STATE OF MICHIGAN
SOURCE WATER ASSESSMENT PROGRAM REPORT

Alpena Water Treatment Plant, Alpena, Michigan

for submittal to the

U.S. Environmental Protection Agency

by

DEQ

Michigan Department of Environmental Quality
Water Bureau
December 2004

MICHIGAN SOURCE WATER ASSESSMENT PROGRAM REPORT

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MICHIGAN SOURCE WATER ASSESSMENT PROGRAM
Executive Summary

The reauthorization of the federal Safe Drinking Water Act (SDWA) of 1996, P.L. 104-182, Section 1453 required federal guidance and defines state requirements for a Source Water Assessment Program (SWAP). The SDWA requires the state to:

- Identify the areas that supply public tap water.
- Inventory contaminants and assess source water susceptibility to contamination.
- Inform the public of the results.

Michigan has almost 12,000 public water supplies with an estimated 18,000 sources requiring assessments. Of these, approximately 10,650 are noncommunity public water supplies with groundwater as the source. There are approximately 1,250 community systems, including 650 systems using groundwater sources and supplies that purchase water. There are only 60 surface water intakes, but these 60 sources provide drinking water to over 75 percent of the persons served by public water systems or about 50 percent of the state's population. These figures presented Michigan with some unique challenges in developing a SWAP.

In 1998, the Michigan Department of Environmental Quality (MDEQ) convened a SWAP Advisory Committee composed of stakeholders from federal, state regulatory, local health departments (LHDs), universities, nonprofit organizations, and representative trade associations to assist with developing the Michigan SWAP. The final SWAP document was submitted to the U.S. Environmental Protection (USEPA) in February 1999 and approved in October 1999.

The MDEQ established a unique partnership with numerous federal, state, and local agencies in working to complete the SWAP. For the noncommunity public supply water assessments (NCPWS), Michigan State University (MSU) Institute of Water Research, Groundwater Education in Michigan (GEM) Centers, and LHD staff coordinated roles in completing assessments. Staff from the Michigan Department of Agriculture completed assessments of the migrant labor camps defined as NCPWS. The MDEQ staff was primarily responsible for completing community groundwater sources. Michigan surface water sources were assessed using protocol developed with the USEPA Region 5 states and refined with methodologies developed and completed by the U.S. Geological Survey (USGS), MDEQ Groundwater Section staff, and the Michigan Public Health Institute. The National Oceanic and Atmospheric Administration, Detroit Water and Sewerage Department, and Environment Canada also played significant roles in assisting with the connection channels flow model used to delineate intakes in Southeast Michigan.

Of the approximately 10,650 noncommunity public water supplies, significant financial and staff resources were invested addressing these systems. The present Noncommunity Public Water Supply (NCPWS) Program includes a sanitary survey of each system every five years. These surveys are done through contracts with LHDs. It was decided to tie the source water assessments of these sanitary surveys to make the system more efficient and to make the assessments a tool for future use. The work on the noncommunity assessments was completed using existing programs and expertise and directed toward providing tools that assist with improving protection efforts.

The noncommunity Source Water Assessment Score (SWAS) is based upon evaluation of the following:

1. The geologic sensitivity of the NCPWS well.
2. The construction, maintenance, and use of the NCPWS well.
3. Chemistry data from the NCPWS well water.
4. Isolation of the NCPWS well from sources of contamination.

Michigan State University provided support in all aspects of the noncommunity assessment process, proving oversight for contractual efforts with the GEM centers. These centers provided assistance to the LHDs, as needed, for using the Global Positioning System (GPS) units and assisting in other areas of the program.

Michigan has a voluntary Wellhead Protection Program (WHPP). There are 120 Community Public Water Supplies (CPWSs) that have approved WHPPs and an additional 80 that have an approved delineation. The remaining 953 systems (of which 397 are Mobile Home Parks) were assessed using a protocol similar to the noncommunity system.

A WHPP provides information necessary for source water assessment. The geologic sensitivity was determined from data derived from wellhead protection area (WHPA) delineation reports. Potential sources of contamination were derived from the WHPP report. For communities with approved delineations, but no program approval, the potential sources of contamination were identified in the WHPA, and the assessments were completed and analyzed as a separate group.

The community groundwater systems without WHPPs were completed using state staff or a third party contractor. The assessments on the remaining small systems are similar to those conducted for the noncommunity systems.

Public surface water supply intakes were assessed using procedures defined in the Great Lakes Protocol and with assistance from water treatment plant personnel.

The Michigan SWAP defined susceptibility to contamination for sources of public drinking water and recommended protection activities. The protection of Michigan's sources of drinking water can be accomplished through a variety of local, state, and federal programs. Information derived from the source water assessments will enhance these protection programs. Public and private well construction and isolation requirements in the Michigan SDWA and Public Health Code, along with the technical expertise of local and state department personnel, have been the foundation of the state's water supply program. Properly constructed and isolated wells are considered the first line of defense in Michigan for source water protection of groundwater sources. Routine field surveillance and sanitary surveys by DEQ and LHD staff have also been a strong focal point in source water protection. The integration of results of the source water assessments into the ongoing sanitary surveys enhances the protection of the supplies. Geographic Information System (GIS) tools and data will improve productivity and effectiveness of the LHDs.

The results of the assessments and use of GIS tools developed and disseminated under the SWAP should be used to prioritize protection efforts. CPWSs that have been determined to be “High” or “Very High” susceptibility should be reviewed and plans developed to address protection efforts at these sites.

Community groundwater supplies that are not pursuing wellhead protection should be encouraged to do so. Public surface water supplies should develop protection programs similar to wellhead protection on a watershed basis. Tools for providing source water protection of surface water supplies are available through the federal Clean Water Act.

CHAPTER 1 – INTRODUCTION

Michigan has almost 12,000 public water supplies with over 18,000 sources requiring source water assessments. Of these, approximately 10,650 are noncommunity public water supplies with groundwater as the source. There are approximately 1,250 community systems, including 650 systems using groundwater sources and supplies that purchase water. There are only 60 surface water intakes, but these 60 sources provide drinking water to over 75 percent of the persons served by public water systems, or about 50 percent of the state's population. These figures presented Michigan with some unique challenges in developing a SWAP.

The efforts toward developing the SWAP in Michigan were divided into three sections with a total of seven assessment categories:

- Noncommunity Groundwater Supplies

- Community Groundwater Supplies
  - Wellhead Protection Program
  - Wellhead Protection Area Delineations
  - Remaining Groundwater Assessments

- Community and Noncommunity Surface Water Supplies
  - Great Lakes Sources
  - Great Lakes Connecting Channels
  - Inland Lakes and Rivers

The present NCPWS Program includes a sanitary survey of each system every 5 years. These surveys are done through contracts with LHDs. The surveys were expanded by these contractual efforts through a contract amendment to include an assessment using an assessment survey form, scoring different criteria that affect the vulnerability of the source, and tabulating an assessment score for the site. These assessments evaluated major potential sources of contamination within 800 feet of the water source. Eight hundred feet is the separation requirement between a source of contamination and a NCPWS source as defined in the Michigan Safe Drinking Water Act. An on-site visit was required to locate the well in a statewide groundwater data base through the use of GPS units along with submittal of a water well and pump record (well drilling record) where available. The well construction, pumping capacity, chemical monitoring records, and the geological setting were assessed. All noncommunity systems, both transient and nontransient, were assessed in the same manner.

MSU provided oversight for contractual efforts with the GEM centers. These centers provided assistance to the LHDs, as needed, for using the GPS units and assisting in other areas of the program.

The master contract with MSU included provisions to map the elevations of “first water.” This information will assist in determining direction flow for “first water” throughout the state. When contaminants enter the ground, they generally follow the direction of this “first water” flow. Knowledge of this flow direction will assist in evaluating the threat of contaminants to public drinking water supplies.

Evaluation of work done by the LHDs was assessed as the work was submitted to the state. The GPS locations were verified through an assessment system along with the well drilling record entries. Payment was made for work completed.

The community groundwater systems without WHPPs were completed using state staff or a third party contractor. The assessments on the remaining small systems are similar to those conducted for the noncommunity systems.

A small number of public water supplies derive their water from karst hydrologic systems (KHSs). Groundwater flow in KHSs is typically controlled by a continuum of vertical and horizontal conduits formed in and enhanced by dissolution of limestone, dolomite, gypsum, and other soluble rocks and minerals. Groundwater flow rates in KHSs are typically an order (or orders) of magnitude faster than groundwater flow in porous media (typically hundreds of feet per day in a KHS). Karst hydrologic systems that are near or at the earth's surface provide a pathway for surface drainage and contaminants to directly enter drinking water supplies. Areas in the state where karst or fractured bedrock were within 25 feet of the surface were mapped. The source water assessments in these areas were completed using criteria developed jointly by the MDEQ and the USGS, Michigan District.

The SWAP included susceptibility determinations that take into account source sensitivity related to area geology or hydrology and contaminant sources within the assessment area. These factors are used to determine the potential to draw water contaminated by inventoried sources at concentrations that would pose concern. For groundwater sources, the sensitivity could be determined by reviewing depth to "first water," recharge from precipitation and surface waters, thickness of confining layers, plus well construction, maintenance, and pumpage. The sensitivity analyses are then evaluated with the source chemical and/or isotope data and isolation from contaminant sources to determine susceptibility.

