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Independent Evaluation of the:

Estuary Subwatershed Study Assessment of the Physical and Biological Condition of the Santa Clara River Estuary, Ventura County, California Final Synthesis Report [1] and the Environmental Effects of the City of Ventura Wastewater Reclamation Facility Discharge to the Santa Clara River Estuary

June 14, 2011

Background

The Santa Clara River Estuary (SCRE) is a seasonally closed estuary. In general, the estuary opens during the wet season when high river flow and ocean waves breach the sand barrier, and then closes in spring when river flow is reduced and ocean waves rebuild the sand barrier. The alternating open and closed conditions of the estuary are essential characteristics for the ecology of the SCRE ecosystem.

The natural breaching regime for the estuary is not known (although there is currently a study of the historical ecology of the Santa Clara River that will provide important information about this and related dynamics via the Historical Ecology of Southern California Wetlands under the umbrella of the Southern California Coastal Water Resource Project). In particular, the amount of water (both surface and subsurface) delivered to the estuary during the dry season is not well quantified. This is a critical aspect of the hydrology because it determines the volume of water in the estuary when it is closed, its salinity, and whether it would breach over the summer. As noted below, all of these aspects of the estuary have important consequences for the species living in it.

The extent and nature of the SCRE has changed substantially over the past 150 years, although the location of the river's mouth has varied little (Figure 1). In the mid-1800s,

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more than half of the SCRE consisted of open water, with approximately one quarter each of salt flat and vegetated wetland habitats (Grossinger *et al.* 2011). Compared to the estuaries of other large South Coast rivers, the SCRE had relatively little estuarine habitat, with a large area of willow-cottonwood riparian forests (Grossinger *et al*. 2011). Figure 6-1 of the Synthesis report provides a nice comparison of vegetation in 1855 compared to 2009. The total area mapped from the 1855 T-sheet is 989 acres, with 118 acres of open water, 168 acres of salt flat/playa, 313 acres of woody riparian forest, 48 acres of vegetated wetland, and the rest beach, bluff, dune, and upland habitats. The area was apparently more extensive in the past. Aggregate extent was slightly more expansive historically (an 8% reduction in aggregate wetland; see Table 6-1) with some landscape types changing greatly such as an apparent 70% (Stillwater Sciences 2007) to 91% (Nautilus Environmental 2005) reduction in riparian extent since the mid 19th century. The 2009 vegetation mapping effort reported 126 acres of open water, 225 acres of riparian forest, 75 acres of vegetated marsh (70 acres of freshwater marsh and 5 acres of salt marsh). The area of open water is remarkably similar between the 1855 and 2009 mapping efforts, although it is not clear how representative the 1855 "snapshot" is of general conditions around that time. The salt flat/playa from the 1855 topographic sheet (so-called "T-sheet") is interpreted by Stillwater Sciences (2011) to be recently scoured, unvegetated floodplain.

Development in the watershed has changed the quantity and timing of water delivered to the estuary (as well as the quality of that water). There likely have also been changes in the groundwater around the estuary. The two major disturbances to the natural hydrologic regime have been the diversion of water from the watershed (most prominently at the upstream Freeman Diversion) and the discharge of treated wastewater into the estuary from the Ventura Water Reclamation Facility (VWRF).

For this report, we focus on how the VWRF has altered the SCRE hydrology and ecology, and the consequences of this alteration for the species living in the estuary, particularly steelhead and tidewater goby. On the face of it, it could be considered that the addition of treated wastewater balances the loss of water from the upstream diversions. Of course, it is not this simple. Under natural conditions, the Santa Clara River would deliver a high volume of freshwater to the estuary in the wet season, tapering to a low volume, and perhaps to no water, during various periods of the dry season. Depending on the inflow of freshwater from groundwater and a host of other factors (see Salinity section below), the salinity of the estuary might increase during the dry season due to evaporation of the water in the estuary, but we have not seen evidence that the estuary ever became hypersaline as other coastal wetlands in southern California are reported to have become. Under current conditions, the basic pattern of water delivery from the Santa Clara River slows or ceases during the dry season. However, the VWRF discharges a fairly constant amount of water into the estuary year-round. Thus, there is a substantial amount of low-salinity water flowing into the lagoon during the dry season. This maintains the estuary water at a low salinity when the sand barrier closes. It also increases the volume of water in the estuary above what it would otherwise be. While the introduction of a large enough volume of water can shift the average water quality within a circumscribed area, that increased volume may also alter the distribution of the aquatic community itself. There are at least two such consequences of such and increased volume with important ecological implications: (1) the lagoon is more likely to breach during the summer and fall, and (2) there is a larger flooded area in the estuary than we would expect given the extant upstream water diversions.

Figure 1. Historical SCRE conditions in1855 from historic T-sheet (T-683) and historical ecological interpretation (Grossinger *et al*. 2011).

Breaching due to excessive freshwater inflow can result in high mortalities of native fish and macroinvertebrate species. Comment on September 2010 breach that killed seven steelhead and thousands of tidewater gobies (ENTRIX 2010).

Many factors influence the frequency of berm breaching. Stillwater Sciences (2011), comparing the SCRE mouth berm in the 1855 T-sheet and aerial photographs from the past 80 years, concluded that the mouth berm length decreased by hundreds of meters since development began. They suggest that this indicates the SCRE historically had a higher berm seepage rate and therefore likely breached less frequently during low-flow conditions in both drier months (periods of low river and groundwater discharge) and wetter months (baseflow conditions after storms but elevated groundwater discharge rates to the SCRE).

Breaching due to excessive freshwater inflow can result in high mortalities of native fish species. Comment on September 2010 breach that killed seven steelhead and thousands of tidewater gobies (ENTRIX 2010).

Organismal Ecology

The SCRE provides important habitat for a variety of fish, invertebrates, birds and plants. However, particular attention has been focused on two endangered fish species, southern California steelhead and tidewater goby. We concentrate on these species because, as aquatic species, they feel the biggest influence of the VWRF.

Southern California Steelhead

Steelhead is the anadromous form of the species *Onchorynchus mykiss* (the non-anadromous form being the rainbow trout). The annual steelhead runs in southern California have declined from 32,000-46,000 returning adults historically to less than 500 returning adults today (Good *et al*. 2005). Many factors have contributed to this decline, including urbanization, dams and other barriers, stream habitat loss, estuarine habitat loss, species interactions, hatcheries, drought and climate change, and wildfire (Moyle *et al*. 2008).

Historically, the Santa Clara River supported an important steelhead population, with perhaps one of the largest steelhead runs in southern California (Moore 1980, Bowers 2008, Kentosh 2008). Populations appear to have numbered in the thousands, even after stocking of the anadromous form switched to stocking of resident rainbow trout in the 1930s (Bowers 2008, Kentosh 2008). However, changes in the watershed during the mid 1900s, including the construction of dams and other barriers to migration, dramatically reduced the steelhead run (Stoecker and Kelley 2005). Spawning fish returning from the sea documented in recent years in the Santa Clara River number in the dozens at best. The 2009 monitoring of fish passing the Freeman Diversion recorded only 162 steelheads in total, 160 of which were smolts from above the diversion heading downstream towards the estuary (Howard and Gray 2009).

Estuaries are key habitats for steelhead because they are used by both immigrating adults and emigrating juveniles moving between the marine and freshwater environments. Estuaries can be important habitats for young steelhead to feed before moving to the ocean. Few studies of steelhead use of estuaries have been conducted in southern California, but their importance can be inferred from studies elsewhere. Smith (1990) and others (*e.g.,* Atkinson 2010) have made extensive observations in central California. These studies have demonstrated the potential for rapid growth of young steelhead in estuaries when food is abundant and water quality (especially oxygen, but often mediated by salinity distributions) is appropriate. Hayes *et al*. (2008) found that the majority of steelhead in Scott Creek (Santa Cruz County) reaching typical ocean entry sizes (150–250 mm FL; age 0.8–3.0 years) were estuary–lagoon reared, which indicates a disproportionate contribution of this habitat type to survival of Scott Creek steelhead. Estuarine growth rates were among the fastest reported for wild steelhead in the literature (1–2% per day). Steelhead that rear in lagoons also smolt at an earlier age than most stream fish (Smith 1990, Cannata 1998, Bond 2006, Hayes *et al*. 2008). In fish, survival is often related to size, and larger steelhead smolts likely have higher survival rates in the ocean than smaller smolts (Ward *et al*. 1989, Smith 1990, Tipping 1997, Bond 2006). Bond (2006) found that 85% of the returning adult steelhead in the Scott Creek watershed in Santa Cruz County had reared in the estuary as age 0+ or 1+ of despite the fact that these individuals comprised only 8%-48% of the juvenile steelhead production in that watershed. Thus, steelhead using estuaries typically grow faster, smolt at an earlier age, and survive in the ocean better than fish reared in streams.

