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# THE MICHIGAN SOURCE-WATER ASSESSMENT PROGRAM: METHODS USED FOR THE ASSESSMENT OF SURFACE-WATER SUPPLIES

Water-Resources Investigations Report 03-4134

Prepared in cooperation with the
MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

U.S. Department of the Interior
U.S. Geological Survey

**Cover photo:** The Great Lakes area. Photo by SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE, April 24, 2000.

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*By* Michael J. Sweat, Richard S. Jodoin, Tiffiny A. Rossi, and Bradley B. Brogren

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**CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM**

| Multiply | By | To obtain |
|---|---|---|
| | **Length** | |
| inch (in) | 2.54 | centimeter (cm) |
| foot (ft) | .3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| | **Volume** | |
| cubic foot ($ft^3$) | .02832 | cubic meter ($m^3$) |
| | **Velocity** | |
| foot per second (ft/s) | .3048 | meters per second (m/s) |
| inches per hour (in/hr) | 2.54 | centimeters per hour (cm/hr) |
| | **Flow (volume per unit time)** | |
| cubic foot per second ($ft^3/s$) | .02832 | cubic meter per second ($m^3/s$) |

## Abbreviations

| | |
|---|---|
| BASINS | Better Assessment Science Integrating Point and Nonpoint Sources |
| CAZ | Critical assessment zone |
| DEM | Digital elevation model |
| DRG | Digital raster graphic |
| ESRI | Environmental Systems Research Institute, Inc. |
| GIS | Geographic information system |
| GPS | Global positioning system |
| IFD | Industrial facilities discharge database |
| MCL | Maximum-contaminant level |
| MDA | Michigan Department of Agriculture |
| MDEQ | Michigan Department of Environmental Quality |
| NPL | National priority list database |
| NPRI | National pollutant release inventory database |
| NOAA | National Oceanic and Atmospheric Administration |
| NRCS | National Resources Conservation Service |
| PAC | Public advisory committee |
| PCSD | Permit compliance system database |
| PCS | Potential contaminant-source |
| PWS | Public water supply |
| RCRIS | Resource Conservation Recovery Information System Sites |
| RF3 | River reach file version 3 |
| SDWA | Safe Drinking Water Act |
| SOC | Synthetic organic carbon compound |
| STATSGO | State soil and geographic database |
| SWA | Source-water area |
| SWAP | Source-water assessment program |
| TAC | Technical advisory committee |
| TOT | Time of travel |
| TRI | Toxic release inventory database |
| USEPA | U.S. Environmental Protection Agency |
| USGS | U.S. Geological Survey |
| VOC | Volatile organic compound |
| WTP | Water-treatment plant |

## Vertical Datum

In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

# The Michigan Source-Water Assessment Program: Methods Used for the Assessment of Surface-Water Supplies

*By* Michael J. Sweat, Richard S. Jodoin, Tiffiny A. Rossi, and Bradley B. Brogren

## ABSTRACT

The U.S. Geological Survey and the Michigan Department of Environmental Quality, in compliance with requirements of amendments to the Safe Drinking Water Act, developed methods to assess the 67 surface-water supplies located in Michigan. The source-water assessment program is designed to evaluate the susceptibility of surface-water supplies to potential contaminants. The program provides information to surface-water treatment facility personnel and community planners for developing protection initiatives to safeguard drinking- water sources and improve watershed management. Reports containing the source-water assessment results are presented to each surface-water treatment facility. The State of Michigan must then work with surface-water suppliers to inform the public of these results. Communities are encouraged by the U.S. Environmental Protection Agency (USEPA) to develop source-water protection plans, using information obtained from the assessments, to protect their drinking water from potential contaminant sources within their source-water area.

The source-water assessments involved gathering and compiling information from: oral and written information provided by surface-water treatment facility supervisors; sanitary surveys; consumer confidence reports; surface-water treatment facility historical reports; surface-water treatment facility monthly operator reports; surface-water intake construction blueprints; lake current studies; stream discharge magnitudes; county soil surveys; climatological reports; and geographic information system (GIS) data and processing results.

GIS data and software used in support of these assessments was available through Better Assessment Science Integrating Point and Nonpoint Sources software and data set, Version 2.0. This software was developed by the USEPA, and interfaces with ArcView GIS software, Version 3.3, developed by Environmental Systems Research Institute. GIS-based methods facilitated the assessment process, which began with source-water area delineation for each surface-water-supplied system. A source-water area boundary was delineated based upon the location of each primary surface-water supply intake and by using elevation data, surface-water data, and hydrologic unit code boundary data to determine the contributing area for surface-water drainage up current of the intake. The source-water area boundary was used to limit the extent of the area to be assessed. The remainder of the assessment process included: performing a water-intake sensitivity analysis; defining the critical assessment zone around the water-intake; identifying potential contaminant sources within the source-water area; determining susceptible areas within the source-water area; compiling an inventory of potential contaminant sources located within the critical assessment zones and susceptible areas; calculating soil permeabilities; and conducting an intake susceptibility determination.

All reports included illustrations showing the extent of the source-water area, the area adjacent to the water intake and critical assessment zone, and potential contaminant source locations in relation to soil permeability and land use. All reports also included an inventory of potential contaminant sources with the critical assessment zone and susceptible area, results of the susceptibility determination, and a narrative of procedures used for conducting the assessment. The source-water assessment results serve as a guide for

the development of community-driven source-water protection strategies.

## INTRODUCTION

Section 1453a of Public Law 104-182, reauthorization of the Safe Drinking Water Act (SDWA) of 1996, required Federal guidance and defined State requirements for the development and implementation of a ***source-water assessment program*** (SWAP). The U.S. Environmental Protection Agency (USEPA) published the State Source-Water Assessment and Protection Programs Guidance in August 1997 to assist States in developing an acceptable SWAP. The program's three primary functions are to: (a) delineate the boundaries of areas that supply water to public supplies, (b) identify potential sources of regulated and unregulated contaminants in the area, and (c) determine the susceptibility of surface-water supplies to those contaminants. Assessment results are to be presented to each surface-water treatment facility. Surface-water treatment facilities then work in cooperation with the State to inform the public of these results, while encouraging the communities to assist in developing source-water protection plans for their drinking water.

The Michigan Department of Environmental Quality (MDEQ) and the U.S. Geological Survey (USGS) are implementing the SWAP in Michigan by assessing the 67 community surface-water supplies within the State (fig. 1, table 1). These surface-water supplies provide drinking water to over 55 percent of the State's population, or about 5.5 million people. Three pilot assessments were completed for each of the three surface-water ***intake*** types (table 2). Surface-water intake types include Great Lakes, Great Lakes connecting channels, and inland river and (or) inland lakes. Experience gained from the nine pilot assessments assisted MDEQ and USGS in refining the methods used to assess the remaining 58 supplies. A Technical Advisory Committee (TAC) and a Public Advisory Committee (PAC) aided in guiding and reviewing the process.

The source-water assessment process involved using ***geographic information system*** (GIS)-based analyses to illustrate relations among potential contaminants in the ***source-water area*** (SWA) to the water intake, surface-water features, land use, soil permeability, and other environmental, political, and geographical features. The first step in this process was to delineate the SWA boundary for each surface-water supplied system to limit the extent of the area to be assessed. The remainder of the assessment process included: performing a water-intake ***sensitivity*** analysis; defining the ***critical assessment zone*** (CAZ) around the water-intake; identifying ***potential contaminant sources*** (PCS) within the SWA; determining ***susceptible areas*** within the SWA; compiling an inventory of PCS located within the CAZ and susceptible areas; calculating soil permeabilities; and conducting an intake susceptibility determination. The completed assessments include a map of the SWA; a map of the CAZ and adjacent area; maps showing PCS in relation to land use and soil permeability; a table of PCS, by permit type, located within the CAZ and susceptible areas; results of susceptibility determination; and a narrative of procedures followed for conducting the assessment.

Inland lake and river intake assessments (eight supplies in Michigan) are watershed based. The assessment process for these source-waters includes reviewing water-quality monitoring records and identifying PCS. Great Lakes and Great Lakes connecting channels intake assessments (59 supplies) follow the "Assessment Protocol for Great Lakes Sources" http://www.michigan.gov/documents/DEQ-swap99_4707_.pdf, Appendix L developed by Great Lakes States in USEPA Region 5.

Assessments of water intakes that use Great Lakes connecting channels as their source (14 supplies) are planned to be included in a two-dimensional hydrodynamic flow model of the St. Clair River–Lake St. Clair–Detroit River waterway. The flow model is planned to define the SWA, track contaminant source-water-quality concerns, and assist in developing contingency plans. A partnership established among the USGS, MDEQ, USEPA, U.S. Army Corps of Engineers, and the Detroit Water and Sewerage Department, with assistance from Environment Canada, will complete this model. The American Water Works Association Research Foundation is supporting the partnership to enhance the contaminant-tracking model capabilities.

Terms in ***bold italicized text*** are defined in the glossary.


**Figure 1.** Location of public water supplies in Michigan using surface water as their source of supply.

**Table 1.** Water supplies in Michigan using surface water as their source, by supply type

| Supply type | Supply source | Number of supplies using this source |
|---|---|---|
| Inland River | Chippewa River | 1 |
| | Flint River | 1 |
| | Huron River | 1 |
| | Indian River | 1 |
| | Pine River | 1 |
| | River Raisin | [1]3 |
| Great Lakes Connecting Channel | St. Mary River | 1 |
| | St. Clair River | [1]7 |
| | Lake St. Clair | 4 |
| | Detroit River | [1]3 |
| Great Lake | Lake Michigan | [1]20 |
| | Lake Superior | [1]10 |
| | Lake Huron | [1]13 |
| | Lake Erie | 1 |

[1] One or more supplies using this source of water were assessed as part of the pilot assessment process.

**Table 2.** Water supplies in Michigan participating in pilot assessments

| Supply type | Supply source | Community water-supply assessed |
|---|---|---|
| Inland River | River Raisin | Adrian |
| | | Blissfield |
| | | Deerfield |
| Great Lakes Connecting Channel | St. Clair River | Marine City |
| | Lake St. Clair | Mt. Clemens |
| | Detroit River | Detroit – Belle Isle |
| Great Lakes | Lake Michigan | St. Joseph |
| | Lake Superior | L'Anse |
| | Lake Huron | Alpena |

Once all assessments are completed and approved, MDEQ will: (a) provide technical assistance to communities for source-water protection, (b) initiate community outreach programs, and (c) use a GIS framework to display the results of the assessments (Brogren, 1999).

### Purpose and Scope

The purpose of this report is to document methods developed and used for the Michigan source-water assessment program. The scope of the study includes methods used to assess public water supplies that use surface water as their source of supply. The report does not provide details or assessment results, as these are found in the reports completed for each surface-water supply. The geographic area included covers the State of Michigan, parts of four Great Lakes, parts of six inland rivers, and watersheds upstream, upcurrent, and (or) onshore from intakes of all public water supplies that use surface-water as their drinking-water source.


### Acknowledgments

MDEQ field offices, engineers, and resource analysts are thanked for their cooperation and assistance with this project. The authors also would like to thank each surface-water supply supervisor and their staff for providing data used in each assessment.


## STUDY AREA

The study area encompasses the State of Michigan, including parts of watersheds of the Chippewa, Detroit, Flint, Huron, Indian, Pine, Raisin, St. Clair, St. Joseph, and St. Marys Rivers; and parts of the Lakes Erie, Huron, Michigan, St. Clair, and Superior watersheds (fig. 1).

