ENVIRONMENTAL
Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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Guidelines for Developing an Artificial Recharge Project
In an Unconfined Stratified Drift Aquifer near Drinking Water Supply Wells

The purpose of this document is to provide regulatory and technical guidelines for developing, operating and maintaining artificial recharge facilities in an unconfined stratified drift aquifer near drinking water supply wells. This document is designed to provide a project manager representing a consulting firm or drinking water supply well owner, such as a community water system, with regulatory and technical guidance for increasing recharge to an unconfined aquifer via infiltration with raw (untreated) water obtained from an existing surface water source to basins excavated into the unsaturated zone.

Artificial recharge of aquifers can reduce the vulnerability of water supplies caused by periods of low precipitation. However, before developing an artificial recharge facility, the viability and feasibility of the project should be assessed to verify that:

1) Artificially recharged water does not cause geochemical reactions to occur in the subsurface that adversely impact aquifer water quality.
2) The artificial recharge project is able to provide the desired additional water supply being sought.
3) The construction, operation and maintenance of the artificial recharge project are technically feasible.

If it is decided to pursue the development of an artificial recharge facility, a project manager would not be required to complete all of the activities described in this document. In order to obtain approval from the N.H. Department of Environmental Services, the project manager would only have to demonstrate that the artificial recharge water would not directly or indirectly cause Ambient Groundwater Quality Standards (AGQS) or drinking water quality standards to be exceeded. Many aspects of these guidelines describe how to optimally design an artificial recharge facility and approaches to assessing the benefits of such a facility. However, the extent that these issues are investigated by the project manager is left to his or her discretion, and is not a requirement of DES.

Guidelines for Developing an Artificial Recharge Facility

Adequacy of Water Supply

The project manager should develop an understanding of past, present and future water supply needs of the water system prior to completing a detailed assessment on the viability of developing an artificial recharge facility near the existing drinking water wells. This information should be used to develop performance objectives for the artificial recharge project and to compare these objectives against the seasonal availability of surface water. Utilizing this information, the objective of the artificial recharge project should be determined. Typical objectives of artificial recharge projects include:

1) Seasonal storage and recovery of water.
2) Long-term water storage.
3) Short-term water storage.

4) Enhance well field production.
5) Restore groundwater levels and replace overdraft.
6) Improve quality of surface water by soil-aquifer treatment.
7) Defer construction or expansion of surface water treatment facilities.

Hydrogeology

Data should be obtained to verify that the aquifer and overlying unsaturated zone to be artificially recharged exhibit the following characteristics:

1) Adequate permeability, thickness, and lateral extent to meet the desired performance standards for the artificial recharge facility.
2) Unconfined and free from layers that would restrict downward flow.

For an unconfined aquifer, the potential amount of storage that can be used for artificial recharge is the amount between the upper operating water level limit and the lower operating water level limit. Also, a portion of the vadose zone needs to be maintained to buffer against the effects of flooding or the break-out of groundwater that could cause damage to private property or the environment. The values of aquifer parameters, vertical and horizontal groundwater flow gradients, and other geological features that control the movement of groundwater within the basin should be determined and used to identify the proper location(s) and size(s) for recharge basin(s).

The infiltration rate and the degree of mounding for each potential recharge site should be evaluated. The analysis may be based on results obtained from analytical equations. However the most reliable results are obtained by field-testing using pilot-scale to full-scale hydraulic discharge loading tests to the extent possible. If loading tests are completed, water level and infiltration rates should be measured in and around the recharge basin to assess mounding.

The size, location, and distribution of artificial recharge basins should be determined to optimize storage and recharge of the wells to meet the project objectives described in Section 2.1. It may be necessary to locate and develop multiple hydraulically independent basins to provide for the flooding, drying, and cleaning of each basin. The project manager may also want to consider installing additional water supply wells to improve the capture rate of recharged water. All artificial recharge basins should be located at least 100 feet from water supply wells and be constructed in a manner that prevents bacteria contamination from being introduced into the recharge basins from birds and other sources. Monitoring wells should be installed between the water supply wells and the recharge basins to assess water quality.

Water Quality

Water quality analyses of the possible sources of water for artificial recharge and water currently present in the aquifer to be recharged must be obtained. Additional water quality assessment must be completed utilizing analytical equations and models, laboratory batch testing, column experiments and pilot or full scale testing of the proposed artificial recharge project. Many of the parameters that need to be measured in order to complete geochemical process analyses are not sampled by public water systems because they are not regulated by the Safe Drinking Water Act. However, having data that facilitates the assessment of the compatibility of the recharge water, receiving groundwater, and minerals in subsurface soils is essential for determining whether a proposed recharge project will allow the recovery of groundwater that meets drinking water quality standards. Because surface water quality can change seasonally, and the volume of water that may be recharged can change seasonally, variations in water quality and the volume of water recharged must be considered when making the water quality compatibility assessments.

