Implications of an Improved Hydrologic Model for Understanding Near Shore Hydrodynamics:

Impacts of the Clinton River Spillway on Predicting Beach Water Quality

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The Problem

A linked hydrologic-hydrodynamic model of the Clinton River is being verified for use as a predictive beach water quality model. The objective of this study was to determine the flow split between the natural Clinton River channel and the Clinton spillway (Fig. 1). The model developed was based on the flows at the USGS Moravian Drive gage just upstream of our study site and the hourly water level on Lake St. Clair.

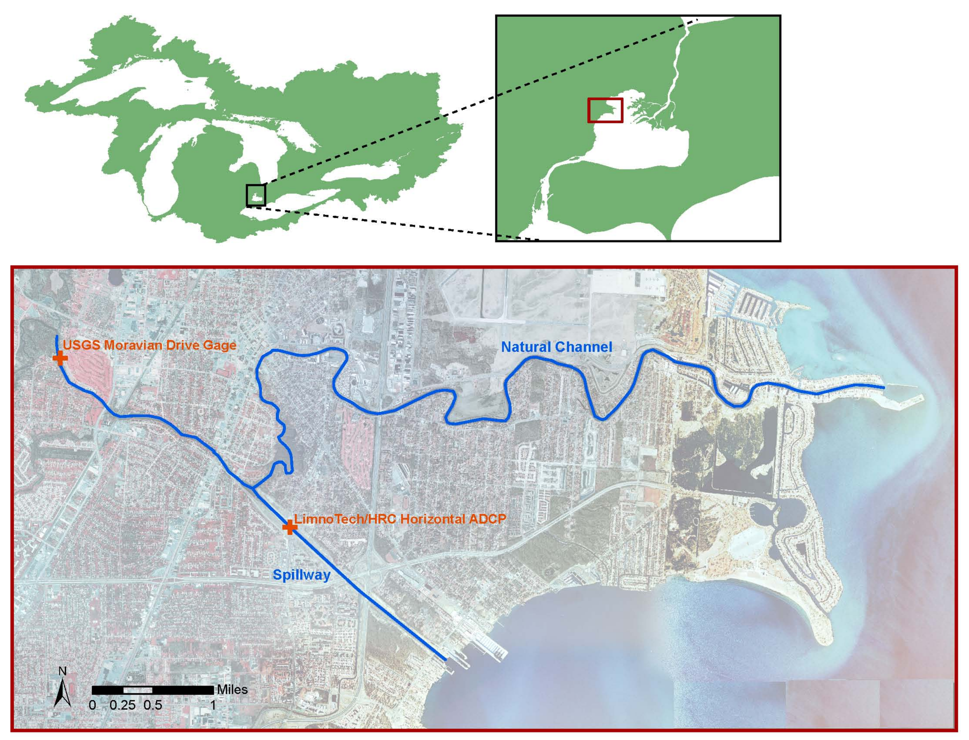


Figure 1. Project area map showing the USGS gage and the location of the spillway gage.

Study Site

The Clinton River, an urban stream with a partially agricultural watershed, flows into Lake St. Clair near one of the most heavily used public beaches in the Detroit metropolitan area. A spillway channel was constructed upstream of Mount Clemens in the early 1950's to relieve downtown flooding (Fig. 2). To develop a predictive water quality model for forecasting beach closures, the hydrologic split between the natural channel and spillway had to be determined. Discharge measurements from both the river channel and the spillway (Fig. 3) were used in conjunction with Lake St. Clair water levels to approximate this relationship.

