Low Impact Development (LID)

A Sensible Approach to Land Development and Stormwater Management

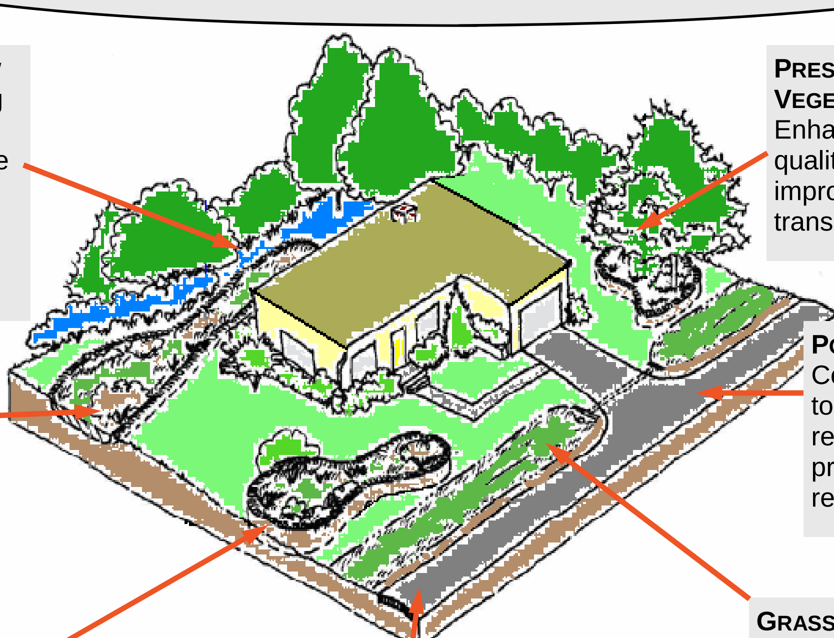
CALIFORNIA WATER & LAND USE PARTNERSHIP

An educational program for land use decision makers that addresses the relationship between land use and natural resource protection.

What is Low Impact Development (LID)?

LID is an alternative method of land development that seeks to maintain the natural hydrologic character of the site or region. The natural hydrology, or movement of water through a watershed, is shaped over centuries under location-specific conditions to form a balanced and efficient system. When hardened surfaces such as roads, parking lots, and rooftops are constructed, the movement of water is altered; in particular, the amount of runoff increases and infiltration decreases. This results in increased peak flow rate and volume, and pollution levels in stormwater runoff. LID designs with nature in mind: working with the natural landscape and hydrology to minimize these changes. LID accomplishes this through source control, retaining more water on the site where it falls, rather than using traditional methods of funneling water via pipes into local waterways. Both improved site design and specific management measures are utilized in LID designs. LID has been applied to government, residential, and commercial development and redevelopment, and has proven to be a cost-efficient and effective method for managing runoff and protecting the environment.

Using LID Tools in Residential Development



NATURAL DRAINAGE FLOW
Reduces need for grading and constructed drainage systems by building house in a location that permits preservation of natural pattern of stormwater drainage

PRESERVED NATIVE VEGETATION
Enhances the aesthetic quality of community and improves the evaporation-transpiration rate

BIORETENTION CELL OR RAIN GARDEN
Depressions that contain soil amendments that promote infiltration of stormwater

POROUS PAVEMENT
Concrete that allows rain to infiltrate, thereby reducing runoff and promoting groundwater recharge

AMENDED SOIL
Soil enriched with sand and organic materials increases the capacity of soil to infiltrate water

REDUCED HARDSCAPE
Narrower streets, sidewalks, and driveways increases pervious areas and open spaces

GRASSY SWALE
Vegetated channels that slow stormwater runoff and promotes infiltration, traps sediment, and helps treat pollutants

Diagram adapted from Prince George's County Maryland Low-Impact Development Design Strategies

Traditional vs. LID Stormwater Management

Historically, in the U.S., the motto for stormwater management has been **"conveyance:"** move water away from the site where it falls as quickly and efficiently as possible. Traditional management tools include street gutters and curbs, pipes, and canals to remove water from the developed areas. To receive this increased volume, creeks and rivers are re-shaped and lined with concrete. Detention ponds, some with water quality filtration devices, regulate discharge to reduce peak flow impacts on receiving waters. For the most part, these practices reduce flood impacts, but do not completely address water quality, and aquatic and riparian habitat degradation issues.

