AECOM
99 Commerce Drive 204 477 5381 tel
Winnipeg, MB, Canada R3P 0Y7 204 284 2040 fax
www.aecom.com

Project:	**Kildonan-Redwood Feeder Main Pipe Inspection**	Date:	March 29, 2019
Contractor:	J-Con Civil Ltd.	Project #:	60549028
Owner:	City of Winnipeg	Weather:	Snow, Blustery, -5° C

Inspection Report

On March 29, 2019, Marshall Gibbons of AECOM performed a visual inspection of the 600mm-diameter Kildonan-Redwood Feeder Main within the tunnel on the west side of the Red River crossing (Figure A 1 and Figure A 2). The purpose of AECOM's inspection was to:

- Evaluate the exterior condition of the feeder main and its joints within the tunnel;
- Detect and measure sites of corrosion on the exterior of the pipe and measure remaining pipe wall thickness at said locations using an ultrasonic thickness gauge. The data collected would be compared with the results of the inline electromagnetic (EM) survey of the feeder main completed by Pipeline Inspection and Condition Analysis Corporation (PICA);
- Evaluate the general condition of the tunnel structure based on cursory visual inspection; and
- Evaluate the accuracy of information depicted on historic WWD drawings (WA-12530 and WA-12531).

Concurrently, two workers from PICA examined the exterior condition of the feeder main, with attention being given to locations where electromagnetic anomalies were detected by the inline EM survey. Selected photos from the inspection are attached as Appendix A.

Background

Notes on historic drawing WA-12530 and details included in a water industry publication [1] indicate the river crossing pipe was constructed primarily of 610 mm (24-inch) diameter spiral-welded steel with a wall thickness of 7.94 mm (0.3125 inch) and conforming to American Water Works Association (AWWA) standard specification 7A.4-1949 [2]. The steel riser pipe in the shaft on the west side of the river crossing was to have a wall thickness no less than 12.7 mm (0.5 inch). For protection against corroding, the interiors and exteriors of the pipes were coated with coal tar enamel (CTE), with an added protective felt wrap installed on the exterior of the pipe, in conformance with AWWA standard specification 7A.6 [3]. Flanged pipe joints with stainless steel fasteners were used in preference to welded pipe joints, and a few Victaulic-coupled joints were used within the tunnel.

Inspection

At the start of the inspection, AECOM attached a measuring tape to the flange of the 90-degree elbow at the base of the tunnel shaft, and PICA layed-out the tape along the top of the feeder main to the east end of the tunnel. As this was being done, AECOM measured the locations of pipe features along the tunnel. PICA then

[1] *W.L. Wardrop, A New 24" Watermain Crossing Under The Red River At Redwood Avenue, Western Canada Water and Sewage Conference, Sep. 20, 1955, 13 pp.*
[2] *AWWA Standard Specification 7A.4 – 1949, Steel Water Pipe Of Sizes Of 4 Inches Up To But Not Including 30 Inches.*
[3] *AWWA Standard Specification 7A.6, Coal Tar Enamel Protective Coatings For Steel Water Pipe, Sizes Up To 30 Inches.*

returned to the tunnel shaft and commenced their inspection of the feeder main in an eastward direction. After reaching the east end of the tunnel, AECOM inspected the feeder main and tunnel in a westward direction, with the locations of features and defects being recorded based on distance from the base elbow and clock position around the pipe circumference (clock reference facing westward). A summary of feeder main features and their condition is provided in Table 1.

Table 1 - Summary of Feeder Main Features and Their Condition.

Feature	Distance From East Wall of Shaft (m)	Asset Condition	
		Connector	Fasteners
Face of Lower Elbow Flange	-1.18	--	--
E Wall of Shaft	0.00	Good	Good
Victaulic Coupling	2.77	Poor	Good
Pipe Strap and Pedestal	5.25	Good	Good
Flange Connection	7.09	Good	Good
Victaulic Coupling	11.36	Poor	Good
Pipe Strap and Pedestal	12.35	Good	Good
Flange Connection	15.63	Good	Good
Pipe Strap and Pedestal	18.34	Good	Good
Flange Connection	19.91	Good	Good
Victaulic Coupling	24.19	Poor	Good
Pipe Strap and Pedestal	24.74	Good	Good
Flange Connection	28.45	Good	Good
Pipe Strap and Pedestal	30.92	Good	Good
Flange Connection	32.73	Good	Good
Victaulic Coupling	37.01	Poor	Good
Pipe Strap and Pedestal	37.75	Good	Good
Flange Connection	41.27	Good	Good
Pipe Strap and Pedestal	43.89	Good	Good
Flange Connection	45.55	Good	Good
East Wall of Tunnel	49.02	Good	Good

