Hydromodification Computer Modeling

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Introduction

Hydromodification is the change in runoff volume, magnitude, and duration caused by changes in land use. Municipal stormwater discharge permits are required for NPDES Phase I and II communities to prevent degradation to natural stream systems and to meet the requirements of the federal Clean Water Act. These discharge permits include the development of Hydromodification Management Plans (HMPs). Accurate computer modeling of the impacts of hydromodification and the sizing of mitigation facilities is critical to prevent further degradation to natural stream systems and to meet Clean Water Act goals.

The hydromodification control standard requires that post-project runoff shall not exceed pre-project rates and/or durations, over a defined range of storm event sizes. Research has shown that the changes in a project site’s hydrology cannot be evaluated for a single storm event with traditional design storm approaches. The change in hydrology must be evaluated over a longer time frame using a continuous simulation hydrologic model, and the results used to size mitigation facilities to match pre-project flow duration patterns. This paper focuses on the continuous simulation hydrologic modeling approach used in multiple jurisdictions in California and Washington and how it can be applied anywhere in the country.

The continuous simulation hydrologic modeling approach selected by Clear Creek Solutions uses EPA’s HSPF as its computational engine within an easy-to-use Windows environment. The original hydromodification computer modeling software was developed by Clear Creek Solutions for the Washington State Department of Ecology. That version of our hydromodification software is known as the Western Washington Hydrology Model (WWHM). Today we have also created versions for the San Francisco Bay Area (BAHM) and San Diego County (SDHM).

The major components of hydromodification modeling consists of a user-friendly graphical interface through which the user inputs information about the project and desired mitigation facility (for example, stormwater pond or underground vault); a computational engine that automatically loads appropriate parameters and meteorological data and runs the continuous simulation model HSPF to generate flow duration curves; a module that sizes the mitigation facility to achieve the hydromodification control standard; and a reporting module that documents the model input and output.

BMPs, LIDs, and water quality facilities such as green roofs, bioretention cells, sand filters, rain gardens, planter boxes, compost amended soil, and permeable pavement are included in the model and can be used to reduce stormwater runoff.
Results from the hydromodification computer modeling quantitatively identify the important analysis considerations that must be kept in mind when designing stormwater mitigation facilities in an urban environment and the practical effectiveness of implementing these facilities and practices to protect private property and public resources.

**Major Requirements**

The major requirements for successful hydromodification computer modeling are: (1) accurate simulation of the hydrology, (2) a flexible set of hydromodification mitigation options and tools, and (3) software ease of use.

**Accurate simulation of the hydrology**

Accurate simulation of the hydrology requires parameters that represent the full range of soils, vegetation, and topographic conditions that describe the hydrology of a specific region or climate, and algorithms that calculate all of the individual components of the hydrologic cycle including surface runoff, interflow (shallow subsurface flow), groundwater, soil moisture, and evapotranspiration. HSPF, since its introduction in 1980, meets all of these requirements and has become the industry standard for continuous simulation hydrologic modeling.

Key to the ability to accurately simulate the hydrology is to be able to reproduce observed streamflow records for both large and small drainage areas and watersheds. HSPF demonstrates its ability to simulate observed streamflow data through the calibration process. In the 19 counties of Western Washington the HSPF hydrology parameters have been calibrated on numerous small and large watersheds. In the San Francisco Bay Area the same exercise was conducted on four watersheds in Alameda and Santa Clara counties. In other locations we have made use of our general HSPF hydrology parameter value knowledge base to identify and select appropriate parameter values to accurately simulate the hydrology of a particular locale. These parameter values are based on the local soils, vegetation, and topographic conditions.

Another key to accurately simulating the hydrology is the inclusion of long-term local hourly precipitation in the model. Precipitation drives the hydrology. A long precipitation record in the range of 35 to 50 years is required to generate a sufficiently long period of runoff on which flow frequency and duration statistics can be calculated. Hourly precipitation is needed to accurately represent the variations in precipitation intensity during storm events. For this reason our hydromodification software uses one or more long-term local hourly precipitation gages for each county and then scales the precipitation to the user’s site using published NOAA rainfall map data.

