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February 12, 2016

Mr. Jonathan Schapekahm
City of Waukesha – Engineering Division
130 Delafield Street
Waukesha, Wisconsin 53188

Subject: Proposal for Odor Study for East Moreland Boulevard

Dear Mr. Schapekahm:

CH2M HILL Engineers, Inc. (CH2M) is pleased to submit this proposal to conduct an odor study to mitigate odor complaints along East Moreland Boulevard. The scope of work is based on conversations between you and John Siczka in December, 2015, and February, 2016. CH2M has extensive odor control expertise and particularly in Milwaukee. John Siczka and Bill Desing who reside in CH2M's Milwaukee office have over 35 years combined experience in odor and corrosion management. Bill is CH2M's global leader for odor and air quality management. We look forward to serving the City of Waukesha.

Please contact me at (414) 847-0258 if you have any questions.

Sincerely,

CH2M HILL Engineers, Inc.

John Siczka, PE
Project Manager

Kurt Hellermann, PE
Vice President

# Section 1: Project Understanding

The Ruben Drive Pump Station conveys wastewater through a 12-inch diameter ductile iron force main that discharges to a manhole on East Moreland Boulevard. The wastewater flows by gravity through a 12-inch and then 15-inch diameter polyvinyl chloride (PVC) sewers before discharging into a 27-inch diameter reinforced concrete gravity sewer at the intersection of Whiterock Avenue and East Moreland Boulevard Avenue. The PVC sewers have a steep slope ranging from 0.8% to 2.5%. Numerous odor complaints have occurred along the 2,300 foot length of gravity sewer between the force main discharge manhole and Whiterock Avenue. Residents have complained of odors emanating from both the sewer manholes and away from the sewer. One possible source is odor emission from the soil pipes on houses that connect to the gravity sewer. The City of Waukesha (City) has taken a number of measures to control odors including the use of Odor Knocker™ manhole inserts, but the odors and odor complaints persist. In addition to the odors, the sewer manholes and chimneys have experienced excessive corrosion. In 2013, the city reconstructed the manholes and lined them with an epoxy coating and replaced the chimneys with high density polyethylene to resist corrosion. The City contacted CH2M to conduct a study and provide a recommendation to resolve the odor issue.

The Scope of Work described herein includes an evaluation of existing conditions, a sampling plan, sampling, odor modeling of the force main and gravity sewer, and an alternatives evaluation for odor and corrosion control.

# Section 2: Scope of Work

The following tasks are required to complete an odor control and corrosion control evaluation for the Ruben Drive Pump Station force main and discharge gravity sewer:

Task 1 – Meetings

Subtask 1.1 – Kick-off Meeting

Subtask 1.2 – Final Alternatives Meeting

Task 2 – Data and Information Collection

Task 3 – Develop Sampling Plan and Sampling

Task 4 – Modeling

Task 5 – Alternatives Evaluation

Task 6 – Prepare Report

These tasks and subtasks are further described below.

## Task 1: Meetings

The Consultant will conduct two project meetings with the City as follows:

- Kick-off Meeting (Subtask 1.1)
- Final Alternatives Meeting (Subtask 1.2)

### Subtask 1.1: Kick-off Meeting

The first step in the project will be to hold a kick-off meeting with the City. The kick-off meeting will be attended by key City and the Consultant staff. Following are the objectives of the meeting:

- Discuss scope.
- Prepare a concise statement of problems, issues, and project objectives.
- Discuss project tasks, as well as our proposed approach to each task, which will allow the City an opportunity to provide feedback so the approach can be adjusted.

- Review the City's history of odor and corrosion control efforts and operating history with the force main and gravity sewer, including incidents of odor complaints, to foster a common background understanding and starting point for the project.
- Review and refine, if necessary, the project schedule, deliverables, and work plan.

Draft meeting minutes in form of presentation slides (MS PowerPoint) will be developed and issued to stakeholders following the meeting, and finalized upon receiving review comments.

### Subtask 1.2: Final Alternatives Meeting

The Consultant will conduct a meeting to present the most favorable alternative(s) for mitigation of odor and corrosion control along the gravity sewer on East Moreland Boulevard.

Draft meeting minutes in form of presentation slides (MS PowerPoint) will be developed and issued to stakeholders following the meeting, and finalized upon receiving review comments.

## Task 2: Data and Information Collection

The Consultant will conduct a site visit on the same day of the kick-off meeting and will also review existing data. The following is a preliminary list of data to be provided by the City at the kick-off meeting, or soon after:

- Drawings of the Ruben Drive Pump Station, force main, and discharge gravity sewer along East Moreland Boulevard to Whiterock Avenue
- Flow estimates from sewer branches entering the discharge gravity sewer
- A history of odor complaints
- Historical and current data available for odor or hydrogen sulfide ($H_2S$) levels

The data will be summarized and used in subsequent alternative evaluation tasks.

## Task 3: Develop Sampling Plan and Sampling

The Consultant will develop a sampling plan to achieve the following objectives:

1) Obtain liquid phase and headspace gas phase parameters needed to set up and calibrate a comprehensive sewer process model for the force main and discharge gravity sewer along East Moreland Boulevard to Whiterock Avenue
2) Obtain quantitative data on headspace $H_2S$ concentrations to inform later odor control equipment design
3) Obtain quantitative headspace pressure data for use in characterizing out-gassing potential

Liquid phase parameters will include biochemical oxygen demand (BOD), temperature, pH, oxidation reduction potential, dissolved oxygen, and dissolved sulfide. The City's lab will provide BOD analysis. All other parameters are field measurements measured by the Consultant using equipment and supplies provided by the Consultant. Grab samples will be collected of these parameters at the pump station wet well, force main discharge, and various points along the gravity sewer. The City will provide traffic control during sampling to maintain a safe working environment. Continuous monitoring of vapor phase $H_2S$ over a three day period will be collected from at least three manholes along the discharge gravity sewer along East Moreland Boulevard to Whiterock Avenue. Continuous monitoring of headspace pressure data will be collected over the same three day period will be collected from at least three manholes along the discharge gravity sewer along East Moreland Boulevard to Whiterock Avenue. The pressure data should be collected in a way that will aid in determining if and when the gravity sewer pressurizes potentially causing a discharge of odorous air from the soil pipes. Continuous monitor/loggers will take measurement at regular discrete intervals and log the value for later retrieval.

## Task 4: Modeling

The Consultant will employ a computer-based model that predicts the generation, transport, and fate of $H_2S$ using a mass balance approach and uses a simultaneous solution of liquid- and gas-phase steady state mass

balances. The results of the modeling will be used to evaluate alternatives to control odors and corrosion. The model should represent the following important reactions/processes:

- Liquid phase–based generation of sulfides
- Temperature and BOD effects on sulfide generation
- Liquid phase bulk transport of sulfides
- Liquid phase natural oxidation of sulfides
- pH-dependent sulfide species distribution: $H_2S$, $HS^-$, $S^{-2}$
- Liquid-vapor mass transfer of $H_2S$
- Liquid drag–induced natural ventilation rates
- Vapor phase bulk transport of $H_2S$
- Concrete pipe corrosion rate estimation

The model shall require inputs for each section of pipe—type (gravity flow, force main), length, and slope—as well as initial values for flow, $BOD_5$, temperature, dissolved sulfide concentration, and dissolved oxygen concentration.

The Consultant will model the Ruben Drive Pump Station force main, discharge gravity sewer, and selected branches connected to the discharge gravity sewer to estimate liquid and vapor phase sulfide concentrations. Sampling data collected in Task 3 will be used to calibrate the model. The model will estimate liquid and vapor phase $H_2S$ concentrations along the gravity sewer and identify manhole emission hotspots. Additional model runs should be executed to estimate the effectiveness of liquid phase treatment options.

## Task 5: Alternatives Evaluation

The Consultant shall work with the City to determine the available options to control odors and corrosion.

First, alternatives shall be screened to determine a list of five alternatives that, based on the Consultant's experience, will be the most effective. The five alternatives will include both liquid phase treatment options and vapor phase treatment options. Then the Consultant will perform the following for at least three of the most advantageous alternatives:

- Create preliminary sketches / layouts of the required equipment
- Describe the advantages and disadvantages
- Prepare preliminary, conceptual construction cost estimates
- Identify any waste streams generated
- Estimate annual operating, maintenance and life cycle costs

Following the evaluation, a draft report will be prepared that:

- Presents the information described for each alternative
- Recommends an alternative
- Identifies operational and maintenance requirements
- Identifies any noise issues that may be associated with the recommended alternatives, and noise mitigation techniques
- Includes preliminary (conceptual level) design drawings of the selected alternative suitable for use in a future design RFP

The following are general categories of mitigation options that shall be considered:

- **Vapor-phase treatment:** Air is extracted from the gravity sewer using a fan and directed to an odor control device such as carbon, a biofilter, a biotrickling filter, or a chemical scrubber.
- **Liquid-phase treatment:** Chemicals are added to the wastewater to reduce odors through mechanisms, such as oxidation or precipitation.

