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To: Veronica Pearson, Marin County Parks

From: Laurel Collins, Watershed Sciences

Date: 7/26/2018

Subject: Notes about the influence of Cal Trans' culverts along State Route 1 that influence creeks draining into Bolinas Lagoon

These notes are in reference to 10 July 2018 letter to Ralph Camicca from Cal Trans regarding clearing culverts and ditches of debris along the intersection of Olema-Bolinas Road and Fairfax-Bolinas Road prior to the 2018 rainy season. Four associated location priority maps developed by Cal Trans for the clearing work are referred to in this memo.

This memo provides key important topics regarding the influence of the SR1 culverts and lays out the need for prudent planning efforts that should go beyond the routine and ineffective strategies of the past. Several figures are attached to support the key topics.

1. Tidal datum and sea level rise projections in Bolinas Lagoon are:
   - For 2016, MHHW is reported[2] as 5.6 feet NAVD88;
   - For 2030 sea level rise[3] of about 1 foot, MHHW will equal an elevation of about 6.6 feet NAVD 88;
   - For 2050 sea level rise[2] of about 2.0 feet, MHHW will equal an elevation of about 7.6 feet NAVD88; and
   - For 2100 sea level rise[2] of 5.5 feet, MHHW will equal an elevation of about 11.1 feet NAVD88.

2. SR1 culverts intersect numerous channels draining into the Bolinas Lagoon from the Bolinas Ridge. Under the existing SR1 infrastructure setting, the conveyance of water and sediment in many of these culverts will become an increasing challenge to maintain because of the geomorphic location of these structures in the landscape. The culverts exist along the toes of alluvial fans, either just upstream or within the upper transition zones of high tide influences.

3. Generally, at the toes of coastal alluvial fans near Bolinas Lagoon:
   - Sediment deposition and outward growth of the fan and its delta is a natural and perpetual process unless sea level is rising or sediment supply becomes interrupted or limited, in which case the fan could become submerged if sea level rise rates exceeds the rate of sediment supply and deposition.
   - Transport of large woody debris is a natural and perpetual process along these streams. Its abundance and supply can influence the transport and storage of sediment.
   - Lateral and vertical channel instability is the expected norm causing streams to migrate, form multiple distributaries, and create overflow channels.

Attachment #4

- The diurnal tidal range establishes base level for groundwater emerging from the watershed. It establishes where groundwater in the fan converts to surface flow or if surface flow is percolated into the fan to become base flow. This tidal-freshwater transition zone includes the upstream extent of backwater flooding when terrestrial floods coincide with high tides. As sea level rises, the transition zone of flooding and subsequent sediment deposition could move farther back in the watershed as the toe becomes increasingly submerged.
- Natural sediment supply rates to the fan toes are naturally high because the very steep headwater channels that occur within highly fractured bedrock have been carved over thousands of years by debris flows triggered by intense rainfall and by large-scale landsliding triggered by seismic events. Dry ravelling of rock material from steep hillsides along the inner gorge slopes is prevalent along the creeks draining the ACR watersheds. Tree fall is also a pervasive and natural contributor of sediment to the channels, especially during extended drought or disease of trees.
- During the last 200 years the fans have been building upwards in their valleys and outwards into the lagoon. Rates of erosion were accelerated and perhaps at their peak during the period of logging, grazing, wildfire, and road building that occurred from the mid 1800s to early 1930s. These legacy impacts matter today because sediment loading in the streams and valleys from these early impacts is still being transported to the toes of the fans today, especially when post logging and fire era debris jams become dislodged and release their stored sediment. Post 2000 rates of accelerated rates of sediment supply are still influenced by the Bolinas-Fairfax Road that was initially constructed in the early 1880s.
- Man-made obstructions created by the SR1 road berms have interrupted both groundwater conveyance to the Bolinas Lagoon and its surface stream flow. The culverts in these locations are not designed to deal with aggrading or migrating channels or convey the supplies of water, sediment or woody debris that is expected from these steep coastal watersheds. Natural ecological stratification of wetland and brackish water plants along the fans and deltas downstream of the SR1 may be limited due to the interruption of groundwater, sediment and streamflow by SR1 infrastructure.