The assessments were enhanced with the use of data previously collected from vulnerability assessments and from data collected during sanitary surveys. This information will also be beneficial for future sanitary surveys.

Michigan has a voluntary WHPP. There are 120 CPWSs that have approved WHPPs and an additional 80 that have an approved delineation. The remaining 953 systems (of which 397 are Mobile Home Parks) were assessed using a protocol similar to the noncommunity system.

A WHPP provides information necessary for source water assessment. The geologic sensitivity was determined from data derived from WHPA delineation reports. Potential sources of contamination were derived from the WHPP report. For communities with approved delineations, but have not had their programs approved, the potential sources of contamination were identified in the WHPA, and the assessments were completed and analyzed as a separated group.

Table 1. Michigan Public Water Supplies

Noncommunity Groundwater Supplies		
Transient =	8,930	
Nontransient =	1,720	
Subtotal =	10,650	with approximately 13,000 wells to assess
Community Supplies		
Groundwater =	1,123	with an estimated 5,000 wells to assess
		Purchased Groundwater Systems = 42
Surface Water Intakes		
Inland Rivers	8	
Great Lakes	52	
Subtotal =	60	Purchased Surface Water Systems = 233
Total Active Community Systems =	1,460	
Total Number of Public Water Supplies =	12,108	

Approximate Number of Sources to be Assessed = 18,000

CHAPTER 2 – NONCOMMUNITY ASSESSMENTS

Program Implementation
The SWAS was developed cooperatively among the Environmental Health, Groundwater, and Field Operations Sections within the Water Division, MDEQ. Staff from these sections may utilize the SWAS to assign monitoring requirements and identify NCPWSs that should receive follow-up activities.

The assessments of noncommunity groundwater supplies were conducted by LHD staff and were coordinated with the sanitary survey requirements that mandate a sanitary survey every 5 years. This required the state to begin the program as soon as possible to allow completion within the 5-year sanitary survey cycle. All public water supply assessments include an assessment area derived from standard and major contamination source isolation areas. Standard and major contaminant isolation areas as defined by the Michigan SDWA are 75 feet and 800 feet for noncommunity groundwater supplies.

Contaminants of concern and contaminant sources were evaluated in each assessment area. The program identified known and potential sites of environmental contamination that are included on a contaminant inventory list. Known sites of environmental contamination include leaking underground storage tanks, Superfund sites, Part 201 sites of Act 451, sites of environmental contamination, and oil and gas contamination sites. Other sites that represent a potential for contamination include registered underground storage tanks, certified aboveground storage tanks, hazardous waste generators, abandoned wells, plus surface and groundwater discharges. Land use associated with agricultural operations, commercial facilities, manufacturing and industrial facilities, institutional facilities, and utility companies may also have been considered potential sources of contamination, particularly as they relate to nonpoint source discharges. Contaminants from these sources that threaten public health were considered as contaminants of concern.

These contaminants and potential sources in combination with the source hydrogeology or hydrology sensitivity analysis yield a susceptibility determination. The critical factors considered in determining susceptibility are the relationships between the integrity and construction of the well or surface water intake, source sensitivity, and potential contaminant sources. This determination also took into account any maximum contaminant level (MCL) violations related to source water quality or contaminants of concern detected in the source water.

Source water assessments were completed for approximately 10,650 NCPWSs throughout the state. The objectives of the groundwater assessments were:

- Accurately establish, through the use of GPS and GIS, the location of NCPWS wells.
- Provide for the entry of water well and pump installation records into an electronic data management system.
- Identify the location and proximity of sources of contamination located within 800 feet of NCPWS wells.
- Establish a Source Water Assessment Score (SWAS) that reflects the "inherent vulnerability" of the NCPWS well and source water. This includes assessment of the integrity of the well and geologic setting.

Obtaining accurate location information and well drilling record information for NCPWS wells was an essential first step in the state SWAP. The location and well drilling record information was entered into the statewide groundwater data base (Wellogic). To obtain this data, the technical expertise and networking developed by the Kellogg Foundation, GEM Grant Program, was used. Training of LHD staff and the compilation of data was done by state staff and the GEM regional centers located around the state. The effort was coordinated by the MSU Institute of Water Research.

Location information was collected for each NCPWS well using GPS. LHDs, at their option, contracted for site visits to conduct assessments to obtain GPS locations on all NCPWS wells. State staff conducted assessments if the LHDs did not contract for the program. The majority of the LHDs did the program under contract with the state. The GPS locations were "corrected" to provide accurate well locations before the information was entered in Wellogic. Corrected locations were obtained through postprocessing collected location information to provide accurate locations.

Some LHDs received additional funds for corrected and accurate well locations. The supplemental funds were used to purchase new GPS units or upgrade existing GPS capabilities, if the LHD provided corrected and accurate GPS locations for entry into Wellogic. The state purchased 12 Trimble Geo Explorer II GPS units with a differential accuracy of 2 to 5 meters. These units were rotated among LHDs that did not purchase GPS units.

Information from well drilling records is critical to the SWAP. As part of SWAP, available well drilling records for NCPWS wells were compiled. Wellogic contains location verified well information compiled from well drilling records that had the NCPWS information added. WELLKEY was the software program that allows well drilling record information to be stored in a data base format and provided for the automated entry, storage, and retrieval of well information. The LHDs, at their option, were contracted to enter the well record information for NCPWS wells in WELLKEY. During the grant period, WELLKEY was replaced with Wellogic, which allows internet data entry.

GIS is an essential tool for analysis and display of SWAP data. ESRI products including ArcView were used. The GPS location and well drilling record information obtained by the LHDs was compiled and incorporated into the statewide GIS for use in the analysis of information and the presentation to the public. Through GIS the results are being used in protection efforts for public water supplies and can also be used to focus groundwater protection efforts for private water supply wells. Under the MSU contract, a special version of the Michigan MapImage Viewer was developed. A description of the GIS software is included as Appendix F (Community Ground Water Supply Source Water Assessment Worksheet).

In addition to the GPS/GIS phases of the source water assessment, the vulnerability of NCPWS wells was evaluated by determining a SWAS. The SWAS equates to a susceptibility determination. The SWAS has been created as a numeric system that assigns points for situations that represent a "perceived risk" based upon the evaluation of four criteria. The evaluation criteria provide a "qualitative assessment" of groundwater movement and the potential for movement of contaminants into the subsurface.

The SWAS is based upon evaluation of the following:

- The geologic sensitivity of the NCPWS well.
- The construction, maintenance, and use of the NCPWS well.
- Chemistry and/or isotope data from the NCPWS well water.
- Isolation of the NCPWS well from sources of contamination.

The criteria are evaluated in a manner such that a higher SWAS is equated to a greater potential of risk for the NCPWS source water.

Establishing a SWAS provides a rationale for identifying NCPWSs that should receive a priority in the NCPWS program. The SWAS system has been developed cooperatively with the Noncommunity Unit, Groundwater Section, Water Division, MDEQ. The Noncommunity Unit can utilize the SWAS to assign monitoring requirements and identify NCPWSs that should receive priority in the performance of sanitary surveys.

A more detailed description of how the methodology was developed and how it is calculated for NCPWS is included as Appendix B. The source water assessment worksheet used in the assessments is included as Appendix C.

The scores developed in the assessment process were used to determine system susceptibility using a digital version of the flow diagram in Figure 7.

Source water assessments in Karst Systems were completed using criteria developed jointly by the MDEQ and the USGS, Michigan District. These systems were assigned a "Very High" susceptibility based on the high geologic sensitivity of a karst hydrologic system that does not have significant overlaying drift material.

The SWAS system is based upon the accumulation of points for situations that represent a perceived risk to the NCPWS source water. The SWAS is derived from a sum of a geologic sensitivity score ($SWAS_G$); a well construction score ($SWAS_W$); a score for chemistry and isotope data ($SWAS_C$); and isolation and control from sources of contamination score ($SWAS_S$).

Geologic Sensitivity - $SWAS_G$ - The $SWAS_G$ is factored into the SWAS based on the total thickness of Continuous Confining Material (CCM) such as clay, clay-rich till, or shale penetrated in construction of the NCPWS well; or the total thickness of Continuous Partially Confining Material (CPCM) such as a mixture of sand and clay or sandstone and shale. The total thickness of CCM and CPCM should be determined from the well drilling record for the NCPWS well. Where a well drilling record is not available, well drilling records from adjacent wells or test hole borings may be used. Geologic maps (i.e., lithologic cross-sections) may also be used if they provide adequate coverage of the area in which the NCPWS well is located. If no lithology information is available, the well is considered highly sensitive for the assessment scoring.

Well Construction - $SWAS_W$ - The design, physical condition, and operation of a NCPWS well may allow the entrance of contaminants into the well despite a high level of intrinsic geologic protection. To account for this possibility, the SWAS is assigned points through the $SWAS_W$ based upon four criteria related to the construction and use of the NCPWS wells. The $SWAS_W$ is assessed points based upon well grouting, the age of the well, the casing depth, and the pumping rate of the well.

