Project Overview

Onyx Special Services, Inc was retained to complete required routine Department of Transportation Inspections on 2 each, 24 inch diameter steel pipelines crossing the Straits of Mackinac. These lines run parallel to each other and are separated by approximately 1000 feet along the 4.6-mile length of the crossing, and are situated in water depths ranging from 0 to 250ffw. Both lines are buried out to water depths of approximately 50 feet, then lie uncovered on the bottom.

The focus of this inspection was to positively identify existing conditions, which could potentially compromise the safety of the line. Examples of these conditions could include exposed or unsupported areas of pipe, severely degraded or missing coating, or damage caused by impact.

Inspection services began with multi-beam sonar inspection, which were completed on June 7, 2003. Once the initial multi-beam sonar inspection was complete, a remote operated vehicle was mobilized. ROV video records indicated that numerous spans exceeded the design tolerances of the line. As such, Onyx was mobilized to place designed supports within these problem spans. This report includes data on this repair operation as well as the initial inspection.

Equipment and Personnel Overview (Inspection Only)

For this inspection, Onyx mobilized a vessel and respective sets of equipment. The multi-beam system was used to chart bathymetry on and 250 feet around the length of each line. This package consisted of the following:

- 40' crew vessel "Timmy V"
- Sound velocity meter (for calibrating to sound velocity in actual water conditions)
- Differential GPS equipment (sub-meter accuracy)
- Offshore safety package
- Motion reference unit (TSS – DMS)
- Multi-beam sonar (Sea bat 8125)
- Trent Nedens – Lead survey technician
- Jerry Knisley – Survey technician
- John Schilla – Survey Technician

At the conclusion of the Multi-beam survey equipment and personnel for the ROV inspection were also mobilized. This included the following:

- 40' crew vessel "Timmy V"
- Phantom HD2 remote operated vehicle
- Sector scanning sonar
- Link Quest tracking, short base line acoustic tracking system
- Differential GPS equipment (sub-meter accuracy)
- Computer navigation system
- Video recording equipment
- Comprehensive field spares kit
- Offshore safety package
- Trent Nedens – Project Superintendent
- John Schilla – ROV pilot / survey tech
- Cory Teneyck/Roger Wollangur – Deckhand
- Lee Barnhill – Boat Captain

The Phantom ROV is equipped with a remote pan and tilt video camera with zoom and auto focus controls, as well as 1000 watts of total lighting. For this inspection, the vehicle was also fitted with a sector scanning sonar, which enabled the operator to see objects out of the visual range of the video camera. Navigation was provided by the Link Quest tracking system in concert with DGPS tracking and a standalone computer with Coastal Oceanographic's Hypack software. In use, the ROV is fitted with an acoustic pinger, which sends out a sound signal to be picked up by a hydrophone mounted on the side of the surface support vessel. The offset of the vehicle (calculated by Link Quest) is fed to the navigation computer that plots a corresponding XY position based on DGPS information. Video from the on-board camera is recorded in VHS format, with the operator entering position information to the on-screen display.

Summary of Methods / Equipment Limitations (Inspection Only)

Multi-beam Sonar

The multi-beam system employed for this survey utilized a Reson Sea bat 8125 multi-beam echo sounder and processor capable of 455kHz, 120° swath, 240 focused beams 0.5° x 1.0°, max range 120. The swath width and update rate varied with depth (i.e., swath width is equal to twice the water depth below the sonar head). Onyx used HYPACK (a multi-beam sonar integrating and operating system by Coastal Oceanographics) as the multi-beam sonar integrating and operating system. A Trimble AG132 DGPS unit, TSS Standard gyro (heading), and TSS DMS 2, MRU usually round out the system. On average, for the depths associated with this survey, the multi-beam system was accurate to ± 3 to 4".