3. Four specific priority sites are listed by Cal Trans for clearing work prior to the onset of the rainy season of 2018. Three priority sites drain creeks from Audubon Canyon Ranch:

- Pike County Gulch where the low point of the SR1 roadbed at Priority Location #1, at mile post 16.47, is less than 7.5 feet elevation NAVD88. This is indicated by profile of 2010 Golden Gate LiDAR plotted by Kaman Hydrology for Audubon Canyon Ranch in 2016[1]. The invert of the culvert is shown to be 7 feet[1].

- Garden Club Gulch where the low point of SR1 roadbed at Priority Location #2, at mile post 16.1, is less than 8.6 feet elevation NAVD88. The invert of the culvert is shown to be 7 feet[1].
- Volunteer Gulch, where the low point of SR1 roadbed at Priority Location #3, at mile post 15.4, is less than 8.6 feet elevation NAVD88. The invert of the culvert is also shown to be 7 feet[1].
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An additional Priority Location #4, at mile post 12.6, near the south end of Bolinas Lagoon is Easkoot Creek that drains to the Stinson Beach parking area, which is managed by Golden Gate National Recreation Area.

Given the sea level projections and the 7-foot elevations of the inverts, the SR1 culverts will most likely be fully submerged at tides equal to or greater than MHHW by year 2050.

4. Based upon reconnaissance during February 2017 at Pike County Gulch and April and July 2018 at both Pike County and Garden Gulches, the SR1 culverts were both fully clogged at the time of observed flooding across the highway.

5.The recurrence interval of the peak discharge during 8 April 2018 for the various Bolinas Ridge gulches and for the gaged Redwood Creek (to the south of Bolinas Lagoon) is preliminarily assessed to be about a 5-year event. This is based upon Redwood Creek gage records from GGNRA[5] and post high flow discharge estimates conducted by Watershed Sciences at Wilkins Creek, located at the north end of Bolinas Lagoon. The tides for several days before and after 8 April were predicted[6] to be well under 4 feet, NAVD88, therefore tidal influences on flooding were most likely not strong.

Yet, numerous impacts were observed at several locations along the alluvial fans from this relatively small but relatively frequent flow event:

- Sediment deposited to the elevation of the SR1 roadbed and aggraded the channel upstream of the clogged Pike County Gulch and Garden Gulch culverts and SR1 road berm. The highway berm functioned as a dam causing backwater flooding at portions of ACR properties including their driveways turning in from SR1.
- Upstream of the SR1 culverts, Pike County and Garden Club Gulches came out of their former streambeds for at least a few hundred feet and created new pathways and distributary channels that do not align with the culvert locations.
- Abundant coarse and angular bedload was deposited above the former channel bed elevations of both Pike County and Garden Club Gulches for at least 700 feet upstream of SR1.
- Water and sediment transported across SR1 creating driving hazards; and
- Easkoot Creek flooded the Stinson Beach parking lot and deposited abundant coarse sediment across it as it filled and flowed out of its sediment basin located about 700 feet downstream of SR1 culvert.

- The 8 April storm occurred at a time when soils were not saturated and tides were not high. These factors may have prevented resource damages, landslide hazards, and greater flooding that could have been much more serious.
- It is not clear if the recent April 2018 flood had an exceptionally abundant supply of sediment or if it was atypical for a 5-year event. It is not clear at this point if several years of drought might have had some influence on loading the streambeds with more sediment than during years of normal precipitation or if their was something particularly unique about rainfall intensity or duration of high flow.

