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Spill Reference Tables for the St. Clair River

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Spill Reference Tables for the St. Clair River

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1. INTRODUCTION

Serving as the international border between the United States and Canada, the St. Clair River provides a source for public drinking water as well as a hub for petrochemical refineries and commercial shipping (Fig. 1). This dichotomy creates the potential threat to public health via drinking water contamination in the event of a toxic spill from commercial freighters or refineries within the waterway. Due to the high flow rates experienced in the river (average discharge of 5,200 m^3/s; Holtschlag and Koschik 2002), once released, contaminants can travel to downstream public water intakes within minutes (Anderson and Schwab, 2012; Tsanis et al., 1996; Derecki 1983; Sun et al., 2013). As a result, water intake managers may need to react immediately in order to mitigate contaminant uptake. However, the common approach for spill response is to use real-time operational hydrodynamic models to predict currents in the system and then simulate spill transport forecasts via Lagrangian particle transport simulations, a process that may not provide decision makers with the necessary spill information in time.

In this work, several contaminant spill scenarios are simulated using the Huron-Erie Connecting Waterways Forecasting System (HECWFS), a real-time hydrodynamic model of the St. Clair River. Results from these scenarios are compiled into reference tables that contain information on spill travel times, peak concentrations, lateral mixing, and duration. These static reference tables can be used for spill response planning or used immediately in the event of a spill to estimate when a particular point of interest might be impacted and for what period of time.

The goal of this work is to provide water intake managers and other decision makers within an intermediate step between spill awareness and a more comprehensive spill forecast model approach. A brief description of the model is included below, as well as the list of spill scenarios, instructions for using the reference tables, model limitations, and an appendix of the compiled spill reference tables.

2. HYDRODYNAMIC MODEL

Hydrodynamic and spill scenario simulations are carried out using the Huron-Erie Connecting Waterways Forecasting System (HECWFS), a real-time three-dimensional hydrodynamic model that predicts currents, water levels, and temperatures in the St. Clair River, Lake St. Clair, and Detroit River (Anderson et al., 2010; Anderson and Schwab, 2011; Anderson and Schwab, 2012). The model is based on the Finite Volume Coastal Ocean Model (FVCOM, Chen et al., 2006), and uses the three-dimensional integral form of the continuity (Eq. 1), momentum (Eq. 2), and energy equations to simulate hydrodynamics on an unstructured grid with a sigma-coordinate (terrain following) vertical system. For horizontal and vertical diffusion, the model uses the Smagorinsky parameterization and Mellor-Yamada level 2.5 closure scheme, respectively.

Eq. 1

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

Eq. 2

$$\frac{Du}{Dt} - fv = \frac{1}{\rho}\frac{\partial P}{\partial x} + \frac{\partial}{\partial z}\left(K_m \frac{\partial u}{\partial z}\right) + F_u$$
$$\frac{Dv}{Dt} - fu = \frac{1}{\rho}\frac{\partial P}{\partial y} + \frac{\partial}{\partial z}\left(K_m \frac{\partial v}{\partial z}\right) + F_v$$
$$\frac{\partial P}{\partial z} = -\rho g$$

Eq. 3

$$\frac{d\grave{x}}{dt} = \acute{v}(\acute{x}(t), \tau) d\tau$$
$$\acute{x}(t) = \acute{x}(t_n) + \int_{t_n}^{t} \acute{v}(\acute{x}(t), \tau) d\tau$$