Key observations from the inspection are as follows:

- The exterior of the feeder main pipe appears in very good condition; no corrosion of the pipe was observed.
- Locations of pipe features are accurately depicted on historic drawing 12531.
- Defects/conditions observed on the pipe segments include:
  - Only one break in the pipe coating was observed, 50 mm from east end of tunnel at 2:30 o'clock. The break was 25 mm-diameter and occurred only in the exterior CTE-saturated felt outer wrap. The outer wrap was slightly delaminated from the inner primary coating around the break, and groundwater had seeped into the space between the coating layers.
  - Several blemishes in the coating as may be caused by lifting the pipe with straps or forks while the coating was soft.
  - Dents or gouges in the steel pipe and coating caused by mechanical forces, which required the coatings to be repaired. PICA advised that such damage may be detected by their EM tool because it causes stress-related changes in the steel.
- Flanged connections were in good condition, exhibiting only slight general corrosion. Fasteners, which appeared to be galvanized or stainless steel, also were in good condition.
- Galvanized pipe straps at pedestals were in very good condition.
- Victaulic couplings were severely corroded and should be replaced. The bodies of the couplings were unevenly corroded with the appearance of grey cast iron, a brittle material. The underlying restraining rings

on the feeder main pipes, where visible, appeared in good condition and were smooth-surfaced with no pitting observed. The fasteners on the couplings also appeared in good condition.

- The finished tunnel length is 49.02 m (160.83 feet), not 57.3 m (188 feet) as shown on historic drawing WA-12531. The water industry publication discussed numerous difficulties that were encountered while constructing the east end of the tunnel.
- Tunnel was in good condition, but water was observed seeping (dripping to slow running) from some of the concrete cold-pour joints that were spaced at 4 or 6 feet along the tunnel.
- The original Universal cast iron air piping had been replaced with aluminum pipe, which has suffered galvanic corrosion due to direct contact with the steel or iron pipe hanger assemblies. Condition of the aluminum piping ranged from being relatively uncorroded to being completely perforated.
- The built-in air piping system was effective in ventilating the tunnel.

Since the length of the tunnel was shorter than depicted on drawing 12531, AECOM requested that PICA review the EM data to determine if any of the features outside the tunnel (bends, connections and pedestals) also had been relocated. PICA advised the following (see Figure 1):

- The data shows what potentially are two welds associated with each of the 30° flanged bends. At each bend there is a single 30° deflection at the weld furthest away from the flange. Drawing 12531 depicts this construction accurately.
- The apparent increase in wall thickness for the pipe at 170 to 174 m (shown with a dashed black line) may be due to rebar within the concrete encasement.
- Regarding the water stop shown within the east tunnel wall on drawing 12531, two wall-gain signals associated with possible water stop locations were identified. However, the signals are quite different from each other so if they are both puddle flanges, the actual flange make-up is different for each.
- In the EM data, PICA can distinguish between flanged and Victaulic connections. The connection just beyond the east tunnel wall appears to be a Victaulic, as is shown on drawing 12531. However, the pipe strap and pedestal shown further east does not appear to be present, though it is possible that the wall gain signal marked as a possible puddle flange is in fact the strap support at a relocated position.

