CHAPTER 3

Pollutant Types and Effects on Receiving Waters

3.1 Erosion and Sedimentation

Erosion and sedimentation are natural processes whereby soil materials are detached, transported, and then deposited from one location to another due to the action of water, wind, ice, or gravity.

These natural processes are accelerated by land disturbance activities, including highway construction projects. Accelerated erosion and sedimentation can result in significant adverse impacts on receiving waters, therefore affecting recreational uses, aquatic life, water stability, safety, roadway structures, aesthetics, and maintenance. Areas where rapid development has occurred will show an increase in channel degradation, usually accompanied by bank erosion.

3.1.1 Types of Erosion

Common types of erosion include the following:

- **Sheet Erosion –** Transporting of small soil particles loosened by impacts of raindrops on soils by runoff flowing in a thing layer over the ground surface.
- **Rill Erosion –** Formation of numerous small channels several inches deep.
- **Gully Erosion –** Accumulation of water in narrow channels, increasing their depth.
- **Channel Erosion –** Scouring action in channel banks and bottom.

3.1.2 Factors Affecting Erosion

The erosion potential of any area is determined by four interrelated factors, as described below.

Soil Characteristics. The soil characteristics that influence erosion by rainfall and runoff are the infiltration capacity of the soil and the resistance of the soil to detachment and being carried away by falling or flowing water. Granular soils containing high percentages of fine sands and silt are normally the most erodible. Cohesive soils with a higher content of clay and organic matter are less erodible. Clays act as a binder to soil particles, thus reducing erodibility. However, while clays have a tendency to resist erosion, once eroded they are easily transported by water. Soils high in organic matter have a more stable structure that improves their permeability. Such soils resist raindrop detachment and allow more rainwater infiltration. Clear, well-drained, and well-graded gravels and gravel-sand mixtures are usually the least erodible soils. Soils with high infiltration rates and permeabilities reduce the amount of runoff.

Vegetative Cover. Vegetative cover plays an important role in controlling erosion by shielding the soil surface from the impact of falling rain, holding soil particles in place, maintaining the soil's capacity to absorb water, slowing the velocity of runoff, and removing subsurface water between rainfalls through the process of evapotranspiration.

Topography. The size, shape, and slope characteristics of a watershed influence the amount and rate of runoff. As both slope length and gradient increase, the potential for erosion is magnified.

Climate. The frequency, intensity, and duration of rainfall are fundamental factors in determining the amount of runoff produced from a given area. As both the volume and velocity of runoff increase, the capacity of runoff to detach and transport soil particles also increases. Where storms are frequent, intense, or of long duration, erosion risks are high. Seasonal changes in temperature, as well as variations in rainfall, help to define the high erosion risk period for the year. When precipitation falls as snow, erosion will take place. However, in the spring, the melting snow produces runoff that increases erosion hazards. If the ground is still partially frozen, its absorptive capacity is reduced. Frozen soils are relatively erosion-resistant. However, soils with high moisture content are subject to uplift by freezing action and are usually easily eroded upon thawing.

3.2 Pollutant Types and Sources

The main pollutant resulting from erosion is sediment. Sediments are typically present in inorganic form as silt, clay, or sand particles, and in organic form as fine particulates. Less common pollutants are metals, or nutrients such as nitrogen or phosphorus, associated with minerals exposed by erosion or excavated during construction activities.

Other potential pollutants, not associated with erosion, are chemicals that are used and stored at construction sites. Table 3-1 lists pollutants that may be present during highway construction activities.

TABLE 3-1
Construction Site Pollutants

Source	Pollutants
Adhesives	Phenols, Formaldehydes, Asbestos, Benzene, Naphthalene
Cleaners	Metals, Acidity, Alkalinity, Chromium
Plumbing	Lead, Copper, Zinc, Tin
Painting	VOCs, Metals, Phenolics, Mineral Spirits
Woods	BOD, Formaldehyde, Copper, Creosote
Masonry/Concrete	Acidity, Sediments, Metals, Asbestos
Demolition	Asbestos, Aluminum, Zinc, Dusts
Yard O & M	Oils, Grease, Coolants, Benzene and derivatives, Vinyl Chloride, Metals, BOD, Sediments, Disinfectants, Sodium Arsenite, Dinitro compounds, Rodenticides, Insecticides
Landscaping and Earthmoving	Pesticides, Herbicides, Fertilizers, Nutrients, BOD, Acidity, Alkalinity, Metals, Sulfur, Aluminum Sulfate
Materials Storage	Spills, Leaks, Dusts, Sediments

Source: Adapted from *California Storm Water Best Management Practice Construction Handbook* (30).

3.3 Effects of Receiving Waters

A direct effect of sediments discharged into receiving waters is the increase in turbidity due to the increase in concentration of suspended solids. Increase in turbidity will result in higher costs for water treatment and will affect aquatic biota by reducing the photosynthetic activity. An increase in suspended solids can damage water supplies and will affect feeding and nesting habits of creatures in the receiving waters.