(a)

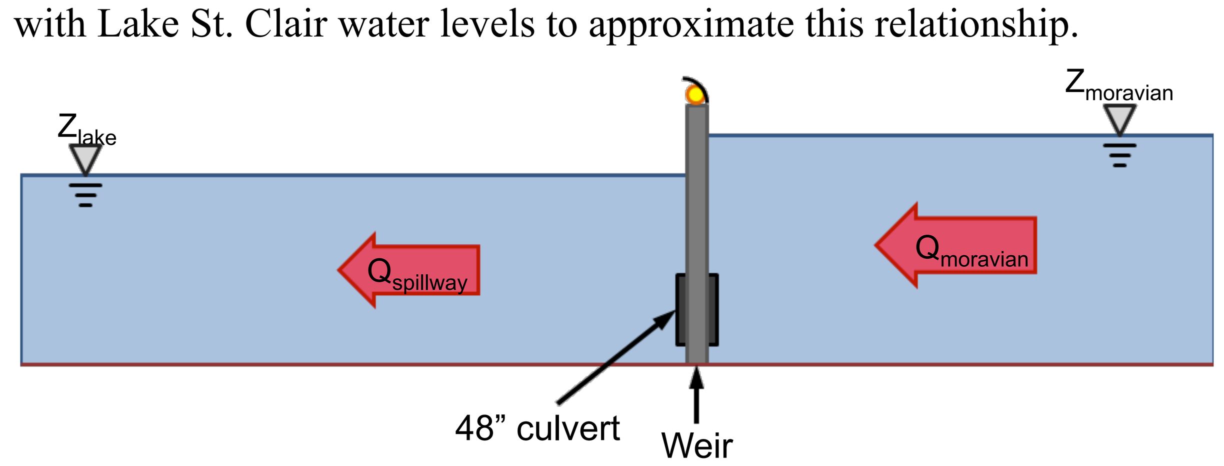


Figure 2.
a) Diagram of the Clinton River spillway weir.

b) The Clinton spillway weir, shown here in the fully open position. From 1995 until May 2010, this weir operated in a self-regulating way, allowing more flow down the spillway in times of high discharge. Since then, the weir has been left in the down position.