The multi-beam sonar system was used to collect data in the specified survey area where the current water depth was > 10' deep. Daily QA/QC procedures involved system checks for the TSS standard gyro, and the MRU. The Multi-beam sonar then was tested by running programs called "patch tests" through the HYPACK collection software; these tests calculated and applied correction values to the data to compensate for any sonar reading inaccuracies. In addition, a final "bar check" was done after the patch tests were completed to check the corrected sonar depth value. The bar check was done daily during all multi-beam surveys. After all tests and checks were complete, the system was ready to collect data.

HYPACK records the corrected multi-beam data as survey line files. A survey line file is created by starting the data logging function within the software at the beginning of a survey run. The software collects 240 depth points along a line perpendicular to the boat's travel path (called the "swath") at an update rate of 10 to 15 times per second (the update rate is variable, and is dependant on water depth and sound velocity). Once data are being recorded, the boat operator guides the boat along a path through any areas not previously covered by the sonar. The amount of data collected in a file is dependent on the length of the survey line. After all the data that can be collected on a particular run are recorded, the data logging function is deactivated and the data are stored as one complete survey line file (000_####.xyz). The data is saved in ASCII Delimited Text x,y,z format within the survey line file. This process is repeated until all portions of the survey area have been covered.

The goal of this multi-beam survey was to provide enough coverage to create a bathymetric map of the entire survey area and cross- sections at 200' intervals. HYPACK can convert geographic coordinates; thus, allowing the user to collect survey data in a number of different horizontal and vertical datums. The multi-beam data for this survey was collected in the *State Plane (NAD 83) - Michigan Central Zone* horizontal datum, and vertical datum *IGLD 85*.

After the raw line survey data files were downloaded from the survey boat computers, post-processing of the data was performed. Raw multi-beam data contains a small amount of "spikes",

irregular "returns", and other anomalies that must be filtered and edited out before it can be used. The HYPACK software contains a data editor, which was used to remove these anomalies. After the data was edited, it was re-saved as survey line files (with the same .dat or .xyz extension) in .xyz format. All of the individual survey line files then were combined into one unified data file with either a (.dat) or (.xyz) extension. Over 36.8 million data points were retained after editing and used to create the maps and cross-sections for this survey.

Next, the unified bathymetric data file was converted into a grid-file using SURFER 7.0 software. SURFER offers eight different grid interpolation methods for gridding survey data. Each user-specified method uses a different algorithm to calculate grid nodes. The data set for this project favors the Triangulation w/ Linear Interpolation gridding method due to the high number of data points in the surveyed area. Using this method, a grid size of 5' square was determined to be the best fit for the survey data.

The final step was to generate a contour map and cross sections of the bottom using the grid file. A contour map was generated, and the pipeline routes, were overlaid onto it. Next, cross sections were drawn every 1000' along each pipeline.

Remote Operated Vehicle

Once data has been gathered as acoustic records, video documentation is encouraged in order to provide definitive ground truthing of the indications on the sonar record. The ROV is a free-swimming vehicle tethered to a surface support vessel and controlled by personnel on-board. Navigation and positioning is provided by differential GPS with an acoustic link to the ROV, all plotted out on a separate computer screen.

The main limitations to this equipment are related to water clarity (visibility), water current, and surface weather and wave conditions. Obviously, in highly turbid water conditions, an acceptable video record is impossible to generate, Fortunately water clarity for this project was exceptional, allowing for a very clear video record. Higher water velocities (current) can pose difficulties in keeping the vehicle on station, or even getting it to the target. Currents of 1 to 2 knots were encountered during this project, which did pose challenges.

