New Jersey Geological Survey — Information Circular

Nitrate-Dilution Model: *Frequently Asked Questions*

Why care about the quality and safety of our ground water? Because we want the water we drink, cook with, and wash in to be clean and pose the least possible risk to our health and environment. This is especially urgent for those of us relying on water wells and septic systems. Nitrate is one contaminant that can cause trouble. Nitrate-dilution modeling is an important, but complex planning tool that can help prevent these problems by helping communities make informed land-use decisions. It estimates the maximum number of properly-functioning septic systems that can be maintained in an area without causing undue risks. These risks come from nitrate contamination of the ground water system and thus to our drinking water and streams. This information circular does two things: 1) answers some of the more frequently asked questions about nitrate-dilution analysis; and 2) answers questions about the nitrate-dilution model released in 1999 by New Jersey Geological Survey (NJGS) and updated by Hoffman and Canace (2004).

What are nitrates and why should we be concerned about them?

Some nitrates (chemically abbreviated as NO_3) are produced by bacteria from ammonia found in human waste. Discharged from a septic system into the ground (fig. 1), nitrates can pose both human and ecological risks. Infants who consume high concentrations can succumb to methemoglobinemia or "blue baby syndrome." This can cause lethargy, excessive salivation, loss of consciousness and death. The environment is also vulnerable. Nitrates can promote excessive buildup of algae in surface waters. As the algae die and decompose oxygen levels are depleted. This may kill fish and other aquatic organisms.

Finally, high concentrations of nitrates may indicate the presence of other contaminants in ground water. If we improperly dispose of toxic chemicals like cleaning fluids and solvents by dumping them into a sink or toilet these materials, which are dangerous in high-enough concentrations, may also end up in the ground water. People do not always realize the risks of disposing of these materials through a septic system.

If my community is served by a public-water supply, does nitrate contamination really matter?

Yes. Nitrate contamination may still affect streams, reservoirs and fish. Polluted ground water may also affect people in nearby areas that rely on domestic or public supply wells.

Figure 1. *Illustration showing a home septic system and path of effluent leaving the leachate field. From the 'Septic System Owner's Guide' web site of the Univ. of Minnesota, College of Agricultural, Food, and Environmental Sciences, Extension Service at www.extension.umn.edu/distribution/naturalresources/DD6583.html.*

What does a nitrate-dilution model tell us?

Such a model enables us to estimate the average size a residential building lot needs to be to generate enough ground-water recharge to dilute a septic system's effluent to acceptable levels as measured by its nitrate component.

The nitrate-dilution model is based on a technique that enables us to estimate average annual ground-water-recharge rates (Charles and others, 1993). Data on climate, impervious cover and soils are used to determine the recharge rates.

The model also requires information on the number of people per home and total amount of nitrate generated per person per year. It estimates the average lot size required in a development that will keep nitrate concentrations in ground water below a specified target concentration (fig. 2). This model may be used to determine average lot sizes, but cannot be used to predict the specific quality of water entering any specific well due to the complex and specific nature of local hydrology.

How does the New Jersey Department of Environmental Protection (NJDEP) currently use the NJGS nitrate-dilution model?

It is used in two ways. First, the NJDEP's Division of Watershed Management expects this model (or another acceptable model) to be applied whenever a community submits a Wastewater Management Plan for approval or amendment. Second, the Bureau of Non-Point Pollution Control within the Division of Water Quality runs a nitrate-dilution analysis to evaluate development applications of 50 units or more served by individual septic systems.

