# CHAPTER VII

# ST. CLAIR RIVER

## A. STATUS OF THE ECOSYSTEM

### 1. Ecological Profile

#### Watershed Characteristics

The St. Clair River flows in a southerly direction forming the international boundary between the United States and Canada. This navigable waterway physically separates Lambton and Kent Counties in Ontario, and St. Clair County in Michigan. The St. Clair River is not a typical river system, occupying an alluvial valley, but must technically be regarded as a strait (1). This system is a true connecting channel or conduit which transports water, nutrients, sediments, and biota from Lake Huron to Lake St. Clair (Figure II-3).

The complex connecting channel between Lake Huron and Lake Erie that involves the St. Clair River, Lake St. Clair, and the Detroit River came into existence nearly 10,000 years ago with the retreat of the Pleistocene ice sheet. As the massive weight of ice was removed, an uplift in the form of glacial rebound occurred, leaving the St. Clair River/Lake St. Clair/Detroit River channel as the dominant outlet for the waters of the Upper Great Lakes. As time passed, the actions of the moving water enhanced the exit mechanism, until some 3,000 years ago, when the complex connecting channel became a permanent feature of the landscape.

The St. Clair system overlays 4,200 metres of sedimentary Paleozoic bedrock resulting from the hardening of ancient silts and muds to form extensive deposits of sandstones, limestones, dolomites, salts and shales. This thick depositional sequence rests upon a foundation of Precambrian igneous and metamorphic rocks. Fossil fuels have been extracted from the area for more than a century, beginning with the first oil field in North America developed at Oil Springs, Ontario, in 1858. Minerals of evaporative origin, such as halite (rock salt), have been extensively extracted by the Morton Salt Company for decades in St. Clair, Michigan.

The geologic origin of the St. Clair River resulted in a river system which forms the single outlet for Lake Huron, conducting its waters approximately 64 km southward to Lake St. Clair. Sediments in the river consist of gravel with sand in the interstices over glacial clay. Very little sediment deposition occurs along the river channel above the river delta. Prior to entering Lake St. Clair, the diminished velocities of the river with broadening provided an extensive depositional area. Thus, a large river delta system developed containing numerous distribution channels and an extensive region of wetlands. The shoreline of the St. Clair River, including the principal delta distribution channels, is 192 km in length.

Hydrology

As might be expected, water velocities within the St. Clair River are highest in the northern stretch of the river adjacent to the exit of Lake Huron, and lowest in the southern delta area. The total flow time from Lake Huron to Lake St. Clair is shown in Figure VII-1. It has been estimated to be 21.1 hr from Lake Huron to Lake St. Clair (2). The total average fall in this stretch is 1.5 m in vertical height (3). The mean water velocity is 3.5 km/hr, with a minimum of 1.1 km/hr in the delta area adjacent to Lake St. Clair (Figure VII-1)(2).

The river flow ranges between approximately 3,000 $m^3$/sec and 6,700 $m^3$/sec (2). The mean monthly discharge was 5,200 $m^3$/sec between 1900 and 1981 (6). Eight percent of this mean flow (410 $m^3$/sec) passes through the Ontario channels of the St. Clair Delta; the remainder (92 percent) passes through the more westerly main channels of the delta (7).

The river behaves like three separate panels of water: two nearshore sections strongly influenced by discharges; and a centre panel which passes through the river with minimal change.

On the Michigan side of the St. Clair River, four heavy industries are the principal users of river water for metal plating, paper manufacturing, and salt processing. By far, the heaviest municipal and industrial use occurs on the Canadian side of the river with ten major industrial plants in the Sarnia area producing refined petroleum, petrochemical and agricultural products. A large coal-fired power generating station is also located on the Ontario shore. A number of studies have shown that effluents

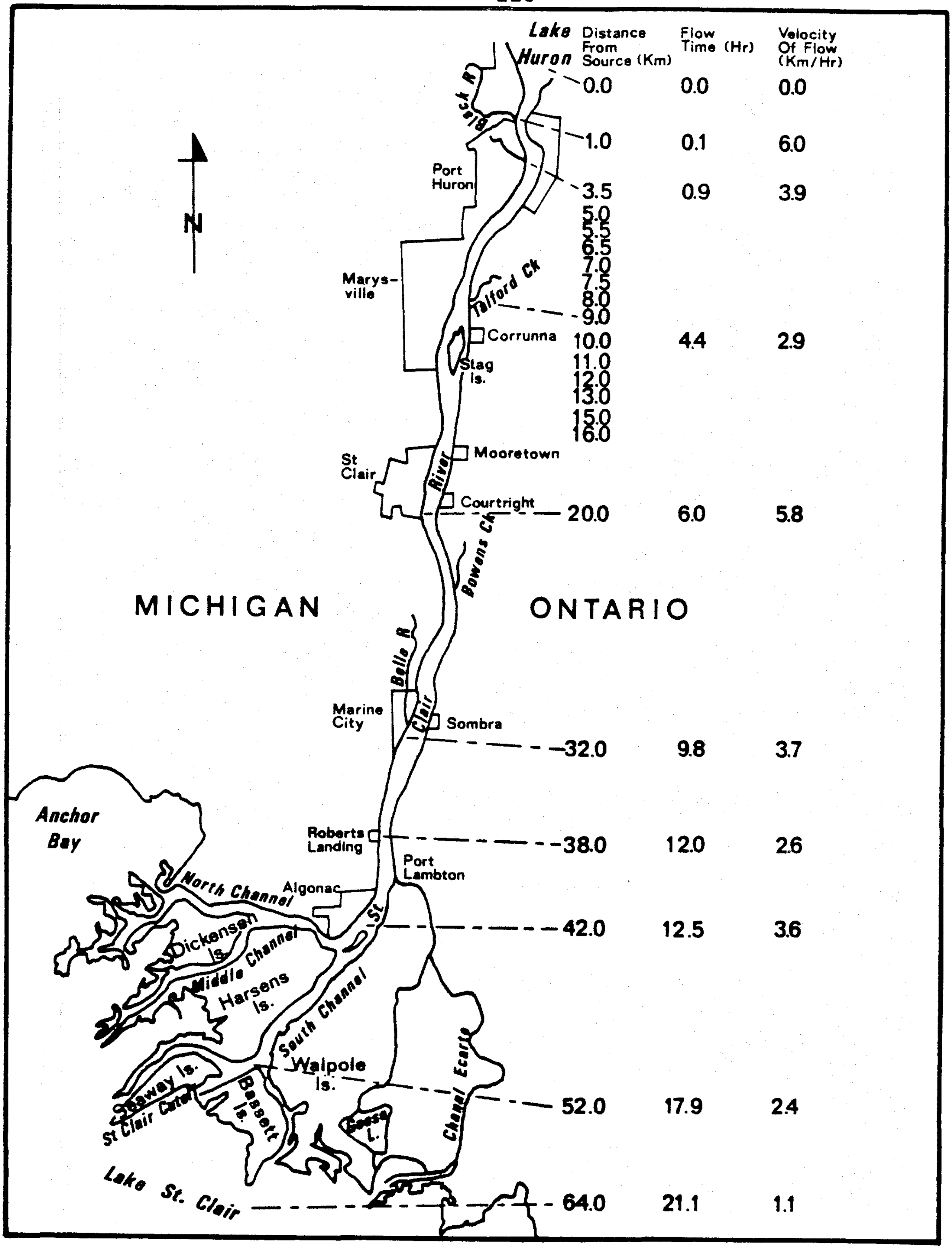



FIGURE VII-1. St. Clair River indicating approximate flow times and velocities of flow of various reaches of the river.

from a number of these plants have degraded the quality of the St. Clair River system (8-12).

Historically, waterborne commerce has been a very heavy user of the St. Clair River system. Traditionally, iron ore, limestone, and coal account for 90 percent of commercial shipping on the St. Clair River (13).

## Habitats and Biological Communities

The St. Clair River ecosystem consists of five fundamentally distinct biologic zones: (i) open-water, (ii) submerged wetland, (iii) emergent wetlands, (iv) transition or ecotone, and (v) upland. Each of these zones may be subdivided by the community of organisms which occupy them, or by their physical characteristics.

The open-water zone may be subdivided into two major groups: (i) the channelized flow communities, and (ii) the open-water marsh communities. The channelized flow communities include such diverse groups as free-swimming nekton, e.g., fish, amphibians, and reptiles; drift communities, e.g., uprooted submerged and emergent plants, phytoplankton, and zooplankton; and sessile, burrowing, or attached communities, e.g., immature aquatic insects, invertebrates, and mollusks. The open-water marsh communities predominate in the St. Clair Delta area. They are typically either bullrush marshes, or cattail marshes. The open-water bullrush marsh is prevalent in the abandoned channels of the St. Clair Delta, or mixed with cattail marshes where water depth and sandy sediments favour the development of bullrush communities. Open-water cattail marshes are found in delta sections of the river where peaty or clayey hydrosoils predominate, and where water depth exceeds 15 cm (5).

The St. Clair River system contains approximately 550 ha of coastal wetlands. The primary type of wetlands in the St. Clair River belong to the river wetland group, and are composed largely of submerged species (5,14,15). These shoreward, submerged communities may be conveniently divided by location into the delta channel, and the river shoulder. The delta channel communities include both abandoned and active delta channels. The river shoulder communities border the channelized area of the river for a distance of 30-40 m, and rarely exceed 2 m in depth (2). Emergent wetland communities occasionally occupy the river shoulder area, but more often, these forms are to be found on point bars and within the river delta structure.

The transition zone, or ecotone, may be conveniently subdivided into three major categories of community types: (i) the island shoreline and transgressive beach, (ii) sedge marshes, and (iii) the transition wet-meadow. Long, narrow beaches of fine sand which support emergent vegetation are found on the Canadian side of the river delta. Transgressive or stranded beaches are also found on the islands of the delta area which support intermediate or transition communities, including tussock sedge (Carex sp.), reed (Phragmites australis), swamp thistle (Cirsim muticum), bluejoint grass (Calamagrostis canadensis), willows (Salix sp.), and the eastern cottonwood (Populus deltoides). The sedge marsh communities occupy a very narrow zone of transition between the wetter cattail marshes and the more terrestrialized upland zones. Typical residents of this community are nearly all members of the tussock sedge group (Carex sp.), with the exception of bluejoint grass (Calamagrostis canadensis). The transition wet-meadow communities represent a transition state between the sedge marshes and the upland communities. This community lies above the water table and is infrequently flooded. It consists of a mixture of grasses, herbs, shrubs, and water-tolerant trees, including quaking aspen (Populus tremuloides), red ash (Fraxinus pennsylvanica), red osier dogwood (Cornus stolonifera), swamp rose (Rosa palustris), bluejoint grass (Calamagrostis canadensis), rattlesnake grass (Glyceria canadensis), and panic grass (Panicum sp.).

The terrestrialized upland communities bordering the St. Clair River system include upland shrub, and deciduous hardwood. The upland shrub community consists of mixed shrubs and water tolerant trees, including eastern cottonwood and quaking aspen (Populus sp.), red ash (Fraxinum pennsylvanica), red osier dogwood and gray dogwood (Cornus sp.), wild grape (Vitis palmata), and hawthorn (Crataegus sp.). The deciduous hardwood community adjacent to the St. Clair River begins on an average of 1-3 m above the level of the river. Major species in this community include red ash (Fraxinus pennsylvanica) and members of the genus Quercus, including swamp white oak, pin oak, and burr oak. Other hardwoods include silver maple (Acer saccharinum), the American elm (Ulmus americana), eastern cottonwood (Populus deltoides), and shagbark hickory (Carva ovata). The terrestrialized upland communities are chiefly found in the less industrialized portions of the basin, particularly in southern reaches of the river, and notably in the island complex associated with the delta area.

i) Macrozoobenthos

The macrozoobenthos of the St. Clair River exhibits a higher taxonomic diversity than Lake St. Clair. The number of individual species observed in the river is in excess of 300 (2). Members of the Oligochaeta, Chironomidae, Gastropoda, Ephemeroptera, Trichoptera, and Amphipoda contribute most significantly to total macrozoobenthic biomass. Large numbers of Hydra sp. are present, but contribute little to biomass.

The genera Cricotopus, Parachironomus, Parakiefferiella, Rheotanytarsus, and Stictochironomus are the dominant chironomid forms. The most common amphipod is Hyalella, and the common trichopteran genera include Cheumatopsyche, Hydropsyche, and Oecetis. Species diversity is greatest in the Chironomidae, Trichoptera, and Oligochaeta. Numerous freshwater mussels are present in abundance in the St. Clair River, as are the common snail genera Amnicola and Elimia.

ii) Zooplankton, Phytoplankton and Macrophytes

The St. Clair River harbors relatively low densities of limnetic zooplankton (16). Several authors report that the St. Clair River zooplankton community is dominated by fugitive drift communities of zooplankton from Lake Huron (2,16,17). A total of 18 rotifer genera, 9 calanoid copepods, 4 cyclopoid copepods, and 6 cladocerans have been observed in the St. Clair River (18). While rotifers were most frequently seen (17), the dominant zooplankton species observed were Bosmina longirostris, Cyclops thomasi, and Diaptomus minutus.

The primary production system of the St. Clair River consists of phytoplankton, emergent macrophytes, submerged macrophytes, and the periphyton community associated with the submerged portions of the latter two groups. A single source of information is available regarding the phytoplankton composition of the St. Clair River. This study was completed more than a decade ago (17,19), and suggests that the phytoplankton community of the St. Clair River is dominated by diatoms occurring in patterns similar to the communities of Lake Huron. Dominant species reported in 1974 included Cyclotella sp., Fragillaria sp., Melosira sp., Stephanodiscus sp., Synedra sp., and Tabellaria sp. At the time of preparation of this manuscript, no published data were available related to native periphyton communities in the St. Clair River.

Submerged macrophytes are a prominent feature of the littoral waters of the St. Clair River. These extensive macrophyte beds provide food, shelter, and habitat requirements for fish and wildlife populations. Not only do they support a wide variety of migratory waterfowl, but young fish were observed to be more abundant from spring to fall among the submerged macrophytes than in the plant-free areas of the St. Clair River islands (20).

More than 20 submerged macrophyte taxa occur in the St. Clair River system (20,21). In order of frequency of occurrence, these include Chara sp., Vallisneria americana, Potamogeton sp., and Heteranthera dubia. Of this group, only Chara forms single species or monotypic stands of vegetation. Typically, submerged macrophyte stands are composed of 2-3 species; however, a stand with a maximum of 11 taxa has been reported (2). The greatest depth of water colonized by submerged macrophytes is not documented for the St. Clair River system, but most stands occur in water depths of 3.7 m or less. The 3.7 m depth contour accounts for 16 $km^2$ of the St. Clair River shoreline. It has been estimated that 88 percent of the St. Clair River bottom is covered by plant material within the 0-3.7 m range of depths (2).

A total of three submerged macrophyte taxa are found in the St. Clair River system. These species include Potamogeton crispus, Nitellopsis obtusa, and Myriophyllum spicatum. P. crispus is one of the first aquatic plants to appear in the spring. This plant serves as a host for aquatic invertebrates which are consumed by northward migrating waterfowl (1). Since it is also one of the most abundant macrophytes in the river during April to June, P. crispus provides an important spawning substrate for fish (22). N. obtusa was first reported in the St. Clair River in 1984 (23). M. spicatum was first observed in Lake St. Clair in 1974 (24), and became the fourth most common submerged macrophyte in the St. Clair River system by 1978 (21).

Emergent macrophyte distributions are less well understood. While Herdendorf et al. (5) provide some discussion of the emergent forms of the lower St. Clair River, no definitive study of species compositions, abundance, distribution, occurrence, or productivity has yet been made. Estimates, however, suggest that as much as 3,380 ha of the St. Clair River may be colonized by emergent vegetation (25,26). It is further estimated that 95 percent of the stands of emergent vegetation occur in the lower reaches of the river (1). Typical emergent vegetation within the river area proper includes cattails (Typha sp.) and reed (Phragmites australis). Within the delta, numerous canals, ponds, and abandoned channels support a wide diversity of emergent plant communities, including the yellow and white water lilies (Nuphar advena and Nymphaea tuberosa, respectively), buttonbrush (Cephalanthus occidentalis), arrowhead (Sagittaria latifolia), bullrush (Scirpus sp.), and water smartweed Polyhonum amphibium).

iii) Fish

With regard to fish populations, the St. Clair River is important in two respects: (a) it supports its own native fishery, and (b) it serves as a conduit, providing a means of access for movement of fish to both Lakes Huron and Erie. The latter aspect is particularly significant in association with fish spawning.

The St. Clair River is critical to the spawning and nursing of juvenile fish of between 23 and 41 taxa (4,27,28,29), with larval fish densities averaging 296 per 1000 $m^3$. Fish species observed within the river include walleye, muskellunge, rainbow trout, lake sturgeon, smelt, coho and chinook salmon, smallmouth bass, channel catfish, yellow perch, and freshwater drum (30).

Juvenile and adult fish were most often observed in the lower reaches of the river where macrophyte communities were abundant.

Forty-eight fish species are known or presumed to utilize the wetland areas associated with the St. Clair River. The management of this system is critical to protect both the habitat of these fish and the fish themselves from accumulating body burdens of chemical contaminants.

Haas et al. (31), conducted seven monthly surveys of fish in the St. Clair River which identified rock bass, yellow perch, and walleye as the most common forms. Fish populations vary seasonally, with smallmouth bass most numerous in the fall, and white suckers dominating the spring populations.

As was noted above, the river serves as a corridor for fish movement between Lakes St. Clair and Huron. Walleye are known to spawn in the delta area and tributaries of Lake St. Clair, and to move in late spring through the St. Clair River to southern Lake Huron. These fish typically return through the river in the fall of the year (30). This migration pattern is further complicated by walleye breeding migrations in which fish from Lake Erie move into the St. Clair River complex to spawn. Spawning areas in the St. Clair River area are also important for the rare lake sturgeon. The lake sturgeon enters the St. Clair River to spawn in the north channel of the St. Clair River Delta.

## Regional Climate

The St. Clair River basin is characterized by typical inland climatic patterns modified by the water mass of the Great Lakes which surrounds it. Summer temperatures are regarded as warm and mild, and winter temperatures are moderately cold. Mean annual temperature regimes range from a high of 23.6°C in July, to a low of -4.4°C in January. Periodic cyclonic storms of varying intensity occur throughout the year, with the general exception of the high summer months (June, July, and August). During this period, thunderstorms are common as a function of atmospheric convectional uplift.

The modifying influence of the adjacent Great Lakes provides the St. Clair River region with the second longest frost-free season in the Great Lakes basin. On an average, the interval between the last vernal frost and the first autumnal frost is 160 days. The fall warming effect provided by the surrounding water masses retards the occurrence of autumn frost, thus extending the growing season. The spring cooling effects of the lakes also prevent premature vegetational growth, lessening the chances of crop and plant loss to late spring frosts (32). The length and intensity of the growing season may also be estimated from the accumulation of growing degree-days. This value is an index of the amount of heat available during a given growing season. The growing degree-day index is normally defined as the number of degrees of mean daily temperature above a threshold value of 5.6°C for the period in which that limit is exceeded. A normal year in the Port Huron/Sarnia area consists of 2,056°C (2).

Average annual water temperature values describe a classic sigmoidal curve, with winter minima occurring in mid-February (approximately 0.5°C), and the annual maxima being achieved in mid-August at values approaching 21°C (4). Mean water temperature recorded for the St. Clair River for the years 1967-1982 was 11.8°C (5).

Characteristically, the climate of the Great Lakes region is marked by a lack of major seasonal fluctuations in precipitation patterns. Extensive records for three adjacent weather stations - Mount Clemens, Michigan (1940-1969); Detroit City Airport, Detroit, Michigan (1940-1069); and Windsor, Ontario Airport (1941-1970) - indicate that the mean annual precipitation is 77.83 cm (33).

## 2. Environmental Conditions

### Water Quality

Despite the highly industrialized character of the upper reaches of the St. Clair River, water clarity in the river is exceptionally high. This exceptional clarity is largely because Lake Huron is the primary source for the waters of the river. As a result, the suspended sediments are largely silicate in nature, derived from southern Lake Huron shoreline sands (1,2).

Urban centres are found along the length of the St. Clair River, and a major petrochemical complex is concentrated along the Ontario side in the Sarnia-Corunna area. Concerns relating to bacterial contamination, phenols, metals (particularly iron and mercury) and phosphorus were identified as early as the 1940s (34). Mercury (35) and lead (10) have been the metals of most concern. Phenols, oil and grease, and a variety of chlorinated organics including PCBs, hexachlorobenzene, octachlorostyrene, hexachlorobutadiene, and volatile organics were considered the major problem organics in the river (8,12,36).

Many of these inputs have been reduced significantly as a result of implemented control programs. Over the years, the focus of attention has shifted from nutrients and conventional pollutants to toxic substances that have been detected throughout the system, and concern for their effects on human health and the ecosystem.

The high flows in the St. Clair River are conducive to dilution of material inputs from sources along the river. But it should be kept in mind that, because of the flow pattern of the river, contaminant plumes tend to hug the shoreline, and thus, only a portion of the total flow (perhaps 5%) is available for dilution. Nonetheless, the concentrations of many of the contaminants of concern in the water column are extremely low, often from undetectable to the low *ng/L* range. This requires the use of state-of-the-art sampling and analytical methodologies to provide accurate results. Higher concentrations are often found in close proximity to sources. It should be recognized, however, that even low concentrations coupled with the high flow still produce loadings that are often significant. Table VII-1 illustrates approximate loadings for several UGLCCS parameters at typical concentrations and flows found in the river. While organisms respond in the short term to concentrations (e.g., acute toxicity), the system as a whole is ultimately responsive to loadings. This is particularly critical for persistent toxic organic pollutants and toxic metals, since these contaminants can have a severe impact on downstream lakes.

TABLE VII-1

Loading Ranges for UGLCCS Parameters in the St. Clair River.

| Parameter Concentration Range | | Associated Loading Range (kg/yr) | Chemical |
|---|---|---|---|
| 1-10 | ppm(mg/L) | $1.7x10^{8}-1.7x10^{9}$ | Chloride |
| 10-100 | ppb(ug/L) | $1.7x10^{6}-1.7x10^{7}$ | Phosphorus, Iron |
| 0.1-1.0 | ppb(ug/L) | $1.7x10^{4}-1.7x10^{5}$ | Lead,Cobalt, Copper |
| 10-100 | ppt(ng/L) | $1.7x10^{3}-1.7x10^{4}$ | Mercury |
| 1-10 | ppt(ng/L) | $1.7x10^{2}-1.7x10^{3}$ | PCBs, PAHs, Cadmium |
| 0.1-1.0 | ppt(ng/L) | 17-170 | HCB, OCS |

Even though considerable dilution does occur, the lack of lateral mixing leads to a considerable concentration gradient across the St. Clair River. For example, at Port Lambton (a distance of 34 km downstream of point sources in Sarnia), 95% of the contaminants still remain in Canadian waters. To illustrate, on September 23, 1985, HCB and OCS concentrations at Port Lambton were 1.6 and 0.05 ng/L, respectively, near the Canadian shore, and 0.02 ng/L and not detected near the U.S. shore. Similar gradients were found on three other occasions for samples collected at 100 m intervals across the river (37). These results show that contaminant inputs along each shoreline travel downstream in plumes which tend to hug the shoreline with limited lateral, cross-stream mixing. This fact has implications for locating water intakes for communities downstream of industrial sources using St. Clair River water for drinking purposes.

A comparison of typical ambient concentrations of UGLCC Study chemicals in the river and concentrations near point sources to water quality and drinking water guidelines for 1986 are shown in Table VII-2. Hexachlorobenzene (HCB) concentrations in the river near point sources below Sarnia are far in excess of both the Canadian water quality and WHO drinking water guidelines. Ambient water samples collected near the Canadian shoreline at Port Lambton are about one-tenth of the guideline values. No guidelines are available for octachlorostyrene (OCS), but an estimated water quality guideline can be calculated by multiplying the HCB guideline by the ratio of the bioconcentration factors of the two substances, $BCF_{HCB}/BCF_{OCS}$. This procedure assumes that HCB and OCS have similar toxicities. Comparing the OCS water concentrations to this estimated guideline suggests that OCS would exceed this calculated value in the river near point sources, but mean ambient values would be below this guideline. On the other hand, PCBs do not appear to present such an acute problem in the St. Clair River, even in the industrialized Sarnia area.

Benzo-a-pyrene (BaP) was assessed as a representative polynuclear aromatic hydrocarbon (PAH). No direct measurement of water concentrations was made for BaP. The BaP water concentration was estimated by using the Ontario Ministry of Environment's (OMOE) caged clam data (38) downstream of Imperial Oil (20 ng/g) and dividing by the bioaccumulation factor for invertebrates found by Frank <u>et</u> <u>al</u>., 680 (39). Near Sarnia and downstream at Port Lambton, the estimated BaP water concentration appears to exceed the guidelines by a factor of 3 or 4.

All metals, with the exception of lead near Sarnia and near Ethyl Corporation in Corunna, are well below the guidelines. The lead values near point sources slightly exceed the Canadian water quality objectives, but are well below drinking water standards.

Some other significant St. Clair River organic contaminants are compared to the guidelines in Table VII-3. All parameters exceed guideline values near point sources. Exceedences were particularly evident for perchloroethylene, carbon tetrachloride, hexachlorethane, hexachlorobutadiene, and pentachlorobenzene. Ambient mean concentrations are well below guidelines for all parameters. Maximum concentrations found well downstream of the sources are within an order of magnitude of the guidelines for benzene, perchloroethylene, and carbon tetrachloride.

Table VII-4 compares the concentrations of chemicals in suspended solids and unfiltered water at the head and mouth of the St. Clair River. The data clearly show that major sources of

TABLE VII-2

Comparison of UGLCC parameter concentrations in unfiltered[1] water to water quality and drinking water guidelines (all concentrations ug/L).

| Chemical | GLWQA Specific Objectives+ | Ontario++ Water Quality Objectives | WHO+++ Drinking Water Guidelines | Ambient Near Canadian Shore: Near Industrial Outfalls Mean | Near Industrial Outfalls Maximum | Downstream of Sources Mean | Downstream of Sources Maximum |
|---|---|---|---|---|---|---|---|
| Hexachlorobenzene | -- | 0.0065 | 0.01 | 0.4 | 2.4 | 0.0008 | 0.0016 |
| Octachlorostyrene | -- | (0.0006)* | -- | 0.027 | 0.14 | 0.00024 | 0.00012 |
| PCB | -- | 0.001 | 3 | < 0.02 | < 0.02 | 0.0015 | 0.0022 |
| Benzo-a-Pyrene | -- | -- | 0.01 | (0.03)** | -- | (0.04)** | -- |
| Lead | 25 | 25 | 50 | 1.5 | 2.7 | 0.33 | 2.0 |
| Cadmium | 0.2 | 0.2 | 5 | -- | -- | 0.01 | 0.09 |
| Mercury (Filtered) | 0.2 | 0.2 | 1 | 0.011 | -- | 0.007 | 0.04 |
| Copper | 5 | 5 | 1000 | -- | -- | 0.42 | 1.3 |
| Iron | 300 | 300 | 300 | 140 | -- | 240 | 310 |
| Cobalt | -- | -- | -- | -- | -- | 0.16 | 0.18 |

1 From (36,37,41,51).
\+ International Joint Commission, Canada and the United States, Great Lakes Water Quality Agreement of 1978 (as amended 1987).
++ Ontario (Provincial) Water Quality Objectives (PWQO)(101).
+++ World Health Organization (WHO)(102).
* Estimated using the guideline 0.0065 ug/L for HCB and multiplying by $BCF_{HCB}/BCF_{OCS}$(22,000/240,000)(103).
** Estimated from Ontario Min. of the Env. caged clam studies (38).
\- Mercury - Filtered.
\- All other metals - Total.