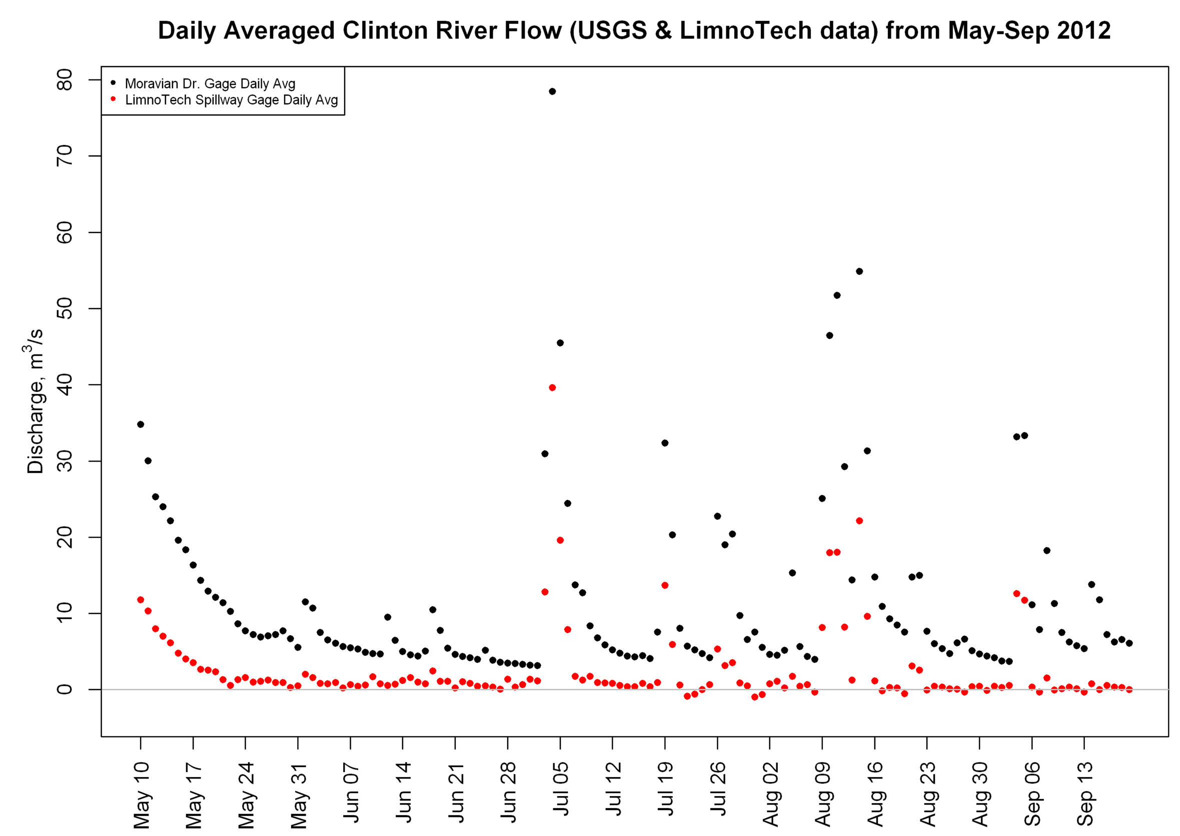
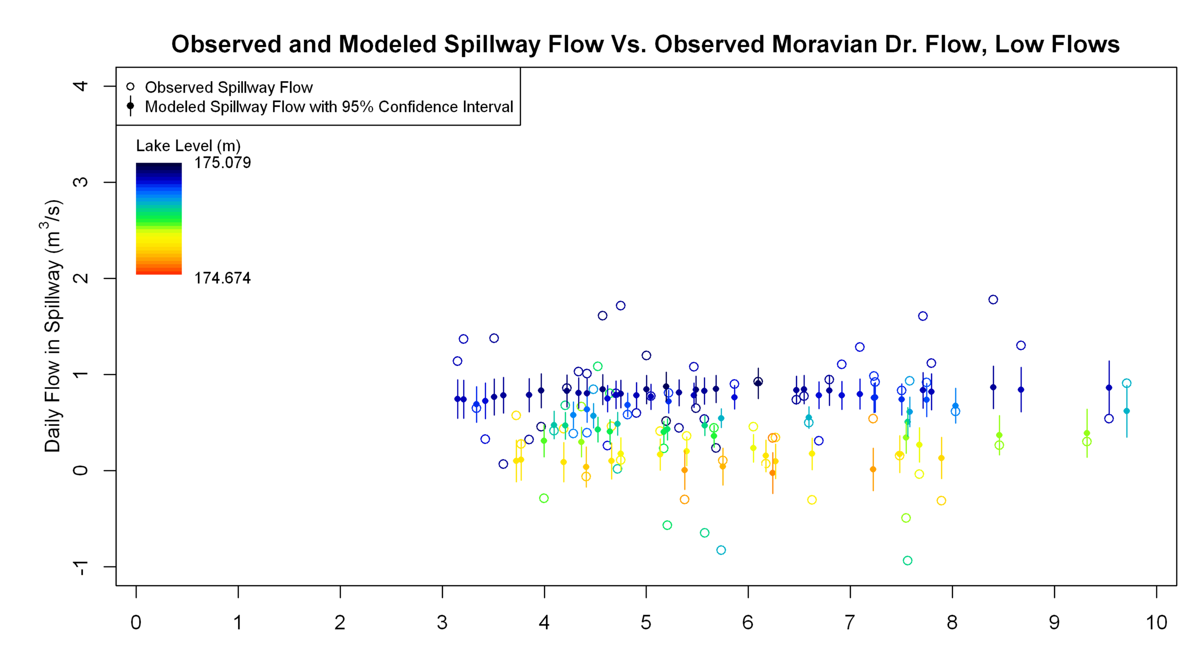


Figure 3. Flow data from the USGS gage at Moravian Drive and a LimnoTech/HRC horizontal ADCP on the Clinton spillway from May – September 2012 were used in this analysis.

