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M E M O R A N D U M

DATE: June 27, 2018

TO: Scott Salsbery – City of Lawrence Utilities

FROM: Brian Payne – American Structurepoint

RE: Summary of Indian Creek Interceptor Inspection

CC: Derek Urban – American Structurepoint, Cindy Fort – American Structurepoint

On March 3rd and March 4th, 2018 Redzone Robotics performed inspections of the Indian Creek Interceptor from upstream of Indian Lake (Manhole 30321017) to just downstream of the lake (Manhole 30322044), totaling approximately 3,750 feet. Two different inspection platforms were used: a multi-sensor robot (utilizing closed circuit television (CCTV), sonar, and laser) and a sonar-only robot.

Multi-sensor inspections were successfully completed in the direction of flow for the first 1,366 feet of the interceptor, and against the flow for the last 166 feet of the interceptor for a total of 1,533 feet. The high flow and relatively small pipe diameter prevented the multi-sensor platform from inspecting all 3,750 feet of the interceptor as the multi-sensor robot flipped over multiple times. Sonar profiling was successfully completed for portions of the interceptor that could not be reached by the multi-sensor robot.

Redzone provided an inspection report, CCTV reports, CCTV video, and access to the inspection results through their ICOM software. The reports provided by Redzone are attached to this report along with an Inspection Key Map summarizing the extent of the inspections. For ease of use the Inspection Key Map also labels the sewer segments inspected from 1 to 11, starting from upstream and going downstream.

The CCTV video may be downloaded here: https://structurepoint.sharefile.com/d-sda9188d0398475ca

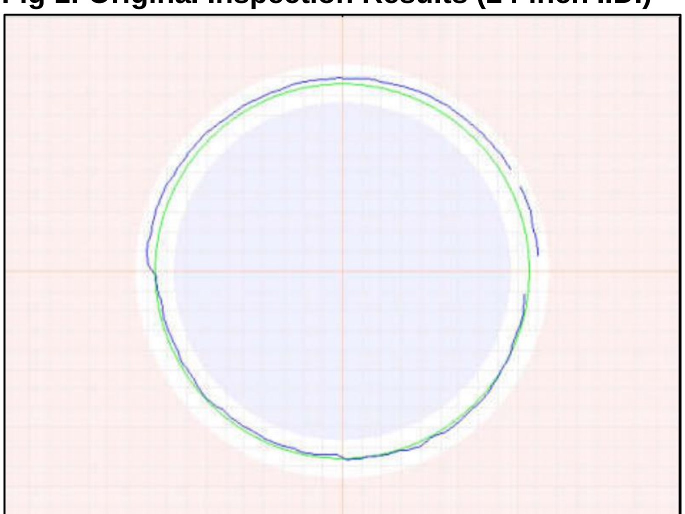
Instructions to download and access the ICOM software are also attached.

The original inspection report from RedZone documented heavy corrosion (0.75 inches to 1.2 inches deep) occurring in some pipe segments. The amount of corrosion or deposition is calculated by comparing the existing inside diameter of the pipe measured at the time of inspection (using laser and sonar) against a reference shape with an inside diameter equal to that of the original pipe when it was installed. Unfortunately, the inside diameter of the original pipe is not known. The as-builts drawings only indicate the pipe material and nominal pipe size, and even this information wasn't entirely accurate as it neglected to indicate the first 100 feet of the sewer was concrete pipe. The actual inside diameter varies depending on the pipe material and class of pipe. A 24-inch concrete pipe does actually have an inside diameter of 24 inches whereas modern 24-inch ductile iron pipe may have an inside diameter of 24.7 inches to 24.9 inches depending on the class of the pipe (with a wall thickness of 0.33 to 0.43 inches excluding the cementitious/asphalt liner).

The heavy corrosion originally calculated would likely have exceeded the thickness of ductile iron pipe resulting in holes in the pipe which were not observed during the inspection. The original pipe wall thickness is unknown, however with help from the Ductile Iron Pipe Research Association (DIPRA) an expected wall thickness of 0.6 inches (including a thin 1/8-inch cementitious lining) was determined for ductile iron pipe installed in 1977. After consultation with RedZone and DIPRA, it was determined that the inside diameter of the ductile iron pipe would be more accurately evaluated as 24.5 inches rather than the 24 inches used in the original inspection report. According to DIPRA, 24.5 inches would be closer to the typical inside diameter of ductile iron pipe manufactured at the time the interceptor was installed (1977).

Redzone issued a revised report on June 18th with the revised 24.5-inch reference diameter for the ductile iron pipe (the first 100 feet of concrete pipe was left at 24-inch diameter). Changing the reference diameter also reduced the overall corrosion which was more consistent with what was visually observed in the CCTV sewer inspection video. The two figures that follow show the sonar and laser inspection results (blue line) at the same sewer location before and after changing the reference shape diameter (green line). Where the blue line is inside of the green line there is deposition; where the blue line is outside of the green line there is corrosion; and where the blue and green line match the pipe is unchanged from its original dimensions at time of installation.

