Drinking Water Source Assessment for the City of Toledo

Protecting Ohio's Drinking Water Sources

Ohio EPA

SUMMARY

Source Water Assessment and Protection. The following report for the City of Toledo was compiled as part of the Source Water Assessment and Protection Program for Ohio. This program is intended to identify drinking water protection areas and provide information on how to reduce the risk of contamination of the waters within those areas. The goal of the program is to ensure the long term availability of abundant and safe drinking water for the present and future citizens of Ohio.

The 1996 Amendments to the Safe Drinking Water Act established the national Source Water Assessment and Protection Program, targeting drinking water sources for all public water systems in the United States. A public water system is a facility that provides drinking water to 15 or more service connections or that regularly serves at least 25 people a day for at least 60 days a year, whether from an underground well or spring, or from an above ground stream, lake, or reservoir. The program does not address residential wells or cisterns. In Ohio there are approximately 5,800 public water systems.

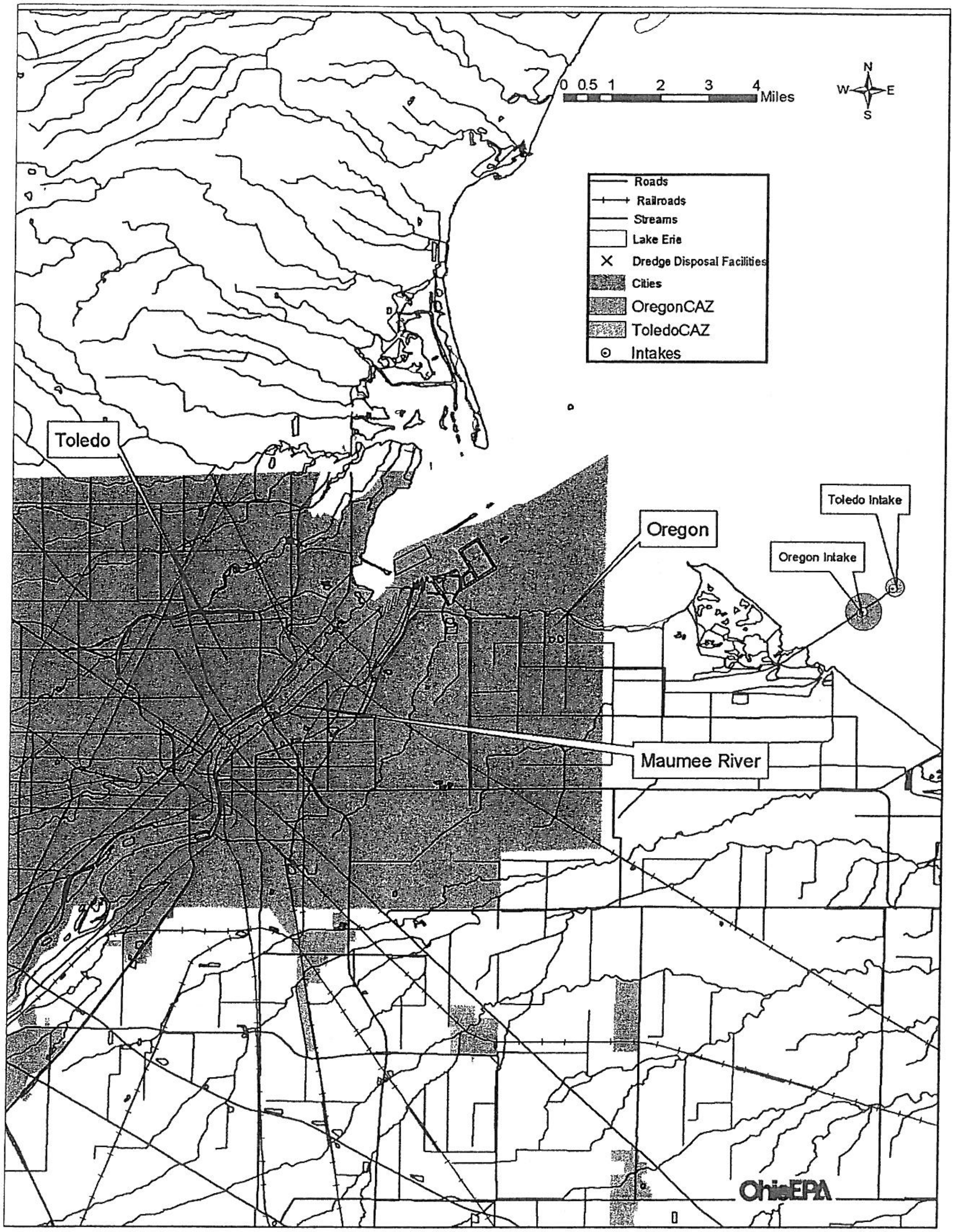
Background. The City of Toledo Public Water System operates a community public water system that serves a population of approximately 454,000 people and has 129,411 service connections. The water treatment system obtains its water from Lake Erie. Total plant design capacity is 181 million gallons per day based on 4gpm/sf filtration loading rate.

Protection Areas. The drinking water source protection area for Toledo is shown in the following figure. Ohio EPA collected and presented on a map electronic database information about the facilities, water activities, and land uses within the SWAP area that potentially could contaminate the drinking water source. Threats to Lake Erie include contamination from municipal sewage treatment plants, industrial wastewater, and home sewage disposal system discharges, air contaminant deposition, combined sewer overflows, runoff from residential, agricultural and urban areas, oil and gas production and mining operations, as well as accidental releases and spills, especially from commercial shipping operations and recreational boating.

Protective Strategies. The ultimate goal of source water assessment is implementation of protective strategies that will better protect the drinking water source. Strategies for protecting the City of Toledo drinking water source, Lake Erie, include an effective and efficient emergency response plan as well as a plan to educate the responsible parties of potential contaminant sources. Continuation of intake monitoring efforts and consultation with U. S. Coast Guard officials regarding response to threats from spills and other sources is recommended. The contingency plan for the water system should be updated as necessary. It is further recommended that a coordinated Lake Erie biological and water quality monitoring system be instituted by state and/or federal agencies.

Future development and a change in land use practices may impact the ecological health of the Lake Erie watershed. This valuable water system should be protected to avoid further degradation of water quality by point and nonpoint sources of pollution such as those listed above. Local watershed planning efforts may also be underway to guide stream restoration and protection activities. These efforts can also serve to increase protection of the drinking water source. Additional management measures are underway for Lake Erie through the Lakewide Management Plan and Remedial Action Plan programs. More information on these programs can be obtained at the Ohio EPA district offices in Bowling Green and Twinsburg.

For More Information. Additional information on protective strategies and how this assessment was completed is included in the detailed Drinking Water Source Assessment Report for the City of Toledo. For information on how to obtain a copy of this report, please visit Ohio EPA's Source Water Assessment and Protection Program Web page at http://www.epa.state.oh.us/ddagw/pdu/swap.html or contact the City of Toledo Public Water System for a copy.
Current information on the quality of the treated water supplied by the Division of Water is available in the Consumer Confidence Report (CCR) for the Toledo Public Water System. The CCR is distributed annually and it reports on detected contaminants and any associated health risks from data collected during the past five years. Consumer Confidence Reports are available from the City of Toledo.



