Appendix A

Connor Creek Hydrologic and Hydraulic Analysis

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This document summarizes the hydrologic and hydraulic analysis of Connor Creek located near Ocean City and Copalis Beach in Grays Harbor County, Washington. The lower portion of Connor Creek was studied from the Connor Creek confluence with the Pacific Ocean to SR 109. The total reach length studied is about 4 miles.

Basin Description

The Connor Creek basin is generally forested in the upland areas with low density commercial and residential development in the lowland areas. The topography of the area is characterized as flat with a single steeply sloped area located in the southeastern part of the basin. Underlying soils are comprised of glacial outwash material with generally poor drainage and a high water table. The tributary drainage area at SR 109 is approximately 12.0 square miles and the tributary drainage area at the outlet to Pacific Ocean is approximately 13.0 square miles.

Detailed hydraulics were computed for Creek between the confluence with the Pacific Ocean and SR 109. For descriptive purposes, the study reach of Connor Creek can be divided into three sub-reaches: upper, middle, and lower. Channel and overbank characteristics within each sub-reach exhibit similar characteristics and are described in more detail below:

The upper sub-reach extends from SR 109 downstream to the bridge at the Leisure Time I Resort. The channel in this reach meanders slightly but is generally straight and uniform with a width of about 100 feet. The channel is lined with silt and sand and contains a moderate amount of vegetation and small number of woody debris jams. The left and right overbank areas are wooded with dense undergrowth.

The middle sub-reach extends from the bridge at the Leisure Time I Resort to a point about one mile downstream of the Surfcrest Condominiums. The channel is about 200 feet wide in this reach and is fairly irregular due to the historic movement of the creek outlet to the ocean. The channel is lined with silt and sand and is generally free of vegetation and debris. The left overbank is the landward side of the ocean dune and is mostly open with little vegetation. The right overbank is wooded with a moderate amount of undergrowth.

The lower sub-reach extends from a point about one mile downstream of the Surfcrest Condominiums to the outlet to the Pacific Ocean near Copalis Beach. The channel in this reach is generally straight and uniform with a width of about 100 feet. The channel is lined with silt and sand and is free of vegetation and debris. The left overbank is the landward

side of the ocean dune and is mostly open with no vegetation. The right overbank is mostly open with little vegetation.

Data Sources

The following data sources and reports were used in the analysis:

- USGS topographic mapping.
- Field survey data collected by Grays Harbor County staff during the spring of 1999. The datum used as for the filed survey was NAVD 1988
- Field reconnaissance conducted by CH2M HILL staff in February, 1999.
- *Connor Creek Stabilization Project Feasibility Study* (Pacific International Engineering, 1997)
- *Grays Harbor Flood Insurance Study* (FEMA 1983)
- Aerial photography (North Bay Resources,1999)
- Hydraulics Manual (WSDOT, 1997)

Connor Creek Basin Hydrologic Analysis

Peak discharge rates for the 2-, 10- and 100-year return frequency events were computed using the USGS regional regression equations for Region 1, Washington. The computed peak discharges are shown in Table 1.

TABLE 1
Peak Discharge Rates (in cfs) from the Connor Creek Basin

Return Frequency (years)	USGS Regression Equation[a]	Connor Creek at SR 109	Connor Creek at Pacific Ocean
2	$9.61\ A^{0.931}\ P_2^{1.61}$	570	610
10	$13.9\ A^{0.925}\ P_2^{1.68}$	880	940
100	$19.3\ A^{0.926}\ P_2^{1.70}$	1,250	1,340

Note:

a. A is the basin area in mi^2 and P_2 is the 2 year rainfall depth. P_2 is assumed to be 3.0 inches

The corresponding peak unit discharge computed for each return frequency was compared to peak unit discharge rates for comparable watersheds. This comparison was made to ensure the regional regression equations were providing a reasonable estimate of the peak discharge rate. Table 2 shows a comparison between peak unit discharge rates.

TABLE 2
Comparison of Peak Unit Discharge Rates (in cfs/mi²)

Stream	Drainage Area (mi^2)	2-Year	10-Year	100-Year
Newman Creek Confluence with Vance Creek	13.5	--	66	107
Cloquellum Creek above Wildcat Creek	39.6	--	76	104
Connor Creek at Pacific Ocean	13.0	47	72	103

Newman Creek and Cloquellum Creek peak unit discharge data Grays Harbor, Washington Flood Insurance Study (FEMA, 1983).