TABLE VII-3

Comparison of other organic compounds found in the St. Clair River[1] to water quality and drinking water guidelines (all concentrations in ug/L).

| Chemical | Ontario Water Quality Objective | WHO** Drinking Water Guideline | Near Industrial Outfalls Mean | Near Industrial Outfalls Maximum | Ambient Near Canadian Shore Downstream of Sources Mean | Ambient Near Canadian Shore Downstream of Sources Maximum |
|---|---|---|---|---|---|---|
| Benzene | 25(interim) | 10 | 5.3 | 23 | 0.56 | 4.3 |
| Toluene | 250(interim) | -- | -- | -- | 0.71 | 2.2 |
| Perchloroethylene | - | 10 | 81 | 1120 | 0.21 | 2.4 |
| Carbon Tetrachloride | - | 3 | 38 | 665 | 0.33 | 2.0 |
| Hexachloroethane | - | -- | 0.2 | 0.83 | 0.004 | 0.007 |
| Hexachlorobutadiene | - | -- | 0.40 | 1.3 | 0.002 | 0.006 |
| Pentachlorobenzene | 0.03 | -- | 0.005 | 0.15 | 0.00007 | 0.00001 |

[1] From (36,37,73,74).

* Estimated using the guideline 0.1 ug/L for HCBD and multiplying by $BCF_{HCBD}/BCF_{HCE}$ (17,000/1,200)(75).

** World Health Organization (WHO)(102).

TABLE VII-4

Comparison of chemical concentrations in unfiltered water (UW) and suspended sediments (SS) at the head and mouth of the St. Clair River.

| Compound | UGLCCS Parameters Head | | Mouth | |
|---|---|---|---|---|
| | SS(ng/g) | UW(ng/L) | SS(ng/g) | UW(ng/L) |
| Hexachlorobenzene | 2.0 | 0.03 | 130 | 0.8 |
| Octachlorostyrene | 0.7 | 0.008 | 23 | 0.12 |
| PCBs | -- | 2.3 | -- | 1.5 |
| | SS(ug/g) | UW(ug/L) | SS(ug/g) | UW(ug/L) |
| Lead | 23 | <3 | 42 | <3 |
| Cadmium | 1.0 | (0.01)* | 0.8 | (0.008)* |
| Mercury | 0.04 | 0.002 | 0.28 | 0.011 |
| Copper | 24 | (0.24)* | 25 | (0.25)* |
| Iron | 16000 | 110 | 16000 | 140 |
| Cobalt | 17 | (0.17)* | 16 | (0.17)* |
| Chloride | -- | 6200 | -- | 8400 |

| Compound | Other Parameters Head | | Mouth | |
|---|---|---|---|---|
| | SS(ng/g) | UW(ng/L) | SS(ng/g) | UW(ng/L) |
| Benzene | -- | ND | -- | 560 |
| Toluene | -- | ND | -- | 710 |
| Perchloroethylene | -- | ND | -- | 210 |
| Carbon Tetrachloride | -- | ND | -- | 330 |
| Hexachloroethane | 0.5 | 0.16 | 0.5 | 3.6 |
| Hexachlorobutadiene | 1.0 | 0.09 | 20 | 2.3 |
| Pentachlorobenzene | 2.2 | 0.012 | 4.5 | 0.072 |

* Estimated assuming an average suspended sediment concentration of 10 mg/L.

chemicals such as HCB, OCS and mercury occur along the river. There is no water or compound solids data for PAHs, but other media (caged clams and sediments) show that there are significant PAH sources in the Sarnia area. The chloride concentration also increases over the river's course. Marginal increases occur in lead and mercury concentrations; whereas, cadmium, copper, and cobalt do not exhibit significant concentration differences between the head and mouth. There is no apparent change in PCB concentrations along the river based on this very limited data set.

Some chemicals not on the UGLCCS contaminant test list that show significant sources along the river are the volatiles benzene, toluene, perchloroetheylene, and carbon tetrachloride. Hexachloroethane, hexachlorobutadiene, and pentachlorobenzene also display significant positive changes in concentration between the head and mouth of the river.

The partitioning of chemicals between the suspended solids and dissolved phase has a considerable impact on the ultimate fate of the contaminant. The more volatile organics such as benzene, toluene, perchloroethylene, carbon tetrachloride, and hexachloroethane exhibit little tendency to bind to suspended sediments. These compounds will be subjected to continual dilution as they move downstream, and will also be lost from the water by the process of volatilization. The other organics and the metals in Table VII-4 exhibit a much stronger tendency to become adsorbed to suspended particulates. This adsorption reduces the tendency of the chemicals to volatilize from the system. The ultimate fate of the particle-bound organics and metals will be temporary storage in Lake St. Clair followed by transport via the Detroit River to Lake Erie.

Once the particle-bound material reaches these lakes, it is partially available to benthic organisms. These organisms serve as a food source for fish, so the presence of these chemicals in the lake sediments causes an increase in the contaminant burden in consumable sport fish through the process of bioaccumulation. Details of the sediment/water partitioning of some of the persistent organics have been documented as part of the UGLCC Study (37,40).

In addition to concerns about the effect of effluent discharges on water quality, serious consideration must also be given to the effects of intermittent spills on aquatic life and drinking water quality in the river and in downstream areas, including Lake St. Clair and the Detroit River. Between 1974 and 1986, there were a total of 32 spills involving 10 metric tonnes or more of deleterious materials discharged directly to the St. Clair River (36). The most studied spill was that of 9,400 gallons of perchloroethylene (August 13 to 16, 1985) by Dow Chemical Company of Sarnia (36). Drinking water supplies in the downstream towns of

Wallaceburg, Walpole Island, Windsor, Amherstburg, and Marysville, Michigan, were analyzed twice weekly after the spill. As would be expected because of the lack of lateral mixing of the river no perchloroethylene was detected in the Marysville treatment plant on the U.S. side of the river. The highest concentration observed was 7 ppb in raw water at Wallaceburg and Walpole Island. Perchloroethylene concentrations of 2-3 ppb were found much further downstream at Windsor and Amherstburg on the Detroit River. The former values approach the World Health Organization (WHO) drinking water standard for lifetime exposure of 10 ppb.

Some water sampling conducted during the UGLCC Study indicated that higher concentrations of such chemicals as hexachlorobenzene and octachlorostyrene in unfiltered water and suspended sediments were associated with rainfall events (41,42). Further studies are required to assess the importance of such events to water quality.

## Biota Impairments

A number of studies of various biologic components of the St. Clair River ecosystem, (phytoplankton, wetlands, submerged macrophytes, macrozoobenthos, and fish), suggest that the river is increasing in biological productivity in formerly impaired habitats (9,15,19,21,43,44). This increase in productivity is apparently a function of remedial actions to control the input of conventional pollutants and toxic substances and to improve the quality of the river water.

The distribution of macrozoobenthos in an aquatic ecosystem is often used as an index of the impacts of contamination on that system. Undisturbed benthic populations are normally characterized by very diverse populations with a relatively high number of organisms per unit area. Frequently, these populations include significant numbers of pollution intolerant organisms. Perturbed or impaired areas will demonstrate a characteristically reduced diversity of species, an absence of pollution intolerant forms, and typically a reduced number of organisms per unit area, except in the case of pollution with organic materials (e.g., sewage), where certain species tolerant of these conditions can thrive at incredible densities.

Distributions of macrozoobenthos in the St. Clair River have been well documented (1,2,9,45,46,47,48). In 1968, the Canadian shoreline exhibited macrozoobenthic populations characteristic of degraded conditions, compared with the U.S. shoreline. By 1977, however, it was clear that significant improvement had occurred, apparently in response to improved effluent treatment initiated some years prior.

Currently, benthic health along the U.S. shore is good (49,50), although there have been some historical problems downstream of the Black River (46). Figure VII-2 shows the water quality zones along the Canadian side of the river based on benthic invertebrate community structure. Term definitions in the figure are: toxic = no benthic organisms; degraded = large numbers of pollutant tolerant organisms; impaired = lower numbers of pollutant tolerant organisms plus facultative species; fair = atypical community structure; good = normal benthic community structure.

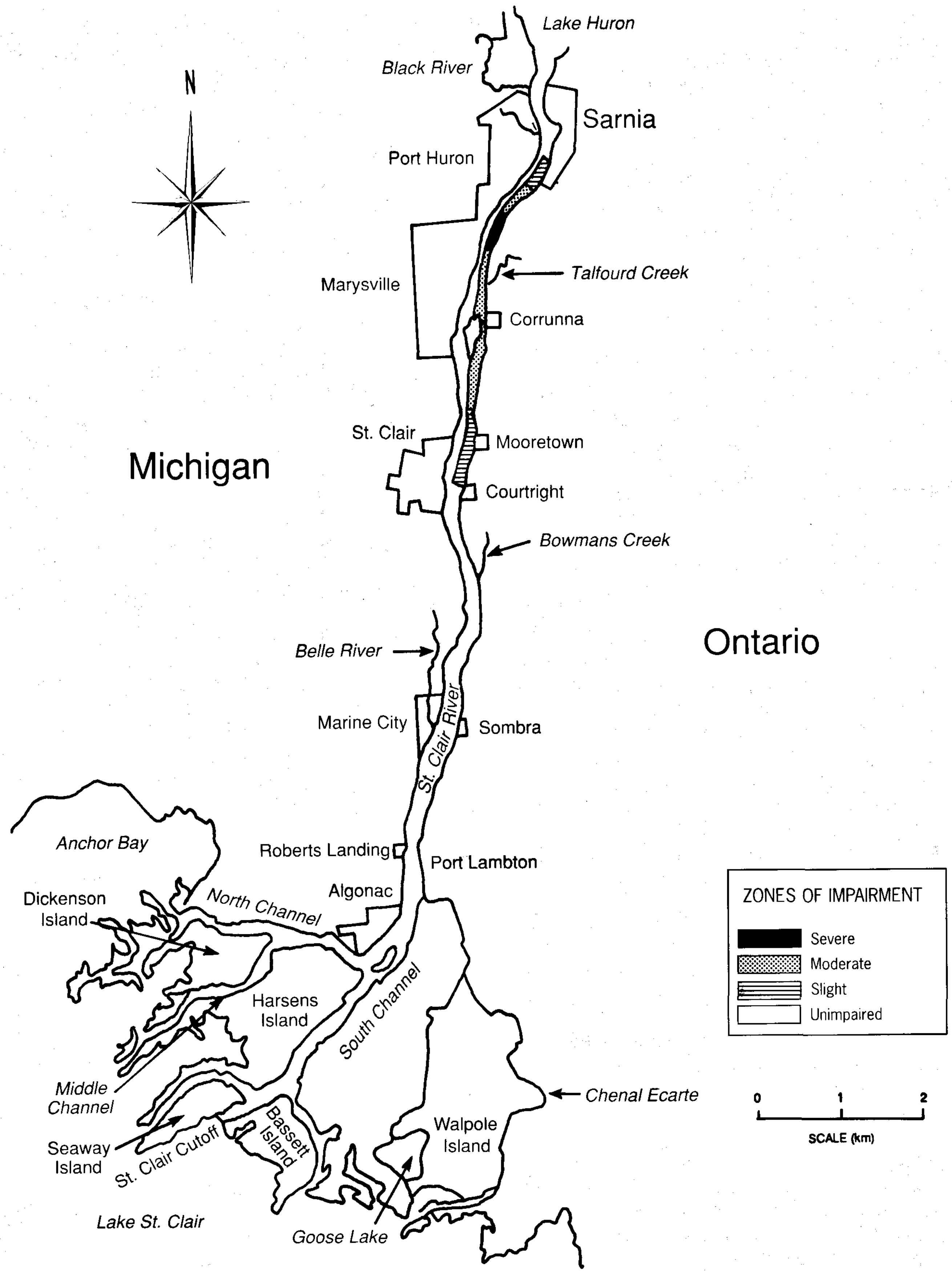
The benthic community begins to be impacted at km 5 near Sarnia's industrial complex. Conditions deteriorate to toxic downstream of Dow Chemical (km 6.5). The ecological status gradually improves until Talfourd Creek (km 10) where the water quality changes adversely to a degraded state. Following this 1 km zone, the benthic community along the Canadian shoreline gradually improves and reaches a "good" condition at km 20.

Historically, conditions along this river shore were much worse. In 1968, the toxic and seriously degraded zone extended over the entire portion of the river surveyed (at least 44 km). This major impact zone decreased to 21 km in 1977. A further improvement is evident from the above 1985 data which showed a major impact zone of 12 km (46).

Direct contaminant toxicity impacts to benthic fauna in the St. Clair River appear to be confined to the Sarnia industrial waterfront and a few km downstream. Recent studies (51) have shown that the sediments from the industrial area are lethal to Hexagenia, Hydallela, and fathead minnows. This confirms earlier work that showed only pollution-tolerant benthic organisms could survive in this region of the river (9).

A wider ranging problem is the bioconcentration and bioaccumulation of chemicals in biota at all trophic levels in the river and in downstream Lake St. Clair. Elevated concentrations of several contaminants with known sources in the St. Clair River have been found in plankton (51), macrophytes (51), benthic organisms [including native (36) and introduced clams (52)], young-of-the-year spottail shiners (36,53), and sportfish (36) in the river.

Of the UGLCCS contaminants, hexachlorobenzene, octachlorostyrene, and mercury are of greatest concern in the St. Clair River. Concentrations of between 50 and 100 ng/g of HCB and OCS have been found in various sportfish from the river (36), although some species contain little or no HCB or OCS. Elevated concentrations of chlordane, G-BHC and mercury were found in young-of-the-year spottail shiners at the mouth of Perch Creek on Lake Huron near the head of the St. Clair River (36). No fish consumption guidelines exist for these compounds, but the World Health Organization (WHO) has set a very low drinking water




NOTE:
Zones of impairment refer to the relative occurrence of pollution tolerant species and to the diversity of benthic species in general.

**Figure VII - 2. Zones of benthic fauna impairment in the St. Clair River.**

guideline of 10 parts per trillion for HCB. OCS is probably of comparable concern since it has a higher bioconcentration factor than HCB.

The University of Windsor (54) studied waterfowl and muskrats on Walpole Island in the St. Clair River. Their data show that the nonmigratory ducks contained consistently higher HCB and OCS residues than did their migratory counterparts. Muskrats on the island also contained measurable HCB and OCS residues. Weseloh and Struger (55) showed that flightless Peking ducks released on Bassett Island in the St. Clair River rapidly accumulated HCB. Residues of PCB, HCB, DDT and other chlorinated organics found in diving ducks in the Lower Detroit River also suggest that waterfowl in the St. Clair River may be a source of human toxicity (56).

Mercury levels in the edible portion of walleye from the Lake St. Clair/St. Clair River vicinity have shown a steady decline from a 1970 maximum value of nearly 2.5 mg/kg or ppm. Current mercury concentrations for walleye up to 45 cm in length are reported as less than 0.5 ppm and are suitable for unlimited consumption (57). Walleye in the 45-65 cm length class generally contain 0.5 to 1.0 ppm mercury, and above 65-75 cm are between 1.0 and 1.5 ppm (57).

In 1970, mercury in northern pike fillets was more than double that of walleye. Levels now, however, are less than 25 percent of the 1970 values. Northern pike up to 55 cm contain less than 0.5 ppm mercury while those larger than 55 cm contain between 0.5 and 1.0 ppm. Similar reductions in the mercury levels in white bass have been observed (57). Individuals up to 30 cm contain less than the 0.5 ppm consumption guideline. Larger fish of most species still contain mercury concentrations in excess of 0.5 ppm. This may be due, in part, to historical mercury contamination and to mercury recycling within the system. The PCB content of most fish in the St. Clair River and Lake St. Clair is below the 2 ppm consumption guideline set by the OMOE and the Michigan Department of Natural Resources (MDNR), as well as the U.S. Food and Drug Administration action level, but levels exceeding the Great Lakes Water Quality Agreement (GLWQA) Specific Objective of 0.1 ppm were found.

Alkyl lead compounds have been detected in game fish near Ethyl Corporation (11). Since the organolead compounds are much more toxic than inorganic lead, some attention may be required to control loadings from this source. There are no fish consumption guidelines for these compounds, although a tentative consumption guideline of 1.0 mg/kg was established by OMOE in 1984 for total alkyl lead.

Elevated concentrations of several PAHs have been found in caged clams downstream of Sarnia's industrial discharges. The data on these chemicals in the river are too limited at this stage to say whether or not these chemicals are a problem. Other trace metals on the UGLCCS parameter list, including cadmium, iron, copper, and cobalt do not appear to pose any problems in biota along the river.

Other contaminants that have been found at elevated concentrations in caged clams and fish from the river are: hexachloroethane, hexachlorobutadiene, pentachlorobenzene, perchloroethylene, carbon tetrachloride, and benzene (36). These contaminants may exert an individual toxicity effect. Further, the potential additive, antagonistic, or synergistic effects of multiple contaminant exposure to the river's biota and to fish and water consumers is completely unknown.

## Bottom Sediments

The St. Clair River is essentially a conduit of water between Lake Huron and Lake St. Clair. Very little sediment accumulates because of the high current velocities in the river (0.6 - 1.8 m/s). Sediments are largely a pavement of well-rounded cobbles and boulders, with sand or till in the interstices over cohesive glacial clay, and sand ripples and dunes moving as bed load. There was no consistent trend along the shore in sediment thickness, but variations in an offshore direction indicate a wedge-shaped deposit that is thickest at the shoreline. The average thickness of the deposit is 9 cm, with a mean width of 100 m. The average texture of the samples was 63% sand, 32% gravel, and 5% silt-clay, with a mean grain size of 1.7 mm (58).

Based on very limited sampling, the inorganic elemental composition of the St. Clair River sediments was: $SiO_2$, 65%; $Al_2O_3$, 6.3%; $Fe_2O_3$, 6.9%; MgO, 3.5%; CaO, 12.7%; $Na_2O$, 1.3%; $K_2O$, 1.6%; $TiO_2$, 0.4%; MnO, 0.06%; and $P_2O_5$, 0.05% (59). On average, the organic carbon content of the sediments is fairly low (0.9%) as would be expected from the coarse nature of the river's sediments (60).

The most extensive recent sediment surveys of the river were conducted by the OMOE (60) in 1985 (78 stations), and by Oliver and Pugsley (61) in 1984 (45 stations). In addition, a more limited study of 33 stations (21 in the U.S.), in which the only organics analyzed were PCBs and oil and grease, was conducted in 1985 by the United States Fish and Wildlife Service (62). A more intensive survey covering 60 stations in the Sarnia industrial area was conducted by Environment Canada and Ontario Ministry of the Environment in 1985 (36).

These samples were collected using a variety of techniques including cores, Shipek dredge, and divers. The information derived from all these sampling methods is similar in this river because most of the surficial sediment is of recent origin (36). Only limited historical information is available from sediments in the river, since they are shallow and transitory in nature.

Despite the coarseness of the sediments, some heavily contaminated deposits were found in the river. Table VII-5 compares the sediment chemical concentrations to the criteria for open-water disposal of dredged spoils. The contaminant range indicates that a sediment guideline is exceeded at some location for every parameter except nitrogen and phosphorus. In the cases of PCBs, mercury, lead, copper and iron, the mean contaminant concentration in river sediments exceeds both the Ontario and several U.S.EPA guidelines. Most guideline exceedances occurred along Sarnia's industrial waterfront, but sediment samples collected at several other locations along both the Canadian and United States shores of the river also exceeded the guidelines for some parameters.

No sediment objectives are available for two of the important UGLCCS parameters, hexachlorobenzene (HCB) and octachlorostyrene (OCS). These chemicals are present at high concentrations in several locations along the river.

The UGLCC Study shows that the mean values for all parameters are highest along Sarnia's industrialized waterfront and gradually decrease downstream. The wide range of concentrations encountered in each river reach shows the extreme variability of sediment contamination along the river. This is likely due to the transitory nature of the sediment and their lack of homogeneity.

Areas of elevated concentration for HCB and OCS are found downstream of the Cole Drain (also known as the Township Ditch) and adjacent to Dow Chemical's First Street sewer discharge. Concentrations of HCB and OCS are in the high ppm range at the latter site. These extremely high sediment concentrations are caused by contamination of the area with nonaqueous waste material that has leaked from the Dow site in the past (63). The Dow First Street Sewer has been closed. It should be noted that some HCB/OCS-containing streams have been diverted to Fourth Street since the time of this survey. The HCB and OCS concentrations in bottom sediments diminished by one or two orders of magnitude downstream of Dow, but remained elevated, well above background levels, along the entire length of the Canadian Shoreline to Lake St. Clair (61).

Sarnia's industrial waterfront sediments also contain high concentrations of oil and grease. For oil and grease, other high concentration areas along the Canadian shoreline were found adjacent to downtown Sarnia upstream of major industries (2,200 and 1,300 ppm), adjacent to Imperial Oil (1,200 ppm), just above Talfourd Creek (4,700 and 1,200 ppm), just north of Corunna (2,300 and 1,100 ppm), and below Courtright (1,400 ppm).

## TABLE VII-5

St. Clair River sediments compared to various criteria for open water disposal of dredged material (mg/kg).

| | Criteria | Criteria | Criteria U.S.EPA 1977 | | | St. Clair River Sediments* | |
|---|---|---|---|---|---|---|---|
| Chemical | (Canada) | (Ontario) | Non-Polluted | Moderately Polluted | Heavily Polluted | Range | Mean |
| PCBs | -- | 0.05 | -- | -- | >10 | ND-2.6 | 0.13 |
| Oil and Grease | 1500 | 1500 | < 1000 | 1000-2000 | >2000 | 43-5300 | 1000 |
| Mercury | 0.3 | 0.3 | < 1.0 | -- | >1.0 | ND-51 | 2.2 |
| Lead | -- | 50 | < 40 | 40-60 | >60 | ND-620 | 59 |
| Cadmium | -- | 1 | -- | -- | >6 | ND-2.2 | 0.51 |
| Copper | -- | 25 | < 25 | 25-50 | >50 | 3.3-190 | 30 |
| Iron | -- | 10,000 | < 17,000 | 17,000-25,000 | >25,000 | 3,300-75,000 | 12,000 |
| Phosphorus | 1000 | 1000 | < 420 | 420-650 | >650 | 100-500 | 230 |
| Kjeldahl Nitrogen | 2000 | 2000 | < 1000 | 1000-2000 | >2000 | ND-1400 | 420 |

* Data from (76).

Somewhat elevated concentrations of PCBs were found in the Sarnia area, but this may be due to an analytical interference problem from other chlorinated organics (64). The only additional PCB elevated concentration area was located just below Ontario Hydro, downstream of the industrial complex (1,900 ppb), and could indicate a PCB source to the river at this location.

In general, sediments on the U.S. side of the river do not contain significant quantities of HCB and OCS. PCB concentrations along this shoreline are also quite low, ranging from undetectable to 150 ppb (mean value, 36 ppb). A few minor areas of elevated concentrations for oil and grease were found above the Blue Water Bridge adjacent to Port Huron (2,300 ppm), above the Belle River adjacent to Marine City (2,000 ppm), and along the North Channel downstream of Algonac (1,200, 1,200 and 1,300 ppm).

The concentrations of metals along the Canadian shoreline from OMOE's complete river study (1985) show cadmium and cobalt concentrations are low and reasonably constant over the entire length of the river. A few minor exceedences of dredging guidelines are found for iron and copper, but in general, the concentrations of these metals in the sediments do not appear to be a problem. The highest value of copper (180 ppm) was found just downstream of Sarnia's sewage treatment plant outfall. The highest iron concentration (7.5%) was observed just south of Beckwith Street, Corunna, and the Corunna Waste Water Treatment Plant.

Total lead concentrations in the sediments were low over most of the river except just south of Ethyl Corporation. The highest value found was 330 ppm for the site closest to Ethyl, with downstream concentrations decreasing systematically (244 ppm, 180 ppm, and 79 ppm). Ethyl Corporation produces alkyl lead compounds which are used as anti-knocking agents in gasoline. It is likely that the sediments contain a mixture of inorganic and organic lead forms, all of which have been shown to bioconcentrate in fish (11). The high sediment lead concentrations at these sites indicate an active lead source in this location.

Historically the most serious heavy metal problem in the St. Clair River has been mercury. Mercury is present at significantly elevated values at and downstream from Sarnia's industrial complex. The highest mercury value (51 ppm) was recorded adjacent to Dow Chemical but all sites below the Cole Drain exhibit high concentrations. Although these concentrations are considerably lower than peak mercury values observed in the late 1960s and early 1970s (1,470 ppm)(35), they are still quite high. This suggests that continuing, albeit low level, sources of mercury in the area may be inhibiting reductions in sediment concentrations.

Prior to 1973, Dow Chemical operated mercury cell chlor-alkali plants on site. These plants were identified as the source of mercury. These facilities have since been decommissioned and replaced by new plants using the diaphragm process which does not use mercury. Point source data show that low concentrations (< 1 ug/L) of mercury are still discharged from the Dow site (65).

For the metals on the U.S. side of the river, the only major anomalous value was 620 ppm for lead for a site just downstream of the Canadian National Railway tunnel. The next site (approximately 1 km downstream) had a somewhat elevated concentration of 69 ppm. This site is also downstream of the Black River which had an elevated lead level in river mouth sediments. Most of the other metal concentrations on the U.S. side of the river are near Lake Huron background values. Sediment nutrient concentrations were low on both sides of the river and do not seem to be a problem (64).

Many other organic compounds not included in the UGLCCS parameter list are present in St. Clair River sediments. Hexachlorobutadiene, hexachloroethane, and pentachlorobenzene are other major components of waste byproducts from Dow's chlorinated solvent production. These compounds are present at high concentrations in the sediments adjacent and downstream of Dow, and are strongly correlated with HCB and OCS distributions. Similarly, the solvents perchloroethylene and carbon tetrachloride have been found at concentrations up to the percent range in sediments opposite Dow due to solvent spillage and leakage of non-aqueous wastes into the river at this site (61). Dow has taken action to reduce these problems since these analyses (66).

Polynuclear aromatic hydrocarbons (PAHs) have been found at concentrations up to 140 ppm near Sarnia's industrial complex. The alkylated PAHs were present in all samples at lower concentrations than the parent compounds. As high temperature combustion does not produce alkyl-PAHs, their presence indicates petroleum as a likely source. The presence of n-alkane concentrations that correlate well with oil and grease distributions in the area support the contention that refineries and petro-chemical plants are the probable sources.

A limited amount of data are available on dibenzo-p-dioxins and dibenzofurans in St. Clair River sediments (36). Maximum concentrations of total dioxins and furans found downstream of Dow's First Street sewers were 12 and 100 ppb, respectively. Most of these compounds consisted of the octa- and heptacongeners. The 2,3,7,8 tetrachlorodibenzo-p-dioxin was not found in any of the samples.

Four other chemicals were found at high concentrations in sediments collected near Sarnia: diphenylether, biphenyl, 4-ethylbiphenyl, and diethyl biphenyl (67). The concentrations of these chemicals ranged from undetectable (ND) to 490 ppm for diphenylether, from ND to 150 ppm for biphenyl, from ND to 5 ppm for

4-ethylbiphenyl, and from ND to 5.2 ppm for diethylbiphenyl. The ratio of these chemicals in the sediments is similar to that present in heat transfer fluids. Two such fluids, Dowtherm A (73.5% diphenylether/26.5% biphenyl) and Therminol VP-1, are produced only in the United States by Dow and Monsanto. These fluids also contain ethyl and diethylbiphenyls as lesser components. The sediment data indicated that heat exchange fluids entered the river from Sarnia's industrial complex.

## Tributary Sediments

Sediment samples were collected from the mouths of tributaries entering the St. Clair River to identify other potential contaminant sources to the river. The analysis of the Canadian tributaries was conducted by the Ontario Ministry of the Environment in 1984 and 1985 (68). The Canadian tributary that contributes the greatest chemical burden to the river is the Cole Drain. While no bottom sediment samples were obtained at the Cole Drain during the Canadian tributary study, water quality and suspended sediment data reflect treated leachate and untreated runoff from several industrial landfill sites upstream. Levels of HCB (0-210 ng/L), HCBD (0-345 ng/L), HCE (0-550 ng/L) and OCS (0-160 ng/L) in whole water were generally 1-2 orders of magnitude higher than at other tributaries (68). Sediment samples from Talfourd Creek and Murphy Drain contained HCB levels of 55 and 103 ppb, respectively. Metal contamination in tributary sediments resulted in provincial dredging guidelines being exceeded at several Ontario tributaries for chromium, copper, iron and nickel. Mercury guidelines were exceeded in a single sample obtained from the Talfourd Creek mouth (0.76 ppm). Mean instantaneous loadings based on suspended sediment and water chemistry and instantaneous flow were calculated for four Ontario tributaries (Table VII-6).