- **Dual liquid and vapor-phase treatment:** A combination of vapor and liquid-phase treatment are employed.
- **Physical mitigation measures:** In addition to liquid and vapor phase treatment options, the Consultant will also evaluate physical mitigation measures such as reducing turbulence in the gravity sewer, resizing the force main, and relocating the force main discharge to up to two locations selected by the City. The analysis will estimate sulfide generation and odorous emissions using the model but not include a cost analysis.

## Task 6: Prepare Report

A draft report will be prepared describing the findings and results of Tasks 2 – 5. The draft report will be provided to the City prior to the Final Alternatives Meeting (Subtask 1.2). Comments received during the meeting will be incorporated into a final version of the report.

# Section 3: Project Approach

This section provides CH2M's approach for completing the Scope of Work.

## Modeling

Collection system modeling to predict odor levels in collection systems have advanced significantly since the initial models were developed. A commonly used method is based on a fundamental equation developed almost 40 years ago by Pomery and Parkhurst – a common form of which is:

$$\frac{d[S]}{dt} = \frac{M'[EBOD]}{r} - \frac{N(sv)^{\frac{3}{8}}[S]}{dm}$$

This only considers a few parameters BOD, temperature, wetted perimeter and single constant mass transfer coefficient. Also, importantly it only estimates the sulfide generated in the liquid wastewater and does not estimate the vapor phase $H_2S$ in the sewer headspace. The $H_2S$ in the headspace is what causes odor and corrosion problems and therefore estimating it is critical to determining how to mitigate odor and corrosion. If the wastewater liquid sulfide concentration were predicted by the simplified model to be say 1 mg/l the vapor phase $H_2S$ concentration in the sewer headspace could vary greatly from perhaps 5 ppm to as high as 50 ppm or higher depending on many factors including wastewater flow turbulence and the headspace ventilation rate. A sewer that has low flow, is well ventilated, has a quiescent surface and few drops and elevation changes would have a low $H_2S$ headspace concentrations. Conversely, a turbulent, poorly ventilated flow sewer with large drops would have a much higher concentration. Estimating the sewer headspace concentration is critical to determining the design criteria for odor control methods and ensuring the most cost effect methods are selected. CH2M's odor model predicts the generation, transport, and fate of $H_2S$, both dissolved and vapor phase, in wastewater collection systems.

## Approach to Evaluation of Odor and Corrosion Control Mitigation Alternatives

The subsection describes CH2M's proposed approach for evaluating the mitigation alternatives.

### *Liquid-phase Mitigation*

The general categories of liquid-phase mitigation that we will consider are shown in Exhibit 1. Liquid-phase treatments often are not as effective as vapor-phase treatments, but many times they are appropriate for collection systems, especially when odors are intermittent. Computer modeling is often the most effective method for evaluating control of odors in collection systems. A model can be used to characterize the generation and fate of odors under varying system-specific conditions. CH2M's model was the first model to be able to predict vapor-phase concentrations, which is the key to determining the true odor and corrosion impacts. Collection system components known to significantly impact odor generation and release such as force mains, drop structures, and siphons can all be accurately represented within the model. We will use the model to model chemical dosing at the Ruben Drive Pump Station to assess the impact on the gravity sewer..

**EXHIBIT 1**

Liquid-phase Odor Control Methods

| *Method* | *Description* |
|---|---|
| **Oxygenation and aeration** | Ambient air or pure oxygen is injected into the waste stream to oxidize sulfides or to maintain an aerobic biofilm. |
| **Chemical oxidation** | Chemical oxidizing agents are added to the waste stream to oxidize dissolved sulfide to sulfate, which remains in solution. |
| **Sulfur precipitation** | Metal salts are added to the wastewater stream to form a metal sulfide precipitate with the dissolved sulfide, thus removing it from the waste stream. |
| **Nitrate addition** | Nitrate salts such as U.S. Filter's Bioxide® are added to the wastewater stream, displacing sulfate as the preferred electron acceptor for anaerobic bacteria and preventing sulfide formation. |

| | |
|---|---|
| **pH adjustment** | The pH of the waste stream is changed to inhibit growth of $H_2S$-producing bacteria or to drive volatile $H_2S$ to soluble $HS^-$. |
| **Biological treatment** | Process changes or microbial cultures are used to affect the ability of bacteria to produce $H_2S$. |

### *Vapor-phase Mitigation*

Vapor-phase control is one of the most common and effective odor mitigation methods. Exhibit 2 lists the types of vapor-phase control methods that we will consider for the project. While vapor-phase controls can be highly effective, if not properly selected and designed, vapor-phase mitigation can be very costly and may not achieve the desired high removal efficiencies. One of the important factors to consider in selecting a vapor-phase mitigation method is the odor source characteristics. Different types of sources contain different types of odorous compounds, and it is critical to identify the compounds and then select a mitigation option that can effectively control those compounds. Exhibit 2 shows which vapor-phase control devices are most effective at controlling different odorous compounds. This often makes it important to analyze odorous sources for these compounds so that an appropriate treatment technology can be selected. However, a comprehensive analysis is not always required because a technology can sometimes be selected based on experience with similar odorous sources at other utilities or collection systems.

**EXHIBIT 2**

Vapor-phase Odor Control Methods

| ***Method*** | ***Description*** |
|---|---|
| **Wet scrubbers** | Packed tower or atomized mist scrubbers wash odorous compounds from the air stream into a liquid scrubbing solution. |
| **Carbon adsorption** | Odorous compounds are removed by adsorption onto activated carbon. |
| **Thermal treatment** | Odorous compounds are destroyed by burning or thermal destruction. |
| **Biological Systems** | Odorous air is passed through biologically active media (biofilter) or over inert media with nutrient spray (biotrickling filter). This method is a combination of absorption, adsorption, and biological oxidation of odorous compounds. |
| **Hydroxyl Ion Fogger** | Ozone is aspirated into a water stream to create a “hydroxyl ion fog.” The fog typically is injected into wet wells or other headspaces, where it reduces odors and corrosion. |
| **Ozone systems** | Odors are treated by providing contact chambers injected with ozone that comingle with the odorous air. |
| **Ionization Systems** | Ambient air is passed over ionization tubes before entering the building. Ion tubes produce “charged negative and positive ions” that strip electrons from oxygen and then group into ion clusters of oxygen molecules. The clusters react with odorous compounds such as volatile organic compounds, $H_2S$, and ammonia. |
| **UV/Carbon Systems** | UV with catalytic surfaces is used to generate hydroxyl ion radicals that react with odors in an enclosed treatment vessel or in the headspace of a process tank. The flow is polished by passing it through carbon. |
| **Other adsorption systems** | Solid-phase adsorption products such as Iron Sponge and SulfaTreat are based on iron and sulfide reaction chemistry |

### *Physical Mitigation*

During a conversation with the City, physical mitigation measures were discussed. The City has a potential project 10 or so years in the future to resize and relocate the force main. The existing 12-inch force main is oversized for the flow it conveys resulting in a long detention time that allows for excessive dissolved sulfide generation. A smaller diameter force main would decrease the detention time. Shortening the force main would

also reduce the detention time. CH2M will model the impact of a resizing and shortening the force main on sulfide generation and vapor phase $H_2S$ release at a relocated discharge point. The City may elect to accelerate the project as a resized force main and relocated discharge could eliminate future odor issues.

CH2M will also evaluate other physical modifications to the gravity sewer to reduce turbulence and stripping of dissolved sulfides to the vapor phase. One particularly opportunity to reduce turbulence is the 9 foot drop at the manhole at the intersection of Waukesha Avenue and East Moreland Boulevard.

The physical mitigation analysis will not include a cost analysis.

### Cost Estimates for Mitigation Alternatives

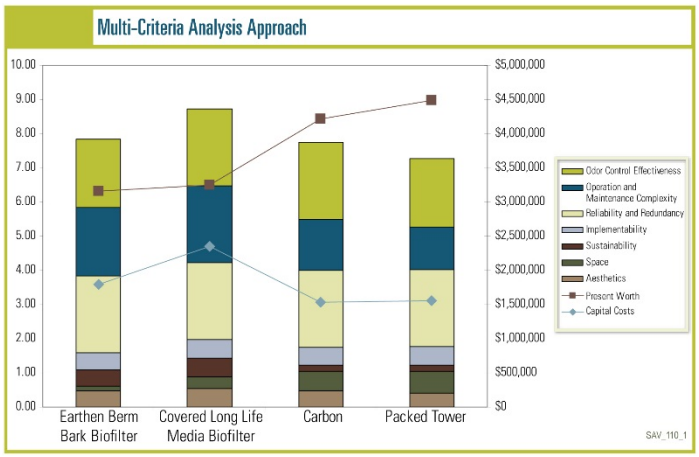
Cost estimates curves will be developed for up to five different options. CH2M has developed an odor control cost estimating tool that incorporates cost curves and pricing from past odor control work that we will use for this project. Chemical cost often vary greatly by location so obtaining local chemical raw material and delivery costs is important.

