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Technical Memorandum 4.3A

Digester Piping Tunnel Ventilation

Prepared for: San Jose/Santa Clara Water Pollution Control Plant

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Subject: Digester Piping Tunnel Ventilation

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1. EXECUTIVE SUMMARY

The digester piping tunnels at the San Jose – Santa Clara Water Pollution Control Plant (WPCP) contain sludge gas piping, natural gas piping, and fuel oil piping. The digester tunnels are not physically separated from the other tunnels in the plant wide tunnel system that also contain hazardous substances, or from the motor control center (MCC) room near Digester 10. The existing ventilation system and other conditions are not sufficient to exempt these spaces from being classified as hazardous areas under the National Fire Protection Associations (NFPA) Standard for Fire Protection in Wastewater Treatment and Collection Facilities (NFPA 820). As such, the digester tunnels should currently be considered an explosion hazard.

We find that most of the electrical equipment in the area is not rated for use in classified areas and that WPCP is in violation of the National Electrical Code (NEC). We recommend declassifying the digester piping tunnels by constructing physical barriers between the digester tunnels, the MCC room, and the other connecting tunnels, removing all hazardous fluid piping from the digester piping tunnels, and making some minor ventilation modifications.

This assessment refers to the digester tunnels only. We recommend that the City investigate hazardous classification of other plant-wide tunnels and consider upgrades there as necessary. In addition, the City should immediately consult with their Safety Engineer to assure that appropriate operational protocols are in place to ensure safe access in the tunnels until such time as these recommended upgrades can be made.

2. SCOPE OF WORK

The scope of work for Service Order No. 1 calls for evaluation of heating, ventilation, and air conditioning requirements for the digester piping tunnels, and drainage system. The following subjects are covered in the scope of work:

- Capacity analysis of the existing ventilation system.
- NFPA requirements for ventilation of underground piping tunnels containing sludge gas piping.
- Drainage system overview.

The digester piping tunnels included in this scope of work include Tunnels A through G, ending at the Sludge Control Building basement. Other tunnels in the plant tunnel network connect to the digester piping tunnels; there are no physical barriers between these tunnels, and the atmospheres of these tunnels communicate with each other. The objective of this TM is to determine the code classification for the existing tunnel, and to recommend modifications as necessary.

3. REQUIREMENTS FOR TUNNEL VENTILATION

NFPA 820 includes hazard classification for processes and areas, including underground piping tunnels. Underground piping tunnels containing natural gas piping or sludge gas piping are treated separately from those that do not. The digester piping tunnel contains digester gas piping and natural gas piping, as well as fuel oil. It should be noted that NFPA 820 is a guideline and is typically interpreted and enforced by the local Fire Marshall. Insurance carriers also often rely on NFPA classifications in defining their requirements.

NFPA 820 defines areas as either Class I, Division 1; Class I, Division 2; or unclassified. These classifications correspond to National Electric Code (NEC) area electrical classifications, which dictate requirements for explosion-proof equipment. Class I, Division 1, is the most restrictive; whereas unclassified areas have no restrictions.

NFPA 820 allows for declassifying the digester piping tunnels with ventilation, provided that:

- The air flow provides at least six air changes per hour;
- The spaces are served by both supply and exhaust fans;
- The space is negatively pressurized relative to ambient;
- Air is introduced to and exhausted from hazardous areas in a manner that scavenges all portions of the spaces, and promotes removal of both heavier- and lighter-than-air gases;
- Ventilation systems are powered by a primary power source, and have the means to accept alternate power sources;
- Power failure of the primary power source is alarmed; and
- Ventilation failure and combustible gas detection alarms are provided inside the spaces, at entrances, and at other specified locations.

Areas that are unclassified by virtue of a ventilation system as described, may still have classified areas 10 feet around valves, flanges, or other appurtenances on hazardous fluid pipes; this envelope is Class I, Division 2. Exterior to the tunnel, NFPA 820 defines a Class I, Division 1 envelope within a 5-foot radius around the digester and gas handling equipment. It also defines a Class I, Division 2 envelope between 5 and 10 feet from the digester or gas handling equipment. Any air intakes within those areas require classification of the air supplied space to take on the classification of the intake location.

