

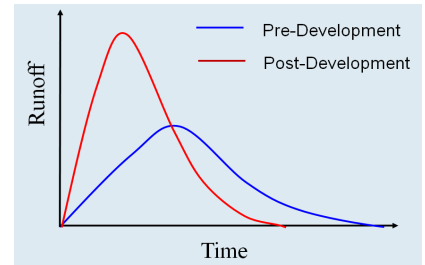


HYDROMODIFICATION

Principles, Problems, and Solutions



As watersheds urbanize, soil is compacted and covered with hardscape such as buildings and roads, known as **impervious cover**. This can cause an alteration of flow (**hydromodification**) that increases the volume of runoff and decreases the infiltration of rainwater, an important source of groundwater recharge. **Figure 1** shows stormwater discharges in an urban watershed (red line) and a pre-urban watershed (blue line). The greater volume and increased rate of flow that are associated with urbanization results in degradation of aquatic habitat and increased flood risk. This factsheet presents an overview of hydromodification and possible approaches to preventing and mitigating its effects.



Effects of Hydromodification on the Water Cycle

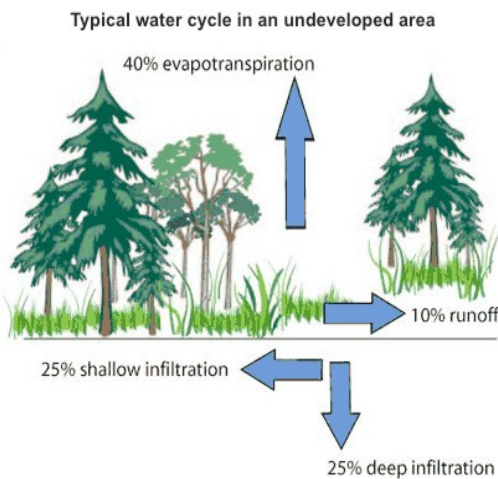


Figure 2a (left): Water balance on undeveloped land. With natural cover, more rain and snowmelt infiltrates into the ground and less ends up as runoff.

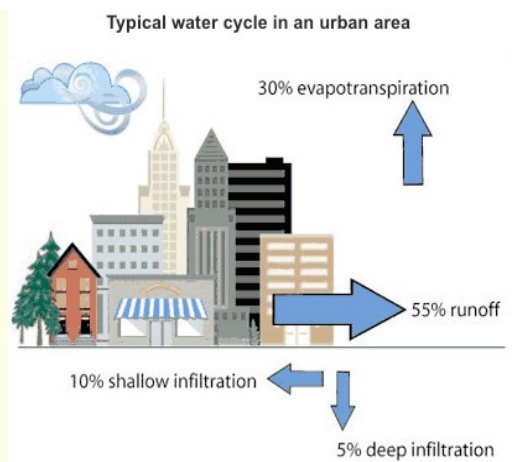


Figure 2b (right): Water balance on developed land. As urbanization increases, less water infiltrates and runoff increases, up to 5-fold. There is a loss in the volume of groundwater recharge and reduced evapotranspiration (the uptake of water from plants and soils).

How Hydromodification Shifts the Water-Sediment Balance

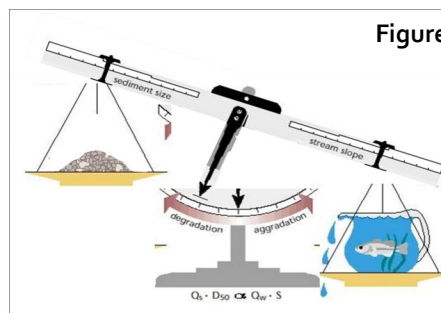
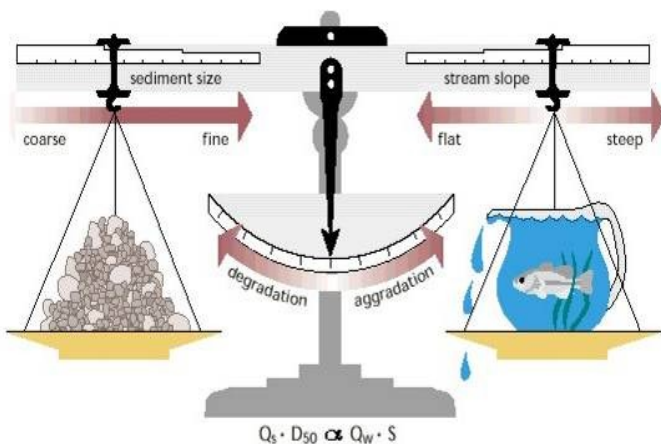


