

APPENDIX A
GLOSSARY

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ALLUVIUM - material deposited by streams and rivers.

AQUIFER - geologic material capable of yielding a useable quantity of water to a well.

ARTESIAN AQUIFER - see CONFINED AQUIFER

ARTESIAN PRESSURE - the pressure exerted by water in a confined aquifer that will raise the water level in a well above the top of the aquifer.

BEDROCK - solid rock. See also CONSOLIDATED DEPOSITS.

BMP - Best Management Practice

COLLUVIUM - loose deposits at the foot of slopes and cliffs.

CONFINED AQUIFER - an aquifer which is completely saturated, is overlain by a confining layer and is under artesian pressure.

CONFINING LAYER - a geologic unit of low permeability.

CONSOLIDATED DEPOSITS - firm and coherent earth materials; cemented sediments.

DNR - Minnesota Department of Natural Resources

DRAWDOWN - the lowering of ground water level (head) caused by pumping a well.

DRIFT (glacial) - any rock debris, such as boulders, till, gravel, sand or clay, transported and deposited by ice or meltwater.

EAW - Environmental Assessment Worksheet

EIS - Environmental Impact Statement

FLUVIAL - produced by river action.

GROUND WATER - water in the saturated zone.

HEAD - height of water in a well above a specific measuring point. - see also
POTENTIOMETRIC SURFACE

LCMR - Legislative Commission on Minnesota Resources

LOESS - silt-sized material deposited by the wind.

MGS - Minnesota Geological Survey

NPDES - National Pollutant Discharge Elimination System

OUTWASH - stratified sandy sediment deposited by glacial meltwater streams.

PEDOLOGIC SOIL - the material making up the soil profile, from the land surface to a
depth of about six feet.

PIEZOMETER - an observation well.

PIEZOMETRIC SURFACE - the surface to which water from a given aquifer will rise in a
well. - see also POTENTIOMETRIC SURFACE

PERCHED WATER - ground water that is not part of a water table aquifer because
unsaturated materials occur beneath it. Generally isolated areas above a
continuous water table.

PERMEABILITY - a measure of the relative ease with which water can move through a
geologic material.

POROSITY - the percentage of void space in a geologic material.

POTENTIOMETRIC SURFACE - the surface representative of the static water level in a
well cased into a single aquifer.

RIM - Reinvest in Minnesota

SATURATED ZONE - the portion of the subsurface in which all voids and cracks in
geologic materials are completely filled with water.

SDS - State Disposal System

SOIL - earth material modified by natural physical, chemical and biological agents and capable of supporting the growth of plants.

SOIL HORIZON - a layer of soil material that is different from other layers by characteristic properties such as structure, color or texture.

STATIC WATER LEVEL - the level to which water will rise in an unpumped well that is open to a single aquifer.

TILL - unsorted sediment deposited by a glacier. - see also DRIFT

UNCONFINED AQUIFER - an aquifer in which the upper portion is unsaturated or which is saturated but under less than artesian pressure.

UNSATURATED ZONE - zone above the water table where voids and cracks are not completely filled with water.

UNCONSOLIDATED DEPOSITS - loose material overlying bedrock. Includes soil, glacial deposits, stream sediments, windblown deposits, weathered bedrock, and organic deposits.

USGS - United States Geological Survey

VADOSE ZONE - see UNSATURATED ZONE.

WATER TABLE - the surface separating the unsaturated and saturated zones.

WATER TABLE AQUIFER - the uppermost aquifer which has a water table; more generally, an unconfined aquifer..

APPENDIX B
SOURCES OF SUBSURFACE GEOLOGIC INFORMATION

SOURCES OF SUBSURFACE GEOLOGIC INFORMATION

Subsurface geologic information is the basis for assessing the susceptibility of ground water to contamination. There are various types of information describing subsurface conditions, ranging from detailed maps and reports to uninterpreted records of water wells and borings.

PUBLISHED REPORTS AND MAPS

The state is covered in varying degrees of detail by published reports and maps, depending on the level of detail and coverage of the various investigative and mapping efforts. The degree to which these reports are useful depends on the scale and detail of the questions being asked of them. Soil atlases and county soil surveys cover the entire state, but are concerned with only the upper 5-6 feet of the earth's surface. Geologic and hydrogeologic maps of Minnesota at various scales are available from the Minnesota Geological Survey (MGS). Hydrologic Atlases published by the U.S. Geological Survey (USGS) provide statewide coverage and are useful for establishing the general hydrogeologic setting for the area to be assessed. Other sources include MGS county atlases and USGS reports including Water Resources Investigations, Water Supply Papers, and Open-File Reports. Additional information can be found in studies conducted by state agencies, colleges and universities, and consulting firms. The coverage across the state by these reports is uneven.

The "Minnesota Ground Water Bibliography" published by the Department of Natural Resources (DNR) in 1989 is a useful guide to published reports and maps. The Minnesota Geological Survey "List of Publications in Print" is also useful.

WELL RECORDS AND BORING LOGS

Records from water wells and test borings are the most important and basic source of subsurface geologic information for the state.

Water well records - Since 1975 water well contractors have been required to submit to the Minnesota Department of Health (MDH) a record (driller's log) for each well drilled. MDH then distributes copies to other agencies including DNR and MGS. An example of a water well record from Greenfield township in Hennepin County is shown in Figure B-1.

The location and geologic information contained in water well records range in quality from very good to poor. The MGS is responsible for organizing and interpreting water well records as part of state efforts to develop a ground water information system. In addition, the MGS is the lead agency for organizing the state's water well record library. A portion of the records on file at MGS have been field-located and interpreted by geologists, and are likely to portray the geology accurately. Other records which have not been field-located and geologically interpreted may have questionable accuracy.