Fig 1: Original Inspection Results (24-inch I.D.)



26.4ft General Observation - Measurement outside reference to 0.7"

Fig. 2: Revised Inspection Results (24.5-inch I.D.)

26.4ft General Observation - Measurement outside reference to 0.4"

Before the diameter change, the reference shape generally matched very closely to the sonar profile (pipe measured below the flow line). RedZone indicated this is typical for relatively clean sewer pipe like the Indian Creek Interceptor. Generally, following the diameter change the shape of the invert and crown of the inspected pipe still match the reference pipe diameter well, but closer to the spring lines of the pipe deposition was now measured near and below the flow line and corrosion above the flow line. There is actually some grease buildup visible in some of the sewer segments near the spring line, which is consistent with this measurement.

Overall, the change of the reference shape to 24.5-inch diameter for Ductile Iron Pipe produced more accurate, realistic results that better fit what was visually observed during inspection. RedZone revised their report based on the new reference shape. The revised inspection report is included with this memo and was used as the basis of this memo.

The sonar inspection of the interceptor provided a complete picture of debris within the inspected portion of the sewer:

- Generally there is very little debris in the interceptor.
- The maximum debris depth is 6 inches and occurs around 120 feet into sewer segment 1 (see Inspection Key Map for segment labeling). Total sediment volume in segment 1 was estimated to be 14.4 cubic feet.
- All other instances of debris are 2 inches deep or less and extend only short distances along the sewer (10 feet or less).

The multi-sensor inspection, although not completed for the entire interceptor sewer, did provide information on corrosion and defects within a sample of the sewer:

- Most of the corrosion observed is half an inch deep or less and occurs just above the average flow depth in the pipes.
- The most extensive corrosion occurs for approximately 150 feet in Segment 1, from 235 feet to 385 feet.
- The maximum corrosion calculated is approximately 0.75 inches deep and occurs around 261 feet, 339 feet, 369 feet, 432 feet, and 450 feet into Segment 1. In these locations, the depth of corrosion calculated exceeds the expected wall thickness of the pipe (0.6 inches). If this were true, holes and likely active infiltration would've been visually observed – but they were not. Therefore, the corrosion doesn't currently exceed the wall thickness but it is uncertain how much wall thickness remains in these locations.

The most significant defects, maximum corrosion depth, and debris depth all occur within sewer segment 1:

- There is a large separated joint approximately 100 feet into segment 1. Encrustations indicate past infiltration but no active infiltration observed.
- The maximum debris depth occurs just downstream of this separated joint. It is unclear if this is just coincidence, or whether the debris may be entering the pipe through the joint. It is also possible that the separated joint modifies the pipe hydraulics creating a location where solids can settle.
- There is a change from reinforced concrete pipe to ductile iron pipe at about 166 feet into segment 1.
- There is also an intruding gasket 193 feet into segment 1.

The remaining segments that were multi sensor inspected had only minor defects and the extent and depth of corrosion were significantly less. Generally, the depth of corrosion was 0.5 inches or less with the exception 0.6 inches of corrosion depth identified in Segment 2 at 59.2 feet, 75.5 feet, 123.2 feet, and 186 feet. No holes were observed in these locations so corrosion hasn't exceeded the wall thickness but it is uncertain how much wall thickness remains. There were several instances of grease attachments, but all were less than 5% of the cross section area.

Conclusion

There are several locations where the inspection results indicate that the corrosion depth has either exceeded the wall thickness or is approaching it. There were no instances of holes visually observed during the inspection, so the pipe wall had not been corroded through at the time of inspection. The differences in corrosion between what was visually observed during inspection and what the sensors (laser and sonar) calculated is concerning. The actual pipe thickness is not known, so a pipe that is thicker than expected could explain the inconsistences. Variances in the pipe manufacturing, particularly the thickness of the cementitious liner inside the ductile iron pipe could also explain some of the inconsistency. The inspection results leave no doubt that corrosion is occurring within the interceptor, but it is still difficult to know with certainty how close the corrosion is to causing failure of the pipe and thus the immediacy for replacing or rehabilitating the sewer.

If the wall thickness of the ductile iron pipe could be determined it would improve the accuracy of the inspection results and allow for better assessment of the existing condition of the pipe. It is not possible to get better information about the original pipe wall thickness, but two methods were developed for possibly measuring the existing wall thickness.

