Reach Assessment for Norris Slough at SR 105

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June 2006

Washington State Department of Transportation
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INTRODUCTION

This report presents a site and reach assessment to identify solutions to culvert failures at the Norris Slough crossing of SR 105. The culvert and surrounding road embankment are collapsing in response to scour at the inlet and deterioration of the pipe. This has already undermined the road shoulder and threatens the stability of the SR 105 roadbed. The ***Site Assessment*** describes conditions in the immediate vicinity of the US 101 culvert. The ***Reach Assessment*** examines stream processes upstream and downstream of the project site that could influence the long-term stability of the slough. Site- and reach-based factors are then considered together to identify alternative solutions to the problem.

SITE ASSESSMENT AND PROBLEM DESCRIPTION

SR 105 crosses Norris Slough at Milepost 16.5, just west of Raymond near Toke Point (Figure 1). Norris Slough passes under the highway in a 5-foot corrugated metal pipe. It flows into the north end of Willapa Bay, and drains an estuarine marsh that extends about 1700 feet inland of SR 105.

The culvert originally included a tide gate that limited tidal flows and fish passage upstream of SR 105. The gate fell off in 1993, and has not been replaced. The culvert has been steadily deteriorating since the late 1990's, and has required frequent maintenance at the inlet. In 1999 WSDOT replaced a 20-foot section of pipe that had rusted off. In 2002 the road embankment began to erode and collapse around the culvert inlet (see Figure 2). In 2003 WSDOT attempted to insert a new pipe into the collapsed culvert inlet. This repair was unsuccessful, and since then WSDOT has focused on temporary stabilization of the failing road embankment and repair of the sunken asphalt shoulder.

Figure 1. Location of the Norris Slough Watershed.

Figure 2. 2003 photo of collapsing shoulder at the culvert inlet.

The culvert is undersized relative to the volume of tidal and flood flows conveyed by Norris Slough. Contraction and acceleration of flows at the inlet and outlet have created deep scour holes that undermine the culvert and the road embankment. The culvert was installed without wingwalls or bed armoring, and has rusted with exposure to saltwater. Unless it is replaced, it will eventually collapse and undermine the SR 105 roadbed.

REACH ASSESSMENT

The reach assessment for this project focuses on Norris Slough from its mouth in Willapa Bay to the upstream extent of tidal influence above SR 105. We also examine watershed-scale conditions where appropriate.

Watershed Conditions and Land Cover

Norris Slough drains 673 acres (1.05 square miles) at the SR 105 crossing. The watershed originates on low ridges in the coastal hills surrounding the north end of Willapa Bay. Elevations range from 400 feet above Mean Sea Level on the ridges to almost sea level at SR 105. The lower valley floor is nearly flat and transitions from tidal wetlands and sloughs near SR 105 to freshwater marshes at the upper end of the valley. Aerial photos indicate that the tidal marsh covers about 16 acres inland of SR 105 (Figure 3). Most of the valley floor is covered by fallow pasture and wetlands. Ridges and hillslopes in the basin are covered by managed forest and recent clear cuts. There is no substantial residential, commercial, or industrial development in the watershed. Unpaved forest roads generally follow the ridgelines. High forest road densities have caused landslides, erosion, and sedimentation in most Willapa Basin rivers and streams (Washington Conservation Commission, 1999).

Geology and Soils

The ridges that define the Norris Slough basin consist of Quaternary marine terrace deposits that have been eroded by streams. The valley floor is made up of fine-grained alluvium. In the last ice age sea levels were about 300 feet lower, and Willapa Bay was a river valley. As the glacial ice melted sea levels rose and inundated Willapa Bay. Valleys like Norris Slough gradually filled in with fine-grained alluvial sediment brought in by tributary streams and incoming tides. Norris Slough's valley floor now consists of a broad marshplain drained by small meandering tidal channels.

The valley floors are covered by Ocosta silty clay loam, a clayey alluvial soil deposited in coastal bays (USDA, 1979). Upland areas are covered by Newskah loam and Willapa silt loam soils that typically develop in marine sediment on coastal terraces.

