



In watersheds with large amounts of impervious surface, the larger volumes, faster rates and extended durations of discharge often cause natural creeks or earthen channels to erode, as the channel enlarges in response to the increased flows. **Problems from this additional erosion** often include property damage, degradation of stream habitat and loss of water quality, and have not been addressed by traditional detention designs. Figures 7-2 and 7-3 illustrate the effect of increasing urbanization on stormwater volumes.

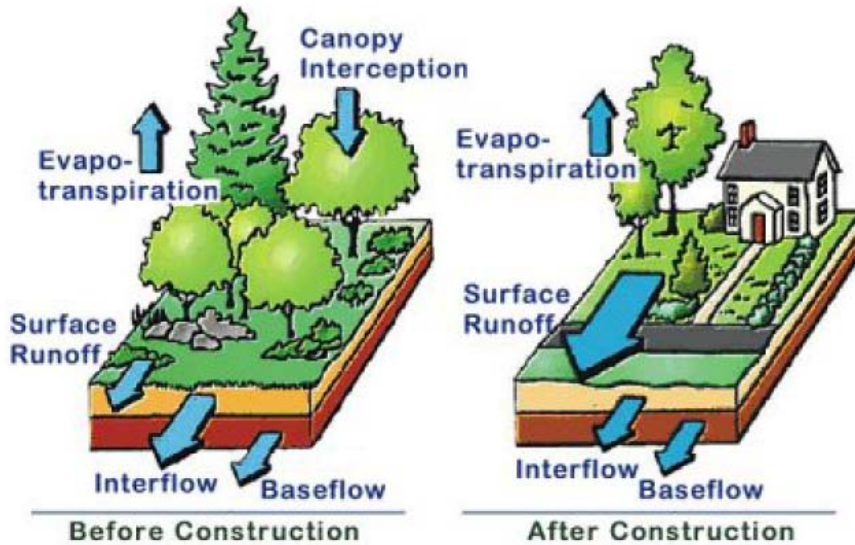


Figure 7-2: Effects of Urbanization on the Local Hydrologic Cycle (Source: 2000 Maryland Stormwater Design Manual)

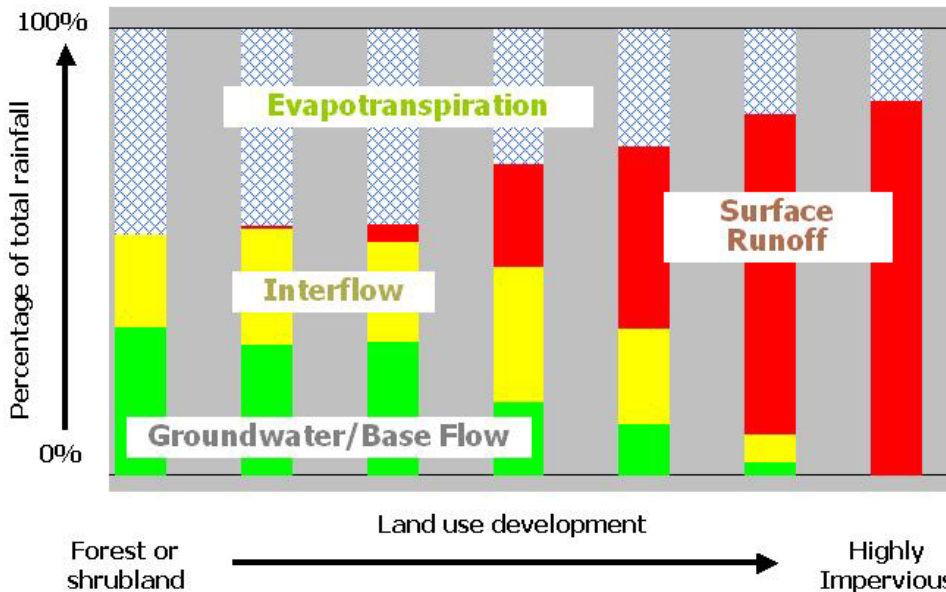


Figure 7-3. Variation in rainfall contribution to different components of the hydrological cycle for areas with different intensity of urban development. (Chart used by permission of Clear Creek Solutions.)