The U.S. tributaries were analyzed in 1985 by the Great Lakes National Program Office (GLNPO) of the U.S.EPA (69). For the U.S. tributaries, a high value for lead (270 ppm) and somewhat elevated copper concentrations (160 ppm) were found in Black River sediments (Table VII-7). The Black River is potentially a source for anomalous lead concentrations observed south of the Black River confluence on the St. Clair River. Elevated concentrations for several parameters (PCBs 76 ppb, PAHs 33 ppm, oil and grease 11,600 ppm, lead 230 ppm, TKN 6,600 ppm and phosphorus 1,300 ppm) were found in an unnamed creek across the river from Lambton Generating Station. The only other anomalously high concentrations were found for PCBs, 490 and 95 ppb, in the Belle River. High levels of calcium, strontium and sodium were found in sediments near the Diamond Crystal Salt Company and suggest continuing inputs of total dissolved solids. Otherwise the

TABLE VII-6

Mean instantaneous loading values from Ontario tributaries[1] for suspended solids (SS) and water (WA)[2].

| Parameter | Perch Creek | | Cole Drain | | Talfourd Creek (upstream) | | Talfourd Creek (mouth) | | Baby Creek | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (ss) | (wa) | (ss) | (wa) | (ss) | (wa) | (ss) | (wa) | (ss) | (wa) |
| **Chlorinated Organics (ug/sec)** | | | | | | | | | | |
| HCB | 0.00 | 0.00 | 17.6 | 50.00 | 0.50 | 1.00 | 3.70 | 17.00 | 0.08 | 0.00 |
| OCS | 0.00 | 0.00 | 14.6 | 20.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.07 | 0.00 |
| PCBs | 41.5 | 0.00 | 4.00 | 0.00 | 9.80 | 0.00 | 1.70 | 0.00 | 0.30 | 0.00 |
| HCBD | NA[3] | 0.00 | NA | 59.0 | NA | 0.00 | NA | 3.00 | NA | 0.00 |
| HCE | NA | 0.00 | NA | 62.0 | NA | 0.00 | NA | 18.0 | NA | 0.00 |
| **Pesticides (ug/sec)** | | | | | | | | | | |
| Atrazine | 0.0 | 186.0 | 1.0 | 89.0 | 0.0 | 512.0 | 0.0 | 557.0 | 0.0 | 271.0 |
| alpha-BHC | 0.00 | 0.0 | 0.04 | 2.5 | 0.00 | 0.9 | 0.00 | 6.8 | 0.00 | 0.0 |
| gamma-BHC | 0.00 | 5.0 | 0.01 | 0.4 | 0.00 | 0.2 | 0.00 | 0.9 | 0.00 | 0.02 |
| Dieldrin | 0.4 | 0.0 | 0.2 | 0.0 | 0.4 | 0.0 | 0.7 | 0.0 | 0.02 | 0.0 |
| Endosulphan-I | 0.00 | 0.0 | 0.1. | 0.0 | 0.00 | 0.0 | 1.1. | 0.0 | 0.01 | 0.0 |
| pp-DDE | 0.03 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| **Metals (mg/sec)** | | | | | | | | | | |
| Cadmium | 0.17 | 0.09 | 0.02 | 0.03 | 0.07 | 0.17 | 0.05 | 0.57 | 0.01 | 0.05 |
| Chromium | 14.3 | 20.7 | 1.5 | 0.2 | 3.4 | 5.7 | 7.2 | 5.9 | 0.7 | 1.4 |
| Copper | 4.4 | 32.6 | 4.4 | 0.1 | 2.9 | 7.3 | 6.1 | 1.9 | 1.0 | 2.1 |
| Iron | 6332 | 9163 | 434 | 372 | 2494 | 2648 | 1644 | 1124 | 512 | 550 |
| Lead | 5.02 | 13.644 | 1.02 | 2.43 | 1.93 | 3.573 | 2.9 | 7.442 | 0.42 | 0.364 |
| Mercury | 0.009 | 0.063 | 0.006 | 0.019 | 0.041 | 0.012 | 0.019 | 0.054 | 0.001 | 0.004 |
| Zinc | 26.44 | 62.64 | 6.1 | 12.33 | 11.62 | 19.32 | 13.22 | 25.24 | 2.67 | 5.53 |

1 Data from reference (68).
2 The tributaries are arranged in a downstream order relative to the St. Clair River.
3 NA = Analyses Not Available.

TABLE VII-7

Summary of sediment quality in mouths of Michigan tributaries to the St. Clair River.

| | NUMBER OF ANALYTICAL DETECTIONS | MAXIMUM | MINIMUM | MEAN | STANDARD DEVIATION |
|---|---|---|---|---|---|
| MAJOR METALS AND TRACE METALS (mg/kg) | | | | | |
| CALCIUM | 10 | 350000 | 11000 | 65200 | 96051 |
| MAGNESIUM | 10 | 7500 | 4600 | 5150 | 812 |
| SODIUM | 10 | 3400 | 100 | 477 | 978 |
| POTASSIUM | 10 | 1100 | 200 | 570 | 337 |
| ALUMINUM | 10 | 8100 | 1100 | 4490 | 2259 |
| IRON | 10 | 17000 | 2100 | 10610 | 4203 |
| ARSENIC | 10 | 9.2 | 1.4 | 5.25 | 2.46 |
| BARIUM | 10 | 81 | 11 | 41.50 | 20.05 |
| BERYLIUM | 10 | 0.4 | 0.1 | 0.19 | 0.08 |
| BISMUTH | 10 | 17 | 8 | 9.99 | 3.17 |
| CADMIUM | 10 | 0.6 | 0.2 | 0.36 | 0.18 |
| CHROMIUM | 10 | 84 | 1.3 | 19.71 | 22.19 |
| COBALT | 10 | 9.7 | 1 | 5.51 | 2.60 |
| COPPER | 10 | 160 | 3.1 | 38.53 | 42.97 |
| LEAD | 10 | 270 | 7 | 86.50 | 87.76 |
| MANGANESE | 10 | 340 | 52 | 202.80 | 95.60 |
| MOLYBDENUM | 10 | 4.5 | 1 | 2.13 | 0.98 |
| NICKEL | 10 | 62 | 4 | 18.76 | 15.65 |
| SILVER | 10 | 0.3 | 0.3 | 0.30 | 0.00 |
| STRONTIUM | 10 | 2700 | 8.3 | 303.93 | 798.88 |
| VANADIUM | 10 | 22 | 2.8 | 13.62 | 6.12 |
| ZINC | 10 | 150 | 14 | 85.50 | 41.26 |
| TIN | 10 | 5.2 | 4 | 4.27 | 0.46 |
| LITHIUM | 10 | 22 | 3.7 | 13.81 | 5.42 |
| SELENIUM | 10 | 0.6 | <0.1 | 0.24 | 0.20 |
| YTTRIUM | 10 | 8.6 | 1.1 | 5.10 | 2.27 |
| MERCURY | 7 | 0.5 | 0.1 | 0.21 | 0.14 |
| NUTRIENTS AND OTHERS PARAMETERS IN ST. CLAIR RIVER TRIBUTARY SEDIMENTS (mg/kg) | | | | | |
| COD | 10 | 91000 | 3000 | 29300 | 24742 |
| OIL AND GREASE | 10 | 11600 | 650 | 2146 | 3235 |
| AMMONIA | 10 | 250 | 8.3 | 83 | 61 |
| TKN | 10 | 6600 | 190 | 1627 | 1771 |
| PHOSPHORUS | 10 | 1300 | 93 | 576 | 321 |
| CYANIDE | 10 | 0.7 | 0.1 | 0.24 | 0.16 |
| TOTAL SOLIDS (%) | 10 | 74.7 | 13.5 | 58.05 | 17.19 |
| TOTAL VOLATILE SOLIDS (%) | 10 | 20 | 1.3 | 5.73 | 5.04 |
| TOTAL PCBs, PAHs, PHTHALATE ESTERS, AND DDT & METABOLITES (ug/kg) | | | | | |
| TOTAL PCBs | 7 | 490 | 39 | 150.86 | 151.53 |
| TOTAL PAHs | 6 | 32600 | 200 | 6866.67 | 11552.44 |
| TOTAL DDTs | 7 | 83 | 2 | 24.29 | 26.91 |
| TOTAL PHTHALATES | 8 | 1900 | 300 | 768.75 | 516.56 |
| SELECTED OTHER ORGANICS (ug/kg) | | | | | |
| HCB | | 6 | 8 | 2 | 3.33 |
| 2.13 | | | | | |
| DICHLOROMETHANE | 10 | 65.6 | 1.2 | 26.41 | 20.23 |

Michigan tributaries do not appear to be significant sources of contaminants to the river.

Most sediments in the St. Clair River are transitory, having a lifetime in the river of less than one year (61). The moving bed sediments constitute only a very minor component (less than 1 percent) of total contaminant transport along the river (64). The ultimate sink of this fine sand that constitutes bed load appears to be the St. Clair River Delta. Sand cores taken from the delta area contain mercury and other contaminants to a considerable depth (64). Because of the contaminant storage in this area, contaminant body burdens in wildlife could remain elevated for a considerable period, even after control measures have been implemented. Most of the contaminants are transported via water and suspended solids which would be carried and dispersed further down the system into Lake St. Clair and Lake Erie.

## B. SPECIFIC CONCERNS

A summary of specific concerns including contaminants and associated use impairments, media affected and location is provided in Table VII-8.

### 1. Conventional Pollutants

#### Nutrients

Phosphorous reduction programs have had a major impact on the discharge of phosphorus to the St. Clair River. Water column concentrations for total phosphorus (1984) were low, ranging from 0.009 to 0.03 mg/L (41). These values are much lower than reported for the river in the 1970s (45). Bottom sediments (64) and suspended sediments (41) for the river are both below the 1000 ppm guideline for open-water disposal of dredged sediments. The nitrate/nitrite concentration range found in the river (0.29-0.31 mg/L) is typical of that found in oligotrophic waters (70). Thus, the discharge of nutrients to the St. Clair River seems to be largely under control.

#### Chloride

Chloride loadings to the St. Clair River are very high. The chloride concentration changes from a mean of 6.2 mg/L at the head of the river, to 7.7 mg/L at the river's mouth (41). This change amounts to a daily river loading of about 585 metric tonnes of chloride. Chloride is a conservative parameter that will not be lost from the system. The increased salinity of the lower Great Lakes from these very large chloride inputs could potentially have a significant effect on the structure of biological communities in the system (71). A shift in the organism diversity to more saline-tolerant species (halophilic) could occur over long time scales.

#### Bacteria

Concentrations of bacteria increase along the course of the St. Clair River. Heterotroph counts in bottom waters along the Canadian shore increased from 2,200 organisms/ml at the head of the river, to 10,500 at the mouth (51). Sediment bacteria increased from 1,500 bacteria/ml at the head, to 450,000 at the mouth. Head to mouth changes along the U.S. shore were 110 to 13,000 organisms/ml for the water, and 700 to 27,000 heterotrophs/ml for the sediments. In some cases, swimming areas along the river have been closed due to bacterial contamination (72).

TABLE VII-8

Specific concerns in the St. Clair River, uses impaired, and geographic scope of the perceived problem.

| CONCERN | USE IMPAIRMENT | MEDIA | GEOGRAPHIC SCOPE |
|---|---|---|---|
| <u>Conventional Pollutants</u> | | | |
| chloride | potential alteration of biological community structure | water | whole river<br>lower Great Lakes |
| bacteria | potential human health hazard | water, sediments | some areas along river, increases downstream |
| <u>UGLCC Parameters</u> | | | |
| hexachlorobenzene | toxicity to biota<br>human health | water, sediments, biota<br>fish | below Sarnia<br>whole river |
| octachlorostyrene | toxicity to biota<br>human health | water, sediments, biota<br>fish | below Sarnia<br>whole river |
| PAHs | toxicity to biota | sediments, biota | below Sarnia<br>below Lambton |
| oil and grease | toxicity to benthic community | sediment<br>water (?) | whole river (esp. Ontario shore) |
| PCBs | human health hazard<br>toxicity to fish | some fish<br>sediments, biota | whole river<br>below Lambton |
| mercury | human health<br>toxicity to biota | fish, sediment | whole river (below Sarnia, esp. near Dow) |
| lead | human health<br>toxicity to biota | fish<br>sediment | below Ethyl Corp.<br>below Ethyl Corp. |
| <u>Other Contaminants</u> | | | |
| hexachlorobutadiene<br>hexachloroethane<br>pentachlorobenzene | ?<br>?<br>? | water, sediments, biota<br>water, sediments, biota<br>water, sediments, biota | below Sarnia (esp. near Dow) |
| benzene<br>perchloroethylene<br>carbon tetrachloride | toxicity to biota<br>toxicity to biota<br>toxicity to biota | water, biota<br>water, biota<br>water, biota | below Sarnia<br>below Sarnia<br>below Sarnia |
| diphenyl ether<br>biphenyl | ?<br>? | sediments<br>sediments | Sarnia<br>Sarnia |
| phenols | ? | * | Sarnia dischargers |
| pesticides | ? | water | whole river |

? - Further studies required to determine potential impact.

* - Historical problem, however, little data available on present concentrations in various media.

## 2. UGLCCS Toxic Organics and Heavy Metals

The priority contaminants in the St. Clair River found from the water, biota, and sediment reports are remarkably consistent. Hexachlorobenzene (HCB) and octachlorostyrene (OCS) are the two chlorinated UGLCCS chemicals of most concern. These chemicals are associated with Dow Chemical's Sarnia operations. Major sources include Dow Chemical's direct sewer discharges, and indirect leachate from Dow's Scott Road landfill via the Cole Drain. HCB in the St. Clair River water exceeds water quality guidelines near the discharges, and OCS exceeds an approximate guideline value calculated from bioconcentration considerations. The river sediments are contaminated with HCB and OCS all the way to Lake St. Clair (59,76). HCB and OCS are also bioaccumulated by all trophic levels of biota including plankton, benthic organisms, young-of-the-year fish, and sport fish.

PAHs, including benzo-a-pyrene, have been found in caged clams and sediments in the river. PAHs were not detected in water samples obtained from the mouth of Talfourd Creek, Baby Creek, Murphy Drain or the Cole Drain in 1984. Data on PAHs in the St. Clair system are limited at present, but sufficient information exists to demonstrate cause for concern.

The importance of PCB loadings to the St. Clair River is not a clear-cut issue. PCB concentrations in bottom sediments along Sarnia's industrial waterfront appear to be elevated. However, analytical difficulties in PCB determinations in this area have been cited (64). The presence of other halogenated organics may be leading to false high PCB readings (by a factor of 4) in sediments from this region (64,77). PCBs in fish from the river may also be misidentified and overestimated. Maximum PCB levels in sediments from Ontario tributaries were observed at the mouth of Talfourd Creek (65 ppb).

PCB levels appear to be somewhat elevated in sediments and young-of-the-year fish downstream of Lambton Generating Station. Because this site is about 15 km downstream of Sarnia's industrial discharges, PCB analytical interferences may be less significant at this site. Thus, a PCB discharge to the river may be occurring in this region. The PCB residues in fish from the river and Lake St. Clair have declined by 50% since 1976 (36). Except for a few of the larger fish of some species, most sport fish are less than the 2 ppm guideline.

Because of the considerable number of refineries and petrochemical plants along the Canadian side of the river, oil and grease discharges to the river are of concern. Oil and grease in sediments are highest along Sarnia's industrial waterfront, with many values exceeding open-water dredge disposal guidelines. Tar-saturated sediments were observed from just north of the Imperial/ Polysar boundary, to south of the Suncor property (36).

They occur at or just below the surface in cores collected up to 25 meters from the shore. The cohesion provided by the tar apparently stabilizes the contaminated sediments and hinders their incorporation into bed load transport.

Additional areas on the Canadian shoreline with high sediment oil and grease levels were adjacent to downtown Sarnia (upstream of the industrial complex), just above Talfourd Creek, just north of Corunna, and below Courtright. On the U.S. side of the river, oil and grease sediment levels were high above the Blue Water Bridge adjacent to Port Huron, above the Belle River adjacent to Marine City, and along the north channel downstream of Algonac. An unnamed creek across the river from Lambton Generating Station also contained anomalously high oil and grease sediment concentrations. However, the creek has no visible discharge to the St. Clair River and the high level here may be the result of a spill on Michigan Highway 29 (64). Oil and grease levels measured at the mouths of Baby Creek and the Murphy Drain were generally an order of magnitude higher than other Ontario tributaries with a maximum value of 7,380 ppm observed at the Murphy Drain.

Of the UGLCCS heavy metals, only mercury and lead appear to be of concern. Mercury concentrations of the larger fish of some species still exceed the consumption guideline of 0.5 ppm. Sediment mercury concentrations near Dow are still elevated, indicating a continuing mercury source in the area. The discharge of mercury to the river has been reduced dramatically since the 1970s, and fish mercury concentrations may be due, in part, to mercury recycling in the system.

Lead concentrations in sediments and biota are elevated downstream of Ethyl Corporation. Because a portion of the lead loading from this source is the more toxic alkyl lead compounds (11), the environmental implications of this discharge to the river are of concern.

### 3. Other Specific Contaminants

Three other contaminants associated with Dow's chlorinated solvent production that are consistently present in water, sediments, and biota in the river are hexachlorobutadiene, hexachloroethane, and pentachlorobenzene. The concentrations of these contaminants are highly correlated with HCB and OCS. The discharge of volatile organics to the river is also fairly high. Volatile substances of greatest concern in the area are benzene, perchloroethylene, and carbon tetrachloride. Near source inputs, these chemicals are found at higher concentrations than recommended water quality guidelines. They are also found in biota, including fish, in the river. Diphenylether and biphenyl are found at very high concentrations in sediments along Sarnia's industrial waterfront. The loss of heat exchange fluids to the river at this location is apparent.

Phenols have been a historical problem along the Canadian side of the river downstream from Sarnia. Since the implementation of improved waste water treatment by industrial waste dischargers in the area, the phenol loadings to the river have been drastically reduced (78). Very little data on phenols was produced for the water, biota, and sediment studies. The Point Source Workgroup (65) showed that discharges of phenols were still of concern in certain industrial and municipal discharges in Sarnia.

Pesticides are common organics that have been studied extensively throughout the Great Lakes Basin. Several common pesticides such as DDT and its breakdown products, alpha- and gamma-benzene hexachloride, and dieldrin are found in the St. Clair River (79). However, the concentration of these contaminants does not change significantly over the river's course, indicating that there are no significant sources along the river (37,79). Elevated concentrations of chlordane, gamma-BHC and mercury were found in young-of-the-year spottail shiners at the mouth of Perch Creek on Lake Huron near the head of the St. Clair River (36). Several pesticides were frequently detected in Ontario tributaries to the St. Clair River. These included alpha-BHC, a breakdown product of the insecticide lindane and atrazine, a triazine herbicide, found in whole water samples. The latter compound was estimated to account for a nearly 1 mg/s loss to the St. Clair River, from Talfourd and Baby Creeks and Murphy and Cole Drains. The predominant pesticide occurring on suspended solids was dieldrin; however, total loading from these creeks was in the order of 0.9 ug/s (68).

## 4. Habitat Alterations

Historically, humans made considerable changes in the St. Clair river for navigational purposes (80). Recent physical habitat alterations along the St. Clair River appear to be minimal; however, more information about shoreline development and its effects is needed before a definitive statement can be made. There has been periodic dredging in the lower channels of the river about every two years. Chemical alteration of the habitat is a problem for 12 km downstream of Sarnia's heavy industry, as indicated by benthic studies (49).

## C. SOURCES

### 1. Municipal and Industrial Point Sources

A study by the UGLCCS Point Source Workgroup (65) indicates that a total of 52 known point sources were discharging to the St. Clair River in 1986. The total point source flow was estimated at 91,800 x $10^3$ $m^3/d$. Apparently, 96 percent of this total was utilized by electrical generating facilities for once-through, noncontact cooling; of the remainder of the flow, 2,590 x $10^3$ $m^3/d$, was contributed from industrial sources. Eighteen of these sources were sampled for a total of 26 study parameters. The calculated loadings from these analyses are presented in Table VII-9.

Industrial sources were found to be important contributors of most of the UGLCC Study parameters, compared with municipal facilities. The predominant sources were the petrochemical plants in the Sarnia, Ontario area, known as "Chemical Valley". The majority of the sources were located in the upper 10 km of the St. Clair River. These industrial sources were responsible for the majority of the loadings of HCB, OCS, PAHs, oil and grease, lead, mercury, copper, nickel, cobalt, iron, chromium, chlorides, total organic carbon (TOC), total suspended solids (TSS), and a spectrum of organic contaminants including volatile hydrocarbons, acid and other base neutral extractable hydrocarbons.

A comparison of municipal direct and indirect sources, and industrial direct and indirect sources by country of origin for each parameter of concern is shown in Table VII-10. Direct sources are those discharged to the river, indirect are discharged to tributaries or drains which flow into the St. Clair River.

The point source data are too limited (single day survey by the U.S., and three to six day surveys by Canada) to permit the calculation of precise annual loadings. For more common parameters, the data were compared to self-monitoring data collected by the industries and municipalities. This provides an indication as to how representative the sampling was. For most parameters, the point source samples were within normal ranges. Despite the limitations, the data are adequate to make conclusions and recommendations concerning relative point source contributions, and identify major point sources of concern.

The point source contributions of the following parameters were considered important by the Point Source Workgroup Report (65), based on concentration alone, for the reasons indicated:

TABLE VII-9

Loading summary of principal sources of UGLCCS paramerers to the St. Clair River (based on data collected in 1986).

| PARAMETER | TOTAL LOADING (kg/d) | PRINCIPAL SOURCE(S) | % OF TOTAL | LOADING (kg/d) | CONCENTRATION RANGE (ug/L) | IMPORTANT PARAMETER (*)[1] |
|---|---|---|---|---|---|---|
| Total PCBs | 0.006 | Dow Chemical | 53.3 | 0.0032 | ND-0.441[2] | - |
| | | Port Huron WWTP | 33.4 | 0.002 | 0.025 | |
| Hexachlorobenzene | 0.0247 | Dow Chemical | >90 | 0.03 | ND-0.829 | * |
| Octachlorostyrene | 0.0047 | Dow Chemical | ~100 | 0.0047 | 0.024-0.094 | - |
| Total Phenols | 12.2 | Sarnia WPCP | 35.5 | 4.32 | 52-165 | * |
| | | Dow Chemical | 14.6 | 1.78 | 3.5-4.5 | |
| | | Pt. Edward WPCP | 13.9 | 1.69 | 11-1780 | |
| PAHs | 0.331 | Cole Drain | 32.6 | 0.172 | 1.2 (avg) | -,* |
| | | Polysar Sarnia | 30.8 | 0.163 | 0.49 (avg) | - |
| Total Cyanide | 3.22 | Marine City WWTP | 55.9 | 1.8 | 270 | * |
| Oil and Grease | 3170 | Cole Drain | 41.0 | 1,300 | 1,700 (avg) | - |
| Total Cadmium | 0.143 | Sarnia WPCP | 95.8 | 0.137 | ND-7 | - |
| Total Lead | 29.0 | Ethyl Canada | 65.9 | 19.1 | 293-910 | * |
| Total Zinc | 44.9 | Sarnia WPCP | 47.9 | 19.7 | 110-710 | - |
| Total Mercury | 0.0445 | Dow Chemical | 64.5 | 0.0287 | ND-0.88 | - |
| Total Copper | 11.8 | Dow Chemical | 52.9 | 6.24 | ND-107 | - |
| Total Nickel | 4.37 | Sarnia WPCP | 22.3 | 0.973 | 5-15 | - |
| | | Polysar Sarnia | 15.0 | 0.657 | 26-44 | |
| | | Dow Chemical | 14.7 | 0.644 | 0.82 (avg) | |
| Total Cobalt | 0.857 | Polysar Sarnia | 78.2 | 0.67 | 29-41 | - |
| Total Iron | 582 | CIL Inc. | 35.9 | 209 | 530-670 | - |
| | | Sarnia WPCP | 23.6 | 137 | 1950-3150 | |
| Chloride | 356,000 | Dow Chemical | 76.1 | 283,820 | 211,000 - 1,271,000 | - |
| Phosphorus-P | 89.9 | Sarnia WPCP | 27.4 | 43.6 | 550-1300 | - |
| | | Port Huron WWTP | 15.5 | 24.6 | 480 | |
| Ammonia-N | 1670 | Sarnia WPCP | 37.9 | 633 | 5800-20000 | * |
| | | Polysar Sarnia | 21.0 | 350 | 17300-20000 | |
| | | CIL Inc. | 15.3 | 256 | 600 (avg) | |
| | | St. Clair County - Algonac WWTP | 10.8 | 181 | 21,000 | |
| Total Organic Carbon | 6700 | Polysar Sarnia | 34 | 2,200 | 45000-60000 | - |
| | | Sarnia WPCP | 28 | 1,850 | 33000-51000 | |
| Total Suspended Solids | 9400 | CIL Inc. | 53 | 4,980 | 17000-24000 | - |
| Biochemical Oxygen Demand | 7740 | Sarnia WPCP | 26 | 2,000 | 41000 (avg) | - |
| Total Chromium | 16.1 | CIL Inc. | 56 | 8.96 | 20-22 | * |
| | | Polysar Corunna | 16 | 2.5 | 258-567 | |
| Total Volatiles | 254 | Polysar Sarnia | 51 | 124.0 | ND-37,400 | * |
| | | Dow Chemical | 20 | 51.0 | ND-1,500 | |
| | | Ethyl Canada | 17 | 43.2 | ND-1,500 | |
| Total Acid Extractables | 1.09 | Polysar Sarnia | 66.4 | 0.74 | ND-77 | - |
| Total Other Base/Neutrals | 1.03 | Dow Chemical | 76 | 0.78 | ND-5 | - |

1 Facilities and parameters are designated as "important" under the condition described in the text and in the UGLCCS Point Source Workgroup Report (65).