Hydrology

The Norris Slough basin receives about 75 inches of mean annual precipitation (USGS, 2005). There is no significant winter snow pack in the watershed. Flood events are generally driven by a combination of high rainfall intensities and storm surge tides during coastal storms. The nearest USGS flow gage is on Clearwater Creek near Raymond, which produces about 67 cfs per square mile during a 2-year storm. Table 1 summarizes peak flow statistics estimated for Norris Slough using regional regression equations (WSDOT, 2004).

Table 1. Flow Statistics for Norris Slough at US 105

Event	Estimated Peak Flow (cfs)
2-year	77
10-year	121
25-year	142
50-year	161
100-year	180

Except for the largest storm events, flows in the Norris Slough culvert are dominated by tides. Table 2 shows the tidal characteristics at the nearest tidal benchmark station, Toke Point.

Table 2. Tidal Elevations for Toke Point (NOAA, 2003)

Tide	Elevation (feet NAVD 88)
Highest Observed	13.59
Mean Higher High Water (MHHW)	8.10
Mean High Water (MHW)	7.36
Mean Tide Level	3.96
Mean Lower Low Water (MLLW)	-0.82

The Flood Insurance Study for Pacific County identifies a 100-year high tide level of 14.4 feet NAVD 88 (10.8 feet NGVD) on the southwest side of Tokeland Peninsula (FEMA, 1985).

Channel Geometry and Flow Characteristics

The tidal portion of Norris Slough upstream of the culvert is about 2600 feet long, and meanders across a 200- to 550-foot wide marshplain (Figure 3). Near SR 105 the channel is a deep slough lined with tidal mud. The upper bank within the root zone is nearly vertical, but transitions to sloping mud that extends from the bottom of the root zone to the channel invert (Figure 4). WSDOT field surveys measured an average channel top width of 50 feet at the Mean Higher High Water elevation (8.1 feet NAVD). In many locations the active channel contains a 10-20 foot wide terrace at about +5.5 to +6.0 feet NAVD. These terraces are inundated by most high tides, and are typically colonized by Lyngby sedge.

