1. MONITORING PLAN (REVISED, DECEMBER 2013)

1.1 Introduction

This section presents a summary of the San Diego HMP's revised Monitoring Plan in 2013, reflecting the changes developed through a re-evaluation and consultation process with the HMP Technical Advisory Committee (TAC). The summary explains technical concepts and approaches to monitor the effectiveness of the HMP as required by provision D.1.g of Regional Water Quality Control Board (RWQCB) Order No. R9-2007-0001 and as subsequently required in RWQCB Order R9-2013-0001 part D.1.a.(2).).

Part 1(k) of provision D.1.g requires that the HMP shall "include a description of pre- and post-project monitoring and other program evaluations to be conducted to assess the effectiveness of implementation of the HMP." For the purposes of developing an HMP monitoring approach, an effective HMP is defined as a program that results in no significant stream degradation due to increased erosive force caused by new development.

The monitoring approach provides for the optimum 5-year effectiveness assessment within currently available funding resources. Monitoring Plan activities were selected to achieve statistical data collection requirements while balancing regional financial constraints and highly variable and evolving scientific, regulatory, and physical elements. Monitoring Plan activities presented herein have been developed to answer the following questions regarding HMP program effectiveness assessment:

- **Do field observations confirm that the HMP appropriately defines the flow rate (expressed as a function of the 2-year runoff event) that initiates movement of channel bed or bank materials?** Since most of the sediment transport modeling prepared as part of the HMP development relied on laboratory flume data, it is important to supplement the sediment transport data set with field observations. This data may be used in the next permit cycle to determine whether critical shear stress is the appropriate parameter for selecting the lower flow threshold of the geomorphically significant flow range.
- **Are mitigation facilities adequately meeting flow duration design criteria outlined in the HMP?** Observed HMP mitigation facility outflow data can be analyzed to determine if mitigation facilities are matching the mitigated post-project peak flow frequency and flow duration curves to the pre-project curves (within tolerances set forth in the HMP). This data can also be used to analyze the precision of LID sizing factors, extended detention facility design criteria, and to potentially recommend changes to more closely match the mitigated post-project curves to pre-project condition peak flow frequency and flow duration curves.
- **What is the effect of development on downstream cross section stability?** Since the mitigation of accelerated channel degradation as a result of development is the central purpose of the HMP, analysis of channel cross sections downstream of development projects is a component of the Monitoring Plan. However, uncertainties involved with this comparison tool (namely the problem of disentangling erosion due to current project-related hydromodification from erosion due to historic land use changes or natural disturbance events such as fire or floods) make policy determinations less likely within the time frame of the 5-year monitoring plan (as compared to sediment transport modeling and flow duration modeling detailed in the previous two questions).

Such a question-driven plan is consistent with the Framework for Developing Hydromodification Monitoring Programs prepared by the Southern California Coastal Water Research Project (SCCWRP – Technical Report 752, March 2013).

During the past three years of implementing the HMP Monitoring Plan, the Copermittees have assembled a comprehensive team of technical experts to provide input in refining the Monitoring Plan to effectively address the three core study questions listed above. The team is comprised of the Hydromodification Monitoring Subworkgroup, a Technical Advisory Committee, and Consultants with expertise in hydromodification monitoring as follows:

Hydromodification Monitoring Subworkgroup Members

- Jim Nabong, P.E., City of San Diego (Chair)
- Jim Hook, City of San Diego
- Summer Hasenin, P.E., City of San Diego
- Christine Sloan, County of San Diego (Land Development Workgroup Chair)
- Deborah Mosley, County of San Diego
- René Vidales, P.E., County of San Diego
- Greg Carlton, P.E., County of San Diego
- Andrea Santos, County of San Diego

Technical Advisory Committee Members

- Eric Berntsen, formerly of the State Water Resources Control Board (hydromodification),
- Christina Arias, P.E., San Diego RWQCB
- Dr. Eric Stein, SCCWRP (hydromodification and water quality)
- Dr. Felicia Federico, UCLA (hydromodification)
- Jo Ann Weber, County of San Diego (water quality and Copermittee watershed planning)
- Dr. Trent Biggs, San Diego State University (geology and hydrology)
- Dennis Bowling, P.E., Rick Engineering (hydromodification)

