CAPITOL LAKE ALTERNATIVES ANALYSIS
LOW-LYING INFRASTRUCTURE

Prepared for:

General Administration
STATE OF WASHINGTON

Tacoma Rail line (photograph source: EDAW)

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Executive Summary

Washington State Department of General Administration and the CLAMP Steering Committee are developing an 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 provides an assessment of the effects of sea level rise on low-lying infrastructure in the vicinity of Capitol Lake. The report compares possible future management alternatives: continued management of the lake as a lake (the Lake Alternative), and restoration of the Deschutes Estuary with or without a separate reflecting pool (the Estuary Alternatives).

The analysis of the future risk from flooding relies on recent hydraulic modeling results prepared by Moffatt & Nichol. These results included the conclusion that peak flood elevations were identical for the two Estuary Alternatives: consequently, this report does not consider the two alternatives separately. Increases in mean sea level of 0.5 feet, 1.0 feet, and 2.0 feet are considered.

Table ES-1 provides the 2-year and 100-year flood levels developed by Moffatt & Nichol for the two alternatives and under different sea level scenarios.

Table ES-1. Response of Floodplain Elevations to Sea Level Rise

Flood Elevations (feet, NGVD29)	Lake Alternative	Estuary Alternatives
2-year flood		
Current Sea Level*	8.6	10.0
Sea Level Increase of 0.5 feet	8.9	10.5
Sea Level Increase of 1.0 feet	9.2	11.0
Sea Level Increase of 2.0 feet	9.9	12.0
100-year flood		
Current Sea Level*	10.4	11.0
Sea Level Increase of 0.5 feet	10.9	11.5
Sea Level Increase of 1.0 feet	11.3	12.0
Sea Level Increase of 2.0 feet	12.1	13.0

* These elevations are used in this report and make reasonable assumptions regarding current and likely future operation of the Capitol Lake Dam. The published 100-year flood elevation is +11.0 feet NGVD29 based on earlier dam operations (FEMA 1981).

Average groundwater levels will either remain constant (under the Lake Alternative) or decrease compared to existing levels (under the Estuary Alternatives). While some effects of increased groundwater fluctuations are anticipated under the Estuary Alternatives, these are not highly dependent on increases in mean sea level.

Table ES-2 summarizes the identified major effects, mitigation measures, and costs associated with sea level rise for the Lake Alternative and the Estuary Alternatives. The costs in all cases are similar for the two alternatives. Costs are given as program costs in 2008 dollars. Some of the infrastructure in Olympia is already subject to flooding problems, and it was necessary to make reasonable assumptions as to which costs are associated with mitigating current flooding problems and which are associated with sea level rise.

Table ES-2. Effects and Mitigation Measures for Sea Level Rise

Infrastructure Effect and Mitigation	Cost	Triggering Sea Level Rise	
		Lake Alternative	Estuary Alternatives
Downtown Olympia			
Raise berm along Arc of Statehood	$2 M	1.0 ft	0.5 ft
Install stormwater pump station*	$4 M	Now*	Now*
Transportation Corridors			
Raise Deschutes Parkway near BNSF crossing	$4 M	1.0 ft	At most 0.5 ft*
Replace BNSF Railroad Trestle	$9 M	2.0 ft	0.5 to 1.0 ft
Raise rail track west of Capitol Lake	$3 M	Varies†	Varies†
Parks and Buildings			
Construct perimeter dike for parking and restroom at Marathon Park	$0.1 M	0.5 to 1.0 ft	At most 0.5 ft*
Construct perimeter dike for parking at GA Powerhouse	$0.2 M	0.5 ft	Now*
Construct or raise perimeter dike to protect the Old Brewhouse	$0.5 M	1.0 to 2.0 ft‡	1.0 to 2.0 ft‡

* This activity could reasonably be excluded from the costs associated specifically with sea level rise.

† This could be chosen to coincide with either the replacement of the BNSF Railroad Trestle or with raising Deschutes Parkway.

‡ The need for protection of the Old Brewhouse depends on the nature of any building restoration efforts that may be implemented.

As suggested by Table ES-1, increasing sea level can be expected to affect infrastructure in similar ways regardless of the selected lake management alternative. The effects will be felt earlier for the Estuary Alternatives.

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1. Introduction

1.1 Background

Capitol Lake was created in 1951 through the construction of the Capitol Lake 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; environmental concerns mean that ongoing dredging of the lake is increasingly difficult and expensive. 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 Overview of Infrastructure in the Vicinity of Capitol Lake

The purpose of this report is to develop an understanding of the effects of sea level rise on low-lying infrastructure in the vicinity of Capitol Lake. The report compares possible future management alternatives: continued management of the lake as a lake (the Lake Alternative), and restoration of the Deschutes Estuary with or without a separate reflecting pool (the Estuary Alternatives). The analysis of the future risk from flooding uses recent hydraulic modeling results (Moffatt & Nichol 2008). These results included the conclusion that peak flood elevations were identical for the two Estuary Alternatives: consequently, this report does not consider the two alternatives separately.

The focus of this report is a comparison of infrastructure vulnerability under the different management alternatives. Consequently, the report does not consider the infrastructure north of the Capitol Lake Dam, such as Percival Landing, the LOTT facility, and the Port of Olympia. Sea level rise would affect this infrastructure in the same way under either the Lake Alternative or the Estuary Alternative – water levels in Budd Inlet are not affected by the future management alternatives under consideration.

The majority of the low-lying infrastructure that may be affected by rising sea levels is in downtown Olympia on the eastern shore of the North Basin, in the vicinity of Heritage Park. Significant low-lying transportation corridors that may be affected are Deschutes Parkway and the Burlington Northern Sante Fe (BNSF) Railroad (now operated by Tacoma Rail); major utility lines are also routed along these corridors. Finally, the parks adjacent to the lake and the Old Brewhouse in Tumwater are on low-lying ground and vulnerable to increasing water levels.

2. Potentially Affected Infrastructure

2.1 Introduction

This section summarizes the infrastructure that may be affected by rising sea levels. Figure 1 provides an overview of the infrastructure, other than utilities, listed in this section, and Figure 2 provides an overview of the utilities. As mentioned previously, this report does not consider infrastructure that is primarily vulnerable to flooding from Budd Inlet.

This section additionally outlines the information that was used to estimate critical elevations for this infrastructure. This report uses elevations relative to the National Geodetic Vertical Datum of 1929 (NGVD29). The NGVD29 datum is close to Mean Sea Level (MSL; see Table 2 on page 14). In Olympia, NGVD29 is often referred to as MSL.

Topographic information, based on Lidar data collected by the Puget Sound Lidar Consortium in 2002, was provided by Thurston GeoData Center. This topographic information was used to estimate the elevations of infrastructure elements for which specific elevation information was not available.

2.2 Utilities

Utility reference drawings were provided by the City of Olympia Public Works. Figure 2 shows a composite of the existing utilities. In addition to the utilities within the downtown Olympia area in the vicinity of Heritage Park, major utility corridors along Deschutes Parkway and across the BNSF Railroad Trestle and the Capitol Lake Dam are potentially vulnerable to rising sea levels.

Electrical utilities are not shown on this figure; the electrical utilities in downtown Olympia are generally above ground and do not have specific vulnerability to flooding and sea level rise.