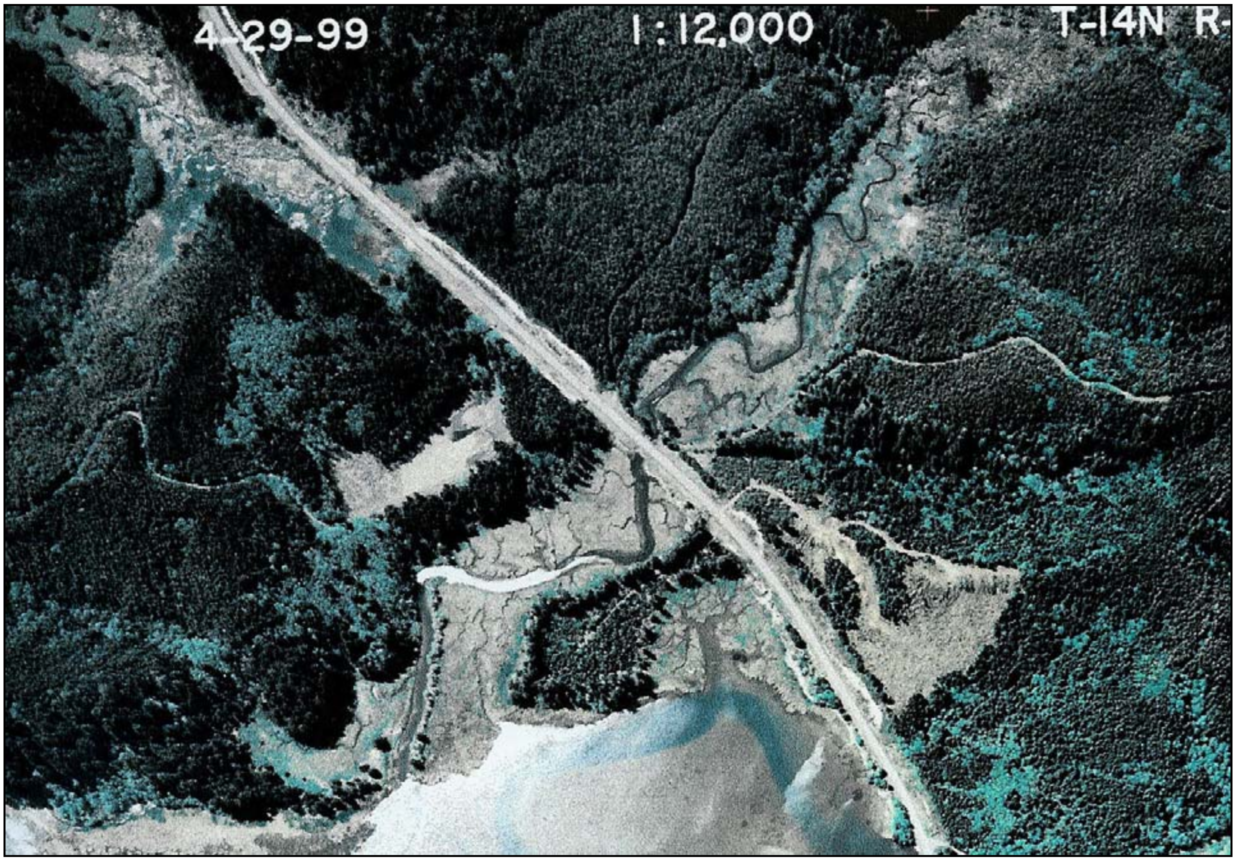

Figure 3. Aerial Photo of the Norris Slough Valley

Philip Williams and Associates (2001) analyzed data for reference marshes near Potters Slough in South Willapa Bay, and developed the following relationships between tidal channel characteristics and marsh drainage area:

Cross-Section Area at MHHW, ft^2 = 10.78 (Marsh Area at MHHW, acres)$^{1.1811}$

Channel Depth, feet = 4.754 (Marsh Area at MHHW, acres)$^{0.1966}$

Applying these relationships to Norris Slough (Marsh Area = 16 acres) yields a channel cross-section area of 285 square feet and a depth of 8.2 feet. Assuming a section shape similar to that shown in Figure 4, this corresponds to a channel top width of about 50 feet at MHHW. This is remarkably consistent with widths surveyed by WSDOT at Norris Slough.

Channel Profile and Sediment Transport

The existing SR 105 culvert has an invert elevation of +0.71 feet NAVD. Tidal flows have scoured deep holes at the inlet and outlet of the culvert that extend below –3 feet NAVD (WSDOT, 2003). Outside of these scour holes the channel gradient near SR 105 is nearly flat.

Because of its low gradient, Norris Slough has a limited ability to transport coarse sediment. Most of the coarse sediment is therefore deposited well above SR 105, where the freshwater tributaries transition onto the valley floor. At SR 105 the streambed and banks are made up of fine-grained silt and tidal mud. Much of this fine-grained sediment is carried into the system by daily tides from Willapa Bay. Flood flows during large storm events will also periodically convey fine sediment into the tidal marsh from the upper watershed.

