

INTRODUCTION

PURPOSE AND USERS OF THIS HANDBOOK

The primary purpose of this BMP Handbook is to provide guidance for selecting and implementing water quality Best Management Practices (BMPs) that reduce or prevent the pollutants of concern identified in the Lake Tahoe Total Maximum Daily Load (TMDL) and other pollutants from entering surface and ground waters. It is also provided to assist property owners with planning and implementing proper inspection, maintenance, and monitoring of their BMP drainage improvements.

The intended users of the manual include developers, planners, design engineers, contractors, subcontractors, construction staff, and agency staff involved in BMP retrofits, new development, redevelopment, and public projects within the Lake Tahoe Region.

Implementation of the design guidance provided in this manual will help to reduce stormwater runoff volumes and pollutants, decrease erosion and sedimentation in rivers, creeks, and streams, improve the water quality of receiving waters, increase groundwater recharge, assist with water conservation efforts, and reduce the potential for flooding.

RELATIONSHIP TO OTHER MANUALS AND HANDBOOKS

During the design of water quality improvements, the designer should cross-reference the appropriate jurisdictions drainage design manuals to ensure consistency with local government technical requirements and related policies and procedures, based on the jurisdiction where the project is located.

Small residential property owners and residents may want to reference the Home Landscaping Guide for Lake Tahoe and Vicinity, published by the University of Nevada Cooperative Extension (UNCE). It contains a broad spectrum of information covering BMPs, invasive weeds, native and adapted landscaping, and other related conservation topics. Contractors installing BMPs on small residential sites may also reference another UNCE publication titled How to Install BMPs on Small Sites in the Lake Tahoe Region.

USE AND ORGANIZATION OF THIS HANDBOOK

This BMP Handbook is organized into eight chapters:

- Chapter 1 Urban Hydrology
- Chapter 2 Site Analysis
- Chapter 3 BMP Planning and Selection
- Chapter 4 BMP Toolkit
- Chapter 5 Soil and Vegetation Management
- Chapter 6 Inspection, Maintenance, and Monitoring
- Chapter 7 Permitting

- Chapter 8 Shorezone BMPs and Protective Structures

Chapter 1 provides an overview of hydrologic and associated stormwater quality analysis methods and includes summaries of these methods commonly used for planning and implementing effective stormwater BMPs in the Lake Tahoe Region.

Chapters 2 and 3 represent a systematic approach for analyzing a site and selecting BMPs for a project.

Chapter 4 is a toolkit of distinct BMPs representing four categories including hydrologic source controls, pollutant source controls, treatment BMPs, and temporary construction BMPs.

Chapter 5 gives general guidelines for revegetation projects, and includes plant species lists based on common site conditions and an overall list of approved species for the Lake Tahoe Region.

Chapter 6 provides information for developing an inspection, maintenance, and monitoring plan for stormwater BMPs, including example templates.

Chapter 7 covers common permits that may be necessary when planning and implementing a stormwater quality improvement project.

Chapter 8 includes shorezone protective structure planning and selection, and covers various temporary and permanent BMPs used in the shorezone to prevent or minimize shoreline erosion.

LAKE TAHOE WATERSHED

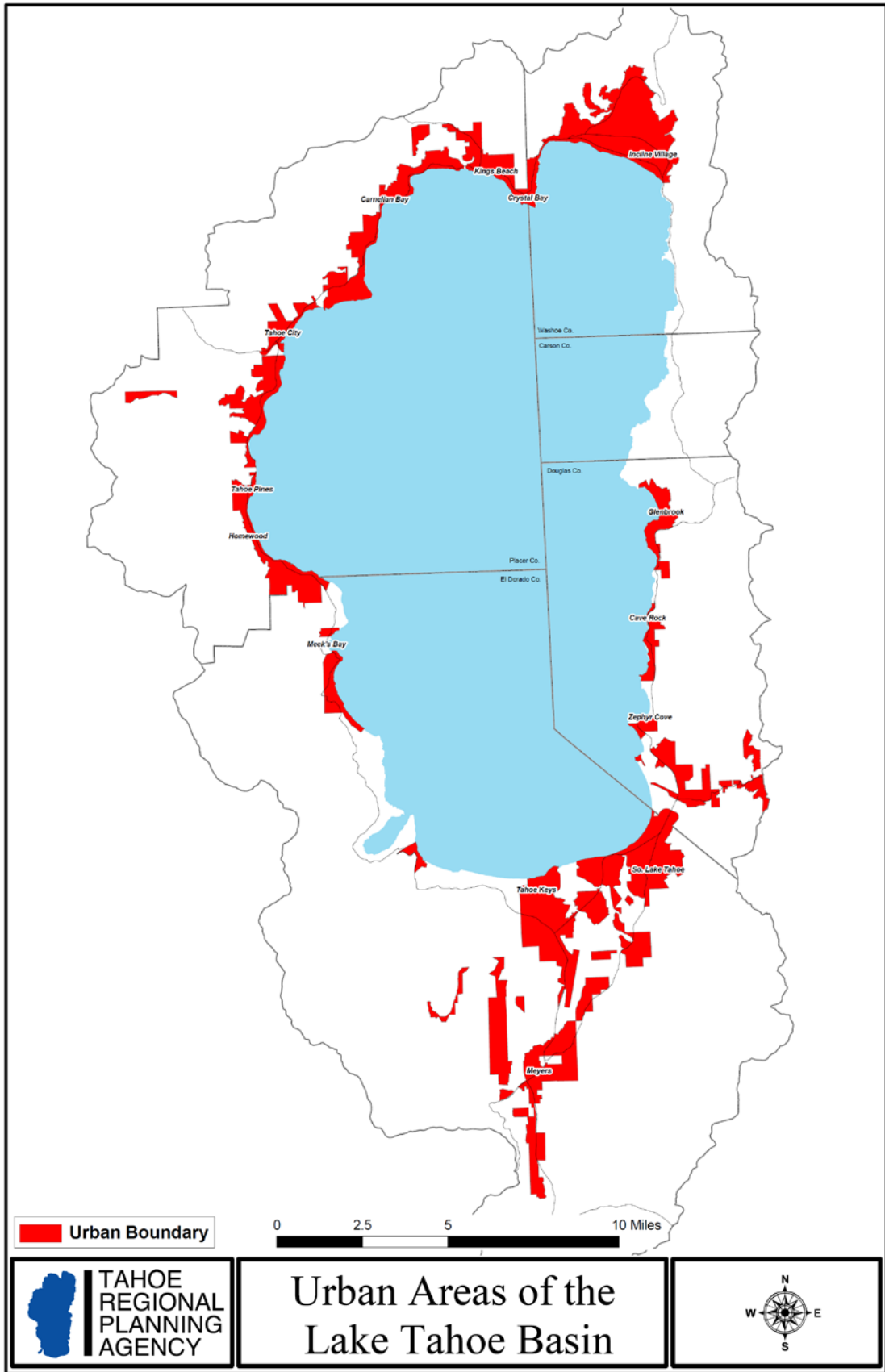
Lake Tahoe's vast depth and small ratio of watershed to lake area, combined with mostly granitic geology produces a lake of very low fertility. Known as ultra-oligotrophic, these conditions help create the lake's renowned high transparency.

