1. IMPACTS OF DEVELOPMENT ON RUNOFF

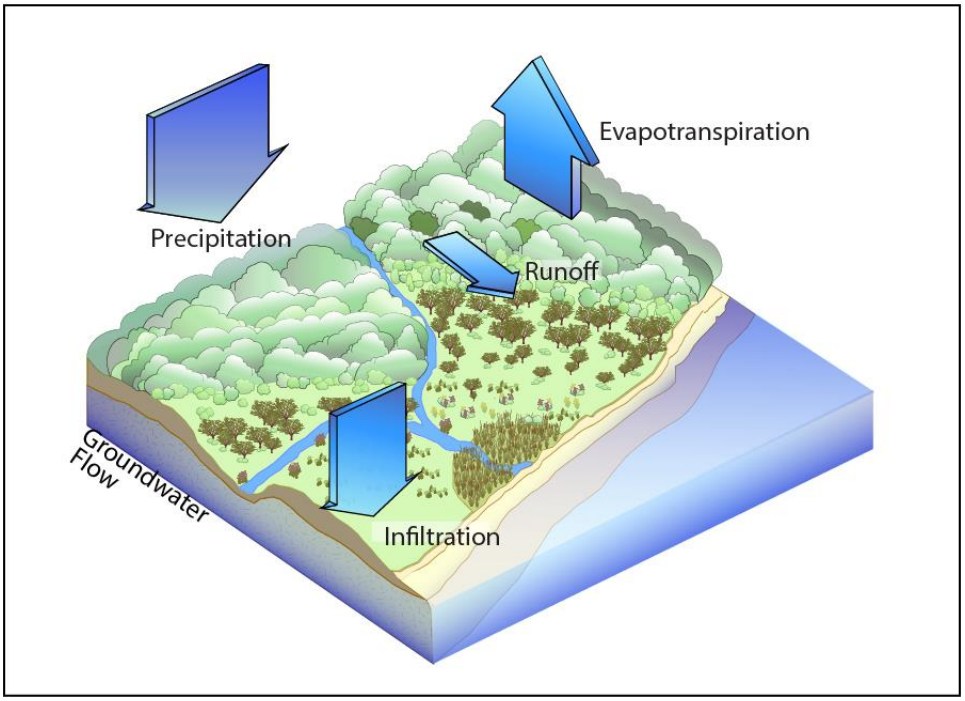
Introduction

This chapter describes the potential adverse impacts that improperly managed land development can have on groundwater recharge, stormwater quality and stormwater quantity both at and downstream of a development site. The chapter also reviews the fundamental physical, chemical, and biological aspects of the rainfall-runoff process and how they can be altered by development. Minimizing the impacts of runoff from development is addressed by a number of Department rules and permits, including the Stormwater Management rules at N.J.A.C. 7:8 and the New Jersey Pollutant Discharge Elimination System (NJPDES) permits, specifically the Municipal Separate Storm Sewer (MS4) permits and the Combined Sewer Outfall (CSO) permits.

Hydrologic Cycle

The hydrologic cycle describes the movement of water through the environment, which is affected by a number of factors, including vegetation, land cover, and topography. Altering these factors through land development affects the hydrologic response of an area to rainfall, and when these changes occur over large areas, the hydrology of entire watersheds may be significantly altered.

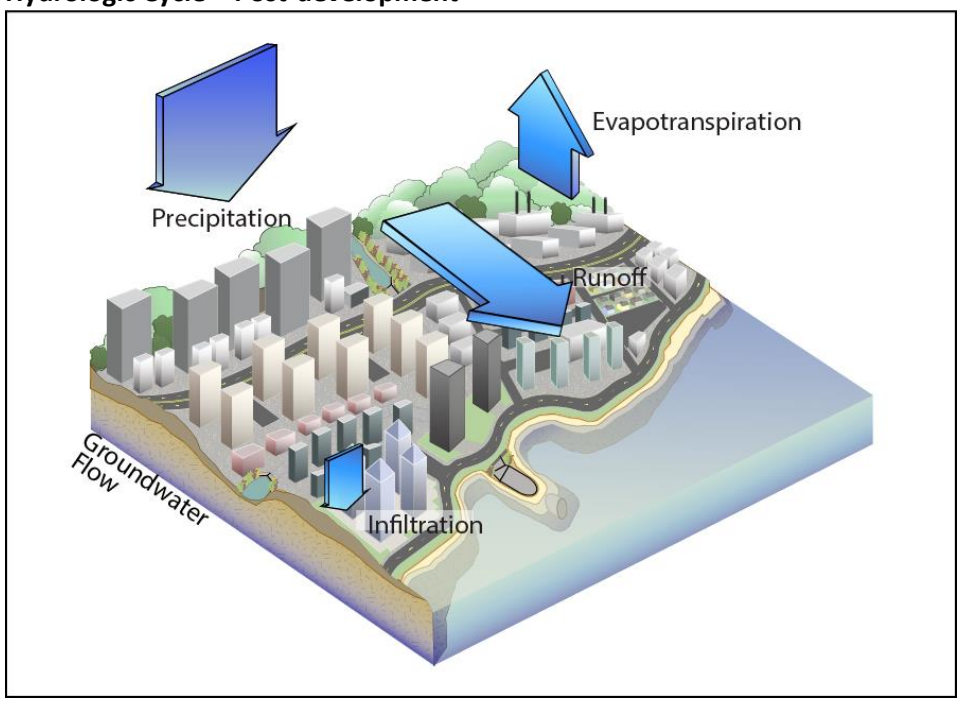
Hydrologic Cycle – Pre-development



Water from oceans, rivers, lakes, and soils evaporates and then condenses in the atmosphere to form clouds; the water then returns to the surface through precipitation. Under natural conditions, vegetation intercepts some of the precipitation, which then evaporates back into the atmosphere after the storm.

