TUDOR ROAD PUMP STATION
ODOR CONTROL
CONCEPTUAL OPTIONS EVALUATION

PREPARED FOR

CITY OF LEE'S SUMMIT, MISSOURI

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1.0 EXECUTIVE SUMMARY

This report documents the results of an odor control study and recommended improvements for implementation by the City of Lee's Summit, Missouri (City) to meet odor control objectives within the sanitary sewer collection system receiving discharges from the Tudor Road Pump Station (Pump Station).

Study efforts and odor control objectives evolved in a multi-phase approach as follows:

- Initial base scenario evaluation; March 2016
- Screening of technology alternatives for base scenario with initial recommendations; July 2016
- Implementation of initial recommendations and ferric chloride pilot testing; December 2016 - January 2017
- Review of initial ferric pilot test results and revised odor control objectives; March 2017
- Additional ferric chloride pilot testing (two (2) trials); October 2017 – February 2018
- Review of additional ferric pilot results and revised/final odor control objectives; March 2018 - May 2018.

Details of these study efforts and the resulting operational scenario, odor control objectives, and recommended improvement alternative are presented herein.

The final operational scenario for odor control is comprised of a range of discharge flow rates to either of the two current discharge locations: via 20-in force main to Little Cedar or via 30-in force main to Maybrook (see collection system map in Appendix A for locations). Minimum discharge flows to either location is determined by an adjustable minimum speed setpoint for single, dry-weather pump operation. Maximum discharge flows to either location are determined by the design output for single wet-weather pump operation (see Pump/System curves in Appendix F).

An important additional operational parameter is that odor control shall be maintained during the "first flush" of transition flows following the switch-over of discharge locations, comprised of a volume of wastewater resident in the force main for long or indefinite time periods. This "first flush" may occur at any flow condition in the operating range from minimum, dry weather to single-pump wet weather flow rates.

Odor control objectives for the project consist of maintaining a negligible head space concentration (<20 ppm) of hydrogen sulfide gas (H2S) at control discharge manholes, combined with a material reduction in dissolved sulfide concentrations for the full operational scenario.

The recommended improvements to meet the odor control objectives are the installation of Vortex Flow Inserts at each existing force main discharge location as summarized in Table I-1.

TABLE 1-1: REVISED VORTEX FLOW INSERT ALTERNATIVE DATA

Location	Quantity	Size	Selection Point (GPM)	Minimum Flow (GPM)	Maximum Flow (GPM)
Little Cedar Discharge (MH 23-016)	1	20-in	7,000	1,050	8,050
Maybrook Discharge (MH-14-017/ Pig Station)	1	30-in	10,000	1,500	11,500
Total Project Cost (Incl. Engr, Contingency)				**$972,000.00**	

2.0 INTRODUCTION AND BACKGROUND

The services of Olsson Associates (Olsson) were requested by the City to perform an odor control study and recommended solutions for odor control within the sanitary sewer collection system receiving discharges from the Tudor Road Pump Station. The request was prompted by a series of complaints about strong odors from businesses along the west side of I-470, south of NE Strother Road. Complaints centered around manhole MH 14-012 on NE Jones Industrial Drive, located just downstream of the 30-in force main discharge from the Tudor Road Pump Station to the Maybrook Watershed.

3.0 PROJECT TIMELINE AND REFINEMENT OF STUDY OBJECTIVES

3.1 Initial Base Scenario Evaluation and Recommendations

The initial study efforts were focused on a base scenario of continuing current operations with all discharge flows from Tudor Road Pump Station discharging through 30-in force main to Maybrook watershed and odor control at the "control" manhole MH 14-012. (See Appendix A for location).

Treatment technology alternatives were evaluated and screened for this initial operational scenario based on the treatment of dry weather flows only. A draft report summarizing initial odor control objectives and alternatives analysis was submitted to the City in early July 2016 for review and is included herein as Sections 6 through 9.

On July 14, 2016 Olsson met with the City to discuss the draft report and recommendations for the project moving forward. It was determined that a pilot test would be completed for the two no capital cost options, Alternative - E Alternate Low Flow Discharge option and Alternative - F Ferric Chloride Feed Modification.

This initial recommendation basically called for re-instating the pump station's original design operational scenario, routing all dry weather flows through the 20-in force main to Little Cedar watershed. Elevated wet weather flows would be diverted to the 30-in Maybrook discharge via control valves on the force main located at Rice Road Valve Vault.

Initial recommendations also called for re-instatement of ferric feed tubing to original location at influent to wetwell and installation of submerged mixer previously purchased by City and stored on site.

However, on July 23, before the first pilot test could begin, the first of a series of catastrophic events occurred at the Tudor Road Pump Station. At this time, Olsson was tasked with developing a report detailing the extent of damages, probable cause(s), document repairs, and provide recommendations to address issues and restore normal operation. This report was titled "Tudor Road Pump Station Emergency Repairs Incident Report" and was submitted to the City in November 2016. Throughout this period, the odor control project was put on hold.

3.2 Initial Ferric Chloride Pilot Testing and Revised Odor Control Objectives

Following, the resumption of odor control activities, efforts to complete first pilot testing of Alternatives E and F in early 2017 encountered a series of additional operational and equipment-related failures, unreliable sampling data and reliability issues in the existing ferric supply and feed systems. Restoration of the proper feed point for ferric was deemed more effective than mechanical mixer and given the inferior durability of the mechanical mixer, it was removed from service.

On March 20, 2017, Olsson met with the City to discuss the results of the first pilot test and discuss the next steps for the project. Results of the initial ferric feed pilot testing were deemed inconclusive and the meeting focused on details of correcting reliability and operational challenges in preparation for conducting additional ferric pilot testing trials.

Also, the operational and equipment-failure related challenges encountered during the first pilot test facilitated further consideration and adjustment to the "normal" and potential range of operational scenarios for the Pump Station. By extension, the range of expected odor control operational scenarios similarly evolved and was refined.

3.3 Feed Reliability and Additional Ferric Pilot Testing

As a result of the initial pilot test review meeting, City staff made several improvements to feed systems and quality control of ferric supply prior to conducting a second set of pilot testing tailored to revised odor control operational scenarios. These feed reliability and additional pilot testing steps are summarized in Sections 10 and 11.

3.4 Additional Ferric Pilot Testing Results and Final Odor Control Objectives

The results of Odor Control Trial 2 show that the addition of ferric chloride to the Tudor Road Pump Station wet well is reasonably effective for odor control during dry flows to Little Cedar discharge and marginally effective for the Maybrook discharge. However, neither results meet the final objectives for head space or dissolved concentrations.

In addition, discussions with City staff which began during the earlier operational and equipment challenges starting in the first pilot test, led to a final refinement of odor control objectives and operational scenarios.

The resultant inclusion of capabilities to effectively treat the "first flush" transition flows encountered during discharge switch-over led to the practical elimination of odor technologies located centrally at the Tudor Road Pump Station, requiring 'end of pipe' solutions and a duplication of facilities at each discharge. In the process, 'no capital cost' options were eliminated, despite initial alternative evaluation and scoring.

Given these final odor control objectives, the highest scoring alternative from the initial alternatives analysis, Alternative A - Vortex Flow Insert (VFI), is recommended for scale-up and implementation, as described in Section 12.

4.0 EXISTING FACILITIES

There are three (3) influent lines into the Pump Station. Influent flow from two of the lines are primarily gravity fed, but all flow from the third line is received from another lift station which creates a fluctuation in the inflow volumes throughout the day. The Pump Station consists of six (6) pumps; with two (2) being dry weather pumps and four (4) being wet weather pumps.

Currently, the City is adding ferric chloride to the wastewater at the Tudor Road Pump Station in an attempt to mitigate the odor in the downstream collection system. Based on discussions with City staff, ferric chloride is drip fed into the south wet well of the Tudor Road Pump Station. This feed rate has been varied over time. The optimum feed rate for the ferric chloride feed system which reduces the volatile hydrogen sulfide concentrations to a non-detectable limit at the force main discharge is still undetermined. The current feed system has no mixing and is disabled during peak flow conditions. Based on discussions with City staff, the current contract with the chemical supplier has a purchasing price of 1.22 dollars per gallon of ferric chloride. Ferric chloride is a very corrosive chemical. The City has expressed interest in getting away from this process if there is a more cost-effective alternative for reducing odor downstream.

The Pump Station discharges to the Tudor Road Force Main which runs west to the Rice Valve Vault where the flow can split. One section of the force main is 20-in diameter that continues west and discharges to the Little Cedar Watershed. The other is 30-in diameter that runs to the north and discharges to the Maybrook Watershed. The majority of the flow at this vault was initially directed north towards the Maybrook Watershed, at all times. During the course of the study, operation of control valves in Rice Valve Vault have been restored and flow may be diverted to either discharge during dry weather or wet weather flows. The force main running north eventually discharges to MH 14-017 where flow then travels by gravity through the Maybrook Watershed. The west force main is much shorter than the north force main and discharges to gravity flow at MH 23-016. It receives little to no flow during dry weather conditions. A map of the Tudor Road Sanitary Sewer System is included in Appendix A of this report.

5.0 PREVIOUSLY COMPLETED STUDIES

Odor control has been a reoccurring problem downstream of the Pump Station. Multiple studies have been completed over the years that proposed solutions to this issue.

In 1998, George Butler Associates (GBA) performed a comprehensive study on the Maybrook Watershed odor and corrosion problem. This study examined the possible sources of the odor and corrosion at that time and also researched and made recommendations for numerous alternatives to be implemented to minimize the odor and corrosion problem. The information outlined in the study performed by GBA is still relevant; however, it is important to note that more recent data will provide a more accurate representation of the current conditions for the Pump Station and sanitary system.

Another limited study was completed in 2013 by HDR, which addressed the Tudor Road odor and corrosion problem. As with the GBA study, this study examined the potential sources leading to the odor and corrosion problem in the Maybrook Watershed and also made recommendations for suitable alternatives to reduce this problem. The proposed recommendations included a dissolved oxygen injection system and a sparger system with onsite generation equipment along with a detailed cost estimate for both options.

Both reports were reviewed and utilized as a reference throughout this study.

6.0 REVIEW OF INITIAL STUDY TESTING RESULTS

The three (3) main odorous compounds that are present in wastewater are hydrogen sulfide, ammonia, and mercaptans. It is believed that hydrogen sulfide gas is the main constituent leading to the odor issue at MH 14-012. An analysis of the information received during this study has been conducted to examine the existing conditions in the collection system and analyze the formation of hydrogen sulfide downstream of the Pump Station. This analysis helped determine a variety of suitable solutions for the existing odor problem.

Initially, hydrogen sulfide testing was performed on air samples that were gathered from several manholes in the Maybrook Watershed area. The results of these tests revealed high concentrations of hydrogen sulfide at MH 14-012. Following these findings, wastewater samples were taken by the City from the Pump Station, pig catch station, and MH14-014 and tested for total sulfide concentrations using a Hach Unit. The results were inconclusive which lead to the development of a more thorough sampling plan.

The new testing plan was completed and included wastewater grab samples taken at the Pump Station and at locations along the force main and gravity main flowing to the Maybrook Watershed. These locations included the Pump Station influent stream prior to the addition of ferric chloride, the pump station discharge stream after ferric chloride addition, air release valve (AR) 24-003, manhole (MH) 14-017, and MH 14-007. These locations were selected to determine how detention time in the force main and gravity main was attributing to the formation of hydrogen sulfide in the wastewater. The grab samples were taken by the City at three (3) times throughout the day starting on April 17, 2016 and continuing into April 18, 2016. The samples were sent to Pace Analytical for testing to determine dissolved sulfide concentrations in the wastewater. Pace Analytical also conducted biological oxygen demand (five day) testing on the pump station influent stream. The location of each sampling point is highlighted on the collection system map included in Appendix A. The flow data and testing results of each sample is included in Appendix B.