Summary Figure -Location of Toledo and Oregon Intakes

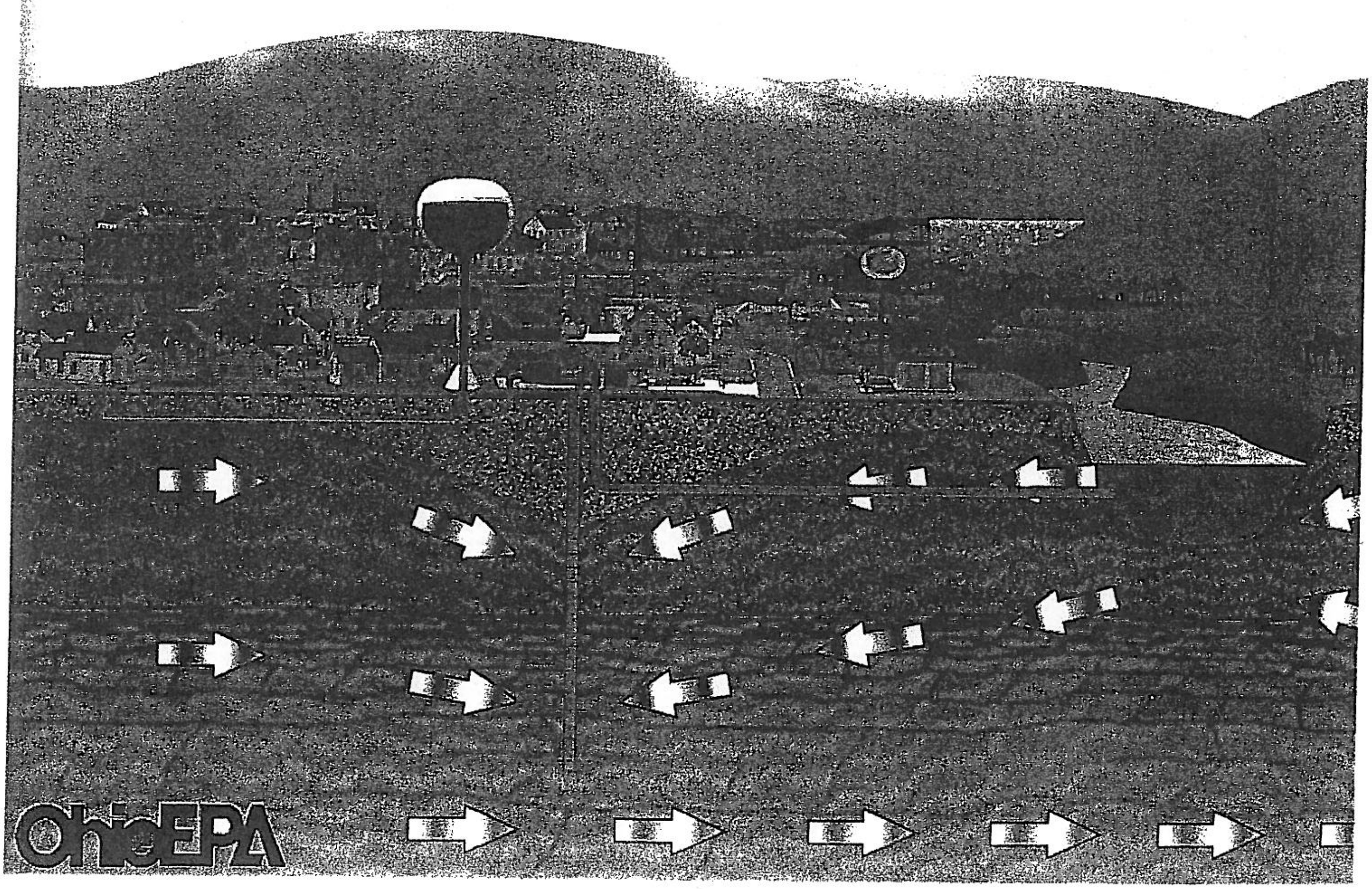
Drinking Water Source Assessment for the City of Toledo

Public Water System # 4801411

Lucas County

Prepared by:
Ohio Environmental Protection Agency
Division of Surface Water
Division of Drinking and Ground Waters
Central Office and Northwest District Offices

August, 2003



How to Use this Assessment

Clean and safe drinking water is essential to every community. Protecting the source of drinking water is a wise and cost effective investment. The purpose of this source water assessment is to provide information your community can use to develop a local Drinking Water Protection Program. The Source Water Assessment benefits your community by providing the following:

A basis for focusing limited resources within the community to protect the drinking water source(s).

The assessment provides your community with information regarding activities within the Drinking Water Source Protection Area that directly affect your water supply source area. It is within this area that a spill or improper use of potential contaminants may cause contaminants to migrate toward the surface water intake. By examining where the source waters are most sensitive to contaminants, and where potential contaminants are located, the assessment illustrates the potential risks that should be addressed first.

A basis for informed decision-making regarding land use within the community.

The assessment provides your community with a significant amount of information regarding where your drinking water comes from (the source) and what the risks are to the quality of that source. This information allows your community planning authorities to make informed decisions regarding proposed land uses within the protection area that are compatible with both your drinking water resource and the vision of growth embraced by your community.

A start to a comprehensive plan for the watershed and source water area.

This assessment can be the beginning of a comprehensive plan for the water resource, and addresses all of the uses the water resource provides. An ecologically healthy lake or stream will provide a stable, high quality resource for drinking water.

For information about developing a local Drinking Water Source Protection Program, please contact the Ohio EPA Division of Drinking and Ground Waters at (614) 644-2752 or visit the Division's web site at http://www.epa.state.oh.us/ddagw/ddagwmain.html.

1.0 INTRODUCTION

The 1996 Amendments to the Safe Drinking Water Act established a program for all states to conduct source water assessments for all public water systems. The Source Water Assessment and Protection Program is designed to help Ohio's public water systems protect their sources of drinking water from becoming contaminated.

The purpose of this assessment is to identify where and how the source water is at risk of contamination. The report:

- Identifies the drinking water source protection area which is comprised of the Critical Assessment Zone (CAZ) and if applicable, the Potential Influence Zone (PIZ);
- Examines the characteristics and water quality of the lake and watershed;
- Identifies potential contaminant sources within the drinking water protection area, and evaluates impacts associated with shipping and dredging operations; and
- Discusses the susceptibility of the source water to contamination

Finally, the report suggests actions that the public water supplier and local communities may take to reduce the risk of contaminating this source of drinking water and ensure the long term availability of abundant and safe drinking water resources.

Results and recommendations presented in this report are based on the information available at the time of publication. Ohio EPA recognizes that additional information may become available in the future that could be used to more accurately determine the drinking water source protection area. Also, changes in land use may occur after Ohio EPA completes the potential contaminant source inventory. This report should be used as a starting point to develop a plan to protect drinking water resources. Ohio EPA is not responsible or liable for interpretations or decisions based on this report.

This report was written by Linda Merchant-Masonbrink and Rich McClay, Ohio EPA, Division of Surface Water, Central Office.

2.0 PUBLIC WATER SYSTEM DESCRIPTION

The City of Toledo operates a community public water system that serves a population of more than 454,000 people and has 129,411 service connections. A community public water system is a system that regularly supplies drinking water from its own sources to at least 15 service connections used by year-round residents of the area or regularly serves 25 or more people throughout the entire year.

Surface water from Lake Erie is used as source water for the treatment plant. The two story water intake was constructed in 1942 after a three-year study by Greely and Hanson of Chicago. The intake was located out of the normal flow of the Maumee River and is usually out of the Detroit River flow to the north.

Integrity of the intake structure is inspected in the spring of each year. The present water treatment plant has a capacity of 181 million gallons per day based on 4gpm/sf filtration loading rate. The average daily production is 80 million gallons per day (winter) and 140 million gallons per day (summer). The system has 70 million gallons of finished water storage at the plant and 10.5 million gallons of ground storage in the distribution system. Processes include lime softening, sedimentation, filtration, fluoridation, coagulation, flocculation, stabilization and disinfection prior to distribution.

Distribution systems can be connected at six points. The Toledo water line, which is separate from the Oregon line, is a 108-inch pipe and extends 3 miles from Lake Erie to the low service pumps.

In 2001, water system improvements included rebuilding the two Low Service (Raw Water) Pumps and improvements to the High Service (Treated Water) Pumps. In addition, 30 filters were equipped with a low-level turbidimeter to measure clarity of filtered water. (Toledo Water Quality Report)

3.0 DELINEATION OF PROTECTION AREAS

The drainage area upstream of the point where the water is withdrawn from a surface source and within the Critical Assessment Zone (CAZ) is defined as the source water assessment and protection area (SWAP area). The SWAP area includes the Potential Influence Zone (PIZ) which is an area along any contributing tributaries and the length of shoreline that intercepts or is opposite the CAZ which includes some of the potential pollutant sources that may impact the intake.

To provide some continuity for assessing the Great Lakes intakes, the concept of a CAZ around each intake was developed. The two factors used for this zone which effect the sensitivity of Great Lakes intakes are the perpendicular distance from shore or length of the intake pipeline (L) in feet and the water depth (D) of the structure in feet. The shallower, near shore intakes are more sensitive to shoreline influences than the offshore, deep intakes. The factor for sensitivity (S) can be calculated by the formula: LxD=S. Generally, S values less than 25,000 represent highly sensitive intakes while S values greater than 125,000 indicate lower sensitivities.

The perpendicular distance from shore and the depth of the intakes based on 1985 low water datum and measured from the top of the bell is 15.2 feet at 569.2 IGLD 1985. The perpendicular length from shore is 10,700 feet. Based on this formula, the sensitivity of the Toledo intake was calculated to be low (162,640), and the CAZ was determined to be a circle with a 1,000 foot radius around the intake. See Figure 1 for the location and delineation of the CAZ for the Toledo and Oregon Public Water Supplies.

