DRAFT

HYDROMODIFICATION MANAGEMENT PLAN

Prepared for

County of San Diego, California

May 1, 2009

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EXECUTIVE SUMMARY

Background

Provision D.1.g of Regional Water Board Order R9-2007-0001 requires the San Diego Stormwater Copermittees to implement a Hydromodification Management Plan (HMP) "…to manage increases in runoff discharge rates and durations from all Priority Development Projects, where such increased rates and durations are likely to cause increased erosion of channel beds and banks, sediment pollutant generation, or other impacts to beneficial uses and stream habitat due to increased erosive force."

To address this permit condition, the Copermittees, represented by the County of San Diego, hired a consultant team and proceeded with developing an HMP that meets the intent of the Permit Order. The permit requires the Copermittee to develop an HMP for all Priority Development Projects, with certain exemptions. The HMP must develop standards to control flows within the geomorphically-significant flow range. Supporting analyses must be based on continuous hydrologic simulation modeling.

HMP Development Process

All 21 Copermittees participated in the development of the HMP, both financially, and through their participation in the Copermittees Hydromodification/SUSMP Workgroup. The Workgroup was convened ten times over the course of the project at times that corresponded with key decision points in developing the HMP and the update to the Standard Urban Storm Water Mitigation Plan (SUSMP).

A key element of the San Diego HMP was the creation and involvement of a Technical Advisory Committee (TAC). The TAC members consisted of respected individuals from academia, technical resource agencies, the development community, consulting engineers, and environmental organizations. The TAC was tasked with providing technical input to the scientific approach and interpretation of results integral to the establishment of numerical flow control standards for the HMP, and met six times since October 2007.

Literature Review

Pursuant to Permit Section D.1.g(1)(e), the consultant team conducted a literature review as a basis for the initial development of the HMP. The review focused on several key technical areas, including an analysis of the flow control approach as well as approaches to managing rainfall data, determination of rainfall losses due to infiltration, and determination of rainfall losses due to evaporation.

Methodology and Technical Approach

Per the Permit Order, a range of runoff flow rates must be determined to identify the range for which Priority Development Project post-project runoff flows and durations shall not exceed pre-project runoff flows and durations. The Order further requires a continuous hydrologic simulation of the entire rainfall record to be generated. In January 2008, Interim HMP standards were developed in order to meet the Regional Board Order.

Per final hydromodification management criteria developed for San Diego County, which will be applicable to all Priority Development Projects, results of a hydromodification management analysis must adhere to the following criteria.

- For flow rates between the pre-project lower flow threshold (see below) and the pre-project 10-year runoff event, the post-project discharge rates and durations may not deviate above the pre-project discharge rates and durations by more than 10 percent over more than 10 percent of the length of the flow duration curve.
- Lower flow thresholds may be determined using a nomograph currently being developed by the consultant team to identify lower flow thresholds for a range of channel conditions. The finalized nomograph will be recommended for use when the receiving channel consists of materials other than unconsolidated sand. The lower flow threshold nomograph and text describing its development are located in Appendix G, in a memo titled *"Lower Flow Threshold Alternatives,"* prepared by Brown and Caldwell and dated April 30, 2009. Note – this criteria has been discussed by the TAC and is pending review and approval from the Copermittees.
- A minimum flow threshold determined to be protective for receiving channel segments consisting of channel materials other than unconsolidated sand will be recommended, pending approval by the TAC and Copermittee HMP Workgroup. It is thus recommended that, for channel bed materials other than unconsolidated sand and in cases where either $0.1Q_2$ or the flow recommended through use of the lower flow threshold nomograph is less than the minimum flow threshold, then the lower flow threshold from a project site shall be set at the minimum flow rate. This minimum flow criteria is discussed in Appendix G, in a memo titled *"Lower Flow Threshold Alternatives,"* prepared by Brown and Caldwell and dated April 30, 2009.
- The lower flow threshold may alternately be determined as 10 percent of the pre-project 2-year runoff event. Details of this lower flow threshold determination are presented in Appendix F, in a memo titled *"Flow Threshold Analysis for San Diego HMP,"* prepared by Brown and Caldwell and dated April 30, 2009.

The project proponent may also use Low-Impact Development (LID) integrated management practices to mitigate hydromodification impacts, using design procedures, criteria and sizing factors developed by the consultant team with input from the TAC and Copermittees. The sizing factors shall be determined using a continuous simulation of runoff from the long-term rainfall record. To assess the effectiveness of storm water devices to meet hydromodification criteria, peak flow frequency and duration statistics must be developed. A literature review examining these statistical methods indicated that the use of a partial-duration series is preferred for climates similar to San Diego County. The need for partial-duration statistics is more pronounced for control standards based on more frequent return intervals (such as the 2-year design storm), since the peak annual series statistics do not perform as well in the estimation of such events. This phenomenon is especially pronounced in the San Diego region's semi-arid climate. Partial-duration series frequency calculations consider multiple storm events in a given year while the peak annual series considers just the peak storm event.

Information regarding the analysis and categorization of streams from a geomorphic context, as well as the analysis of cumulative watershed impacts, is being prepared in a concurrent grant-funded hydromodification study by the Southern California Coastal Water Research Project (SCCWRP). In addition, SCCWRP is developing screening tools which are being prepared to identify channel susceptibility to hydromodification impact. These include tools to classify receiving streams as having either a High, Medium or Low susceptibility to channel erosion impacts. Where receiving stream channels are already unstable, the standard is to avoid acceleration of the existing erosion problems. Where receiving channels are in a state of dynamic equilibrium, hydromodification management may prevent the onset of erosion or other problems. In situations where the receiving channel is aggrading, then geomorphic analysis may show that hydromodification flow controls are not required.

In situations where the benefits of a proposed stream restoration project would substantially outweigh the potential impacts of additional runoff from a proposed project, the project proponent (pending TAC approval) may consider implementation of planning measures such as buffers and restoration activities, revegetation and use of less-impacting facilities at the point of discharge in lieu of implementation of storm water flow controls.

Requirements/Standards for Projects

Priority Development Projects are required to implement hydrologic control measures so that post-project runoff flow rates and durations do not exceed pre-project flow rates and durations where they would result in an increased potential for erosion or significant impacts to beneficial uses or violate the channel standard. This can be demonstrated by showing that there will be no increase in impervious area and resultant peak flow rates, installation of flow control BMPs that meet design requirements to control runoff from new impervious areas, preparation of continuous simulation hydrologic models and comparison of the pre-project and mitigated post-project runoff peaks and durations (with hydromodifcation flow controls) until compliance is achieved, or by showing that projected increases in runoff peaks and/or durations would not accelerate erosion of receiving stream reaches.

Exceptions

Hydromodification management flow controls would not be required in the following scenarios: (1) Discharges into hardened conveyance systems, such as concrete channels, storm drain systems, or riprap-lined channels, where the lining extends downstream to the discharge location to either San Diego Bay or the Pacific Ocean; (2) Construction of projects where the sub-watershed area downstream of the project site (i.e., the watershed area between the project site and either San Diego Bay or the Pacific Ocean) contains an impervious area percentage equal to or greater than 70 percent and the potential for single-project or cumulative impacts is minimal; or (3) If the project applicant conducts a sediment transport analysis for the range of geomorphically significant flows and, to the satisfaction of the governing agency, demonstrates that the project flows and sediment reductions will not adversely impact the receiving waters.

Selection and Implementation of BMPs

Implementation of flow control BMPs and LID design features is the key to a viable and effective HMP. Facilities must be designed to be practically built and maintained within the urban environment. Since the HMP will be implemented through the municipal development review process, design criteria must be specified and be incorporated into conditions of approval. This HMP advocates the use of LID design approaches to provide both treatment of the 85th percentile water quality event as well as flow control for hydromodification criteria. To assure compliance with hydromodification flow control requirements, design criteria and specifications will be provided for a variety of LID-based flow control methods including bioretention basins, grassy swale / bioretention areas, storm water capture devices, self-retaining areas, porous pavement, etc. Provisions will also be provided for the design of larger extended detention basin flow control scenarios.