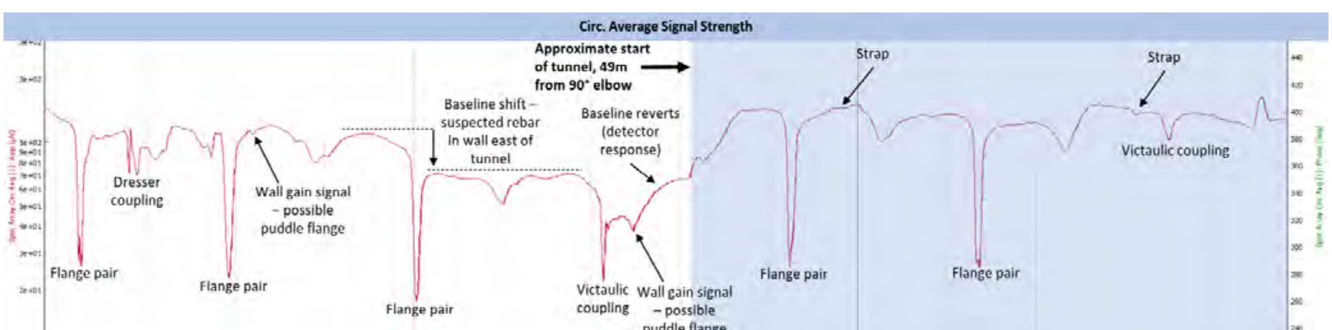

Figure 1 - Electromagnetic Inspection Data for the Feeder Main at the East Tunnel Wall. (East is left; vertical bends are on left side; tunnel area is shown grey)

Recommendations

If the feeder main will remain in service, the following recommendations should be implemented:

- Replace the Victaulic couplings.
- Install a petrolatum tape coating repair (mastic and tape wrap) around the feeder main pipe at the coating break near the east tunnel wall. The repair should extend from the wall to 0.2 m from the wall.
- Install petrolatum tape coating system over all flanged connections. Clean dirt and corrosion from flanges prior to coating and use profiling mastic to fill irregular spaces between flange fasteners, creating a smooth surface for tape wrapping.
- Repair or replace the deteriorated tunnel ventilation pipe. Options include:
  - Replace the existing aluminum piping with plastic piping (PVC or CPVC) that will not undergo galvanic corrosion on contact with the ferrous metal pipe anchors and will not corrode in the humid tunnel environment. Piping could be socketed for joining by solvent welding.
  - Wrap a neoprene sheet gasket around the air pipe at the hanger points to isolate the aluminum from the steel / iron hangers (eliminate galvanic corrosion) and seal the perforations through the pipe. Gaskets may be held in place by plastic zip ties.
  - Repair or replace the corroded aluminum piping at the anchor locations and secure the piping to the hangers with non-metallic anchors (for example, FRP anchor system).
- Monitor the condition of the ladders in the tunnel shaft.
- Seal cracks and / or joints in the tunnel structure from water infiltration by injecting them with hydrophilic polyurethane grout. Similar repairs have been made throughout the Shoal Lake Aqueduct.