Underground formations can act as natural physical, biological, and chemical filters that can remove both chemical and particulate constituents from lower quality recharge water as it moves through them, especially in the unsaturated zone. Properly evaluating the filtration capacity of the formation material is an essential part of any recharge project and commonly requires completion of column studies that measure differences in pre- and post-filtered recharge water to evaluate the formation material's removal efficiencies for typical surface water indicators and pathogens (e.g., color, organic carbon, chlorophyll, bacteria, particulates, etc). Too little removal of these constituents implies that the formation material may not suitably filter recharge water and that water withdrawn by the associated recovery well may need further treatment. This, in turn, underlines the importance of determining the proper loading of the recharge water where filtration of chemical and particulate constituents in the recharge water is an objective of the process. Discharges to areas of known contamination should also be avoided.

Incompatibility of the recharged water constituents with the aquifer water may produce various impacts. There are various kinds of chemical reactions that can occur within an aquifer. These reactions could affect the hydraulic performance of the aquifer (storage and transmission) or overall aquifer water quality. Of particular concern is the potential for chemical reactions that create insoluble species that plug the aquifer and therefore reduce aquifer performance, such as calcium carbonate, ferric hydroxide, and several manganese oxide precipitates. In addition, there are a variety of other reactions such as cation exchange, dissolution of mineral phases, and expansions of clays that can occur in an aquifer that can significantly change the transport properties of the aquifer. Also, nutrient- and organic-rich recharge waters can promote biological growths that can plug the aquifer. The quality of the recharge water needs to be assessed to determine whether treatment is required to prevent clogging of infiltration basins over time. Organic-rich water that is recharged to the aquifer and extracted from a well and then disinfected may result in the formation of disinfection byproducts at concentrations that exceed drinking water standards.

Many chemicals of concern, such as metals, have multiple oxidation states and in some circumstances the mixing of artificial recharge water with the minerals in the soil and natural groundwater may cause insoluble metals to become soluble in the aquifer. The fate and transport of these chemicals depend on the redox (reduction/oxidation) conditions of the aquifer. The redox condition of an aquifer is largely controlled by the presence of dissolved oxygen in recharge waters. The dissolved oxygen content in groundwater is typically zero to a few milligrams per liter (mg/L). Surface recharge waters normally contain several mg/L of dissolved oxygen, but also contain several mg/L of biological oxygen demand. The amount of biological oxygen demand in surface water is typically sufficient to consume oxygen in those waters with a result that the recharge water becomes anoxic (without oxygen) in the aquifer. An anoxic condition, in turn, causes a variety of reactions that are detrimental to water quality, such as those that result in the formation of soluble iron, manganese, arsenic, and sulfide. Iron, manganese, and arsenic are typically derived from aquifer solids, although some may be attributed to the recharge water. Sulfide is largely derived from bacterial reduction of sulfate in recharge water. Anoxic conditions also control a large number of biochemical reactions, such as the conversion of nitrate to nitrogen gas and oxides in the presence of organic carbon.

Although underground formations can act as natural physical, biological, and chemical filters that can remove chemical constituents from lower quality recharge water as it moves through them when artificial recharge is occurring, additional organic matter may still be introduced into an aquifer. This may increase the occurrence of disinfection byproducts in water derived from the well. Also, the taste of water derived from the well could be altered by an artificial recharge project, and if these impacts were found to be undesirable, it could take several months to years after the artificial recharge has been terminated for the aquifer water quality to regain its original characteristics.

Guidelines for Operating an Artificial Recharge Facility

The actual operation of an artificial recharge facility needs to be periodically compared to the predicted operation. An assessment of operational parameters graphed versus time may reveal negative trends that require a change in the operation to correct, such as preventive maintenance of the recharge basins. Maintenance to artificial recharge basins can be accomplished by allowing the basin to empty and become dry, and then removing deposited sediment, organic material, and vegetation; or by scarifying the basin bottom. The use of heavy machinery on the basin bottoms should be minimized to avoid soil compaction. The depth of the recharge basin should be restored after removing sediment, vegetation and organic material by adding additional pea gravel to make up for any material that was removed during maintenance.

Routine water quality samples should be obtained from the water supply wells and monitoring wells located between the water supply wells and the recharge basins to assess whether the artificial recharge may be adversely impacting water quality. Furthermore, basic water quality parameters such as specific conductance can be measured in the recharge basin and in water derived from the wells to estimate the percentage of artificially recharged water that is being recovered. In addition, water level monitoring in near-basin monitoring wells should also be obtained on a fixed frequency. This will allow the project manager to measure the effectiveness and potentially optimize the operation to artificially recharge the aquifer.

Regulatory Process
The requirements of Env-Wq 402.10 for obtaining a groundwater discharge permit must be complied with for developing and operating an artificial recharge facility.

Additional Information
A comprehensive set of guidelines for developing, operating and maintaining artificial recharge projects for groundwater aquifers is titled "Standard Guidelines for Artificial Recharge of Groundwater," which was published in 2001 by the American Society of Civil Engineers (document number EWRI/ASCE 34-01).

Please contact the Drinking Water and Groundwater Bureau at (603) 271-2513 or dwgbinfo@des.nh.gov or visit our website at http://des.nh.gov/organization/divisions/water/dwgb/index.htm. All of the bureau's fact sheets are online at http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm. All drinking water and related rules can be accessed at http://des.nh.gov/organization/commissioner/legal/rules/index.htm#drinking.

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