Some precipitation will reach the ground and then will either infiltrate into the soil or flow over the land surface as runoff. Surface runoff will either flow into a surface water body or wetland or be stored in depressions that allow infiltration into the soil. Once water enters the soil, it will be temporarily stored and then evaporate, infiltrate into the groundwater table where it will be stored or provide baseflow to streams, or be taken up by vegetation where it will return to the atmosphere as water vapor through evapotranspiration.

Hydrologic Cycle – Post-development



Land development usually alters this process in many ways, which, if not managed properly, can lead to dramatic changes in the way water moves through the environment. The removal of vegetation from the site has a significant impact on both the interception of precipitation and evapotranspiration, which results in more precipitation reaching the ground surface, and therefore an increase in the amount of runoff. Grading of the site affects runoff onsite in two ways: first, grading generally creates a more uniform topography, which removes existing depressions that stored runoff and reduced the flow leaving the site; second, clearing and grading of a site often compacts soil, reducing its ability to absorb precipitation. Placement of impervious surfaces, such as roads, parking lots, and rooftops also impacts runoff onsite by preventing precipitation from infiltrating, resulting in the majority of precipitation becoming runoff. Finally, many stormwater conveyance systems consist of pipes, gutters, and channels that directly connect the impervious surfaces to the receiving waterbody, resulting in the runoff quickly discharging to the surface waters. As a result of all these changes, the total amount of precipitation that becomes runoff and the rate at which it leaves a site are greatly increased, causing a number of significant environmental problems.

Runoff Quantity

As land development increases, runoff discharges to surface waterbodies more quickly and for a longer period of time. Because of this change in volume, rate and duration, surface waterbodies may be unable to convey the increased flow downstream, which may lead to flooding of nearby areas. In addition, increased flow rates and velocities in waterbodies may lead to erosion of stream channels and increased pollution entering waterbodies.

To reduce the potential negative effects of land development on flow rates leaving the site, the New Jersey Stormwater Management rules at N.J.A.C. 7:8 establish design and performance standards for runoff quantity. This design and performance standard can be met by meeting one of three options:

i. *Demonstrate through hydrologic and hydraulic analysis that for stormwater leaving the site, post-construction runoff hydrographs for the 2-, 10- and 100-year storm events do not exceed, at any point in time, the pre-construction runoff hydrographs for the same storm events;*

ii. *Demonstrate through hydrologic and hydraulic analysis that there is no increase, as compared to the pre-construction condition, in the peak runoff rates of stormwater leaving the site for the 2-, 10- and 100-year storm events and that the increased volume or change in timing of stormwater runoff will not increase flood damage at or downstream of the site. This analysis shall include the analysis of impacts of existing land uses and projected land uses assuming full development under existing zoning and land use ordinances in the drainage area; or*

iii. *Design stormwater management measures so that the post-construction peak runoff rates for the 2-, 10- and 100-year storm events are 50, 75 and 80 percent, respectively, of the pre-construction peak runoff rates. The percentages apply only to the post-construction stormwater runoff that is attributable to the portion of the site on which the proposed development or project is to be constructed.*

For more information on the water quantity design and performance standard, see *Chapter 5: Computing Stormwater Runoff Rates and Volumes.*

Groundwater Recharge

Groundwater recharge is defined as the amount of water from precipitation that infiltrates into the ground and is not evapotranspired. Therefore, not all runoff that infiltrates into the soil is recharged; only that portion that infiltrates past the root zone will recharge the groundwater table. Groundwater is an important water resource; it is an important source of potable water, and it is crucial for surface waterbody baseflow particularly during dry conditions when it may be the sole source of water feeding streams or ponds. When soil is compacted or covered by impervious surfaces, less precipitation is able to infiltrate, resulting in less groundwater recharge.

To reduce the negative effects of land development on groundwater recharge, the New Jersey Stormwater Management rules at N.J.A.C. 7:8 establish design and performance standards requiring recharge on major developments. This design and performance standard can be met by meeting one of two options:

i. Demonstrate through hydrologic and hydraulic analysis that the site and its stormwater management measures maintain 100 percent of the average annual pre-construction groundwater recharge volume for the site; or

ii. Demonstrate through hydrologic and hydraulic analysis that the increase of stormwater runoff volume from pre-construction to post-construction for the two-year storm is infiltrated.

For more information on the groundwater recharge design and performance standard, please see *Chapter 6: Groundwater Recharge*.