In contrast with the traditional approaches, the guiding principle of low impact development approaches is not conveyance; it is **"source control and infiltration"**. LID techniques seek to maximize the area available for infiltration so that runoff volume and pollutant concentrations are reduced. This is achieved through a variety of site design and engineered infiltration techniques. Site design techniques include locating open spaces in low-lying areas to serve as a detention/retention basin and avoid development on permeable soils to promote infiltration and groundwater recharge. Engineered techniques include the use of grassy swales, bioretention cells, and porous pavement.

LID Benefits

Water Quality
- Contributes to groundwater recharge through infiltration
- Improves surface water quality
- Protects stream and lake quality from large volumes of polluted runoff

Meets Clean Water Act Requirements
- Source control reduces the pollutant level and volume of runoff entering a water body, complying with National Pollutant Discharge Elimination System (NPDES) and anti-degradation policy;
- This also aids in complying with 401 certification requirements

Flood Control
- Reduces frequency & severity of floods
- Reduces peak flow volume & velocity

Habitat Protection
- Preserves stream & riparian habitats
- Preserves regional trees & vegetation
- Reduces eroded sediment loading into streams & lakes

Community Value
- Increases aesthetics and recreational opportunities in protected riparian habitats
- Increases land value by having a cleaner environment
- Increases public/private collaborative partnerships

LID Challenges

Lack of Information
- Many municipal planners, consultants and the general public are unfamiliar with the benefits of LID practices and how to utilize them in different environments.

Inflexible Regulations/Ordinances
- Existing rules often lack the flexibility to implement LID solutions

Maintenance
- Some LID tools require maintenance by homeowners and local public works departments to function properly

Presence of Contaminants
- Use of filtration practices can threaten groundwater quality if high levels of soil contaminants are present.

Stormdrain leading to bioretention cell

Roof runoff drains to grassy swale

www.main.nc.us/riverlink/content/12chap/chap12.htm

Economic Issues

The **economic benefits** of LID include:

- Reduced costs of stormwater infrastructure, including curbs and gutters
- Reduced stormwater utility fees
- Increased land value
- Decreased spending on current and future environmental conservation programs

Specific cost savings vary on a case by case basis. There can be **additional costs**:

- Higher installation costs for certain soil types and gradients
- Increased landscape maintenance costs

Issue	Savings
Higher Lot Value	$3000 more per lot
Lower Cost Per Lot	$4800 less cost per lot
Enhanced Marketability	80% of lots sold in first year
Added Amenities	23.5 acres of green-space/parks
Recognition	National, state, and professional
Total Economic Benefit	Over $2,200,000 added to profit

The above table, from **Gap Creek residential subdivision,** Sherwood, AR, illustrates the financial benefits of using LID methods. *Tyne & Associates, North Little Rock, AR*

Addressing LID Implementation Challenges

Solutions

Clay Soils/Limited Space

The combination of clay soils and small lot sizes can work well together. As clays are naturally less pervious, less engineering and land is required to achieve predevelopment infiltration rates. Use integrated stormwater management techniques, a combination of traditional and LID approaches. Significant stormwater runoff reduction can still be achieved.

Local Codes Aren't LID-friendly

Revise local codes & ordinances to support use of LID techniques. Check out the Center for Watershed Protection's website for suggested guidelines (www.cwp.org/COW_worksheet.htm).

Don't know what would work and where

Educate planning & public works staff. Numerous references are available on the use of LID in a variety of settings (see Online References).

Some communities that have found solutions

Hercules has modified stormwater management guidelines that fit LID principles, city codes that allow administrative approval for LID projects, and limited street lengths.

Contra Costa incorporated LID measures into their Standard Urban Stormwater Management Plan (SUSMP) for new development (http://www.cccleanwater.org/construction/nd.php). **Sacramento**, likewise, is publishing their own design manual in Fall, 2006 that includes LID measures.

San Diego has new parking standards for intensive commercial zones that include smaller parking spaces and driveways, plus new guidelines requiring reduced imperviousness for parking spaces.

Santa Monica encourages LID by requiring that all new developments and substantial remodels submit an "Urban Runoff Mitigation Plan", and reduce projected runoff for the site by 20%. The city recommends LID technologies.

