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INDEPENDENT STATE AUDITOR'S REPORT ON REVIEW OF CORROSION ACTIVITY AT THE MASSACHUSETTS WATER RESOURCES AUTHORITY'S SEWAGE TREATMENT FACILITIES

NOVEMBER 1990 THROUGH DECEMBER 1999

OFFICIAL AUDIT REPORT

JULY 20, 2000

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The Massachusetts Water Resources Authority (MWRA) was established by Chapter 372 of the Acts of 1984 to assume the duties and responsibilities of the Metropolitan District Commission's Water and Sewer Division. These responsibilities include providing water and sewage services to approximately 2.6 million people in 61 communities within the Commonwealth. The MWRA also maintains 400 miles of water pipes, aqueducts, and tunnels, and 240 miles of sewers. The MWRA's service area covers approximately 410 square miles and includes approximately 850,000 homes and 6,000 businesses. Collectively, these homes and businesses produce approximately 480 million gallons of sewage each day.

On September 5, 1985, the Federal District Court ruled that wastewater discharged into Boston Harbor was in violation of the 1972 Federal Clean Water Act requirements and ordered the MWRA to develop and implement a program to provide treatment of its wastewater discharges as required by that law. In accordance with a court-ordered schedule, the MWRA undertook a program of improvements to the wastewater collection and treatment facilities serving the metropolitan Boston area. The MWRA currently estimates that the total cost of the Boston Harbor Project (BHP) will amount to $3.5 billion. Upon completion, the Deer Island Treatment Plant (DITP) will be the nation's second-largest treatment plant and will bring the region into compliance with federal environmental law. The MWRA currently estimates that the project will be completed in the late fall of 2000.

This interim audit report of the MWRA included a review of the additional costs for repairs and replacements due to excessive concentrations of hydrogen sulfide (H_2S) and related high levels of sulfuric acid (H_2SO_4) over those concentrations anticipated in the design specifications for the BHP. The objectives of our audit were to determine whether these activities complied with applicable laws and regulations and whether they resulted in an effective, economical, and efficient utilization of resources. To date, our 15 interim reports have identified over $157 million in questionable, unnecessary, or excessive costs.

Additional Project Costs of Approximately $37.7 Million Necessary to Correct Odor Control and Corrosion Problems at The Deer Island Treatment Plant and Nut Island Headworks: Shortly after bringing the newly constructed DITP into operation in 1995, the MWRA experienced odor control problems and concrete and equipment corrosion due to the presence of high levels of H_2S and H_2SO_4. Further studies indicated that a similar situation would occur at the Nut Island Headworks (NIH) facility in Quincy, Massachusetts once the NIH commenced operations. Both facilities were designed to handle H_2S concentrations to a maximum level of 25 parts per million (ppm), whereas actual levels packed as high as 250 ppm, resulting in the odor and corrosion problems.

On January 27, 2000, the MWRA instituted legal action for damages against the lead design engineer to recover excess project costs due to design deficiencies related to the Boston Harbor Project. The cost related to the H_2S problem outlined in the suit is $37.7 million.

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INTRODUCTION

Background

The Massachusetts Water Resources Authority (MWRA) was established by Chapter 372 of the Acts of 1984 to assume the duties and responsibilities of the Metropolitan District Commission's Water and Sewer Division. These responsibilities include providing water and sewer services to approximately 2.6 million people in 61 communities within the Commonwealth. The MWRA also maintains 400 miles of water pipes, aqueducts, and tunnels, and 240 miles of sewers. The MWRA's service area covers approximately 410 square miles and includes approximately 850,000 homes and 6,000 businesses. Collectively, these homes and businesses produce approximately 480 million gallons of sewage each day.

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The MWRA established an in-house Program Management Division (PMD) to manage the design and construction of the new treatment facilities. Two consultant teams assist the PMD: the Lead Design Engineer (LDE) and the Construction Manager (CM). The LDE contract was awarded to Metcalf & Eddy (M&E) in August 1988 and is currently valued at $87.5 million. In June 1990, the MWRA approved ICF Kaiser Engineers, Inc., (Kaiser) as the CM. The current value of the CM contract is $309.4 million. M&E was subsequently awarded a contract as Project Design Engineer for Secondary Treatment Facilities, and that contract is currently valued at $17 million.