Runoff Quality

Annually, approximately 90% of the storm events in New Jersey are 1.25 inches or less; on an undeveloped site, there is very little runoff during these small, frequent storm events. The runoff that does come off the site has had significant time to interact with the vegetation and flow into and through depressions on site, which allows for some pollutant treatment through filtration and settling. On a developed site where vegetation has been removed, topography has been made more uniform, and runoff is collected and conveyed through a system of pipes, runoff has little time to lose any of its pollutant load resulting in direct discharge into waterbodies. Additionally, the types of surfaces common on developed land often consists of impervious surfaces and lawns, which accumulate a variety of pollutants, including metals, suspended solids, hydrocarbons, pathogens, and nutrients.

To reduce the negative effects of land development on stormwater runoff quality, the New Jersey Stormwater Management rules at N.J.A.C. 7:8 establish design and performance standards requiring water quality BMPs on major developments. The rules focus primarily on two pollutants: total suspended solids (TSS) and nutrients.

Total Suspended Solids (TSS)

Total suspended solids include sediment and other pollutants that can be removed from water through filtration. One of the most significant sources of total suspended solids is sediment. Sediments consist mainly of soil particles that are eroded or deposited as a result of natural processes and human activities.

The greatest total suspended solids loading in stormwater runoff often occurs during the construction phase of land development. During construction, large quantities of soil are often exposed to stormwater and the removal of vegetation makes the area more prone to erosion. Therefore, adequate sediment and erosion control must be installed and maintained at the site to prevent the delivery of large quantities of sediment into downstream waterways and waterbodies. Requirements for erosion control can be found in the *Standards for Soil Erosion and Sediment Control in New Jersey*, which is available from the State Soil Conservation Committee or local Soil Conservation Districts.

Total suspended solids in stormwater runoff can also be increased in post-construction developments. Soil, sediment, and other pollutants can be deposited on impervious surfaces by vehicles, landscaping activity, wind erosion, and many other processes.

High concentrations of suspended solids in streams and lakes may cause increased turbidity, which can significantly impact surface water ecology; these impacts include reduction of light penetration, clogging of gills, smothering of benthic communities, alteration of substrate, and filling in channels and ponds. Additionally, TSS may also include toxins and metals, further impacting the aquatic ecosystem.

To address the issues created by the increase in TSS in stormwater runoff from major developments, the Stormwater Management rules establish a design and performance standard requiring an 80% TSS reduction in the post-construction runoff from a major development that increases impervious surfaces by 0.25 acres or more. This reduction is achieved by conveying runoff through one or more onsite BMPs.

It is important to note that TSS removals for any specific BMP are highly variable due to many factors, including storm intensity and duration, recent rainfall conditions, and the conditions of the drainage area. For more information on TSS removal rates for specific BMPs, please see *Chapter 9: Structural Stormwater Management Measures*.

Nutrients

Nutrients in stormwater runoff are generally a result of agriculture, fertilizers used on lawns and animal waste. The two main nutrients of concern in stormwater runoff are phosphorous and nitrogen. Phosphorous and nitrogen are nutrients used by plants during photosynthesis. In excessive amounts, phosphorous and nitrogen over-stimulate plant growth in the aquatic environment, resulting in dense algal blooms. When the algae die, microorganisms break down the organic matter, consuming large amounts of oxygen in the process and reducing the dissolved oxygen concentration of the water. This process, known as eutrophication, can result in water discoloration, strong odors and the release of toxins.

To address the issues created by the increase in nutrients in stormwater runoff from major developments, the Stormwater Management rules establish a design and performance standard requiring nutrients to be reduced to the maximum extent feasible. This standard can be achieved by implementing source controls limiting the amount of nutrients entering stormwater, and by conveying runoff through one or more onsite BMPs that treat nutrients, such as submerged gravel wetlands and infiltration basins. Due to the multiple forms and complex behavior of nutrients in stormwater runoff and the similarly complex processes by which nutrient loading is altered by BMPs, actual removal rates for specific BMPs and development sites may vary. For more information on nutrient removal rates for specific BMPs, please see *Chapter 4: Stormwater Pollutant Removal Criteria.*

Source controls may include things such as proper application of fertilizer and pet waste ordinances. A significant amount of nutrients in stormwater runoff are a result of the overuse of fertilizers on lawns; therefore, lawns should be minimized in favor of other types of vegetative cover. However, when lawns are used, soil testing to measure nutrient levels should be conducted to determine if fertilizer is necessary, and if so, the appropriate application amount and schedule. By only applying

what is needed, the cost of lawn maintenance may be reduced. Additionally, once a lawn is well established, it is often sufficient to use no phosphorus fertilizers. The New Jersey Fertilizer Law establishes requirements for appropriate fertilizer application that avoid adverse impacts on NJ waters. In addition to fertilizers, pet waste is a source of nutrients in stormwater runoff. Ordinances that require the proper disposal of pet waste can significantly reduce the problems associated with pet waste and help minimize the amount of nutrients in runoff. In addition to local ordinances, homeowner associations can include such requirements in homeowner's agreements, and proper education and signage are critical to teach the community about the importance of pet waste management.