CHAPTER 2:

2 INTEGRATED APPROACH TO STORMWATER MANAGEMENT

In order for site designs to reflect the best stormwater management strategies, it is essential that stormwater be considered early in the site design process—before the site layout is established. Otherwise, the choice/location of stormwater controls will be constrained by prior site design decisions (e.g., predetermined grading contours), and may be limited to more expensive, higher maintenance, and less aesthetically pleasing options.

When stormwater controls are considered early, they can be effectively integrated into site design and planning. There are often opportunities to use existing or proposed site features for stormwater controls and/or repeat small-scale stormwater controls over an entire site. Small-scale controls are typically low-cost and cumulatively very effective.

In some cases, site design necessitates trade-offs among competing goals; however, especially when considered early in the process, stormwater goals can often complement other goals and agency requirements, including those related to vegetation preservation, landscaping, aesthetics, open space, recreational areas, and/or habitat.

2.1 STRATEGIES FOR STORMWATER QUALITY MANAGEMENT INTO PROJECT DEVELOPMENT

2.1.1 ASSEMBLE A COLLABORATIVE TEAM EARLY

In order for site designs to reflect the best stormwater management strategies, stormwater controls must be considered early in the site design process. To do that, involve the project engineer and other design professionals during the conceptual design stage, when the initial site layout is being determined. In the past, only planners and architects may have been involved at this stage of the design.

The collaborative design process may involve the following members of the Project Delivery Team (PDT) or Cross Functional Team (CFT):

- Project Owner
- Project Manager
- Planners
- Designers
- Engineers (Civil, Geotechnical, Etcetera.)
- Hydrologists
- Surveyors
- Landscape Architects
- Arborists
- Environmental Consultants
- Landscape Architects
- Land Management Agencies
- Permitting Agency Staff

It is also helpful to arrange a meeting with the local permitting agency to get agency input at the conceptual design stage; in most jurisdictions, this is referred to as the pre-application meeting.

It is equally important that those involved in site planning and design work collaborate throughout the site design process; that way, stormwater quality features can be optimally integrated into the site and project design. This might be facilitated by periodic meetings of the project team and by routing various designs to the different disciplines for review and comment.

2.1.2 Consider the Site and its Surroundings

Gather information about the following site characteristics, which will greatly influence the type of stormwater quality controls used on your project:

- Climatic region and terrain may lead to design modifications or BMP preferences
- Existing natural hydrologic features and natural resources, including any contiguous natural areas, wetlands, watercourses, seeps, or springs.
- Existing site topography, including contours of any slopes of 4% or steeper, general direction of surface drainage, local high or low points or depressions, and any outcrops or other significant geologic features.
- Zoning, including requirements for setbacks and open space. Location-specific restrictions could impact the selection of BMPs
- Soil types (including hydrologic soil groups) and depth to groundwater, which may determine whether infiltration is a feasible option for managing site runoff. A preliminary determination of infiltration feasibility may be made using maps in hydrology and flood control design manuals published by the local permitting agency. Also, site-specific information (e.g. from boring logs or geotechnical studies) may be required by the permitting agency, depending on the site location and characteristics.
- Existing site drainage. For undeveloped sites, determine drainage patterns by inspecting the site and examining topographic maps and survey data. For previously developed sites, locate site drainage and connections to the municipal storm drain system from a site inspection, municipal storm drain maps, and/or the approved plans for the existing development (typically on file with the local municipality).
- Existing vegetative cover and impervious areas, if any.
- Existing trees and arborists reports, if any.

2.1.3 Identify Opportunities and Constraints

Using the site features information gathered above, identify the principal opportunities and constraints for stormwater quality management on the site.

Opportunities might include existing natural areas, low (depressed) areas, oddly configured or otherwise un-developable parcels, easements, and open space (which potentially can double as locations for stormwater quality controls with the permitting agency's approval). Also look at elevation differences on the site which might provide hydraulic head (difference in water surface elevation between inflow and outflow) for structural treatment control measures.

Constraints might include impermeable soils, high groundwater, contaminated soils or groundwater, steep slopes, geotechnical instability, high intensity land use, expected heavy pedestrian or vehicular traffic, safety concerns, or compatibility with surrounding land uses. Also there might be competing environmental concerns on the project site.

2.1.4 Preserve Valuable Site Features

Consider these techniques to preserve natural and environmentally-sensitive features on your site:

- Define the construction limits and boundaries for protected areas, identifying areas that are most suitable for development and areas that should be left undisturbed.
- Cluster the disturbance, including staging and stockpile areas, to reduce disturbance and conserve natural areas.
- Preserve natural vegetation. Vegetation is an integral part of the natural hydrologic cycle. Vegetation intercepts rainfall, and plant roots take up water that soaks into the ground. Also, roots and decaying organic matter such as leaf litter protect the soil structure and soil permeability, and therefore help preserve the pollutant-removal processes that occur in soil. When designing a site, retain as much natural vegetation as possible.
- Consider preserving trees (consider the number, quality and health and location of existing trees), even if the local jurisdiction would allow their removal, for all the reasons given above.
- Set back the construction from rivers, streams, gulches, wetlands, riparian habitats, and shorelines when practicable, or consider context sensitive solutions when designing permanent and temporary structures in these locations (See Figure 10 versus 11). Check with regulatory agencies for additional permitting requirements when designing in these environments.
- Designate and protect natural buffers for waterways and natural areas. If disturbing buffer areas during construction is unavoidable, make revegetation plans to replant them with plants and trees adapted and suited to the site conditions, preferably low-maintenance plants that are suited to the riparian zone. Such plants have a better chance of survival and adaptation to the site over time without an over reliance on water and fertilizers/pesticides.
- Understand the regulatory status of the receiving water to which the site drains. Depending on the nature of the receiving water, certain BMPs may be promoted, restricted or prohibited, or special design or sizing criteria may apply.
    - Determine if the watershed has characteristics that may require special design considerations or constrain the BMP selection.
    - Determine if the watershed and receiving water characteristics require special design considerations that affect the BMP selection. The BMP design is influenced by the type and condition of the receiving waters downstream. Higher pollutant removal may be needed to protect the downstream resources, leading to a shorter BMP selection list.