2 **Detected once only in 5 samples of First Street 54" sewer (MDL 0.06 ug/L).**

TABLE VII-10

Loadings of contaminant parameters for sources surveyed on the St. Clair River[a] (kg/d).

| PARAMETER | | MDL(s) (ug/L) | MUNICIPAL DIRECT | MUNICIPAL INDIRECT | INDUSTRIAL DIRECT | INDUSTRIAL INDIRECT | TOTAL DIRECT | TOTAL INDIRECT | PT. SOURCE TOTAL | % OF PT. SOURCE TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| FLOW[a] $10^3 m^3/d$ (SOURCES SURVEYED) | U.S. | -* | 86.8 | NS** | 20.1 | 30.6 | 107 | 30.6 | 138 | 6.5 |
| | CDN. | - | 53.2 | 0.49 | 1,760 | 161 | 1,810 | 161 | 1,974 | 93.5 |
| | TOTAL | - | 140 | 0.49 | 1,760 | 192 | 1,920 | 192 | 2,110 | 100 |
| TOTAL PCBs[b] | U.S. | .0001 | 0.0025 | NS | 0.00029 | NA | 0.00577 | - | 0.00577 | 64.3 |
| | CDN. | .1 | 0.0 | NA*** | 0.0032 | 0.0 | 0.0032 | 0.0 | 0.0032 | 35.7 |
| | TOTAL | - | 0.0025 | - | 0.0035 | 0.0 | 0.00897 | 0.0 | 0.00897 | 100 |
| HCB[b] | U.S. | .00001 | 0.00012 | NS | 0.0000148 | NA | 0.000076 | - | 0.000076 | 0.3 |
| | CDN. | 0.02 | 0.0003 | NA | 0.0238 | 0.0005 | 0.0241 | 0.0005 | 0.0246 | 99.7 |
| | TOTAL | - | 0.00042 | - | 0.0238 | 0.0005 | 0.0242 | 0.0005 | 0.0247 | 100 |
| OCS[b] | U.S. | - | 0.000005 | NS | NA | NA | - | - | - | - |
| | CDN. | 0.02 | 0.0 | NA | 0.0046 | 0.0001 | 0.0046 | 0.0001 | 0.0047 | - |
| | TOTAL | - | 0.000005 | - | - | - | - | - | - | - |
| TOTAL PHENOLS | U.S. | 10 | 0.500 | NS | 0.0 | 0.158 | 0.500 | 0.158 | 0.657 | 5.4 |
| | CDN. | 1 | 6.01 | NA | 4.52 | 0.983 | 10.5 | 0.983 | 11.5 | 94.6 |
| | TOTAL | - | 6.51 | - | 4.52 | 1.14 | 11.0 | 1.14 | 12.2 | 100 |
| PAHs | U.S. | 1-15 | 0.0 | NS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 |
| | CDN. | 1-2 | 0.119 | NA | 0.0396 | 0.172 | 0.159 | 0.172 | 0.331 | 100 |
| | TOTAL | - | 0.119 | - | 0.0396 | 0.172 | 0.159 | 0.172 | 0.331 | 100 |
| TOTAL CYANIDE | U.S. | 5 | 2.37 | NS | 0.0 | 0.0 | 237 | 0.0 | 2.37 | - |
| | CDN. | 1 | NA | NA | 0.171/NA | 0.683 | 0.171/NA | 0.683 | 0.854+ | - |
| | TOTAL | - | - | - | - | 0.683 | 2.53+ | 0.683 | 3.22+ | - |
| OIL & GREASE | U.S. | 2,000 | 357 | NS | 32.8 | 294 | 390 | 294 | 684 | 21.6 |
| | CDN. | 100 | 268 | NA | 899 | 1,320 | 1,170 | 1,320 | 2,490 | 78.4 |
| | TOTAL | - | 625 | - | 932 | 1,610 | 1,560 | 1,610 | 3,170 | 100 |
| TOTAL CADMIUM | U.S. | 0.2 | 0.00497 | NS | 0.0 | 0.0 | 0.00497 | 0.0 | 0.00497 | 0.3 |
| | CDN. | 5 | 0.137 | NA | 0.0014 | 0.0 | 0.138 | 0.0 | 0.138 | 99.7 |
| | TOTAL | - | 0.142 | - | 0.0014 | 0.0 | 0.143 | 0.0 | 0.143 | 100 |
| TOTAL LEAD | U.S. | 1 | 0.158 | NS | 0.020 | 0.0306 | 0.178 | 0.0306 | 0.208 | 0.7 |
| | CDN. | 5 | 2.20 | NA | 25.7 | 0.889 | 27.9 | 0.889 | 28.8 | 99.3 |
| | TOTAL | - | 2.36 | - | 25.7 | 0.919 | 28.1 | 0.919 | 29.0 | 100 |
| TOTAL ZINC | U.S. | 2 | 3.42 | NS | 0.305 | 0.0613 | 3.72 | 0.0613 | 3.79 | 8.4 |
| | CDN. | 5 | 19.9 | NA | 18.5 | 2.69 | 38.4 | 2.69 | 41.1 | 91.6 |
| | TOTAL | - | 23.1 | - | 18.8 | 2.75 | 42.1 | 2.75 | 44.9 | 100 |

TABLE VII-10. (cont'd)

| PARAMETER | | MDL(s) (ug/L) | MUNICIPAL DIRECT | MUNICIPAL INDIRECT | INDUSTRIAL DIRECT | INDUSTRIAL INDIRECT | TOTAL DIRECT | TOTAL INDIRECT | PT. SOURCE TOTAL | % OF PT. SOURCE TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL MERCURY | U.S. | 0.0001 | 0.00144 | NS | 0.000046 | NA | 0.00148 | - | 0.00148 | 3.7 |
| | CDN. | 0.025 | 0.0021 | NA | 0.0354 | 0.0053 | 0.0375 | 0.0053 | 0.0428 | 96.3 |
| | TOTAL | - | 0.00354 | - | 0.0354 | 0.0053 | 0.0389 | 0.0053 | 0.0443 | 100 |
| TOTAL COPPER | U.S. | 1 | 0.864 | NS | 0.107 | 0.104 | 0.971 | 0.104 | 1.08 | 9.0 |
| | CDN. | 5 | 1.66 | NA | 7.64 | 1.46 | 9.30 | 1.46 | 10.8 | 91.0 |
| | TOTAL | - | 2.52 | - | 7.75 | 1.56 | 10.3 | 1.56 | 11.8 | 100 |
| TOTAL NICKEL | U.S. | 4 | 0.425 | NS | 0.0410 | NA | 0.466 | - | 0.466 | 10.8 |
| | CDN. | 5 | 1.03 | NA | 2.11 | 0.761 | 3.14 | 0.761 | 3.90 | 89.2 |
| | TOTAL | - | 1.46 | - | 2.15 | 0.761 | 3.61 | 0.761 | 4.37 | 100 |
| TOTAL COBALT | U.S. | 0.001 | 0.024 | NS | 0.003 | NA | 0.027 | - | 0.027 | 0.5 |
| | CDN. | 5 | 0.170 | NA | 0.670 | 0.0 | 0.830 | 0.0 | 0.830 | 99.5 |
| | TOTAL | - | 0.194 | - | 0.673 | 0.0 | 0.857 | 0.0 | 0.857 | 100 |
| TOTAL IRON | U.S. | 14 | 56.0 | NS | 1.63 | 6.95 | 57.6 | 6.95 | 64.6 | 11.1 |
| | CDN. | 5 | 151 | NA | 338 | 28.3 | 489 | 28.3 | 517 | 88.9 |
| | TOTAL | - | 207 | - | 338 | 35.3 | 546 | 35.3 | 582 | 100 |
| CHLORIDE | U.S. | 1000 | 8,830 | NS | 4,720 | 398 | 13,500 | 398 | 14,000 | 3.9 |
| | CDN. | 500 | 6,720 | NA | 336,000 | 16,300 | 342,000 | 16,300 | 342,000 | 96.1 |
| | TOTAL | - | 15,500 | - | 341,000 | 16,700 | 355,000 | 16,700 | 356,000 | 100 |
| PHOSPHORUS AS P | U.S. | 10 | 51.8 | NS | 0.60 | 5.79 | 52.4 | 5.79 | 58.2 | 64.7 |
| | CDN. | 100 | 48.2 | 0.412 | -26.8[c] | 9.94 | 21.4 | 10.3 | 31.7 | 35.3 |
| | TOTAL | - | 100 | 0.412 | -26.2[c] | 15.7 | 73.8 | 16.1 | 89.9 | 100 |
| AMMONIA AS N | U.S. | 10 | 282 | NS | 1.45 | 0.89 | 283 | 0.89 | 284 | 17.0 |
| | CDN. | 100 | 658 | NA | 721 | 4.62 | 1,380 | 4.62 | 1,380 | 83.0 |
| | TOTAL | - | 940 | - | 722 | 5.51 | 1,560 | 5.51 | 1,670 | 100 |
| TOTAL ORGANIC CARBON (TOC) | U.S. | 10 | 874 | NS | 105 | 551 | 979 | 551 | 1,530 | 22.8 |
| | CDN. | 100 | 1,980 | NA | 2,760[e] | 434 | 4,740[e] | 434 | 5,170[e] | 77.2 |
| | TOTAL | - | 2,850 | - | 2,870 | 985 | 5,720 | 985 | 6,700 | 100 |
| TOTAL SUSPENDED SOLIDS (SS) | U.S. | 4,000 | 969 | NS | 287 | 306 | 1,250 | 306 | 1,560 | 16.6 |
| | CDN. | 1,000 | 525 | 23.3 | 6,340 | 943 | 6,870 | 966 | 7,840 | 83.4 |
| | TOTAL | - | 1,490 | 23.3 | 6,630 | 1,250 | 8,120 | 1,270 | 9,400 | 100 |
| BIOCHEMICAL OXYGEN DEMAND (BOD5) | U.S. | 2,000 | 1,220 | NS | 78.8 | 735 | 1,300 | 735 | 2,040 | - |
| | CDN.[d] | 2,000 | 5,700 | 6.88 | NA | NA | - | - | - | - |
| | TOTAL | - | 6,920 | 6.88 | - | - | - | - | - | - |

MDL = Method Detection Limit
* "-" = Not Applicable
** NS = No Sources
*** NA = Not Analyzed
a - Data from (65).
b - Note significant differences for MDLS.
c - Negative net loadings at CIL, Dow Chemical 4th Street Sewer, Polysar 54" Sewer.
d - Selected Canadian Industrial sources only.
e - Not including CIL (negative 4130 kg/d TOC).

| UGLCCS Parameters: | Non-UGLCCS Parameters: |
|---|---|
| i. Hexachlorobenzene (HCB) | vii. Chromium |
| ii. Total Phenols | viii. Total Volatiles |
| iii. Chrysene, Pyrene and Fluoranthene | |
| iv. Cyanide | |
| v. Lead | |
| vi. Ammonia Nitrogen | |

i) Hexachlorobenzene (HCB): the major source of HCB, the Dow Chemical 1st Street 42" and 54" sewers, had variable concentrations (ND-0.829 mg/L). Although effluent quality cannot be directly compared to ambient water quality standards or guidance, effluent concentrations exceeded the Provincial Water Quality Objective of 0.0065 ug/L. Since the survey, the process streams containing HCB have been diverted to a spill containment pond. The pond discharges to the Dow 4th Street Sewer. The effect of this change on the loadings is unknown. The total loading was 25 grams/day.

ii) Total Phenols: the Ontario Industrial Discharge Objective of 20 ug/L was exceeded at Polysar Sarnia and Suncor. Effluent concentrations at the Sarnia WWTP and the Pt. Edward WWTP also exceeded the Ontario Municipal Effluent Objective of 20 ug/L. The total loading was 12.2 kg/d of which about 70% was contributed by these four facilities.

iii) Chrysene, Pyrene, Fluoranthene: these PAHs were found in one source and only at low concentrations. However, these concentrations were in excess of the U.S.EPA AWQC Human Health Criteria for total PAHs for fish ingestion of 31.1 ng/L; the only ambient water quality guidance available for PAHs. This criterion is below the method detection limit of the analytical methods used. This suggests that other point sources may too be discharging at levels of concern. The total loading of these three compounds was 190 g/d.

iv) Total Cyanide: an exceptionally high concentration of total cyanide (270 ug/L) was found at the Marine City WWTP. The City has an industry that discharges potential cyanide containing waste water to the WWTP and cyanide has been detected in the WWTP in the past. Other point sources discharged total cyanide at levels below industrial discharge objectives and often below ambient water criteria. The total loading was 3.22 kg/d.

v) Total Lead: this parameter is of concern only in the Ethyl Canada effluent. This is due to its presence in concentrations in excess of the GLWQA specific objective and the OMOE Provincial Water Quality Objective (PWQO) of 25 ug/L. The total loading of lead was 29 kg/d, 66% of which was attributed to Ethyl Canada.

vi) Ammonia-Nitrogen: concentration in excess of the 10 mg/L Ontario Industrial Discharge Objective were present in the Sarnia WWTP and the Polysar Sarnia Biox effluents. The total loading was 1.67 tonnes/d.

vii) Total Chromium: high concentrations (258 to 567 ug/L) were detected at Polysar Corunna. The effluent would require substantial dilution to meet the GLWQA Specific Objective of 50 ug/L and the Michigan Rule 57 allowable level of 1.5 ug/L at the edge of the mixing zone. The total loading from all sources was 16.1 kg/d.

viii) Total Volatiles: the total loadings of this group of compounds was 254 kg/d. Benzene, chloroethane and toluene accounted for 72% of the total. Polysar Sarnia (51%), Dow Chemical (20%), and Ethyl Canada (17%) were the main contributors of these compounds. Each facility had concentrations of one or more volatiles well in excess (> 10x) of ambient guidelines.

Principal Effluent Contributors:

In terms of effluent loadings, the following facilities were considered to be the principal contributors of one or more of the parameters studied.

Canada:

a. Sarnia WWTP - phenols, nickel, phosphorus, and ammonia.

b. The Cole Drain, Sarnia - PAHs, oil and grease, and cyanide.

c. Polysar, Sarnia - benzene, phenols, cobalt, and ammonia.

d. Dow Chemical, Sarnia - HCB, OCS, PCBs, copper, mercury, and volatiles.

e. Suncor, Sarnia - volatile aromatics (associated with a process upset at the time of the survey).

f. Ethyl Canada, Corunna - lead, mercury, volatiles (chloroethane).

g. CIL, Courtright - iron, TSS, and chromium.

U.S.:

a. Port Huron WWTP - PCBs, phosphorus.

b. Marine City WWTP - cyanide.

c. St. Clair County - Algonac WWTP - ammonia.

## 2. Urban Nonpoint Sources

### Michigan

There is a remarkable lack of data regarding the impacts of urban nonpoint sources on the water quality of the St. Clair River system from Michigan. In 1986, the Michigan Department of Natural Resources (81) completed a stormwater discharge inventory of the areas adjacent to the St. Clair River. The data within this inventory consisted only of location and size of discharge pipes within the St. Clair River study area. No data relative to flows, water quality, contaminant concentration, annual discharge, or loading values were provided.

The inventory reports that, on the Michigan shoreline, three urban areas have storm sewers which drain directly or indirectly into the St. Clair River. These urban areas include: Port Huron, which identified 10 storm sewers discharging directly into the St. Clair River, and 14 which discharge into the Black River; Marine City, which describes three storm sewer outlets discharging into the Belle River; and Algonac, which reports two storm sewers discharging directly into the St. Clair River. The cities of Marysville and St. Clair, Michigan, have no stormwater discharges.

### Ontario

No data were available for contaminants in U.S. sources of urban stormwater and combined sewer overflow. But a comparison of Canadian discharges due to urban nonpoint sources, with industrial/municipal point sources is shown in Table VII-11. In most cases, the point source to nonpoint source ratio is much greater than one, suggesting that most materials are derived from industrial and municipal point sources.

While the total number of stormwater discharges on the Ontario side of the St. Clair River were not identified, considerably more information is available from the study of Marsalek and Ng (82) for the urban runoff for the city of Sarnia. The 50,200 residents of the City of Sarnia are served by combined and separate sewers, and in some of the less developed areas, by open channels. Combined sewers serve the older areas of the city (540 ha) and discharge into an interceptor which runs along the St. Clair River. The interceptor has four overflow structures which allow direct dumping of untreated combined sewage into the St. Clair River when interceptor capacities are exceeded. In nonoverflow periods, the sewage is conducted to the sewage treatment plant.

Available resources prevented Marsalek and Ng (82) from directly measuring combined sewer flow rates. Instead, they used the U.S. Army Corps of Engineers STORM model (83) to estimate urban runoff

TABLE VII-11

Comparison of industrial/municipal point source discharges with urban stormwater and combined sewer overflow[a] (kg/yr, Canadian sources only).

| PARAMETER | ST. CLAIR RIVER | | |
|---|---|---|---|
| | POINT | URBAN NON-POINT SARNIA | PS/NPS RATIO |
| Ammonia-Nitrogen | 505,000 | 7,300<br>18,600 | 69<br>27 |
| Phosphorus | 27,000[b] | 2,200<br>5,100 | 12<br>5.3 |
| Chloride | 131,000,000 | 1,180,000<br>2,360,000 | 111<br>56 |
| Cadmium | 50.4 | 8.6<br>48.2 | 5.9<br>1.05 |
| Cobalt | 0.84 | 150 | 0.0054 |
| Copper | 3,930 | 460 | 11 |
| Iron | 189,000 | 43,100<br>48,800 | 4.4<br>3.9 |
| Lead | 10,500 | 2,030 | 5.2 |
| Mercury | 15.6 | 0.8<br>1.5 | 19<br>10 |
| Nickel | 1,420 | 149<br>242 | 9.5<br>5.9 |
| Zinc | 15,000 | 2,430 | 6.2 |
| Oil and Grease | 907,000 | 47,200<br>73,400 | 19<br>12 |
| Total Phenols | 4,200 | 121<br>136 | 35<br>31 |
| Cyanide | 311[b] | 23 | 13 |
| HCB | 8.9 | 0.8 | 11 |
| OCS | 1.7 | 0.015 | 113 |
| Total PCBs | 1.2 | 1.4<br>1.5 | 0.86<br>0.80 |
| 17 PAHs | 120 | 52<br>74 | 2.3<br>1.6 |

[a] Based on Canadian Industrial/Municipal Point Source Survey Data (daily average multiplied by 365), and results reported by Marsalek and Ng (82). Some urban runoff values have upper/lower estimates.

[b] Industrial point sources only.

and combined sewer overflow. Using this model, they calculate annual surface runoff in Sarnia to be 6.7 x $10^6$ $m^3$/yr, and a combined sewer overflow value of 1.0 x $10^6$ $m^3$/yr, for a total annual average of 7.7 x $10^6$ $m^3$/yr.

Contaminant concentrations in Sarnia stormwater and combined sewer overflows were measured in samples collected during storm events. Mean values for these parameters are presented in Table VII-12. For parameters with a significant percentage of data below detection limits, a low estimate where undetected values are considered zero, and a high estimate, where they are set equal to the detection limit, are reported.

The concentrations for the various contaminant parameters measured in field studies were multiplied by annual flow volumes to yield annual contaminant loading estimates. The results of these calculations are presented in Table VII-13. Where applicable, both low and high loading estimates are given.

When loadings derived from stormwater and sewer overflows are compared, overflow incidents are a major source of ammonia and phosphorus. Both sources are apparently equal in their contributions of loadings of oil and grease, zinc, and mercury; but for all remaining parameters, stormwater is the dominant source. Marsalek and Ng (82) estimate that stormwater contributes approximately 80 percent of total loadings of industrial chemicals derived from urban runoff.

### 3. Agricultural Nonpoint Source

The watershed of the St. Clair River region includes a geographic area of approximately 340,000 ha, of which approximately 6 percent, 20,976 ha, are located within Lambton County, Ontario. Within this drainage area, major tributary watersheds include Talfourd Creek in Canada, and the Belle, Pine, and Black Rivers in Michigan (84).

A total of nearly 70 percent of the St. Clair River geographic area is agricultural land. More than 60 percent of the total cropland in both Canada and the U.S. is under intensive cultivation. The chief cash crops grown are corn and soybeans. Livestock operations are dominated by beef and dairy farming, followed by swine and poultry husbandry.

Nonpoint sources of aquatic pollution associated with agricultural operations have traditionally included the additions of nutrient compounds, increases in particulate burdens from land erosion, and the inputs of fugitive pesticides and herbicides (84).

TABLE VII-12

Mean concentrations observed in stormwater and combined sewer overflows in Sarnia (82).

| Parameter | Unit | Stormwater | | | Combined Sewer Overflows |
|---|---|---|---|---|---|
| | | Residential | Commercial | Industrial | |
| Ammonia (N) | mg/L | 0.4 | 0.27 | 0.70 | 3.9 |
| | | | | | 15.7* |
| Phosphorus | mg/L | 0.37 | 0.16 | 0.22 | 0.4 |
| (total) | | | | | 3.4 |
| Chloride | mg/L | -- | 172[a] | -- | 32.9 |
| | | -- | 343[a] | -- | 65.3 |
| Cadmium | mg/L | 0.00 | 0.0023 | 0.0007 | 0.005 |
| | | 0.006 | 0.008 | 0.009 | 0.008 |
| Cobalt | mg/L | 0.00 | 0.00 | 0.00 | 0.00 |
| | | 0.02 | 0.02 | 0.02 | 0.02 |
| Copper | mg/L | 0.009 | 0.051 | 0.087 | 0.14 |
| Iron | mg/L | 3.1 | 5.0 | 9.4 | 2.5 |
| | | -- | -- | -- | 8.4 |
| Lead | mg/L | 0.066 | 0.28 | 0.45 | 0.29 |
| Mercury | mg/L | 0.00006 | 0.00004 | 0.00018 | 0.00005 |
| | | 0.000063 | -- | -- | 0.00075 |
| Nickel | mg/L | 0.018 | 0.005 | 0.030 | 0.005 |
| | | 0.026 | 0.025 | 0.039 | 0.023 |
| Zinc | mg/L | 0.18 | 0.33 | 0.48 | 0.24 |
| | | -- | -- | -- | 1.64 |
| Oil & Grease | mg/L | 2.1 | 4.1 | 10.3 | 7.5 |
| | | -- | -- | -- | 34.8 |
| Phenols | mg/L | 0.0170 | 0.0107 | 0.0188 | 0.0099 |
| | | -- | -- | -- | 0.0255 |
| Cyanide | mg/L | 0.0035 | 0.0017 | 0.0030 | 0.0030 |
| HCB | ng/L | 1.55 | 4.4 | 257 | 12 |
| | | -- | -- | -- | 43 |
| OCS | ng/L | -- | 2 | -- | 2 |
| PCBs (total) | ng/L | 75 | 146 | 324 | 150 |
| 17 PAHs | ng/L | 8,500 | 2,800 | 6,700 | 5,000 |
| | | 12,000 | 3,300 | 7,000 | 15,400 |

* For parameters with a significant percentage of data below detection limits, a low estimate where non-detected values are considered zero, and a high estimate, where they are set equal to the detection limit, are reported.

[a] Equivalent mean concentration.

TABLE VII-13

Summary of annual loadings in urban runoff from the Sarnia area (kg/yr) (82).

| Parameter | Stormwater | Overflows | Total |
|---|---|---|---|
| Ammonia (N) | 3,600 | 3,700 | 7,300 |
| | -- | 15,000* | 18,600 |
| Phosphorus | 1,800 | 400 | 2,200 |
| | -- | 3,300 | 5,100 |
| Chloride | 1,150,000 | 31,600 | 1,180,000 |
| | 2,300,000 | 62,700 | 2,363,000 |
| Cadmium | 3.8 | 4.8 | 8.6 |
| | 40.2[a] | 8.0[a] | 48.2[a] |
| Cobalt | 0 | 0 | 0 |
| | 131(23)[a] | 19(3)[a] | 150(26)[a] |
| Copper | 326 | 134 | 460 |
| Iron | 40,700 | 2,400 | 43,100 |
| | -- | 8,100 | 48,800 |
| Lead | 1,750 | 280 | 2,030 |
| Mercury | 0.7 | 0.1 | 0.8 |
| | 0.8 | 0.7 | 1.5 |
| Nickel | 144 | 5 | 149 |
| | 220 | 22 | 242 |
| Zinc | 2,200 | 230 | 2,430 |
| Oil & Grease | 40,000 | 7,200 | 47,200 |
| | -- | 33,400 | 73,400 |
| Phenols | 112 | 9 | 121 |
| (total) | -- | 24 | 136 |
| Cyanide | 20 | 3 | 23 |
| HCB | 0.8 | 0.0 | 0.8 |
| OCS | 0.013 | 0.002 | 0.015 |
| PCBs (total) | 1.3 | 0.1 | 1.4 |
| | -- | 0.2 | 1.5 |
| 17 PAHs | 47 | 5 | 52 |
| | 59 | 15 | 74 |

* Where applicable, both low and high loading estimates are given.

[a] Loadings calculated from data above the detection limit.

## Nutrient Additions

The use of commercial fertilizers and livestock manure as soil builders potentially contributes to the pollution of adjacent aquatic resources by adding excessive burdens of bacteria, nitrogen, and phosphorus. On the U.S. side of the St. Clair River, commercial fertilizers are applied to approximately 78 percent of tillable land, while livestock wastes are added to 8 percent. The total quantity of phosphorus generated from manure has been estimated at 3,800 tonnes/yr (85). In Canada, croplands receive an estimated 3,800 tonnes of commercial fertilizer per year. This value translates to 376 kg/ha. Analysis of soil fertility and crop requirements indicate that as much as two times more phosphorus fertilizer is being used than is required in both the U.S. and Canada. Livestock operations on the Canadian side of the river generate a further 6.3 tonnes/yr of phosphorus, ultimately disposed of on farm land.

Studies of the Black River (84,85), a U.S. tributary to the St. Clair River, noted that phosphorus concentrations ranged from 0.03 to 0.73 mg/L, and averaged 0.14 mg/L. The PWQO for phosphorus in rivers is 0.03 mg/L. In Ontario, several creeks were monitored with similar results. Phosphorus concentrations ranged from 0.033 to 0.665 mg/L in Talfourd Creek, Baby Creek, Murphy Drain and the Cole Drain (68,84,86). All samples from the Ontario tributaries exceeded provincial water quality standards for phosphorus.

## Pesticide Additions

Agricultural pesticides are used extensively in the St. Clair River basin for the control of weeds, plant diseases, and insects. Wall et al. (84,85) estimate that some 500,000 kg were used annually on the U.S. side. The majority (75 percent) of the compounds used were herbicides, with atrazine, alachlor (now banned in Canada), cyanazine, and metolachlor being the most frequently used. Additionally, nearly 9,000 kg of restricted-use pesticides were sold in four counties of the St. Clair River area (84). In this category, parathion and other organophosphorus insecticides were highest in sales. In Canada, approximately 30,000 kg of pesticides were applied annually (2.3 kg/ha). At the time of the study, the most common herbicides used were identical to those used on the U.S. side.

The Belle and Black rivers on the U.S. side were monitored for pesticides between April and August of 1985 (84). The loads to the Black River for atrazine, alachlor, cyanazine, and metolachlor were reported as 0.3, 0.22, 0.99, and 0.07 g/ha, respectively. Loadings for the same compounds to the Belle River were reported as 0.12, 0.03, 0.03, and 0.07 g/ha, respectively.

Analysis of sedimentary materials from the St. Clair River tributaries yielded the observation that restricted-use pesticides were present in 70 percent of the samples. Chlordane and metabolites of DDT were most frequently observed.

Ontario tributaries were monitored for pesticides including organochlorine, organophosphorus and carbamate insecticides as well as phenoxy acid and triazine herbicides.

Atrazine was detected in 47% of all water samples from Ontario tributaries of the St. Clair River at concentrations up to 8,450 ug/L. Additional pesticides which were detected less frequently, included gamma-BHC, pp-DDE and endrin. Alpha-BHC was detected in 62% of water samples but typically at levels below 5 ng/L.

The frequency of sampling was insufficient to estimate annual loadings; however, mean instantaneous loadings for atrazine indicate that Talfourd Creek is discharging approximately 0.5 mg/sec to the St. Clair River.

Industrial organic compounds were detected primarily on suspended solids and were consequently observed in bottom sediments at the tributary mouths. Concentrations of HCB, OCS and PCBs were observed in whole water, suspended solids and bottom sediments from Ontario. Several elevated levels were measured on suspended solids at the Cole Drain (HCB - 5,800 ng/g; OCS - 5,400 ng/g) and at Talfourd Creek (PCBs - 77,840 ng/g)(68,84,85). The significance of these intermittent peaks cannot be determined based on the limited data available.

## 4. Atmospheric Deposition

Direct atmospheric deposition of contaminants to the St. Clair River is likely to be negligible because of the relatively small surface area of the river. However, atmospheric deposition may be defined as the sum of the contaminants deposited from the atmosphere on a stream or lake surface (direct input), plus that material which has fallen on upstream areas and is transported through the connecting channels to downstream bodies of water. This phenomenon is likely the mechanism responsible for the regular observation of common pesticides observed in the St. Clair River (87). Such compounds as the metabolites of DDT, alpha- and gamma-benzene hexachloride, and dieldrin are routinely reported in water samples from the St. Clair River, but the concentration of these contaminants does not change significantly over the length of the connecting channel. This fact suggests that there are no active sources along the St. Clair River (37,79).

5. Groundwater Contamination/Waste Sites

Three different groundwater flow systems contribute to the overall groundwater discharge, or flux, including discharge from surficial aquifers, from intermediate flow systems and from deep bedrock systems. Groundwater in the unconsolidated surficial deposits generally flows to the St. Clair River. Locally, however, the direction of groundwater flow is influenced by surface water drainage and glacial landforms. Groundwater flow directions in the deeper units are as yet not well defined.

Total groundwater seepage directly to the St. Clair River was estimated by three independent teams of investigators to range between 645 L/s and 741 L/s and to average about 700 L/s. The U.S. Geological Survey estimated total groundwater discharge to the river from groundwater discharge areas, based upon tributary baseflow information. The University of Wisconsin - Milwaukee used a combined geophysical and hydrological method to compile continuous measurements of groundwater flow passing through the St. Clair River bed. The University of Windsor Great Lakes Institute deployed seepage meters and mini-piezometers to measure seepage in the Sarnia area (88).