Figure 3b Effects of hydromodification. The combination of reduced sediment supply and increased flow rate, associated with urbanization, causes degradation of the stream beds and bank.

watershed characteristics. Urbanization alters this balance by paving over sediment source areas and increasing runoff volume. The excess runoff volume and flow rate applies significant force to channel beds and banks, causing erosion and bed scour. This alters the balance of water and sediment in the stream, causing an increase in the stream gradient (slope from mountains to ocean), as shown in **Figure 3b**. This can result in habitat changes which can be detrimental to aquatic organisms and plants, frequently decreasing biodiversity. For example, salmon in California need cold, clear water and spawning gravel to reproduce. When spawning gravel is filled with fine sediment, fish eggs and hatchlings are smothered, adversely affecting salmon populations. There are a variety of solutions for reducing hydromodification and minimizing its impacts, described in the next section of this factsheet.

Solution #1: Low Impact Development (LID)

LID is an alternative method of land development that seeks to maintain and mimic the natural hydrologic processes by infiltrating, retaining, and slowly releasing stormwater on a site by site basis. LID often begins with careful site planning that considers the location of natural features and incorporates them into the stormwater management plan whenever possible. This may include retaining a wide riparian corridor to allow for natural stream processes, identifying and preserving areas with coarse sediment, protecting locations suitable for groundwater recharge, and considering soil permeability and slope when siting bioretention areas. This approach is generally known as **natural resource-based planning**. By taking advantage of nature's plumbing, infiltration capacity can be optimized.

LID is about source control: keeping water where it falls, rather than funneling it through pipes or channels that drain into local waterways. These techniques foster natural hydrologic processes and reduce the volume of runoff. Implementing these techniques can minimize the changes in the hydrological cycle that lead to erosion and degradation of aquatic habitat.

LID Applications

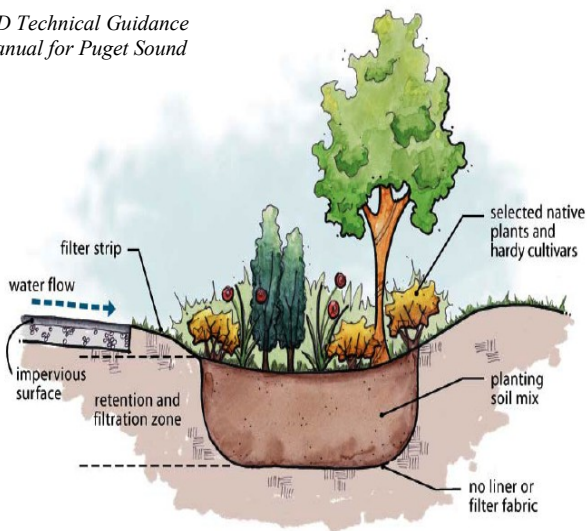


LID methods are especially cost effective in parking lots because pavement of one type or another makes up a significant percent of impervious areas in cities. **Interlocking concrete pavers** (left) allow water to infiltrate at the joints, while **perVIOUS concrete or asphalt** (right) is made without sand, creating voids that promote infiltration.



Bioretention areas are small-scale facilities designed to promote infiltration/retention, and are incorporated into a site design most effectively when integrated with other LID techniques. A **rain garden** (below) is a planted depression that contains amended soil and drought-tolerant vegetation.

*LID Technical Guidance
Manual for Puget Sound*



Rain gardens are designed to handle most smaller storm events. If native soils are not amended and have a high percentage of clay, an under-drain or dry well could be placed under the garden to promote infiltration. Rain gardens can be used in a variety of commercial, residential and municipal settings (see right).



Curb cuts (right) permit water from parking lots and roads to enter the bioretention area where it is retained and infiltrated instead of ending up as runoff in a storm drain system. This helps to keep pollutants such as oil and heavy metals like copper and zinc (products of tire and brakepad wear) out of local waterways.