### Non-monetary Considerations and Advantages/Disadvantages

In addition to cost considerations, we will document non-monetary factors and advantages to be evaluated when choosing an odor control method. Examples of these are:

- Ability to consistently meet required control efficiency
- Operability
- Reliability
- Maintenance requirements
- Site requirements including space required

**EXHIBIT 3**




This multi-criteria analysis approach along with cost estimate curves (Exhibit 3) allows comparison of these factors to help aid in the selection of control devices that meet the specific preferences of the City by weighting them based on what is most important to the City.

# Section 4: Optional Tasks

The two optional tasks described below may be prudent. CH2M will assess the value of the optional tasks as the study proceeds. The cost of these optional tasks is not included in this scope of work, but would be based on a more detailed scope to be develop after the preliminary work is complete, if the City chooses to proceed with them.

### Bench-Scale Testing

Liquid-phase chemical treatment dosages needed to remove sulfide can vary widely depending on wastewater characteristics. Non-$H_2S$ compounds can compete with or interfere with treatment chemicals resulting in higher dosages than would otherwise be required. In some cases, a treatment chemical may not be effective at all. Conservative chemical dosages will be assumed in Task 5. Bench-scale testing may be beneficial should liquid-phase treatment be the recommended treatment option. Bench-scale testing will compare the effectiveness of various treatment chemicals to remove sulfide by either chemical oxidation or sulfur precipitation. CH2M has developed testing protocols to test chemicals such as ferric chloride, ferrous sulfate, hydrogen peroxide, and sodium hypochlorite. CH2M would use space in the City's lab to conduct the tests. Bench-scale testing can result in significant cost savings by selecting the most cost-effective chemical.

### Fan Testing

The ventilated airflow can significantly impact the cost of vapor-phase treatment systems. If the air flow rate selected is too high, the system will be unnecessarily large and costly. If the system is sized to be too small, it will not be able to pull a negative pressure in a large enough length of the sewer and odors will escape. A fan test can determine the optimum air flow required. A fan test involves connecting a blower to a manhole and using a pressure data loggers in upstream and downstream manholes to determine the airflow required to maintain a negative pressure in the gravity sewer.

# Section 5: Qualifications

This section describes CH2M's qualifications to provide the services described in the preceding section. Qualifications including resumes for the key individuals to execute the project for the City are described in the subsection Project Team, followed by the subsection Firm Qualifications and References.

## Project Team

The following are brief descriptions and resumes of key staff proposed to serve the City on this project.

**Project Manager, John Siczka, P.E.,** is a licensed Professional Engineer in Wisconsin, a Project Manager and Senior Technical Consultant with CH2M's Water Market. He also serves as CH2M's Wet Weather Treatment Global Technology Leader. John is based in CH2M's Milwaukee office. John has over 15 years' experience in working on odor control projects for client throughout the United States and internationally. He recently lead the design for NEW Water's (Green Bay) R2E2 project that included the design of a 19,000 cfm and 14,400 cfm biotrickling filters with carbon polishing to control odors from septage receiving operations, gravity belt thickeners, sludge holding tanks, sludge fermentation tank, dewatering centrifuges, biosolids dryer, and nutrient extraction processes. He is currently leading a collection system odor study for the City of San Mateo, CA.

**Senior Technical Consultant, Bill Desing, P.E.,** has 30 years of experience in odor and corrosion management and wastewater planning, design, and operation. He is CH2M's global leader for odor and air quality management where he manages a group of 15 technologists located in North America, Australia, Europe, and Asia. The group is responsible for developing tools, methods and practices for managing and controlling odors and air emissions for wastewater and water utilities world-wide. He has been involved in more than 30 odor related projects including development of comprehensive odor control master plans for several wastewater utilities such as those operated by Cincinnati Ohio, Orange County California, and Louisville, Kentucky. Bill will serve as a technical resources and attend all key meetings.

# John Siczka, PE, Project Manager

## Education and Professional Registrations

M.S., Environmental Engineer, Virginia Polytechnic Institute and State University
B.S., Civil Engineering, Virginia Polytechnic Institute and State University

Professional Engineer: Wisconsin

## Distinguishing Qualifications

- Experienced in managing projects of various sizes and technical areas for municipal and industrial clients
- Wastewater treatment plant odor control design expertise
- Wastewater treatment plant and collection system odor modeling expertise
- Hydraulic modeling experience
- Wet weather treatment technology and pilot testing expertise
- Wastewater treatment plant process mechanical design
- Security and vulnerability assessments for municipal clients
- NPDES negotiations, Industrial storm water permit, best management practices, stormwater pollution prevention plan, SPCC plan, FRP, and Title V expertise

## Representative Projects

**Design Lead, R2E2 Project, Green Bay Metropolitan Sewerage District, Green Bay, Wisconsin.** Evaluated odor control treatment technologies for treating odorous air from a fermenting WAS tank, anaerobically digested sludge holding tanks, nutrient recovery reactors, centrate tank, dewatering centrifuges, sludge dryer, vapor condenser, scum concentrator, high strength waste receiving tanks, septage receiving operations, primary and secondary sludge holding tanks, gravity belt thickeners, thickening centrifuge, and thickened sludge wet wells. Recommended two combined biotrickling filter and carbon vessels to treat 14,400 cfm from solids processes and 19,000 cfm from thickening/high strength waste receiving/septage receiving processes. Calculated airflows and sized ductwork. Sized biotrickling filter/ carbon vessels. Developed specifications for biotrickling filter/carbon vessel and ductwork. Developed mechanical and I&C drawings.

**Senior Engineer, Preliminary Modeling of Odor for Thames Tideway Tunnel, Thames Water Utilities, London, England.** Led modeling efforts to estimate the likely concentration and character of odors generated within the drop shafts, main tunnel, and rider tunnels of the Thames Tideway Tunnel and Lee Tunnel and proposed preliminary, conceptual mitigating measures for odor control. The Thames Tideway Tunnel and Lee Tunnel are to intercept 36 combined sewage outfalls (CSOs) which presently spill into the River Thames and River Lee in London. The Thames Tideway Tunnel will be nominally 32 km long, 7.2 m internal diameter and intercept 34 CSOs. The Lee Tunnel will be nominally 6 km long, 7.2 m internal diameter and intercept 2 CSOs. The tunnel system discharges to the Beckton sewage treatment works. Used existing computer models and developed new models to perform the analysis. Estimated liquid sulfide emissions and mass of hydrogen sulfide stripped to the tunnel headspace throughout the length of the tunnel. Estimated emissions from drop shafts and access shafts and concentrations of hydrogen sulfide in ground-level atmosphere at varying distances from shaft outlets. Estimated the frequency of odor complaints and developed general, conceptual methods for reducing and controlling odors. Prepared the technical memorandum reporting the results.

**Senior Engineer, Wet Weather Capacity Improvements and Nitrogen Reduction – Phase 1, Greater New Haven Water Pollution Control Authority, New Haven, CT.** Led the design for a new, centralized 114,000 cfm wet scrubber system to provide odor control for the East Shore Water Pollution Abatement Facility. The centralized system consists of three scrubbers (two duty, one standby) that replaced an existing five scrubber decentralized system. The treatment plant is located in close proximity to residents of New Haven making mitigation of odors a high priority. Odor control was provided for the following sources: sludge storage tanks, gravity thickeners, belt presses, gravity belt thickeners, sludge blend tanks, thickened waste activated sludge tanks, comminutors,

and primary influent wet well. The design included sizing and routing of large diameter odorous air ductwork throughout the plant, new chemical storage tanks for sodium hypochlorite and sodium hydroxide, new chemical metering pumps, and new control system.

**Project Manager, Fort Wayne Water Pollution Control Plant Odor Control Study, Fort Wayne, IN.** Managed an odor control study of the Fort Wayne Water Pollution Plant. Developed a sampling plan to help estimate levels and sources of odors at the two largest odor sources. Estimated odorous emissions from other sources using calculations and sampling data from other similar facilities. Developed and conducted jar tests to estimate chemical dosing rate for hydrogen sulfide control. Screened treatment options for the odor sources. Performed life-cycle cost per unit of odor emission reduction for each odor source to prioritize selecting locations to treat. Developed recommendations for odor sources to control based on worker safety, corrosion, and cost. Prepared the report presenting the results.

**Senior Engineer, Norwalk WWP Solids Building Odor Control Preliminary Assessment, City of Norwalk, Norwalk, CT.** Conducted a preliminary odor control assessment for the City of Norwalk's Solids Building. The building contains numerous odorous sources including two blended sludge tanks, two gravity belt thickeners, a thickened waste activated sludge wet well, a blended sludge dewatering belt filter press, dewater sludge conveyors, and sludge dumpster. The existing odor control consists of sodium permanganate solution added upstream of the belt filter press. Performed a site visit and reviewed air sampling data. Obtained quotes and developed cost estimates to control odors using chemical treatment with ferric chloride and ferric sulfate and/or vapor phase treatment with activated carbon. Drafted a technical memorandum that recommended a trial of ferric chloride and ferric sulfate to determine their effectiveness compared to the much more expensive sodium permanganate. Activated carbon may also be necessary.

**Senior Engineer, Resolution of Malodors South Coast WWTP, Barbados Water Authority, Barbados.** Evaluated odor control treatment technologies to provide odor control for the headworks facility at the South Coast WWTP. Selected air flows, sized ductwork, and developed site plans. Assisted in writing the technical memorandum.