Flow was monitored using the flow meters at Site 9, 10, and 11 during the sampling period. Flow data for the three (3) separate influent lines into the Pump Station were received from the City. The location of each site is shown in Appendix C. Site 9 includes the majority but not all of the gravity flow entering the Pump Station. It was assumed that the unaccounted-for flow was negligible for the analysis. This data was used to develop combined flow rates for the Tudor Road Force Main over the duration of the sampling period. The combined flow data was then used to estimate wastewater detention time to each sampling location. The detention times and corresponding dissolved sulfide test results were compared at each location in an effort to develop a direct correlation between the two. However, the results of this comparison did not reveal any clear relationship between the detention time and the dissolved sulfide concentration. Despite the unclear results, the flow data shows that there were long detention times within Tudor Road Force Main during the monitoring period. When wastewater experiences long detention times with slow movement, the oxygen within the water is used up creating an anaerobic environment in the system. These conditions are ideal for the formation of hydrogen sulfide and other undesirable gases in the sanitary line. When the wastewater is exposed to the atmosphere and encounters turbulence, these gases are volatilized, eventually escaping through manholes and other openings to the environment.

There are several ways to address this problem and effectively reduce the hydrogen sulfide in the sanitary sewer line. One option would be to reduce the detention time of the wastewater within the sanitary sewer line. This would give the hydrogen sulfide gas less time to form. Another option would be to add chemicals to the wastewater that will oxidize dissolved sulfide and prevent hydrogen sulfide from developing. The final option would be to treat the air after hydrogen sulfide has formed and volatilized by running it through an air filtration system to remove the odorous gases. The specific improvement alternatives that were explored are discussed in detail in the following section of this report.

7.0 INITIAL IMPROVEMENT ALTERNATIVES

In review of the data collected throughout the initial study on the Pump Station and sanitary sewer line, Olsson has developed a list of possible alternatives to mitigate the existing odor and meet the initial odor control objective. Each alternative was examined based on its feasibility and effectiveness for the issues discussed in this report. The summary of each option below details the equipment and work required as well as an opinion of probable capital cost and annual cost for each. A detailed breakdown of the individual cost estimates is included in Appendix D.

Alternative E – Alternative Low Flow Discharge Location and Alternative F – Install Mechanical Mixer in Wet Well was recommended and selected for further consideration and initial pilot testing.

7.1 Alternative A – Vortex Flow Insert

This alternative includes the installation of the VFI at the pig catch station where the Tudor Road Force Main discharges into the Maybrook gravity line. This insert reduces odor by running the influent flow through a spiral shaft creating a downward flow of air that entrains oxygen into the wastewater when it hits the bottom of the vortex. This oxidizes the dissolved sulfide in the water inhibiting its ability to form hydrogen sulfide gas. The shaft also pulls any odorous gases that have already formed into this flow of air, entraining it back into the wastewater and eliminating its ability to escape to the environment.

The VFI is designed to effectively treat wastewater over a specific range of flows based on its design flow. In this case, the VFI would be designed specifically for treatment during low flow conditions when dissolved sulfide concentrations are at their highest. The effective range of this system would be 15% to 115% of the design flow. Based on the flow data during the monitoring period we recommend that this system would be designed for 3 million gallons per day (MGD). This would provide an operating range of 0.45 to 3.45 MGD. Because of this, the insert does not have the capacity required to pass high flow volumes. A bypass valve and associated piping would be required to allow bypass of the VFI of some flow during high flow events.

Based on the design criteria, the VFI requires about eight feet of drop height from the invert of the force main to the base of the flow insert to effectively operate. The existing layout of the line does not provide this drop height at the discharge location. Therefore, reconfiguration of the force main at the pig catch station would be required to provide enough drop height. The force main and VFI would likely rise above the existing ground elevation as a result. The proposed VFI would be installed adjacent to the pig catch station and would require the installation of structural concrete to provide sufficient structural support and protection. The increased elevation of the force main would also create a larger static and dynamic head demand on the pumps at the Pump Station. Based on the dry weather pump characteristic curve, the existing dry weather pumps would have enough power to overcome the increased demand with no modifications. However, this would increase the horsepower required of each pump, which would increase the operating cost for the pump station.

The total probable capital cost for this alternative is $332,000.00. This estimate includes all equipment and labor required for the installation of the flow insert and structure as well as the parts and modifications necessary for the reconfiguration of the force main. The estimated annual cost for this option is $3,600.00. A detailed cost estimate is included in Appendix D.

7.2 Alternative B – Bioxide

This alternative would replace the existing ferric chloride feed system at the Pump Station with a new bioxide feed system. It would include the installation of a new flow meter on the influent line and supervisory control and data acquisition (SCADA) equipment that will regulate the feed rate based on influent flow and temperature in the system. Bioxide would be drip fed into the wet well like the current ferric feed system. SCADA equipment would ensure that excess chemical is not being added to the wastewater in order to limit overall chemical usage and reduce chemical costs. It should be noted that bioxide is currently being added at a number of lift stations upstream of the Pump Station.

The total probable capital cost for this alternative is $396,000.00. This estimate includes the cost for removal of the existing ferric chloride feed equipment and all equipment and labor required for the installation of the new bioxide feed system. The estimated annual cost for this option is $140,000.00. A detailed cost estimate is included in Appendix D.

7.3 Alternative C – Air Scrubbing

This option would implement an air scrubbing filtration system that would pull air from the sanitary sewer line and pass it through a series of filter beds and eventually emit the treated air back to the atmosphere. This system would be designed primarily to remove hydrogen sulfide gas from the air but is also capable of removing other undesirable constituents. The filtration system does not have the ability to treat any sulfides still present in the wastewater and will only remove the hydrogen sulfide that has already volatilized in the sewer system up to that location. An air scrubbing system typically comes as a preassembled package making for easy installation. This system would be located at or near the manhole responsible for releasing the odor, MH 14-012. It would include a fan along with ductwork that will draw air from the collection system upstream and downstream of MH 14-012. The intake system draws the air out of the surrounding sewer line by creating a negative air pressure at the extraction point. It would be sized to conduct six (6) air changes per hour of the air volume in a 300 feet radius of the sanitary sewer system surrounding MH 14-012.

The filter media in the scrubbing system must be replaced periodically and monitoring systems are usually installed to measure the consumption rate of the media to determine when the filter media has reached capacity. Based on information received, it is estimated that replacement is typically required every 15 months for the level of treatment necessary. This option would need to be located above grade requiring the construction of a concrete pad and proper landscaping and fencing. This could create potential difficulties with placement because of the close proximity to commercial development and the right of way requirements and sight obstructions of the unit.

The total probable capital cost for this alternative is $108,000.00. This estimate includes all equipment and labor required for the installation of the air scrubbing system and the materials and labor for the construction of the concrete pad. The estimated annual cost for this option is $12,000.00. A detailed cost estimate is included in Appendix D.

7.4 Alternative D – Dissolved Oxygen Injection

This alternative proposes the installation of dissolved oxygen (DO) injection equipment at the Pump Station. With this option, piping modifications would be necessary to create a sidestream that will run to the DO injection system. The sidestream would pass through the system where gaseous oxygen is injected into the wastewater stream effectively dissolving it. This DO rich wastewater would then be added back to the main wastewater stream providing sufficient dissolved oxygen to effectively oxidize the dissolved sulfide within the wastewater.

This system would require a constant supply of oxygen to operate. Multiple supply options are available. The first is a liquid oxygen system. This includes routine liquid oxygen deliveries from a local gas supplier along with the installation of a storage tank and associated equipment. The second option would use an onsite oxygen generation system and storage tank. With this option, all oxygen required will be generated and stored onsite to meet the demands in the wastewater. The onsite generation system has a much higher capital cost than the liquid oxygen system, but the annual costs can be significantly lower. DO injection alternative assumed that liquid oxygen would be used for the evaluation of alternatives.

The total probable capital cost for this alternative with the liquid oxygen supply is $1,066,000.00. This estimate includes all equipment and labor required for the installation of the dissolved oxygen injection system and all necessary modifications to the existing piping. The estimated annual cost for this option is $61,400.00. A detailed cost estimate for both the liquid oxygen and oxygenation option is included in Appendix D.

7.5 Alternative E – Alternative Low Flow Discharge Location

With this option, part or all of the flow in the Tudor Road Force Main (during low flow conditions) would be redirected at the Rice Valve Vault to enter the force main traveling west and discharge to the Little Cedar Watershed. Under current operating conditions, the majority of the flow is being directed to the much longer north force main. This is leading to significant detention times in the line itself which creates ideal conditions for the formation of hydrogen sulfide. The goal of switching to the other force main is to reduce the overall detention time within the system.

There is currently a motor operated plug valve installed on both the north force main and west force main just past the Rice Valve Vault. Based on information from the City both valves are operational. This option would change the current operation of the Rice Valve Vault. During low flow conditions, the north plug valve would be closed, redirecting the flow through the west force main to the Little Cedar Watershed. The force main leading to the Little Cedar Watershed is more than 4000 feet shorter than the force main leading the Maybrook Watershed, giving the wastewater a significantly shorter detention time. Theoretically, a shorter detention time will result in less hydrogen sulfide formation within the sanitary line. During peak flow conditions at the Tudor Road Pump station both valves would be opened to allow the pumps to operate at full capacity.

The Little Cedar Force Main discharges into a gravity line near the Lee's Summit Police Department and a large commercial area. This could create a similar problem to the current odor issue in the Maybrook Watershed area if hydrogen sulfide within the wastewater volatilizes and escapes at or downstream of this discharge point in the Little Cedar Watershed.

One advantage to this option is that it can be tested very easily to determine its effectiveness prior to any full commitment. Using the existing valves, the flow could be redirected to the Little Cedar Watershed during low flow conditions. If this option is tested, we recommend that the air be monitored at various locations downstream of the Tudor Road Force Main discharge to the Little Cedar Watershed. This will allow us to determine if hydrogen sulfide is being released at any point within the watershed.

This option would still require the addition of ferric chloride to minimize odor downstream of the new discharge location. There would be no capital cost for this option. The estimated annual cost would equal $107,000.00.

7.6 Alternative F – Install Mechanical Mixer in Wet Well

For this option, a desk top study was performed analyzing the current ferric chloride feed rate and method. This feed rate was compared to a theoretical ideal ferric chloride to hydrogen sulfide ratio to determine if sufficient ferric chloride was being added to react with the hydrogen sulfide. The results of the study reveal that the current feed rate should be adequate to effectively treat the levels of hydrogen sulfide being experienced in the influent stream. Therefore, the amount of ferric chloride being added does not appear to be the limiting factor. Based on this, the ferric chloride might not be adequately mixed into the influent stream.

For this alternative, one submersible mixer would be installed in the wet well. The City currently has a mechanical mixer in storage at the Pump Station that is not being used. Adding a mixer should increase the ferric chloride effectiveness and reduce odors downstream. There would be no capital cost for this option. The annual maintenance and power cost for the facility would be increased with the operation of the mixer. The estimated annual cost would equal $114,000.00. A detailed cost estimate is included in Appendix D.

7.7 Other Options Not Explored

Due to limitations involved in the scope of this study additional options that could reduce or eliminate odor in the collection system downstream of the Station were not explored. One option that could be effective but was not explored was odor control through the addition of hydrogen peroxide.

8.0 SUMMARY OF INITIAL IMPROVEMENT ALTERNATIVE COSTS

A summary of the estimated capital cost and annual cost of the existing system and each option to achieve the initial odor control objective is shown in Table 8-1. The detailed cost estimate for each option is provided in Appendix D. For some alternatives, there is a side benefit regarding the corrosiveness potential for downstream structures. This is noted in Table 8-1 as well.

TABLE 8-1: INITIAL ALTERNATIVE ODOR CONTROL COST

Existing System	Level of Corrosion Control Downstream of Maybrook Watershed	Estimated Capital Cost	Estimated Annual Cost
Ferric Chloride (240 gpd)	Moderate	$0.00	$107,000.00
Alternative	**Level of Corrosion Control Downstream of Maybrook Watershed**	**Estimated Capital Cost**	**Estimated Annual Cost**
Vortex Flow Insert	High	$332,000.00	$3,600.00
Bioxide	Moderate	$396,000.00	$140,000.00
Air Scrubbing	Low	$108,000.00	$12,000.00
Dissolved Oxygen Injection (with Liquid Oxygen Option)	Moderate	$1,066,000.00	$61,400.00
Alt. Low Flow Discharge	N/A	$0.00	$107,000.00
Install Mechanical Mixer in Wet Well	Moderate	$0.00	$114,000.00

9.0 INITIAL ODOR CONTROL ALTERNATIVE EVLAUATION

A scoring matrix was developed to determine the most suitable option for odor control for the Tudor Road Pump Station. This matrix is provided in Table 9.1. Alternative E – Alternative Low Flow Discharge and Alternative F – Install Mechanical Mixer in Wet Well were pilot tested, and thus were not included in the evaluation. It should be noted that the mechanical mixer was installed and pilot tested, however, the results were indeterminate and the mixer was later removed from the wet well by the City.