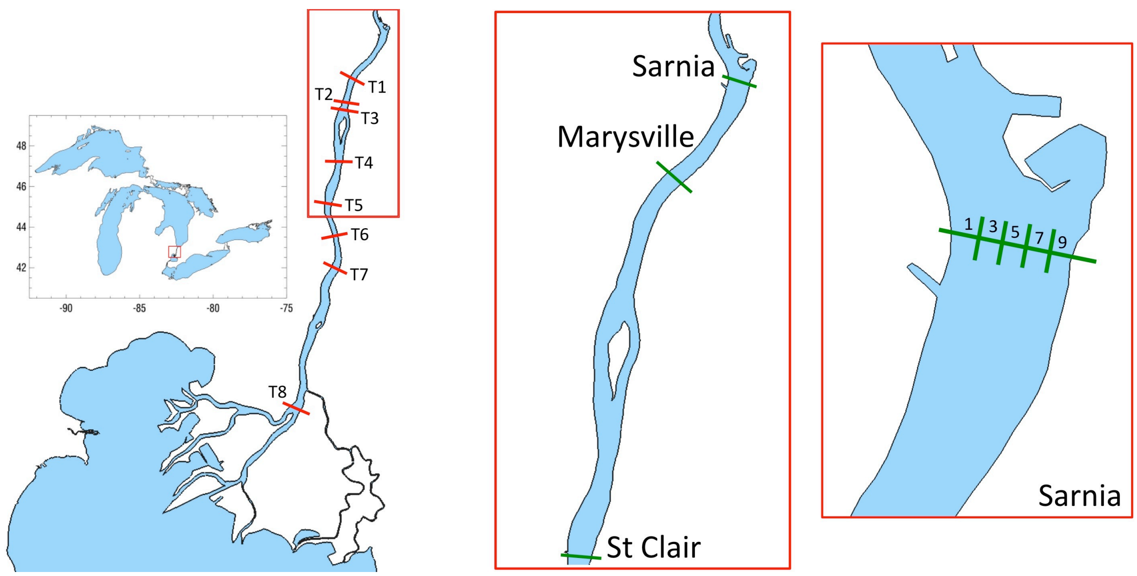

Figure 1: (left) Transect locations for report spill parameters, (middle) three spill release locations, (right) detailed spill release locations shown for Sarnia case, “1” represents 10% across river, “3” = 30%, “5” = 50%, “7” = 70%, “9” = 90%, measured from the US shore (west).

The model is driven with 6-minute water level boundary conditions at the head of the St. Clair River (Lake Huron) and the mouth of the Detroit River (Lake Erie), serving as the primary inlet and outlet to the model. Water level conditions are taken from National Ocean Service (NOAA NOS) gauges at Dunn Paper, MI for the inlet and a combination of the Gibraltar and Fermi Power Plant gauges for the outlet. Surface forcing conditions, such as wind forcing and heat flux, are interpolated from nearby meteorological stations for hourly inputs. However, for the spill scenarios carried out in this work, wind conditions and water temperature were not considered. Further description of the model, including spill calibration and validation are available in *Anderson et al. 2010*, *Anderson and Schwab 2011*, and *Anderson and Schwab 2012*.

In addition to the hydrodynamic simulations, a Lagrangian particle transport model was used to simulate spill movement for each scenario (Eq. 3). The particle model is an included module in FVCOM, and has been applied to the St. Clair River for spill calibration studies (Anderson and Phanikumar, 2011; Anderson and Schwab 2012). In each case, the particles (n=100,000) were placed at the desired scenario location within a 5-m radius. Particles were then transported downstream using model-simulated currents, where specific spill information such as arrival time, duration, concentration, and mixing were computed at several downstream transects (up to 8). For each transect, particle density was converted to a normalized concentration, and break-through curves of concentration versus time were created to compute the leading edge, trailing edge, and peak concentration times for each spill (Fig. 2). Additional description of the process is described in *Anderson and Phanikumar 2011* and *Anderson and Schwab 2012*.