The ventilation system for the digester piping tunnel does not meet the requirements for an unclassified space. It has no supply fans, the configuration does not adequately scavenge all areas, some of the intakes are themselves located within classified areas, and the power and alarm conditions are noncompliant. We find therefore, that the entire tunnel system, including the MCC room and connecting tunnels, is a Class I, Division 1 classified area.

4. CAPACITY ANALYSIS OF EXISTING VENTILATION SYSTEM

4.1 Existing System Description

The WPCP's sixteen anaerobic digesters are connected via a network of underground tunnels that contain piping systems for the anaerobic digestion processes. Figure 4-1 shows the tunnel arrangement. The piping includes a system conveying combustible digester gas. Plant operations and maintenance staff regularly work in the piping tunnels. The tunnels are continuously ventilated to help prevent digester gas accumulation in case of leakage from the gas piping.

The digester piping tunnels are connected to the plant-wide tunnel system which also contains gas piping. There are no physical separations between the various tunnels; ventilation can flow freely between them, and for classification purposes they are essentially the same space. Our investigation did not include an analysis of the ventilation or classification of the other tunnels. The MCC room near Digester 10 is also connected to the tunnel with no physical separation, and has the same hazardous classification as the tunnel.

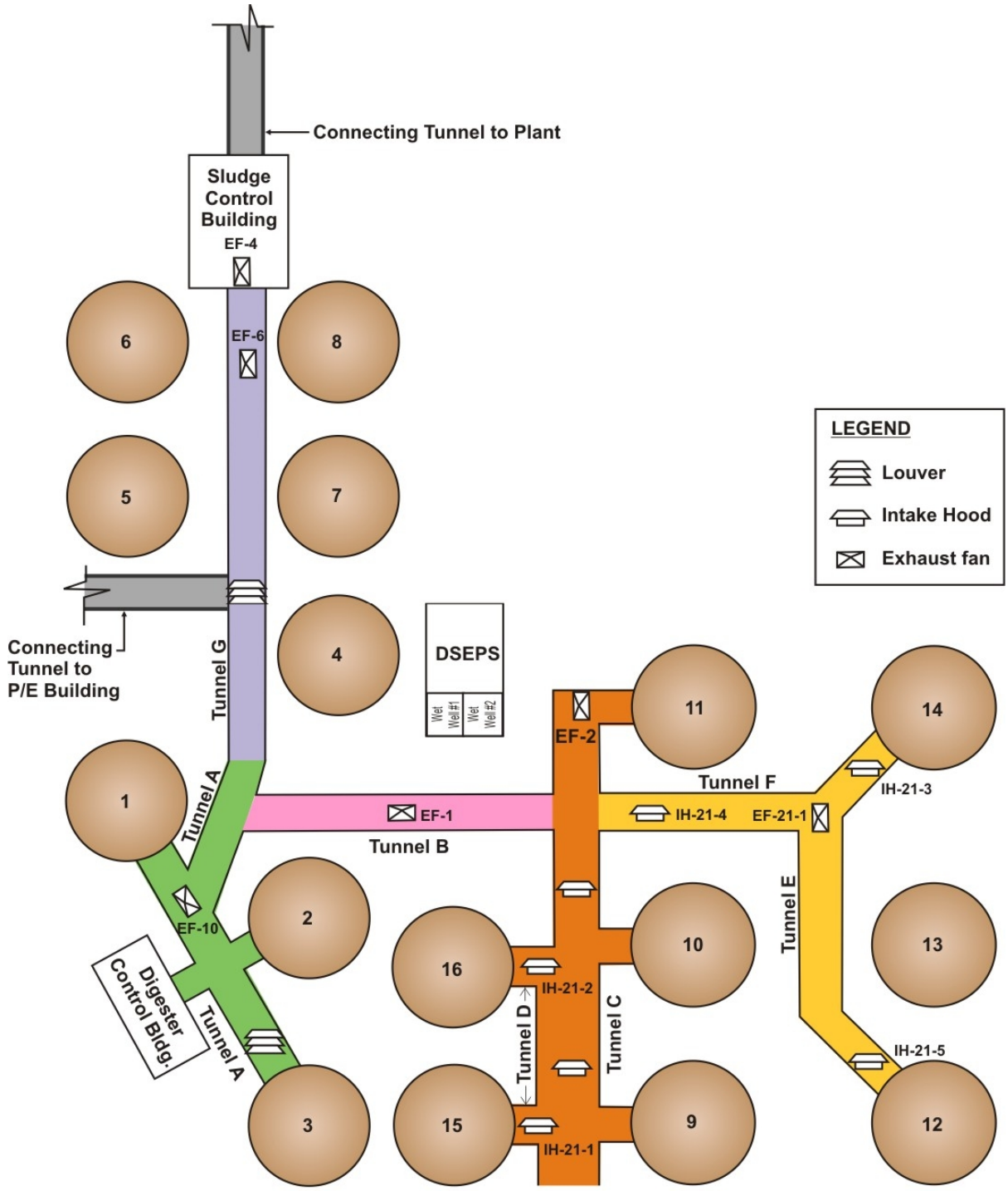

Figure 4-1. Digester piping tunnels at San Jose / Santa Clara WPCP

4.1.1 Tunnel Summary

The digester piping tunnel system is divided into several discreetly identified tunnels connecting the various digesters. The tunnels are labeled "A" through "G." The tunnels are described in Table 4-1 and shown in Figure 4-1.

Table 4-1. Digester Piping Tunnels at San Jose/Santa Clara WPCP

Tunnel	Description
A	Serves Digesters 1, 2 and 3. Connects to Tunnels B and G.