## 7.2 Hydromodification Management (HM) Controls

Hydromodification management (HM) measures can be grouped into three types:

- **Integrated management practices**, or IMPs, which are small-scale, stormwater management techniques that are generally distributed throughout a project site. IMPs are designed to minimize directly-connected impervious areas, slow runoff, and maximize infiltration (where appropriate) as described in *Start at the Source* (BASMAA, 1999: [www.cleanwaterprogram.org/uploads/SAS\\_Manual\\_index.pdf](http://www.cleanwaterprogram.org/uploads/SAS_Manual_index.pdf)). IMPs may also include the use of bioretention areas, vegetated buffer strips, vegetated swales, roofs that detain water, and multi-functional landscape areas.
- **Flow duration control measures** are used to manage excess runoff from the site after IMPs are applied. These “**end-of-pipe**” measures mitigate the effects of hydrograph changes from stormwater collected in pipes and channels before the runoff is discharged to a natural channel that could suffer adverse effects. Examples include extended detention basins, wet ponds and constructed wetlands. Please note that there is a difference between the design approach for sizing measures to remove pollutants from stormwater and the approach for designing flow duration controls to prevent an increase in the potential for creek bank erosion. The treatment of stormwater pollutants targets capture of 80% of average runoff volume, which means that treatment measures will be bypassed every one to two years. Flow duration controls must be sized to control the statistical duration of a wide range of flow levels under simulated runoff conditions. Depending on pre-project and post project conditions, the required detention volume is **likely to be greater** than the capture volume required for treatment. Flow duration controls are typically used on-site, but larger facilities, such as detention basins, may be sized to control runoff from a regional drainage area.
- **In-creek or restorative measures** that modify susceptible watercourses to withstand projected increases in runoff flows and durations without increasing erosion or other impacts to beneficial uses. In-creek measures are more complicated to use than the IMPs and flow duration controls, and are best suited for creeks or channels that have **already received impacts** from previous development and have only localized channel instability. Examples include biostabilization techniques using roots of live vegetation roots to stabilize banks and localized structural measures such as rock weirs, boulder clusters or deflectors. These measures will not automatically provide HM protection for channel reaches farther downstream and may require longer planning timelines and cooperation among multiple jurisdictions compared to flow duration controls.

Flow duration control measures are sized to control the flow and duration of stormwater runoff according to a **Flow Duration Control** standard, which is often greater than size requirements for volume-based treatment.



## 7.3 Hydromodification Management Plan (HMP) Requirements

The Water Board required the Countywide Program to prepare a hydrograph modification management plan, or “**Hydromodification Management Plan**” (**HMP**) in order to reduce erosive flows that result from increasing impervious surfaces in the watersheds of natural creeks. The Water Board is scheduled to adopt an amendment to the countywide municipal stormwater NPDES permit approving the HMP in March 2007. The HMP requirements will go into effect immediately, or as specified in the permit amendment.

### HMP Management Objective

Key Point



The HMP’s management objective is to control stormwater discharges from non-exempt development projects so that these discharges do **not increase the erosion potential** of the receiving creek over the pre-project (existing) condition. This will be accomplished by implementing four performance criteria:

- Projects shall **provide hydromodification management (HM) controls** as needed to maintain the pre-project creek erosion potential. These controls may include a combination of on-site or off-site (regional drainage area and/or in-creek) control measures. An erosion potential (Ep) of up to 1.0 shall be maintained for creek segments downstream of the discharge point. Ep can be expressed as the ratio of post-project to pre-project erosive “work” done on the creek.
- On-site stormwater controls that are designed to provide **flow duration control** to the pre-project condition shall meet the erosion potential management objective and comply with the HMP. Flow duration controls shall be designed so that the post-project stormwater discharge rates and durations match those of the pre-project condition, from 10 percent of the pre-project two-year peak flow up to the pre-project 10-year peak flow.
- **Where on-site measures are impracticable** for achieving flow duration control criteria, projects shall comply with the HMP requirements through the use of appropriate site design, source control and treatment control measures with flow control benefits to the maximum extent practicable. In addition, where available, off-site control measures must be used to meet the hydromodification management objective.
- Projects may use **off-site control measures** in lieu of or in combination with on-site controls, where an approved plan – including an appropriate funding mechanism – is in place and accounts for the creek changes expected to result from changes in project runoff conditions. The off-site control measures or combination of controls shall be designed to achieve the management objective of keeping the erosion potential (Ep) at 1.0 or less, from the point of discharge to the creek as far down stream as potential impacts will occur.