**Flexible set of hydromodification mitigation options and tools**

A flexible set of hydromodification mitigation options and tools includes the ability for the user to select the appropriate mitigation solution(s) from a large menu of options. These options should include best management practices (BMPs), low impact developments (LIDs), and water quality facilities such as stormwater ponds and vaults, tanks/pipes, infiltration facilities, green roofs, bioretention cells, sand filters, rain gardens, planter boxes, compost amended soil, permeable pavement, and other mitigation options defined by the user. These mitigation options can then be used individually or in
combination to reduce the post-project runoff so that it does not exceed pre-project rates and durations over a defined range of storm event sizes. Clear Creek Solutions hydromodification modeling software includes all of these options plus the ability to route flows through conveyance systems using auxiliary programs such as HY-8 and SWMM.

Flexibility in the input of HSPF hydrology parameter values and long-term local hourly precipitation time series is also important in adjusting the hydromodification software to include new information. The Clear Creek Solutions hydromodification software is built on a flexible standard platform that allows for quick and seamless modification and/or replacement of HSPF PERLND and IMPLND parameter values and hourly precipitation time series. As new data become available the models can be updated accordingly. In addition, the software can be expanded to new jurisdictions and regions with just a few simple modifications.

Different jurisdictions and regions have different hydromodification flow control standards to control erosive flows. For example, the 19 counties of Western Washington use a standard criterion that the post-development flow duration values cannot exceed any of the pre-development flow levels between 50% of the 2-year pre-development peak flow and 100% of the 50-year pre-development peak flow value. The San Francisco Bay Area counties of Alameda, Santa Clara, and San Mateo use a criterion of 10% of the 2-year existing peak flow to 100% of the 10-year peak flow and San Diego County selected 20% of the 5-year existing peak flow to 100% of the 10-year peak flow.

Other jurisdictions and regions have and will select flow control standards that are specific to their soils, geology, and politics. Clear Creek Solutions hydromodification software provides the user with the flexibility to specifically select the duration criteria to match the local flow control standard, as shown in Figure 1. In addition, flow duration analysis can be based on a user-defined flow value range instead of the standard flow frequency range.

![Figure 1. Flow Duration Criteria Options](image)
Software ease of use

All of the above described features and options are important in hydromodification modeling, but if the software is not easy to use then it will be ignored in favor of software that is easy to use. Ease of use includes the flexibility of tools and options, discussed above. Just as important, ease of use means the ability to quickly and efficiently create a hydromodification project, optimally size the mitigation facility, and document the results.

With Clear Creek Solutions hydromodification software creating a hydromodification project is relatively simple. The user locates the project site on the appropriate county map (Figure 2). The user can zoom in or out on the map to find the exact location. The model uses this information to select the appropriate precipitation record and multiplier for this location.

![Figure 2. Map Screen](image)

The user then goes to the Scenario Generator screen (Figures 3a and 3b) where the soil, vegetation, and land slope information are specified. The user inputs the number of acres of pre-development land use in each of the different land categories and does the same for the proposed development.
Figure 3a. Pre-development Land Use

<table>
<thead>
<tr>
<th>Subbasin Name</th>
<th>Impervious Area</th>
<th>Effective Impervious Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Figure 3b. Development Land Use

<table>
<thead>
<tr>
<th>Subbasin Name</th>
<th>Impervious Area</th>
<th>Effective Impervious Area</th>
</tr>
</thead>
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The user selects the type of mitigation facility to include in the analysis. As listed above, this can include stormwater ponds and vaults, tanks/pipes, infiltration facilities, green roofs, bioretention cells, sand filters, rain gardens, planter boxes, compost amended soil, permeable pavement, and other mitigation options defined by the user.

The mitigation facility can be either manually sized to meet the flow control standards or, for some facilities, optimization routines (for example, AutoPond) are available to size the facility. An AutoPond example is shown in Figure 4.

