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Application of Watershed Loading and Estuary Water Quality Models to Inform Nutrient Management in the Santa Margarita River Watershed

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SYNTHESIS OF FINDINGS AND RECOMMENDATIONS

The Santa Margarita River Estuary (SMRE) and various tributaries within the Santa Margarita River watershed are listed on the 2010 Clean Water Act (CWA) section 303(d) list of water quality limited segments as impaired due to nutrients and eutrophication. The Santa Margarita River Watershed Nutrient Initiative (NMI), a stakeholder group formed in 2011, has supported the development of science to support improved assessments of nutrient-related impairment, and if warranted, identify nutrient targets and management actions as needed for the river, estuary, and tributaries. The SMR Stakeholder Group is funded largely through the Integrated Regional Water Management (IRWM) process and is currently receiving a Proposition 84 grant from the State of California with matching funding and in-kind services by the Counties of Riverside and San Diego and U.S. Marine Corps (USMC) Base Camp Pendleton, with the first phase focused on the SMRE.

In order to support nutrient management discussions for the SMRE, a watershed loading model (Hydrologic Simulation Program Fortran-HSPF) and receiving water model (Environmental Fluid Dynamics Code-EFDC and Water Quality Simulation Program-WASP) were applied in order to inform five major science objectives of the Santa Margarita River Watershed Nutrient Management Initiative (Phase I), focused on the SMRE:

Using the SMRE EFDC+WASP Model

1) Summarize understanding of the major pathways that supply nutrients that can fuel eutrophication in the SMRE

2) Estimate the range of allowable loads to SMRE, including wet versus dry weather

3) Illustrate how choices in selection and interpretation of numeric target(s) affect estimates of allowable loads

4) Conduct a preliminary set of scenarios to inform what kind of nutrient management activities should be considered to support SMRE beneficial uses

Using the HSPF Watershed Loading Model

5) Estimate the nutrient sources and amounts of nutrient loads delivered to the SMRE and the uncertainties in those estimates

A summary of findings and recommendations relevant for nutrient management are provided below.

Major Findings

Major Pathways of Nutrient Loads that Can Support Eutrophication in the SMRE

• Eutrophication is a dry weather issue in SMRE. Eutrophication symptoms are present during dry weather, and exhibit their peak during summer dry weather. As simulated by the WASP model, wet weather does not have a major impact on eutrophication symptoms in SMRE, contributing < 5 % to eutrophication symptoms during an open tidal inlet condition. However, wet weather can influence groundwater concentrations and ultimately baseflow during dry weather, a pathway that is inadequately captured by the model. Because iii groundwater has a long residence time in the aquifer, the magnitude, timing and source of nutrients to groundwater are not easily extrapolated from surface water runoff. In addition, if SMRE is more often in a semi-closed or closed state, wet weather flows that do not open the mouth may result in the appearance of eutrophication symptoms. Thus, wet weather discharges are a factor to consider in nutrient management strategies.

• As configured in WASP model, major external source of TN to the estuary during dry weather are watershed SW and local groundwater inputs, while major P sources include watershed SW and upstream aquifer discharge. Uncertainties exist in estimates of groundwater exchanges from local agricultural fields and from upstream aquifer. Calculated inputs of groundwater from the upstream aquifer are particularly constrained by the lack of phosphorus data, so the concentration was back-calculated based on the residual required to calibrate TP concentration in the Estuary. In addition, uncertainty exists in the estimates of local groundwater inputs to SMRE from agricultural fields found along the northern bank, for three reasons: 1) Groundwater discharge measurements began in 2010, after the ag fields had been fallowed from active production and thus were temporally offset from calibration year; 2) independent data from 2008 show ag-dominated groundwater inputs in an area more spatially expansive than measured just at I-5 bridge and what was used to model local ag groundwater inputs; and 3) groundwater discharge and concentration data are limited in temporal resolution. Even so, SPAWAR groundwater monitoring data provides solid evidence that local groundwater loading to the estuary has been declining over time.

• Benthic flux can be an internal source of nutrients to surface waters during dry weather. As configured in the WASP model, benthic flux presents a large contribution to available nutrients. This component appears to be largely driven by the accumulation and settling of organic matter to the sediment bed as macroalgal blooms die and decay. The importance of benthic flux in supporting eutrophication symptoms in the estuary is likely overestimated, for the following reasons: First, the magnitude of modeled benthic effluxes (out of the sediment) appear high and in the opposite direction from measured influxes (into the sediment) in winter dry weather and early summer dry weather. This is due to the fact that the benthic microalgae were not simulated as a component of benthic primary producers. Second, the model does not simulate sediment transport, deposition and scouring that are important to the spatial patterns of eutrophication in the estuary. It also does not capture the interannual scouring of sediments that occur during extreme high flow events that can cause the removal of accumulated organic matter, which fuels benthic flux. Third, the observed flux data may include a potential source from advective groundwater, but that advective groundwater fluxes cannot be simulated in the SFM. For this reason, the WASP model is likely overestimating the importance of benthic flux in driving eutrophication in this river mouth estuary.