Flow Duration Control looks at the full range of flows in a simulated long-term history, and is **not directly comparable** to approaches based on one or a few synthetic “design storms”.

Map of Exempt Areas

The HMP includes a map showing areas that are exempt from the HMP requirements, due to their **limited potential for hydromodification** to occur. These areas were identified as exempt because they met at least one of following three criteria:

- Low-gradient bayside areas within or adjoining the tidal zone;
- Areas that are tributary to channel segments that have been hardened on all three sides and/or culverted continuously downstream to their outfall to low-gradient bayside areas or Pacific Ocean; and/or
- Highly developed areas with potential for infill projects.

The exempt areas tend to be **heavily developed areas of the bayside**, while the more open and residential hillside, and coastside areas are subject to the HMP. Four municipalities -- East Palo Alto, Foster City, Daly City, and Colma – are totally exempt, while all of the other municipalities have at least portions of their jurisdictions subject to the HMP.

Before they can be implemented, key provisions of the Program’s HMP must be approved by the Water Board. Full implementation of the HMP will be required upon approval. Use this link, [www.flowstobay.org/pdfs/New%20Development/HMP%20Report%20Final.pdf](http://www.flowstobay.org/pdfs/New%20Development/HMP%20Report%20Final.pdf), to access the HMP on the Internet.

## 7.4 Determining Applicability



Unless it is listed as exempt in Table 7-1, your project will be required to comply with the HMP if it meets the following applicability criteria:

- The project creates one acre or more of new impervious surface.
- The project is not located in an exempt area, as shown on the HMP’s map of exempt areas (included in Appendix J).

If your project will create one acre or more of impervious surface, the local municipality will use the map in Appendix J to determine whether it will need to comply with the HMP requirements. Specific types of projects are also exempt from the HMP requirements, as listed in Table 7-1. Please note that projects located in areas subject to the HMP should include appropriate integrated management practices (IMPs) for hydromodification management if they are likely to cause hydrograph changes, **even if they do not meet the other applicability criteria.**

<b>Table 7-1 Projects Exempt from HMP Requirements</b>	
1	The construction of a single-family residence that is not part of a larger plan of development (NOTE: the permit requires the project to use pollutant source control, site design, and landscaping to treat stormwater runoff from impervious surfaces.)
2	A redevelopment project that does not increase the amount of impervious surface and the time

<b>Table 7-1 Projects Exempt from HMP Requirements</b>	
	of concentration of stormwater runoff (NOTE: these projects should use appropriate integrated management practices (IMPs) to prevent the volume of runoff and time of concentration from increasing compared with the pre-project condition.)
3	A transit type of development within ¼ to ½ mile of a transit station and/or intermodal facility
4	A project within a “Redevelopment Project Area” that redevelops an existing brownfield site or creates housing units affordable to persons of low or moderate income.

## 7.5 How to Implement HMP Requirements

Projects subject to HMP requirements need to consider HM at every stage of project development, following the step-by-step instructions for C.3 submittals in Chapter 3. The most effective use of land and resources may require a combination of IMPs, flow duration control facilities and in-creek measures, which are described in Section 7.2. In general, the strategy for designing HM measures should:

- **Start with site design** to minimize the amount of runoff to be managed (see Chapter 4).
- Where possible, **maximize infiltration** to further reduce detention requirements. Note that infiltration is limited by site constraints such as slope stability concerns, low-permeability soils or groundwater protection constraints.
- Use **flow duration controls** to detain the remaining calculated runoff from the site enough to **control its release** in a way that meets the remaining runoff design requirements. This may be accomplished with a measure that also provides volume-based treatment, such as an extended detention basin. For some project locations, off-site options may be available to reduce or eliminate the need for onsite detention.