In addition to the growth and consequent survival advantages from rearing in estuaries, estuaries provide a transition zone that allows salmonids to adapt gradually to changes from freshwater to the marine environment and vice versa (Healey 1982). Juvenile salmonids that were deprived of an estuary residence suffered from higher physiological stress during saltwater entrance than those that had longer estuary residence times (MacDonald *et al*. 1988).

Water temperatures in southern California rivers and estuaries are generally higher than the "preferred" range for steelhead (often determined in more northerly latitudes), but the fact that southern California populations flourished here historically demonstrates the local genotypes are able to withstand higher temperatures than fish from more northerly populations. Growth of Ventura County steelhead juveniles appears more rapid than the growth rates of those more northerly steelhead populations (*e.g*., Moore 1980, Busby *et al*. 1996, McEwan and Jackson 1996) and may give them an increased thermal tolerance relative to steelhead that evolved in more northerly climes, however we have little life history information or experimental manipulations for steelhead in southern California.

Moyle *et al*. (2008) indicate that juvenile southern steelhead may spend less time in fresh water than northern steelhead because southern California streams often have inhospitable conditions (low flows and warm temperatures). Thus, southern steelhead may migrate to the ocean or have greater dependence on coastal lagoons during their first year compared to other stream-oriented northern steelhead populations. However, there is little information about steelhead use of estuaries in southern California.

Little is known about current steelhead use of the SCRE. In a one-year study, Kelley (2008) tagged and released 81 smolts on the Santa Clara River, 48 of which (59%) survived the migration to the ocean. Kelley found that smolts spend only a few days at most before moving to the ocean when the estuary was open to the ocean. Kelley identified the major potential problems for smolts as high turbidity, high water temperatures, insufficient cover to hide from predators, and resident populations of avian predators, most of which have been exacerbated by anthropogenic changes to the SCRE. Kelley's study included only one season of data and focused on smolts, so it provides a limited view of steelhead use of the SCRE (Kelley 2011). In addition, Kelley did not tag smolts smaller than 150 mm, 51 of which fish were captured but not tagged (Table 2 in Kelley 2008), presumably because they were smaller than 150 mm. Thus, the behavior of small smolts in SCRE is not known, but it is possible that they may have had longer residence in the estuary, possibly spending the summer in the estuary to grow to a larger size. This would be consistent with one of the steelhead life history pathways proposed by Hayes *et a*l. (2008) for Scott Creek steelhead in central California.

Observations of steelhead after the breach on September 17, 2010 indicate that steelhead smolts can reside for an extended time in the SCRE and grow substantially during that time. Seven dead *Onchorhynchus mykiss* were collected, ranging in size from 227 to 310 mm standard length. After observing the steelhead killed in the summer 2010 breach, ENTRIX (2010) noted that "[t]he relatively large size and robust condition of these fish (Photos 2-4) indicate they were doing relatively well in or near the estuary and that adequate conditions existed for them in at least part of the local habitat."

For central California estuaries, Smith (1990) reported good steelhead growth and survival when the lagoons were open to the ocean and when the berm was closed and the lagoon was largely fresh water. If the sand barrier was closed but there was salinity stratification, the salt lens could cause higher temperatures on the bottom of the lagoon and low dissolved oxygen concentrations, which led to low steelhead growth. Smith (1990) also found that frequent or artificial breaching of the sand berm could cause poor steelhead growth because it maintained salinity stratification and warm temperatures. Similar studies have not been conducted at SCRE or other southern California estuaries. However, Kelley (2008) did not find salinity stratification and associated low dissolved oxygen concentrations in the SCRE during her study. In compiling water quality data from many different sources, the Synthesis report states that only the upper and lower outfall locations exhibited any signs of density stratification in some sampling events due to freshwater flows from the VWRF (Stillwater Sciences 2011, page 81).

Steelhead in estuaries feed on invertebrate species. Robinson (1993) has reported the changes in benthic and epibenthic invertebrates in Pescadero Lagoon, a seasonally open lagoon in central California, as the lagoon changed from an open to closed condition. Although the invertebrate assemblage changed from marine to euryhaline and freshwater species, the invertebrate assemblage in Pescadero Lagoon had previously been shown to support good steelhead growth (Smith 1990). Martin (1995) found that steelhead in Pescadero Lagoon, studied at the same time as Robinson (1993) and Smith (1990), changed their diet as the lagoon condition changed from open to closed. When the lagoon mouth was open, steelhead fed mainly on gammarid amphipods, shrimp and isopods. After the lagoon closed, steelhead ate mainly freshwater-dependent dragonfly nymphs, mayfly nymphs and midges. Martin concluded that steelhead food was abundant throughout the lagoon when it was open to the ocean, but was most available where there was fresh water with abundant pondweed. Robinson's results are similar in some ways to what has been found in the SCRE. Monitoring at SCRE since 1997 indicated that the benthic invertebrate assemblage was composed of freshwater or estuarine species, and tended to be dominated by three or four tolerant species, and varied seasonally and among years (Stillwater Sciences 2011). The species found at SCRE include some of the taxa reported in the diet of steelhead from central California, though not shrimp, isopods, dragonfly nymphs or mayfly nymphs. In comparison to Pescadero Lagoon, salinity in the SCRE does not get as high, so the invertebrate assemblage is never dominated by marine taxa. In addition, invertebrate abundances are sometimes low; for example, the abundance of invertebrates in October 2009 was very low at stations sampled by ABC Laboratories (2010) and restricted to only a few freshwater taxa, primarily oligochaetes and chironomids. During these times, food might be limiting for steelhead growth.

Although the hydrology of the SCRE system has clearly been altered by human activities, the natural habitats of the estuary have also changed substantially. Stillwater Sciences (2011, Section 9.1.2) reports:

> "Historically, the floodplain of the lower Santa Clara River contained a dense riparian zone with marshy areas that were regularly re-connected with in-channel habitats at higher flows. Prior to the establishment of levees in the lower river in the 1900s, meander and migration processes regularly eroded channel banks causing a retreat of floodplain habitat on the outside of meander bends, depositing fresh sediment and forming new floodplain habitat on the inside of meander bends. Under idealized conditions, this process of erosion on the outside of meander bends maintains scour pools and causes tree recruitment into the river, which provides cover and other habitat functions for fish and other aquatic organisms. Interruption of these processes has resulted in greatly simplified habitat structure with limited available cover resident fish species."

Little is known about how steelhead use different habitats in estuaries, and this is especially true in southern California. We do know that protection from predators, both aquatic and bird predators, is important (Kelley 2008). A refuge from undesirable physical conditions, which might include deep water, is also likely to be important. It is possible that the habitat simplification at SCRE has reduced the quality of the estuary for steelhead. This might provide some restoration opportunities, but more needs to be known about steelhead habitat use.