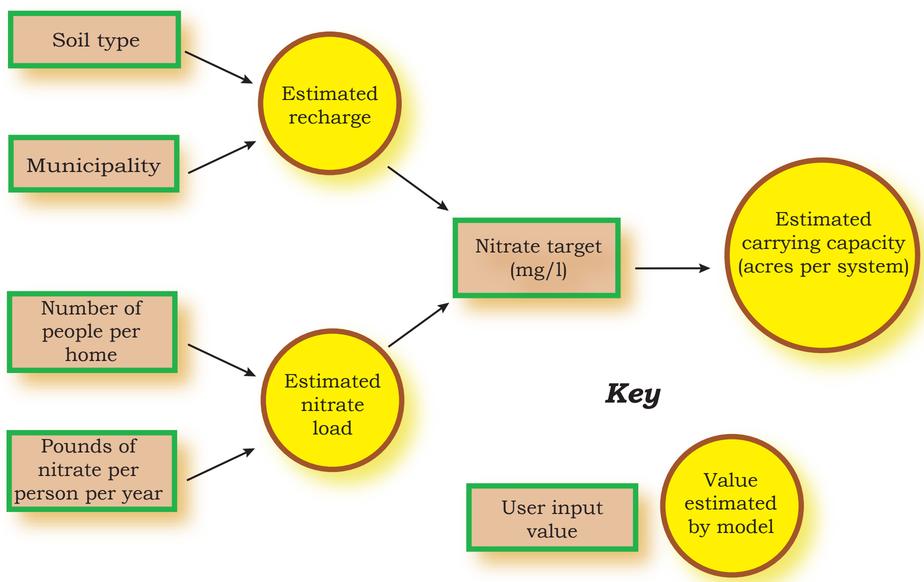

Figure 2. *Data inputs for and values estimated by the NJGS nitrate-dilution model.*

Figure 3 shows an application of the nitrate-dilution model to Stockton Borough and Delaware Township in Hunterdon County. This test case assumes that there are 3.14 persons per home, each person adds 10 pounds of nitrate per person per year to the ground water through the septic system, and the nitrate target is 1.6 milligrams per liter (mg/L). These values were selected by the Hunterdon County Planning Board after a year-long investigation into appropriate values for the county. Preserved open space, wetlands, hydric soils (soils that tend to get wet and stay wet) and areas in a sewer service area were omitted from the analysis. The result is an estimated land area, in acres per system, that produces enough ground-water recharge to dilute the nitrate discharging from a single home's septic system to the target value. If different input values were to be used the results would be different.

When NJDEP utilizes the model, what nitrate level does it consider acceptable in ground water?

In nondegradation areas (areas that meet specific criteria contained in the Ground Water Quality Standards, N.J.A.C. 7:9-6) no degradation of ground-water quality is allowed. Since no increase in nitrate concentrations is permitted, local conditions govern nitrate targets. There are also special nitrate values set for the Pinelands Protected Area and Highlands Preservation Area. Outside these areas, the NJDEP proposes a maximum concentration level of 2.0 mg/L (N.J.A.C. 7:15-5.25). However, a municipality may provide justification for lowering the nitrate target level below this number in its wastewater management plan; its submission will be considered by the Division of Watershed Management.

What nitrate level is considered "safe" in our drinking water?

The U.S. Environmental Protection Agency currently prohibits nitrate concentrations in drinking water that exceed 10.0 mg/L. This is a primary drinking water standard, and ground water that exceeds this limit is considered contaminated. The NJDEP's lower standard (2.0 mg/L) reflects an effort to protect the State's ecosystem as well as provide a larger margin of safety in protecting human health.

Can municipalities or counties establish their own maximum nitrate concentration levels in determining appropriate residential lot size ranges?

Yes. The appropriate nitrate target may be based on local environmental concerns in the municipality. However, municipalities should recognize that nitrate-dilution modeling is only one component of planning in general and of water-resource-based planning in particular. Therefore, it should never be relied on exclusively. Available water supply, for example, may be a far more limiting factor in some places than the risk of nitrate contamination.

How do lot sizes derived from a nitrate-dilution analysis relate to "open-space developments" (cluster development) where lot sizes are reduced in exchange for open-space preservation?

In general, unpaved portions of the entire site (preserved open space and clustered developed area) is used to calculate the volume of recharge generated. The open space must be deed restricted to prevent additional sources of nitrate and cannot be used in dilution calculations for additional development. If the clustered housing is dependent on wells and septic tanks, then careful site design and engineering are needed to protect the drinking-water quality. This can include increasing the length of well casings to tap deeper water, locating wells upgradient from septic systems to minimize the possibility of effluent contaminating wells, and by siting open space to protect wells. If proper protective measures are neglected, the risk of nitrate contamination is greater where wells and septic systems are closer together than called for by a reliable analysis.

Should communities use nitrate-dilution analysis as the sole means of determining appropriate lot size ranges?