B	Connects Tunnels A and G (Digesters 1 thru 8) to Tunnels C and F (Digesters 9 thru 16).
C	Serves Digesters 9, 10 and 11. Connects to Tunnels B, D, and F.
D	Serves Digesters 15 and 16. Connects each digester to Tunnel C.
E	Serves Digesters 12, 13, and 14. Connects to Tunnel F.
F	Connects Tunnels C and E (Digesters 12 thru 14).
G	Serves Digesters 4, 5, 6, 7, and 8. Connects to Tunnels A and B, and the Sludge Control Building.

4.1.2 Exhaust Fans

Exhaust fans drive the digester tunnel ventilation. The exhaust fans are located at grade (on top of the tunnels) and draw air out of the tunnels, Figure 4-2 is an example. None of the fans are ducted. The fans are intended to operate continuously. The fans vary in capacity, size, and condition, but all have significant remaining life. Table 4-2 summarizes the exhaust fan locations, nameplate capacity, and function. The exhaust fans are regularly maintained (belts and lubrication). During a January 6, 2009 field visit, all fans were running except for EF-21-1, which was being repaired and is normally operational. At the time of the visit, regular preventive maintenance was being performed on all of the fans. All of the exhaust fans are belt-driven. Belt drives give more options for fan sizing and speed adjustment, but belts also represent the most common cause of fan failure. When needed, these fans should be replaced with direct-drive fans. This change will reduce maintenance effort and will eliminate belt failure, which is the most common failure mode for this type of equipment.

Figure 4-2. Typical exhaust fan (EF-2 shown)

Exhaust fan equipment information was retrieved from fan nameplates or from equipment information cards in the Air Conditioning (AC) Shop, located near the waste gas flares. Model and sizing information was compared to current vendor information to determine approximate airflow. Where current catalog

information was not available, such as EF-4, airflow was determined from similar-sized fans by other manufacturers. There is no apparent monitoring or alarming for loss of power or flow to these fans.