The VWRF discharge into the SCRE directly affects the quality and quantity of water in the estuary. The VWRF effects on water quality, especially increased nutrients and eutrophication and the consequent turbidity, would likely have a negative effect on steelhead (*e.g.*, Kelley 2008). There may also be negative effects on steelhead due to contaminant concentrations, both those that have been measured (*e.g.*, copper) and emerging contaminants that generally are not measured. The VWRF effects on water quantity are varied. On the one hand, increased freshwater input into the estuary in the dry season increases the volume of water in the estuary, which increases the aquatic habitat area. This could potentially benefit steelhead, but the actual benefit is not easily determined because it is not clear that habitat is in any way limiting steelhead populations or growth in the estuary. Although the increase in wetted area at different estuary stages has been calculated, no analysis has been done to indicate whether the increased area was good quality habitat. As suggested above, it is possible that habitat simplification in the estuary has reduced the quality of SCRE for steelhead, and simply increasing the amount of low quality habitat (though, in the absence of an assessment of habitat quality we don't know if the increased habitat is low or high quality) would have little benefit for steelhead. Thus this putative benefit, although asserted by the Synthesis Report, is uncertain. What is certain, on the other hand, is that excessive breaching of the estuary during the dry season is detrimental to steelhead in the estuary. As with many southern California coastal wetlands, the SCRE historically was closed during most of the dry season (D. Jacobs and E. Stein, personal communication). The extra water introduced into the estuary during the dry season raises the level of the lagoon and increases the frequency of dry-season breaching. This certainly has a negative effect on steelhead residing in the lagoon at the time of breaching.

Tidewater goby

The tidewater goby is a small benthic fish that occurs in estuaries in California. It is typically an annual species that is restricted to estuaries (although adults and larvae may spend a short time in the marine environment during dispersal, especially following floods; Swift *et al*. 1989, Lafferty *et al*. 1999b). Tidewater gobies prefer brackish water, typically less than 12 ppt although they tolerate a wide salinity range (0 to 54 ppt; Worcester and Lea 1996). Reproduction typically occurs year-round although distinct peaks in spawning, often in early spring and late summer, do occur (Swenson 1999, Ambrose and Meffert 1994). Most of the estuaries where tidewater gobies occur are closed seasonally to the ocean.

The tidewater goby is a federally listed endangered species. Principal threats to the tidewater goby include loss and modification of habitat, water diversions, predatory and competitive introduced fish species, habitat channelization, and degraded water quality (USFWS 2005).

Although the tidewater goby was listed as an endangered species, its listing was based on its extirpation from many of its historic locations. Where there is suitable habitat, the tidewater goby is often numerous; it is frequently the most abundant fish species in many of the lagoons and estuaries where it occurs (Lafferty *et al*. 1999a).

Male tidewater gobies begin digging breeding burrows in relatively unconsolidated, clean, coarse sand in April or May, after lagoons close to the ocean (Swift *et al*. 1989; Swenson 1995).

Tidewater gobies feed mainly on small animals, usually mysid shrimp, gamarid amphipods, ostracods, and aquatic insects, especially chironomid midge larvae (Swift *et al*. 1989; Swenson 1995; Moyle 2002). Many of these species have been recorded in the SCRE (ENTRIX 2003, Kelley 2008, ABC Laboratories 2008, 2010).

Because tidewater gobies prefer brackish water, changes to an estuary that limit or reduce brackish water habitats have an adverse effect on tidewater goby populations. In southern California, a common impact is the frequent breaching of the sand barrier separating a lagoon from the ocean. According to the U.S. Fish and Wildlife Service, in their tidewater goby recovery plan:

> A trend in southern California is for more water to be available all year in streams that receive municipal waste discharges. Today many streams (*e.g*., Santa Ynez River and Malibu Creek) are flowing with much more water in the dry season than probably occurred historically. This water is high in nutrients that contribute

> to enrichment of lagoon water and the associated decreases in dissolved oxygen. This extra water can cause the lagoon to rise and increase the frequency of breaching experienced under natural conditions, causing erratic fluctuations in water level. These erratic fluctuations result in decreases in habitat that increase chances of predation and leave spawning burrows exposed to the air. The sudden draining of a lagoon in late spring or summer also can allow marine water to dominate the lagoon for months until winter rains return (Swift *et al*. 1989).

The sudden breaching of a lagoon is a particular risk to tidewater gobies because of their association with shallow water burrows. When the lagoon water level is high, the gobies build their burrows in the expanded habitat. Unlike a free-swimming fish that can simply move with the changing water level (although even these species are stranded when a lagoon is breached), tidewater gobies cannot relocate their burrows in response to the rapidly declining water level, and thus they are stranded, in addition to being washed out into the ocean. Both outcomes were well documented in the aftermath of a berm breach in September 2010 (Cardno ENTRIX 2010). Mass standings/mortalities of thousands of tidewater gobies occurred across the suddenly-dry shallows of the lagoon. In addition, hundreds of dead/dying gobies were scattered across the oceanward beach, attesting to a significant proportion of the SCRE population being flushed out to sea.

Birds

Pacific coast populations of western snowy plovers (*Charadrius alexandrinus nivosus*) are listed as federally endangered due to declining populations over the previous several decades. Plovers feed primarily on small invertebrates along sandy beaches, mudflats, and salt pannes from the low intertidal to well above the high tide line (FWS 2007). Less frequently they may pick invertebrates from coastal strand or wetland plants and have even been reported to flycatch in southern California (Fancher, *et al*. 1998). Their inclusion here as an identified indicator species appears primarily related to their potential reliance upon forage sources within the SCRE.

California least terns (*Sterna antillarum browni*) are a federally and state listed endangered species declining for reasons identical to western snowy plovers: disturbance of their beach nesting habitat by coastal development and recreational activities (FWS 2006). Terns hunt small fish, most commonly in coastal estuaries, lagoons, and lakes. This potential foodchain support therefore motivated their inclusion in this study as an indicator species.

Healthy populations of invertebrates in/around the coastal strand and healthy populations of estuarine fish in either the SCRE or McGrath lake could be sufficient but not necessary for a consistent population of plovers or terns in or around the SCRE. Both species nest around the terrestrial edges of the SCRE. As such, the health of both of these bird species are related to the dynamics of the VWRF, but only indirectly. While a healthy estuary would be a positive factor facilitating recovery of these birds, it is by no means necessary or even the greatest factor in their population dynamics. Ecological factors outside the SCRE and the influence of VWRF such as human disturbance and beach grooming (Lafferty 2001) appear to drive the dynamics of these populations. Hence, these are relatively equivocal indicator species relative to aquatic species directly influenced by SCRE dynamics such as steelhead and gobies.

Other Potential Aquatic Focal Species: Lampreys and Sticklebacks

Owing to the indirect linkages between the proposed focal bird species and the functioning of the SCRE and VWRF discharge levels, we suggest two potential alternative candidate species. Both the Pacific lamprey (*Lampetra tridentata*) and the partially-armored threespine stickleback (*Gasterosteus aculeatus microcephalus*) are native fish species in the SCRE. While the Pacific lamprey has been in decline over the past several decades, it remains much more abundant in the Santa Clara River and Estuary than the nearly extirpated steelhead even though they share a similar anadromous life history (Chase 2001). The partially-armored threespine stickleback is second only to tidewater goby in SCRE resident fish abundance (Nautilis 2009). Both of these fish demonstrate an ecology that is likely much more impacted by habitat quality and quantity than either plovers or terns.

Invertebrates

The invertebrate assemblage of the SCRE reflects the dynamic nature of the estuary, with a marine influence when the mouth is open, a transition through brackish conditions starting after the mouth closes, and freshwater conditions during much of the dry season. Superimposed on this natural seasonal dynamic is the relatively constant inflow of water from the VWRF; although the discharged volume is relatively constant, its influence varies seasonally, with the greatest effect during periods (*i.e.*, the dry season) when surface inflows from the Santa Clara River have historically been very low or nonexistent. As such, VWRF flows act to reduce the seasonal contrasts that SCRE invertebrate communities have experienced and evolved with for millennia.

Typical estuarine communities are well represented by crustaceans, molluscs (bivalves and gastropods), and polychaetes (Kennish 1986). Anthozoans, Hydrozoans, and Echinoderms are also often present. The presence of gastropods, bivalves, Polychaeta, Crustacea, and Echinodermata in many estuaries reflects the typical estuarine communities described by Kennish (1986). In contrast, the lack of bivalves, low numbers of Polychaeta and Echinodermata, as well as the large presence of Ostracods, set the benthic community of the SCRE apart from the benthic communities of many other estuaries. This difference is driven various factors including the seasonality of the mouth opening at SCRE, which leads to greater variability in physical conditions through the year, and generally lower salinity (which reduces or eliminates more marine taxa such as Echinoderms and bivalves that cannot tolerate low salinity).