No. Although the nitrate-dilution model is a powerful planning tool, it is only one of many. Other considerations, such as water supply, phosphorous contamination, air quality, and ecosystem protection (of stream corridors, wetlands, forests and endangered species, for example) should play a very important role in planning. And planning must go beyond natural-resource capacities. Municipalities may find issues of transportation, economic development, housing needs, agriculture, historical sites, and community character to be of equal or greater importance.

How does the NJGS methodology estimate ground-water-recharge rates?

The NJGS method derives ground-water-recharge rates from information on climate, land use, and soils. The climate data are based on a 30-year period. This accounts for times of drought as well as abundant rainfall. Therefore, the recharge rates used by the NJGS represent long-term averages. The model development process calibrated net ground-water recharge to stream base-flow data. This is described in more detail in "A method for evaluating ground-water-recharge areas in New Jersey" (Charles and others, 1993).

Are there other ways to estimate ground-water-recharge rates?

Yes. Base flow (water supplied to streams by ground water) can be used to calculate ground-water recharge. However, it is an indirect method that gives a net value for all areas upstream of the point where base flow is measured. It cannot be used to contrast recharge from two neighboring land tracts. An additional complication is that there are multiple ways to estimate base flow from streamflow data, each yielding a different result. Nevertheless, the NJGS relies on baseflow estimates for some specific applications.

Another way to measure recharge is to install instruments in the ground to directly measure soil moisture. However, this approach is time consuming and expensive. The NJGS considers the site-specific average-annual recharge method to be the more direct and effective means of calculating recharge rates to the soil zone where septic effluent is discharged.

Isn't it better to assume drought conditions than rely on long-term averages to calculate ground-water recharge rates?

Not necessarily. Ground-water-recharge rates based solely on drought conditions would provide a very large margin of safety. This may be appropriate for areas of special ecological significance. In other areas an approximation based on normal and wet conditions, as well as drought, would provide adequate protection. The NJGS long-term average-recharge estimates should be viewed as a realistic measure of average ground-water recharge.

Since we sometimes experience drought, shouldn't we take a more conservative approach to estimating ground-water recharge to make sure we adequately protect drinking water?

It is important to realize that most summers appear to be drought periods from a ground-water perspective. That's because very little ground-water recharge takes place during the growing season over most of New Jersey. This is normal. It is during the other seasons when recharge, or lack of it, becomes a concern for ground-water issues. Additionally, in most places ground water moves very slowly, less than a foot a day. Nitrate discharged from a septic system may flow for a long period before it might enter a nearby well — longer, typically, than the summer season or a moderate drought (assuming adequate distances between septic systems and wells). As a result, the wet periods during the Fall, Winter and Spring provide the needed recharge and thus the necessary dilution of nitrates. Should we experience an extreme drought, nitrate contamination may become more of an issue. In planning for such a severe drought, however, other environmental considerations, like water supply, may predominate.

How is it possible that we can find good ground-water recharge in areas that yield low volumes of water to wells?

Ground-water recharge is the water that penetrates the soil below plant roots or root zone. Once the water travels below the root zone, it splits or "partitions" generally in two directions. In sand and rock that is porous or highly fractured, water will generally travel down into the aquifer and then laterally enter a well or discharge area. Other areas, however, are underlain by rock which is hard and tight and wells generally have low yields. One example of this is the Sourland Mountain area in Hunterdon County which is underlain by diabase, also known as "trap rock." Here, most recharge is deflected by the buried rock surface and moves laterally. This water eventually discharges to a spring or a stream lower on the hillside. Also, areas of reasonably high ground-water recharge may have low well yields if they are underlain by poorly producing aquifers.

The NJGS nitrate-dilution model acknowledges that ground water can flow vertically, laterally, or some combination of these once the water moves vertically downward through the upper soil zone. Before this partitioning happens, however, the water is available to dilute septic tank effluent.

In areas supplied by low-yielding aquifers, available water-supply may be a far more limiting factor than nitrate-dilution capability in evaluating appropriate residential lot sizes.

Is it possible to find areas where nitrate may be sufficiently diluted even though underlying aquifers have very poor well yields?