![AutoPond-sized Stormwater Pond](image)

AutoPond uses a complex set of rules to select pond dimensions and outlet orifice diameters and heights. Once AutoPond has made an initial selection of pond and orifice sizes, the model runs HSPF to generate the 40+ years of hourly runoff. The runoff is routed through the stormwater control facility and a flow duration comparison is made with the pre-development flows. If the post-development flow duration results do not pass the flow control standard criteria then AutoPond changes dimensions and tries again. If the post-development flow duration results pass the standard then AutoPond tries to make the pond smaller. This produces the smallest (and most efficient) pond possible to meet the flow control standard. Any time during this process the user has the option to stop AutoPond and make manual changes, if desired.

AutoPond reduces mitigation facility optimization time from hours to minutes.
Flow frequency calculations are automatically made to determine the flow duration criterion lower and upper limits. The flow frequency calculations are based on the 40+ years of hourly runoff generated by the model. In Western Washington we have found that the Log Pearson Type III distribution best represents the flood frequencies; in California the Weibull distribution works best.

Clear Creek Solutions hydromodification software produces model output in both graphical and tabular form. The major graphical output of interest is the flow duration plot of pre-development flow and mitigated post-development flow (Figure 5). All of the mitigated post-development flow values must be on or to the left of the pre-development values.

Figure 5. Flow Duration Analysis Output

Numeric output is provided in tabular form. The model produces a project report (Figure 6) that lists all of the input and output information. This includes the precipitation station and multiplier factor used, both pre- and post-development land use types and acreages, and dimensions and specifications of the flow control mitigation facility.

The project report also lists the number of hours the pre- and post-development flows exceed each of the 100 flow duration levels and whether or not the flow control facility passes or fails the flow control standard for that level. Failure at any one of the 100 levels means the facility fails to meet the flow control standard.

The report can be saved to disk as a Word document file or a standard text file.
Figure 6. Report Window

Clear Creek Solutions hydromodification software also computes the flow rate or volume required by a jurisdiction or agency for water quality treatment based on treating a specified percent of the total annual runoff volume. Other analysis options include calculation of mitigation facility drawdown time.

The user has the option of saving the project file to disk. This project file can be later read into the Clear Creek Solutions hydromodification program by the original user or a reviewer to check or further modify the project.

From start to finish a hydromodification mitigation project often can be created, sized, and saved in less than an hour.

Summary

Hydromodification is the change in runoff volume, magnitude, and duration caused by changes in land use. Municipal stormwater discharge permits are required for NPDES Phase I and II communities to prevent degradation to natural stream systems and to meet the requirements of the federal Clean Water Act.

The hydromodification flow control standard requires that post-project runoff shall not exceed pre-project rates and/or durations to prevent additional erosive flows. The best approach to meeting this requirement is to use continuous simulation hydrologic modeling to size mitigation facilities to match pre-project flow duration patterns. This paper has described the continuous simulation hydrologic modeling approach used by Clear Creek Solutions in multiple jurisdictions in California and Washington and how this approach and software can be applied anywhere in the country.
Clear Creek Solutions uses EPA’s HSPF as its computational engine within an easy-to-use Windows environment. The major components of hydromodification modeling software consists of a user-friendly graphical interface through which the user inputs information about the project and desired mitigation facility; a computational engine that automatically loads appropriate parameters and meteorological data and runs the continuous simulation model HSPF to generate flow duration curves; a module that sizes the mitigation facility to achieve the hydromodification control standard; and a reporting module that documents the model input and output. This paper has described these features and the mitigation options available to the user.

Because of its flexible software architecture the Clear Creek Solutions hydromodification software can be customized for a specific jurisdiction or region anywhere in the United States to accurately represent the hydrology of the jurisdiction’s watersheds and/or to include new criteria or standards to meet local, state, and federal Clean Water Act goals.

Today throughout Washington and California hydromodification mitigation facilities are being designed and built using Clear Creek Solutions hydromodification software. These facilities are neighborhood amenities that also protect and enhance the natural environment while allowing new land use development and redevelopment.

For more information contact the author or go to www.clearcreeksolutions.com.