Solution #2: Instream Restoration Practices

Instream restoration practices (IRPs) modify the banks and beds of waterways using natural materials to return the stream to a less impacted condition and improves aquatic habitat. IRPs can affect two of the variables associated with hydromodification: the increased quantity of fine sediment (small particle size) and the increased slope (gradient) of streams and rivers (see Fig. 3b). IRPs contrast with conventional methods such as retaining walls and riprap, which damage aquatic habitat and often fail over time. All waterways are unique, constantly evolving, and change in response to urbanization, so it's important to use restoration techniques best suited to the condition of the particular waterway.

Solutions for Bank Erosion

Bank erosion is a natural process, but is accelerated by the effects of hydromodification, which can have multiple negative effects on the aquatic ecosystem and riparian habitat. Intense stormwater flows associated with compacted soil and impervious cover are a major contributor to bank erosion. The rate of erosion varies, depending on existing vegetation type and location, soil composition, and the frequency and intensity of flows. Multiple methods are available to address this problem, including **live stakes** (LS) and **brush mattresses**. LS (left) involves installation of live, woody cuttings into the bank that permits trees to grow and anchor the soil, and provides riparian habitat. Brush mattresses (right) are a thick mat of branches placed on the bank and held down with stakes. They provide a foundation that, over time, roots into and anchors the bank. A modification of LS are **joint plantings** (JP), which are live stakes that are pounded into the openings in riprap. These techniques are low in cost and complexity but reduce erosion and offer multiple ecological benefits.



Live stakes offer protection from shear stress and also allow the stream to adjust to change naturally.

Brush mattresses (right) are a thick mat of branches placed on the bank and held down with stakes. They provide a foundation that, over time, roots into and anchors the bank. A modification of LS are **joint plantings** (JP), which are live stakes that are pounded into the openings in riprap. These techniques are low in cost and complexity but reduce erosion and offer multiple ecological benefits.

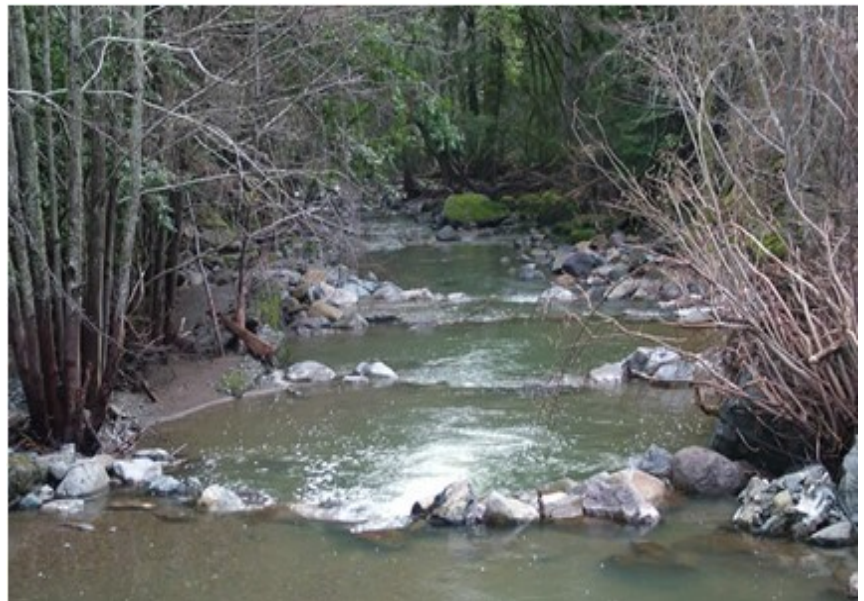


Brush mattress branches are laid perpendicular to water flow, then anchored with stakes and twine.

Pictures: J. Turek, NOAA (left), Urban Creeks Council (right)

Solutions for Bed Scour

Channel bed scour refers to the erosion of the beds of streams and rivers. Like bank erosion, scour can be detrimental to the aquatic ecosystem, and varies depending on local geology (sand vs. less erodible clay and bedrock), sediment size, slope, and the rate of flow. One method to reduce scour is the installation of rock weirs, which span a stream in a variety of patterns. They function to reduce high flows and to maintain a low flow channel. Unlike a dam, rock weirs have depressions that permit the movement of sediment, which helps to maintain the water-sediment balance. A variation of rock weirs are step pools, which are a series of boulders constructed along a stream (see inset) to form pools that ultimately slow water flow, reduce scour, and reduce gradient changes, resulting in improved aquatic habitat. Another way to reduce bed scour is to remove undersized culverts, which increase erosive forces and inhibit fish from migration.