Water well records suitable for assessing geologic sensitivity should have their location verified and the geological and hydrologic information interpreted. Field located well

records have been plotted on 7.5 minute topographic quadrangles or more detailed maps such as housing subdivision plats. The MGS should be contacted for advice on locating and interpreting well record data. Interpreted water well records are available for many counties and are filed either manually or on a computer data base. Unlocated well logs can be used, but the user must verify their locations. This is a time consuming process.

As an example of the types of problems that result from unlocated well logs, the water well record in Figure B-1 was incorrectly located by the driller as being in the extreme southwest corner of section 10. Field location showed it to be in the extreme southeast corner. Without the additional field location effort by the MGS, the well location and any interpretations based on it would be in error by nearly a mile.

Many water well records list very brief descriptions of the material overlying bedrock. In Figure B-2, it is not possible to determine the texture of the vadose zone material or the presence of low permeability units because it is located within the zone labeled as "drift." Drift is a collective term used to describe all unconsolidated deposits left by glaciers. The term "drift" is too general to use to identify texture or permeability. The conclusion one should reach about such a well log is that it does not contain enough information to identify vadose zone materials for a Level 2 assessment. Vague terminology makes many well records useless for Level 2 or 3 assessments.

FIGURE B-2. Well log of a bedrock well.

UNIQUE NO.: 207284
WELL NAME: INVER GROVE HTS. NO. 3
LOCATION: TOWNSHIP 27 NORTH, RANGE 23 WEST, SECTION 3, CCBCCA
ELEVATION: 855 FT. **WATER LEVEL:** 132 FT.
DEPTH: 407 FT. **DATE:** 70/02/27
COMPLETED: 70/02/27 **AQUIFER(S):** JORDAN

<u>From</u>	<u>To</u>	<u>Description</u>
0	145	DRIFT
145	150	SANDSTONE
150	307	DOLOMITE
307	407	SANDSTONE

Descriptions of geologic material vary in quality from driller to driller. Soil and engineering terms such as "loam" and "silt" are not generally used by water well drillers. "Clay" has a wide range of meanings; it may be clay in the geological sense, or it may describe silt or loam containing as little as ten per cent clay.

Test boring logs - Various types of test drilling also provide valuable information about subsurface and hydrogeologic conditions. For example, the Minnesota Department of Transportation has many engineering test boring records acquired from road and bridge construction projects. Test boring records can be obtained for other types of construction projects from private consultants. Environmental borehole and monitoring well records from landfills and other types of environmental assessments

are another source of data. Figure B-1 shows a record from test boring which is within a few hundred feet of the water well discussed earlier. Notice the difference between them in the level of detail used to describe subsurface geologic materials.

ASSESSING DATA COVERAGE

If little or no subsurface data are available or vague terms are used to describe the subsurface materials, it may not be possible to complete a Level 2 or Level 3 assessment. Unfortunately there are no set rules to define the amount of data that should be collected in order to have "enough." Data needs are dependent on the purpose for which the assessment is being prepared, the scale of the area being assessed and the complexity of local hydrogeologic conditions.

A Level 1 assessment using soil parent materials information can be used as a guide to evaluate the complexity. Large areas with the same parent material indicate relatively simple geology, at least near the surface. On the other hand, an intricate pattern of soil parent materials could indicate a complex setting. Also, if the subsurface data and soil parent materials map are in general agreement, the soil parent materials information can be used to fill in the data deficient areas. When subsurface conditions can be predicted by correlating other data points, the data coverage is probably adequate. If, however, the geologic setting appears to be complex, as indicated by a wide variety of geologic materials within a relatively small area, estimating the geology from soil parent materials becomes difficult. Most areas will not have enough data to map strictly by data points; geological interpretation will be necessary. The experienced geologist may interpret aerial photographs and topographic maps to identify landforms and infer geologic history to extrapolate available data points. Unfortunately, extrapolation of existing data may produce unreliable results. In this case, collection of additional subsurface data are required to complete a reliable evaluation of geologic sensitivity.

APPENDIX C
WORKING WITH MAPS

WORKING WITH MAPS

A map is a representation or abstraction of a portion of the world. A map is also a way of organizing information. A map never shows all the information or detail that an observer might actually see. Map makers must choose which information to show within the limited confines of a map. Much of the detail and complexity of the world must be simplified for clarity. This means a map is really an interpretation of a selected set of information describing the world.

Mapping projects start with choosing or making an appropriate map base. The choice is a balancing of a number of factors, including purpose, availability of various map bases, cost, reliability, the information that will be organized on the map, and how different maps will work together.

MAP SCALES

Maps are constructed in different proportions, or scales, to the world. A scale of 1:2 means that one measurement unit on the map equals two measurement units on the ground. The units of measurement can be anything, as long as the same "yardstick" is used for both the map and on the ground. In Table C-1, several different map scales are listed. A scale of 1:100,000 means that one inch on the map represents 100,000 inches on the ground. For convenience, 100,000 inches is normally converted into another unit that may be easier to work with. For example, 100,000 inches is the same as about 1 1/2 miles.

Different map scales may be more suitable for different purposes. A state road map, for instance, would not be much help when designing a neighborhood traffic plan. It is important to match the need to the right map with the most suitable scale. Table C-1 shows several common map scales and their suggested uses. The map scale of 1:100,000 is used by the Minnesota Geological Survey in the County Geologic Atlas program. The 1:24,000 topographic maps prepared by the U.S. Geological Survey are useful for many local-scale activities, including city, township and watershed planning. For many of the activities listed earlier in Table IV-1, one of the map scales listed in Table C-1 could be considered.

Table C-1. Suggested map scales and applications.

