Technical Memorandum

Date: November 22, 2011

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From: Jeffrey Zahller, PE

Subject: Odor and Corrosion Control Strategy

1.0 Introduction

The purpose of this memo is to document the preferred approach and initial sizing of a foul air management system for the Murray Combined Sewer Overflow (CSO) project. The primary purpose of the project is construction of a wet weather storage facility to limit untreated combined sewer overflows from the existing Murray Pump Station, as required by State and Federal regulations, to an average of one event per year. The new facility will require odor control to prevent fugitive emissions to the neighboring community and this odor control must be integrated with the existing pump station foul air management system.

2.0 Background and Existing Conditions

2.1 Existing Murray Pump Station

Figure 1 provides a layout of the existing wet well ventilation system currently in operation at the Murray Pump Station. The wet well is isolated from the main pump room and odor control is only provided for the wet well (separate ventilation is included for the remainder of the pump station). Figure 1 was extracted from the facility O&M manual and delineates the primary components of the odor control system as it currently exists. Key features of the system include:

- A passive supply air vault (with a backdraft damper) for the wet well. This is located on the south side of the site.
- An exhaust fan (inline centrifugal, 2,330 cubic feet per minute (cfm), 7.5 horsepower (hp)) mounted on the north wall of the wet well (directly below the access hatch).
- The exhaust fan pushes air through the odor scrubber vault and out the odor exhaust tower on the southeast corner of the site.

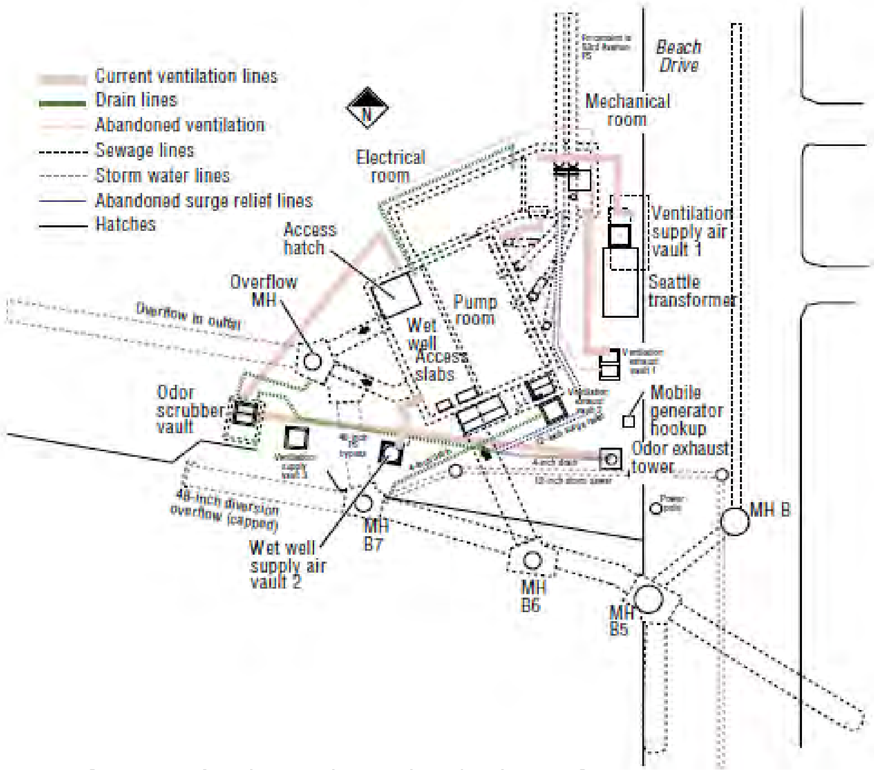

Figure 1: Current Ventilation and Odor Control Layout for the Murray Pump Station.

Figure 2 is a photo of the existing site, looking to the southwest towards the odor scrubber vault. Figure 3 is the current odor exhaust stack located on the southeast corner of the pump station site.

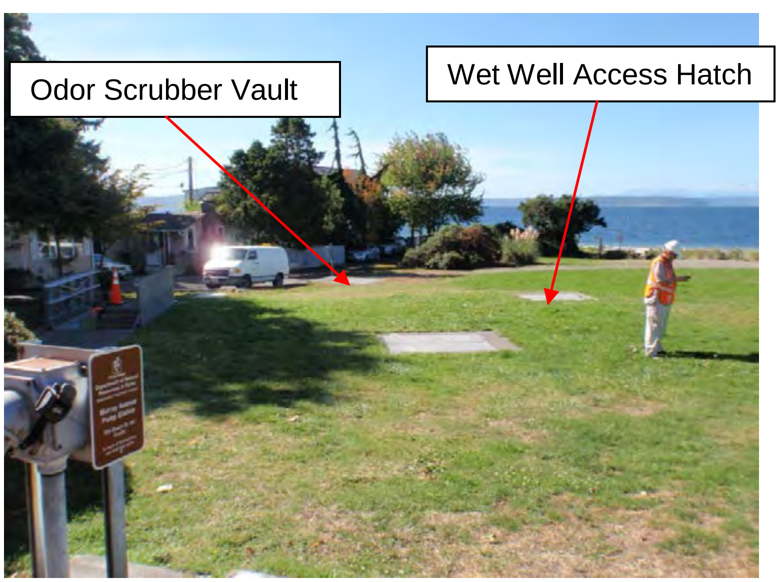

Figure 2: Murray Pump Station Site, Looking Southwest.

Figure 3: Odor Control System Exhaust Stack.

The odor scrubber treatment vessel is a horizontal fiberglass reinforced plastic (FRP) structure (approximate dimensions of 6 ft wide x 7 ft long x 6 ft high) located in the odor scrubber vault on the southwest corner of the site (Figure 4). The vessel is filled with activated, impregnated (potassium hydroxide) carbon that adsorbs and chemically reacts with the reduced sulfur compounds in the foul air. The vessel houses approximately 5,850 lbs of carbon in a 3 ft deep bed and is rated for 2,400 cfm of flow. Carbon change-out is accomplished by opening the vault hatch, unbolting the vessel flange, and using a vactor truck to remove the spent carbon.

Figure 4: Odor Control Carbon Vessel.