2.1.5 Lay Out the Site with Topography and Soils in Mind

To minimize stormwater-related impacts, consider applying the following design principles to the site layout:

- Choose a design that replicates the site's natural drainage patterns as much as possible.
- Where possible, conform the site layout to natural landforms.
- Identify topographic lows that might be suitable for locating stormwater quality treatment features.
- Concentrate construction on portions of the site with less permeable soils, and preserve areas that will actively promote infiltration.
- When possible, avoid disturbing steep slopes and erodible soils.
- When possible, avoid excessive grading and disturbance of vegetation and soils.
- When possible, avoid the use of closed conduit systems.
- When possible, avoid compacting soils in open and/ or landscape areas.
- Include grading notes addressing temporary drainage and phasing for disturbed soil areas.

2.1.6 Put Landscaping to Work

Stormwater quality features can often be integrated into landscape areas such as the site perimeter, ditches, medians, and roadside areas. For example, instead leveling waste material, consider creating depressed areas (i.e. bioretention, biofiltration, bioswales) to accept and filter water before sending it off the site. Using landscape areas for stormwater quality features may require some changes in the conventional approach to landscape designs, and may result in larger/wider disturbance areas.

2.1.7 Stop Pollution at Its Source

Rather than managing stormwater runoff only at the final point of discharge from a site, look for opportunities to manage pollution where it is first generated. Source control measures keep pollutants from entering stormwater to begin with, whereas treatment control measures remove pollutants from stormwater runoff.

Evaluate the site to look for opportunities to prevent pollution sources on the land from becoming mobilized by runoff. Construction sites can be one of the largest sources of nonpoint source pollution, especially sediment, during the period of time when the soil is exposed and susceptible to erosion. Control of these sites during this exposure is essential to proper stormwater management. During this step assess whether any Better Site Design (BSD), Low Impact Development (LID) or temporary sediment control techniques can be applied at the site to prevent erosion and minimize site disturbance during construction.

Many sources of information on the control of construction site runoff are available and are incorporated by reference to this guide. Only general descriptions of the temporary sediment control practices will be given in the Manual because the details associated with these practices are available in many other publications.

- Vegetated buffers
- Access/egress and drainage protection
- Runoff control (sediment control basins)
- Perimeter controls (access and egress, inlet protection)
- Soil and Slope stabilization
- Exposed soil covers and reinforcement
- Inspection and maintenance

Keeping the project site clean of debris, proper storage and application of chemicals, exposure of unprotected soil and adequate air quality regulation are all pollution control elements that should be exercised before the BMP selection process even begins. Specific recommended practices include things such as:

- Good Housekeeping (or other suitable term) including landscaping, street sweeping, pavement maintenance, catch basin maintenance and litter control
- Chemical controls including fertilizer/pesticide management and spill prevention
- Streambank stabilization

2.1.8 Reduce Runoff Close to Its Source

Another way to stop pollution at its source is to reduce runoff wherever possible through the incorporation Low Impact Development (LID) also known as Better Site Design (BSD) or Sustainable Development measures. Reducing site runoff will also reduce the volume and duration of flows to local creeks, thus reducing the potential for downstream erosion and habitat impairment. LID measures can reduce project costs for projects that typically require runoff treatment because this can reduce the need for stormwater quality treatment.

The main ways to reduce runoff are to promote infiltration, minimize impervious surfaces, disconnect impervious surfaces (disconnecting impervious surfaces means to intercept the runoff by draining the roof or pavement to a pervious area and not directly to the storm drain system), and promote planting of trees and shrubs to intercept and slow the runoff.

2.1.9 Promote Infiltration Where Feasible

On undeveloped, undisturbed land, rain slowly percolates into the soil and impurities are filtered out and transformed through natural biological processes. When designing a site, look for ways to promote infiltration by disconnection of impervious surfaces and allowing soil to filter and naturally transform impurities. For example, consider dispersing runoff over a landscaped area rather than concentrating in a ditch. Of course, infiltration is not appropriate where it may pose a threat to groundwater quality or cause other problems such as destabilizing a site.

As part of an amended soil layer, proper mulch can also have a measurable benefit in promoting infiltration by supporting a healthy soil, trapping moisture, and slowing the runoff.

Consider infiltration stormwater quality treatment control measures for your site where feasible including such devices as: the infiltration basin and infiltration trench.