Although 85 percent of the land in the Lake Tahoe Region is undeveloped National Forest, urbanization has been concentrated much along the perimeter of Lake Tahoe. An interconnected set of roadways and stormwater pipes carry pollutant runoff from the urbanized uplands into tributary creeks and ultimately the lake.



Lake Tahoe's world renowned blue waters.

Figure I-a: Urban Boundaries in the Lake Tahoe Region



Urbanization in the Lake Tahoe watershed has eliminated and damaged wetlands, wet meadows, and riparian habitat, all crucial for natural water quality treatment. Aquatic biodiversity has been altered due to changes in environmental conditions and the introduction of exotic species. Air quality degradation is visible and atmospheric deposition directly to the lake surface has fundamentally changed the nutrient balance in the lake.¹



Filling the wetlands at the outlet of the Upper Truckee River prior to comprehensive regulation in the Lake Tahoe Region removed a natural filtration system for pollutants.

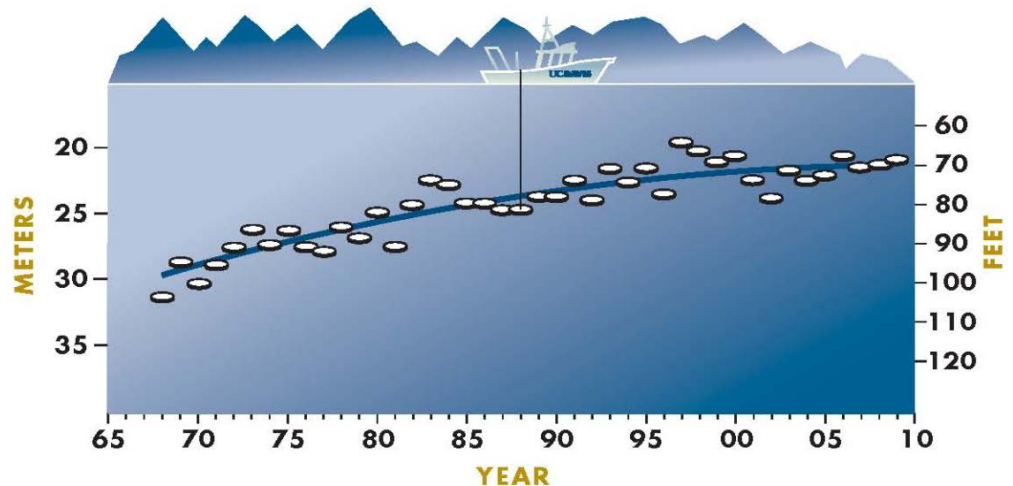
Measurements of Lake Tahoe's clarity have been ongoing since 1968. The deterioration of Lake Tahoe's world-renowned clarity and cobalt-blue color has prompted regional, state, and federal agencies to adopt a large collection of regulations. California designated Lake Tahoe as an Outstanding National Resource Water under the Federal Clean Water Act and considers noncontact recreation (aesthetic enjoyment of the Lake's clarity) as a primary beneficial use. Similarly, the Nevada Division of Environmental Protection (NDEP) has designated Lake Tahoe as a "water of extraordinary ecological or aesthetic value."