Water Chemistry and Isotope Data - $SWAS_C$ - Water chemistry data provides a refinement to the SWAS through the $SWAS_C$ that may increase or decrease the SWAS. As examples, the presence of nitrates, nitrites, volatile organic compounds, or synthetic organic compounds, even at low levels, regulated inorganic chemicals, and regulated radionuclides are indicators of source water vulnerability and increase the SWAS. Tritium is a naturally occurring radioactive isotope of hydrogen that was greatly increased in the atmosphere as a result of nuclear weapons testing in the 1950s. One tritium unit (TU) equals one tritium atom per 10^{18} hydrogen atoms and an equivalent gross beta radiation of 3.2 picocuries/liter. The absence of tritium in the source water indicates the source water is older than early 1950s and not vulnerable, thereby decreasing the SWAS. $SWAS_C$ cannot be less than 0 when tritium is less than 1 tritium unit. Review of chemical monitoring records should go back 5 years or more if appropriate.

Isolation from Sources of Contamination - $SWAS_S$ - *Isolation from Standard and Major Sources -* The isolation of a NCPWS well from sources of contamination is an important criterion in the source water assessment. The maintenance and control of isolation distances can significantly reduce the perceived risk associated with the use of a well. The $SWAS_S$ is assessed points for failure to maintain and/or control adequate isolation between "potential" sources of contamination and "known" sources of contamination. Known sources of contamination include those sources where the groundwater has been impacted, such as a leaking underground storage tank or other sites of environmental contamination.

An analysis of about 8,600 source water assessment scores has been completed. Each component of the source water assessment was evaluated. If necessary data was not available, the assumption was made for the “worst-case,” resulting in higher assigned susceptibility of the supply. Information and knowledge form LHD staff or the supply owner could be used to make adjustment to the scores. For example, a well without an available well drilling record was rated as “high sensitivity” unless the LHD staff had information supporting lower sensitivity.

The $SWAS_G$ in Figure 1 shows the distribution of the geologic sensitivity. Wells without an accurate well drilling record were rated as “high sensitivity” unless the LHD staff had information supporting lower sensitivity. Figure 2 shows the distribution of scores of wells with records.

FIGURE 1

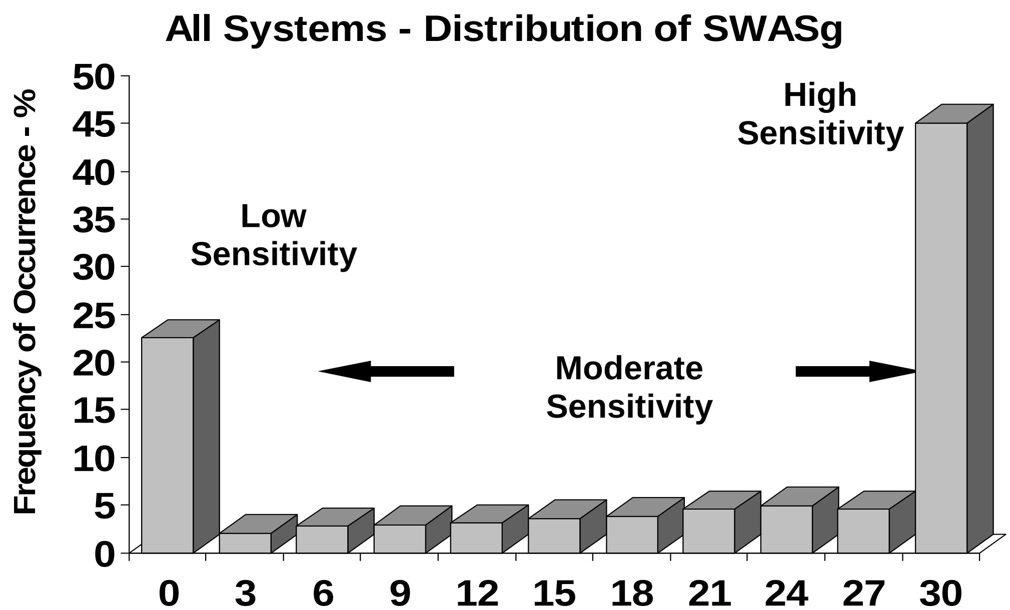
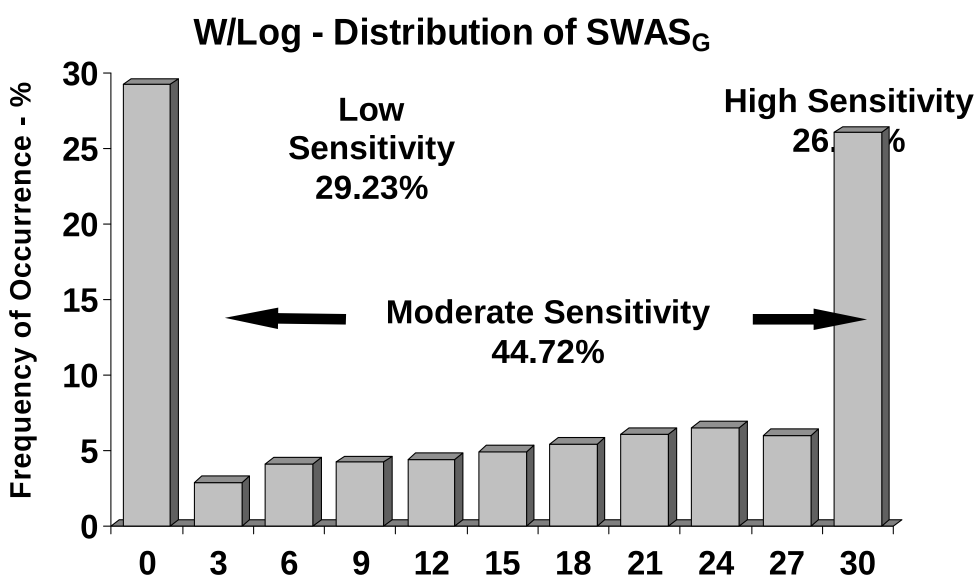
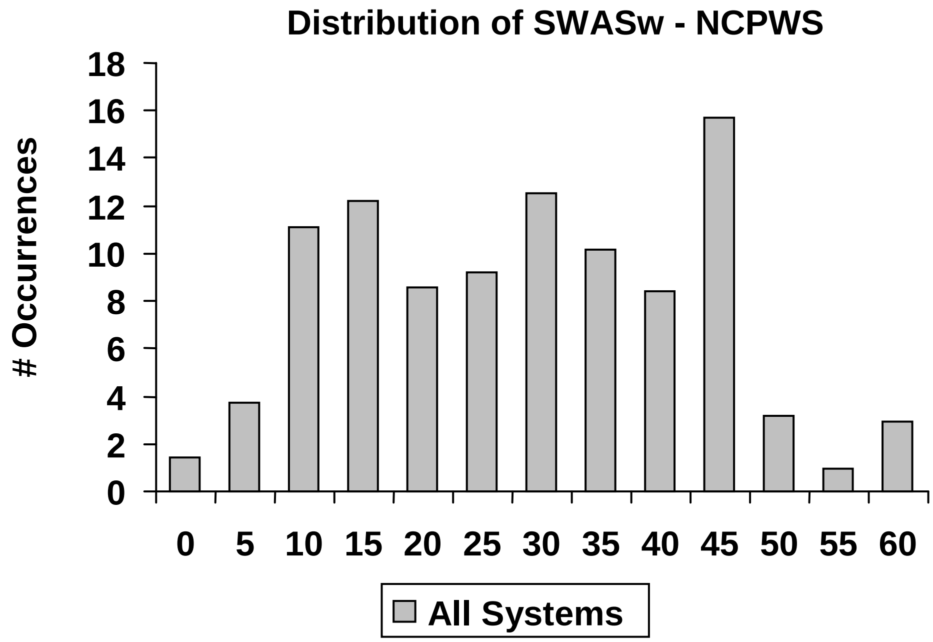


FIGURE 2



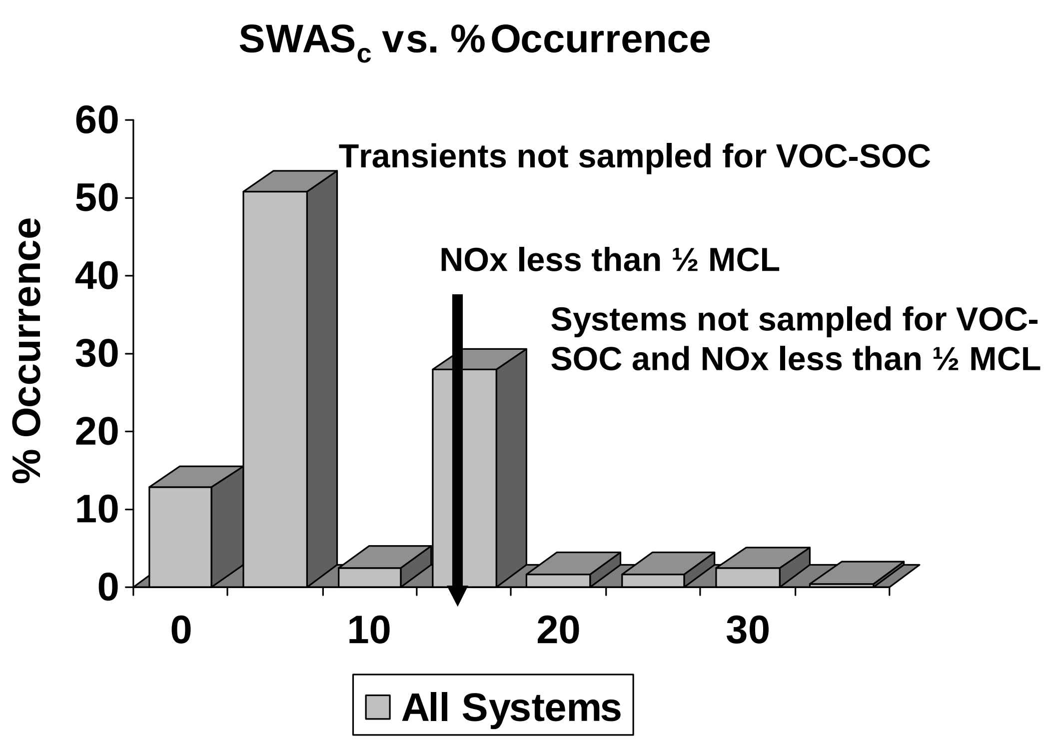
The $SWAS_W$ in Figure 3 shows the distribution of scores for well construction, including evaluation of well grouting, age of wells, casing depth, and pumping rates. This distribution is also impacted by lack of data. Much of this information is determined from the well drilling record. Note that the peak of scores is at 45. This score would result from no well drilling record and no supplemental data available.