Little is known about the benthic invertebrate community in a relatively undisturbed, seasonally open lagoon in southern California. Although there have been studies of invertebrates in SCRE (*e.g.*, ENTRIX 2003, Kelley 2008, ABC Laboratories 2008, 2010) and other seasonally open lagoons in southern California (*e.g.*, Malibu Lagoon, Ambrose *et al*. 1995), these lagoons have been substantially modified by human activities (including the discharge of treated wastewater). Robinson (1993) has reported the changes in benthic and epibenthic invertebrates in Pescadero Lagoon, a seasonally open lagoon in central California, as the lagoon changed from an open to closed condition. The invertebrate assemblage changed from marine to euryhaline and freshwater species. Robinson's results are similar in some ways to what has been found in the SCRE. Monitoring at SCRE since 1997 indicated that the benthic invertebrate assemblage was composed of freshwater or estuarine species, and tended to be dominated by three or four tolerant species, and varied seasonally and among years. In particular, species of midge larvae (Diptera: Chironomidae), oligochaete worms, copepods, ostracods, and amphipods have tended to dominate during the 1997–2008 monitoring period (Stillwater Sciences 2011). In comparison to Pescadero Lagoon, salinity in the SCRE does not get as high, so the invertebrate assemblage is never dominated by marine taxa. In addition, invertebrate abundances are sometimes low; for example, the abundance of invertebrates in October 2009 was very low at stations sampled by ABC Laboratories (2010) and restricted to only a few freshwater taxa, primarily oligochaetes and chironomids

The VWRF discharge into the SCRE alters the estuary chemistry and lagoon mouth dynamics, and these changes undoubtedly affect the invertebrate assemblage in the SCRE. It is difficult to assess these changes quantitatively because of the lack of appropriate reference data (see our Recommendations section below), but some qualitative effects can be inferred. It is also important to keep in mind that the VWRF discharge is only one anthropogenic influence on the SCRE; berm breaching, changes in water quantity, and especially water quality in the Santa Clara River inflow undoubtedly also affect invertebrates in the estuary.

One physical effect of the VWRF discharge likely to impact the SCRE invertebrate community is altered salinity within the estuary. Compared to some other seasonally open estuaries, the salinity in the SCRE stays relatively low even when the mouth is open. For example, instead of full seawater salinity, such as reported for Malibu Lagoon (Ambrose *et al*. 1995) and central California lagoons (Smith 1990), the SCRE salinity currently reaches only 15-16 ppt near the mouth (Stillwater Sciences 2011). When Santa Clara River flow is high, the VWRF discharge would have little influence on SCRE salinity, but the discharge might keep the salinity lower than it would be otherwise when the SCR flow is low but the mouth still open. The VWRF discharge has a great influence once the sand barrier has closed the mouth. Because of the extra freshwater input, the salinity of the estuary will freshen up faster than it would in the absence of the VWRF discharge. In addition, salinity might be lower in the summer than it would otherwise be. Summertime salinity is a balance of evaporation and freshwater inflow (see our Salinity section below). This balance changes from year to year. In the absence of historic measurements, we don't really know what the conditions were like at SCRE, but likely salinity was often higher. All of these effects of the VWRF discharge would lead to an invertebrate assemblage more dominated by freshwater taxa than would otherwise be the case.

Perhaps more importantly, by adding water to the SCRE when the estuary mouth is closed, the VWRF discharge increases the frequency of breaching. Breaching leads to rapid change in the physical conditions of the lagoon, from freshwater to brackish in just a matter of hours. Some species cannot tolerate such rapid changes in salinity. Moreover, if there are repeated breaching and rebuilding of the sand barrier, there is never an extended period for either brackish or freshwater invertebrate assemblages to develop; as a consequence, an assemblage of low species richness and low abundance would be expected. These changes will be most stressful near the ocean, where fewer species would be expected to flourish. In fact, these assemblage characteristics do sometimes occur in the SCRE (ABC Laboratories 2010).

The Synthesis Report recognizes the variability in the benthic invertebrate data due to environmental conditions (as well as variability in the data due to changes in sampling methods). In describing the recovery of benthic invertebrate populations after disturbance, the Synthesis Report reports that "[t]his provides further evidence that the SCRE BMI community is adapted to the harsh conditions found in this dynamic environment." This is a tautological conclusion, since of course the organisms living in the SCRE are adapted to live in that environment. This idea that the organisms living the SCRE are adapted to a harsh environment seems to influence the Synthesis Report's conclusions about the effects of the VWRF discharge. The Report concludes (p. 131) that "the weight of evidence to date indicates that the VWRF effluent is not adversely affecting BMI populations in the SCRE (ABC Laboratories 2009)." We do not agree with this conclusion. The absence of suitable undisturbed reference estuaries makes it difficult to draw conclusions about how the VWRF discharge might have affected the benthic invertebrate assemblage in the SCRE (see our Recommendations section below). However, as noted above, the discharge alters the estuary in ways that almost certainly would influence the invertebrates living there. Most significantly, more frequent breaching through the summer, especially repeated breaching events, would increase the physical stresses on the organisms living in the estuary and likely lead to reduced abundances and species richness, especially in the area closest to the mouth.

Invasive Species

Over the past century our development and alteration of riparian/estuarine systems in southern California has tended to ameliorate annual variation in water quality and quantity. This tendency to reduce contrasts between seasons (*i.e.*, winter vs. summer; Ambrose, *et al*. 1995) has generally benefitted aggressive non-native, invasive species (NIS). Previously, more extreme abiotic conditions (often occurring during the summer, dry season) acted as something of a barrier to the establishment of such non-indigenous animals. As we have removed these potentially stressful conditions (*e.g.*, prevented extreme salinity, stabilized temperature, moderated pH, *etc*.) with more consistent year-round flows into our estuaries, native species whose estuarine abundance owes much to their ability to tolerate those stressful physical conditions (Mitsch and Gosselink 2000) have lost important ecological advantages. In the case of the SCRE, numerous NIS now compose the aquatic fauna. Consistent surface water inputs from the VWRF into the estuary have likely aided in the establishment/maintenance of at least some NIS, although the specific contribution of the VWRF input relative to numerous other anthropogenic impacts is unstudied. Potential impacts from NIS include reduced growth, reproductive output, and abundance of native individuals, an increased probability of native population extinction, and depressed ecological functioning of the community as a whole.

Introduced species commonly encountered during aquatic SCRE surveys (ENTIRX Inc. 2009, Nautilus Environmental 2009, Cardno ENTRIX 2010) include: carp (*Cyprinus carpio*), Arroyo chub (*Gila orcutti*), prickly sculpin (*Cottus asper*), fathead minnow (*Pimephales promelas*), mosquitofish (*Gambusia affinis*), green sunfish (*Lepomis cyanellus*), Mississippi silverside (*Menidia audens*), prickly sculpin (*Cottus asper*), Louisiana crayfish (*Procambarus clarki*), and African clawed frog (*Xaenopus laevis*). Less abundant non-natives encountered in the SCRE include suckers (*Catostomus santaanae, C. fumeiventris,* and their hybrids) and yellowfin goby (*Acanthogobius flavimanus*). Note that the Arroyo chub and suckers are both native to our coastal southern California region and species of concern in our state. While they were introduced into the Santa Clara watershed, their presence is probably a beneficial one from the overall regional perspective as their presence in the Santa Clara in effect minimizes the probability of their global extirpation. Most of these NIS are either direct or indirect competitors with native SCRE fish and amphibians or predators upon larval or adult SCRE fish, amphibians, or invertebrates.

Reductions in the quantity of VWRF discharge released into the summertime SCRE will have the effect of reducing the propensity of the berm to breach and foster longer dry season closed-mouth conditions that tend to establish a clear seasonal difference in SCRE abiotic conditions. Additionally, many of the predatory NIS fish such as carp and green sunfish refuge in the deeper water main channels out of range of avian predators. Reduced VWRF discharges that reduce overall stage height of the lagoon will tend to eliminate these refugia for these exotics. Steelhead and tidewater goby may also refuge in these deeperwater reaches, but the steelhead also frequently occupy vegetated shallower reaches and tidewater goby utilize waters generally shallower than 1 to 1.5 m. The apparent disproportional use of deepwater habitats by some NIS was illustrated by the berm breach on September 16, 2010 assessed the following morning by the Cardno Entrix team (2010). Thousands of native tidewater goby (all size classes), many hundreds of juvenile green sunfish, and many hundreds fathead minnow (all size classes) mortalities were common across the then-exposed mudflats of the drained lagoon. Far fewer suckers, prickly sculpin, adult green sunfish or carp were stranded. The Cardno Entrix team observed hundreds of living adult carp and "hundreds if not thousands" of living African clawed frogs (juvenile and adult) in the deeper reaches of the SCRE during their surveys.

