\$59.6
10-18	\$8.3	\$9.7	\$12.6	\$12.6
19-27	\$10.4	\$12.2	\$15.9	\$15.9
28-36	\$5.2	\$6.1	\$8.0	\$8.0
37-45	\$10.4	\$12.2	\$15.9	\$15.9
Total Cost	\$57.8	\$67.9	\$87.6	\$138.8

1. Costs are given per nine-year period, consistent with the Lake Dredging results in Table 11. No dredging occurs in years 46-50, so these years are not shown. Numbers may not sum exactly due to rounding.

Finally, Table 21 gives construction costs based on an initial construction date of 2015 and escalation at 3.5 percent annually. The Net Present Value (NPV) of the total project cost is also given, based on the 2008 Federal interest rate of 4.875 percent.

Table 21. Cost timelines for the Estuary Alternative with marina and port dredging: escalation at 3.5 percent annually, interest rate at 4.875 percent annually

Year(s)	Low-Cost (\$millions)	Medium-Cost (\$millions)	High-Cost (\$millions)	Worst-Case (\$millions)
2015	\$13.0	\$15.3	\$19.1	\$34.1
2016-2024	\$20.7	\$24.3	\$31.5	\$92.4
2025-2033	\$16.7	\$19.7	\$25.6	\$25.6
2034-2042	\$30.4	\$35.7	\$46.5	\$46.5
2043-2051	\$20.6	\$24.2	\$31.5	\$31.5
2052-2065	\$56.4	\$66.4	\$86.3	\$86.6
Total Cost	\$157.9	\$185.6	\$240.5	\$316.5
NPV of Total Cost	\$42.4	\$49.9	\$64.2	\$108.5

Note: Numbers may not sum exactly due to rounding.

9. References

- Austin, R.S. 2004. Solidification/Stabilization Treatment of Dredged Material from the Port of San Diego. Available online at < http://www.cement.org/waste/wt_apps_san_diego.asp>. Viewed August 14 2008.
- Bachmeier, J. 2008. Personal communication. Telephone conversation between Joe Scott, Moffatt & Nichol, and Jim Bachmeier, Thurston County (360-357-2491) on 23 July 2008.
- Baker, T. 2008. Personal communication. Telephone conversation between Margaret Schwertner, Moffatt & Nichol, and Thomas Baker, Washington State Department of Transportation (360-709-5401), 20 June 2008.
- Burke, J. 2008. Personal communication. Telephone conversation between Margaret Schwertner, Moffatt & Nichol, and Jamie Burke, Cedar Grove Composting (425-432-2395). Maple Valley, WA. 27 June 2008.
- Capitol Lake Adaptive Management Plan (CLAMP) Steering Committee. 1999. Capitol Lake Adaptive Management Plan – 1999 to 2001.
- Capitol Lake Adaptive Management Plan (CLAMP) Steering Committee. 2000. Capitol Lake Adaptive Management Plan Phase I Task 11 – Sediment Management: Answers to technical Questions. July 2000.
- Capitol Lake Adaptive Management Plan (CLAMP) Steering Committee. 2002. Capitol Lake Adaptive Management Plan. A Vision for the Next Ten Years – 2003 to 2013.
- Capitol Lake Adaptive Management Plan (CLAMP) Technical Work Group. 2007. Technical Work Group notes, December 18, 2007.
- Cooke, G., E. Welch, S. Peterson, and P. Newroth. 1993. Restoration and Management of Lakes and Reservoirs. Boca Raton, Florida: CRC Press LLC.
- Dredged Material Management Program (DMMP). 2008a. Available online at <<http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=dmmo&pagename=home>>. Viewed August 4, 2008.
- Dredged Material Management Program (DMMP). 2008b. Evaluation and Disposal Procedures (User's Manual). Prepared by the Dredged Material Management Office – US Army Corps of Engineers – Seattle District. July 2008.
- Entranco, Inc. 1997. Technical Memorandum – 1991-1996 Capitol Lake Survey – Sediment Volume Calculations. Memorandum from David Morency to Nick Cockrell, Washington State Department of General Administration. March 5, 1997.
- Entranco, Inc. 2000a. Capitol Lake Adaptive Management Plan 1999 to 2001. Phase One – Task 11 Sediment Management: Answers to Technical Questions. July 2000.
- Entranco, Inc. 2000b. Capitol Lake Adaptive Management Plan 1999 to 2001. Phase One – Task 3 Hydraulic Scour Analysis. April 2000.
- ESA/Adolfson. 2008. Draft Lacey, Olympia, and Tumwater Shoreline Analysis & Characterization Report. Prepared for: Thurston Regional Planning Council. June 2008.
- General Administration (GA). 1996. Draft Supplemental Environmental Impact Statement. Capitol Lake Restoration and Recreation Plan: Revised Sediment Removal Plan. February 16, 1996.