### 7.5.1 Flow Duration Control

Flow Duration Control (FDC) differs from traditional “design storm” approaches used to design detention facilities for flood control or water quality treatment. Instead of specifying static holding times for one or a few discrete events, the Flow Duration standard manages runoff discharge over the full range of runoff flow levels predicted through continuous hydrologic simulation modeling, based on a long-term precipitation record. Flow Duration Control requires that the increase in surface runoff resulting from new impervious surfaces be **retained on-site with gradual discharge** either to groundwater through infiltration, losses by evapotranspiration, and/or discharge to the downstream watercourse at a level below the critical flow that causes creek channel erosion. **Critical flow**, or  $Q_c$ , is the lower threshold of in-stream flows that contribute to sediment erosion and sediment

The duration of channel flows below the “**critical flow**” may be increased indefinitely without significant contribution to hydromodification impacts.

Key Point



transport or effective work. The duration of channel flows below  $Q_c$  may be increased indefinitely without significant contribution to hydromodification impacts.

### 7.5.2 Application of Flow Duration Control to Project Areas

The Flow Duration approach involves a continuous model that applies a time series of at least 20 years of rainfall records to a watershed area or project site to generate a simulated stormwater runoff record based on two sets of inputs, one representing future development and the other representing pre-project conditions. The 20-year precipitation record is the minimum length necessary to capture the range of runoff conditions that are cumulatively responsible for most of the erosion and sediment transport in the watershed, primarily flow levels that would recur at average intervals of 10 years or less in the pre-project condition. The design objective is to **preserve the pre-project cumulative frequency** distribution of flow durations and sizes under post-project flows. This is done with a combination of site design, infiltration and detention. Typically the post-project increase in surface runoff volume is routed through a **flow duration control basin** or other structure that detains a certain portion of the increased runoff and discharges it through a **specialized outlet structure** (see Figure 7-4).

The flow duration basin, tank or vault is designed conceptually to incorporate multiple pools that are filled with different frequencies and discharge at different rates. The low-flow pool is the bottom level designed to capture and retain small to moderate size storms, the initial portions of larger storms, and dry weather flows. These flows are discharged through the lowest orifice which allows continuous **discharge below the critical flow rate** for a project ( $Q_{cp}$ ). Successively higher-flow pools store and release higher but less frequent flows through other orifices or graded weir notches to approximate the pre-project runoff durations. In practice the multiple pools are usually integrated into a single detention basin, tank or vault that works as a unit with the specialized outlet structure. Matching the pre-project flow durations is achieved through fine-tuning of the number, heights and dimensions of orifices or weir notches, as well as depth and volume of the basin, tank or vault.

As shown in the example chart of Figure 7-4, the post-project flow duration curve (red, or dark line) is reduced by the facility to remain **at or below the pre-project curve** (yellow, or light line), except for flows less than  $Q_{cp}$ . Minor exceedances are permissible at a limited number of higher flows since at other flow levels the post-project duration is actually less than the pre-project condition.

Flow Duration facilities are subject to **Operations and Maintenance** reporting and verification requirements similar to those for numerically sized treatment measures.

Try this!



If feasible, **combining flow duration and water quality treatment** into a single facility reduces the overall land requirements for stormwater management. Adequate maintenance of the low-flow orifice or notch is critical to proper performance. The outlet may be in a protective enclosure to reduce risk of clogging. Please note that Flow Duration facilities are subject to Operations and Maintenance verification requirements similar to those for numerically sized treatment measures.