## GENERAL ASSESSMENT METHODS

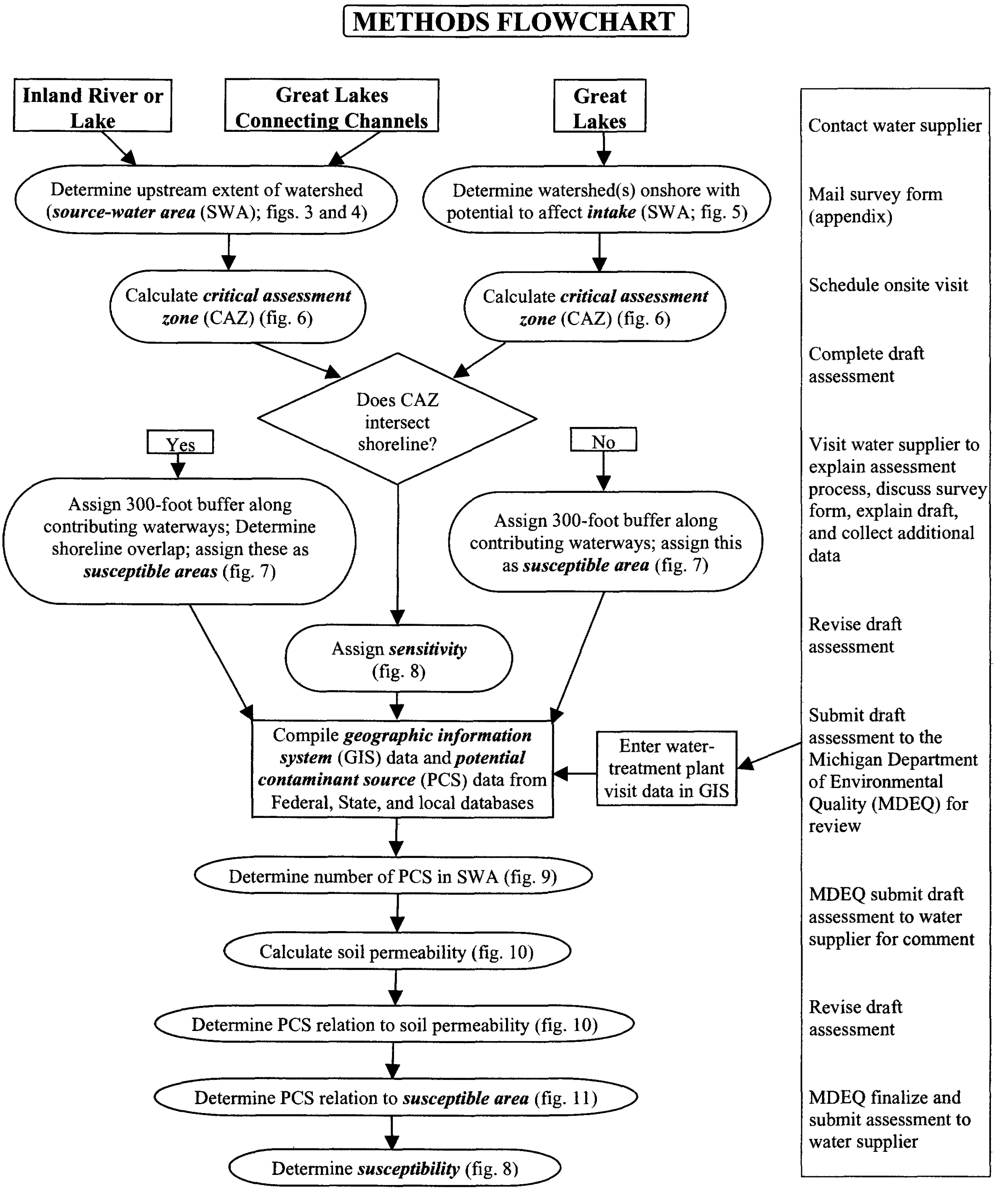
Assessment methods evolved as the concept was developed, and different approaches were used for different surface-water supply types (fig. 2). Each assessment included an initial contact with the surface-water treatment facility supervisor or operator, by either phone or mail. A SWAP inventory form (Brogren, 1999; http://www.michigan.gov/documents/DEQ-swap99_4707_.pdf, p. 105-106, December 2002; appendix) was sent to the each surface-water treatment facility with a request that it be completed before MDEQ and USGS personnel visited. A meeting was scheduled with each surface-water treatment facility supervisor at which the inventory was discussed and a rough-draft assessment, including text and site-specific illustrations, was presented and explained. Surface-water treatment and intake facilities were toured and intake locations verified and documented.

Data were entered into a GIS database using USEPA's Better Assessment Science Integrating point and Nonpoint Sources (BASINS) program (U.S. Environmental Protection Agency, 1997a; 1997b; 1998) upon completion of the meeting. Data were analyzed for correlation of water-quality parameters with atmospheric conditions, lake currents, discharge magnitudes, and other variables as appropriate. Additional data were requested from the surface-water facility as needed, and previous studies, where available, were incorporated into the assessment. A preliminary draft assessment was completed about 3-6 months after each plant visit, and sent to MDEQ for review.

Draft assessments were modified, as needed, and forwarded by MDEQ to the respective surface-water supply supervisor, city or governmental authority, and MDEQ field offices, for a 60-day review and comment period. Comments were reviewed by MDEQ and USGS at the end of the comment period, and incorporated into the assessment, as appropriate. The term "final draft" was added to the assessment title, and the completed final draft assessment was distributed to the surface-water supply. Final-draft assessments are considered complete, pending final approval by the TAC and PAC, at the conclusion of the SWAP in May 2003.

## ASSESSMENTS BY TYPE OF SURFACE WATER SOURCE

All source-water assessments followed the same general protocols for determining sensitivity, defining a CAZ, calculating soil permeability, inventorying PCS, and source-water intake susceptibility determinations. There were subtle differences, however, among intake types regarding the SWA and susceptible area delineations.




[1] Steps box on right are conducted concurrently with steps to the left of box.
[2] Terms in bold italicized text are defined in the glossary.

**Figure 2.** Diagram of methods followed in completing a source-water assessment in Michigan.

### Inland Rivers

Inland river assessments were less complicated than others considered, with the least amount of variation in methods among surface-water supplies. In general, the watershed upstream of the intake defined the SWA, although this likely overestimated the susceptible area if time of travel (TOT) was considered. TOT criteria, establishing for how far upriver a SWA should extend, was determined to be 24 hours (Elgar Brown, Michigan Department of Environmental Quality, oral commun., 2000). For example, on the Pine River (Alma, MI, SWA) a USGS streamflow-gaging station is located downstream of the intake. Based on 72 years of record, the average discharge velocity at this station was 1.24 feet per second (ft/s) indicating an average 24-hour TOT of 20.3 miles (mi). The distance from the intake to the headwaters is 67.2 mi, more than three times the indicated 24-hour TOT.

A similar analysis was made of the Mt. Pleasant SWA on the Chippewa River, using a USGS gaging station about 5 mi downstream of the intake. Based on 70 years of record, the average discharge velocity at this station was 1.81 ft/s, indicating an average 24-hour TOT of 29.6 mi. The distance from the intake to the headwaters of the Chippewa River is 54.2 mi, about twice the indicated 24-hour TOT.

Rivers with multiple surface-water supplies (intakes) at various locations resulted in the upstream extent of one SWA coinciding with the downstream extent of the next SWA located upstream. Surface-water suppliers then could concentrate management efforts on their own smaller areas, and encouraged surface-water suppliers to maintain communication with adjacent surface-water supplies. This communication provided opportunities to share information regarding changes in source-water characteristics with other surface-water suppliers located downstream.

The generally shallow and narrow nature of inland rivers resulted in all intakes for these sources being defined as highly sensitive, with their CAZ defined as a 3,000 feet (ft) radius oriented upstream of the intake. The susceptible area included all shoreline upstream of the intake within the SWA. The PCS inventory included the SWA for the intake of interest, and by reference, any upstream SWAs. By definition, the intake was either very highly susceptible (PCS were located in the susceptible area) or highly susceptible (no PCS were located in the susceptible area) to contamination.

### Great Lakes Connecting Channels

Great Lakes connecting channel intakes are similar to inland rivers in that the SWA is readily identified as a part of the watershed upstream of the intake. These intakes, however, usually are located farther from shore than inland river intakes, in deeper water, and tend to have greater flow volumes and velocities, making these intakes generally less sensitive than inland river intakes.

The contaminant source inventory for these intakes is more involved and complex than the inventory for inland rivers. Flow and mixing characteristics in the connecting channels can result in preferred flow paths along which contaminants may reach an intake. Simply identifying the watershed upstream of the intake may include PCS that are not likely to contribute to the intake. This method also might preclude PCS with a high likelihood of contributing to the intake. All connecting channels assessments will be re-evaluated upon completion of a two-dimensional hydrodynamic model and particle tracker for the St. Clair-Lake St. Clair-Detroit River waterway (Holtschlag and Koschik, 2001).

Water depth, distance from shore, and flow volumes all contributed to connecting channels intakes generally being highly to moderately sensitive, and highly to moderately susceptible. TOT estimates for St Clair and Detroit Rivers were based on generalized velocities of 2 to 4 ft/s (David Holtschlag, U.S. Geological Survey, oral commun., 2002). The St. Clair River is about 29 mi from its head at the outlet of Lake Huron to its mouth at the distributary delta to Lake St. Clair, and TOT ranged from 14 to 28 hours. The shipping channel in Lake St. Clair is about 35 mi from the distributary delta of the St. Clair River to the head of the Detroit River, with TOT ranging from 13 to 26 hours. The Detroit River is about 32 mi from its head at the outlet of Lake St. Clair to its outlet to Lake Erie, and TOT ranged from 12 to 23 hours. These values were generalized TOT, and actual values may be faster or slower, depending on actual velocities. It is likely that these values underestimated the TOT in

Lake St. Clair, as velocities through this reach were appreciably slower than in the rivers. Average water exchange in Lake St. Clair varies from hours in the shipping channel to days in some bays.

#### Great Lakes

Great Lakes intakes were categorized in one of four ways: near shore, shallow-water intakes; near shore, deep-water intakes; offshore, shallow-water intakes; and offshore, deep-water intakes. Each intake had unique characteristics that affected the assessment. Hydraulic and hydrologic conditions differed for each lake and each intake, making it difficult to apply uniform assessment methods to these intakes. Methods described in the Great Lakes Protocol (Brogren, 1999) and this report worked well in assessing these types of intakes, with some modifications, described below.

### Near shore, shallow-water intakes

Near shore, shallow-water intakes are those that, generally, are less than 1,000 ft from shore and in less than 20 ft of water. These intakes are most likely to be categorized as highly sensitive and highly susceptible. Lake currents and passing boat traffic can disturb bottom sediments, causing high turbidity. Storms and changes in wind patterns can disrupt the flow of water over these intakes, causing rapid changes in water quality, which in turn create treatment difficulties for operators (Jerry Plume, Alpena Water Treatment Plant, oral commun., 1999). Overland runoff and shoreline discharges are more likely to affect these intakes because of their limited isolation from land, and smaller water volumes available for dilution. Recreational boaters, fishers, and divers often are aware of the location of these intakes and they are favored anchoring locations because of their relative ease of access.

These shallow-water intakes often are located in bays or other sheltered areas, which isolates them from large-lake currents. This isolation limits the amount of water exchange near the intake, which in turn affects water quality. Water temperatures rise more rapidly in shallow water during warm periods, and rise higher than in deeper water. Water temperatures also fall more rapidly during cold periods than they might in deeper water, and the formation of ***frazil ice*** can become a problem. The emergency intake at Alpena, Michigan is an example of this type of intake. The emergency intake is located approximately 1,000 ft from shore in about 5 ft of water. The emergency intake is used in the winter to mitigate the effects of frazil ice formation. This assessment was based on the intake nearest to the shore.

### Near shore, deep-water intakes

Near shore, deep-water intakes are those that, generally, are less than 1,000 ft from shore, and in more than 20 ft of water. These intakes are most often categorized as highly sensitive, though if deep enough they might be only moderately sensitive. They are under hydrologic conditions similar to those of near shore, shallow-water intakes, except that they are less likely to be under the full range of conditions of shallower intakes. Overland runoff and shoreline discharges are the most prevalent issues, followed by atmospheric changes and recreational water uses. An example of this type of intake is L'Anse, Michigan, where the primary intake is almost 1,000 ft from shore in about 50 ft of water.