Table 4-2. Digester Tunnel Exhaust Fans

Exhaust Fan	Location Tunnel	Nameplate Capacity, cfm	Comments
EF-1	B	9,500	Located at grade near Digested Sludge Effluent Pumping Station, running
EF-2	C	5,500	Located at grade near Digester 11, running
EF-4	G	17,000	Located on roof of Sludge Control Building, above stairwell, running – Primarily serves Sludge Control Building basement and tunnels beyond project boundaries
EF-6	G	8,000	Located at grade near Digester 8, running
EF-10	A	4,000	Located at grade near Digester 2, running
EF-21-1	E	6,000	Located on top of stairwell near Digester 14, out of service (1/6/09)

The locations of the exhaust fans are not conducive to scavenging all portions of the space. A more effective system would use exhaust fans at the ends of each tunnel branch, and include ducting to capture both light and heavy gases with registers both near the floor and near the ceiling.

4.1.3 Air Intake

Air intake hoods and louvers allow fresh air into the piping tunnel. Intake hoods are located at most tunnel dead-ends, typically where a tunnel section terminates at a digester. These are passive intakes; there are no powered supply fans meeting the requirements of NFPA for an unclassified tunnel. Table 4-3 summarizes the intake locations and sizes. The size of the intakes affects the velocity of air going through them and the barometric pressure inside the zones. Louvers and intake hoods were measured in the field for reference and appear to be sized appropriately.

Air intake locations should be located in unclassified/nonhazardous areas, defined as 10 feet away from digester walls or gas piping appurtenances. If an air intake is located in a hazardous area, then the serviced space is considered hazardous as well. Some of the existing intake hoods are located within hazardous areas. The intake hoods at Digesters 15 and 16 (IH-21-1 and IH-21-2) are located within 1 foot of the digester wall as seen in Figure 4-3. This is within the 5-foot Class I, Division 1 envelope around the digester (the Class I, Div 2 envelope extends an additional 5 feet beyond).

Figure 4-3. Poor intake hood location – IH-21-1 too close to Digester 15 (IH-21-2 and Digester 16 similar)

Table 4-3. Digester Tunnel Air Intake

Intake	Location	Size	Comments
Louver	Tunnel A	39"x33"	Located in wall of stairwell near Digester 3 in nonhazardous area, needs new insect screen
Intake Hood	Tunnel C	48"x48"	Large blue intake hood near Digester 9 in nonhazardous area
Intake Hood	Tunnel C	10"x10"	Located on roof of MCC room near Digester 10 in nonhazardous area
Intake Hood IH-21-1	Tunnel D Digester 15	16"x16"	In hazardous area.
Intake Hood IH-21-2	Tunnel D Digester 16	16"x16"	In hazardous area.
Intake Hood IH-21-5	Tunnel E	30"x30"	Near Digester 12 in nonhazardous area
Intake Hood IH-21-3	Tunnel E	16"x16"	Near Digester 14 in nonhazardous area
Intake Hood IH-21-4	Tunnel F	24"x24"	Located near Digester 11 in nonhazardous area
Louver	Tunnel G	58"x45"	Located in wall of stairwell near Digester 5 in nonhazardous area

4.2 Gas Appurtenances in Tunnels

NFPA 820 defines the envelope within ten feet of potential leak source appurtenances to be a higher hazard classification than the surrounding area. If the area beyond this envelope is unclassified, then the area within the envelope is Class I, Division 2. If the area beyond the ten foot envelope is Class I, Division 2, then the area within the envelope is Class I, Division 1. For the digester piping tunnel, these appurtenances include valves, flanges, and gas piping drip traps.

4.2.1 Combustible Gas Detection System

The digester tunnel system is monitored for methane by a combustible gas detection system. There are multiple sensor locations throughout the tunnel. Control panels for the MSA Model 5300 Gas Monitor

system are located in the MCC room above Tunnel C, and in the Sludge Control Building as seen in Figure 4-4. This system is maintained and calibrated by the instrumentation group.

Figure 4-4. Gas detection system panel

The gas detection system initiates alarms if methane is detected in the tunnel. This is for both personnel safety and corrective action. The lower explosive limit (LEL) for methane is 5 percent and most sources recommend alarm setpoints at 10 percent of the LEL or 0.5 percent methane.

