CLEAR CREEK SOLUTIONS, INC.

15800 Village Green Drive #3
Mill Creek, WA 98012
425-892-6454
www.clearcreeksolutions.com

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TO: Dale Bowyer, Section Leader, SE Bay Section, SFB RWQCB
Janet O'Hara, CA RWQCB 2

CC: Arleen Feng, ACCWP
Jill Bicknell, SCVURPPP
Matt Fabry, SMCWPPP

FROM: Douglas Beyerlein, P.E., P.H.
Joseph Brascher

SUBJECT: Comments on TetraTech's Comparison of BAHM and Contra Costa IMP

Dr. Jonathan Butcher of TetraTech has provided a review of BAHM and the Contra Costa IMP for the California Regional Water Quality Control Board. Dr. Butcher's review is summarized in his memo titled "Comparison of BAHM and Contra Costa Approaches to Hydromodification Management Plan Requirements", dated 7 December 2007. We received a copy of this review on 15 February 2008. We appreciate Dr. Butcher's thorough review of the two software packages. The purpose of this memo is to respond to some of the issues Dr. Butcher raised in his review.

Dr. Butcher describes how the two software packages (BAHM and IMP) use HSPF to generate stormwater runoff data for use in sizing hydromodification facilities. He presents a comparison of the results produced by each package and makes recommendations on how each package can be improved. His BAHM-specific recommendations are:

1. BAHM simulation of IMPs should be improved. There appear to be errors in the way BAHM sets up the flow-through planter representation. In addition, the representation of infiltration is simplistic and should be refined.

2. The BAHM simulation of LID devices should consider providing for outflow limitation control on underdrains. The user would then have the option of employing such devices either as the primary control on flows (in which case the underdrain outflow should be limited to the flow corresponding to the base of the control range), or as a secondary component (without such strict limitations on underdrain outflow) that helps to reduce the size of detention ponds.

We appreciate Dr. Butcher's recommendations, but would like to clarify some issues related to his apparent misunderstanding of how BAHM simulates IMP/LID facilities.

First, there is the inference that BAHM is not designed to size IMP/LID facilities ("BAHM does not size LID devices directly", p. 1, last paragraph). Actually, the BAHM user is given the freedom and tools to size whatever type of hydromodification facility (or combination of facilities) the user thinks will work best for the project site in question. While the stormwater pond option is used in the BAHM User Manual Quick Start as an example, the user can control all of the runoff using planter boxes if desired. BAHM does size LID devices directly using the same flow duration matching used for ponds, vaults, tanks, etc.

Second, there is the statement that BAHM does not correctly model bioretention facilities (flow through planter, etc.). This statement is incorrect and is mistakenly based on the misinterpretation of how two HSPF FTABLEs are used to represent the bioretention facility. Dr. Butcher misinterpreted the division of the storage between the two FTABLEs as represented in BAHM. He states,

> "The upper RCHRES (FTABLE) represents the amended soil layer plus freeboard in the planter above the soil surface and the riser. The lower RCHRES (FTABLE) represents the gravel layer and underdrain." (p. 14, second paragraph)

This may be the way that it is set up in the Contra Costa IMP software package, BUT it is not how it is set up in BAHM.

BAHM divides the upper FTABLE and lower FTABLE differently than IMP. The BAHM upper FTABLE represents the storage ABOVE the surface of the amended soil. (A side note here: BAHM gives the user the option of specifying up to three material layers in the amended soil column. One of these layers can be a gravel layer if the user so decides. For the purposes of the following discussion the amended soil INCLUDES a gravel layer.)

The lower FTABLE represents the storage in the amended soil (including a gravel layer) and outflow through the underdrain. The underdrain is at the bottom of the lowest layer defined by the user. This at the bottom of the amended soil layer(s), which would be at the bottom of the gravel layer, if a gravel layer is included.

In addition, BAHM "flips" the lower FTABLE so that the water entering the lower FTABLE fills the storage space from the surface of the amended soil downwards until it reaches the underdrain and/or infiltrates into the native soil (IMP apparently does not). By flipping the FTABLE stage-storage relationship the water must travel through the soil layer(s) before becoming available to discharge out through the underdrain. Otherwise, the water will go directly to the bottom of the planter and become immediately available for discharge via the underdrain. This flipping of the FTABLE also explains why BAHM sets the height of the underdrain discharge where it does. The dead storage that Dr. Butcher refers to is the storage in the soil ABOVE the underdrain. It is not dead storage; it is just the soil storage before the water can get to the underdrain.

BAHM also uses HSPF Special Actions to make sure that water is not moving from the upper FTABLE to the lower FTABLE if the soil column is fully saturated. Without using Special Actions there is no way to provide feedback to the upper FTABLE and the model will continue to send water from the upper FTABLE to the lower FTABLE even when the lower FTABLE is full (the soil column is fully saturated). It is not clear how IMP handles this situation.

It is unfortunate that Dr. Butcher did not ask us for an explanation of how the BAHM bioretention upper and lower FTABLEs work, nor give us an opportunity to review and provide feedback on his assumptions and conclusions prior to publication of his findings. We could have saved him from this confusion.

Dr. Butcher also exhibited some confusion over how BAHM models evapotranspiration from bioretention facilities (page 14, first paragraph). Water on the surface of the soil (upper FTABLE) is evaporated at 50% of the potential evapotranspiration (PET) rate. Water rarely sits on the surface for very long and, therefore, this is only a minor component of the ET process. The reason why this upper FTABLE evaporation rate is not 100% is because we don't want to double count the combined evaporation from the surface and the transpiration from the soil column (lower FTABLE). Water in the soil column is transpired at 70% of the PET rate. This transpiration is from the plants and their root systems in the soil column (lower FTABLE). We believe that this transpiration rate is appropriate for the soil depth of a typical planter.

Other than the misinterpretations described above, we acknowledge that BAHM can be improved by (1) adding a more complex infiltration methodology based on water head and (2) adding an outflow limitation control on the underdrain.

We are currently investigating the computer programming required to add a more complex infiltration methodology that takes into account head and pore suction effects. We will be adding this enhancement to BAHM as soon as feasible.

We have added an outflow limitation control on the underdrain. This outflow limitation control is an orifice that the user can size.

Finally, there was a software bug related to bioretention freeboard in the July 2007 version of BAHM used by TetraTech for their review. This bug was noted by TetraTech. We found it also and it was corrected in the November 2007 version of BAHM, which is currently available from both our web site (www.clearcreeksolutions.com) and the official BAHM web site (www.bayareahydrologymodel.org). We recommend that all BAHM users download and use the most recent version of BAHM.

In summary, we appreciate TetraTech's review of BAHM. We regret that there was confusion over how BAHM represents the bioretention element used to model planter boxes and other LID/IMP facilities. We hope that this memo clarifies this issue and reassures the California Regional Water Quality Control Board, our supporting agencies, and the BAHM user community that BAHM is technically correct and accurately sizes hydromodification facilities to meet state and federal Clean Water Act requirements.