Marshall Gibbons, C.E.T.
Senior Municipal Technologist
Water
MAG/pab

Appendix A

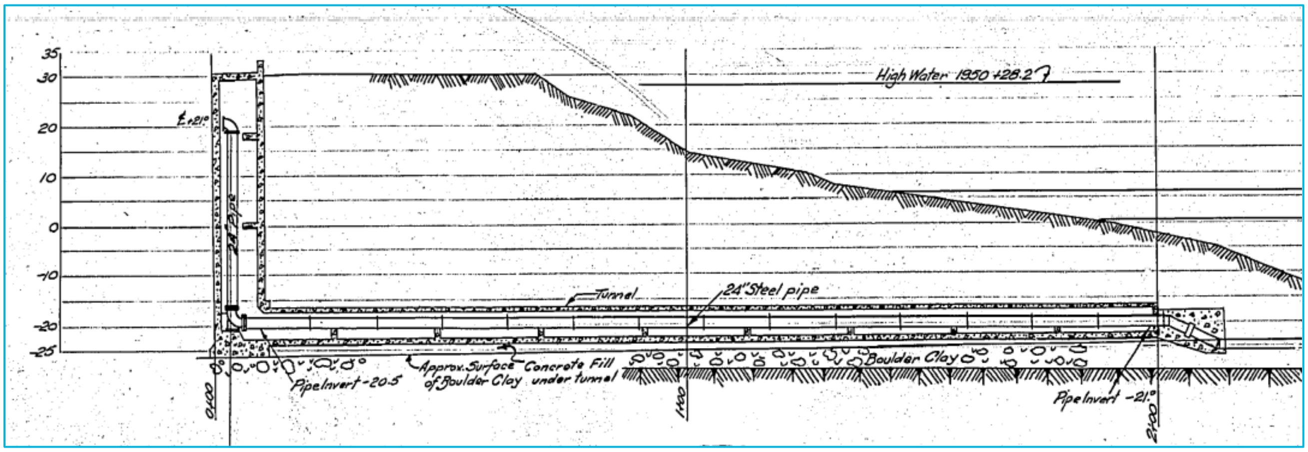

Figure A 1 –Feeder Main and Tunnel on West Side of Red River, View Looking Northward. (From WWD Historic Drawing WA-12535).

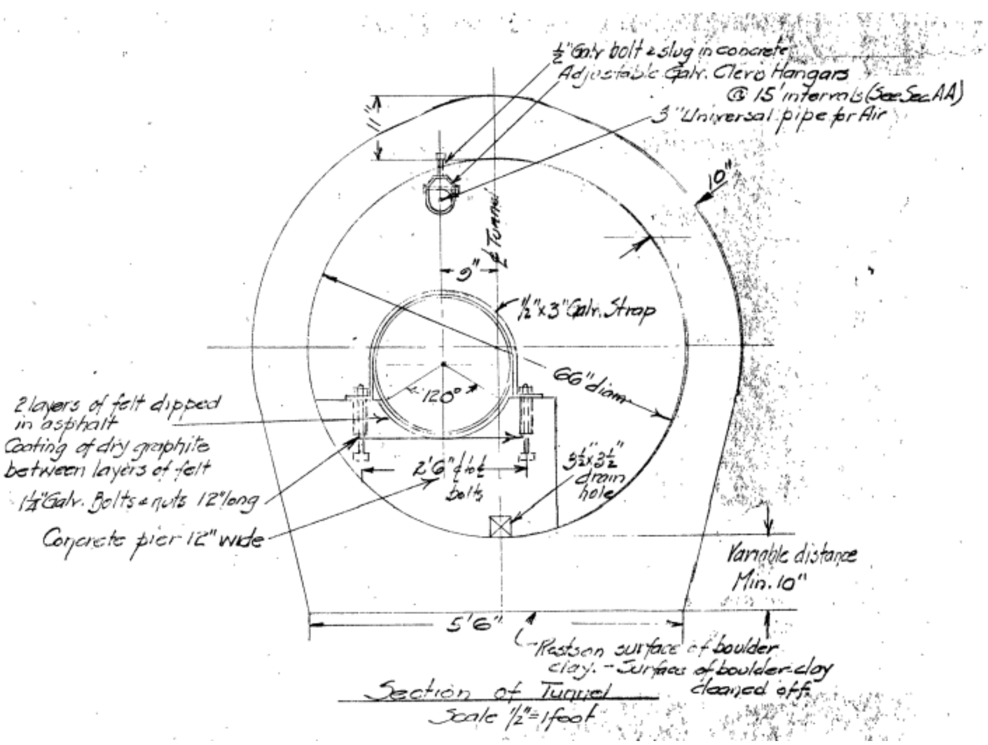

Figure A 2 – Cross-Sectional View of Feeder Main and Tunnel, View Looking Westward. (From WWD Historic Drawing WA-12531).

Figure A 3 – Contractor's Equipment at Top of Shaft on Redwood Avenue.

Figure A 4 – View Into Shaft on Redwood Avenue.

Figure A 5 – View Into Base of Shaft Showing Condition of Galvanized Ladder.

Figure A 6 – View Into 350 mm Water Main Through West Wall of Shaft.

Figure A 7 – East End of Tunnel, 49.0 m From Shaft.

Figure A 8 – End of Aluminum Air Pipe at East End of Tunnel.

Figure A 9 – View of Tunnel, Looking Westward From East End.

