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SUBJECT: Development of Interim Hydromodification Criteria

Regional Water Quality Control Board Order R9-2007-0001 Provision D.1.g (6) (Board Order) requires the County of San Diego and its NPDES Co-permittees to identify Interim Hydromodification Criteria (IHC) within 365 days of Order adoption (i.e., by January 24, 2008). The interim criteria will apply until the final Hydrograph Modification Management Plan (HMP) is implemented. The IHC is described in the order as "an interim range of runoff flow rates for which Priority Development Project post-project runoff flow rates and durations shall not exceed pre-project runoff flow rates and durations." The purpose of the IHC is to prevent development-related changes in stormwater runoff from causing, or further accelerating, stream channel erosion or other adverse impacts to beneficial stream uses. This memorandum provides background on fluvial geomorphology and hydrograph modification management, describes flow control criteria applied in other HMPs, and provides a recommendation for developing the San Diego IHC.

GEOMORPHIC CONTEXT

Stream channels form in response to the sediment and runoff delivered from the watershed, in combination with channel slope and underlying geology. In a stable stream channel, water and sediment are in balance so that the channel neither aggrades nor erodes over time, though the channel may adjust dynamically to individual storm events. There are environmental influences that alter channel geomorphology including fire, landslides and tectonic uplift or subsidence. When these changes occur, stream channels adjust over time to achieve a new dynamic equilibrium under the altered conditions.

Anthropogenic land use changes have altered the balance of runoff and sediment supply in many Southern California watersheds, beginning with the introduction of cattle grazing in the 19th century. Modern land development tends to increase the rate and volume of runoff delivered to stream channels, due to the increase in impervious surfaces and drainage efficiency. In the Southern and Central coast regions of California, these anthropogenic changes have caused degradation of many stream channels, and the magnitude and rate of these changes has not allowed for adjustment to a new equilibrium state.

HYDROGRAPH MODIFICATION

Hydrograph modification refers to changes in the magnitude and frequency of stream flows as a result of urbanization, and the resulting impacts on the receiving channels in terms of erosion, sedimentation and degradation of instream habitat. The degree to which a channel will erode is a function of the increase in driving forces (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) or widening (bank erosion) or both. Increases in flow below critical shear stress levels have little or no effect on the channel.

The existing (pre-project) geomorphic condition of the receiving channel is important because it influences the response of the channel to the imposed stresses. Stream channels that have been previously impacted by earlier land use changes or direct interventions may not be in equilibrium with existing conditions, and these instabilities can influence channel response to hydrograph modification. For example, in an aggrading channel an increase in effective stress may *increase* channel stability by bringing sediment transport capacity closer to sediment load, while in an eroding channel a small increase in effective stress may cause a large increase in erosion. Changes in sediment or water delivery can also cause fundamental geomorphic thresholds to be crossed, for example by converting a wide and shallow braided channel into a narrow and deep single thread channel.

The standard for hydrograph modification management is to meet pre-project conditions. 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, hydrograph modification management may prevent the onset of erosion or other problems.

HYDROLOGIC CRITERIA

It is well established that watershed urbanization tends to increase the frequency and duration of stormwater runoff, and the effect is most dramatic for smaller, more frequent runoff events (Beighley et al., 2003, Hollis 1975). Rainfall events that may have been absorbed or retained by a natural ground surface produce runoff when those surfaces are paved. These smaller events are also associated with stream flows that are most important for erosion, due to the combination of their magnitude and frequency. The most geomorphically-effective flows are those that are both large enough to move an appreciable amount of sediment and frequent enough to have a significant cumulative impact, generally around the 1- to 5-year recurrence interval (Q1-Q5) (Wolman & Miller, 1960). Much of the impact of hydrograph modification is an increase in the frequency of geomorphically effective flows.

One way to manage hydrograph modification is to control site runoff to levels that are equal to or less than pre-project runoff, as required by the IHC. The other fundamental approach is to allow increased flow to channels but to modify the gradient, cross section and/or boundary materials to achieve stable conditions under the changed flow regime. Hydrograph Modification Management

Plans that have been adopted in the Bay Area (Contra Costa, Santa Clara, Alameda) and approaches under consideration in other areas of California (Sacramento, Los Angeles, SCWRPPP) vary as to the emphasis placed on flow control versus other approaches. However, there is a general consensus that both the frequency and duration of flows must be controlled, necessitating the use of continuous simulation hydrologic modeling for evaluating potential impacts of development (as opposed to design storm methods typically used in flood control analysis). It is also generally accepted that events smaller than Q10 are the most critical for hydrograph modification management. The examples below illustrate how different regulatory approaches have led to different compliance criteria.

Flow Control Approach
Conventional flood control detention basins are designed to control peak flows for large events to pre-project levels and meter the excess runoff out over a longer period. This approach can increase the duration of small but still erosive flows and can cause extensive channel erosion (WA State Department of Ecology, 2001). More recently, detention basins for hydrograph modification management have employed multi-stage outlet works designed to match both the duration and magnitude of flows within a critical range. To avoid the erosive effect of extended low flows, the maximum rate at which excess water is eventually released is set below the erosive threshold. The Santa Clara (SCVURPPP) HMP focused on the use of detention basins for hydrograph modification management and therefore strongly emphasized the lower flow control limit for site runoff. SCVURPPP defined the lower flow control limit as the flow rate (expressed as a percentage of Q2) that generates the critical shear stress on a channel (Qc); that is, the minimum flow that could initiate erosion in the channel bed and banks. SCVURPPP estimated Qc to be 0.1Q2, based on an estimate of bed and bank material shear resistance at selected cross sections in two creeks. As a result of this study, both the Santa Clara and Alameda HMPs adopted 0.1Q2 as the lower limit for flow control regulation.

