THE MICHIGAN SOURCE WATER ASSESSMENT PROGRAM FOR EVALUATION OF PUBLIC SURFACE WATER SUPPLIES

Michael J. Sweat

Mr. Sweat is a hydrologist with the Water Resources Division of U.S. Geological Survey. He is responsible for assessing the impact of potential contaminant sources on surface water supplies. Other current projects include restoration of sheet flow in fens and a variety of studies involving geophysics, ground water, wetlands, and surface water.

Paul M. Erickson

Mr. Erickson is a senior at Michigan State University pursuing a degree in environmental geosciences. He has been assisting the Michigan source water assessment program by creating geographic-information-system coverages, analyzing data, and maintaining project databases.

Bradley B. Brogren

Mr. Brogren is an engineer with the Michigan Department of Environmental Quality, Drinking Water and Radiological Protection Division. He is responsible for designing the state's Source Water Assessment Program and coordinating its implementation. Previously, he was a field engineer for MDEQ working with local water supplies.

ABSTRACT

In response to the reauthorization of the Safe Drinking Water Act of 1996, the United States Geological Survey and the Michigan Department of Environmental Quality are cooperatively assessing the safety of public water supplies from inland rivers and the Great Lakes. Assessments to identify activities that could adversely impact water quality will use local data on land use and contamination sources (sewer outfalls, leaking storage tanks); information from water plant personnel (influent chemistry, effects of weather, lake currents); and centralized state and federal data resources (census data, permitted discharges). Assessment of 60 Great Lakes supplied systems will follow the "Assessment Protocol for Great Lakes Sources" developed by the Great Lakes States in United States Environmental Protection Agency Region 5. Assessments of nine river-supplied systems will be based on an inventory of contaminants of concern, identification of potential contamination sources, and determination of susceptibility to contamination.

INTRODUCTION

The 1996 Amendments to the Safe Drinking Water Act (Section 1453) require primacy states to develop and implement a source water assessment program (SWAP) to: (a) delineate the boundaries of areas that supply water to public systems to define the source water areas (SWAs), (b) identify potential sources of regulated and unregulated contaminants in the SWA, and (c) determine the susceptibility of public water systems to those contaminants. Based on information obtained during the assessments, the state will help communities develop plans to protect their drinking water.

The Michigan Department of Environmental Quality (MDEQ) has developed a SWAP using a Citizens Advisory Committee, which includes a Technical Advisory Committee and a Public Advisory Committee to guide and review the process. MDEQ will expand the existing EPA-approved groundwater-based drinking water protection program (also known as the wellhead protection program) to include surface water sources.

Implementation of the SWAP in Michigan will be accomplished primarily by the MDEQ and the USGS. The USGS will perform assessments, consistent with MDEQ's groundwater-based drinking water protection program, of some of the State's 69 community surface-water systems. The USGS will perform pilot assessments of three surface-water systems with Great Lakes intakes and four surface-water systems with inland lake or river intakes. Assessments will include delineation of source water areas (SWA), potential contaminant inventories, and

susceptibility analyses conducted in a manner consistent with MDEQ's existing drinking water protection program. The USGS and the MDEQ will perform contaminant inventories and susceptibility analyses of these seven pilot systems in order to develop methods to be used in assessing the remaining supplies. Complete assessments will include a map of the SWA, a list of potential contaminant sources, the location of potential contaminant sources shown on a map, a map of the susceptibility determination, and a narrative of the procedures for conducting the assessment. MDEQ will provide technical assistance to communities, initiate community outreach programs, and take the lead in developing a geographic information system (GIS) framework for displaying the results of the assessments to the public.

DELINEATION OF SURFACE SOURCE WATER AREAS

The USGS has developed GIS-based methods for delineating SWAs for surface water systems. The State's major drainage basins and sub-basins have been delineated based on topographic information. MDEQ and USGS are also involved in watershed and water quality assessment and restoration projects in the State. In sub-basins that have been identified as water-quality limited under the Clean Water Act, there have been increased efforts to delineate and establish riparian areas and/or buffer zones to improve water quality. Through these delineation efforts and technical assistance programs, MDEQ and USGS will integrate drinking water protection issues with other ongoing watershed restoration work.

Location of Water Supply Intakes

Existing surface-water intake locations will be confirmed by use of a global positioning system (GPS) unit during site visits by MDEQ and USGS. Location data will be assembled from field and office visits, and incorporated into a GIS network. Preliminary analysis indicates that locations are accurate for about 95 percent of the 69 public surface-water supplies.

Delineation of Intake Watershed

The SWA delineation process begins by identifying watershed boundaries. SWA delineation will include the entire basin upstream of the public water system intake structure. This area will be determined by identifying the perimeter of the basin that provides water to the surface water intake. Where water is diverted from one watershed to another, for example, a Great Lakes intake, the delineation of source areas will include all applicable basins.

The SWA delineation process will use available digital basin boundaries. Basins will be further subdivided, as needed, using local or other expert input and federal watershed delineation guidelines. Figure 1 (p 20) is an example of GIS watershed delineation for a surface water intake, designating the SWA for the intake.

Delineation of the Critical Assessment Zone and Susceptible Area

After delineating a watershed, USGS will delineate the critical assessment zone (CAZ) as defined in the *Assessment Protocol for Great Lakes Sources* (MDEQ, 1999, Appendix L, pp. 99-103) and susceptible areas within the watershed, to determine the susceptibility of the public water system. Susceptible areas serve as areas for a focused inventory of potential contaminant sources. Susceptible areas also designate where there are potential risks of contamination by spills or other contaminant releases, and are considered nominal. Thus, these areas can be larger based on site-specific data and time-of-travel calculations performed by the public water supply. The radius and setback methods involve using a horizontal distance, but a slope distance can also be calculated as needed for site-specific analysis.