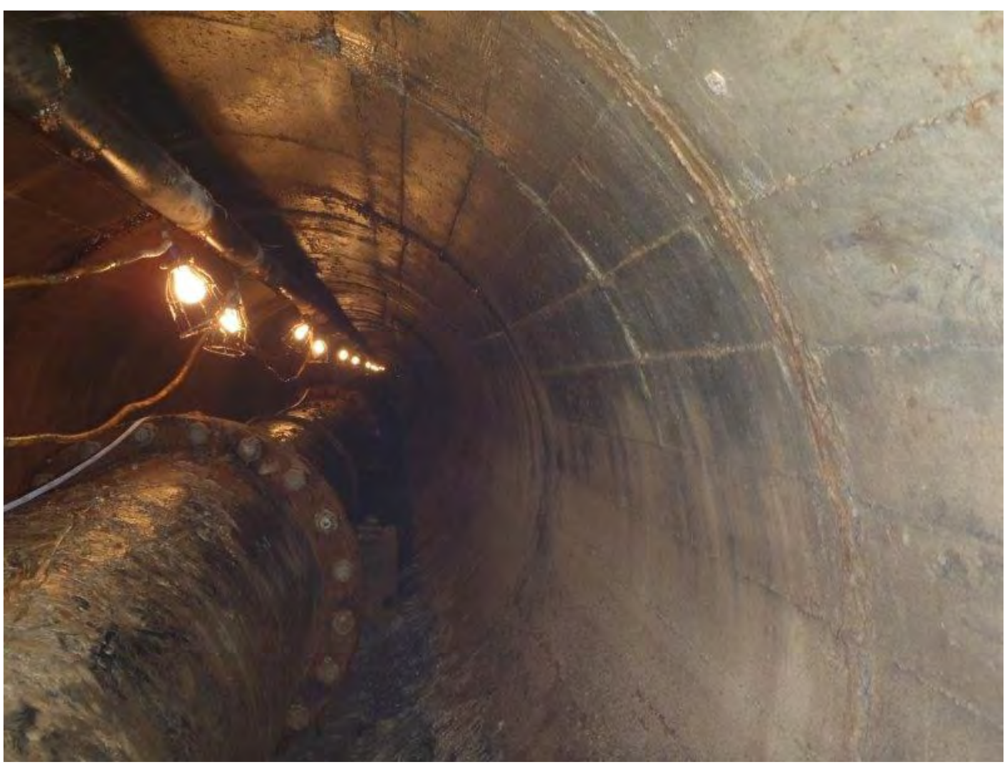

Figure A 10 – View of Tunnel, Looking Westward From East End.

Figure A 11 – Water Infiltrating at Concrete Cold Pour Joint 4.5 m from Tunnel End.

Figure A 12 – Water Infiltrating at Concrete Cold Pour Joint 4.5 m from Tunnel End.

Figure A 13 – Flange Connection at 10:00 o'clock, 46.78 m from Shaft. Note Corrosion Tubercle Between Bolt Heads at 9:30 o'clock.

Figure A 14 –Flange Connection at 6:00 o'clock, 46.78 m from Shaft.

Figure A 15 – Underside of Flange Connection at 46.78 m from Shaft.

Figure A 16 – Typical Galvanized Pipe Strap and Pedestal, 45.12 m From Shaft.

Figure A 17 – Typical Galvanized Pipe Strap and Pedestal, 45.12 m From Shaft.

Figure A 18 –Feeder Main on Pedestal at 6:00 o'clock, 45.12 m From Shaft.

Figure A 19 – Flange Connection at 2:00 o'clock, 42.50 m from Shaft.

Figure A 20 –Flange Connection at 6:00 o'clock, 42.50 m from Shaft.

Figure A 21 – Underside of Flange Connection at 42.50 m from Shaft.

Figure A 22 – Typical Corrosion of Aluminum Air Pipe at Anchor Point, ~40.0m From Shaft.

Figure A 23 – Victaulic Connection at 12:00 o'clock, 38.24 m from Shaft.

Figure A 24 – Victaulic Connection at 2:00 o'clock, 38.24 m from Shaft.

Figure A 25 – Underside of Victaulic Connection at 8:00 o'clock, 38.24 m from Shaft.

Figure A 26 – Underside of Victaulic Connection at 4:00 o'clock, 38.24 m from Shaft.