Ventilation in the wet well is accomplished through the single, inline centrifugal exhaust fan mounted on the wall of the wet well (Figure 5). The fan pulls directly from the room without a permanent grease filter. Operations staff currently place temporary, throw-away filters on the inlet of the fan to help prevent grease/moisture from reaching the carbon scrubber.

The air inlet to the wet well is a passive design (no forced air blower). An existing reinforced concrete pipe (RCP) located in the southwest corner of the wet well (Figure 6) is tied to a small vault with a grating cover and backdraft damper/insect screen. The system is designed to simply allow air into the wet well, at a relatively low negative pressure, as required to balance the flow from the exhaust fan.

Figure 5: Wet Well Exhaust Fan (mounted on north wall, with filter).

Figure 6: Wet Well Supply Air Inlet (from Supply Air Vault).

2.2 Existing System Improvements and Integration with CSO Storage

One of the primary goals of the CSO project will be integration of the existing wet well odor control system with odor control for the new CSO Storage Tank. Integration will provide an opportunity to update and improve various components of the pump station odor control as well as provide a single point of treatment for both facilities (CSO Storage Tank and pump station) to allow for more efficient operation as well as relocation of the scrubber outside of Lowman Beach Park.

The final system design will provide for the following improvements to the existing pump station odor control system:

1. Relocation (replacement & upsizing) of the wet well exhaust fan to a more accessible (and safer) location across Beach Drive at the new CSO facility.
2. Addition of a supply fan to provide a forced air supply to the wet well and improve the sweeping effect of air through the space.
3. Addition of a permanent grease filter to provide for more efficient, long term O&M.
4. Relocation (replacement & upsizing) of the carbon scrubber to a larger, more accessible below grade or partially below grade structure across Beach Drive at the new CSO facility.

3.0 Summary of Design Criteria

3.1 King County Design Standards

All design features of the Murray CSO facility will comply with the King County Odor and Corrosion Control Design Standards as well as the design criteria established as part of the general CSO Beaches Project Design Standards (Carollo, August, 2011; modified by King County in October, 2011). The odor control design criteria for the CSO Beaches Projects was further modified in a recent memorandum (CSO Storage Facility, Odor Control Criteria, November 18, 2011).

Table 1 provides a summary of HDR's interpretation of the King County Design Standards as they apply to specific features of this project. These specific design criteria are an expansion and application of the criteria established in the CSO Beaches Project Design Standards as well as discussions in team meetings:

1. Size odor control facilities for anticipated fill rates of the underground CSO Storage Tank as well as to maintain negative pressure.
2. Do not size CSO Storage Tank ventilation for manned entry bypass capacity (this will be accomplished through portable ventilation equipment).
3. Utilize 50 fpm across the water surface when the tank is full as a baseline for maintaining negative pressure in CSO Storage Tanks, unless such a requirement is not feasible due to hydraulic or layout limitations. This criterion was removed from the project by the November 18, 2011 memorandum.
4. Provide for two air flow setpoints from the CSO Storage Tank: one rate to maintain negative pressure when the tank is not in use and one rate to provide negative pressure when tank is filling from an overflow event. These criteria were added as part of the November 18, 2011 memorandum.
5. The preferred (pre-design) treatment technology is carbon adsorption scrubbers (evaluated in Section 4.3).

Table 1: Murray CSO Project Design Criteria

Design Component	Required Design Criteria
Murray Pump Station Wet Well	Provide negative pressure (-0.1 inches water column (w.c.))
	Provide both forced supply and forced exhaust air
CSO Storage Tank	Provide negative pressure (-0.1 inches w.c.)
	Exhaust fan and passive air supply
	Provide two setpoints for negative pressure under both operating (filling) and non-operating conditions.
Fan and Odor Scrubber Rooms	Locate below grade or partially below grade
Foul Air Duct	Fiberglass (FRP) construction
	Air Velocity: < 3,000 feet per minute (fpm)
	Friction: 0.1-0.15 inches w.c./100 ft
	Exhaust Velocity: 3,000 fpm

Design Component	Required Design Criteria
Supply Fan	Fiberglass (FRP) construction
	Air Movement and Control Association (AMCA) certified
	Energy efficient, explosion proof motors
	In-line duct heater (freeze protection)
	Noise attenuating inlet air louver
Exhaust Fans	Fiberglass (FRP) construction
	AMCA certified
	Energy efficient, explosion proof motors
	Discharge silencer (noise reduction)
Carbon Scrubber[1] (if used)	FRP vessel fabricated to RTP-1 standards
	Operated under negative pressure
	Horizontal bed design
	Mist/Grease eliminator upstream
	Headloss: 2 inches w.c./ft bed depth
	Air Loading: 50-60 cfm/sf
	Empty Bed Contact Time (EBCT): 3-4 seconds
	Carbon type in compliance with King County Standards[2]

[1]The Water Environment Federation Manual of Practice (MOP) 25, "Control of Odors and Emissions from Wastewater Treatment Plants", will be used for supplementary design standards in addition to King County requirements.

[2]The selected carbon type will be dependant on the H_2S levels measured in the pump station wet well. This data has not yet been provided.

3.2 Code Compliance

Code compliance from an odor control/ventilation standpoint must be addressed for both the existing pump station and the new CSO facility (including odor control scrubber and equipment rooms). The requirements for each facility are unique and there are some regulatory gray areas that must be addressed.

3.2.1 Murray Pump Station

NFPA (National Fire Protection Association) Standard 820 is the generally accepted governing standard for ventilation in wastewater treatment plants and collection facilities. It is accepted as part of the King County design standards and utilized by the Department of Ecology's Criteria for Sewage Works Design (Orange Book). It ties ventilation requirements and associated fire protection to an area rating classification that directly affects the degree of explosion hazard present and type of electrical equipment allowed for installation.

For the wet well portion of the pump station, in order to achieve the required Class 1, Div 2 standards, the following criteria must be met:

- Provide a minimum of 12 ACH (air exchanges per hour) at all times in the wet well.
- Maintain a differential air pressure of -0.1 inches w.c. relative to atmospheric conditions.

- Provide a means of combustible gas detection (CGD) in the wet well (set at 10% of the lower explosion limit [LEL]). The CGD shall include visual and audible alarms to notify operations staff if combustible gas levels exceed the setpoint.
- Provide flow monitoring on the ventilation fans to automatically determine when a fan failure or loss of flow has occurred (i.e. the system is not able to achieve 12 ACH).