Shallow groundwater in the study area, which does not discharge directly to the St. Clair River, contributes about 10% of stream flow to the tributaries of the St. Clair River. Rates of groundwater seepage to the St. Clair River generally decreased downstream, with higher fluxes noted in the Sarnia and Port Huron area, and between Stag Island and Courtright coinciding with areas having the largest number of sources of groundwater contamination.

Although the total amount of discharge to the St. Clair River is small relative to the St. Clair River's water budget, the heterogeneities that are apparent in the nature and the distribution of groundwater flux suggest that inputs of contaminated groundwater may be locally significant.

Surface Runoff from Landfills

Groundwater is not a principal route of contaminant transport from many waste sites in the St. Clair study area. Low hydraulic conductivities of surficial materials here restrict infiltration and groundwater movement. Surface runoff from waste sites to storm drains, and small tributaries which flow to major surface water bodies appears to be of greater importance as a contaminant transport pathway.

Michigan's Potential Groundwater Contamination Sources

Groundwater movement was investigated in an area extending 19 km inland along the St. Clair River. An inventory of active and inactive waste sites within this area was conducted as part of this investigation. Twenty-six sites of known, or potential groundwater contamination were identified and ranked. The majority of sites are solid waste landfills, regulated and unregulated hazardous waste disposal sites, storage sites and spills. Other potential sources that were reviewed included leaking underground storage tanks, contaminated well water, and underground injection wells. Underground injection wells were not ranked for potential contributions to contaminant burdens and are treated separately below.

Those sites in areas which discharge directly to the river were ranked and assigned priorities for potential impacts upon the St. Clair River. Ranking of sites, using a modification of U.S.EPA's DRASTIC ranking system, was based on their potential for contributing contaminants directly to the St. Clair River via groundwater by evaluating the hydrogeology, the nature of waste material as described in state and federal files, and the distance to the river (89). The 7 highest ranked sites had the greatest potential for impact upon the St. Clair River (Table VII-14). The water table in this region was generally less than 4.6 m below the land surface and the individual sites had priority pollutants and/or inorganic contaminants.

Evaluation of Potential Impacts

One round of samples were collected from 8 observation wells that were installed by the U.S. Geological Survey (USGS) in each groundwater discharge area. Actual locations of wells depended upon the number of up gradient waste sites, the size of the groundwater discharge area, and on permission for drilling from landowners. It was possible to locate two wells near waste sites, including a well installed down gradient of both A and B Waste Disposal and the Hoover Chemical Reeves Company, and a well installed down gradient from the Wills Street Dump Site. Other locations were chosen to provide background information. Analyses were made for 72 volatile, base neutral, acid extractable, and chlorinated extractable hydrocarbons, and 24 trace metals and other chemical parameters. These analyses were compared to both surface water quality criteria and objectives, and drinking water standards.

i) Organic

The pesticide endosulfan was detected in one sample. Phthalate esters were found in four of eight samples. N-nitrosodiphenylamine, was detected in a well at a level in excess of U.S.EPA

TABLE VII-14

**Confirmed or possible Michigan contamination sites within the St. Clair River groundwater discharge areas*.**

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1. Grand Trunk Railroad (CERCLIS/RCRA/Act 307)
The Grand Trunk Railroad site is an oil pipeline leak. There is a perched water table about 2 feet below the surface that is underlain by about 100 feet of lake clays and a gravel aquifer. Oil may have discharged to a sewer and ditch (MDNR). Groundwater contamination is not indicated in the Act 307 listing. There are no monitoring wells. The upper, perched aquifer is contaminated with diesel fuel. Sandy soils on site are saturated with oil and may contribute oils to the shallow aquifer (observed, 1979, from PA). Oils and #2 diesel fuel flowed to WWTP via storm drain on site (observed 1978 - 1979, from PA). Note: CERCLA authorities were not applied because the observed release was limited to petroleum products which are covered under the Clean Water Act.

2. A and B Waste Disposal (CERCLIS/RCRA/Act 307)
The A and B Waste Disposal site is a transfer facility where wastes are sorted for resale/cycling and disposal. Soil and groundwater samples contain toluene, xylene, trichloroethylene and tetrachloroethylene. There are alleged incidents of dumping paint thinner on the ground. Groundwater contamination is not indicated in the Act 307 listing. There are no monitoring wells.

3. Hoover Chemical Reeves Company (CERCLIS/RCRA/Act 307)
The Reeves Company buys and distributes paint products locally. In the past, the facility built fiberglass buildings for Port-a-john. Hoover Chemical manufactures adhesives. Drums containing paint and adhesive wastes are stained on site. Groundwater contamination is not indicated in the Act 307 listing. There are 5 monitoring wells.

4. Eltra Corp. Prestolite Wiring (CERCLIS/RCRA/Act 307)
This company is a RCRA generator and treatment/storage/disposal facility. Various halogenated and non-halogenated solvents, electroplating wastes, lead and ketones are stored in containers on site. There are no monitoring wells.

5. Wills Street Dump Site (CERCLIS/Act 307)
The Wills Street Dump Site is located within one-half mile of the St. Clair River. Drums from the St. Clair Rubber-Michigan Avenue plant were dumped into open pits each year for 8 years. These liquid wastes included toluene, acids, and polyurethane. Over the eight year period, as many as 1,500 drums were dumped. A ditch just east of the site empties into the St. Clair River (MDNR). Groundwater contaminations is not indicated in the Act 307 listing. There are no monitoring wells.

The site was not submitted to NPL for the following reasons: Marysville's drinking water surface water intake is located 1.5 mi. upstream of the Wills St. Dump and 90' of clay overlies the aquifer used for drinking water. Nonetheless, the site is near a wetland. On-site soil samples contained low levels of 1,1-dichloroethane, 1,1,1-trichloroethane and toluene. Also found were elevated levels of phenol and Arochlor - 1260.

6. General Technical Coatings (Act 307)
Paint and solvents are stored in barrels at the General Technical Coatings site. The site is within one-quarter mile of the St. Clair River. Ground-water contamination is not indicated in the Act 307 listing. The site was removed from the Act 307 list after cleanup.

7. Winchester Disposal Area (CERCLIS/Act 307)
The Winchester Disposal Area site is an unlicensed refuse dump. It is located in a low marshy area near Port Huron. The site is unfenced and continued dumping is possible. No records of the types or amounts of wastes present exist. Drums have been seen on the site and more may be buried (MDNR). Ground-water contamination is not indicated in the Act 307 listing. There are no monitoring wells.

The fill on-site is at least ten feet thick in some areas. No cover was ever applied. Drums, concrete and household appliances are exposed. Tens of thousands of tires are stacked on site up to ten feet high in areas. In 1981 three monitoring wells in this area were sampled. Down-gradient wells in the vicinity of Winchester Disposal Area, showed higher concentrations of phenolics, cadmium, copper, lead, zinc and iron than were found in an up gradient well in the vicinity of the Winchester Disposal Area.

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CERCLIS: Site is listed within the information system for Superfund and is considered for clean-up under the Comprehensive Environmental Compensation and Recovery Act of 1980.
RCRA: Facility has a Resource Conservation and Recovery Act identification number.
Act 307: Site is listed on Michigan's compilation of sites of known and possible environmental degradation.
* Information from (88).

Human Health Criteria for carcinogens at a $10^{-6}$ risk level. It is possible that phthalate esters were introduced during sampling or shipment.

ii) Inorganic

U.S.EPA Drinking Water Primary Maximum Contaminant Levels (MCL) were exceeded for chromium at one well, for lead at six of eight wells and for barium at two wells.

Table VII-15 contains a summary of groundwater quality in these wells based on unfiltered samples (88). The metals are generally associated with finely-divided particulates. Groundwater that discharges to the St. Clair River is thought to be free of fine particulates, and thus of lower trace metals concentration than determined for these samples. Thus, a computation of the loading of the St. Clair River by chemical substances transported by groundwater does not seem feasible at the current time.

Several sites that were selected as priorities for investigation by the USGS may have potential for local impacts upon the St. Clair River.

Elevated levels of barium, cobalt, copper, lead, zinc, and nickel contamination, as well as the n-Nitrosodiphenylamine contamination in well G3 appear to be related to discharges from A and B Waste disposal, or Hoover Chemical Reeves Company, or a combination of the two. The proximity of well G3 and of the two sites to the St. Clair River suggests that seepage of contaminated groundwater originating from the sites may result in local impacts upon St. Clair River biota or water quality.

Elevated lead, mercury, and zinc in well G4 might be attributable to the Wills Street Dump Site.

Elevated chromium, lead, iron, zinc and phosphorus concentrations in well G1, and elevated barium, copper, iron, lead, nickel, total organic carbon, and oil and grease concentrations in well G8 had no identifiable source.

Generally, it seems that environmental problems of waste, storage, treatment and disposal facilities are associated with overland flow or runoff, rather than through groundwater discharge. Low hydraulic conductivities, and hydraulic gradients suggest that groundwater is not a major route of contaminant transport to the St. Clair River from these sites. Nonetheless, the possible presence of unidentified discontinuous stringers of sand and gravel may serve to enhance contaminant transport locally.

TABLE VII-15

Summary of St. Clair River area groundwater quality[1] in Michigan U.S.GS wells[2].

| | NUMBER OF ANALYTICAL DETECTIONS | MAXIMUM | MINIMUM | MEAN | STANDARD DEVIATION |
|---|---|---|---|---|---|
| Antimony, total (ug/L) | 8 | 13 | <1 | 3.25 | 4.60 |
| Arsenic, total (ug/L) | 8 | 15 | <1 | 7.38 | 5.24 |
| Barium, dissolved (ug/L) | 8 | 2100 | 51 | 568.38 | 710.51 |
| Beryllium, dissolved (ug/L) | 8 | 21 | <1 | 3.13 | 6.88 |
| Cadmium, total (ug/L) | 8 | <1 | <1 | <1 | 0.00 |
| Chromium, total (ug/L) | 8 | 59 | <1 | 20.63 | 16.19 |
| Cobalt, total (ug/L) | 8 | 200 | <1 | 36.38 | 62.75 |
| Copper, total (ug/L) | 8 | 730 | 2 | 170.63 | 243.14 |
| Iron, total (mg/L) | 8 | 500 | 1.2 | 110.93 | 158.86 |
| Lead, total (ug/L) | 8 | 6300 | 23 | 1457.38 | 1954.81 |
| Mercury, total (ug/L) | 8 | 0.5 | <0.1 | 0.23 | 0.21 |
| Nickel, total (ug/L) | 8 | 1300 | <1 | 253.13 | 415.85 |
| Selenium, total (ug/L) | 8 | <1 | <1 | <1 | 0.00 |
| Zinc, total (mg/L) | 8 | 390 | 2.5 | 83.59 | 119.87 |
| Carbon, total organic (mg/L) | 8 | 190 | 3.6 | 41.58 | 56.72 |
| Chloride (mg/L) | 8 | 250 | 11 | 91.50 | 82.63 |
| Cyanide, total (mg/L) | 8 | <0.01 | <0.01 | <0.01 | 0.00 |
| Dissolved solids (mg/L) | 8 | 1560 | 145 | 541.13 | 439.20 |
| Oil-grease, total (mg/L) | 8 | 18 | 3 | 7.00 | 4.42 |
| Nitrogen, total (mg/L) | 7 | 2.5 | 0.2 | 1.69 | 0.72 |
| pH (units) | 8 | 11.2 | 8.1 | 10.11 | 1.13 |
| Phenols, total (ug/L) | 8 | 6 | 2 | 4.13 | 1.05 |
| Phosphorus, total (mg/L) | 8 | 0.57 | 0.021 | 0.19 | 0.19 |
| Specific conductance (us/cm) | 8 | 2380 | 322 | 928.88 | 622.58 |
| Endosulfan (ug/L) | 1 | 0.08 | 0.08 | 0.08 | 0.00 |
| Bis (2-ethylhexyl)phthalate (ug/L) | 3 | 1500 | 6 | 528.67 | 687.50 |
| Butyl benzyl phthalate (ug/L) | 2 | 6 | 6 | 6.00 | 0.00 |
| n-Nitrosodiphenylamine (ug/L) | 1 | 10 | 10 | 10.00 | 0.00 |

1 Data from (88).
2 All wells were installed by U.S. Geological Survey.

Ontario's Potential Groundwater Contamination Sources

On the Ontario side of the St. Clair River, a total of 16 designated waste disposal sites were identified in Lambton County. The Ontario sites were prioritized to determine those sites that require monitoring or remedial investigations. In designing criteria for this evaluation, emphasis was placed on identifying sites which lack specific information that is important in assessing environmental impacts. Thus, sites lacking particular information could rank higher than sites having evidence of impact. Seven main groups of criteria were selected:

1. Geologic Information
2. Hydrologic Information
3. Hydrogeologic Information
4. Geochemical Information
5. On Site Monitoring
6. Waste Characterization and Containment
7. Health and Safety

Specific questions within these groups, that are significant in assessing the site environmental impact were used to derive a quantitative score. Three categories of priorities were developed, including:

Priority 1 Sites: those sites with a definite potential for impact on human health and safety;

Priority 2 Sites: those sites which require immediate investigation in order to determine the potential for impact either on the environment or human health and safety; and

Priority 3 Sites: those sites requiring additional monitoring, but with lesser potential to impact their surrounding environment.

The Nonpoint Source Workgroup (88) reported that three sites in Lambton County were categorized as Priority 1 Sites. Included in this category were:

1) Dow Chemical, Scott Road
2) Polysar Limited, Scott Road
3) P and E Oil Recyclers, Petrolia.

Ten sites in Lambton County were identified as Priority 2 Sites. These locations included:

1) K and E Solid Waste, Sarnia Township
2) Unitec, Inc., Moore Township
3) C.I.L., Inc., Lambton Works, Sombra Township
4) City of Sarnia Landfill, Sarnia Township
5) Canflow Services, Petrolia

6) Dow Chemical, La Salle Road, Moore Township
7) Ladney, Moore Township
8) Sun Oil Company, City of Sarnia
9) Fiberglass Canada, Ltd., City of Sarnia
10) DuPont of Canada, Ltd., Moore Township.

Priority 3 sites in Lambton County included three listings. These were:

1) Walpole Island, Walpole Island Indian Reserve
2) Esso Petroleum, Scott Road, City of Sarnia
3) Johnson Construction, Sarnia Township.

It is important to note that the ranking schemes for U.S. and Canadian sites are not strictly comparable. Site characteristics of the four highest priority sites are provided in Table VII-16.

Most contamination problems associated with waste sites are centered in the Scott Road area of Sarnia. Shallow groundwater and surface water drainage here is to the Cole Drain. In addition to Dow and Polysar landfills, other waste disposal sites may be contributing contaminants to the Cole Drain and are situated adjacent to the Dow and Polysar landfills. These include the City of Sarnia sludge lagoons, Fibreglas Canada's landfill site, and further south the Esso Petroleum Landfill site. Due to the uncertainty of the origin of contaminants in the Cole Drain, the Ontario Ministry of the Environment has undertaken a study of surface runoff within the Scott Road watershed. Preliminary findings to date indicated the presence of slightly elevated levels of hexachlorobenzene and octachlorostyrene in surface water draining from the landfill area.

## Underground Injection Wells

i) Michigan

In the United States, the U.S.EPA has the primary responsibility to establish and enforce protection of underground sources of drinking waters through its Underground Injection Control (UIC) program. This program regulates five classes of injection wells:

Class 1: Industrial and municipal disposal wells which inject below the lower most formation containing underground sources of drinking water.

Class 2: Injection wells associated with oil and gas production and liquid hydrocarbon storage.

Class 3: Special process wells used in conjunction with solution mining of materials.

TABLE VII-16

Site characteristics of Ontario high priority waste sites in the St. Clair River area*.

1. Dow Chemical, Scott Road - The site has been in operation since 1948. Disposal operations consisted of controlled land filling and clay capping hazardous and non-hazardous solid and liquid waste that originated from the production of vinyl chloride. Included were various oily sludges and solvents containing chlorinated hydrocarbons, specifically hexachlorobutadiene. Also, contaminated soils and equipment from around the production facilities have been transported to the waste disposal site. Approximately 1000 tonnes of waste (28% non-hazardous, 26% liquid and 46% hazardous waste, MOE 1984) were disposed annually. Surface and groundwater monitoring systems have been in place since 1980, as well as a leachate control and treatment system. The leachate control system consists of a collecting/holding ditch along the north boundary of the site. The contents of the ditch are treated with activated carbon beds and released to the Scott Road ditch, which drains to the Cole Drain. The effectiveness of a steel sheet pile wall to contain off site groundwater flow has not been demonstrated. Surface runoff is the most likely pathway for movement off site. Surface runoff is not properly contained and may be migrating towards the adjacent Fibreglas Canada site. Ground water mounding within the landfill is likely to create a large hydraulic gradient across the sheet pile wall resulting in short circuiting of the wall, and increased off site ground water flow. The present monitoring program is inadequate and needs to be improved. Dow has also found and removed contaminants from the Cole Drain.

2. Polysar Limited (Scott Road) - The Polysar Limited disposal site off Scott Road in Sarnia serves the nearby Polysar manufacturing facilities. The site has been in operation since 1942 and consists of industrial wastes and fly ash areas. Disposal operations consist of controlled land filling of various inert sludges, plastic resins and alkali, inorganic and rubber-accompanied waste over an area of approximately 11 hectares. At present, approximately 25,000 $m^3$ of liquid wastes are received per year. Land filling is waste with fly ash or imported clay and silted clay material. Surface runoff and waste leachate are directed into surface storage lagoons where monitoring and treatment is required. Monitored parameters include pH, total organic carbon, phenols, copper and ammonia. Off site releases of surface waters has ceased, and all surface waters are now treated at the company's biological oxidation treatment plant. In general, groundwater monitoring in this site is inadequate to determine whether or not contamination is leaving the site. The company is in the process of retaining a consultant who will be charged with the task of initiating a more detailed hydrogeological investigation of the site, including more frequent sampling of existing piezometers.

3. P & E Oil Recyclers - The P & E Oil Recyclers site stores used oil in underground tanks and disposes of oil field brines in two deep disposal wells. In 1982, 50 $m^3$ (10,000 gal) of waste were accepted at the site. The major industries served are: Dome Petroleum, Imperial Oil, Polysar Limited, and Uniroyal. No surface water of groundwater monitoring programs are in effect. The site was developed in the latter part of the 19th century by the Canadian Oil Company for the subsurface storage of crude oil in underground cedar-lined tanks. The tanks were excavated in heavy clay soil to depths ranging from 4 m (13 ft) to 18 m (60 ft) below grade. In 1965 and 1969 two deep disposal wells were drilled into the Detroit River Group and were used for the disposal of liquid industrial wastes until 1974, when the Ontario Ministry of the Environment regulated against the disposal of industrial wastes, except for oil field brine, in this fashion. This regulation led to the storage of industrial waste in the subsurface storage tanks. The underground storage tanks have capacity to hold over 13,650 $m^3$ (3,000,000 gal), and the last documented reports indicate that all tanks are full. The liquid contents of the tanks were determined to contain oil, brine, water, caustic and/or acidic compounds, phenolic compounds, mineral salts and heavy metals, including lead and chromium. The potential for off-site migration exists and has been documented. At present, there is virtually no on-site containment for the off-site migration. In addition, many of the tanks are uncovered, or those that are covered have weakened, rotting wooden roofs, therefore allowing infiltration of precipitation which will cause overflows of the contents. A Control Order has been proposed by the Ministry of the Environment

4. CIL, Lambton Works - The Canadian Industries Limited Plant near Courtright, produces chemical fertilizers. There is little topographic relief, but surface drainage is either directed to the St. Clair River, or eastward to Clay Creek. Prior to the decommissioning of the phosphate plant, the facility used phosphate rock which naturally contains minor amounts of radioactive radium and uranium. These elements appear in waste gypsum slurry which was discharged into two 50 hectare holding ponds. The ponds also contain phosphate, ammonia, and fluoride, with a water pH of 1.0. Due to the use of sulphuric acid originating from one of the company's other facilities in Quebec, the pond waters have become contaminated with dinitrotoluene (DNT). From 1975 to 1981, separation filters containing radium concentrations as high as 12,000 pCi/g from the CIL manufacturing process were disposed at the Sombra Township (Wilkesport Landfill Site). This disposal resulted in areas of elevated radiation exposure rate and localized hot spots. Under the direction of the Ontario Ministry of the Environment and the Ministry of Labour, CIL removed several truck loads of contaminated soil from the landfill for storage in the berm of one of CIL's gypsum ponds. The waste soil and debris are presently contained inside the walls of the gypsum pond, all radioactive materials are now stored in a concrete bunker on site.

* Information from (88).

Class 4: Hazardous waste wells which inject into or above underground sources of drinking water (wells in this category were banned in 1985).

Class 5: Wells not falling into one or more of the above categories; including heat exchange wells, domestic waste wells, and cesspools.

A total of 72 injection wells are presently rule authorized or permitted on the U.S. side of the St. Clair River. Of this total, 63 are in current operation, two are temporarily abandoned, and seven are permanently plugged and abandoned.

Class 1 Wells:

Consumers Power Company Facility in Marysville, Michigan currently has two temporarily abandoned Class I Non-Hazardous Industrial Waste wells. These wells will be reclassified as salt water disposal wells (2D) per clarification of 1986 Safe Drinking Water Act Amendments. The wells are designed to inject brine associated with the hydrocarbon storage operations at their facility. The injection zone for these fluids are the Eau Claire and Mt. Simon Formations at a depth greater than 1,380 m at a pressure of 12,757 kPa (1,850 psi).

Class 2-D Salt Water Disposal Wells:

Eleven Class 2-D salt water disposal wells are currently operating in the St. Clair area. One additional salt water disposal well is temporarily abandoned, and two others have been permanently plugged and abandoned. Disposal intervals for Class 2-D wells in this area range from the Detroit River Group of formations at a depth of 267 m to the Eau Claire Formation at a depth of 1,350 m. Permitted injection pressures range up to 8,960 kPa (1,300 psi). All Class 2-D wells in the area with one exception have passed mechanical integrity tests: one of the ANR Pipeline Co. wells had failed its mechanical integrity test on April 9, 1986 and was shut down, but has since been reworked and retested for mechanical integrity, and is functioning properly as of June 6, 1986.

Class 2-H Hydrocarbon Storage Wells:

Class 2-H, Hydrocarbon Storage Wells service natural gas storage reservoirs, or are used for storage of refined petroleum products, or liquified petroleum gas (LPG). Gas storage reservoirs for natural gas are depleted gas fields into which gas produced in other areas is stored for future marketing. Injection and withdrawal of gas is typically through former gas production wells which have been converted to storage. Injection and withdrawal may be through the same well, or through separate wells. Observation wells are used to monitor reservoir pressures, reservoir capacity and other parameters.

Currently there are 11 hydrocarbon storage fields or facilities located in the St. Clair River area with an average surface area of 406 acres. These fields have all been converted to hydrocarbon storage since 1970. Most gas storage reservoirs in St. Clair County are in the Middle Silurian Niagaran Reefs, and Salina Carbonates and Evaporites. Depths to the gas storage reservoirs range from 659 to 884 m and the thickness of the reservoirs ranges from 1 to 92 m. The Middle Silurian Reefs are used principally for the storage of natural gas that is produced elsewhere and stored for future marketing. This activity is carried out principally by the Consumers Gas Company. The Salina Evaporites are primarily used for the storage of LPG and other refined petroleum products.

Amoco Productions company operates a LPG storage facility having seven wells in the Salina-A Evaporite. The depth to these caverns ranges from 690 to 750 m and the estimated capacity of all the caverns is 2,265,000 L. Consumers Power Company operates 9 wells completed in the Salina-B Salt for the storage of refined petroleum products.

Class 2-R Enhanced Oil Recovery Well:

Five Class 2-R, enchanced oil recovery wells, operate in the St. Clair River area in the Detroit River Group of Formations and the Niagaran Dolomite. One well, formerly operated by Vans Tank Truck Service, failed its mechanical integrity test in April of 1986 and is no longer in operation.

Class 3-G Solution Mining Wells:

Solution mining wells operate through production of artificial brines by wells completed a hundred m or more apart in the same salt bed. Salt is dissolved by pumping water through one well into the bedded salt, and out through the second well. The brine that is produced is processed to recover bromine, iodine, and sodium, calcium and magnesium chlorides. The Salina Group evaporites presently produce brines, but the Devonian Detroit River Group has also been used in the past for production.

Eight Class 3-G solution mining wells are operated by Diamond Crystal Salt Co. Four additional solution mining wells have been operated in the past by Morton Salt Co. but have since been plugged and abandoned.

Other Wells:

No Class 4 wells operate in the St. Clair River area. Seventeen Class 5 wells operate in the St. Clair River area.

The impacts of Michigan Underground Injection wells in the area upon the St. Clair River are uncertain. However, it appears that, with the exception of short-term mechanical integrity problems for a salt water disposal well and an enhanced oil recovery well, all wells are operating in an environmentally sound manner.

ii) Ontario

In Lambton County, Ontario, deep injection wells were used to dispose of industrial wastes during the period 1958-1972 and are still used for the disposal of cavern brines and oil field brines (88). There are about 35 deep wells in Lambton County (Figure VII-3). The Lucas formation of the Detroit River Group was heavily utilized prior to 1976 for the injection of industrial waste. The freshwater aquifer lies above this bedrock, therefore the potential exists for wastes to flow upwards into the aquifer and thus migrate to the St. Clair River.

The industrial waste wells were located in three areas. The most heavily utilized area was the industrialized section south of Sarnia, adjacent to the St. Clair River. In this location wells were used by Imperial Oil Ltd. (5 wells), Shell Canada Ltd. (2 wells), Sun Oil Company (1 well), Polymer Corp. (1 well), and Dow Chemical Ltd. (2 wells to the Salina formation) (Figure VII-3).

The second area is located inland from the river and included the well of Marcus Disposal (1 well), Thompson Wright Co. (2 wells), and Tricil-Goodfellow (2 wells). A third area is found in Courtright adjacent to the St. Clair River, and consists of 2 wells belonging to Canadian Industries Ltd. (CIL) (Figure VII-3).

The Primary waste types disposed into the wells were spent caustics, acids, phenols, minor hydrocarbons, and brine. The volumes of industrial wastes disposed of into the Detroit River Group total 7,513,722 $m^3$. In the industrial area of Sarnia, it was usually necessary to inject waste under pressure to achieve the required injection rate. The wells close to the St. Clair River often required pressures up to 3,103 kPA (450 psi) at surface to inject the waste. The average injection pressure was 2,758 kPa (400 psi).

Cambrian Disposal Ltd., owned and operated 7 wells in Lambton County, for the disposal of cavern-washing brine waters. Between 1971 and 1985 the total volume of waste injected under gravity into these wells, was 10,194,889 $m^3$. All wells used for the disposal of brine materials have established monitoring well networks on adjacent properties to determine water quality in the freshwater aquifer. The company is also required to pay a levy for each cubic metre of waste injected for the perpetual care of the well once it is abandoned.