Monitoring and BMP Evaluation

Proof of a long-term ongoing maintenance responsibility and mechanism will be required for all post-construction BMP and flow control facilities. If not properly designed or maintained, hydromodification flow control devices may create a habitat for vectors such as mosquitoes or rodents. Maintenance activities for flow control and LID devices will be specified in the proposed project's Storm Water Management Plan (SWMP).

1. INTRODUCTION

Hydromodification refers to changes in the magnitude and frequency of stream flows as a result of urbanization and the resulting impacts on receiving channels in terms of erosion, sedimentation and degradation of in-stream habitat. The degree to which a channel will erode is a function of the increase in driving force (shear stress), the resistance of the channel (critical shear stress), the change in sediment delivery, and the geomorphic condition of the channel. Critical shear stress is the stress threshold above which erosion occurs. Not all flows cause erosion -- only those that generate shear stress in excess of the critical shear stress of the bank and bed materials. Urbanization increases the shear stress exerted on the channel by stream flows and can trigger erosion in the form of incision (channel downcutting), widening (bank erosion) or both. Increases in flow below critical shear stress levels have little or no effect on the channel.

Provision D.1.g of the San Diego Regional Water Quality Control Board Permit Order R9-2007-0001 requires the Copermittees to implement a Hydromodification Management Plan (HMP) "…to manage increases in runoff discharge rates and durations from all Priority Development Projects, where such increased rates and durations are likely to cause increased erosion of channel beds and banks, sediment pollutant generation, or other impacts to beneficial uses and stream habitat due to increased erosive force." Where receiving stream channels are already unstable, it can best be thought of as a method to avoid accelerating or exacerbating existing problems. Where receiving stream channels are in a state of dynamic equilibrium, hydromodification management may prevent the onset of erosion or other problems.

To address this permit condition, the San Diego Storm Water Copermittees, represented by the County of San Diego, hired a consultant team and proceeded with developing an HMP that meets the intent of the Order. Permit Order R9-2007-0001 contains certain requirements that strongly influence the methodology chosen in development of the HMP. The Permit requires the Copermittees to develop an HMP for all Priority Development Projects (with certain exemptions) and develop standards to control flows within the geomorphically-significant flow range. Supporting analyses must be based on continuous hydrologic simulation modeling.

2. COPERMITTEE HMP DEVELOPMENT PROCESS

Although the County of San Diego serves as the lead agency for development of the HMP, all 20 of the other Copermittees have participated in its development, both financially and through participation in the Copermittees' Hydromodification/SUSMP Workgroup, which is a subcommittee of the Copermittees' Land Development Workgroup. The Hydromodification/SUSMP Workgroup was convened periodically over the course of the project at times corresponding with key decision points in developing the HMP and the update to the Model Standard Urban Storm Water Mitigation Plan (SUSMP).

This workgroup is tasked with providing regional standards and consistency in the development, implementation, assessment, and reporting of urban runoff activities and programs related to hydromodification management. As required by Permit Section D.1.g. the Workgroup is assisting in the development of the regional hydromodification management plan.

It should be noted that Copermittees' Regional Land Development Workgroup will continue to meet after submittal of the HMP to discuss and resolve any issues that may arise during the HMP implementation phase. The Workgroup will also assist in the refinement and reinforcement of methodologies, criteria, and standards established in the HMP.

The Copermittee HMP Workgroup met ten times during since July 2007. The table below summarizes meeting dates, locations, and agenda items.

Table 1. Copermittee Workgroup Meetings Summary

Date	Location	Agenda
July 26, 2007	County of San Diego 9325 Hazard Way San Diego, CA	• Formation of a Technical Advisory Committee • Discussion of HMP requirements in other permits • Consultant contract for HMP
August 23, 2007	City of San Diego 2392 Kincaid Road San Diego, CA	• Formation of a Technical Advisory Committee • Consultant contract for HMP
October 18, 2007	County of San Diego 9325 Hazard Way San Diego, CA	• Development of interim hydromodification criteria • Technical Advisory Committee
November 5, 2007	County of San Diego 5201 Ruffin Road San Diego, CA	• Development of interim hydromodification criteria
December 13, 2007	County of San Diego 5201 Ruffin Road San Diego, CA	• Development of interim hydromodification criteria
May 12, 2008	County of San Diego 5201 Ruffin Road San Diego, CA	• Development of interim hydromodification criteria

Table 1. Copermittee Workgroup Meetings Summary		
Date	Location	Agenda
June 19, 2008	County of San Diego 5201 Ruffin Road San Diego, CA	• HMP progress report
October 21, 2008	County of San Diego 5201 Ruffin Road San Diego, CA	• HMP submittal to the Regional Board
December 16, 2008	County of San Diego 5201 Ruffin Road San Diego, CA	• HMP submittals to the Regional Board • Rain gage data for HMP continuous simulation modeling
January 15, 2009	City of Chula Vista 1800 Maxwell Road Chula Vista, CA	• Approval of Draft HMP for submittal to RWQCB • Approval of Model SUSMP for submittal to RWQCB

3. TECHNICAL ADVISORY COMMITTEE

A key element of the San Diego HMP was the creation and involvement of a Technical Advisory Committee (TAC). The TAC members consist of respected individuals from academia, technical resource agencies, the development community, consulting engineers, and environmental organizations. Dennis Bowling of the San Diego APWA chairs the TAC. A list of all TAC members is attached in Appendix A of this document. The TAC, which has been convened on six occasions that correlated with key decision-making points in the development of the HMP, was tasked with providing technical input to the HMP's scientific approach and interpretation of results integral to the establishment of numerical flow control standards. At each TAC meeting, the consultant team presented a PowerPoint presentation describing the technical approach, and solicited feedback and buy-in from TAC members.

Some of the key input received from the TAC included agreement with the Consultant Team's approach to using a synthetic watershed modeling approach to develop flow control standards (due to time constraints and a lack of published information on local geomorphology); agreement with the selection of 20 representative rain gauges and methodology to address data gaps (to provide the historical rainfall record for the required continuous simulation hydrologic modeling); and agreement on the use of scaled Lindbergh Field data to conduct the initial modeling efforts (since available local rain gauge data sets were not in a format suitable for use with continuous simulation software at the time they were required).

The table below summarizes meeting dates, locations, and agenda items for all TAC meetings.

Table 2. Technical Advisory Group Meetings Summary

Date	Location	Agenda
February 20, 2008	City of San Diego Metro Biosolids Conference Room San Diego, CA	• Formation of a Technical Advisory Committee • Introduction of Consultant Team • Proposed approach to developing HMP and Model SUSMP Update (presentations by Dan Cloak, Dan Cloak Environmental Consulting and Andy Collison, PWA) • Input on how much channel erosion is tolerable • Input on how aggrading channels should be addressed
May 29, 2008	City of San Diego Metro Biosolids Conference Room San Diego, CA	• Recap of Interim HMP Standard • Input on/agreement with approach on synthetic watershed modeling approach (presentation by Andy Collison, PWA) • Input on/agreement with approach to conducting geomorphic assessment • Discussion of approach to conducting continuous hydrologic simulation modeling

Table 2. Technical Advisory Group Meetings Summary		
Date	Location	Agenda
August 5, 2008	City of San Diego Metro Biosolids Conference Room San Diego, CA	• Input on/agreement with approach to selection of representative gauges and management of rainfall data (Presentation by Eric Mosolgo, Brown and Caldwell) • Overview of approach to conducting continuous hydrologic simulation modeling (Presentation by Eric Mosolgo, Brown and Caldwell) • Overview of BMP Sizing Tool Development (Presentation by Eric Mosolgo) • Initial results of synthetic watershed modeling based on 2 watersheds in San Diego County (Presentation by Andy Collison, PWA)
October 14, 2008	City of San Diego Stormwater Department Conference Room 9370 Chesapeake Drive San Diego, CA	• Recap of meeting with Regional Board to discuss HMP and Model SUSMP Update submittals • Input on/agreement with approach to supplementing rain gauge data sets and selection of proper rain gauge(s) for a project (Presentation by Eric Mosolgo, Brown and Caldwell) • Additional discussion of continuous hydrologic simulation modeling, including use of partial duration series data (Presentation by Eric Mosolgo and Tony Dubin, Brown and Caldwell) • Discussion of findings of synthetic watershed modeling (Presentation by Andy Collison and Christie Beeman, PWA)
February 12, 2009	City of San Diego Stormwater Department Conference Room 9370 Chesapeake Drive San Diego, CA	• Review of Draft HMP submittal to RWQCB, review of concurrent SCCWRP modeling, summary of flow threshold modeling efforts (Presentation by Eric Mosolgo, Brown and Caldwell) • Presentation of flow threshold analysis and lower threshold alternatives including watershed position and channel characteristics (Presentation by Andy Collison and Christie Beeman, PWA)
April 21, 2009	City of San Diego Stormwater Department Conference Room 9370 Chesapeake Drive San Diego, CA	• Review of comments prepared by Dr. Richard Horner, prepared on behalf of Coastkeeper, pertaining to the Draft HMP submitted to the RWQCB; review of SCCWRP work for San Diego HMP; requirements for partial duration rainfall series analysis; watershed position affects on lower flow threshold; and development of the HMP implementation decision matrix (Presentation by Eric Mosolgo, Brown and Caldwell) • Development of lower flow threshold nomograph and determination of alternate minimum flow rate (Presentation by Christie Beeman, PWA).

