Appendix J: Hydrodynamic and Sediment Transport Modeling Summary

Introduction

A hydrodynamic and sediment transport model and technical report were developed to evaluate tidal restoration alternatives at Nisqually NWR (ENSR 1999). This computer model was used to simulate water, sediment, and salinity characteristics under various restoration scenarios using a mean tide and mean annual river flow condition, and under 1996 river flood conditions. This modeling effort was useful in evaluating critical physical components involved in restoration, including water flow, timing, velocity, bed shear, salinity, sedimentation, and extent of tidal inundation. The model was also used to assess extreme flood conditions and alternative dike configurations.

Methods

The study area included the Nisqually River, McAllister Creek, I-5, and Puget Sound/Nisqually Reach as limits on each side. Existing data were used as much as possible on river and delta geometry, bathymetry, currents, salinity, and sediment characteristics. In addition, new data were gathered in the Nisqually River and McAllister Creek to fill information gaps, including river bathymetry, velocity time-series, salinity profiles, water surface elevations, suspended sediment concentration, and creek and pond bathymetry inside the diked area. The models used were RMA-10 for hydrodynamics and RMA-11 for sediment and salinity transport. These models can account for the effects of temperature, salinity, and suspended sediment on flow in rivers, estuaries, lakes, and reservoirs. The models were calibrated and verified using data collected during spring 1998 from the Nisqually River and McAllister Creek.

Eight alternatives were examined (with a variation in breach width on one alternative), ranging from Alternative 1, no changes in existing dike configuration (status quo), to Alternative 8, with maximum tidal restoration (approximately 80% of the diked area). Each alternative assumed the dikes were reduced down to grade in estuarine restoration areas, and the adjacent borrow ditch was filled, except for two alternatives that included breaching and bridging dikes in specific locations and retaining the dike system, with the borrow ditch left unfilled. Breaches in Alternative 3 had widths of 45 to 55 feet, creating restricted tidal flow. Breach widths were also modified in Alternatives 3 and 4 with breach widths sized to be slightly wider than the size of the existing tidal sloughs, so as to try ensure that high tidal volumes could enter and exit the restoration site. This made breaches very wide, from approximately 240 to 325 feet. These modifications were referred to as Alternatives 3W and 4b. Alternative 6, the 70% tidal restoration alternative, included a low berm to create a riparian restoration zone along the Nisqually River. All alternatives were designed to protect Nisqually NWR headquarters facilities within dikes.

Modeling Results and Discussion

The model provides important information that is useful in assessing some of the key components of estuarine restoration projects. Successful estuarine restoration typically depends on recreating a fully functional tidal system, where the tidal prism or volume is sufficient for full tidal inundation in the restored area with each tidal cycle. Natural patterns in tidal flushing and circulation are critical to flush soils, carry nutrients and sediments to all parts of a restored site, and create the intricate system of tidal channels that feed a salt marsh. Conversely, tidal waters must be able to evacuate the site, to avoid ponding and fish entrapment. Excessive ponding will create lagoon-like or subtidal conditions, rather than a salt marsh. Isolated ponding can create artificially high salinities in water or soils due to evaporation and lack of flushing. Successful estuarine restoration also depends on the ability of sediments to reach the restored site, to accumulate soils and build the elevations necessary to grow salt marsh vegetation. Areas requiring tidal restoration are often subsided, and sedimentation is a critical component of successful restoration. Another important factor in successful estuarine restoration includes minimizing areas of high water velocity or bed shear to avoid creating highly erosive features. High bed shear could result in erosion of salt marsh, dikes, or breaches that would present potential failure sites or constant maintenance needs.

Dike Configuration and Water Movement: In alternatives where the dikes were removed to grade and the borrow ditch filled, full tidal penetration occurred with each of the alternatives. In Alternative 3, when dikes were breached with narrow openings along McAllister Creek, the peak water surface elevation in the restored area decreased by approximately 1.7 feet, and the peak was delayed by 40 minutes from what would be expected with unrestricted tidal conditions. Even wide breaches (Alternatives 3W and 4b) produced a slight delay due to the distance from the mouth of McAllister Creek. For Alternative 4b, the 50% restoration alternative in which the dikes were retained and very wide breaches added, the peak water surface elevation and timing of the tide phase were not significantly decreased. However, the wide breaches apparently reduced outflow during the receding tide, so stored water could not completely drain, leaving ponding within the restored area and in the unfilled borrow ditches. Leaving the borrow ditches unfilled (Alternatives 3, 3W, and 4b) also showed that tidal waters were partially diverted into the borrow ditches on incoming tides, affecting tidal circulation in sloughs.