#### Offshore, shallow-water intakes

Offshore, shallow-water intakes are those that, generally, are greater than 1,000 ft from shore, and in less than 20 ft of water. These intakes are most often categorized as highly sensitive, though if far enough from shore, they might be only moderately sensitive. These intakes are not as susceptible to overland runoff and shoreline discharges because of their distance from shore. Their location, however, can result in higher susceptibility to discharge from inland rivers. Discharge from inland rivers generally enter a lake and is incorporated in the prevailing lake current. These currents occasionally carry river water over an intake prior to dilution and absorption of a contaminant into lake water. This action causes change in turbidity, temperature, general chemistry, and biologic conditions of the source-water, especially during times of high overland runoff and discharge from inland rivers.

These intakes also potentially are susceptible to disturbances in water quality caused by recreational boating and commercial ship traffic. A ship with sufficient draft could strike the intake directly, disturb lake-bottom sediments that could affect influent water quality, or disturb water flow near the intake, perhaps through ballast exchange or prop wash. The primary intake at Alpena, Michigan is a good example. This intake is approximately 2,000 ft from shore in about 10 ft of water, and source-water chemistry indicates effects from the Thunder Bay River (fig. 5) under certain atmospheric conditions (Sweat and others, 2000b).

### Offshore, deep-water intakes

Offshore, deep-water intakes are those that, generally, are greater than 1,000 ft from shore, and in more than 20 ft of water. These intakes usually are categorized as moderately sensitive. Because of their distance from shore, they are isolated from overland runoff and shoreline discharges. They generally are located such that lake currents and lake volume provide the potential for large volumes of dilution in the event of a spill or contaminant event, and of inland river discharge. Atmospheric conditions are less likely to affect water quality at these depths and distances from shore. The greatest potential for change to water quality is from occasional shifts or changes in currents. Thermal mixing can result, requiring the water treatment plant (WTP) to compensate by adjusting treatment methods.

Offshore, deep-water intakes are less susceptible to disturbances in water quality caused by recreational boating and commercial ship traffic, although commercial ship traffic does pose some threat to these intakes in the form of ballast water exchange, illegal dumping, accidental discharge, and collision. The Saginaw Midland Municipal Water Supply Corporation, Michigan is an example of this intake type. This primary intake is more than 6,000 ft from shore in about 35 ft of water.

### Buried collectors

Buried collectors or infiltration beds terminate in a lake or river bottom, using lateral collectors beneath gravel and sand to prefilter the water. Laterals generally are located between 10 and 100 ft below the land surface or lake bottom. Sensitivity is not affected by this intake type, but susceptibility results because of the inherent filtering capacity of this collector type. Surface-water intakes located in Mt. Pleasant, Bridgman, Grand Haven, Lexington, Harbor Beach, and Caseville, Michigan are examples of surface-water supplies using buried collectors.

## CONTENT OF SOURCE-WATER ASSESSMENTS

The SDWA Amendments require that completed source-water assessments be made available to each public water supply (PWS), as well as by each PWS to their customers after assessments are completed. PWS are provided with copies of the assessment for their supply after MDEQ and USGS complete the assessment. Assessments, titled "Source-Water Assessment Report" for each public water supply, contained the following:

1. Map of the SWA
2. Results of sensitivity determination shown on a map (CAZ)
3. Tables of PCS by type and location
4. Locations of PCS shown on soil permeability and land use maps
5. Results of susceptibility determination shown on soil permeability and land use maps
6. Narrative of procedures for conducting the assessment.

### General geographic information system–based methods

USGS developed GIS-based methods to assist in the source-water assessment process. The software used to perform these GIS-based methods primarily was ArcView GIS 3.3 (Environmental Systems Research Institute, Inc. (ESRI), 1992-2002), with some additional processing in ArcInfo Workstation 8.2 (Environmental Systems Research Institute, Inc. (ESRI), 1982-2002). This GIS software was chosen because of the capacity to integrate the BASINS program with the ArcView 3.3 framework. BASINS, version 2.0, is a multipurpose environmental analysis system that operates on a watershed-based context

(U.S. Environmental Protection Agency, 1997a; 1997b; 1998).

The BASINS system is instrumental in the source-water assessment process. Beneficial features of BASINS include a `Watershed Delineation` tool and the ability to generate soil permeability maps and soil permeability reports using the `State Soil Characteristics Report` tool.

The BASINS system also supplies digital data from local, State, and nationally derived databases in the ArcView shapefile format. The BASINS data layers used in the source-water assessment process included: drinking-water supply sites; hydrologic unit boundaries; land use and land cover; State Soil and Geographic (STATSGO) database; river reach files (RF3) - version 3 alpha; Resource Conservation and Recovery Information System (RCRIS) sites; Industrial Facilities Discharge (IFD) sites; Permit Compliance System Database (PCSD) sites and Computed Loadings; Superfund National Priority List (NPL) sites; Toxic Release Inventory (TRI) sites; digital elevation models (DEM); State and County boundaries; and urbanized areas.

The BASINS data were available in various scales, and the metadata is available through the BASINS Web site at http://www.epa.gov/waterscience/BASINS/metadata.htm (accessed 10/09/02). Additional data used in the assessment process included National Pollutant Release Inventory (NPRI) for Canadian contaminant sources upstream of Great Lakes connecting channel intakes (Environment Canada, 2001), 1:24,000 USGS ***digital raster graphics*** (DRG), and georeferenced LandSat Thematic Mapper imagery (30-meter resolution) for surface feature verification.

The preferred projection for this area of study was Michigan GeoRef, because of the minimal distortion across the entire State of Michigan. Thus, all digital data used in the GIS were converted from original projections into Michigan GeoRef using the `Project` command in ArcInfo Workstation 8.2. Parameters for this projection can be accessed at http://www.michigan.gov/documents/DNR_Map_Proj_and_MI_Georef_Info_20889_7.pdf (accessed 10/09/02). A projection suited to the specific area of study should be chosen prior to adopting these methods.

**Delineation of watershed upstream or up current of intake**

The source-water assessment process began by locating the water-supply intake to be studied in the assessment. Water-supply intake locations were determined from the public water-supply-intake database provided in the BASINS software package. Latitude and longitude locations in this database were compared to the State drinking-water-intake database supplied by MDEQ. Both databases were found to have inaccurate locations in some cases. All latitude and longitude locations were provided to the water-supply operator for verification, and where needed, corrected. During site visits by MDEQ and USGS personnel, surface-water intake locations for the public surface-water supplies were field checked by using a ***global positioning system*** (GPS) receiver.

Surface-water intake locations were verified using as-built specifications, blueprints, sanitary surveys, water-plant operator descriptions, and (or) estimates on the USGS DRG using the ArcView `Measure` tool. Latitude and longitude coordinates were determined from the DRG with the offshore distance and angle provided by water-plant blueprints or the water-plant operator. Accurately mapped intake locations were required to assess which watershed(s) to include in the delineation of the respective SWA.

The SWA delineation process was based on available watershed boundary data. The extent of the SWA was determined by identifying the watershed, or portion thereof, that discharges toward a known surface-water intake (Lanier and Falls, 1999). The SWA delineation process is facilitated in BASINS using the `Watershed Delineation` tool. Accurate SWA delineation required the available digital watershed boundaries, surface-water intake locations, DEMs (variable scale), and river-reach data (U.S. Environmental Protection Agency, 1997a, 1997b, 1998). Intake location data were incorporated into the GIS framework to determine the downstream limit of each source-water area.

In cases where the SWA was so large that adjacent watersheds would overlap, the watersheds were subdivided using elevation, TOT, and distance from the intake to delineate contiguous areas unique to the up current area of each intake. Different watersheds, or portions of watersheds, that qualified collectively as drainage areas directly affecting the intake, were combined into one SWA using the ArcView `Dissolve`

Terms in `courier text` identify specific software commands or tools.

tool. This combination resulted in a SWA unique to the intake, preserving the attributes necessary for BASINS to recognize the data as a watershed, and enabling the SWA to function with other modules within BASINS.

Refinements to SWA delineation can stem from water-plant supervisors who are able to indicate specific effects on their intake, such as increased turbidity or increased alkalinity, caused by wave action or changes in lake currents. Great Lakes intakes, where water may be diverted from one watershed to another, involve the delineation of source-water areas to include all applicable watersheds that potentially contribute water to the intake.

A two-dimensional, hydrodynamic flow model of the St. Clair River—Lake St. Clair—Detroit River waterway is planned to define source-water areas for the Great Lakes connecting channels surface-water supplies (Holtschlag and Koschik, 2001). Model-simulation results will allow for determination of contributing areas from watersheds tributary to the Great Lakes connecting channels. The model is being developed through a partnership among MDEQ, USGS, USEPA, U.S. Army Corps of Engineers, and Detroit Water and Sewerage Department, with assistance from Environment Canada (Holtschlag and Brogren, 2000). A particle-tracking routine will be used in model-simulation to aid in determining travel mechanisms and origins of potential contaminants (American Water Works Association Research Foundation, 2001), and is expected to be available in September 2003. SWAs and assessments for Great Lakes connecting channel intakes will be redefined at that time.

An example of SWA delineation for inland river intakes depicting the SWA for the Adrian, Michigan intake in Lake Adrian on Wolf Creek is shown in figure 3. An example of SWA delineation for Great Lakes connecting channel intakes depicting the SWA for the Detroit—Belle Isle intake in the Detroit River is shown in figure 4. An example of SWA delineation for Great Lakes intakes depicting the SWA for the Alpena intake in Thunder Bay on Lake Huron is shown in figure 5. SWAs are shown for each source-water type to illustrate the differences among assessment protocols.

**Determination of sensitivity and critical assessment zone**

Sensitivity to contaminants is a measure of the protection afforded to the SWA by its environment (Brogren, 1999). Sensitivity was determined for each water supply by multiplying the distance the intake lies offshore by the depth of the intake underwater (Brogren, 1999). Larger values indicate intakes that are farther offshore, in deeper water, or both. Thus, the larger the result of this calculation, the less sensitive an intake is to its environment. Sensitivity values were used to determine the area around the intake, called the critical assessment zone (CAZ), which received the most focus during the assessment. This area is defined in the Assessment Protocol for Great Lakes Sources (Brogren, 1999, appendix L, p. 99-103), and was delineated for each intake (fig. 6).

The CAZ for Great Lakes intakes is determined by the distance of the intake from shore (L) in feet, and the water depth of the intake structure (D) in feet. Multiplying L and D yields a sensitivity value (Brogren, 1999, p. 100) that determines the CAZ radius (fig. 6), resulting in a 1,000, 2,000, or 3,000-ft radius around the intake. For example, a Great Lake intake with an offshore distance of 200 ft, and a water depth of 40 ft, has a sensitivity value of 8,000 (unitless), and a CAZ radius of 3,000 ft (Brogren, 1999, p. 100; fig. 6).

Great Lakes intakes were considered less vulnerable to contamination than inland river intakes and (or) inland lake intakes (fig. 7) given that the Great Lakes contain large volumes of water relative to inland rivers and lakes, and that Great Lakes intakes generally are located farther away from land effects.

The same method was used to determine the CAZ for Great Lakes connecting channels intakes. Connecting channel CAZs will be modified using the results of the hydrodynamic flow model planned by USGS (Holtschlag and Koschik, 2001).

The CAZ determination for both the Great Lakes and Great Lakes connecting channels intakes was facilitated using GIS. Because offshore distance and depth of water-supply intake(s) were vital to the delineation of the CAZ, these parameters were estimated when incomplete or inaccurate data were in the databases. Overlaying USGS DRGs with the water supply intake data facilitated this determination.