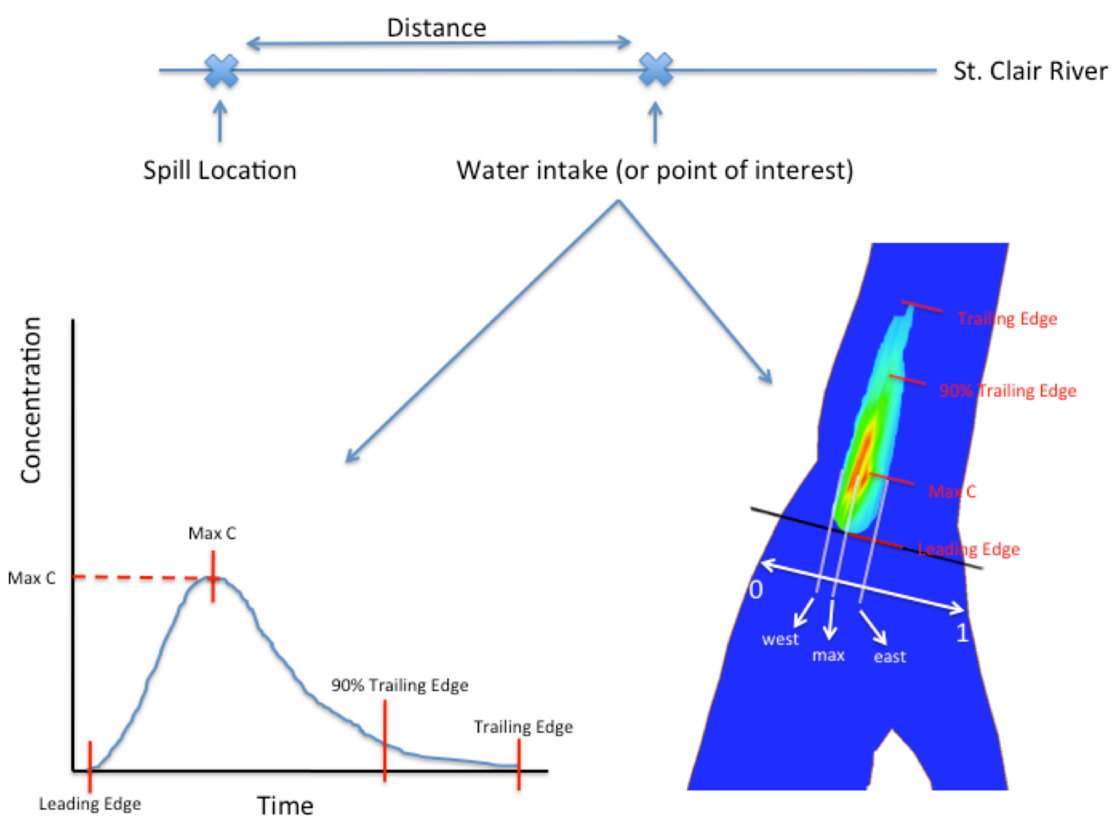

Figure 2: Plume characteristics used in the creation of the spill reference tables. Given a spill location and type, users can determine the leading edge time, trailing edge time, peak concentration, peak timing, and lateral spread of the plume (figure and text used with permission from *Anderson and Schwab, 2012*).

3. SPILL SCENARIOS

To categorize contaminant transport in the St. Clair River, 30 spill scenarios are simulated for the St. Clair River (Fig. 1; Appendix). These cases cover three primary release transects near Sarnia, Ontario, Marysville, MI, and St. Clair, MI (Table 1). At each transect, five lateral release locations we chosen as a function of river width (10, 30, 50, 70, and 90%, as measured from the US shoreline). For these locations, surface and bottom spills were considered, individually, and released instantaneously over a 5-meter radius patch. Spill simulations were carried out under constant water level conditions at the inlet (St. Clair River) and outlet (Detroit River), yielding a constant river discharge of 5,053 m^3/s for all simulations. Wind effects were not considered for these simulations, as hydraulic forcing is the primary transport mechanism for contaminants.

Spill characteristics were computed for up to eight downstream measurement transects (Table 2) in order to determine: (1) the arrival time of the leading edge of the spill plume, (2) the peak concentration within the plume (relative to initial release concentration), (3) the timing of the peak concentration given in minutes after the leading edge, time of trailing edge of the spill plume given in minutes after the leading edge (spill duration, essentially), (4) time taken for 90% of the plume to reach the transect (as plume tails can extend at very low concentrations), and lateral mixing parameters for the (5) western boundary, (6) eastern boundary, and (7) peak concentration location of the plume, given as measures of normalized lateral distance from the US shore (e.g. 0.30 would be 30% across the river as measured from the US shore, hence for a 600 meter river width, 0.30 × 600 m = 180 m). These spill parameters were chosen to give an estimate of plume shape, time of impact, and extent of impact.

As only a limited number of measurement transects were considered in this work, the format of the spill reference tables allow for interpolation of spill arrival times and shape for points of interest that may reside between two transects. Although a linear interpolation is only a first-order approximation of spill transport between transects, this method will still provide valuable insight into spill impact and timing in the event of a contaminant release.

Spill Locations	U.S. coordinate	Canadian coordinate
Sarnia	-82.418479, 42.974884	-82.409213, 42.973573
Marysville	-82.444407, 42.944786	-82.439163, 42.940808
St. Clair	-82.485258, 42.819163	-82.475167, 42.817529

Table 1: Spill-release transect coordinates given in longitude and latitude for the western (US shoreline) and eastern (Canadian shoreline) points of each release transect. Specific release locations were given as percentages of distance from the US shore to the Canadian shore, and as either surface (floating) or bottom (sinking) releases.

Transect Locations	U.S. coordinate	Canadian coordinate
1	-82.459945, 42.923867	-82.452897, 42.922759
2	-82.466132, 42.907140	-82.458320, 42.904660
3	-82.469530, 42.903000	-82.457792, 42.899905
4	-82.473744, 42.861314	-82.462754, 42.861258
5	-82.485395, 42.819877	-82.475066, 42.818041
6	-82.476859, 42.789327	-82.470707, 42.790585
7	-82.475120, 42.755746	-82.465661, 42.752995
8	-82.527063, 42.621088	-82.515584, 42.614302

Table 2: Transect location coordinates, given in longitude and latitude for the western (US shoreline) and eastern (Canadian shoreline) points of each transect.

4. INSTRUCTIONS FOR USING THE SPILL REFERENCE TABLES

The reference tables (Appendix) can be used in two modes: (1) *quick access* and (2) *interpolation*. In the *quick access* mode, users can look up the spill characteristics defined above for one of the prescribed spills for each transect. The advantage of this mode is that no additional work is necessary to determine when and how a particular site will be impacted. The user can simply look up these impacts by spill location and choose the measurement transect nearest to their point of interest. However, as the point of interest might be between two of the prescribed measurement transects, this approach may only be appropriate for some cases or as a first approximation of spill timing and concentration.