Flooding: During extreme flood conditions, the Nisqually River overtops its banks upstream of the Refuge, on the south side of the I-5 bridge. The water inundates the floodplain and flows into the diked area, with approximately 70% of flood waters entering the southeast corner of the Refuge through a channel and opening under I-5 and about 30% entering through an overflow channel adjacent to McAllister Creek. All alternatives showed flooding in the diked area under 1996 flood conditions. The alternatives that restored 70% and 80% of the diked area and eliminated cross dikes along the McAllister Creek side of the Refuge reduced flood impacts to the Refuge. These alternatives allowed flood waters from the McAllister Creek overflow channel to empty unimpeded into the McAllister Creek tidal system, instead of emptying inside of diked habitat. However, diked areas in all alternatives were still flooded by flows from the overflow channel at the southeast corner of the Refuge.

Water Velocities and Bed Shear: Water velocities in tidal channels outside the dike under current conditions (status quo) were lower than restored alternatives where dikes were removed. This illustrates one of the effects of diking, where tidal channels outside the dike have a reduced tidal prism or volume because of the loss of tidal area. Alternatives that created new crossdikes that blocked tidal channels created this same backwater effect, producing a reduced volume or flow in tidal channels than would occur in a system without dikes. Alternatives with no crossdikes along McAllister Creek (70% and 80% alternatives) alleviated this effect, producing fuller tidal flow in the sloughs and channels along McAllister Creek.

Water velocities and bed shear, another measure of potential erosion, were much higher in fixed breaches, as compared to unrestricted tidal channels where dikes were removed. This illustrates the difficulty in protecting fixed breaches from eroding or widening, especially during flood conditions. In addition, velocities in the Nisqually River were confirmed to be much higher at large bends in the river, particularly during flood conditions, illustrating the highly erosive conditions that lead to dike failures, when these high velocities are forced to stay within constricted channels.

Salinity: Salinity patterns were only modeled for two tidal cycles. Longer simulations may show greater salinity penetration. Alternatives where dikes were breached and retained showed less salinity penetration in the restored area. Less salinity penetration was also observed in McAllister Creek in a 50% alternative, due to the dike constriction along McAllister Creek, which reduced tidal flow up McAllister.

Sedimentation: Sediment loads are small in the Nisqually River, McAllister Creek, and the Nisqually Reach during near annual flow conditions. Maximizing sediment deposition in restored areas is important to enhance success in a sediment-poor system like the Nisqually delta. The major source of sediments comes down the Nisqually River during flood events, when large amounts of sediment are carried in flood waters. An extended simulation period may be needed to evaluate more long-term deposition patterns; however, deposition during the 1996 flood event provides an example of potential sedimentation patterns. Dike configuration affected sediment deposition patterns. In general, alternatives where more dike was removed along the Nisqually River showed more sediment deposition along the river and in restored areas. Alternative 3, which had narrow dike breaches, showed little sediment deposition.

Conclusions

The model was very useful in evaluating various estuarine restoration scenarios, using a variety of dike configurations. Full tidal penetration occurred when dikes were removed to grade and the borrow ditch filled. Narrow breaches restricted tidal flow, reducing water surface elevations on incoming tides and delaying tidal flows. Breaches greater than the width of channel openings also allowed full tidal penetration, but stored water did not completely drain in receding tides, resulting in ponding in marshes and borrow ditches. Borrow ditches partially diverted incoming tidal flows when left unfilled, affecting circulation in restored tidal channels. Restoration scenarios retaining dikes with breaches also reduced sedimentation and altered salinity patterns. Water velocities and bed shear in channels moving through dike breaches indicated that fixed breaches may be difficult to protect from erosion.

Flooding upstream of I-5 is not expected to be adversely impacted by habitat restoration. Alternatives resulting in 70% and 80% estuarine restoration reduced flooding in the diked area, by allowing the McAllister overflow channel to empty directly into McAllister Creek. Salinity tended toward marine conditions, but some brackish areas may occur near the margins of marine water penetration. The Nisqually River is a sediment-poor system, due to dams upstream on the Nisqually River which trap much of the sediments. However, during flood events, the Nisqually River provides a major source of sediment. Dike configurations with more dike removed along the River allowed a greater amount of sediment to deposit in the restored area.

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