7. Identifying the sources of sediment is a key question to determining what processes are responsible for supplying sediment to the toes of the fans at the SR1 culvert sites, as well as for planning for sea level rise and access to adjacent lands. Based upon recent July 2018 reconnaissance observations:

- The source of most of the sediment deposited on the lower alluvial fans of Pike County Gulch and Garden Gulch was likely derived from stream sources, principally bed incision throughout the mainstem, some tributary channels, and the heads of the alluvial fans. Note that the Garden Gulch fan head was observed during field reconnaissance but Pike County fan head has not. It seems probable, however, that these two watersheds have similar geomorphic characteristics because similarities have been observed at their headward channels and their lower and middle alluvial fans.
- The source of most of the sediment deposited on the lower alluvial fan of Easkoot Creek and parking lot of Stinson Beach also appears to be from streambed incision of previously but relatively recently deposited gravel bars and previously aggraded streambed in the middle reaches of its alluvial fan for at least 700 feet upstream of the SR1 culvert. In addition, there is a box culvert on Arenal Ave, about 500 feet downstream of SR1 on Easkoot Creek that became nearly filled with gravels. It is further exacerbating local flooding and sediment deposition at the Stinson Beach parking lot where stream flow eroded away a portion of the lot adjacent to the beach.
- No new landslides of sediment supply significance have been observed to be caused by the 8 April storm, Therefore landslide sediment contribution from this storm was not unique or above background rates associated with formerly active and eroding scars.
- The steep mainstem channel and headward tributary reaches have alternating conditions of stream incision and streambed aggradation behind woody debris jams. Numerous debris jams contained post logging stumps and fire debris that periodically gets released and transported farther downstream where it can be caught up in another debris jam or deposited as available bedload.

8. Redesign of SR1 and its culverts needs to be addressed and planned.

- People need to have reliable access and egress from their driveways stemming off of SR1 and be able to travel between Stinson and Bolinas.
- Flooding from 5-yr recurrence discharges and greater at the SR1 culverts appears to be commonplace and will become increasingly so as culverts become increasingly clogged and submerged.
- If a 5-year recurrence flow created such flooding and hazards at the SR1 culverts, what will be the scale of damages if a 10-year or greater event occurs or if soils are saturated, landslides are generated, and a large flood coincides with high tides?
- Clearing of ditches and culverts as planned on the Priority locations will not insure that the culverts will function through the rainy season or even during a single storm that is sufficient enough to create discharges that transport bedload and woody debris.
- Now that the streambed elevation is equal to the height of the roadbed along the ACR priority clearing sites, the elevation of the SR1 roadbed is too low to withstand flooding even if the culverts are cleared of debris and sediment. The Cal Trans stream debris clearing is proposed for such short distances beyond the inlet and outlets of the culverts that the "dug out holes" will fill rapidly with sediment and stream gradient will be insufficient to keep the cleared channel and culvert free of sediment deposition.
- Sea level rise will submerge the roadbed and culverts in short order. An elevated causeway for SR1 would eliminate the problem of passing floods, sediment and woody debris through culverts. Removing the road berm will remove impediments of fresh groundwater flow to the lagoon. Building sufficiently elevated causeways that span the full width of the alluvial fans will maximize the opportunity for the geomorphic processes of channels, fans, deltas and associated ecological functions to adapt to sea level rise and provide a potentially diverse array of wildlife habitat. It will also remove the influence of backwater flooding and sediment deposition on ACR lands that are presently caused by SR1 infrastructure.

1. Highway 1 profile of 2010 Golden Gate LiDAR plotted by Kaman Hydrology for Audubon Canyon Ranch, 2016.
2. AECOM, 2017. Conceptual Design Report Bolinas Lagoon North End Restoration Project report for Marin County Parks and Open Space.
3. Bolinas Lagoon North End Restoration Project – Site Conditions Report by AECOM for Marin County Open Space District, June 2016.
4. Bolinas Lagoon North End Restoration Project Technical Memorandum Current and Historic Geomorphology and Hydrology by AECOM and Watershed Sciences for Marin County Open Space District, January 2016.
5. Stream hydrograph records and hydrology reports provided by Carolyn Shoulders, Natural Resource Specialist, GGNRA.
6. https://tidesandcurrents.noaa.gov/noaatidepredictions.html?id=9414958&units=standard&bdate=20180406&edate=20180506&timezone=LST/LDT&clock=12hour&datum=MLLW&interval=6&action=dailychart