The most prevalent limitation of this equipment is imposed by weather conditions. High winds/waves make for difficulties in keeping the vessel on station (dragging anchors) as well as degrading the accuracy of the acoustic tracking system (due to the pitching and rolling of the vessel and hydrophone combination). Throughout the survey period we encounter zero weather days:
Multi-beam – June 5-7, 2003
ROV survey – June 19 – 21, 2003
ROV survey – July 28 – 31, 2003
Sea-Spider retrieval and deployment – July 31 through August 1

In operation, the vessel crew positions the support vessel over the pipeline utilizing a 2 point anchoring system. With evidence of a strong differential lock on the GPS as well as a solid return from the vehicle tracking system, the vehicle is launched from the surface to begin its descent to the bottom. Once on bottom, the operator utilizes both the navigation system as well as the sector scan sonar to guide the vehicle to the pipeline. With the pilot free to fly the vehicle, the survey supervisor takes notes with further direction given by the client representative on site. "Parking" the vehicle at the desired location attains accurate location of anomalies, while the Link Quest

tracking and DGPS stabilize and update the position. This position is noted in the inspection log as well as typed into the on-screen display for future reference.

Findings

The ROV survey inspection took place at two separate intervals. June 19 – 21, 2003 were dates for the ROV inspection of the east pipeline. July 28 – 31, 2003 were dates survey inspection for the west pipeline. Data obtained by the ROV survey inspection closely followed past findings and data obtained in the 2001 survey. During this time, spans over 195' in length, notification was given that the line would have to be shut down until the necessary repairs had been made. Spans of over 140' in length were documented as in need of repair. Spans under the 140' in length were documented. The spans, which were identified as needing immediate attention, are as follows:

Span #	Pipe Line	NAD 83 Begin (Y)	NAD 83 End (Y)	Span Length	Span Height	Water Depth
1	East	913913	913704	224	48"- 60"	61
5	East	914168	914317	157	24"	160
8	East	912288	912443	164	48"- 60"	220
19	East	911941	911786	163	12"	140
23	East	906150	905975	185	18"- 24"	80
32	East	907621	907424	201	18"- 24"	100
34	East	907263	907127	139	24"	80
1	West	904937	904788	153	24"	80
29	West	909038	908895	147	36"	140
42	West	910618	910482	140	42"	170
43	West	910469	910325	149	60"	160
48	West	911328	911188	144	30"	175
58	West	913768	913665	106	24"	190
59	West	913665	913390	286	30"	220
60	West	913916	914072	162	24"	155
68	West	912063	911920	148	30"	220
72	West	912214	912337	124	48"	220

Note: The above locations are based on the Y coordinate plotted along the mapped pipeline route.

On July 31, 2003 through August 1, 2003 of the ROV survey, data collection from the recovery of sea spiders and profilers, that were located in specific locations along the east and west pipelines. Data was downloaded, batteries changed and spiders/profilers were re-deployed to specific locations, which are listed below:

Unit #	Pipe Line	NAD 83 Spider	NAD 83 Profiler	Deploy Date	Estimated Battery Life	Water Depth
1	East	913991	913970	07/31/03	300 days	200
2	West	912082	912075	07/31/03	300 days	220
3	West	909429	909410	08/01/03	300 days	110
4	East	905920	905918	08/01/03	300 days	80

Identified Spans (East Pipeline):
Note: The spans in bold are also listed in the table above.

