Chapter

7

Hydromodification Management Measures

This Chapter summarizes the requirements for controlling erosive flows from development projects.

7.1 Why Require Hydromodification Management?

Changes in the timing and volume of runoff from a site are known as “hydrograph modification” or “hydromodification”. When a site is developed, much of the rainwater can no longer infiltrate into the soils, so it flows offsite at ***faster rates and greater volumes***. As a result, erosive levels of flow occur more frequently and for longer periods of time in creeks and channels downstream of the project. Hydrograph modification is illustrated in Figure 7-1, which shows the stormwater peak discharges after rainstorms in an urban watershed (the red, or dark, line) and a less developed (the yellow, or light, line). The axes indicate the volume of water discharged, and the time over which it is discharged.

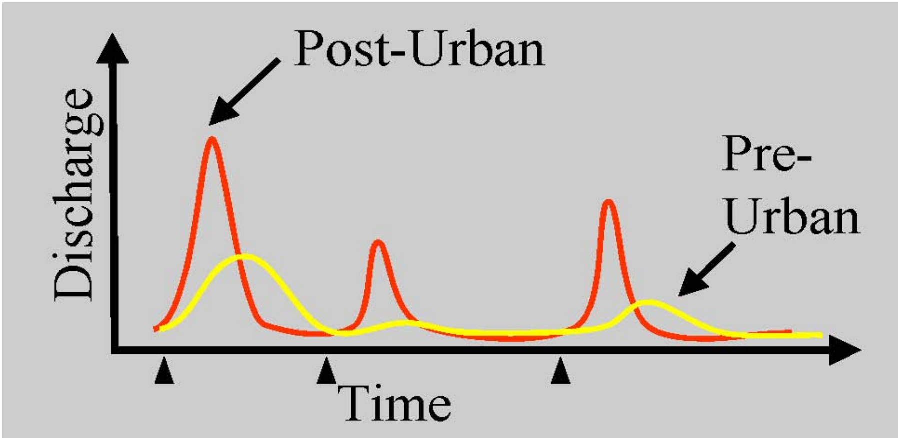


Figure 7-1: Stormwater Peak Discharges in Urban (Red) and Less Developed (Yellow) Watersheds (Source: NEMO-California Partnership, No Date)

In watersheds with large amounts of impervious surface, the larger volumes and faster rates of flow, with extended durations of flows that cause erosion, 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.

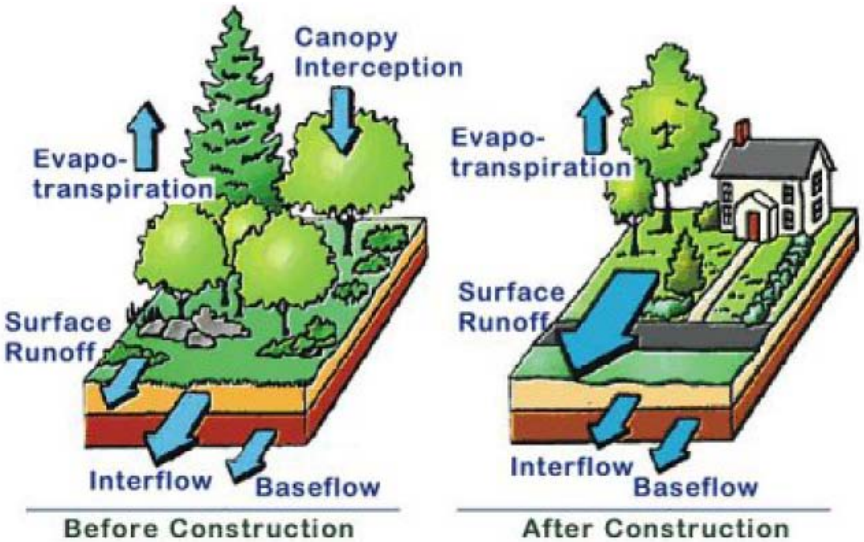


Figure 7-2: Effects of Urbanization on the Local Hydrologic Cycle (Source: 2000 Maryland Stormwater Design Manual)

