TECHNICAL NOTES

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NITROGEN TRANSPORT RISK ASSESSMENT

This Nitrogen Transport Risk Assessment is a 5 x 5 matrix that uses a limited number of site and management characteristics to determine the probability of off-site transport of nitrogen. Off-site transport refers primarily to transport below the crop root zone, although other mechanisms include transport in overland flow and gaseous losses. The assessment is part of an overall planning process imbedded within the ONEPLAN Nutrient Management Planner program. The assessment, together with a nutrient management plan, is used as a tool for understanding the contributions that individual landform and management parameters have on nitrogen transport and the potential for applied conservation practices (Best Management Practices) to mitigate situations where transport/loss can occur.

Nitrogen Concerns in the Environment

Concerns about agriculture's role in nitrogen (N) delivery to the environment have increased over the past decade. Nitrogen is a major input to crop and livestock production, and industrial production of N fertilizers has resulted in increased yields and more intensive agricultural operations. However, nitrogen use efficiency of most agricultural systems is currently estimated at only 30 - 50% worldwide, leading to nitrogen losses that degrade air and water quality.

One of the most widespread contaminants in Idaho ground water related to land use is nitrate. This is a major concern, since more than 90% of Idahoans get their drinking water from ground water sources. Twenty-five nitrate priority areas have been designated by the Idaho Department of Environmental Quality. Of those areas with sufficient data for trend analysis, 35% showed long-term increases in nitrate concentration and 40% demonstrated short-term increases. The southern portion of the state is especially impacted, where contamination is correlated with large nitrogen inputs and the vulnerability of the Snake River Plain Aquifer. Vulnerability is determined by the intrinsic susceptibility of the aquifer based on physical properties, coupled with management factors.

Water carrying nitrates and other contaminants can take decades to flow through the soil substrate. Schumann et al. (2002) calculated nitrate movement at 1 m/year through silt loam soils. ARS watershed studies in Iowa found that nitrates applied to soil took nearly 30 years to reach a 70-ft deep water table (Pons 2003). The slow rate of movement and lack of dilution in saturated zones means that contamination may persist for a long time period, even with improvements in management. Surface waters can also be degraded by nitrogen. The high flux of nitrates in streams during irrigation season can result from both overland flow and from groundwater inflow.

Nitrogen Movement in the Landscape

Nitrogen is one the most dynamic and mobile nutrients in the plant-soil-air continuum, with many pathways for loss (Figure 1). There is a large reservoir of N in soil, but most of this is in the organic form. Organic N is mineralized through microbial action under typical soil conditions to ammonium. Oxidation by specialized bacteria rapidly converts ammonium to nitrite and then nitrate (nitrification) under optimum conditions of soil temperature, aeration and moisture. The mineralized form of N (nitrate and ammonium) is readily available for uptake by plants. It is estimated that only 2-3% of organic N is mineralized annually. Therefore, intensive agricultural systems rely on inputs of fertilizer N to meet crop and animal demands.

The N cycle is both spatially and temporally variable within agricultural systems. Variability of soil properties impacts nitrogen movement and loss within agricultural operations, including soil organic matter, residual nitrate, crop residue amount, crop yield variability, and changes in soil chemical and physical properties across the field. Losses of nitrogen to the air can occur through denitrification of nitrate or volatilization of ammonia. Nitrogen can also be lost in solution, or attached to soil and organic matter, via overland flow. The primary loss mechanism of nitrogen in agricultural systems, however, is leaching of nitrate below the root zone. Nitrate is a negatively charged ion that is highly mobile in the soil. The amount of water that percolates through and below a crop's root zone is important in determining the amount of nitrate leached. Soil, crop, climate and management factors interact to determine the amount of percolation.