Map scales	Suggested Uses
1:200,000	Regional planning
1:100,000	County-wide planning
1:24,000	Local planning

Commonly, maps from different sources prepared at different scales must be combined to produce the desired map. Maps may need to be reduced from their published scale. Such changes should not be undertaken lightly. The next section discusses the problems of combining maps and introduces some specific techniques by which map combinations can be done in an appropriate manner.

COMBINING MAPS WITH DIFFERENT SCALES

Level 1 assessments are done at the scale of soil maps; the common scale for modern soil surveys is 1:15,840, or 4 inches to the mile. Higher level assessments may be done on topographic maps at the scale of 1:24,000, roughly 3 inches to the mile. In order to complete the higher level assessment, all data must be plotted at a common scale. Where two maps need to be combined, the larger one should be reduced to the scale of the smaller one. Enlarging the smaller one will give a false sense of precision to the combined map. Where two map scales are only moderately different, as in the case of 1:15,840 soil survey maps and 1:24,000 topographic maps, rules for combining maps become less stringent.

Combining maps of similar scale can be done several ways. Two methods that are generally suitable for sensitivity assessment maps are freehand sketching and mechanical/photographic. Either method can be used to enlarge or reduce.

When combining maps using freehand sketching, simply transfer the lines from one map to the other by constant reference to the original map. Most areas of the state have a fairly regular road network based on the one-mile grid of section lines. Other points of reference include houses, lakes and streams, which are shown on the topographic maps and can be recognized on the air-photo base of the soil maps. It is important to remember that some houses may not be on one map or the other, and lakes may be a different size and shape because the maps were made at different times. Even the road networks may be different.

Freehand sketching is adequate when the lines to be transferred are relatively simple and where there are enough landmark features on both maps. In areas where landmark features are sparse and the lines to be transferred are complex, some mechanical or photographic method must be used. The cheapest and simplest is photocopy machine reduction. Lines based on the soil survey at 1:15,840 can be copied at 66% reduction to 1:24,000, the scale of topographic maps. Then they can be traced onto the topographic base map. Even though nominally at the same scale, they will still not match perfectly because of paper shrink and swell and because the photos on the soil map base are unrectified. ("Rectified" air photos, corrected for the various distortions inherent in air photos, match a grid of surveyed control points.) Thus it is necessary to include some landmark features on the soil lines such as the road grid. This will allow the lines to be traced more accurately. The overlying map must be moved from time to time during tracing in order to achieve the best fit.

Various types of reflecting projectors and zoom transfer scopes may be used to change scale. Each has its own advantages and drawbacks. Each requires lining up landmark features on both maps. Accuracy is generally best in the center of the field of view, and the maps must be moved and realigned frequently. This method has been used successfully at the Minnesota Geological Survey but it is time-consuming and requires expensive specialized equipment. Photographic enlargement or reduction is more precise, but is not recommended for general use because the inherent imprecision of the lines does not justify the accuracy.

To easily examine geologic sensitivity on a county-wide basis, the assessment results shown on larger scale soils and/or topographic maps may be reduced in scale and traced onto a smaller-scale base map of the whole county. A county road map at 1 inch to the mile or 1/2 inch to the mile may be used. A drawback to the county road maps is that they greatly exaggerate the widths of the roads, showing them several

hundred feet wide. They also normally show section lines as a regular grid, even though, in places, the section lines are irregular due to early survey errors.

The same principles and techniques discussed above for combining maps may be used for the county-wide maps, but one other factor must be considered. When a map is greatly reduced, its lines must be generalized because the line becomes "wider" in terms of the width that it covers on the ground. Small details cannot be shown. Small areas must be dropped, in effect absorbing them into surrounding areas with a different rating. Tight line squiggles need to be replaced with broad, sweeping curves, which in turn will reduce down to tight squiggles.

This process illustrates why small areas cannot be confidently rated by a county-wide map; the area in question may be an unmapped inclusion in an area of contrasting sensitivity. And of course the precision of the lines drawn in the first place is variable. County maps of geologic sensitivity should be used only to illustrate which parts of the county are generally sensitive, not to determine the geologic sensitivity of specific parcels of land. The advantage of small-scale maps is that they allow recognition of major trends, without the distraction of small details. This may be especially true when comparing a geologic sensitivity map with plotted water-quality data. Smaller-scale maps will be less affected by local ground water flow, and may give a better general look at the relationship between water quality and predicted sensitivity.

MAP RELIABILITY AND DATA COVERAGE

In addition to properly combining maps of different scales, users should carefully consider the reliability of the maps they use. High quality data are, of course, very important. However, enough data need to be collected and mapped. Interpretations or area boundaries based on too little information will be misleading. Determining when sufficient data has been collected should be a careful and deliberate decision. As a general rule of thumb, enough data have been collected when a user is able to predict most of the time the result of the next data collection effort. The issue of sufficient data collection must be carefully considered when assessing geologic sensitivity, especially when conducting Level 2 and Level 3 assessments. For example, in areas with relatively predictable geology and little topographic relief, less data may be needed than in areas of highly variable geology and greater relief. Reviewing available information before beginning an assessment project will help identify the level of effort needed to collect enough information to complete the assessment.

APPENDIX D
OTHER SENSITIVITY RATING METHODS

OTHER SENSITIVITY RATING METHODS

Many sensitivity assessment methods or techniques are currently available for estimating ground water vulnerability to contamination. The methods vary in the type of information produced, the information required and the scale of application. Each method is appropriate for certain applications and not others. Suitable applications for the proposed geologic sensitivity guidelines presented in this document were discussed in Chapter IV. This appendix provides a brief introduction to other techniques, primarily empirical, for evaluating ground water vulnerability.