An indirect effect of erosion is the deposition of sediments in a stream's channel bottom, which will lower the survival of fish eggs, damage bottom organisms, and destroy aquatic plants. Sediments reduce the oxygen in the water, deteriorate the health of fish and other aquatic creatures, and endanger survival of aquatic organisms. Excess sediments will accumulate in reservoirs and ponds, reducing their storage volume and potentially causing flood damages.

3.4 Highway Runoff

Operation of the highway system produces pollutants that are transported by runoff and cause adverse impacts to receiving waters. The Federal Highway Administration (FHWA) has sponsored significant research to determine highway runoff pollutant types and sources, impacts to receiving waters, and methods to estimate those impacts. Some of the findings of FHWA's research are summarized in this section.

3.4.1 Factors Affecting Pollutant Types and Concentrations

The types and concentration of pollutants present in highway runoff are affected by many factors, including the following:

- Traffic characteristics
- Climatic conditions
- Maintenance practices
- Surrounding land use
- Pavement characteristics
- Vegetation types on the right of way
- Institutional characteristics (i.e., litter laws, speed limit enforcement, and car emission regulations)

The FHWA has assigned levels of importance (low, medium, high) to various factors that affect the characteristics of highway runoff, as listed in Table 3-2.

TABLE 3-2
Factors Affecting Highway Runoff Characteristics

Factor	High	Medium	Low
Climatic conditions	X		
Pavement Quantity	X		
Right-of-Way Vegetation	X		
Average Daily Traffic (ADT)	X		
Surrounding Land Use	X		
Highway Drainage Features	X		
Atmospheric Deposition		X	
Highway Configuration		X	
Pavement Composition/Condition		X	
Vehicular Inputs		X	
Maintenance Practices		X	
Highway Design			X
Institutional Characteristics			X

Traffic density has been suggested as one of the main factors affecting highway runoff. However, studies have not shown a direct correlation between Average Daily Traffic (ADT) and pollutant concentrations. ADT is certainly a very important factor, but it does not seem to dominate over the combined effects of the other factors.

One factor that has a major influence on highway runoff characteristics is the surrounding land use. Major differences occur between highways in urban areas versus highways in rural areas. An ADT of 30,000 vehicles per day is used to distinguish between urban, rural urban, and rural highways. Highway runoff characteristics are similar to those of urban runoff. Common pollutants found in highway runoff, as well as their sources, are listed in Table 3-3.

TABLE 3-3
Sources of Common Highway Pollutants

Pollutants	Source
Particulate	Pavement wear, vehicles, atmosphere, maintenance
Nitrogen, Phosphorus	Atmosphere, roadside fertilizer application
Lead	Leaded gasoline, tire wear, oil and grease, bearing wear
Zinc	Tire wear, motor oil, grease
Iron	Autobody rust, steel highway structures, engine parts
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides, insecticides
Cadmium	Tire wear, insecticide application

TABLE 3-3
Sources of Common Highway Pollutants

Pollutants	Source
Chromium	Metal plating, moving engine parts, brake lining wear
Nickel	Fuels, oils, metal plating, bushing wear, brake lining wear, asphalt paving
Manganese	Moving engine parts
Bromide	Exhaust
Cyanide	Anticake compound used to keep deicing salt granular
Sodium, Calcium	Deicing salts, grease
Petroleum	Spills, leaks, oils, antifreeze and hydraulic fluids, asphalt surface leachate
Polychlorinated-biphenyl, pesticides	Spraying of highway ROW, background atmospheric deposition, PCB catalyst in synthetic tires
Pathogenic bacteria	Soil, litter, bird droppings, trucks hauling livestock and stockyard waste
Rubber	Tire wear
Asbestos	Clutch and brake lining wear

Source: *Sources and Migration of Highway Runoff Pollutants* (3).

As part of the FHWA research, highway runoff from 31 sites (including one site in Denver on I-25) and from 993 storm events was evaluated. Event Mean Concentrations (EMCs) were determined for common and significant highway pollutants in both urban (ADT>30,000) and rural (ADT<30,000) areas. Median EMC concentrations, designated as the site median, are shown in Table 3-4. The median site (50th percentile) provides the most probable value for the site median concentration.

TABLE 3-4
Median EMC Concentrations (mg/l)

Pollutant	ADT<30,000	ADT>30,000
Total Suspended Solids	41	142
Volatile Suspended Solids	12	39
Total Organic Carbon	8	25
Chemical Oxygen Demand	49	114
Nitrate plus Nitrite	0.46	0.76
Total Kjeldahl Nitrogen	0.87	1.83
Total Phosphorus	0.16	0.40
Copper	0.022	0.054
Lead	0.080	0.400
Zinc	0.080	0.329

Source: *Pollutant Loadings and Impacts from Highway Stormwater Runoff* (5).

3.4.2 Effects of Highway Runoff on Receiving Waters

Three sites were selected during the FHWA research to determine impacts of highway runoff on receiving waters. Two of the sites represented highway discharges into streams, while the third site represented discharges into a lake. All sites represented highway systems with low to medium traffic volume (ADT<30,000) and no curb and gutter drainage design. This type of highway system is typical of the majority of CDOT highways. The study at each site included highway runoff flow measures, wet weather monitoring, sediment and vegetation sampling, and biological assessment.