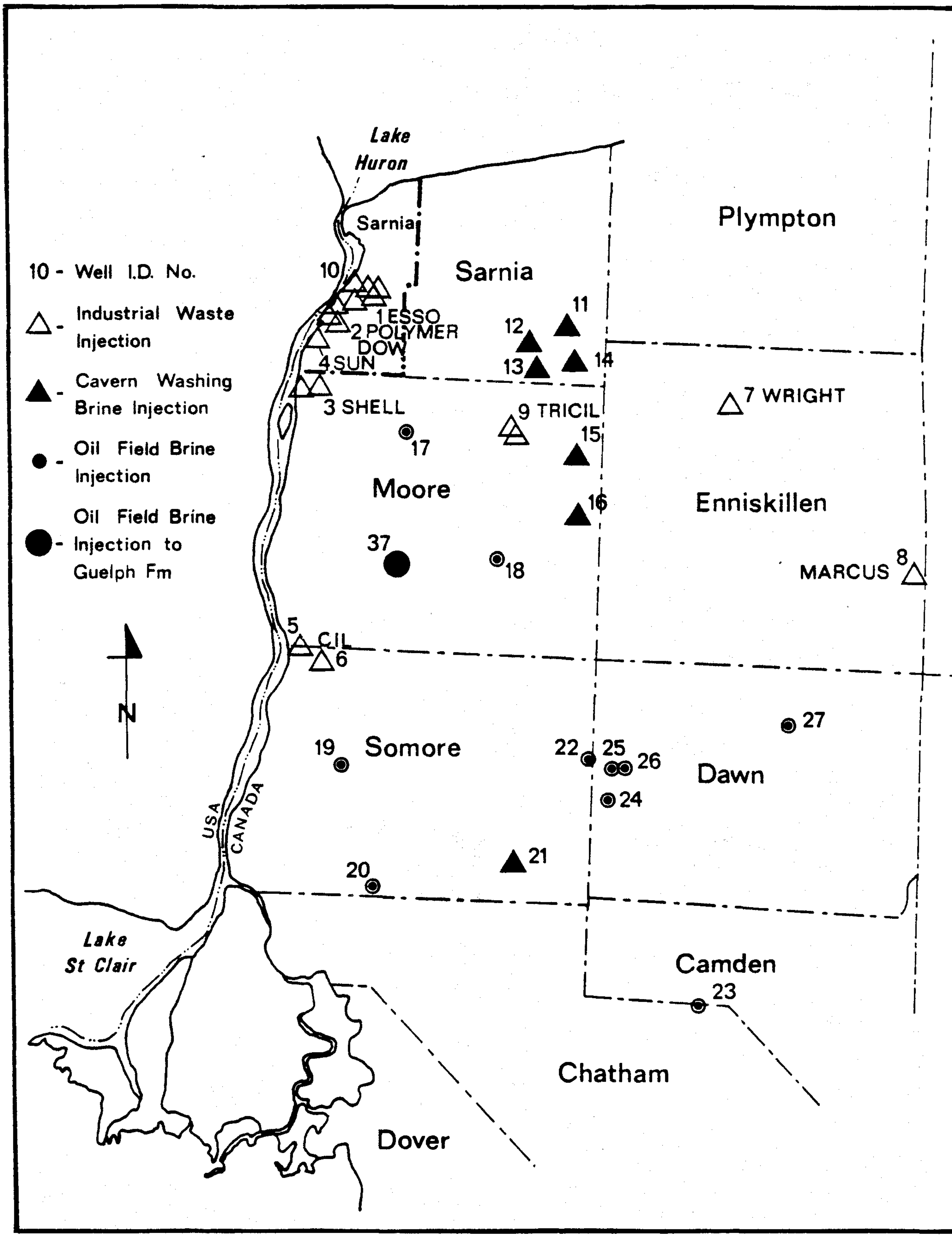


FIGURE VII-3. Injection wells.

Of concern to the Ontario Ministry of the Environment and the Federal Department of the Environment is the past practice of injection of industrial wastes into the Detroit River geologic formation, and the potential for contamination of the freshwater aquifer. Because of high pressures used for injection and the large volumes of wastes disposed, the potential exists for contaminants to migrate from the disposal unit to the freshwater aquifer and hence, to the St. Clair River. The possible pathways of migration include the following:

1. Numerous bore holes, many of them abandoned and unplugged, provide open conduits through the bedrock confining units;

2. Poorly constructed injection wells could allow waste to migrate along the outside of the casing;

3. Faults, fractures and joints are likely to exist in the bedrock confining units. It is possible the pressurized waste could travel great distances via these fractures; and

4. The permeability of the confining shale and limestone units may be of sufficient magnitude to allow pressurized wastes to migrate via pore spaces to the shallow aquifer.

In view of the possible migration pathways and the fact that there were documented cases of upwelling in the Sarnia area, which occurred between 1966 and 1972, there was the possibility that the groundwater system had been pressurized above its natural state. This being the case, it was possible that the displacement of formation fluids, or the upwelling of industrial wastes, may have contaminated the freshwater aquifer in the St. Clair River area or have migrated across the St. Clair River to Michigan.

Detailed studies of the fresh water aquifer and the movement of injected wastes were undertaken from 1986 to late 1988 by the federal and provincial governments, and industry. The preliminary results of these studies were reported by Intera Technologies Inc. (90). The executive summary of this report is reproduced below:

> "This report .... describes the results of a hydrogeologic study of the fresh water aquifer and deep geologic formations in the Sarnia Ontario area. The study was undertaken to assess the extent to which the St. Clair river and a thin sand and gravel aquifer (fresh water aquifer) located at the bedrock surface have been impacted by past practices of industrial waste disposal to the Detroit River Group of Formations located at 150 to 200 m below bedrock surface.... this study included: drilling, testing and installation of fifteen groundwater monitoring wells to the fresh water aquifer; drilling, testing and installation of one 300 m

deep borehole to the disposal formation in the Detroit River Group of formations; and quarterly groundwater sampling and hydraulic head monitoring of a 29 point monitoring well network of the fresh water aquifer and of the deep borehole. The computer modeling included a numerical simulation of groundwater flow in the fresh water aquifer and simulation of waste migration within the disposal zone. The potential size of contaminant plumes that may result from vertical migration through an open abandoned borehole between the disposal zone and the fresh water aquifer was also simulated using a computer model.

"The results of this study show that the fresh water aquifer is a thin, discontinuous aquifer located at or near the bedrock surface with an average hydraulic conductivity of $5 \times 10^{-6}$ m/s. A buried bedrock valley of depth 60-80 m below ground surface and 30-40 m below surrounding bedrock is located about 500-1000 m east of the current channel of the St. Clair River. The fresh water aquifer has a higher hydraulic conductivity of about $1 \times 10^{-4}$ m/s within the bedrock valley due to the presence of alluvial sands and silts. The freshwater aquifer is generally overlain by 30-70 m of low permeability clay till; however, below the St. Clair River the thickness of confining till in places may be a thin as 3 m.

"Groundwater flow within the fresh water aquifer toward the bedrock valley averages 0.57 $m^2$/yr per unit aquifer width. Within the bedrock valley some flow is directed down to deeper geologic formations and some of the flow is discharged to the St. Clair River. No groundwater flows under the St. Clair River within the fresh water aquifer to the U.S.

"Phenol contamination of the fresh water aquifer by injected industrial waste is evident on the Esso Petroleum Canada property near the St. Clair River and below the St. Clair River in the area of the CN Railway tunnel. Loading to the St. Clair from this 800 m by 600 m contaminated zone is calculated at 5.2 g/d which, given the volume of flow in the St. Clair River, is rapidly reduced to below detection levels. Chloride contaminant loading to the River from the same area is calculated at 50 kg/d.

"It is recognized that some undetected contaminant plumes may exist in the vicinity of disposal wells due to waste migration up abandoned boreholes. Assuming such plumes did exist adjacent to the St. Clair the total potential phenol loading to the River is estimated at 25 g/d. This would result in an increase in phenol concentration in the River of 1.9 ng/L which is about 500 times less than the minimum detection limit of 1 ug/L.

"Industrial Waste characterized by Phenol (30,000 - 40,000 ug/L) volatile organics (e.g., benzene, toluene, etc., 200 - 5,800 ug/L) and naphthalenes (50 - 829 ug/L) is restricted to a narrow 11 m interval between 185.9 and 196.6 m depth in the upper section of the Lucas dolomite. Vertical migration of this waste through the pore space of the overlying and underlying rocks has been negligible and measured hydraulic heads show fluid flow in the adjacent rocks is now to the disposal zone. This study suggests that there is a relatively active flow system within the disposal formation today and that understanding the fate of 8,000,000 $m^3$ of waste disposed to the Detroit River Group will require knowledge of the current rates and directions of flow within the disposal zone.

"The hydraulic head within the disposal zone is now 14 to 15 m below that in the fresh water aquifer and 8 m below the level of the St. Clair River. Therefore current flow directions are from the fresh water aquifer and St. Clair River to the disposal zone.

"A significant finding of this study was the occurrence of high hydraulic conductivity limestone layers in the Hamilton Group of formations at 74 and 123 m depth that likely contain industrial waste at phenol concentrations of 6000 - 10,000 ug/L and hydraulic heads above those in the fresh water aquifer. The 2 m thick limestone layer at 74 m depth is of particular concern to this study because groundwater from this horizon likely discharges to the fresh water aquifer within the bedrock valley and this horizon flowed industrial waste in 1967 and 1969 at rates of 10 to 238 L/min. The extent of contamination in this and the 123 m depth horizon is not known but is likely significant as the only two monitoring wells to these horizons (from this and an earlier study) detected industrial waste. This waste was likely introduced to these limestone horizons from improperly completed disposal, cavern or abandoned wells."

6. Spills

A recent, well-publicized spill of perchloroethylene in the Ontario waters of the St. Clair River underscored the potential for accidental loss of large quantities of materials in this river system (36). This incident prompted a major investigation on the biological effects of spills and related discharges (91). The results of the study demonstrated that the waters, sediments, and biota of the St. Clair River system were adversely affected by discharges of contaminants to the river, and that the perchloroethylene spill aggravated an existing condition.

The perchloroethylene spill was not an isolated event. Rather, it was simply another incident in a long history of accidental spills. The data presented in Table VII-17 indicate that, on the Canadian side, 11 major oil spills of 10 tons or more (a total of 1,282 tons) and 21 major spills of other hazardous compounds (a total of 10,390 tons) occurred between 1974 and 1985.

The Michigan shoreline is considerably less industrialized than the Ontario portion of the river. However, between 1973 and 1979, there were 120 spills of petroleum related compounds from land based facilities and vessels which released over 18,500 L of these materials into the St. Clair River. An additional spill released 208 L of other hazardous substances to the river during this period.

Tables VII-17a and 18 provide information on spill occurrences during 1986. In 1986, a total of 48 surface water spills to the St. Clair River were reported. There were 17 U.S. spills including 3 chemical, 4 non-PCB oil, and 10 raw sewage. Sixteen chemical, and 22 non-PCB oil spills to the Canadian waters of the St. Clair were reported. Very recently, (May 1988) a spill of acrylonitrile (maximum 12,000 kg) occurred at Polysar Sarnia, but the chemical was not detected in the St. Clair River.

Although improvements in water and sediment quality have been made in the St. Clair River system in recent years, spills from vessels and land-based facilities continue to threaten the suitability of the river for fish and wildlife populations.

7. Contaminated Sediments

The sediments along the Canadian shore are significantly contaminated with a variety of chemicals (58,59,67). But compared to chemicals in water and suspended sediments, much less than one percent of the contaminants moving along the river are transported by bed sediment movement (67). The total mass of contaminants such as HCB and OCS in Canadian shoreline sediments in the river is comparable to the annual loadings of these contaminants (37,59). Unless a significant percent of this material is being desorbed each year, it is unlikely that contaminated sediments contribute significantly to the loading in the water column. However, because no measurements have been made, it is not possible to come to a definite conclusion at this time.

Another way sediments can act as source of contaminants is through the biological community. Benthic organisms have been shown to accumulate contaminants from sediments in the river (50). These organisms serve as a food source for higher trophic levels such as fish. Thus contaminated sediments can act as a source of higher body burdens of chemicals in biota in the system. Sediments from the Sarnia industrial area are lethal to Hexagenia, Hydallela, and fathead minnows.

TABLE VII-17

Spills of hazardous materials in excess of 10 tons into the Ontario waters of the St. Clair River and its tributaries, 1974 - 1985[a].

| Source | Substance Spilled | Year | Amount (Tons) Spilled | Unrecovered[b] |
|---|---|---|---|---|
| Suncor | Bunker & oil | 1976 | 150 | 30 |
| Suncor | Bunker & oil | 1976 | 300 | 0 |
| CNR | Bunker & oil | 1977 | 86 | 17 |
| Esso Petroleum | Gas Oil | 1978 | 29 | 0 |
| Hall Corp. (Vessel) | Bunker & Oil | 1980 | 21 | 13 |
| CNR | Bunker & Oil | 1981 | 21 | 4 |
| Esso Petroleum | Gasoline | 1981 | 348 | 0 |
| Esso Petroleum | No. 2 fuel Oil | 1984 | 116 | 23 |
| Esso Petroleum | No. 2 fuel Oil | 1984 | 16 | 3 |
| Imp. Bedford (Shell) | Catalytic cracker | 1985 | 75 | 1 |
| Esso Chemical | Slop Oil | 1985 | 120 | 0 |
| Total | | | 1,282 | 91 |
| Polysar | Latex | 1975 | 17 | 17 |
| Polysar | Latex | 1976 | 18 | 18 |
| Polysar | Latex | 1980 | 87 | 87 |
| Polysar | Latex | 1980 | 20 | 20 |
| Total | | | 142 | 142 |
| Dow | Styrene | 1974 | 4,504 | 2,700 |
| Polysar | Styrene | 1978 | 411 | 80 |
| Total | | | 4,915 | 2,780 |
| Dow | Hydrochloric Acid | 1974 | 21 | 21 |
| Dow | Sodium hydroxide | 1975 | 28 | 28 |
| Dow | Sodium chlorate | 1979 | 4,080 | 4,000 |
| Dow | Sodium chloride | 1981 | 379 | 76 |
| Polysar | Sulphuric acid | 1981 | 13 | 13 |
| Suncor | Hydrochloric acid | 1982 | 16 | 0 |
| Esso Chemical | Sodium hydroxide | 1983 | 19 | 4 |
| Esso Petroleum | Brine | 1984 | 164 | 33 |
| Total | | | 4,720 | 4,175 |
| Polysar | Lignin liquor | 1975 | 159 | 33 |
| Esso Petroleum | Phenolic wastewater | 1975 | 239 | 239 |
| Suncor | Process water | 1975 | 91 | 73 |
| Eagle Transport | Xylene | 1975 | 11 | 2 |
| Dow | Ethylene Glycol | 1976 | 13 | 0 |
| Esso Petroleum | Waste Water | 1982 | 46 | 46 |
| Dow | Perchloroethylene | 1985 | 54 | 4 |
| Total | | | 613 | 397 |

a - Data from (36).
b - Estimate based upon reports of percent recovered.

TABLE VII-17a

Spills from Canadian sources to the St. Clair River (1986).

(chemicals)

| DATE | SOURCE | CHEMICAL | VOLUME | RECEIVING WATER | LOCATION | RESOLUTION | RECOVERED AMOUNT |
|---|---|---|---|---|---|---|---|
| 86/03/28 | Dow Chemical | Polyethyene Powder | - | St. Clair River | Sarnia | - | - |
| 86/03/29 | CIL | 30% Phosphoric Powder | 150 kg phosphorus | St. Clair River | Courtright | - | - |
| 86/05/11 | Suncor Refinery | Toluene | 204L | St. Clair River | Sarnia | - | - |
| 86/06/12 | Dow Chemical | Styrene Benzene | 2 kg each | St. Clair River | Sarnia | - | Storm overflow |
| 86/06/12 | Dow Chemical | 35% Ethylene Glycol | 2273 L | St. Clair River | Sarnia | - | - |
| 86/07/12 | Dow Chemical | Unknown | - | St. Clair River | Sarnia | Samples taken | - |
| 86/07/25 | Imperial Oil Refinery Fueling Dock | Diesel Fuel | 3500 L | St. Clair River | Sarnia | Booms deployed | Tug fueling leak |
| 86/07/30 | Dow Chemical | Ethyl Benzene Styrene | 181 L | St. Clair River | Sarnia | Plume modelling | - |
| 86/07/31 | Imperial Oil Refinery Fueling Dock | Diesel Fuel | 204 L | St. Clair River | Sarnia | - | 100% |
| 86/08/07 | Polysar | Tertiary Butyl Alcohol | 272 L | St. Clair River | Sarnia | - | - |
| 86/08/12 | Fiberglas Canada | Phenolic Resin | 227 L | Cole Drain | Sarnia | - | - |
| 86/08/12 | Dow Chemical | Benzene | 25 kg | St. Clair River | Sarnia | Plume modelling | - |
| 86/08/13 | Polysar | Halo-Butyl Rubber | 900-1360 L | St. Clair River | Sarnia | Booms deployed | - |
| 86/11/24 | Fiberglas Canada | Phenol Dyes Formaldehyde | 90 L | St. Clair River | Sarnia | - | - |
| 86/11/29 | Polysar | Calcium & Zinc Stearates | 5-10 kg | St. Clair River | Sarnia | Booms deployed | 100% |
| 86/12/18 | Polysar | Stearic Acid | 20 L | St. Clair River | Sarnia | - | - |

TABLE VII-17a. (cont'd)

(non-PCB oils[1])

| Date | Source | Volume | Receiving Water | Location | Resolution | Recovered Amount | Comments |
|---|---|---|---|---|---|---|---|
| 86/04/10 | Shell Refinery | 4.54 L | Talfourd Creek | Corunna | Booms deployed | - | - |
| 86/04/18 | Suncor Refinery | 45.4 L | St. Clair River | Sarnia | Booms deployed | 36.3 | 9 litres lost to River |
| 86/05/07 | Shell Refinery | 9.08 L | St. Clair River | Sarnia | Booms deployed | 9.08 | All materials recovered |
| 86/05/16 | Imperial Oil Refinery | 9.08 L | St. Clair River | Sarnia | - | - | Oil not recoverable |
| 86/05/18 | Polysar | 13.62 L | St. Clair River | Sarnia | - | - | - |
| 86/06/05 | Ontario Hydro | 10 L | St. Clair River | Courtright | - | - | - |
| 86/06/11 | Shell Refinery | 13.5 L | Talfourd Creek | Corunna | Booms deployed | - | Overflow due to heavy rain |
| 86/06/11 | Shell Refinery | 1818 L oily water | Talfourd Creek | Corunna | Booms deployed | - | Overflow due to heavy rain |
| 86/07/02 | Imperial Oil Refinery | - | St. Clair River | Sarnia | Booms deployed | - | - |
| 86/07/07 | Imperial Oil Refinery | - | St. Clair River | Sarnia | Booms deployed | - | - |
| 86/07/12 | Imperial Oil Refinery | 4.5 L | St. Clair River | Sarnia | Booms deployed | - | De-oiler heat exchanger leak |
| 86/07/12 | Polysar | 4773 L | St. Clair River | Sarnia | Booms deployed | - | Overflow due to heavy rain |
| 86/07/12 | Shell Refinery | 4096 L | Talfourd Creek | Corunna | Booms deployed | - | Overflow due to heavy rain |
| 86/07/20 | Polysar | 4091 L | St. Clair River | Sarnia | - | - | Biox bypass due to heavy rain |
| 86/08/02 | Shell Refinery | 9 L | Talfourd Creek | Corunna | Booms deployed | - | Overflow due to heavy rain |
| 86/08/07 | Shell Refinery | 36 L | Talfourd Creek | Corunna | Booms deployed | - | Stormwater runoff |
| 86/08/08 | Shell Refinery | 2.2 L | Talfourd Creek | Corunna | Booms deployed | - | Stormwater runoff |
| 86/08/29 | Polysar | 9,000 L | St. Clair River | Sarnia | - | - | Pumps failed |
| 86/08/05 | Polysar | 25,000 L | St. Clair River | Sarnia | - | - | Power failure |
| 86/09/22 | Polysar | 4,000 L | St. Clair River | Sarnia | Booms deployed | - | Overflow due to heavy rain |
| 86/10/03 | Polysar | 45-90 L | St. Clair River | Sarnia | Booms deployed | - | - |
| 86/10/26 | Imperial Oil Refinery | 22 L | St. Clair River | Sarnia | Clean up initiated | - - | - - |

[1] There were no reported spills of PCB contaminated oils.
[2] In addition there were 3 reports of oil sheens on the river.

TABLE VII-18

U.S. raw sewage spills (1986).

| PEAS | Date | Source | Volume | Receiving Water | Location | Resolution | Recovered Amount | Comments |
|---|---|---|---|---|---|---|---|---|
| 2922-86 | 8/15/86 | City of Port Huron WWTP | 24 hrs. at 6000 gal per hr | St. Clair River via Black River | St. Clair Co. Port Huron | --- | none | |
| 2931-86 | 8/16/86 | City of Port Huron WWTP | 24 hrs. at 200 gal per min. | St. Clair River via Black River | St. Clair Co. Port Huron | --- | --- | |
| D-001-86 | 9/23/86 | Marine City WWTP | 1900 gpm for ~ 24 hr | St. Clair River | St Clair Co. Marine City | Spill controlled and cleaned up. | 80 gals | |
| 2992-86 | 08/15/86 | City of Port Huron WWTP | 24 hr at 6000 gal per hr | St. Clair River via Black River | St. Clair Co. Port Huron | --- | none | Stormwater caused partial bypass. |
| 2931-86 | 08/16/86 | City of Port Huron WWTP | 24 hr at 200 gal per min. | St. Clair River via Black River | St. Clair Co. Port Huron | Station got flooded. | none | Stormwater caused partial bypass. |
| D-001-86 | 09/23/26 | Marine City WWTP | 1900 gpm ~24 hr | St. Clair River | St. Clair Co. Marine City | --- | none | Stormwater caused partial bypass. |
| 06-86 | 01/02/86 | Mueller Brass | 30-50 gal | St. Clair River via Black River | St. Clair Co. Port Huron | Pauls Road Oiling contacted for clean-up. | ~20 gals | Clean up supervised by USCG. |
| 2803-86 | 08/08/86 | Mueller Brass | 10-15 gal | St. Clair River via Black River | St. Clair Co. Port Huron | Pauls Road Oiling contacted for clean-up. | ~5 gals | Company instituted in-plant controls to reduce # of spills. |
| 1539-86 | 05/24/86 | Detroit Edison | 1 gal | St. Clair River | St. Clair Co St. Clair | Boom in place. (Barrel tipped over) | none | - |
| 0166-86 | 11/19/86 | Detroit Edison | 120 gal | St. Clair River | St. Clair Co. St. Clair | Partially contained. USCG notified. | 80 gals | - |
| | TOTAL | | 186 gal (704.91) | | | | 105 gals (398.1) | |

## 8. Navigation

As stated earlier, ship traffic through the St. Clair River is considerable. These ship movements cause some minor sediment resuspension but should have little impact on the movement and effects of contaminants in the river. Periodic dredging is required in the lower channels of the river for navigation purposes. The material dredged from the Canadian channels is placed in a confined disposal facility (the Southeast Bend Cutoff Site, Seaway Island), because it exceeds open water disposal guidelines for oil and grease, and mercury. Periodic U.S. shoal removal in the upper reaches of the river of a few hundred $m^3$ of sediment are disposed in Lake Huron. A few hundred thousand $m^3$ of sediments are removed by the U.S. in the lower reaches of the river approximately every three years. These materials are placed in the Dickinson Island Confined Disposal Facility.

## D. DATA REQUIREMENTS AND ASSESSMENTS

In answering the source/sink question for the St. Clair River, data sets from single laboratories were used. Thus, even if the analyses were biased high or low, the relative changes in concentrations would still be apparent. Some of the bottom sediment data for several parameters were combined and averaged. The laboratories that generated these data performed acceptably in the round-robins conducted by the Data Quality Management Workgroup (Chapter IV), and comparable data for the different studies were found for overlapping sampling stations.

For the point source study, the United States methods provided much lower detection limits (DL) for three organics than did the Canadian methods. For most chemicals, this did not impact the study because of the lower concentrations found in the U.S. sources for most organic parameters. However, for PCBs (U.S. DL 0.0001 ug/L; Canadian DL 0.1 ug/L), the difference in detection limits could affect the ranking of the PCB sources along the river. Fortunately, PCB discharges to the St. Clair River appear to be fairly low, so remedial measures for PCBs may not be required.

While sensitivity analyses were applied to most of the models used to simulate conditions in the St. Clair River, the quality of the initial data utilized in most modeling exercises is difficult to judge. Furthermore, Monte Carlo simulations and other uncertainty analyses are almost entirely lacking for the process models developed to date. These shortcomings render existing modeling tools less than fully useful for management authorities. Additional resources will undoubtedly be a priority to overcome these deficits.

## E. MODELING AND MASS BALANCE CONSIDERATIONS

### 1. Dispersion Models

The St. Clair River, like the other connecting channels of the Great Lakes is the recipient of large volumes of effluents. Under normal circumstances, the apparent impact of these additions would be less noticeable because of the large volume of water conducted through this channel. However, because of the necessity to maintain broad channels for navigation, shore based discharge structures must be maintained relatively close to shoreward margins of the river. This fact dictates that only a relatively small portion of the total river flow is available for waste dispersal.

In an early study of lateral dispersion, Hamdy and Kinkead (92) adapted an existing numerical dispersion model to predict in-stream concentration of a conservative substance (chloride) from shore based discharge outfalls to the St. Clair River. These authors found that the nondimensional dispersion coefficient measured in the field was in a range of 0.93 - 1.0, based upon a shear velocity of 0.042 m/s and a depth of 10 m. This coefficient observed in the St. Clair River was substantially greater than the classic value of 0.23 normally used in dispersion predictions.

A simultaneous parallel study conducted by Akhtar and Mathur (93) used equations identical to Hamdy and Kinkead, but incorporated the classic 0.23 value for the nondimensional dispersion coefficient. When Akhtar and Mathur reran their model using the Hamdy and Kinkead value of 0.96, the transverse chloride distribution predicted by the model agreed reasonably well with observed values. The reported data suggest that the bulk of chlorides were contained close to the Canadian shoreline. Shoreward concentrations of 80 mg/L were observed, while concentrations declined to levels approaching zero 50 m off shore. Validation of the model was made against 1976 chloride data for the St. Clair River at the same sites. In this case, shoreward concentrations of nearly 100 mg/L were shown to decrease laterally to concentrations approaching zero 45 m off shore. The 1976 verifications were made against a point source loading for $Cl^-$ of 2.6 kg/s, a function of a discharge rate of 3 $m^3$/s and an initial concentration of 860 mg/L.

In a report to the Water Resources Branch of the Ontario Ministry of the Environment, McCorquodale and Bewtra (94) provide a users manual for a model designed to assess the convection-dispersion and decay of vertically mixed pollutants from multiple outfalls. The authors state that this model was developed using OMOE field data on chlorides and phenols in the St. Clair River. While the model was intended to simulate phenol concentrations along the entire length of main channel of the St. Clair River, neither data nor model simulations are provided. No evidence of calibration, verification, or application of this model is available.

In the same short report to OMOE, McCorquodale and Bewtra (95) consider the dispersion and transport of phenols in the St. Clair River. These authors describe adapting a previously existing model (characterized only as "The Detroit River Model") to conditions existing in the St. Clair River.

Although this modified far-field model was used to simulate phenol concentrations in the St. Clair River from outfall A to the Delta, only estimations of pollutant loadings in the channels of the St. Clair River delta are provided. The authors report that 5 percent of the total flow and 14 percent of the total phenol load exit the St. Clair River by way of Chenal Ecarte. This loading approximates 4 kg/d of phenol. The South Channel is responsible for conducting 42 percent of the total flow and 81 percent of the total phenolic load (23 kg/d, phenol) from the St. Clair River. A total of 20 percent of the river flow, but less than 5 percent of the total phenolic load exists the St. Clair River via the Middle Channel. This burden represents only about 1.4 kg/d of phenol. While the North Channel is responsible for conducting 33 percent of the total river flow, only a trace of the total phenol loading is found in this channel. The authors note that these values represent loadings without consideration for decay. If degradation rates were added, the phenol loadings to the channels could be reduced by as much as 30 percent.

Chan et al. (37) modeled the fluxes and the concentration distribution profiles in water column transects across the upper and lower St. Clair River for the contaminants hexachlorobenzene (HCB), hexachlorobutadiene (HCBD), pentachlorobenzene (QCB), and octachlorostyrene (OCS). The data they derived clearly demonstrated a plume of these contaminants for the Sarnia Industrial Area. Dieldrin concentrations, on the other hand, were quite consistent for all stations sampled, fluctuating about a mean of approximately 0.25 ng/L. The ubiquitous distribution of this contaminant suggests long-range transport as the likely mechanism involved in this widespread contamination. The authors report that similar concentration distributions to dieldrin were observed for several other organic substances including alpha and gamma BHC and PCBs.