Elevations for buried water, reclaimed water, sanitary sewer, and storm sewer lines were gathered from a variety of sources including design drawings for the recently upgraded facilities and discussions with the City of Olympia Public Works.

2.3 Downtown Olympia and Heritage Park

A significant portion of downtown Olympia lies below the 100-year flood elevation of +10.4 feet NGVD29 based on current and likely future lake management practices (Moffatt & Nichol 2008).

A visual inventory of the buildings in the downtown Olympia area was prepared to characterize these building and their vulnerability. In the downtown affected area, the buildings are generally characterized as commercial/retail and do not appear to have substructures such as basements: see for example Figure 3. The finish floor elevation of these buildings is assumed close to the level shown in the topographic information. Information regarding low points in the downtown area was provided by Thurston Regional Planning Council 2006 (TRPC 2006).

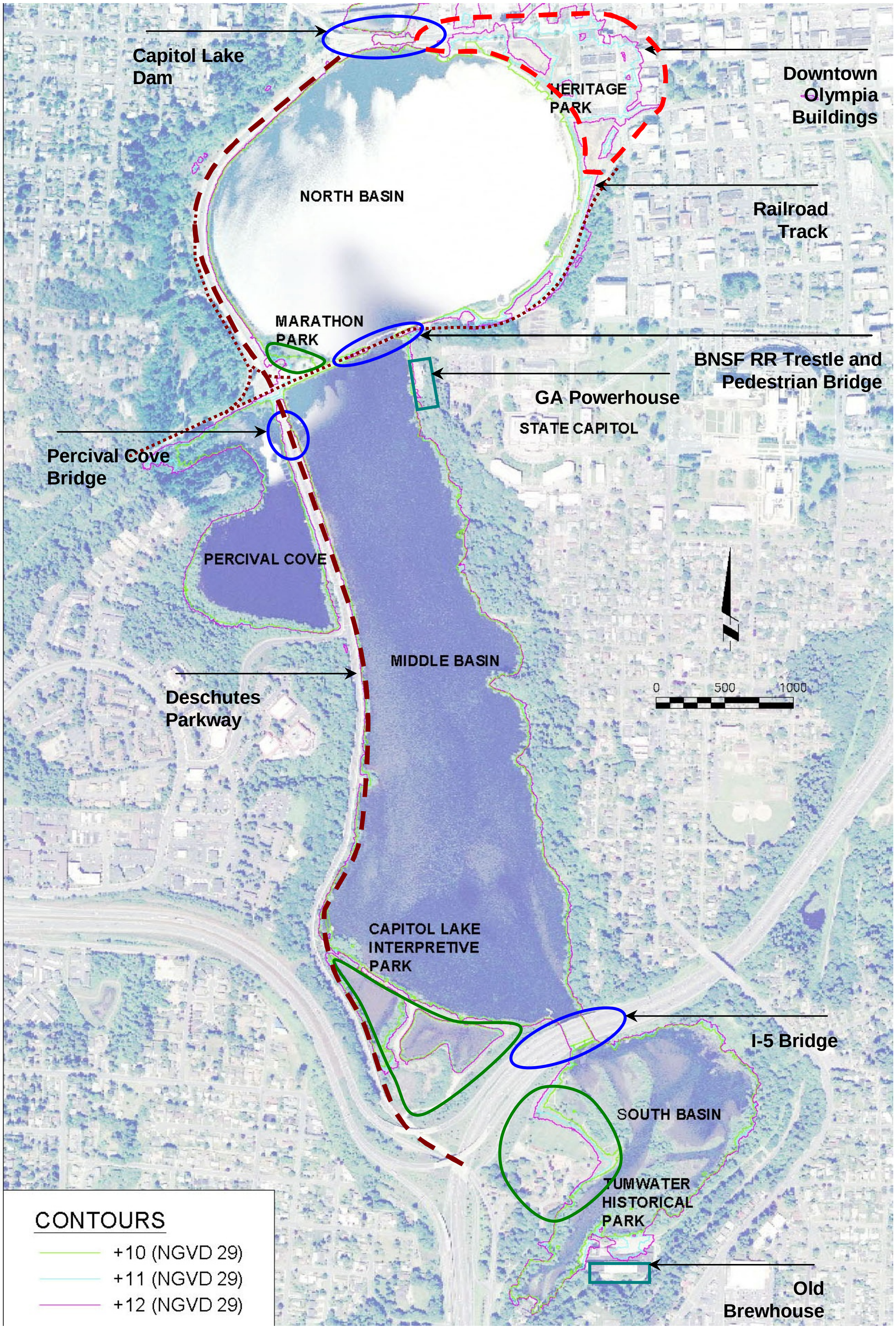

Figure 1. Overview of Vulnerable Infrastructure

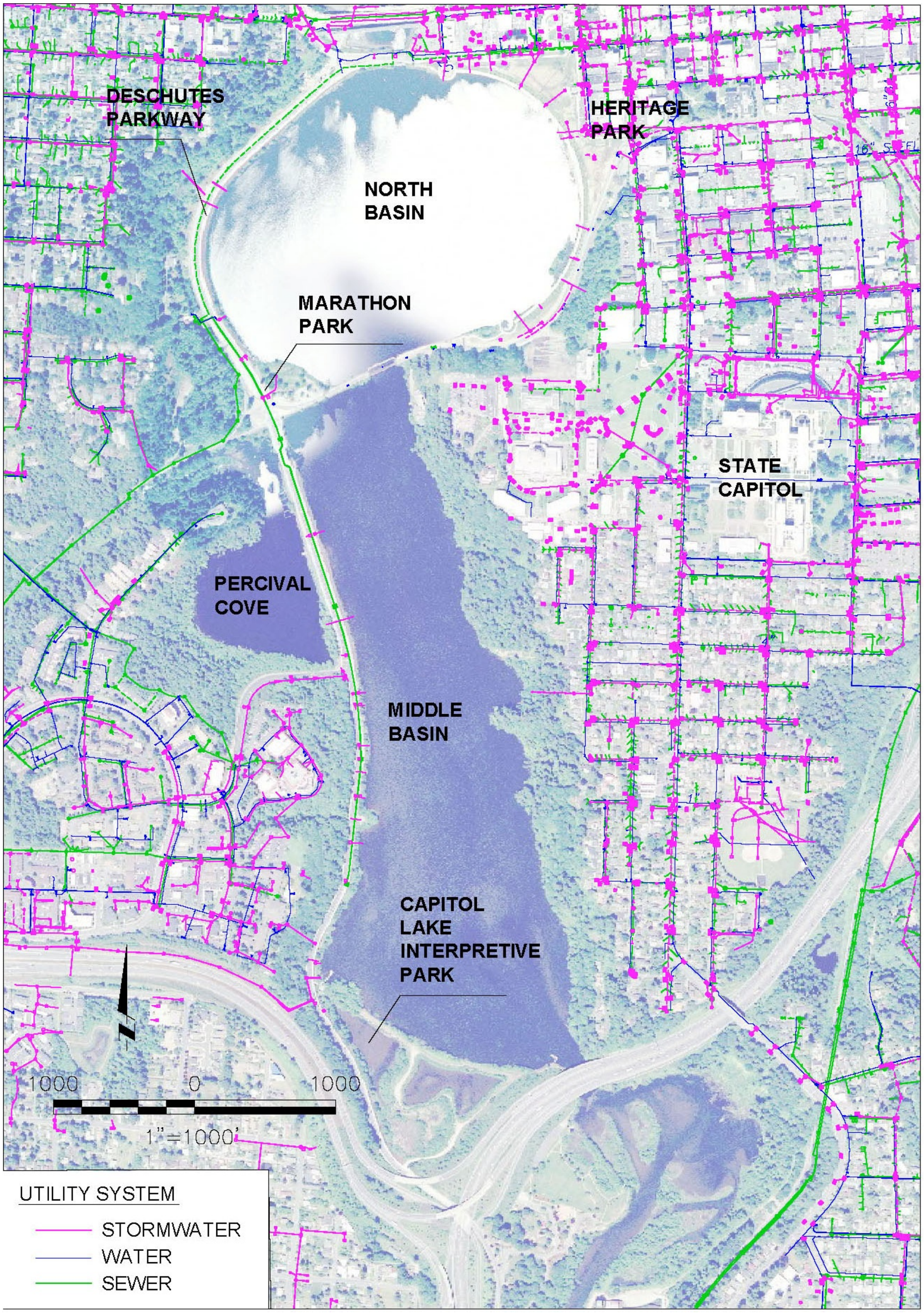

Figure 2. Overview of Major Utilities

Figure 3. Low-lying buildings in Olympia

Heritage Park is also low-lying. The Arc of Statehood is a concrete bulkhead structure that includes a section where steps lead down to Capitol Lake. In 2006, improvements to Heritage Park included the construction of a low-height berm behind the Arc of Statehood, and alongside Powerhouse Road to the Powerhouse which provides a perimeter protection at elevation +11.5 feet. However, floodwaters from Capitol Lake can still reach downtown Olympia through the storm drain system (see Section 4.2).

Figure 4. Arc of Statehood

2.4 Transportation

Two major low-lying transportation corridors are shown in Figure 1: Deschutes Parkway, which lies along the western shore of the North and Middle Basins, and the BNSF railroad line (now operated by Tacoma Rail), which crosses over Capitol Lake between the North and Middle Basins. Elevations along Deschutes Parkway were obtained from WSDOT 2003 with additional information regarding benchmarks from Mead, personal communication, 2008. Detailed information regarding the railroad track, other than at road crossings, was not obtained by M&N and was estimated from the topographic information.

Figure 5. Railroad crossing at Deschutes Parkway, adjacent to Marathon Park

Four bridges cross over or are adjacent to Capitol Lake: the I-5 Bridge, the BNSF Railroad Trestle, the adjacent pedestrian bridge, and the Percival Cove Bridge. The Fourth Avenue Bridge crosses Budd Inlet and is outside the study area for this assessment.

Complete drawings for these bridge structures were not available to Moffatt & Nichol. Original design drawings for the BNSF Railroad Trestle – including its original drawbridge configuration – were obtained from Tacoma Rail (Northern Pacific Railway Company 1928). Some information regarding bridge soffit and deck elevations for the Percival Cove Bridge was obtained from drawings of the force sewer main along Deschutes Parkway, provided by LOTT. Other information was estimated from the topographic files, from photographs, and from earlier studies of bridge scour (Entranco 2000).

Figure 6 is a photograph of the I-5 Bridge taken at very low water (during a lake drawdown event).

Figure 6. I-5 Bridge

Source: WDFW

Figure 7 includes several views of the BNSF Railroad Trestle. The pedestrian bridge immediately north of the BNSF Railroad Trestle is shown in Figure 8.

Figure 7. BNSF Railroad Trestle

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Figure 8. Pedestrian Bridge, located next to BNSF Railroad Trestle

Figure 9 is the bridge at Percival Cove, along Deschutes Parkway

Figure 9. Percival Cove Bridge Source: EDAW

Relatively complete drawings for the Capitol Lake Dam were available. The Capitol Lake Dam would be removed under the Estuary Alternatives and replaced with a new Fifth Avenue Bridge. This report assumes any new bridge would be designed and constructed to withstand the effects of sea level rise within the limits considered in this report.