A Potential Influence Zone (PIZ) was not delineated for the Toledo and Oregon intakes. It was determined that a map illustrating the general concentration of potential pollutant sources in the Toledo and Oregon area and a land use map showing percentage of agricultural land in the watersheds draining to Lake Erie would best describe the sources of potential pollutant impact (See Figures 2 and 5).

The intake's degree of sensitivity combined with information obtained from the survey form and local data such as intake construction, lake bottom characteristics, localized flow patterns, thermal effects and benthic nepheloid layers can be used to complete a sensitivity analysis. The benthic nepheloid layer is a zone of suspended sediment kept suspended by the interactions of current and sedimentation. The layer's characteristics around an intake depend on sediment density, water temperature, bottom currents and animal activity.

4.0 HYDROLOGIC SETTING

Water Quality Monitoring

Available chemical and biological water quality data collected from the SWAP area *(CAZ)*, and sampling results from finished water reported to Ohio EPA by the public water system were screened for possible water quality impacts. For the purposes of the Source Water Assessment and Protection program, a water quality impact is defined as a sampling result that exceeds an established concentration of concern. For synthetic organic compounds (SOCs) and volatile organic compounds (VOCs), a water quality impact is defined as any value at or above the level of detection, since the presence of these compounds usually indicates a human source. For nitrates, a water quality impact is defined as 2.0 milligrams per liter (mg/l) or greater. The drinking water standard, or the Maximum Contaminant Level (MCL) for nitrates is 10 mg/l. For metals and contaminants other than SOCs, VOCs or nitrates, the concentration of concern is 50 percent of the MCL for the contaminant.

A review of the Toledo Public Water System compliance monitoring data from 1991-2002 revealed no MCL exceedences for the parameters listed in Table 1.

Table 1. Water Quality Monitoring Summary of Treated Water City of Toledo Public Water System

Ohio EPA Public Water System Compliance Monitoring Database (1991- 2002)

Contaminant (units)	Levels Found	Primary MCL	Exceeds MCL [1]	Typical Source
Inorganic Contaminants				
Barium (mg/l)	0.008 - 0.021	2	No	Discharge of drilling wastes; Discharge from metal refineries; Erosion of natural deposits
Fluoride (mg/l)	0.83 - 1.30	4	No	Erosion of natural deposits; Water additive which promotes strong teeth; Discharge from fertilizer and aluminum factories
Mercury [inorganic] (µg/l)	0.2 - 0.3	2	No	Erosion of natural deposits; Discharge from refineries and factories; Runoff from landfills; Runoff from crop land
Nickel (µg/l)	11.0 - 16.0	100	No	Erosion of natural deposits; Discharge from electroplating, stainless steel, and alloy products; Mining and refining operations.
Nitrate (mg/l)	0.2 - 5.8	10	No	Runoff from fertilizer use; Leaching from septic tanks, sewage; Erosion of natural deposits
Nitrite (mg/l)	0.010 - 0.028	none	NA[2]	Runoff from fertilizer use; Leaching from septic tanks, sewage; Erosion of natural deposits
Phosphorus (mg/l)	0.02 - 0.25	none	NA	Runoff from fertilizer use; Leaching from septic tanks, sewage; Erosion of natural deposits; Discharge of industrial waste
Sulfate (mg/l)	14.0 - 32.0	none	NA[2]	Erosion of natural deposits; decomposition product of organic matter; discharge from mining and industrial waters; detergents in sewage; component of precipitation in metropolitan areas
Synthetic Organic Contaminants including Pesticides and Herbicides				

Table 1. Water Quality Monitoring Summary of Treated Water City of Toledo Public Water System

Ohio EPA Public Water System Compliance Monitoring Database (1991- 2002)

Contaminant (units)	Levels Found	Primary MCL	Exceeds MCL [1]	Typical Source
Atrazine (µg/l)	0.19 - 1.3	3	No	Herbicide runoff
Radioactive Contaminants				
Beta/photon emitters (pCi/L)	4.4	AL=15	No	Decay of natural and man-made deposits
Volatile Organic Contaminants				
TTHMs [Total Trihalomethanes] (µg/l)	1.8 - 109	80	No[3]	By-product of drinking water chlorination
Bromodichloromethane (µg/l)	10.0 - 16.6	none	NA[3]	By-product of drinking water chlorination
Chloroform (µg/l)	29.0 - 88.9	none	NA[3]	By-product of drinking water chlorination
Bromoform (µg/l)	0.5 - 1.3	none	NA[3]	By-product of drinking water chlorination
Dibromochloromethane (µg/l)	1.0 - 7.5	none	NA[3]	By-product of drinking water chlorination
Dibromoacetic Acid (µg/l)	1.5	none	NA[3]	By-product of drinking water chlorination
Dichloroacetic Acid (µg/l)	6.7 - 11.1	none	NA[3]	By-product of drinking water chlorination
Trichloroacetic Acid (µg/l)	1.5 - 2.8	none	NA[3]	By-product of drinking water chlorination

MCL = Maximum Contaminant Level (AL = Action Level).

MFL = Millions of fibers per liter

[1] MCL set by federal or state drinking water standards. A sampling result that exceeds the MCL value does not necessarily indicate a violation by the public water system. MCL violations for many contaminants are based on a running annual average.

[2] Secondary Maximum Contaminant Level (SMCL) for this parameter. SMCLs are non-health-related limits.

[3] Total Trihalomethanes (TTHMs): (MCL = 0.80 mg/l) calculated as the sum of the concentrations of Bromodichloromethane, Dibromochloromethane, Bromoform, and Chloroform.

Five Haloacetic Acids (HAA5): (MCL = 0.060 mg/l) calculated as the sum of the concentrations of Monochloroacetic acid, Dichloroacetic acid, Trichloroacetic acid, Monobromoacetic acid, and Dibromoacetic acid.

It should also be recognized that sampling results presented in this report can only provide information on the quality of the water at the time the sample was collected. Water quality may change over time due to a number of reasons.

There are a number of organizations and entities that are involved in water quality monitoring in the western basin. These include the Lake Erie Research Center, Franz Theodore Stone Laboratory, Maumee RAP, Ohio Department of Health, Ohio EPA Northwest District Office, U.S. Army Corps of Engineers, Toledo Environmental Services, Toledo Edison, Limnotech and Davis Bessie Power Plant.

In addition, the U.S. Coast Guard has developed the Western Lake Erie Contingency Plan and has recently updated this information. Lucas County EMA has developed the All Hazards Plan to address spills and meets bimonthly with Ohio EPA. The Toledo Mutual Assistance Association (TMAA) meets quarterly since the 1960s to address issues related to refineries, pipeline and major industry. The police chief and the fire chief attend the quarterly meetings.

Biological and Chemical Monitoring

Fluctuations of raw water quality have been observed by the Public Water System during certain months of the year, during certain weather events and human activities. Water quality is at its worst when winds originate out of the northeast and improved water quality is observed in the winter during icing conditions. There is an increase in nitrates associated with agricultural runoff in the spring and occasional problems with algal blooms due to nutrient and phosphorus loading of the lake from the Maumee River and along the shoreline. This is related to zebra mussel colonization in the lake (DuPage Water Commission). Blue-green algae is detected in the fall, diatom flagellates and green algae in the spring, and actinomycetes in late July which may result in an earthy or musty odor at very low levels (DuPage Water Commission - Glossary). Algae problems are predicted when lake pH rises to 8.0-8.1. Activated carbon and potassium permanganate is used through the chemical feed lines to clear up algae problems.

Problems with Zebra Mussels have also been experienced in the CAZ at the intake. Diesel generated feeders inject potassium permanganate into the bell from May to late September to remove the mussels and to keep the intake flow clear. Non-indigenous species such as the Zebra Mussel are a real concern for the plant operators.

Fine suspended sediments are frequently encountered in the CAZ and is associated with a high sediment load from the Maumee River, and may be associated with dredge spoiling activities immediately to the east of the Toledo and Oregon intakes. In addition, higher turbidity is experienced around late November when a lake turnover is experienced in the eutrophic western basin.

A significant amount of sediment from agricultural activities is delivered to the lower Maumee River and Bay which necessitates the dredging of between 900,000 - 1,000,000 cubic yards of material to maintain navigational clearance for shipping and recreational boating. About half of the dredged material is returned to the lake. A significant amount of sediment load stays in the near shore area and travels from west to east toward and around the intakes. The finer grain material stays in the water column for a longer period of time and may be causing some of the turbidity problems at the intake, including when open-water dredge spoiling takes place to the east of the intake. Extra flocculation using alum and lime is periodically used to reduce the turbidity. The U.S. Army Corps of Engineers routinely notifies the Toledo Public Water System when dredge spoiling operations will occur near the intake so turbidity levels can be closely monitored.