It is possible to include control features in the design to operate at only 6 ACH while maintaining a Class 1, Div 2 status. However, this mode of operation can only be utilized if all of the following criteria are met:

- The wet well is unoccupied (this can be detected automatically through motion detectors or hatch switches).
- The ambient supply air temperature is 50°F or less.
- The CGD is below 10% of the LEL.

A variable speed fan could potentially be balanced to operate at two setpoints, depending on the status of the variables listed in the above criteria.

In addition, the Operational Safety and Health Administration (OSHA) required confined space entry regulations (Code of Federal Regulations; CFR 1910.146) will apply to the wet well. The 12 ACH provided under NFPA will serve to achieve the "permanent ventilation" system necessary to avoid a Permit Required Confined Space (PRCS) entry designation under the CFR.

3.2.2 CSO Facility

The new CSO portion of the facility will include three structures directly related to odor control:

- CSO Storage Tank.
- Odor Control Fan Room (housing supply and exhaust fans).
- Odor Scrubber Room.

The CSO Storage Tank will be vented according to the WTD standards listed in Section 3.1. These standards are meant to achieve negative pressure in the tank; they are not designed to satisfy NFPA requirements. Under NFPA 820, the inside of the tank will be a Class 1, Div 1 designation similar to any non-ventilated sanitary sewer or combined sewer wet well. This designation will affect all electrical equipment located in the structure. Any entry to the tank will be a Permit Required Confined Space (PRCS) and need to follow County protocol.

The Fan Room will house the supply and exhaust fans associated with the odor control system. Though the foul air will be contained within ductwork, there is the potential for leakage of explosive gases at the fan, duct fittings, dampers, and any other flanged joint or mechanical connection. Consequently, per NFPA 820, the area will be ventilated at 6 ACH to maintain an unclassified status throughout the room, with the exception of any area within 3 ft of a potential leakage point. These areas will be designated Class 1, Div 2. General fire protective measures for the room, as suggested by the NFPA, include fire extinguishers, fire/smoke detectors, and combustible gas detection.

The Odor Scrubber Room will be isolated from the Fan Room and may or may not include permanent ventilation. If a permanent ventilation system is installed at 6 ACH, it will fall under the same NFPA designation as the Odor Control Fan Room. If a ventilation system is not installed, the entire vault will be Class 1, Div 2. Status under OSHA for entry into the vault will be related to both entry/exit as well as ventilation. If only limited entry/exit is provided (i.e. a ladder as opposed to stairs), the area will be designated a confined space. If permanent ventilation is not provided, the area will also qualify as a PRCS.

3.2.3 Summary of Code Requirements

Table 2 provides a summary of the code designations for the various areas affected by the odor and corrosion control system:

Table 2: Murray CSO Code Summary (Odor and Corrosion Control)

Area/Room	Standard	Designed Ventilation	Designation
Pump Station Wet Well	NFPA 820	12 ACH	Class 1, Division 2
	OSHA (CFR 1910.146)	12 ACH (6 ACH required)	Not a confined space.
CSO Storage Tank	NFPA 820	See Section 3.1	Class 1, Division 1
	OSHA (CFR 1910.146)	See Section 3.1	Permit Required Confined Space (PRCS).
Odor Control Fan Room	NFPA 820	6 ACH	Class 1, Division 2 within 3 ft of leakage point; Unclassified everywhere else
Odor Scrubber Room	NFPA 820	None	Class 1, Division 2
		6 ACH	Class 1, Division 2 within 3 ft of leakage point; Unclassified everywhere else
	OSHA (CFR 1910.146)	None	Permit Required Confined Space (PRCS).
		6 ACH	Confined space.[1]

[1]Assumes restricted means of access into the vault (such as a ladder).

4.0 Schematic Design and Equipment Selection

The following sections apply the design criteria listed in Section 3 to the Murray CSO facility as currently envisioned. The design approach is a summary of the decisions made in team meetings and includes the explicit assumption that the CSO facility will be a circular tank with rectangular channels tied to the outlet of the pump station wet well via a 48 inch diameter overflow pipe.

4.1 Alternatives for Foul Air Flow Management

The new CSO Storage Tank and the existing pump station will be completely separated in terms of foul air management. This separation is recommended based on the recent November 18, 2011 design criteria memorandum that indicated a preference for multiple flow rate setpoints from the CSO structure (for off-line and on-line status). Application of multiple CSO flow setpoints would require one of the following approaches:

1. Utilize a single scrubber and exhaust fan for both the CSO Storage Tank and the pump station wet well (merging exhaust lines from both structures). Modulating control valve(s) would be required to maintain a stable flow from the wet well while varying the flow conditions from the CSO Storage Tank.
2. Keep a single scrubber and exhaust fan for both the CSO Storage Tank and the pump station wet well and increase the speed on the fan when required by CSO Storage Tank

conditions. The increased flow would be pulled from both the wet well and the CSO Storage Tank.

3. Separate the foul air system for the wet well and CSO Storage Tank and provide two independent exhaust fans. This would allow flow modification at the CSO Storage Tank that would not affect the wet well.

To avoid the complexity of the first approach, as well as the wasted energy inherent in the second approach, separate systems are recommended. This will provide an arrangement that is robust, flexible, and easy to operate. The layout and additional advantages of this arrangement are discussed in the following section.

4.2 Proposed Foul Air Management Strategy

Figure 7 displays the proposed schematic for air flow management and control for the Murray CSO project, assuming an overflow pipe from the wet well to the CSO Storage Tank (which is currently the preferred hydraulic option). The system includes three primary components: the existing pump station, the new CSO Storage Tank, and the new rooms housing the fans and treatment scrubbers. Air flow is managed from each structure in the following way:

- Pump Station –
  - Supply: a supply fan provides fresh air directly into the pump station. In addition, a non-specified amount of air will be brought into the wet well through passive drag forces acting on the upstream gravity sewer. An additional backdraft damper will provide passive air entry and maintain negative pressure when the drag forces vary and the exhaust rate remains constant.
  - Exhaust: air will be exhausted from the wet well ($Q_{pumpstation}$) to Scrubber 2 via a dedicated line that includes a control damper for balancing and a grease filter/mist eliminator upstream of the scrubber.
- CSO Storage Tank –
  - Supply: when the CSO Storage Tank is not in use, a backdraft damper will provide passive air entry (along with leakage through hatches) and maintain negative pressure relative to the set exhaust rate. When the tank is being filled hydraulically, and air volume is being displaced by the overflow rate, the backdraft damper will make up any additional flow required to maintain a set negative pressure on the vessel. A flap gate or curtain will be provided on the end of the overflow line to help isolate the CSO Storage Tank from the pump station.
  - Exhaust: air will be exhausted from the CSO Storage Tank (Q_{CSO}) to Scrubber 1 via a dedicated line that includes a control damper for balancing and a grease filter/mist eliminator upstream of the scrubber.