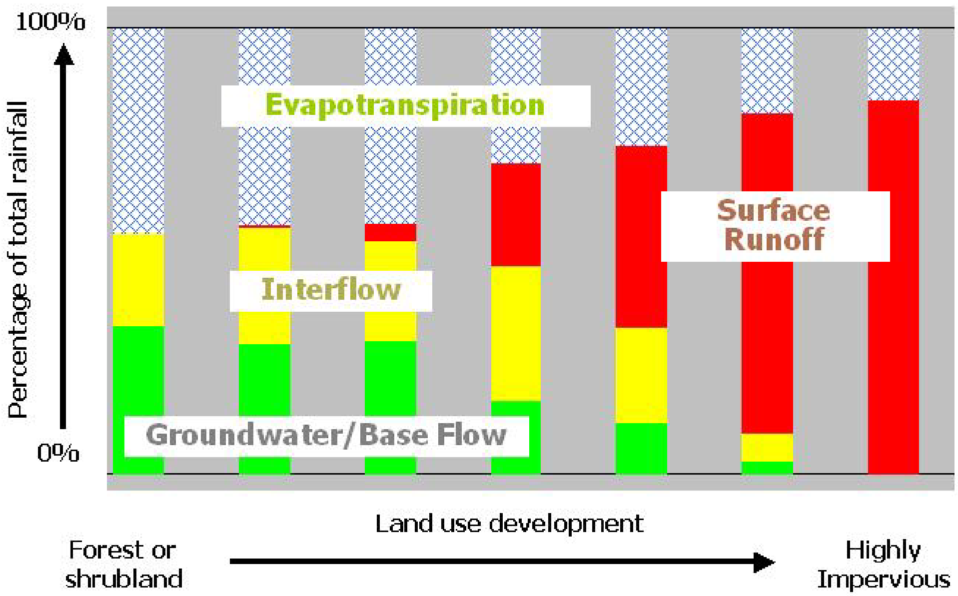


Figure 7-3. Variation in rainfall contribution to different components of the hydrological cycle for areas with different intensity of urban development. (Chart used by permission of Clear Creek Solutions.)

Since 2007, hydromodification management (HM) techniques have been required in areas across the San Francisco Bay Area that are susceptible to hydromodification. These techniques focus on ***retaining, detaining or infiltrating runoff*** and matching post-project flows and durations to pre-project patterns for a specified range of smaller, more frequent rain events, to prevent increases in channel erosion downstream. Within Alameda County, a simple map-based approach is used to determine which parts of the drainage network are susceptible to hydromodification impacts. Projects that meet certain criteria, and from which runoff passes through the susceptible areas, are be required to incorporate one or more HM measures in the design in order to reduce erosive flows from a wide range of runoff conditions.

> Hydromodification management (HM) techniques focus on ***retaining, detaining or infiltrating runoff.***

7.2 Which Projects Need to Implement HM?

Unless it is a single family home that is not part of a larger of development, your project will be required to comply with the HM requirements if it meets the following applicability criteria:

- The project ***creates and/or replaces one acre or more of impervious surface***,
- The project ***will increase impervious surface*** over pre-project conditions, AND
- The project is ***located in a susceptible area***, as shown on the default susceptibility map.

Appendix I shows a schematic view of a portion of the hydromodification susceptibility map. The full map may be downloaded from the Clean Water Program website in an interactive format that enables zooming to a closer view of the project vicinity with local streets. The requirements do not apply to projects that drain directly to the bay or tidal channels nor to projects that drain into channel segments that have been hardened on three sides and/or are contained in culverts continuously downstream to their outfall in a tidal area. Note that project sites draining to earthen flood control channels are not automatically exempt from HM requirements.

For guidance on whether it is necessary to implement controls, see the following description of the color coding used in the countywide map.