Each alternative was evaluated based on total capital cost, annual O&M Cost, operability of the system, maintainability of the system, and reliability of the system. Total capital and annual O&M cost is provided in Table 8-1. The alternative with the lowest total cost will receive 20 points. The remaining alternatives will be proportioned based on the ratio of the difference from the lowest cost alternative. The score for the annual O&M cost will be determined the same way as the total cost score.

Operability of the system is based on the alternatives operational requirements. The alternative which requires the least amount of operability requirements will receive the highest score (10 points).

Maintainability of the system is based on maintenance requirements for the odor control alternative. The alternative which requires the least amount of routine maintenance will receive the highest score (10 points).

Reliability of the system is based on how reliable the alternative is for effective odor control. The most reliable odor control system will receive the maximum score (10 points).

Based on this scoring system the VFI alternative had the highest overall score at 51.

Table 9-1: Odor Control Alternative Evaluation

Parameter	Max Pts	Vortex	Bioxide	Air Scrubbing	Dissolved Oxygen	Ferric Chloride Feed Mod.
Economic (Total Weight = 40 pts)						
Total Capital Cost (Maximum 20 Points)	20	7	5	20	2	4
Annual O&M Costs (Maximum 20 Points)	20	14	2	20	2	2
Operability, Maintainability, and Reliability (Total Weight = 30 Points)						
Operability of the System (Maximum 10 points)	10	10	6	3	2	1
Maintainability of the System (Maximum 10 points)	10	10	1	3	3	3
Reliability of the System (Maximum 10 points)	10	10	5	4	4	4
TOTAL POINTS (Total Out of 70)		51	19	50	13	14

10.0 RESTORING RELIABILITY IN EXISTING FERRIC FEED SYSTEM

Based on discussions with City staff, operability issues with the existing ferric chloride feed system has made the system less reliable than desired. The following procedure was developed and implemented to increase the reliability of the ferric chloride system.

1. Remove accumulated sludge from Ferric Chloride Holding Tank
2. Void existing contract with chemical supplier, look to multiple new chemical suppliers for ferric chloride
3. Continue recent enforcement of quality control specs on incoming ferric chloride

11.0 ADDITIONAL PILOT TESTING OF EXISTING FERRIC FEED SYSTEM

After effective feed control was established with the existing ferric chloride system, a second pilot test of existing ferric chloride addition was conducted, consisting of two trial operational scenarios. Each trial was conducted during periods of stable, dry weather operation with in-trial adjustments to ferric feed rates, continual vapor phase H2S monitoring at discharge points, and in-process dissolved sulfide sampling.

Trial 1 routed dry weather flows to Little Cedar discharge and Trial 2 routed dry weather flows to Maybrook discharge. The goal of the Odor Control Trials was to determine the optimum feed rate of ferric chloride at the Pump Station to reduce volatile hydrogen sulfide (H2S) concentrations to near zero (<20 ppm) at the outfall when discharging to the Little Cedar (Trial 1) and Maybrook Watersheds (Trial 2), during dry (low) flow conditions.

<u>Odor Control Trial 1</u>

Trial 1 was conducted with the Pump Station continuously discharging to the Little Cedar Watershed. The trial occurred over a three-week period (October 31 – November 17, 2017), starting initially with a lower ferric chloride feed rate and two successive increases in feed rate roughly each week. Trial 1 was completed during an extended dry weather period with no rainfall during the trial. Oda-loggers were used for "head space" concentration measurements downstream at the force main outfall (MH23-016) and cow pasture (MH23-013). The sampling locations are highlighted in the map provided in Appendix A.

A summary of Odor Control Trial 1 is included in Appendix E. Based on the results, it appears that the optimum ferric feed rate to reduce volatile H2S concentrations below 20 ppm at the force main outfall when discharging to the Little Cedar watershed (during dry conditions) is 240 gpd.

<u>Odor Control Trial 2</u>

Trial 2 was conducted after the completion of Trial 1 (February 5 – February 20, 2018) with the Pump Station continuously discharging to the Maybrook Watershed. The procedure used in Trial 1 was modified slightly for Trial 2. The ferric chloride feed rate at the Pump Station was started with maximum output from the feed system and then discreetly adjusted downward as the trial continued. Oda loggers were installed at the Maybrook Watershed Outfall (MH14-017) and near the ABC Roofing Supply Company building (MH14-007). The sampling locations are highlighted in the map provided in Appendix A. Additional operational measures were added to Trial 1 which include the following:

1. Timing: Coordinate to occur outside regular business hours, to extent feasible
2. Notification: Contact businesses/customers near discharge location, especially those with prior odor complaints
3. Explanation: This is a non-typical operational trial and odors may be noticeable leading up to or during early stages as reasonable attempts are being made to minimize odors
4. Action/advisories: Ask businesses/customers to be sure and fill P-traps and know who to contact for questions/concerns
5. City's internal preparations: "Stock-Pile" volume in storage at the Pump Station and/or Scruggs Road Pump station to provide flushing volume to displace the initial volume of the 30-inch force main as quickly as possible prior to starting the trial

A summary of Odor Control Trial 2 is included in Appendix E. Based on the results, the maximum dosage rate (>450 gpm) from the existing ferric chloride system was unable to reduce H2S concentrations below 20 ppm consistently. This shows that the existing ferric feed system will not be a reliable solution to odor control for the Maybrook Watershed.

12.0 REVISED VORTEX FLOW INSERT ALTERNATIVE

The revised project objective (from the March 20, 2018 meeting) is that the selected odor control alternative must provide effective odor control, when discharging to either the Little Cedar Watershed or Maybrook Watershed during both dry and wet weather events.

Specifically, the final operational scenario for odor control is comprised of a range of discharge flow rates to either of the two current discharge locations: via 20-in force main to Little Cedar or via 30-in force main to Maybrook (see Appendix A for locations). Minimum discharge flows to either location is determined by an adjustable minimum speed setpoint for single, dry-weather pump operation. Maximum discharge flows to either location is determined by the design output for single wet-weather pump operation (see Pump/System curves in Appendix F).

An important, additional operational parameter is that odor control shall be maintained during the "first flush" of transition flows following the switch-over of discharge locations, comprised of a volume of wastewater resident in the force main for long or indefinite time periods. This "first flush" may occur at any flow condition in the operating range from minimum, dry weather to single-pump wet weather flow rates.

Odor control objectives for the project consist of maintaining a negligible head space concentration (<20 ppm) of hydrogen sulfide gas (H2S) at control discharge manholes, combined with a material reduction in dissolved sulfide concentrations for the full operational scenario.

The VFI alternative is a non-chemical, "end of pipe" solution, which scored highest in the alternative evaluation in Section 8. This alternative was selected as described in Section 3 as the recommended alternative for implementation to provide odor control in the receiving system for the Pump Station discharges.

As stated in Section 7.1, the VFI is effective for odor control for a flow range of 15% to 115% of the determined design flow. Flow conditions to both the Little Cedar Watershed and Maybrook Watershed was used to determine the optimum design flow for the vortex flow inserts.

The maximum flow condition to each watershed was determined based on the Tudor Road Pump Station Operations manual. The minimum flow for each watershed was determined to be one dry weather pump running at full speed at the Pump Station. Appendix F contains the pump and system curves (both dry and wet weather pumps) for the Little Cedar and Maybrook Watersheds. The maximum and minimum flow conditions for each watershed are shown in Table 12-1.

TABLE 12-1: FLOW CONDITIONS

	Little Cedar Watershed	Maybrook Watershed
Maximum Flow (GPM)	7,000	10,000
Minimum Flow (GPM)	3,800	6000

Based on these design flow conditions there will be a total of two (2) vortex flow inserts recommended for the project, one for Little Cedar Watershed and one for Maybrook Watershed. It should be noted that current operation of the Pump Station includes directing dry weather flow and initial wet weather flows to Maybrook Watershed. If the City decides that this operational sequence is to be continued, and that wet weather flows to Little Cedar Watershed do not need to be treated for odor, then the vortex at the Little Cedar Watershed would not be necessary.

The design characteristics for the Little Cedar Vortex and Maybrook Vortex are shown in Table 12-2. The minimum and maximum flow are based on the effective flow range as stated by the Vortex product representative. As discussed, earlier in this section, the minimum flow condition to each watershed was based on one dry weather pump running full speed. The dry weather pumps at the Pump Station are controlled on vortex design flow (VFD) and have thus have the ability to operate at a lower RPM which would pump less wastewater. At this time, the low flow set point on the VFD's is unknown. However, it is not expected that the flow rate would be below the minimum flow (15% of design flow) to remain effective for odor control, listed in Table 12-2.

TABLE 12-2: VORTEX DESIGN FLOW

Little Cedar Vortex		
Design Flow	7,000	GPM
	10.1	MGD
Minimum Flow (15%)	1050	GPM
	1.5	MGD
Maximum Flow (115%)	8,050	GPM
	11.6	MGD
Maybrook Vortex		
Design Flow	10,000	GPM
	14.4	MGD
Minimum Flow (15%)	1,500	MGD
	2.2	MGD
Maximum Flow (115%)	11,500	GPM
	16.6	MGD

The installation site for the Maybrook discharge location would be adjacent to the existing 'pig catch' facility. Construction of the new VFI facility could occur in parallel with minimal interruption to force main service. Recommendations do not currently include automatic operation of bypass valves as the VFI is currently sized to handle the full range of force main flows. However, the VFI installation will include manually operated bypass valves in the force main to allow diversion from the VFI during force main cleaning or "pigging" operations.

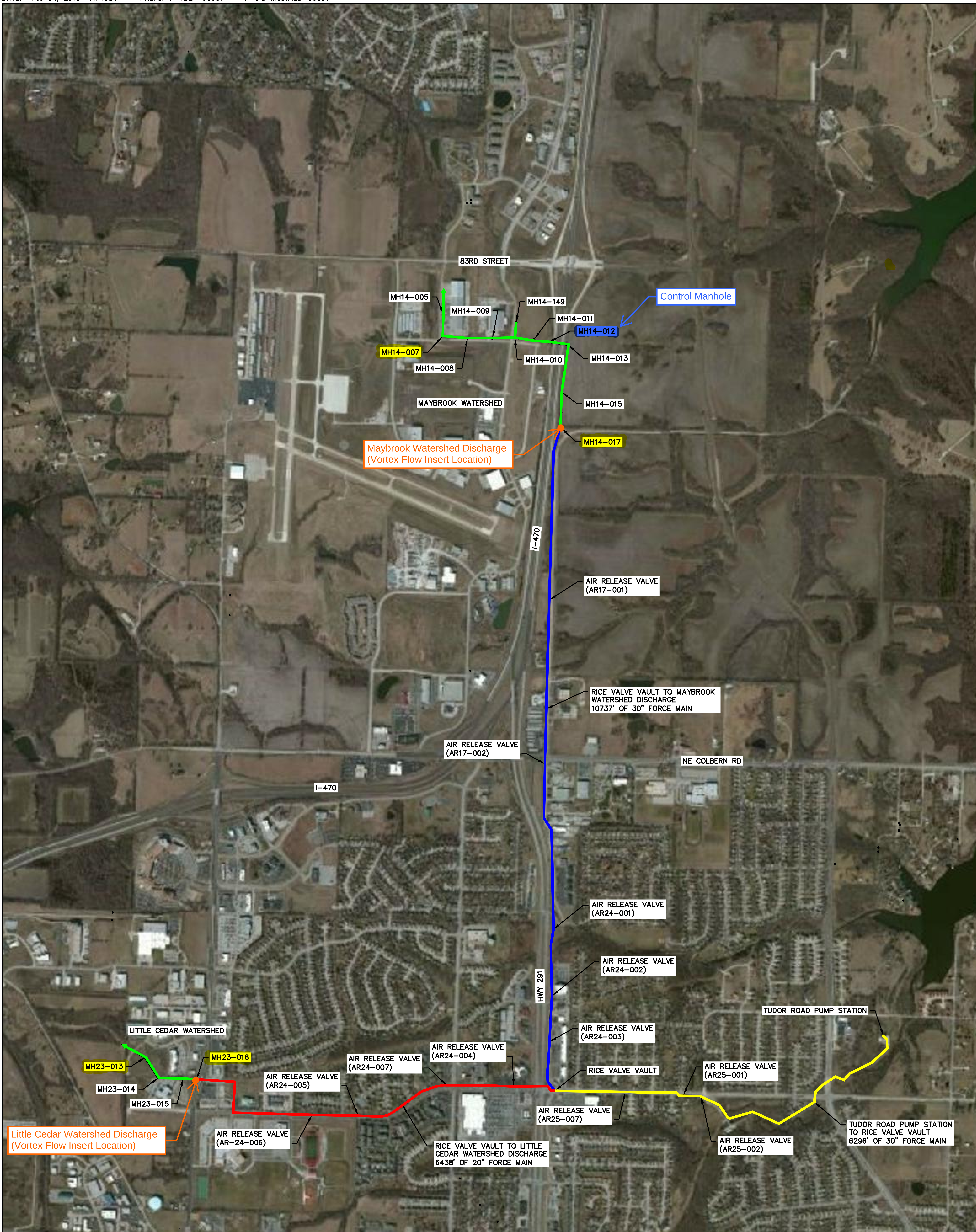
Although not required for effective odor control, Olsson recommends continuation of the ferric chloride feed as a corrosion prevention measure for force main piping and appurtenances beyond the proper function of the existing air release valves.