We do not suspect the SCRE would commonly become hypersaline during the summer season in the absence of VWRF discharge (see our above discussion on salinity) as occurs in some other southern California estuaries, but we do presume a variety of factors would combine to create the salinity conditions of a VWRF-free SCRE. It is well within the range of possibilities that the SCRE would be brackish during summer months. This could at times be enough to reduce the abundance of some NIS. For example, both carp and African clawed frogs are sensitive to brackish water. Clawed frogs show decreased performance with salinities as low as 8-9 ppt (Munsey 1972) but some may be able to tolerate upwards of 20 ppt water for at least limited periods (Wells 2007). Carp can tolerate water up to 12-15 ppt (Kasim 1983). Conspicuous living carp seen during those Cardno ENTRIX surveys (2010) had migrated riverward (the largest concentration were proximate to the Harbor Boulevard Bridge), with individuals in the brackish waters created by the sudden seawater intrusion showing increased mortality as the day progressed.

Whatever the vector of introduction or factors leading to their expansion, it is clear the presence of abundant exotic species in the SCRE is likely detrimental to native species of concern such as tidewater goby (Lafferty, *et al*. 1999a) and steelhead (Kelley 2004). Any efforts to create environmental conditions less hospitable for such invaders will ultimately benefit native flora and fauna throughout the SCRE and beyond.

We note that our discussion of invasive species has only examined the aquatic fauna of the SCRE. To be sure, numerous invasive plants and algae exist throughout this and all southern California estuaries. The most problematic of these plants, Giant Cane (*Arundo donax*) and Tamarisk (*Tamarix spp.*), are a major threat to native diversity, hydrologic functioning, fire management, and recreational use (*e.g.*, VCRCD 2006) of our estuaries and riparian corridors. However, their spread and maintenance is largely driven by upstream forces and not particularly influenced by the dynamics of the estuary proper. Hence our motivation to de-emphasize the invasive SCRE flora in our discussion.

Hydrology

Water quantity

There is not enough information about the natural hydrologic cycle of the SCRE to know with confidence how the VWRF discharge has, in concert with other hydrological changes to the Santa Clara River system, changed it.

However, Synthesis Report implies that the discharge is compensating for reduced flow, and thus by implication is restoring a more natural cycle. For example many reports (*e.g.*, 2002 BMI study, the Synthesis report) include a statement such as this:

> "The natural hydrology of the Santa Clara River and estuary is typical of coastal Southern California watersheds, which normally have very low, dry-season flows and large storm driven peak flows that dissipate rapidly. The natural hydrology of the Santa Clara River, though, has been greatly altered by upstream diversions and irrigation. In contrast, the VWRF outfall constantly discharges tertiary treated wastewater into the Estuary. Flow from the Santa Clara River typically does not reach the Estuary during much of the year due to agricultural and municipal water diversions. *In part, the VWRF discharge compensates for upstream water diversions and provides a water source during periods when the Estuary would otherwise be dry*. In turn, this continuous water source provides habitat for a wide array of aquatic organisms, waterbirds, and other vertebrates in the Estuary." (Synthesis report 2002, emphasis added)

The first part of this excerpt is consistent with our understanding of the Santa Clara River and most other southern California rivers and estuaries. But the highlighted section implies the VWRF discharge is replacing water that would naturally be present in the lagoon if it weren't for the upstream diversions. This may be true during spring, when flows in the River would be below their peak but not yet to the minimum. At this time, water diversions might significantly reduce the flow in the River, and the VWRF might be seen as replacing this water. But in summer, it would appear that there normally would be relatively little surface flow into the SCRE, with or without water diversions, so that the VWRF discharge would be an artificial supplement to the volume of water in the Estuary.

Despite the implication of the passage quoted above, even the Synthesis Report's authors recognize that the VWRF discharge is an artificial supplement to the Estuary in the summer. For example, page 45 of the Synthesis Report includes a graph (Figure 4-6) showing the monthly average discharge volumes for the Santa Clara River and the VWRF, and the statement: "This combined flow results in a summer and fall surface water flow into the SCRE that is likely greater than would be expected from an unregulated southern California river during closed-mouth conditions (ESA 2003)."

We do not find data supporting the contention that the SCRE would become unsuitable for steelhead, tidewater goby, or other resident species if the VWRF was not discharging into the Estuary. The estuary persisted without artificial water supplementation historically, as do many other seasonally open estuaries in southern and central California.

One important consequence of the VWRF discharge into the SCRE is increased frequency of breaching. Although breaching is influenced by a complex mixture of fluvial and marine processes and breaching timing and frequency varies from year to year (see Smith 1990), many coastal wetlands in southern California naturally remained closed from the end of the wet season in February or March through the end of the dry season in November or so (Dave Jacobs, personal communication). Increasing the volume of water stored in an estuary through artificial supplementation can dramatically increase the number of times an estuary breaches in summer.

Summer-time breaching can have dramatic negative effects on both of the target species considered in this report. The effects of summer-time breaching is well illustrated by the breach in summer 2010, which was well documented by the fish survey that was scheduled for the next day (ENTRIX 2010). Thousands of tidewater gobies were stranded and killed when the lagoon drained rapidly and seven large juvenile steelhead were documented to have died.

Although the adverse effects of summer-time breaching are clear and well understood, various arguments have been made that the extra water in the summer time provides some ecological benefits to the SCRE. The main argument is that the extra water, by raising the water elevation in the lagoon, results in more habitat for steelhead and tidewater goby.

Note: http://www.venturariver.org/2010/09/estuary-breach-kills-fish.html reports "Two separate federal agencies are charged with stewarding the fish - NOAA Fisheries for the steelhead trout, and Fish and Wildlife Service over the tidewater goby. Past decisions have been based upon the need for continued water for the tidewater goby, based upon the fear that reduced flows from the wastewater plant would limit habitat in the estuary. And although steelhead often struggle to get downstream with limited flows past migration barriers, studies have revealed that steelhead rely upon the estuary in order to grow to a size which ensures their survival once they enter the ocean."

Water quality

Although the timing and quantity of water delivered to the SCRE has clear ecological consequences for steelhead, tidewater goby, and other species living in the Estuary, the quality of water is also important.

Salinity

Salinity levels have major ramifications for the distribution and abundance of many organisms found throughout the SCRE. As with many other SCRE parameters, understanding the historic and current salinity fluctuations is key to evaluating the impact any VWRF discharge might be having upon estuarine organisms. Pre-VWRF discharge (pre-1958) water quality data is non-existent and all modern Estuary sampling is confounded by the contiguous VWRF discharges. While we can infer previous general salinity levels from detailed historic ecology studies of the SCRE (now underway) or from our contemporary understanding of analogous, seasonally open systems, we are often left to rely upon models to predict the specific "undisturbed" salinity condition of the SCRE in the critical summer dry season that is so central to the focus of much of this Report.