Choice of Indicators of Eutrophication for Numeric Targets and Science Supporting the Selection and Interpretation of Numeric Targets

• Use of existing TN and TP numeric translators of SD Diego Water Board basin plan objectives is not recommended because 1) ambient TN and TP concentrations do not have a strong linkage to beneficial use impairments, and 2) exceedances of dry weather TP concentrations are driven by the concentrations of TP imposed on upstream aquifer discharge in order to calibrate the WASP model. No data are yet available to inform what these concentrations should be.

• Dissolved oxygen (DO) and macroalgal biomass and cover have demonstrated linkages to beneficial uses, have a predictive relationship with nutrient loading to the estuary, and have a practical and generally cost-effective methods for measurement and interpretation of data. These two indicators seem to be well suited for further consideration as numeric targets for SMRE.

• Existing science relevant to California native fish and invertebrates supports the use of 5.0 mg L-1 DO as an upper bound to protect long-term survival and reproduction in nonsalmonid, warm-water fisheries in California estuaries. Documentation of DO conditions in minimally disturbed “reference” bar-built estuaries similar to SMRE indicate that during the period of April-October, the average period of time bottom waters spent below 5 mg/L was 32%. The SD Water Board should consider setting expectations for percentage of the time in which SMRE attains the DO WQO, taking into account tidal inlet status (open, closed) and what can be attained in reference estuaries.

• Sutula et al. (2016b) provides a synthesis of the status of science on adverse effect thresholds of macroalgae on benthic habitat quality, and proposes an assessment classification scheme based on the use of macroalgal biomass and cover. For the purposes of assessment, we strongly urge the use of both biomass and cover in assessing attainment of beneficial uses. However, the WASP model does not predict % cover, but rather assumes uniform distribution within each grid cell. Therefore, we recommend reliance on the synthesis of threshold supporting decisions on biomass only for interpretation of model output to determine allowable loads. It is unclear the threshold at which macroalgal biomass of 30 to 90 g dw m-2 causes adverse effects to benthic habitat quality. Analysis of collateral data on benthic macroinvertebrate (BMI) community composition shows the BMI to be in moderate to low ecological condition during a year in which monitored macroalgae exceeded 90 g dw m-2. Given the lack of evidence in the macroalgal biomass thresholds that are protective of estuaries beneficial uses in the range of 30-90 g dw m-2, a bioconfirmation approach using benthic macroinvertebrates is recommended.

Estimated Ranges of Allowable Loads

• As modeled by EFDC + WASP, very little difference existed between wet and dry weather reductions of nutrient loads versus dry weather load reductions only that met the range of DO and macroalgal targets under consideration. At face value, the implication of this finding is that wet weather structural BMPs, which generally cost an order of magnitude or more to implement, may not provide any additional environmental benefit to SMRE than implementation of dry weather BMPs alone. That said, the complexity of the fate and transport of wet weather nutrient loading and its influence on nutrients in watershed dry weather baseflow as well as the groundwater aquifers at the top of the Gorge and on Camp Pendleton is not captured by WASP, nor by the HSPF watershed loading model. At a macroalgal biomass target of 50 g dw m-2, the WASP model predicts 91 ± 4 % reduction of dry weather 2008 loads would be required; at a biomass target of 90, the required reduction of dry weather loads would be in the range of 52 ± 4 %; at a biomass target of 110, the required reduction of dry weather loads would be in the range of 20 ± 5. At a whole estuary scale and during an open mouth condition, a macroalgal biomass of 71 ± 2 g dw m-2 would meet 5 mg L-1 90% of the time, based on the 10th percentile of 7-day DO minima. Meeting this target would require a 73 ± 46 % reduction in dry weather loads. A TP target of 0.1 mg/L drives the most stringent load reductions, but the use of such a target is unreasonable because the load reduction is driven by the concentration of TP in groundwater discharge from the upstream aquifer, for which no data are available.

Watershed Nutrient Loads and Sources

The watershed loading (HSPF) model provides a quantitative basis for summarizing the nutrient loads and sources for the Santa Margarita watershed, for the purpose of supporting nutrient management discussions. The tools can be improved, but the basics are there. However, there are many nuances for how the data are summarized for its applicability to nutrient management.