Span #	Pipe Line	NAD 83 Begin	NAD 83 End	Span Length	Span Height	Water Depth
1	**East**	**913913**	**913704**	**224**	**48"- 60"**	**61**
2	East	913688	91600	92	12"- 24"	220
3	East	913332	913271	73	60"- 72"	220
4	East	914008	914140	133	36"	200
5	**East**	**914168**	**914317**	**157**	**24"**	**160**
6	East	914533	914604	77	24"	120
7	East	914627	914696	71	12"	100
8	**East**	**912288**	**912443**	**164**	**48"- 60"**	**220**
9	East	912498	912531	35	12"	220
10	East	912604	912662	64	48"- 60"	220
11	East	912670	912732	69	48"	223
12	East	912795	912836	45	12"	228
13	East	912898	913019	122	36"- 48"	228
14	East	913038	913116	83	36"- 48"	230
15	East	912251	912172	81	36"	190
16	East	912166	912120	47	48"	180
17	East	912056	912037	19	12"	160
18a	East	912004	911985	21	24"	160
18b	East	911975	911949	28	24"	160
19	**East**	**911941**	**911786**	**163**	**12"**	**140**
20	East	911777	911800	40	12"	140
21	East	911717	911742	26	12"	140
22	East	911586	911659	76	72"	140
23	**East**	**906150**	**905975**	**185**	**18"- 24"**	**80**
24	East	905872	905818	56	18"	80
25	East	905729	905636	96	12"- 18"	80
26	East	905595	905551	49	12"	80
27	East	906241	906298	61	12"- 18"	80
28	East	906355	906475	126	24"	80
29	East	906490	906548	59	12"	80
30	East	906573	906646	77	24"	85
31	East	907675	907640	37	18"	100
32	**East**	**907621**	**907424**	**201**	**18"- 24"**	**100**
33	East	907404	907363	43	18"	100
34	**East**	**907263**	**907127**	**139**	**24"**	**80**
35	East	907113	907039	83	12"	80
36	East	906999	906964	35	12"	75
37	East	906951	906902	49	12"	75
38	East	906735	906703	32	6"	75
39	East	907739	907815	80	24"	100
40	East	908157	908241	85	12"	100
41	East	909162	909095	71	18"	100
42	East	908964	908867	102	24"- 36"	101
43	East	908837	908786	54	18"	100
44	East	908714	908689	30	18"	100

45	East	908545	908492	53	18"	101
46	East	908469	908412	57	24"	96
47	East	909323	909387	68	18"	100
48	East	909411	909518	108	24"	100
49	East	910717	910689	30	24"	140
50	East	910665	910615	53	30"	140
51	East	910615	910494	127	48"	140
52	East	910486	910469	18	?	130
53	East	910469	910364	108	24”	130
54	East	910362	910266	102	30"	120
55	East	910254	910204	52	24"	120
56	East	910103	910192	90	18"	120
58	East	910834	910898	66	48"- 60”	140
59	East	911084	911168	33	60"	140
60	East	911290	911177	115	42"	140
61	East	911358	911290	72	24”	140
62	East	911439	911403	38	42"	140
63	East	911458	911478	23	36"	140
64	East	911492	911550	60	36"	140
65	East	915198	915095	108	24"	70
66	East	910062	910084	23	12"	120
67	East	910062	910018	46	4"	120
68	East	910018	909984	36	4"	120
69	East	909984	909936	50	4"	120
70	East	909936	909870	68	4"	120
71	East	905229	905291	65	6"	70
72	East	905291	905329	40	12"	70
73	East	905087	905007	85	6"	70
74	East	905007	904920	92	12"	70
75	East	904838	904762	85	12"	70

Identified Spans (West Pipeline):
Note: The spans in bold are also listed in the table above.