A marked plume of contaminants was apparent, originating for the Sarnia area. This plume was observed for HCB, HCBD, QCB, and OCS. Very little of these compounds are present at the head waters of the St. Clair River. At Port Lambton, however, peak values were observed near the Canadian shoreline, with decreasing concentrations across the river. This observation corroborates the lateral distribution calculated for chloride by Hamdy and Kinkead (92). Chan et al. (37) report that downstream, however, Chenal Ecarte contained the highest concentrations, the South

Channel was described as having significant levels, and very low concentrations were observed in the North Channel. Unfortunately, no flow data are provided to enable an exact comparison of channel burdens with the various values provided by McCorquodale and Bewtra (95). However, if the normal flow value of 5,100 $m^3/s$ for the St. Clair River provided by McCorquodale et al. (86) is used, and if the percent of total flow reported by McCorquodale and Bewtra (95) for Chenal Ecarte (5 percent of total), South Channel (42% of total), and the North Channel (33 percent of total) are accepted, a comparison of values may be made. This comparison is presented in Table VII-19 below.

An order of magnitude agreement between the percentage contributions of the contaminants in the two data sets exists when the differences in methodologies are considered. Chan et al. (37) measured HCB in centrifuged water samples at the Port Lambton stations. These samples represented `dissolved phase' HCB, since the majority of suspended solids had been removed. The authors note that 41 percent of the HCB observed at Port Lambton was in the dissolved phase. When the percentage contributions to total HCB loadings are adjusted for suspended solids concentrations, the sum of the channel values approach 100 percent of the total HCB loading rate of 1.63 kg/d reported by Nettleton (96).

Chan et al. (37) also used the observed contaminant concentrations and water depths to calculate the flux of each compound across the river cross section at Port Lambton. Good agreement of values was obtained when compared with Environment Canada and Ontario Ministry of the Environment district monitoring data. Between August and October of 1985, HCB fluxes ranged from 59 to 280 gm/day, QCB was observed from 22 to 31 gm/day, HCBD 240 to 1,700 gm/day, and OCS 5 to 15 gm/day.

These authors then calculated lateral mixing in the river channel using a transverse mixing coefficient derived by varying the coefficient until the calculated concentration profile matched the measured profile. The original calculation of this factor was made against the HCB data and applied to other measured parameters. With the exception of a single HCBD data set for 23 September 1985, excellent agreement with measured concentration profiles was achieved. This single data set demonstrated no plume-like distribution, but rather a relatively constant concentration across the river cross section. All other calculations demonstrated a plume which tended to remain near the Canadian shore of the St. Clair River.

These authors also note that future studies should consider special sampling procedures for modeling studies. They report that the results of the water/suspended sediment partitioning study showed that measurements should be made on both dissolved and suspended sediment phases, or on unfiltered water samples if contaminant fluxes or loadings are to be calculated.

TABLE VII-19

A comparison of burdens of chemical contaminants in the various channels of the St. Clair River Delta (kg/d).

| Distributary Channel | Phenol Burden[a] | % of Total Phenol Load | HCB Burden[b] | % of Total HCB Load[c] |
|---|---|---|---|---|
| Chenal Ecarte | 4.0 | 14 | 0.286 | 17 |
| South Channel | 23.0 | 81 | 0.740 | 45 |
| Middle Channel | 1.4 | <5 | -- | -- |
| North Channel | Trace | Trace | 0.073 | 4 |

a - Data from (86).
b - Data from (37).
c - A total of ± 45% of HCB loadings are unaccounted for, since Chan *et al.* (37) used centrifuged water to measure HCB at the Port Lambton stations. They note that 41% of the HCB observed at Port Lambton was in the 'dissolved phase'.

## 2. Hydrodynamic Model

A river transport model has been constructed by McCorquodale _et al._ (86) which has potential for application to the St. Clair River. This model has been variously referred to as the University of Windsor K-E model and the University of Windsor K-E River Mixing Model (96). This model is a steady state, depth average, turbulent mixing model designed to simulate complex river systems with multiple outfalls. Nettleton (96) reports that velocity distributions and dispersion characteristics of the St. Clair River were computed with this model. The model divides the St. Clair River into 14 segments, estimating the flow in each segment using U.S. Army Corps of Engineers data adjusted to interpolated sections in each segment based upon a normal flow rate of 5,100 $m^3/s$ (187,000 cfs).

Nettleton reports that the model was calibrated by adjusting parameters for the lateral profile of the velocity to provide predicted results similar to those measured. This author writes that in addition to velocities and dispersion coefficients, this model also provides the lateral locations of river streamlines in the various river segments. Nettleton concludes that, based upon the results of this and other OMOE applications of the hydrodynamic model, it would appear that the model is well suited for use in the St. Clair River. At the present time, however, there is no report of verification of this model.

## 3. Chemical Transport Models

Nettleton (96) reports that, to date, chemical transport modeling for the St. Clair River has been accomplished only for the contaminant hexachlorobenzene (HCB). Two models were used to study the chemical transport of HCB. One of these models, the University of Windsor Hydrodynamic Model discussed above, calculates the depth averaged total contaminant concentrations in two dimensions in the water column. The U.S.EPA TOXIWASP model (97), estimates the dissolved, sediment sorbed, and biosorbed concentrations of the contaminant in both the water column and the sediment bed of the river.

The University of Windsor transport model was run with both average and maximum loadings using both average and minimum flow rates. The best agreement with measured field data was achieved using average flows and maximum loadings of HCB. Nettleton (96) reports that, under these conditions, the total loading rate of HCB to the St. Clair River System was 1.63 kg/d. He notes that in excess of 97 percent of this total loading results from a single point source, the Dow Chemical First Street sewer complex.

Comparisons of the river model predictions of HCB concentrations with measured values were reported to be in good agreement (86).

The magnitudes of predicted concentrations were generally within the probable error of field data measurement (96).

The TOXIWASP model is a multiple cell model which divides the water column and bed into segments both vertically and horizontally. The principal mass transfer mechanisms considered by this model include contaminant advection and dispersion, sediment settlement and resuspension, volatilization and biological degradation of the contaminant, and point and nonpoint sources of contaminant to the water column, including sediment bound materials.

In relation to the St. Clair River, this model was run using only one layer of water column and bed sediments. The river was divided horizontally into four flow panels. Both "fine" and "coarse" grid patterns were used. The "coarse" grid considered the entire river to the Delta area, while the "fine" grid was used to concentrate on the analysis of the river in the vicinity of the outfalls.

Nettleton (96) reports that comparisons between water column concentrations of HCB predicted by TOXIWASP with those measured in the field were satisfactory. He notes that both the trends and the magnitudes of the predicted values are in good agreement with the measured field data. Bed sediment predictions occasionally tended to over-predict both magnitudes and trends when compared with field data. However, both magnitude and trend predictions appear to be within the estimated field measurement accuracy.

Nettleton concludes that it would appear that both the University of Windsor transport model and the TOXIWASP model can predict the chemical transport of HCB relatively accurately within the St. Clair River. He notes, however, that these results must be regarded as preliminary. Confirmatory results (and presumably model verification) await the final assembly of the 1986 St. Clair River Municipal Industrial Strategy for Abatement data base.

4. Unsteady Flow Model

An unsteady flow model for the St. Clair River from Lake Huron to Lake St. Clair was developed by Derecki et al. (98). This model simulates hourly and daily flow rates of the river. Unlike other single-stem river models, the unsteady flow model provides flow separations in the vicinity of Stag and Fawn Islands and in the North, Middle, South, and Cutoff Channels of the St. Clair River Delta. The model predicts stage, discharge, and velocity data required to simulate the fate and transport of toxic substances.

Derecki *et al*. (98) suggest that the model has been calibrated. This calibration consisted of adjusting the roughness coefficients of the river channel. These coefficients were derived from 14 sets of flow measurements conducted by the U.S. Army Corps of Engineers between 1959-1979. No evidence of validation of this model is available.

## 5. Other Models

In a departure from the usual academic modeling format, Nettleton and Hamdy (91) have created a user-oriented model for assessment of effects of spilled contaminants. The modeling format is termed `The St. Clair River Spill Manual'. This device was developed to provide a convenient, easily used, rapid assessment methodology for predicting the downstream effects of spilled contaminants on water intakes. A total of 21 outfalls located in the Chemical Valley near Sarnia are considered in this manual. Using this well-designed instrument, assessments of impact are possible all along the Canadian shoreline and at five Michigan intake sites, including St. Clair, East China Township, Marine City, Algonac, and Old Club. The Marysville intake was found to lie outside of all the plumes observed, and is, therefore, not considered in the manual.

Users desiring to assess impacts of a spill need only know the type and total mass of contaminant spilled, the duration of the event, and the total river flow at the time of the spill. If decay characteristics are known, there is a possibility to incorporate this information into the analysis.

With these data available, the manual is then consulted to ascertain the peak contaminant concentration expected, and times of arrival and departure of the spill plume at a given water intake. This adaptation and coupling of two mathematical models in a specific user-oriented fashion will undoubtedly be extremely useful to managers charged with the responsibility of providing of safe drinking water.

## 6. Model Applications

A major application of these hydrodynamical dispersion models and fate and transport models, after calibration, is for the analysis of hypothetical effluent discharge scenarios proposed in remedial studies. This analysis can be approached in two ways: i) effluent loadings may be established based upon treatment technology, and the models used to ascertain the resulting short and long-term changes expected in the quality of the downstream water/sediment/biota of the receiver; or ii) the models can be used to estimate appropriate effluent criteria assuming known ambient water quality criteria downstream of the outfall.

As an example, effluent loading criteria for HCB discharged to the St. Clair River from Dow Chemical can be determined (Table VII-20). There are two important reasons to develop effluent criteria for HCB: i) it has been shown to impact exposed sediment and biota within the effluent plume due to its chemical characteristics (e.g., large $K_{OW}$); and ii) when reduced via the appropriate industrial treatment, other related contaminants should also be reduced from the effluent.

For this example, three criteria are used in the analysis for HCB. The first is the 6.5 ng/L freshwater aquatic life guideline for concentrations in the water column. The second criterion is that HCB concentrations in the sediment are not to increase by more than 1 ng/L above the background level. The third criterion is that HCB concentrations in biota, as a result of bioconcentration, is not to increase more than 50 ug/L above the background level. The second and third criteria are arbitrarily selected (for demonstration purposes) for protection of the sediment and biota under long-term steady state conditions.

The calculations (as summarized in Table VII-20) are performed for two selected mixing zone lengths. The first mixing zone is to the south property line of Dow Chemical (about 1,200 m downstream of Dow's First Street sewer complex). In this case, the total HCB load is assumed proportional among the various outfalls as measured in 1986. The second mixing zone is two Dow's Second Street outfall (about 300 m downstream of the First Street complex). In this case, all loading is assumed to be discharged via Dow's First Street complex.

In this particular example, the arbitrary biota criterion for the shorter mixing zone would result in the most stringent effluent loading.

TABLE VII-20

Loads required to limit zones of effect for HCB discharged from Dow Chemical.

| Criterion No. | Loads (kg/d) to limit the zone of effect to: | |
|---|---|---|
| | Dow's south property line (1,200 m)[1] | Second Street outfall (300 m)[2] |
| 1. Water (6.5 ng/L) | 0.106 | 0.065 |
| 2. Sediments (1 ppm above background) | 0.517 | 0.317 |
| 3. Biota (50 ug/L above background) | 0.041 | 0.025 |

Notes:

1. Assumes load is proportioned - 83, 2, 5, 10% to Dow's 1st, 2nd, 3rd and 4th street outfalls, respectively.

2. Assumes load is entirely from Dow's 1st Street outfalls.

## F. OBJECTIVES AND GOALS FOR REMEDIAL PROGRAMS

### 1. Water Quality, Sediment, and Biota Standards, Guidelines and Objectives

Setting goals and objectives based on water quality, sediment, and biota guidelines is difficult because guidelines do not exist for many of the contaminants found in the St. Clair River. The guidelines and objectives that do exist are chemical specific and do not take into consideration the cumulative toxicity of exposure to multiple contaminants. However, comparing media concentrations to relevant guidelines or objectives which exist allows the identification of areas and ecosystems likely to be impacted by contaminants.

One of the goals of the UGLCC Study is to protect and maintain the channels for the highest attainable use. If this goal is achieved near industrial and municipal point sources of contaminants, then impacts to the river and downstream water bodies should be greatly reduced. During the study, water samples collected near point sources exceeded many of the Ontario Provincial Water Quality Objectives (see Tables VII-2 & 3) for the protection of freshwater aquatic life. Objectives are available for several chemicals of concern in the St. Clair River. However, for some chemicals found to be impacting the river, such as octachlorostyrene and hexachloroethane, there are currently no surface water objectives.

Objective 1. **Develop water quality guidelines or objectives for OCS, hexachloroethane and other chemicals not currently possessing water quality objectives.**

Objective 2. **Reduce surface water concentrations of organic and inorganic contaminants found to be impacting the St. Clair River surface water quality to concentrations below the most restrictive water quality guidelines with virtual elimination as a goal.**

Several sets of sediment criteria are available with which to compare sediment contaminant concentrations in the St. Clair River. These include the Ontario Ministry of the Environment Guidelines for Dredge Spoils for Open Water Disposal, the GLWQA Guidelines for Open Water Disposal of Dredged Materials, and the U.S.EPA Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments. Even though present sediment guidelines are generally inadequate, a comparison with contaminant concentrations in St. Clair River sediments indicates that there are several locations with which to be concerned. Many of these locations are along Sarnia's industrial waterfront, although there are impacted areas along other reaches of the river, as well. Guideline exceedences occur for oil and grease, lead, and mercury (Table VII-5). Sediment guidelines do not exist for many contaminants found in the sediments of the St. Clair River, including hexachlorobenzene, pentachlorobenzene and octachlorostyrene.

Objective 3. **Delineate more accurately, the extent of contaminated sediments in the St. Clair River, especially along Sarnia's industrial waterfront. Sediment contaminant concentrations should also be determined for the major St. Clair River tributaries; Talfourd Creek, the Black River, the Cole Drain.**

Objective 4. Develop sediment guidelines for organic chemicals of concern in St. Clair River sediments for those not currently having guidelines (e.g. HCB and OCS).

Objective 5. **Reduce the discharge (concentration and loading) of chemicals which are impacting St. Clair River sediments from known point sources to the lowest level achievable through the use of best available technology with virtual elimination as a goal.**

Fish consumption guidelines are available for only a few St. Clair River contaminants. The only exceedences occur for mercury and PCBs in the larger fish of some species (such as carp). There are no fish consumption guidelines for most of the chemicals of concern in the river.

Objective 6. **Reduce inputs (with a goal of virtual elimination) of mercury, PCBs and other chemicals to the St. Clair River which are resulting in concentrations of contaminants in fish exceeding guidelines.**

Objective 7. **Develop fish consumption guidelines for chemicals** found in St. Clair River biota which do not currently have objectives, such as OCS and HCB, and reduce, to the extent practicable, inputs of these contaminants to the St. Clair River.

It is necessary for regulations to move away from requirements and objectives based solely on concentrations towards those which include targets for reducing the total mass loading of pollutants entering the system. Basing effluent limitations on concentrations alone does not account for the long term effect of persistent contaminants which remain in sediments and biota. The discharge of persistent toxic substances should be reduced to as close to zero as possible (99), in keeping with the goals of the Great Lakes Water Quality Agreement. The only practical way of reducing/eliminating release of toxic substances to the environment is at the source of the release.

Several point sources which were identified as providing significant loadings of chemicals to the St. Clair River discharged in compliance with their concentration based discharge limitations. However, the magnitude of their effluent flow was such that significant loads were still provided to the St. Clair River. In other instances, significant discharges of chemicals originated from point sources that were not regulated with respect to that chemical (e.g. HCB, OCS and mercury from Dow Chemical and HCB and PAH from Polysar Sarnia).

Objective 8. **Develop mass loading limitations for the point source discharges of contaminants found to be of concern in the St. Clair River.**

Several municipal waste water treatment facilities, both in Canada and the United States, periodically exceeded discharge requirements for certain parameters during the study (e.g., Sarnia WWTP, Port Edward WWTP and St. Clair WWTP). Most municipal facilities are only required to control conventional parameters, such as total suspended solids, phosphorus and BOD5. Better control of operating conditions at these facilities and some upgrading may be required to ensure that they are discharging in compliance.

In some instances, municipal facilities were found to be significant contributors of unconventional and toxic substances which are not regulated, such as, phenols, PAHs, cyanide, zinc and iron, among others (e.g. Port Huron WWTP and Sarnia WWTP). Identification of the sources of these contaminants to the municipal facilities needs to be performed and programs to reduce such inputs developed if further control is required.

Objective 9. **Upgrade the technology and operating procedures at municipal waste water treatment facilities found to be exceeding discharge limits to ensure compliance with all effluent requirements.**

Objective 10. **Develop additional effluent requirements, in both mass loading and concentration form, at waste water treatment facilities identified as providing significant inputs of nonregulated contaminants impacting the St. Clair River.**

Objective 11. **Identify the sources of unconventional and toxic substances entering the municipal facilities (i.e. industrial contributors) and reduce such inputs.**

Urban nonpoint sources in Canada, such as stormwater and combined sewer overflows, increase the river contaminant burden for several parameters including oil and grease, PAHs, lead and iron. A thorough evaluation of this pollution source on the United States side of the river was not carried out for the UGLCC Study, but is needed.

Objective 12. **Upgrade or redesign municipal facilities operating CSOs, such as the Port Huron and the Sarnia WWTPs, to ensure that CSOs do not occur.**

Objective 13. **Identify the original sources of contaminants contained in urban runoff (e.g. atmospheric sources and spills) and take regulatory and management steps to reduce or eliminate contaminant input.**

Rural and urban industrial nonpoint sources have been poorly characterized for the St. Clair River. Contaminant loadings determined for the Black River and the Cole Drain showed these tributaries to be significant contributors of many contaminants including phosphorus, nitrogen, nickel, copper, zinc and cadmium (Black River) and PAHs, cyanide, and oil and grease (Cole Drain).

Although no contaminant loadings were determined for Talfourd Creek, the presence of herbicides and pesticides commonly used in agriculture and high concentrations of some metals supports the supposition that Talfourd Creek may be a significant contributor of contaminants.

Objective 14. **Develop programs within the agricultural community to reduce excessive use of phosphorus and pesticides. Develop new programs and support existing ones which provide instruction on the use of conservation tillage techniques and livestock waste management.**

Several waste disposal sites have been ranked as having a high potential to pollute the river. Several other waste disposal sites appear to need additional information to assess their present and future hazard. Improved contaminant and leachate control and treatment systems may be required for some sites, others may require more intensive remediation. Sludges from municipal and industrial wastewater treatment plants are either incinerated or placed in approved land disposal facilities. The transport of contaminants in surface runoff or groundwater leachate plumes from the disposal facilities has not been fully assessed.

The ultimate fate of injected wastes disposed in the past by pressurized injection in Ontario and by continuing pressurized injection in Michigan is unknown.

Objective 15. Determine the actual state of containment of the waste sites having a potential to contaminate the St. Clair River and its tributaries and monitor groundwater and surface water discharges. For those sites providing contaminant inputs to the St. Clair River, remedial and enforcement actions should be undertaken.

Objective 16. Further delineate the impacts, location and migration trends of past and present liquid waste injection into disposal wells, particularly the role of the buried valley in transporting wastes to the St. Clair River.

Chemical and oil spills into the river are a continuing problem which require increased diligence. The feasibility of constructing spill containment facilities at several of the major industries which frequently experience spills should be analyzed on a case by case basis. Improved spill prevention plans and worker training as well as better monitoring devices are other methods of reducing spills at industrial sites.

Objective 17. Eliminate chemical and oil spills to the St. Clair River. Management plans and prevention structures of industries regularly experiencing spill events should be studied and modified, if necessary.

## 2. Habitat Goals

At present, portions of the river support a naturally diverse assemblage of aquatic organisms generally indicative of an unimpaired habitat, while in other portions of the river contaminant discharges have extirpated or reduced the abundance of pollution intolerant benthic invertebrates that typically have key trophic roles and contribute substantially to the maintenance of fish populations. Contaminant controls are required to make the entire river habitable.

Observable negative impact on benthic communities is apparent for about 12 km downstream of Sarnia's industrial waterfront. Because most sediments in the river are transient, reduced contaminant discharges should lead to fairly rapid restoration of the habitat. To restore sediments along the 4-5 km industrial waterfront, from the Cole Drain to Suncor, may require dredging or suction removal. Some of the sediments in this area are aggregated with a black tarry substance and show little tendency to move down the river. There are several other smaller localized impact zones along the river (described earlier) which will require the same type of discharge control strategies for cleanup.

**Objective 18.** **Maintain the existing high quality wildlife habitats throughout the river and delta area.**

**Objective 19.** **Restore a healthy biotic community in the 12 km reach of the St. Clair River along the Sarnia industrial waterfront.**

## 3. Uses to be Maintained and Restored

At present, the river is inhabited by a variety of aquatic organisms. Because of contaminant discharges to the river, selected regions are inhabited by few, if any, species, or species that have a high pollution tolerance. Pollution control improvements will make the entire river a suitable habitat for diverse aquatic species.

The river is also used extensively for sports fishing. Fish from the river contain a variety of contaminants for which fish consumption guidelines have not been developed. The fish obtain their chemical body burden from direct uptake from water and through consumption of contaminated lower food chain organisms. Reduction of discharges to the river would result in a lowering of contaminant residues in fish and minimize any potential adverse impact to fish consumers. These improvements would undoubtedly lead to more recreational use of the river and downstream lakes for fishing and other tourism activities.

The river is used by several communities as a drinking water source. Not all contaminants found in the St. Clair River have drinking water guidelines. Although drinking water requirements are more extensive than water quality guidelines, development of such requirements is needed. The control of chemical discharges to the river would reduce any potential health effects to drinking water consumers.

**Objective 20.** **Ensure that the quality of fish, waterfowl, other wildlife and drinking water is suitable for human consumption by addressing the sources of contaminants.**

Bacteria concentrations increase along the course of the St. Clair River from head to mouth. Areas along the river which are used for swimming have been posted, at times, due to bacterial contamination.

**Objective 21.** **Reduce the bacterial contamination of the river to concentrations below public health guidelines for body contact.**

## G. ADEQUACY OF EXISTING PROGRAMS AND REMEDIAL OPTIONS

### 1. Projection of Ecosystem Quality Based on Present Control Programs

Trend Analysis

The pollution situation in the St. Clair River has improved steadily over the years. Benthic surveys conducted along the Canadian shoreline in 1968, 1977, and 1985 showed the seriously degraded zone had decreased from over 44 km in 1968, to 21 km in 1977, to 12 km in 1985 (49). Yearly sportfish analysis by the Ontario Ministry of the Environment in the St. Clair System has shown that PCB and mercury concentrations in fish have steadily declined since the 1970s (36). Restrictions in use to closed systems, then finally banning PCBs, are the reason for the PCB declines. Mercury discharges to the river have declined dramatically since Dow Chemical (the major source) changed its chlorine production process from mercury electrodes to the diaphragm process.

Phenol violation zones (water concentrations above 1 ug/L) along the Canadian shoreline near Sarnia's industrial waterfront and downstream have decreased significantly in size since 1979 because of improved wastewater treatment (78). Also, the discharge of hexachlorobenzene and octachlorostyrene have been moderated by the addition of a carbon treatment system at Dow's Scott Road Landfill and by dredging of the Cole Drain (78).

Because of the transitory nature of bottom sediments in the St. Clair River, the use of sediment cores to infer historical contaminant trends is difficult and perhaps impossible. But a detailed radiochemical analysis of one sediment core collected downstream of Dow showed that some of the material had been there for at least 10 years. The uppermost recent layer of this study core was more contaminated with HCB and OCS than the deeper older layers. This observation is probably due to the direct contamination of the sediment with nonaqueous waste material lost from the Dow site (36). Thus, it is possible that effluent discharges of these chemicals have decreased in recent years yet the sediments are more contaminated due to this direct contaminant contact. Dow has made several modifications to its site and have installed a nonaqueous waste recovery system in the river. The amount of material lost to the river has decreased significantly since the time of the UGLCC Study (100).

Superimposed on the large steady wastewater discharges to the river are intermittent discharges which likely cause considerable variability in water quality. Sampling in the river for the UGLCC Study was too infrequent to pick up this variability. But some studies showed that the concentrations of several contaminants in the river increased after rainfall events (41,42). Precipitation leads to contaminant loadings in urban runoff and combined sewer overflows. Also, contaminated stormwater from several industrial sites is discharged directly to the river. Stormwater at other industrial sites goes through wastewater treatment lagoons prior to discharge. This can cause overloading of low capacity systems. Several industries in the area have increased their lagoon capacities to eliminate this problem (100). Precipitation events also lead to increases in leachate discharge from the waste disposal sites in the area.

Pollution control during rainfall events appears to require special measures. Better housekeeping practices by industry would lead to a lowering of contaminant concentrations in stormwater. Also, improved stormwater storage and treatment systems, and better leachate treatment for landfills would reduce contaminant loadings from these sources. The urban pollution loadings could also be reduced by better collection and treatment methods.

Another variable source of contaminants to the river is spills. Forty-eight spills occurred in 1986 (65). Large spills can have a severe impact on biota near the source, and even well downstream because of the panelled nature of the flow in the river. The regular occurrence of spills to the St. Clair must be stopped if the river is to be restored.

The St. Clair River system should respond quickly to reduced chemical loadings. The water residence time from Lake Huron to Lake St. Clair is only 21 hours. Surficial bottom sediments remain in the river for less than one year. There are a few pockets of deeper sediments over bottom undulations, and some of the deeper sediments along Sarnia's industrial district seem to be congealed together with black, tarry material. Some of these sediments may require removal, but it is possible that they will gradually disappear through natural weathering processes.

## Mass Balance Model Scenarios

No mass balance models were constructed for the St. Clair River because of insufficient data. Before useful mass balance models can be constructed for the river, more detailed information on loading from various point and nonpoint sources, loadings during precipitation events, and loadings from ambient water measurements will be required. Ontario's Municipal and Industrial Strategy for Abatement (MISA) program should provide sufficient information on Ontario industrial and municipal contributions. However, data for the U.S. sources and tributary/ambient water measurements will still be required to provide sufficient data for a mass balance model.

Calculations show that the majority of contaminant discharge to the river for most chemicals originates from point sources in Canada. Net inputs to the river occur for HCB, OCS, PAHs, chloride, mercury, and lead. Other parameters not on the UGLCCS list; benzene, toluene, perchloroethylene, and pentachlorobenzene, also have sources along the river. Thus, even though a complete mass balance model was not produced during the UGLCC Study, the study still provided sufficient information to prioritize sources and begin the cleanup task.

## 2. Assessment of Technical Adequacy of Control Programs

### Adequacy of Present Control Technology

The largest users and dischargers of water on the St. Clair River are four coal-fired power plants (89,170 x $10^3$ $m^3/d$): Detroit Edison's St. Clair, Marysville, and Belle River Plants and Ontario Hydro's Lambton Generating Station. For the most part, water discharged is once-through cooling water. The effects of this warm-water discharge on the ecosystem was not assessed during the UGLCC Study. The maximum temperature of discharge water was within government guidelines most of the time. The cooling water at all facilities is normally chlorinated to prevent slime buildup on the condenser tubes. The impact of the chlorine residuals on St. Clair River biota should be limited to near-field effects, because chlorine will quickly react and disappear in the river. The impact of chlorine residuals from the power plants was not accessed for the UGLCC Study.

Other contaminant sources from the power plants are storm runoff from the coal piles and stormwater losses of fly and bottom ash. All plants have settling basins to minimize the losses of these potentially toxic solids. The suspended solids concentration in the effluents was within government guidelines. Analysis of the contaminant concentration on these suspended solids has not been performed, and seems to be needed before a proper assessment on their effects on the environment can be made. Fly ash may contain chlorinated dioxins and dibenzofurans, and coal fines will contain PAHs.

PCBs were used in capacitors and transformers in the electrical generating industry. Elevated PCB concentrations were found in the sediments downstream of Lambton Generating Station. PCB loadings from this facility need further evaluation.

The loadings of contaminants from the power plant effluents was difficult to evaluate because of the large cooling water dilution that occurs. More detailed studies appear to be needed to assess whether or not the current minimal wastewater treatment from these facilities is adequate.