4. LITERATURE REVIEW

Pursuant to Permit Section D.1.g(1)(e), this section will provide the results of a literature review conducted as a basis for the initial development of the Hydromodification Management Plan (HMP).

4.1 Flow Control Approach

Hydromodification Management Plans that have been developed in the San Francisco Bay Area of California (Contra Costa, Santa Clara and Alameda Counties) vary with regard to the emphasis placed on lower flow control thresholds as compared to other approaches, such as distributed LID methods. However, there is consensus in that both the frequency and duration of flows must be controlled, requiring the use of continuous simulation hydrologic modeling (as opposed to the more standard design storm approach used for flood control design) for evaluation of potential development impacts. It is also generally accepted that events smaller than the 10-year design flow are the most critical for hydromodification management.

The Santa Clara HMP focused on the use of detention basins for hydromodification management and strongly emphasized the lower flow control limit for site runoff. Extended detention flow control basins can utilize multi-stage outlets to mitigate both the duration and magnitude of flows within a prescribed range. To avoid the erosive effects of extended low flows, the maximum rate at which runoff is discharged is set below the erosive threshold. Per the Santa Clara HMP, the lower flow control limit was defined as the flow rate that generates critical shear stress on the channel bed and banks. Both Santa Clara and Alameda Counties correlated the lower flow control limit to a value equal to 10 percent of the 2-year runoff event.

The Contra Costa HMP strongly emphasized the use of Low-Impact Development (LID) methods to meet hydromodification management criteria. LID approaches to hydromodification management rely on site design and distributed LID Best Management Practices (BMPs) to control the frequency and duration of flows and to mitigate hydrograph modification impacts. By minimizing directly connected impervious areas and promoting infiltration, LID approaches mimic natural hydrologic conditions to counteract the hydrologic impacts of development. Because more runoff is retained onsite and in distributed facilities, the lower discharge limit is less critical for LID facilities since different facilities will discharge to the stream system at different times.

The County of San Diego and Copermittees interviewed three consultant teams as part of the selection process to develop the HMP. The selection panel, which included representatives from the County of San Diego, City of San Diego, City of Chula Vista, and the City of Encinitas, selected the team led by Brown and Caldwell and including Phillip Williams Associates and Dan Cloak Engineering. This team had previously developed the HMP for Contra Costa County and thus, the Contra Costa approach was selected as the base approach for the San Diego HMP.

For the San Diego region's interim hydromodification management criteria, the range of flows to be managed under the hydrograph curve-matching approach (matching of peak flows and durations within the geomorphically significant range) was expressed as a percentage of the 5-year runoff event, based on the understanding that the 5-year runoff event is considered the dominant channel-forming discharge for Southern California streams. This assumption was based upon the paper titled, "*Effect of Increases in Peak Flows and Imperviousness on the Morphology of Southern California Streams," by Coleman, MacRae, and Stein.* The following list details the range of flows recommended in the San Diego region's interim hydromodification criteria.

- For flow rates between 20 percent of the pre-project 5-year runoff event and the pre-project 10-year runoff event, the post-project discharge rates and durations may not deviate above the pre-project discharge rates and durations by more than by more than 10 percent over more than 10 percent of the length of the flow duration curve.
- For flow rates between 20 percent of the pre-project 5-year runoff event and the pre-project 5-year runoff event, the post-project flows shall not exceed pre-project flows. For flow rates between the 5-year and 10-year runoff events, post-project flows may exceed pre-project flows by up to 10 percent for a 1-year frequency interval.
- The project proponent may also use Low-Impact Development (LID) integrated management practices to manage hydromodification impacts, using design procedures, criteria and sizing factors (ratio of the required LID area to the tributary impervious area) specified by the Copermittees.

The interim hydromodification management criteria listed above has been in place since January 2008 for development projects that disturb 50 acres or more.

4.2 Rainfall Data

Standards developed as part of this HMP to control runoff peak flows and durations are based on a continuous simulation of runoff using local rainfall data. To provide for clear climatic designation between coastal, foothill and mountain areas of the County, and to distinguish amongst the major watershed units, historical records for a series of 20 rainfall data stations located throughout San Diego County were compiled, formatted and quality controlled for analysis.

Long-term hourly rainfall records have been prepared for the 20 rainfall stations. These rainfall record files are located on the *Project Clean Water* web site for public use. Sources of the rainfall data include ALERT data from the County of San Diego (which extends back to 1982), the California Climatic Data Archive, NOAA, the National Climatic Data Center, and the Western Regional Climate Center. In all cases, the length of the overall rainfall station record is 35 years or the overall length of the rainfall record, whichever is longer.

The continuous modeling approach detailed above also requires a statistical analysis of peak flow frequency. Peak flow frequency statistics estimate how often flow rates will exceed a given threshold. In this case, the key peak flow frequency values would be the lower and upper bounds of the geomorphically significant flow range. To assess the effectiveness of storm water devices to meet hydromodification criteria, peak flow frequency statistics should be developed using either a partial-duration or peak annual series. Partial-duration series frequency calculations consider multiple storm events in a given year while the peak annual series considers just the peak storm event.

The need for partial-duration statistics is more pronounced for control standards based on more frequent return intervals (such as the 2-year runoff event), since the peak annual series does not perform as well in the estimation of such events. This phenomenon is especially pronounced in the San Diego region's semi-arid climate. Per the advice of the Hydrologic Research Center, with whom the project team has consulted throughout the project, and a review of supporting literature, the use of a partial-duration series is recommended for semi-arid climates similar to San Diego County, where prolonged dry periods can skew peak flow frequency results determined by a peak annual series for more frequent runoff events.

Flow duration statistics must also be summarized to determine how often a particular flow rate is exceeded. To determine if a storm water facility meets hydromodification criteria, peak flow frequency and flow duration curves must be generated for pre-project and post-project conditions. Both pre-project and post-project simulation runs should extend for the entire length of the rainfall record.

For the statistical analysis of the rainfall record, partial duration series events have been separated into discrete rainfall events assuming the following criteria.

- To determine a discrete rainfall event, a lower flow limit was set to a very small value, equal to 0.002 cfs per acres of contributing drainage area.
- A new discrete event is designated when the flow falls below 0.002 cfs per acre for a time period of 24 hours.

Continuous hydrologic models are typically run using either 1-hour or 15-minute time steps. Based on a review of available rainfall records in San Diego County, we are recommending the use of a 1-hour time step (15-minute time series rainfall data is very limited). Continuous models generate model output for each time step – in this case, hydrologic output would be generated for each hour of the continuous model. A continuous simulation model with 35 years of hourly precipitation data will generate 35 years of hourly runoff estimates, which corresponds to runoff estimates for 306,600 time steps for the 35-year simulation period.

Use of the continuous modeling approach allows for the estimation of the frequency and duration by which flows will exceed a particular threshold. The limitations to increases of the frequency and duration of flows within that geomorphically significant flow range is the key component to San Diego County's approach to hydromodification management.

Details regarding continuous simulation hydrologic criteria are presented in Appendix E in a memo titled *"Minimum Criteria for Evaluation of Storm Water Controls to Meet Interim Hydromodification Criteria,"* prepared by Brown and Caldwell and dated April 30, 2009.