The LDE's responsibilities include developing design criteria and standards and preparing the conceptual design and specifications for the Deer Island Treatment Facilities and the Nut Island Headworks. The LDE is also responsible for managing the work of each of the project design engineers, who prepare the detailed designs for specific project segments based upon the conceptual design prepared by the LDE.

Audit Scope, Objectives, and Methodology

Our audit of the MWRA, which is ongoing, included a review of the costs to repair and replace recently installed equipment, as well as the costs associated with the application of additional protective coatings to metal and concrete surfaces due to excessive concentrations of hydrogen sulfide (H_2S) and sulfuric acid (H_2SO_4). The objectives of our audit were to determine whether these activities complied with applicable laws and regulations, and whether they resulted in an effective, economical, and efficient utilization of resources.

To accomplish our objectives, we reviewed applicable laws, regulations, and internal policies and procedures, and interviewed MWRA and Kaiser officials. In addition, we conducted site visits to Deer Island and Nut Island and physically inspected the affected areas, reviewed contracts, change orders, amendments, correspondence files, and other pertinent documentation to assess the effectiveness of the MWRA's internal operating controls and the appropriateness of its monitoring activities.

Our audit, which covered the period November 1990 through December 1999, was conducted in accordance with applicable generally accepted government auditing standards and included such audit tests and procedures as we considered necessary under the circumstances.

AUDIT RESULTS

Additional Project Costs of Approximately $37.7 Million Necessary to Correct Odor Control and Corrosion Problems at The Deer Island Treatment Plant and Nut Island Headworks

Shortly after bringing the newly constructed Deer Island Treatment Plant (DITP) into operation in 1995, the Massachusetts Water Resources Authority (MWRA) experienced odor control problems and concrete and equipment corrosion due to the presence of high levels of hydrogen sulfide (H_2S) and sulfuric acid (H_2SO_4). Further studies indicated that a similar situation would occur at the Nut Island Headworks (NIH) facility in Quincy, Massachusetts. Both facilities were designed to handle H_2S concentrations to a maximum level of 25 parts per million (ppm), whereas actual levels experienced were significantly higher, resulting in the odor and corrosion problems.

Sulfides are a natural by-product of wastewater. The most prevalent form of sulfide in wastewater is hydrogen sulfide (H_2S). When wastewater containing levels of dissolved sulfides is released to areas of normal atmospheric pressure, the dissolved sulfides are released from the liquid wastewater and form H_2S gas odors, which, if combined with water, reacts to form sulfuric acid corrosion. Sulfuric acid (H_2SO_4), can act directly on metals including iron, silver, aluminum, and copper, and is also corrosive to cement, mortar, concrete, and ferrous metals.

H_2S gas is very hazardous to humans in higher concentrations and can cause a number of health-related problems or even death. In concentrations as low as 10 ppm, it can cause nausea, headaches, and conjunctivitis. Above 100 ppm, it can cause serious breathing problems (apnea), loss of the sense of smell, and burning of the eyes and respiratory tract. Above 300 ppm, death can occur within a few minutes. Exposure to excessive levels of H_2S has been reported to be a leading cause of death for people working in sewers and associated structures, according to the American Society of Civil Engineers.

After DITP began operations in January 1995, the MWRA undertook an 18-month monitoring program designed to provide air emissions data from the facility and to assess the performance of the air pollution control systems. This monitoring program commenced in April 1995 and concluded in late

October 1996. During that period, air emissions were measured and characterized at the east, west and residuals management Air Emissions Control (AEC) facilities. The AEC facilities consist of chemical scrubbers for H_2S removal and carbon adsorption units for volatile organic compound removal. The H_2S daily inflow concentrations steadily increased from 35 ppm in April 1995, to 80 ppm in July, to over 180 ppm in September, with peaks as high as 250 ppm.