FIGURE 3



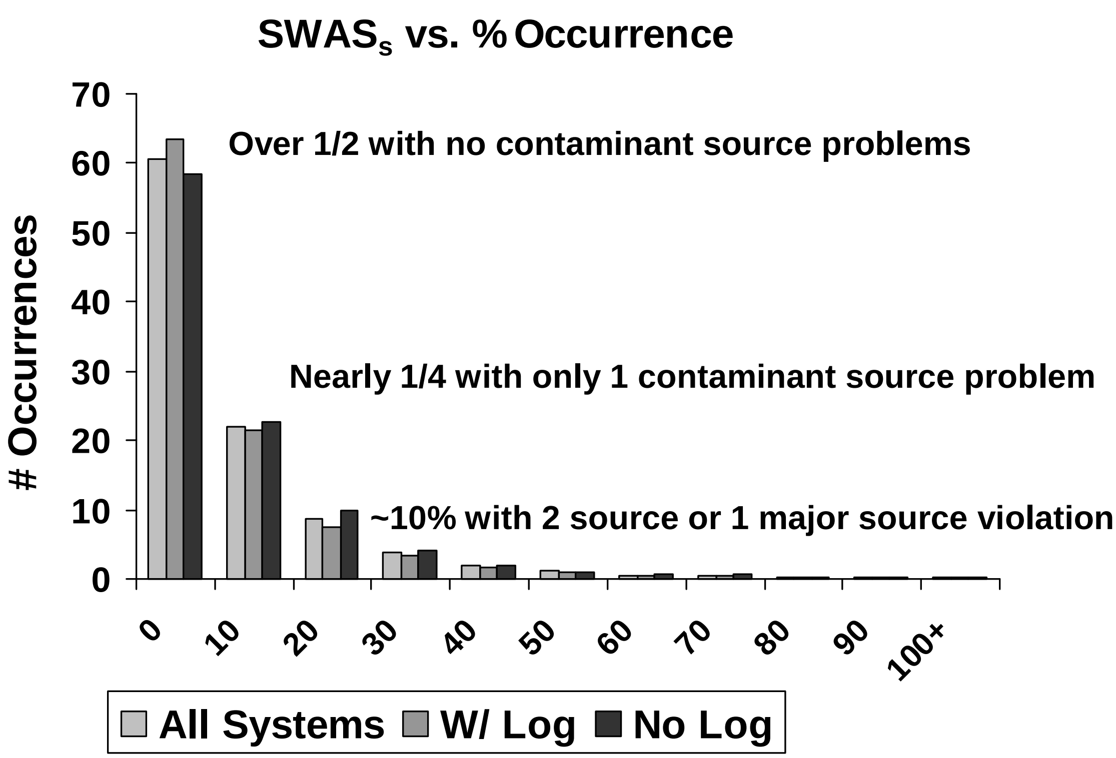
The $SWAS_C$ in Figure 4 shows the distribution of the scores from detection of VOC, SOC, Nitrates, and Nitrites.

FIGURE 4



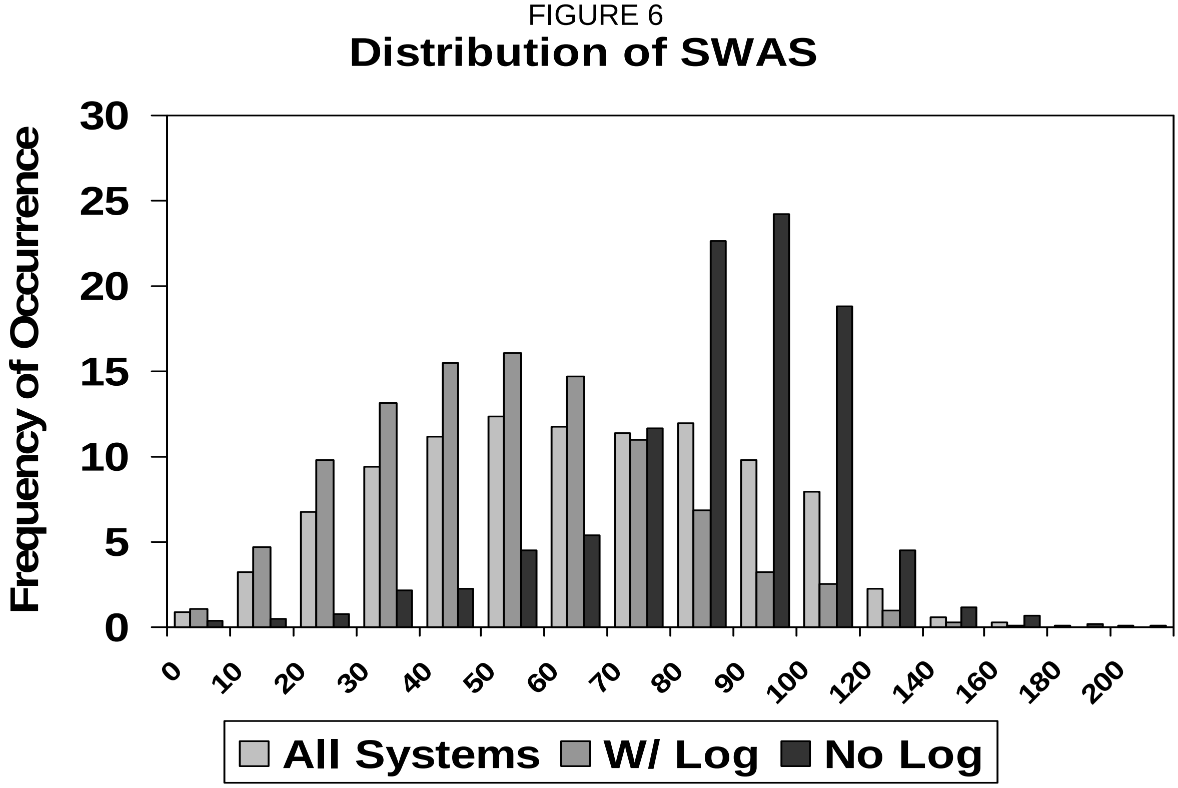
The $SWAS_S$ in Figure 5 shows the distribution of scores from well separation from potential or known sources of contamination.

FIGURE 5



The distribution of SWA scores is shown in Figure 6. Note the concentration of higher scores of wells with no records. The distribution of source water assessment scores of all wells is shown in Figure 6.

FIGURE 6



The "weighting" of each component of the scores were:

- Well Construction provides 44.8 percent of the score
- Chemical History represents 13.5 percent of the score
- Geology contributes 29.5 percent of the score
- Contamination Sources is 12.2 percent of the score

The susceptibility was determined using a susceptibly flow diagram (Figure 7). Karst Hydrologic Systems were assigned "Very High" susceptibility. Figure 7 shows the significance of not having a well drilling record on the distribution of susceptibility, with a significantly higher percentage of no record systems classified as "Moderately High" or "High." The distribution of scores for all systems is shown in Figure 8. The final analysis shows an excellent distribution of scores, providing clear distinctions of systems needing priority.