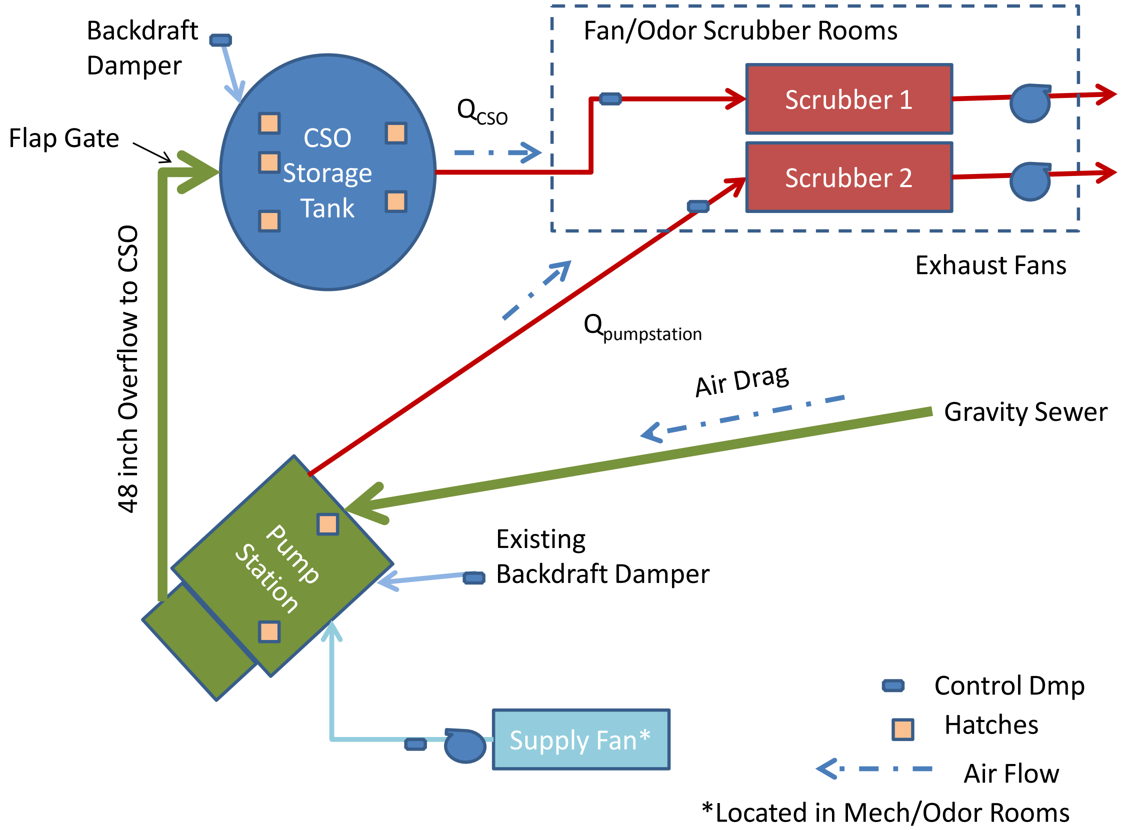

Figure 7: Proposed Foul Air Flow Schematic

The proposed alignment shown in Figure 7 would provide the following operational and control advantages:

- Each primary component (CSO Storage Tank and existing pump station) can be balanced, isolated and controlled independently of the other. Operators can open hatches at either the CSO Storage Tank or pump station wet well and still maintain ventilation at the other portion of the facility.
- Foul air from the wet well will be managed separately from the CSO Storage Tank. With the help of a flap gate or curtain at the outlet of the CSO overflow pipe, this will minimize H_2S in the CSO Storage Tank and facilitate improved long term corrosion performance.
- Balancing of each exhaust line can be done through easily accessible control dampers within the Odor Control Fan Room. Operators need not enter any confined space.
- Carbon usage in Scrubber 1 will be reduced due to the mild and infrequent loading. This will potentially allow for a less expensive (virgin activated) carbon to be utilized and reduce O&M costs for the CSO portion of the foul air flow
- Backdraft dampers provide protection from pulling an excessive vacuum on either structure (and thus having difficulty opening hatches, etc.) and allow for a simple, low energy method to provide make-up air into the system. They automatically close under positive pressure, but open under a set negative pull.

- Supply and exhaust ductwork to and from the wet well can share the same trench across Beach Drive as the 48 inch overflow pipe. This will allow all mechanical equipment to be located in the new Odor Control Fan Room and Odor Scrubber Room at the CSO facility.
- The exhaust fan for the CSO Storage Tank would include a Variable Frequency Drive (VFD) to allow for automatic adjustment of the flow between on-line and off-line conditions. The VFD can be programmed with two speed setpoints and, in conjunction with the SCADA system, operate at one or the other setpoint based on the status of the CSO Storage Tank (filling or empty).

It is recommended that the flow pattern in Figure 7 be utilized for foul air management on the Murray CSO project.

4.3 Determing Ventilation Rates

Ventilation rates for wastewater facilities are typically based on achieving target goals in one or more of the following categories:

- 1-Ventilation for Code (Health/Safety)
- 2-Odor Control
- 3-Corrosion Protection

Ventilation for code issues (1) is based on meeting NFPA requirements or OSHA standards for manned entry, as described in Section 3. This typically involves a set number of volumetric air exchanges per unit of time.

Odor control (2) is essentially a matter of achieving zero emissions of fugitive sewer gas. Thus, design criteria are based on maintaining negative pressure and sealing leak points. The air flow required for this is not any set volume or velocity, but simply whatever is required to meet zero emissions for the particular structure under consideration.