2.1.10 Minimize Impervious Surfaces

During design, try to limit overall coverage of pavement. This can be accomplished—where consistent with project purpose and need—by designing narrower streets and sidewalks, smaller parking lots (fewer/smaller stalls where possible, and more efficient lanes), indoor or underground parking, and incorporating porous pavement into the design. Examine site layout and circulation patterns and identify areas where landscaping, porous pavement, or stormwater measures can be substituted for pavement.

2.1.11 Where Feasible, Avoid Draining Impervious Areas Directly to a Storm Drain

When the built and landscaped areas are defined on your project plans, look for opportunities to minimize impervious areas that are directly connected to the storm drain system. Several options that can be considered for this, include:

- Direct runoff from impervious areas to adjacent pervious areas or depressed landscaped areas.
- Select porous pavements and surface treatments. Inventory paved areas on the preliminary site plan and identify locations where permeable pavements, such as crushed aggregate, turf block, or unit pavers can be substituted for conventional concrete or asphalt paving. Typically, these materials work best in low-traffic parking areas, rather than high-traffic areas such as drive aisles.

2.1.12 Treat Runoff

Treating runoff is required for projects above certain size thresholds (which vary with respect to project category). As previously noted, providing LID measures can reduce or possibly even eliminate the required treatment.

Treatment is accomplished by either detaining runoff long enough for pollutants to settle out or by filtering runoff through sand, soil, or an engineered soil matrix. Typically, the limiting design factors will be available space, available hydraulic head, and soil permeability. In some cases, a small adjustment of elevations within the design can make a particular treatment option feasible and cost effective.

When developing a drainage and treatment strategy, also consider whether to route most or all drainage through a single detention and treatment control measure or to disperse smaller control measures throughout the site. Directing runoff to a single treatment area may be simpler and easier to design, but designs that integrate smaller techniques such as swales, small landscaped areas, and planter boxes throughout the site are typically more cost-effective, less maintenance intensive, and more attractive. The various treatment control measures that may be acceptable for use are:

Bioretention

- Rain gardens
- Depressed parking lot islands

- Road medians
- Tree pits/stormwater planters

Filtration

- Media filters (surface, underground, perimeter) described by media and function
- Surface flow (vegetative) filters (grass channels dry or wet swales, filter strips)
- Combination media/vegetative filters

Infiltration

- Trenches
- Basins
- Dry wells
- Underground Systems

Stormwater Ponds (design based upon components needed to fulfill the desired function)

- Components include pre-treatment, various storage volumes (detention needed), and biologic character.
- Functions include water quality (including thermal impact) and flow control (rate and volume), which determine whether they are wet/dry or some combination

Constructed Wetlands (selection criteria similar to ponds)

- Components include pre-treatment (see also next section), various storage volumes (detention needed), biologic character
- Functions include primarily water quality and flow control, but could also include ecological factors

2.1.13 HYDROMODIFICATION MANAGEMENT

Urbanization, vegetation removal, agricultural practices will often cause an increase in peak flow as well as runoff duration. Hydromodification Management addresses changes to runoff characteristics from urbanization and other sources that would otherwise result in the artificially altered rate of erosion or sedimentation within downstream natural channels. Hydromodification control measures should be provided (as required) to mitigate this effect. These measures function through attenuation, infiltration, and dispersion of runoff.

2.2 CONSTRUCTION SITES AND POTENTIAL POLLUTANTS

Stormwater runoff contains numerous natural constituents. However, activities such as construction, if not adequately managed, can increase these constituent concentrations to levels that may impact water quality. Pollutants associated with stormwater may include sediment, nutrients, pesticides, metals, pathogens, litter, petroleum products and chemicals.

There are a number of potential storm water pollutants that are common to Transportation construction sites. The soil-disturbing nature of construction activities and the use of a wide range of construction materials and equipment are the sources of contaminants with the potential to pollute storm water discharges.

Common construction activities that increase the potential for polluting storm water with sediment include:

- Clearing and grubbing operations
- Demolition of existing structures
- Grading operations
- Soil importing and stockpiling operations
- Clear water diversions and Isolation Technique BMPs (Refer to Chapter 5)
- Landscaping operations
- Excavation operations
- Concrete placement and finishing operations

Common construction materials with the potential to contribute pollutants, other than sediment, to storm water include the following:

- Vehicle fluids, including oil, grease, petroleum, and coolants
- Asphalt concrete and Portland cement concrete materials and wastes
- Joint seal materials, form oil, and concrete curing compounds
- Paints, solvents, and thinners
- Wood products
- Metals and plated products
- Fertilizers, herbicides, and pesticides

Construction-related waste must also be managed to prevent its introduction into storm water. Typical waste on construction sites includes:

- Used vehicle fluids and batteries
- Wastewater from vehicle cleaning operations
- Green waste from vegetation removal
- Non-storm water from dewatering operations
- Trash from materials packaging, employee lunch/meal breaks, etc.
- Contaminated soils
- Slurries from sawing and grinding operations

- Wastewater/waste from concrete washout operations
- Hazardous materials waste
- Sanitary waste
- Partially empty buckets and drums improperly sealed

Erosion and sedimentation during construction are perhaps the most visible water quality impacts due to construction activities. Other less visible impacts are associated with offsite discharge of pollutants such as metals, nutrients, soil additives, pesticides, construction chemicals, and other construction waste. After the construction project is complete, the changes to the landscape due to the project may alter the existing runoff regime or introduce new sources of pollutants that continue to impact water quality into the future. The magnitude of stormwater impacts depends on construction activities, climatic conditions, and site conditions. Development of a comprehensive SWPPP requires a basic understanding of the impacts, pollutant sources and other contributing factors, as well as suitable BMPs which can eliminate or reduce these impacts. A brief summary of common stormwater pollutants associated with transportation facilities and their impact on water quality are described below.