Model Development

The analysis included investigating correlations between spillway flow (Q_S) and fraction of total flow in the spillway (Q_S/Q_M), impacts of local and areal averaged precipitation, flow at Moravian Drive (Q_M), and Lake St. Clair water level (Z_L). Plotting spillway flow against Moravian Drive flow revealed a logical break point in the relationship close to $Q_M = 10$ m^3/s (Fig. 4). A clear linear relationship was observed for $Q_M > 10$ m^3/s. For $Q_M < 10$ m^3/s, no clear relationship (high variability) with Q_S was observed, though some relationship with lake level was observed. Two linear models were developed using $Q_M = 10$ m^3/s as the break point. Q_M and Z_L were treated as independent variables to determine Q_S.

$$Q_S = \begin{cases} -656.323 + 0.019 \cdot Q_M + 3.755 \cdot Z_L & \text{if } Q_M < 10 \text{ m}^3/\text{s} \\ -1602.517 + 0.526 \cdot Q_M + 9.131 \cdot Z_L & \text{if } Q_M \geq 10 \text{ m}^3/\text{s} \end{cases}$$



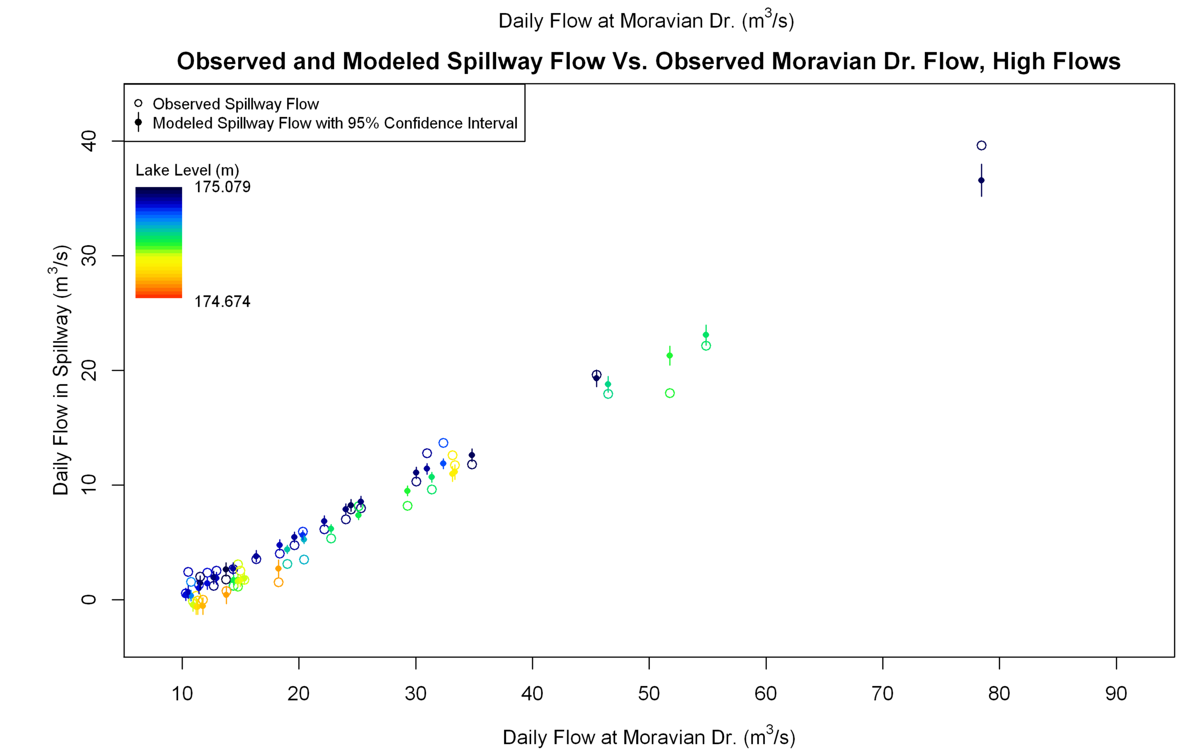


Figure 4. Observed daily flow at Moravian Drive vs. observed and modeled daily flow in the spillway, m^3/s. Values are color-coded by lake level on Lake St. Clair, which exerts a backwater effect on the spillway mouth.