**Project Engineer, Collection System Odor Control, Green Bay Metropolitan Sewerage District, Green Bay, WI.** Analyzed and developed odor control alternatives for two municipal interceptors that convey wastewater to Green Bay MSD's De Pere WWTP. Analyzed and developed odor control alternatives for an industrial force main to the De Pere WWTP and two municipal force mains between the De Pere and Green Bay WWTPs. Used the INTERCEPTOR model to quantify sulfide generation and emissions and quantify dosing requirements for various chemical treatment alternatives. Sized dosing equipment. Developed and conducted jar tests to quantify chemical treatment alternatives for a high strength, high temperature industrial force main. Presented results to client staff. Provided expert guidance to control sulfide generation in municipal interceptor with a significant industrial load until industrial force main is completed.

**Process Engineer, Facility Upgrade and Expansion of the Rochester Water Reclamation Plant, Rochester, MN.** Assisted in developing odor control conceptual design for headworks facility, primary clarifier/aeration basins, and solids storage tank. Lead detailed design efforts for three separate wet scrubbing systems to control hydrogen sulfide and other odorous compounds for a 4.5 mgd expansion and upgrade. Lead detailed design for emergency chlorine gas dry scrubber. Responsibilities included sizing and selecting equipment, air and hydraulic calculations, duct and mechanical layout, and electrical and hazardous atmosphere classification code issues. The emergency scrubber required major modifications to the existing HVAC and emergency ventilation control systems. Prepared mechanical drawings and specifications. Performed shop drawing review, operation and maintenance manual review, RFI response, and training.

# Bill Desing, PE, Principal Technologist

## Education and Professional Registrations

M.S., Environmental Engineering, Marquette University
B.S., Civil Engineering, Marquette University
Professional Engineer: Wisconsin, Illinois

## Distinguishing Qualifications

- 29 years of experience
- Leader of CH2M HILL's Global Odor Control and Air Quality Management Practice.
- Experience assisting more than 30 municipal WWTPs in addressing air quality and odor issues, including odor control master planning, odor control system design, air dispersion modeling and air permitting
- Author of several publications and presentations regarding odor issues including the upcoming revised WEF Odor Control Manual of Practice

## Representative Projects

**Senior Technologist/Lead Engineer, Odor Control Master Plan, Metropolitan Sewer District of Greater Cincinnati's 200-mgd Mill Creek Plant, Cincinnati, OH.** Evaluation included sampling and estimation of odorous emissions, optimization of chemical scrubber systems, dispersion modeling to determine offsite odor impacts and conceptual design of new odor control systems needed to reduce offsite impacts. Led the evaluation of wastewater process changes that could reduce odorous emissions.

**Project Manager, Clean Air Act Part 70 Title V Air Operating Permits, Metropolitan Water Reclamation District of Greater Chicago, Illinois,** Managed the preparation of the Clean Air Act Part 70 Title V air operating permits for the Metropolitan Water Reclamation District of Greater Chicago's Stickney plant. Lead engineer for the preparation of federally enforceable synthetic operating permits for the District's Calumet, Northside Plant, Kirie Plant and Egan Plant. The permitting included developing estimates of hazardous air pollutants from all wastewater and combustion sources at each plant.

**Lead Engineer Thames CSO Tunnel Odor Control, London.** Led a study to estimate odor emissions and odor control mitigation alternatives for the City of London, England Thames CSO Tunnel. The study included development of dynamic and steady state models to estimate odor generation, stripping, emissions and impacts on the population along a 15-mile tunnel route. The study resulted in a recommendation for use of a carbon systems with a total capacity of more than 200,000 cfm with air bypass capacities of more than 1 million cfm.

**Project Manager/Senior Technologist, Odor Control Master Plan, Louisville Metropolitan Sewerage District, Louisville, KY.** The plan addressed five plants and significant parts of the collection system, as well as odors from CSO storage facilities. Modeled more than 50 miles of force mains and gravity sewers located primarily in sensitive areas. Then used the model to determine the optimum location for chemical addition that would minimize dosing rates and ensure complete reactions. The model combined with bench-scale testing was used to estimate dosage rates required to reduce odors in the interceptors, force mains and pump stations. Preliminary design of odor control systems for the interceptors and pump stations was completed.

**Lead Engineer, Odor Control Master Plan, Orange County, CA.** One of the lead engineers for the preparation of the Orange County Sanitation District's master plan. Extensive sampling was done to characterize odors from the collection system and two plants that have a combined capacity of 250 mgd. Full-scale pilot testing was done to determine the cost-effectiveness of liquid chemical treatment for odor control in the collection system.

**Quality Control Reviewer, Composting Facility Odor Control Upgrades Davenport, IA.** Primary Quality Control Reviewer for project that included odor control upgrades for composting operation which treats 210,000 cfm of odorous process air through an 8 cell wood chip based biofilter. Project evaluated various biofilter aeration distribution flooring systems, media types, and O&M enhancements with media change-outs.

**Senior Technologist for Odor Control System Design, Metropolitan Council Environmental Services.** Senior technologist for design and construction of a biofilter system to control odors from a large septage receiving station.

**Senior Technologist for Biofilter Improvements Study, Western Lake Superior Sanitary District.** Paper mill wastewater discharged to the wastewater treatment plant was the source of odor-causing sulfides emitted at the plant. The study evaluated methods to improve the performance of a 50,000-cfm capacity open bed organic media biofilter. It also evaluated replacing the biofilter with other odor control technologies.

**Lead Odor Control Engineer, Wastewater Plant Upgrade Design, Rochester, MN.** Odor control systems included three packed tower chemical scrubbers with a total capacity of over 100,000 cfm. The systems control odors from the screenings, grit, primary clarifiers, aeration, and sludge storage tanks.

**Senior Reviewer, Green Bay Metropolitan Sewerage District, Collection System Odor Studies, Green Bay, WI.** Used CH2M HILL's INTERCEPTOR model to predict the generation, transport, and fate of $H_2S$ in several interceptor sewers. Vapor phase $H_2S$ sampling data from the interceptors were used to calibrate the model. Solutions to control sulfide generation and vapor phase $H_2S$ were developed. Used INTERCEPTOR to determine chemical dosing requirements to prevent nuisance odors, worker safety issues and sulfide toxicity from occurring in the facility's aeration basins.

**Project Manager and Lead Engineer for Odor Control Study and Design, Grand Chute-Menasha West Sewerage Commission.** Managed a study to identify and prioritize odor sources. An odor control system that used a biotrickling filter was designed and installed to control odors from influent channels, bar screens and septage receiving.

**Senior Reviewer, Northern Kentucky Sanitary District, Tunnel Odor Control, KY.** Performed senior review for all phases of design of odor control systems for a 7-mile-long, 10-foot-diameter tunnel used to store and convey wet weather and sanitary wastewater flow. The design included development of customized odor computer models to estimate odorous emissions from vortex dropshafts and tunnel access shafts. The models used computational fluid dynamics and the results of a 1/15 vortex dropshaft scale model testing used to design the Milwaukee Metropolitan Sewerage District's Inline Storage Tunnel system.

**Lead Engineer, Little Blue Valley Sewer District, Odor Control for $70 million Atherton Wastewater Treatment Plant Improvements.** Leader for odor control for the facility plan and preliminary design, and completed the final odor control design. Odor control includes minimizing odors through process design such as using enclosed pipes instead of open channels, and installing 21,000- and 12,000-cfm biofilters and a 4,000-cfm thermal oxidizer system.

**Assistant Project Manager and Predesign Manager, Design of Odor Control Facilities, Southerly Plant, Northeast Ohio Regional Sewer District, Cleveland, OH.** Facilities designed included recuperative thermal oxidation for Zimpro solids handling facilities, and odor control for a skimmings handling facility, gravity thickeners, sludge storage, and vacuum filters.

**Lead Engineer, Identification and Quantification of Odorous Sources at Wastewater Treatment Plants in the Cities of Las Vegas, Sacramento, and Oakland.** Estimated fugitive emissions from open tanks and surfaces using computer modeling and direct measurement using a flux chamber. Estimated emissions from point sources using modeling, mass balances, and direct measurement. Conducted air dispersion modeling to determine the impacts of odors on the surrounding community. An analysis was done to compare odor control alternatives for those sources determined to have the largest community impact.

## Firm Qualifications and References

CH2M has completed more than 300 odor control projects for wastewater agencies in the United States, Australia, Europe, and Asia. The projects include facilities ranging in size from less than 1 mgd to more than 500 mgd. The CH2M team has the wide variety and multi-discipline experience needed to complete the project including the following:

**Odor Mitigation Options:** We have designed odor control systems for virtually all of the available vapor and liquid phase odor mitigation options including biological treatment, carbon, chemical scrubbers, ozone system and multiple types of liquid chemical treatment systems. The systems that we have designed have included systems with capacities of more than 1 million cfm—which are likely some of the largest wastewater odor control systems in the world. Our team includes some of the industry's top experts in detailed and theoretical design who have helped advance the state of knowledge and capability in odor control devices. We have designed odor mitigation options for all of the types of odor sources, including a variety of pump stations, liquid and biosolids treatment sources, collections systems and CSO tunnel systems.