The next largest effluent discharges to the river (1,150 x $10^3$ $m^3/d$) are chemical companies. A list of the major chemical companies, their locations, and their wastewater treatment methods are listed in Table VII-21. Methods of treatment vary from primary, physical/chemical treatment to secondary biological treatment, depending on the nature of the product and wastewater generated.

In general, these companies are required to meet annual average discharge limits for ammonia, phenols, suspended solids, and oil and grease. All facilities complied with government discharge limits. But, many toxic and persistent contaminants are not controlled by government effluent permits. An excellent example of this is Dow Chemical which is the largest discharger of hexachlorobenzene to the St. Clair River. One of the effluent streams at Dow is biologically treated, but the largest HCB loadings are from effluents that go into the river after receiving only primary treatment. Biological treatment is not an appropriate method for HCB. Decreases in HCB effluent concentrations which occur during biological treatment are due to adsorption of HCB by the sludge. However, this simply transforms the phase of the material, and therefore does not really eliminate the problem from an ecosystem perspective.

Generally, biological treatment does not adequately treat persistent chemicals. Even though these companies are putting more emphasis and money into environmental control programs (100), much more effort is needed to minimize the formation of persistent toxic organics and/or to destroy them on-site. These persistent chemicals should not be discharged into the environment.

The next largest dischargers (543 x $10^3$ $m^3/d$) to the St. Clair River are four petroleum refineries; Imperial Oil (Sarnia), Suncor (Sarnia), Polysar (Corunna), and Shell (Corunna). As with the chemical companies, these industries are regulated for ammonia, phenols, suspended solids, sulphide, pH and oil and grease. All companies are in compliance. The treatment for all companies involves oil separators, dual media filters, and biological treatment. Studies have shown that this treatment sequence efficiently removes not only the regulated parameters, but also the aromatic hydrocarbons and PAHs from the wastewater (66). Whether or not these chemically are biodegraded or simply transferred to the air or sludge is an important question that should be addressed.

Municipal wastewater treatment plants are the next largest dischargers (151 x $10^3$ $m^3/d$) to the river. All plants except Sarnia and Point Edward have secondary biological treatment plus phosphorus removal. Sarnia and Point Edward WWTPs have only primary treatment plus phosphorus removal. Upgrading of these two plants would reduce the discharge of some contaminants to the river. The municipal wastewater treatment plants were significant

TABLE VII-21

Major industrial facilities on the St. Clair River.

| Company | Location | Products | Treatment |
|---|---|---|---|
| a) <u>Canada</u> | | | |
| Canadian Industries Ltd. | Courtright | - fertilizer | - physical/chemical |
| Dow Chemical Canada Ltd. | Sarnia | - polyethylene<br>- chlorinated hydrocarbons<br>- vinyl chloride<br>- polystyrene<br>- propylene oxide | - physical/chemical<br>- secondary biological treatment on selected streams |
| Dupont Canada, Inc. | Corunna | - polyethylene | - plastic bead skimming |
| Esso Chemicals Canada Ltd. | Sarnia | - polyethylene<br>- polyvinyl chloride<br>- benzene, toluene, xylene | - oil separators/dual media filters/carbon contactors |
| Ethyl Canada, Inc. | Corunna | - tetraethyl lead<br>- ethyl chloride | - physical-chemical treatment on selected process streams |
| Novacor Ltd. | Corunna | - polyethylene resins | - process water recycle |
| Polysar Ltd. | Sarnia | - synthetic rubber | - secondary biological<br>- physical/chemical for selected streams |
| b) <u>United States</u> | | | |
| Diamond Crystal Salt Co. | St. Clair | - salt | - sedimentation |

sources for some of the persistent contaminants; for example, PCBs and trace metals. Since these materials are not readily degradable, efforts must be made to stop their discharge into the sanitary sewers at source.

Another significant source of industrial wastewater to the river is the Cole Drain (147 x $10^3$ $m^3/d$). In dry weather, the flow in this open municipal ditch is largely industrial (65). Major discharges to the drain were: leachates from disposal sites along Scott Road owned by Polysar, Dow, Fiberglas, Imperial Oil, and the City of Sarnia (sewage sludge); Canadian National Railway yard runoff; Dome Petroleum; Esso Chemical (stormwater); Cabot Carbon, Fiberglas, and Polysar (stormwater). Dow Chemical has carbon treatment on the Scott Road landfill leachate, but this seems to be inadequate to prevent the discharge of HCB, OCS, and other persistent chlorinated organics to the drain. The Cole Drain is also a significant source of PAHs, cyanide, and oil and grease. Individual discharges to the ditch will need to be quantified before the source of these chemicals can be traced. It is apparent that much better treatment and control of effluents discharged to the ditch will be required.

Urban runoff has also been shown to be a significant source for some contaminants (82). At present, this water is completely untreated. Agricultural nonpoint sources are the most significant contributor of phosphorus to the St. Clair River (84,85). Improved tillage practices and reduced use of unnecessary commercial fertilizers would be the only way to reduce these inputs. Such a program would require extensive education of farmers in modern agricultural techniques.

Several waste disposal sites could potentially seriously impact the St. Clair River. These sites have been ranked by the Nonpoint Source Workgroup (88). Clay or synthetic liners, leachate collection systems, and monitoring well networks have not been required for most of the sites. For most sites, there is minimal or no treatment of waste or leachate.

## 3. Assessment of Regulatory Adequacy

Major industrial dischargers in the Sarnia area are subject to discharge limits specified in Certificates of Approval, Control Orders or the Ontario Industrial Effluent Guidelines. The industries are required to self-monitor on a regular basis and supply the OMOE with the data. It is a violation of the Environmental Protection Act to "knowingly give false information". The Ministry collects audit samples to check the validity of the self-monitoring data. Sampling visits are frequently arranged in advance. This could be a weakness in the system because surprise visits would be more effective.

The companies discharging to the St. Clair River are largely in compliance with the regulations. Since problems in the river still persist, this would seem to indicate that the laws and regulations are insufficient to provide environmental protection. If tougher regulations came into force, more environmental policing will likely be required. More frequent auditing of the self-monitoring data will also be necessary.

## H. RECOMMENDATIONS

The UGLCC Study for the St. Clair River has revealed several problems which need to be addressed. Point source discharges, particularly in Sarnia's Chemical Valley, need to be reduced. These sources represent the largest contributors of many contaminants to the system, so remedial measures here will provide cost effective improvements in river quality. In addition, tributary contributions and urban runoff appear to be supplying significant loadings of certain contaminants. Sources of these contaminants need to be identified and addressed.

Comparison of river media concentrations to guidelines is a quick way of identifying areas of probable environmental impact or impairment. However, the ecosystem approach may give a better indication of contaminant impacts on the system as a whole. A multi-media perspective must be developed so that the overall impact on the system is assessed.

The following recommendations are designed to address the objectives identified in Section F. As these recommendations are implemented, monitoring programs should be undertaken to ensure the objectives are being met.

### A. Industrial and Municipal Point Source Remedial Recommendations

1. Ontario and Michigan should incorporate the Great Lakes Water Quality Agreement's goal of the virtual elimination of all persistent toxic substances into their respective regulatory programs.

2. Polysar Sarnia should take action to significantly reduce benzene and phenols in the American Petroleum Institute (API) stereo separator effluent. The operation of the Biox treatment system should be optimized to attain the Ontario Industrial Effluent Objectives for total phenols and ammonia-nitrogen. Effluent requirements (in both concentration and mass loading form) should be instated for PAHs and HCB at the most stringent levels attainable through the use of the best available technology.

3. Dow Chemical should significantly reduce its discharge of organic chemicals to the river. The facility was a major contributor of 5 of the 7 organic groups studied. It is noted that current self-monitoring data is being made publicly available to demonstrate the effect of recent remedial efforts at this facility. Many improvements in operation have been implemented at Dow Chemical since the time of the UGLCCS survey. Self-monitoring data and other sampling results should be reviewed to determine if additional remedial actions are needed.

4. The sources of ongoing mercury discharges from Dow Chemical and Ethyl Canada should be identified and eliminated.

5. Ethyl Canada should improve the operation of its treatment plant to reduce concentrations of tetra ethyl lead to meet the GLWQA specific objective and the PWQO of 25 ug/L. In addition, enforceable mass loading limitations for lead should be instated at this facility. Volatiles, especially chloroethane, should also be significantly reduced in the effluent.

6. Polysar Corunna should reduce the concentration of chromium and zinc in the final effluent. This facility should consider substituting less persistent additives in the recycle cooling water system.

7. Effluent concentrations for chloride were generally below drinking water objectives, but the total point source loading to the system was very large (356 tonnes/day). Most was from facilities in the Sarnia area. The extreme loadings may be affecting aquatic organisms downstream of these facilities. Chloride concentration and loading limitations should be considered for those facilities discharging significant amounts of chlorides.

8. All potential sources of releases of heat exchanger fluids should be identified and controlled.

9. The Sarnia WWTP should be expanded and upgraded to secondary biological treatment with phosphorus removal. In conjunction with the upgrading, the Point Edward WWTP (a primary plant) should be considered for use as a pretreatment facility which would discharge to the Sarnia Plant. The loading of ammonia-nitrogen, total phenols, heavy metals, and organics to the St. Clair River would be significantly reduced by this action.

10. American Tape in Marysville should be evaluated to ensure compliance with their NPDES permit, Michigan Water Quality Standards and BAT requirements for toluene and xylene in its discharge.

11. The City of Marysville should be evaluated to ensure compliance with their NPDES permit and Michigan Water Quality Standards for toluene in its discharge.

12. The National Pollution Discharge Elimination System permit for the Marine City WWTP should be evaluated to ensure compliance with Michigan Water Quality Standards for cyanide. The pretreatment program should be reviewed to ensure that cyanide is adequately regulated. Acute and chronic bio-

assays for cyanide may be required at this facility.

13. A survey should be conducted at the St. Clair County-Algonac WWTP to evaluate the efficiency of the treatment system. An ammonia-nitrogen effluent limitation should be considered for the facility. Nitrogen loading to the river and Lake St. Clair may be reduced by these actions.

14. The City of St. Clair WWTP should be resurveyed to ensure that the expanded plant is operating effectively.

15. A study of industrial contributors to the Port Huron WWTP should be undertaken to identify the source or sources of CN- and PCBs to this facility. Pretreatment requirements for all industrial contributors should be examined, and modified if needed. Effluent requirements for CN- and PCBs should be considered for inclusion in the facility's NPDES permit.

16. Biomonitoring studies should be conducted at the major dischargers to determine whole effluent toxicity at these facilities. This study evaluated the point sources only on a parameter-by-parameter basis, with no attempt made to determine the impact of any additive or synergistic effects the parameters may exhibit.

B. Nonpoint Source Remedial Recommendations

17. Sources of PAHs and total cyanide to the Cole Drain, Sarnia, should be identified. If the sources are exceeding applicable effluent guidelines, they should be remediated.

18. The loadings via surface water runoff and groundwater discharge from landfills in the Scott Road area to the Cole Drain need to be determined and treated as necessary.

19. Licensing requirements for sludge disposal facilities should ensure that surface water and groundwater are properly monitored and treated.

20. A and B Waste Disposal, Hoover Chemical Reeves Company, and Wills St. Dump Site were all scored under the Superfund Hazard Ranking System (HRS) apparently without consideration of groundwater quality information. The State of Michigan should determine, based upon USGS chemistry information, the State priority for action at each site. Development of more complete groundwater information on-site would allow the State the options of pursuing Federal action under Superfund by rescoring the site under the new HRS (when it is approved), or pursuing remediation under Act 307 (MERA). Furthermore, the facilities needs for RCRA permitting need to be assessed, or reassessed.

21. The proximity of Eltra Corp. Prestolite to the St. Clair River, and the nature of wastes on site call for careful evaluation of impacts on groundwater and on the St. Clair River prior to facility closure under RCRA authorities. In the event that a satisfactory evaluation of groundwater contamination and runoff impacts upon the St. Clair River are not secured, a Site Investigation (SI) under Superfund authorities should be undertaken. The SI should include assessment of both groundwater and surface runoff impacts upon the St. Clair River.

22. The State of Michigan needs to restrict access of dumpers to Winchester Landfill. The State's development of groundwater information for this site would assist in scoring by the HRS.

23. Michigan and Ontario municipal combined sewer overflows should be intensively surveyed to determine their contribution of pollutant loadings to the river. In the long term (due to the enormous cost), combined sewers in all municipalities should be eliminated. In the interim, the municipalities should institute in-system controls to minimize the frequency and volume of overflows.

24. The Michigan Pollution Emergency Alerting System and spill reports from the Ontario Spills Action Centre should be improved so that all information on recovery, volume (if known), and final resolution are fed back to the central reporting system to complete each report for inventory purposes.

25. Spill management programs at all facilities should be reviewed and enhanced to reduce the frequency and magnitude of spills to the St. Clair River with the goal of eventually eliminating all spills.

26. Aggressive educational programs on the use of conservation tillage techniques and pesticide, fertilizer, and manure application techniques should be provided to farmers to reduce rural runoff contaminant contributions. Stricter legislation to control such application should be developed and enforced.

C. Surveys, Research and Development

27. Water quality guidance needs to be developed binationally for OCS, individual or total PAHs, hexachloroethane and chlorides. In addition, Canada needs to develop guidance for hexachlorobutadiene, and the U.S. needs water quality guidance for hexachlorobenzene, phosphorus and pentachlorobenzene. The Great Lakes Water Quality Agreement needs to develop specific objectives for all of these parameters.

Fish consumption and sediment guidance are needed for HCB, OCS, PAHs, alkyl lead, and other chemicals found to be of concern in this study.

28. More data are needed to assess the impact of PAHs on the St. Clair River. Ambient water concentrations, and point and nonpoint source loadings should be measured. Monitoring should be detailed enough to allow for the finger printing of sources.

29. The importance of contaminant loadings during rainfall events needs to be evaluated.

30. The loadings of all chemicals with high bioconcentration and bioaccumulation potential should be reduced to minimize contaminant body burdens in resident and spawning fish.

31. Assess the significance of mercury contamination to biota from sediments relative to ongoing discharges and develop remedial actions as necessary.

32. Industrial and municipal facilities discharging to St. Clair River tributaries should be surveyed to determine their contribution of contaminants to the St. Clair River. In particular, contaminant loadings from Talfourd Creek in Ontario and the Black River in Michigan should be determined.

33. The potential PCB source in the vicinity of the Lambton Generating Station should be investigated and quantified.

34. The loadings and sources of PCBs, PAHs, oil and grease, lead, ammonia, and phosphorus from the unnamed creek in Michigan across from the Lambton Generating Station should be determined and controlled to ensure compliance with Michigan Water Quality Standards.

35. The lead source to the Black River in Michigan should be located and controlled.

36. Sources of bacterial contamination to the river should be traced and eliminated.

37. A waterfowl consumption advisory should be considered by Ontario and Michigan for the St. Clair River.

38. A study on the magnitude of contaminant input to the St. Clair River from Michigan urban runoff should be undertaken, and an additional, more refined study on Canadian urban runoff should also be performed. Management control options for urban runoff should be developed.

39. Contamination from waste disposal sites, identified as high priority by the Nonpoint Source Workgroup (88), need to be further investigated with regard to contaminant pathways, including surface water runoff and groundwater seepage, and environmental impacts.

40. Continued monitoring of water levels and water quality in the freshwater aquifer in the Sarnia area is required.

41. The potential for transboundary migration and contamination of the St. Clair River and/or the fresh water aquifer in the Sarnia area from industrial waste in the 74 m and 123 m depth limestone layers of the Hamilton Group should be investigated. Of particular concern, is the 74 m depth horizon which likely flows into the fresh water aquifer in the deeper sections of the bedrock valley.

42. To understand the fate of the industrial waste disposed to the Detroit River Group, additional deep boreholes to the disposal formation are required to quantify the current directions and rates of groundwater movement.

43. Michigan should co-operate with Ontario in the deep well studies. A number of deep wells are needed in St. Clair County to supplement the information from the Ontario studies. If evidence of impacts upon Michigan groundwater is developed, a variety of authorities, including Superfund, may be applicable for remediation of identified problems.

44. The potential biological consequences of increased chloride concentrations in the St. Clair River and downstream should be examined.

45. Better methods for analysis of PCBs in the St. Clair River need to be undertaken.

46. Studies on the bioavailability of particle-bound contaminants, and contaminant desorption from suspended and bottom sediments are required to make a better assessment of the impact of in-place pollutants.

47. Studies on the effects of multicontaminant exposure to aquatic life.

48. Studies to better understand the fate and transport of sediment-borne contaminants are needed. These studies should include profiling the age and contamination of sediments in St. Clair River and delta depositional areas.

# I. LONG TERM MONITORING

## 1. Purposes for Monitoring and Relationships Between UGLCCS and Other Monitoring Programs.

A presentation of the purposes for monitoring and surveillance activities is included under Annex 11 of the 1978 GLWQA, and a discussion of considerations for the design of a long term monitoring program can be found in Chapter 7 of the Report of the Niagara River Toxics Committee (1984). Because the focus of the UGLCC Study was toward remedial actions to alleviate impaired uses of the Connecting Channels System, long term monitoring recommendations will likewise focus on the evaluation of trends in environmental quality in order to assess the effectiveness of remedial actions. In general, post-UGLCCS monitoring should be sufficient to 1) detect system-wide trends in conditions noted by the UGLCCS, and 2) detect changes in ambient conditions which have resulted from specific remedial actions. Monitoring programs should be designed to specifically detect the changes intended by the remedial actions so as to ensure relevance in both temporal and spatial scales.

Two major programs sponsored by the IJC also contain plans for long term monitoring: the Great Lakes International Surveillance Plan (GLISP) and the Areas of Concern Remedial Action Plans (AoC-RAPs). The GLISP for the Upper Great Lakes Connecting Channels is presently incomplete, pending results of the UGLCC Study, but it is expected to provide monitoring and surveillance guidance to U.S. and Canadian agencies responsible for implementing the provisions of the WQA that include general surveillance and research needs as well as monitoring for results of remedial actions.

The St. Clair River is one of the AoCs, and a RAP is being developed jointly by Michigan and Ontario. The RAP will present details of uses impaired, sources of contaminants, specific remedial actions, schedules for implementation, resources committed by Michigan and Ontario to the project, target clean-up levels, and monitoring requirements. Results and recommendations coming from the UGLCC Study will be incorporated extensively into the RAP, which will then be the document that influences State and Provincial programs in the St. Clair River. The recommendations for long term monitoring that are presented below are intended for consideration and incorporation into either or both the GLISP and RAP for the St. Clair River.

## 2. System Monitoring for Contaminants

### Water

Knowledge of the concentrations of the principal contaminants in the water of the St. Clair River should be used to indicate general exposure levels for the biota, to identify changes and trends over time in the concentration levels, and to be used for general assessment of contaminant impacts. The parameters to be monitored include HCB, OCS, total phenols, cyanide, mercury, lead, total volatiles and chlorides. Monitoring stations should be located where elevated concentrations of the contaminants are known or predicted from dispersion models. Suggested locations include the head of the St. Clair River and at Port Lambton, particularly on the Canadian side. Sampling frequency should be influenced by the variability in contaminant sources. Spring high flow conditions and late summer low flow conditions would be expected to bracket the normal seasonal variability in flow that could influence measured contaminant concentrations.

A mass balance approach to contaminant monitoring will help to identify any changes in the contaminant mass over time, and it will provide the basis for targeting future remedial actions by providing a comparison of the magnitude of the sources. A mass balance analysis should be conducted approximately once every five years, assuming that some effective remedial action has been implemented against one or more sources such that the total loadings of contaminants, or the relative contribution of the sources to the loading, has changed. The sources to be measured should include:

1) Head and mouth transects. The number and location of stations should relate to measured and predicted plume distributions. Suggested locations include the head of the St. Clair River and at Port Lambton. The Port Lambton transect will be consistent with past dispersion measurements and modeling work, and will help delineate contaminant loading into Lake St. Clair. Both dissolved and particulate fractions should be analyzed. The quantity of suspended sediment flux should also be measured.

2) Municipal and industrial point sources. During the survey, the sampling must be frequent enough to accurately reflect the likely loading fluctuations from the major point sources. The sources include the major outfalls of Sarnia WWTP, Cole Drain, Polysar Sarnia, Polysar Corunna, Dow Chemical, Suncor, Ethyl Canada, CIL Inc., Port Edward WWTP, and Marine City WWTP.

3) Tributaries. Efforts should be focused on seasonal and storm event loadings of contaminants to the St. Clair River from Talfourd Creek and the Belle, Pine and Black Rivers. A channel near Fawn Island also diverts some of the Sydenham River drainage to the St. Clair River during severe spring runoff events. Tributary mouth stations should be sampled and analyzed for both dissolved and sediment-associated contaminant loadings.

4) CSOs and Urban Runoff. To provide an estimate of contaminant mass loadings expected during storm events, occasional studies on selected urban drainage areas should be conducted. Some estimates have been made for Sarnia, Ontario. Similar estimates should be made for other urban areas along the river.

5) Groundwater inflow. The quantity and quality of potential contaminant releases from waste disposal sites adjacent to the St. Clair River or its tributaries should be determined. Permits should require groundwater monitoring, an assessment of surface water runoff and determination of overall loadings to surface water. Characterize the distribution, composition and movement of deep well injected waste. Evaluate the impacts of Michigan and Ontario injection pressure regimes on the movement of the waste.

6) Sediment transport. Preliminary studies indicate that less than 1% of the contaminants in the St. Clair River are transported by bed-load sediments movement. However, the quantity of contaminants being desorbed from the sediments should be determined in order to assess loadings from these in-place polluted sediments.

7) Atmospheric deposition. Direct atmospheric deposition of contaminants to the St. Clair River is expected to be minor. Deposition to the drainage basin and subsequent runoff into the river or its tributaries, however, could be an important source for some contaminants. Estimates of contaminant mass in both wet and dry deposition to the drainage basin should be made when unidentified non-point sources are found to be a major contributor of any of the contaminants of interest.

## Sediments

Monitoring of sediments for concentrations of contaminants should be conducted periodically throughout the St. Clair River in order to assess both the trends in surficial contaminant concentrations and the movement of sediment-associated contaminants within the River. The grid used by the U.S. Fish and Wildlife Service during the 1985 survey would be appropriate for consistency in sampling sites and sediment composition. An analysis of sediment chemistry including bulk chemistry, organic and inorganic contaminants, and particle size distribution should be conducted every 5 years, in conjunction with a biota survey (see "habitat monitoring" below). In the St. Clair River, particular attention should be given to sediment concentrations of chlorinated organics (PCBs, HCB, OCS, HCBD), benzene, phenols, oil and grease, and heavy metals, including mercury.

Because the grid stations are distributed throughout the river reach and are associated with appropriate habitat for a sensitive benthic invertebrate (Hexagenia), the periodic survey will allow assessment of 1) contaminant concentrations in the river sediments throughout the river reach, 2) relative movement of the contaminants within the river sediments between surveys, and 3) correlation of contaminant concentrations with benthic biotic communities.

The sediments at any stations established at the mouths of tributaries to the St. Clair River should be monitored for organic and inorganic contaminants on an annual or biannual basis when significant remedial actions are implemented within the watershed of the tributary. In order to trigger the more frequent sediment monitoring program, the remedial actions should be expected to measurably reduce loadings of one or more particular contaminants via the tributary.

## Biota

Long term monitoring of concentrations of contaminants in biota will provide a time series useful to track the bioavailability of contaminants to selected representative organisms. Three long term monitoring programs are already in place in the Great Lakes basin and should be expanded into the St. Clair River.

i) Annual or Bi-Annual Monitoring of Sport Fish.

This program should focus especially on PCBs, mercury and/or other contaminants (e.g. dioxins and dibenzofurans) that are considered to be known or suspected health hazards. Because many of the fish species in the river are transitory, efforts should be made to identify and sample those species that have an extended residence time in the river as well as those that are most sought by anglers. The monitoring should be continued regardless of the differences that may be observed between acceptable concentrations or action levels that may be established by government agencies and the measured contaminant concentrations in the fish flesh. As a link between human health concerns and integrated results of remedial programs to reduce contaminants in the UGLCC System, this program is critically important.

ii) Spottail Shiner Monitoring Program.

This program is designed to identify source areas for bioavailable contaminants. In locations where spottail shiners or other young-of-the-year fish contain elevated levels of contaminants, additional studies should be conducted to identify the sources of the contaminants. Some upstream studies in tributaries may be required. Spottails should also be employed to confirm that remedial actions upstream to a previous survey have been effective in removing or reducing the loading of one or more contaminants.

iii) Caged Clams Contaminants Monitoring.

Caged clams should continue to be used at regular time intervals, perhaps in conjunction with spottail shiners, to monitor integrated results of remedial actions to reduce contaminant loadings to the water. Clams may be located at tributary mouths and downstream of suspected source areas. Repeated assays from the same locations should confirm results of remedial actions.

3. Sources Monitoring for Results of Specific Remedial Actions

Remedial actions intended to reduce concentrations and/or loadings of contaminants from specific point sources generally require monitoring for compliance with the imposed criteria or standards. The monitoring may be conducted by the facility or by the regulating agency, whichever is applicable, but attention must be given to the sampling schedule and analytical methodology such that mass loadings of the contaminants can be estimated, as well as concentrations in the sampled medium. Monitoring of the "nearfield" environment, i.e., close downstream in the effluent mixing zone, should be conducted regularly to document reductions in contaminant levels in the appropriate media and to document the recovery of impaired ecosystem processes and biotic communities. Such monitoring may be required for a "long time", but over a restricted areal extent, depending on the severity of the impact and the degree of reduction of contaminant loading that is achieved.

For the St. Clair River, eleven actions were recommended that would affect specific sources of contaminants, and that would require site specific monitoring for compliance or other effects of the action at the following locations: Marine City WWTP (cyanide concentration), St. Clair County-Algonac WWTP (ammonia-nitrogen limits), American Tape in Marysville (xylene and toluene), City of Marysville WWTP (toluene), Sarnia WWTP (phosphorus, ammonia-nitrogen, total phenols, heavy metals and organics), Cole Drain, Sarnia (PAHs, cyanide, oil and grease), Polysar Sarnia (benzene, phenols), Dow Chemical (several organic chemicals), Ethyl Canada (lead, volatile organics, mercury, and chloroethane), and Polysar Corunna (chromium and zinc).

Other recommendations for specific contaminant sources involve an assessment of the present conditions or a study to quantify concentrations or loadings: survey the St. Clair County-Algonac WWTP and the City of St. Clair WWTP to document the efficiency of the treatment system, intensively survey CSOs in Michigan and Ontario for determining the contribution of pollutant loadings to the River, establish biomonitoring studies at a major point source contributors, assess impact of PAHs on St. Clair River and estimate their loadings, measure contaminant loadings during rainfall events, obtain better estimates of the mercury losses from the Dow site, quantify loadings of contaminants from urban nonpoint sources, evaluate contamination from waste disposal sites, etc. Each of these items requires a specific program of data collection and analysis. Additional needs for longer term monitoring may be identified as a result of these studies.

4. Habitat Monitoring

Habitat monitoring should be conducted to detect and describe changes in the ecological characteristics of the St. Clair River through periodic analysis of key ecosystem elements. The following items are recommended:

a) The abundance and distribution of the mayfly *Hexagenia* should be determined every five years. The grid used by the U.S. Fish and Wildlife Service during the 1985 survey would be appropriate for consistency in sampling sites each survey. An analysis of sediment chemistry, including bulk chemistry, organic and inorganic contaminants, and particle-size distribution, should be conducted for samples taken concurrently with the *Hexagenia* survey. These data will provide information on the quality of the benthic habitat for a common pollution-sensitive organism that would serve as an indicator species of environmental quality.

b) Quantification of the extent of wetlands along the St. Clair River should be conducted every five years, in conjunction with the *Hexagenia* survey. Aerial photography or other remote sensing means would be appropriate to discern both emergent and submergent macrophyte beds that are important as nursery areas for larval fish and other wildlife. Verification of areal data should be conducted by inspection of selected transects for plant species identification and abundances. Changes in wetland areas should be correlated with fluctuating water levels and other natural documentable influences so that long term alterations in wetlands can be tracked and causes identified.

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