The CAZ for river intakes is a 3,000-foot (ft) radius from the center of the intake. For Great Lakes intakes, the CAZ is defined by the distance from shore of the intake pipeline (L) in feet, and the water depth of the intake crib (D) in feet. Multiplying L times D yields a sensitivity value (MDEQ, 1999, p. 100) that determines the CAZ for Great Lakes intakes.

For streams, the CAZ is a 3,000 ft radius upstream of intake and the susceptible area is a 300 ft setback from centerline of the intake stream and all perennial tributaries within the twenty-four hour time of travel. This distance is consistent with what is used to designate riparian buffers (susceptible areas).

For Great Lakes and reservoir intakes, the CAZ is a 1,000, 2,000 or 3,000 ft radius from the intake (MDEQ, 1999, p. 100), a 1,000 ft setback inland from the shore adjacent to the intake pipeline, and a 300 ft setback from the centerline of all streams and all perennial tributaries flowing into the water body within the CAZ, within the twenty-four hour time of travel from stream mouths.

CONTAMINANT-SOURCE INVENTORIES

After a SWA has been delineated, potential sources of contamination will be identified, located, and inventoried. The USGS will conduct contaminant-source inventories with assistance from the MDEQ, the public water systems, watershed councils, drinking water protection committees, and local citizens. Contaminant-source inventories will use a GIS and existing Federal, State, and local databases. This approach will focus on facilities, activities, and land uses that are considered high or moderate risks to drinking water.

The procedure for conducting each inventory consists of identifying and locating potential sources of contaminants, and includes:

- Create a land use/ownership GIS map for the delineated area.
- Conduct database searches and plot existing data on the GIS map.
- Collect other existing sources of information.
- Provide a preliminary inventory form and map to public water supply, planners, and community team.
- Field locate (optional) and verify potential high-risk activities.
- Finalize the inventory form and the GIS base map.

After potential sources of contamination are identified and located, an inventory of potential sources will be conducted. The inventory will:

- Provide information on contaminants used or stored by potential sources, especially those that present the greatest risks to a water supply;
- Provide an effective means of educating the public about potential contaminants; and
- Provide a reliable basis for developing a local management plan to reduce risks to water supplies.

Contaminants of Concern

Contaminant releases to water bodies can occur from nonpoint or point sources. Major contaminants of concern from nonpoint sources in Michigan are sediments, nitrates, microorganisms, and pesticides. Major contaminants of concern from point sources in Michigan are volatile organic compounds, microorganisms, and petroleum compounds. Sources of contamination can come from industrial facilities, sewage or waste disposal sites, managed forest or agricultural lands, accidental spills, small businesses, and residential activities.

Inventories will focus on potential sources of contaminants regulated under the SDWA. This includes contaminants with a maximum contaminant level, contaminants regulated under the USEPA surface water treatment rule, and the microorganisms Cryptosporidium and Giardia lamblia.

Four broad categories of contaminants affect the quality of water resources in Michigan. These categories are:

1. Microorganisms:
    - Viruses:
        - Hepatitis A, Norwalk type
    - Protozoa:
        - Giardia lamblia, Cryptosporidium
    - Bacteria:
        - Coliform (Escherichia coli, fecal, enterococcus).
2. Turbidity / Sediments
3. Inorganics:
    - Nitrates
    - Metals (lead, arsenic, chromium)
4. Organics:
    - Volatile Organic Compounds:
        - Chlorinated solvents (trichloroethylene/ tetrachloroethylene)
        - Aromatics (benzene, toluene)
    - Petroleum Compounds:
        - Fuels (diesel, gasoline)
        - Lubricants (oil)
    - Semi-Volatiles:
        - Pesticides (herbicides, insecticides)
        - Polynuclear aromatic hydrocarbons
        - Phenols (pentachlorophenol)

Scope of Contaminant-Source Inventory

The contaminant source inventory will identify and locate significant potential sources of contaminants of concern within a SWA. Potential sources of contamination can be defined as any facility or activity that stores, uses, or produces contaminants of concern and has a sufficient likelihood of releasing such contaminants to the environment at levels that could contribute significantly to the concentration of these contaminants in the source waters of the public water supply. Contaminants can reach a surface water body from activities occurring on or below the land surface.

It is important to identify potential risks to the water supply within the SWA. Operating practices and environmental awareness varies among facility operators and landowners. When considering potential risks to water bodies, one question that can be asked is whether the operator or owner is employing good management practices or pollution prevention. Regardless of the quality of management practices or pollution prevention methods employed, the highest potential risks will generally be from the facilities or land use activities that use, store, or generate high-risk chemicals.

The relation between type of facility and sources of contamination is shown in table 1 (p. 18-19). Not all facilities or potential sources of contamination in the SWA will need to be inventoried. The inventoried areas will be limited to a sub-set of the entire watershed, focusing on the highest risk areas identified through the delineation of the CAZ.

After SWA delineation and the contaminant-source inventory are complete, communities can develop a management plan to protect the public water supply. In this process, sources that pose little threat to the public water supply can be screened out. For example, if business activities are conducted in a manner that already have a low likelihood of contamination release, a facility would not need to re-evaluate its practices. The purpose of developing a management plan based on inventory results is to address business and land use activities that pose risks to a public water supply.