Connor Creek Hydraulic Analysis

The backwater computation program HEC-RAS v2.2 (HEC, 1998) was used to compute the associated peak stages in Connor Creek for 2-, 10- and 100-year return frequency peak discharge rates. Cross section data collected during the field survey was used to define the Connor Creek channel geometry. The cross section interpolation feature in HEC-RAS was used to develop intermediate cross sections for surveyed cross sections greater than 1,000 feet apart. Field survey data was also used to define bridge structures at the locations shown in Table 3.

TABLE 3
Structure Location

Location	Survey Structure Number	Stream Station (feet)
SR 109	1	24870
2nd Avenue	2	17870
Leisure Time Resort I	4	15740
Leisure Time Resort II	6	14700
Private Drive for 2747 SR 109	7	14065
Ocean Mist Resort	8	13110
Surfcrest Condominiums	9	11925

Channel and overbank roughness characteristics were selected based on field observations and aerial photography. The starting water surface elevation for all profiles was assumed to be 9.5 feet (NAVD 1988; equivalent to 12.0 feet MLLW as used in the ocean tide tables) and is based on an estimate of the reasonable high tide conditions.

Results of the hydraulic analysis are shown in Table 4, 5, and 6. Table 4 shows peak water surface elevations at selected locations in Connor Creek, Table 5 shows the headloss through

the structures, and Table 6 identifies the structure with flood flows overtopping the roadway. Figure 1 shows the computed water surface profile in Connor Creek for the 2-, 10-, and 100-year events.

TABLE 4
Peak Stream Stages (feet NAD88) in Connor Creek

Location	2-Year	10-Year	100-Year
Upstream of Bridge at SR 109	15.9	17.4	18.9
Upstream of Bridge at 2nd Avenue	15.0	16.4	17.6
Upstream of Bridge at Leisure Time Resort I	14.6	15.9	17.1
Upstream of Bridge at Leisure Time Resort II	14.1	15.3	16.4
Upstream of Bridge at Private Drive for 2747 SR 109	13.8	14.6	15.5
Upstream of Bridge at Ocean Mist Resort	13.5	14.2	14.9
Upstream of Bridge at Surfcrest Condominiums	13.3	14.0	14.6
Heath Road Extended	9.6	9.6	9.7
Outlet to Pacific Ocean	9.5	9.5	9.5

TABLE 5
Headloss Through Structure (feet)

Location	2-Year	10-Year	100-Year
Bridge at SR 109	0.01	0.04	0.04
Bridge at 2nd Avenue	0.02	0.02	0.04
Bridge at Leisure Time Resort I	0.04	0.07	0.06
Bridge at Leisure Time Resort II	0.05	0.16	0.36
Bridge at Private Drive for 2747 SR 109	0.02	0.02	0.04
Bridge at Ocean Mist Resort	0.01	0.02	0.03
Upstream of Bridge at Surfcrest Condominiums	0.0	0.0	0.01

TABLE 6
Overtopping Depth (feet)

Location	2-Year	10-Year	100-Year
Bridge at SR 109	--	0.4	1.9
Bridge at 2nd Avenue	--	--	--
Bridge at Leisure Time Resort I	1.9[a]	3.2[a]	4.4[a]
Bridge at Leisure Time Resort II	--	--	--
Bridge at Private Drive for 2747 SR 109	--	0.6[a]	1.5[a]
Bridge at Ocean Mist Resort	--	0.2[a]	0.9[a]
Bridge at Surfcrest Condominiums	--	--	--

Notes:

a. Overtopping occurs at left approach. Bridge does not overtop.

Discussion

The analysis showed that floodwaters overtop SR 109 by almost two feet during the 100-year event due to backwater effects of the downstream channel. Roadway overtopping also occurs at other structures also but is generally confined to bridge approach areas. Table 5 shows that the downstream structures do not cause a large headlosses and hence increases in backwater. An exception is the bridge at Leisure Time II Resort which contributes about 0.4 feet to the backwater increase.

Figure 1 shows a rise in the channel about 4,000 feet upstream of the outlet to the Pacific Ocean. The rapid increase in the water surface profile at this location indicates that this rise contributes significantly to backwater conditions in the stream. The permanence of this rise is unknown and it may be reasonable to assume that it is comprised of a highly erodable material, such as sand, and may be flushed out to the ocean during high flow periods. This phenomenon was not investigated because the study did not include an analysis of scour and deposition of bed material in the channel.