Details regarding the rainfall station locations and criteria for rainfall station selection are presented in Appendix B, in a memo titled *"Rainfall Station Selection Criteria,"* prepared by Brown and Caldwell and dated April 30, 2009.

4.3 Rainfall Loss / Infiltration Data

Standards developed as part of this HMP to control runoff peak flows and durations are based on a continuous simulation of runoff using locally derived parameters for initial infiltration. A review was conducted of available continuous hydrologic simulation modeling reports in Southern California. These included TMDL models developed for the San Diego RWQCB, regional continuous models developed by the Southern California Coastal Water Research Project (SCCWRP), and watershed-level continuous models developed for river and large creek systems in Ventura County. In conducting this review, particular interest was focused in determining how local and regional continuous hydrologic models simulated the pervious land surface[1] for various combinations of soils and land use types, because this component of hydrologic modeling is typically the most variable and difficult to describe.

The technical reports reviewed demonstrate that a variety of detailed HSPF modeling studies have occurred in the past 10 years in Southern California. However, adapting these modeling efforts for use on the San Diego HMP project will require additional work, which will be completed in association with development of the implementation Sizing Calculator. That effort includes meetings with report authors, including representatives from the Southern California Coastal Water Research Project (SCCWRP), as well as meetings with HSPF modeling experts from Aquaterra to ascertain appropriate values for initial infiltration parameters.

[1] Characterized by PERLND/PWATER parameters in the EPA's public domain Hydrologic Simulation Program – FORTRAN, HSPF.

Details regarding the infiltration parameter data review are presented in Appendix C, in a memo titled *Summary of HSPF Modeling Reports in Southern California*, prepared by Brown and Caldwell and dated April 30, 2009.

4.4 Rainfall Loss / Evaporation Data

Standards developed as part of this HMP to control runoff peak flows and durations are based on a continuous simulation of rainfall runoff using locally derived parameters for evaporation and evapotranspiration.

Known data sources for evaporation and evapotranspiration data in San Diego County are listed below.

- California Irrigation Management and Information System web site – evapotranspiration stations include San Diego, Oceanside, Escondido, Ramona, Otay Lakes, Miramar, Torrey Pines and Borrego Springs.
- Historical Reservoir Level and Evaporation Data for Lake Heneshaw.
- Historical Evaporation Data from City of San Diego Reservoirs.
- Historical Evaporation Data from Helix Water District for Lake Cuyamaca.

Details regarding the evaporation and evapotranspiration data assembly are provided in Appendix D, in a memo titled *Summary of Evaporation and Evapotranspiration Data for the San Diego Region*, prepared by Brown and Caldwell and dated April 30, 2009.

5. METHODOLOGY AND TECHNICAL APPROACH TO REGIONAL HYDROMODIFICATION DEVELOPMENT

As outlined in Permit Section D.1, the San Diego Copermittees shall implement a program to manage increases in runoff discharge rates and durations from Development Projects that are likely to cause increases to erosion of channel beds or banks, silt pollutant generation, or other impacts to beneficial uses and stream habitat due to increased erosive force. This section provides a detailed description of the methodology and approach used in the development of the HMP (Permit Section D.1.g(1)), and specifically of the approach taken to identify the geomorphically significant flow range.

5.1 Flow Control Limits

Per the Permit Order, a range of runoff flow rates must be identified for which post-project runoff flows and durations from Priority Development Projects shall not exceed pre-project runoff flows and durations. The Permit Order further requires a continuous simulation of the entire rainfall record to be generated and that the lower flow threshold boundary shall correspond to the critical channel flow producing critical shear stress that initiates channel bed movement or erosion at the toe of the channel banks.

A continuous simulation hydrologic model, such as HSPF, may be used to simulate the pre-project and post-project hydrologic response. HSPF can simulate the effects of proposed BMPs, detention basins, or other stormwater management facilities on rainfall runoff response. The Permit requires that project proponents simulate the full rainfall record using the most applicable and nearby rainfall data station.

Per final hydromodification management criteria developed for San Diego County and detailed in this section, which will be applicable to all Priority Development Projects, results of a hydromodification management analysis must adhere to the following criteria.

- For flow rates between the pre-project lower flow threshold (see below) and the pre-project 10-year runoff event, the post-project discharge rates and durations may not deviate above the pre-project discharge rates and durations by more than 10 percent over more than 10 percent of the length of the flow duration curve.
- Lower flow thresholds may be determined using a nomograph currently being developed by the consultant team to identify lower flow thresholds for a range of channel conditions. The finalized nomograph will be recommended for use when the receiving channel consists of materials other than unconsolidated sand. The lower flow threshold nomograph and text describing its development are located in Appendix G, in a memo titled *"Lower Flow Threshold Alternatives,"* prepared by Brown and Caldwell and dated April 30, 2009. Note – this criteria has been discussed by the TAC and is pending review and approval from the Copermittees.
- A minimum flow threshold determined to be protective for receiving channel segments consisting of channel materials other than unconsolidated sand will be recommended, pending approval by the TAC and Copermittee HMP Workgroup. It is thus recommended that, for channel bed materials other than unconsolidated sand and in cases where either $0.1Q_2$ or the flow recommended through use of the lower flow threshold nomograph is less than the minimum flow threshold, then the lower flow threshold from a project site shall be set at the minimum flow rate. This minimum flow criteria is discussed in Appendix G, in a memo titled *"Lower Flow Threshold Alternatives,"* prepared by Brown and Caldwell and dated April 30, 2009.

- The lower flow threshold may alternately be determined as 10 percent of the pre-project 2-year runoff event. Details of this lower flow threshold determination are presented in Appendix F, in a memo titled *"Flow Threshold Analysis for San Diego HMP,"* prepared by Brown and Caldwell and dated April 30, 2009.

The project proponent may also use Low-Impact Development (LID) integrated management practices to manage hydromodification impacts, using design procedures, criteria and sizing factors (ratio of the required LID area to the tributary impervious area) specified by the Copermittees. The consultant team will run a series of continuous simulation hydrologic models to determine sizing factors for various hydromodification flow control and treatment options. The TAC and Copermittee work group will be involved in the process in a supervisory and review role.

Assumptions and the overall direction of the flow threshold analysis have been discussed with stakeholders including the Copermittees and the TAC. Decisions related to the flow threshold analysis were influenced based upon the compressed timeline associated with the Permit Order deadline. The consultant team reviewed flow threshold analysis methodology at multiple meetings of the TAC prior to embarking upon the full hydrologic and sediment transport analysis. Subsequent to the submittal of the preliminary flow threshold limit analysis, the Copermittees contracted with West Consultants to provide an independent third-party review.

Summary of Preliminary Flow Threshold Limit Analysis

As part of the San Diego regional HMP, the effectiveness of different flow control standards was evaluated for mitigating potential erosion impacts of new development using computer simulations of a wide range of watershed and channel conditions. The goal of this task was to identify a suitable standard (or standards) to protect creeks from additional erosion above baseline levels.

Background

Phillip Williams and Associates (PWA), which led the consultant team's efforts with regard to the preliminary flow threshold limit analysis, initially planned to perform rainfall-runoff and sediment transport modeling for numerous field sites throughout the County, using a combination of field data collection and available cross-section survey data. Project-induced erosion would have been estimated by comparing pre- and post-project stream channel cross-sections, providing an empirical basis for calculating erosion thresholds. Stream channel cross-section data representing baseline conditions and post-project channel response were requested from numerous sources, including the SCCWRP, San Diego Copermittees and HMP TAC members, but available data proved to be very limited. An effort was also made to identify field sites where existing channel conditions could be surveyed, but project deadlines precluded the collection of significant field data in time to be incorporated into the analysis, and the field effort was halted.

Given the lack of available data, the time constraints of the RWQCB deadline, and because so many independent variables affect channel response, the project team revised the approach. In place of surveyed cross-sections, a matrix of channel characteristics was developed representing a wide range of channel conditions likely to occur in western San Diego County. While this approach is more theoretical and lacks field validation, it allowed for sensitivity testing of a much wider range of channel conditions and runoff controls.

In all, the response of over 200 possible channel configurations was modeled with 40 years of rainfall runoff from 24 different watershed scenarios, a significant modeling effort for four technical staff over three months. By comparison, the Santa Clara HMP flow control thresholds were based on the assessment of four channels using actual existing conditions and assumed pre-development conditions.