LID as a Re-design Strategy

Retrofit a Parking Lot to increase permeability. Over sixty-five percent of impervious areas are associated with "habitat for cars". Using porous pavement in parking lots is a simple way to increase infiltration and reduce runoff. When the US Navy Yard in Washington, D.C. needed to repave its parking lot, they used porous pavers. They also added bioretention cells to the landscaped areas and disconnected downspouts. The re-design did not alter the amount of parking spots, but reduced peak runoff and pollution, thus protecting and helping to restore the Anacostia and Potomac Rivers and the Chesapeake Bay.

Porous pavement covers about 1/3 of each parking space in the D.C. Navy Yard parking

LID street design: vegetated swales, no curbs, and narrower streets promote infiltration of stormwater.

Alter street design to increase infiltration. In a landmark project in Seattle, the Street Edge Alternative or SEA project involved building vegetated swales, bioretention cells, and narrower streets without curbs to promote an effective drainage and filtration system. The system reduced peak runoff for the 2 year flood event by 98%, and is capable of conveying the 25 year flood event. The local watershed provides spawning habitat for endangered salmon. The project was so successful that similar ones are being planned throughout the city.

Replace lawns with rain gardens. Rain gardens are small bioretention cells landscaped with plants, trees, and grasses. They are a particularly good way for individual homeowners to enhance their landscaping while protecting water quality. By planting easy-care native wildflowers, hardy perennials and grasses, attractive gardens can be constructed that have the added environmental benefits. More information on rain gardens is available at: http://www.healthylandscapes.org/raingarden.htm. Information on plants compatible for use in a California rain garden is posted at: http://www.bbg.org/gar2/topics/design/2004sp_raingardens.html.

Rain garden in a small backyard that collects runoff from roof and patio.

LID as a Design Strategy

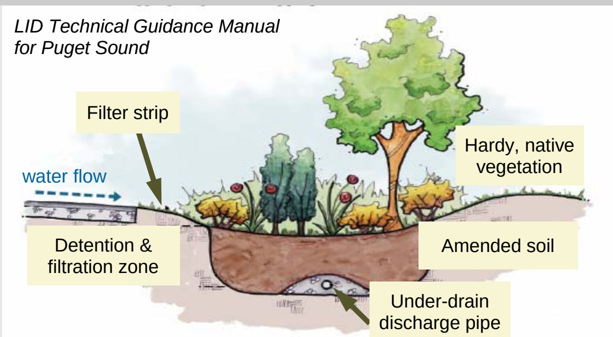
LID is more than a collection of engineered tools. It is a comprehensive design technique incorporating site planning and integrated management measures.
LID design principles include:

- Extensive site assessment of hydrology, topography, soils, vegetation and water features;
- Higher density, clustered housing, preserving open spaces to facilitate infiltration and protect habitats;
- Street layout that minimizes road length and width, calming traffic while allowing safe access of emergency vehicles.

LID Technical Guidance Manual for Puget Sound

In this example, LID design reduces imperviousness by changing the cul-de-sac design, reducing street width and lot size, and instead clustering houses around common green spaces that also serve as infiltration sites and preserving natural features.

Examples of LID



Basic Components of a Bioretention Cell
To see how to engineer bioretention cells with the proper gradient and components visit: www.lowimpactdevelopment.org/epa03/biospec.htm

Rain Gardens and grass swales between houses are used at Douglas Ranch, Granite Bay, CA to catch and filter runoff from roofs and driveways before entering a local stream.

Curb Cuts permit stormwater to flow into grassy swales to reduce roadway contaminants that flow into nearby waterways. They can also be used in *existing* landscaped areas.

Hollywood Driveways have a dividing strip of grass in order to reduce the amount of impervious surface. Another way to reduce driveway space is to share one with a neighbor.

Online Resources

Low Impact Development Center	www.lowimpactdevelopment.org
U.S. Environmental Protection Agency	www.epa.gov/owow/nps/urban.html
Stormwater Manager's Resource Center	www.stormwatercenter.net
National NEMO Network	www.nemonet.uconn.edu
LID Urban Design Tools	www.lid-stormwater.net
National Association of Home Builders	www.toolbase.org/index-toolbase.asp
California Stormwater Quality Association	www.cabmphandbooks.com

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CA WALUP is an educational program for land use decision makers addressing the relationship between land use and natural resource protection. The CA WALUP is a Charter Member of the National NEMO Network. CA WALUP website: http://cawalup.usc.edu

How Urbanization Affects the Water Cycle

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Why is the Water Cycle Important?