The first and simplest method would be to physically measure the existing ductile iron pipe wall thickness (metal pipe and cementitious liner) where it comes into the downstream manhole. Field observations indicate that the pipe is ductile iron at the downstream manhole, as opposed to the concrete pipe at the upstream manhole. Manned entry would provide the most accurate measurements although it may be possible to measure the pipe from the surface using a Pipe-Mic. The high flow in the interceptor would make manned entry challenging.

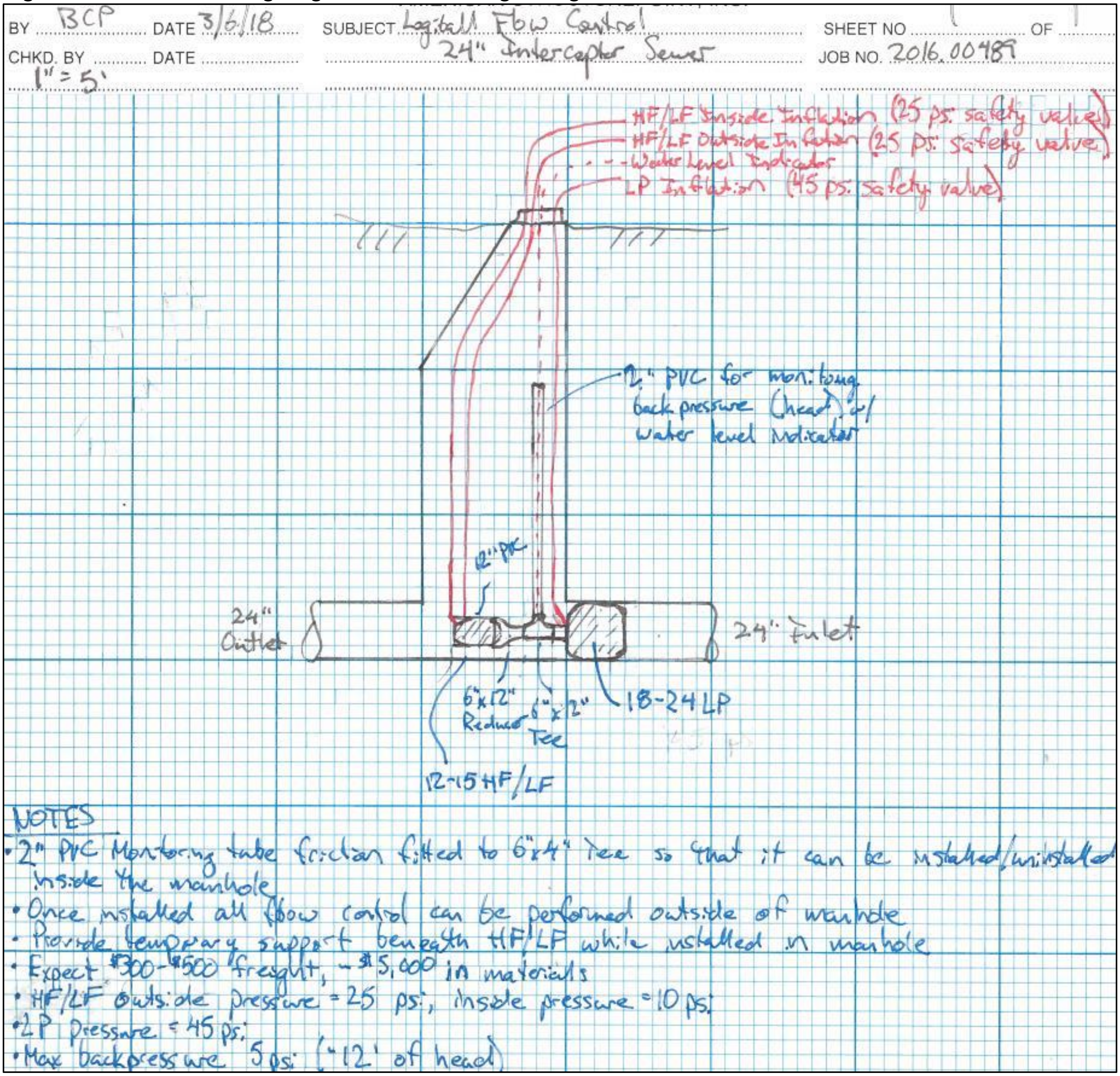
A low flow time could be selected to perform the pipe wall measurements. Alternatively (or in conjunction with low flow timing), flow could be controlled at the upstream manhole to either temporarily reduce or stop the flow in the interceptor as shown in Figure 3.