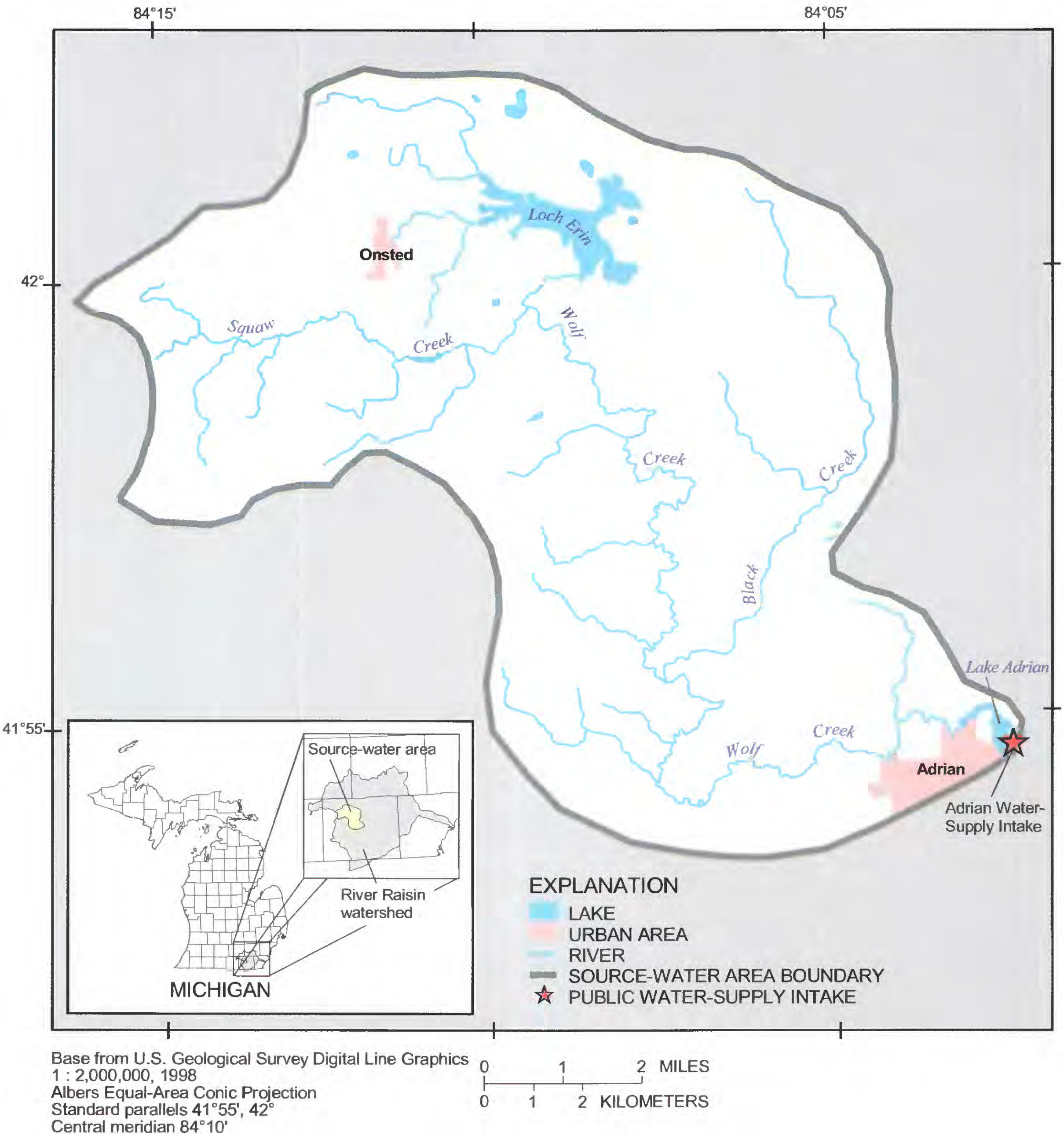



**Figure 3.** Source-water area for the Adrian, Michigan water-supply intake (inland river source).

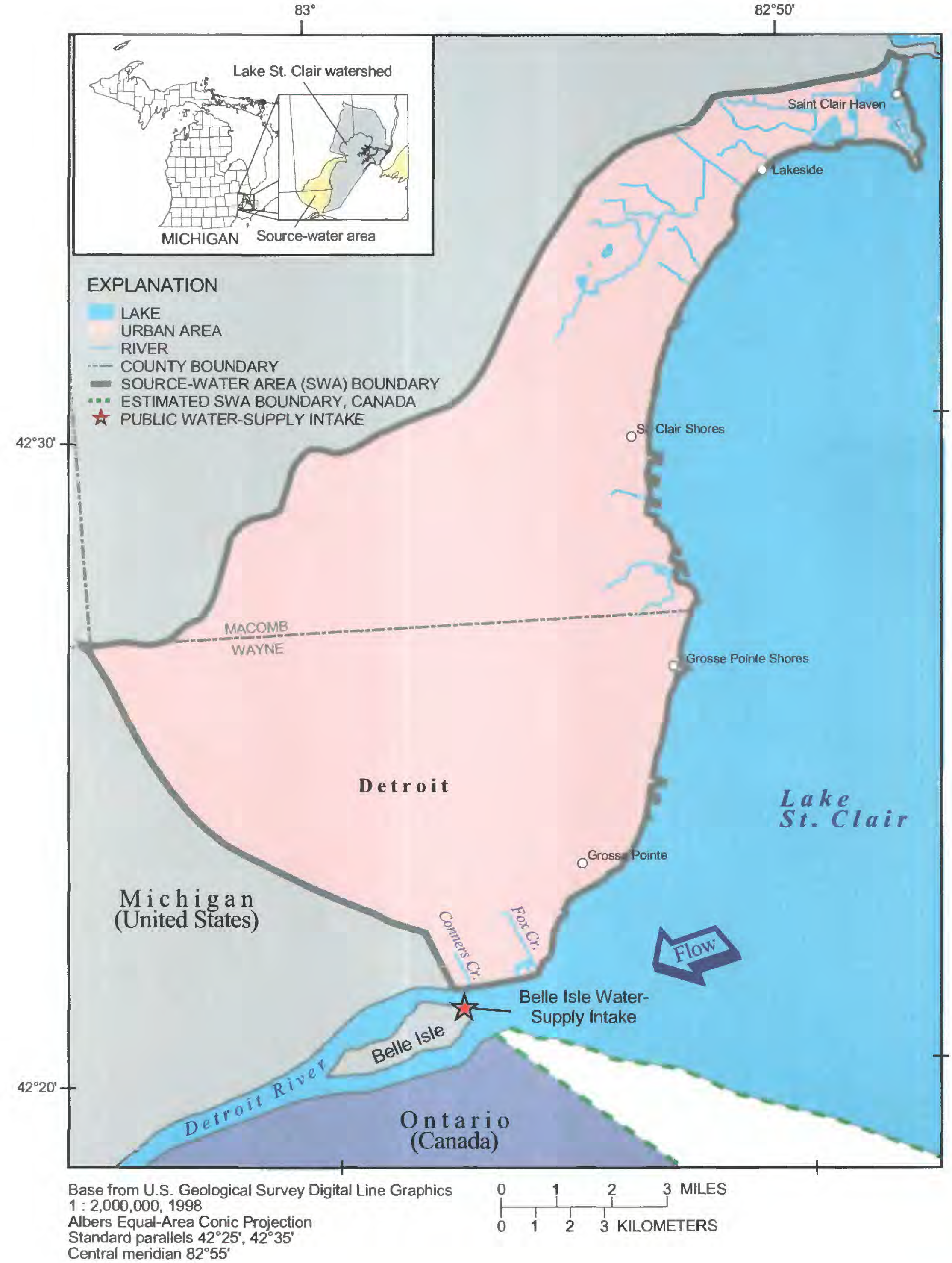



**Figure 4.** Source-water area for the Detroit-Belle Isle, Michigan water-supply intake (Great Lakes connecting channel source).

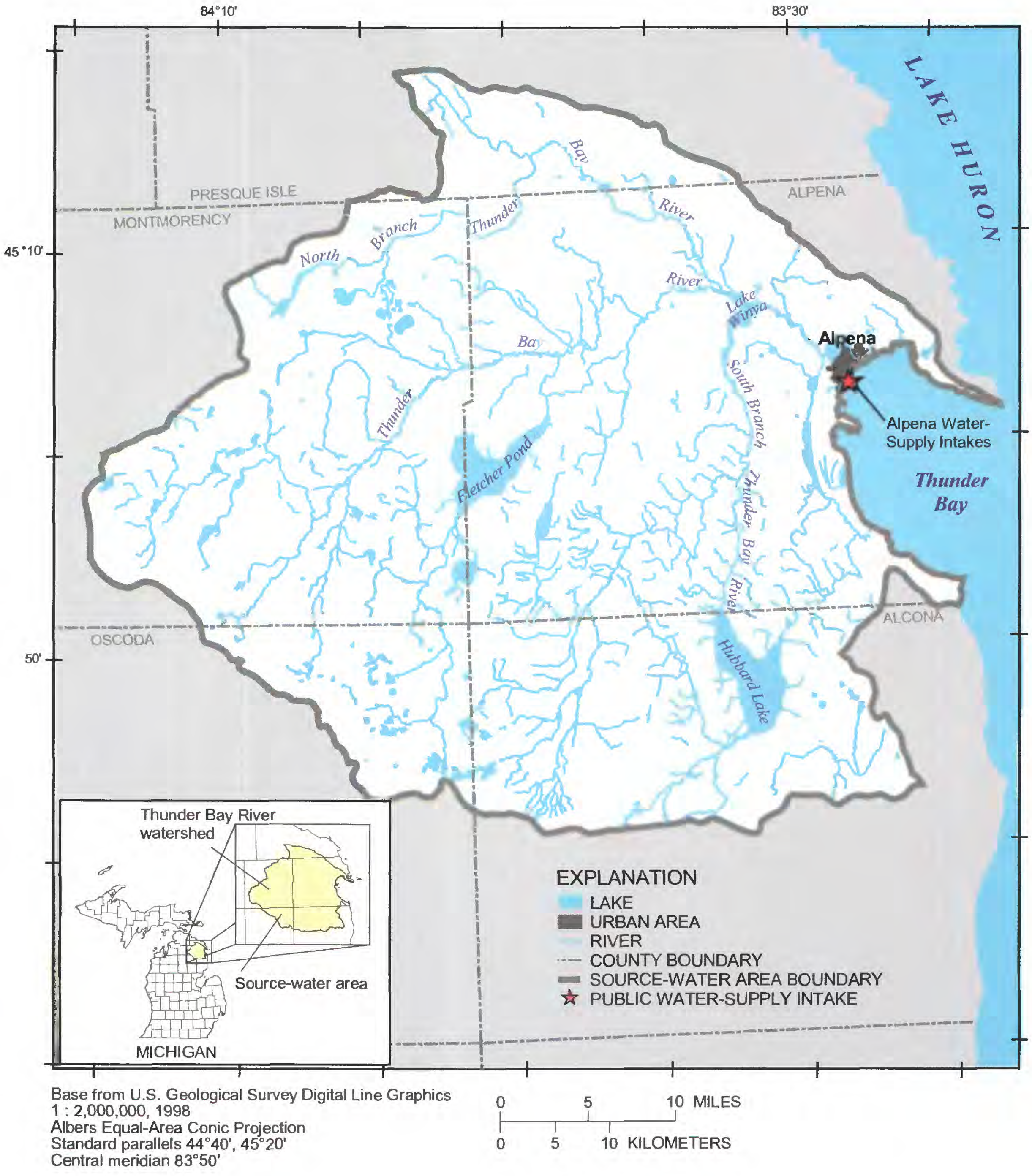



**Figure 5.** Source-water area for the Alpena, Michigan water-supply intake (Great Lakes source).

| Sensitivity Value (Length (L) X Depth (D)) | Critical Assessment Zone (CAZ) | Shoreline Distance (SL) | Distance Inland (DI) |
|---|---|---|---|
| < 25,000 | 3,000-foot radius (R) | $SL=\sqrt{(3{,}000^2 - L^2)}$<br>*if L > 3,000; SL=0;* | DI=3,000-L<br>*DI=0* |
| 25,000-125,000 | 2,000-foot radius (R) | $SL=\sqrt{(2{,}000^2 - L^2)}$<br>*if L > 2,000; SL=0;* | DI=2,000-L<br>*DI=0* |
| > 125,000 | 1,000-foot radius (R) | $SL=\sqrt{(1{,}000^2 - L^2)}$<br>*if L > 1,000; SL=0;* | DI=1,000-L<br>*DI=0* |