Yes. In some aquifers with few pore spaces and/or sparse fractures much of the water that percolates below the root zone is blocked by the surface of tight rock or clay and then flows laterally until it emerges as a spring or stream. Regardless of where it eventually flows the recharge can dilute nitrates that are introduced by septic tanks near the land surface, just below the root zone.

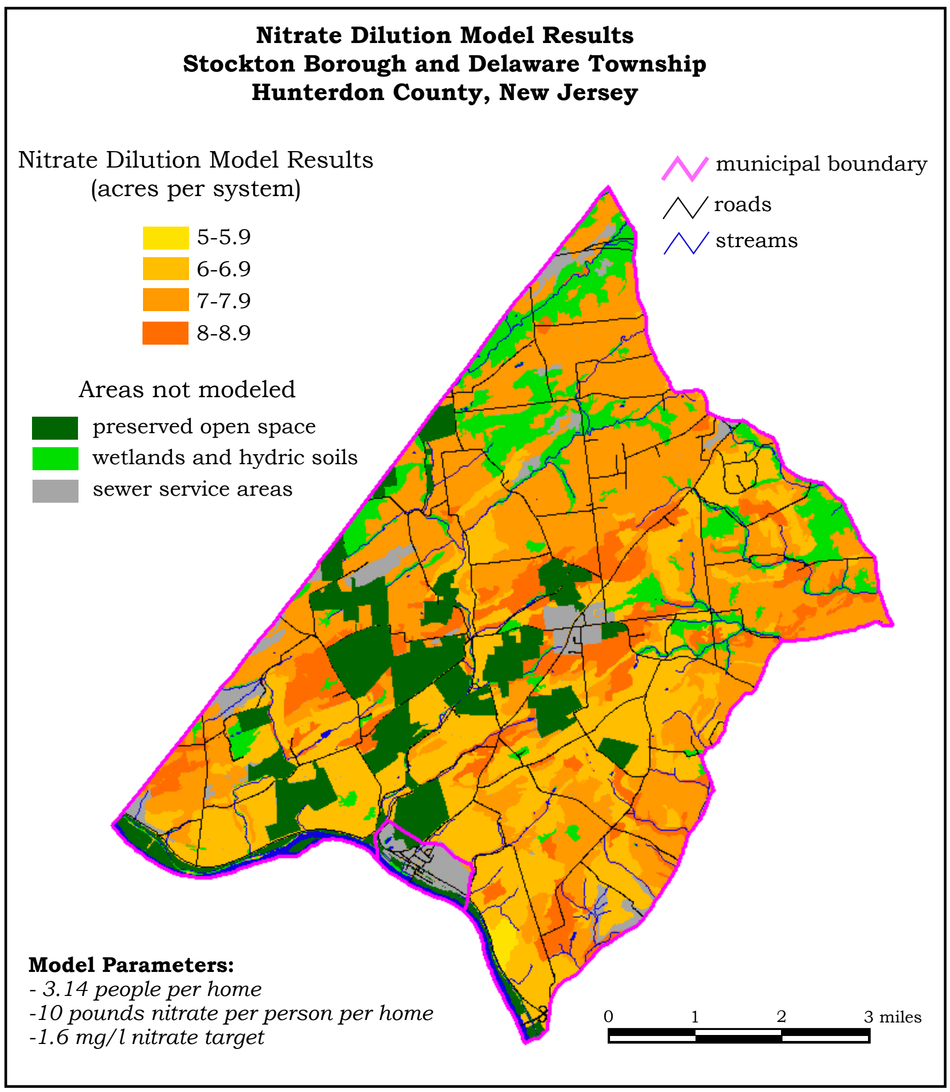

Figure 3. *Example of outputs from nitrate-dilution model for Stockton Borough and Delaware Township, Hunterdon County.*

The NJGS model omits slopes in calculating ground-water recharge. Don't slopes contribute to greater surface-water runoff and thus to reduced ground-water recharge?

Slopes are a factor during high-intensity rainstorms, when the water falls faster than it can soak into the ground and instead flows downhill as surface runoff. However, over the course of a year most water falls during moderate or low-intensity rains. These do not generate much runoff and precipitation is able to penetrate the ground even on steep slopes.

Does the NJGS model consider other sources of nitrate contamination besides septic systems?