FIGURE 7

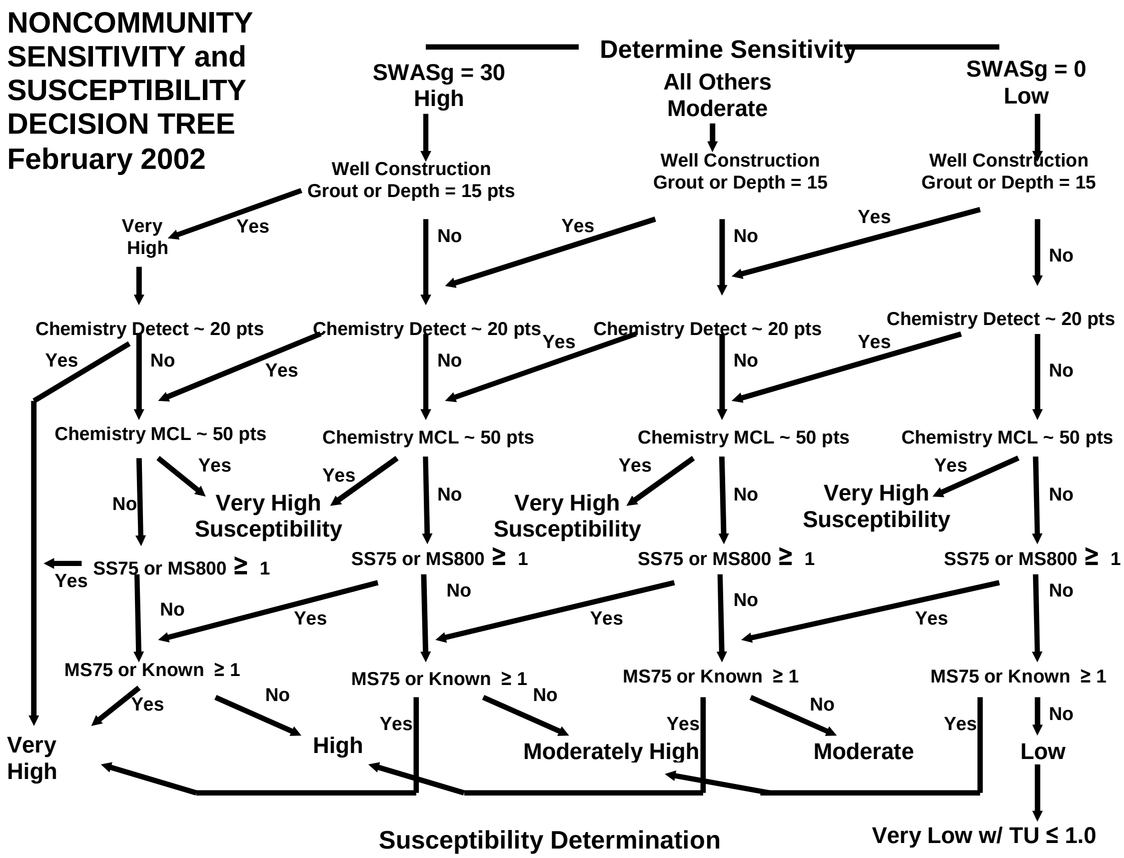
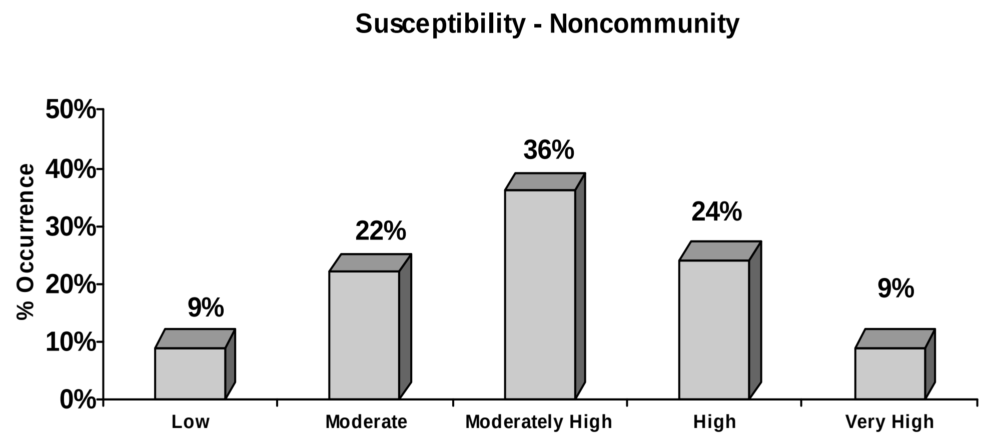


FIGURE 8



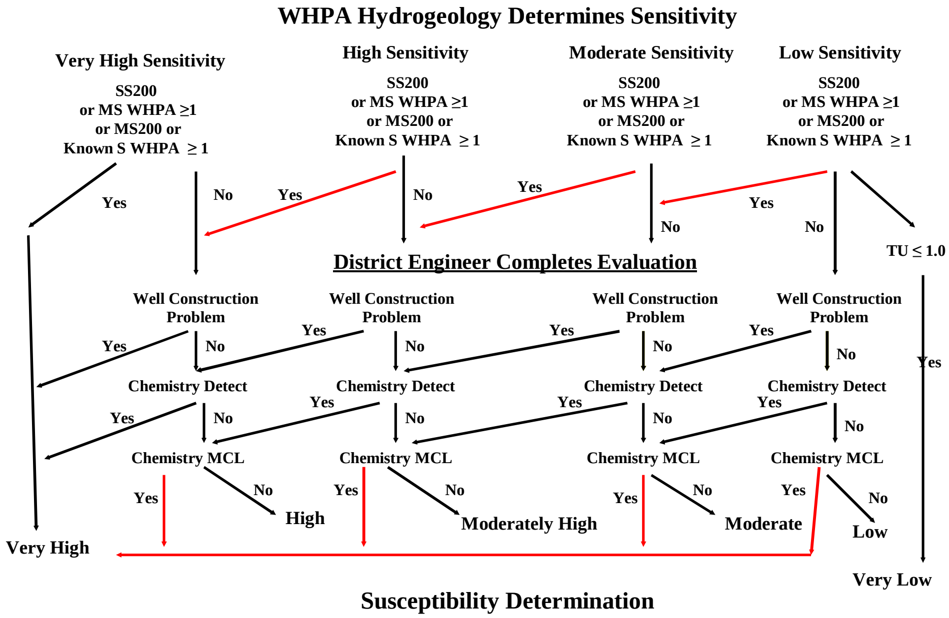
The MDEQ and LHDs provided narrative summaries of the assessments by direct mailings to the public water suppliers following a comparative analysis of the data and then completion of the assessment. Copies were sent to LHDs. An example of the Assessment Report and letter sent is included as Appendix D.

CHAPTER 3 – COMMUNITY PUBLIC WATER SUPPLY GROUNDWATER ASSESSMENTS

For communities with an approved WHPP, the geologic sensitivity was determined from data derived from WHPA delineation reports. Potential sources of contamination were derived from the WHPP report. Susceptibility was defined using the flow chart below. These communities, which have taken an active role in protecting their water supply, were sent a letter summarizing the results of the assessments. This letter emphasized the importance of remaining active with wellhead protection efforts and provided staff of the Wellhead Protection Unit and Michigan Rural Water the opportunity to follow up with community leaders on the status of their program. See Appendix H for an example.

Figure 9

WHPP COMMUNITY SENSITIVITY and SUSCEPTIBILITY DECISION TREE - November 2002



For communities with approved delineations, but no program approval, the potential sources of contamination were identified in the WHPA. The assessments were completed and analyzed as a separate group. Letters to these communities encouraged completion of the wellhead program to help provide protection of the source of their water supply.

The community groundwater systems without WHPPs were completed using state staff or a third party contractor. The assessments on these remaining small systems are similar to those conducted for the noncommunity systems. Source water assessments were performed on CPWS throughout the state that did not participate in wellhead protection. The assessment form used is provided in Appendix H. The source water assessments were completed meeting the following objectives:

- Accurately establish, through the use of a GPS and GIS, the location of CPWS wells.
- Provide for the entry of well drilling records into an electronic data management system.
- Identify the location and proximity of sources of contamination located within 2,000 feet of CPWS wells.
- Establish a SWAS that reflects the “inherent vulnerability” of the CPWS well and source water, assessing the integrity of the well and the geologic setting.

The GPS location and well record information were compiled and incorporated into the statewide GIS for use in the analysis of information and the presentation to the public. Through GIS the results can

be used in protection efforts for public water supplies and also be used to focus groundwater protection efforts for private water supply wells.
In addition to the GPS/GIS phases of the source water assessment, the vulnerability of CPWS wells were evaluated by determining a SWAS. The SWAS has been created as a numeric system that assigns points for situations that represent a "perceived risk" based upon the evaluation of four criteria. The evaluation criteria provide a "qualitative assessment" of groundwater movement and the potential for movement of contaminants into the subsurface. The SWAS is based upon evaluation of the following:

1. The geologic sensitivity of the CPWS well.
2. The construction, maintenance, and use of the CPWS well.
3. Chemistry and/or isotope data from the CPWS well water.
4. Isolation and control of the CPWS well from sources of contamination.

The criteria are evaluated in a manner such that a higher SWAS is equated to a greater perceived risk for the CPWS source water.

The SWAS system has been developed cooperatively among the Environmental Health, Groundwater, and Field Operations Sections within the Water Division, MDEQ. Staff from these sections may utilize the SWAS to assign monitoring requirements and identify CPWSs that should receive follow-up activities.

The SWAS system is based upon the accumulation of points for situations that represent a perceived risk to the CPWS source water. The SWAS is derived from a sum of a geologic sensitivity score ($SWAS_G$); a well construction score ($SWAS_W$); a score for chemistry and isotope data ($SWAS_C$); and isolation and control from sources of contamination score ($SWAS_S$).

Geologic Sensitivity - $SWAS_G$ - The $SWAS_G$ is factored into the SWAS based on the total thickness of Continuous Confining Material (CCM) such as clay, clay-rich till, or shale penetrated in construction of the CPWS well; or the total thickness of Continuous Partially Confining Material (CPCM) such as a mixture of sand and clay or sandstone and shale. The total thickness of CCM and CPCM should be determined from the well record for the CPWS well. Where a well drilling record is not available, well drilling records from adjacent wells or test hole borings may be used. Geologic maps (i.e., lithologic cross-sections) may also be used if they provide adequate coverage of the area in which the CPWS well is located.

Well Construction - $SWAS_W$ - The design, physical condition, and operation of a CPWS well may allow the entrance of contaminants into the well despite a high level of intrinsic geologic protection. To account for this possibility, the SWAS is assigned points through the $SWAS_W$ based upon four criteria related to the construction and use of the CPWS wells. The $SWAS_W$ is assessed points based upon well grouting, the age of the well, the casing depth, and the pumping rate of the well.

