REPORT

February 2008

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT DETROIT RIVER INTERNATIONAL CROSSING

EVALUATION OF ALTERNATIVE BRIDGE SITES

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EXECUTIVE SUMMARY

Purpose and Scope of Work

This report presents the results of geotechnical explorations and testing related to the bridge crossing portion of the Area of Continued Analysis (ACA) associated with the Detroit River International Crossing (DRIC) between Windsor, Ontario, and Detroit, Michigan. This work was undertaken as part of an on-going study for a joint partnership between the Ministry of Transportation Ontario, Transport Canada, the Michigan Department of Transportation (MDOT), and the US Federal Highway Administration (FHWA).

Three locations for a new bridge crossing of the Detroit River are under consideration and two of these are close to historic salt mining facilities. In 1954, a sinkhole developed on a solution mining site operated by Canadian Industries Limited (now Windsor Salt) that is within the overall DRIC ACA study area. The sinkhole and concerns related to the overall stability of the rock mass adjacent to the sinkhole prompted an evaluation of the solution mining activities and to define boundaries around the former solution mining site beyond which the ground would be suitable for the proposed bridge.

The work completed for the geologic and geotechnical evaluation of alternative crossing locations for the DRIC project consisted of a program of deep drilling, down-hole geophysical logging, cross-well seismic surveys, surface seismic reflection surveys, numerical analysis, and historical research. This study included the following tasks:

- literature review of research regarding solution mining practices and subsidence issues as applicable to the geology of Windsor, Ontario, and Detroit, Michigan;
- critical review of available historical documents related to solution mining and subsidence in the greater Windsor and Detroit areas;
- completion of a surface seismic reflection survey in early 2006, as an initial means to identify potential areas affected by solution mining;
- drilling of 12 exploratory wells (boreholes) to depths of nearly 500 m in areas being considered for the proposed crossing locations and in areas relevant to defining the potential influences of nearby solution mining on the rock mass;
- use of down-hole geophysical tools to characterise the rock mass near the exploratory wells;
- laboratory testing of rock core specimens;
- use of cross-well geophysical methods, typically used for resource (oil) exploration, to assess the condition of the rock mass between the wells along nineteen profiles;
- computer simulation of the rock mass and various subsurface solution mining conditions to calibrate this study to field conditions that precipitated a sinkhole on a nearby site in 1954; and
- geological and engineering evaluations to define the boundaries of solution mining influence and the future performance of the rock mass beneath the potential bridge sites.

On the basis of this work, a number of conclusions have been drawn and recommendations made to assist with selection of an appropriate bridge site.

Summary of Field Explorations and Testing

Field drilling investigations in most of the explored areas encountered bedrock conditions in the upper rock formations that are considered typical of the Windsor-Detroit region. These formations (Detroit River Group) in the top approximately 110 to 120 m of rock exhibited fractures and open joints that produce artesian water flows and hydrogen sulphide gas when this water is exposed to atmospheric pressures. The water pressures and flow volumes caused difficulties during drilling and construction of the well casings. In two of the exploratory wells, the conditions in the upper formations appear to have been influenced by subsidence over solution mined areas. In the salt-bearing Salina Formation, where salt beds were encountered between about 290 to 301 m below the ground surface, the explorations did not encounter any solution mining cavities, though some wells near the former solution mining site encountered rock and salt masses that have likely been influenced by solution mining. Measurements of fluid pressures during and subsequent to drilling activities assisted in defining the groundwater conditions at the subject sites.

Down-hole geophysical logging provided detailed measurements of the geology and character of the rock mass immediately surrounding each of the well holes. Data from this logging indicated that those wells that were drilled in close proximity to the former solution mining site exhibited thinned salt beds and horizontal fractures or open joints and bedding planes within the rock masses above the salt beds.

The cross-well seismic survey data, when combined with the down-hole data at each well location, provided evidence defining areas in which the rock mass remains in its natural state and other areas where the rock mass has been disturbed. The cross-well surveys also revealed several areas suspected of being near solution mining cavities with two surveys indicating evidence of potential brine-filled zones and cavity remnants.

Summary of Geology and Engineering Evaluations

Down-hole logging data was used to develop a three-dimensional model of the subsurface geology in which interfaces between rock formations were interpolated between wells to develop a number of topographic surfaces for these layers. This model included details of rock layer interface elevations, rock fracture data, groundwater and drilling fluid information, and well hole wall characteristics. Interpreted geologic interfaces between rock types were also developed based on the cross-well seismic data and these were used to build a second series of topographic rock formation surfaces. Four of the surface seismic profiles were used within the model to examine the conditions around the northern edge of the former solution mining site. Historical

data related to former solution mining wells was also incorporated into this three-dimensional model. Information related to solution mining operations, from the former Canadian Industries Limited site and nearby facilities, coupled with a number of simplifying assumptions was used to develop three-dimensional representations of areas from which salt was likely removed since the available information was limited in detail. This model permitted spatial correlation between all forms of subsurface and historical information.