Potential Contaminant-Source Inventory Procedure

To structure the potential contaminant-source inventory procedure, the USGS will create a land use and ownership GIS map for each SWA. The goal of mapping land use and ownership is to divide the delineated area into the following four land use categories: residential and municipal, commercial and industrial, agricultural and forest, and miscellaneous.

It is important to have a map at an appropriate scale that allows accurate plotting of each potential source on the map. The land-use map, coupled with the locations of potential contaminant sources, soils, transportation, drains, etc., will assist in identifying threats from current land uses to the quality of the water supply. Sources of information for this map include existing statewide GIS maps and a community's zoning map or current land use map, which identifies specific land uses, including residential, commercial, and industrial uses. County and city

transportation, planning, or public works departments or chambers of commerce will be contacted to locate the best available land use map for the delineated area, to be used in conjunction with the GIS map. Aerial photos may also be useful for dividing SWA into general land use categories if a zoning map is not available.

Federal, State, and local databases will be searched for contaminant-source data that may be available for each SWA. Databases at various government levels contain information and(or) existing permits related to water quality, underground injection, hazardous waste, solid waste, underground storage tanks, air quality, water supply wells, toxic release inventory, water rights, irrigated areas, pesticide records, etc. Databases that may provide information about potential sources of contamination within the SWA include:

- Leaking underground storage tanks
- Dry cleaners
- Underground storage tank cleanup list, addressed sites
- Registered hazardous waste generators
- Spills
- Environmental cleanup site information
- Solid waste facilities
- Water quality monitoring
- Wastewater discharge reporting system
- Source information system
- Underground injection control
- Total maximum daily load permits (TMDL)
- Voluntary cleanup program sites
- Drinking water permits
- Water rights permits
- Confined animal feeding operations
- Hazardous materials handlers and hazardous material incidents
- National Water Quality Assessment
- National Water Information System
- National Assessment of Stream Quality Network
- Water Science and Technology Services
- Better Assessment Science Integrating Point and Nonpoint Sources
- National Priority List
- National Pollutant Discharge Elimination System
- Toxic Release Inventory System

To supplement the database information, public water system officials, planners, and interested citizens will be contacted. At the local level, a substantial amount of information on historical, current, or future potential contamination sources exists in the form of routine records or documents in county or city files. Local citizens also have knowledge of potential sources that are not listed elsewhere in databases or on maps. Specific sources of information for local data on land uses and activities may include:

- Planning department
- Public works
- Fire departments
- Historical societies
- Libraries
- Telephone books
- Chambers of commerce
- City/county permit files
- Property transfer records
- Health departments
- Local transportation departments
- Aerial photos
- Flood control districts
- Business licenses
- Construction permits
- Tax assessors
- Solid waste collectors
- Septic handlers

When identifying land uses, existing, historical, and intended uses of the land will be considered. Historical uses often have a major role in the land's current capacity to provide high quality water. For example, on land that was used for agricultural purposes it will be necessary to identify chemicals such as pesticides used, stored, or disposed of on-site. Former gasoline stations and dumpsites are considered potential risks to ground water. Searching records and(or) interviewing long-time residents will help ensure that past sources of contamination are not overlooked.

Aerial photographs can be helpful in identifying both present and historic land uses. Aerial photos may be available from the county seat or transportation officials. They can also generally be obtained from the Corps of Engineers, Natural Resources Conservation Service, local flood control districts, or from commercial aerial photographers. Other resources include colleges and universities. For example, Michigan State University has an extensive collection of aerial photos of most of Michigan in their photogrammetric library that can be used to identify changes in land use.

To identify potential sources of contamination, MDEQ will prepare a comprehensive inventory form to ensure a consistent approach by USGS and MDEQ. The inventory form will include a comprehensive list of potential sources of contamination. Because there are significant variations in land uses and activities across the State, especially in agricultural areas, the list of potential sources of contamination can be expanded or adapted to more adequately apply to each SWAP. The inventory form and a map of land use, potential contaminant sources, and location of the water supply intake will be sent to the public water system officials with a request to verify and complete the inventory at the local level.

The level of field reconnaissance needed will depend on the complexity of land uses and potential contaminant sources within the SWA. In some cases, USGS and MDEQ staff can perform the entire inventory with local community assistance without the need for any fieldwork. However, it may be necessary to conduct an in-depth survey for more densely developed areas, where GIS mapping may not be sufficient to identify individual potential contaminant sources. This survey involves driving through portions of the SWA and using GPS to field check the locations of potential contaminant sources identified during the previous data collection, and noting any unreported potential contaminant sources that are seen during the survey.

Once the potential contaminant inventory process is completed, it will be necessary to determine which potential contaminant sources pose the greatest threat to the water supply. Identifying high-risk threats will provide input for developing a protection strategy based on prioritized areas or individual sources. The contaminant source inventory will provide a map showing the location of potential contaminant sources. This potential source map will then be combined with an overlay of the SWA. Potential contaminant sources that lie within the SWA are considered to pose the greatest risk to the water source.

The overall success of each SWAP will depend on identifying potential contaminant sources so that tools can be used to reduce risks from these sources. As communities move into planning how to protect their public water supply, they may want to re-visit high-risk activities and land use areas and conduct a more in-depth assessment.

DETERMINATION OF SUSCEPTIBILITY

For purposes of the SWAP, MDEQ defines susceptibility determination as the potential for a public water system to draw water contaminated by inventoried sources within their SWA at concentrations that would pose concern (Michigan Department of Environmental Quality, 1999). The susceptibility determination is designed to be a relative comparison among potential contaminant sources within the SWA. The objective is to provide meaningful assessment results to public water systems and communities; this is accomplished by providing a map with the CAZ and potential contaminant sources within the CAZ identified within each SWA. This map becomes the basis for prioritizing efforts to protect each system's drinking-water source area.