Consultant Team

- Dr. Andy Collison and Brian Haines of ESA PWA (hydromodification and geomorphology),
- Dave Renfrew, CPSWQ and Garth Engelhorn, CPSWQ of Weston Solutions, Inc. (monitoring and reporting)
- Scott Cartwright, P.E., RBF
- Dr. Trent Biggs, San Diego State University (geology and hydrology)
- Kris Taniguchi, San Diego State University (geology and hydrology)

1.2 Technical Concepts

1.2.1 Hydromodification Concepts

As required in the 2007 Permit, the evaluation of increased erosive force is limited to the geomorphically significant flow range, which is defined between the flow associated with critical shear stress and the ten-year return interval flow (Q10). The value of the lower flow threshold indicates the flow at which sediment erosion from the stream bed or banks begins to occur. The HMP uses two calculation tools (the low flow calculator and the SCCWRP Field manual for assessing channel susceptibility, 2010) to determine the low flow threshold based upon substrate type, channel slope, roughness, channel cross section, and other stream assessment conditions. The resulting lower flow threshold will be expressed as a multiple of the two-year return interval flow (Q2):

- $0.1Q_2$ for streams with HIGH susceptibility to channel erosion
- $0.3Q_2$ for streams with MEDIUM susceptibility to channel erosion
- $0.5Q_2$ for streams with LOW susceptibility to channel erosion

1.2.2 HMP Effectiveness Validation Measures

Sediment Transport Studies. This approach monitors suspended sediment and/or bed sediment transport rate throughout a storm event and can be used to directly evaluate the validity of a low flow threshold for a particular stream segment. Bedload and/or suspended load are monitored depending on which transport mechanism appears to dominate at the project site. Measuring the sediment transport rate and flow rate over a range of flows allows a relationship to be developed (i.e., a sediment rating curve) to assess the calculated low flow threshold in comparison to where sediment transport is observed to occur for a given channel susceptibility type. This approach is the most labor intensive, because it involves measuring flow and sediment rate concentration during numerous storm events to develop a statistically valid data set for each channel susceptibility type. The sediment transport monitoring activities involve a combination of up to five measurements depending on the dominant transport mechanism at the site: continuous measurements of water stage using a pressure transducer, point measurements of velocity, depth and cross section area to measure discharge during flow events, direct point measurements of bedload and suspended sediment concentration (SSC) and turbidity during flow events. Continuous turbidity monitoring using a data logger will be used at high susceptibility sites to develop correlations between turbidity and SSC to estimate SSC where point measurements are not available.. These approaches are most likely to produce information on HMP effectiveness on a relatively short time frame, provided that a sufficient range of storm event sizes can be sampled during the monitoring program.

Flow Duration Curves. Another measure of HMP effectiveness is determining if, within the geomorphically significant flow range, the post-project flow-duration curve is comparable to or below the pre-project flow duration curve. The 2010 Monitoring Plan did not adequately describe how the flow measurements could be used to generate a flow duration curve which is normally created using 30 years or more of data. Therefore, the 2013 Monitoring Plan shifts the emphasis to assessing the accuracy of the continuous simulation model within the scope of this project in representing rainfall-runoff relationships found using field measurements. Field data from the HMP study will be used to validate the continuous simulations model, while long-term gage records from small watersheds in San Diego Region will be used to calibrate the model input parameters. Refinement of the continuous simulation model is important, as the model was originally developed using field data from watersheds that are much larger than typical HMP sites. Field measurements of rainfall and flow rate will be collected and hydrographs prepared for the pre-project condition. The same field measurements will be collected and analyzed for post-development conditions, if the timing of development project construction allows this. If mitigated development projects are not completed in the study catchment within the study timeframe, then assessment of the rainfall-runoff simulation accuracy for the urbanized study sites will need to suffice as a representation of conditions for a developed but unmitigated watershed. The Copermittees will also look for opportunities to monitor hydromodification controls that are not in the study catchment (referred to as "decoupled" monitoring in the HMP Monitoring Plan Revision Technical Report). This monitoring activity will also depend on development timelines. This information will ultimately be used to evaluate the accuracy of the continuous simulation model in producing flow duration curves which HMP mitigation facility design standards are built around.