**EXPLANATION**

- L DISTANCE OF INTAKE FROM SHORELINE IN FEET
- D DEPTH OF INTAKE IN FEET
- R RADIUS OF CRITICAL ASSESSMENT ZONE

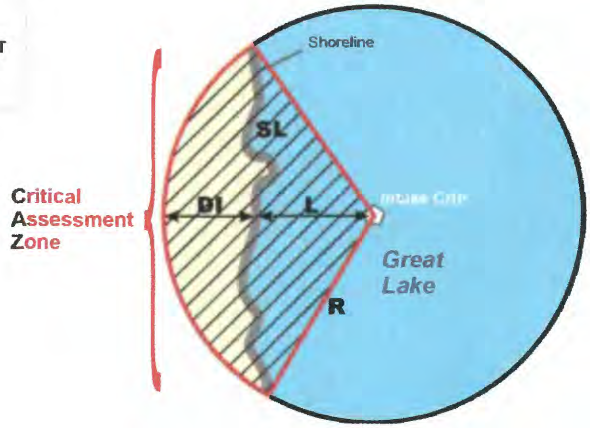
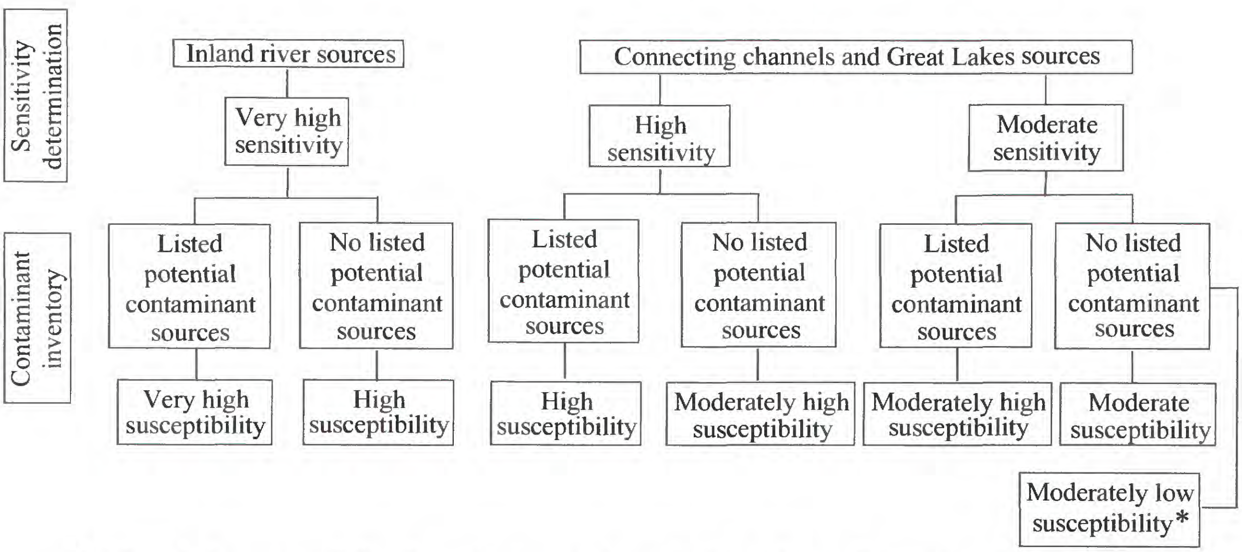



**Figure 6.** Critical-assessment zone determination for the Michigan source-water assessment program (modified from Brogrem, 1999).




*Moderately low susceptibility determination is only applicable to deep, offshore Great Lake intakes, free from littoral zone interferences, with excellent raw water quality histories, and where current flows and lake volume provide the potential for large volumes of dilution in the event of a spill or contamination event.

**Figure 7.** Surface-water source sensitivity determination and susceptibility analysis for the Michigan source-water assessment program (modified from Brad Brogren and Brant Fisher, Michigan Department of Environmental Quality, written commun., 2000).

To estimate offshore distance, the ArcView `Measure` tool was used to determine the distance from the intake to the nearest shore position shown on the DRG. Depth was estimated using the near-shore bathymetric contours on a 1:24,000-scale DRG.

A buffer zone with the appropriate radius was generated around the surface-water supply intake using the ArcView `Buffer` wizard, once the intake depth and offshore distance were determined, and the radius of the CAZ was calculated. The CAZ and the intake location were overlain on a DRG, denoting the area where the CAZ intersected the shoreline. If the CAZ did not intersect the shoreline, the zone remained circular (fig. 6). In situations where the CAZ did intersect the shoreline, the circular buffer zone was modified into a conical shape, extending from the intake, to where the CAZ intersected the shoreline, and inland to the full radius of the CAZ. This modification was done to limit the focus of the CAZ to identify those PCS located near the intake.

The intake usually was rated highly sensitive for Great Lakes and Great Lakes connecting channels intakes if the CAZ intersected the shoreline. If the CAZ did not intersect the shoreline, the intake was rated moderately sensitive. Therefore, Great Lakes and Great Lakes connecting channels intakes generally were rated with moderate or high sensitivity, depending upon the depth of the intake and distance of the intake offshore. Inland river intakes, which usually are in shallow waters at relatively close proximity to land, tend to be more vulnerable to contaminants, and generally were rated as very highly sensitive.

The CAZ for inland rivers is 3,000 ft, given their generally shallow and narrow channels. Similar assumptions apply to inland lake intakes as they typically are near shore in relatively shallow water. For these two types of intakes, the CAZ was delineated in the same manner as the Great Lakes and Great Lakes connecting channels, and clipped to the SWA (fig. 8)

**Delineation of susceptible area**

Susceptible areas were established around surface-water features within the SWA after determining the radius of the CAZ. Susceptible areas were used to focus PCS inventories where higher potential of contamination by spills or other contaminant releases were present. These areas varied in size based on site-specific data and, where available, TOT calculations were performed by the public-water supply. Ultimately, the areas in close proximity to surface-water features within the SWA, as well as the CAZ were designated as susceptible areas.

Determining the CAZ and susceptible areas by the radius and setback methods involved using a fixed horizontal distance from the intake (fig. 6; Brogren, 1999) and a 300-ft setback from the shores of all perennial tributaries within the SWA (Brad Brogren, Michigan Department of Environmental Quality, oral commun., 2000) (figs. 8-9). The setback is consistent with the designation of riparian buffers by MDEQ. The 300-ft susceptible areas were generated in the GIS using the ArcView `Buffer` tool to create buffer zones around RF3 data within the SWA. Where TOT information was available, the upstream extent of the susceptible area from the intake was constrained using TOT limits suggested by MDEQ.

The susceptible area for river intakes is a 3,000-ft CAZ, from the center of the intake to the intersection of each shore, and a 300-ft buffer on each side of the shores of the intake stream and all perennial tributaries within the SWA (figs. 8-9).

The susceptible area for Great Lakes intakes is the CAZ, as determined by the intake depth and distance offshore (fig. 6; Brogren, 1999), a 300-ft buffer around surface-water features within the SWA, and a Great Lakes shoreline buffer that is equal to the distance inland that the CAZ overlaps the shoreline, if at all (fig. 6). The CAZ and surface-water buffers were generated in the same manner used for the inland river intake assessments. The shoreline buffer, created in the GIS using the ArcView `Buffer` tool, was calculated by subtracting the offshore distance of the intake from the radius of the CAZ. The result was the distance the