Step pool application along a stream. Riffles are produced from partly submerged boulders, where water moves rapidly. Riffles provide habitat for aquatic insects and spawning sites for many fish. Slow-moving, deep water is found in pools, where fish can find shelter.

Solution #3: Flow Duration Control Basins

Flow duration control (FDC) basins are another technique that effectively manage flow-related impacts caused by hydromodification. FDC basins are designed to capture and reduce the difference in pre- and post- development runoff volumes, in an effort to mimic pre-project flow conditions. They retain excess urban runoff, preventing erosive flows (flow rates that cause erosion). Stormwater initially fills in zone 'A', where it can infiltrate or be released at a non-erosive rate through small outlet pipes (see Figure 4). If the basin continues to fill, water will rise to zone 'B', where it may be discharged through a weir or evaporates. FDC basins differ from traditional detention/retention basins in that zone 'A' is larger to permit it to release water at slower, non-erosive flow rate. A limitation for all types of basins is that they trap sediment and can potentially contribute to the water-sediment imbalance.

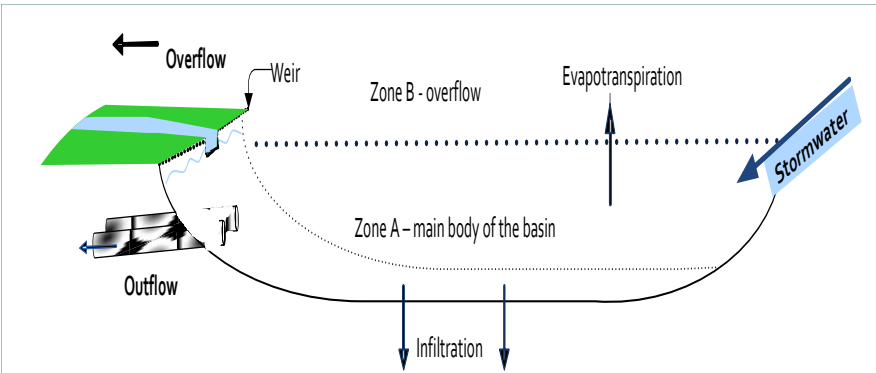


Figure 4

Figure 4. An FDC basin. Water enters the FDC basin and can exit via infiltration, evaporation, or discharge. If the water volume is smaller than the capacity of zone 'A', it can flow through small outlet pipes designed to release water at a non-erosive rate. If the volume is larger, it spills over the weir into a channel that moves water to the main waterway.

Source: Gary Palhegyi, Entrix

Conclusion

The techniques summarized in this factsheet provide measures to avoid, minimize, and mitigate the impacts of hydromodification. In the majority of cases, the best step is to consider the natural resources on and near the site, including the condition of local waterways. Hydromodification can often be reduced with thoughtful planning and the use of LID techniques. LID is usually the simplest approach to implement as well. If these changes can't be avoided, additional solutions can be used, including flow duration control basins and instream restoration. When new development occurs at sites near streams that have already been degraded, more emphasis on stream restoration should be considered. The following table summarizes one way to think of managing hydromodification:

| Management Goal | Approach (listed by priority) |
|-----------------------------------|---|
| Avoid | Natural-resource based planning, source control (LID) |
| Minimize | LID, FDC basins, instream restoration |
| Mitigate / prevent further damage | Instream restoration, LID, FDC basins |

More Information

The Low Impact Development Center
 Stormwater Manager's Resource Center
 The Center for Watershed Protection
 National NEMO Network
 Sacramento County Rain Gardens
 Federal Interagency Stream Corridor Restoration Manual
 Fluvial Geomorphology Training Module
 Stormwater Program, SWRCB

www.lowimpactdevelopment.org
www.stormwatercenter.net
www.cwp.org
www.nemonet.uconn.edu
www.riverfriendly.org/raingardens
www.nrcs.usda.gov/technical/stream_restoration
www.fgmorph.com
www.waterboards.ca.gov/water_issues/programs/stormwater

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