Channel Stability. The most obvious measure of stream erosion is to physically measure the pre-project and post-project cross sections, and determine if the channel is unstable and either aggrading or degrading over time. This is accomplished by conducting geomorphic assessments and channel surveys downstream of a planned development before and after construction. In addition to physical measurements, comparison of current and historical photos, aerial photography, and site inspection for signs of channel instability can provide important supporting evidence. The labor for conducting such an assessment at a single location is lower compared to the effort needed to conduct sediment transport studies. Costs are driven by the number of sites assessed, as well as the need for establishing pre-project trends (e.g., rate of pre-project channel incision per year). Although this monitoring approach is the most direct measure of whether stream instability is occurring, it is difficult to use the method to differentiate between existing geomorphic effects (e.g. effects of converting native vegetation to cattle ranching) and post-project geomorphic effects. To do so would require a long-term baseline of pre-project channel erosion and sedimentation rates along with post-project monitoring. To capture the range of annual rainfall conditions encountered in Southern California, decades of information are generally recommended to quantify pre-project baseline trends. Therefore, while baseline data will be collected and will be useful for future analyses, this monitoring plan focuses on validation measures likely to provide meaningful data within 2 to 5 years. It is possible that tentative conclusions may be reached regarding channel instability at the conclusion of the 5-year monitoring plan.

1.2.3 Temporal and Spatial Variability of Monitoring Locations

Temporal Variability. As noted above, the single most important factor affecting the temporal variability inherent to measuring stream degradation is variable inter-annual rainfall frequency and intensity. Droughts in California can last years, with little to no rainfall occurring in Southern California. During El Nino years, anomalously high storm frequencies and intensities can result in sudden geomorphic changes. Rainfall intensity also varies intra-annually. However, if a sufficient range of storm intensities is encountered in a particular year, then short duration monitoring approaches, such as flow-duration curves and sediment transport studies can provide valuable information on HMP effectiveness on shorter timescales.

Spatial Variability. Sampling an adequate variety of channel susceptibility types, along with a sufficient number of replicates for each susceptibility type, is important to capture the range of watershed conditions present in the permit coverage area. Other important factors that affect stream responses to hydromodification include channel grade, channel material, watershed area, vegetated cover, and existing channel instability In addition to channel and watershed features, location within the watershed is an important consideration. Monitoring stations should be located in the watershed headwaters just downstream of a development project of sufficient size, so that hydromodification effects from the proposed development can be isolated for comparison purposes to the maximum extent practicable. Monitoring sites located closer to the development site provide more definitive measures of HMP effectiveness because they can more directly correlate effects to the specific development project. The concept of providing hydromodification effectiveness measurements in the watershed headwaters is supported by SCCWRP. Research by SCCWRP has shown that hydromodification effects of a development project become muted with increasing distance from the development site (defined by SCCWRP as the Domain of Effect). Sites located in the middle watershed and lower watershed are likely to be influenced by confounding variables such as mass wasting and impacts from natural tributary confluences and other existing development projects, including phased developments over many years, in the watershed. Therefore, middle and lower watershed monitoring sites would require much more time to assess overall program effectiveness.

While the San Diego HMP has been written to require onsite hydromodification flow controls at each applicable new development and redevelopment site, thus minimizing the potential for cumulative watershed impacts as a result of new development and redevelopment, monitoring station locations have been selected to include the effects of multiple upstream developments.

1.3 Recommended Approaches to Assess Effectiveness

Selection of HMP effectiveness assessment monitoring techniques was subject to two primary constraints. The schedule constraint involved the RWQCB's desire to have some preliminary information on HMP effectiveness prior to re-issuance of the new MS4 Permit (RWQCB Order R9-2013-0001), which was issued on May 8, 2013. This schedule constraint created an added "practicality" issue, since it was unlikely that much meaningful data could be acquired in such an abbreviated timeline. While the monitoring plan extends for five years, interim data was presented to the Regional Board to assist with development of the new MS4 Permit.