The most recent SCRE geomorphology data (1-m resolution LiDAR surveys conducted by both Ventura County and the United Stages Geologic Survey in 2005) analyzed and reported in the Synthesis Report (Stillwater Sciences 2011) combined with other data collected and analyzed (*i.e.* NOAA Santa Barbara Tide Station 9411340 data) therein suggests that seawater enters the estuary primarily when the berm is breached and overall SCRE stage height is low. So salinity levels in the Estuary during open conditions (typically the wet period of the year) are only somewhat influenced by the VWRF discharge, with particular salinity levels fluctuating over the course of any given day as tidal forcing and river flushing alternate to allow a marine lens to migrate in and out of the Estuary. When the Estuary mouth is closed, relatively little saltwater appears to percolate through the sandy barrier across that SCRE mouth (although direct measurements are lacking to confirm this prediction). This owes to the fact the minimum estuary bed elevation is 3 feet (NAVD88) and the Mean Tide Level is only 2.71 feet (NAVD88). More than 80% of the estuary bed is higher than the 5.3 feet (NAVD88) equivalent to Mean Higher High Water (Stillwater Sciences 2011). Our independent analyses of the Santa Barbara Tide Station data shows tides exceed 3 feet (NAVB88) 46% of the time, exceed 4.5 feet (NAVD88) only 16% of the time, and exceed 6 feet (NAVD88) less than 2% of the time (these values hold for both the year as a whole and for the summer seasonal tides in isolation). If we assume Stillwater's monitoring was adequate to correctly characterize the groundwater gradients, McGrath Lake typically creates a net inflow of subsurface water into SCRE when the SCRE stage height is less than 5.3 to 6.3 feet (NAVD88) during the summer (Stillwater Sciences 2011). We therefore concur with the Synthesis Report's estimate that if we were to cease VWRF input into the SCRE during the dry summer months (when the SCRE experiences little or no surface riverine flows), the SCRE stage height would likely hover around 8 feet (NAVD88) in elevation. Assuming no rains or other surface inflows, the primary forcing function for those summertime inputs into the SCRE would be the rate of evaporation within the Estuary. As water elevation is drawn down, fresh, groundwater subsurface flows would tend to replace that volume lost to evaporation. The resulting summertime salinity of the Estuary would therefore be heavily dependent upon the volume of seawater retained within the SCRE at the moment the berm reforms across the mouth and ceases direct tidal exchange with the sea. Should the berm form rapidly and retain a large volume of seawater, we expect a relatively saline and perhaps even hypersaline lagoon as water evaporates and salts are concentrated into a lower stage/smaller volume lagoon. Should the berm form slowly and retain a comparatively small volume of seawater, we expect a fresher, slightly brackish lagoon. Given these caveats, we estimate that a VWRF-free summertime SCRE would probably more often than not tend towards brackish but likely experience elevated water temperatures.

Even if we are presented with a relatively stable fresh or brackish Estuary overall during closed-mouth summertime conditions, we could still potentially get sections of the Estuary that are more saline than other sections and hence influence organismal distribution within the lagoon itself. As with the system overall, a variety of factors come into play to determine that distribution of salinity across the lagoon. The extremes are represented by a completely (vertically and horizontally) homogenized state or a highly stratified state. The primary factors that come into play here are frequency and speed of surface winds blowing across the lagoon's surface, the amount of water restricted to very shallow depths (generally around the lagoon's perimeter), location relative to the primary percolation/subsurface inflow points in the lagoon (*i.e.* segments closest to McGrath Lake), and the amount of hydrogeomorphic partitioning (side channels, vegetation) that acts to increase hydrologic roughness and minimize mixing.

Evidence for wind-induced mixing of the SCRE is equivocal and data collected for this current Subwatershed study confirm stratification of DO, salinity, *etc*. is common (Stillwater Sciences 2011). Consistent stratification in small, central Californian estuaries has been implicated in slower growth of estuary-dependent animals such as steelhead (Smith 1990). However, should wind-induced mixing occur, that would tend to homogenize the SCRE as a whole, moderating any temperature increases and keeping the overall salinity levels in shallow reaches and vegetation-rich back channels lower than in a putative stratified condition.

This complex mix of marine and freshwater fluxes, geomorphology, and physical processes emphasizes the dynamic nature of this overall system and the importance of variable "initial" conditions at the onset of mouth closure and of stochastic events even were the VWRF to discharge nothing into the SCRE.

Nutrients

The Synthesis Report states that:

> Under current conditions, water quality regulation in the SCRE is directly impacted by excess nutrients arriving from the VWRF. The elevated nutrient levels in the VWRF outfall channel relative to other locations in the SCRE combined with the elevated trophic state index values suggest the SCRE is currently eutrophic. Although recent scour events may influence the relative amounts of rooted submerged aquatic vegetation (SAV), the lack of SAV has also been linked with nutrient enrichment in estuaries (*e.g*., Orth and Moore 1983).

The eutrophication of the SCRE has consequences for most species using the estuary. In particular, steelhead may be adversely affected by the low Dissolved Oxygen that occurs at times in some places of the estuary, most notably in the reaches proximate to the VWRF discharge during the warm summer months in pre-dawn hours where respiring algal biomass robs the water column of oxygen (see Figure 5-6). As noted by the Synthesis Report (p. 166), "the VWRF discharge may be directly linked to periods of low DO levels due to algal growth." Controlling nutrient inputs is an increasingly important goal across our region and key to a healthy estuary.

Dissolved Oxygen

Dissolved oxygen (as noted in the previous section) is a seasonal problem in the SCRE. Low oxygen conditions in the SCRE are primarily associated with nutrient enrichment, and algal blooms. As such the most common management action is to reduce nutrient inflows as already discussed. It is important to note, however, that low oxygen conditions may manifest in the absence of eutrophication, if waters are significantly stratified for extended periods of time. When a large biomass of vegetation, protists, or sessile animals are held within such a stagnant body of water, normal respiration may be enough to rob the water segment of available oxygen and create dangerously low DO. They solution to such stress is to induce water column mixing, thereby allowing exchange with oxygen-rich surface waters. Widespread, persistent stratification in the SCRE to the point of routinely suppressing DO is uncommon in the SCRE.

Temperature

Temperature typically ranges over 10°C (from a wintertime low around 13°C to a summertime high of 25°C; Stillwater Sciences 2011) over the course of the year in the central SCRE. While we have measured temperatures ranging to greater extremes in the shallow water perimeter reaches of the SCRE (Anderson unpublished data), temperatures are roughly similar to those of other southern California estuaries and not of particular management concern at this point. Typical temperature ranges are within those identified for steelhead and tidewater goby.

Anthropogenic Pollutants: Heavy Metals, Pesticides, and Emerging Contaminants

Various human created, modified, or distributed compounds from numerous sources can be found throughout the SCRE. State Water Board policy (LARWQCB 1994) requires toxicity tests and for water bodies to achieve the somewhat illusory "no acute toxicity" standard. Problematic identified contaminants to date include copper, nickel, lead, zinc which have all exceeded the US EPA (2000) California Toxics Rule (CTR) criteria for these metals (Stillwater Sciences 2010). It is worth noting that ammonia levels were periodically above toxicity criteria established under that same policy (Section 5.2.1, of LARWCB 1994). Regional Water Quality Control Board mandated toxicity tests included acute (Lethal Concentration or LC50) toxicity for fathead minnow (*Pimephales promelas*), and chronic toxicity tests for growth, reproduction, or survival. Model organisms included fathead minnow, a freshwater green alga (*Selenastrum capricornutum*), and daphnia (*Ceriodaphnia dubia*).

While all of these metals are potentially problematic to aquatic organisms (particularly developing individuals), copper has received the bulk of the attention from the perspective of our focal species. A decade ago, attention was raised when copper exceedances were identified in about 10% of the samples collected over the course of a year (ENTRIX 2002). Copper, lead, and nickel continue to violate identified monthly NPDES targets, although copper (and other metals for that matter) may well be entering the SCRE from upstream, open ocean or non-point sources (VWRF NDPES Monthly Reports 2008-2011, Stillwater Sciences 2011). Whatever the source, copper has the potential to impact salmonid olfaction and food chain support at concentrations as low as 0.59-2.1 ppb and behavior or growth at concentrations as low as 0.75-2.5 ppb (Baldwin, *et al*. 2003, Hecht, *et al*. 2007 and references therein). These sublethal impacts can manifest as recruitment failure, difficulty foraging, or other consequences. It should be noted that the detection limit for the EPA approved method used to measure copper in the SCRE and VWRF discharge (2 ppb) is above the lower end of these sublethal effects concentrations. From 1999 to 2004 Copper in the SCRE ranged from 0.5 to more than 140 ppb (ENTRIX 2002, Nautilus 2005). Data over the past 5 years shows copper now typically ranges from 2-20 ppb in the SCRE water column.