2.3 Potential Pollutants

2.3.1 Total Suspended Solids (TSS) AKA Sediment and Soil

Sediment or TSS is considered a pollutant when it significantly exceeds natural concentrations and can have a detrimental effect on the beneficial uses designated for the receiving water. Possible sources of TSS include natural erosion, runoff from construction sites, and other operations where the surface of the ground is disturbed. In addition, increased runoff from new impervious surfaces can accelerate the process of channel erosion, which in turn can increase TSS in runoff.

Sediment from soil erosion is made up of soil particles and gravel washed into rivers, lakes, streams and marine environments. It is the major pollutant in surface waters. Excessive sediment in waterbodies impairs aquatic ecosystems, reduces public water storage and increases drinking water treatment costs. These sediment particles are also a vehicle to transport other pollutants including nutrients, metals, petroleum products and bacteria to surface waters.

Runoff from construction sites is the major source of sediment in urban areas under development. Another major source of sediment is off-site streambank and streambed erosion. Though part of natural processes as described in the last section, this erosion can be by product caused from higher peak runoff flow rates and volumes in modified landscapes.

2.3.2 Nutrients

Excessive inputs of nutrients such as phosphorus and nitrogen to receiving waters can overstimulate the growth of aquatic plants to the detriment of other aquatic life and to some beneficial uses of the receiving water. Nutrients generally have more adverse effects in water bodies with slow flushing rates, such as slow moving streams and lakes. Also, nutrients attached to TSS in storm water runoff can cause problems where they settle out downstream.

Sources of phosphorus that may be present in highway runoff include tree leaves, surfactants and emulsifiers, and natural sources such as the mineralized organic matter in soils. Phosphorus may be present in storm water discharges as dissolved or particulate orthophosphate, polyphosphate, or organic phosphorous.

Potential sources of nitrogen in highway runoff include atmospheric fallout, nitrite discharges from automobile exhausts, fertilizer runoff, and natural sources such as mineralized soil organic matter. Nitrogen may be present in storm water discharges as nitrate, nitrite, ammonia/ammonium, or organic nitrogen.

Phosphorus and nitrogen are the primary forms of nutrients that can cause water pollution. Lawn fertilizers used to establish and maintain vegetation can be significant sources of phosphorus. Nitrogen comes from fertilizer, too, but is also found in animal wastes, grass clippings and effluent from leaking septic systems.

Phosphorus and nitrogen are sources of food for the algae and bacteria that live in lakes, streams, rivers and marine environments. Waters polluted with these nutrients develop large numbers of algae and bacteria that can deplete available oxygen, causing fish and other beneficial organisms to die (Hypoxic and Anoxic conditions).

Nutrient pollution can be prevented by composting grass clippings and animal wastes, and repairing leaking septic systems. Nutrient pollution from construction sites can be minimized by applying fertilizer at the rate recommended by a soil test, or conserving topsoil to reduce or eliminate the need for fertilizer soil amendments.

2.3.3 Pesticides

A pesticide is a chemical agent designed to control pest organisms. The most common forms of pesticides are organic chemicals designed to target insects (insecticides) or vascular plants (herbicides). Pesticides have been repeatedly detected in surface waters and precipitation in the United States. Water is one of the primary media in which pesticides are transported from targeted applications to other parts of the environment. As the use of pesticides has increased, concerns about the potential adverse effects of pesticides on the environment and human health have also increased.

2.3.4 Metals (Particulate and Dissolved)

Metals in storm water runoff may be in a dissolved phase or a particulate form attached to TSS. Some Treatment BMPs are effective for removing specific particulate metals, but not for removing dissolved metals. If there are special requirements to remove dissolved metals (e.g., to address a TMDL or other site-specific requirement), then the designer should contact the DOH-CWB to identify the appropriate BMP requirements. Metals in the particulate phase may be removed through sedimentation or biofiltration.

Possible sources of metals in highway runoff include the combustion products from fossil fuels, the wearing of brake pads, and the corrosion of metals, paints and solder. Metals can also reach receiving waters through the natural weathering of rock and soil erosion.

2.3.5 Pathogens

Pathogenic microorganisms including viruses, bacteria, protozoa, roundworms, tapeworms, and flatworms (aka flukes) are of concern in storm water runoff. The direct measurement of specific pathogens in water is extremely difficult. For that reason, the coliform group of organisms is commonly used as an indicator of the potential presence of pathogens of fecal origin.

Sources of total and fecal coliforms in storm water runoff are ubiquitous (e.g., soil particles, droppings of wild and domestic animals, etc.). Human sources could include illicit sewer connections and seepage from septic tanks.

2.3.6 Trash

Trash in storm water is defined as manufactured objects made from paper, plastic, cardboard, glass, metal, etc. This definition does not include materials of natural origin such as gravel or vegetation. Trash in surface waters can inhibit the growth of aquatic vegetation, harm aquatic organisms by ingestion or entanglement, convey other pollutants, such as toxic substances, and cause aesthetic problems on shorelines.