The water cycle, also known as the hydrological cycle, is the continuous exchange of water between land, waterbodies, and the atmosphere. Approximately 97% of the earth's water is stored in the oceans, and only a fraction of the remaining portion is usable freshwater. When precipitation falls over the land, it follows various routes. Some of it evaporates, returning to the atmosphere, some seeps into the ground, and the remainder becomes surface water, traveling to oceans and lakes by way of rivers and streams. Impervious surfaces associated with urbanization alter the natural amount of water that takes each route. The consequences of this change are a decrease in the volume of water that percolates into the ground, and a resulting increase in volume and decrease in quality of surface water. These hydrological changes have significant implications for the quantity of fresh, clean water that is available for use by humans, fish and wildlife [1].

Impervious Cover (IC):
all hard surfaces that do not allow water to penetrate the soil, such as rooftops, driveways, streets, swimming pools, and patios

MORE WATER FASTER

DEVELOPED LANDS
Rain pours more quickly off of city and suburban landscapes, which have high levels of impervious cover

NATURAL LANDS
Trees, brush, and soil help soak up rain and slow runoff in undeveloped landscapes

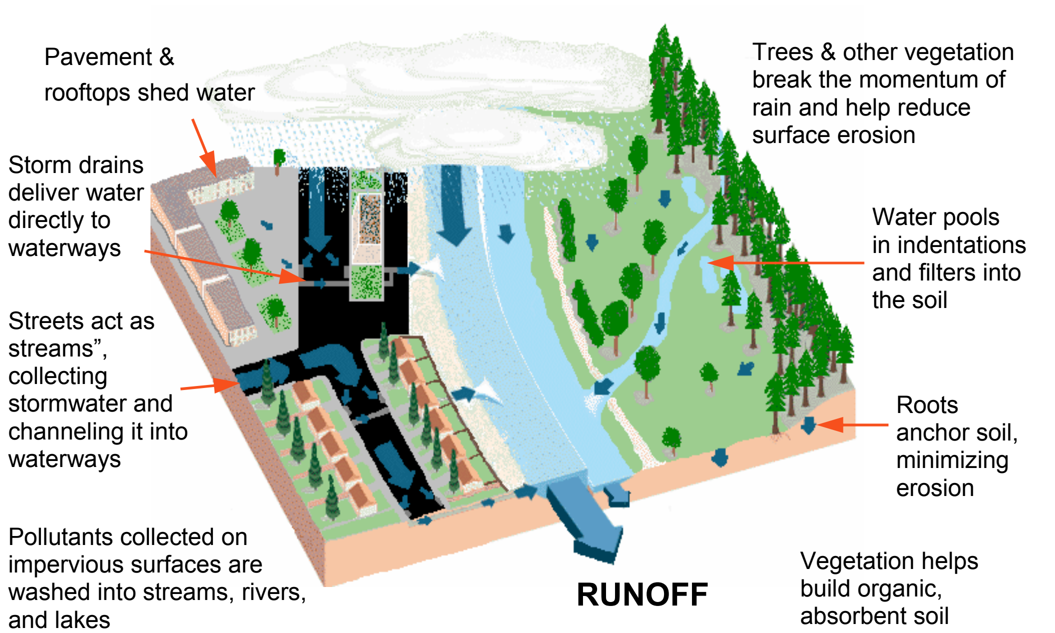


Figure 1 (left) illustrates how impervious cover and urban drainage systems increase runoff to creeks and rivers. The larger volume, velocity and duration of flow acts like sandpaper on stream banks, intensifying the erosion and sediment transport from the landscape and stream banks. This often causes channel erosion, clogged stream channels, and habitat damage.

Channelized rivers and streams exhibit similar problems accommodating large peak runoff volumes and supporting aquatic ecosystems [4,5].