The budget constraint involved the San Diego County Copermittees' limited resources for monitoring. Given the fact that the Copermittees are currently committed to a multi-million dollar (in excess of $3 million per year) annual regional water quality monitoring plan effort, and given the current economic climate in which multiple local municipalities have been forced to reduce both budget and staff, expansion of existing monitoring mandates required significant financial consideration and analysis. Thus, the Copermittees were compelled to evaluate how to develop the best possible monitoring approach to evaluate HMP effectiveness within the available budget.

Details of this Monitoring Plan are above and beyond details of existing regional water quality monitoring efforts. Wherever possible, the Copermittees have sought opportunities to utilize relevant data from the existing water quality monitoring efforts to achieve an economy of scale. The Copermittees have also sought to ensure there is no duplication of effort between the various monitoring programs.

This Monitoring Plan focuses on using concentrated monitoring activities so that almost all potentially sediment transporting events are monitored at a small number of locations to obtain the maximum amount of data regarding sediment transport and flow duration monitoring. It is the opinion of the Copermittees that acquisition of continuous data at a statistically justified number of monitoring locations is more valuable (from a data analysis standpoint) as compared to obtaining a large number of isolated runoff events from more distributed monitoring locations. Therefore the Copermittees agreed on using a combination of continuous and event-based monitoring plus the application of adaptive monitoring to yield even more valuable data.

Considering the constraints and technical approach detailed above, specific approaches were recommended in the 2010 Monitoring Plan. Various monitoring locations were chosen for the purpose of evaluating HMP effectiveness on a variety of channel susceptibility types. Based on study constraints and improved field knowledge realized during early implementation of the Monitoring Plan, this 2013 Monitoring Plan modifies the approach as described below.

- **Monitor effectiveness using Sediment Transport and Flow Duration Studies.** As noted above, continuous and point measurements of sediment transport and flow duration studies can provide direct measures of HMP effectiveness on a relatively short timescale. These studies are important to verify HMP assumptions about the lower flow thresholds and to verify flow duration design criteria is being achieved. Development of the sediment transport studies would also provide stream cross section data, as well as photographic evidence, that could serve as a baseline for future stream morphology comparisons.

- **Monitor the Upper Watershed.** Upper watershed monitoring is recommended to eliminate confounding lower watershed variables that would skew the analysis and minimize the potential for reaching meaningful conclusions.
- **Monitor Replicates of Two Channel Susceptibility Types.** In the development of the San Diego County HMP, receiving streams have been classified into one of three channel types, pursuant to a State Board-funded study conducted by SCCWRP. The stream classification system is consistent with the analysis, findings, and tools developed in the SCCWRP study and classifies streams into the following stream susceptibility categories:
  - HIGH susceptibility
  - MEDIUM susceptibility
  - LOW susceptibility

  Monitoring locations have been selected from HIGH and MEDIUM susceptibility channel segments, whenever possible, in order to focus study resources on the most critical stream types.
- **Monitor Two MEDIUM Reference Sites, Two HIGH Reference Sites, and Three HIGH Development Sites.** Multiples of the same type of site are referred to as "replicates" in the 2010 Monitoring Plan; the goal being a large enough sample size to account for spatial variability in the analysis. Providing replicates of each channel type provides sufficient data to characterize the range of conditions present in San Diego County. The "Reference" monitoring station would be located in a watershed for which no upstream development (existing or future) is anticipated. Data from the reference stations can be used to supplement pre-project condition data obtained at the replicate "Development" sites, since the amount of pre-project condition data that can be obtained at such sites is dependent on the land development process. The term "Development" refers to sites where the catchment is currently undeveloped and future development subject to HMP requirements is planned. Providing this number of replicate stations balances the need to characterize spatial variability against the cost of monitoring and provides the data needed to estimate the median and range of the lower flow threshold for a given susceptibility type, or to estimate the standard deviation of an average value. The challenges encountered in obtaining suitable sites have necessitated simplification of the site categories. No MEDIUM susceptibility Development sites were secured as part of the extensive site selection process conducted to date. However, the presence of two Reference sites with MEDIUM ratings will provide beneficial knowledge of these systems. Additional Development monitoring sites should only be added if they are perfect candidates, will be developed in the immediate future, and possess a MEDIUM susceptibility to hydromodification. Through careful selection of available sites and by other improvements and augmentation made to the Monitoring Plan as part of the 2013 revision, it is expected that the strength of the findings will be similar to what was anticipated with the original 2010 Monitoring Plan.
- **Monitor the Middle Watershed.** Middle watershed monitoring, one MEDIUM and one HIGH susceptibility channel will be monitored, both of which will be located downstream of existing urbanized areas with watershed impervious areas greater than 40 percent.