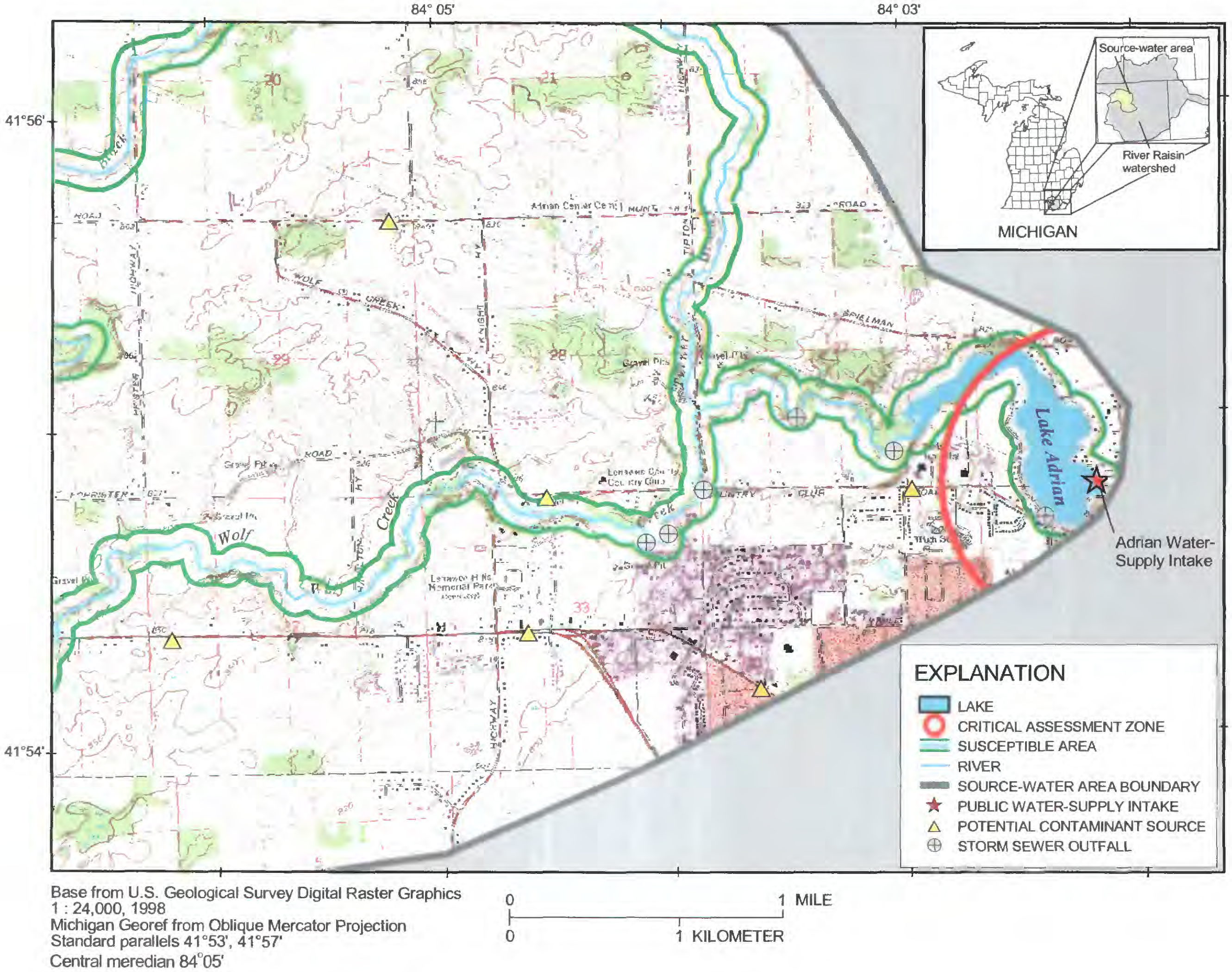



**Figure 8.** Inland river critical assessment zone and suscptible area for Adrian, Michigan.

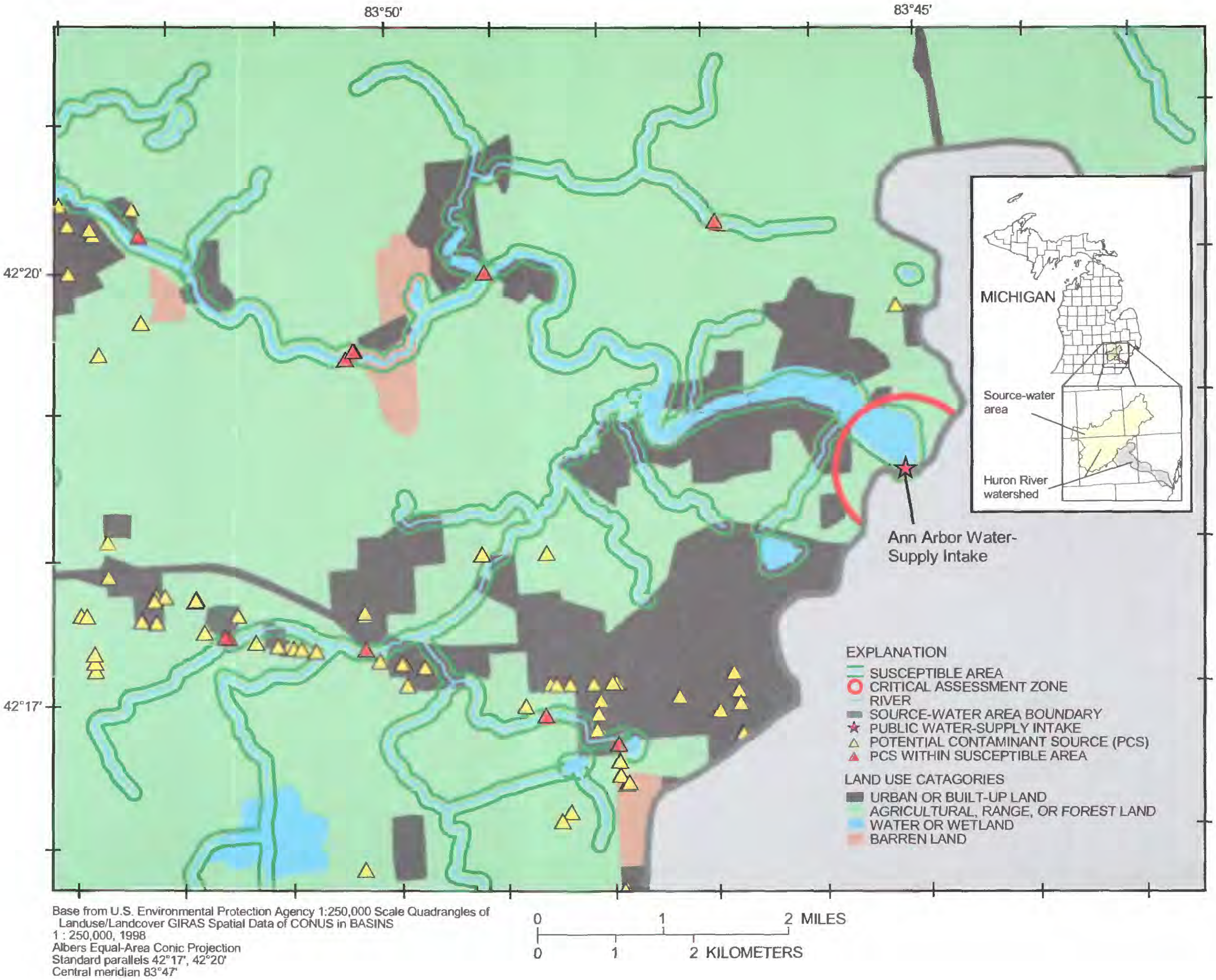



**Figure 9.** Potential contaminant sources in the Ann Arbor, Michigan source-water area.

CAZ extended inland, hence, the inland distance of the shoreline buffer. The linear extent of this buffer followed the shoreline to the nearest stream(s) that potentially could transport contaminants to the intake based upon offshore currents and or historical reports from the WTP operators.

The SWA was constrained further by applying TOT restrictions to the analysis for larger watersheds, where TOT information was available. Currently (2003), no State or Federal regulatory agencies have TOT restrictions or limitations for Great Lakes intakes, but as assessment results are used to formulate source-water protection plans, it is likely that, where available, TOT data will be used to prioritize source-water protection areas and activities.

The CAZ and susceptible area were determined for Great Lakes connecting channels intakes in a manner similar to Great Lakes intakes. Once the two-dimensional, hydrodynamic flow model and particle tracker are completed, assessments for Great Lakes connecting channels intakes will be refined to incorporate the contributing areas defined by the model and particle tracker results (Holtschlag and Brogren, 2000; Holtschlag and Koschik, 2001). SWA and PCS inventories, modified from these results, could differ appreciably from draft SWA and PCS inventories.

**Contaminant source inventory**

PCS are any facility or activity that stores, uses, or produces contaminants of concern at levels that could contribute to the detectable concentration of these contaminants in the source waters of the public water supply (Brogren, 1999). PCS inventories were created with assistance from public water-supply operators, watershed councils, drinking-water protection committees, and local citizens. Inventories were compiled from available Federal, State, and local databases, using a GIS for database manipulation and illustration production. This approach focused on facilities, activities, and broad land use categories that MDEQ and local health departments considered high or moderate risks to drinking water, and for which, in general, a Federal or State discharge permit had been issued.

Each inventory consisted of identifying and locating PCS, and included the following steps:

1. Creating a land use map for the SWA.
2. Conducting database queries and plotting applicable data on a land use map.
3. Creating a soil permeability map for the SWA.
4. Conducting database queries and plotting applicable data on a soil permeability map.
5. Compiling anecdotal and other sources of information as made available on a per water-supplier basis.
6. Providing a preliminary inventory form, land use map, soil permeability map, and PCS inventory to the public water-suppliers, planners, and community teams.
7. Field locating (optional) and verifying potential high-risk activities.
8. Finalizing the inventory form and the base maps.

The PCS inventory provided location information about potential contaminants used or stored within the SWA, with emphasis placed on collecting information on those that presented the greatest risks to a water supply. PCS inventory results were available for map display, depicting the spatial relation between PCS and receiving waters, salient soils, general land use, and the drinking-water intake. The PCS inventory served as an effective means of educating the public about potential contaminants in their area. Finally, the PCS inventory provided a reliable basis for developing a local management plan to reduce identified risks to water supplies.

## Scope of contaminant source inventory

The PCS inventory identified the general location of PCS of concern within a SWA. Contaminants can reach surface-water bodies from activities at or below the land surface, and may be attenuated, amplified, or altered during transport.

Operating practices and environmental awareness vary among landowners and surface-water facility operators. Regardless of the quality of management practices or pollution-prevention processes, the highest potential risks generally are from facilities or land-use activities that use, store, or generate high-risk chemicals. High-risk chemicals are defined by USEPA as chemicals having either a maximum-contaminant level (MCL) or a secondary maximum-contaminant level goal (MCLG) for drinking water.

Inventoried areas were limited to a subset of the entire watershed, focusing on the highest risk areas identified through the delineation of a CAZ and susceptible area. Upon completion of the contaminant source inventory, communities were encouraged by MDEQ and USEPA to develop a management plan to protect their public-water supply. The purpose of developing a management plan based on inventory results is to address business and land use activities that pose risks to the water source. In this process, PCS that pose little threat to the public-water supply can be excluded. If business activities are conducted in ways with little likelihood of contaminant release – for example, pollution abatement or waste-reduction practices – a facility would not need to re-evaluate its activities. Some examples, which show the relation among PCS and types of contaminants in Oregon, are available online at http://www.deq.state.or.us/wq/dwp/SWAPCover.htm (accessed June 24, 2002).

## Contaminants of concern

Contaminants can be released to water bodies from a variety of sources. PCS can include, but are not limited to, industrial facilities, sewage- or waste-disposal sites, managed forest or agricultural lands, accidental transportation spills, small businesses, and residential activities. Principal contaminants of concern from nonpoint sources in Michigan include sediments, nutrients, microorganisms, and pesticides. Principal contaminants of concern from point sources in Michigan include ***volatile organic compounds*** (VOC), ***synthetic organic compounds*** (SOC), microorganisms, and petroleum compounds.

Contaminant source inventories focused on PCS that are regulated under the SDWA. These inventories included contaminants with a MCL or MCLG, contaminants regulated under the USEPA surface-water treatment rule, and the microorganisms *Cryptosporidium* and *Giardia lamblia*. Contaminants that affect the quality of water resources in Michigan include microorganisms (viruses such as Hepatitis A, Norwalk type; protozoa, such as *Cryptosporidium, Giardia lamblia;* and bacteria such as coliform (*Escherichia coli*, fecal, *Enterococcus*)), turbidity, inorganics (such as nitrates and metals), organics (such as VOC, SOC, petroleum compounds, and semi-volatiles), and esthetic parameters (such as taste, odor, and color).

## Contaminant-source inventory procedure

Land use maps were created for each SWA and categories were defined for the contaminant-source inventory. Mapping land use allowed the delineated SWA to be divided into four broad land use categories: urban or built-up; agricultural, range or forest; water or wetland; and barren. Maps at the SWA scale allowed accurate plotting of each potential source point within the SWA. The land use map, coupled with the locations of PCS, soils, rivers, and drains, for example, assisted in identifying threats from current land uses to the quality of the water supply.

Current, historical, and planned land uses were considered when associating land use with PCS. Historical land uses usually had an effect on present water quality. For example, on agricultural land, it was necessary to identify chemicals, such as regulated pesticides, that were used, stored, or disposed of on-site. Former gasoline stations and dumpsites were considered potential risks to ground water, which can constitute an appreciable amount of surface-water flow. Searching records and (or) interviewing long-time residents identified past sources of contamination that might otherwise have been overlooked.

Aerial photographs also were helpful in identifying both present and historic land uses. Aerial photographs were available from the county seat or transportation officials.

officials. Photographs also were obtained from the U.S. Army Corps of Engineers, Natural Resources Conservation Service, local flood-control districts, or from commercial sources. Other resources for aerial photographs included colleges and universities. For example, the Center for Remote Sensing and GIS at Michigan State University has an extensive collection of aerial photographs in their photogrammetric library that were used to identify changes in land use.

Geographic databases were collected and (or) created to facilitate the contaminant source inventory. Federal, State, and local databases (including Canadian) were searched for available contaminant-source data for each SWA. Databases from various government levels may contain information and (or) available permits related to water quality, such as the 303(d) list of impaired water bodies (MDEQ, 2002), underground injection, underground storage tanks, water rights, water-supply wells, hazardous waste, irrigated areas, pesticide records, solid waste, air quality, and toxic release inventories. Databases that may provide information about PCS within a SWA are listed in Sweat and others (2000a).

Public water-supply officials, planners, and interested citizens were contacted to supplement the database information. At the local level, a substantial amount of information on historical, current, or future PCS was available in the form of routine records or documents in county or city files. Local citizens also had knowledge of potential sources that were not listed elsewhere in databases or on maps. Some specific sources of information for local data on land use may include: planning departments; public works; chambers of commerce; city or county permit files; health departments; business licenses; and aerial photographs.

MDEQ developed a comprehensive inventory form to identify PCS and ensure a consistent assessment approach. The inventory form (appendix) is available on MDEQ's Web site at http://www.michigan.gov/documents/DEQ-swap99_4707_7.pdf, p. 105-106 (accessed October 9, 2002). This form, along with maps showing the SWA boundary, land use, PCS, and the location of the water-supply intake, was sent to officials of each water supply with a request to verify and complete the inventory at the local level. Because of variations in land use and activities across the State, especially in agricultural areas, the list of PCS was adapted to each supply based upon the completed inventory form.