Despite stringent water quality goals and associated watershed regulations, Lake Tahoe has continued to lose its famed clarity at a rate of nearly nine inches per year since the late 1960's and has failed to meet transparency and clarity standards.²

¹ Reuter, John E., Goldman, Charles R., Cahill, Thomas A., Cliff, Steve S., Heyvaert, Alan C., Jassby, Alan D., and Rizzo, David M., 2003, *Managing for Healthy Ecosystems An Integrated Watershed Approach to Studying Ecosystem Health at Lake Tahoe*, pp. 1283-1298

² Roberts, David M. and Reuter, John E., September 2007, *Lake Tahoe Total Maximum Daily Load Technical Report*

Figure I-b: Decline of Lake Tahoe's Water Clarity



Decline in Lake Tahoe Clarity between 1965 and 2009. From Tahoe State of the Lake Report 2010, UC Davis Tahoe Environmental Research Center.

As a result of not meeting specific numeric transparency and clarity standards, Lake Tahoe is considered "impaired" with respect to the aesthetic-recreation beneficial use. Impaired water bodies are placed on the Federal Clean Water Act Section 303(d) list, which also identifies the pollutant(s) that cause the impairment. Lake Tahoe is impaired from an input of too much nutrients (nitrogen and phosphorus) and fine (less than 16 microns) sediment.

For detailed information about the Lake Tahoe TMDL, reference the State Water Resources Control Board website at: http://www.swrcb.ca.gov/lahontan/water_issues/programs/tmdl/lake_tahoe/index.shtml.

TOTAL MAXIMUM DAILY LOAD FINDINGS

A TMDL is a water quality restoration plan required by the U.S. Federal Clean Water Act to achieve water quality standards in impaired surface water bodies. A TMDL identifies the maximum pollutant load a water body is able to assimilate while maintaining its water quality standards and supporting its designated beneficial uses. The Lake Tahoe TMDL is managed jointly by the California Lahontan Regional Water Quality Control Board and the Nevada Division of Environmental Protection. The Lake Tahoe TMDL quantifies the source and amount of fine sediment and nutrient loading from various land-uses and outlines an implementation plan to achieve an annual average Secchi depth of 29.7 meters as required by existing water quality standards.³

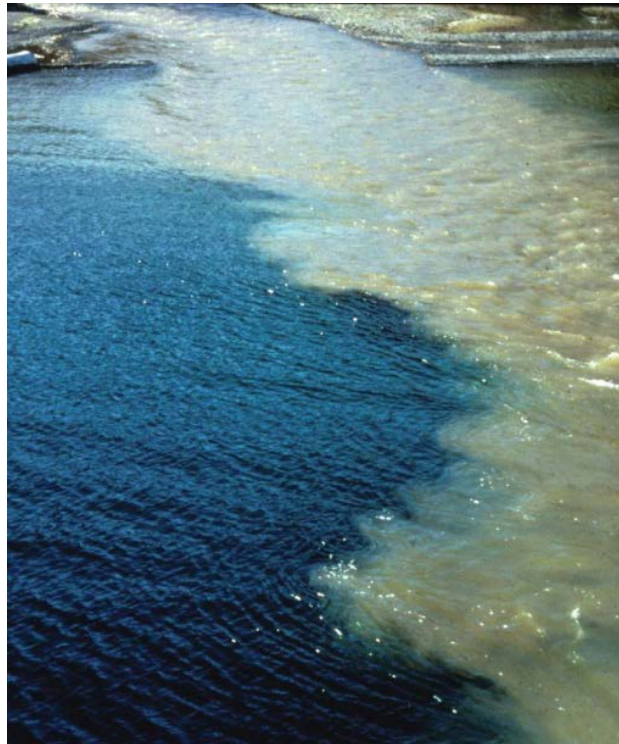
LAKE TAHOE WATER CLARITY AND POLLUTANTS OF CONCERN

Dr. Ted Swift, of UC Davis, determined that very fine particles of inorganic matter are the most important factor in Lake Tahoe's clarity loss. These silt and clay-sized particles are only 0.5 to 10 microns in diameter and are extremely difficult to remove from runoff migrating toward the lake. Swift's research reports that suspended fine inorganic particulates cause approximately 50 percent of the light scattering that deteriorates clarity in Lake Tahoe, 30 percent of clarity loss is caused

³ Roberts, David M. and Reuter, John E., September 2007, *Lake Tahoe Total Maximum Daily Load Technical Report*

by algae particles, and 20 percent is caused by light absorption by pure water and dissolved organic matter.⁴

Ultra-fine particles can remain suspended in the lake for months and even years before settling to the bottom. Theoretical calculations show that a 10-micron soil particle of typical shape and density will take over 100 days to settle to the average depth of the lake floor (1,027 feet) under ideal conditions, while a 4-micron particle will take almost 1,000 days to settle. However, winter storms often mix lake water to a depth of 300 meters, so particles are frequently brought back up hydrodynamically toward the lake surface before they resume settling to the bottom. Nitrogen and phosphorus stimulate algae growth, which in turn absorbs light and reduce how far light can penetrate the water.



Left: Fine sediment laden runoff from a commercial parking lot.

Right: Suspended fine sediment mixing with Lake Tahoe waters.

The Lake Tahoe TMDL Technical Report provides detailed discussion on the sources and amounts of these pollutants. Mitigating the urbanized uplands with BMPs is targeted in the Lake Tahoe TMDL Pollutant Load Reduction Opportunity Report as providing the highest potential pollutant load reductions⁵.

IMPERVIOUS COVER AFFECTS ON HYDROLOGY

While the Lake Tahoe Region has experienced human use for thousands of years, the period of rapid urban development following the winter Olympics at Squaw Valley in 1960 prompted the today's water quality protection regulations BMPs.