2.3.7 Petroleum Products

Petroleum products float on water and are visible. The hydrocarbons in petroleum have a strong characteristic for attaching to sediment particles. Hydrocarbons are known to be toxic to aquatic organisms. Common sources of petroleum products at the construction site are oil storage, fuel facilities, leaks from crankcases and improper disposal of drain oil.

2.3.8 Chemicals

Paints, solvents, sealants, cleaning agents and caulks may be found on construction sites. These chemicals along with chemically composed or treated construction materials may enter the runoff water. Water quality is easily degraded by these chemicals and removal during water treatment processes may be feasibly, fiscally, and logistical difficult.

2.4 Water Chemistry

Pollutants in stormwater can be affected by multiple chemical factors including pH, hardness, salinity, and temperature.

2.4.1 pH

pH is a measure of hydrogen ion concentration, with low pH ($pH<7$) being acidic, pH = 7 being neutral, and high pH ($7<pH<14$) being basic or alkaline. In addition to direct impact on fish and other wildlife, pH also significantly affects other chemical characteristics of stormwater. Lowering pH increases the solubility of metals, resulting in a higher fraction of metals present in the dissolved state. Raising pH increases the levels of the more toxic form of ammonia.

2.4.2 Hardness

Water hardness measures the presence of multivalent cations (positively charged ions) dissolved in water, particularly calcium and magnesium divalent cations (ions with a charge of +2). Increased water hardness typically decreases the toxicity of metals for fish. Hardness does not have a substantial effect on the toxicity of metals for fish in marine waters.

2.4.3 Salinity and Temperature

Salinity is the dissolved salts content of a body of water. Increases in salinity of surface waters can reduce the amount of oxygen that can be dissolved in the water. Increased temperature has a similar effect on dissolved oxygen. Salinity also affects metal toxicity, frequently increasing it.

2.5 Transport of Stormwater Pollutants

Stormwater pollutants enter receiving waters through many routes. The following sections describe what happens to stormwater pollutants when these substances come into contact with stormwater.

2.5.1 Initial Transport

Pollutants are deposited on road surface as particulates (e.g., brake pad dust, dirt, and salt) and liquids (e.g., oil, antifreeze, gasoline), then washed off the undercarriage of vehicles during storm events (e.g., rusted metal, hydrocarbons), or washed onto roads from adjacent exposed soils or landscaping. Pollutants on the roadway surface may coat or bind to soil particles, or may remain unbound on the road surface.

When precipitation hits impervious surfaces such as roadways, roofs, and sidewalks, contaminants may be picked up and transported in stormwater runoff, whether bound to particulate matter, dissolved in solution, or in suspension. Particulate material may be transported as suspended load or as bed load (bumping along the bottom or "bed" of the channel).

2.5.2 During "First Flush"

First flush describes the elevated pollutant concentrations that are often experienced during the initial part of a storm. Pollutant concentrations may peak during the "first flush" of a storm, but concentration peaks may or may not coincide with the load peaks since that is a factor of both concentration and volume of runoff. Different pollutants may also have peaks at different times during a storm, depending on how easily they are entrained. The prominence of the first flush varies considerably between storms and between locations. Factors influencing the magnitude of the first flush include the availability of pollutants on the road surface, and the form of the drainage area. The simpler and shorter a drainage area is, the more likely it is that the first flush will be clearly expressed.

Along with the storm event first flush, there may be a seasonal first flush when pollutants that have accumulated during an extended dry period are collected during the first storms of the season. Larger pollutant loads and higher median concentrations are often observed during the first storms of the season than storms later in the wet season or those closely following a series of storms. A seasonal first flush is not always present.

2.5.3 After Entry into a Water Body

Once stormwater carrying pollutants enters a receiving water body, several things can happen to the pollutant load. Compounds bound to soil and other solids may settle out of the water column or be filtered out by vegetation. Chemicals can be removed from the water column by biological uptake (i.e., plants and aquatic animals), or become attached to sediment and organic matter. Pollutants also may be degraded biologically (e.g., by microbes), chemically, or with sunlight (photodegradation). Compounds that are not removed from the water column may be transported to other water bodies. Pollutants that are deposited and removed from the water column may be re-entrained later, either by erosion, or by reentering a dissolved state if the chemical environment changes.

2.5.4 During Downstream Transport

During transport downstream, the concentration of pollutants from a discharge of highway runoff will decrease through three mechanisms. The first is dilution by increased flow in the stream from tributaries and additional base flow. Second is pollutant removal as described above. Finally, dispersion as the plume of stormwater becomes elongated due to mixing and irregular flow within the stream. This last effect means that the peak concentration in the plume will decrease, while the extent of the plume will increase.

2.6 Impacts of Water Quality Pollution on Aquatic Organisms

Fisheries are an important resource in Hawaii. However, despite the abundance of fresh water and hundreds of streams, the only freshwater fishes native to Hawaiʻi are four gobies and an eleotrid, collectively known as oʻopu. Two marine fishes, aholehole and mullet, are transient inhabitants of lower stream reaches. While these species have differing habitat requirements and tolerances, all are vulnerable to increased pollutant loads and concentrations.