Data collected during the delineation and inventory can then be used to develop a management strategy by the community to protect its drinking water supply. The susceptibility analysis will provide tools to help the MDEQ and communities develop protection plans with management efforts directed at high and moderate risks in the most susceptible areas.

Susceptibility Analysis

Susceptible areas are areas where potential contaminant sources or land use activities have the potential to impact a water supply. Other factors, such as location of potential contaminant sources and land use within the CAZ, are then taken into account to further designate susceptible areas in the watershed. There are several factors to take into account when establishing susceptible areas. It is important to note that some factors may be limited by available data or require additional research. Examples of factors to be considered in determining the susceptible areas include:

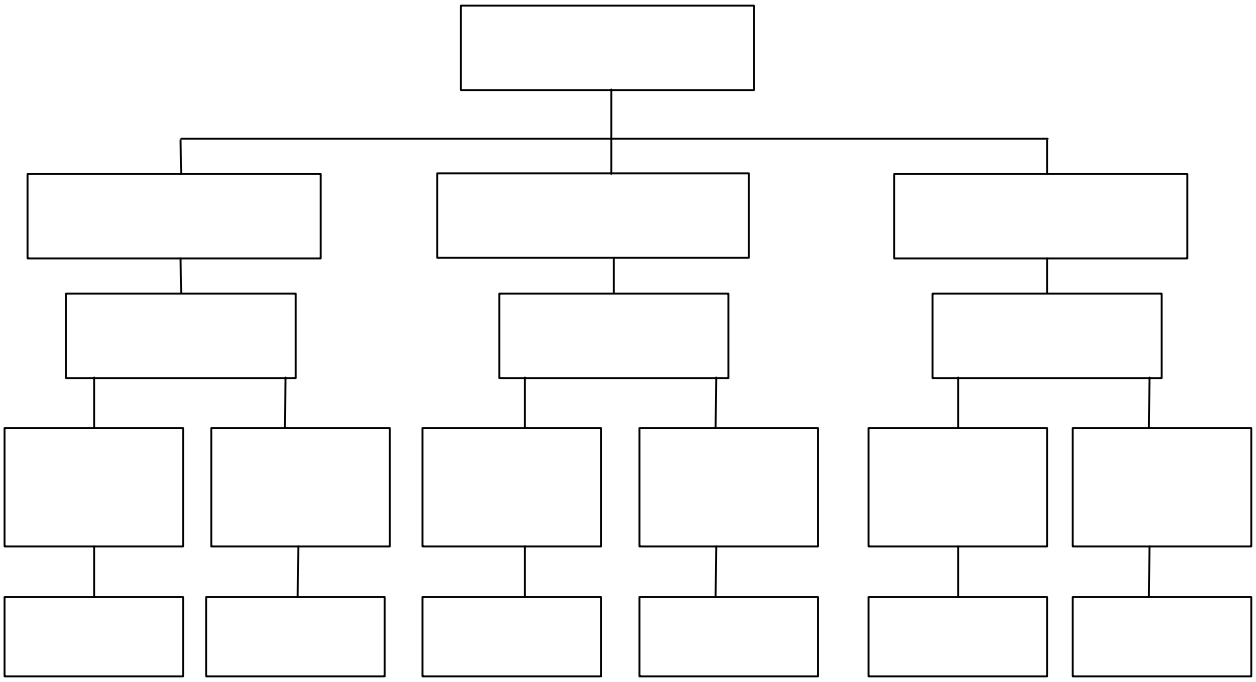
- High Erosional Soils:
  - Example: High percent clay soils, steep slopes, developed areas.
  - Source: Soil survey maps, digitized data, assistance from forest/agricultural agencies.

- High Permeability Soils:
  - Example: Recent alluvial deposits, high percent sand soils.
  - Source: Soil survey maps, GIS layers.
- Susceptible Area Adjacent to Intake (1,000, 2,000 or 3,000 ft):
  - Example: Shallow or near-shore intake, storm drains adjacent to intake.
  - Source: Water supply operator, drain commission, road commission.
- Susceptible Area Adjacent to Streams (300 ft):
  - Example: Lawns abutting stream, development along stream.
  - Source: Land use maps, extension service, water supply operator.
- Susceptible Area Adjacent to Reservoirs/ Lakes (1,000 ft):
  - Example: Lawns abutting shoreline, development along shoreline, recreational uses.
  - Source: Land use maps, parks/recreation department.
- High Rainfall/Irrigation – Runoff:
  - Example: Tillable land abutting shoreline, storm drains.
  - Source: NOAA and local databases; NRCS/MDA and extension agents.

Susceptible areas will be determined within each SWA. Data collection for determining the susceptible areas within the SWA will be done as part of the delineations of the surface water systems. After susceptible areas within a SWA are identified, a map will be generated of the locations of potential contaminant sources determined during the inventory to be within the susceptible area. Potential contaminant sources that fall within susceptible areas will be identified to the public water system. Maps of the combined susceptible areas and potential contaminant sources will provide the community with information that can be used to prioritize and tailor management strategies to address potential contaminant sources.

Susceptibility Determination Results

Susceptibility determinations will provide an overall estimate of the sensitivity of a system's drinking water (see flow chart) within the CAZ. The analysis will help illustrate potential threats to a community's drinking water, and will help communities prioritize their efforts in protecting their drinking-water supply. Figure 2 (p. 21) provides an example of a final susceptibility map for an assessed public water system.