In addition to the three-dimensional computer model of the site subsurface conditions, a series of computer simulations (models) of the mechanical rock mass behaviour were completed to assess past and potential future performance of the ground near the bridge sites. Several simulations were compared to the estimated field conditions immediately preceding development of the sinkhole in 1954 and the resulting ground settlement. Other simulations were compared to conditions at nearby and existing solution-mined cavities now used for underground storage of petroleum products. After achieving reasonable correspondence between the computer simulations and observed behaviour, additional work was completed to define zones of rock that could have been disturbed by subsidence of the rock mass over and adjacent to solution mined zone. The results of all simulations were used to assess the potential for future rock mass displacements and for defining areas that could be considered to be suitable for support of bridge foundations from a geotechnical perspective.

Summary of Conclusions

A detailed review of historical evidence, coupled with the evidence from field investigations has assisted in defining the limit of mass salt dissolution from the former Canadian Industries Limited solution mining operation, defined for this study as the Limit of Primary Solution Mining Influence. Field evidence, historical data, and numerical modelling have also formed the basis of defining limits within which the rock mass has been altered to some degree by displacements associated with the nearby solution mining, defined for this study as the Limit of Secondary Solution Mining Influence. These limits are shown on Figure ES-1 and summarized in geographical coordinate form in Section 9 of this report. These limits are considered reasonable and prudent for this project since:

- the limit of primary solution mining influence, being zones where salt was directly removed by the mining, is based on inferred extents of former dissolution based on thinned salt beds, even though rock-on-rock (salt) contact was observed in all exploratory well locations.
- the limit of secondary solution mining influence, being zones where the rock mass outside the area of primary influence experienced a degree of displacement or disturbance, is based on reasonable numerical analyses coupled with settlement observations on a nearby site, and this limit is projected beyond the primary zone of influence described above;
- the limits of primary and secondary solution mining influence are consistent among several different methods of processing and interpretation of the geophysical data; and

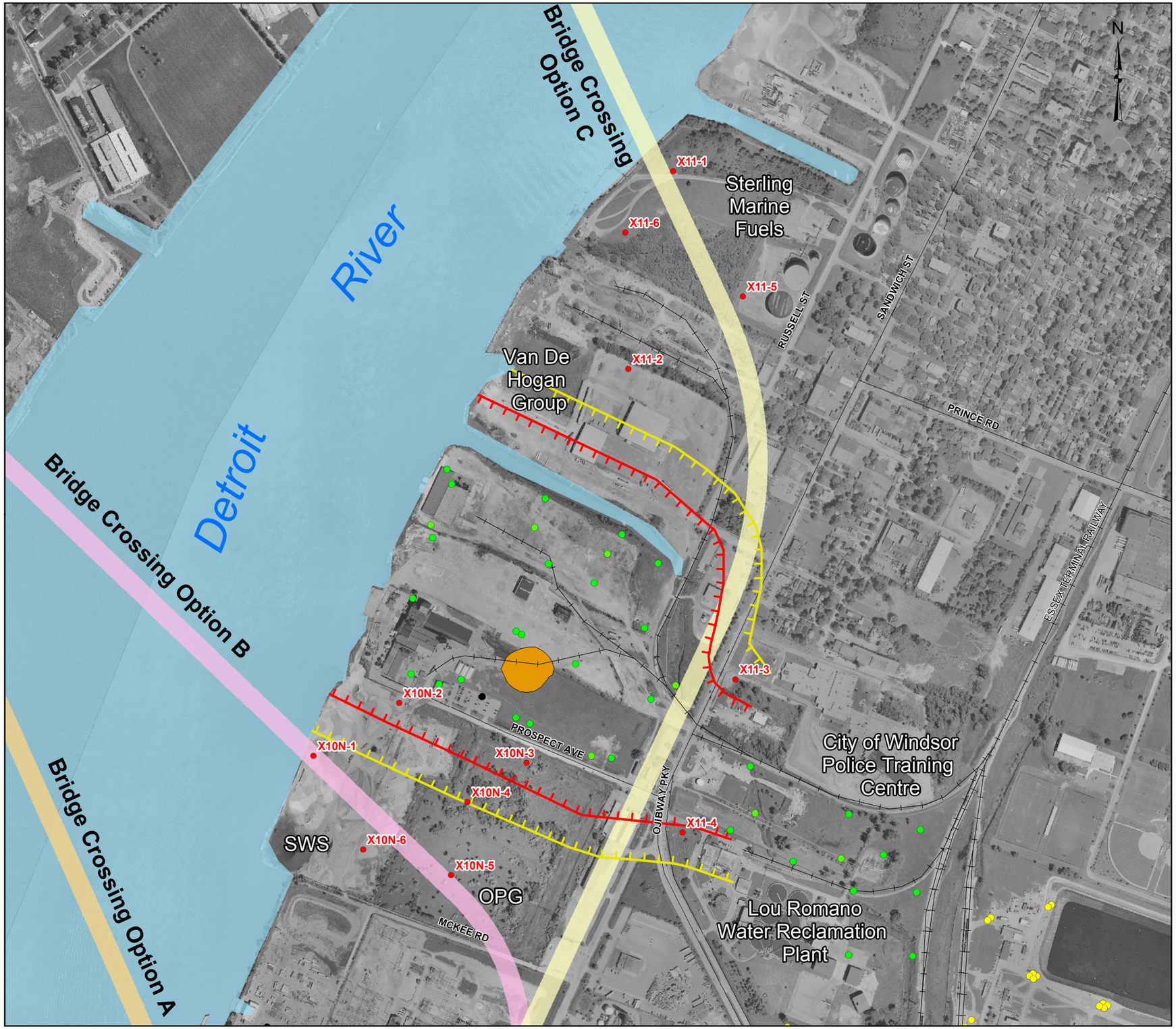
- the limits of primary and secondary influence, as defined for this project, fall outside of other boundaries that could be defined using a variety of alternative interpretations of subsurface conditions and different geology and engineering analysis approaches.