Figure 10. Capitol Lake Dam

2.5 Parks

Four parks occupy the shoreline of Capitol Lake: Marathon Park, Capitol Lake Interpretive Park, Tumwater Historical Park, and Heritage Park. Heritage Park occupies the eastern shore of the North Basin and is adjacent to the low-lying areas of downtown Olympia.

This report considers Heritage Park in the overall context of downtown Olympia: the park is not discussed separately. Infrastructure at the other parks includes low-lying trails, parking areas, restrooms, and similar park facilities. Elevations for this infrastructure were generally estimated from the topographic information.

2.6 Individual Affected Buildings

Aerial photography was used to identify individual buildings that may be in the elevation ranges affected by sea level rise.

The General Administration Powerhouse building is immediately south of the railroad bridge on the east side of the Middle Basin. Information regarding the finish floor elevation of this building was available from drawings of a recent upgrade to the slope protection and parking areas.

Figure 11. General Administration Powerhouse

The Old Brewhouse is located within the City of Tumwater, at the base of the Tumwater. This building, which is on the National Registry of Historic Places, lies within the existing 100-year floodplain. The building is currently in a derelict condition; the City of Tumwater has plans to protect the building. Elevation information for this building was estimated from the topographic information.

Figure 12. Old Brewhouse

2.7 Contaminated Sites

Contaminated sites are not considered infrastructure. However, sea level rise could potentially affect contaminated sites through changes in the water table.

Rising groundwater levels, and increases in the rate of groundwater movement, could mobilize existing contaminants in the groundwater. There are several contaminated sites in low-lying areas of downtown Olympia, which potentially could be affected. Figure 13 shows active cleanup sites in areas close to Capitol Lake (Washington State Department of Ecology 2008).

Figure 13. Approximate Locations of Contaminated Areas

Given the long lead-times associated with increases in mean sea level, this report assumes known contaminated sites will be cleaned up in the next decade or two – before sea level rise significantly affects the sites. While there may be further contaminated sites in the area, it can also be assumed that these will be cleaned up in a timely fashion after identification. Consequently, this report assumes there will be no significant effects of sea level rise on the movement of contaminated groundwater.

3. Criteria for Infrastructure Effects

3.1 Overview

The criteria used to identify infrastructure that may be affected by changes in water levels due to increases in mean sea level, and to assess the impacts and possible mitigation measures, include the following:

- Elevations that lie within typical water levels (lake management levels for the Lake Alternative, and the intertidal zone for the Estuary Alternatives);
- Elevations that lie within the new 100-year floodplain as well as the floodplain for lower return periods;
- Elevations that lie within the new water table.

In addition, the analysis of downtown Olympia considers lake or estuary elevations at which storm drainage may be affected by adverse hydraulic gradients.

3.2 Mean Sea Level

The University of Washington Climate Impacts Group and the Washington State Department of Ecology (2008) provides estimates of future increases in mean sea level as shown in Table 1.

Table 1. Estimates of Washington (Puget Sound) Sea Level Change

	Increase Relative to 1980-1999 Average	
Estimate	**By 2050**	**By 2100**
Very Low	3”	6”
Medium	6”	13”
Very High	22”	50”

In order to capture the range of variability over the next 50 years, increases of 6 inches, 12 inches, and 24 inches (0.5 feet, 1.0 foot, and 2.0 feet) relative to 1980-1999 average conditions were included the in hydraulic analysis (Moffatt & Nichol, 2008).