The total probable capital cost for this alternative is $972,000.00. This estimate includes all equipment and labor required for the installation of the flow insert and structure as well as the parts and modifications necessary for the reconfiguration of the force main. The estimated annual cost for this option is $56,000.00. A detailed cost estimate is included in Appendix G.

APPENDIX A

COLLECTION SYSTEM MAP

DWG: F:\2016\0001-0500\016-0091\40-Design\AutoCAD\Exhibits\P_GEN_60091.dwg USER: mrdavis
DATE: Feb 04, 2016 11:48am XREFS: P_TBLK_60091 P_GIS_MODIFIED_60091



NOTES

1. HIGHLIGHTED LOCATIONS ON MAP REPRESENT LOCATIONS WHERE GRAB SAMPLES AND ODOR RECORDINGS WERE COLLECTED DURING ODOR TRIALS 1 & 2.

SANITARY GRAVITY MAIN

FORCE MAIN FROM TUDOR ROAD PUMP STATION TO RICE VALVE VAULT

NORTH SANITARY FORCE MAIN

WEST SANITARY FORCE MAIN

N

SHEET 1

drawn by: MRD
checked by:
approved by:
QA/QC by:
project no.: 016-0091
drawing no.:
date: 02.02.16

PROPOSED SAMPLING LOCATIONS

ODOR CONTROL
TUDOR ROAD PUMP STATION

LEE'S SUMMIT, MISSOURI 2016

REV. NO.	DATE	REVISIONS DESCRIPTION	BY

REVISIONS

OLSSON ASSOCIATES
7301 West 133rd Street, Suite 200
Overland Park, KS 66213-4750
TEL 913.381.1170
FAX 913.381.1174
www.olssonassociates.com

APPENDIX B

FLOW DATA AND TESTING RESULTS

Client: City of Lee's Summit, MO
Project Name: Lee's Summit Tudor Road Odor
Project Number: 016-0091
Description: Flow Data into Tudor Road Pump Station
Date: 7/8/16

Flow Data into Tudor Road Pump Station				
Date and Time	Site 9 Flowrate (mgd)	Site 10 Flowrate (mgd)	Site 11 Flowrate (mgd)	Combined Flowrate (mgd)
4/16/16 0:00	0.856	0.243	0.040	1.139
4/16/16 0:15	0.820	0.202	2.178	3.200
4/16/16 0:30	0.723	0.219	0.043	0.985
4/16/16 0:45	0.717	0.207	2.080	3.004
4/16/16 1:00	0.688	0.191	0.026	0.905
4/16/16 1:15	0.621	0.189	1.595	2.405
4/16/16 1:30	0.610	0.176	0.220	1.006
4/16/16 1:45	0.629	0.178	0.032	0.839
4/16/16 2:00	0.593	0.212	2.455	3.260
4/16/16 2:15	0.601	0.169	0.062	0.832
4/16/16 2:30	0.589	0.146	0.000	0.735
4/16/16 2:45	0.550	0.141	2.013	2.704
4/16/16 3:00	0.522	0.132	0.036	0.690
4/16/16 3:15	0.517	0.144	0.000	0.661
4/16/16 3:30	0.513	0.130	2.365	3.008
4/16/16 3:45	0.497	0.126	0.045	0.668
4/16/16 4:00	0.521	0.140	0.000	0.661
4/16/16 4:15	0.492	0.125	2.240	2.857
4/16/16 4:30	0.430	0.112	0.052	0.594
4/16/16 4:45	0.494	0.122	0.000	0.616
4/16/16 5:00	0.444	0.122	0.000	0.566
4/16/16 5:15	0.505	0.139	2.383	3.027
4/16/16 5:30	0.535	0.125	0.021	0.681
4/16/16 5:45	0.492	0.138	0.000	0.630
4/16/16 6:00	0.537	0.129	0.475	1.141
4/16/16 6:15	0.563	0.142	0.023	0.728
4/16/16 6:30	0.545	0.143	0.000	0.688
4/16/16 6:45	0.528	0.145	0.654	1.327
4/16/16 7:00	0.569	0.185	0.027	0.781
4/16/16 7:15	0.630	0.198	2.328	3.156
4/16/16 7:30	0.806	0.199	0.164	1.169
4/16/16 7:45	0.881	0.251	2.418	3.550
4/16/16 8:00	0.969	0.264	0.642	1.875
4/16/16 8:15	1.087	0.325	2.301	3.713
4/16/16 8:30	1.009	0.332	1.962	3.303
4/16/16 8:45	1.060	0.331	0.045	1.436
4/16/16 9:00	1.230	0.395	2.289	3.914
4/16/16 9:15	1.222	0.410	1.021	2.653

Flow Data into Tudor Road Pump Station				
Date and Time	Site 9 Flowrate (mgd)	Site 10 Flowrate (mgd)	Site 11 Flowrate (mgd)	Combined Flowrate (mgd)
4/16/16 9:30	1.276	0.379	2.114	3.769
4/16/16 9:45	1.386	0.408	2.003	3.797
4/16/16 10:00	1.351	0.411	2.313	4.075
4/16/16 10:15	1.279	0.416	2.045	3.740
4/16/16 10:30	1.352	0.413	0.070	1.835
4/16/16 10:45	1.403	0.413	2.171	3.987
4/16/16 11:00	1.408	0.408	2.031	3.847
4/16/16 11:15	1.396	0.385	0.131	1.912
4/16/16 11:30	1.408	0.371	1.884	3.663
4/16/16 11:45	1.474	0.404	2.079	3.957
4/16/16 12:00	1.401	0.429	2.317	4.147
4/16/16 12:15	1.460	0.391	0.074	1.925
4/16/16 12:30	1.258	0.390	2.351	3.999
4/16/16 12:45	1.318	0.372	0.130	1.820
4/16/16 13:00	1.398	0.408	2.145	3.951
4/16/16 13:15	1.438	0.383	1.872	3.693
4/16/16 13:30	1.373	0.377	2.082	3.832
4/16/16 13:45	1.395	0.374	2.149	3.918
4/16/16 14:00	1.277	0.383	1.820	3.480
4/16/16 14:15	1.330	0.400	2.105	3.835
4/16/16 14:30	1.194	0.413	0.133	1.740
4/16/16 14:45	1.280	0.384	1.930	3.594
4/16/16 15:00	1.423	0.394	0.129	1.946
4/16/16 15:15	1.282	0.385	2.084	3.751
4/16/16 15:30	1.285	0.365	2.145	3.795
4/16/16 15:45	1.260	0.400	0.036	1.696
4/16/16 16:00	1.363	0.396	2.262	4.021
4/16/16 16:15	1.330	0.368	0.044	1.742
4/16/16 16:30	1.272	0.344	2.008	3.624
4/16/16 16:45	1.240	0.336	2.228	3.804
4/16/16 17:00	1.340	0.372	1.989	3.701
4/16/16 17:15	1.212	0.340	1.821	3.373
4/16/16 17:30	1.231	0.338	2.031	3.600
4/16/16 17:45	1.244	0.340	2.145	3.729
4/16/16 18:00	1.305	0.364	1.873	3.542
4/16/16 18:15	1.288	0.321	2.164	3.773
4/16/16 18:30	1.408	0.322	0.027	1.757
4/16/16 18:45	1.326	0.352	2.012	3.690
4/16/16 19:00	1.220	0.331	0.048	1.599
4/16/16 19:15	1.295	0.373	2.359	4.027
4/16/16 19:30	1.332	0.312	0.121	1.765
4/16/16 19:45	1.215	0.364	2.096	3.675
4/16/16 20:00	1.307	0.392	0.794	2.493
4/16/16 20:15	1.323	0.340	2.233	3.896
4/16/16 20:30	1.384	0.358	2.316	4.058
4/16/16 20:45	1.207	0.335	0.043	1.585
4/16/16 21:00	1.180	0.349	2.050	3.579
4/16/16 21:15	1.174	0.397	0.062	1.633
4/16/16 21:30	1.112	0.371	2.245	3.728
4/16/16 21:45	1.145	0.388	0.347	1.880
4/16/16 22:00	1.100	0.356	1.980	3.436

Flow Data into Tudor Road Pump Station				
Date and Time	Site 9 Flowrate (mgd)	Site 10 Flowrate (mgd)	Site 11 Flowrate (mgd)	Combined Flowrate (mgd)
4/16/16 22:15	1.091	0.336	2.031	3.458
4/16/16 22:30	1.058	0.343	1.893	3.294
4/16/16 22:45	1.114	0.342	2.240	3.696
4/16/16 23:00	1.167	0.323	0.017	1.507
4/16/16 23:15	1.063	0.301	2.119	3.483
4/16/16 23:30	0.859	0.305	0.051	1.215
4/16/16 23:45	0.928	0.310	1.940	3.178
4/17/16 0:00	0.795	0.261	0.032	1.088
4/17/16 0:15	0.857	0.266	1.922	3.045
4/17/16 0:30	0.769	0.227	0.041	1.037
4/17/16 0:45	0.786	0.202	2.226	3.214
4/17/16 1:00	0.753	0.194	0.070	1.017
4/17/16 1:15	0.668	0.202	0.006	0.876
4/17/16 1:30	0.685	0.184	0.217	1.086
4/17/16 1:45	0.674	0.191	0.031	0.896
4/17/16 2:00	0.616	0.183	2.193	2.992
4/17/16 2:15	0.562	0.157	0.049	0.768
4/17/16 2:30	0.597	0.149	0.016	0.762
4/17/16 2:45	0.579	0.165	0.949	1.693
4/17/16 3:00	0.540	0.129	0.058	0.727
4/17/16 3:15	0.480	0.145	0.000	0.625
4/17/16 3:30	0.465	0.138	2.489	3.092
4/17/16 3:45	0.484	0.136	0.023	0.643
4/17/16 4:00	0.465	0.124	0.000	0.589
4/17/16 4:15	0.471	0.128	2.083	2.682
4/17/16 4:30	0.505	0.132	0.072	0.709
4/17/16 4:45	0.444	0.129	0.000	0.573
4/17/16 5:00	0.628	0.132	0.030	0.790
4/17/16 5:15	0.408	0.137	0.130	0.675
4/17/16 5:30	0.442	0.135	0.023	0.600
4/17/16 5:45	0.410	0.138	0.000	0.548
4/17/16 6:00	0.459	0.127	1.115	1.701
4/17/16 6:15	0.434	0.151	0.030	0.615
4/17/16 6:30	0.488	0.132	0.000	0.620
4/17/16 6:45	0.533	0.155	2.349	3.037
4/17/16 7:00	0.509	0.168	0.041	0.718
4/17/16 7:15	0.649	0.256	0.000	0.905
4/17/16 7:30	0.712	0.248	2.147	3.107
4/17/16 7:45	0.724	0.255	0.053	1.032
4/17/16 8:00	0.855	0.274	2.194	3.323
4/17/16 8:15	0.895	0.296	0.019	1.210
4/17/16 8:30	1.005	0.332	2.220	3.557
4/17/16 8:45	1.177	0.371	0.207	1.755
4/17/16 9:00	1.259	0.375	2.274	3.908
4/17/16 9:15	1.337	0.370	2.018	3.725
4/17/16 9:30	1.320	0.384	0.069	1.773
4/17/16 9:45	1.449	0.392	2.240	4.081
4/17/16 10:00	1.455	0.438	1.941	3.834
4/17/16 10:15	1.599	0.448	1.857	3.904
4/17/16 10:30	1.531	0.376	0.419	2.326
4/17/16 10:45	1.543	0.382	2.048	3.973