The existing and future rock mass conditions in the vicinity of Crossing A are expected to be no different than in other areas of western Windsor that have been unaffected by solution mining. Crossing A is outside the Limits of Primary and Secondary Solution Mining Influence.

The proposed Crossing B alignment falls outside the Limits of Primary and Secondary Solution Mining Influence, and the rock mass performance for this crossing is expected to be no different than in other areas of western Windsor that have been unaffected by solution mining.

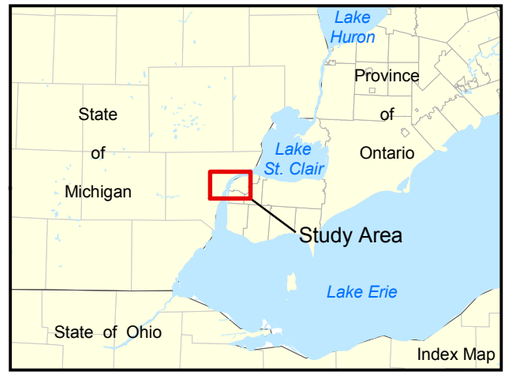
The main bridge pier locations for Crossing C, are outside the Limits of Primary and Secondary Solution Mining influence and future rock mass conditions in an area where the rock mass conditions are expected to be no different than in other areas of western Windsor that have been unaffected by solution mining. However, the proposed approach to Crossing C passes over the eastern end of the former solution mining well field and a subsurface anomaly that is suspected to be a brine-filled cavity, rubble zone, and disturbed rock mass. Initial estimates suggest that the rock mass above this anomaly might experience subsidence ranging up to values on the order of 2 m. The proportion of such subsidence that has already occurred or may occur in the future cannot be quantified at this time because of uncertainties associated with the nature and position of the identified anomaly. Should this crossing alignment be considered further, additional study will be required to refine the range of risks and orders of magnitude of future settlement that should be accommodated by design. The field exploration and testing program and historical data are not sufficient to clearly assess the three-dimensional extent, specific location, or potential limits of influence of this subsurface anomaly. The level of effort (investigation, testing, and analysis) that may be required to further refine these issues relative to the Crossing C approach alignment is extensive and, if undertaken, may still be insufficient to consider supporting structures on the rock within and adjacent to the identified limits of solution mining influence within an acceptable degree of risk.

Regardless of the bridge site selected, all bridge foundations will likely derive their support from the rock of the Dundee and Lucas Formations (approximately the top 50 m of rock). These rock formations exhibit natural open joints, fractures, and other features, typical to these formations throughout the region. During conventional investigations for detail design, particular attention should be given to these features through a combination of angled and vertical cored holes to ascertain whether or not a program of foundation rock improvement may be required during construction. Provided that the bridge structures are located outside the limits described in this report, it is considered that issues associated with these natural features, artesian groundwater conditions, and hydrogen sulphide within the groundwater, may be the most significant geologic issues for foundation design and construction.



LEGEND

- Drilled Holes
- Other Wells or Boreholes
- Cavern Storage Well
- Solution Mining Well
- Boundary of Primary Solution Mining Influence
- Boundary of Secondary Solution Mining Influence
- Major Road
- Local Road
- Sinkhole, 1954
- Water



REFERENCE

Base Data - MNR NRVIS, obtained 2004, CANMAP v7.3 2003
Orthophotos - URS, obtained 2004 and 2005
Wells from AMEC and the Ontario Ministry of Natural Resources, Oil Salt and Gas Resources Library.
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Datum: NAD 83 Projection: UTM Zone 17N

0 100 200 400 600
Metres

PROJECT
DETROIT RIVER INTERNATIONAL CROSSING

TITLE
BOUNDARIES OF PRIMARY AND SECONDARY SOLUTION MINING INFLUENCES

Golder Associates
Mississauga, Ontario

PROJECT No. 04-1111-060			SCALE 1:7,500	REV. 1
DESIGN	CC	24 May 2006		
GIS	PB	08 Feb. 2008		
CHECK	JM	08 Feb. 2008		
REVIEW	SB	08 Feb. 2008		

FIGURE: ES-1

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