Span #	Pipe Line	NAD 83 Begin	NAD 83 End	Span Length	Span Height	Water Depth
1	**West**	**904937**	**904788**	**153**	**24"**	**80**
2	West	905987	905930	59	24"	70
3	West	905912	905872	41	24"	70
4	West	905870	905852	18	24"	70
5	West	90633	905558	77	12"	70
6	West	906000	906067	69	24"	70
7	West	906154	906172	79	18"	70
8	West	906180	906199	21	12"	70
9	West	906232	906283	53	24"	75
10	West	906667	906618	50	18"	75
11	West	906423	906385	40	36"	75
12	West	906811	906900	91	30"	85
13	West	906970	907034	66	24"	85
14	West	907067	907117	52	12"	85
15	West	907459	907415	47	12"	90
16	West	907155	907120	37	12"	90
17	West	907574	907612	40	9"	100
18	West	907625	907718	96	18"	120
19	West	907718	907818	103	24"	120
20	West	907862	907900	40	12"	120
21	West	908290	908220	73	18"	120
22	West	908168	908136	33	9"	120
23	West	908094	907983	114	9"	120
24	West	907963	907903	61	24"	120
25	West	908390	908426	41	6"	120
26	West	908508	908571	65	16"	120
27	West	908657	908679	24	18"	120
28	West	909095	909051	46	24"	140
29	**West**	**909038**	**908895**	**147**	**36"**	**140**
30	West	908754	908682	75	24"	135
31	West	909219	909241	24	18"	140
32	West	909241	909320	81	9"	140
33	West	909338	909381	43	6"	130
34	West	909415	909515	101	24"	130
35	West	909836	909718	122	12"	130
36	West	909718	909627	99	12"	130
37	West	909599	909522	78	12"	130
38	West	909911	909947	38	6"	135
39	West	909947	909961	14	12"	135
40	West	909961	910020	61	12"	135
41	West	910178	910239	62	36"	140
42	**West**	**910618**	**910482**	**140**	**42"**	**170**
43	**West**	**910469**	**910325**	**149**	**60"**	**160**
44	West	910301	910240	65	12"	150
45	West	910646	910664	18	12"	170

46	West	910731	910779	49	9"	180
47	West	910934	910974	41	48"	180
48	**West**	**911328**	**911188**	**144**	**30"**	**175**
49	West	911188	911123	67	30"	175
50	West	911099	911084	16	6"	170
51	West	911047	910969	81	24"	175
52	West	911330	911396	68	9"	165
53	West	911505	911601	103	4"	175
54	West	912975	912904	73	36"	240
55	West	912867	912814	57	18"	240
56	West	912638	912586	53	12"	240
57	West	913053	913124	74	36"	235
58	**West**	**913768**	**913665**	**106**	**24"**	**190**
59	**West**	**913665**	**913390**	**286**	**30"**	**220**
60	**West**	**913916**	**914072**	**162**	**24"**	**155**
61	West	914152	914234	87	18"	130
62	West	914591	914547	46	12"	100
63	West	914896	914959	66	9"	80
64	West	915316	915229	89	6"	75
65	West	915219	915145	77	12"	75
66	West	915733	915682	53	18"	75
67	West	915483	915399	87	21"	75
68	**West**	**912063**	**911920**	**148**	**30"**	**220**
69	West	911803	911725	81	9"	180
70	West	911688	911618	70	21"	180
71	West	912157	912214	57	48"	220
72	**West**	**912214**	**912337**	**124**	**48"**	**220**
73	West	912358	912433	78	18"	245
74	West	912433	912510	82	24"	250
75	West	912542	912584	44	16"	250

Both the East and West pipelines show intermittent suspension over their entire length. Previous grout bag repairs were noted on the West line where the pipeline no longer rested on the bag. The exposed portion of the pipeline is heavily covered in zebra mussel growth, making a detailed analysis of the coating and actual pipe condition impossible. Additionally, areas of debris encroachment as well as cables lying over the pipeline were noted (see attached inspection log).

Repair Operations

On June 12, 2003 Onyx Special Services, Inc. was contracted along with Durocher Marine to mobilize equipment and personnel necessary for repairs to effected areas. Onyx Special Services, Inc. would provide the diving and navigation/positioning services while Durocher Marine would provide barges and tug boat.

Diving operations for the east line repairs began on June 23, 2003 and went through July 3, 2003. Spans on the east pipeline, which were of immediate concern, were:

- East Line - # 32, because span length of 201' in length, which required the line to be shut down until repair was done. Then repairs to #1, #5, #8, #19, #23, and #34, not in specific order. (Also, see table above)

Diving operations for the west line repairs began on July 28, 2003 and went through August18, 2003. Spans on the west pipeline, which were of immediate concern, were:

- West Line - # 59, because span length of 286' in length, which required the line to be shut down until repair was done. With the length of this span being so long, it required two designed anchors. Then repairs to #1, #29, #43, #48, #58, #60, #68, and #72, not in specific order. (Also, see table above)

Given the length of the spans, Enbridge Energy determined importance and placement of designed screw anchor repairs. In total there were 150 spans identified. Of this number, 2 have been identified over 195' in length, which require the pipe line to be shut down and 17 total have been identified as spanning over 140' in length, with 17 total spans currently repaired.