1.4 Summary and Conclusions

The revised 2013 Monitoring Plan, scheduled for implementation over the remainder of the 5-year period, includes the following specific activities:

Baseline Monitoring Plan:

- Adherence to the Quality Assurance Project Plan for Effectiveness Assessment Monitoring for the San Diego Hydromodification Management Plan (pursuant to Sect. D.1.g(1)(k) of the Regional Board Order No. R9-2007-0001) that was developed at the beginning of the study (Weston Solutions, Inc., June 2013).

- Selection of monitoring replicates of MEDIUM and HIGH channel susceptibility types (Completed 2013, as detailed in the site selection memorandum submitted to the Regional Board in December of 2013)
- Rainfall gauge and stream gauge analysis, installation, inspection and maintenance at all monitoring sites (continued through 2016)
- Installation of permanent site specific tipping bucket rain gauges at all monitoring sites (completed September, 2013)
- Hydrologic studies to verify the use of HSPF models for small watersheds (2013-2016)
- Annual data analysis (Continued through 2016)
- Incorporation of recommendations from the HMP Re-evaluation Monitoring Plan Revision Technical Report that was based on input from the HMP Monitoring Technical Advisory Committee and review of final SCCWRP Hydromodification Monitoring Report (released in March 2013)
- Report preparation (final report to be prepared in 2016)

Channel Assessments:

- Initial geomorphic assessment at each monitoring location (to determine stream susceptibility type – completed in 2013)
- Baseline cross section surveys at each monitoring location (completed in 2013)
- Annual abbreviated* geomorphic assessments at each monitoring location (to assess channel condition and response, 2012-2016) to be expanded to a full assessment if significant changes are identified.
- Total Station cross section surveys (after 5 years) at each monitoring location (2016)
- Annual rod and level surveys of thalweg and cross section at each monitoring location (to assess temporal changes over the five year period, annually through 2015)
- Remote sensing of channel dimensions and sediment sources (to support conclusions on channel instability, 2013-2016)

Sediment Transport Analysis:

- Flow and sediment monitoring station installation
- Continuous and event-based pre-project, post-project and reference station flow, sediment and rainfall data collection (through 2016; monitoring can be terminated at a given site once sufficient data has been obtained to develop a valid relationship between sediment transport rate and flow rate duration curve, with updated monitoring only if conditions warrant)

Flow Duration Analysis:

- Pre-project rainfall and flow rate data collection.
- Development of flow duration curves using continuous simulation models for pre-project and post project conditions.
- HMP facility inflow and/or outflow monitoring station installation and/or level logger installation; depending on the availability of facilities to monitor and the ability to incorporate flow measurement devices into the facility. Post-project HMP facility outflow data collection (through 2016 dependent on availability of facilities)

* Abbreviated geomorphic assessments are performed if little or no channel adjustment has occurred since the initial assessment, and it entails walking the domain of the receiving channel and documenting signs of channel instability that may eventually affect the monitoring site; examples include downstream headcuts, upstream sedimentation, and accelerated bank erosion. The abbreviated assessment gathers important information regarding the stability of the receiving channel within the domain of analysis without collecting unnecessary and redundant data. A full geomorphic assessment is based on the SCCWRP Hydromodification screening tools, which includes a series of qualitative observations and measurements to characterize

the general form, composition, and stability rate of the receiving channel. A full geomorphic assessment should be conducted if the monitoring location is experiencing substantial changes in channel form or composition due to instability of the fluvial system.