Icing conditions are also a concern at the intake. If ice and zebra mussels block the intake, the Toledo Public Water System plans to clear the line by back flushing. A bubbler is used to relieve icing conditions. Also, in the early spring every 6-7 years, the Public Water System has observed that when there is a quick ice melt in the Maumee River, there is an export of decaying organic material that affects the intake. During this week long event, it is necessary to closely monitor chlorine levels to ensure adequate chlorination.

5.0 POTENTIAL CONTAMINANT SOURCES

A review of available regulated facility databases indicates that there are numerous potential contaminant sources in the Toledo and Oregon area and within watersheds that drain to the Maumee Bay which could potentially affect the Toledo and Oregon intakes. There are no potential pollutant sources within the Toledo and Oregon CAZs. A table was prepared and submitted to the City of Toledo Public Water System providing a list of the identified potential contaminant sources in the Toledo and Oregon area as identified in Figure 2. Please contact the Toledo Public Water System for a copy.

It is important to note that this inventory represents potential contaminant sources, and not actual sources of contamination. A source is included in the inventory if it has the potential to release a contaminant to surface waters which may eventually make its way to the CAZ. It is beyond the scope of this study to determine whether any specific potential source is actually releasing a contaminant, or to what extent any potential source(s) may be contributing to the overall pollutant load.

The transportation network is a potential source of contamination through vehicular accidents that release hazardous materials. There are four road crossings and three railroad crossings over the Maumee River from I-75 and lakeward. Accidents on these bridges may cause contaminants to enter the river and approach the drinking water intakes.

Petroleum storage along Otter and Duck Creeks, and gas stations along Wolf Creek and Route 2 are potential pollutant sources. Shipping lanes for Sun Oil and BP Oil barges connect Detroit with the Port of Toledo. In addition, shipping lanes go north and south of the intake and inside and outside of the Oregon intake.

From early March to early January, raw materials are transferred through the Port of Toledo. Iron ore from Minnesota, Michigan, and eastern Canada are transported to Toledo. Toledo, Sandusky, Ashtabula, and Conneaut represent the largest segment of the Great Lakes coal trade. Toledo plays a major role in international export of corn, wheat and soybeans. At the Maumee River terminals, more than 80 million bushels of grain are loaded on ships for export. In addition, Toledo is a major cement-receiving port and petroleum products exporter. (Great Lakes Carriers Association http://www/lcaships.com/ohio/ohbro5.html.)

6.0 SUSCEPTIBILITY ANALYSIS

For the purposes of source water assessments, all surface waters are considered to be susceptible to contamination. By their nature surface waters are open systems with no confining layer to impede contaminant or pathogen movement and have relatively short travel times from source to the intake. The source water assessment for the Toledo Public Water System indicates that the source water is susceptible to potential future contamination. Based on the information compiled for this assessment, the Toledo Public Water System CAZ is susceptible to contamination from accidental spills or releases associated with commercial shipping and recreational boating, sediments from river dredging disposal operations, air contaminant deposition, point and nonpoint source discharges from industrial and agricultural operations along the shore and along streams that empty into the lake, contamination from oil & gas production and mining operations, natural processes such as erosion, contaminated storm water runoff from urban areas, municipal sewage treatment system and home sewage disposal system discharges, and combined sewer overflows (CSOs).

Lake Erie waters in the SWAP area generally flow from the Maumee river west to east along the shoreline and across the Toledo and Oregon intakes. The Detroit River also impacts flow throughout the western basin which sets up a southerly flow toward the Toledo and Oregon intakes. Figure 3 is false color infrared satellite imagery that illustrates the flow of sediments from the Maumee River along the shoreline to the east.

Figures 4A-D show surface and bottom currents to the east of the Toledo and Oregon intakes that are dependent on wind direction and intensity. The combination of direction, velocity, duration, and open-water fetch of the wind determines the strength of the waves and the resulting currents (Herdendorf). The 15-mile stretch of shoreline west of Locust Point to Maumee Bay is characterized by weak northwest drift due to the long easterly fetch and the corresponding shorter fetch for westerly winds (Herdendorf). Bottom currents should also be considered when wind conditions from the north, southwest and west may result in bottom currents from Locust Point toward the west. The surface and bottom currents in the opposite direction from the flow of the Maumee River may be a consideration when evaluating potential pollutant sources to the east of the intake, particularly when there is low flow from the Maumee and a moderate or strong east, northeast or southeast wind affecting the surface current.

Land use in the watersheds of rivers discharging to Maumee Bay is illustrated in Figure 5. More than 72% of the watershed area is dedicated to row crop agriculture. Runoff containing eroded soils from agricultural land is a major concern of the Toledo and Oregon treatment plants. Even though the intakes are located to the east of the Maumee River outfall, these intakes experience problems with turbidity that may be linked to erosion in the greater watershed area.

It is important to note that this assessment is based on available data, and therefore may not reflect current conditions in all cases. Water quality, land uses and other activities that are potential sources of contamination may change with time.

7.0 PROTECTIVE STRATEGIES

Source water protection efforts should be directed toward the establishment of an effective and efficient emergency response plan as well as a plan to educate the responsible parties of potential contaminant sources if one does not currently exist.

The City of Toledo works in cooperation with the Coast Guard, Lucas County EMA and the Toledo Mutual Assistance Association to address potential pollution problems. The Coast Guard developed the Western Lake Erie Contingency Plan and the Lucas County EMA developed the All Hazards Plan to address spills. The City of Toledo meets with Lucas County EMA bimonthly and with Toledo Mutual Assistance Association quarterly regarding refineries, pipelines and major industry.

Source water protection efforts in the area surrounding the Critical Assessment Zone (CAZ) should include:

1) Continuation of intake monitoring efforts and consultation with Coast Guard officials regarding response to threats from spills and other sources.
2) The contingency plan for the water system should be updated annually.
3) Support of current or future legislation to prevent oil and gas well drilling in Lake Erie should be provided.
4) Support for Lake Erie LaMP, and Maumee River RAP objectives, programs and projects to maintain and improve water quality of Lake Erie should be provided.
5) A coordinated long-term Lake Erie biological and water quality monitoring system should be instituted by state or federal agencies.

Future development and a change in land use practices and water activities may impact the ecological health of Lake Erie and affect the CAZ. This valuable water system should be protected to avoid further degradation of water quality by the excessive loading of nutrients and suspended solids. A watershed management plan such as the Draft Areawide Water Quality Management Plan (June 2002) should be finalized and utilized to guide future protection activities.