⁴ Swift, T.J., Perez-Losada, J., Schladow, S.G., Reuter, J.E., Jassby, A.D. and Goldman, C.R., 2006, Aquatic Sciences, 68, 1, *Water Clarity Modeling in Lake Tahoe: Linking Suspended Matter Characteristics to Secchi Depth*

⁵ Lahontan Regional Water Quality Control Board and Nevada Division of Environmental Protection, September 2007, *Lake Tahoe TMDL Pollutant Load Reduction Opportunity Report*

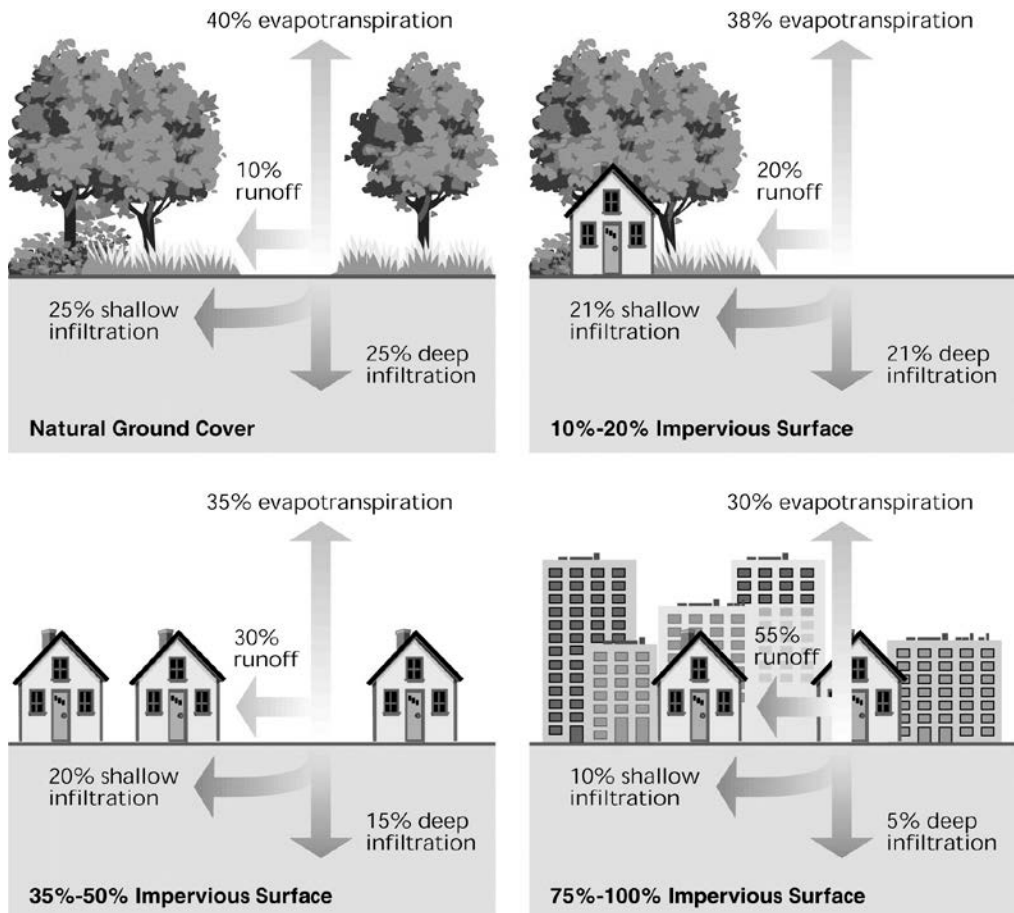
A detailed natural and human history of the Basin is provided in the Lake Tahoe Watershed Assessment.

Source: USDA (United States Department of Agriculture), 2000. Lake Tahoe Watershed Assessment. Volume 1. Pacific Southwest Research Station, USDA Forest Service.

Impervious land coverage is a fundamental characteristic of urban and suburban landscapes. Rooftops, roadways, parking areas, and other impervious surfaces cover the soil that, before development, allowed rainwater and snowmelt to infiltrate. Infiltration is the process by which surface water enters the soil and is influenced by many factors including soil structure, porosity, texture, moisture content, and vegetation among other attributes. Impervious surfaces such as asphalt, concrete, and compacted soils, prevent or reduce infiltration of water into the soil.

In a naturally functioning watershed, rain and snowmelt slowly infiltrates close to where it drops, or is captured through evapotranspiration. In contrast, impervious surfaces cause rainfall to run off quickly, taking with it pollutants that have collected over time on the surface. While roads and rooftops are the most prevalent types of impervious surface, other types include sidewalks, patios, bedrock outcrops, and compacted soil. As development increases and alters a natural landscape, the percentage of the land covered by impervious surfaces also increases.

Figure 1-c: Impervious Cover versus Surface Runoff



Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface runoff. As little as 10 % impervious cover in a watershed can result in stream degradation. Taken from: In Stream Corridor Restoration: Principles, Processes, and Practices (10/98). By the Federal Interagency Stream restoration Working Group (FISRWG) (15 Federal agencies of the U.S.)