CONTENTS OF SOURCE WATER ASSESSMENT REPORT

The SDWA Amendments require that SWAP results be made available to each public water system after they are complete. Assessment results, known as the "Source Water Assessment Report" for each public water system, will contain the following:

- Map of the SWA
- List of potential contaminant sources and locations shown on SWA map
- Results of susceptibility determination shown on SWA map
- Narrative of procedures for conducting assessment

Each public water system will be provided with a copy of the complete report for their system after MDEQ and USGS conduct the assessment.

Making Assessments Available to the Public

Assessments will result in a compilation of a significant hydrologic, hydrogeologic, and location databases that will be useful to public water system officials, community planners, state agencies, and others. A source water assessment report, informational brochures, and a website with links to data found in the assessments will be provided. Public water system operators will be able to select from a variety of methods to inform the public of the assessment results, and encouraged to include the results in the newly mandated Consumer Confidence Reports (CCR). Copies of the complete source water assessment report will be made available to the public at the following locations:

- Public water system offices
- City halls
- Local libraries
- MDEQ Regional offices
- NRCS or USGS field offices
- Local Post Offices

The drinking water protection database that is developed as part of each assessment will serve a variety of informational needs. It will store latitude and longitude coordinates and accuracy information for surface water intakes for delineation and assessment purposes, which will link with GIS systems for mapping and analysis. Sources of contaminants and data collection methods will be stored for each SWAP completed. As assessments are completed for each public water supply, the database will provide an indication of the status of the source water assessment program in Michigan. The database will support sharing information on the Internet, GIS mapping activities, and data analysis. The result will be database tables that link to delineated areas.

Public water system officials and members of the public will be able to perform queries on SWAPs. Individuals will be able to access a specific water system by name, or by stepping through a web-based application, identifying a county or watershed from a display of the state, and identifying a community or area from the displayed county or watershed map. Individuals will be able to view the delineation of the water system of their choice on a topographic base map. Text will provide a brief explanation of the meaning of each map. Data files will provide additional information about the drinking water source, for example, the length or depth of the intake pipeline, the source name, or the most recent water-quality sampling results. The location of potential contaminant sources will be available in map form to overlay on top of the SWA delineation. Information in the database will be updated as needed.

Public water systems are responsible for notifying their customers of assessment results. Public water systems serving 1,000 connections or more are mandated to include notification of the source water assessment results in their CCR, per the 1996 Amendments to the Safe Drinking Water Act. Notification about the availability of assessment results for smaller public water systems may best be made by a statement on water bills that includes notification that the assessment has been completed, and information on where a complete copy of the assessment can be found. There are many ways that a public water system could provide the assessment results to the public. Some of the options include:

- Fact Sheets
- Cable Access Television
- Press Releases
- Newsletters
- Posters and Flyers
- CCR
- Public Meetings
- Local Watershed Councils

Integration With Other Ongoing Water Quality Programs

Clean Water Action Plan: In February 1998, the USEPA and U.S. Department of Agriculture issued a "Clean Water Action Plan" (CWAP) that provides a strategy for restoring and protecting the Nation's water resources. One of the initial key elements of the CWAP required States and Tribal governments to work with agencies, governments, and the public to assess the condition of the Nation's water resources and to prioritize watersheds for restoration. Existing assessment and prioritization efforts, developed with extensive public input, were to be used. Michigan's water-resources restoration priorities will be reviewed annually and updated as needed to reflect changing conditions and more detailed watershed information. The priorities will be used to help target increased funding associated with the CWAP and to identify where collaborative restoration opportunities exist.

Michigan's Clean Water Act Section 303(d) List: Section 303(d) of the Clean Water Act requires each state to develop a list of water bodies that do not meet standards that protect beneficial uses such as drinking water, cold water fisheries, industrial water supply, recreation, and agricultural uses. MDEQ must monitor water quality and review available data and information to determine if the standards are being met. MDEQ must submit an updated list to USEPA every 2 years. The list provides a way for the public to identify problems, to develop and implement watershed recovery plans, and for the protection of beneficial uses of the States water resources, while achieving federal and state water quality standards. Federal law requires that streams, rivers, lakes, and estuaries that appear on the 303(d) list must be managed to meet state water quality standards. In most cases, rivers and streams receive discharges from both point sources of pollution, and from surface runoff, also known as non-point pollution. MDEQ's watershed approach for restoring and protecting water quality includes developing TMDLs for both point and non-point sources. When developing a TMDL, pollution from all sources in the watershed will be taken into account, and limits will be calculated for each pollutant entering a water body. Management plans to restore streams and rivers to water quality standards will be developed in cooperation with landowners and other agencies. In implementing the SWAP, MDEQ will seek to identify all public water system intakes so that drinking water beneficial uses can be taken into account as TMDL work progresses.

SUMMARY

The source water assessment program for the evaluation of surface water supplies in Michigan will provide information to water supply personnel and community planners that will be useful in planning for future operating practices of each supply. MDEQ will expand the existing USEPA approved groundwater-based drinking water protection program to include surface-water sources. MDEQ and USGS have developed a source water assessment program using a citizens advisory committee to guide the process.