GENERAL REVIEWS OF SENSITIVITY METHODS

Several reviews of various sensitivity assessment methods have been completed (Trojan, 1986; Canter et al., 1987; Geier and Perry, 1990). Trojan (1986) identified five general categories of methods: Predictive, general geologic criteria, mathematical modeling/routing, water balance and monitoring. Canter et al. (1987) provided a synopsis of nine empirical assessment methodologies. The nine methods were all pollutant source prioritizing methodologies, according to the authors. Geier and Perry (1990) evaluated in detail a more extensive group of empirical methodologies which would also belong to the predictive category of Trojan (1986). The evaluation by Geier and Perry (1990) included a comparison between methods of the intended application(s).

The sensitivity assessment methodologies reviewed and categorized by Trojan (1986) included the models listed in Table D-1. A predictive method such as EPA's DRASTIC model (Aller et al., 1985) assesses the potential for contamination to impact the subsurface. Predictive methods may evaluate a variety of factors, including the physical system, chemical characteristics, and perhaps land use or water use. Predictive methods may be site specific or they may be designed to assess larger areas not related to any particular use. General geologic criteria methods typically apply simplified rules based on physical attributes for determining vulnerability to contamination. These methods are also predictive and may or may not be site specific. Mathematical models are best applied to individual sites with identified or potential contamination problems. Mathematical models are constructed by developing a set of equations to describe the physical system. Equations of infiltration and ground water flow are matched to real conditions. If contaminants are a concern, existing or potential transport of contaminants is added to the physical system model. Water balance methods are site specific techniques for estimating leachate impact on local ground water conditions. Monitoring of wastes is an assessment technique that may be useful in limited situations where sources of potential contamination can be clearly identified and the quantities are limited.

The review by Canter et al. (1987) included the nine pollutant source prioritizing methodologies listed in Table D-2. Each method was summarized, with emphasis on the process by which a rating is obtained. The authors asserted that all the listed methodologies were suitable for site specific assessments, however DRASTIC was not designed for site specific application. Although the idea of geologic vulnerability and other assessment purposes were introduced several times, the authors focused their discussion on the technical development of site specific rating methods, particularly for pollution sources such as landfills. The authors also provided some limited information on the mysterious process of factor identification, setting factor weights and developing scaling functions.

Table D-1. Sensitivity assessment methodologies reviewed by Trojan (1986).

Type/Method	Source(s)
Predictive	
DRASTIC	Aller et al. (1985)
LeGrand	LeGrand (1964, 1983)
EPA SIA	Silka and Swearingen (1978)
Fuller Land Treatment	Fuller (1986)
EPA HRS	U.S. EPA (1985)
Florida DRASTIC	Higher and Waller (1986)
Kansas	Kansas Dept. of Health and Envir. (1986)
New Jersey	New Jersey Geological Survey (1983)
Massachusetts	Roy and Bowley (1986)
Wisconsin	Schmidt (1986)
Missouri	Duley (1983)
Illinois	Berg et al. (1984)
Michigan SAS Mich.	Dept. of Nat. Res. (1983)
General Geologic Criteria	
Septic tank fields	Waltz (1972)
Missouri	Stohr et al. (1981)
Ohio	Stein et al. (1981)
South Dakota	Meyer (1986)
Minnesota	Olsen et al. (1983)
Mathematical Modeling/Routing	
Contaminant transport	Watson (1984), Oberlander and Nelson (1984), Gray and Hoffman (1983), Enfield et al. (1982) MacFarland (1983)
Water Balance	
Landfill leachate	Fenn et al. (1975), Remson et al. (1986)
Monitoring	
Nebraska	Nebraska Dept. of Env. Control (1985)

Table D-2. Empirical pollutant source prioritizing methodologies reviewed by Canter et al., (1987)

Method	Source
Surface Impoundment Assessment (SIA)	U.S. EPA (1978)
Landfill Site Rating	(cited reference incorrect)
Waste-Soil-Site Interaction Matrix	Phillips et al. (1977)
Site Rating System	Hagerty et al. (1973)
Hazard Ranking System (HRS)	Caldwell et al. (1981)
Site Rating Methodology	Kufs et al. (1980)
Brine Disposal Methodology	Western Mich. Univ. (1981)
Pesticide Index	Rao et al. (1985)
DRASTIC	Aller et al. (1985)

Geier and Perry (1990) chose to catalogue and review different empirical assessment models according to their intended applications. The assessment models were organized into six categories based on intended use:

- selection of candidate waste disposal sites
- prioritize existing sites for remediation
- evaluate sensitivity over large areas
- rank and evaluate individual contaminants according to pollution potential
- evaluate candidate sites for Land Surface Treatment
- evaluate pollution potential from oil and gas field activities.

The organization into these categories is intended to help users identify the appropriate empirical method for a particular need. Table D-3 lists the models reviewed, the method categories and the applications.

ASSESSING SENSITIVITY IN AGRICULTURAL SETTINGS

In Chapter III, the surficial application of agricultural chemicals was introduced as one of several special cases. Agricultural practices apply specific chemicals directly on the surface of the earth or in the soil zone. Consideration of any particular chemical cannot be addressed by the general geologic sensitivity criteria. This kind of activity requires a specialized approach.