4.3 Existing System Ventilation Rate

Ventilation system performance for underground tunnels is typically quantified as a rate of air changes per hour. Air change rate for a piping tunnel is calculated by dividing the estimated airflow by the tunnel volume. Because the space is a network of tunnels served by many exhaust fans and intake locations, the digester piping tunnel must be split into zones that define discreet ventilation intake and exhaust areas, with each zone evaluated separately. The zones are defined in Table 4-4 along with ventilation rates and reference the tunnel designations (shown in Figure 4-1) they encompass. Tunnel volumes were estimated from construction drawings. There are no physical barriers between these zones and the air change rates are approximate based on the relative locations of intakes and exhaust fans.

Table 4-4. Digester Tunnel Zones and Ventilation Rates

Zone	Exhaust Fan	Tunnel	Digesters	Airflow cfm	Volume ft^3	Ventilation Rate, Air Changes per Hour
I	EF-1	B	4	9,500	43,000	13
II	EF-2	C, D, F	11 thru 16	5,500	45,000	7
III	EF-4	Sludge Control Building basement	6 and 8	17,000	160,000	6
IV	EF-6	G	5 thru 8	8,000	46,000	10
V	EF-10	A	1 thru 3	4,000	25,000	10
VI	EF-21-1	E, F	12 thru 14	6,000	43,000	8
Total				50,000	362,000	8.3, average rate for digester tunnel spaces

4.4 Potential Leak Sources, Hazards, and Electrical Classification Issues

Brown and Caldwell inspected the digester tunnels for hazards related to classification issues. Results are summarized in Table 4-5. It should be noted that only the digester tunnels discussed have been inspected. Other plant tunnels should similarly be evaluated by the City.

Table 4-5. Observations of Hazards and Classification Issues from Site Visit September 07, 2010

Area	Hazard or Classification Issues
Tunnel A	Piping: Digester gas (Victaulic), natural gas (2", threaded) Electrical Equipment: hot water pumps/motors (appeared to be TEFC, which is Class I, Div 2), lights (rated for Class I, Div 2), controls Hazards: electrical outlets, drip traps
Tunnel B	Piping: Digester gas (Victaulic), natural gas (threaded) Electrical Equipment: lights (rated for Class I, Div 2), controls, sump pumps Hazards: electrical outlets, drip traps, leaky gas piping joints have been sealed
Tunnel C	Piping: Digester gas (flanged), natural gas (2", threaded), fuel oil piping in this area is abandoned Electrical Equipment: MCC room (above grade, but air is drawn through room from gallery), hot water pumps/motors (appeared to be TEFC, which is Class I, Div 2), lights (rated for Class I, Div 2), controls Hazards: electrical outlets, drip traps
Tunnel D	Piping: Digester gas (flanged) Electrical Equipment: hot water pumps/motors (appeared to be TEFC, which is Class I, Div 2), lights (rated for Class I, Div 2), controls Hazards: electrical outlets, drip traps Note - the intake hoods are too close to the digesters, but there appears to be an access hatch in place (open at time of visit) about 10' from digester that could be modified to serve as an intake
Tunnel F	Piping: Digester gas (flanged/Victaulic) Electrical Equipment: hot water pumps/motors (appeared to be TEFC, which is Class I, Div 2), lights (rated for Class I, Div 2), controls Hazards: electrical outlets, drip traps Note - the gas compressor skid at D14 is gone - no more issue there
Tunnel G	Piping: Digester gas (flanged), blend gas (flanged), natural gas (2", threaded), fuel oil (4", welded), and lots of sludge services Electrical Equipment: hot water pumps/motors (appeared to be TEFC, which is Class I, Div 2), lights (rated for Class I, Div 2), controls Hazards: electrical outlets, drip traps
Sludge Control Building Basement	Piping: Digester gas (flanged), blend gas (flanged), natural gas (2", threaded), fuel oil (4", welded), and lots of sludge services (type of all tunnels) Electrical Equipment: pumps/motors, lights, controls Hazards: electrical outlets, extension cords, drip traps

5. TUNNEL DRAINAGE

The digester piping tunnel drains to sumps. Drainage is pumped from the sumps back to the WPCP headworks. Digester gas condensate and liquid ring compressor water continuously flow into the tunnel. Digester gas moisture removal is addressed in TM 4.4. The wastewater from the liquid ring compressors accounts for most of the tunnel drainage. The flow rate tends to use most of the sump pump capacity. The liquid ring compressors are used for digester mixing.