Proposed Alternatives

General Concerns of Proposed Alternative Modeling Approach

Interpreting alternatives is complicated by the poor characterization of current conditions of the extant system. The Summary Report authors have indeed done much work to model the effects of various candidate future manipulations. As with all such efforts, the key to this model's utility lies within the assumptions made. As such we would first like to explore some of the important caveats and assumptions associated with their modeling efforts:

1) For simplification purposes, all alternatives explore conditions within the relatively **dry time of the year** (late Spring through Summer) only.

Relatively wet periods of the year are often characterized by constant or at least frequent open-mouth conditions and the dwarfing of VWRF releases by main stem Santa Clara Rive flows. We find these assumptions and general focus on dry season conditions reasonable.

2) **2009-2010 hydrologic conditions** adequately characterizes typical system performance. We have some reservations with this given (as the authors note in section 11.2) the relatively wet conditions of 2009-2010 WY (although not as wet as the 2010-2011 WY is proving to be) and would have liked to have seen data from a range of years spanning comparatively dry years. Having said this, we believe that insight can still be gained even with models parameterized with only a subset of the natural range of physical conditions.

3) **Water Mass Balance Model** (articulated in section 4.2) characterizes water quantity in the SCRE via essentially independent estimation of component inflows and outflows. The numerous assumptions used to generate each of these components necessitate great caution when interpreting the aggregate model outputs. This model appears particularly sensitive to predicted stage height, ground water pressure gradients/inflow rates, and berm open/closed status. We have highlighted several concerns about these components/assumptions previously. Alteration of the VWRF discharge rate is the primary forcing factor in future scenarios.

4) Acute **Nutrient Accumulation/Mass Balance Model** (articulated in section 5.5) estimates Total Inorganic Nitrogen and Phosphate concentrations/mass loading to the SCRE. Similar to the above estimate of water quantity, this approach relies on assumptions about the various inputs and biological uptake/utilization rates. In particular we are concerned about the assumption that there are no biological “reactions” with regards to the nutrients in the system. This assumption can only hold if biological removal rates are low. In effect this says biological removal is not an issue by definition. This does not appear to be borne out by vetting of the overall ability of this model to predict extant conditions (see Figure 5-16). In addition it is a bit unclear as to how the future condition parameters for Table 11-2 were set. For example, why does the VWRF pond groundwater flow rate increase across scenarios 4, 5, & 6 (presumably due to an increase in hydraulic gradients as the overall water level decreases in the estuary and surrounding groundwater flows increase). This appears a key assumption as the model output predicts identical nutrient conditions/concentrations in Alternative 3, 5, and 6. Lastly, there is no clear link between nutrient concentration and habitat quality for the identified focal species other than general qualitative assertions that reduced nutrient concentrations should lead to less algal bloom or bloom-like conditions.

5) **Deterministic Models.** The models used to predict extant and potential future condition are deterministic. As such they paint a potentially misleading picture of those potential future condition of the SCRE; running this model again and again will merely produce the identical output and yield no measure

of the error (or confidence we have in the reported output). Without such a measure of our confidence in the model result, decision makers may take away an assumption of certitude that does not exist. Emphasizing variance (between weeks, months, *etc*.) or incorporating some level of stochasticity would boost our confidence in this exercise. We recognize the challenges of such a more intense modeling effort, but numerous observations and data collected for this assessment point to the very dynamic nature of this coastal system. Indeed many of the key forcing factors within this system appear to be dictated by variation (*e.g*., breaching frequency) rather than the overall central tendency (*e.g*., average stage height) of the system. Modeling that central tendency is more expeditious but may not capture the key drivers of ecological functioning. For example, these models may predict a stage of height of say 10 feet after one month. Even if a brief breach then occurs, this model would predict another 10 foot elevation one month later and identical conditions to those of the previous month. The key determinant of the ecological functioning within that lagoon would be the breach event (the deviation if you will) and not the average condition.

6) **Stage height** is the sole determinant of aquatic volume and in turn of the habitat quantity for focal species. As the authors point out, their approach depends entirely upon robust benthic topography, which has only been mapped to a high degree of accuracy twice in the last decade (2000, 2005). The assumption that the 2005 condition is an accurate predictor of topographies decades into the future is dubious. While a fine first pass, this approach is insufficient to characterize the overall quality of this aquatic habitat for our focal species. One example of the problem of this stage height-habitat area assumption can be found with the tidewater goby field surveys. Surveys conducted in the Spring of 2008 (see the Nautilis 2009 report) showed no effect of mouth breaching (*i.e*. different stage height) on tidewater goby abundance/incidence. If their habitat was so sensitive to stage height as implied by the core assumption of this model, we would expect goby abundance/incidence to decrease following a reduction in stage height. As such, using this single parameter as a predictor of goby habitat quality is flawed. While it is absolutely the case that gobies do require a minimum water level, other factors such as spatial refugia, prey availability, and predator abundance may well prove more accurate predictors of the adequacy of the SCRE as goby habitat. These were not assessed in this study. A similar argument can be made for steelhead (see above). While higher stage results in greater aquatic habitat area, the additional habitat may not be of higher quality for steelhead or gobies (as acknowledge by the author).

7) Model only captures **short-term dynamics**. The authors are explicit in arguing that they designed this model to only address the situation in the 4-month, immediate aftermath period following a mouth closure. While we feel such a short-term approach is fine to compare the short-term dynamics of various management options, it is important to keep in mind that this ignores any longer-term shift in community dynamics. This weakness was recognized

with regards to the potential expansion of tern and plover nesting (the authors felt the need to bring in longer term community dynamic estimates when they noted a lowered overall stage height such as under Alternative 6 would in all likelihood lead to only a temporary expansion of potential nesting area due to presumed vegetative encroachment in subsequent years), but not for putative salmon habitat. As their assumptions put a higher value on shallow/vegetated fringe regions of the marsh for focal fish species, their failure to consider possible longer-term dynamics (*i.e.*, vegetation colonizing/redistributing to the periphery of new, lowered water levels under Alternatives 4-6) leads to an overly pessimistic estimate of the potential quantity of such habitat for fish rearing, *etc*. The authors could remedy this concern relatively easily by simply running additional simulations with a potentially redistributed vegetation polygon. This could at least help bound their results. Our concerns regarding the differences between habitat quality and quantity aside, we feel remaining cognizant of potential longer-term dynamics is always beneficial for managers/decision makers.

Interpretation of Alternative Scenarios

The discharge-stage height and discharge-nutrient concentration models predict improvements for most organisms with reduced water quantity and nutrient discharges into the SCRE from the VWRF. The stage-height model predicts specific conditions, while the nutrient models predict general conditions lacking specific predictions upon species performance. Given the lack of predictive power of the nutrient model, the alternatives can be generally aggregated based on the discharge-stage model; continued discharge grouping (Alternative 1, 2, 3), 30% reduction is discharge group (Alternative 4, 5), and the no discharge group (Alternative 6). The authors' interpretation largely follow these groupings.

The Synthesis Report's discharge-stage models predict or relatively little effect on focal species under scenarios 1, 2, and 3. McGrath State Beach would continue to flood under scenarios 1, 2, and 3. Effects upon focal species habitat begin to be felt under scenarios 4 and 5, although these effects are generally minimal according to the Report. Flooding of McGrath campground (and presumed recreational impairment) ceases under scenarios 4, 5, and 6. Scenario 6 would reduce potential steelhead habitat quantity by 70%, with that for other species moderately impacted or unimpacted. Unfortunately we believe none of these model outcomes are of any utility to decision makers due to the caveats we have already mentioned and absence of any clear relationship between these predictions and the actual health of SCRE populations or functioning of the system.

The authors are correct in their assertions that reduced VWRF discharges will likely decrease the freshening of the estuary and so make the SCRE generally less hospitable to invasive aquatic species that compete or prey upon our focal species. This is recognized as an improvement in ecological functioning. Similarly reductions in nutrient concentration from the VWRF will tend to reduce the conditions leading to eutrophication, algal blooms, low DO, *etc*. (although the expected magnitude of that improvement is unknown). This would represent an improvement in water quality to the background level of the water entering the system from upstream/groundwater.