Flow control is accomplished in Figure 3 using a pair of inflatable flow-through plugs manufactured by Logiball (product brochures attached). The method was developed in consultation with the manufacturer and has the following benefits and costs:

- The flow rate is adjustable from outside the manhole using pressurized air to inflate and deflate the 12-15” high flow / low flow plug.
- Backpressure (surcharging) can be monitored in real time with water level indicator in the 2” PVC monitoring pipe
- Total cost is approximately $5,000 for the materials plus $500 in freight. Some minor labor would require to assemble the piping and plugs

The length of time that the flow in the interceptor could be reduced would depend on the existing flow in the interceptor and the amount that the flow is reduced by the plugs. This method could also be used if future inspections are performed in the interceptor that would benefit from reduced flow.

Fig 3: Flow Control Using Logiball Flow-Through Plugs



A second method to determine the existing ductile iron pipe wall thickness would be to locate, excavate, and then inspect the first segment of the sewer before it continues underwater beneath Indian Creek and Indian Lake. Approximately the first 180 feet of the interceptor sewer is located under soil and vegetation before continuing beneath Indian Creek and Indian Lake, although the first 100 feet are concrete pipe. Several additional technologies and inspection techniques were evaluated for the potential to provide additional information about the current condition of the sewer:

- Electromagnetic locating and potholing of the sewer (where it isn't located beneath Indian Creek or Lake)
- Ground penetrating radar (GPR) locating and potholing of the sewer

- Non-destructive condition assessment (externally applied technology such as Russell NDE Systems Bracelet Probe)

On further evaluation there are several challenges and constraints that would make this method of additional inspection difficult and ultimately impractical.

First, the exact alignment of the interceptor isn't known. In fact, based on the CCTV inspection there seems to be at least one less bend in the actual alignment then shown on the as-builts. It's possible more or less of the sewer may be underwater than the as-builts show. The interceptor will have to be located from the ground surface before any additional inspection can be performed.

Blood Hound was consulted about the logistics and cost of locating the sewer. The sewer's depth (over 15 feet below ground surface) exceeds the ideal depth range of 6 to 8 feet for electromagnetic and GPR locating. Blood Hound put the odds of being able to locate the sewer at less than 50/50. Additionally, GPR requires flat, open ground in order to be implemented. The existing trees would make GPR impractical.

Even if the sewer could be located electromagnetically, potholing would be required for any additional inspection to occur. Again the depth would pose a challenge. Additionally, the close proximity to Indian Creek means dewatering will also almost certainly be required. Tree clearing would likely also be required before any excavation can occur. The hydro-excavating equipment also has a limit of 150 feet of hose length (at most). Because the first manhole is about 50 feet from the road, that means only the first 50 to 100 feet of the sewer could even possibly be exposed, and this would all be concrete pipe.

To do any inspection beyond confirming the outside diameter of the pipe will require benching and shoring of the excavation to make it safe for manned entry. The ductile iron pipe would have to be completely exposed for a tool such as the Bracelet Probe to be placed on the outside of the pipe. However, if all this could be done, it may be possible to assess the remaining wall thicknesses of the pipe. Unfortunately, the only pipe accessible to this method is likely only concrete pipe. If you could get a bit further to the ductile iron pipe it wouldn't be the most heavily corroded. The most heavily corroded segments of the pipe all appear to be either beneath the creek or the lake. Even in the best case scenario these additional inspection methods will be unable to reach the most critical portion of the sewer to determine the remaining wall thickness in the most heavily corroded segments of the pipe.

Finally, with flow control and/or timing inspection for extreme low flows, it may be possible to complete multi-sensor inspection of the remaining sewer. However this would require a separate mobilization (unless coordinated with RedZone as part of future inspections of the Lawrence collection system). The additional inspection would also still be limited by not knowing the original inside diameter and wall thickness of the pipe. The additional inspection could confirm the presence (or not) of corrosion in the remaining sewer segments, but there would still be uncertainty about the remaining wall thickness. Although less than half of the 3,750 of sewer was able to be completely assessed by RedZone's multi-sensor inspection, it's reasonable to assume that the remaining sewer is in similar condition. It was all installed at the same time, by the same contractor, and constructed of the same type of pipe.

It is our recommendation that Lawrence begin planning for either replacement or rehabilitation of the 3,750 feet of the Indian Creek Interceptor evaluated in this memo. Significant corrosion has occurred within portions of the inspected sewer, although there is uncertainty about the actual depth of the corrosion and how much pipe wall thickness remains. Physical measurement of the ductile iron pipe in the downstream manhole may help reduce some of this uncertainty, although any additional methods of assessing the pipe condition seem impractical at this time. If Lawrence does hire Redzone to perform inspections of additional portions of its collection system it would be worth asking them to attempt to inspect the remaining uninspected portions of the sewer utilizing the flow control described in this memo and/or performing the inspection during extreme low flows. However, the risk of another partially-completed inspection and the potential uncertainty in the data don’t warrant the cost of a separate mobilization just for inspection of the Indian Creek Interceptor.