Hydrology

Three representative watersheds were selected from western San Diego County. After studying County general plans and meeting with members of the TAC and Copermittee Workgroup, the consultant team determined where development was most likely to occur in the next 5-10 years. Three target watersheds (Otay, Penasquitos and Batiquitos), where development is occurring or is likely to occur, were identified. These watersheds were geographically distributed and represented a range of hydrologic conditions. Continuous simulation hydrologic models were developed to simulate development scenarios, size infiltration and detention facilities, and to test different flow control standards. Runoff was simulated from the three watersheds under eight different scenarios.

- Pre-developed conditions (1 scenario)
- Unmitigated post-developed conditions (1 scenario)
- Post-developed conditions with 3 detention basin controls (3 scenarios)
- Post-developed conditions with 3 infiltration basin controls (3 scenarios)

In totality, a total of 24, 40-year rainfall-runoff simulations were prepared. The controls were simulated to match the pre-project flow-duration curves for lower flow control limits of 0.1Q2, 0.1Q5 and 0.2Q5.

Sediment Transport Modeling

For synthetic channel modeling based on existing terrain (i.e., drainage area) and climate (i.e., precipitation), comparisons were made between several regression methods for estimating baseline channel geometry dimensions. Plots of drainage area versus channel width to depth ratios were made to determine the applicability of these relations in future synthetic modeling efforts. Representative channel configurations and sediment sizes were selected for use in the sediment transport portion of the analysis, resulting in a total of over 200 different channel/sediment combinations.

Output from the hydrologic simulations was used to run sediment transport models of the different channel/sediment combinations, resulting in hundreds of sediment transport scenarios being tested in HEC-RAS 4.0. The results of the sediment transport analyses were evaluated in terms of percent increase in erosion as compared to pre-project conditions, which allowed comparison of the effectiveness of the various controls simulated in the hydrologic models.

Results of the preliminary flow threshold analysis are summarized below.

- The results show that without flow control, typical levels of unmitigated impervious area development would result in dramatic increases in channel erosion over baseline conditions (in the order of 200-300% for most conditions).
- Further, the results show great variability in the degree of channel sensitivity to urbanization and to the different flow controls, depending on channel type (width, depth, slope and sediment size). Many of the predicted erosion results vary by 100-200% when only one variable is altered (e.g. flow control, or sediment size), and where multiple variables are altered larger differences are found. This is typical for long-term sediment transport modeling simulations, where many independent variables affect channel response and small differences are amplified over time.
- Results indicate that infiltration basin controls (in this case defined as unlined extended detention basins) are generally more effective than the detention basin controls because they completely eliminate many of the small runoff events that cumulatively contribute to erosion.
- Sediment reduction has a great effect on the erosion rate of the receiving water, with 50% reductions in sediment input causing a 50-100% increase in the erosion of the upstream segment of the receiving channel according to model results. This effect would be expected to diminish downstream somewhat,

subsequent to the initial erosion of the receiving water channel. It should be noted that as part of the analysis, the incoming sediment load was reduced by various percentages (e.g., 50%) to check for sensitivity to resultant erosion in the various sediment transport models.

- The different lower limits for flow control tested in the models resulted in significantly different channel erosion levels. Higher values for the lower flow control limit resulted in higher channel erosion rates.
- As with other studies, modeling results indicate that very small, frequent runoff events have a significant impact on channel erosion, resulting in very low values for the lower flow control limit.

This study evaluated lower flow control limits expressed as a percentage of the 2-year and 5-year runoff events for the test watersheds. The preliminary sediment transport modeling results indicated convergence to a lower flow threshold limit equal to 10 percent of the 2-year runoff event if a singular countywide lower flow limit was selected, assuming the most conservative parameters.

For very small watershed areas, a fraction of the 2-year runoff event could translate to a flow rate below the critical rate for sediment movement. In addition, a quick analysis suggested that for some small watersheds (tens of acres or smaller), channel bed infiltration losses may significantly reduce the effective flow. Further evaluation of this issue was subsequently modeled, with the goal of establishing a minimum flow rate that may be applied in small watersheds. Results of this subsequent analysis are detailed in this chapter under the section titled "Lower Flow Threshold Alternatives."

For more detailed information regarding the preliminary flow threshold analysis, refer to the attached memo titled *Determining Flow Control Thresholds to Avoid and Minimize Channel Erosion due to Hydrograph Modification,* prepared by PWA and dated November 12, 2008.

Third Party Review

West Consultants conducted an in-depth, independent third-party review of the preliminary flow threshold analysis. The following list presents a summary of the third-party review.

- Concern was noted regarding the lower flow control limit suggested by the modeling results (10 percent of the 2-year runoff event), especially with regard to implementation practicality and its derivation based solely on sediment movement.
- The review noted that literature suggests standard hydrologic design practices may be inadequate for characterizing cumulative effects of urbanization for flow events more frequent than the 2-year runoff event – specifically with regard to sediment transport and channel disturbance potential.
- The review questioned the use of a specific frequency discharge as an indicator of shear stress to move particles given the variability of other site-specific parameters such as grain size, slope, roughness, and channel shape.
- The review suggested that hydraulic and sediment transport results should be supplemented with actual field data (slope, sediment properties, roughness, and channel shape) to set thresholds (flows, shear stresses, or velocities).
- Concern was noted regarding the use of a single and conservative uniform size for sediment grain sizes. The use of a distribution of grain sediment sizes was recommended.

PWA agreed with the recommendation that additional field data (channel dimensions and slope, and sediment size distribution) is desirable both to verify receiving channel conditions and to make direct measurements of critical shear stress. Efforts were made to pursue the former data, but were unable to obtain field permission in time to meet the project deadlines. As the third-party review notes, any revised lower flow threshold calculated using field data is as likely to decrease as increase.

Subsequent to the preliminary flow threshold analysis, PWA ran sediment transport models using a distribution of grain sizes (rather than a single uniform size) for two channel configurations. The results of this limited sensitivity test (see discussion below titled "Summary of PWA Sensitivity Analysis") did not show a consistent trend toward more or less erosion.

For more detailed information regarding West Consultants' independent third-party review, refer to the memo titled *Review of Hydromodification Work by Phillip Williams and Associates (PWA),* prepared by West Consultants and dated December 19, 2008.

Summary of PWA Sensitivity Analysis

Subsequent to the preliminary flow threshold analysis, the Copermittees requested that a sensitivity analysis be conducted based on historical rainfall records in the vicinity of the test watershed sites. The purpose of the sensitivity analysis based on the revised rainfall input data is described below. There were two potential concerns associated with the use of the hydrologic analysis developed in the preliminary flow threshold analysis.

- First, the analysis used a single rainfall time series (Lindbergh Airport) for all simulations. Rainfall records for other areas were synthesized by taking the difference in mean annual rainfall between a nearby rain gage and developing a linear adjustment for the Lindbergh series (e.g. if the test site's mean annual rainfall is 15% greater than the mean annual rainfall at Lindbergh, then 15% is added to all hourly rainfalls). The preliminary flow threshold analysis used this scaled data approach since other data were not available at the time of the initial analysis. Long-term rainfall data for 20 gauges throughout San Diego County has subsequently been prepared and is thus more relevant to the test simulations performed for this study. A test hydrologic analysis showed significant hydrologic response differences between the historical rainfall record for Lower Otay Reservoir and the scaled data from Lindbergh Field.
- Second, the preliminary flow threshold analysis used an "annual peak" method to calculate the rainfall recurrence interval, rather than a partial duration series method. The two methods result in significantly different predictions of the two year runoff event (Q2). From discussions with rainfall statistical experts at the Hydrologic Research Center, it has been determined that the partial duration series is a more applicable rainfall series for the semi-arid climate in San Diego County. Partial duration flow statistics have been prepared and the test hydrologic analysis showed significant hydrologic response differences between the partial duration series and annual peak series methods.