The USGS will use GIS-based methods for delineating source water areas for surface-water systems. Existing surface-water intake locations will be confirmed by use of a GPS. After delineating watershed boundaries, a critical assessment zone will be identified for each intake, and susceptible areas within each water-supply watershed will be determined. Once the critical assessment zone and susceptible areas are defined, a contaminant source inventory will be conducted. The contaminant source inventory will identify and locate significant potential sources of contaminants within each source water area. Completed source water area delineations and contaminant source inventories will allow communities to develop a management plan to protect the public water supply.

The SWAP will determine the potential for public water supplies to draw water contaminated by inventoried sources within their source water area. This susceptibility determination will link data collected during the delineation and inventory with the development of a management strategy by the community to protect its drinking water supply. The result of each susceptibility determination will be a map of the locations of potential

sources that fall within the susceptible area, and will provide an overall estimate of the sensitivity of a system's drinking water within the critical assessment zone.

The SDWA amendments require that source water assessment results be made available to each public water system. MDEQ and USGS will prepare assessment reports that include: a map of the source-water area; a listing of potential contaminant sources with their locations shown on a map; results of the susceptibility determination shown on a map; and, a narrative of procedures used for conducting the assessment. These assessments are similar to those being prepared under the wellhead protection program for ground-water supplies. In coordination with other programs such as the Clean Water Action Plan and Michigan's Clean Water Act, assessments will allow for improved protection of surface-water-supply intakes from potential sources of contamination.

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Table 1. Potential Sources of Drinking Water Contaminants

Land Use/Facility/Source	Typical Contaminants
Commercial/Industrial	
Automotive, Boat Services/Repair, Body Shops/Repair Shops, Car Washes, Gas Stations/Sumps, Fleet/Trucking/Bus Terminals, Junk/Scrap/Salvage Yards, Machine Shops, RV/Mini Storage.	Fuels, oils; solvents; acids; paints; automotive wastes; miscellaneous cutting oils; soaps; detergents; waxes; miscellaneous organic chemicals; hydrocarbons; solvents; PCBs; lead; sludges; degreasers (tetrachloroethylene); miscellaneous wastes.
Cement/Concrete Plants, Electrical/Electronic Manufacturing, Furniture Repair/Manufacturing, Hardware/Lumber/Parts Stores, Home Manufacturing, Medical/Veterinary Offices, Metal Plating/Finishing/Fabricating, Mines/Gravel Pits, Photo Processing/Printing, Plastics/Synthetics Producers, Wood Preserving/Treating, Wood/Pulp/Paper Processing and Mills	Diesel fuels; solvents; oils; miscellaneous wastes; cyanides; metal sludges; caustic (chromic acid); alkalis; acids; paints and paint sludges; calcium fluoride sludges; methylene chloride; perchloroethylene; trichloroethane; acetone; methanol; toluene; PCBs; X-ray developers and fixers; infectious wastes; radiological wastes; biological wastes; disinfectants; asbestos; beryllium; dental acids; sodium and hydrogen cyanide; metallic salts; hydrochloric acid; sulfuric acid; chromic acid; boric acid; heavy metals; plating wastes; cyanides; surfactants; creosote; mine spoils or tailings containing metals; highly corrosive mineralized waters; metal sulfides; mineral sulfides.
Dry Cleaners, Funeral Services/Graveyards	Solvents (perchloroethylene, petroleum solvents, Freon); spotting chemicals (trichloroethane, methylchloroform, ammonia, peroxides, hydrochloric acid, rust removers, amyl acetate).
Food Processing	Nitrates; salts; phosphorus; miscellaneous food wastes; chlorine; ammonia; ethylene glycol.
Office Buildings/Complexes, Parking Lots/Malls, Research Laboratories	Building wastes; lawn and garden maintenance chemicals; gasoline; motor oil; hydrocarbons; heavy metals; building wastes; X-ray developers and fixers; infectious wastes; radiological wastes; biological wastes, disinfectants; asbestos; beryllium; solvents; infectious materials; drugs; disinfectants; (quaternary ammonia, hexachlorophene, peroxides, chlornexade, bleach); miscellaneous chemicals.
Agricultural/Forest	
Auction Lots, Chicken/Turkeys, Confined Animal Feeding Operations, Dairies, Lagoons/Liquid Wastes, Swine	Livestock sewage wastes; nitrates; phosphates; coliform and noncoliform bacteria; giardia, viruses; total dissolved solids; potassium; total dissolved solids; salts; livestock sewage wastes; chloride; chemical sprays and dips for controlling insect, bacterial, viral and fungal pests on livestock; salts; phosphates.
Farm Chemical Distributor/ Application, Farm Machinery Repair, Pesticide/Fertilizer/Petroleum Storage & Transfer Areas	Pesticides; fertilizers; petroleum (tanks, vehicles); welding wastes.
Crops-irrigated and Nonirrigated, Managed Forest Lands	Pesticides; fertilizers; nitrates; phosphates; potassium (can be worsened by over-watering); sediments; bacteria.
Rural Homesteads	Machine shops; Automotive wastes; welding wastes; solvents; metals; lubricants; sludges Septic systems; Septage; coliform and noncoliform bacteria; viruses; nitrates; heavy metals; synthetic detergents; cooking and mother oils; bleach; pesticides; paints; paint thinner; photographic chemicals; swimming pool chemicals; septic tank/cesspool cleaner chemicals; elevated levels of chloride, sulfate, calcium, magnesium, potassium, and phosphate.