- **Solid pink areas** – Pink designates hilly areas with high slopes (greater than 25 percent). The HM Standard and all associated requirements apply in areas shown in solid pink on the map. In this area, the HM Standard does *not* apply if a project proponent demonstrates that all project runoff will flow through enclosed storm drains, existing concrete culverts, or fully hardened (with bed and banks continuously concrete-lined) channels to the tidal area shown in light gray.
- **Purple/red hatched areas** – These are upstream of areas where hydromodification impacts are of concern because of factors such as bank instability, sensitive habitat, or restoration projects. The HM Standard and all associated requirements apply in areas shown in purple/red (printer-dependent) hatch marking on the map. Projects in these areas may be subject to additional agency reviews related to hydrologic, habitat or other watershed-specific concerns.

- **Solid white areas** – Solid white designates the land area between the hills and the tidal zone. The HM Standard and all associated requirements apply to projects in solid white areas *unless* a project proponent demonstrates that all project runoff will flow through fully hardened channels. Short segments of engineered earthen channels (length less than 10 times the maximum width of trapezoidal cross-section) can be considered resistant to erosion if located downstream of a concrete channel of similar or greater length and comparable cross-sectional dimensions. Plans to restore a hardened channel may affect the HM Standard applicability in this area.
- **Solid gray areas** – Solid gray designates areas where streams or channels are tidally influenced or primarily depositional near their outfall in San Francisco Bay. The HM Standard does not apply to projects in this area. Plans to restore a hardened channel may affect the HM Standard applicability in this area.
- **Dark gray, *Eastern County* area** – Dark gray designates the portion of eastern Alameda County that lies outside the discharge area of this NPDES permit. This area is in the Central Valley Regional Water Quality Control Board's jurisdiction.

Please note that projects located in susceptible areas are encouraged to include hydrologic source control measures for HM if they are likely to cause hydrograph changes, ***even if they create and/or replace less than one acre of impervious surface.***

7.3 Hydromodification Management (HM) Measures

Provision C.3.g.iv identifies three types of hydromodification management (HM) measures: on-site controls, regional controls, and in-stream measures, as described below.

- ***Onsite HM controls*** consist of hydrologic source controls (site design measures), LID features and facilities, flow duration control structures, which collectively prevent increases in runoff flow and volume, to meet the HM Standard described in Section 7.4 at the point(s) where stormwater runoff discharges from the project site.
  - ***On-site hydrologic source control measures***, which are generally distributed throughout a project site as site design measures, minimize hydrological changes caused by development beginning with the point where rainfall initially meets the ground. Examples include minimizing impervious area, disconnecting roof leaders and providing localized detention – which also helps reduce stormwater pollution.
  - ***On-site LID features and facilities,*** which are generally included in order to meet stormwater treatment requirements described in Provisions C.3.c and C.3.d, also contribute to hydromodification management by infiltrating and detaining runoff.

Figure 7-4: Draining roof runoff to a landscaped area is an example of hydrologic source control.

- ***On-site structural HM measures*** manage excess runoff from the site after hydrologic source control measures are applied. These ***"end-of-pipe" measures*** mitigate the effects of hydrograph changes. Stormwater is temporarily detained, and then the runoff is gradually discharged to a natural channel at a rate calculated to avoid 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 HM measures 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. Structural HM measures must be sized for ***flow duration control for frequent, small runoff events*** (with average occurrence ranging from less than two-years to approximately ten-years). The structural HM measures are 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.

- ***Regional HM controls*** are flow duration control structures that collect stormwater runoff discharge from multiple projects (each of which shall incorporate hydrologic source control measures as well) and are designed such that the HM Standard described in Section 7.4 is met for all the projects at the point where the regional HM control discharges.

- ***In-stream measures*** are an option only where the stream, which receives runoff from the project, is already impacted by erosive flows and shows evidence of excessive sediment, erosion, deposition, or is a hardened channel. ***In-stream measures involve modifying the receiving stream channel slope and geometry*** so that the stream can convey the new flow regime without increasing the potential for erosion and aggradation. In-stream measures are intended to improve long-term channel stability and prevent erosion by reducing the erosive forces imposed on the channel boundary.