There is significant variability in the HEC-RAS modeling results for the different channel and sediment scenarios, as reflected in the results of the preliminary flow threshold analyses. Therefore, it is important to focus on the general trends reflected in the sensitivity analysis results rather than the specific numerical results. As such, the sensitivity analysis modeling results confirm that the selection of rainfall data, and flow frequency methodology and sediment size distribution do affect the results of the flow control analysis. However, the cumulative effect of these changes did not affect the consultant's preliminary conclusion that a singular countywide lower flow threshold limit would converge on 10 percent of the 2-year runoff event.

For more detailed information regarding the PWA sensitivity analysis based on revised rainfall data, refer to the memo titled *Sensitivity of Changing Rainfall Series and Analysis on Erosion Threshold*, prepared by PWA and dated January 5, 2009.

Lower Flow Threshold Alternatives Analysis

In an attempt to simplify implementation, the consultant team made an effort to identify a single countywide lower flow control standard. This approach required the assumption of conservative values for a variety of channel conditions, including the channel particle size (D50), and channel slope. Values assumed in the analysis include the following:

- Channel width to depth ratios of 3, 6, 10, and 20 were modeled. Channel dimensions were scaled for flows of 10 cfs and 20 cfs.
- Sediment sizes of 0.5 mm and 2 mm were modeled
- Channel slopes of 0.005, 0.015 and 0.025 were modeled.

Based on the comprehensive assessment of a wide range of potential receiving channel conditions using sediment transport modeling and equations, the consultant team identified $0.1Q_2$ as the potential lower flow threshold.

The consensus amongst the consultant team and the independent Technical Advisory Committee, however, is that the singular use of channel critical shear stress for the lower flow threshold (as calculated using sediment transport equations) has limitations and that the lower flow threshold of $0.1Q_2$, which was derived using a collection of conservative assumptions, is too conservative and restrictive. The consultant team and the County of San Diego concluded that further analysis should be conducted to identify alternative lower flow thresholds in certain situations, including the following:

- Erosion-resistant channel bed - alternate lower flow threshold based on shear stress nomograph
- Very low runoff (e.g. small project) - alternate lower flow threshold based on minimum flow rate
- Discharge to very large channel - alternate lower flow thresholds based on watershed position

Therefore, based on the consultant team's analysis and input from the Technical Advisory Committee, the consultant team recommended providing alternate low flow thresholds for certain conditions. These alternative thresholds are discussed in more detail below. The applicability and use of alternate thresholds will be incorporated into a decision matrix to assist with implementation of the final Hydromodification Management Plan (HMP). This decision matrix will be a flow chart based tool to guide project applicants through the HMP compliance process. It will recommend a suite of mitigation options, appropriate flow thresholds, and the required level of analysis for specific receiving stream susceptibilities and proposed project impacts.

Identification of Alternate Lower Flow Thresholds for Erosion-Resistant Channels

While the single lower flow control threshold ($0.1Q_2$) may be appropriate for less resistant channel bed materials such as unconsolidated sand, an alternate standard is recommended when the receiving channel is comprised of consolidated channel materials, gravel or cobbles. This is because the critical shear stress increases dramatically in such conditions as compared to the unconsolidated sediment assumptions from which the lower flow threshold of $0.1Q_2$ was derived. Additionally, multiple other channel factors, such as bed armoring, bed consolidation, vegetation, etc. have the cumulative effect of increasing critical shear stress above levels predicted by standard sediment transport equations.

The consultant team's subsequent analysis regarding alternatives to the lower flow threshold included the following approaches:

- Bed infiltration losses estimated for unconsolidated channel materials such as sand. These losses include runoff that infiltrates through the channel floor into the groundwater system and is thus lost to the receiving streamflow system within the domain of analysis.
- Evaluated relationship between *applied shear stress* that could cause erosion and discharge (Q) for a range of typical channel configurations (varying channel width to depth ratios, roughnesses, slopes)
- Compared these values to *critical shear stress* for larger range of bed material types (grain size, degree of consolidation). For values where the applied shear stress exceeds the critical shear stress, sediment movement is predicted.

As a result of the analysis, the consultant team has developed preliminary nomographs to identify potential alternate lower flow thresholds for a range of channel conditions. A range of channel scenarios, from steep/rough/incised to flat/smooth/shallow, were evaluated with respect to both shear stress and discharge. Channel dimensions were scaled for bankfull flow conditions of 10 cfs and 20 cfs. The nomographs relate shear stress to discharge and identify nomograph zones for various channel bed conditions including compact clayey soils, coarse gravel, compact sandy clay, unconsolidated sandy clay, and coarse sand. An example lower flow threshold nomograph is presented in Appendix G.

Critical shear stress varies from 0.006 lb/ft^2 for sand to 1.107 lb/ft^2 for cobbles – this variability of critical shear stress provides a clear basis for identifying alternate lower thresholds based on channel characteristics. A standardized protocol will be provided to allow the applicant to demonstrate that the appropriate channel conditions are met. Such a protocol could include the development of a critical shear stress calculator which would be dependent on the user-defined value of D_{50} for the receiving channel segment. Protocols would also be developed for situations where the receiving channel segment contains a mixture of channel bed materials within the domain of analysis.

Identification of a Minimum Flow Rate as an Alternate Lower Flow Threshold

It is the consensus of the independent Technical Advisory Committee that under field conditions, erosion would not actually occur at the lowest flows predicted by the sediment transport modeling. The following discussion details the reasons why the consultant team agrees with the Technical Advisory Committee's opinion regarding this issue.

The majority of published critical shear stress data results and empirical sediment transport equations used in numerical models were derived from laboratory flume experiments. In these experiments, clean, unconsolidated sediment is placed in the flume. Simulated flow is then initiated until particles begin to move. These flume conditions omit many field conditions that would increase resistance to sediment movement.

While these differences between flume and field conditions are less relevant at the medium to high flows which are generally modeled in sediment transport evaluations, they are more significant around the threshold of sediment motion, which is the focus of hydromodification management programs. These factors include channel bed armoring by coarser sediment, bed consolidation, the presence of fine sediment that increases cohesion, the presence of vegetation, bed form roughness, etc. Additionally, the potential for channel bed infiltration becomes significant at lower flow rates, thus reducing the effective flow in the channel. These factors are site specific and difficult to quantify, but have the cumulative effect of increasing critical shear stress above the levels predicted in sediment transport equations.

The consultant team and the Technical Advisory Committee thus agree that a minimum flow rate should be applied to the lower flow control threshold. Preliminary sediment rating curve calculations, prepared by PWA using spreadsheets and incorporating sediment transport equations, indicate that the implementation of a minimum flow rate of roughly 1 cfs would provide adequate protection for most small creek systems (with the exception of unconsolidated sand channels). It is recommended that the determined minimum flow rate (specific value still to be finalized pending approval by the TAC) be used as the lower flow control threshold in cases where $0.1Q_2$ is less than the minimum flow rate.

- The consultant team's preliminary calculations show that a lower flow threshold of 1 cfs would be protective for most channels (i.e. lower flow threshold = the higher of $0.1Q_2$ or 1 cfs)
- It is difficult to identify a lower flow boundary for an unconsolidated sand bed channel.

It is noted that the lower flow threshold above may require adjustment in relation to the size of the proposed project site. For instance, smaller sites (<10 acres) may require a lower flow threshold as compared to larger sites. These determinations will be made pending approval by the TAC and be incorporated into the final decision matrix.

To mitigate flows from small systems, flow control devices may require small outflow orifices. A minimum orifice size or a list of standard orifice sizes will be developed for both unprotected and protected outlet orifice scenarios. To prevent orifice clogging and potential subsequent safety and vector issues, it is imperative that operation and maintenance protocols be followed in the design and maintenance of these flow control facilities.

The consultant team and the County of San Diego have requested information regarding detention basin and BMP maintenance from operation and maintenance staff in all San Diego municipalities. These responses will be consolidated in a comprehensive summary of practical design and maintenance considerations, which will be detailed in a separate technical memorandum.

Alternate Lower Flow Threshold Based on Watershed Position

The final decision matrix will include provisions regarding the determination of alternate lower flow thresholds in the following situations.

- Where the project site is very small as compared to the contributing watershed area to the receiving channel.
- Where the project site directly discharges runoff to a large receiving channel
- Where the potential for cumulative impacts in the watershed are minimal

Pending approval by the TAC and Copermittee Workgroup, policy decisions will be made regarding alternate lower flow limits and thresholds correlating to the following ratios.