**Odor Sampling:** CH2M has in-house crews that collect odor samples and perform odor field measurements. In addition, we own most of the equipment required for collection samples and making in field measurements including Odalogs, Nasal Rangers, anemometers, and colorimetric field testing kits.

**Dedicated Odor Professionals:** CH2M has a group of more than 20 staff who are odor specialists working almost exclusively on odor related projects—most of which are for municipal wastewater agencies and cities. As specialists, they stay current on the latest developments in odor issues. Many of them began their careers as wastewater process engineers allowing them to help address the odor challenges unique to municipal wastewater facilities.

Just a few of the many odor projects completed by CH2M are described below. Exhibit 4 summarizes CH2M's additional odor project experience.

# Reference Projects

## Virginia Initiative Plant (VIP) Odor Master Plan, Hampton Roads Sanitation District, Norfolk, Virginia


### Project Highlights

- Extensive odor control work performed due to the adjacent golf course
- Project received the American Consulting Engineers' Council Outstanding Achievement Award

### Project Description

In 2005, CH2M performed an Odor Control Master Plan (OCMP) for the Hampton Roads Sanitation District (HRSD) as part of the VIP. The study was performed due to the construction of a golf course and sports stadium adjacent to the site and the subsequent loss of the buffer zone. The OCMP included source sampling, evaluation of existing odor control systems, and dispersion modeling to identify any odor sources that might impact the new golf course and sports stadium.

***"CH2M did an outstanding job in guiding HRSD in making the correct decision when dealing with offsite odors."***

***Sami Ghosn, PE Plant Manager***

Because of its location in an environmentally sensitive area within a growth corridor in Virginia Beach, the District adopted proactive "good neighbor" policies. An extensive public information program maintained communications between the District and area residents, environmentalists, and permitting agencies. Public meetings and workshops were held to discuss the results of the pilot plant testing and the plans for the full-scale implementation. Odor control was a significant part of the good neighbor program. With both anaerobic and aerobic processes, attention to the appropriate design of odor control mechanisms was a high priority. Wind patterns and dispersion models were generated and controls were designed for maximum effectiveness.

Working with the client, CH2M selected an odor impact goal of 2 dilutions to threshold (D/T) with 100 percent compliance for odor impacts that could last up to 1 hour. The criteria selected was very conservative, and CH2M also set a secondary goal of meeting a 3-minute odor puff impact level of 7 D/T 99.9 percent of the time. To do that, odors from the headworks and portions of the aeration basins that had not been covered had to be mitigated.

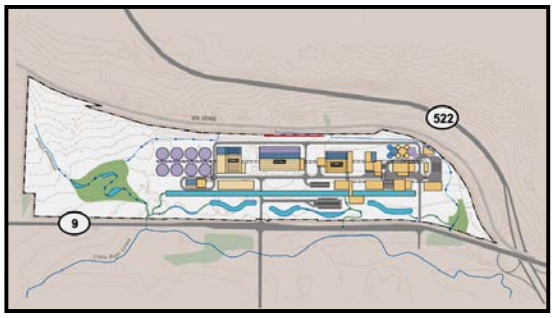
The original plant is a CH2M design and is rated at 40 mgd design flow able to handle peaks up to 80 mgd. Initial work included covered primary clarifiers with multi-stage packed tower chemical scrubbers on top of the primaries, which continue to be in service.

The OCMP work eventually resulted in installation of a two-stage odor control system using a biotower with second-stage packed tower for headworks odors and additional covers and treatment for the aeration basins. The concept of the new odor control system was developed by CH2M.

### Client Reference

Mark Feltner, Hampton Roads Sanitation District, 1434 Air Rail Avenue, Virginia Beach, VA 23455
757-460-4254, mfeltner@hrsd.com

# Public Outreach, Siting Study and Design, Brightwater Treatment Plant, King County, Washington




## Project Highlights

- Extensive public outreach
- Multiple-stage state-of-the art odor control
- Totally enclosed facility with no odorous emissions

## Project Description

This project consisted of three phases: the first being to provide public outreach assistance to King County for the new green field advanced treatment wastewater plant (Brightwater), the second to select the most desirable site location for the plant and prepare the Environmental Impact Statement, and the third to design the new treatment plant. Odor control was a very important aspect of all three phases and key to gaining public support for the project. CH2M assisted in numerous public meetings that were held regarding the odor control approach. King County ensured the community that the odor control at Brightwater Plant would be the best in the world and the plant would not smell – ever. To meet this challenge, totally enclosed facilities and multiple-stage odor control were coupled together as the core of the odor control design. CH2M played an active role in supporting King County in gathering information and responding to community concerns for odor control issues. The success of the odor control approach was key to get the plant sited and accepted by the community.

The siting study involved developing preliminary design criteria, sizing plant processes, developing conceptual treatment plant layouts, and writing the Environmental Impact Statement (EIS) for this 36-mgd plant. Odor source characterization and dispersion modeling was done for the EIS by sampling sources at an existing local plant with similar processes and similar wastewater. This source data was then used to do dispersion modeling using ISCST3 to project the fenceline impacts of the proposed site.

In working to site the new plant, CH2M worked with plant staff and community stakeholders to develop aggressive design criteria for acceptable odor impacts at the fenceline. These included fenceline threshold criteria that were among the most stringent ever for a wastewater facility and an order of magnitude or more less than typical standards: 1 D/T odor; 0.0008 ppmV hydrogen sulfide; and 2.8 ppmV ammonia. The planned odor control system was designed to these low levels because that was needed to get the new plant accepted by the community. The design consists of 3 localized scrubber complexes treating a total of 400,000 cfm of foul air. Additional capacity (120,000 cfm) is also provided for redundant units and for handling increased ventilation during tank maintenance operations. All facilities are either fully enclosed buildings or covered tanks. All ventilation air is sent to the odor control system. The ventilation dilutes the peak odor intensities that the scrubber systems will have to face and ensures very effective capture of odors.

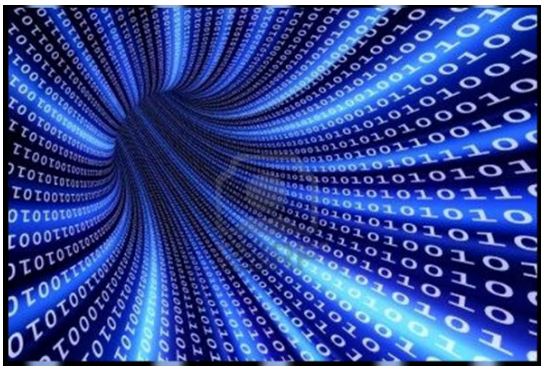
The overall odor control system also includes aggressive liquid phase odor control treatment in the incoming interceptor system to reduce the odor generation potential of the wastewater after it comes into the plant and an aggressive approach to ventilation. The liquid phase treatment reduces the odor generation potential. The multi-stage scrubber system consists of biotowers followed by a single-stage chemical scrubber plus carbon at two facilities, and a single-stage scrubber followed by carbon at the third facility. The multiple stage approach treats a full range of odor-causing compounds. King County pilot tested biotowers in 2004/2005, which contributed to the decision to include biotowers in the design. The biotowers will reduce the chemical demand of the odor control system, safer for workers and the environment, and requiring fewer chemical truck deliveries to the site.

## Client Reference

Stan Hummel, Project Manager, King County, 201 South Jackson St. Suite 503, Seattle, WA 98104-3855
206-684-1844, stan.hummel@kingcounty.gov

# Sewer Corrosion and Odor Research Program (SCORe), Australian Research Council, Australia

## Project Highlights



- $20 million collaborative 5 year academic and industry research program
- 15 water industry partners and 5 university partners with CH2M as the only consulting engineering firm
- Project goal is to provide knowledge and technology support to the wastewater industry for cost-effective and efficient corrosion and odor management in sewers.

## Project Description

Sewer corrosion and odor problems are spread worldwide, particularly in countries with a warm climate. CH2M helped to set up this multi- and inter-disciplinary approach of the SCORe program and created value for CH2M and our clients in several ways:

- Greater fundamental understanding of the processes involved in various aspects of odor and corrosion
- Improved collection system odor models
- Created sampling methods to gather field data for input to modeling tools in a more cost-effective, reliable, and safe manner
- A better solutions toolbox for corrosion/odor problems

Sewer ventilation can be a critical factor in determining the solution for either existing or potential corrosion and odor issues in wastewater collection systems. Full scale wastewater collection systems contain both large and very small diameter, gravity, side laterals and/or forced main pipes and have unique layouts that can include siphons, drops, junction boxes, bends, tunnels that can cause wastewater turbulence or system pressurization. Most sewer systems are buried, under roadways, and are very difficult to fully assess because of confined space entry considerations, variation in wastewater flows and general human size-scale entry limitations.

**Corrosion and Odor Control through Integrated Management of Assets:**

Guidance tools were also developed to improve the designs of sewer systems and corrosion and odor control systems into a more cost-effective corrosion and odor prevention approach.