Water Chemistry and Isotope Data - $SWAS_C$ - Water chemistry data provides a refinement to the SWAS through the $SWAS_C$ that may increase or decrease the SWAS. As examples, the presence of nitrates, nitrites, volatile organic compounds, or synthetic organic compounds, even at low levels, regulated inorganic chemicals and regulated radionuclides are indicators of source water vulnerability and increase the SWAS; the absence of tritium in the source water indicates the source water is old and not vulnerable, thereby decreasing the SWAS. Review of chemical monitoring records should go back 5 years or more if appropriate. SWASc cannot be less than 0 when tritium is less than 1 tritium unit.

Isolation from Sources of Contamination - $SWAS_S$ - *Isolation from Standard and Major Sources -* The isolation of a CPWS well from sources of contamination is an important criterion in the source water assessment. The maintenance and control of isolation distances can significantly reduce the perceived risk associated with the use of a well. The $SWAS_S$ is assessed points for failure to maintain and/or control adequate isolation between “potential” sources of contamination and “known” sources of contamination. Known sources of contamination include those sources where the groundwater has been impacted as a leaking underground storage tank or other sites of environmental contamination.

Control of Standard Isolation Area - The Michigan Safe Drinking Water Act requires a CPWS to own or control through a lease or easement the defined isolation area around each well. Failure to own or properly control this area affects the future vulnerability of the well.

Community public water supplies that do not participate in wellhead protection were assessed similar to noncommunity groundwater supplies. These supplies were mainly mobile home parks, nursing homes, condominiums, apartments, subdivisions, small community systems, and correctional facilities. These assessments considered regulated contaminants and isolation areas defined by the Michigan SDWA. The assessment area was a 200 foot radius for standard contaminants (sewers, surface water, fuel storage, etc.) and 2,000 feet for major contamination sources (large scale wastewater disposal, landfills, chemical disposal or storage, etc.)

A numerical scoring system, similar to the noncommunity assessments, was used to compile raw data reflecting area geology, well construction, contaminant sources, and water quality. This data was analyzed, then adjusted to reflect assessments that are most useful for prioritizing protection efforts.

An analysis of the scores has been completed. If necessary data was not available, the assumption was made for the “worst-case,” resulting in higher assigned susceptibility of the supply. Information and knowledge from DEQ district staff or the supply owner could be used to make adjustment to the scores.

The susceptibility was determined using a susceptibly flow diagram (Figure 9). Karst Hydrologic Systems were assigned “very high” susceptibility.

The MDEQ provided narrative summaries of the assessments by direct mailings to the public water suppliers following a comparative analysis of the data and then completion of the assessment. An example of the assessment report and letter sent is included as Appendix G. A comparative analysis was conducted to assure uniformity in the assessments completed. In addition, hydrogeological sensitivity and susceptibility determinations were summarized.

The $SWAS_G$ in Figure 10 shows the distribution of scores for the geologic sensitivity. Wells without an available well drilling record were rated as “high sensitivity” unless the district engineer had information supporting lower sensitivity.

Figure 10

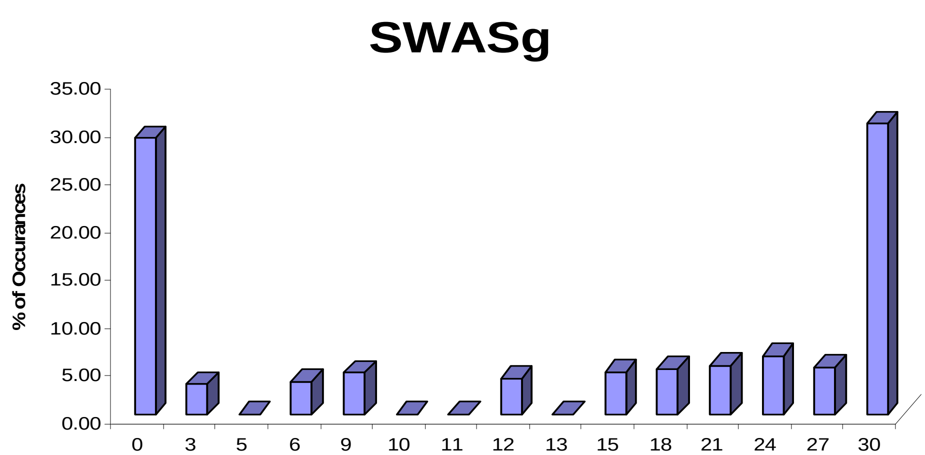


Figure 10: Percent occurrence of geologic sensitivity.

The $SWAS_W$ in Figure 11 shows the distribution of scores for well construction, including evaluation of well grouting, age of well, casing depth, and pumping rates. Figure 11 also shows the distribution of $SWAS_C$ scores from detects of VOC, SOC, Nitrites, and Nitrates.

Figure 11

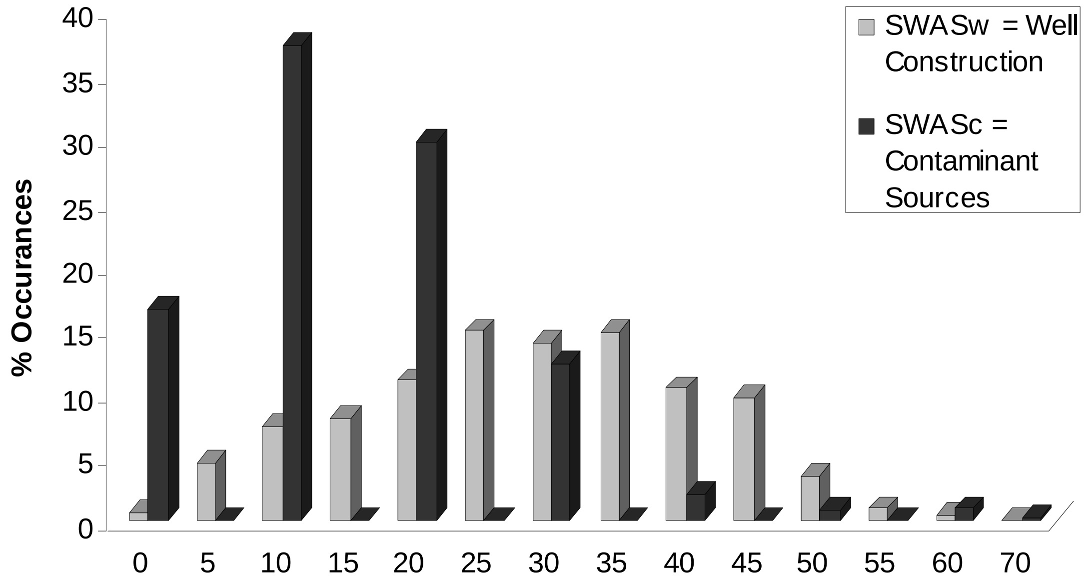
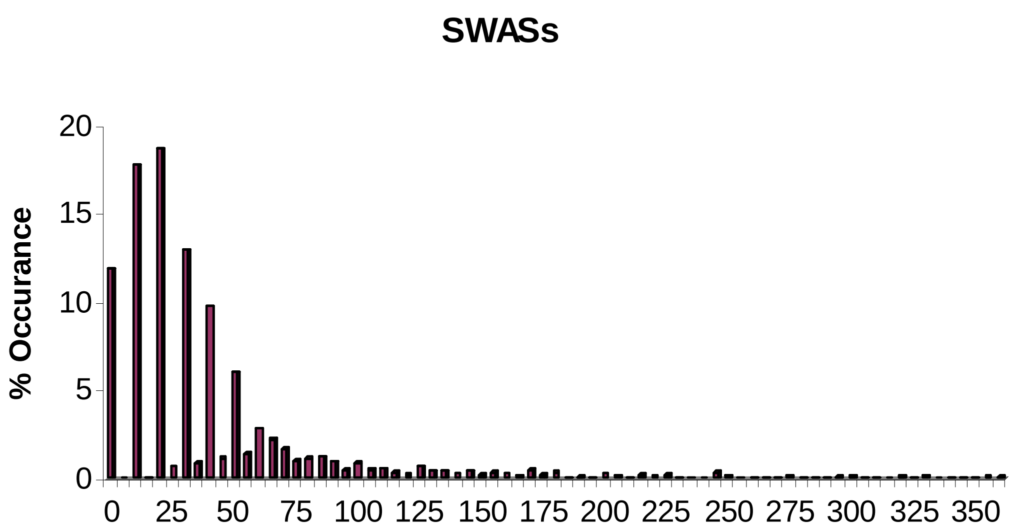


Figure 11: Percent occurrence of the well construction scores and contaminate sources.

The $SWAS_S$ in Figure 12 shows the distribution of scores from well separation from potential or known sources of contamination.

Figure 12



The total SWAS scores are shown in Figure 13. The high values are the result of numerous existing potential sources of contamination within the source water assessment area. The distribution is shown in Figure 13. The final analysis shows an excellent distribution of scores, providing clear distinctions of systems needing priority.