Table 1. Potential Sources of Drinking Water Contaminants (continued)

Residential/Municipal	
Airports (Maintenance/Fueling Areas), Camp Grounds/RV Parks, Motor Pools, Railroad Yard/Maintenance/Fueling Areas	Jet fuels; deicers; diesel fuel; chlorinated solvents; automotive wastes; heating oil; building wastes; septage; gasoline; pesticides; household hazardous wastes; herbicides for rights-of-way; creosote form preserving wood ties; solvents; paints.
Apartments and Condominiums, Housing, Schools, Septic Systems	Household hazardous wastes; Household cleaners; oven cleaners; drain cleaners; toilet cleaners; disinfectants; metal polishes; jewelry cleaners; shoe polishes; synthetic detergents; bleach; laundry soil and stain removers; spot removers and dry cleaning fluid; solvents; lye or caustic soda; household pesticides; photo chemical; paints; varnishes; stains; dyes; wood preservatives (creosote); paint and lacquer thinners; paint and varnish removers and deglossers; paint brush cleaners; floor and furniture strippers; urban runoff/storm water; gasoline; oil; other petroleum products; nitrates; cryptosporidium; giardia; septage; coliform and noncoliform bacteria; viruses;
Drinking Water Treatment Plants	Mechanical repair and other maintenance products; Automotive wastes; waste oils; diesel fuel; kerosene; #2 heating oil; grease; degreasers for driveways and garages; metal degreasers; asphalt and roofing tar; tar removers; lubricants; rust proofers; car wash detergents; car waxes and polishes; rock salt; refrigerants.
Fire Stations	General building wastes; hydrocarbons form test burn areas.
Golf Courses, Parks	Fertilizers; herbicides; pesticides for controlling mosquitoes, ticks, ants, gypsy moths, and other pests.
Landfills/Dumps, Utility Station/Maintenance Areas, Waste Transfer/Recycling Stations	Leachate; organic and inorganic chemical contaminates; oils; nitrates; metals; solvents; PCBs; solvents; sludges; acids; metal plating solution (chromium, nickel, cadmium); herbicides; residential and commercial solid waste residues
Wastewater	Municipal wastewater; sludge; treatment chemicals; nitrates; heave metals; coliform and noncoliform bacteria.
Miscellaneous	
Above Ground Storage Tanks, Historic Gas Stations, Underground Storage Tanks	Heating oil; diesel fuel; gasoline; kerosene; other chemicals and petroleum products.
Construction/Demolition Areas	Solvents; asbestos; paints; glues and adhesives; insulation; lacquers; tars; sealants; epoxy waste; miscellaneous chemical wastes; explosives.
Historic Waste Dumps/Landfills, Injection Wells/Drywells/Sumps	Leachate; organic and inorganic chemicals; waste from households and businesses; nitrates; oils; heavy metals; solvents; storm water runoff; spilled liquids; used oils; antifreeze; gasoline; solvents; other petroleum products; pesticides.
Military Installations	Diesel fuels; jet fuels; solvents; paints; waste oils; heavy metals; radioactive wastes; explosives.
Transport Corridors	Herbicides; road salt (sodium and calcium chloride); anti-caking additives (ferric ferrocyanide, sodium ferrocyanide); anti-corrosives (phosphate and chromate); automotive wastes; fertilizers.
Wells – Water Supply Wells, Monitoring Wells, Unsealed or Abandoned Wells, and Test Holes	Storm water runoff; solvents; nitrates; septic tanks; hydrocarbons.