This program was awarded the IWA Asia Pacific Winner for Applied Research in 2014.

## Client Reference

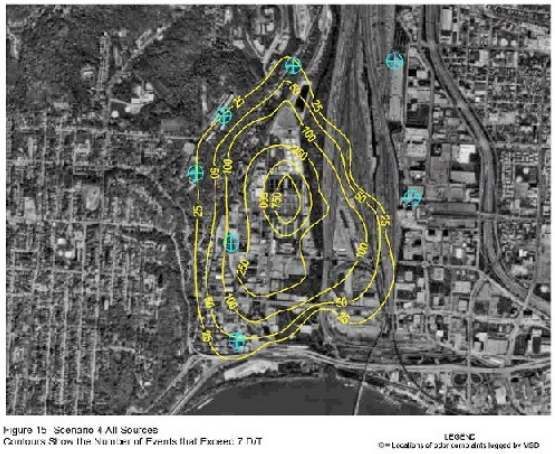
Prof Zhiguo Yuan, PhD, IWA Fellow, Deputy Director, Advanced Water Management Centre,
The University of Queensland, The University of Queensland, Level 4 Gehrmann Building (60),
Brisbane QLD 4072 Australia

61-7-3365-4374, ezhiguo@awmc.uq.edu.au

# Odor Control Evaluation and Strategic Plan, Mill Creek Wastewater Treatment Plant, Metropolitan Sewer District of Greater Cincinnati, Ohio

## Project Highlights

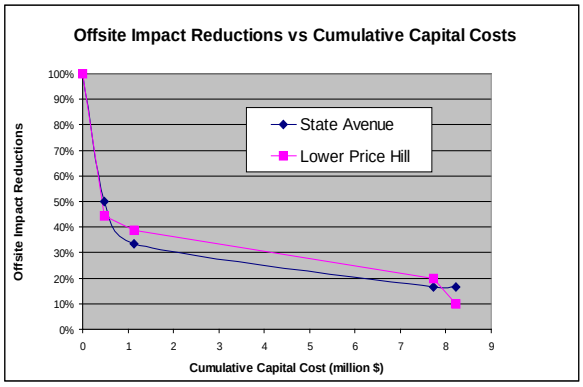
- Odor Source Characterization was completed by means of an initial subjective site odor survey with plant staff followed by bag sample collection and analysis for odor-causing compounds.
- Optimization analysis was completed for existing packed tower scrubber systems. This analysis focused on the impact of unusually high CO2 levels in the odorous air stream.
- Odor sources were then ranked to show their offsite impact by means of dispersion modeling.



## Project Description

The Metropolitan Sewer District of Greater Cincinnati (MSD) desired to complete an Odor Control Evaluation and Strategic Plan for the 130-mgd Mill Creek Wastewater Treatment Plant (WWTP). The purpose of the project was to assess the effectiveness of the existing odor control measures and identify other areas that required odor control at the WWTP.

## Odor Control Strategy




Individual odor source characterization was completed throughout the plant. This was done in a 2-step process starting with a subjective site survey with plant staff followed by detailed source emissions sampling. Both odor panel analysis and GC analysis for individual odor-causing compounds was completed. Using this source characterization, the impacts of the odorous sources on the communities surrounding the plant were determined along with the level of control needed to minimize the offsite impacts. The impacts on the community were estimated using air dispersion modeling and a neighborhood survey. Initial recommendations were made for improvements to existing chemical scrubber systems and potential process changes in order to reduce offsite impacts to an acceptable level. In addition, recommendations for long-term capital improvements were made based on a ranking of the improvements that would result in the largest decrease in offsite impacts that was cost effective. A cost-benefit analysis was completed showing the overall reduction in the frequency of offsite impacts to sensitive odor receptors compared to the capital implementation costs

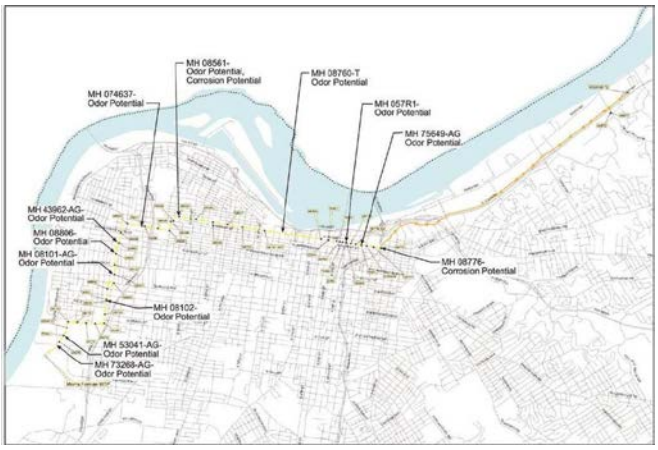
# Collection System and Treatment Plant Master Plan, Louisville and Jefferson County Metropolitan Sewerage District, Louisville, Kentucky

## Project Highlights

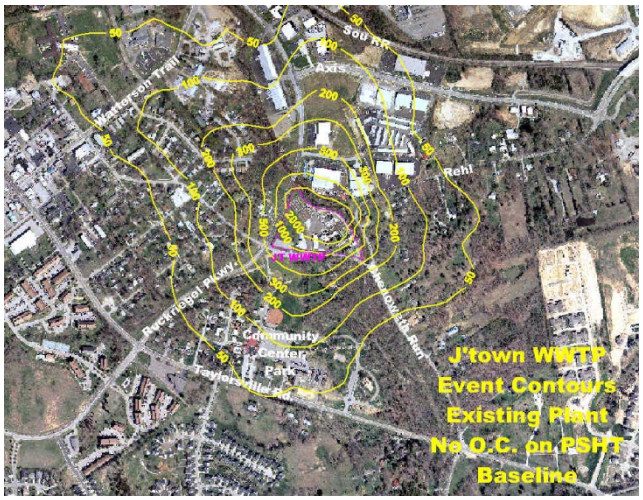
- Odor control master plan for six plants and a large collection system
- Comprehensive wastewater collection odor generation assessment including field survey, sampling, modeling, and bench-scale chemical testing

## Project Description

The Louisville and Jefferson County Metropolitan Sewer District owns and operates 6 wastewater treatment plants, 230 pump stations, 30 small treatment plants, and more than 3,000 miles of sewer collection systems. Odors from these facilities have the potential to negatively impact homes and nearby businesses. To address the negative impacts of odors from District facilities, an Odor Control Master Plan was completed. The purpose of this plan was to reduce offsite odorous impacts to acceptable levels by using the most cost-effective combination of available mitigation methods. This included systems to control emissions from selected odorous sources




*Odor event contours at a wastewater treatment plant*




*Odor and corrosion potential in the collection system*

### Odor Control Master Plan

CH2M developed an odor control master plan that addressed six plants and significant portions of the collection system.

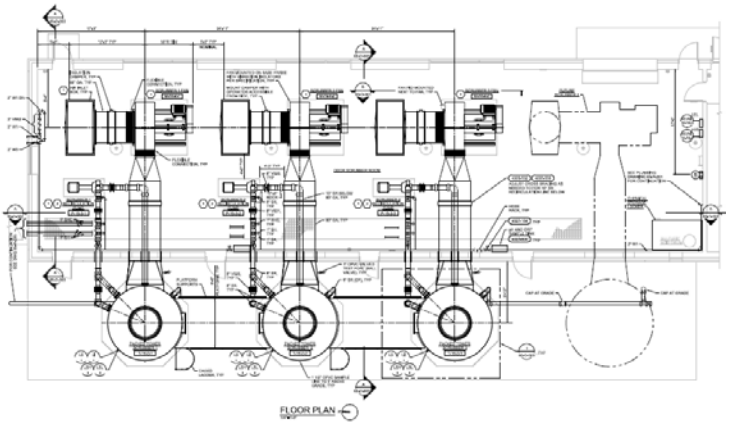
Odorous emissions from each of the plants were characterized using odor sampling, and offsite impacts were determined using air dispersion modeling. Over 100 samples were collected and analyzed for several parameters including total odor (D/T), reduced sulfides, hedonic tone and ammonia. Preliminary design of odor control devices was completed in order to mitigate offsite odor impacts.

For the collection system, CH2M's INTERCEPTOR computer model was used to determine both liquid- and vapor-phase hydrogen sulfide concentrations throughout the collection system in order to determine potential odor and corrosion "hot spots." More than 50 miles of the force mains and gravity sewers located primarily in sensitive areas were modeled. The model was then used to determine the optimum location for chemical addition that would minimize dosing rates and ensure complete reactions. Combined with bench-scale testing, the model was used to estimate dosage rates required to reduce odors in the interceptors, force mains, and pump stations. In addition, preliminary design of odor control systems for the interceptors and pump stations was completed.