The Secondary Treatment Facilities Plan, prepared by Camp, Dresser & McKee in 1988, initially estimated H_2S at an average concentration of 15 ppm, reportedly based on the experience of other wastewater facilities. Metcalf and Eddy (M&E), as project design engineer for both CP-103 (North System Headworks) and CP-105 (Primary Clarifier Batteries A and B), used a peak value of 25 ppm, reportedly based on the experience of large wastewater treatment plants.

Although the odor control equipment was designed for H_2S concentrations of 25 ppm, as time passed and concentrations steadily increased, problems began to develop. Some of the components within the odor control system began to show corrosion effects from the high H_2S concentrations. An inspection of the clarifiers in Batteries A and B showed concrete coating deterioration in the launder troughs[1] and influent and effluent channels in Batteries A and B. Moreover, in a December 13, 1995 staff summary report to the MWRA Board of Directors, it was noted that higher-than-expected H_2S concentrations were experienced regularly throughout the summer and fall of 1995. The H_2S levels created odor problems, concrete coating failures, and limited corrosion damage in the treatment plant. High levels of H_2S were identified as a problem particularly in the areas of the grit facility and primary clarifier decks and galleries. It was also noted that mild to moderate corrosion of copper piping and electrical components was experienced in the galleries and electrical buildings, as well as surface corrosion of concrete above the influent channels and primary clarifiers. In addition, the air stack emissions monitoring program

[1] Launder troughs are open pipes that direct treated effluent water from clarifiers to the effluent tunnel.

documented that, during certain periods, the facility exceeded the anticipated permit levels at the exit of the stack.

In response, DITP staff increased the output of the hydroxide pumps[2] from six to 20 gallons per hour to try to control H_2S levels. In addition, staff implemented both short- and long-term approaches to investigating and resolving this issue.

The short-term approach included upgrades to the existing odor control facilities at the North System Headworks, including increasing the size of the scrubber's chemical feed pumps, covering the grit classifiers,[3] and rebalancing the grit chambers' odor control air flow system. In addition, an interim planned chemical pretreatment line was put into place to protect the facilities from further damage from cyclically high H_2S levels.

The long-term approach was to form a task force that included participation from MWRA, M&E, and ICF Kaiser Engineers, Inc. This task force was to evaluate and recommend modifications to the odor control equipment, investigate corrosion of electrical and copper components, and investigate the mechanics of sulfide generation in the Deer Island wastewater collection and treatment facilities by conducting more detailed sampling during the summer of 1996.

In an April 10, 1996 report to the MWRA Board of Directors, the task force recommended the following three-part strategy to address the H_2S issue:

(1) <u>Pretreatment Program</u>: Conduct a pretreatment study including a full-scale trial of selected chemical compounds for the control of H_2S. Of the four chemicals tested, hydrogen peroxide was the recommended pretreatment for both north and south system flows due to its effectiveness, ease of application and control, cost, and very short chemical reaction time requirement.

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[2] Hydroxide pumps are used to pump sodium hydroxide into the system.

[3] Chambers that mechanically separate grits by weight (coarse, fine, and very fine) from wastewater flows.

(2) Odor Control System Improvements: Design and install capacity improvements to the existing odor control system to handle H_2S concentrations of up to 250 ppm; or 10 times the original design parameters. Modify and upgrade equipment under new and existing construction contracts.

(3) Coating/Protection Program: Apply Linabond PVC liner system (for concrete) and 100% high solids epoxy coatings (for metals and areas inappropriate for Linabond application) to approximately 485,000 square feet. Phase I involved coating applications to high priority areas that would not be readily accessible once the Inter-Island Tunnel and Battery B of secondary treatment were placed into service, along with areas that had not been put into service and were clean and ready to be coated. Phase II consisted of upgrading coatings in the clarifier batteries that were already in operation.