The U.S. Dept. of Agriculture Soil Conservation Service (SCS) in cooperation with the Agricultural Research Service (ARS) and the Minnesota Cooperative Extension System (MES) has developed a system for rating soils on their potential for pesticides to leach through them. Each soil mapping unit is assigned a rating of "nominal", "intermediate", or "high". Each pesticide is given a rating of "small", "medium", or "large", based on its

Table D-3. SUMMARY OF SELECTED SENSITIVITY ASSESSMENT METHODOLOGIES FOR VARIOUS NEEDS (Modified from Geier and Perry, 1990)

Section 1. Site Selection Methodologies

Empirical Assessment Method	Primary Source	Evaluates Geologic Sensitivity	Evaluates Contaminant Prop/Behav.	Explicitly Evaluates Hazardous Wastes	Screens Potential Indust. Waste Pond Sites	Screens Potential Septic Sys. Sites	Screens Potential Landfill Sites	Rates Land Treatment Sites	General Planning/Regulatory Application
LeGrand (1964)	LeGrand, 1964	X			X	X		X	X
Surface Impound Assessment (SLA)	Silka and Swearingen, 1978	X	X	X	X	X		X	X
Soil/Waste Interaction Matrix	Phillips, et al., 1977	X	X	X	X	X		X	X
Hazardous Waste/Land-Fill Site Ranking System	Hagerty, et al., 1973	X	X	X			X	X	X
LeGrand (1983)	LeGrand, 1983	X	X		X	X	X	X	X

Table D-3. SUMMARY OF SELECTED SENSITIVITY ASSESSMENT METHODOLOGIES FOR VARIOUS NEEDS (Modified from Geier and Perry, 1990) (Cont'd)

Section 2. Site Remediation Methodologies

Empirical Assessment Method	Primary Source	Evaluates Geologic Sensitivity	Evaluates Contaminant Prop/Behav.	Explicitly Evaluates Hazardous Wastes	Rates Existing Industrial Waste Ponds	Rates Existing Septic Systems	Rates Existing Landfill Sites	Rates Land Treatment Sites	General Planning/Regulatory Application
Geologic Ranking System	Nelson and Young, 1981	X					X		
Ground Water Contamination Site Ranking Method	Olivieri, et al., 1986	X	X	X	X		X	X	
New Jersey Site Ranking Method	Hutchinson and Hoffman, 1983	X	X	X	X		X		
Kansas Ranking System	Kansas DHE, 1986	X	X		X	X	X	X	
Site Rating Methodology	Kufs, et al., 1980	X	X	X	X		X		
Hazard (HRS)	CFR, 1989	X	X	X			X		

Table D-3. SUMMARY OF SELECTED SENSITIVITY ASSESSMENT METHODOLOGIES FOR VARIOUS NEEDS (Modified from Geier and Perry, 1990) (Cont'd)

Section 2. Site Remediation Methodologies (Cont'd)

Empirical Assessment Method	Primary Source	Evaluates Geologic Sensitivity	Evaluates Contaminant Prop/Behav.	Explicitly Evaluates Hazardous Wastes	Rates Existing Industrial Waste Ponds	Rates Existing Septic Systems	Rates Existing Landfill Sites	Rates Land Treatment Sites	General Planning/Regulatory Application
Michigan Site Assessment System (SAS)	Michigan DNR, 1983	X	X	X			X		
California Ranking System	Dlugosz and Ingham, 1985	X	X	X			X		

Table D-3. SUMMARY OF SELECTED SENSITIVITY ASSESSMENT METHODOLOGIES FOR VARIOUS NEEDS (Modified from Geier and Perry, 1990) (Cont'd)

Section 3. Large-Scale Sensitivity Ranking Techniques

Empirical Assessment Method	Primary Source	Evaluates Geologic Sensitivity	Evaluates Contaminant Prop/Behav	Explicitly Evaluates Hazardous Wastes	Screens Areas for Industrial Waste Ponds	Screens Areas for Septic Systems	Screens Areas for Landfill Sites	Screens Areas for Land Treatment Sites	General Planning/Regulatory Application
Drastic	Aller, et al., 1985	X							X
Minnesota Sensitivity Map	Porcher, 1989	X							X
Wisconsin Sensitivity Map	Schmidt, 1987	X							X
Illinois Ground Water Contamination Potential Rating System	Berg, et al., 1984	X			X	X	X	X	X
Minnesota Sensitivity Rating Method	Minnesota DNR, 1990	X			X	X	X	X	X
Trojan-Perry Method	Trojan and Perry, 1988	X	X		X	X	X	X	X

Table D-3. SUMMARY OF SELECTED SENSITIVITY ASSESSMENT METHODOLOGIES FOR VARIOUS NEEDS (Modified from Geier and Perry, 1990) (Cont'd)

Section 4. Contaminant Indices (scale not applicable)

Empirical Assessment Method	Primary Source	Evaluates Geologic Sensitivity	Evaluates Contaminant Prop/Behav	Explicitly Evaluates Hazardous Wastes	Rates Industrial Waste Ponds	Rates Septic System Sites	Rates Landfill Sites	Rates Land Treatment Sites	General Planning/Regulatory Application
Leaching Index	Laskowski, et al., 1982		X						X
Pesticide Index	Rao, 1985	X	X						X
Minnesota Pesticide Index	Becker, et, al., 1989		X						X

Table D-3. SUMMARY OF SELECTED SENSITIVITY ASSESSMENT METHODOLOGIES FOR VARIOUS NEEDS (Modified from Geier and Perry, 1990)(Cont'd)

Section 5. Land Treatment Site Methodologies

Empirical Assessment Method	Primary Source	Evaluates Geologic Sensitivity	Evaluates Contaminant Prop/Behav	Explicitly Evaluates Hazardous Wastes	Rates Industrial Waste Pond Sites	Rates Septic System Sites	Rates Landfill Sites	Rates Surface Application Sites	General Planning/Regulatory Application
Fuller Land Treatment Methodology	Fuller, 1984	X						X	
Mobility Degradation Index	Mahmood, et al., 1986	X	X	X				X	

solubility, persistence, and soil absorption value. The two ratings are combined in a matrix to yield a potential for leaching through the soil, ranging from Potential 1 (largest) to Potential 3 (smallest). This system is simple, easy to use, and the necessary data for its application are available for most of Minnesota. It is a guide for managing individual fields. A similar matrix has also been developed for evaluating pesticide surface runoff potential. Local county agents should be contacted for further information.