  In-stream measures, or a combination of in-stream and onsite controls, are designed to achieve the HM Standard described in Section 7.4 from the point where the project(s) discharge(s) to the stream to the mouth of the stream or to achieve an equivalent degree of flow control mitigation (based on amount of impervious surface mitigated) as part of an in-stream project located in the same watershed. ***Designing in-stream controls requires a hydrologic and geomorphic evaluation*** (including a longitudinal profile) of the stream system downstream and upstream of the project. Examples of in-stream measures 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 on-site measures. As with all in-stream activities, other regulatory permits must be obtained by the project proponent.

> Structural HM measures must be 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.

7.4 Requirements for Hydromodification Management

7.4.1 Meeting the HM Standard

The HM Standard specified in Provision C.3.g.ii requires that storm water discharges from ***HM projects shall not cause an increase in the erosion potential of the receiving stream*** over the pre-project (existing) condition. HM controls shall be designed such that post-project stormwater discharge rates and durations match pre-project discharge rates and durations from 10 percent of the pre-project two-year peak flow up to the pre-project 10-year peak flow. HM controls designed using the Bay Area Hydrology Model (BAHM) and site-specific input data shall be considered to meet the HM Standard.

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. For projects subject to HM requirements, ***consider HM at every stage of project development*** and incorporate the step-by-step instructions for C.3 submittals, provided in Chapter 3. The most effective use of land and resources may require combining measures from all three categories described above. In general, the strategy for designing HM measures should :

- ***Start with site design*** to minimize the amount of runoff to be managed (see Planning Steps 2 & 3 in Chapter 3).
- Where possible, ***maximize infiltration*** to further reduce detention requirements, using hydrologic source controls (site design measures) and LID features and facilities. Note that infiltration is limited by site constraints such as slope stability concerns, low-permeability soils or groundwater protection constraints.
- Use ***structural HM measures*** to detain the remaining calculated runoff from the site enough to ***control its release*** in a way that meets the remaining runoff design requirements. For some project locations, off-site options may be available to reduce or eliminate the need for onsite detention.

7.4.2 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 Qc***,*** is the lower threshold of in-stream flows that contribute to sediment erosion and sediment transport or effective work. The duration of channel flows below Qc may be increased indefinitely without significant contribution to hydromodification impacts.

7.4.3 Application of Flow Duration Control to Project Areas

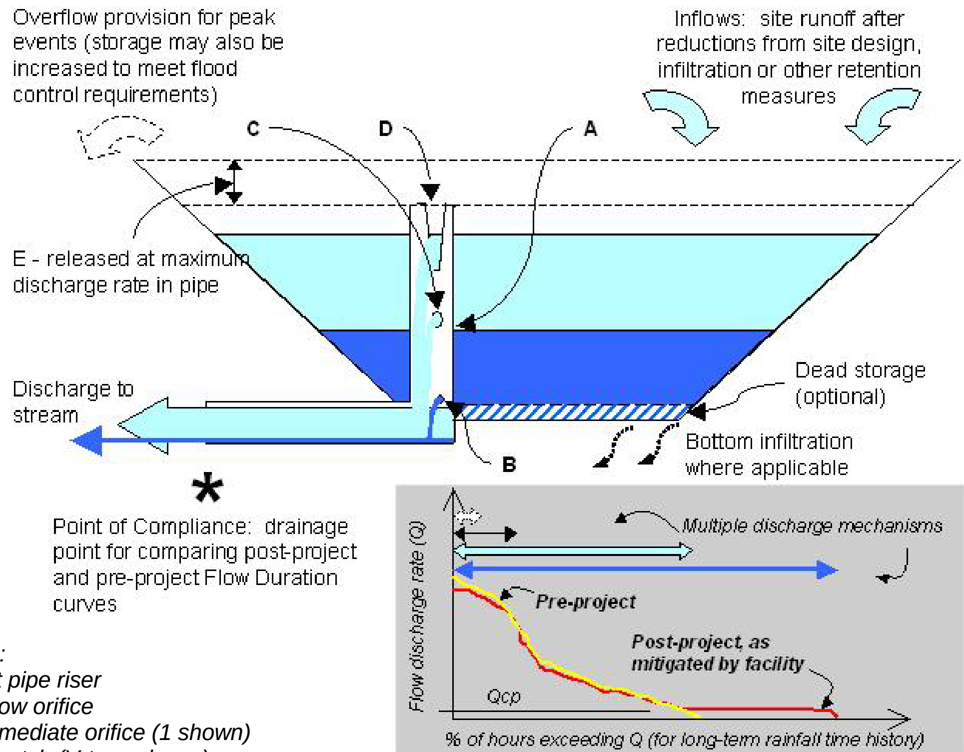
The Flow Duration approach involves a continuous model that applies a time series of at least 20 years of rainfall records to a watershed area or project site to generate a simulated stormwater runoff record based on two sets of inputs, one representing future development and the other representing pre-project 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 pond*** 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 duration of channel flows below the ***"critical flow"*** may be increased indefinitely without significant contribution to hydromodification impacts.