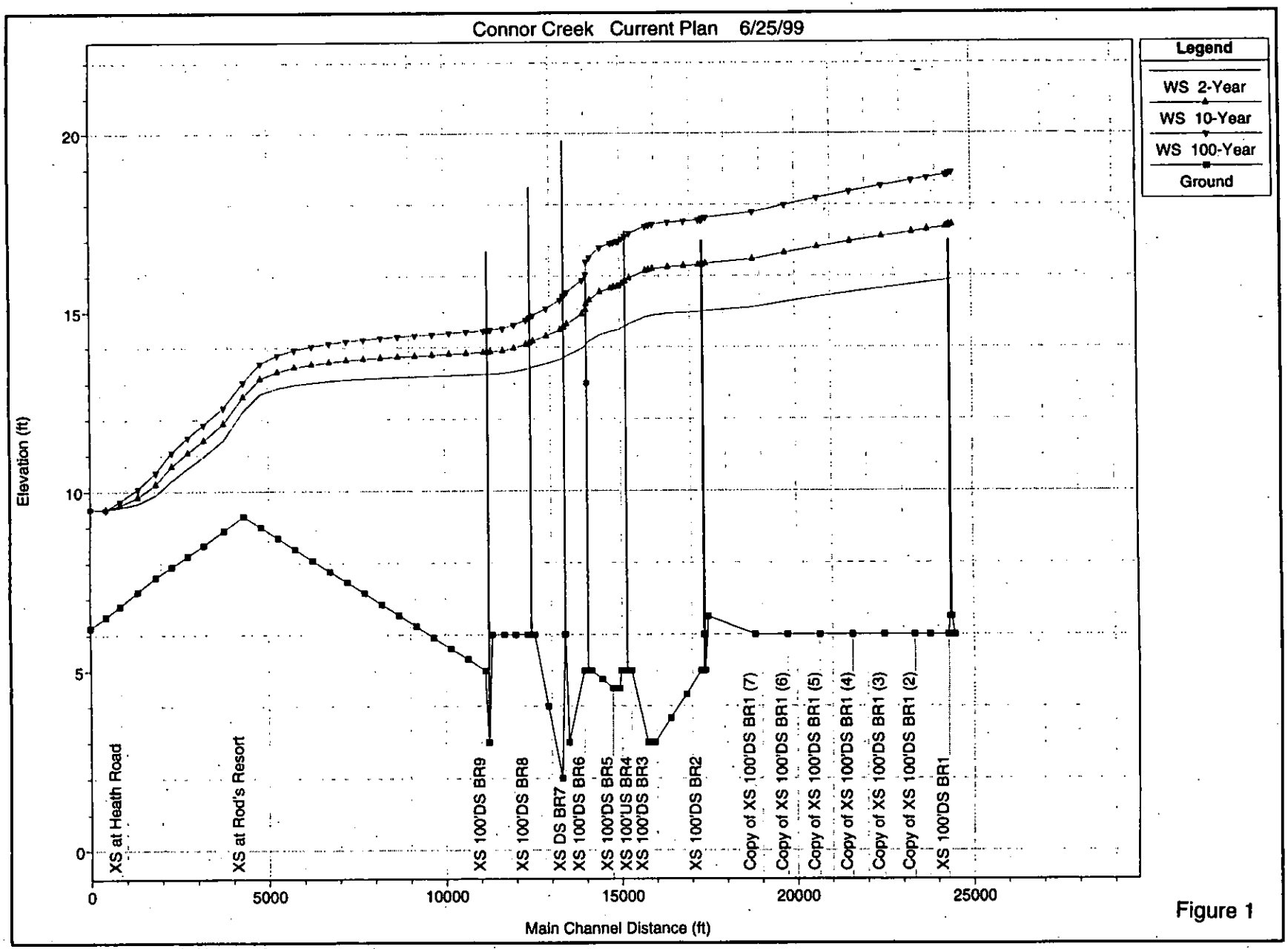
Connor Creek Current Plan 6/25/99
Legend
WS 2-Year
WS 10-Year
WS 100-Year
Ground
Elevation (ft)
Main Channel Distance (ft)
0
5
10
15
20
0
5000
10000
15000
20000
25000
XS at Heath Road
XS at Rod's Resort
XS 100'DS BR9
XS 100'DS BR8
XS DS BR7
XS 100'DS BR6
XS 100'DS BR5
XS 100'US BR4
XS 100'DS BR3
XS 100'DS BR2
Copy of XS 100'DS BR1 (7)
Copy of XS 100'DS BR1 (6)
Copy of XS 100'DS BR1 (5)
Copy of XS 100'DS BR1 (4)
Copy of XS 100'DS BR1 (3)
Copy of XS 100'DS BR1 (2)
XS 100'DS BR1
1 in Horiz. = 4000 ft 1 in Vert. = 4 ft

Figure 1