In the second mode, *interpolation*, the user can determine translated spill information for different points of interest through a simple linear interpolation. Although, linear interpolation is also an approximation, it will provide a better estimate of travel times and plume characteristics for cases where the points of interest lie far from the prescribed locations. Both methods are described below:

Quick Access Mode

(1) Choose the nearest spill location: Sarnia, Marysville, or St. Clair
(2) Choose the nearest lateral release location (if known): 1, 3, 5, 7, or 9.
Lateral location is the distance across the river from the US shoreline toward the Canadian shoreline at each measurement transect. In this case, 10% across the river = 1, 30% = 3, 50% = 5, 70% = 7, and 90% = 9. For locations on either shoreline (i.e. <10% or >90%, cases 1 or 3 can be used, but model predictions are not calibrated for conditions closer than 50 meters from the shoreline). If the lateral release location is not known but the spill is detected by water intake or some other means, this lateral distance can be used instead.
(3) Choose "surface" or "bottom" for location of release or detection point.
Vertically-mixed spills can be approximated as surface releases within the reference tables for distances greater than 2 km downstream of the release/detection location.
(4) Choose the measurement transect that is nearest to the point of interest for determining spill impact.
(5) Locate the appropriate reference table based on spill location, lateral location, surface/bottom, and read values for the chosen measurement transect.
(6) If the initial concentration of the release (C_0) or the initial detection concentration is known, then the peak concentration values can be scaled accordingly: $C_{peak} = C_0 \times C_{table}$

Interpolation Mode

(1) Choose the nearest spill location: Sarnia, Marysville, or St. Clair
(2) Choose the nearest lateral release location (if known): 1, 3, 5, 7, or 9.
Lateral location is the distance across the river from the US shoreline toward the Canadian shoreline at each measurement transect. In this case, 10% across the river = 1, 30% = 3, 50% = 5, 70% = 7, and 90% = 9. For locations on

either shoreline (i.e. <10% or >90%, cases 1 or 3 can be used, but model predictions are not calibrated for conditions closer than 50 meters from the shoreline). If the lateral release location is not known but the spill is detected by water intake or some other means, this lateral distance can be used instead.

(3) Choose “surface” or “bottom” for location of release or detection point. *Vertically-mixed spills can be approximated as surface releases within the reference tables for distances greater than 2 km downstream of the release/detection location.*

(4) Determine point of interest, P_i, downstream of the spill

(5) Choose nearest upstream measurement transect, T_{up}

(6) Choose nearest downstream measurement transect, T_{down}

(7) Located the appropriate reference tables for T_{up} and T_{down}

(8) Determine along-stream distance of P_0 from T_{up} and T_{down}, defined as L_{up} and L_{down}, respectively.

(9) Use linear interpolation to adjust spill parameters from the appropriate tables of T_{up} and T_{down}:

$$P_i = P_1 + [P_2 - P_1]\frac{L_2}{L_1 + L_2}$$

where P_i is the new adjusted parameter (e.g. leading edge travel time, etc), P_2 is the downstream parameter, P_1 is the upstream parameter, and L_1 and L_2 are the upstream and downstream distances from the actual spill locations to the nearest spill transects.

(10) If the initial concentration of the release (C_0) or the initial detection concentration is known, then the peak concentration values can be scaled accordingly: $C_{peak} = C_0 \times C_{table}$

5. ACKNOWLEDGEMENTS

The Great Lakes Observing System (GLOS) provided funding support for model development and experimental dye releases in the St. Clair River. Applied Science Inc. (ASI) Detroit carried out the dye releases in the river, measurement, and data processing.

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APPPENDIX: SPILL REFERENCE TABLES

For each case, spill parameters are given for each downstream transect. Leading edge time is given in hours from the initial release, distance (km) is the downstream distance from the release location to the transect, average depth (m) is given for each transect, peak concentration is normalized relative to the initial concentration, time of peak concentration is given in minutes after the leading edge, trailing edge time is given in minutes after the leading edge, trailing edge 90% is given in minutes after the leading edge (and represents when 90% of the spill plume will have reached the transect), west edge, peak location, and east edge are give as normalized distances across the river (measured from the US shore to the Canadian shore) relative to the river width at the transect location. The west edge, peak location, and east edge provide the western and eastern extents of the plume boundary and the location of the predicted highest concentration.

Sarnia "1" Surface Floating

Transect	Leading Edge (hr)	Distance (km)	Avg. Depth (m)	Peak Conc.	Time Peak Conc. (min)	Trailing Edge (min)	Trailing Edge 90% (min)	West Edge	Peak Location	East Edge
1	1.60	6.64	8.76	0.0257	19	58	35	0.13	0.34	0.77
2	2.10	8.51	9.12	0.0270	28	68	43	0.13	0.22	0.81
3	2.25	9.04	6.85	0.0271	29	77	45	0.18	0.25	0.77
4	3.57	13.42	7.82	0.0189	51	175	71	0.08	0.17	0.83
5	5.22	18.08	8.07	0.0138	48	194	86	0.05	0.17	0.88
6	6.17	21.16	8.66	0.0144	54	202	98	0.06	0.29	0.86
7	7.33	24.77	7.88	0.0152	65	216	109	0.13	0.30	0.80
8	12.32	40.29	7.86	0.0063	128	426	238	0.02	0.17	0.97

