Sitka Sedge State Natural Area
Executive Summary of Results from Hydrology Modeling

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Hydrological consultants Pacific Groundwater Group (PGG) and Environmental Science Associates (ESA) used surface-water and groundwater data collected from a variety of locations and monitoring wells to develop both surface-water and groundwater models for the area centered on Beltz Marsh and Tierra del Mar (TDM). The object of their investigation is to estimate the expected effects of different Beltz Dike modification scenarios on groundwater levels beneath TDM. Hydrogeologic characterization indicated that there are two distinct water-bearing layers beneath TDM: the Shallow Aquifer and the Deep Aquifer. Hydraulic communication between the Shallow and Deep Aquifers is limited by an intervening clay/silt layer.

After characterizing the surface-water and groundwater systems, the next step in the modeling process was to identify potential Beltz Dike configurations along with hydrologic conditions under which these configurations would be assessed. Initial dike configurations and hydrological conditions were selected to span a wide range of potential hydrological effects. Initial modeling scenarios, run over the range of dike configurations and hydrologic conditions, allowed assessment of groundwater responses under both average and extreme conditions, and provided a basis to re-engage stakeholders in scoping additional modeling and assessment needs. As a result of stakeholder review and consultant recommendations, several supplemental analyses were identified for further assessment. These supplemental analyses focused on exploring modifications to the existing scenarios, evaluating model sensitivity to identified uncertainties, or additional related scoping rather than formulation of entirely new scenarios.

The initial scenarios are driven by three dike configurations: 1) the existing, malfunctioning tide gate; 2) replacing the existing tide gate with a modern muted tide gate that meets fish passage regulation requirements; and, 3) a dike breach sized to pass enough tidal water so that water-surface elevations in Beltz Marsh would match water-surface elevations outside the dike in Sand Lake. The surface-water model was adapted to represent each of these configurations, and run over a 38-day period that included a 28 day period of average wet-season conditions along with a 10 day period with a simulated 50-year storm event combined with an extreme “King” tide event. Surface-water model predicted inundation in Beltz Marsh was input to the groundwater model to predict water-level responses beneath TDM. The groundwater model provided the following predictions:

1. **Modern Tide Gate Scenario** - Relative to the current leaking tide gate, the model predicts that a modern tide gate would reduce Shallow Aquifer groundwater elevations beneath TDM by very small amounts (<1/8 inch) during average wet-season conditions. During storm/king tide conditions, the model predicted water-level reduction of up to 2 inches in a shallow-aquifer monitoring well located adjacent to Beltz Marsh. The predicted groundwater level reduction rapidly diminishes with distance from the marsh, and is not evident in any other Shallow-Aquifer monitoring wells in the study area. The reduced predicted groundwater elevations result from lower surface-water elevations in Beltz Marsh, which result from: 1) more efficient drainage achieved by the modern tide gate, and 2) the tide gate’s design, whereby the gates close to prevent tide water from entering the marsh after water surface elevation inside the dike exceeds 7.0 feet.

2. **Dike Breach Scenario** - Relative to existing conditions, the dike-breach simulations predicted insignificant change in Shallow Aquifer groundwater elevations beneath TDM during average conditions and reduced groundwater elevations during the storm event. During average conditions, water levels in the Shallow-Aquifer monitoring well located adjacent to Beltz Marsh were predicted to exhibit increases up to ¼ inch. This minor increase occurs because the breached dike allows more tidal exchange, resulting in higher peak surface-water elevations in Beltz Marsh for short durations. The water-level increase is predicted to decrease rapidly with distance from Beltz Marsh, and is not predicted for any other Shallow-Aquifer monitoring wells in the study area. During storm conditions, Shallow-Aquifer groundwater levels are predicted to be lower than existing conditions by up to 1.7 inches in the well near Beltz Marsh. This effect diminishes rapidly in monitoring wells located farther south. Reduced groundwater elevations during storm conditions arise because better drainage through the dike breach reduces the accumulation of stream inflows behind the dike, causing less prolonged inundation.
3. **Deep Aquifer Effects** - Model predictions for the Deep Aquifer exhibit the same trends as noted above for the Shallow Aquifer, but water-level changes are predicted to be larger than for the Shallow Aquifer. This difference occurs due to the confined nature of the Deep Aquifer, which transfers hydrologic effects at the marsh farther into the groundwater system beneath TDM. In contrast, higher available storage in the (unconfined) shallow aquifer tends to reduce the influence of water-level variations from Beltz Marsh to areas underlying TDM. Furthermore, the clay confining layer that separates the Shallow and Deep Aquifers limits the influence of predicted changes in the Deep Aquifer on water levels in the Shallow Aquifer. Thus the model predicts that water-level changes in the Deep Aquifer will have minimal impact on the Shallow Aquifer.