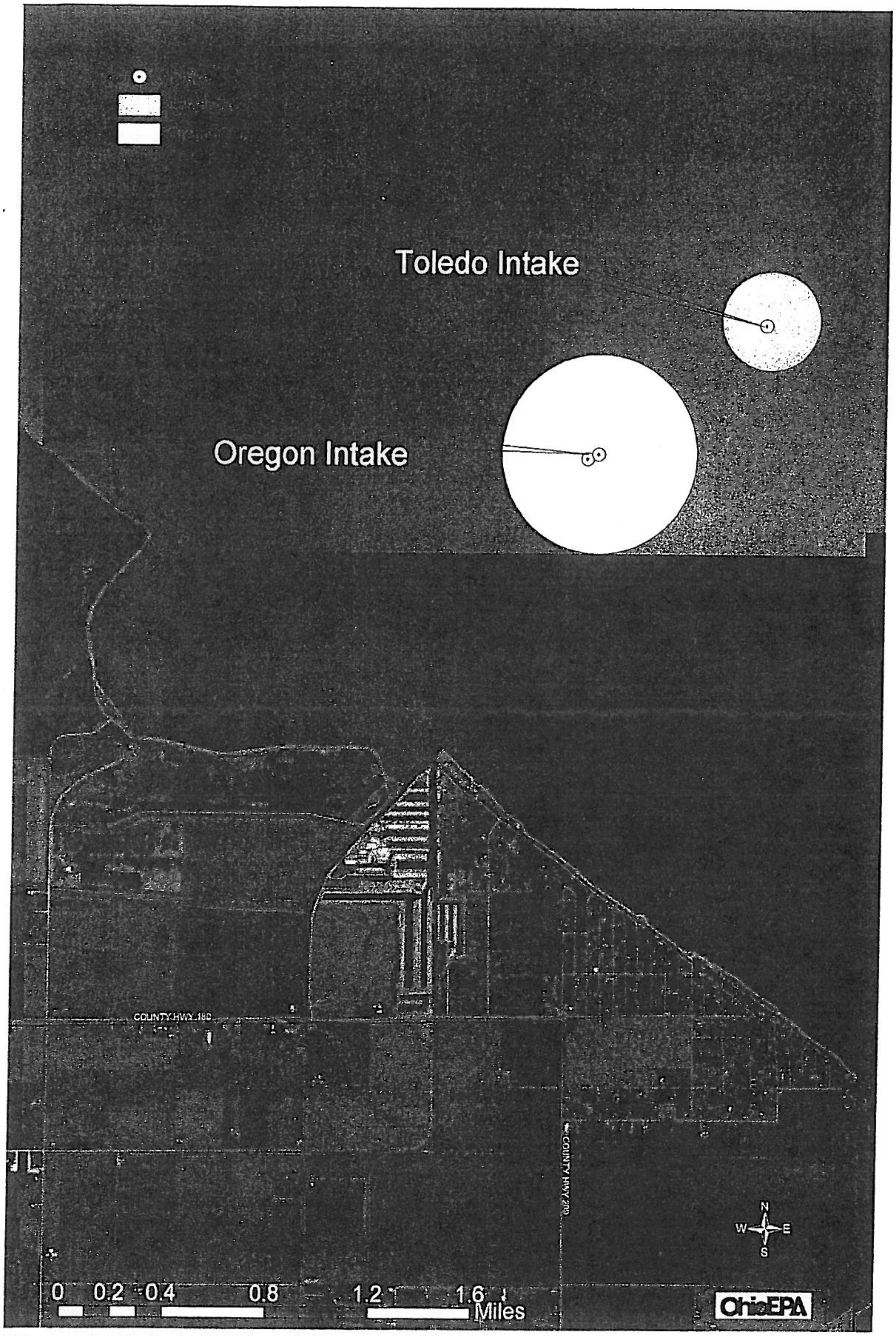


Figure 1 - Toledo CAZ and Oregon CAZ

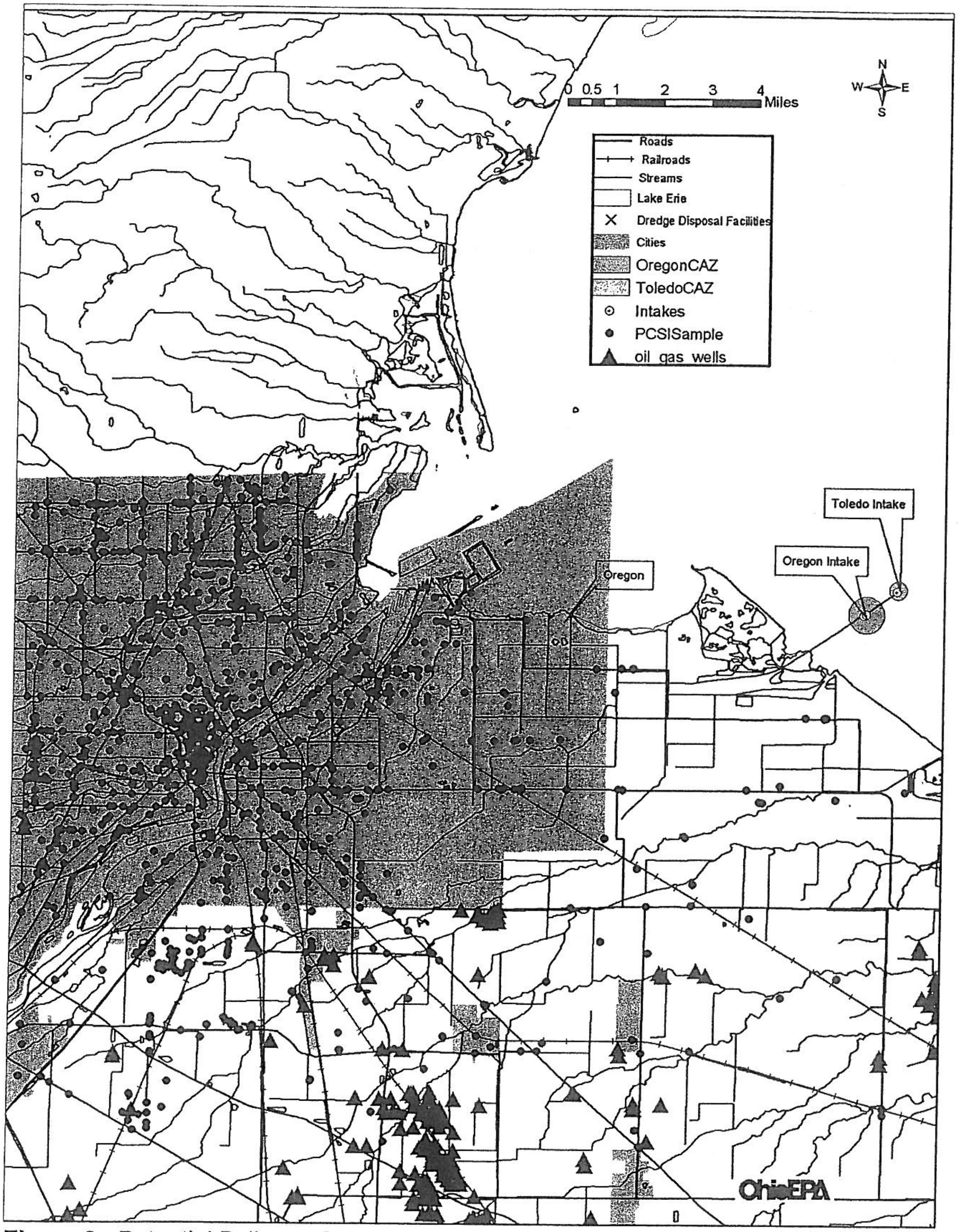


Figure 2 - Potential Pollutant Sources in the Toledo and Oregon Area

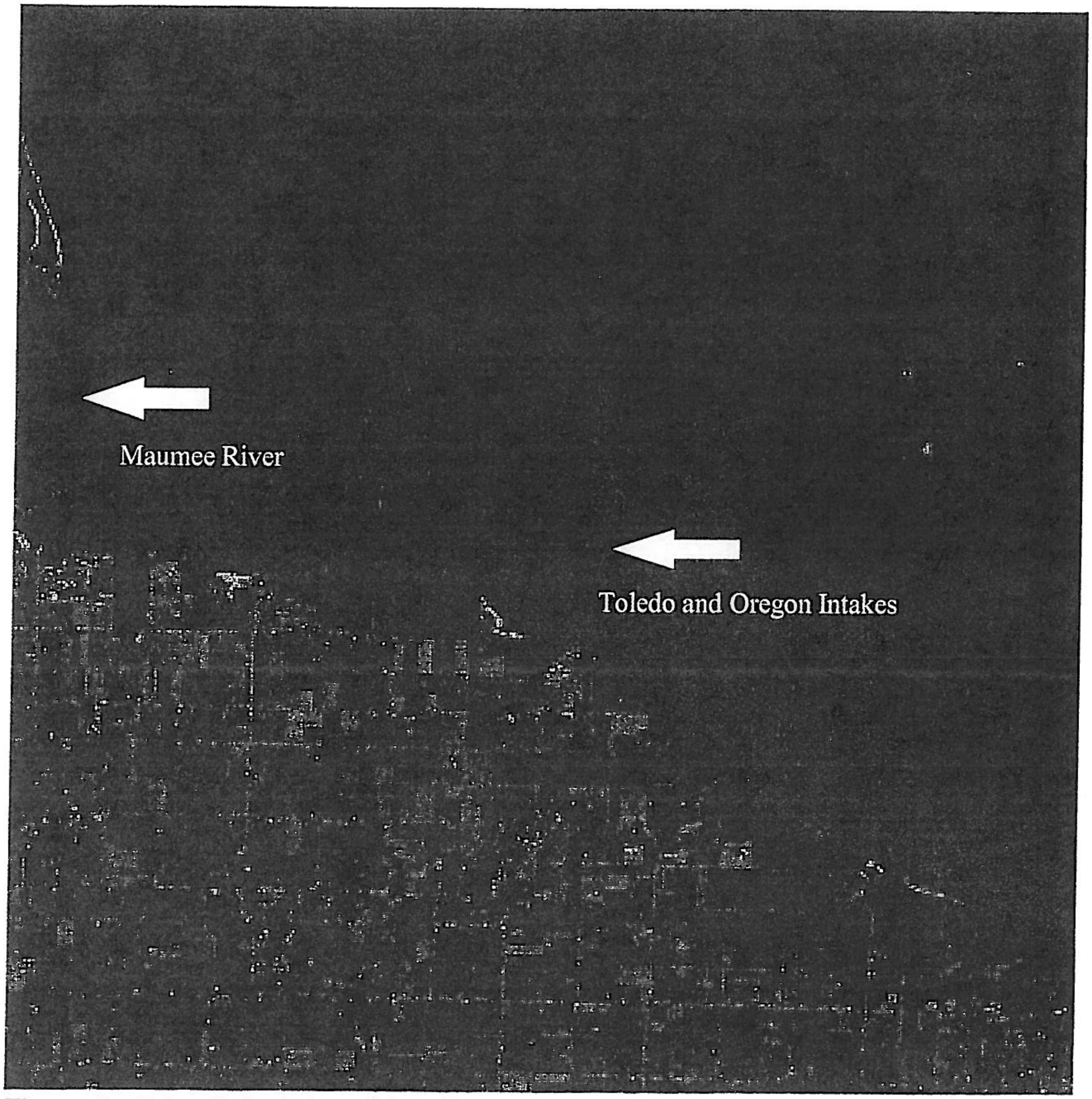