Sarnia "3" Surface Floating

Transect	Leading Edge (hr)	Distance (km)	Avg. Depth (m)	Peak Conc.	Time Peak Conc. (min)	Trailing Edge (min)	Trailing Edge 90% (min)	West Edge	Peak Location	East Edge
1	1.67	6.68	8.76	0.0335	16	42	28	0.18	0.59	0.85
2	2.17	8.54	9.12	0.0267	23	67	39	0.16	0.58	0.86
3	2.30	9.07	6.85	0.0176	26	73	42	0.19	0.49	0.85
4	3.68	13.43	7.82	0.0175	45	207	95	0.10	0.45	0.91
5	5.22	18.09	8.07	0.0127	53	226	119	0.05	0.46	0.93
6	6.18	21.16	8.66	0.0116	81	233	130	0.08	0.67	0.91
7	7.37	24.77	7.88	0.0070	51	236	141	0.17	0.36	0.85
8	12.57	40.29	7.86	0.0047	217	553	262	0.02	0.87	0.98

Sarnia	"5"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	1.92	6.73	8.76	0.0600	23	58	35	0.31	0.76	0.90
2	2.43	8.57	9.12	0.0476	44	87	57	0.27	0.79	0.91
3	2.57	9.11	6.85	0.0366	47	91	61	0.27	0.79	0.86
4	3.97	13.45	7.82	0.0260	60	499	100	0.19	0.78	0.91
5	5.52	18.10	8.07	0.0178	87	526	142	0.11	0.81	0.93
6	6.47	21.16	8.66	0.0205	103	533	156	0.13	0.77	0.92
7	7.63	24.77	7.88	0.0098	144	523	184	0.24	0.78	0.87
8	12.77	40.29	7.86	0.0072	288	575	357	0.05	0.91	0.98

Sarnia	"7"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	2.45	6.79	8.76	0.0967	22	64	39	0.69	0.92	0.97
2	3.03	8.62	9.12	0.1045	48	95	63	0.62	0.93	0.97
3	3.20	9.16	6.85	0.0810	52	103	71	0.60	0.85	0.95
4	4.90	13.48	7.82	0.0716	80	135	97	0.57	0.89	0.96
5	6.87	18.12	8.07	0.0451	103	175	131	0.68	0.88	0.96
6	7.88	21.17	8.66	0.0354	122	191	144	0.48	0.90	0.95
7	8.98	24.77	7.88	0.0264	160	277	185	0.41	0.82	0.95
8	14.05	40.30	7.86	0.0117	331	534	425	0.17	0.92	0.98

Sarnia	"9"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	3.05	6.85	8.76	0.0039	21	317	2637	0.88	0.92	1.00
2	4.10	8.67	9.12	0.0056	16	621	2578	0.88	0.93	1.00
3	4.48	9.21	6.85	0.0073	21	692	2552	0.84	0.95	1.00
4	6.62	13.51	7.82	0.0054	30	697	2426	0.83	0.94	1.00
5	9.03	18.15	8.07	0.0044	49	951	2282	0.87	0.94	1.00
6	10.28	21.18	8.66	0.0033	39	1073	2212	0.77	0.90	1.00
7	11.88	24.78	7.88	0.0023	65	1072	2109	0.62	0.82	0.98
8	17.70	40.31	7.86	0.0011	220	1080	1729	0.38	0.92	0.97

Sarnia	"1"	Bottom	Sinking							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	3.11	6.64	8.76	0.2258	8	20	17	0.43	0.42	0.49
2	3.98	8.51	9.12	0.2851	7	19	16	0.44	0.50	0.52
3	4.23	9.04	6.85	0.3265	8	19	16	0.39	0.44	0.47
4	6.78	13.42	7.82	0.6303	3	11	9	0.47	0.50	0.50
5	9.24	18.08	8.07	0.5985	3	11	9	0.37	0.40	0.40
6	10.75	21.16	8.66	0.5347	3	11	8	0.71	0.67	0.71
7	12.47	24.77	7.88	0.4949	5	12	10	0.46	0.48	0.49
8	21.13	40.29	7.86	0.4516	10	20	15	0.87	0.87	0.89

Sarnia	"3"	Bottom	Sinking							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	2.80	6.68	8.76	0.5782	3	5	4	0.53	0.58	0.57
2	3.70	8.54	9.12	0.8047	3	4	4	0.60	0.64	0.66
3	3.97	9.07	6.85	0.7778	2	4	4	0.59	0.61	0.67
4	7.01	13.43	7.82	0.1135	20	592	8	0.55	0.67	0.68
5	9.50	18.09	8.07	0.0852	19	586	7	0.44	0.60	0.64
6	11.07	21.16	8.66	0.1163	15	583	7	0.71	0.71	0.78
7	12.91	24.77	7.88	0.0913	13	579	2	0.47	0.52	0.53
8	21.74	40.29	7.86	0.1115	42	567	1	0.87	0.88	0.91