The study concluded that highway runoff from "low to medium traffic volume (ADT<30,000) rural highways exert minimal to no impact on the aquatic components of most receiving waters." Specific conclusions applicable to the studied sites are as follows:

- Annual pollutant loads from highways were low compared to loads from entire watersheds.
- There were no significant violations of state water quality standards or EPA acute criteria at any of the sites during discrete storm events.
- No discernible trends or consistently elevated accumulations of pollutants in sediments were observed at the two stream sites.
- At the lake site, direct discharge of highway runoff from the bridge deck scupper drains caused a localized increase in metals and salts in near shore (i.e., near the bridge) sediments and cattails. It can be inferred from the quarterly benthos sampling and in-situ flow-through bioassays at this site that the impact is minimal.
- Of five species (mayfly, isopod, water flea, gammarid, and fathead minnow) used in the acute laboratory bioassays, only the gammiarid exhibited a toxic response to undiluted highway runoff. Two week (chronic) algal assays did demonstrate reduced growth for Selenastrum exposed to undiluted runoff compared to controls. Dilution effects were not determined in the laboratory bioassays. Flow-through in-situ bioassays at the lake site, where dilution occurred naturally, did not indicate an impact for six species.

3.4.3 Procedures to Estimate Impacts on Receiving Waters

The NPDES stormwater regulation does not require at this time that stormwater discharges meet a certain numeric water quality standard. Therefore, a quantitative water quality analysis will be necessary on very few CDOT projects, and should only be completed when required by a regulatory agency or when deemed necessary by the designer.

FHWA developed a procedure to perform quantitative water quality analyses. This procedure is described in FHWA's publication *Pollutant Loadings and Impacts from Highway Stormwater Runoff* (5). To apply the procedure, the following site and highway characteristics data are needed:

- Drainage area
- Rainfall
- Average Daily Traffic (ADT)
- Dissolved pollutant concentration

- Target receiving water concentration
- Stream flow

Application of the predictive procedure, whether the discharge is into a stream or a lake, is not complicated. Site and highway characteristic data are gathered, highway runoff water quantity and quality calculations are performed, and impacts to the receiving water are estimated. The procedure allows for computation of the following:

- Average number of storms per year
- Highway runoff rate and volume
- Ratio of highway runoff to stream runoff
- Pollutant mean event concentration
- Pollutant mass loads
- Once in three year stream pollutant concentration
- Average lake phosphorus concentration

The procedure estimates the once in three year stream pollutant concentration, which is then compared with EPA's acute criteria and National Urban Runoff Program threshold effect level. If the ratio of the predicted pollutant concentration to EPA's acute criteria is less than 0.75, it is unlikely that a toxicity problem exists. If the ratio is greater than 5, then interception of the pollutant will be required and BMPs should be considered.

For lake impact analysis, if the predicted phosphorus load from the highway is less than 0.01 mg/l, it is unlikely that any adverse impacts will be experienced. If the predicted phosphorus concentration is greater than 0.02 mg/l, BMPs should be considered.

BMPs used to improve highway runoff quality are described in section 5.3 of this guide.

3.5 Highway Maintenance Practices

Highway maintenance practices have the potential for resulting in adverse impacts to receiving waters. Highway maintenance practices need to be identified, and their effects determined, so that appropriate BMPs can be established and impacts to receiving waters can be minimized. FHWA has performed research in this area. This section summarizes FHWA's findings.

Highway maintenance practices can be classified according to their potential to impact water quality. Type I refers to practices that will have a probable impact on receiving waters, Type II are practices that have a possible impact, and Type III are practices that have no probable impact. Typical highway maintenance practices, as they relate to each of the three types described above, are listed in Table 3-5.

TABLE 3-5
Highway Maintenance Practices

Type I – Probable Impact
Repairing slopes and slides
Cleaning or repairing hydraulic structures
Painting bridges
Substructure repair
Chemical vegetation control
Type II – Possible Impact
Pavement repairs, cleaning, marking
Highway surface treatments
Blading and restoring unpaved berms and/or shoulders
Repairing curbs, gutters, and paved ditches
Bridge surface cleaning and deck repairs
Mowing
Planting or care of shrubs, plants, and trees
Seeding, sodding, fertilizing
Care of rest areas
Washing and cleaning maintenance equipment
Storage of non-fuel materials and fuels, and disposal of used oils
Blading unpaved surfaces
Snow plowing
Sanding
Deicing
Type III – No Probable Impact
Pothole patching and surface repairs
Filling and sealing joints and cracks
Pavement jacking
Planing pavements
Bridge joint repair
Superstructure repair
Guardrail and crash attenuator repair
Snow fence installation and removal
Highway lighting
Sign maintenance
Control and proper disposal of roadside litter

Source: *A Reference Manual for Assessing Water Quality Impacts from Highway Maintenance Practices* (24).