6. TUNNEL UPGRADE ALTERNATIVES

Currently, the entire digester piping tunnel, including the MCC room near Digester 10, is a Class I, Division 1 classified area. Since there is no physical separation between the digester piping tunnel and other plant tunnels with hazardous fluid piping, all the connecting tunnels are also classified areas. Most of the electrical equipment (lights and outlets) in the tunnel is not rated for this classification and this constitutes a violation of the NEC. For these reasons, the existing digester tunnels are currently an explosion hazard. This situation should be corrected as soon as practical.

We recommend that the WPCP modify the digester piping tunnel to conform to the requirements of an unconfined space by removing all piping and components with hazardous fluids, relocating air intakes outside of hazardous areas, and constructing physical separations between the digester piping tunnel and all connecting tunnels and the MCC room. This alternative is Option 1. If these steps are taken, no additional changes to the ventilation system or electrical components will be necessary.

There is one other option (Option 2); to leave some or all of the hazardous fluid piping in the tunnel and to declassify the tunnel by means of ventilation. This would require constructing a physical separation between the connecting tunnels and MCC room, modifying the ventilation system with ductwork and new fans in new locations, powering all ventilation equipment with a primary power source, providing alternate power options for the ventilation system, and modifying the power failure and gas detection alarm locations. The remaining tunnels would be Class I, Division 2 classification ten feet from any potential leak sources.

Tables 6-1 and 6-2 present conceptual level cost estimates for comparing the two options. NFPA requires that ventilation be provided to classified areas to achieve the lowest area electrical classification possible; it is not an option to replace the electrical equipment with rated components and leave the entire tunnel as a classified space.

Table 6-1. Conceptual Level Cost Estimate for the Recommended Option 1

Activity	Estimated Cost With Markups Allocated
1. Construct Physical Separation	$55,800
2. Demo 30" DG Pipe	$144,300
3. Demo 2" NG Pipe	$8,100
4. Demo 4" fuel Pipe	$4,000
5. Install 2" NG Pipe	$100,200
6. Install 4" fuel Pipe	$58,000
7. Relocate air intakes	$1,800
Recommended Option Total	$372,200

Table 6-2. Conceptual Level Cost Estimate for the Alternate Option 2	
Activity	Estimated Cost With Markups Allocated
1. Construct Physical Separation	$99,600
2. Demo 30" DG Pipe	$144,300
3. Install fans	$122,400
4. Upgrade Gas Alarm	$23,100
5. Add Loss of Power Alarm	$11,200
6. Relocate Lights	$29,200
Alternative Option Total	$429,800

7. SUMMARYAND RECOMMENDATION

The existing digester tunnels are not compliant with NFPA 820 and are an explosion hazard. This is due to the following:

- Some ventilation intakes are next to digester walls;
- Gas pipe joints and equipment are in tunnels;
- No powered ventilation in and out;
- Tunnel has ventilation dead zones
- Tunnels are connected to electrical areas; and
- Some equipment is not rated for Class 1 Division 1

Option 1 for declassifying the tunnel is recommended because it results in an intrinsically safe tunnel. This option includes removing the hazardous fluid piping, physically separating the tunnel from other classified tunnels, and relocating ventilation intakes that are too close to digester walls Option 1 does not rely on ventilation and gas detection for safety, and has the additional benefit of being less costly than the other alternative.

This assessment refers to the digester tunnels only. We recommend that the City investigate hazardous classification of other plant-wide tunnels and consider upgrades there as necessary. In addition, the City should immediately consult with their Safety Engineer to assure that appropriate operational protocols are in place to ensure safe access in the tunnels until such time as these recommended upgrades can be made.

8. REFERENCES

NFPA 820, 2008 Edition. *Standard for Fire Protection in Wastewater Treatment and Collection Facilities*. 2008.

San Jose – Santa Clara WPCP Infrastructure Condition Assessment, May 2007 (CH2M Hill).