Sarnia	"5"	Bottom	Sinking							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	2.85	6.73	8.76	0.4489	2	7	6	0.63	0.66	0.67
2	3.81	8.57	9.12	0.4180	3	9	8	0.73	0.71	0.76
3	4.08	9.11	6.85	0.4076	2	9	8	0.77	0.80	0.80
4	6.60	13.45	7.82	0.3062	5	21	16	0.83	0.83	0.86
5	9.57	18.10	8.07	0.2724	24	34	28	0.89	0.88	0.91
6	11.24	21.16	8.66	0.2443	16	35	29	0.87	0.90	0.89
7	13.41	24.77	7.88	0.1694	18	41	33	0.65	0.70	0.76
8	24.61	40.29	7.86	0.1670	25	339	87	0.94	0.96	0.97

Sarnia "7" Bottom Sinking										
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	3.76	6.79	8.76	0.3028	43	45	44	0.87	0.92	0.92
2	5.09	8.62	9.12	0.3485	46	49	48	0.88	0.93	0.93
3	5.42	9.16	6.85	0.2550	51	54	52	0.86	0.90	0.88
4	8.40	13.48	7.82	0.2789	52	58	55	0.89	0.89	0.91
5	11.74	18.12	8.07	0.2500	55	62	58	0.91	0.94	0.93
6	13.41	21.17	8.66	0.1888	55	62	58	0.88	0.90	0.90
7	15.58	24.77	7.88	0.1364	57	71	61	0.64	0.70	0.75
8	26.86	40.30	7.86	0.1828	52	260	57	0.94	0.96	0.96

Sarnia "9" Bottom Sinking										
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	4.32	6.85	8.76	0.3703	4	24	14	0.92	0.92	0.97
2	5.73	8.67	9.12	0.4684	5	25	16	0.93	0.93	0.96
3	6.15	9.21	6.85	0.3765	7	31	19	0.88	0.90	0.90
4	9.18	13.51	7.82	0.3519	7	33	20	0.91	0.89	0.92
5	2.58	18.15	8.07	0.3051	8	37	21	0.92	0.94	0.93
6	4.24	21.18	8.66	0.2379	8	37	22	0.88	0.90	0.90
7	6.42	24.78	7.88	0.1520	12	42	25	0.64	0.70	0.75
8	7.47	40.31	7.86	0.2054	20	319	36	0.94	0.96	0.96

Marysville "1" Surface Floating										
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	0.97	2.64	8.76	0.1506	12	34	26	0.07	0.08	0.14
2	1.75	4.52	9.12	0.1171	20	45	36	0.07	0.07	0.19
3	1.97	5.05	6.85	0.1132	24	57	48	0.08	0.15	0.22
4	3.58	9.54	7.82	0.0622	43	103	77	0.04	0.11	0.22
5	5.38	14.23	8.07	0.0362	80	187	130	0.04	0.06	0.31
6	6.40	17.42	8.66	0.0257	83	196	139	0.04	0.10	0.60
7	7.62	21.10	7.88	0.0286	126	237	179	0.09	0.18	0.68
8	13.08	36.54	7.86	0.0134	244	562	395	0.01	0.08	0.88

Marysville	"3"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	0.7	2.6	8.76	0.1622	4	20	12	0.13	0.15	0.49
2	1.25	4.48	9.12	0.1109	11	32	21	0.12	0.21	0.53
3	1.4	5.01	6.85	0.0885	15	39	25	0.16	0.21	0.49
4	2.78	9.48	7.82	0.0401	27	78	50	0.07	0.16	0.46
5	4.3	14.17	8.07	0.0268	43	139	79	0.05	0.14	0.54
6	5.28	17.35	8.66	0.0212	49	158	91	0.05	0.23	0.71
7	6.43	21.02	7.88	0.0198	63	192	109	0.09	0.28	0.76
8	11.67	36.47	7.86	0.0076	197	479	245	0.02	0.13	0.96

Marysville	"5"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	0.60	2.58	8.76	0.1690	2	19	16	0.19	0.24	0.63
2	1.10	4.44	9.12	0.0647	4	37	30	0.16	0.28	0.71
3	1.25	4.98	6.85	0.0503	5	42	32	0.18	0.26	0.73
4	2.57	9.43	7.82	0.0256	35	241	74	0.08	0.39	0.74
5	4.07	14.12	8.07	0.0184	28	257	81	0.05	0.19	0.77
6	5.08	17.30	8.66	0.0205	35	265	89	0.07	0.23	0.81
7	6.18	20.97	7.88	0.0158	46	273	101	0.14	0.34	0.82
8	11.27	36.42	7.86	0.0064	197	479	245	0.02	0.13	0.96