Figure A 27 – Corroded Body of Victaulic Connection at 1:00 o'clock, 38.24 m from Shaft.

Figure A 28 – Corroded Body of Victaulic Connection at 1:00 o'clock, 38.24 m from Shaft.

Figure A 29 – Corroded Body of Victaulic Connection at 1:30 o'clock, 38.24 m from Shaft.

Figure A 30 – 125 mm-square Dimple in Coating at 2:30 o'clock, 37.20 m From Shaft.

Figure A 31 – Flange Connection at 9:00 o'clock, 33.96 m from Shaft.

Figure A 32 – Flange Connection at 12:00 o'clock, 33.96 m from Shaft.

Figure A 33 – Flange Connection at 5:00 o'clock, 33.96 m from Shaft.

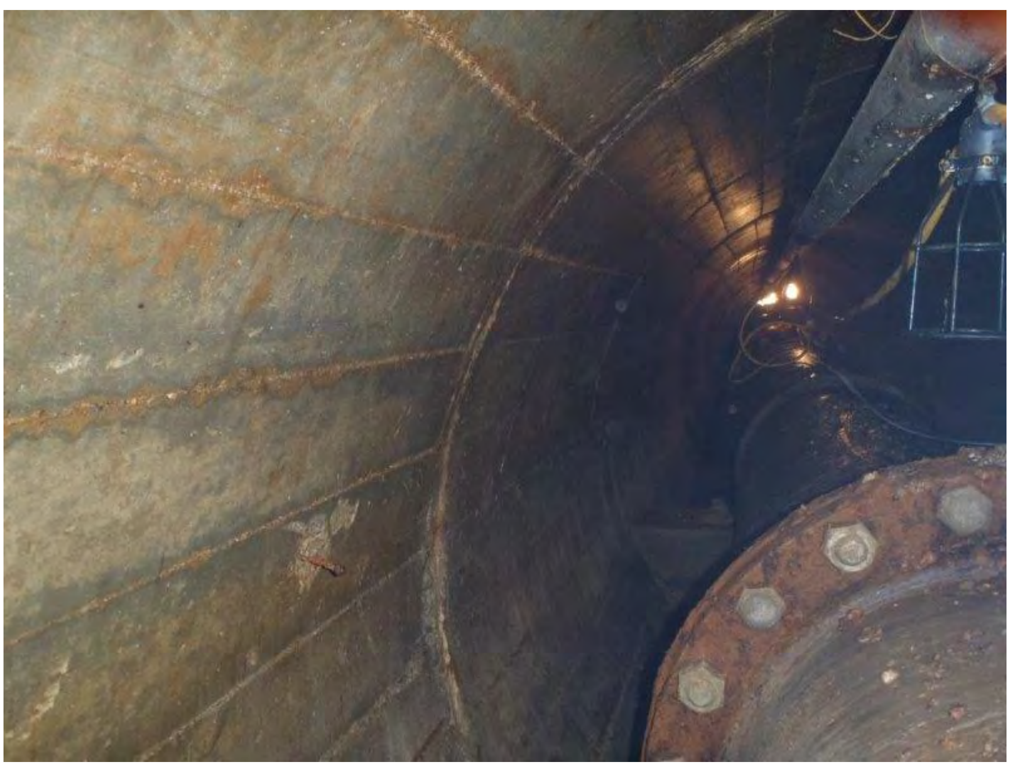

Figure A 34 – View of Tunnel, Looking Westward at 33.96 m From Shaft.

Figure A 35 – View of Tunnel, Looking Westward at 33.96 m From Shaft.

Figure A 36 – Flange Connection at 12:00 o'clock, 29.68 m from Shaft.

Figure A 37 – Flange Connection at 9:00 o'clock, 29.68 m from Shaft.

Figure A 38 –Flange Connection at 6:00 o'clock, 29.68 m from Shaft.

Figure A 39 – Coating Dimple at 11:00 o'clock, 26.30 m From Shaft. Possible Dent in Pipe.

Figure A 40 – Victaulic Connection at 12:30 o'clock, 25.42 m from Shaft.