Flow Data into Tudor Road Pump Station				
Date and Time	Site 9 Flowrate (mgd)	Site 10 Flowrate (mgd)	Site 11 Flowrate (mgd)	Combined Flowrate (mgd)
4/17/16 11:00	1.553	0.413	2.008	3.974
4/17/16 11:15	1.463	0.434	0.098	1.995
4/17/16 11:30	1.625	0.396	2.164	4.185
4/17/16 11:45	1.544	0.376	2.091	4.011
4/17/16 12:00	1.606	0.364	2.075	4.045
4/17/16 12:15	1.575	0.433	0.041	2.049
4/17/16 12:30	1.622	0.452	2.088	4.162
4/17/16 12:45	1.671	0.372	0.080	2.123
4/17/16 13:00	1.445	0.366	2.082	3.893
4/17/16 13:15	1.499	0.361	2.001	3.861
4/17/16 13:30	1.252	0.329	0.044	1.625
4/17/16 13:45	1.331	0.327	2.204	3.862
4/17/16 14:00	1.601	0.357	2.031	3.989
4/17/16 14:15	1.596	0.387	1.910	3.893
4/17/16 14:30	1.513	0.342	2.124	3.979
4/17/16 14:45	1.353	0.316	0.091	1.760
4/17/16 15:00	1.410	0.345	2.160	3.915
4/17/16 15:15	1.480	0.343	1.257	3.080
4/17/16 15:30	1.469	0.361	2.178	4.008
4/17/16 15:45	1.247	0.340	2.141	3.728
4/17/16 16:00	1.211	0.397	0.068	1.676
4/17/16 16:15	1.330	0.344	2.015	3.689
4/17/16 16:30	1.227	0.322	0.148	1.697
4/17/16 16:45	1.309	0.322	1.935	3.566
4/17/16 17:00	1.572	0.304	2.083	3.959
4/17/16 17:15	1.342	0.334	2.298	3.974
4/17/16 17:30	1.350	0.337	2.066	3.753
4/17/16 17:45	1.298	0.335	0.045	1.678
4/17/16 18:00	1.538	0.369	2.316	4.223
4/17/16 18:15	1.423	0.329	0.518	2.270
4/17/16 18:30	1.330	0.354	2.293	3.977
4/17/16 18:45	1.458	0.352	2.469	4.279
4/17/16 19:00	1.362	0.395	0.052	1.809
4/17/16 19:15	1.282	0.412	2.047	3.741
4/17/16 19:30	1.541	0.362	2.134	4.037
4/17/16 19:45	1.323	0.396	0.167	1.886
4/17/16 20:00	1.409	0.417	2.532	4.358
4/17/16 20:15	1.531	0.368	2.126	4.025
4/17/16 20:30	1.474	0.418	0.307	2.199
4/17/16 20:45	1.583	0.457	2.090	4.130
4/17/16 21:00	1.646	0.450	2.105	4.201
4/17/16 21:15	1.455	0.382	1.952	3.789
4/17/16 21:30	1.690	0.384	2.022	4.096
4/17/16 21:45	1.564	0.398	2.137	4.099
4/17/16 22:00	1.362	0.375	2.015	3.752
4/17/16 22:15	1.517	0.383	1.919	3.819
4/17/16 22:30	1.305	0.328	2.218	3.851
4/17/16 22:45	1.209	0.319	2.110	3.638
4/17/16 23:00	1.161	0.311	1.927	3.399
4/17/16 23:15	1.120	0.265	2.120	3.505
4/17/16 23:30	1.004	0.242	0.061	1.307

Flow Data into Tudor Road Pump Station				
Date and Time	Site 9 Flowrate (mgd)	Site 10 Flowrate (mgd)	Site 11 Flowrate (mgd)	Combined Flowrate (mgd)
4/17/16 23:45	0.987	0.240	2.407	3.634
4/18/16 0:00	0.830	0.226	0.029	1.085
4/18/16 0:15	0.831	0.204	2.055	3.090
4/18/16 0:30	0.791	0.181	0.139	1.111
4/18/16 0:45	0.722	0.182	0.024	0.928
4/18/16 1:00	0.651	0.159	0.390	1.200
4/18/16 1:15	0.652	0.153	0.020	0.825
4/18/16 1:30	0.571	0.206	1.864	2.641
4/18/16 1:45	0.553	0.160	0.086	0.799
4/18/16 2:00	0.575	0.128	0.000	0.703
4/18/16 2:15	0.548	0.124	0.000	0.672
4/18/16 2:30	0.530	0.126	0.127	0.783
4/18/16 2:45	0.560	0.137	0.013	0.710
4/18/16 3:00	0.522	0.096	2.163	2.781
4/18/16 3:15	0.536	0.101	0.070	0.707
4/18/16 3:30	0.503	0.119	0.015	0.637
4/18/16 3:45	0.493	0.131	1.716	2.340
4/18/16 4:00	0.505	0.112	0.059	0.676
4/18/16 4:15	0.434	0.112	0.014	0.560
4/18/16 4:30	0.499	0.110	0.000	0.609
4/18/16 4:45	0.498	0.115	1.412	2.025
4/18/16 5:00	0.593	0.115	0.031	0.739
4/18/16 5:15	0.553	0.132	0.000	0.685
4/18/16 5:30	0.660	0.121	2.336	3.117
4/18/16 5:45	0.614	0.154	0.044	0.812
4/18/16 6:00	0.831	0.193	0.000	1.024
4/18/16 6:15	0.803	0.204	2.282	3.289
4/18/16 6:30	0.948	0.236	0.033	1.217
4/18/16 6:45	1.135	0.330	2.367	3.832
4/18/16 7:00	1.195	0.387	0.034	1.616
4/18/16 7:15	1.170	0.375	2.005	3.550
4/18/16 7:30	1.313	0.359	2.003	3.675
4/18/16 7:45	1.290	0.375	2.203	3.868
4/18/16 8:00	1.194	0.376	1.833	3.403
4/18/16 8:15	1.255	0.350	1.875	3.480
4/18/16 8:30	1.356	0.338	2.267	3.961
4/18/16 8:45	1.273	0.362	0.056	1.691
4/18/16 9:00	1.277	0.366	2.098	3.741
4/18/16 9:15	1.596	0.335	0.211	2.142
4/18/16 9:30	1.634	0.337	2.118	4.089
4/18/16 9:45	1.449	0.329	0.170	1.948
4/18/16 10:00	1.531	0.376	2.034	3.941
4/18/16 10:15	1.593	0.329	0.564	2.486
4/18/16 10:30	1.548	0.349	2.008	3.905
4/18/16 10:45	1.481	0.343	2.457	4.281
4/18/16 11:00	1.650	0.352	0.041	2.043
4/18/16 11:15	1.623	0.347	2.09	4.060
4/18/16 11:30	1.678	0.369	0.042	2.089
4/18/16 11:45	1.682	0.393	2.184	4.259
4/18/16 12:00	1.803	0.380	0.052	2.235
4/18/16 12:15	1.923	0.394	1.945	4.262

Flow Data into Tudor Road Pump Station				
Date and Time	**Site 9 Flowrate (mgd)**	**Site 10 Flowrate (mgd)**	**Site 11 Flowrate (mgd)**	**Combined Flowrate (mgd)**
4/18/16 12:30	1.645	0.422	0.08	2.147
4/18/16 12:45	1.937	0.428	2.329	4.694
4/18/16 13:00	1.602	0.396	0.06	2.058
4/18/16 13:15	1.783	0.403	2.25	4.436
4/18/16 13:30	1.661	0.373	1.789	3.823
4/18/16 13:45	1.598	0.422	0.031	2.051
4/18/16 14:00	1.670	0.421	1.958	4.049
4/18/16 14:15	1.616	0.395	0.026	2.037
4/18/16 14:30	1.611	0.373	2.066	4.050
4/18/16 14:45	1.451	0.420	0.069	1.940
4/18/16 15:00	1.515	0.396	2.147	4.058
4/18/16 15:15	1.595	0.379	0.069	2.043
4/18/16 15:30	1.420	0.409	2.254	4.083
4/18/16 15:45	1.418	0.389	0.12	1.927
4/18/16 16:00	1.544	0.422	2.299	4.265
4/18/16 16:15	1.517	0.377	0.784	2.678
4/18/16 16:30	1.625	0.399	1.963	3.987
4/18/16 16:45	1.738	0.395	2.013	4.146
4/18/16 17:00	1.657	0.395	0.041	2.093
4/18/16 17:15	1.778	0.414	2.197	4.389
4/18/16 17:30	1.694	0.439	0.026	2.159
4/18/16 17:45	1.653	0.428	1.936	4.017
4/18/16 18:00	1.629	0.549	0.227	2.405
4/18/16 18:15	1.878	0.505	2.132	4.515
4/18/16 18:30	1.670	0.474	0.256	2.400
4/18/16 18:45	1.933	0.502	1.979	4.414
4/18/16 19:00	1.673	0.503	1.929	4.105
4/18/16 19:15	1.557	0.496	0.363	2.416
4/18/16 19:30	1.646	0.535	2.063	4.244
4/18/16 19:45	1.700	0.536	2.268	4.504
4/18/16 20:00	1.591	0.525	0.091	2.207
4/18/16 20:15	1.643	0.547	2.144	4.334
4/18/16 20:30	1.622	0.528	1.807	3.957
4/18/16 20:45	1.759	0.531	1.915	4.205
4/18/16 21:00	1.623	0.524	1.975	4.122
4/18/16 21:15	1.718	0.599	2.028	4.345
4/18/16 21:30	1.533	0.524	2.388	4.445
4/18/16 21:45	1.677	0.533	2.085	4.295
4/18/16 22:00	1.365	0.596	0.049	2.010
4/18/16 22:15	1.503	0.523	2.166	4.192
4/18/16 22:30	1.364	0.517	2.167	4.048
4/18/16 22:45	1.511	0.488	2.019	4.018
4/18/16 23:00	1.186	0.411	2.295	3.892
4/18/16 23:15	1.198	0.404	0.602	2.204
4/18/16 23:30	1.165	0.393	2.087	3.645
4/18/16 23:45	1.033	0.373	0.728	2.134

Client: City of Lee's Summit, MO
Project Name: Lee's Summit Tudor Road Odor
Project Number: 016-0091
Description: Wastewater Analytical Results Sulfide Dissolved
Date: 7/8/16