Low Impact Development (LID) Approach
The LID approach to hydrograph modification management relies on site design and best management practices to mitigate for hydrograph modification impacts. By minimizing directly connected impervious area and promoting infiltration, LID approaches mimic natural hydrologic conditions to counteract the hydrologic effects of development. Because more water is retained on-site and in distributed facilities, the lower discharge limit is less critical for LID facilities since different facilities will discharge into the stream system at different times. By contrast to the Santa Clara approach, the Contra Costa HMP strongly emphasized the use of LID for hydrograph modification management. The HMP is therefore targeted the range of flows most likely to cause erosion impacts (i.e., less than Q10), without defining a specific lower limit for flow control.

RECOMMENDATION
The Board Order specifically requires defining a “range of runoff flow rates” to be regulated under the IHC. Runoff flow rates are commonly understood as design storm peak flow rates such as Q2 or Q10, and in fact the interim standard recently adopted by the County of Los Angeles consists of a single peak flow rate (Q2). This approach is appealing because it is very simple and can be evaluated using design storm models and methods commonly used for flood control analysis. However, it is widely recognized that the design storm approach is not adequate for characterizing the most critical hydrograph modification effects of development (i.e., increased duration and frequency of small runoff events).

Continuous simulation hydrologic modeling permits statistical analysis of the frequency, magnitude and duration of runoff over an extended period (typically 20 years or more) and is based upon actual, historical rainfall records for a project area. Potential project impacts on the frequency and duration of smaller flows can be readily evaluated by comparing model output for pre- and post-project conditions. The Board Order acknowledges the efficacy of continuous simulation for hydrograph modification analysis and requires its use in the development of the HMP. Because continuous simulation hydrologic modeling is the most appropriate analytical tool and because the Board Order requires its use, we recommend using a continuous simulation compliance standard for the IHC.

We recommend the following Interim Hydrologic Criteria, which are modified from the Contra Costa HMP. Two compliance options are provided – curve-matching based on continuous simulation modeling, and implementation of LID. The curve-matching approach, as described below, would be available to project proponents once the IHC are approved by the Co-permittees. The LID implementation option would become available later. It would rely on design and sizing procedures created and approved (by Co-permittees) during the course of developing the final HMP. If the Co-permittees do not approve LID design guidance during the period that the IHC are in place, the curve-matching standard would be the default compliance standard.

The range of flows to be managed under the curve-matching option is expressed as a percentage of the 5-year peak flow (Q5) based on the understanding that dominant discharge for Southern CA streams is in the vicinity of Q5. The curve-matching range is presented as an estimate at this time and may be refined prior to adoption of the final IHC.

1. Estimated post-project runoff durations and peak flows do not exceed pre-project durations and peak flows. The project proponent must use a continuous simulation hydrologic computer model such as USEPA's Hydrograph Simulation Program—Fortran (HSPF) to simulate pre-project and post-project runoff, including the effect of proposed IMPs, detention basins, or other stormwater management facilities. To use this method, the project proponent shall compare the pre-project and post-project model output for a rainfall record of at least 30 years, and shall show the following criteria are met:

    a. For flow rates from 20% of the pre-project 5-year runoff event (0.2Q5) to the pre-project 10-year runoff event (Q10), the post-project discharge rates and durations shall not deviate above the pre-project rates and durations by more than 10% over more than 10% of the length of the flow duration curve. *(Note that the 0.2Q5 end of the range may be modified).*

    b. For flow rates from 0.2Q5 to Q5, the post-project peak flows shall not exceed pre-project peak flows. For flow rates from Q5 to Q10, post-project peak flows may exceed pre-project flows by up to 10% for a 1-year frequency interval. For example, post-project flows could exceed pre-project flows by up to 10% for the interval from Q9 to Q10 or from Q5.5 to Q6.5, but not from Q8 to Q10. *(Note that the 0.2Q5 end of the range may be modified).*

2. Implementation of Low Impact Development Integrated Management Practices (LID IMPs). The project proponent may implement LID IMPs to manage hydrograph modification impacts, using design procedures, criteria, and sizing factors (ratios of LID IMP volume or area to tributary area) specified by the Co-permittees. The Co-permittees' LID IMP designs and sizing factors shall be determined using continuous simulation of runoff from a long-term rainfall record.

The Order provides for exemptions from the IHC of development projects disturbing 50 acres or more when:

> "(a) The project would discharge into channels that are concrete-lined or significantly hardened (e.g., with rip-rap, sackcrete, etc.) downstream to their outfall in bays or the ocean;
>
> (b) The project would discharge into underground storm drains discharging directly to bays or the ocean; or
>
> (c) The project would discharge to a channel where the watershed areas below the project's discharge points are highly impervious (e.g. >70%)."

In addition, we recommend adding another exemption criterion (currently not written in the permit) to provide some additional flexibility for applicants in complying with the Interim Hydromodification Criteria, as follows:

> (d) The applicant conducts an assessment incorporating sediment transport modeling across the range of geomorphically-significant flows that demonstrates to the permitting agencies satisfaction that the project flows and sediment reductions will not detrimentally affect the receiving water.

REFERENCES

Beighley, R.E., J.M. Melack, and T. Dunne, 2003. Impacts Of California's Climatic Regimes And Coastal Land Use Change On Streamflow Characteristics. *Journal of the American Water Resources Association*, 39(6):1419-1433.

Hollis, G.E., 1975. The Effect of Urbanization on Floods of Different Recurrence Interval. *Water Resources Research*, 11(3): 431-435.

Wolman, M.G. and Miller, J.P. 1960. Magnitude and frequency of forces in geomorphic processes*; J. of Geology*, vol. 68, no.1, pp54-74.

Washington State Department of Ecology, 2001. Stormwater Management Manual for Western Washington, Volume III.