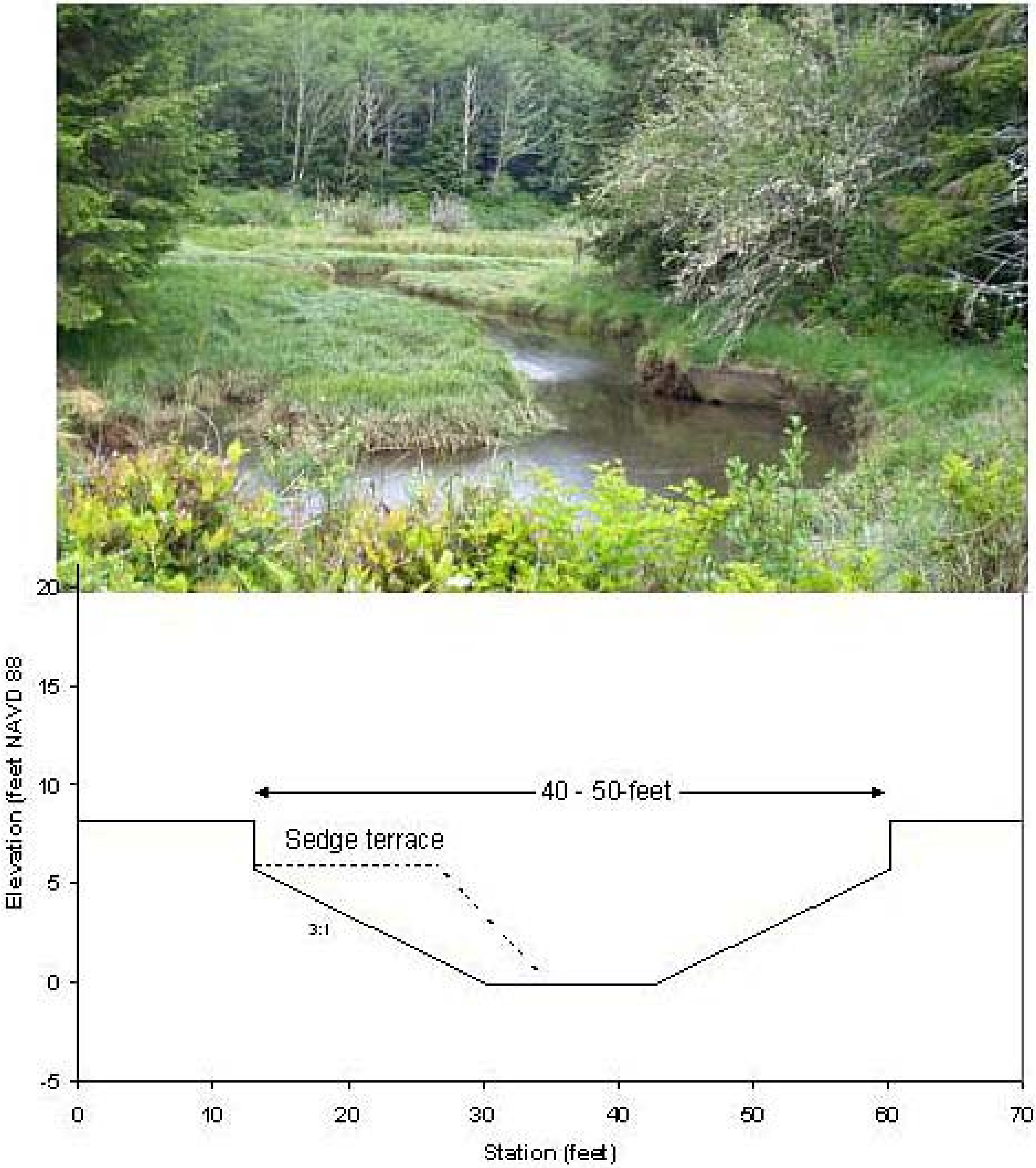

Figure 4. Typical Cross Section of Norris Slough near SR 105

Riparian Condition and Large Woody Debris

Trees are generally absent from the Norris Slough valley floor, except for scattered Sitka Spruce and alders on upland mounds adjacent to SR 105 (Figure 3). The valley floor has historically been cleared for pasture, and tidal flooding and saline soils limit the establishment of trees along Norris Slough. Low areas next to sloughs are covered by Lyngby sedge. High marsh areas are dominated by a variety of sedges, marsh grasses, and pasture vegetation. The culvert at SR 105 limits the movement of large woody debris into lower reaches of Norris Slough.

The upper end of the valley floor is covered by freshwater marshes and beaver ponds. Trees are also largely absent from these areas. High water levels may limit the establishment of trees in these wetlands. Tributary streams flow through managed coniferous forest.

Water Quality

There is no data in Ecology's EIM database for Norris Slough, and it is not on Ecology's 303(d) list of impaired waters (Washington State Department of Ecology, 2005). Willapa Bay is listed as a Category 2 Water of Concern for Carbaryl at the mouth of Norris Slough and the Cedar River. Water quality at the mouths of the Willapa River and North River is impaired by fecal coliform.

Fish Utilization and Habitat Availability

State fish distribution inventories show coho salmon as present in the non-tidal portions of Norris Slough and five small tributaries (WDFW, 2006). These small streams and associated freshwater wetlands provide potential spawning and rearing habitat. Cutthroat trout may also be present, but there has been little formal mapping of their distribution in the Willapa Bay basin. Prior to 1993 the tide gate at SR 105 blocked juvenile salmon access to the upper slough and its tributaries (Washington State Conservation Commission, 1999). The gate has now fallen off, but contraction of peak tidal flows at the culvert creates periods of high velocities that are not favorable for juvenile fish passage.