To summarize primary/initial scenario findings: during significant storm conditions, models for both the Modern Tide Gate scenario and the Dike Breach scenario predict a reduction in prolonged retention of backed-up surface water in Beltz Marsh, which results in predicted lower groundwater elevations in the Shallow Aquifer near the marsh. Lower marsh levels occur due to increased drainage effects compared to the current leaking tide gate. Under conditions of average precipitation and tides, the Modern Tide Gate scenario is predicted to insignificantly reduce shallow groundwater compared to the existing leaking tide gate. The Dike Breach scenario, under conditions of average precipitation and tides, is predicted to insignificantly increase shallow groundwater relative to the existing leaking tide gate in only the well closest to the marsh (no significant change is predicted for any other wells in the study area). Compared to both the Modern Tide Gate and existing tide gate scenarios, the Dike Breach scenario would result in increased frequency of tidal inundation of the areas in Beltz Marsh and East Marsh within an elevation range of 7.5 and 12 feet, but these areas would have a decreased duration of inundation under storm conditions compared to the existing tide gate.

Sitka Sedge State Natural Area Hydrology Study: Results from Initial Hydrological Modeling Scenarios

		Storm and Tide inputs		
		Shallow Aquifer Groundwater level change relative to existing tide gate: Average precipitation and tides	**Shallow Aquifer Groundwater level change relative to existing tide gate: 50-year storm and king tides**	**Surface water characteristics comparison**
Dike Configuration Scenario	Existing Leaky Tide Gate	NA (existing condition compared to itself)	NA (existing condition compared to itself)	Longest duration of inundation of upper elevations (7-12+ ft) in Beltz and East Marsh under significant storm conditions due to restricted outflow through dike. Lower frequency of inundation of upper marsh elevations under average conditions than Dike Breach, higher than Modern Tide Gate.
	Modern Tide Gate	Less than 1/8 inch decrease	Up to 2 inches decrease in well closest to Beltz Marsh, and no change evident in other wells to the south	Lowest Beltz Marsh water surface elevations. Rapid drainage. Lowest duration of inundation of upper marsh elevations under both average and extreme conditions.
	Dike Breach	Up to ¼ inch increase in well closest to Beltz Marsh. No effect in wells further from the Marsh.	Up to 1.7 inch decrease in well closest to Beltz Marsh. No effect in other wells.	Increased frequency of inundation of upper elevations of marsh (7'-12') relative to Existing Tide Gate and Modern Tide Gate under average conditions. Decreased duration of inundation of upper elevations of marsh relative to Existing Tide Gate under storm conditions due to rapid drainage.

After completion and presentation of the initial modeling work, supplemental analyses were completed to address comments and suggestions of stakeholders received during review. Some of these supplemental analyses were addressed qualitatively, others using simplified quantitative calculations, and others using the surface-water and groundwater models. These supplemental analyses and their results are summarized below:

1. Evaluation of the feasibility of constructing a setback dike located south of Reneke and Beltz Creeks that would allow for full tidal reconnection of the majority of Beltz Marsh while maintaining muted tides in the area of the marsh closest to TDM. Under this scenario (which would require a tide gate) the setback dike would retain freshwater inputs from No-Name Creek/East Marsh, TDM ditches, surface water and groundwater drainage, and direct precipitation in a smaller storage basin while the tide gate is closed at high tide. Beltz and Reneke Creeks would be outside of the setback dike.

   Result: *The analysis indicated that a setback dike could accommodate freshwater/stormwater inputs without resulting in higher marsh surface water or TDM groundwater relative to the previously assessed scenarios.*

2. Characterization of the effect of surface water "backing up" upstream of the Sand Lake Road culvert in the East Marsh, or in the TDM east ditch along Sand Lake Road when water is high in Beltz Marsh.

   Result: *Analysis indicated that some limited backing-up of water is possible, but this effect would be minimal and unlikely to significantly affect groundwater or result in significant difference in surface-water patterns.*

3. Characterization of the protective value of an overtopped dike for its ability to reduce peak water levels or delay rising water levels upstream of Beltz Dike.