Corrosion protection (3) requires a minimum amount of air flushing to keep corrosive compounds (typically H_2S for sewage) to a minimum. Minimum flushing is often set at approximately 2 ACH, but can vary depending on the situation. Corrosion protection also requires attention to the airflow patterns within a vessel. Corners and dead spaces must be avoided to prevent pockets of corrosion within an otherwise well ventilated structure.

4.3.1 Pump Station Ventilation Rates

The primary ventilation criteria for the pump station wet well are the NFPA and OSHA codes for manned entry (see Section 3). This necessitates 12 ACH for Class 1, Div 2 occupation, as well as negative pressure (-0.1 inches w.c.) and will drive the size of the supply air fan (which must provide fresh air to meet that volume rate).

Though code compliance is the primary issue, the pump station will also see flow from the upstream gravity sewer that is induced by drag and brought into the wet well. To avoid pockets of high pressure, this air must be accounted for in the exhaust rate. Empirical data has been published that presents broadly applicable methods for the calculation of drag rates in gravity sewers (Eftekharzadeh, S., et. al., *Mathematical Modeling of Airflow in the City of Los Angeles Main Interceptor System*, WEFTEC, 2011). Applying this data to the Murray system implies a very high potential drag rate due to the extremely steep (18% slope) incoming 48 inch diameter sewer (see Table 3). The actual rate will almost certainly be less than this amount, due to upstream restrictions on available air, however, without more extensive field testing (air pressure readings from the pipe) or modeling of air flow in the upstream sewer system, the actual rate cannot be determine more precisely. As this air flow rate could be significant, and the flow will have a large effect on the final odor control vessel size, it is recommended that more extensive modeling of the upstream system be done in order to better determine the expected air flows. HDR is currently expanding the analysis of the drag flow parameters to refine this estimated flow rate and attempt to reduce the associated scrubber size.

Since the drag effect will be variable, a backdraft damper set at a minimum negative pressure of approximately -0.1 inches w.c. would be necessary to supply additional air into the wet well at times when the drag effect is less significant than expected but the wet well exhaust rate remains the same. When such a situation occurs, the damper will open and allow make-up air into the wet well to maintain the minimum negative pressure. This will prevent the exhaust fan from pulling an excessive negative pressure on the wet well or the upstream gravity sewer system. An overly high negative pressure could potentially affect residential side sewers as well as make wet well access hatches difficult to open.

In addition to drag effects, a potential leakage through surface hatches should be accounted for as part of the total air exhausted from the pump station. A conservative estimate for leakage rates around hatches, based on published data on gasket sealed tank covers as well as verbal field testing results provided by typical suppliers (Bilco), would be 1 cfm/ft around the edge of any access point.

The total flow balanced from the pump station ($Q_{pumpstation}$ in Figure 7) will be a combination of the three effects listed previously: code compliance, drag, and leakage. Table 3 is a summary of the calculated values for each of these quantities and the associated maximum foul air flow from the wet well. As the leakage effects are very minor, they are included as part of the much larger potential drag effect.

Table 3: Murray Pump Station Wet Well Ventilation Rates

Category	Basis	Calculated Rate
Code Ventilation Rate	12 ACH	3,000 cfm
Drag Effect[1]	Empirical/Literature	6,000 cfm
Leakage	1 cfm/ft	Included in Drag
$Q_{pumpstation}$		**9,000 cfm**

[1]Flows are very conservative and are currently being verified.

4.3.2 CSO Storage Tank Ventilation Rates

The ventilation rate for the CSO Storage Tank must be determined by comparing the various design criteria assigned by the County. Code compliance is not the driving issue, however, there are several criteria that have been proposed to achieve odor and corrosion control:

- Negative pressure
- Maximum CSO Storage Tank fill rate

Both of these criteria can be calculated independently of the others. Thus, the final design value must be determined by comparing the calculated values and determining which one requires the highest ventilation rate. That number will set the minimum standard to ensure that all applicable criteria are met. The November 18, 2011 County memorandum requested the application of both negative pressure and the maximum CSO fill rate, so each of those ventilation rates are analyzed as part of the following discussion.

Negative pressure (when the tank is off-line) is achieved by simply accounting for the potential leakage points of the structure under a mild negative pressure and balancing the exhaust fan to provide that air flow rate. Thus, all points where foul air could leak out will have a net flow rate into the structure. A smaller, more energy efficient fan could be sized for this scenario only, however, it would be necessary to allow occasional leakage of odorous air during CSO filling events when the displacement rate of the air due to the wastewater inflow exceeds the exhaust fan capacity. This is a relatively minor risk for odor complaints, as CSO events typically occur during rainy weather and are less odorous (due to high dissolved oxygen) than dry weather sewage.

The maximum CSO overflow rate is based on the displacement of air within the tank when the largest CSO event occurs, as determined by previous system modeling. In order to avoid pressurizing the tank, air must be evacuated at a minimum rate equivalent to the displacement rate. The rate set for the Murray CSO facility is approximately 30 million gallons per day (MGD). This rate was selected as an average value from the modeled CSO flow rates included in Appendix A of the Facility Plan. It does not represent the absolute peak flow rates from the model, but a likely average rate as indicated by the flow modeling work.

Table 4 summarizes the flow rates for each of the analyzed criteria. The minimum flows are those necessary to simply maintain negative pressure when the CSO Storage Tank is not operating. The ultimate design flow chosen for the project (Q_{CSO} in Figure 7) will need to meet, at a minimum, the large CSO displacement rate of 30 MGD plus the potential losses from hatch leakage. Thus, it is recommended that the CSO displacement rate be used as the maximum design foul air flow. However, per the County's modified design criteria memorandum (November 18, 2011), basic negative pressure would be used as the design flow when the tank is off-line. Thus, two design setpoints are noted in Table 4, depending on the status of the CSO Storage Tank.

Table 4: Murray CSO Storage Tank Ventilation Rates

Category	Basis	Calculated Rate
Negative Pressure	Hatch Leakage Rate	500-1,000 cfm
Max CSO Fill Rate	30 MGD (approx)	3,000 cfm
Q_{CSO}	**CSO Tank Off-line**	**1,000 cfm (approx)**
Q_{CSO}	**CSO Tank On-line**	**4,000 cfm (1,000 cfm + 3,000 cfm)**

4.3.3 Ventilation Rate Summary

Table 5 summarizes the flows that will be utilized for sizing of the fans and treatment system.