No. Certainly there are other sources of nitrates in ground water. These include precipitation, lawn fertilizers, agricultural applications, decomposition of plant material, and animal waste. Calculating nitrate loading rates from them is beyond the scope of the NJGS model because of potential source variation. Nitrate from these other sources is applied at the land surface where it is affected by surface runoff. The nitrate that is recharged must travel through the root zone where it is taken up by plants as a nutrient. Nitrates discharged from septic systems, on the other hand, are injected into the ground, generally below the root zone and thus are more likely to reach ground water.

Why does northern New Jersey generally have a greater ground-water recharge rate than the sandy south?

First, the northern part of the State receives more rainfall than the south. Second, generally warmer temperatures in the south result in more evaporation and less recharge. On the other hand, more ground-water recharge in the north does not penetrate the dense rock formations to become aquifer recharge. In the south, where the aquifers are sand and gravel, most of the recharge becomes aquifer recharge. Although aquifer recharge rates are important to water-supply issues, they are less relevant to the nitrate-dilution model.

Limestone areas have unique features like "disappearing streams" and "solution channels" where surface water may move directly into the ground-water system bypassing soils and their "cleansing" benefit. Does the NJGS nitrate-dilution model show limestone areas as posing a greater risk of nitrate contamination in ground water?

No. The model does not deal with treatment capabilities of soils. It looks only at how nitrates may be diluted by clean water seeping into the ground. In limestone areas, water for dilution is commonly so abundant that this isn't an issue of much concern. Bacteria are a more significant consideration here. In valleys where coarse sand and gravel overlie limestone, water may move so quickly downward and then laterally that harmful bacterial microorganisms, which usually survive only 30 to 90 days underground, may reach a nearby well. Preventing short travel times is better addressed by the proper design and siting of septic systems and wells in such areas.

If we use the model, is drinking-water quality assured for our wells?

No. This model is a planning tool that assesses average conditions, but does not apply to site-specific situations. Good site design is essential to protect public health, even with the use of nitrate-dilution modeling.

Is nitrate-dilution modeling based solely on science?

No. Municipalities using this tool must recognize that policy also affects the results. For example, a community needs to set the maximum allowable nitrate concentration in its ground water before applying the model. The nitrate target chosen has a significant impact on the resulting lot sizes. This requires a thorough and fair analysis and clear justifications for any decisions that are made.

How does the Highlands Act affect nitrate-dilution modeling?

The rules implementing the Highlands Act call for large lot sizes in the Highlands Preservation Area. These are based on observed nitrate levels in undeveloped areas in the Highlands and conservative estimates of region-wide recharge. The large lot sizes will help protect the special ecological characteristics of the Highlands and its water resources.

How do I find out more information about nitrate dilution?

A report by Hoffman and Canace (2004) describes the nitrate-dilution model. You can get this report by contacting DEP's Maps and Publications Sales Fulfillment Office (609-777-1038). An Excel spreadsheet, which implements the model, is provided on the New Jersey Geological Survey web site. (www.njgeology.org/geodata/dgs02-6.htm)

Acknowledgement

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References

Charles, E.G., Behroozi, Cyrus, Schooley, Jack, and Hoffman, J.L., 1993, A method for evaluating ground-water-recharge areas in New Jersey: N.J. Geological Survey Report GSR-32, Trenton, 95p.

Hoffman, J.L. and Canace, R.J., 2004, A recharge-based nitrate-dilution model for New Jersey: N.J. Geological Survey Open-File Report OFR 04-1, 27p.

Web sites with information

New Jersey Dept. of Environmental Protection, Division of Watershed Management: www.state.nj.us./dep/watershedmgtl

US Environmental Protection Agency consumer fact sheet on nitrates and nitrites: www.epa.gov/OGWDW/dwh/c-ioc/nitrates.html

Iowa Center for Health Effects of Environmental Contamination nitrate fact sheet: www.cheec.uiowa.edu/nitrate/faq.html

US Geological Survey report "Occurrence of nitrate, pesticides, and volatile organic compounds in the Kirkwood-Cohansey Aquifer System, southern New Jersey": www.nj.er.usgs.gov/publications/WRIR/wrir97-4241.pdf

History, Goals and Redesign of New Jersey's Ambient Ground Water Quality Network: www.nwqmc.org/98proceedings/Papers/22-SERF.html

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