   Result: *Analysis indicated that the dike (if it remained intact upon overtopping) could delay the arrival of storm and tide-driven high water under a sea level rise situation. The length of the delay could be from 3.5 hours to 30 minutes with 6 inches to 1 foot of dike overtopping and no previous water accumulation behind the dike. The dike is not designed to sustain overtopping and could potentially be unintentionally breached and eroded by such an overtopping event which could either reduce the delay time because of failure, or make it useful only for the first such overtopping event in a series of high tides. If overtopping were to coincide with high water retention behind the dike during a significant storm, the delay benefit would be substantially decreased or nearly eliminated depending on the water level behind the dike prior to overtopping.*

4. Assessment of how inclusion (or exclusion) of inundation accumulated behind the beaver dam affects surface-water model results (i.e., if substantial additional storage volume could be achieved by removing the beaver dam).

   Result: *Analysis indicated that retention of water behind the beaver dam does not significantly change surface water levels due to the relatively low storage volume occupied. Water levels without the beaver dam could be lower by a maximum of 0.1 foot (1.2 inches).*

5. Surface-water and groundwater modeling for an 8-foot modern tide gate closure setting instead of the previously-modeled 7.0 foot setting.

Result: *Analysis indicated that the 8-foot setting did not increase surface water and groundwater levels very much relative to the 7.0-foot setting. During the king tide/50-year storm event, surface water levels were predicted to be higher than the 7.0 foot closure setting scenario by 0.1 to 0.2ft (1.2 to 2.4 inches). This increase in surface water level translated to a maximum groundwater level increase of 0.01 ft (less than 1/8 inch) in the well with the largest groundwater effect.*

6. Assessment of groundwater model sensitivity to hydraulic connectivity between the Shallow Aquifer beneath TDM and Beltz Marsh, achieved by increasing the local transmissivity of the Shallow Aquifer beneath Beltz Marsh and the hydraulic conductivity of the "skin" sediments on the marsh floor.

   Result: Groundwater modeling *analysis indicated that predictions of water-level responses in the Shallow Aquifer beneath TDM were not sensitive to changes in local aquifer transmissivity and marsh skin hydraulic conductivity, and that previous model calibration remained valid and successful. In order to evaluate the sensitivity of model predictions to an assumed enhanced connection between the marsh and the Shallow Aquifer beneath TDM, PGG developed an "enhanced marsh connectivity" (EMC) version of the model and compared results with the previously run version of the groundwater model. Shallow-Aquifer responses are of greatest concern to TDM, and Shallow-Aquifer predictions generally show no significant difference from results generated with the original model. The only notable difference in the Shallow Aquifer occurs immediately adjacent to Beltz Marsh (e.g. in nearby Well PGG-1i), where the EMC-model predicted enhanced response to marsh flooding equally for all three dike configurations (i.e. groundwater rise under the alternative configurations was the same as for the current configuration) but also predicted enhanced rates of groundwater level decline for the alternative dike configurations. Specifically, the EMC model predicted about 0.25 feet (3 inches) more groundwater rise in Well PGG-1i at the peak of marsh flooding for all configurations, but that (relative to the current dike configuration) declining groundwater levels under the alternative configurations were 0.1 feet (1.2 inches) lower than predicted by the original model four days after the flood peak. Enhanced lowering of groundwater levels towards the end of the flood condition is driven by: 1) reduced surface-water levels predicted in the marsh after the flood peak with the alternative dike configurations and 2) the role of EMC to enhance drainage of the Shallow Aquifer to the marsh as marsh flooding recedes. For both the original and EMC models, the alternative dike configurations are not predicted to exacerbate groundwater flooding beneath TDM relative to the existing tidegate, but are predicted to mildly reduce its duration.*

7. Assessment whether compaction of soils beneath Sand Lake Road is likely to affect the transmissivity of the underlying Shallow Aquifer

   Result: Based on a review of geotechnical literature and discussions with professionals familiar with this question, PGG found that compaction beneath the road is unlikely to significantly affect aquifer transmissivity. Sand Lake Road elevations range from 15-22 feet MSL along TDM, whereas the bottom of the Shallow Aquifer (top of clay layer) generally occurs at an elevation of around 4-5 feet MSL. Assuming that the road was installed directly on native materials or on a built upon a base of crushed rock positioned on top of native materials, the thickness of sandy materials beneath the road is expected to range from about 10-18 feet. Compaction depth for loose sand is generally not expected to exceed 4-5 feet, and the affected zone can be significantly less if the sand is already wave-compacted or if the road does not have a (heavy) fill base. Within the affected zone, compaction also diminishes as a function of depth. Saturation in the Shallow Aquifer is generally expected to occur at least several feet below the road. Applying these concepts to conditions at Sand Lake Road suggests that compaction will not significantly affect groundwater flow beneath the road.