Graphic Sacramento Bee[2]

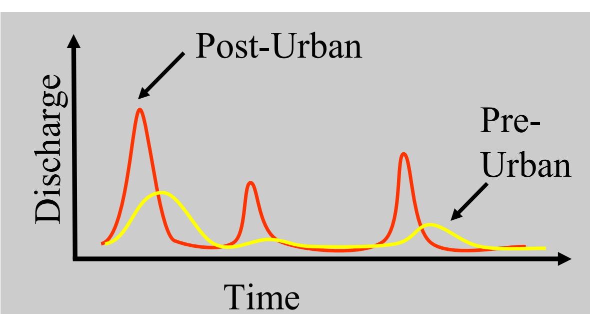
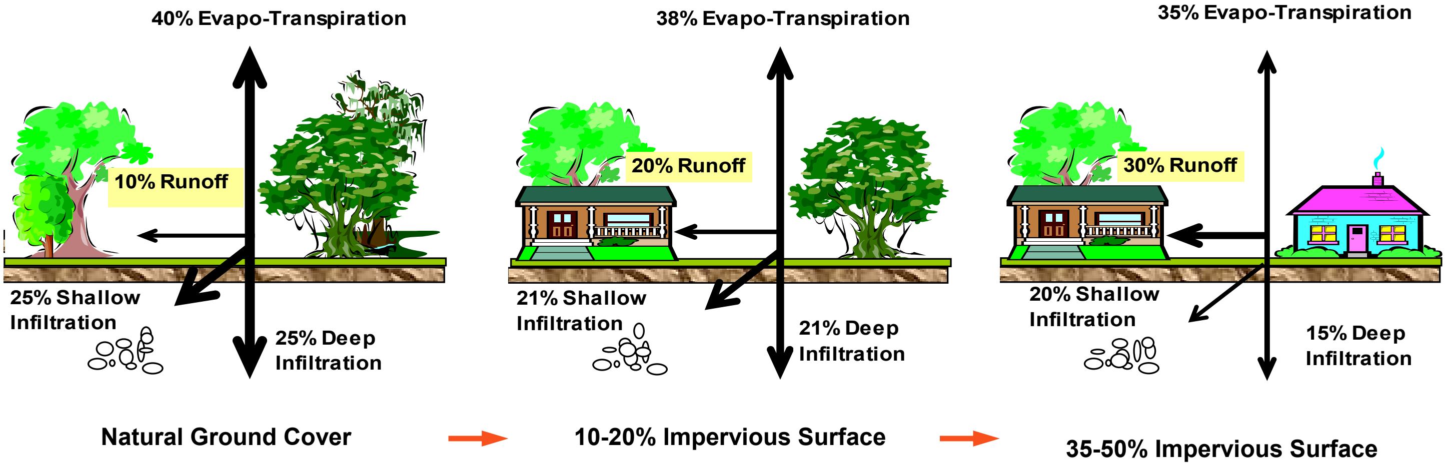


Figure 2 The hydrograph (left) illustrates stormwater peak discharges in a urban watershed (red line) and a less developed watershed (yellow line). In watersheds with large amounts of impervious cover, there is a larger volume and faster rate of discharge than in less developed watersheds, often resulting in more flooding and habitat damage.

Adapted from Santa Clara Hydromodification Management Plan [3]



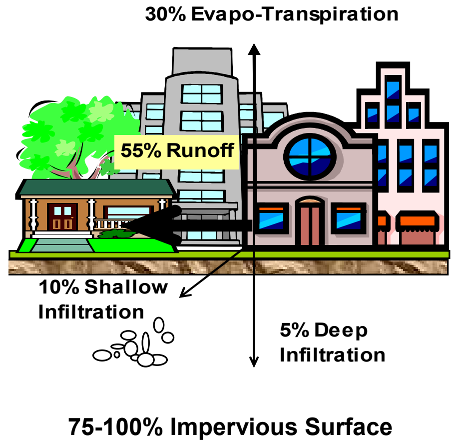


Figure 2. How impervious cover affects the water cycle.

With natural groundcover, 25% of rain infiltrates into the aquifer and only 10% ends up as runoff. As imperviousness increases, less water infiltrates and more and more runs off. In highly urbanized areas, over one-half of all rain becomes surface runoff, and deep infiltration is only a fraction of what it was naturally [6].

The increased surface runoff requires more infrastructure to minimize flooding. Natural waterways end up being used as drainage channels, and are frequently lined with rocks or concrete to move water more quickly and prevent erosion.

In addition, as deep infiltration decreases, the water table drops, reducing groundwater for wetlands, riparian vegetation, wells, and other uses.

Figure 3. Relationship between imperviousness and stream quality.