Marysville	"7"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	0.58	2.56	8.76	0.1772	2	23	17	0.35	0.49	0.82
2	1.05	4.41	9.12	0.0624	10	56	40	0.29	0.50	0.84
3	1.18	4.94	6.85	0.0450	7	63	45	0.29	0.41	0.83
4	2.48	9.38	7.82	0.0260	31	318	146	0.15	0.39	0.91
5	4.00	14.06	8.07	0.0164	45	333	136	0.08	0.42	0.93
6	4.95	17.23	8.66	0.0110	71	346	148	0.10	0.62	0.92
7	6.08	20.90	7.88	0.0070	43	361	177	0.19	0.34	0.86
8	11.17	36.36	7.86	0.0041	241	499	347	0.05	0.88	0.97

Marysville	"9"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	0.60	2.55	8.76	0.1184	7	33	27	0.59	0.75	0.87
2	1.12	4.37	9.12	0.0585	17	68	57	0.52	0.71	0.88
3	1.25	4.91	6.85	0.0553	24	76	62	0.48	0.75	0.86
4	2.78	9.33	7.82	0.0259	33	249	109	0.37	0.78	0.92
5	4.32	14.01	8.07	0.0208	52	258	155	0.33	0.77	0.93
6	5.33	17.17	8.66	0.0191	86	262	167	0.30	0.81	0.91
7	6.53	20.84	7.88	0.0113	91	264	204	0.28	0.76	0.85
8	12.13	36.30	7.86	0.0073	200	526	371	0.07	0.88	0.98

Marysville	"1"	Bottom	Sinking							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	1.47	2.64	8.76	0.2265	19	22	21	0.08	0.08	0.32
2	2.34	4.52	9.12	0.1143	29	47	39	0.09	0.14	0.35
3	2.60	5.05	6.85	0.1156	34	60	49	0.17	0.20	0.33
4	4.87	9.54	7.82	0.0874	63	92	78	0.09	0.11	0.44
5	7.29	14.23	8.07	0.0721	105	140	122	0.04	0.06	0.34
6	8.77	17.42	8.66	0.0595	112	149	130	0.05	0.10	0.71
7	10.44	21.10	7.88	0.0109	148	184	164	0.19	0.19	0.50
8	19.11	36.54	7.86	0.0248	231	255	238	0.08	0.12	0.88

Marysville	"3"	Bottom	Sinking							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
1	1.10	2.6	8.76	0.8495	2	3	3	0.52	0.58	0.57
2	2.03	4.48	9.12	0.8413	1	1	1	0.59	0.64	0.68
3	2.31	5.01	6.85	0.8272	1	1	1	0.58	0.66	0.71
4	4.87	9.48	7.82	0.2647	26	747	71	0.54	0.67	0.73
5	7.42	14.17	8.07	0.2323	23	738	68	0.42	0.60	0.68
6	8.99	17.35	8.66	0.2208	23	735	67	0.71	0.81	0.81
7	10.88	21.02	7.88	0.2133	20	727	61	0.48	0.52	0.56
8	19.89	36.47	7.86	0.1241	34	701	51	0.87	0.88	0.95

Marysville "5" Bottom Sinking										
Transect	Leading Edge (hr)	Distance (km)	Avg. Depth (m)	Peak Conc.	Time Peak Conc. (min)	Trailing Edge (min)	Trailing Edge 90% (min)	West Edge	Peak Location	East Edge
1	1.07	2.58	8.76	0.9800	0	1	1	0.64	0.66	0.72
2	2.08	4.44	9.12	0.7707	2	6	5	0.76	0.78	0.82
3	2.34	4.98	6.85	0.6931	2	7	6	0.80	0.80	0.84
4	5.10	9.43	7.82	0.3451	8	17	15	0.86	0.89	0.89
5	8.28	14.12	8.07	0.2057	12	27	22	0.91	0.94	0.92
6	9.96	17.30	8.66	0.1700	13	27	22	0.88	0.90	0.89
7	12.17	20.97	7.88	0.1158	15	33	27	0.66	0.70	0.76
8	23.58	36.42	7.86	0.0987	87	120	91	0.95	0.96	0.97

Marysville "7" Bottom Sinking										
Transect	Leading Edge (hr)	Distance (km)	Avg. Depth (m)	Peak Conc.	Time Peak Conc. (min)	Trailing Edge (min)	Trailing Edge 90% (min)	West Edge	Peak Location	East Edge
1	1.12	2.56	8.76	0.9793	2	3	3	0.83	0.83	0.86
2	2.41	4.41	9.12	0.8392	4	6	6	0.87	0.87	0.89
3	2.72	4.94	6.85	0.7147	4	7	6	0.85	0.85	0.86
4	5.69	9.38	7.82	0.7323	5	9	7	0.89	0.89	0.90
5	9.03	14.06	8.07	0.5906	8	12	10	0.91	0.94	0.92
6	10.71	17.23	8.66	0.5016	8	12	10	0.88	0.90	0.89
7	12.93	20.90	7.88	0.3580	13	20	15	0.66	0.76	0.76
8	24.22	36.36	7.86	0.2040	69	92	74	0.95	0.96	0.97