Even the smallest rainstorms can generate runoff from impervious surfaces, collecting pollutants and sediment that has accumulated over time, and concentrates into gutters, channels and pipes. This rapid, concentrated water flow can affect the hydrologic cycle in the following ways:

- Increase total runoff volume from a storm event
- Increase runoff flows, usually expressed in cubic feet per second (cfs)
- Increase the concentration and quantity of pollutants
- Reduce groundwater recharge

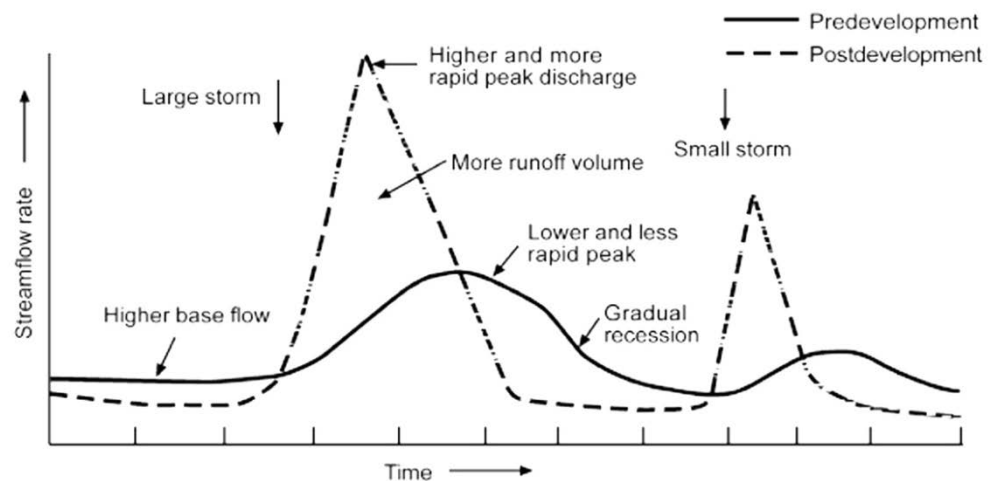
A hydrograph (Figure 1-d) shows the rate and volume of runoff for a particular watershed or site. The area beneath the hydrograph is the total volume of runoff discharged from the site. Under natural (pre-development) conditions, runoff from a site does not begin immediately because of infiltration. Once the soil becomes saturated, (when the rate of precipitation exceeds the rate of permeability of the soils) surface runoff increases rapidly. As precipitation rates decline, runoff rates decline as well. Even in forests and other natural areas, a lot of surface runoff can result during larger storms and snowmelt events. However, this occurs more

frequently in developed impervious conditions, and a host of human generated pollutants such as sediment and oil can be washed into a receiving water body.

Developed areas without any stormwater management controls (e.g. without BMPs) present a hydrograph much different from a natural area. Several observations relating to the Post Development hydrograph can be made:

- Stormwater runoff begins earlier than pre-development.
- Runoff rapidly increases and peaks at a rate considerably higher than the peak rate for pre-development.
- The area under the curve is considerably larger (meaning total runoff discharge is greater) than the area under the pre-development curve.

Figure I-d: Impervious Surfaces Changes to Stream Hydrology



Changes in stream hydrology as a result of urbanization. Taken from Schueler, 1992⁶.

CONNECTED VERSUS DISCONNECTED IMPERVIOUS SURFACES

Impervious surfaces can be described as connected or disconnected. Connected impervious areas drain to stormwater conveyance systems via a hydraulic connection. Connected impervious areas can include driveways or vehicle parking lots that drain into a roadway, or a rooftop that drains directly on asphalt. Connected impervious areas create higher runoff volumes and pollutant loading potential downstream.

⁶ Schueler, T.R., 1992, Metropolitan Washington Council of Governments for Watershed Restoration Sourcebook. Publication 92701, *Mitigating the Adverse Impacts of Urbanization on Streams: A Comprehensive Strategy for Local Government*



Disconnected impervious areas drain to pervious surfaces that promote infiltration, distribution, energy dissipation, or storage before overflowing to a conveyance system.

Disconnected impervious areas can include roadways draining to grass or forested lands, or a parking lot sheet flowing to a natural area or a stormwater infiltration basin.

In BMP planning, finding ways to disconnect impervious areas and infiltrate stormwater helps slow and soften the aggravated hydrographs typical of developed urban areas.

Commercial parking areas directly connected to the highway right-of-way and contributing dirty runoff to a drain inlet.

NONPOINT SOURCE POLLUTION

Although fine sediments and nutrients cause lake clarity decline and are targeted by water quality projects in the Lake Tahoe Region, other non-point source pollutants can damage the overall health of the Lake Tahoe watershed. Controlling these pollutants and restoring native ecosystems are still important elements in a holistic watershed plan.

Unlike pollution from industrial and sewage treatment plants, nonpoint source (NPS) pollution comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, and ground waters.

The following table shows various pollutants, environmental effects, typical sources, and the BMPs contained in this BMP Handbook that can be used to reduce or eliminate the pollution.