Sample ID	Matrix	Date Collected	Time	Date Received	Time	Sulfide, Dissolved - Analytical Method	BOD, 5 day - Analytical Method
TUDOR INFLUENT 6:00 AM	Water	4/17/16	6:30	4/18/16	10:27	0.16 mg/L	-
TUDOR DISCHARGE 6:00 AM	Water	4/17/16	6:30	4/18/16	10:27	0.20 mg/L	-
AR24-003 6:00 AM	Water	4/17/16	7:15	4/18/16	10:27	1.2 mg/L	-
MH14-017 6:00 AM	Water	4/17/16	8:04	4/18/16	10:27	5.2 mg/L	-
MH14-007 6:00 AM	Water	4/17/16	7:55	4/18/16	10:27	2.0 mg/L	-
TUDOR INFLUENT 2:00 PM	Water	4/17/16	14:20	4/18/16	10:27	0.59 mg/L	-
TUDOR DISCHARGE 2:00 PM	Water	4/17/16	14:30	4/18/16	10:27	0.24 mg/L	-
AR24-003 2:00 PM	Water	4/17/16	15:02	4/18/16	10:27	1.4 mg/L	-
MH14-017 2:00 PM	Water	4/17/16	15:15	4/18/16	10:27	0.25 mg/L	-
MH14-007 2:00 PM	Water	4/17/16	15:45	4/18/16	10:27	1.6 mg/L	-
TUDOR INFLUENT 10:00 PM	Water	4/17/16	23:30	4/18/16	10:27	0.46 mg/L	-
TUDOR DISCHARGE 10:00 PM	Water	4/17/16	22:00	4/18/16	10:27	0.45 mg/L	-
AR24-003 10:00 PM	Water	4/17/16	23:00	4/18/16	10:27	1.1 mg/L	-
MH14-017 10:00 PM	Water	4/18/16	0:00	4/18/16	10:27	3.0 mg/L	-
MH14-007 10:00 PM	Water	4/17/16	22:30	4/18/16	10:27	3.2 mg/L	-
TUDOR BOD 1	Water	4/18/16	9:00	4/18/16	10:27	-	292 mg/L
TUDOR BOD 2	Water	4/18/16	9:00	4/18/16	10:27	-	287 mg/L
TUDOR BOD 3	Water	4/18/16	9:00	4/18/16	10:27	-	157 mg/L

APPENDIX C

FLOW MONITORING LOCATIONS

Flow Meters: 25-329 (Short Term), 25-210, and 25-267

APPENDIX D

INITIAL ALTERNATIVES OPINION OF PROBABLE COSTS

OLSSON ASSOCIATES

OPINION OF PROBABLE IMPROVEMENT COST

CITY OF LEE'S SUMMIT, MO
TUDOR ROAD PUMP STATION

ALTERNATIVE A - VORTEX FLOW INSERT

OA Project 016-0091
July 1, 2016

	UNIT	QTY	UNIT COST	TOTAL
<u>Capital Cost</u>				
New Vortex Flow Insert and Associated Equipment	LS	1	$ 35,000	$ 35,000
Vortex Flow Structure	LS	1	$ 75,000	$ 75,000
New Bypass Line	LS	1	$ 50,000	$ 50,000
New Bypass Valve	LS	1	$ 50,000	$ 50,000
New Manhole	EA	1	$ 5,000	$ 5,000
Electrical	LS	1	$ 15,000	$ 15,000
Contingencies		20%		$ 46,000
Engineering		20%		$ 56,000
Total Probable Capital Cost				$ 332,000
<u>Annual Cost</u>				
Power Cost				$ 600
Operation and Maintenance Cost				$ 3,000
Total Probable Annual Cost				$ 3,600

OLSSON ASSOCIATES

OPINION OF
PROBABLE IMPROVEMENT COST

CITY OF LEE'S SUMMIT, MO
TUDOR ROAD PUMP STATION

ALTERNATIVE B - BIOXIDE

OA Project 016-0091
July 1, 2016

	UNIT	QTY	UNIT COST	TOTAL
Capital Cost				
Removal of Existing Ferric Chloride Feed System	LS	1	$ 5,000	$ 5,000
New Bioxide Feed and Monitoring Equipment	LS	1	$ 50,000	$ 50,000
New Flow Meter	LS	1	$ 100,000	$ 100,000
New Storage Tank	LS	1	$ 25,000	$ 25,000
Installation of New Equipment	LS	1	$ 10,000	$ 10,000
SCADA Improvements	LS	1	$ 25,000	$ 25,000
Electrical	LS	1	$ 60,000	$ 60,000
Contingencies		20%		$ 55,000
Engineering		20%		$ 66,000
Total Probable Capital Cost				$ 396,000
Annual Cost				
Power Cost				$ -
Operation and Maintenance Cost				$ 140,000
Total Probable Annual Cost				$ 140,000

OPINION OF
PROBABLE IMPROVEMENT COST

CITY OF LEE'S SUMMIT, MO
TUDOR ROAD PUMP STATION

ALTERNATIVE C - AIR SCRUBBING

OA Project 016-0091
July 1, 2016

	UNIT	QTY	UNIT COST	TOTAL
Capital Cost				
New Air Scrubber and Associated Equipment	LS	1	$ 25,000	$ 25,000
Installation of New Equipment	LS	1	$ 25,000	$ 25,000
New Concrete Pad	LS	1	$ 10,000	$ 10,000
Electrical	LS	1	$ 15,000	$ 15,000
Contingencies		20%		$ 15,000
Engineering		20%		$ 18,000
Total Probable Capital Cost				$ 108,000
Annual Cost				
Power Cost				$ 4,000
Operation and Maintenance Cost				$ 8,000
Total Probable Annual Cost				$ 12,000

OLSSON ASSOCIATES

OPINION OF PROBABLE IMPROVEMENT COST

CITY OF LEE'S SUMMIT, MO
TUDOR ROAD PUMP STATION

ALTERNATIVE D - DISSOLVED OXYGEN INJECTION (LIQUID OXYGEN + TANK PURCHASE)

OA Project 016-0091

July 1, 2016

	UNIT	QTY	UNIT COST	TOTAL
Capital Cost				
New Dissolved Oxygen Injection Equipment (Including Tank)	LS	1	$ 370,000	$ 370,000
Installation of New Equipment	LS	1	$ 95,000	$ 95,000
Piping Modifications	LS	1	$ 75,000	$ 75,000
Electrical	LS	1	$ 200,000	$ 200,000
Contingencies		20%		$ 148,000
Engineering		20%		$ 178,000
Total Probable Capital Cost				$1,066,000
Annual Cost				
Power Cost				$ 6,700
LOX Cost				$ 50,850
Operation and Maintenance Cost				$ 3,850
Total Probable Annual Cost				$ 61,400

OLSSON ASSOCIATES

OPINION OF
PROBABLE IMPROVEMENT COST

CITY OF LEE'S SUMMIT, MO
TUDOR ROAD PUMP STATION

ALTERNATIVE D - DISSOLVED OXYGEN INJECTION (OXYGEN GENERATION)

OA Project 016-0091

July 1, 2016

	UNIT	QTY	UNIT COST	TOTAL
Capital Cost				
New Dissolved Oxygen Injection Equipment	LS	1	$ 800,000	$ 800,000
Installation of New Equipment	LS	1	$ 100,000	$ 100,000
Piping Modifications	LS	1	$ 75,000	$ 75,000
Electrical	LS	1	$ 275,000	$ 275,000
Contingencies		20%		$ 250,000
Engineering		20%		$ 300,000
Total Probable Capital Cost				$ 1,800,000
Annual Cost				
Power Cost				$ 35,000
Operation and Maintenance Cost				$ 25,000
Total Probable Annual Cost				$ 60,000

OPINION OF
PROBABLE IMPROVEMENT COST

CITY OF LEE'S SUMMIT, MO
TUDOR ROAD PUMP STATION

ALTERNATIVE E - ALTERNATIVE LOW FLOW DISCHARGE LOCATION

OA Project 016-0091
July 1, 2016

	UNIT	QTY	UNIT COST	TOTAL
Capital Cost				
Contingencies		20%		$ -
Engineering		20%		$ -
Total Probable Capital Cost				$ -
Annual Cost				
Ferric Chloride Cost				$ 107,000
Total Probable Annual Cost				$ 107,000

OPINION OF
PROBABLE IMPROVEMENT COST

CITY OF LEE'S SUMMIT, MO
TUDOR ROAD PUMP STATION

ALTERNATIVE F - INSTALL MECHANICAL MIXER IN WET WELL

OA Project 016-0091

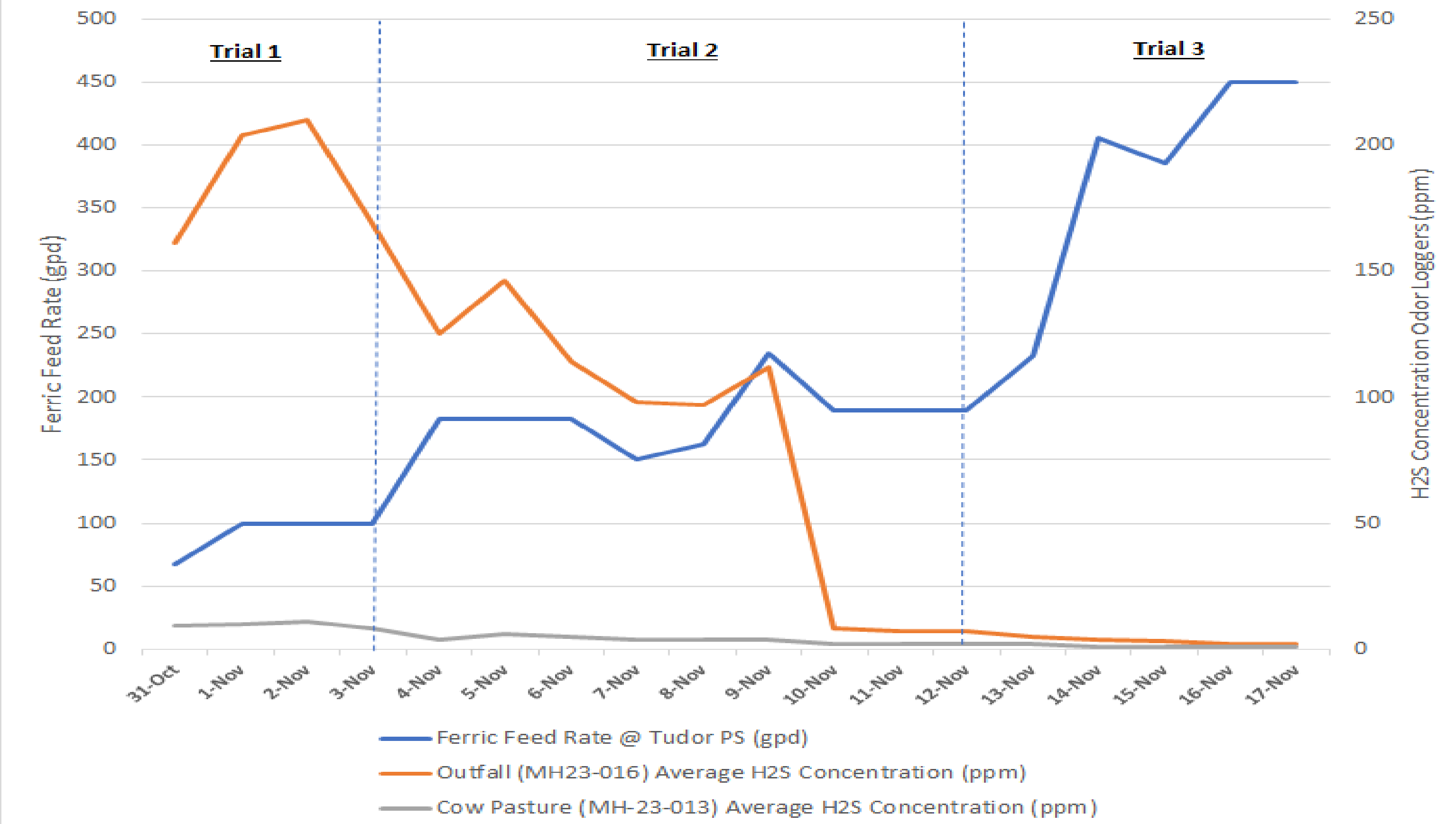
July 1, 2016

	UNIT	QTY	UNIT COST	TOTAL
Capital Cost				
Contingencies		20%		$ -
Engineering		20%		$ -
Total Probable Capital Cost				$ -
Annual Cost				
Ferric Chloride Cost				$ 107,000
Mainentence Cost				$ 5,000
Power Cost				$ 2,000
Total Probable Annual Cost				$ 114,000