3.3 Typical Water Levels

For the Lake Alternative (and under current conditions), General Administration targets a lake elevation of approximately 6.2 feet NGVD29 during the summer, and approximately 5.2 feet NGVD29 during the winter. Water level fluctuations of approximately ±0.5 feet are allowed around these target levels. Thus, the summer lake levels are typically in the range 5.7 to 6.7 feet NGVD29, while winter lake levels (in the absence of a predicted or ongoing storm event are typically in the range 4.7 to 5.7 feet NGVD29.

It is assumed these target elevations would remain constant in response to rising sea level. It is possible the winter lake level could be lowered in order to allow more flood storage; assuming constant elevations is the more conservative approach and is taken here. It is, however, assumed the lake levels would be drawn down to +1 foot NGVD29 in advance of a major storm event – the flood levels used in this report are dependent on this assumption.

For the Estuary Alternatives, the high tide levels are essentially identical to those in Budd Inlet (Moffatt & Nichol 2008). Low tide levels will be muted (higher) compared to Budd Inlet: however, low tide levels are not relevant to concerns regarding increases in mean sea level. Table 2 (NOAA 2008) presents the tidal datums for Olympia, Budd Inlet.

Table 2. Tidal Datums for Budd Inlet (1983-2001 epoch) (NOAA 2008)

Datum Plane	Feet, MLLW	Feet, NGVD29
Highest Observed Tide (12/15/1977)	17.94	10.54
Mean Higher High Water (MHHW)	14.56	7.16
Mean High Water (MHW)	13.55	6.15
Mean Sea Level (MSL)	8.35	0.96
Mean Tide Level (MTL)	8.31	0.91
National Geodetic Vertical Datum of 1929 (NGVD29)	7.40	0.00
Mean Low Water (MLW)	3.07	-4.33
Mean Lower Low Water (MLLW)	0.00	-7.40
Lowest Observed Tide (1/2/1977)	-4.33	-11.73

Elevations above Mean Higher High Water (MHHW) are experienced on a regular basis. This report considers the intertidal zone to include elevations up to +8.6 feet NGVD29, experienced 20 days per year or more based on astronomical (predicted) tides (NOAA 2008). The upper limit of the intertidal zone increases directly with increases in mean sea level.

Table 3 summarizes the upper limit of daily water level fluctuations under the different sea level rise scenarios considered.

Table 3. Response of Daily Water Level Fluctuations to Sea Level Rise

Upper Limit of Daily Fluctuations (feet, NGVD29)	Lake Alternative	Estuary Alternatives
Current Conditions	6.7	8.6
MSL Increase of 0.5 feet	6.7	9.1
MSL Increase of 1.0 feet	6.7	9.6
MSL Increase of 2.0 feet	6.7	10.6

3.4 Floodplain Elevations

Floodplain elevations are taken directly from the hydraulic study (Moffatt & Nichol 2008) used to compare flood levels for the Lake and Estuary Alternatives.

The floodplain elevations for the Lake Alternative are slightly lower than those published earlier (URS Group and Dewberry 2003; FEMA 1981). This results from differing assumptions regarding lake management and the inclusion of more recent data (including the December 2007 storm) in the analysis. By using a consistent analysis method for the Lake and Estuary Alternatives, this report gives consistent predictions that can be used in comparing the different alternatives.

Table 4. Response of Floodplain Elevations to Sea Level Rise

Flood Elevations (feet, NGVD29)	Lake Alternative	Estuary Alternatives
2-year flood		
Current Sea Level *	8.6	10.0
MSL Increase of 0.5 feet	8.9	10.5
MSL Increase of 1.0 feet	9.2	11.0
MSL Increase of 2.0 feet	9.9	12.0
5-year flood		
Current Sea Level *	9.5	10.4
MSL Increase of 0.5 feet	9.9	10.9
MSL Increase of 1.0 feet	10.2	11.4
MSL Increase of 2.0 feet	11.0	12.4
25-year flood		
Current Sea Level *	10.2	10.8
MSL Increase of 0.5 feet	10.6	11.3
MSL Increase of 1.0 feet	11.0	11.8
MSL Increase of 2.0 feet	11.8	12.8
100-year flood		
Current Sea Level *	10.4	11.0
MSL Increase of 0.5 feet	10.9	11.5
MSL Increase of 1.0 feet	11.3	12.0
MSL Increase of 2.0 feet	12.1	13.0

* These elevations are used in this report and make reasonable assumptions regarding current and likely future operation of the Capitol Lake Dam. The published 100-year flood elevation is +11.0 feet NGVD29 based on earlier dam operations (FEMA 1981).

3.5 Groundwater

The Capitol Lake Dam controls the water levels for the lake. These levels in turn influence groundwater elevations along the perimeter areas of Capitol Lake. The groundwater elevation is most influenced by long-term, steady state water elevations in the lake. Current groundwater levels close to the lake shoreline are likely to be close to the target lake levels: approximately 6.2 feet NGVD29 during the summer and 5.2 feet NGVD29 during the winter. The actual distance over which groundwater levels are controlled by lake levels is a function of soil permeability and runoff quantities, and is beyond the scope of the current study. Typical distances in low-lying areas of the Puget Sound are of the order of 100 to 300 feet.

Under the Lake Alternative, the groundwater levels are anticipated to remain constant despite increases in the mean sea level, because the target lake levels remain unchanged.

Under the Estuary Alternatives, the average water level elevations would be lower than the existing lake elevations. By definition, the average water level in Budd Inlet is Mean Sea Level, at approximately +1.0 feet NGDV29 (Table 2). The average water level in the restored estuary would be slightly higher than this, because at low tide the freshwater input and the relatively high channel bottom combine to keep the water relatively high. An average water level of +2.0 feet NGVD29 is assumed for the present discussion. If the groundwater level is +2.0 feet NGVD29 under current conditions, it would increase to +4.0 feet NGVD29 in response to an increase in sea level of 2.0 feet. However, this is still lower than the average groundwater levels under existing conditions.

While the average groundwater levels would be lower than present under the Estuary Alternatives, fluctuations would be observed close to the shoreline. Peak groundwater levels adjacent to the shoreline would match the upper limit of daily water level fluctuations shown in Table 3 – from +8.6 feet NGVD29 under current conditions of sea level to +10.6 feet NGVD29 with a 2.0-feet increase.

An additional effect of the Estuary Alternatives would be to introduce salinity into the groundwater close to the shoreline. This effect, together with the general effects of fluctuating groundwater levels, is excluded from this analysis. It is assumed that any necessary mitigation, such as stabilization of Deschutes Parkway, would be implemented as part of the estuary restoration and would not be considered a response to sea level rise.

3.6 Summary

Table 5 provides an alternative way of regarding the water levels corresponding to different flood levels and different sea level rise values. At increments of 0.5 feet in elevation, the table lists the lowest return period (out of 2-, 5-, 10-, 25-, or 100-years) at which each elevation would be reached assuming different increases in mean sea level.