Figure 3 - False Color Infrared Satellite Imagery showing suspended sediment in the vicinity of the Toledo and Oregon intakes.

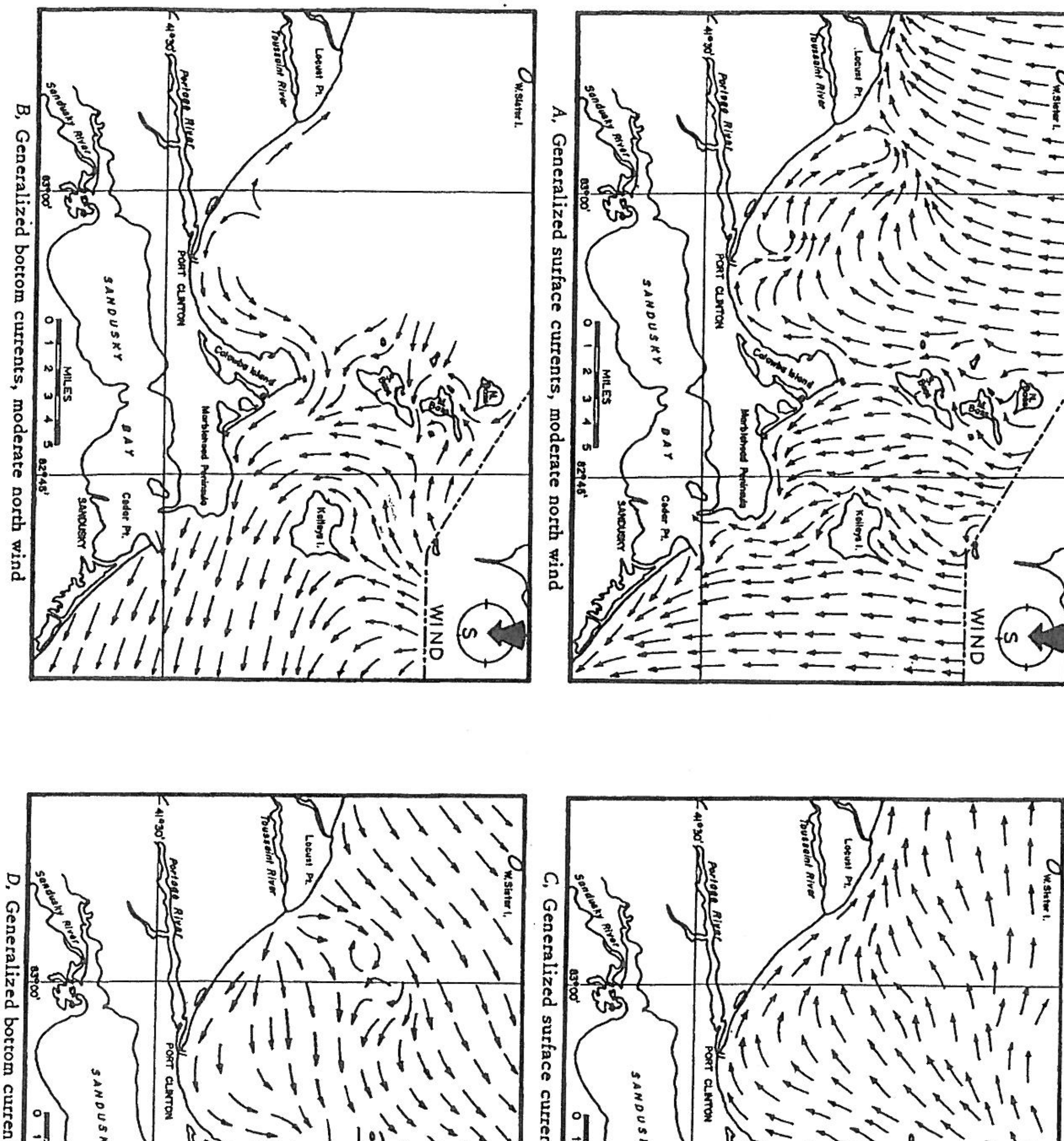
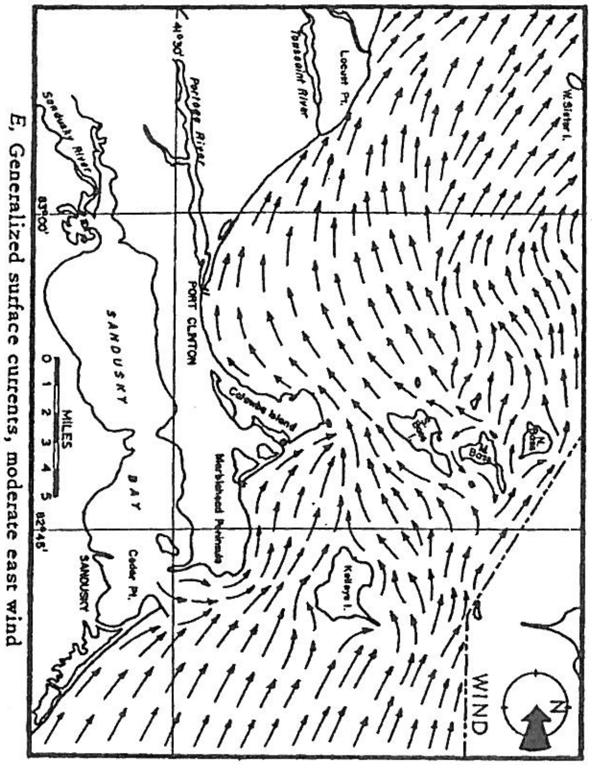
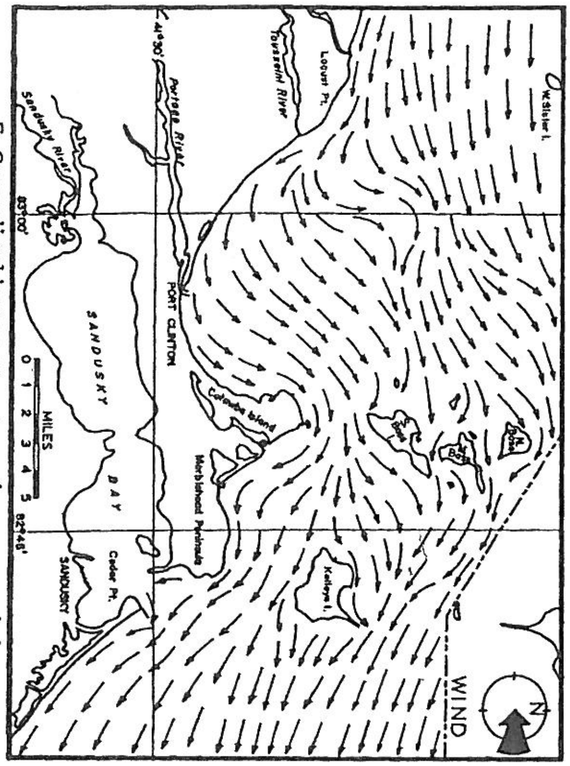