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 (Qcp). 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 7-5, 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 Qcp. 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 control facilities are subject to ***Operations and Maintenance*** reporting and verification requirements similar to those for numerically sized treatment measures.



Legend:
A-outlet pipe riser
B-low flow orifice
C- intermediate orifice (1 shown)
D-weir notch (V-type shown)
E-freeboard above riser (typically 1 foot)

Figure 7-5: *Schematic flow duration pond and flow duration curves matched by varying discharge rates according to detained volume.*

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 Control (FDC) facilities are subject to Operations and Maintenance verification requirements similar to those for numerically sized treatment measures.

7.4.4 Bay Area Hydrology Model (BAHM)

To facilitate the simulation modeling aspect of FDC for project proponents and their engineers, the Clean Water Program collaborated with the Santa Clara and San Mateo 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 is available for downloading at www.bayareahydrologymodel.com, and it 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.
- 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.

Training courses on using the BAHM are offered periodically. For more information, please visit www.bayareahydrologymodel.com.

7.5 HM Control Submittals for Review

Determine the potential applicability of the HM requirements to the proposed project, using the guidelines in Section 7.2, the applicability map shown in Appendix I, and the City-specific Stormwater Requirements Form (available from municipal staff). Then prepare an HM Control Plan as part of the project's Provision C.3. submittal.

Table 7-1 provides a model checklist of submittal requirements for the HM Control Plan. Information on site design and LID treatment measures should also be included, if they are part of the HM Control Plan, and any modeling analyses. Check with the local jurisdiction to determine the specific requirements for your project.

Table 7-1: HM Control Plan Checklist		
Required?*		
Yes	No	**Information on Plan Sheets**
❑	❑	Soil types and depth to groundwater
❑	❑	Existing and proposed site drainage plan and grades
❑	❑	Drainage Management Area (DMA) boundaries
❑	❑	Amount of existing pervious and impervious areas (for total site and each DMA)
❑	❑	Amount of proposed impervious area (for total site and each DMA)
❑	❑	Amount of proposed pervious area (for total site and each DMA)
❑	❑	Proposed site design measures to minimize impervious surfaces and promote infiltration**
❑	❑	Proposed locations and sizes of stormwater treatment measures and HM measures
❑	❑	Stormwater treatment measure and HM measure details
		Information on Modeling Analysis and HM Facility Sizing
❑	❑	BAHM Report with input and output data and additional files as required by municipality
❑	❑	If different model is used, description of model, input and output data
❑	❑	Description of how site is represented in the model, what is proposed and why
❑	❑	Description of any changes to standard parameters (e.g. scaling factor, duration criteria)
❑	❑	Comparison of HM facility sizing per model results vs. details on plan
❑	❑	Description of any unique hydraulic conditions due to HM facility location
❑	❑	Description of orifice/weir sizing, outlet protection measures, and drawdown time
❑	❑	Preliminary maintenance plan for HM facility

* Municipal staff may check the boxes in the “Required” column to indicate which items are required for your project.

** Site design, treatment and HM measures that promote infiltration should be designed consistent with the recommendations of the project geotechnical engineer.

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:

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

- 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.