Viewed in this way, the differences between the Lake Alternative and the Estuary Alternatives are significant. If mean sea level increases by 2 feet, the elevation +12.5 feet NGVD29 will be attained by the 10-year flood under the Estuary Alternatives, but not under the Lake Alternative. Areas below +9.0 feet NGVD29, which are subject to relatively frequent floods under the Lake Alternative (5-year return period) are included in the intertidal zone under the Estuary Alternatives. Overall, the characterization of areas as “subject to frequent flooding” (2- to 5-years or less) affects a larger elevation range for the Estuary alternatives than the Lake Alternative.

Table 5. Vulnerability Criteria for Different Elevations

Water Level (feet, NGVD29)	Occurrence for the Lake Alternative		Occurrence for the Estuary Alternatives	
+8.5	Current MSL:	2-year flood	Current MSL:	Intertidal
	+0.5 feet:	2-year flood	+0.5 feet:	Intertidal
	+1.0 feet:	2-year flood	+1.0 feet:	Intertidal
	+2.0 feet:	2-year flood	+2.0 feet:	Intertidal
+9.0	Current MSL:	5-year flood	Current MSL:	2-year flood
	+0.5 feet:	5-year flood	+0.5 feet:	Intertidal
	+1.0 feet:	2-year flood	+1.0 feet:	Intertidal
	+2.0 feet:	2-year flood	+2.0 feet:	Intertidal
+9.5	Current MSL:	5-year flood	Current MSL:	2-year flood
	+0.5 feet:	5-year flood	+0.5 feet:	2-year flood
	+1.0 feet:	5-year flood	+1.0 feet:	Intertidal
	+2.0 feet:	2-year flood	+2.0 feet:	Intertidal
+10.0	Current MSL:	25-year flood	Current MSL:	2-year flood
	+0.5 feet:	10-year flood	+0.5 feet:	2-year flood
	+1.0 feet:	5-year flood	+1.0 feet:	2-year flood
	+2.0 feet:	5-year flood	+2.0 feet:	Intertidal
+10.5	Current MSL:	N/A	Current MSL:	10-year flood
	+0.5 feet:	25-year flood	+0.5 feet:	2-year flood
	+1.0 feet:	10-year flood	+1.0 feet:	2-year flood
	+2.0 feet:	5-year flood	+2.0 feet:	Intertidal
+11.0	Current MSL:	N/A	Current MSL:	100-year flood
	+0.5 feet:	N/A	+0.5 feet:	10-year flood
	+1.0 feet:	25-year flood	+1.0 feet:	2-year flood
	+2.0 feet:	5-year flood	+2.0 feet:	2-year flood
+11.5	Current MSL:	N/A	Current MSL:	N/A
	+0.5 feet:	N/A	+0.5 feet:	100-year flood
	+1.0 feet:	N/A	+1.0 feet:	10-year flood
	+2.0 feet:	25-year flood	+2.0 feet:	2-year flood
+12.0	Current MSL:	N/A	Current MSL:	N/A
	+0.5 feet:	N/A	+0.5 feet:	N/A
	+1.0 feet:	N/A	+1.0 feet:	100-year flood
	+2.0 feet:	100-year flood	+2.0 feet:	2-year flood
+12.5	Current MSL:	N/A	Current MSL:	N/A
	+0.5 feet:	N/A	+0.5 feet:	N/A
	+1.0 feet:	N/A	+1.0 feet:	N/A
	+2.0 feet:	N/A	+2.0 feet:	10-year flood
+13.0	Current MSL:	N/A	Current MSL:	N/A
	+0.5 feet:	N/A	+0.5 feet:	N/A
	+1.0 feet:	N/A	+1.0 feet:	N/A
	+2.0 feet:	N/A	+2.0 feet:	100-year flood

4. Affected Infrastructure and Potential Mitigation

4.1 Introduction

This section assesses the impacts to infrastructure based on the vulnerability criteria listed in Table 5. The assessment begins with a review of flooding issues in the downtown Olympia area. Flooding in this area is dominated by the limited capacity and adverse hydraulic gradients in the stormwater system, rather than by direct lake overtopping. The assessment continues with a review of utilities that may be affected by changes in the groundwater regime. Stormwater is not discussed explicitly in the context of utilities: rather, effects on the stormwater system are discussed in the context of the areas affected by flooding. Other items, such as transportation corridors, bridges, individual buildings, and parks are discussed directly in terms of the floodplain elevations given in Table 5.

Potential mitigation measures for the most affected items are outlined and planning-level costs are provided. The costs are presented as program costs, which include construction, and allowances for engineering, geotechnical and other investigations, regulatory compliance, and construction management. All costs are stated as 2008 dollars.

4.2 Downtown Olympia and Heritage Park

Figure 14 is an enlarged version of the map in Figure 1, concentrating on the downtown Olympia region. Much of downtown Olympia is within the existing 100-year floodplain of +11.0 feet NGVD29 defined by FEMA (1981) and based on earlier lake management practices. A reasonably large area is within the 100-year floodplain based on current and likely future lake management practices (Moffatt & Nichol 2008).

Low points in the downtown Olympia area include the intersection of 7th Avenue West and Columbia Street SW (+8.4 feet NGVD29), the intersection of Legion Way and Water Street SW (+9.5 feet NGVD29), and the intersection of 7th Avenue SW and Water Street (+9.9 feet NGVD29) (TRPC 2006). The lowest points are in the 2-year floodplain (Lake Alternative) or the intertidal zone (Estuary Alternatives) under present-day sea level conditions.

In part, these areas are protected by the recently constructed berm alongside the Arc of Statehood and Powerhouse Road. The berm located behind the shoreline structure is at elevation +11.5 feet NGVD29 and provides protection for the Heritage Park area. It seems reasonable to assume the berm would be raised when the 25-year flood level reaches +11.0 feet NGVD29 – representing a doubling of the overtopping risk (from 2 percent to 4 percent) compared to existing conditions. This point is reached with a sea level rise of 1.0 feet for the Lake Alternative and 0.5 feet for the Estuary Alternatives.