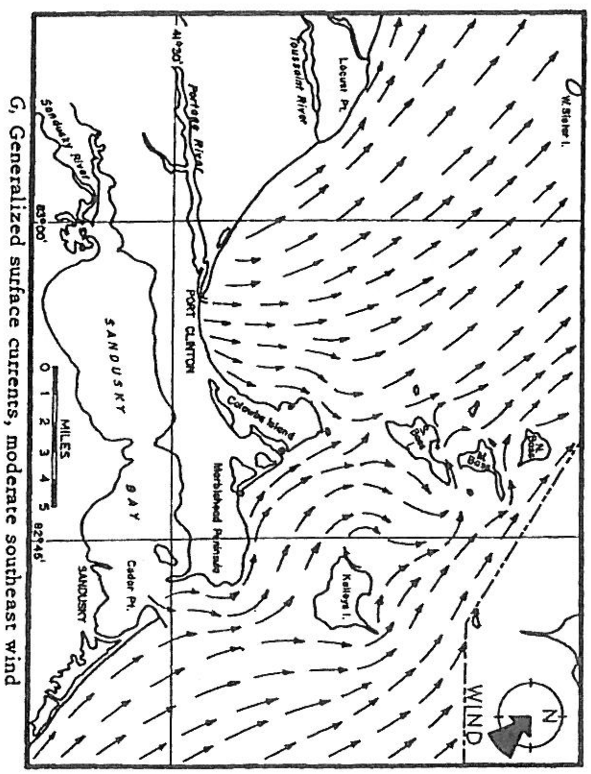
Figure 4A - Surface and Bottom Currents - Moderate North and Northeast Winds



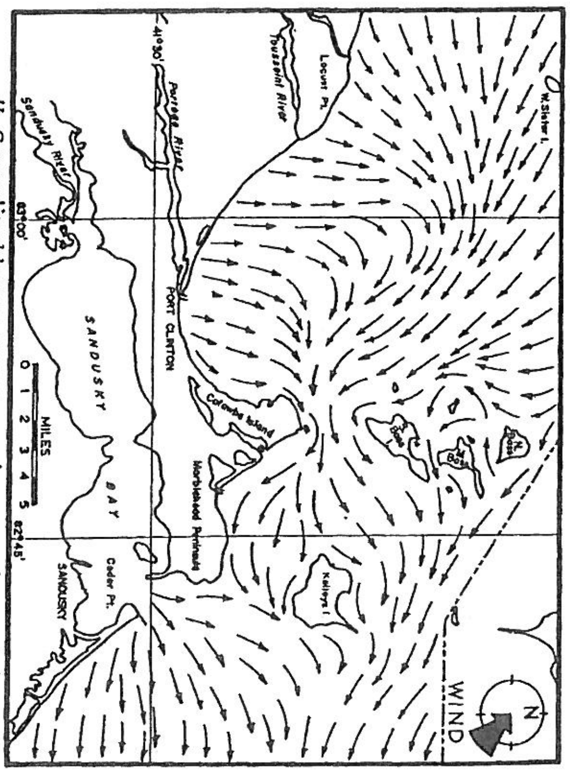
E, Generalized surface currents, moderate east wind



F, Generalized bottom currents, moderate east wind



G, Generalized surface currents, moderate southeast wind



H, Generalized bottom currents, moderate southeast wind

Figure 4B - Surface and Bottom Currents - Moderate East and Southeast Winds

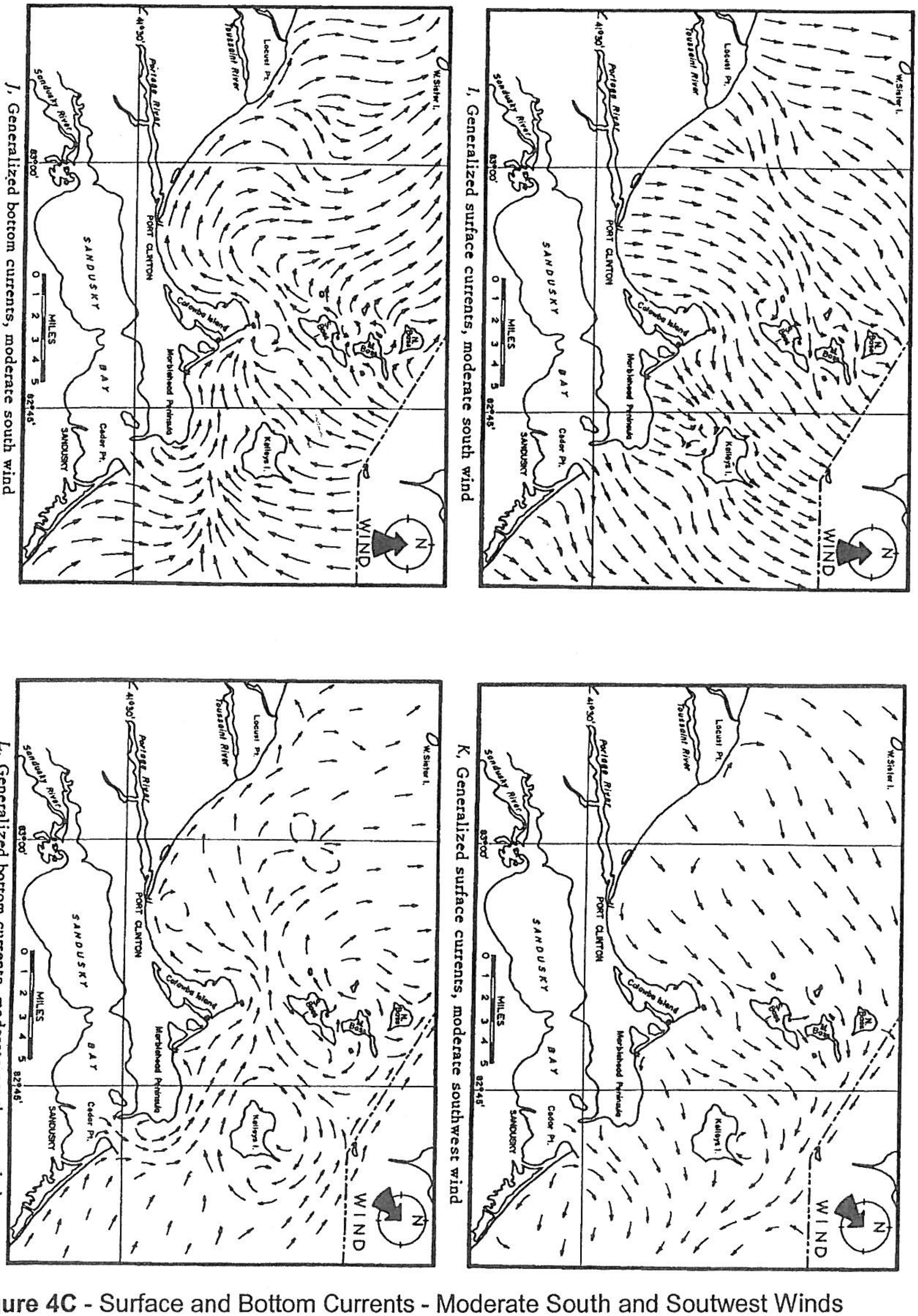
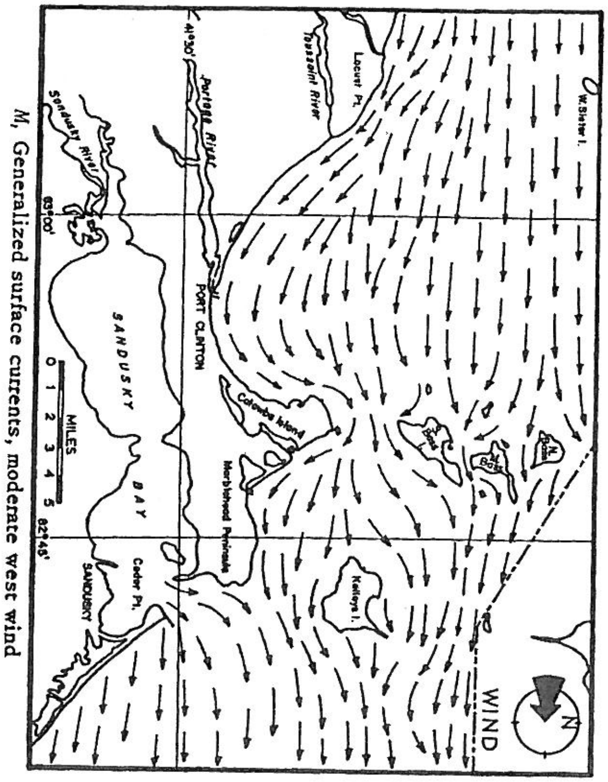
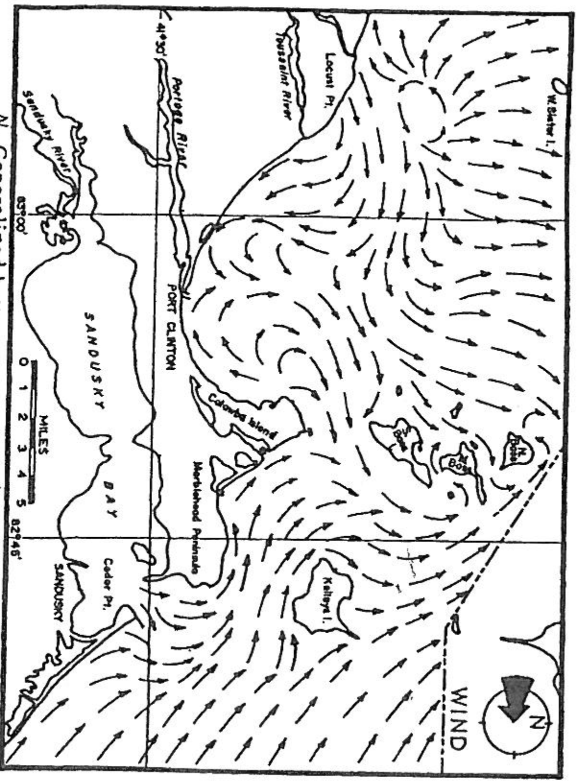