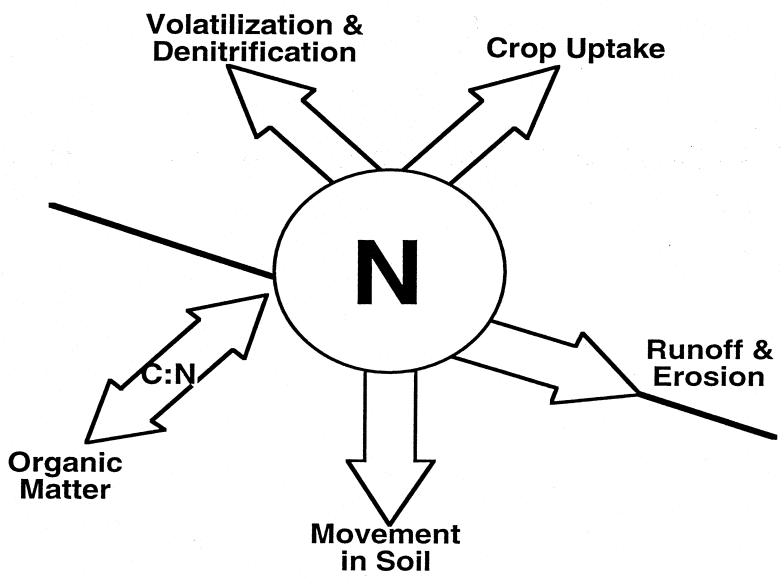

Figure 1. A simplified nitrogen cycle (Source: NRCS-NEDC 2001).

Management plays a critical role in reducing N loss to the environment, and management is the dominant factor influencing long-term nitrate leaching (Shaffer et al. 2002). Soil, climate, watershed and aquifer characteristics must also be taken into account in order to minimize nitrate leaching. Loss of nitrate from agricultural systems can range from 0 - 60% of N applied. In grain production systems, 10 - 30% was the average loss observed (Meisinger and Delgado 2002). Leaching loss is dependent on the concentration of N in soil solution and the volume of water leached. Over-irrigation can lead to nitrate leaching, especially with shallow rooted crops. Effective management is therefore aimed at reducing transport through proper irrigation water management, and optimizing N application amounts and timing in concert with crop uptake. Crop type and cultivation are also important considerations.

Idaho's Nitrogen Transport Risk Assessment

The purpose of the Nitrogen Transport Risk Assessment is to provide field staffs, watershed planners, and land users with a tool to assess the various landforms and management practices for potential risk of nitrogen movement to aquifers and other water bodies.

Shaffer et al. (2002) describe the need for, and the basic elements of, a national nitrate leaching assessment tool. The impacts of crop type, fertilizer, manure and irrigation management, coupled with soils, climate, and watershed factors, are essential parameters of this leaching index. The index would utilize a tiered structure dependent on potential risk:

- Tier 1: Broad-based screening tool that identifies risk level based on controlling factors. Areas identified with higher risk levels would warrant further study (Tier 2, 3).

- Tier 2: Larger-scale quantification of nitrate leaching using appropriate modeling tools.

- Tier 3: Site-specific quantification of nitrate leaching based on current management and site conditions through field studies and research models.

The Idaho Nitrogen Transport Risk Assessment is a Tier 1 screening tool that addresses the key factors identified by Shaffer et al. (2002). A number of climate, soil, hydrology and aquifer site characteristics describe the landform, along with management factors. The Nitrogen Transport Risk Assessment (Table 1) is a simple 5 by 5 matrix utilizing parameters that influence nitrogen availability, retention, management and movement.

There are five site characteristics used in the assessment to evaluate a particular site. Each site characteristic is rated VERY LOW/NOT APPLICABLE, LOW, MEDIUM, HIGH or VERY HIGH by determining the range for each category. A log base of 2 is used for the rating categories. Therefore, a VERY LOW rating is assigned 0 points, while a VERY HIGH rating is assigned 8 points. The higher the point value, the greater the potential for significant problems related to nitrogen movement (Table 1). Particular site characteristics may be more prominent than others in allowing potential nitrogen movement (primarily leaching) from the site. There is

scientific basis for concluding that these relative differences exist; however, the absolute weighting factors assigned to site characteristics to reflect these differences are currently based on professional judgment.

The site characteristics and weighting factors are:

- Deep percolation risk (2.00)
- Irrigation efficiency (1.00)
- N application rate (1.00)
- N application timing (1.00 if non-irrigated, 0.75 if irrigated)
- Water table depth/soil type (1.00 if irrigated, 1.5 if non-irrigated)

The sum of the site characteristic rankings provides an index of the potential for off-site nitrogen transport, primarily leaching through the root zone (Table 2). A description of each site characteristic and the factors that are used in their determination follows.