Figure A 41 – Victaulic Connection at 2:00 o'clock, 25.42 m from Shaft.

Figure A 42 –Victaulic Connection at 6:00 o'clock, 25.42 m from Shaft.

Figure A 43 –Victaulic Connection at 10:00 o’clock, 25.42 m from Shaft.

Figure A 44 – Underside of Victaulic Connection at 8:00 o’clock, 25.42 m from Shaft.

Figure A 45 – Corroded Body of Victaulic Connection at 1:00 o'clock, 25.42 m from Shaft.

Figure A 46 – Flange Connection at 2:00 o'clock, 21.14 m from Shaft.

Figure A 47 – Flange Connection at 5:00 o’clock, 21.14 m from Shaft.

Figure A 48 – Flange Connection at 5:00 o’clock, 21.14 m from Shaft.

Figure A 49 – Coating Dimple at 12:30 to 2:30 o'clock, 20.30 m From Shaft. Possible Dent in Pipe.

Figure A 50 – Corrosion / Perforation of Aluminum Air Pipe, 19.50 m From Shaft.

Figure A 51 – Water Infiltrating (Slow Run) at Concrete Pour Joint, 19.10 m From Shaft.

Figure A 52 – Water Infiltrating (Slow Run) at Concrete Pour Joint, and at 100 mm-diameter honeycomb pocket at 1:00 o'clock, 19.10 m From Shaft.

Figure A 53 – Flange Connection at 1:30 o'clock, 16.86 m from Shaft.

Figure A 54 – Flange Connection at 9:00 o'clock, 16.86 m from Shaft.

Figure A 55 –Flange Connection at 9:00 o'clock, 16.86 m from Shaft.

Figure A 56 – View of Tunnel, Looking Westward, 16.86 m From Shaft.

Figure A 57 – View of Tunnel, Looking Westward, 16.86 m From Shaft.

Figure A 58 – Galvanized Pipe Strap and Pedestal, 13.58 m From Shaft.

**Figure A 59 – Feeder Main Pipe on Pedestal, 13.58 m From Shaft.
Suspect rust staining is from pedestal reinforcing.**

**Figure A 60 – Feeder Main Pipe on Pedestal, 13.58 m From Shaft.
Note graphite paste pipe cushion along surface of coating.**

Figure A 61 – Victaulic Connection at 12:30 o'clock, 12.59 m from Shaft.

Figure A 62 – Victaulic Connection at 2:00 o'clock, 12.59 m from Shaft.

Figure A 63 –Victaulic Connection at 6:00 o’clock, 12.59 m from Shaft.

Figure A 64 –Victaulic Connection at 10:00 o’clock, 12.59 m from Shaft.

Figure A 65 –Victaulic Connection at 8:00 o'clock, 12.59 m from Shaft.

Figure A 66 – Coating Dimple at 1:00 o'clock, 10.50 m From Shaft. Possible dent in pipe.

Figure A 67 – Flange Connection at 2:00 o'clock, 8.32 m from Shaft.

Figure A 68 – Flange Connection at 5:00 o'clock, 8.32 m from Shaft.

Figure A 69 –Flange Connection at 10:00 o'clock, 8.32 m from Shaft.

Figure A 70 – Galvanized Pipe Strap and Pedestal, 6.48 m From Shaft.

Figure A 71 – Galvanized Pipe Strap and Pedestal, 6.48 m From Shaft.

Figure A 72 – Corrosion / Perforation of Aluminum Air Pipe, 7.30 m From Shaft. Water infiltrating tunnel at concrete pour joint near 6.48m from shaft.

Figure A 73 – Victaulic Connection at 2:30 o'clock, 4.60 m from Shaft.

Figure A 74 – Victaulic Connection at 5:30 o'clock, 4.60 m from Shaft.

Figure A 75 –Victaulic Connection at 9:30 o'clock, 4.60 m from Shaft.

Figure A 76 – Base Elbow at Shaft, 2:00 o'clock.

Figure A 77 – Underside of Lower Flange Connection on Base Elbow at Shaft, 4:00 o'clock.

Figure A 78 – Upper Flange Connection on Base Elbow at Shaft, 4:00 o'clock.