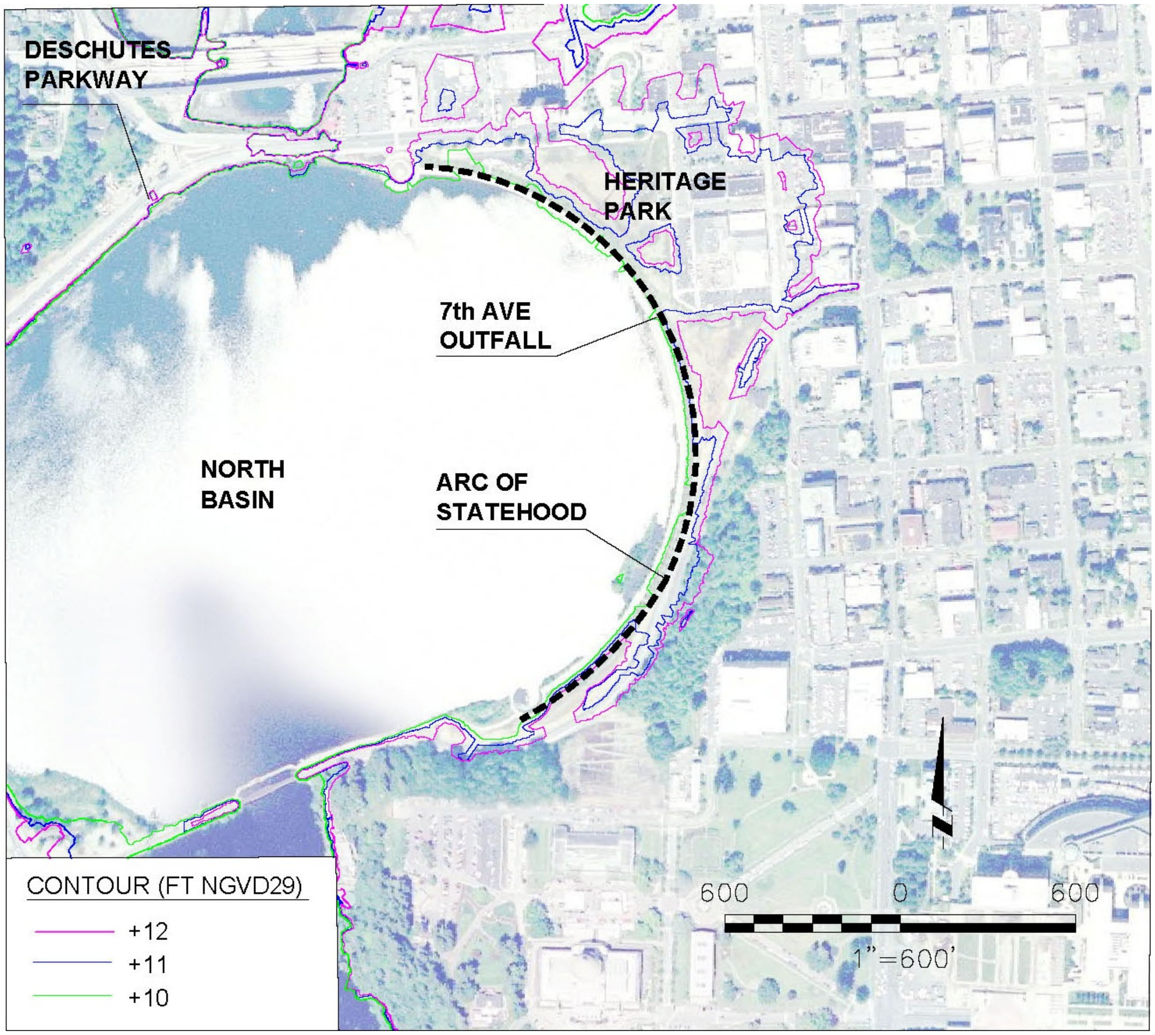

Figure 14. Downtown Olympia Floodplain Detail Map

However, a more critical flooding issue is related to stormwater. The intersection of 7th Avenue SW and Water Street is particularly vulnerable to localized flooding related to the stormwater system.

Increases in the water level of a receiving water body such as Capitol Lake can affect three aspects of an existing stormwater system: conveyance, treatment, and maintenance.

- **Conveyance:** The hydraulic performance of a given pipe run is influenced by the size of pipe, pipe slope, tailwater conditions, and system head loss that must be overcome. If the tailwater elevation (i.e. the receiving water body's surface elevation) rises to the point the outfall is either submerged or partially submerged, the standing water within the pipe will begin to (or continue to in the case of an already submerged outfall) encroach up the pipe. As the hydraulic gradient of the pipe is reduced, pipe capacity is likewise reduced. In low-lying areas or for those pipe systems operating near capacity, the reduced gradient can lead to overtopping of some stormwater structures. This leads to localized flooding.
- **Stormwater Treatment:** For this discussion, treatment systems are divided between surface treatment facilities and structural treatment facilities. Surface treatment facilities are those which typically treat stormwater at ground level after receiving it via surface flow or a higher elevation piped system. Structural treatment facilities are those which are housed in underground vaults with underground inlet and outlet pipes. Surface facilities will likely continue to function unless the outlet is affected by the overtopping scenario

discussed under the conveyance section. Structural facilities, being underground and therefore typically at a lower elevation, are more at risk of encountering backwater conditions that may diminish their treatment capabilities.

- **Maintenance:** There is a greater potential for sediment build up to occur if pools of standing water encroach up the pipe. This sedimentation may reduce the capacity of the pipe and exacerbate the performance impacts discussed above.

Flooding frequently occurs in the vicinity of the intersection of 7th Avenue SW and Water Streets (McGowan, personal communication 2008), associated with the 7th Avenue Outfall. This 36-inch corrugated metal pipe that conveys stormwater from much of downtown Olympia south of 7th Avenue West as well as higher areas surrounding the Capitol Campus. The ground elevation around this intersection is near, and sometimes even below, the Capitol Lake water surface. The centerline ground elevation is at +9.9 feet NGVD29, as mentioned above; the rim elevation of the manhole immediately upstream of the outfall is +10.1 feet NGVD29; and the next upstream manhole has a rim elevation of +8.4 feet NGVD29. A storm event that establishes even a relatively minor hydraulic gradient across the storm drain is therefore likely to cause the stormwater structures to overtop and flood the surrounding area. Under the Estuary Alternatives, this can occur even under normal spring high tide conditions and without any increase in sea level rise. A gravity-flow based solution is not well-suited to these conditions.

To address the flooding, the City has installed a manually operated gate valve upstream of the outfall which allows them to isolate the storm drain system from severe backwater conditions. A pump is used to convey the stormwater in the storm drain to Capitol Lake via a temporary hose.

In the long term, this manually operated solution should be replaced by a permanent pump station and associated conveyance facility to transfer stormwater into the lake or estuary. This could be combined with a gravity system that allows flow into the lake when it is at normal lake levels, or into the estuary at low tide levels. This would provide some benefit in decreasing operation costs for the pump station. Under either alternative, gates should be installed to limit the exposure of the storm drain system to backwater conditions. Tide gates would also allow the inherent volume of the storm drain system to be used for storage, decreasing the size of the pump system. The design of the pump station and conveyance system will be different for the two alternatives: however, the general sizing and overall costs will be similar.

A number of smaller outfalls convey stormwater from localized areas of downtown Olympia into the lake. These parts of the stormwater system should also be tied into the pump station in the long term, to decrease the frequency of localized flooding in these areas.

Planning-level costs (program costs in 2008 dollars) for the mitigation measures discussed here are as follows:

- Raising the perimeter berm along the Arc of Statehood: $2 million for both lake management alternatives. This is required with a sea level rise of 1.0 feet for the Lake Alternative and 0.5 feet for the Estuary Alternatives.
- Installation of a pump station: $4 million. To the extent this is needed in the near term regardless of the lake management alternative, this measure could be excluded from the discussion.

4.3 Utilities

Sanitary sewer infrastructure in the vicinity of Capitol Lake include a 22-inch HDPE gravity line along Deschutes Parkway west of the Middle Basin; 20 to 24-inch force main along Deschutes Parkway west of the North Basin and over the Capitol Lake Dam; a 24-inch ductile iron pipe under the pedestrian bridge adjacent to the BNSF Railroad Trestle; and Percival Pump Station. Some older local sanitary sewer lines are present in downtown Olympia.

Percival Pump Station is at a ground elevation of approximately +18 feet NGVD29, and is not anticipated to be affected by increases in sea level.