Field reconnaissance depended on the complexity of land use and PCS within the SWA, and the size of the SWA. In some cases, the entire inventory was completed with local community assistance, without the need for any field work. However, in more densely developed areas, it was necessary to conduct an in-depth survey where GIS methods were not sufficient to identify individual PCS. This survey included driving through portions of the SWA and noting any unreported PCS. The survey also provided verification of the location of PCS identified during previous data collection.

### Delineation of potential contaminant sources using geographic information systems

PCS within the susceptible area and CAZ were identified once the potential contaminant inventory process was completed. This identification was accomplished using the ArcView `Select by Theme` tool, assigning the CAZ and susceptible areas layers as the target layers, and the PCS data as the selection layer. The `Select by Theme` tool then was used to capture those PCS data points that intersected any portion of the CAZ and susceptible area. Selecting by theme also allowed for selected components within the PCS tables to be exported as a database from ArcView. Identifying high-risk contaminant sources provides input for developing a protection strategy based on prioritized areas or individual sources.

The land use data were overlain with the RF3 data, the CAZ, the susceptible area, and the PCS data. This procedure produced a map showing the location of PCS in the SWA, which was used to determine the susceptibility of the intake. Additionally, this procedure produced a complete list of PCS by type. A typical contaminant source inventory is shown for the Ann Arbor, Michigan SWA in figure 9. A summary of PCS, by type, is given for the Alpena, Michigan SWA in table 3.

The overall success of each assessment depends upon identifying PCS to public water-suppliers so that

**Table 3.** Types of potential contaminant sources in the source-water area for the Alpena, Michigan water–treatment plant

| Type of potential contaminant source (PCS) | Number of PCS | Number of PCS in the susceptible area |
|---|---|---|
| Hazardous or Solid Waste | 72 | 10 |
| Industrial Facilities Discharge | 7 | 7 |
| National Priority List | 1 | 0 |
| Permit Compliance System Database | 9 | 3 |
| Toxic Release Inventory | 5 | 1 |
| National Pollutant Release Inventory | 0 | 0 |

communities can identify methods to reduce risks from these sources. As communities move into planning how to protect their public-water supply (source-water protection), they may want to re-visit high-risk activities and land use areas to conduct a more thorough, area specific assessment.

### Susceptibility determination

MDEQ defined susceptibility determination as: "the potential for a public water supply to draw water contaminated by inventoried sources within their SWA at concentrations that would pose concern" (Brogren, 1999). The susceptibility determination was designed to be a relative comparison among PCS within the SWA. The objective was to provide meaningful assessment results to public water supplies and communities. This objective was accomplished by providing maps and a table of PCS identified within the CAZ and susceptible areas of each SWA.

Data collected during the delineation and inventory can be used by communities to develop a management strategy to protect their drinking-water supply. The susceptibility analysis provided tools, such as maps and PCS tables, to help MDEQ and communities develop protection plans that direct management toward high and moderate risks in the most susceptible areas, with low-risk areas as a lesser priority. Some factors considered when determining susceptible areas are listed in table 4.

Assessments included a map that displayed vertical soil permeability and PCS. This map was provided to supply the community with information of some of the physical characteristics of the SWA. Soil permeability was based on the calculated TOT, in inches per hour (in/hr), for water to move vertically through a saturated soil zone. Soil thickness and permeability values are available in soil survey reports published by the U.S. Department of Agriculture and National Cooperative Soil Survey (variable dates). Permeability ranges from less than 0.06 in/hr, rated as very slow, to more than 20 in/hr, rated as very rapid.

Very slowly permeable soils appreciably reduce the movement of water through the soil zone and, as a result, may allow greater time for natural degradation of contaminants during infiltration. However, these soil types also provide for rapid overland transport of contaminants directly to receiving waters, which in turn may affect the water-supply intake. Erosion and transport of soils by surface waters also can cause an increase in turbidity. In contrast, very rapidly permeable soils allow for rapid infiltration and passage through the soil zone from the surface. These soil types potentially allow rapid transport of contaminants with minimal contact-time available for contaminant breakdown. Providing soil permeability maps displaying the PCS in the SWA can help target

**Table 4.** Factors considered in determining susceptible areas to contamination in the Michigan source-water assessment program

| Factor | Contamination Risk | Example | Data Source |
|---|---|---|---|
| Highly erodible soils | Turbidity, contaminated sediments | Low percent clay soils, steep slopes, developed areas | Soil survey maps, digital elevation models, digital topographic maps, forest/agricultural agencies |
| Rapidly permeable soils | Rapid transport of contaminants to surface water through ground-water discharge | Recent alluvial deposits, high percentage of sandy soils | Soil-survey maps, digital elevation models, land use maps |
| Critical Assessment Zone | Shoreline effect, contamination from runoff or direct discharge | Shallow or near-shore intake, storm drains adjacent to intake | Water-supply operator, drainage commission, road commission, land use maps |
| Susceptible area adjacent to water body (lakes and reservoirs) | Runoff, direct discharge from land use | Lawns or pastures abutting stream, development along shore, recreational use, shipping | Land use maps, parks/recreation dept., extension service, Coast Guard, water-supply operator |
| High rainfall or irrigation areas | Runoff, turbidity, contaminated sediments, direct discharge | Tillable land abutting shoreline, storm drains | National Oceanic and Atmospheric Administration, soil-survey maps, extension service, local agencies and organizations |

management and protection efforts accordingly.

Soil permeability maps were generated in ArcView using the BASINS `State Soil Characteristics Report` tool. The STATSGO soil data, SWA boundary data, RF3 data, and elevation data are available in the tool to create a new data layer that characterizes each soil polygon by mean, area-weighted, depth-integrated permeability in inches per hour. The soil permeability data then were classified according to National Resources Conservation Service (NRCS) soil reports and overlain with the PCS data.

The permeability data then were queried for values greater than or equal to 2 in/hr to isolate soils that were classified as moderately rapid to very rapidly permeable. Determining which PCS were located on moderately rapid to very rapidly permeable soils was achieved by using the ArcView `Select By Theme` tool. This process involved assigning the selected soils (moderately rapid to very rapidly permeable) as the target areas, and the PCS points as the selection data. Those PCS that intersected moderately rapid to very rapidly permeable soils then were depicted on the map in a red symbol, and PCS located on very slow to moderately permeable soils were depicted in yellow. This procedure produced maps showing the location of PCS in relation to soil permeability within the SWA (fig. 10).

Assessments also included a map showing PCS in relation to land use, with surface-water features and susceptible areas shown. This map incorporated results of the contaminant source inventory and methods described in that section of this report. PCS within the susceptible areas on this map were displayed in red, whereas the PCS outside the susceptible areas were displayed in yellow (fig. 11).

### Susceptibility determination results

The susceptibility determination illustrated potential threats to a community's drinking water, and assisted communities in prioritizing their efforts to protect their drinking-water supply. Final susceptibility maps for completed assessments (fig. 11), along with a table of PCS within the susceptible area (table 5), resulted in a susceptibility determination for each intake (fig. 7). The susceptibility determination, along with susceptible area map and table of PCS, provided a basis upon which to begin a source-water protection plan.

## SUMMARY

Reauthorization of the Safe Drinking Water Act (SDWA) of 1996 required Federal guidance and defined State requirements for the development and implementation of a source-water assessment program (SWAP). The SWAP for the evaluation and protection of surface-water supplies in Michigan provides information to water-supply personnel and community planners that is useful in planning for future operating practices of each supply. The Michigan Department of Environmental Quality (MDEQ) and the U.S. Geological Survey (USGS) have included input from a technical advisory committee and a citizens advisory committee to guide the process of developing the SWAP.

Geographic information system-based methods facilitated the process of delineating the source-water area (SWA) for surface-water-supplied systems. Global positioning system coordinates were used to confirm present surface-water-intake locations. After the SWA boundary was delineated, the assessment process included: defining the critical assessment zone (CAZ) for each intake; determining susceptible areas within the SWA; calculating soil permeabilities; identifying and locating potential contaminant sources (PCS) within the SWA; and conducting an inventory of PCS in the CAZ and susceptible area.

Completed source-water assessments indicated the potential for public water supplies to draw water contaminated by inventoried sources within their SWA. Susceptibility determinations included a map of the locations of PCS that fell within the susceptible area, and provided an estimate of the sensitivity of a drinking-water supply within the CAZ. The susceptibility determination, SWA delineation, and PCS inventory served as a starting point for the development of a management strategy by the community to protect its drinking-water supply.

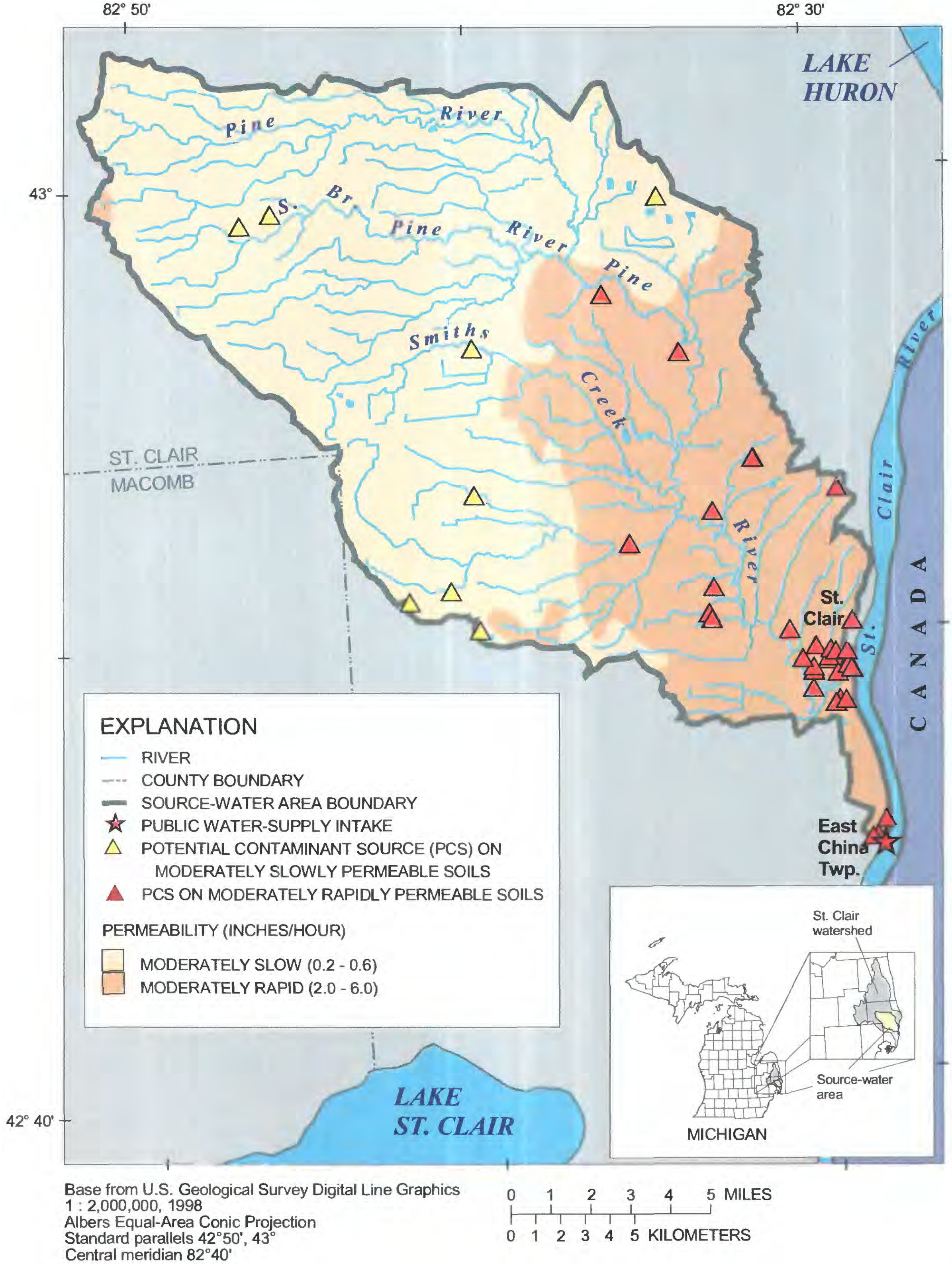



**Figure 10.** Soil permeabilities and potential contaminant sources in the East China Township, Michigan source-water area.