Anthropogenic (human-caused) pollution via stormwater can harm fish by reaching lethal levels of toxicity, by affecting the health and viability of fish populations, by damaging or changing food sources (such as macorinvertebrates), and by physical changes to the aquatic habitat. To protect this dwindling resource, stormwater must be treated based on both pollutants generated and vulnerability of species in receiving waters.

The toxicity to fish of a given chemical is often not directly related to chemical concentration. Instead, toxicity to fish is affected by the bioavailability of the compound. Bioavailability of a compound to fish can be affected by water temperature, pH, dissolved organic carbon, suspended sediment, and hardness (pH and hardness are discussed in water chemistry section of this chapter); other water quality parameters are discussed below.

2.6.1 Water Temperature

Elevated temperatures can have lethal or non-lethal effects to aquatic organisms, depending on the temperature and duration of exposure. Acute non-lethal effects of temperature include behavior adjustments such as reduced feeding and relocation to cooler waters. Chronic non-lethal effects of elevated temperatures include reduced growth and development, both of which can affect survival and reproduction of aquatic species.

2.6.2 Sediment

Sediment can affect fish both directly (when suspended) and indirectly (when settled and accumulating). In suspended form, sediment may damage gill tissue, particularly if the sediment particles are angular. Several fish species are sight feeders, and murky waters can decrease their ability to find food. Suspended solids also can increase the stress response in fish, which in time can disrupt the proper functioning of other systems and alter fish behavior. Suspended solids may have a substantial effect on the bioavailability of other pollutants. Contaminants can absorb or bond to the surface of the particles, preventing them from being absorbed by fish and becoming toxic.

When sediments settle and accumulate they can degrade fish habitat, including sensitive spawning habitat which may requires clean gravel. Changes in a water body's substrate due to excessive sedimentation can also lead to a change in the benthic macroinvertebrate community, and thus food sources for fish. Impairment of habitat can have long-term or delayed adverse effects on fish populations.

2.6.3 Metals

Stormwater from roadways contains metals in concentrations that may be toxic to fish, particularly copper, zinc, lead, and cadmium. The three known physiological pathways of metal exposure and uptake in fish species are gill surfaces, olfactory receptor neurons, and the digestive system. Dissolved metals are the most bioavailable form, and can be taken up by the fish directly through the gills.

Toxicity is affected by water's pH, hardness and salinity, and by other chemicals in the water.

2.6.4 Nutrients

Nutrients consist of chemicals that stimulate growth, particularly nitrogen and phosphorus. The largest concern about nutrients is their overstimulation of algal growth in receiving waters, particularly stagnant waters such as ponds, lakes or sloughs. Algae may affect the food chain by competing for surfaces with organisms that fish use as a food source, or in more extreme cases, cause eutrophication. Eutrophic waters experience explosive growth in algae populations, followed by a crash as nutrients are depleted. The algal die-off and decomposition uses up the dissolved oxygen in the water, causing fish and other aquatic life to suffocate.

Different forms of nitrogen and phosphorous exhibit different degrees of algal growth, with orthophosphates typically having the highest potential to cause eutrophication, usually because phosphorus is the nutrient limiting plant growth—many algae can fix their own nitrogen from the atmosphere. Stagnant waters and slow moving streams are particularly vulnerable to these hazards.

2.6.5 Organic Pollutants

Many different organic pollutants are toxic to salmonids, including pesticides, herbicides, pthalates, phenols, and poly aromatic hydrocarbons (PAHs). Typical levels of these pollutants in roadway runoff are not clearly defined, and in many cases may be below toxic concentrations.

2.6.6 Acute and Chronic Effects

Acute (limited duration) and chronic (longer duration) exposure of fish to contaminants can result in various non-lethal effects. Physiological effects include altered respiration rate, blood chemistry (glucose levels, cortisol levels, etc.), swimming speed, breathing rate, and oxygen consumption. Numerous chemicals act as endocrine-disrupting compounds (EDCs), including estrogenic compounds, PAHs, flame retardants, and metal compounds. Chronic exposure to these compounds can affect fish behaviorally, resulting in altered hormone-dependent behaviors (e.g., spawning, migration), and physiologically, resulting in physical changes (e.g., intersex, the presence of both male and female reproductive organs in an individual).

2.6.7 Indirect Impacts to Water Quality

The placement and design of highway facilities can modify elements of the landscape that have beneficial hydrologic and water quality functions. Those modifications can affect the hydrology and water quality of receiving waters, even if no highway runoff reaches them. The most important of these landscape elements are riparian zones and wetlands.

2.6.7.1 Riparian Zones

Riparian zones can, when in good condition, provide several water quality benefits. Trees and shrubs produce shading, which is important for regulating temperature in smaller streams. They also act as sources of food and nutrients for the biotic community of the stream, including macroinvertebrates, fish, and amphibians. During high flow events, the same trees and shrubs slow down overbank floodwaters and provide refugia for fish. Vegetation on the stream bank is important for controlling lateral erosion. Riparian zones can also be effective at removing nutrients, sediment and other pollutants carried by runoff from adjacent developed or agricultural lands.

Destruction of riparian vegetation can therefore lead to the following adverse impacts:

- Increased stream temperature
- Increased pollutant loads derived from adjacent land use
- Reduced food supply for aquatic animals
- Increased bank erosion, which in turn leads to increased turbidity, and potentially sediment deposits on spawning gravels and modified stream geometry
- Loss of high flow refugia for fish.