Deep Percolation Risk

Deep percolation is dependent on numerous factors, including climate, soil type and irrigation efficiency. The deep percolation factor for sprinkler-irrigated fields is determined from daily evapotranspiration (ET) rates for an individual crop type, totaled over the irrigation season using local climate station data. Total deep percolation loss is calculated from monthly deep percolation loss from a simple water budget developed within ONEPLAN. Deep percolation risk for sprinkler irrigated fields is then calculated as the ratio of deep percolation to total ET, over the irrigation season. For surface-irrigated fields, deep percolation risk is based on the highest monthly deep percolation loss (a relative comparison of the percent water applied that percolates below the root zone in any given month). For non-irrigated fields, nitrogen loss risk is based on the New York Nitrogen Leaching Index (Czymmek et al. 2003) which is essentially a water percolation index based on soil water storage. Slight modifications were made to some of the percolation index equations to adjust for low precipitation zones found in areas of Idaho. Total annual precipitation for specific locations is determined from local climate station data, as is winter precipitation. The percolation index is based on precipitation and hydrologic group. A seasonal index is calculated as the ratio of winter precipitation to annual precipitation. The deep percolation risk is then calculated as the product of the percolation index and seasonal index.

Irrigation Efficiency

Managing irrigation water will minimize nitrogen losses from leaching and surface runoff. Irrigation efficiency and irrigation water management have significant impacts on water movement through the root zone. Monthly NIR (net irrigation requirement) values are determined for crop type based on ET estimates. For sprinkler-irrigated fields, total irrigation water applied is adjusted for system efficiency and runoff to determine season-long irrigation efficiency (NIR/net water applied). For surface-irrigated fields, the lowest monthly irrigation efficiency for the season is used as the index.

N Application Index

Crop nitrogen requirement is determined based on crop yield and University of Idaho fertilizer recommendations. Total available nitrogen is determined from all sources, including prior year

crops. The application index is the ratio of the total N available (application N plus surplus/residual N) to the crop nitrogen requirement.

N Application Timing

Timing of N application directly influences potential transport due to the high mobility of nitrate in soils. The appropriate timing of N application is complicated by the soil processes of nitrification and mobilization, which affect N plant availability. Split applications of N better match crop growth requirements, reducing the likelihood of loss. Fall application in most instances has the greatest potential for loss prior to planting season, and then additional N applications are required to meet crop demand.

Water Table Depth/Soil Type

Soils can stop or slow nitrogen movement depending on their chemical and physical characteristics. Depth of soils, depth to water tables and limiting layers such as hard pans will influence rooting depth, nitrogen movement, and leaching potential. Fine textured soils (Hydrologic Group D) have a lower potential for leaching due to reduced hydraulic conductivity, while coarse textured soils (Hydrologic Group A) have a higher likelihood of nitrate leaching due to the rapid infiltration and movement of water through the profile. If a water table is present within five feet of the surface, the potential for ground water contamination is high despite the soil type.

Making an Assessment Using the Nitrogen Transport Risk Assessment Tool

It is recommended that assessments for nitrogen movement be done within the context of nutrient management planning using the Idaho ONEPLAN. If done manually, the user would need to obtain climatic data for the local area and crop nutrient and water requirements, as well as irrigation application information and soil and hydrologic characteristics.

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Table 1. Nitrogen Transport Risk Assessment. Sum of all weighted rating values is used to determine the site vulnerability.

Site Characteristic	Factor Weight	Rating and Weight				
		Very Low or N.A. 0	Low 1	Medium 2	High 4	Very High 8
Deep Percolation	Sprinkler Irrigated 2.0	< 5	5 - 10	10 - 20	20 - 40	> 40
	Surface Irrigated 2.0	< 10	10 - 20	20 - 30	30 - 40	> 40
	Non-Irrigated 2.0	0	0 – 2	2 – 5	5 – 10	>10
Irrigation Efficiency	Sprinkler Irrigated 0.75	> 90	80 - 90	60 - 80	50 – 60	< 50
	Surface Irrigated 0.75	> 90	75 - 90	60 - 75	40 - 60	< 40
N Application Rate- % of Crop Requirement	1.0	< 80	80 - 120	120 - 140	140 - 180	> 180
N Application Timing	Non-Irrigated 1.0 Irrigated 0.75	None applied	Split application with nitrification inhibitor	Split application	Preplant application in spring	Preplant application in fall
Water Table Depth and Soil Type	Non-Irrigated 1.0 Irrigated 1.5	Water table > 5 feet from surface, Hydrologic Group D	Water table > 5 feet from surface, Hydrologic Group C	Water table > 5 feet from surface, Hydrologic Groups A, B	Water table at surface, ponded, < 5 feet to surface, Hydrologic Groups C, D	Water table at surface, ponded, < 5 feet to surface, Hydrologic Groups A, B

Table 2. Nitrogen Transport Risk Assessment Index rating and site vulnerability.