In most cases, when impervious cover (IC) is less than 10% of a watershed, streams remain healthy. Above 10% impervious cover, common signs of stream degradation are evident. They include [1,4]:

- Excessive stream channel erosion (bed and bank)
- Reduced groundwater recharge
- Increased size and frequency of 1-2 year floods
- Decreased movement of groundwater to surface water
- Loss of streambank tree cover
- Increased contaminants in water
- Increased fine sediment in stream bed
- Overall degradation of the aquatic habitat

Pictures from different reaches of Secret Ravine Creek, Placer County, California

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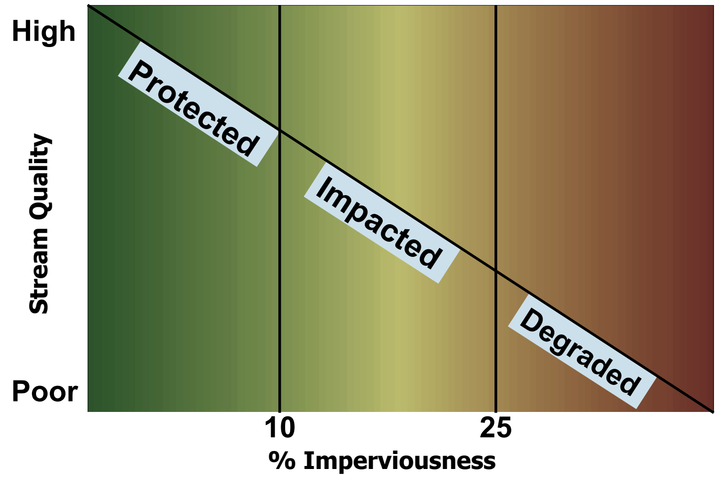
Figure 4. Conceptual relationship between IC and stream habitat quality.

Between 10 – 25% imperviousness, major alterations in stream morphology occur that significantly reduce habitat quality. At greater than 25% impervious cover, streams suffer from loss of habitat, floodplain connectivity, and bank stability, as well as decreased water quality [1].



California Examples

Studies on urban streams across California have consistently found similar patterns of degradation. For example, in Los Penasquitos Creek in San Diego County, watershed development grew from 9% to 37% urbanization between 1966-2000. From 1973-2000, the total annual urban runoff in the upper watershed increased by 4% per year, resulting in more than a 100% increase in runoff for the measured time period. The flood magnitude for the 1-2 year storm also increased by more than 5 fold from 1965-2000 [7].

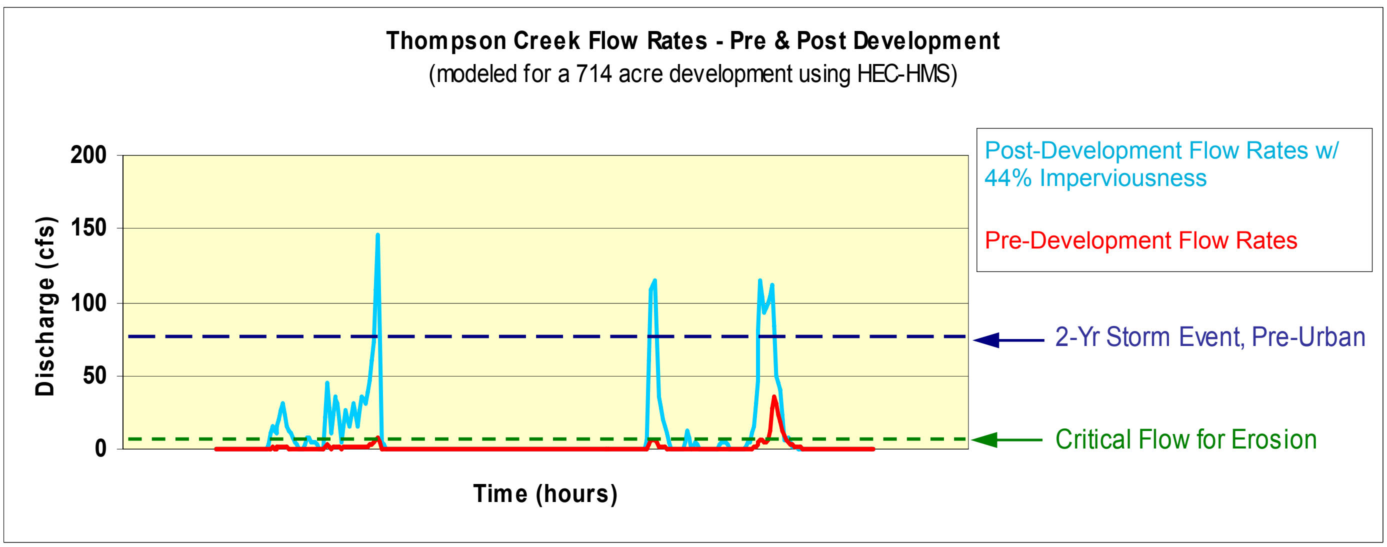


Figure 5. Comparison of Pre- and Post-Development Flow Conditions, Thompson Creek, Santa Clara Valley, CA.