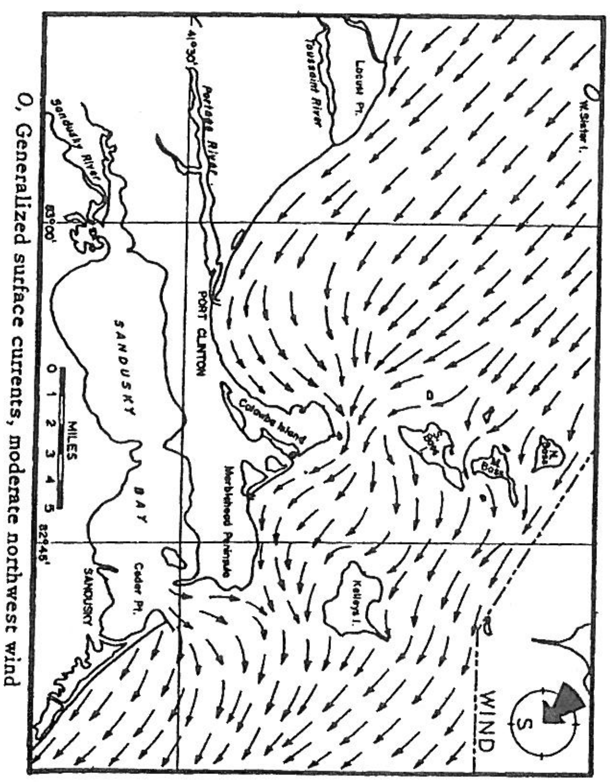
Figure 4C - Surface and Bottom Currents - Moderate South and Soutwest Winds



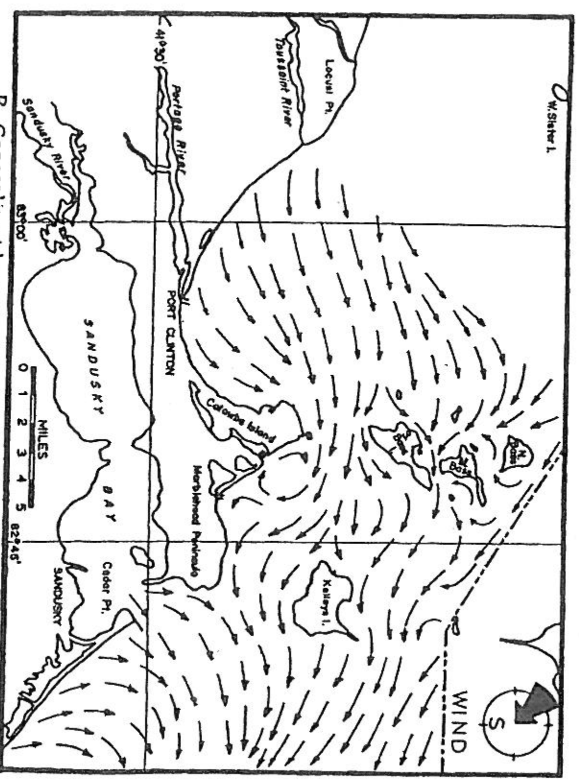
M, Generalized surface currents, moderate west wind



N, Generalized bottom currents, moderate west wind



O, Generalized surface currents, moderate northwest wind



P, Generalized bottom currents, moderate northwest wind

Figure 4D - Surface and Bottom Currents - Moderate West and Northwest Winds

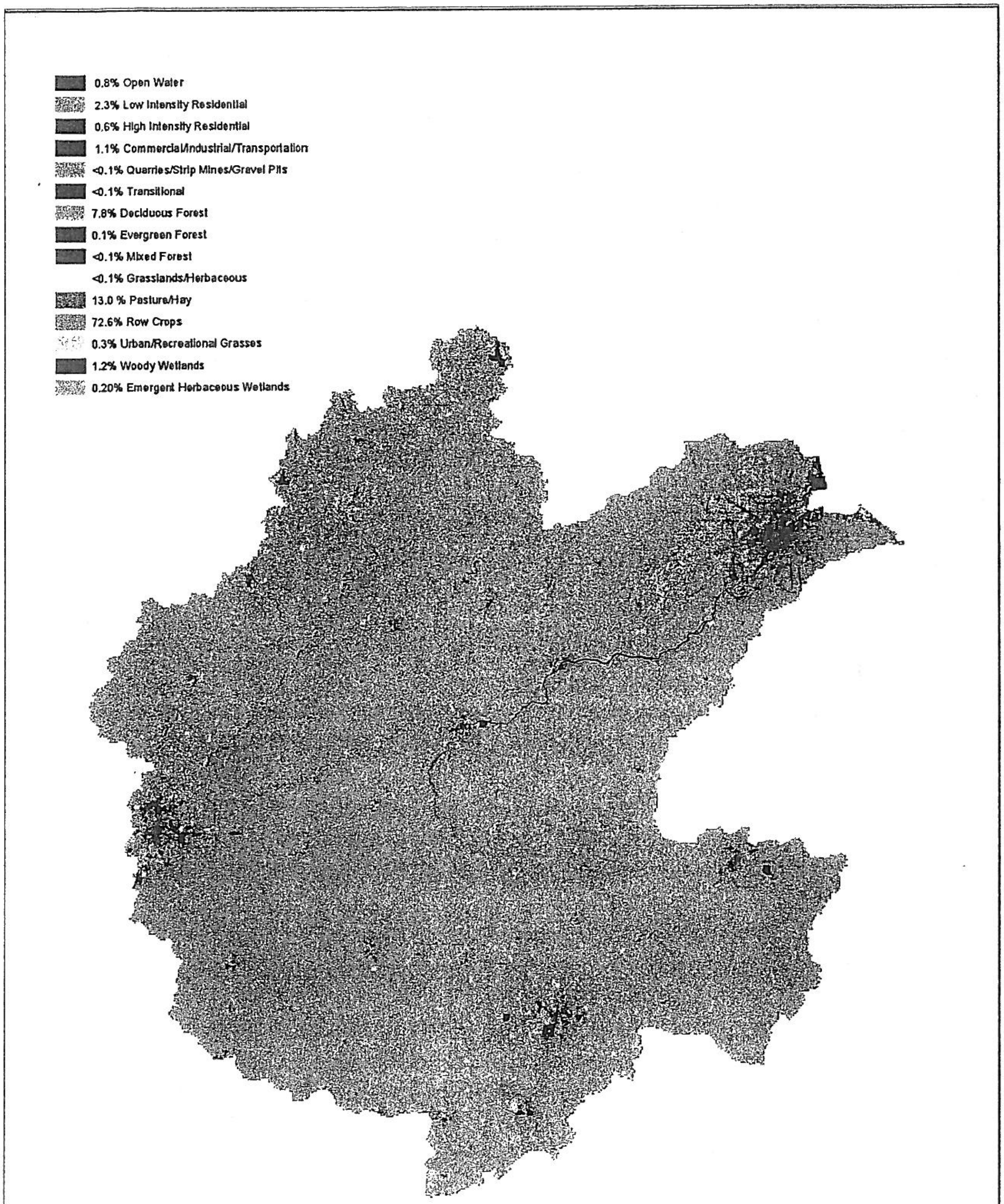


Figure 5 - Landuse in watersheds of streams discharging to Maumee Bay.

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