APPENDIX E

ODOR TRIAL 1 AND 2

Odor Trial 1 - Little Cedar Watershed

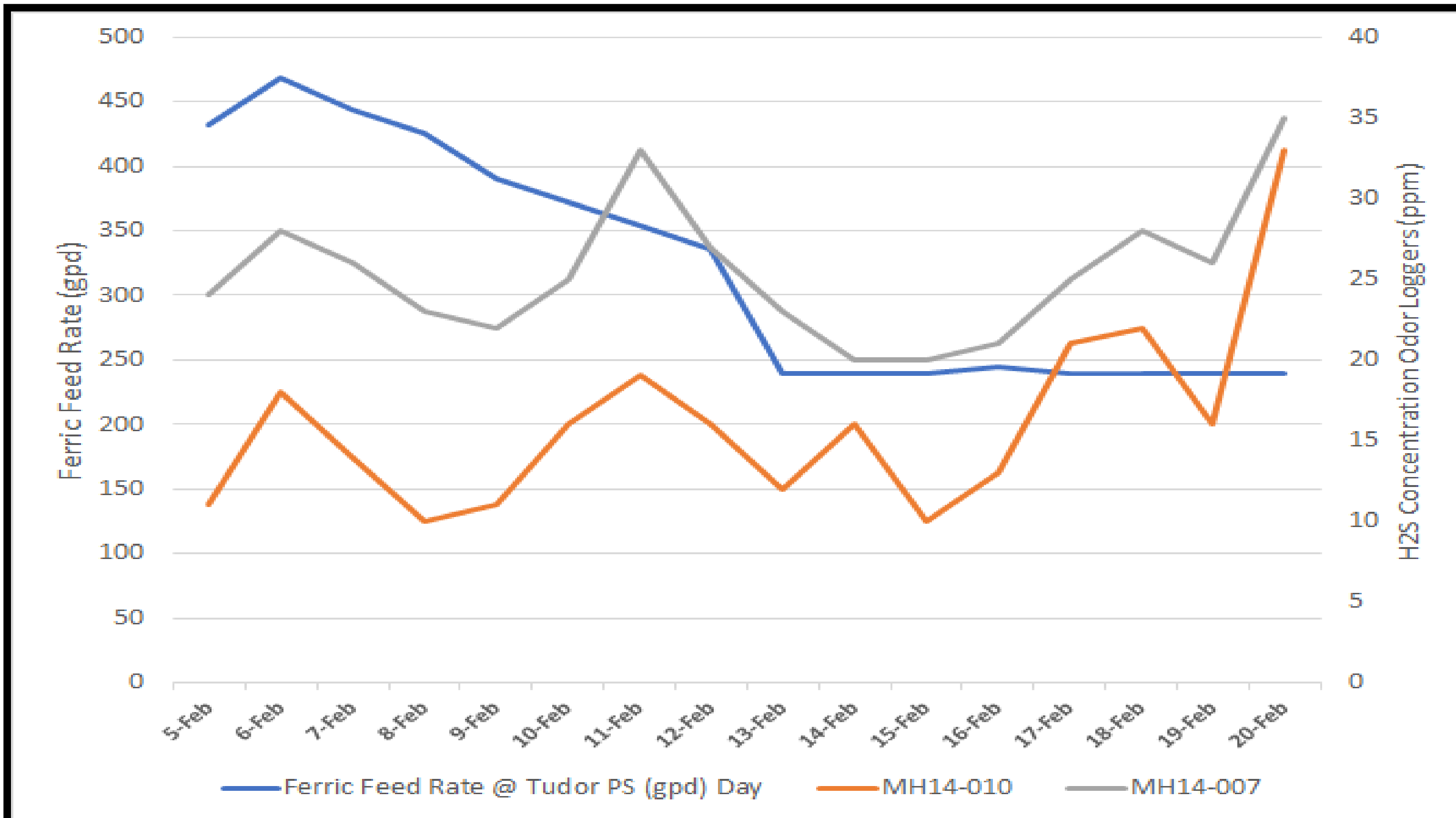


Date	Ferric Feed Rate @ Tudor PS (gpd)	Outfall (MH23-016) Average H2S Concentration (ppm)	Cow Pasture (MH-23-013) Average H2S Concentration (ppm)	Tudor WW# 1 Level	Tudor WW# 2 Level
31-Oct	67	161	9	9.114	8.982
1-Nov	100	204	10	8.982	9.114
2-Nov	100	210	11	8.828	8.996
3-Nov	100	169	8	8.828	8.996
4-Nov	183	125	4	8.632	8.842
5-Nov	183	146	6	8.632	8.842
6-Nov	183	114	5	8.577	8.709
7-Nov	150	98	4	8.577	8.709
8-Nov	163	97	4	8.577	8.709
9-Nov	235	112	4	8.409	8.618
10-Nov	189	8	2	8.835	9.975
11-Nov	189	7	2	9.086	9.212
12-Nov	189	7	2	9.086	9.212
13-Nov	233	5	2	9.282	9.408
14-Nov	405	4	1	9.282	9.408
15-Nov	385	3	1	9.450	9.561
16-Nov	450	2	1	9.450	9.561
17-Nov	450	2	1	8.582	9.722

Analytical Testing Results

Date	Ferric Feed Rate (gpd)	pH			H2S Concentration (mg/L))			Total Sulfide Concentration (mg/L))		
		Tudor Influent	Tudor WW	Outfall	Tudor Influent	Tudor WW	Outfall	Tudor Influent	Tudor WW	Outfall
31-Oct	67	7.1	6.8	7	0.51	0.31	3.1	1.1	0.54	6.4
6-Nov	183	7.1	6.7	6.9	0.27	0.52	2.9	0.58	0.8	5.2
13-Nov	233	6.9	6.7	6.9	0.81	0.66	2.5	1.5	1.1	4.8
17-Nov	450	7.1	6.4	6.9	0.88	0.32	2.3	1.9	0.41	4.5

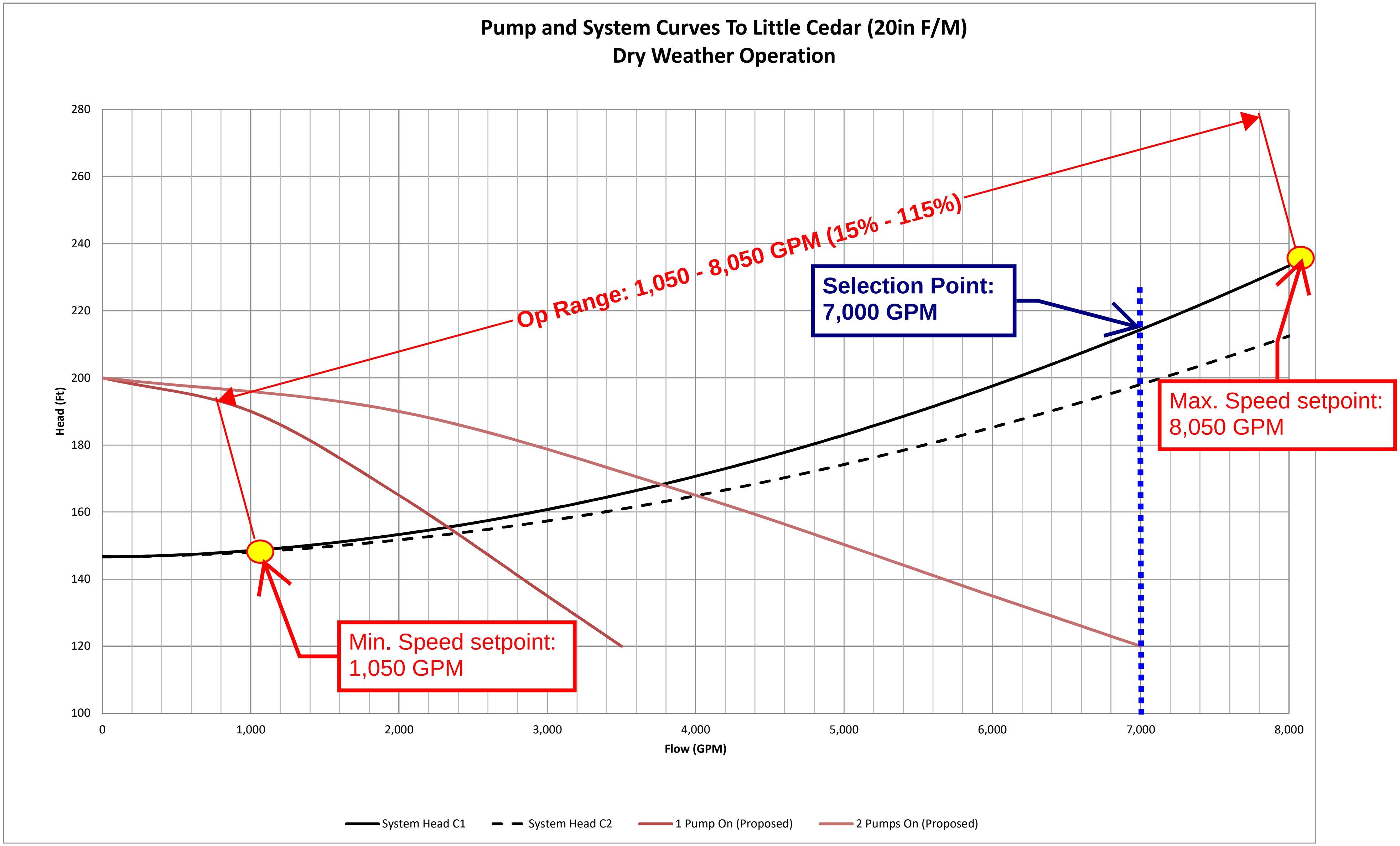
Odor Trial 2 - Maybrook Watershed

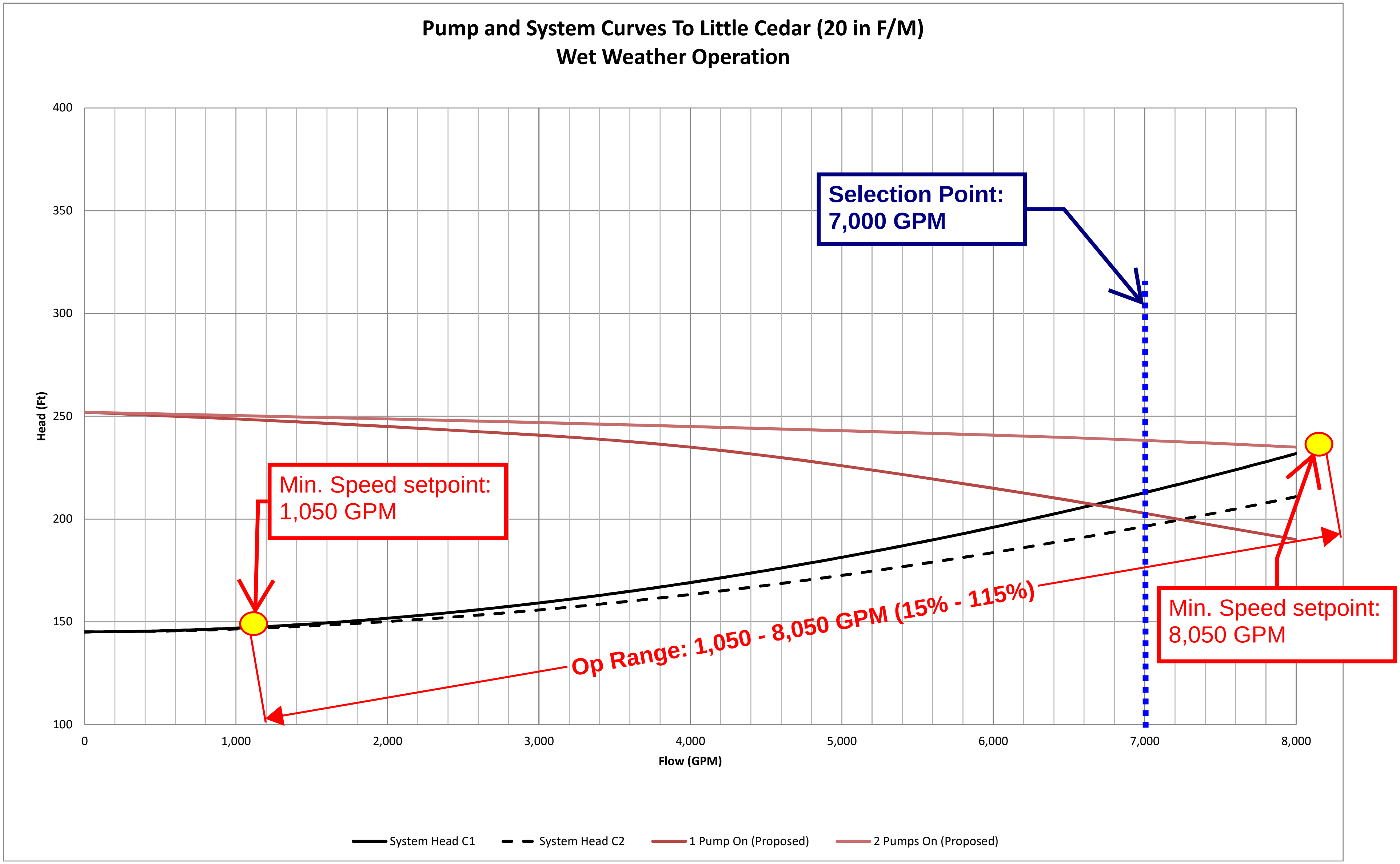


Date	Ferric Feed Rate @ Tudor PS (gpd) Day	MH14-010 H2S Concentration (ppm)	MH14-007 H2S Concentration (ppm)
5-Feb	432	11	24
6-Feb	468	18	28
7-Feb	444	14	26
8-Feb	426	10	23
9-Feb	390	11	22
10-Feb	372	16	25
11-Feb	354	19	33
12-Feb	336	16	27
13-Feb	240	12	23
14-Feb	240	16	20
15-Feb	240	10	20
16-Feb	245	13	21
17-Feb	240	21	25
18-Feb	240	22	28
19-Feb	240	16	26
20-Feb	240	33	35