Table 1-1: Pollutants Commonly Found in Urban Runoff

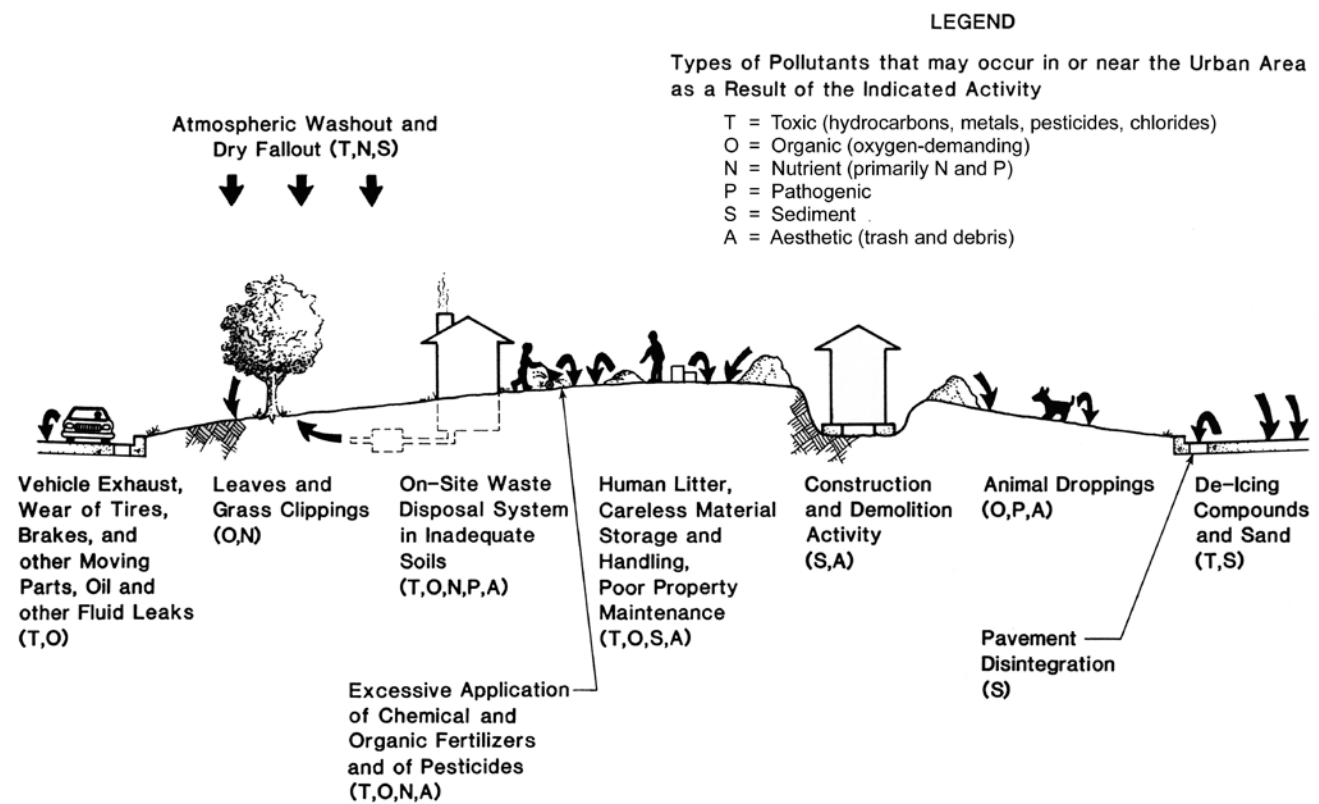
POLLUTANT	EFFECT	URBAN SOURCES	ASSOCIATED BMPs
Sediment	Reduces the amount of light in the water available for plant growth and thereby reducing the supply of food for other organisms. Can clog and damage sensitive tissues such as the gills of fish. Can suffocate organisms which live on or in the bed of lakes and streams by forming thick deposits when this suspended material settles out.	Land surface erosion	Chapter 5 Soil and Vegetation Management
		Unpaved driveways and roads	Section 4.2-i Paving Parking Areas and Roads
		Pavement and vehicle wear	Section 4.2-a to 4.2-c Roadway and Parking Lot Pollutant Prevention
		Road abrasives application	
		Building and construction sites	Section 4.5 Temporary BMPs for Construction
		Snow storage piles	Section 4.2-c Snow Storage
		Vehicle washing	Section 4.2-s Vehicle Washing
		Weathering of buildings/structures	Section 4.1 Hydrologic Source Control BMPs
		Re-suspension out of permanent BMPs such as unmaintained pretreatment BMPs.	Chapter 6 Inspection, Maintenance, and Monitoring
		Atmospheric deposition	Chapter 5 Soil and Vegetation Management and Section 4.5-g Dust Control
Fine Sediment (particles less than 16 micrometers)	Fine Sediment (particles less than 16 micrometers) become suspended for long periods in Lake Tahoe's water column and reduces water clarity. Fine sediment has been determined through the Lake Tahoe Total Maximum Daily Load to be the largest contributing factor in the loss of Lake Tahoe's clarity.	All of the above	Chapter 5 Soil and Vegetation Management, Section 4.1 Hydrologic Source Control, Section 4.2-d to 4.2-h Slope Stabilization, Section 4.2-a to 4.2-c Roadway and Parking Lot Pollutant Prevention, Section 4.4 Stormwater Treatment, Section 4.2-i Paving Parking Areas and Roads
Nutrients (Nitrogen and Phosphorus)	An increase of nutrients in water stimulates the growth of aquatic plants. This causes excessive growth of aquatic weeds and algae that may choke lakes and streams and lead to dramatic daily fluctuations in dissolved oxygen levels. Currently, phosphorus is the limiting nutrient preventing additional algal growth in Lake Tahoe. Decaying organic matter and nutrients can result in a drop in oxygen levels, at times sufficient to kill fish and other aquatic organisms. If all the oxygen in the water is used up, unpleasant odors can result.	Organic matter (e.g. leaf litter, grass)	Chapter 5 Soil and Vegetation Management
		Fertilizer application on residential, nursery, commercial, and landscaping	Chapter 5 Soil and Vegetation Management
		Landscape and nursery businesses	Section 4.2-o Nursery Facility Management
		Sewer overflows, septic tank leaks	4.2-n Hazardous Material Management
		Animal feces	Section 4.2-p Pet Waste Management and Section 4.2-q Livestock Facility Management
		Vehicle washing	Section 4.2-s Vehicle Washing
		Atmospheric deposition	Chapter 5 Soil and Vegetation Management and Section 4.5-g Dust Control
		Spillage, illegal discharge, and improper storage of materials	Section 4.2-m to 4.2-s Waste Management and Materials Pollution Prevention
		Nutrients attached to sediment	See Sediment and Fine Sediment Pollutants above