Nitrogen Transport Risk Assessment Index Rating	Total	Site Vulnerability Chart
LOW	< 9	Low potential for nitrogen loss if current farming practices are maintained.
MEDIUM	9 - 16	Medium potential for nitrogen loss. Some remediation measures should be undertaken to minimize the probability of loss.
HIGH	16 - 25	High potential for N loss and adverse effects on ground water. Soil and water conservation measures and nitrogen management plans are needed to reduce the probability of loss.
VERY HIGH	>25	Very high potential for nitrogen loss and adverse effects on ground water. All necessary soil and water conservation measures and a nutrient management plan must be implemented to minimize loss from this field

ATTACHMENT 1: Example for Conservation Planning

Surface-irrigated crop: sugarbeet – onion – small grain rotation on silty clay loam, water table at 10 feet [Field has a ground water resource concern as defined in ONEPLAN]

Site Characteristic and Rating Value	Factor Weighting X Rating Value
Deep Percolation Risk is 35 = HIGH (value = 4)	2.0 x 4 = 8.0
Irrigation Efficiency is 35 =VERY HIGH (value = 8)	0.75 x 8 = 6.0
N Application Index is 160 =HIGH (value = 4)	1.0 x 4 = 4.0
N Application Timing is Split Application =MEDIUM (value = 2)	0.75 x 2 = 1.5
Water Table Depth and Soil Type =LOW, (value =1)	1.5 x 1 = 1.5
	Sum total of all weighted values = 21.0

Site Vulnerability is **HIGH**

HIGH - This site has a high potential for N loss and adverse effects on ground and/or surface waters. Soil and water conservation measures and nitrogen management plans are needed to reduce the probability of nitrogen loss.

Using the individual site characteristics, identify some factors of concern and management options that could be used to reduce this site vulnerability:

Deep Percolation Risk – The deep percolation risk is HIGH – there is a high potential for nitrate leaching to occur. Apply irrigation water according to crop requirements. Do not apply nitrogen prior to leaching events. Water logging and poor soil aeration may negatively affect crop yields in some areas of field.

Irrigation Efficiency – The irrigation efficiency index under furrow-irrigation with siphon tubes is VERY HIGH (inefficient). Careful management of soil moisture with irrigation scheduling is needed. Be sure that the right amount of irrigation water is applied as uniformly as possible to meet crop needs and minimize leaching from the root zone – consider converting to surge or sprinkler irrigation. Check with irrigation professional to assure that crop growth requirements are being adequately met.

Nitrogen Application Index – The total nitrogen application was HIGH. The potential for nitrogen leaching exists if excess water is applied from irrigation and/or precipitation events. There is potential for detrimental effects of high nitrogen on crop production and quality. Use soil and/or plant tissue tests and appropriate fertilizer recommendations to determine nutrient application rates, taking into account residual N.

The example described above has a high probability for an adverse impact to ground water quality if existing management is not adjusted to reduce the site vulnerability. Sites with a vulnerability rating greater than LOW (especially those in the HIGH and VERY HIGH category) have the greatest potential to adversely impact ground water quality. The assessment can also be used to identify management options available to land users and will allow them flexibility in developing remedial strategies. The first step is to determine the management options appropriate for sites with different N vulnerability assessments. N management is very site-specific and requires a well-planned, coordinated effort between the farmer, extension agronomist and soil conservation specialist. The risk level can be reduced by planning conservation practices and management techniques which will mitigate leaching of nitrate. For example, a particular field has an irrigation efficiency risk rating of VERY HIGH. To correct the problem, the producer applies irrigation water management practices coupled with conversion to surge irrigation to provide more uniform soil moisture to the crop, based on crop demand. With these changes, a MEDIUM rating of 2 is now used to describe the overall risk due to irrigation efficiency.