2.6.7.2 Wetlands

Wetlands provide both water quality and hydrologic benefits. Even degraded wetlands can effectively provide those functions. The wetlands usually perform these functions for the drainage area as a whole, not just for highway runoff. Impacts to wetland can reduce the capability and the capacity of the wetland to perform certain water resources functions. Loss of capability could result from changes in vegetation composition, structure or density, or from altered hydrology. Loss of capacity would result from a reduction of size, diversion of water away from the wetland, or other modification of the hydrology.

Loss of wetlands can lead to the following adverse impacts:

- Increased pollutant loads discharged to streams and lakes
- Higher flood peaks downstream of the wetland
- Reduced low flow discharges downstream of the wetland
- Loss of aquatic habitat.

2.6.7.3 Development

Induced or facilitated development may also be considered a secondary or indirect impact of a project on water resources. In Hawaii, highway projects support the designated land uses, so it is rare that a highway project can be said to cause development, but they do support planned and approved development. The result of development is that expected from the addition of impervious area with new roads, buildings and landscape modifications. It is not the responsibility of the PDT to analyze the impacts from associated development in any depth, but they should be addressed in NEPA analysis if reasonably foreseeable.

2.7 Step by Step Process for SWPPP/IWPPP Development and Implementation.

2.7.1 Internal Roles and Responsibilities

NPDES compliance clearly requires an interdisciplinary approach. However, roles and responsibilities for the various NPDES requirements need to be defined and responsibility/accountability for the overall program needs to be assigned. The following recommendations are made to promote consistency within FLH and thereby facilitate development and maintenance of an FLH NPDES Program. In general:

- Environmental staff should be responsible and accountable for defining the NPDES processes required for program compliance, as well as monitoring and refining those processes for adequacy and continuous improvement.
- Project Management staff should be responsible and accountable for ensuring that all program level processes are addressed and executed to the appropriate degree on the project development and delivery level.
- Environmental staff should be responsible for compiling the stand-alone SWPPP/IWPPP, as well as preparing and submitting the NOI and NOT.
- Design staff should be responsible for development of the Erosion and Sediment Control (ESC) plans and specifications included in the PS&E package.
- Construction staff should be responsible for implementing and maintaining the SWPPP/IWPPP during the life of the construction project.
- Technical Services staff should act as a program and/or project resource to provide necessary support information, such as custom analysis, design, or evaluation of standard drawings, SCRs, and new products.

2.7.2 External Roles and Responsibilities

It is recommended that FHWA and HDOT use program agreements to define general agency roles and responsibilities associated with the NPDES Program. Project Agreements should be used to clearly define project-specific partner roles and responsibilities early in the project development process. Partner agencies should be considered for one or more of the following roles and responsibilities:

- Providing re-vegetation design and specifications

- Removing temporary erosion and sediment control devices that need to be left in place until final stabilization is achieved
- Submitting an NOI and assuming the NPDES responsibilities when construction work is complete but final stabilization has not yet been achieved.

Assigning these roles and responsibilities to the local FHWA or HDOT partner agencies is considered appropriate for three primary reasons:

- The owning agency or the land management agency has intimate local knowledge of the climatic, soil conditions and ground cover type and density that can be supported. This knowledge allows them to identify and develop the most appropriate final stabilization strategy and design.
- The owning agency has responsibility for maintenance of the roadside and thereby, a vested interest in ensuring that final stabilization can be achieved and maintained.
- The brief, contractual nature of the FHWA or HDOT presence makes it very difficult to address NPDES requirements between the end of the construction contract and final stabilization. This is especially true in arid to semi-arid regions of the country where final stabilization may take time to achieve.

2.7.3 Step By Step Process Description and Recommendations

The 2007 EPA Guide included in Appendix C is a reference that can be used by the PDT as basic guidance for project-level compliance. Additional State and local requirements apply for compliance in Hawaii and these have been included in the IWPPP sample found in Appendix G.

The EPA guidance describes seven steps for developing and implementing project-specific SWPPPs. Recommendations for improving the SWPPP development and implementation practices within FLH are listed below in the context of EPA's 7-step process.

2.7.3.1 Step 1: Site Assessment and Planning (Chapter 3 in 2007 EPA Guide (Appendix C)

- **Environment** staff should be responsible for identifying, documenting, and communicating the applicable NPDES requirements and other related environmental issues. This includes identifying the governing construction general permit (CGP), applicable state and local ordinances, and sensitive resources such as impaired waters, presence of aquatic ESA species or critical habitat.
- **Environment** staff should conduct a site assessment jointly with Design, whenever appropriate, to evaluate and document site conditions, risks, and opportunities associated with erosion and sediment control. The EPA SWPPP Template should be used as a checklist when conducting this review. This review should be conducted early in the project development process as part of the early coordination field review or other planned review.