POLLUTANT	EFFECT	URBAN SOURCES	ASSOCIATED BMPS
pH acidity	Increased acidity damages plants and animals	Concrete washouts at construction sites	Section 4.5-m Concrete/Bentonite Management
		Spillage, illegal discharge, and improper storage of materials	Section 4.2-m to 4.2-s Waste Management and Materials Pollution Prevention
		Organic matter decay	Chapter 5 Soil and Vegetation Management
		Erosion of roofing material	Section 4.1 Hydrologic Source Control BMPs
Micro-organisms	Contain very high numbers of bacteria and viruses. Some of these organisms can cause illnesses, including hepatitis and gastroenteritis. Especially prevalent from owners walking their dogs on trails, beaches, and in forests.	Dog and other pet feces	Section 4.2-p Pet Waste Management
		Equestrian and other livestock facilities	Section 4.2-q Livestock Facility Management
		Sewer overflows and septic tank leaks	Section 4.2-m to 4.2-s Waste Management and Materials Pollution Prevention
Pesticides and Herbicides	Can poison living organisms or damage their life processes.	Application on residential, commercial business, and government landscaping	Chapter 5 Soil and Vegetation Management
		Landscape and nursery businesses	
		Spillage, illegal discharge, and improper storage of materials	Section 4.2-m to 4.2-s Waste Management and Materials Pollution Prevention
Heavy metals	Poison living organisms or damage their life processes in some other way. Persists in the environment for a long time.	Concrete washouts from construction sites	Section 4.5-m Concrete/Bentonite Management
		Machine and industrial shops	Section 4.2-m to 4.2-s Waste Management and Materials Pollution Prevention
		Sewer overflows, septic tank leaks	Section 4.2-m to 4.2-s Waste Management and Materials Pollution Prevention
		Weathering of buildings, structures	Section 4.1 Hydrologic Source Control
		Vehicle wear (brake pads, etc.)	Section 4.1 Hydrologic Source Control
Gross pollutants (litter and debris)	Unightly. Animals such as bears, coyotes, and raccoons can eat and choke on this material. Can clog stormwater systems and cause isolated flooding.	Human carelessness	Section 4.2-m Dumpster Management
		Waste collection systems	Section 4.2-m Dumpster Management
		Pine needles and lawn clippings	Chapter 5 Soil and Vegetation Management
Grease, oils, detergents, and shampoos (surfactants)	Highly toxic poison to fish and other aquatic life.	Asphalt pavements	Section 4.1 Hydrologic Source Control Section 4.4 Stormwater Treatment
		Parking lots and leaky vehicles from commercial and industrial parcels	Section 4.1 Hydrologic Source Control Section 4.4 Stormwater Treatment
		Spillage, illegal discharge, and improper storage of materials	Section 4.2-m to 4.2-s Waste Management and Materials Pollution Prevention
		Vehicle washing	Section 4.2-s Vehicle Washing

POLLUTANT	EFFECT	URBAN SOURCES	ASSOCIATED BMPs
Increased water temperature	High temperatures are lethal to fish and other aquatic organisms. Elevated water temperatures stimulate the growth of nuisance plants and algae. This and other effects can lead to decreased levels of dissolved oxygen which can threaten other aquatic life.	Runoff from impervious surfaces	Section 4.1 Hydrologic Source Control
		Removal of riparian vegetation.	Chapter 5 Soil and Vegetation Management

Nonpoint Source Pollutants in the Environment and Associated BMPs. Adapted from Urban Stormwater: Best Practice Environmental Management Guidelines, 1999 Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Figure I-e: Availability of Potential Pollutants on the Land Surface



Nonpoint Source Pollutants from Land Uses.

BEST MANAGEMENT PRACTICES

Historically, stormwater systems were designed to convey (or transport) runoff as quickly and efficiently as possible away from the developed area. To this day nationwide and at Lake Tahoe, stormwater conveyance without BMPs continues to cause downstream flooding, nonpoint source pollution, Lake Tahoe clarity decline, and stream degradation.

All landowners are required at Lake Tahoe to integrate permanent BMPs into stormwater drainage systems for their developed sites in order to prevent and minimize stormwater impacts and to help preserve and restore the natural hydrologic cycle.

An infiltration approach to stormwater management seeks to preserve and restore the natural hydrologic cycle. Infiltrating runoff allows rain or snowmelt to flow into permeable areas and enter the soil profile. Infiltration allows much of the runoff to return to the soil, which reduces runoff volumes, treats light pollutant concentrations, and replenishes groundwater. Infiltration allows light pollutants to settle into the soil where they are naturally mitigated. Even when runoff continues after infiltration of a design storm, the overall pollutant load into the nearest water body is still reduced.



A small landscaped rain garden captures and infiltrates stormwater runoff from a Lake Tahoe marina parking lot.