- Project Discharge / Receiving Channel Discharge
- Project Impervious Area / Receiving Watershed Impervious Area
- Project Impervious Area / Future Planned Impervious Area in Watershed

Finally, a listing of erosion-resistant receiving water bodies may be developed. These could include hardened and armored channels, large rivers, lakes, and lagoon systems.

Summary

Based on the opinions of both the consultant team and the Technical Advisory Committee, the consultant team will develop a decision matrix detailing application of the lower flow threshold standard to assist with implementation of the final HMP. Elements of the decision process include evaluation of alternate lower flow thresholds for erosion-resistant channels, determination of alternate lower thresholds based on a minimum flow rate, and determination of alternate lower thresholds based on watershed position.

5.2 Analysis and Categorization of Streams / Geomorphology

Information for this section is being prepared in a concurrent hydromodification study by the Southern California Coastal Water Research Project (SCCWRP). As discussed with the San Diego Regional Water Quality Control Board staff, results of the SCCWRP study will be included in the San Diego HMP to comply with the following Permit Order requirement.

- Identification of geomorphic standards for channel segments receiving storm water discharges from Priority Projects (Permit Section D.1.g.(1)(a) and (m)). The purpose of these standards is to maintain or improve channel stability.

The SCCWRP study, which is being conducted for the entire Southern California region between Ventura and San Diego Counties, was originally funded by a Prop 50 grant. Because of funding issues that required a work stoppage in late 2008, the County of San Diego has provided funding to SCCWRP to continue its work and meet deadlines required for the San Diego HMP submittal timeline. The overall SCCWRP study approach is summarized in the document titled, "*Stream Channel Mapping and Classification Systems: Implications for Assessing Susceptibility to Hydromodification Effects in Southern California," SCCWRP Technical Report 562, April 2008.*

Screening tools which are being prepared by SCCWRP to identify channel susceptibility to hydromodification impacts will be available in 2009 on a testing basis. Such tools will include the following:

- A tiered, hierarchical approach for channel erosion susceptibility evaluation of multiple channel types. This approach includes determination of watershed characteristics (such as downstream connections to concrete channels or storm drains), vertical channel stability analysis (including transportability of channel bed material), and lateral channel stability analysis (including potential erodibility of channel banks and subsequent channel migration).
- Such rapid assessment tools will provide a preliminary rating of stream susceptibility to erosion (High, Medium or Low) and be provided for a variety of geomorphic scenarios including alluvial fans, broad valley bottoms, incised headwater channels, etc.

Other considerations that may be evaluated by the final SCCWRP study include the following:

- Dependent on the preliminary stream susceptibility rating, recommendations will be generated regarding the appropriate fluvial geomorphic model to assess hydromodification impacts.
- Phase diagrams to assist in stream classifications - such diagrams would exhibit predicted stream parameter responses based upon indicators such as critical discharge, sediment yield, sediment grain size, stream power, etc.
- Quantification of sediment yield changes subsequent to development-related hydromodification
- Quantification of uncertainty associated with risk-based methods
- Regional calibration of geomorphic thresholds, including effects of single-thread to braiding transitions, critical bank heights, and transitions from episodic to continuous sediment transport.
- Assessment of methods to differentiate coarse and fine sediments and to allow the continued conveyance of coarse sediment to receiving watercourses. Such an approach inverts the current treatment and flow control orthodox in which coarse sediment is typically captured in storm water facilities.

Eventually, SCCWRP tools will help quantify the effect of a proposed project on the receiving stream's susceptibility to erosion, based upon factors such as size of the project, impervious footprint, location of the project within the watershed, and stability of the receiving water body.

Development of Hydromodification Management Plans in most Southern California counties is correlated to the ultimate findings of the SCCWRP study, which was originally scheduled for release in March 2010. Though individual regions and municipalities would not be tied to acceptance of the SCCWRP results, it is generally acknowledged that SCCWRP's formulation of regional standards for hydromodification management will serve as a solid baseline for development of HMP's for specific regions in Southern California.

For implementation with the San Diego HMP, the SCCWRP screening tools will be used in association with the decision matrix to determine the appropriate level of required mitigation and level of analysis for the receiving stream. Where receiving streams have a high susceptibility to erosion, then more effective mitigation solutions will be required as compared to receiving streams with a low susceptibility to erosion. In addition, the decision matrix will determine applicable cases where less stringent flow control standards may be required for receiving channels having a low susceptibility to erosion as compared to receiving channels with a high susceptibility to channel erosion. Final determinations will be dependent on findings from the SCCWRP study and would require further discussions with the TAC and Copermittee work group.

5.3 Cumulative Watershed Impacts

Information for this section is being prepared in a concurrent grant-funded hydromodification study by the Southern California Coastal Water Research Project (SCCWRP). As discussed with the San Diego Regional Water Quality Control Board staff, results of the following section of the SCCWRP study will be included into the San Diego HMP.

- Protocols for evaluations of hydromodification impacts downstream of Priority Projects.

Such protocols would include the following:

- Quantification of the domain of assessment – These tools would estimate the downstream reach length for which hydromodification assessment is required. This rule set would include guidelines regarding the receiving downstream channel reaches (aggradational channel, incised channel, etc.), an assessment of the incremental flow accumulations downstream of the site, identification of hard points in the downstream conveyance system, and algorithms to quantify downstream tributary influences.

The effects of cumulative watershed impacts could also affect the implementation of alternative minimum orifice or minimum discharge standards, depending on the degree of development existing within a watershed. Further discussion of cumulative watershed impacts is currently scheduled with the Technical Advisory Committee.

Variables regarding project size and location within the watershed will be addressed by the concurrent SCCWRP work. Hydromodification impacts of a small project located at the downstream end of a highly urbanized watershed would be less significant as compared to the impacts of a large unmitigated development at the upstream end of an undeveloped watershed.

6. REQUIREMENTS / STANDARDS FOR PROJECTS

Priority Development Projects are required to implement hydrologic control measures so that post-project runoff flow rates and durations do not exceed pre-project flow rates and durations where they would result in an increased potential for erosion or significant impacts to beneficial uses or violate the channel standard (Permit Section D.1.g(1)(c)).

The following items, which identify potential methods by which project applicants may demonstrate HMP compliance, are pending approval by the TAC.

- Show that the proposed project would not result in an increase to the pre-project impervious area and that post-project discharge rates are lower as compared to pre-project conditions. Where development would either increase the pre-project impervious area or convey runoff more efficiently, and in turn result in increase peak flows, then project applicants should direct runoff to self-retaining areas or flow control BMPs and prepare hydromodification flow control calculations as detailed in the following step.
- Install BMPs that meet design requirements to control runoff from new impervious areas. BMPs including bioretention basins, vegetated swales, planter boxes, extended detention basins, etc. shall be designed pursuant to standard sizing and specification criteria development to ensure compliance with hydromodification criteria. The Copermittees and TAC will review the development of an automated sizing calculator that will allow project applicants to select and size flow control basins or LID treatment devices. The tool, akin to the sizing calculator developed for compliance with the Contra Costa HMP, uses pre-calculated sizing factors to determine required footprint sizes for flow control BMPs. Continuous simulation hydrologic analyses will be used to determine the sizing factors for various flow control options and development scenarios. Because of the method's ease of implementation and since hydromodification BMPs can also serve as treatment BMPs, it is anticipated that most project applicants will choose this option instead of seeking compliance through site-specific continuous simulation model preparation (as detailed in the following item of this list) or by addressing characteristics of the receiving stream (as detailed in the final item of this list).
- Prepare continuous simulation hydrologic models and compare the pre-project and mitigated post-project runoff peaks and durations (with hydromodification flow controls) until compliance to flow control standards is achieved. The modeler would be required to quantify the long-term pre and post-project runoff response from the site and establish runoff routing and stage-storage-discharge relationships for the planned flow control devices. Public domain software such as HSPF, HEC-HMS and SWMM can be used for preparation of a continuous simulation hydrologic analysis.
- Show that projected increases in runoff peaks and/or durations, along with sediment reductions associated with development, would not accelerate degradation or erosion of receiving stream reaches. In situations where the benefits of a proposed stream restoration project would substantially outweigh the potential impacts of additional runoff from a proposed project, the project proponent (pending TAC approval) may consider implementation of planning measures such as buffers and restoration activities, revegetation and use of less-impacting facilities at the point of discharge in lieu of implementation of storm water flow controls. Such scenarios include the modification of the channel gradient, cross section, or boundary materials to achieve stable conditions in the altered flow regime. Implementation of such measures would require a geomorphic analysis to show that the proposed changes to the stream channel cross sections, vegetation, discharge rates, velocities and durations would not have adverse impact to the receiving channel's beneficial uses. Such measures could not include non-naturally occurring hardscape

materials such as riprap, gabions, or concrete. Plans to restore a channel reach may reintroduce the applicability of HMP control for previously exempt projects.