Higher groundwater elevations can affect older gravity sanitary sewer lines if infiltration increases the volume conveyed in the pipes, and so increases the volume that must be handled by the treatment facility. The average groundwater level is expected to remain constant under the Lake Alternative, and actually to decrease compared to current levels under the Estuary Alternatives, so this is unlikely to be a major issue. If necessary, it could be mitigated by lining the existing pipelines. A typical program cost to line existing sanitary pipes is $450 per lineal foot.

Many of the water lines in the vicinity of Capitol Lake, including an 8-inch line along Deschutes Parkway and a 16-inch line under the pedestrian bridge and under Marathon Park, are of ductile iron. In common with the ductile sanitary line under the pedestrian bridge, under the Estuary Alternative these could potentially be affected by salinity in the groundwater (for underground lines) or in the estuary (for the lines supported by the pedestrian bridge). Ductile utilities should be improved or protected as part of the construction for the Estuary Alternative. However, this is not related to sea level rise: the lines under the pedestrian bridge are at an elevation of approximately +8 to +9 feet NGVD29, so would be in the intertidal zone (or at least the splash zone) immediately after construction.

Finally, most of the electrical distribution in the Capitol Lake area is above-ground and would be affected by sea level rise only through flooding. Mitigation measures for the electrical system can be included in the general flood protection measures, such as raising the berm along the North Basin in Heritage Park.

4.4 Transportation

4.4.1 Deschutes Parkway and Associated Bridges

Elevations along Deschutes Parkway south of Percival Cove are generally above +14 feet NGVD29, and therefore not directly vulnerable to flooding that results from increases in sea level. The elevations drop to a low point of +12.1 feet NGVD29 at the BNSF crossing adjacent to Marathon Park; and are generally in the range of +15 to +17 feet NGVD29 further north of Marathon Park and along the shoreline of the North Basin. The elevations along Deschutes Parkway rise from +12.8 to above +17 feet NGVD29 at the Capitol Lake Dam; Fifth Avenue (which continues Deschutes Parkway) drops to +10.8 feet NGVD29 east of the Dam (Thurston Regional Planning Council 2006; WSDOT 2003; Mead, personal communication 2008).

A reasonable criterion for roadway flood protection is that the elevations should be a minimum 1.0 feet above the 100-year floodplain. Using this criterion, the low point of Deschutes Parkway near the BNSF crossing, with an elevation +12.1 feet NGVD29, is vulnerable to sea level rise. For the Lake Alternative, the roadway would be affected during a 100-year event with a 1 foot sea level rise. For the Estuary Alternatives, this low-lying section of roadway would be affected almost immediately: with a 0.5 feet sea level rise the freeboard would be 1-foot based on the 10-year event.

An issue for the Percival Cove Bridge is the elevation of the bridge soffit, which should be located a minimum of 1 foot above daily water levels. The bridge soffit is at a level of approximately +10 feet NGVD29. For the Estuary Alternatives, the soffit would lie within the 2-year floodplain zone, and within the splash zone for high spring tides. It is assumed that the bridge superstructure would be protected (such as with the use of coatings of exposed surfaces) for this alternative.

Finally, the Capitol Lake Dam deck elevation is above +17.1 feet NGVD29. As such, it would remain above the 100-year floodplain even with a 2.0 feet increase in mean sea level and would not require replacement.

Planning-level costs (program costs in 2008 dollars) for the mitigation measures discussed here are as follows:

- Raising Deschutes Parkway, with associated utility improvements: $4 million for both lake management alternatives. This is required with a sea level rise of 1.0 feet for the Lake Alternative and at most 0.5 feet for the Estuary Alternatives.

4.4.2 Railroad and BNSF Railroad Trestle

The railroad tracks over the BNSF Railroad Trestle are estimated to have a top elevation of +12.5 feet NGVD29. It is normally considered desirable for the top of tracks to be 2 feet above the 100-year floodplain. With the existing floodplain at +11.0 feet NGVD29, this criterion is not currently achieved.

A compromise may be to raise the bridge structure when the 25-year flood elevation reaches within 1 foot of the top of tracks. At present, the 25-year flood elevation is at +10.2 feet NGVD29. For the Lake Alternative, the 25-year flood elevation reaches +11.5 feet NGVD29 (i.e., within 1 foot of the top of track) when the mean sea level has increased by between 1.0 and 2.0 feet. For the Estuary Alternative, this elevation is reached when sea level has increased between 0.5 and 1.0 feet. It is assumed the bridge would be rebuilt at this time.

The elevations of the rail tracks close to Capitol Lake are not known in detail. However, the rail spur north of Marathon Park and the east-west track between Marathon Park and the BNSF Railroad Trestle appear to be at elevations consistent with the surrounding topography. This suggests the rail tracks as well as the road surface have a low point of +12.1 feet NGVD29 at the BNSF crossing adjacent to Marathon Park. The rail spur north of Marathon Park appears to be at an elevation at or above +15 feet NGVD29. It is assumed the low point in the rail track will be raised when Deschutes Parkway is raised as mitigation for future flooding. It is assumed the remainder of the rail track would be raised at the same time the bridge is rebuilt; it could also be raised in coordination with the raising of Deschutes Parkway.

The rail tracks east of Capitol Lake and into downtown Olympia would be protected through stormwater system improvements and through raising the berm along the Arc of Statehood bulkhead, as discussed in Section 4.2. Costs associated with these improvements are not repeated here.

In summary, planning-level costs (program costs in 2008 dollars) for the mitigation measures discussed here are as follows:

- Replacing the BNSF Railroad Trestle and providing transition tracks along both ends of the bridge in order to meet existing rail: $8 million to $9 million for both lake management alternatives. This is required with a sea level rise of between 1.0 and 2.0 feet for the Lake Alternative and between 0.5 and 1.0 feet for the Estuary Alternatives.
- Raising the rail track west of Deschutes Parkway: $2 million to $3 million for both lake management alternatives. This could be coordinated with either the raising of Deschutes Parkway (Section 4.1.1), or the replacement of the BNSF Railroad Trestle.

4.4.3 Pedestrian Bridge and I-5 Bridge

The Pedestrian Bridge located alongside the BNSF Railroad Trestle has a deck elevation at or above +12.5 feet NGVD29. As such, it would be overtopped during a 10-year flood and a 2 foot increase in sea level for the Estuary Alternatives. The Pedestrian Bridge is just above the 100-year flood with a 2 foot increase in sea level rise for the Lake Alternative. Raising or replacing the bridge in response to sea level rise does not appear necessary.

For the Estuary Alternative, it is possible the increased tidal prism associated with increases in mean sea level could increase the lateral loads on the utility pipelines (water and sanitary sewer) supported under the bridge deck. The bridge structure should be reviewed for capacity to support these additional lateral loads. The costs associated with additional bracing, if necessary, are relatively small: in the vicinity of $0.5 million.

The I-5 Bridge has an extremely high deck elevation (over 50 feet) and would not be affected by increases in mean sea level. The trail under the bridge could be flooded in future, as described in Section 4.5.

4.5 Parks

Elevations of infrastructure in the parks surrounding Capitol Lake, with the exception of Heritage Park which was included with downtown Olympia in Section 4.2, are listed in Table 6. The elevations in this table are approximate.