The Nitrogen Fertilizer Task Force has developed voluntary Best Management Practices (BMP's) for nitrogen fertilizers. Nitrogen fertilizer BMP's have been formulated for five Minnesota regions based general soils, climatic and cropping conditions. Figure D-1 shows the five nitrogen fertilizer BMP regions. For each region, the Minnesota Department of Agriculture (MDA) developed specific recommendations for managing nitrogen fertilizer. In the future, the MDA will coordinate the promotion and overall plan of response where high levels of nitrogen fertilizer related compounds are found in surface and ground waters.

The MDA has also issued voluntary BMP's for atrazine, a commonly used pesticide with a high leaching potential.. The BMP's includes recommendations for two application rates; one for general use statewide and a maximum of one-half the statewide rate in sensitive areas. For atrazine management, the MDA has identified sensitive areas as those areas with highly permeable geologic materials such as fractured rock aquifers and sandy areas where the water table is less than thirty feet from the land surface. As shown in Figure D-2, the voluntary atrazine BMP indicates the counties where these conditions are common. The MDA should be consulted for further details.

Soil-based systems such as the SCS leaching index and the geological sensitivity guidelines may be applied to the same area. Table D-4 lists the Level 1 rating and the SCS leaching potential for some Douglas County soils. Experience shows that in many cases there will be good agreement between the systems. An area may be rated High in both soil leaching potential and geologic sensitivity. Another area may be rated Nominal in leaching potential and Moderate or Low in geologic sensitivity. However, some areas may be rated Nominal in leaching potential, but High in geological sensitivity. In many cases where such a discrepancy has been analyzed, it is the result of a relatively low-permeability soil overlaying a high-permeability parent material, for example, loess over outwash, or over carbonate bedrock. In such a case both systems are accurate, in their area of application. A contaminant such as a pesticide used in an area rated Nominal is unlikely to leach through the root zone, but if it does, it is likely to reach ground water if the area has High geologic sensitivity. There is less margin for error, and more need of caution in this case than in a situation where both the soil leaching potential and the geologic sensitivity are rated low.

The other case where discrepancies will commonly turn up between the general geologic criteria and the soil leaching system is in an area with a high water table. In Table V-1, (general geologic sensitivity ratings for Level 1 assessments), a water table of less than six feet changes Moderate ratings to High, and Low ratings to Moderate. This is done because the system is designed to estimate travel time to the first zone of saturation, regardless of whether it is seasonal, perched or the water table aquifer. In an area of a high water table, the water does not have far to go to reach saturated conditions. In an area rated Nominal in leaching potential but High in geologic sensitivity because of a high water table, pesticides are unlikely to leach through the soil, but if they do, they are likely to quickly enter the ground water. This situation is another indicator that extra care may be needed to protect the ground water system.