2.7.3.2 Step 2: SWPPP Development - Selecting Erosion and Sediment Control BMPs (Chapter 4 in 2007 EPA Guide.)

- **Design** staff should develop an erosion and sediment control plan as part of the contract package. The plan should include standard drawings, details, quantities, and specifications for all structural BMPs. BMPs should be selected from the approved BMPs listed within this manual. Wherever possible, rely on erosion controls to keep sediment in place. Back up those erosion controls with sediment controls to ensure that sediment doesn't leave the site.
- **Design** staff should include contract specifications and pay items for non-structural BMPs to address unique site conditions, requirements or risks as needed. Examples include water quality monitoring or an onsite Erosion and Sediment Control Supervisor.
- **Environment** staff should provide progress reviews of the plans and specifications (typically 30, 50, 70, and 95%) to ensure compliance with the NPDES CGP requirements and to facilitate development of the stand-alone SWPPP described in Step 4 and the Notice of Intent (NOI) described in Step 5.

2.7.3.3 Step 3: SWPPP Development – Selecting Good Housekeeping BMPs (Chapter 5 in 2007 EPA Guide)

- **Design** staff should be responsible for selecting good housekeeping BMPs and providing appropriate contract language in the specifications. EPA defines good housekeeping BMPs as those designed to prevent contamination of stormwater from a wide range of materials and wastes at the construction site.

2.7.3.4 Step 4: SWPPP Development - Inspections, Maintenance, and Recordkeeping (Chapter 6 in 2007 EPA Guide.)

- **Design** staff should include contract specifications for inspection, maintenance, and recordkeeping required during construction. Contract specifications should identify the government provided SWPPP as a key project record and require appropriate care and maintenance throughout the life of the construction project including disposition of the SWPPP at the end of construction.

  EPA and many state general permits require that a sign be posted near the main entrance of construction sites. It is common for the permits to require that the sign contain a copy of the NOI, the location of the SWPPP, and a contact person for viewing the SWPPP.

- **Environment** staff should be responsible for compiling a stand-alone SWPPP that will be provided to Construction for directing and documenting the implementation of the SWPPP as described in Step 6. Elements of the stand-alone SWPPP include the CGP, erosion and sediment control plan from the contract package, associated narrative, contract specifications, NOI, inspection forms, and any other information required to comply with the CGP.

2.7.3.5 Step 5: Certification and Notification (Chapter 7 in 2007EPA Guide)

- **Environment** staff should be responsible for preparing the NOI, obtaining an authorized signature on the certification, and submitting the NOI in accordance with the CGP.

2.7.3.6 Step 6: SWPPP Implementation (Chapter 8 in 2007 EPA Guide.)

- **Construction** staff is responsible for ensuring inspections, maintenance, and recordkeeping are performed in accordance with the CGP and the SWPPP.
- **Construction** staff is responsible for reviewing and approving contractor requested modifications to SWPPP.
- **Construction** staff is responsible for directing changes to the SWPPP as needed to ensure compliance with the CGP.
- **Construction** staff is responsible for requesting support from Environment, as needed. As the lead office, Environment should be the single point of contact for managing such requests and enlist the assistance of Design, Tech Services, or others, as needed.
- **Construction Operations Engineer** (COE) or **Project Engineer** (PE) should conduct a Quality Assurance (QA) review of NPDES compliance during every project site visit. The QA review should include inspection of the SWPPP to ensure that it is properly maintained. The QA review should also include an inspection of site conditions to ensure that site conditions match the SWPPP and that erosion and sediment control is effective. The COE's QA reviews should be documented in the SWPPP.
- **Construction** staff should be responsible for submitting the final post-construction SWPPP to Environment when construction work is complete.

2.7.3.7 Step 7: Final Stabilization and Permit Termination (Chapter 9 in EPA guidance.)

- If the owner agency is responsible for final stabilization, Construction should submit the final as-built SWPPP to Environment. Environment should prepare and submit the NOT, and transfer the SWPPP to the owner agency. The owner agency would then be responsible for filing an NOI and assuming all of the NPDES requirements through final stabilization in accordance with the program or project agreement. This is a practice successfully applied in CFL.
- If FLH is responsible for final stabilization, Construction should remain responsible for all NPDES requirements until final stabilization is achieved and the final SWPPP is submitted to Environment. Environment should prepare and submit the NOT and archive all SWPPP related records with the construction records.

2.7.3.8 Task -Specific Recommendations

The following recommendations are provided to assist with the details of completing various tasks associated with SWPPP/IWPPP development and implementation in accordance with the 2007 EPA Guide and state specific requirements.

2.7.3.8.1 Develop Site Plan Design

- Include topographic mapping in SWPPP document to better show drainage patterns and discharge points.
- Show "clearing limits" on Erosion and and Sediment Control plans.
- Determine if a pay item for Erosion Control Supervisor is appropriate,

2.7.3.8.2 Measure Area of Disturbance

- Area of disturbance should be based on clearing limits, not slope stake limits.
- Where no definition is provided by the CGP, consider defining "disturbance" as any erodible surface of 1 acre or more, except travel ways of gravel or better surface type.

2.7.3.8.3 Determine Drainage Area

- Calculate area draining to all non-standard, structural BMP devices. An example is a sediment basin.
- Provide sediment basin(s) when the area of disturbance within a given drainage area is ten acres or more. (EPA sediment basin sizing criteria – lesser of 3600 cu. ft. per acre or volume of Q2 runoff from drainage area.)

2.7.3.8.4 Determine Runoff Coefficient

- Required for sediment basin design in drainage areas of 200 acres or less.

2.7.3.8.5 Construction/Implementation

- Consider paying for maintenance of ESC items with equipment and labor hours, or prorating a lump sum amount over the life of the contract..