Stocks of chinook, chum, and steelhead use the nearby North River and Smith Creek watersheds, but they are unlikely to spawn in the small streams in the Norris Slough watershed. However, all of these salmonids may use the tidal portions of Norris Slough for transition habitat during migration. Chinook and chum juveniles in particular depend on estuarine habitat for successful rearing and growth (Washington State Conservation Commission, 1999).

The loss of estuarine habitat by diking and tide gates is an important limiting factor for salmon throughout Willapa Bay (Washington State Conservation Commission, 1999). The Cedar River no longer supports salmon because of tide gates at the mouth. Loss of estuarine habitat is also identified as a major limiting factor in the North, Willapa, Palix, Nemah, Naselle, and Bear River watersheds. Poor riparian conditions, low levels of large woody debris, sedimentation, channel incision, and fish passage barriers further limit salmon production in the North River and other nearby Willapa Bay tributaries.

No salmonids in the Willapa Bay basin are listed as threatened or endangered under the Endangered Species Act (NOAA Fisheries, 2006; WSDOT, 2006). The U.S. Fish and Wildlife Service lists coastal cutthroat trout as a Federal Species of Concern (WSDOT, 2006).

EVALUATION OF TREATMENT ALTERNATIVES

Mechanisms and Causes of Failure

The mechanisms of failure are undermining of the culvert and surrounding road embankment by scour, and structural collapse of the culvert. This is caused by excessive contraction of flows at the culvert inlet, and by deterioration of the metal culvert by exposure to saltwater.

Project Objectives

The objectives of this project are to:

- Stabilize the SR 105 embankment and roadbed
- Reduce maintenance at the Norris Slough crossing
- Minimize scour at the culvert inlet and outlet
- Provide sufficient capacity at the crossing to convey water, woody debris, and sediment
- Meet WDFW fish passage guidelines

Treatment Alternatives

No Action. The existing Norris Slough culvert would remain in place and continue to deteriorate. Scour would continue to undermine the culvert and surrounding road embankment. WSDOT would periodically attempt to repair the embankment by placing fill and bank armor around the culvert inlet and outlet. As the culvert collapses, it will create sinkholes in the SR105 road surface that will threaten the safety of the driving public and require continual repaving. Although it is not a complete barrier to fish passage, the existing culvert creates high velocities and poor conditions for juvenile salmonid migration. It also disrupts the natural movement of water, woody debris, and sediment through the Norris Slough system. The No Action alternative therefore does not meet the project objectives.

Alternative 1 – Replace culvert with a bridge. The existing culvert would be replaced with an 84-foot long bridge that would span typical natural channel widths upstream of the SR 105. The 84-foot span would meet WDFW stream simulation requirements, and may provide some marshplain area beneath the bridge. This alternative would allow development of a natural channel beneath the roadbed, and minimize contraction of flows at the crossing. This would significantly reduce scour at the inlet and outlet, and allow the movement of water, woody debris, and sediment through the road crossing. This alternative would also increase tidal marsh habitat upstream of SR 105 by eliminating muting of tides at the road crossing. The bridge would cost about $1,025,000 to construct.

Alternative 2 – Replace the culvert with a 3-sided culvert. The existing culvert would be replaced with a 50-foot wide 3-sided structure. The 50-foot span closely matches natural channel widths upstream and downstream of SR 105. This would minimize flow contraction and scour at the culvert inlet, and would improve fish passage. It would also allow the movement of water, woody debris, and sediment through the road crossing, but to a lesser degree than Alternative 1. This alternative would not provide any marshplain area beneath the road.

The bay mud that underlies the site would provide poor conditions for the structure’s foundation. The structure would cost about $1,984,000 to construct.

CONCLUSIONS

Scour and deterioration are undermining the Norris Slough culvert, causing the SR 10 road embankment to collapse and fail. This has led to frequent maintenance at the culvert inlet that is costly, damaging to the aquatic environment, and only marginally effective. The existing culvert is significantly undersized and needs to be replaced.

We examined two alternatives for replacing the culvert. Replacing the culvert with a bridge provides greater environmental benefits, and costs less than replacement with a three-sided structure. We therefore recommend the bridge alternative (Alternative 1) as the long-term solution for SR 105 at Norris Slough.

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