The impact of 44% impervious cover on a variety of hydrological parameters on Thompson Creek were predicted during a random seven-day period. 50 years worth of data was used in the modeling process. The most obvious difference between the pre and post development conditions is the significantly greater volume of runoff generated after development, as seen in the above graph. Whereas pre-development flows were typically at flow rates that would not cause bank erosion (green line), post-development flows mainly exceeded the flow needed to destabilize stream banks. Further, post-development flows, in contrast to pre-development flows, would regularly exceed the historic 2-year storm event.

The impacts of these altered conditions are degradation of the aquatic habitat and increased frequency of flood events. In the Thompson Creek sub-watershed, hydrologists also found that the increased imperviousness associated with development approximately doubled stormwater runoff for peak discharges for 2, 5, and 10-year storm event. Results in this watershed and elsewhere have shown that the 0 – 10 year storms are the events that overwhelmingly alter the shape and size of streams. Thus, doubling of the rate of runoff will have significant impacts on aquatic resources as well as the risk of flooding [3].

In a Nutshell

Increased impervious cover associated with urbanization alters the natural cycling of water. Changes in the shape and size of urban streams, followed by decreased water quality, are the most visible effects of increased imperviousness. Greater frequency and severity of flooding, channel erosion, and destruction of aquatic habitat commonly follow watershed urbanization. Alterations in the aquatic environment associated with these hydrological changes greatly compromise the normal functioning of our waterways.

Resources on the Web

Center for Watershed Protection
www.cwp.org

State Water Resources Control Board(NPS Encyclopedia)
www.waterboards.ca.gov/nps/encyclopedia.html

National NEMO Network
http://nemonet.uconn.edu/

Low Impact Development Center
www.lowimpactdevelopment.org/

EPA information on hydrological cycle
www.epa.gov/seahome/groundwater/src/cycle.htm

The Stormwater Manager's Resource Center
www.stormwatercenter.net

References

1 Center for Watershed Protection. "Impacts of Impervious Cover on Aquatic Systems", Ellicott City, MD, 2003.

2 Knudson, Tom, and Nancy Vogel. Graphic by Scott Flodin. "The Gathering Storm Part II, Bad land-use policies invite a catastrophe." The Sacramento Bee 24 Nov 1997. 21 Jul 2005, www.sacbee.com/static/archive/news/projects/gathering_storm/floodplains.html

3 Santa Clara Valley Urban Runoff Pollution Prevention Program Hydromodification Management Plan, 2005. Posted at: http://ci7e.securesites.net/hmp_final_draft/

4 Booth, Derek B. "Urbanization and the Natural Drainage System-Impacts, Solutions, and Prognosis." The Northwest Environmental Journal 7.1 (1991): 93-118.

5 Hollis, G. E., 1975, The effects of urbanization on floods of different recurrence intervals. Water Resources Research, 11, 431-5

6 Chester L. Arnold and C. James Gibbons. "Impervious Surface Coverage: The Emergence of a Key Environmental Indicator." Journal of the American Planning Association. Spring, 1996. p. 255

7 White, Michael D., and Keith A. Greer. "The effects of watershed urbanization on the stream hydrology and riparian vegetation of Los Penasquitos Creek, California" 2005.

8 Stein, Eric D. "(NB21F-05) "Effect of Increases in Peak Flows and Imperviousness on Stream Morphology of Ephemeral Streams in Southern California." North American Benthological Society (2005).

California WALUP Partners

California Coastal Commission

Office of Environmental Health Hazard Assessment, Cal/EPA

USC Sea Grant

State Water Resources Control Board

California Association of Resource Conservation Districts

Local Government Commission

UC Davis Extension

UC Santa Barbara

NOAA Coastal Services Center

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