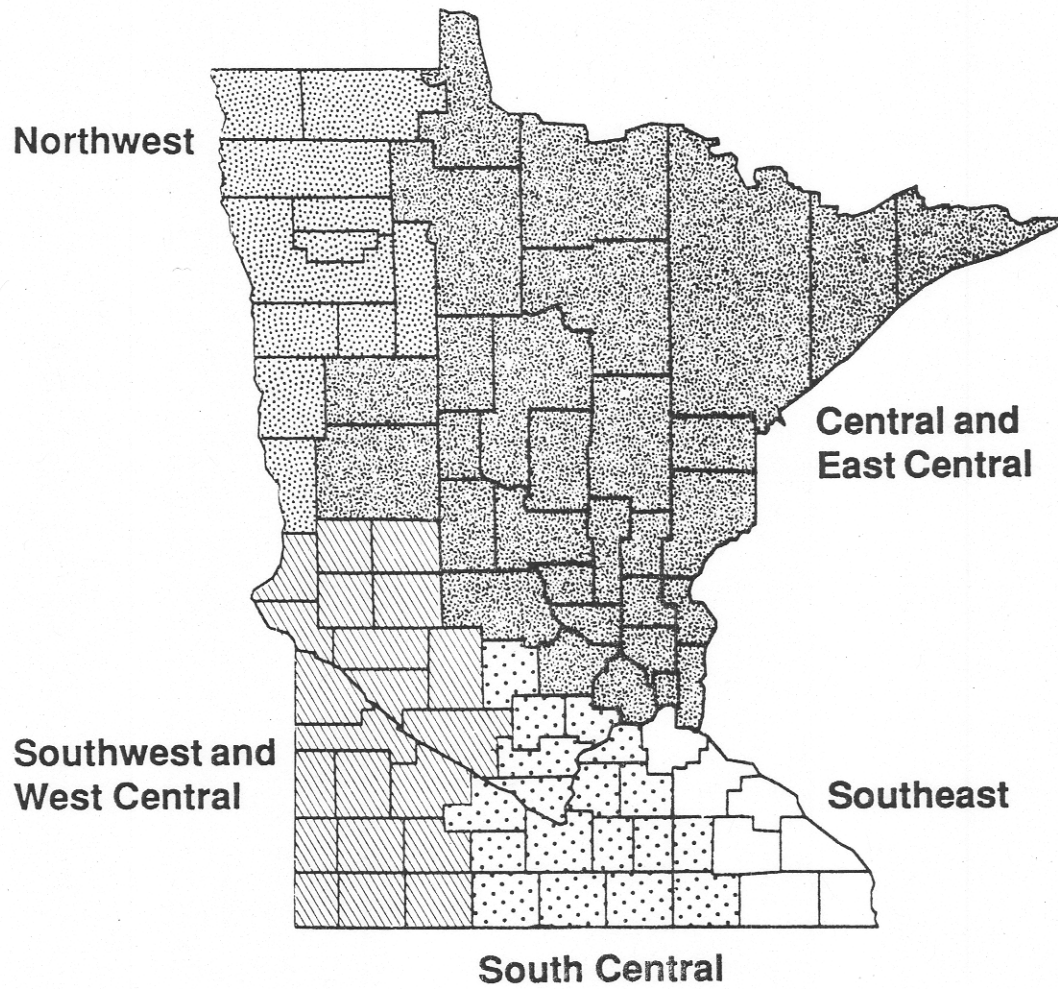


Figure D-1. The five Minnesota regions for which nitrogen BMP's are formulated.



VOLUNTARY ATRAZINE BEST MANAGEMENT PRACTICES

HERBICIDE SELECTION RECOMMENDATIONS

1. Use Integrated Pest Management techniques for pest control
 - a. Scout fields to identify weed species present.
 - b. Assess population levels.
 - c. Determine whether herbicide treatments are merited and if so, which herbicides are appropriate.
 - d. Consider alternatives to atrazine use that may do the same job with potential negative impact on water resources.
 - e. Apply the least amount of herbicide necessary to control the weeds, and only where weed problems exist or are anticipated.
2. Maintain a field history which includes soil test results, crops, pest problems, pesticides used (brand names, active ingredients, rates), application dates, and results.

MIXING AND LOADING

1. Mix, load, or clean equipment containing atrazine a minimum of 150 feet from a sinkhole (outer edge of slope), streambed, lake, wetland, water impoundment, river or similar areas.
2. Mix, load and clean-out equipment on impervious surfaces. Atrazine mixing/loading and equipment clean-out should be carried out on an impervious surface such as a mixing and loading pad. Equipment and container wash waters should be applied evenly over labeled areas or used as part of dilution make-up water.

APPLICATION RATES

1. Sensitive Areas

Limit to one and one-half pounds or less atrazine active ingredient (or 1.6 pounds atrazine active ingredient plus related compounds) per acre per calendar year in sensitive areas. The application rate for atrazine of 1.5 lbs. active ingredient is equivalent to 4L, 2.0 lbs. of 80W, or 1.8 lbs. of 90% WDG or DF formulations. Sensitive areas, until further defined by the Department of Natural Resources, include highly permeable geologic material such as:

 - a. fractured rock aquifers (including karst, sinkhole areas) or;
 - b. where sands, loamy sands, and/or sandy loams are the prevalent soil texture within a field (greater than 50% of the soil surface) and where the water table is less than thirty feet below the surface.



Counties in which these conditions are prevalent include: Anoka, Becker, Benton, Brown, Chisago, Dakota, Fillmore, Goodhue, Houston, Hubbard, Isanti, Morrison, Mower, Olmsted, Ottertail, Pope, Sherburne, Stearns, Todd, Wabasha, Wadena, Washington, Watoowan, and Winona.

It should be noted that portions of every Minnesota county may include one, or all, of these conditions. For example, in addition to the counties listed above, sands, loamy sands, and/or sandy loams are prevalent in river valleys, especially in south western counties such as Rock and Pipestone. Contact your local Soil Conservation Service for further information on specific soil conditions on your farm.

2. Statewide

Limit to no more than 3 lbs. atrazine active ingredient per acre per calendar year. The maximum application rate for atrazine is equivalent to 3 qts. of 4L, 3 3/4 lbs. of 80W, or 3.3 lbs. of 90% WDG or DF formulations except in sensitive areas where rate restrictions apply.

Refrain from using atrazine for nonselective weed control on noncrop land.

ATRAZINE USE RECOMMENDATIONS

1. Only apply atrazine between spring thaw and until corn reaches 12 inches in height. Do not apply atrazine in the fall or winter.
2. Establish and maintain buffer areas. Buffer areas are grassy Water Ways or vegetation strips around sinkholes, drainage wells and other areas where distance limitations apply. Avoid atrazine drift into these buffer areas.
3. Follow proven irrigation management practices to minimize leaching. Do not over irrigate. Contact University of Minnesota Extension Service irrigation Specialists for irrigation recommendations.

CONTAINER MANAGEMENT

1. Rinse containers immediately. Delay in rinsing atrazine containers results in a residue that, upon drying, is highly resistant to rinsing. Proper rinsing may be accomplished by pressure rinsing or triple rinsing immediately after emptying container. Use rinseate as dilution make-up water. Apply rinseate evenly over a labeled site.
2. Properly dispose of rinsed atrazine containers. Recycle or dispose of container as a solid waste. Contact Minnesota Department of Agriculture for further information on recycling and disposal.

LEGAL REQUIREMENT

Atrazine must not be applied through an irrigation system.

ASSISTANCE TO ATRAZINE USERS

Contact the Minnesota Department of Agriculture or the Minnesota Extension service for further information on Atrazine Best Management Practices (BMPs).

Atrazine Best Management Practices are supplemental voluntary management practices. Users must also follow all legal requirements such as:

1. Read and follow label directions. Recent label changes have occurred on atrazine containing products. Be sure to read and follow all directions and precautions appearing on the label in your possession. Certain atrazine Best Management Practices recommendations are mandatory if listed on the label in the users possession.
2. Atrazine is a Restricted Use Pesticide. Purchasers and applicators must have proper Minnesota Department of Agriculture issued licensure or certification. All sales must be reported to Minnesota Department of Agriculture by the Restricted Use Pesticide dealer at the end of each year.
3. Do not mix near wells. Follow Minnesota Water Well Code which currently prohibits mixing, loading or cleaning of application equipment within 150 feet of a well (including, but not limited to, a farm well, drinking water well, abandoned well, irrigation well or drainage well).
4. Properly calibrate equipment so that label rates are accurately delivered to the target site.
5. Avoid back-siphoning by utilization of a fixed airgap or the Minnesota Department of Agriculture/Minnesota Department of Health approved anti-backsiphoning device.