This table demonstrates that much of the park infrastructure around Capitol Lake is vulnerable to flooding, and will remain so under either lake management alternative and whether or not the mean sea level increases. Measures such as replacing some of the trails at Tumwater Historical Park with boardwalks could mitigate the immediate flood risk, although this is not related to sea level rise. Generally, it appears that occasional flooding of the trails would be acceptable.

The parking and restroom at Marathon Park could be protected by a perimeter dike at such time as the flood risk becomes unacceptable in response to sea level rise. The cost associated with this would be less than $0.1 million. Based on earlier discussions, it appears likely that this would be necessary with a sea level rise of 0.5 to 1.0 feet with the Lake Alternative; it could be necessary almost immediately with the Estuary Alternatives.

Table 6. Parks and Trails Infrastructure and Approximate Elevations

Item	Elevation (feet, NGVD29)	Comment
Trails		
Trail along Deschutes Parkway	+10 to +12	Assume this will be raised with Deschutes Parkway
Trail under I-5 Bridge	+10	Vulnerable to flooding
Marathon Park		
Trails	+11	Vulnerable to flooding
Parking	+10 to +11	Vulnerable to flooding
Restrooms	+10 to +11	Vulnerable to flooding
Capitol Lake Interpretive Park		
Trails	+11.5 or more	Occasional flooding
Parking	+12 or more	Occasional flooding
Restrooms	+18	No effects anticipated
Tumwater Historical Park		
Trails	+9.5 or more	Some trails very vulnerable to flooding
Parking and Restrooms	+19 or more	No effects anticipated

4.6 Individual Affected Buildings

The General Administration Powerhouse has a first floor elevation of +13.9 feet NGVD29. As such, it is not vulnerable to flooding, even under the worst case considered here – the Estuary Alternative with a 2.0 feet increase in mean sea level. The parking lot, at an elevation of approximately +10 feet NGVD29, is vulnerable to 100-year flood events under existing conditions. With an increase in sea level of +0.5 feet, it would be vulnerable to the 10-year flood for the Lake Alternative and 2-year flood for the Estuary alternatives. A perimeter dike structure, approximately 400-feet long, could be constructed to protect the parking lot at this time; this structure would also provide additional protection to the building.

The Old Brewhouse lies within the 100-year floodplain: this report estimates the elevation at +11 feet NGVD29. If the building is restored, it is likely a perimeter dike or other measure would be constructed at that time to protect it against the existing 100-year flood. Assuming the dike to have a freeboard of at least 2 feet (compared to the typical FEMA requirement of 3 feet), the dike would not be overtopped by the 100-year flood even with an increase in sea level of 2 feet. However, an allowance is provided to raise the perimeter dike when needed.

Buildings located in areas above elevation +13 feet NGVD29 are considered to have no impacts due to higher water levels and flooding. However, an increase in groundwater elevation may affect properties of foundation soils (such as bearing capacity). Assessment of building foundations is outside the scope of this study but mentioned here in order to identify potential effects.

Planning-level costs (program costs in 2008 dollars) for the mitigation measures discussed here are as follows:

- Constructing a perimeter dike to protect the parking lot at the General Administration Powerhouse: $0.1 million to $0.2 million for both lake management alternatives. This is required with a sea level rise of 0.5 feet for the Lake Alternative and almost immediately for the Estuary Alternatives.
- Raising a perimeter dike to protect the Old Brewhouse: about $0.5 million. This is likely to be required with a sea level rise of 1.0 to 2.0 feet for both alternatives, depending on any flood protection that may be constructed as part of a building restoration project.

5. Summary

This report provides an assessment of the effects of sea level rise on low-lying infrastructure in the vicinity of Capitol Lake. The report compares possible future management alternatives: continued management of the lake as a lake (the Lake Alternative), and restoration of the Deschutes Estuary with or without a separate reflecting pool (the Estuary Alternatives).

The analysis of the future risk from flooding relies on recent hydraulic modeling results prepared by Moffatt & Nichol. These results included the conclusion that peak flood elevations were identical for the two Estuary Alternatives: consequently, this report does not consider the two alternatives separately.

Table 7 provides the 2-year and 100-year flood levels developed by Moffatt & Nichol for the two alternatives and under different sea level scenarios.

Table 7. Response of Floodplain Elevations to Sea Level Rise

Flood Elevations (feet, NGVD29)	Lake Alternative	Estuary Alternatives
2-year flood		
Current Sea Level*	8.6	10.0
Sea Level Increase of 0.5 feet	8.9	10.5
Sea Level Increase of 1.0 feet	9.2	11.0
Sea Level Increase of 2.0 feet	9.9	12.0
100-year flood		
Current Sea Level*	10.4	11.4
Sea Level Increase of 0.5 feet	10.9	11.9
Sea Level Increase of 1.0 feet	11.3	12.4
Sea Level Increase of 2.0 feet	12.1	13.4

* These elevations are used in this report and make reasonable assumptions regarding current and likely future operation of the Capitol Lake Dam. The published 100-year flood elevation is +11.0 feet NGVD29 based on earlier dam operations (FEMA 1981).

Average groundwater levels will either remain constant (under the Lake Alternative) or decrease compared to existing levels (under the Estuary Alternatives). While some effects of increased groundwater fluctuations are anticipated under the Estuary Alternatives, these are not highly dependent on increases in mean sea level.

Table 8 summarizes the identified major effects, mitigation measures, and costs associated with sea level rise for the Lake Alternative and the Estuary Alternatives. The costs in all cases are similar for the two alternatives. Costs are given as program costs in 2008 dollars. Some of the infrastructure in Olympia is already subject to flooding problems, and it was necessary to make reasonable assumptions as to which costs are associated with mitigating current flooding problems and which are associated with sea level rise.

Table 8. Effects and Mitigation Measures for Sea Level Rise

Infrastructure Effect and Mitigation	Cost	Triggering Sea Level Rise	
		Lake Alternative	Estuary Alternatives
Downtown Olympia			
Raise berm along Arc of Statehood	$2 M	1.0 ft	0.5 ft
Install stormwater pump station*	$4 M	Now*	Now*
Transportation Corridors			
Raise Deschutes Parkway near BNSF crossing	$4 M	1.0 ft	At most 0.5 ft*
Replace BNSF Railroad Trestle	$9 M	1.0 to 2.0 ft	0.5 to 1.0 ft
Raise rail track west of Capitol Lake	$3 M	Varies†	Varies†
Parks and Buildings			
Construct perimeter dike for parking and restroom at Marathon Park	$0.1 M	0.5 to 1.0 ft	At most 0.5 ft*
Construct perimeter dike for parking at GA Powerhouse	$0.2 M	0.5 ft	Now*
Construct or raise perimeter dike to protect the Old Brewhouse	$0.5 M	1.0 to 2.0 ft‡	1.0 to 2.0 ft‡

* This activity could reasonably be excluded from the costs associated specifically with sea level rise.

† This could be chosen to coincide with either the replacement of the BNSF Railroad Trestle or with raising Deschutes Parkway.

‡ The need for protection of the Old Brewhouse depends on the nature of any building restoration efforts that may be implemented.

Table 8 shows that increasing sea level would affect infrastructure sooner for the Estuary Alternatives, but the difference would not be dramatic.

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