Figure 13

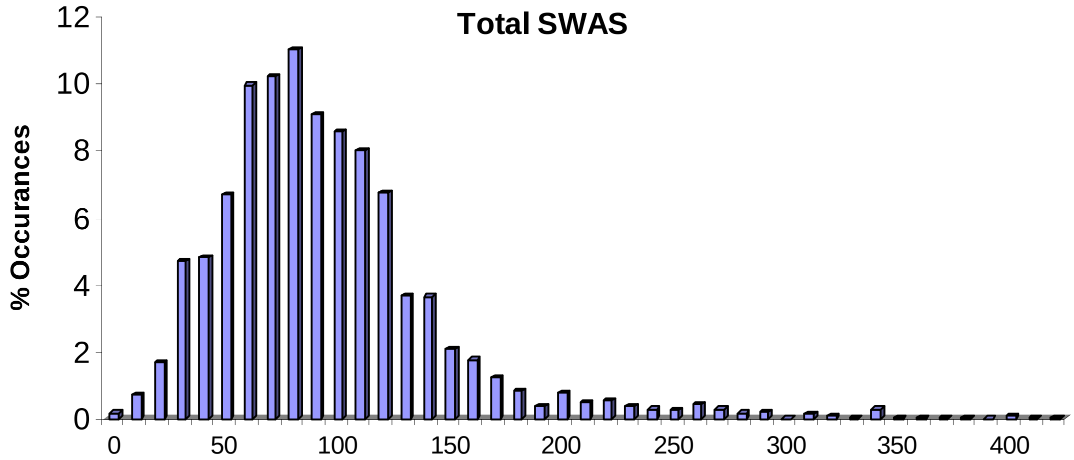


Figure 13: Total SWAS scores.

Figure 14

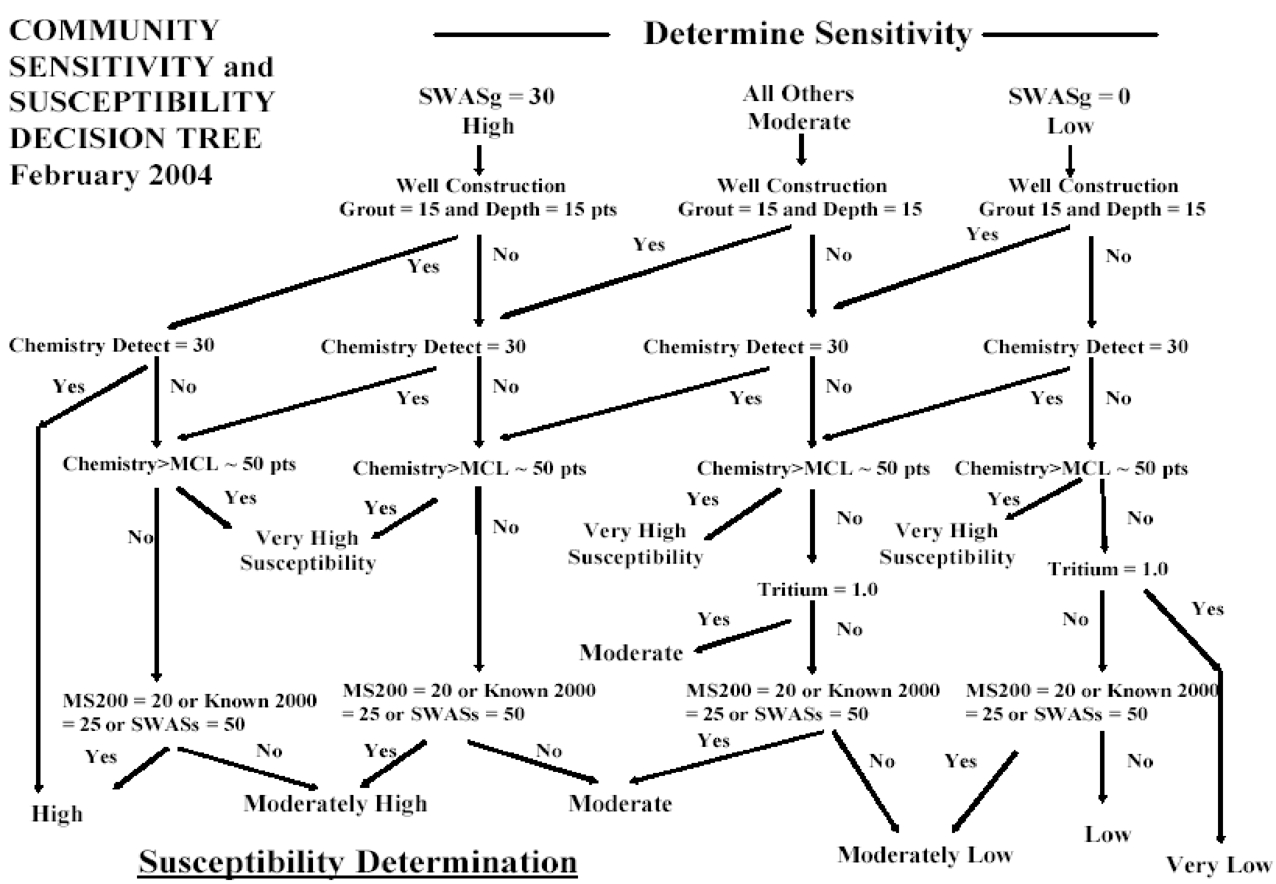
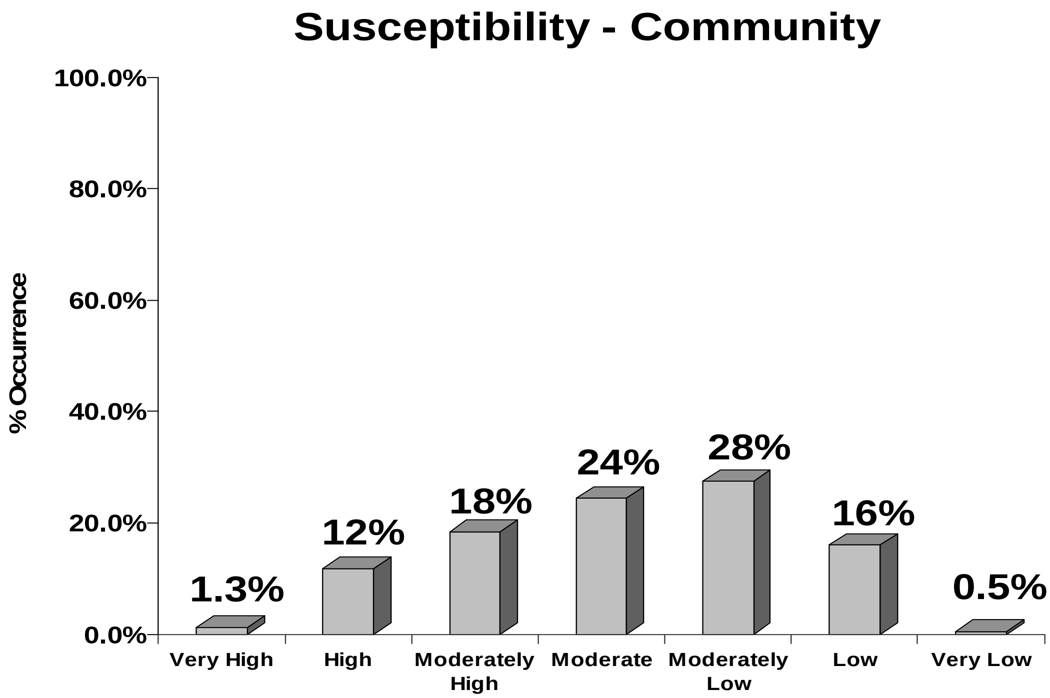


Figure 15


Susceptibility - Community
% Occurrence
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1.3%
12%
18%
24%
28%
16%
0.5%
Very High
High
Moderately High
Moderate
Moderately Low
Low
Very Low

CHAPTER 4 – PUBLIC WATER SUPPLY SURFACE WATER INTAKE ASSESSMENTS

The MDEQ and the USGS implemented the SWAP in Michigan by assessing 58 community and 2 noncommunity surface water supply sources within the state (Appendix M). 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 initially completed for each of the three surface water intake types. 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 57 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 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 (51 sources) follow the "Assessment Protocol for Great Lakes Sources" http://www.michigan.gov/documents/DEQ-swap99_4707_.pdf, Appendix I 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 included in a two-dimensional hydrodynamic flow model of the St. Clair River–Lake St. Clair–Detroit River waterway (Appendix J). The flow model was used 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, developed this model. The American Water Works Association Research Foundation is supporting the partnership to enhance the contaminant-tracking model capabilities.

Assessment methods evolved as the concept was developed and different approaches were used for different surface-water supply types. 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) was sent to 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.

The data was entered into a GIS database using USEPA's Better Assessment Science Integrating point and Nonpoint Sources (BASINS) program (USEPA, 1997a; 1997b; 1998) upon completion of the meeting. The data was analyzed for correlation of water-quality parameters with atmospheric conditions, lake currents, discharge magnitudes, and other variables as appropriate. Additional data was 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 by the USGS 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 30-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 were considered complete after the comment period. Discrepancies noted by the water supplier were resolved to assure acceptance of the assessment by the water supplier.

All surface water, 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.

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.

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 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 channel intakes are similar to inland rivers in that the SWA is readily identified as a part of the watershed upstream of the intake. However, these intakes 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 reevaluated 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. Time-of-travel (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 communication, 2002). The St. Clair River is about 29 miles 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 miles 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 miles 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 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 (Appendix I) and this report worked well in assessing these types of intakes, with some modifications, described below.