As stated in Section 5.0, hydromodification management flow control solutions must meet the following criteria.

- For flow rates between the pre-project lower flow threshold (see below) and the pre-project 10-year runoff event, the post-project discharge rates and durations may not deviate above the pre-project discharge rates and durations by more than by more than 10 percent over more than 10 percent of the length of the flow duration curve.
- Lower flow thresholds may be determined using a nomograph developed by the consultant team to identify lower flow thresholds for a range of channel conditions. This nomograph is recommended for use when the receiving channel consists of materials other than unconsolidated sand. The lower flow threshold nomograph and text describing its development are located in Appendix G, in a memo titled *"Lower Flow Threshold Alternatives,"* prepared by Brown and Caldwell and dated April 30, 2009. Note – this criteria is pending approval from the Copermittee HMP Workgroup.
- A minimum flow threshold determined to be protective for receiving channel segments consisting of channel materials other than unconsolidated sand will be recommended, pending approval by the TAC and Copermittee HMP Workgroup. It is thus recommended that, for channel bed materials other than unconsolidated sand and in cases where either $0.1Q_2$ or the flow recommended through use of the lower flow threshold nomograph is less than the minimum flow threshold, then the lower flow threshold from a project site shall be set at the minimum flow rate. This minimum flow criteria is discussed in Appendix G, in a memo titled *Lower Flow Threshold Alternatives,* prepared by Brown and Caldwell and dated April 30, 2009.
- The lower flow threshold may alternately be determined as 10 percent of the pre-project 2-year runoff event. Details of this lower flow threshold determination are presented in Appendix F, in a memo titled *Flow Threshold Analysis for San Diego HMP,* prepared by Brown and Caldwell and dated April 30, 2009.

Pending full review and approval by the TAC to determine specific interpretation guidelines, hydromodification management flow controls may be waived in the following scenarios.

- Discharges into hardened conveyance systems, such as concrete channels, storm drain systems, or riprap-lined channels, where the lining extends downstream to a discharge location to either San Diego Bay or the Pacific Ocean. For such scenarios, plans for the hardened channel or storm drain system must be referenced for the downstream segment (between the project site and San Diego Bay or the Pacific Ocean).
- Construction of projects where the sub-watershed area downstream of the project site (i.e., the watershed area between the project site and either San Diego Bay or the Pacific Ocean) contains an impervious area percentage equal to or greater than 70 percent and the potential for single-project or cumulative impacts is minimal. For such scenarios, detailed mapping and associated calculations must be provided showing the downstream subwatershed boundaries, impervious area designations, and calculations proving that the subwatershed impervious area is at least 70 percent. The downstream impervious area calculations should be determined using a consistent and valid methodology to be outlined per input from the TAC and Copermittee Workgroup. A listing of applicable data sources will be presented to the TAC and Copermittee workgroup for review.
- If the project applicant conducts a sediment transport analysis for the range of geomorphically significant flows and, to the satisfaction of the governing agency, demonstrates that the project flows and sediment reductions will not adversely impact the receiving waters.

7. SELECTION AND IMPLEMENTATION OF BMPS

As detailed in Permit Section D.1.d and pending review and approval by the Technical Advisory Committee, Copermittees shall outline required approval process criteria for Priority Development Projects. Permit Section D.1.d(4) requires that Low-Impact Development (LID) BMPs be implemented where feasible.

Selection of the appropriate flow control treatment device will depend on the susceptibility of the receiving channel, impacts of the proposed development, and water quality sensitivity of the receiving streams. These factors will be built in the decision matrix being developed to assist with HMP implementation.

Use of LID BMPs minimizes the impacts of urban runoff discharges to receiving waters by collectively minimizing directly connected impervious areas. By directing urban runoff to landscaped areas, LID BMPs help restore the pre-development condition hydrologic cycle of the site, allowing for filtration and infiltration of urban runoff which can significantly reduce post-development peak runoff rates, velocities, volumes, and pollutant loadings in urban runoff.

Use of LID design approaches can provide both treatment of the 85th percentile water quality event as well as flow control for HMP criteria. To assure compliance with hydromodification flow control requirements, design criteria and specifications will be provided for a variety of LID-based flow control methods including bioretention basins, grassy swale / bioretention areas, storm water capture devices, self-retaining areas, porous pavement, etc. Sizing factors will be developed through the use of continuous simulation hydrologic modeling and these factors will be built into the LID/HMP Sizing Calculator to assist with HMP implementation. Provisions will also be provided for the design of larger extended detention pond control scenarios.

Implementation of flow control BMPs and LID design features is the key to a viable and effective HMP. Facilities must be designed to be practically built and maintained within the urban environment. Since the HMP will be implemented through the municipal development review process, design criteria must be specified and be incorporated into conditions of approval.

8. MONITORING AND BMP EVALUATION

This section details the inspections and maintenance to be conducted for management practices and measures to control flow rates and durations and address potential hydromodification impacts (Permit Section D.1.g(1)(j)).

If not properly designed or maintained, hydromodification flow control devices may create a habitat for vectors such as mosquitoes or rodents. Vector habitat creation can be avoided through collaboration with municipalities and both local vector control agencies and the State Department of Health Services during the development and implementation of urban runoff management plans.

Proof of long-term ongoing maintenance responsibility and mechanism will be required for all post-construction BMPs. Maintenance activities for flow control and LID devices will be specified in the proposed project's Storm Water Management Plan (SWMP). The consultant team is currently preparing standards and specifications for flow control facility maintenance, per input from Copermittee maintenance staff.

Information will be gathered through the first years of HMP project implementation to help meet the HMP objectives more efficiently and effectively. The initial step of this process would involve an analysis of a watershed development scenario to evaluate the HMP standard in controlling the cumulative effects of multiple development projects within a single watershed. Based on these results, adjustments could be made to future HMP requirements. Protocols for this long-term monitoring need to be discussed with the TAC and the Copermittee Workgroup.

9. CONCLUSIONS

Implementation of this Hydromodification Management Plan (HMP) satisfies Provision D.1.g of Board Order R9-2007-0001. Adherence to guidelines outlined in the HMP is required "to manage increases in runoff discharge rates and durations for all Priority Development Projects, where such increased rates and durations are likely to cause increased erosion of channel beds or banks, sediment pollutant generation, or other impacts to beneficial uses and stream habitat due to increased erosive force."

Order R9-2007-0001 contains requirements that strongly influence the methodology contained in this HMP. As recommended in the HMP, post-project flows must match pre-project flows within the prescribed geomorphically significant flow range.

Flow control options to meet the criteria include extended detention basins and Low-Impact Development (LID) distributed solutions which promote infiltration or filtration to attain the required flow mitigation. Continuous hydrologic modeling is required to prove conformance with the standards presented in this HMP.

Information presented in the HMP has been prepared in association with the County of San Diego, San Diego Storm Water Copermittees, the Technical Advisory Committee and the consultant team.

10. LIMITATIONS

Report Limitations

This document was prepared solely for County of San Diego in accordance with professional standards at the time the services were performed and in accordance with the contract between County of San Diego and Brown and Caldwell dated September 6, 2007. This document is governed by the specific scope of work authorized by County of San Diego; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by County of San Diego and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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APPENDIX A

Technical Advisory Committee

APPENDIX B

Rainfall Station Selection Criteria

APPENDIX C

Summary of HSPF Modeling Reports

APPENDIX D

Summary of Evaporation Data

APPENDIX E

Minimum Criteria for Evaluation of Storm Water Controls

APPENDIX F

Flow Threshold Determination Technical Memo

APPENDIX G

Lower Flow Threshold Alternatives