The authors are correct in noting that their model only attempts to predict the acute condition of the SCRE given various alternatives. At various points there are references made to potential long-term shifts in vegetation or other landscape elements should a given alternative be in place for an extended period of time (e.g. section 11-2) even though their modeling efforts do not encompass this possibility. While an important caveat, we are not particularly concerned with this eventuality. Even if Alternative 6 (complete cessation of VWRF input) were implemented, we believe the dynamic flows and scouring during the wet season are likely to prevent channels from choking with vegetative or sediment accumulation to the extent we would see a radical alternation of potential habitat for any focal species.

These 4-month long scenarios generally are at or near (within ~1 foot) their equilibrium conditions within 1 to 1.5 months of the onset of the model. The general assessment of each given scenario is therefore driven by those dominant equilibrium or near equilibrium conditions. This ignores the fact that during the summer months, the mouth has remained open approximately 2/3 of the time from the mid-1980s to late 1990s or 1/3 of the time over the past decade (see Figure 4-9). We understand the value of a standardized model with which to compare alternative scenarios. However the propensity to breach is not expressed at all in this exercise. This is a key driver if of ecological functioning of the system and of habitat quality and quantity for our focal species in the SCRE. Even assuming the relatively infrequent summer breaching rate of recent years (30% or less of the time) paints a very different picture of the quantity/duration of habitat available to the focal species. We therefore cannot express how problematic excluded breaching from this scenario comparison exercise is. As we believe breaching is the most important feature of the SCRE from an ecological impact perspective and the greatest impact from the VWRF discharge in particular, any interpretation of these scenario models is limited.

Recommendations

Model Improvements

We have noted several concerns with the modeling effort, but improvements do not necessarily require starting over from scratch. One potentially cost effective approach to improve our understanding of the proposed alternatives is to build upon the considerable effort that went into this existing model. We suggest adding breaching events and explicit measures of habitat quality to this model. This could potentially be done via an integration of the nutrient and stage height elements. The Bight ’08 estuary dataset complied by the Southern California Coastal Water Research Project may be particularly helpful in this regard. While not directly elucidating nutrient-fish relationships, this year-long effort attempted to relate nutrient concentrations to DO and algal bloom events. Such an exercise which attempted to explicitly get at habitat/water quality from this initial model framework would greatly improve decision makers’ ability to distinguish between potential alternative scenarios.

Habitat Quality and Ecotoxicological Studies

Much effort in both this report and the monitoring efforts that have led up to this report have focused on elucidating SCRE habitat quantity or traditional water quality parameters within the SCRE. This was an appropriate starting point. With this foundational work in place, we would like to see the data collection efforts mature to focus more intently upon issues of habitat quality. This includes a better understanding of the productivity rate of prey items for focal species, growth rate studies of focal species, and a better understanding of community assemblages across a range of SCRE sites and comparable reference sites (see below). We also suggest a greater emphasis be given to ecotoxicological studies, particularly sub-lethal chronic and acute studies on focal species (goby or goby models and smolt steelhead or steelhead models) that have received so much attention in this work leading up to this Synthesis Report. Nutrient, heavy metal, organic, and emerging contaminant studies on aquatic species would greatly improve our ability to ascertain the actual value of the habitat quantity.

Our ability to better interpret VWRF-associated impacts and benefits would improve with a more rigorous assessment of the ecotoxicology of various factors upon SCRE organisms. We suggest a series of acute and chronic toxicity tests with EPA approved organisms. Ideally organisms would include species of concern but also other organisms that represent a range life histories and interactions with the environment, developmental periods/ages, and that span a range of sensitivities. We suggest both vertebrate and invertebrate EPA-approved Whole Effluent Toxicity (so-called WET) model organisms. Rainbow trout (*Oncorhynchus mykiss*), fathead minnow (*Pimephales promelas*), and topsmelt (*Atherinops afinis*) could provide good estimates of the range of fish feeding guilds and are relatively robust estuarine organisms that occur in SCRE. Water fleas (*Daphnia* sp.) and mysid shrimp (*Mysidopsis bahia*) would characterize the sensitivity of short-lived invertebrates who may be relatively more susceptible to both acute and chronic impacts from pollutants. We note that fathead minnow, topsmelt, and mysid (and a *Daphnia* analog) were used during water and sediment toxicity tests conducted in the SCRE from 2003-2004 (Nautilus 2005). We suggest building upon this good previous work, however emphasize focal species models and emphasize the more freshwater/brackish suite of models (Nautilus 2005 emphasized marine models). Acute and chronic bioassays for both lethal and sublethal endpoints are well established (see US EPA 2002 and the US EPA's Manual clearing house at http://water.epa.gov/scitech/methods/cwa/wet/index.cfm).

Additionally any attempts to characterize emerging contaminants commonly derived from municipal, agricultural, and industrial wastewater such as endocrine disruptors, cosmetics, and fire retardants would be a positive step. We appreciate that concentrations of such compounds are often at the ppb level, at or near existing detection limits, and that few if any standard monitoring methods have emerged. Nevertheless, such a dataset will go a long way towards helping us understand some of the more subtle impacts of VWRF upon potential habitat quality.

Lack of Adequate Reference Sites for the Santa Clara River Estuary

Perhaps the greatest challenge to rendering a robust judgment upon the health of the SCRE is the lack of an appropriate reference system or systems. At some level (coastal river or coastal estuary), we have many sites with which to compare the SCRE. At such a gross level, we can relatively confidently answer some basic questions such as are there/should we expert there to be steelhead in the SCRE? At this gross level of assessment, nearby sites are acceptable reference sites or historic data can be gathered to determine the historic condition of the SCRE. Unfortunately, for many of the more focused and therefore diagnostic metrics discussed in this report, such gross comparisons are not appropriate. In particular the conditions that derive from the seasonal closure of the river mouth are a challenge. We know of no good extant system that mimics the open-closed nature of this coastal lagoon system that is itself relatively undisturbed. While we may have some suppositions based on our own experiences, there is simply no obvious, objective yardstick with which to compare many of these more detailed metrics discussed herein: infaunal density, ichtyofauna compositional diversity measures, *etc*. For example, in previous reports wherein an effort was made to compare benthic macroinvertebrates within the SCRE to those within other systems in the Southern California Bight, the vast majority of these putative reference sites were fully tidal and so not comparable (even if identical sampling methodologies had been used). In short, the lack of a robust, regional assessment framework is clearly felt. Nevertheless the authors lack of monitoring at a range of reference sites and the short temporal duration of the vast majority of their sampling efforts (we note that discharges in the SCRE began in 1958 and California's inaugural Enclosed Bay and Estuaries Discharge Policy in place since 1974) makes interpreting current performance an equivocal task.

Hydrology Experiments

Given both the shortcomings of the scope and duration of the sampling efforts to date, the lack of obvious reference sites for the SCRE, and limitations of the models utilized, we propose a manipulative experiment to better interpret the current conditions and at least some of the alternative management scenarios. We propose a 3- to 6-month experiment wherein effluent from the VWRF is removed, reclaimed or piped directly offshore via a temporary pipeline akin to the temporary dredging pipeline routinely deployed adjacent to the SCRE for dredging operations in Ventura Harbor. As we lack an adequate model system, such a temporarily cutoff VWRF discharge from the estuary proper would go a tremendous way towards estimating salinity levels, stage height, infaunal responses, *etc*. in a VWRF-free scenario. While there are various shortcomings and risks with such a manipulative approach, we would be on much more solid footing with regards to predicting alternative scenarios. It would directly allow the testing of Alternative 1 and Alternative 6 (and a partial diversion would allow us to evaluate the hydrological components of Alternative 4 & 5) while giving important insight into the other alternatives. Even a short-term experiment may elucidate much of what currently remains unknown or untested.

Conclusions

In summary we feel the Santa Clara River subwatershed studies do not afford enough ecologically-relevant information to say that VWRF discharges into the SCRE are necessarily a net benefit to the system. There are likely to be improvements to the ecological and recreational values with reduced quantities of water and nutrients discharged into the system, but the nature and extent of these benefits are unclear given the information and data provided to date. The summary report is a definite improvement in the effort to better understand the SCRE system and the effect that the VWRF has upon it, but does not provide adequate information to make a fully informed decision as to the current effect of VWRF discharge on SCRE organisms and their ecosystem.

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