Marysville "9" Bottom Sinking										
Transect	Leading Edge (hr)	Distance (km)	Avg. Depth (m)	Peak Conc.	Time Peak Conc. (min)	Trailing Edge (min)	Trailing Edge 90% (min)	West Edge	Peak Location	East Edge
1	1.29	2.55	8.76	0.9275	2	4	4	0.87	0.83	0.88
2	2.65	4.37	9.12	0.9832	2	4	3	0.89	0.86	0.90
3	2.98	4.91	6.85	0.9633	2	5	4	0.86	0.85	0.87
4	5.97	9.33	7.82	0.9866	3	6	4	0.90	0.89	0.91
5	9.34	14.01	8.07	0.9313	3	7	5	0.92	0.94	0.93
6	11.02	17.17	8.66	0.8761	3	8	5	0.88	0.90	0.89
7	13.21	20.84	7.88	0.4020	10	16	12	0.66	0.76	0.76
8	24.52	36.30	7.86	0.1852	6	84	66	0.94	0.96	0.96

St. Clair	"1"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
6	0.88	3.33	8.66	0.1607	4	25	13	0.13	0.19	0.61
7	1.93	7.05	7.88	0.0689	18	48	31	0.21	0.30	0.66
8	7.00	22.26	7.86	0.0115	92	521	182	0.02	0.17	0.92

St. Clair	"3"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
6	0.85	3.28	8.66	0.2161	2	29	15	0.20	0.23	0.71
7	1.83	7.00	7.88	0.0414	15	57	31	0.25	0.34	0.78
8	6.85	22.25	7.86	0.0079	83	293	141	0.03	0.17	0.96

St. Clair	"5"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
6	0.90	3.22	8.66	0.1593	2	31	19	0.28	0.33	0.76
7	1.87	6.95	7.88	0.0259	3	68	41	0.27	0.46	0.79
8	6.80	22.23	7.86	0.0056	67	437	176	0.02	0.25	0.98

St. Clair	"7"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
6	0.88	3.20	8.66	0.1387	2	31	20	0.36	0.43	0.83
7	1.82	6.93	7.88	0.0162	9	79	50	0.30	0.46	0.83
8	6.77	22.24	7.86	0.0068	181	401	205	0.07	0.88	0.97

St. Clair	"9"	Surface	Floating							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
6	0.93	3.18	8.66	0.1253	13	30	18	0.56	0.81	0.89
7	1.90	6.91	7.88	0.0322	48	86	58	0.44	0.76	0.87
8	7.17	22.24	7.86	0.0143	206	486	260	0.14	0.92	0.98

St. Clair	"1"	Bottom	Sinking							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
6	0.91	3.33	8.66	0.0811	11	29	21	0.15	0.29	0.65
7	1.94	7.05	7.88	0.0346	22	52	33	0.22	0.30	0.74
8	7.03	22.26	7.86	0.0085	85	448	137	0.03	0.17	0.96

St. Clair	"3"	Bottom	Sinking							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
6	0.88	3.28	8.66	0.0973	20	32	24	0.23	0.62	0.71
7	1.87	7.00	7.88	0.0178	11	65	44	0.26	0.40	0.78
8	6.81	22.25	7.86	0.0055	126	300	173	0.04	0.88	0.96

St. Clair	"5"	Bottom	Sinking							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
6	0.92	3.22	8.66	0.0888	20	33	24	0.28	0.71	0.77
7	1.90	6.95	7.88	0.0163	37	71	48	0.26	0.70	0.82
8	6.89	22.23	7.86	0.0071	174	466	191	0.06	0.88	0.97

St. Clair	"7"	Bottom	Sinking							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
6	0.91	3.20	8.66	0.0952	18	33	24	0.37	0.71	0.84
7	1.86	6.93	7.88	0.0197	48	77	56	0.29	0.70	0.83
8	6.89	22.24	7.86	0.0100	197	439	224	0.07	0.88	0.97

St. Clair	"9"	Bottom	Sinking							
Transect	**Leading Edge (hr)**	**Distance (km)**	**Avg. Depth (m)**	**Peak Conc.**	**Time Peak Conc. (min)**	**Trailing Edge (min)**	**Trailing Edge 90% (min)**	**West Edge**	**Peak Location**	**East Edge**
6	0.96	3.18	8.66	0.1460	16	31	23	0.56	0.81	0.90
7	1.97	6.91	7.88	0.0464	51	88	64	0.45	0.76	0.85
8	7.15	22.24	7.86	0.0146	215	706	279	0.14	0.92	0.98