- General Administration (GA). 2002. Capital Lake Adaptive Management Plan. A Vision for the Next Ten Years 2003-2013. Washington State Department of General Administration. October 2002.
- General Administration (GA). 2008. Capitol Lake Alternatives – Meeting with Budd Inlet Marinas. June 27, 2008.
- Hanna, D. 2008. Personal communication. Telephone conversation between Margaret Schwertner, Moffatt & Nichol, and D. Hanna, City of Olympia (360-753-8020), 10 July 2008.
- Hartman, G. 2008. Personal communication. Telephone conversation between Joe Scott, Moffatt & Nichol, and Greg Hartman, Dalton, Olmsted & Fuglevand, Inc. (360-692-7345), 14 August 2008.
- Haubrich, G. 2008. Personal communication. Telephone conversation between Margaret Schwertner, Moffatt & Nichol, and G. Haubrich, Washington State Department of Agriculture (509-225-2604), 9 July 2008.
- Herrera Environmental Consultants. 2000a. Capitol Lake Adaptive Management Plan – Sediment Characterization Report. Prepared for Entranco, Inc. and Washington State Department of General Administration.
- Herrera Environmental Consultants. 2000b. Capitol Lake Adaptive Management Plan – Sediment Sampling and Analysis Plan and Quality Assurance Plan. Prepared for Entranco, Inc. and Washington State Department of General Administration.
- Herrera Environmental Consultants. 2003. Green Lake Alum Treatment Study. Technical report prepared for Seattle Department of Parks and Recreation. Prepared by Herrera Environmental Consultants in association with Tetra Tech, Inc. June 5, 2003.
- Johnson, R. 2008. Personal communication. Telephone conversation between Margaret Schwertner, Moffatt & Nichol, and Rick Johnson, Thurston County Noxious Weed Control Agency (360-786-5576), 30 June 2008.
- Kendall, D. 2008. Personal communication. Discussions with Joe Scott and Susan Tonkin, Moffatt & Nichol, and David Kendall of the Dredged Material Management Program, Olympia, WA. DMMP Monthly Meeting held on June 5, 2008.
- Knezevic, Z. S. 2003. Purple loosestrife. UNL-Extension Publication. EC-03-176.
- Legenfelder, J. 2008. Personal communication. Mentioned at General Administration meeting on June 27, 2008. Olympia Yacht Club, Olympia, WA. (360-943-6199), 27 June 2008.
- Miller, S. 2008. Personal communication. Telephone conversation between Margaret Schwertner, Moffatt & Nichol, and Skye Miller, Wildlands, Inc. Marysville, WA. (360-658-4866), 25 June 2008.
- Moffatt & Nichol (M&N). 2007. Deschutes Estuary Feasibility Study, Phase 3. Engineering Design and Cost Estimates. Final Report. February 9, 2007.
- Port of Olympia. 2006. Fact Sheet, Olympia Harbor, WA Maintenance dredging. Available online at <http://www.portofolympia.com/dredging_factsheet.htm>. Viewed March 25, 2007.
- Rittenhouse-Zeman and Associates. 1982. Soils and Foundation Exploration: Capitol Lake Restoration Project. Prepared for Jongejan Gerrard McNeal, Inc., and Washington State Department of General Administration. January 19, 1982.

- Science Applications International Corporation (SAIC). 2008. Sediment Characterization Study, Budd Inlet, Olympia, WA. Prepared for the Washington State Department of Ecology. March 12, 2008.
- Smith, D. 2008. Personal communication. Telephone conversation between Emy Carpenter, Moffatt & Nichol, and Dean Smith, Lakeside Industries (360-491-5460), 17 June 2008.
- Sutherland, D. 1999. Washington Aqueduct Sediment Discharges Report of Panel Recommendations. Prepared by D. Sutherland for the Chesapeake Bay Field Office, US Fish and Wildlife Service. Annapolis, Maryland. March 1999.
- Thurston County Noxious Weed Control Board (TCNWCB) 2008. Available online at <<http://www.co.thurston.wa.us/tcweeds/index.htm>>. Viewed August 4 2008.
- United States Army Corps of Engineers (USACE). 2001. Approved Work Windows for Fish Protection.
- United States Army Corps of Engineers (USACE). 1987. Beneficial Uses of Dredged Material. Engineer Manual 1110-2-5026.
- United States Geological Survey (USGS). 2006. Deschutes Estuary Feasibility Study; Hydrodynamics and Sediment Transport Modeling. U.S. Geological Survey Open-File Report 2006-1318.
- United States Geological Survey (USGS). 2008a. Capitol Lake Alternatives Analysis: Incorporation of Fine-Grained Sediment Erodibility Measurements into Sediment Transport Modeling. Draft version provided to Moffatt & Nichol on June 30, 2008.
- United States Geological Survey (USGS). 2008b. Capitol Lake Grain Size Data: sample dates 10/31/2007 and 11/1/2007. Received from Andrew Stevens, USGS, on May 9, 2008.
- United States Geological Survey (USGS). 2008c. Spread, Impact, and Control of Purple Loosestrife (*Lythrum salicaria*) in North American Wetlands. Available online at <<http://www.npwrc.usgs.gov/resource/plants/loosstrf/biology.htm>>. Viewed June 24, 2008.
- Washington Department of Fish and Wildlife (WDFW). 1999. Gold and Fish. Rules and regulations for Mineral Prospecting and Placer Mining in Washington State. January 1999.
- Washington State Department of Agriculture (WSDA). 2003. Available online at <<http://dnr.metrokc.gov/wlr/lands/weeds/pdf/PPlants203.pdf>>.
- Washington State Department of General Administration. 2008. Capitol Lake Alternatives – Meeting with Budd Inlet Marinas. Meeting Minutes. June 27, 2008.
- Weber, D. 2008. Personal communication. Telephone conversation between Joe Scott, Moffatt & Nichol, and Doug Weber, USACE (206-764-3406), June 4 2008.
- Welch, E. and G. Cooke. 1999. Effectiveness and Longevity of Alum Treatments in Lakes. *Lake and Reservoir Management*. 15:5-27.
- Wubbena, B. Personal communication. Telephone conversation between Joe Scott and Susan Tonkin, Moffatt & Nichol, and Bob Wubbena, Fiddlehead Marina (360-280-9100), June 17 2008.