# Wet Weather Capacity Improvements, Greater New Haven Water Pollution Control Authority, New Haven, Connecticut

## Project Highlights

- Provided 114,000 cfm fully centralized packed tower chemical scrubber system for odor treatment
- System was designed to replace capacity of 5 aging odor control systems and incorporate added odorous air load from new sludge receiving, thickening and storage systems
- Completed odor impact dispersion modeling to ensure the new system met key odor impact goals and local ambient impact criteria




*Centralized 3 train scrubber system layout with allowance for a future 4th train*

- All fans, chemical storage and pumping systems are located indoors protecting them from the winter weather and minimizing potential for fan noise impact to the nearby neighbors

## Project Description

The New Haven Water Pollution Control Authority (WPCA) had a past history where it was under increasing scrutiny from nearby homeowners due to nuisance odors emanating from their 40-mgd East Shore Water Pollution Abatement Facility. CH2M was initially involved in successful odor evaluations that helped with the plant's odor problems. This included optimization of older existing scrubber systems and construction of several key systems in 1997 to control odors from the headworks and primary clarifiers that were covered and vented to a new odor control system.

As a result of that sustained success and the clients satisfaction level, CH2M was engaged in 2012 to complete a plant wet weather capacity upgrade that upgraded the plants aging scrubber systems providing a new fully centralized packed tower chemical scrubber complex treating all plant odors in a single scrubber system location. Single stage packed tower scrubbers were selected as the technology choice based on past plant success and site plan limitations. The new centralized system treats 114,000 cfm of odorous air and has room for further expansion to add an additional 57,000 cfm system if the plant further expands in the future.

The new system will treat odorous air from:

- The existing headworks odorous air currently treated by the Crossflow and Lopro scrubbers
- Existing primary clarifier odorous air currently treated by the Paramount scrubbers
- Dewatering building odorous air currently treated by the NETCO scrubber
- Solids handling and influent pump station odorous Air currently treated by the Ambi scrubber
- A new sludge storage tank
- An existing sludge storage tank converted to serve as a thickener
- An existing sludge thickener tank converted to either thicken or store sludge

Potential future additional odor sources could include a new preliminary treatment building, new additional primary clarifier and a new chlorine contact tank for CSO. The current design under construction in 2014 includes 3 single stage caustic/hypo scrubbers and can accommodate addition of a 4th scrubber stage for future expansion if these new sources are added. Under all conditions a fully redundant scrubber is provided.

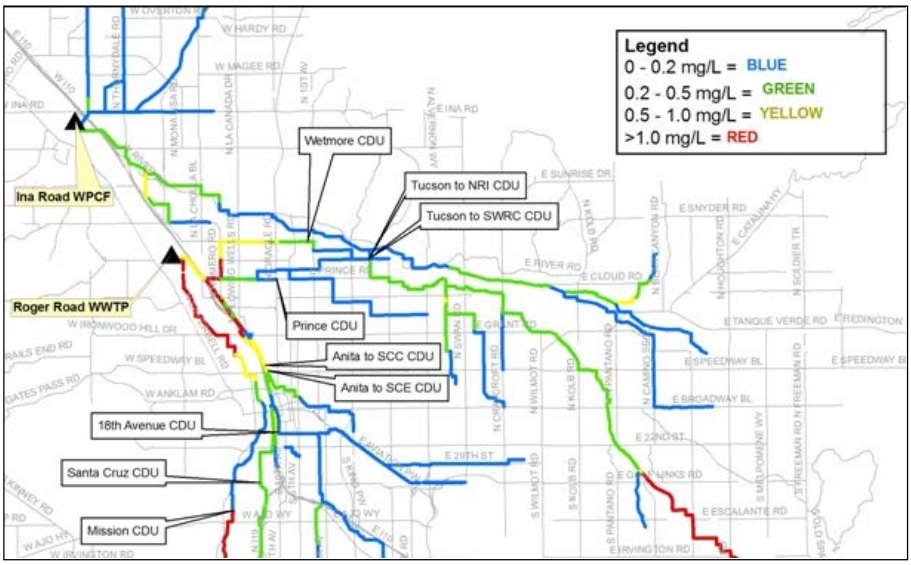
# Odor Control Master Plan, Pima County Wastewater Management Department, Tucson, Arizona

## Project Highlights

- Comprehensive wastewater collection odor generation assessment including field survey, sampling, modeling, and bench-scale chemical testing
- Performance evaluation and novel use of sulfide model to optimize existing chemical dosing stations
- Fast-response design of gas-phase treatment technology

## Project Description

As a result of continued public scrutiny and widespread odor complaints, Pima County Wastewater Management Department contracted with the CH2M team for a system-wide odor control master plan. CH2M was tasked with evaluating odor generation and release throughout the entire Tucson metropolitan area wastewater collection system. The wastewater collection system consists of more than 1,500 miles of pipe, numerous siphons and force mains, four major flow diversion structures, and 11 chemical dosing stations.




*Sulfide fate modeling results for Tucson Metropolitan area wastewater collection system*

CH2M completed an extensive evaluation of the wastewater collection system, that included a comprehensive site survey of major siphon inlets, known and suspected odor hot spots, chemical dosing stations, and flow diversion structures; field sampling of wastewater parameters, headspace hydrogen sulfide, and sewer ventilation air flow; sulfide fate and generation modeling over a domain containing all pipes larger than 18 inches; and bench-scale testing of four liquid phase chemicals on Pima County wastewater. As part of the evaluation, CH2M used a sulfide fate model, in conjunction with field data, to evaluate the performance of each chemical dosing station. This novel approach resulted in increased odor control performance at some stations and reductions of chemical use (without loss of odor control) at others.

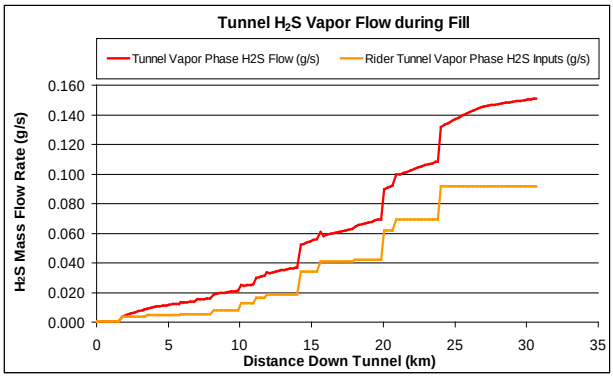
The master plan study resulted in a number of recommendations that enabled the Department to gain control of an intractable public relations challenge. Due to the urgency of the project, CH2M divided recommendations into short-term strategies that could be implemented quickly to head off imminent community relations repercussions, and long term odor control solutions. Recommendations included optimization changes to chemical dose at existing stations, flow pacing chemical injection to diurnal flow, relocating or adding several chemical injection locations to better target sulfide loads, location and design of vapor-phase treatment at key hot spots, cost/benefit analysis of alternate treatment technologies.

# Odor Emissions Study, Thames Water Utilities Limited, London, United Kingdom

## Project Highlights

- Estimated sulfide generation and odor emissions from a highly dynamic wet weather conveyance and storage tunnel
- Estimated sulfide generation and odor emissions from 23 drop shafts, four large diameter tributary rider tunnels, and the 7.2 m diameter and over 40 km long Thames Tunnel
- CH2M drop shaft computer model was used to estimate sulfide stripping in the drop shafts
- CH2M's INTERCEPTOR computer model was used to estimate sulfide generation and stripping in the rider tunnels and Thames Tunnel.
- Emission results used in dispersion modeling to quantify off-site odor and hydrogen sulfide health impacts
- Emissions results used in design of odor control treatment systems

*Exploration for tunnel alignment on Thames River near Palace of Westminster*




*Thames Tunnel odor emissions model results*

## Project Description

Thames Water Utilities Limited selected CH2M as program manager for the Thames Tideway Tunnel Program, one of the biggest and most historic public works programs in London's history. The project involves the construction of London's deepest ever tunnel – the Thames Tunnel – up to 80m below ground level, and spanning over 40 km – will run under the River Thames from Hammersmith in West London, head north to Abbey Mills in Stratford, and the east to Beckton, in East London. The tunnel will capture and transfer combined sewer discharges for treatment, which would otherwise enter the River Thames and its tributaries during heavy rainfall. A major concern is the potential for odorous emissions from the drop shafts and the Thames Tunnel from both a nuisance and health perspective.

**Estimating Sulfide Generation/Emissions**

CH2M utilized its drop shaft computer model to estimate sulfide stripping in 23 drop shafts that discharge into rider tunnels and the Thames Tunnel. Boundary conditions were selected to appropriately model the dynamic conditions of wet weather flow. Model results were used to quantify the mass of hydrogen sulfide emitted from the drop shaft and conveyed to the rider tunnels and the Thames Tunnel headspace.

CH2M's INTERCEPTOR model was used to estimate sulfide generation and stripping in the rider tunnels and Thames Tunnel. Boundary conditions were selected to appropriately model the dynamic conditions of wet weather flow. A computer analysis of pressure and temperature gradients was performed to estimate air flow in the tunnel and the potential for air release at the drop shafts.

Emission estimates were prepared based on the results of the drop shaft model and INTERCEPTOR models. Dispersion modeling was performed to quantify off-site odor and health impacts. Emission results were used in the design of odor control treatment systems.