Exhaust flow rates are shown for when the CSO Storage Tank is off-line and on-line (filling). It is assumed that the VFD controlled CSO exhaust fan will have two speed setpoints and will automatically alternate between the two depending on the Tank status.

Exhaust flow rates for the wet well are shown based on an assumed drag effect (which is currently being verified to determine if a lower flow can be utilized) and the required air exchanges to meet NFPA code requirements.

Table 5: Murray CSO Project Ventilation Rates

Category	Basis	Calculated Rate
Wet Well Supply	12 ACH	3,000 cfm
Wet Well Exhaust	$Q_{pumpstation}$ (Drag rate + ACH)	9,000 cfm (3,000 cfm + 6,000 cfm)
Scrubber 2	**Nominal Size**	**10,000 cfm**
CSO Exhaust (Tank On-line)	Q_{CSO} (Fill rate + Leakage)	4,000 cfm
CSO Exhaust (Tank Off-line)	Q_{CSO} (Negative Pressure)	1,000 cfm[1]
Scrubber 1	**Nominal Size**	**5,000 cfm**

[1]Lower end flow rate will be dependant on fan capabilities.

Each odor treatment scrubber is sized for a nominal flow above the required air flow rate. The exact size of the vessel can be trimmed down once flows are finalized, but Table 5 presents a conservative vessel size for the purpose of cost and layout.

4.4 Alternatives for Foul Air Treatment

Two technologies were evaluated for foul air treatment at the Murray CSO facility. The primary technology evaluated was a carbon scrubber and the secondary technology evaluated was photoionization (ultraviolet).

4.4.1 Carbon Scrubber

Carbon scrubbers are a common technology for odor control treatment at King County pump stations. They are relatively passive systems requiring minimal energy (nothing outside of the fan) and effectively no chemical use or storage. Physio-chemical adsorption on carbon does not require water or nutrients (as would a biological scrubber) and the unit can essential be left alone to operate with occasional O&M requirements for the fan and carbon replacement upon depletion of the media (replacement rates are typically designed for an annual change-out). Removal of hydrogen sulfide (H_2S) is typically guaranteed at 99% of the influent concentration or 0.1 parts per million (ppm), whichever is greater.

The disadvantages of carbon often center on carbon usage rates, which can be expensive as H_2S loading increases, as well as the cost of specialized, higher capacity (increased H_2S adsorption) carbon. Humidity and grease levels can have severe effects on carbon capacity and require demisters and grease filters upstream of the unit.

The design criteria for carbon scrubbers at Murray are detailed in Section 3. Typical horizontal bed systems, designed for a 5,000 cfm and 10,000 cfm capacity per Table 5, are shown in Appendix A. Each FRP vessel is comprised of twin (dual) carbon beds and would be approximately 7-10 ft in diameter and approximately 25 ft in length. The discharge nozzles would be modified for placement on the ends to allow foul air flow to enter the central space between the beds and exhaust treated air out either end under negative pressure from the downstream exhaust fan.

The vessels could also be modified, allowing for some additional length, to provide a physical separation between the two beds and allow for full isolation of either side during carbon change out. This would not be a necessary feature, but could provide some flexibility for operators. The downside is that the flow rate from the effluent fan would need to be reduced when one of the two beds is taken offline to prevent excessively high velocities through the remaining carbon bed (which might damage the carbon and/or discharge partially treated air). It is expected that the unit would normally be operated with both beds online, and carbon would be depleted at the same rate in both beds and changed out at the same time.

The carbon operating load for each vessel is approximately 7,500 lbs (5,000 cfm) and 15,000 lbs (10,000 cfm) respectively. The carbon selected for each Murray scrubber will be determined based on King County standards as well as data provided by the County regarding wet well H_2S concentrations. This data is not yet available, however, based on other King County pump stations as well as the carbon type currently utilized at the Murray pump station, the selected carbon for the wet well will almost certainly be a high capacity or impregnated carbon. Average wet well H_2S concentrations for similar facilities in the area often range from 10-20 ppm, with peaks at 50 ppm and higher. The carbon selected for the CSO scrubber could be a less expensive virgin activated carbon, as the H_2S rates will be much lower for diluted combined sewage and the annual loading to the CSO scrubber will be significantly lower than the wet well scrubber.

If an impregnated carbon is selected, it is recommended that motor operated dampers be installed to isolate the carbon bed (and prevent exposure to oxygen) if the associated exhaust fan is not operating. This is due to the low ignition temperature associated with impregnated carbons and the exothermic reaction that occurs when they are exposed to acidic, reduced sulfides. In general, it would be recommended to select a high capacity carbon with a higher ignition temperature to avoid the safety issues associated with impregnated carbon.

4.4.2 Photoionization

Ultraviolet (UV) ionization treatment of foul air is a technology that has been available for municipal odor control in Europe over the past decade, but has recently been introduced to the United States. It has gained several installations around the country in the past few years with several pilot plants currently operating (including a Portland, OR pilot under operation in November of 2011).

The concept of the technology is based on oxidation of H_2S in the foul air stream via ozone and other free radical oxygen species (similar to how hypochlorite, peroxide, or other oxidizing agents function to eliminate reduced sulfur in the liquid phase). Ultraviolet light, when introduced to a foul air stream, will induce the production of ozone and free radical oxygen species from the O_2 present in the air. This is essentially the same process by which ozone is created in the upper atmosphere. These strong oxidants react with reduced sulfur compounds (including H_2S) to oxidize them to sulfates and other oxidized organic species.

In addition to the UV ionization, the unit is typically equipped with a small carbon catalyst bed which is intended to “polish” the outlet and protect the effluent quality.

Previous pilot data provided to King County indicated that the unit appears to be performing well in studies, achieving 99% removal of H_2S. Appendix B includes a quote from the North American distributor of this technology for a unit in the 6,000 cfm range. A photo of the unit shows the general layout, which is a rectangular, stainless steel enclosure that houses the UV lamps, filters, etc. A 15,000 cfm total capacity unit (to meet the requirements of Murray) would include three of these smaller units in parallel. Two would operate in connection with the wet well and one would operate in connection with the CSO Storage Tank.