Figure D-2. Voluntary Atrazine Best Management Practices (BMP's) for Minnesota

Table D-4. Partial listing of Douglas County Level 1 - Preliminary Geologic Sensitivity Assessment showing comparison of Level 1 rating and SCS Leaching Potential.

Symbol	Soil Name	Parent Material	Texture of lowest described horizon	Water Table*	Level 1 Rating	SCS Leaching Potential
AaA	Aastad clay loam	Loam till	Clay loam, loam	3->6	Moderate	Intermediate
Ad	Alluvial land	Alluvium	Variable, loamy to sandy	1-5	High	High
Ao	Arveson sandy clay loam	Sandy outwash or lacustrine	F. sand, lmy sand, s.loam	1-2	Very High	High/Interm.(D**)
AsA	Arvilla sandy loam, 0-2%	Outwash, stream terraces, beaches	Gravelly coarse sand	>6	Very High	High
AsB	Arvilla sandy loam, 2-6%	Outwash, stream terraces, beaches	Gravelly coarse sand	>6	Very High	High
AsC	Arvilla sandy loam, 6-12%	Outwash, stream terraces, beaches	Gravelly coarse sand	>6	Very High	High
AtA	Arvilla sandy loam, 0-3%	Outwash	Gravelly coarse sand	>6	Very High	Intermediate
BaB2	Barnes loam, 2-6%, eroded	Loam till	Loam	>6	Low	Intermediate
BaC2	Barnes loam, 6-12%, eroded	Loam till	Loam	>6	Low	Nominal
BIB2	Barnes-Langhei loams, 2-6%,	Loam till	Loam	>6	Low	Intermediate
BIC2	Barnes-Langhei loams, 6-12%	Loam till	Loam	>6	Low	Nominal
BmA	Beltrami loam, 1-3%	Loam till	Loam, clay loam	2-4	Moderate	Intermediate
Bp	Brophy peat	Peat	Organic	0	High	High/Interm.(D**)
Ca	Carlos muck	Mucky peat(peat interlayered w/ silt/clay	Organic	0	High	High/Interm.(D**)
Cc	Cathro muck	Muck over silt loam	Sandy lm, lm, silt loam	0	High	High/Interm.(D**)
Ch	Cathro muck, sandy subsoil	Muck over gravelly sand	Gravelly coarse sand	0	Very High	High/Interm.(D**)
CIB2	Clarion loam, 2-6% (Ves)	Loam till	Loam, clay loam	>6	Low	Intermediate
CIC2	Clarion loam, 6-12% (Ves)	Loam till	Loam, clay loam	>6	Low	Nominal
CmA	Clontarf sandy loam, 0-2%	Outwash, terraces, or gl. lacustr.	Sand, f. sand, lmy sand	3-5	Very High	High
Co	Colvin silt loam	Lacustrine, outwash channels	Lm., silt lm, stly cl lm	1-2	High	High/Interm.(D**)
Cp	Colvin silt loam, depress.	Lacustrine silt	Lm, silt lm, stly cl lm	0	High	High/Interm.(D**)
DaA	Damen loam, 1-4%	Colluvium/alluvium	Loam, clay loam	>6	Moderate	Nominal
Dd	Dassel sandy loam (Darfur)	Outwash	Stratified f sand, f sndy lm	1-3	High	High
De	Dassel sandy loam, depress.	Outwash	Strat. lmy sand, coarse sand	0	Very High	High
DoA	Dorset sandy loam, 0-2%	Outwash	Gravelly coarse sand	>6	Very High	High
DoB	Dorset sandy loam, 2-6%	Outwash	Gravelly coarse sand	>6	Very High	High
DoC	Dorset sandy loam, 6-12%	Outwash	Gravelly coarse sand	>6	Very High	High
DpA	Dorset sandy loam, 0-2%	Outwash	Gravelly coarse sand	>6	Very High	Intermediate

*Natural depth in feet to seasonal high and low zones of soil saturation is listed. This is not strictly equivalent to the "water table" in the hydrogeological sense. Drained areas, especially deeply ditched areas may need to be separately considered in assignment of Level 1 ratings and also the Level 2 vadose zone assessment.

**Rated High if undrained; rated Intermediate if drained.

The SCS soil leaching system is designed to be used where the chemical application is at or very near the surface and where the persistence of the chemical can be defined for local climatic conditions. The SCS system should not be used for evaluating threats to ground water that originate under the surface, such as landfills, underground storage tanks, or septic tank drain fields.

SUMMARY

From the discussion above, it should be clear that many sensitivity assessment models are available and include both mathematical models and empirical methods. The choice of an assessment model is area and user specific. Sometimes the choice of which model to use is relatively straightforward. In other cases the choice may be difficult such as when there are conflicting needs, limited data and/or constrained budget.

Using an assessment model is not an easy task. First, the purpose and information needed should be identified. Second, an appropriate method must be chosen to meet the specified purpose and within known information or other limits. Third, the chosen method must be used within the scope of the method design. Finally, the results of the sensitivity assessment must be interpreted and an evaluation conducted to determine if the goals of the assessment process have been achieved. Potential users of any model or method may need to work with experienced professionals to achieve the desired results.

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