## EXHIBIT 4: ODOR RELATED PROJECTS FOR WASTEWATER UTILITIES

| Client Name | Country | State/ Province | Master Plan or Conceptual Planning | Odor Dispersion Modeling | Odor Sampling and Monitoring | Treatment/ Mitigation | Community Outreach and Communications | Design | Commissioning and Staff Training | Liquid Phase Treatment | Gas Phase Treatment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Abu Dhabi | UAE | UAE | ✓ | | ✓ | ✓ | | ✓ | | | ✓ |
| ACTEW | AUS | SYD | | ✓ | | | | | | | |
| ACTEW-AGL | AUS | ACT | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ |
| Alexandria Sanitation Authority | USA | Virginia | | ✓ | ✓ | | | | | | |
| Allegheny County Sanitation Authority | USA | Pennsylvania | ✓ | | ✓ | ✓ | | ✓ | ✓ | | ✓ |
| Australian Research Council | AUS | NSW | | | ✓ | | | | | | |
| Australian Research Council (ARC) Sewer Odour and Corrosion Research | AUS | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| BHPB | AUS | SYD | | ✓ | ✓ | | | | | | |
| Cairns Regional Council | AUS | QLD | | | | ✓ | | ✓ | | ✓ | ✓ |
| Calliope Shire Council | AUS | BRI | | | ✓ | ✓ | | | | | |
| Caltex Kurnell | AUS | SYD | | | ✓ | ✓ | | | | | |
| Charlotte-Meckleburg Utilities | USA | North Carolina | | | ✓ | ✓ | | | | | |
| City of Beloit | USA | Wisconsin | ✓ | | | ✓ | | ✓ | ✓ | ✓ | ✓ |
| City of Calgary | Canada | Alberta | | ✓ | ✓ | ✓ | ✓ | | | | |
| City of Cameron | USA | Missouri | | ✓ | ✓ | | ✓ | | | | |
| City of Clovis | USA | California | | ✓ | | ✓ | | | | | |
| City of Ft. Wayne | USA | Indiana | ✓ | | ✓ | ✓ | | ✓ | ✓ | | ✓ |
| City of Gastonia | USA | North Carolina | | | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| City of Kitchener | Canada | Ontario | | | ✓ | ✓ | | ✓ | | | ✓ |
| City of Las Vegas | USA | Nevada | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| City of Loveland | USA | Colorado | | ✓ | ✓ | | | | | | |
| City of Omaha | USA | Nebraska | | ✓ | ✓ | ✓ | | ✓ | | | |
| City of Ottawa | Canada | Ontario | ✓ | | ✓ | ✓ | | ✓ | ✓ | | ✓ |
| City of Portland | USA | Oregon | | ✓ | ✓ | | | | | | |
| City of Spokane | USA | Washington | ✓ | ✓ | ✓ | ✓ | | | | | |
| City of Stockton | USA | California | | | | | | ✓ | | ✓ | |
| City of Surrey | Canada | British Columbia | | | ✓ | | | | | | |
| City of Toronto | Canada | Ontario | | ✓ | | ✓ | | ✓ | ✓ | | ✓ |
| Clark County Water Reclamation District | USA | Nevada | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| Cleaner Seas Alliance | AUS | BRI | | | | | | | | | |
| Delfin Lend Lease | AUS | SYD | | ✓ | | | | | | | |
| Delta Diablo Sanitation District | USA | California | | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| District of Columbia Water and Sewer Authority | USA | Washington, D.C. | | ✓ | ✓ | | | | | | |
| Dublin San Ramon Services District | USA | California | | ✓ | ✓ | | | | | | |
| East Bay Municipal Utility District | USA | California | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Eastern Municipal Water District | USA | California | ✓ | ✓ | | | | | | | |
| Eurobodalla Shire Council | AUS | SYD | | ✓ | | | | | | | |
| Gippsland Water | AUS | MEL | ✓ | ✓ | | ✓ | | | | | ✓ |
| Gippsland Water | AUS | Victoria | | | | | | ✓ | ✓ | ✓ | ✓ |
| Grand Chute Menasha West Sewerage District | USA | Wisconsin | ✓ | ✓ | ✓ | ✓ | | | | | ✓ |
| Greater New Haven Water Pollution Control Authority | USA | Connecticut | | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ |
| Green Bay Metropolitan Sewerage District | USA | Wisconsin | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Hampton Roads Sanitation District | USA | Virginia | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ |
| Hastings Regional Council | AUS | NSW | | ✓ | | | | | | | |
| Hunter Water | AUS | NSW | | ✓ | | | | | | | |
| Hunter Water | AUS | SYD | | ✓ | ✓ | | | | | | |
| Hunter Water Corporation | AUS | SYD | | ✓ | | | | | | | |
| Jondaryn Council | AUS | BRI | | ✓ | | | | | | | |
| King County Wastewater Treatment Division | USA | Washington | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Little Blue Valley Sewer District | USA | Missouri | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ |
| Loudoun Water | USA | Virginia | ✓ | ✓ | | | | | | | |
| Louisville and Jefferson County Metropolitan Sewer District | USA | Kentucky | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ |
| MCES (Minneapolis) | USA | Minnesota | | | ✓ | ✓ | | ✓ | ✓ | | ✓ |
| Melbourne Water | AUS | MEL | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Metro Vancouver | Canada | British Columbia | ✓ | | ✓ | | | | | | |
| Metropolitan Sewer District of Greater Cincinnati | USA | Cincinnati | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ |
| Milwaukee Metropolitan Sewerage District | USA | Wisconsin | | | | | ✓ | ✓ | ✓ | | ✓ |
| Murray Goulburn Coop | AUS | VIC | | ✓ | ✓ | | | | | | |
| Narragansett Bay Commission | USA | Rhode Island | | ✓ | ✓ | | | | | | |
| Northeast Ohio Regional Sewer District | USA | Ohio | ✓ | ✓ | ✓ | ✓ | | | | | |
| Orange County Sanitation District | USA | California | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Region of Halton | Canada | Ontario | ✓ | ✓ | ✓ | | ✓ | | | | |
| Region of York | Canada | Ontario | | | ✓ | ✓ | | | | | |
| SA WATER | AUS | SA | | | ✓ | ✓ | | | | | |
| Sacramento Regional County Sanitation District | USA | California | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| Sanitation District No. 1 of Northern Kentucky | USA | Kentucky | | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| San Jose/Santa Clara Regional Wastewater | USA | California | ✓ | ✓ | | | | | | | |
| Sausalito-Maron City Sanitary District | USA | California | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| Singapore Public Utilities Board | Singapore | Changi | | ✓ | ✓ | ✓ | | | | | |
| SKM/Melbourne Water | AUS | VIC | | ✓ | ✓ | ✓ | | | | | |
| South East Water | AUS | MEL | | ✓ | | | | ✓ | | | |
| South East Water | AUS | MEL | | | ✓ | ✓ | | | | | ✓ |
| South East Water | AUS | MEL | ✓ | ✓ | | ✓ | | | | ✓ | |
| South East Water | AUS | MEL | | | ✓ | ✓ | | | | | |
| Southern California Alliance of POTW | USA | California | | | ✓ | | | | | | |
| Sunshine Coast Regional Council | AUS | BRI | | ✓ | ✓ | | | | | | |
| Sunshine Coast Regional Council | AUS | QLD | | ✓ | ✓ | | | | | | |
| Sydney Water | AUS | NSW | | ✓ | ✓ | | | | | | |
| Sydney Water | AUS | SYD | | ✓ | ✓ | | | | | | |
| Sydney Water (North Head) | AUS | NSW | | ✓ | ✓ | | | | | | |
| Sydney Water Corp | AUS | SYD | | | ✓ | | | | | | |
| Thames Water Utilities Limited | UK | London | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Town of Yountville | USA | California | | ✓ | ✓ | | | | | | |

# Section 6: Schedule

Exhibit 5 is the proposed project schedule.

**EXHIBIT 5**
**Project Schedule**

| | |
|---|---|
| Kick-off Meeting | March 9, 2016 |
| Sampling | Week of March 28, 2016 |
| Draft Report Submitted | April 25, 2016 |
| Final Alternatives Meeting | April 28, 2016 |
| Final Report Submitted | May 13, 2016 |

Note:

1) The above schedule is contingent upon Notice to Proceed being issued by March 7, 2016.

2) The dates of the Draft Report Submitted, Final Alternatives Meeting, and Final Report submitted are contingent on completing sampling the week of March 28, 2016.

# Section 7: Commercial Terms

## Fee Proposal

CH2M proposes to perform the identified project scope of work to provide the Engineering Services for the East Moreland Boulevard Odor Study on a time and materials not to exceed basis for $24,250. The cost for the optional tasks, if the City wishes to pursue, will be provided at that time. The cost will be contingent on the task scope which depends on findings and decisions from the previous tasks.

### Expenses

Direct Expenses are defined to include those necessary costs and charges incurred for the project with no markup including, but not limited to CH2M's current standard rate charges for direct use of CH2M field equipment, printing and reproduction services, and sampling analytical equipment.

## Terms and Conditions

The same terms and conditions of the Village of Wales Odor Evaluation Review performed by CH2M for the City in 2015 will apply.