In opposition to a carbon scrubber, the UV system relies on energy input (through the UV bulbs) as the active agent. The primary tradeoff is the use of lamps/energy (with a small amount of carbon catalyst) as opposed to a large carbon bed. O&M can be done fairly simply and nothing as extensive as a carbon change-out with a vactor truck would be required. Maintenance on the odor control unit would be similar to routine maintenance on a fan.

This technology, though promising, has not been utilized by King County in the past and would thus be a new type of treatment system that has not been proven in the County system. Footprint and cost comparisons with carbon will be provided in the following sections as well as a final recommendation.

4.5 Odor Control Fan and Odor Scrubber Rooms

Based on previous discussions, it has been noted that the preferred location of the Fan and Odor Scrubber Rooms is below grade or partially below grade. This will assist in the aesthetic impact to the site, minimize fan noise, and, in the case of carbon scrubber treatment vessels, provide an easy and convenient means to access the carbon beds from grade. It also provides consistency with other CSO projects (North Beach), where a similar strategy is being utilized.

4.5.1 Projected Equipment Footprint

Appendix C provides a basic dimensional layout for the Fan and Scrubber Rooms. The layout assumes carbon scrubbers, however, the differences between carbon and photoionization will be discussed below.

Regardless of the treatment technology selected, the Fan Room will be utilized to house the supply fan, both exhaust fans, and a variety of miscellaneous duct equipment (filters, silencers, dampers, etc.). Equipment would be removed through hatches at grade. The room is projected to be approximately 625 sf to effectively house all the equipment and provide room for stair/ladder access by operations staff.

The Odor Scrubber Room would be primarily devoted to housing the treatment vessels. In the case of a carbon scrubber, the room would be large enough to allow access around the vessels, but hatches or grating would be provided at grade for easy access to the carbon beds. A lift slab or removable grating would be utilized over the roof in the event that an entire treatment vessel required removal.

If photoionization units are utilized, access into the room will become more important (as maintenance will be based on working directly at the unit to change lamps, etc.) relative to access from the top. A projected footprint similar, but slightly less than a carbon scrubber would be anticipated. This assumes three parallel units with dimensions of approximately 12 ft long by 7.2 ft wide. Two units would be mounted against opposing walls and one in the center of the room.

The depth of both rooms is recommended at 12-14 ft internal clearance. This would supply enough clearance for either treatment technology and more than enough vertical space to accommodate all of the mechanical equipment.

Table 6 provides a summary of the approximate footprint estimated for the Fan and Scrubber Rooms. This estimate is general and will require refinement during preparation of design drawings when ductwork and more specific layouts can be determined.

Table 6: Estimated Fan and Odor Scrubber Room Footprints

Room	Dimensions	Footprint
Odor Control Fan Room	25 ft x 25 ft x 12 ft	625 sf
Odor Scrubber Room (Carbon)	30 ft x 40 ft x 12 ft	1,200 sf
Odor Scrubber Room (Photoionization)	30 ft x 30 ft x 14 ft	900 sf

4.5.2 Fan Sizing

Per the design criteria established in Section 3, it is recommended that FRP fans be utilized for all air handling (supply and exhaust). This will help maintain consistent materials of construction, style and vendors across the project and keep the odor control equipment distinct and separate from standard building HVAC. It will also reduce corrosion throughout the system, regardless of whether the fan is actively operating on treated air (exhaust fan) or if there is simply some risk of corrosive gases moving back up a duct when a fan is not operating (supply fan).

Table 7 provides a summary of the approximate sizing for the exhaust and supply fans. Based on the increased headloss through the treatment vessel, as well as the relatively high flow, the exhaust fan will be a pad mounted centrifugal unit. The supply fan, having a much lower flow and headloss, will utilize an inline centrifugal to minimize footprint and allow for wall or ceiling mounting.

Table 7: Initial Sizing

Fan	Material	Type/Model	Size[1]
Supply Fan	FRP	Inline Centrifugal	3,000 cfm, 3-5 hp, 480 Volt, 3 Phase
Exhaust Fan 1 (CSO)	FRP	Pad Mounted Centrifugal	4,000 cfm, 15 hp, 480 Volt, 3 Phase (VFD required)
Exhaust Fan 2 (wet well)	FRP	Pad Mounted Centrifugal	9,000 cfm, 30 hp, 480 Volt, 3 Phase (VFD optional)

[1]Sizing is approximate. Full headloss calculations will be performed once the final duct layout is approved.

As noted previously, it is recommended that Exhaust Fan 1 (CSO Storage Tank) include a VFD for easier balancing as well as the capability to easily program multiple speed setpoints when the CSO Storage Tank is moving between an on-line and off-line mode. Exhaust Fan 2 (wet well) would not require a VFD for normal operation.

Location of the fans in a below grade room will greatly assist in localized noise attenuation. Noise radiating from the fan body will be shielded from neighbors and the exhaust fans will include an inline silencer for discharge noise reduction. The inlet air for the supply fan will include a sound attenuating louver.

4.5.3 Treated Air Discharge

The treated air discharge from the exhaust fans can be accomplished in several ways.

- Discharge at grade through a grate or other diffuser.
- Discharge through a stack (aesthetically modeled to look like a tree or light post).
- Discharge through an above grade portion of the structure, either through the roof or horizontally through a wall.

Considering the constraints of the CSO site, as well as the proximity of neighbors to the south, it is recommended that one of the following options be used:

- A stack discharge with sufficient velocity to release the air high enough to pass over the neighbors.
- A horizontal discharge away from the neighbors (to the northwest of the CSO Storage Tank) allowing for additional dilution from winds coming off the water and avoiding a stack structure.

Atmospheric dispersion modeling would be recommended to determine the most advantageous discharge point and configuration relative to the existing topography and homes. This will provide greater assurance that appropriate dilution of the treated air (below the human detection threshold for H_2S) will occur before reaching any potential receptors (neighbors).

A common discharge and silencer for both the CSO and wet well exhaust fans could be used to limit the number of exhaust points, however, this will require check valves on either fan outlet to prevent backflow in the event that only one of the two exhaust fans is online. Separate discharges with separate silencers would keep the systems distinct, but would require two treated air discharge points on the site. In order to keep the systems separate and avoid the additional valving, it is recommended that separate discharge points be utilized.