• Nutrient loading from the watershed varies greatly by season. During winter wet weather, high land-based loads are generated, and these are largely transported through to the Estuary, except for the amount removed by diversions onto Camp Pendleton; however, a significant portion of these loads are transported through SMRE to the ocean. During winter dry weather, there is less load generation and lower rates of transport; however, loads during winter dry weather are likely to be flushed through to SMRE if there are succeeding wet weather events. Summer dry weather loads are strongly affected by water management on Camp Pendleton, including diversions, recharge, and pumping from the alluvial aquifer. Santa Margarita River is intermittent, so flow to SMRE is often discontinuous. During early summer, discharge from the Lower Santa Margarita aquifer to the stream becomes an important source of nutrient load. During later summer, loads from the upper watershed are largely disconnected from the aquifer because most flow past Camp Pendleton is depleted by aquifer demand. While wet and dry weather loads serve to recharge groundwater, there is not a direct linkage between surface runoff and groundwater nutrient loads, because the residence time of groundwater is substantially higher than surface water and the connectivity between the aquifer and surface water exchange is complex and not captured by the watershed loading model in its current form.

• The interpretation of the model into delivered loads from individual sources is dependent on the period that is analyzed – both the scope of years and the division into seasons. The current analyses divide the year into winter (Oct.-Apr.) and summer (May-Sept.) and dry and wet periods. Actual delivery ratios vary by month and by event. It is necessary to make some assumptions to interpret the model results, as individual sources are not tracked through the model to the Estuary, and indeed cannot be due to interactions and cycling with algae. The Mediterranean climate of Southern California is highly variable from year to year, and which years are included makes a difference in the relative importance of different sources. To incorporate a more representative sampling of potential conditions, it may be advisable to conduct simulations that cover multiple decades of weather input, while maintaining current conditions for controlled discharges.

Science Recommendations

Existing uncertainty in the watershed loading can be further constrained by the following:

• Better representation of precipitation and associated improvements in hydrologic simulation through use of PRISM topographically adjusted precipitation time series instead of relying on sparse gauge measurements.
• Extension of both the hydrologic and water quality calibration to 2012 to make use of monitoring conducted since 2012.
• Integration of the simulation output of Camp Pendleton Lower SMR Groundwater Model, developed by Stetson Engineers (hereto referred to as the CP MODFLOW model), for the Pauba and Temecula aquifers (Murrieta vicinity) to improve watershed model simulation of groundwater exchanges, similar to what has been done with the model of the Lower Santa Margarita aquifer.
• More detailed and data-based representation of irrigation and irrigation return flows.
• Incorporation of results of other recent studies on conditions and nutrient loading sources in the watershed.

Existing uncertainty in the estuary hydrodynamic and water quality model can be further constrained by:

• Improvement in the resolution of the model grid to better capture effects of light availability on macroalgal growth.
• Inclusion of benthic microalgae as a primary producer in the WASP model to better capture magnitude and direction of winter and springtime nutrient fluxes and sediment oxygen demand.
• Comparison of macroalgal and cover biomass in the subtidal versus in the intertidal habitat of the estuary.
• Field data collection of concentratons of nitrogen and phosphorus in the upstream aquifer and calibration of the CP MODFLOW model to better estimate loads to the SMRE.
• Synoptic collection of monitoring data to represent inputs (local groundwater, upstream aquifer, ocean boundary, surface water temperature, dissolved oxygen, salnlity, nitrogen and phosphorus forms), major state variables (benthic macro- and microalgae, dissolved oxygen), benthic flux and sediment oxygen demand).

Management Recommendations

• Regulatory action taken should consider taking into account the considerable variability in SMRE tidal inlet dynamics and uncertainty in estimates of loads by pathway, particularly with respect to groundwater, in establishing allowable loads. Regulatory strategies should be flexible and encourage adaptive management practices in the face of such uncertainty. Examples of this flexibility include, but are not limited to, the following: (1) Exploration of inlet management scenarios vis-à-vis habitat support for SMRE resident fauna should be encouraged, with the flexibility to alter the allowable loads to SMRE pending conclusions of such analysis, and (2) an opportunity to revise limits or reductions required in 2-3 years should be considered, pending new watershed data collection and improvement of the EFDC+ WASP model, CP MODFLOW, and watershed loading models.

• The use of the TN and TP numeric translator as the basis for interpretation of the biostimulatory numeric targets should be removed from consideration, given the scientific issues with this guidance.

• Given unknowns in the range of macroalgae that can impact beneficial uses (30-90 g dw m-2) and the interpretation of DO objective in estuaries that are intermittently open to tidal exchange, benthic macroinvertebrate community health as an additional line of evidence should be used in determining attainment with the macroalgal numeric target that may be established.

Full text:
http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/933_AppOfWatershedLoading.pdf