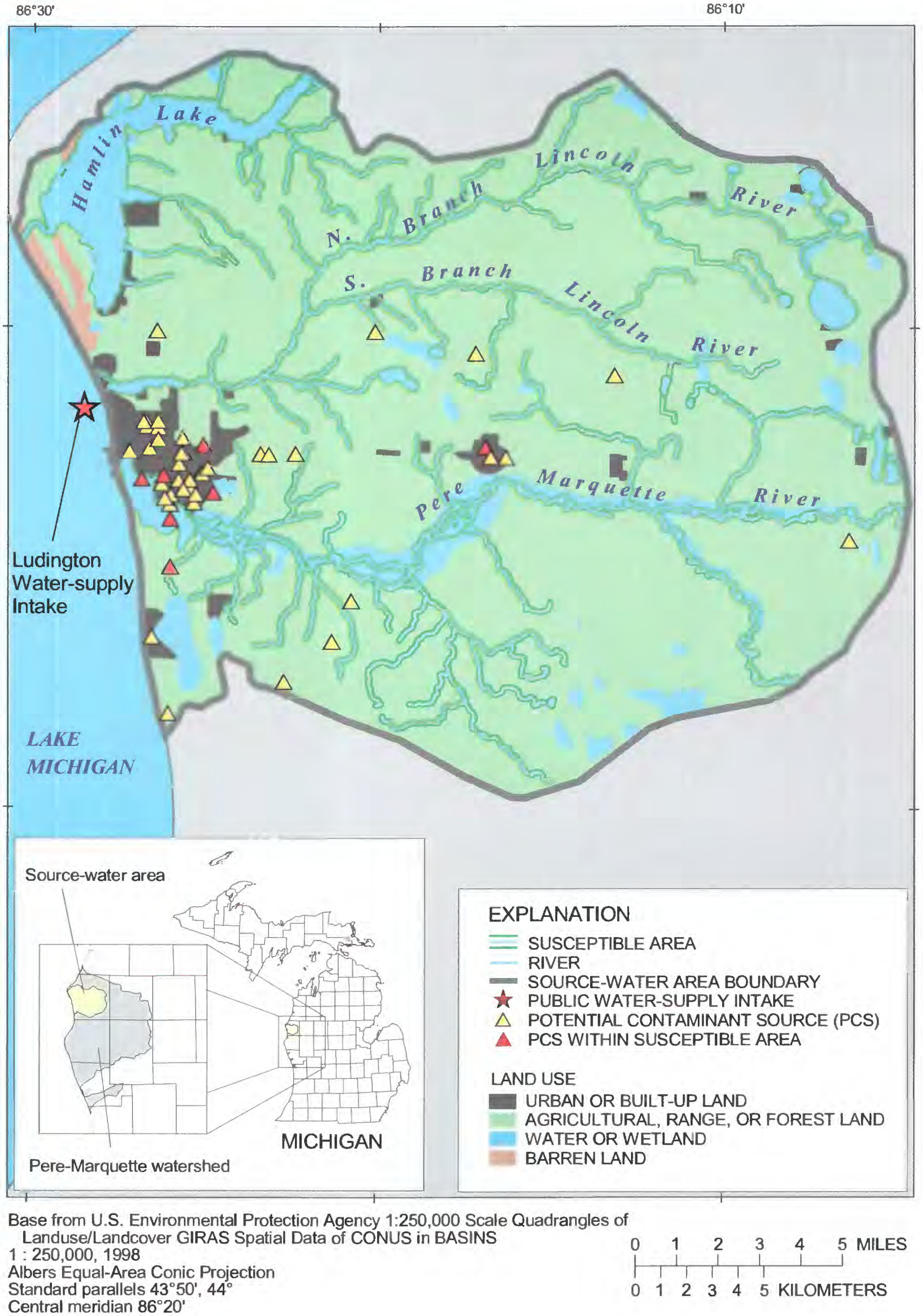



**Figure 11.** Susceptible area with potential contaminant sources for the Ludington, Michigan source-water area.

**Table 5.** Inventory results showing potential contaminant source within the susceptible area for L'Anse, Michigan source-water area

| Site name | Permit number | Reason for permit (reasons given apply to all sites within grouping) | Reason for listing as potential contaminant source (reasons given apply to all sites within grouping) |
|---|---|---|---|
| Celotex Corporation [1] | MID006129332 | Release or manufacturing of toxic compounds | Toxic release inventory |
| Baraga Waste Water Treatment Plant [1] | MID985631068 | Waste water and (or) process water | Permit compliance system database |
| UP Power - L'Anse [1] | MID980006720 | | |
| L'Anse Waste Water Treatment Plant [1] | MID985657048 | | |
| Baraga Water Filtration Plant [1] | Not Available | | |
| Baraga Waste Water Treatment Plant [1] | MI0022250 | Cooling, process, treatment, and (or) waste waters | Industrial facilities discharge site |
| Baraga Water Treatment Plant [1] | MI0024881 | | |
| UP Power - L'Anse [1] | MI0006092 | | |
| L'Anse Waste Water Treatment Plant [1] | MI0020133 | | |
| Ken's Service | MID044395861 | On-site storage | Hazardous- or solid-waste site |
| Village of L'Anse Garage | MID981775422 | | |
| Pettibone Michigan Corporation | MID006129373 | | |
| Michigan Department of Transportation | MID980992234 | | |
| Northern Painting and Coatings | MID001026756 | | |
| Thomas Ford Mercury | MID017187303 | | |
| UP Power Warden Station [1] | MID980006720 | | |
| Village of L'Anse | MID981780141 | | |
| Baraga Products, Inc. | MID106634272 | | |
| Celotex, Inc. [1] | MID006129332 | | |
| Nick's Standard Service | MID041414160 | | |

[1] indicate multiple permits issued for one location, facility, or company and are unique to each related source.

MDEQ and USGS prepared assessment reports that included maps of the SWA, maps showing PCS locations, lists of PCS, results of the susceptibility determination, and a narrative of procedures used for conducting the assessment, which is in compliance with requirements of amendments to the SDWA. Source-water assessments allowed for improved protection of surface-water-supply intakes from PCS, in coordination with other programs such as the Clean Water Action Plan and Michigan's Clean Water Act. Assessment results were provided to each public water supply in printed and electronic media.

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## GLOSSARY

Critical Assessment Zone (CAZ) – the area from the intake structure to the shoreline and inland, including a triangular water surface and a land area encompassed by an arc from the endpoint of the shoreline distance on either side of the onshore intake pipe location.

Digital Raster Graphic (DRG) – a scanned image of a U.S. Geological Survey (USGS) standard series topographic map, including all map collar information.

Frazil Ice – ice that initially accumulates on the upstream face of the debris bars or rack of a water intake. The ice progresses to the upstream sides of the bars, grows in all directions, and eventually bridges over the spaces between bars. The ice blockage starts at the upper part of the rack and progresses downward.

Geographic Information System (GIS) – a system to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.

Global Positioning System (GPS) – a constellation of 24 satellites, developed by the U.S. Department of Defense, that transmit signals which allow a receiver anywhere on earth to calculate its own location.

Intake – the point at which source (raw) water is drawn into a pipe to be delivered to a water- treatment plant.

Maximum Contaminant Level (MCL) – the maximum permissible level of a contaminant in water that is delivered to any user of a public water system.

Potential Contaminant Sources (PCS) – listed and non-listed agricultural sites, businesses, and industries with the potential to cause contaminants to be introduced into source water.

Sensitivity – a measure of the physical attributes of the source area and how readily they protect the intake from contaminants.

Source – the water body from which a water supplier obtains its water.

Source Water Area (SWA) – the land and water area upstream of an intake with the potential to directly affect the quality of the water at the intake.

Source Water Assessment Program (SWAP) – in Michigan, the process defined by the State Department of Environmental Quality to complete assessments of all the State's public water supplies.

Susceptibility – the potential for a public water supply to draw water contaminated by inventoried sources within their source-water area at concentrations of concern.

Susceptible Area – the area defined by the critical assessment zone and a buffer on either side of any drainage that contributes water to an intake.

Synthetic Organic Compounds (SOC) – manmade organic chemical compounds, such as pesticides.

Volatile Organic Compounds (VOC) – organic chemical compounds that volatilize readily at standard atmospheric pressure and temperatures, such as petroleum distillates.

## APPENDIX

**Source Water Assessment Program**
Great Lakes Surface Water Assessment Survey

Water Supply Name: Saginaw-Midland Municipal Water Supply Corporation PWS ID No.: 5880

Intake #1 - Location/Depth: 10000' x 53' Sensitivity Calculation (Length x Depth): 530,000
Intake #2 - Location/Depth: 6000' x 35' Sensitivity Calculation (Length x Depth): 210,000
*Please indicate your level of concern (Very, Somewhat, Low, Don't Know) for each of the following Contaminant Groups and Contaminant Sources with comments where appropriate.*

**Contaminants of Concern**

Microbial (Coliform, Cryptosporidium, etc.) Low

Inorganics (Metals, Nitrates, etc.) Low

Volatile Organics (Benzene, TCE, etc.) Low

Synthetic Organics (PCB's, Dioxin, etc.) Low

Pesticides (Atrazine, etc.) Low

Radioactivity (Radium, etc.) Low

Other Refer to "Raw Water Quality" database

**Contaminant Sources of Concern** - *Complete only those which apply to intake.*

Crop Related Agriculture ______

Grazing Related Agriculture ______

Animal Feeding Operations ______

Municipal Wastewater Discharges ______

Industrial Wastewater Discharges ______

Wastewater Treatment Bypasses ______

Combined Sewer Overflows ______

Urban Runoff/Storm Sewers ______

Construction Runoff ______

Contaminated Sediments ______

Bank or Shoreline Modifications ______

Drainage/Filling of Wetlands ______

Highway Runoff ______

Stream Channelization ______

Dredging ______

**Source Water Assessment Program**
Great Lakes Surface Water Assessment Survey

**Contaminant Sources of Concern (continued)**

Dam Construction

Upstream Impoundments

Land Disposal of Sludge/Wastewater

Landfills

Leaky Underground Storage Tanks

Marinas

Wildlife

Mining Activities

Salt Storage

Logging Activities

Spills Shipping Spills

Shipping Shipping Spills – (2) Lake Huron intakes; 1-mile separation; near shipping lane North of entrance to Saginaw Bay

River/Creek Influences

County Drain Influences

Others

| **Past Raw Water Qualities (5 Years)** | Average | Minimum | Maximum | Comments |
|---|---|---|---|---|
| Turbidity | 1.77 | 0.1 | 80 | |

Total Coliform As a raw water purveyor, Bacteriology is not a requirement of the MDEQ.

Fecal Coliform Bacteriology for internal operation purposes is undertaken however. For

HPC sample reports, refer to "Bacteriological Reports."

Chlorides 7

pH 8

Color Clear

Alkalinity as $CaCO_3$ 79 Hardness as $CaCO_3$ 95

Causes of Raw Water Quality Fluctuations: Wind and Weather

Data Sources/Reports: Refer to "Water Research"

Survey Completed by H. Gary Peters Title Manager Date 05-01-2000 Telephone 517-684-2220

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