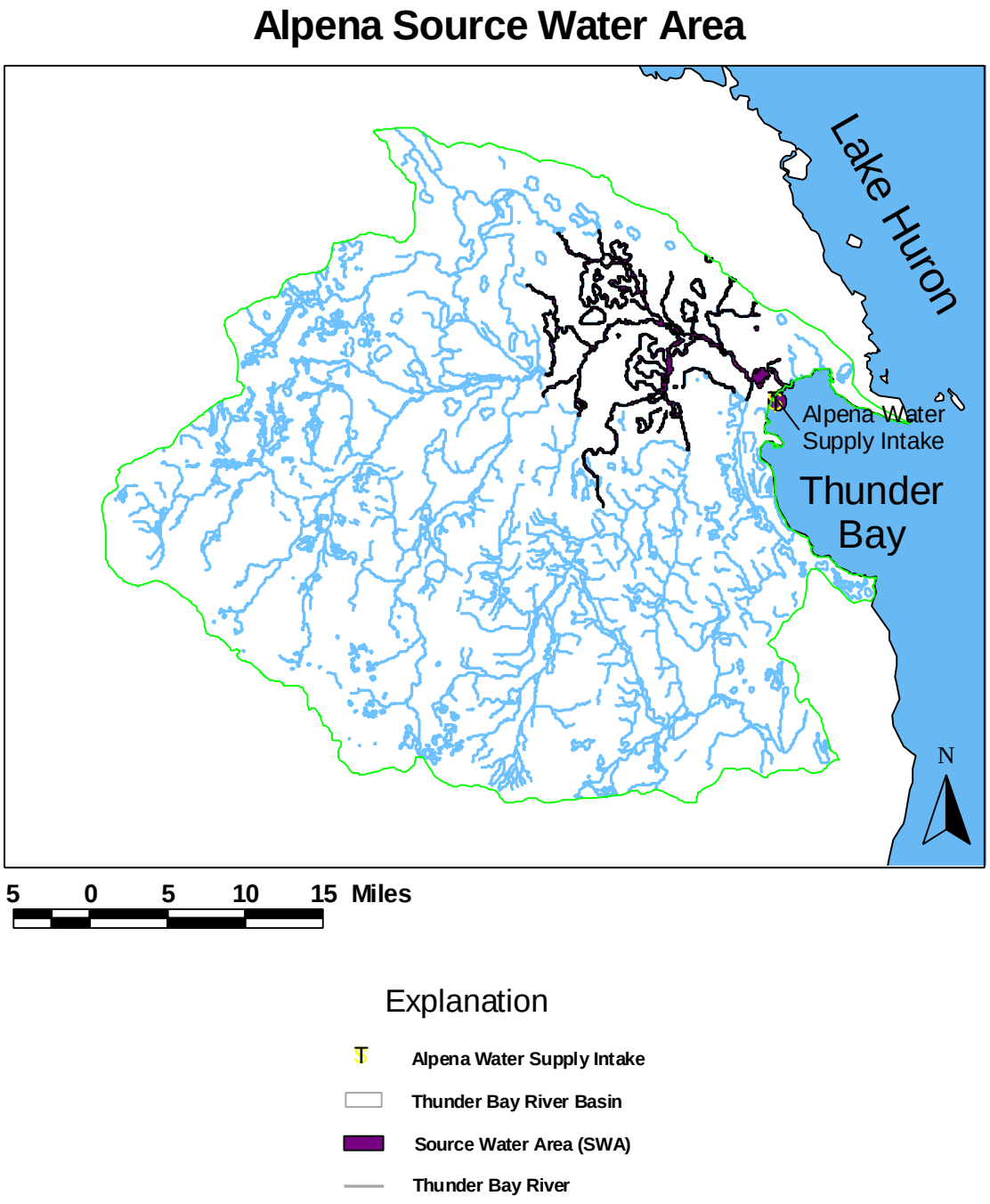

Figure 1. Example of GIS watershed delineation of source-water area for a surface-water intake.

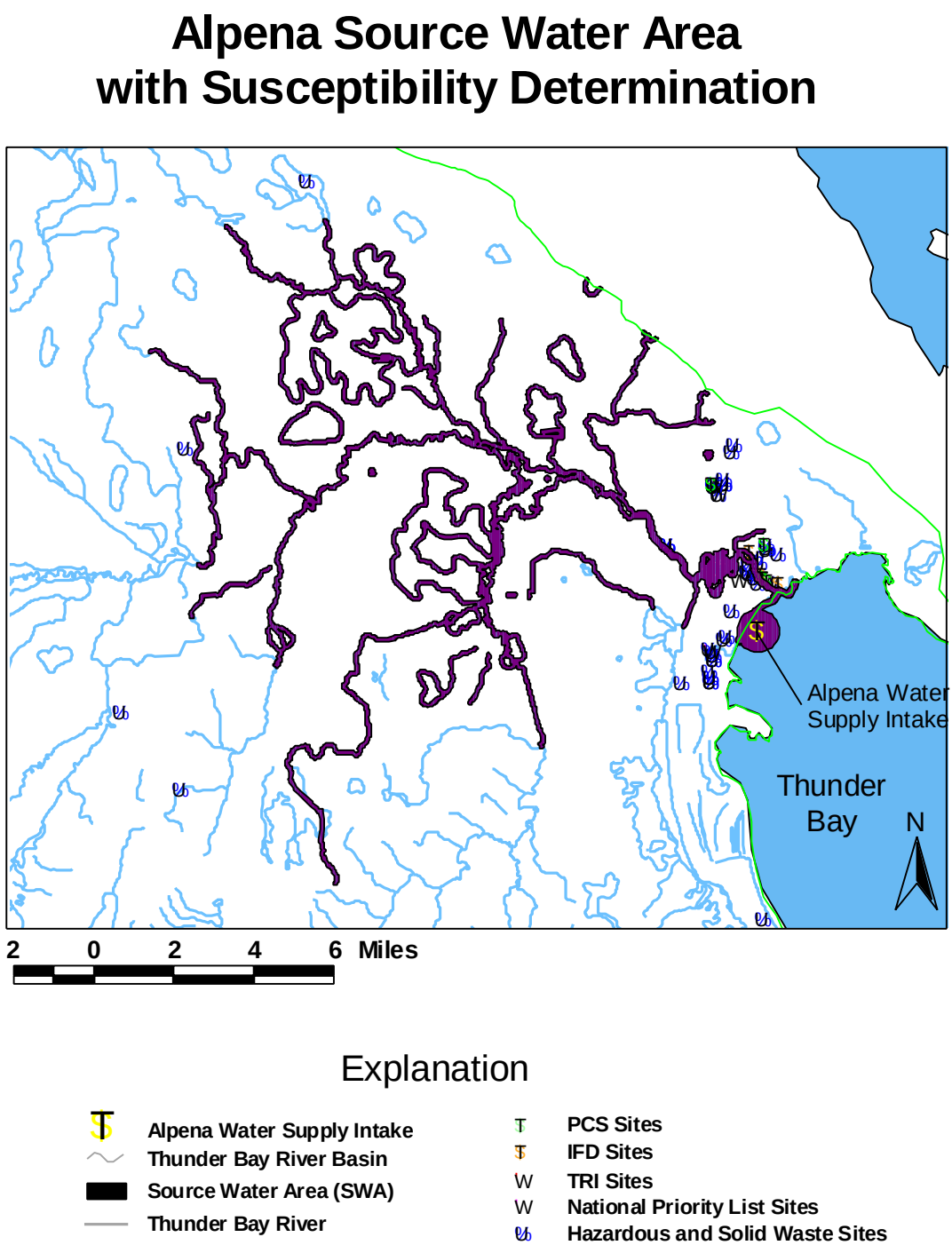

Figure 2. Example susceptibility determination map for Alpena, Michigan water supply.