Potential Impacts on Water Quality Modeling

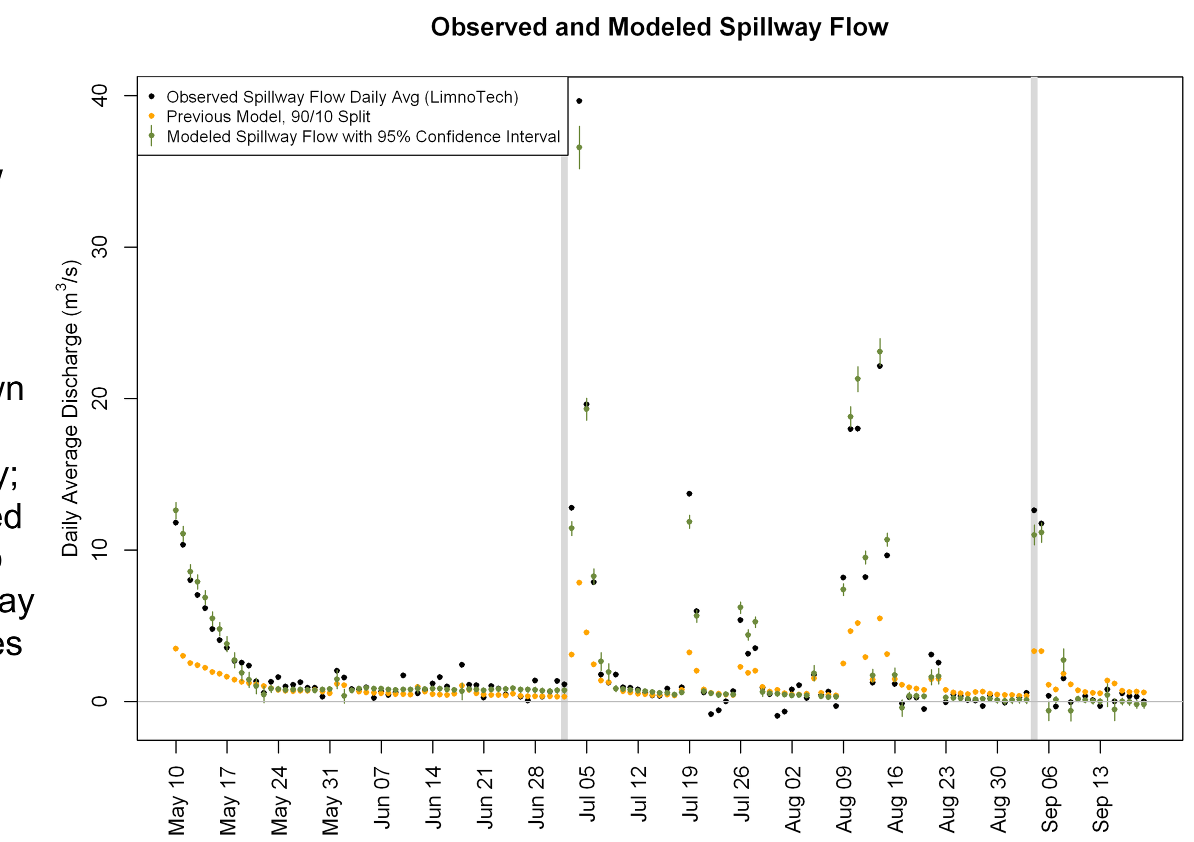


Figure 5. This figure shows observed and predicted spillway flow corresponding to hydrodynamic model panels (b) and (c) shown below: 90% of the upstream flow down the natural channel, 10% down the spillway; and spillway flow based on our model. The two dates highlighted in gray correspond to the dates shown in Figure 6.