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 communication, 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 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 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 are also potentially 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 under certain atmospheric conditions (Sweat and others, 2000b).

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 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 5 and 10 ft below the lake bottom. Sensitivity is not affected by this intake type, but the susceptibility determination improves because of the inherent filtering capacity of this collector type. Surface-water intakes located in Mt. Pleasant, Bridgman, Grand Haven, Ludington, Charlevoix, Lexington, Harbor Beach, and Caseville,, Michigan are examples of surface-water supplies using buried collectors.

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. PWSs are provided copies of the assessment for their supply after MDEQ and USGS complete the assessment. Assessments, titled “Source-Water Assessment Report” for each public surface 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.

The USGS developed general 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 (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 9 (USEPA, 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 was 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 was 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.

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 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 (USEPA, 1997a, 1997b, 1998). Intake location data was 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 10 Terms in courier text identify specific software commands or tools. 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 was developed 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 used in model-simulation to aid in determining travel mechanisms and origins of potential contaminants (American Water Works Association Research Foundation, 2001), and began in September 2003. SWAs and assessments for Great Lakes connecting channel intakes are also redefined.

The Adrian, Michigan intake in Lake Adrian on Wolf Creek is an example of SWA delineation for inland river intakes. The Detroit—Belle Isle intake in the Detroit River is an example of SWA delineation for Great Lakes connecting channel intakes. 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 I), and was delineated for each intake.

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) that determines the CAZ radius, 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). Great Lakes intakes were considered less vulnerable to contamination than inland river intakes and/or inland lake intakes 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 was in the databases. Overlaying USGS DRGs with the water supply intake data facilitated this determination.

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. 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.

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 (Brogren, 1999) and a 300-ft setback from the shores of all perennial tributaries within the SWA. 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.

The susceptible area for Great Lakes intakes is the CAZ, as determined by the intake depth and distance offshore (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. 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 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 (2004), 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.

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 LHDs considered high or moderate risks to drinking water, and that, 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 data base queries and plotting applicable data on a land use map.
3. Creating a soil permeability map for the SWA.
4. Conducting data base 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.

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 an 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 reevaluate 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 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 (VOCs), synthetic organic compounds (SOCs), microorganisms, and petroleum compounds. Contaminant source inventories focused on PCS that are regulated under the SDWA. These inventories included contaminants with an 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 semivolatiles), and aesthetic parameters (such as taste, odor, and color).

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 groundwater, 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. 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 MSU has an extensive collection of aerial photographs in their photogrammetric library (http://ims.rsgis.msu.edu) 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 data bases (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. Data bases 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 F) 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.

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 data base 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 was 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. A summary of PCS, by type, is given for the Alpena, Michigan SWA.

The overall success of each assessment depends upon identifying PCS to public water suppliers so that 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 revisit high-risk activities and land use areas to conduct a more thorough, area specific assessment.

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. Assessments included a map that displayed vertical soil permeability and PCS.

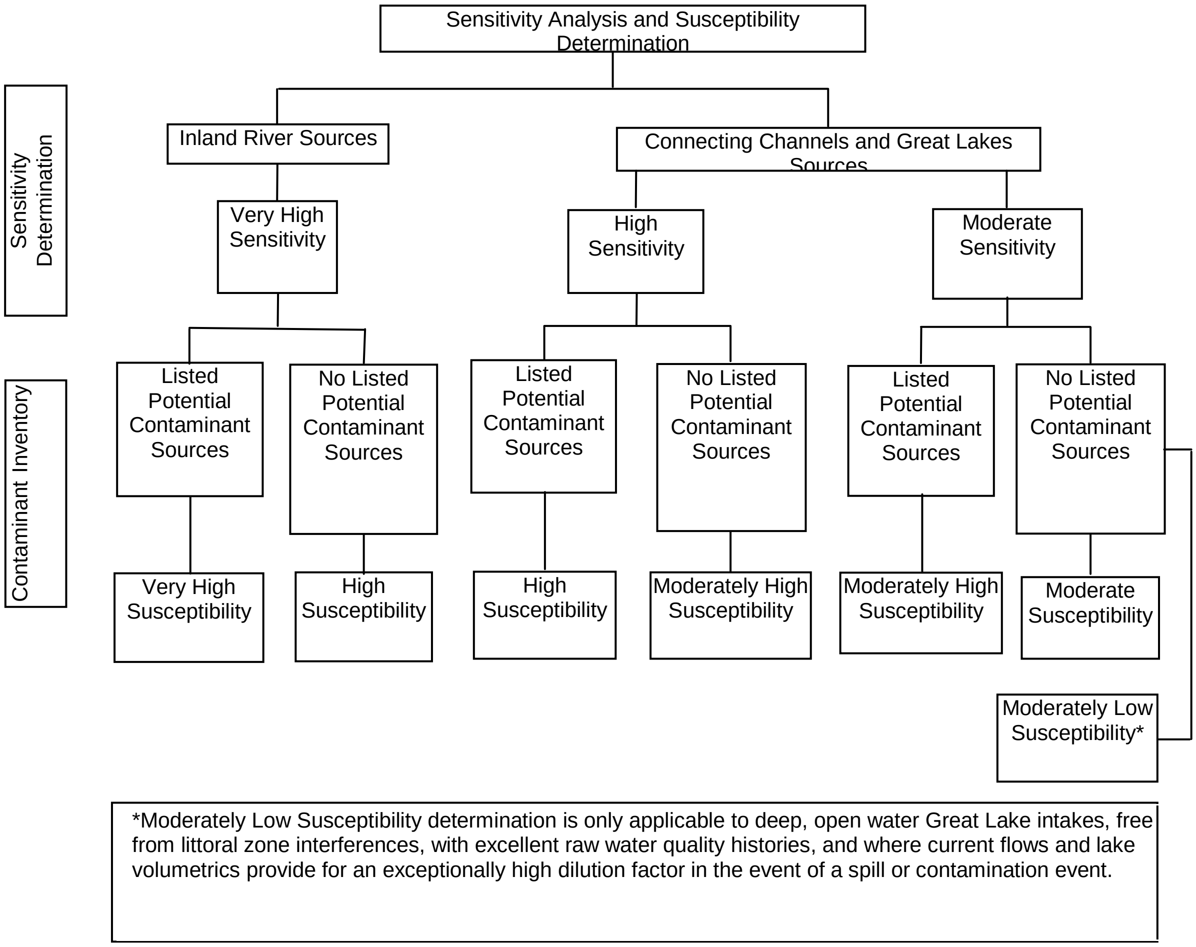
This map was provided to supply the community with information of some of the physical characteristics of the SWA. Soil permeability was based on the calculated TOT, in inches per hour (in/hr), for water to move vertically through a saturated soil zone. Soil thickness and permeability values are available in soil survey reports published by the U.S. Department of Agriculture and National Cooperative Soil Survey (variable dates). Permeability ranged 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 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 in/hour. The soil permeability data was then classified according to National Resources Conservation Service (NRCS) soil reports and overlain with the PCS data. The permeability data was 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 were then 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.

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 along with a table of PCS within the susceptible area, resulted in a susceptibility determination for each intake. The susceptibility determination, along with susceptible area map and table of PCS, provided a basis to begin a source water protection plan.

The following decision tree was used for surface water sources.



Contents of Chapter 3 compiled from U.S. Geological Survey, Water Resources Investigation Report 03-4134; The Michigan Source Water Assessment Program: Methods Used for the Assessment of Surface Water Supplies.

Conclusions

The Safe Drinking Water Act amendments of 1996 required each state to assess the sources for all of its public water supplies. After the passage of the act and once funding was made available, Michigan developed plans and initiated its source water assessment program in early 1998.

Michigan has more noncommunity public water supplies than any other state. Because of the large number of supplies, it was determined early on that the most efficient method for completing the noncommunity assessments would be to conduct them during the required 5-year sanitary survey cycle. Since assessments had to be completed by early 2003, Michigan initiated the program by early 1998. This was done even though final United States Environmental Protection Agency (USEPA) program approval was not received until late 1999.

Michigan had over 10,500 noncommunity systems at the time the assessments were initiated. There were approximately 1,340 community groundwater systems, with only 9 that had approved wellhead protection programs. There were 60 surface water systems. The state contracted with local health departments and Michigan State University (MSU) to assist in completing the noncommunity assessments. The state also contracted with the United States Geological Survey (USGS) to assist in completing the surface water and karst assessments.

The assessment methodology is detailed in the report. The program focused on geology, monitoring history, well construction, and location of potential contaminant sources for the groundwater systems and on intake location, raw water quality, and potential contaminant sources for the surface water systems.

As the program was developed, an advisory committee made up of individuals from utilities, local health departments, universities, local interest groups, and the general public was formed. This advisory committee met regularly during the course of the assessment process. Once the program was completed, the group re-formed as a source water protection advisory committee.

The source water assessment program in Michigan would not have achieved the success it did without the efforts of Bradley Brogren, Source Water Assessment Program manager, and Steve Miller, Wellhead Protection manager, at the state of Michigan. The state is also indebted to the local health departments, the USGS, and MSU.

Michigan is moving forward into a Source Water Protection Program and will focus on obtaining resources to work in this area. After the heavy investment it made in the assessment process, it is hopeful that the USEPA will provide continuing funding for source water protection to follow the source water assessment process. The state hopes to prioritize the assessments as to relative risk to the resource and work on site specific protection efforts. This work is evolving at this time and there are many exciting challenges for the program into the future.