Reasonable steps should also be taken to prevent the illegal discharge of pollution and wastes to jurisdiction drainage systems. BMPs manage waste and hazardous material and are effective at preventing oil, fertilizers, and other hazardous wastes from entering public storm drains, native soil, surface water, and groundwater.

PRIVATE VERSUS PUBLIC BMP IMPLEMENTATION

The importance of the private sector implementing BMPs cannot be overstated. Private BMP implementation contributes to the upkeep of public jurisdictional

The design storm for parcel-based BMPs at Lake Tahoe is the 20-yr/1-hr rainfall event, approximately 1 inch of water falling in 1 hour. This design storm is used to calculate runoff volume capacity of infiltration based BMPs. For the public right of way, local jurisdictions use pollutant load reduction modeling tools for planning and designing BMPs.

stormwater facilities. When private properties do not have BMPs in place, public stormwater treatment facilities can be rendered less effective, be overwhelmed, or create the need for more frequent maintenance.

Public BMP design and implementation follows a standard protocol developed by the Storm Water Quality Improvement Committee (SWQIC) and deal primarily with the public rights-of-ways including roads and highways. Planning and implementing effective BMPs at both the private and public scales is a comprehensive strategy and a watershed based approach that will assist Lake Tahoe Region communities in meeting the goals and objectives of the Lake Tahoe TMDL.

RETROFITTING EXISTING DEVELOPMENT VERSUS NEW OR REDEVELOPMENT

BMP RETROFIT

Stormwater BMP retrofits help restore watersheds by providing stormwater treatment in locations where BMP's previously did not exist or were ineffective. Designers need to simultaneously envision stormwater opportunities and anticipate potential problems within the existing built environment. The design, permitting, and construction of retrofits are almost always more complex, expensive, and time consuming than planning and implementing BMPs for new or redevelopment⁷.

NEW DEVELOPMENT AND REDEVELOPMENT

New and redevelopment projects provide significant opportunities to design stormwater BMPs that fit seamlessly into the proposed project. While opportunities for incorporating Low Impact Development (LID) concepts increase greatly with new and redevelopment projects, LID concepts can still be applied to BMP retrofitting projects.

⁷ Center for Watershed Protection, August 2007, *Urban Stormwater Retrofit Practices*

Table I-2: Differences in BMP Retrofit versus Incorporating BMP into New or Redevelopment

ISSUE	URBAN RETROFIT PRACTICES	NEW OR REDEVELOPMENT
Effectiveness	Usually less effective than new or redevelopment projects.	Usually more effective than retrofits.
Cost	Construction costs are typically 1.5 to 4 times greater	Lower costs because mobilization on-site for all other related construction.
Design	Retrofit may require significant custom design of BMP elements	Standard BMPs, LID, and other practices can be applied to "fit" the site.
Data Collection	Requires significant data collection	Much of the data are already available through the development and/or redevelopment process.
Soils	Disturbed and compacted "urbanized" soils often cannot support infiltration as well.	If native areas are protected during construction, soils may better support overall infiltration.
Utilities/Infrastructure	Installation of designs would generally have to "work around" existing utilities due to prohibitive expense in moving utilities.	Utilities can be consolidated and localized to eliminate conflict with designs.
Feasibility	Physical site constraints may limit the feasibility of on-site BMP implementation	Most sites are able to include on-site BMPs.
Storm Drain Systems/Overflow	Often must tie into the existing stormwater conveyance system	Sometimes creates a new stormwater conveyance system.

Adapted from Urban Stormwater Retrofit Practices, Urban Subwatershed Restoration Manual Series, Center for Watershed Protection 2007.

LOW IMPACT DEVELOPMENT (LID)

The TRPA regulations requiring parcel-based BMP implementation have been in place for decades and are probably some of the earliest and most comprehensive regulatory controls to achieve what has more recently been referred to as Low Impact Development (LID). The principles of LID are intended to reduce the transport of runoff and pollutants from the site at which they are generated. More information on LID principles is available through the US Environmental Protection Agency website⁸. Additionally, many of the BMPs outlined and discussed in this BMP Handbook can be considered LID practices.

The objective of LID site design is to mimic natural hydrology through the use of techniques that maintain hydrologic functions such as runoff storage, infiltration, and ground water recharge, while lowering runoff volumes and frequency of discharges. LID uses integrated and distributed parcel-based and micro-scale stormwater retention and detention areas, reduction of impervious surfaces, and lengthening flow paths and runoff time⁹. Other strategies include the preservation and protection of environmentally sensitive site features such as riparian buffers, wetlands, steep slopes, trees, flood plains, woodlands, and highly permeable soils.¹⁰

LID is unlike conventional approaches that convey and manage runoff in large facilities located at the base of drainage areas. LID can reduce or eliminate the need for traditional storm drain piping and centralized stormwater facilities. LID techniques are encouraged in the Lake Tahoe Region. Although not all LID technologies are represented in this BMP Handbook, a balanced approach for

⁸ EPA websites – www.epa.gov/npdes/greeninfrastructure and www.epa.gov/nps/lid

⁹ Coffman, Larry, Prince George's County, Maryland Department of Environmental Resources, Programs and Planning Division, EPA 841-B-00-003, and EPA 841-B-00-003, 2000, *Low-Impact Development Design Strategies, An Integrated Design Approach*

¹⁰ EPA, October 2000, *Low Impact Development (LID) A Literature Review*

design, implementation, and monitoring is encouraged so that the effectiveness of these technologies can be better understood.