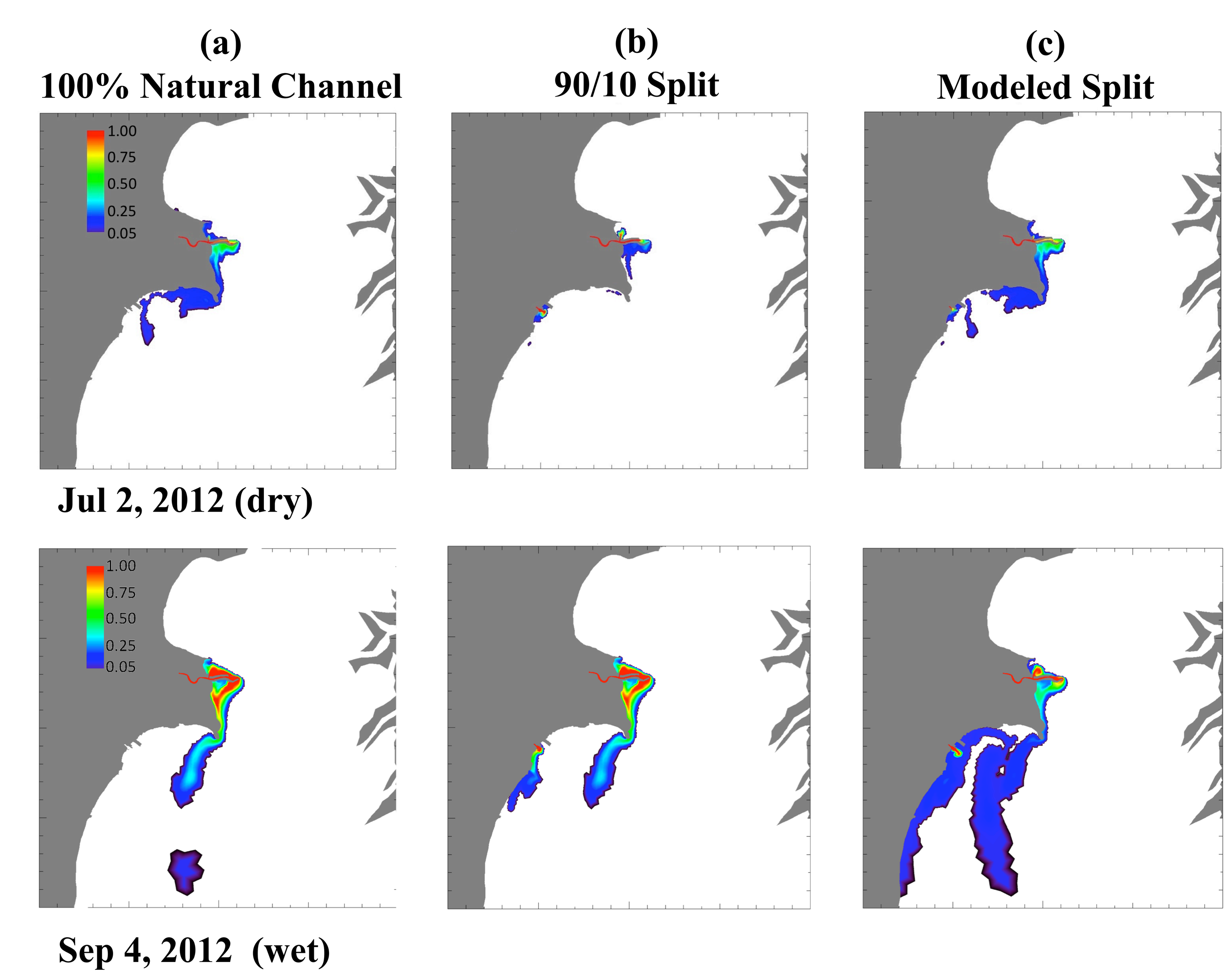


Figure 6. Hydrodynamic model results (Huron to Erie Connecting Waterways Forecast System) using a dye tracer to show the impact of the Clinton River on the beach on two different days. The dye tracks the Clinton River plume as it enters the lake (red indicating highest concentration of river water). The three panels reflect different assumptions about the split between the natural channel and spillway: a) 100% natural channel; b) 90% natural channel, 10% spillway; c) model for the split based on flow at Moravian Drive and Lake St. Clair water level. Note the large impact of the different split assumptions on the model results as well as the variability between different days caused by wind, precipitation, and other physical drivers.

References

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