Montgomery Watson (M/W), the Project Design Engineer for the NIH in Quincy, was instructed to conduct an investigation of H_2S levels at the NIH to determine whether the facilities and equipment would experience similar odor control and deterioration problems as those experienced at Deer Island. M/W determined that the Nut Island facilities would experience similar odor control and deterioration problems once the NIH commenced operations.

On January 27, 2000, the MWRA instituted legal action for damages against M&E to recover excess project costs due to design deficiencies related to the Boston Harbor Project. The cost related to the H_2S problem outlined in the suit is $37.7 million.

In addition to the H_2S problems encountered at Deer and Nut Islands, significant corrosion and odor problems have been observed in the Framingham Extension/Relief Sewers, the Wellesley Extension Sewer, and the West Roxbury Tunnel. Moreover, there have been several instances of sewer collapses due to excessive H_2S levels in these sections of the MWRA's system. An Odor and Corrosion Control Study finalized in June 1999 identified and evaluated conditions in the Framingham Extension/Relief Sewers with respect to odors and corrosion. The study identified industries in Ashland, Framingham, and

Natick whose discharges contain high concentrations of sulfates and Biochemical Oxygen Demand,[4] and the design of the municipal sewers discharging into these sections as the primary causes of the high corrosion rates and pervasive odor problems. The MWRA estimates that approximately $40 million of additional funds will be required to mitigate the situation in the MWRA system.

The MWRA is currently constructing new sewer relief facilities in the Braintree-Weymouth area. The MWRA Braintree-Weymouth Relief Facilities Project will expand and improve the Braintree-Weymouth System and the MWRA's network of sewer pump stations, interceptors, and siphons that serve Braintree, Hingham, Holbrook, Randolph, Weymouth, and parts of Quincy. The project will transform the way that wastewater generated by these six South Shore communities is conveyed to sewer treatment and processing facilities. The current estimated costs to complete design and construction of the facilities is $170 million.

Recommendation: Since the MWRA initiated legal action relative to the DITP and NIH during the course of our review, we will monitor this legal action. However, due to the costly nature of rectifying this problem, we recommend that the MWRA take the necessary actions to ensure that other ongoing and future sewerage projects are designed adequately to minimize similar H_2S complications.

Auditee's Response: The MWRA's Executive Director informed us that:

> The MWRA fully endorses this recommendation. As a result of the H_2S problems encountered on Deer Island, subsequent Boston Harbor Project construction packages have assumed higher H_2S levels. The replacement of the Shirley Gut Siphon (a portion of the North Metropolitan Trunk Sewer), which was performed as part of Western Shoreline Protection (CP-048) involved the installation of precast 108" pipe, which was lined with T-Lock. T-Lock is a PVC liner (similar to Linabond) but is installed prior to pouring the concrete and serves the same function of protecting concrete from the corrosive effects of high H_2S levels. The North Main Pump Station surge containment structure, which is now being completed under the Ancillary Design Modifications III contract (CP-211) is also completely lined with T-Lock.
>
> MWRA is also incorporating appropriate design elements to address elevated H_2S levels in a number of ongoing projects in the MWRA's transport system. These include the Framingham Extension Relief Sewer, Wellesley Extension Sewer Replacement and Union Park Detention

[4] A measure of the amount of oxygen-consuming organic matter in wastewater.

Treatment facility. In those portions of the MWRA system where high H_2S levels are a potential problem, the MWRA is implementing the necessary design features, relying primarily on upgraded coatings or linings and, in more limited instances, on chemical pretreatment. We expect to continue to implement this strategy in the future.

Auditor's Reply: We are encouraged that the MWRA is taking steps to prevent future odor control and corrosion problems caused by excessive H_2S levels. Responding to the need to design future projects that elevated H_2S levels, applying protective coatings, and using chemical pretreatment are positive steps toward preventing a recurrence of the costly corrective measures the MWRA has recently been forced to implement to repair damages to relatively new facilities and equipment.

We will continue to monitor the MWRA's progress in implementing the proper preventative steps to correct the H_2S problem in existing facilities as well as future projects.