4.6 Preliminary Equipment List, Capital Cost and O&M Considerations

Table 8 provides a preliminary major equipment list for the Murray CSO odor control design. The list is based on components previously discussed and sized as well as items required to meet WTD standards and code compliance.

Table 8: Preliminary Equipment List

No.	Equipment Name/Number	Notes
1	Supply Fan (SF-852,XXX)	Located below grade; see Table 7.
2	Inlet Louver (LVR-852,XXX)	Inlet air sound attenuating louver.
3	Filter (FLT-852,XXX)	Inlet air inline filter.
4	Inline Heater (HTR-852,XXX)	Freeze protection for forced air into wet well.
5	Differential Pressure Indicator (PDIT-852,XXX)	One across inlet air filter and one across the supply fan.
6	Exhaust Fan 1 (EF-852,XXX)	Located below grade; see Table 7.
7	Exhaust Fan 2 (EF-852,XXX)	Located below grade; see Table 7.
8	Grease Filter/Mist Eliminator 1 (FLT-852,XXX)	Located in Odor Scrubber Room upstream of the CSO Scrubber 1.
9	Grease Filter/Mist Eliminator 2 (FLT-852,XXX)	Located in wet well to prevent grease build-up in buried exhaust ductwork across Beach Drive to Scrubber 2.
10	Outlet Silencer 1 (SLN-852,XXX)	On Exhaust Fan 1 outlet.
11	Outlet Silencer 2 (SLN-852,XXX)	On Exhaust Fan 2 outlet.
12	Differential Pressure Indicators (PDIT-852,XXX)	One across each grease filter/mist eliminator and each exhaust fan.
13	Odor Scrubber 1 (SCR-852,XXX)	Carbon or UV unit sized for nominal 5, 000 cfm. CSO Storage Tank treatment.
14	Odor Scrubber 2 (SCR-852,XXX)	Carbon or UV unit(s) sized for nominal 10, 000 cfm. Wet well treatment.
15	FRP Ductwork	
	18" diameter	Supply air to wet well
	24" diameter	Discharge air from CSO Storage Tank
	30" diameter	Discharge air from wet well

No.	Equipment Name/Number	Notes
16	Control Dampers (BV-852,XXX)	Butterfly style FRP damper.
17	Isolation Dampers (BV-852,XXX)	Butterfly style FRP damper (sealing seat). Some dampers may require motorized operation if impregnated carbon is selected as the treatment technology.
18	Backdraft Dampers (BDD-852,XXX)	Backdraft dampers for inlet air allowances at both the CSO Storage Tank and the existing wet well.
19	Wet Well Combustible Gas Monitor (GM-852,XXX)	Monitoring of existing wet well LEL for NFPA code compliance.

4.7 Capital Cost and O&M Considerations

Table 9 presents initial equipment capital cost as well as an estimation of Operation and Maintenance (O&M) for both the UV (photoionization) and carbon treatment systems. The costs shown are strictly equipment pricing FOB and do not include allowances for tax, electrical/I&C, Supervisory Control and Data Acquisition (SCADA) programming, or mechanical installation. The O&M cost is based on energy use (fans/equipment) as well as any annual consumables, which will be the largest differentiating factor between the two technologies. It does reflect estimated man hours, but this is assumed to be relatively similar for both types of technologies. The intent in Table 9 is to show the difference in purchase price and primary O&M expenditures between options.

Table 9: Preliminary Capital and O&M Costs

Treatment Technology	Capital Cost	Annual O&M[1]	20 Yr Lifecycle[2]
UV Treatment System	$600,000	$78,000	$1,250,000
Carbon Treatment System	$350,000	$91,000	$1,470,000

[1]Assumes replacement of carbon bed once per year.
[2]Lifecycle cost is based on equipment capital cost, not the facility construction cost. It includes an allowance for energy usage by the treatment system and exhaust fan as well as a general labor allocation.

The UV treatment system is likely to be a more expensive capital investment, however, the O&M costs will likely be less than the carbon system, leading to a more favorable life cycle estimate. The energy usage for each option is similar (with smaller exhaust fans on the UV unit making up for the added cost of UV light), however, the cost of annual carbon replacement for the two carbon scrubbers will be significant.

Both systems will require similar auxiliary features (grease filters, ductwork, dampers, etc.).

5.0 Summary and Recommendations

The following summarizes the recommendations for the odor control design of the Murray CSO facility:

5.1 Treatment Technology Selection

Though UV (photoionization) technology shows promising results based on research of current pilot work and new installations, as well as sizable savings for long-term O&M, it is recommended that carbon be utilized for the following reasons:

- Carbon is the common technology used at similar CSO Storage Tanks in the area as well as most other King County pump station facilities. It is a well established system with very little risk.
- Carbon is being utilized on the North Beach and Magnolia projects. Consistency between sites is generally beneficial to O&M.
- The UV option has not been used in the King County system to date, though there are now some regional installations and pilot work begin produced. Thus, the risk of performance variability is higher than carbon.
- The rigid schedule for the CSO projects does not lend itself to the review of new technologies or extended field pilot work.

The UV option has the potential for a very clean, low O&M facility, however, King County has historically shown a preference to pilot new technologies within their system before utilizing them in design. It would be recommended that the County pursue pilot work for future installations, due to the potential O&M cost savings this technology could afford, despite the fact that horizontal carbon beds appear to be the better overall fit for the Murray CSO project.

Appendix B includes cost information regarding the UV pilot system units that are available from the manufacturer. The current pilot work being done in Portland, OR for Clean Water Services is showing over 99% H_2S removal for a wastewater fermentor with 100 ppm H_2S inlet concentrations.

5.2 Layout and Material Recommendations

In addition to the selected treatment option, it is recommended that the system layout in Figure 7, the ventilation rates in Section 4.3, and the preliminary equipment list detailed in Table 8 be utilized for development of 30% design documents. This system will provide the County with an efficient, low maintenance layout that also supplies the necessary flexibility to control, operate, and maintain the CSO Storage Tank and pump station wet wells properly. It balances equipment and system complexity with control capabilities, minimizing the risk of failure without excessive equipment cost.

APPENDIX A

APPENDIX B

APPENDIX C