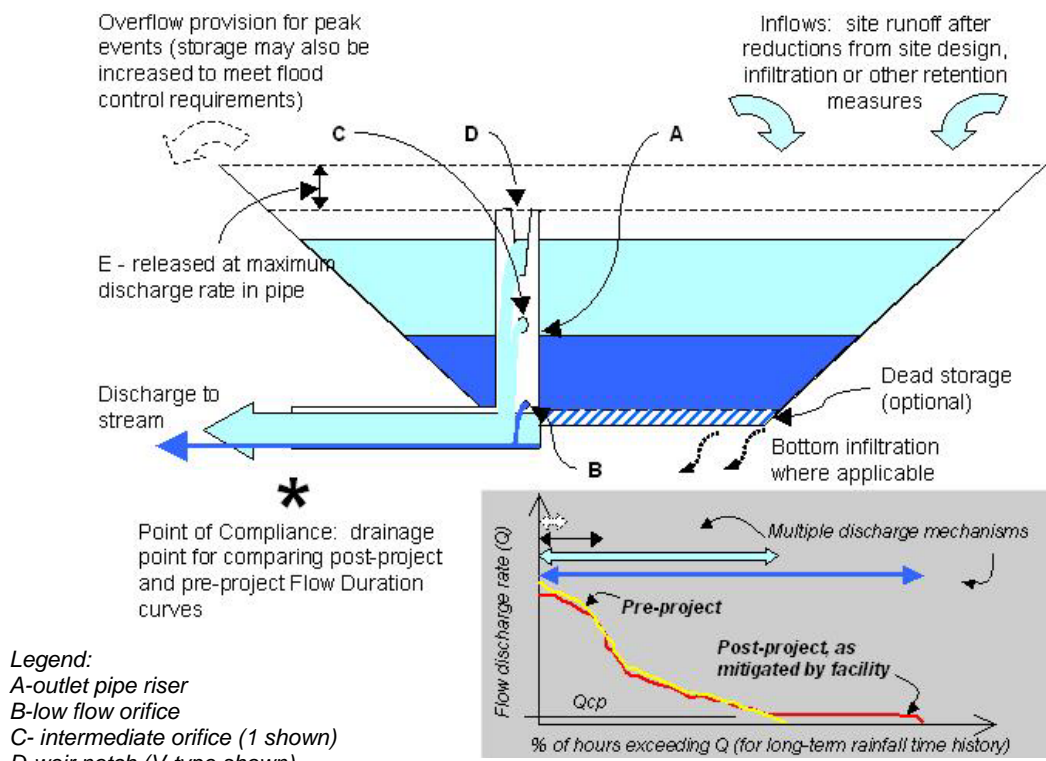


Figure 7-4: Schematic flow duration pond and flow duration curves matched by varying discharge rates according to detained volume. (Source: ACCWP, 2006)

### 7.5.3 Bay Area Hydrology Model (BAHM)

To facilitate the simulation modeling aspect of FDC for project applicants and their engineers, the Countywide Program collaborated with the Santa Clara and Alameda counties' stormwater programs to develop a Bay Area Hydrology Model **software package** that is adapted from Version 3 of the Western Washington Hydrology Model (WWHM) developed by Clear Creek Solutions for the State of Washington Department of Ecology (WDOE). The WWHM was specifically developed to help engineers design facilities to meet a Flow Duration Control standard for development projects.



The BAHM, which may be downloaded from the Program's website together with county-specific data, includes:

- Databases to automatically assign default **rainfall conditions** for a project location selected within the County boundary.
- A user interface for developing a **schematic drainage model** of the project site, with forms for entering areas of land use or impervious surface for multiple sub-basins.

- Continuous simulation modeling of **pre-project and post-project runoff** from the site using actual long-term rainfall records appropriately scaled for the project location.
- A design module for sizing a **FDC detention facility** and designing the discharge structure to meet the Flow Duration standard for matching post-project and pre-project duration-frequency curves. Pre-project and post-project runoff are compared at a “point of compliance” selected by the designer, usually near the point where runoff leaves the project area.
- Options to check facility sizing for **volume-based treatment**, and incorporate runoff reductions attributable to some common hydrologic source control measures.
- Standardized output **report files** that can be saved in Word format, and include all information about data inputs, model runs, facility design, and summary of the hydrological statistics showing the compliance of post-project flow duration curves with the Flow Duration standard. Project input and output data can also be saved in Excel and other formats for other uses.

## 7.6 Area-Specific HM Provisions



Individual municipalities may have special policies or ordinances for creek protection applicable in all or part of their jurisdictions. **Contact the municipal staff from your jurisdiction** to identify any special local provisions that may encourage or affect specific forms of HM implementation. Examples of area-specific HM provisions can include:

- Watershed-based land-use planning measures, such as creek buffers, which may be incorporated in local General Plans, zoning codes or watercourse ordinances.
- Special permitting provisions for project design and review of projects on streamside properties.
- Specific plans for regional HM measures or in-stream restoration projects.
- Any Equivalent Limitation Protocols that may be proposed, in accordance with Provision C.3.f.vii of the municipal stormwater permit, as alternatives to the default HM requirements in specific jurisdictions or watersheds.

Individual municipalities may have special policies or ordinances for **creek protection** applicable in all or part of their jurisdictions.