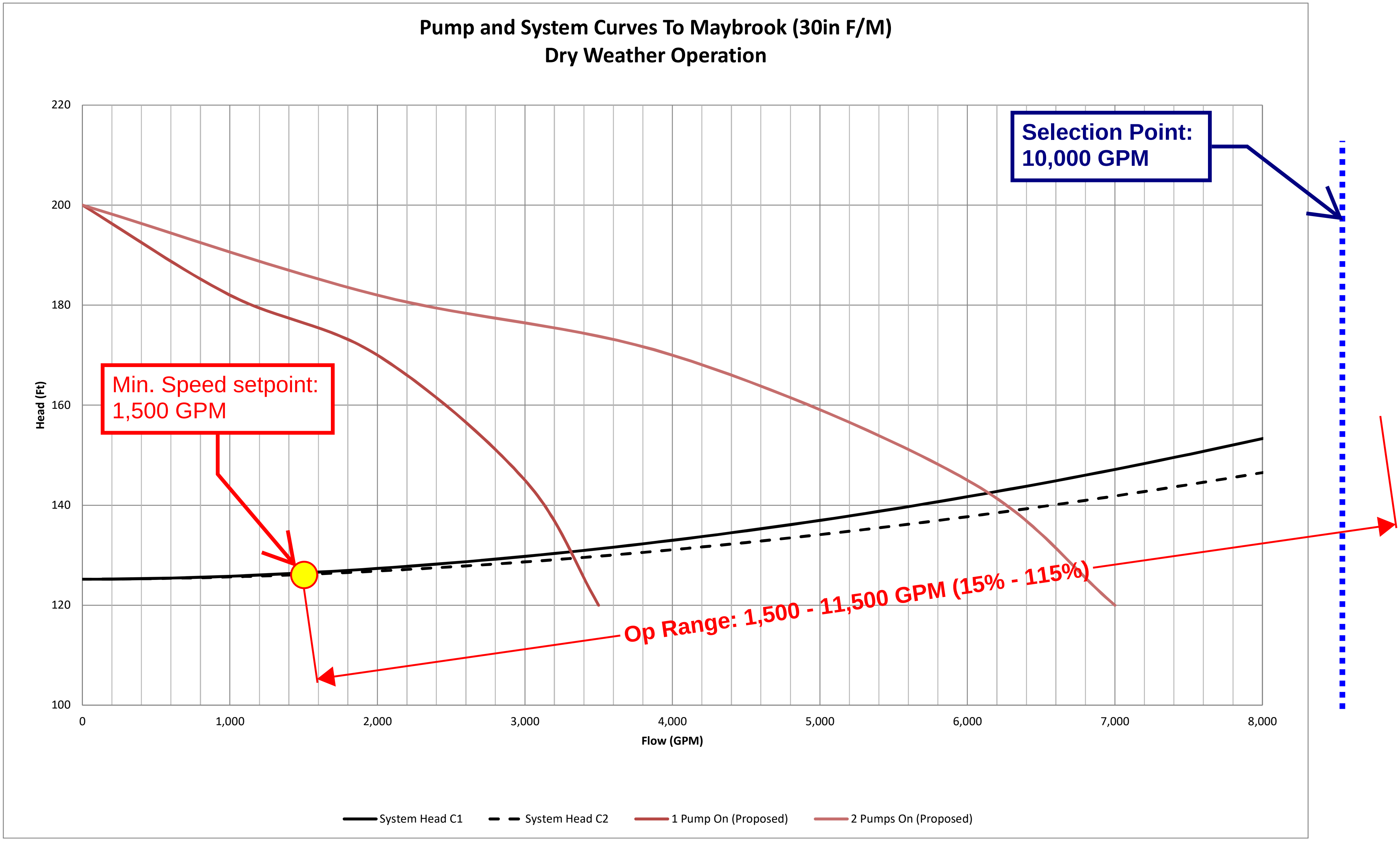
APPENDIX F

PUMP AND SYSTEM CURVES

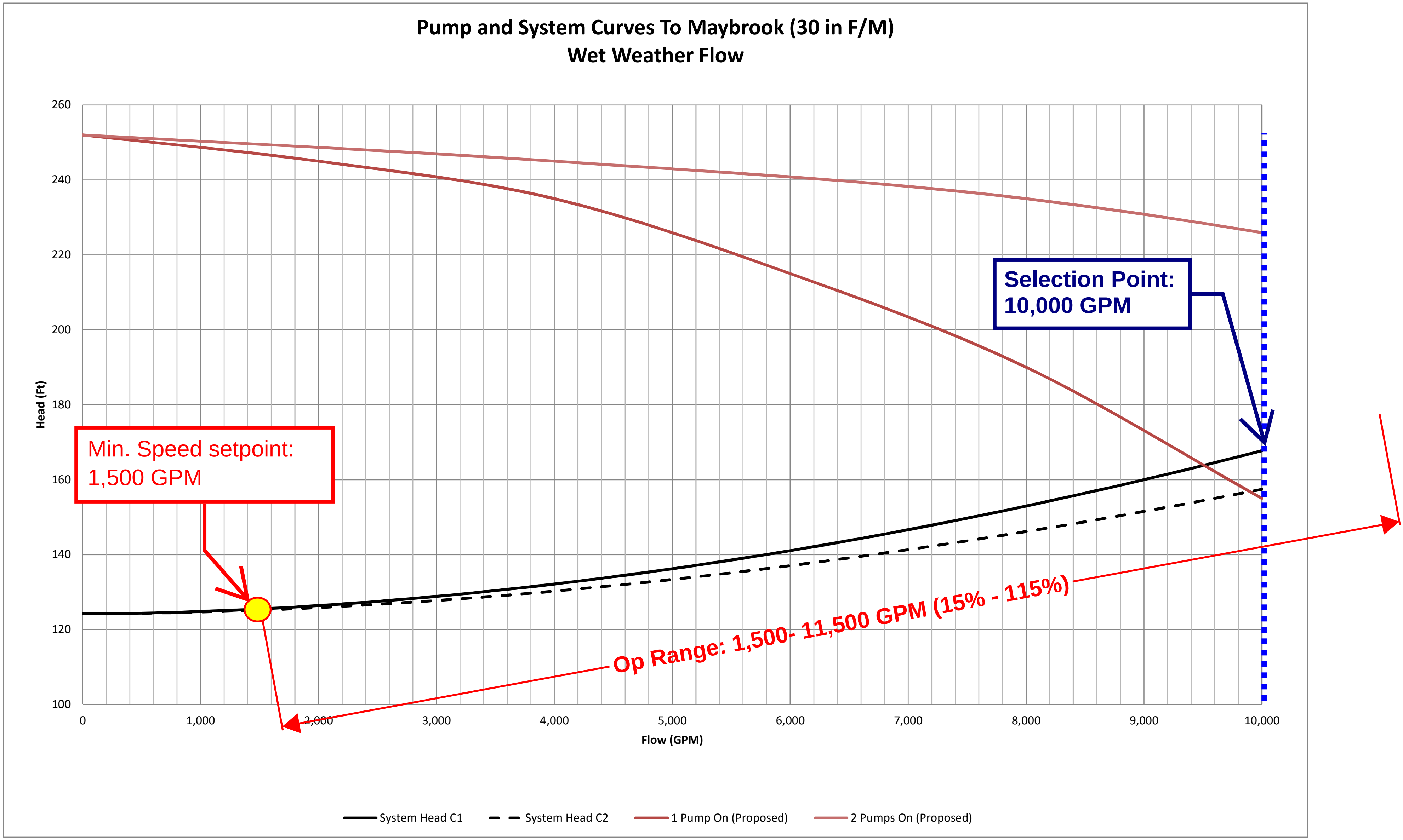

Pump and System Curves To Little Cedar (20in F/M)
Dry Weather Operation
Head (Ft)
280
260
240
220
200
180
160
140
120
100
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Flow (GPM)
Op Range: 1,050 - 8,050 GPM (15% - 115%)
Selection Point:
7,000 GPM
Max. Speed setpoint:
8,050 GPM
Min. Speed setpoint:
1,050 GPM
System Head C1
System Head C2
1 Pump On (Proposed)
2 Pumps On (Proposed)



Pump and System Curves To Little Cedar (20 in F/M)
Wet Weather Operation
Selection Point:
7,000 GPM
Min. Speed setpoint:
1,050 GPM
Min. Speed setpoint:
8,050 GPM
Op Range: 1,050 - 8,050 GPM (15% - 115%)
Head (Ft)
400
350
300
250
200
150
100
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Flow (GPM)
System Head C1
System Head C2
1 Pump On (Proposed)
2 Pumps On (Proposed)



Pump and System Curves To Maybrook (30in F/M)
Dry Weather Operation
Selection Point:
10,000 GPM
Min. Speed setpoint:
1,500 GPM
Op Range: 1,500 - 11,500 GPM (15% - 115%)
Head (Ft)
220
200
180
160
140
120
100
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Flow (GPM)
System Head C1
System Head C2
1 Pump On (Proposed)
2 Pumps On (Proposed)



Pump and System Curves To Maybrook (30 in F/M)
Wet Weather Flow
Head (Ft)
260
240
220
200
180
160
140
120
100
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Flow (GPM)
Selection Point:
10,000 GPM
Min. Speed setpoint:
1,500 GPM
Op Range: 1,500- 11,500 GPM (15% - 115%)
System Head C1
System Head C2
1 Pump On (Proposed)
2 Pumps On (Proposed)

APPENDIX G

REVISED VORTEX FLOW INSERT ALTERNATIVE OPINION OF PROBABLE COST

OLSSON ASSOCIATES

OPINION OF PROBABLE IMPROVEMENT COST

CITY OF LEE'S SUMMIT, MO
TUDOR ROAD PUMP STATION

REVISED VORTEX FLOW INSERT ALTERNATIVE

OA Project 016-0091

July 9, 2018

		UNIT	QTY	UNIT COST	TOTAL
Capital Cost					
	New Vortex Flow Insert and Associated Equipment	LS	1	$ 200,000	$ 200,000
	VFI Structure and Site Improvements	EA	2	$ 170,000	$ 340,000
	New Bypass Line	LS	1	$ 75,000	$ 75,000
	New Bypass Valves	LS	1	$ 50,000	$ 50,000
	New Manhole	EA	1	$ 5,000	$ 5,000
	Contingencies		20%		$ 140,000
	Engineering		20%		$ 162,000
Total Probable Capital Cost					$ 972,000
Annual Cost					
	Power Cost				$ 1,000
	Ferric Chloride (100 gpd)				$ 45,000
	Operation and Maintenance Cost				$ 10,000
Total Probable Annual Cost					$ 56,000

TUDOR ROAD PUMP STATION ODOR CONTROL
CONCEPTUAL OPTIONS EVALUATION
LEE'S SUMMIT, MISSOURI - 2018

July 2018

OA Project No. 016-0091