For details on the repairs completed, see attached Pipeline Repair Information Sheets.

Diving Equipment

The following equipment was mobilized to Durocher Marines yard in Cheboygan Michigan for setup on barges.

- Mixed gas control Trailer
- 2 – 54" deck decompression chambers
- 4 – Hot water machines
- 2 – Quincy 5120 divers air compressors
- 150kw Multiquip generator
- Class 2 diving bell and Handling system
- 2 – Underwater video and lighting systems
- Phantom HD2 Remote Operated Vehicle
- Imigenix sector scan sonar
- Link Quest tracking Plus tracking system with 5 beacons
- 2 - Hypack navigation computers
- Trimble DGPS
- TSS Standard Gyro- compass
- 3 – 600' Divers umbilicals
- Mixed gas stores
    - 100% Oxygen (Decompression gas)
    - 8416 HeO2 (Bottom mix)
    - 8614 HeO2 (Bottom mix, emergency gas)
    - 6040 HeO2 (Decompression gas)
    - 6040 Nitrox (Treatment gas)
- Miscellaneous diving and construction equipment (Hoses, extension cords, torches, tools, etc.)

Due to space and weather considerations the above equipment was setup in storage containers stacked and sea fastened to the barge. Navigation and positioning equipment was set up in both the dive trailer as well as the primary tugboat. The navigation computer mounted in the dive trailer tracked the barge heading and position, ROV position, Bell position and Anchor drilling tool position.

Repair Sequence

- Span coordinates identified from the ROV survey used to plot anchor and mooring locations.
- Barge is positioned over anchor locations identified on the Hypack computer screen. The anchors are then dropped approximately 750' from the pipeline and 1000' apart. Once both anchors are in position (2 anchor spread off the stern of the barge) the barge is towed into position and held in place with a constant speed and heading from the tugboat.
- The ROV is launched so that a specific repair procedure and location can be selected. Locations were selected based on their proximity to the center of the span, type of bottom encountered (smooth or irregular, hardness) and span height.
- The dive bell is then lowered to the work site, guided by the ROV. Adjustments are then made for barge positioning.
- When positioning of the barge is finished, the hydraulic drilling tool is then lowered to the work area and is held by the crane approximately 20' away from the pipeline. Also guided by the ROV.
- The screw anchor and saddle support, which is a prefabricated design. Is designed to drill along both sides of the pipeline. Extensions can be added, for adjustment with sub-bottom material or span height. When drilling into the sub-bottom, a specified hydraulic pressure must be met. At which time, the upper and lower support saddle support is installed. Placing the support over and under the pipeline and then all-thread bolts bring all the support saddle together.
- Dive operation begins and bottom time starts when the diver leaves the surface.
- Once on bottom, the diver will bring the drilling tool over the pipeline and lowers the drilling tool into place. Once in place, drilling to proceed. Diver will monitor drilling process until complete. When drilling is complete, the 3-pin assembly is disconnected and the hydraulic tool is lifted off the screw assembly and safely placed off the East Side of the pipeline to prevent dragging back into the pipe.
- Diver will then assemble the anchor and saddle into place.
- A repair (as detailed in above) is completed.
- The final inspection and position of the pipeline repair is recorded from the ROV. Diver was brought to the surface and decompressed.
- This process usually entailed multiple dives to complete.

Recommendations

With the pipelines left in their current condition, it is the opinion of Onyx Special Services, Inc. that a continued inspection program be implemented. This inspection could be conducted utilizing side-scan sonar, which has proven quite effective at identifying potential spans, as the first step, followed by ROV inspections of any identified areas of concern