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CITY OF DENTON

Manual for the Control, Operation and Maintenance of Zebra Mussels

September 2016

Contract No. 5643

ARCADIS

TEXAS BOARD OF PROFESSIONAL ENGINEERS FIRM REGISTRATION NUMBER: F-533

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CITY OF DENTON

EXECUTIVE SUMMARY

Manual for the Control, Operation and Maintenance of Zebra Mussels

ARCADIS Design & Consultancy for natural and built assets

Contents

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Purpose and Background

The City of Denton (COD) has two raw water systems supplying the Lake Lewisville Water Treatment Plant (LLWTP) and the Ray Roberts Water Treatment Plant (RRWTP) raw water systems that are at risk for zebra mussel fouling. Zebra mussels (*Dreissena polymorpha*) are an invasive species that can cause fouling of water handling facilities (e.g., intake, racks, screens, pipelines, pumps, dam releases, gates, etc.) that are located in or transmit water from potentially infested water sources as well as contribute to changes in source water quality that can affect operations. This fouling is caused by the accumulation of adult mussels that attach to the surface of structures and to each other. The Asian clam is another invasive species that was observed during this project that can collect and grow in water facilities. With continuous flows to provide a constant food and oxygen source, intake structures, piping and other raw water appurtenances are an ideal habitat for mussel proliferation. Once an infestation has occurred, zebra mussels can build a layer up to six inches thick, severely constricting flows and clogging pumps, screens and filters. In addition, zebra mussel infestations may adversely affect the ecosystem and water quality.

The RRWTP raw water system has already been impacted by zebra mussels. In early 2014, the COD discovered that the 60” raw water pipeline downstream of Ray Roberts Lake was 70% clogged with mussels at a low point. Although the COD LLWTP Intake is not currently infested, the Upper Trinity Regional Water District has observed a sustainably reproducing zebra mussel population at their intake near the Lake Lewisville Dam, a heavy settlement of mussels was observed in the Elm Fork arm of Lake Lewisville following the 2015 flooding, and zebra mussels have been observed downstream in the Elm Fork of the Trinity River. To prepare for the likely spread of mussels to the LLWTP raw water system and develop methods to ease future cleaning events in COD raw water systems, the COD commissioned the development of a Manual for the Control, Operation and Maintenance of Zebra Mussels (Manual).

Goal

The *overarching* goal of this Manual is to develop zebra mussel management approaches that balance the risk of future infestations with capital spending and potential unintended downstream consequences.

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Introduction

The management, operation and maintenance approaches recommended in the Manual consider the following:

- **Source water quality** including seasonal water quality changes and the variability of water quality at each structure
- **Physical characteristics** of each structure to assess the susceptibility to fouling and the potential impact of fouling on individual components, accessibility, level of security, proximity to the public, the floodplain elevation and the potential to reuse existing equipment and facilities
- **Hydraulics** including pipeline velocities, capacities and detention times, potential hydraulic capacity reductions due to an infestation and the potential to alternate pipeline or source water use to optimize zebra mussel management
- **Operational impacts** including consideration of required labor hours, current daily operational activities and annual operations and maintenance costs
- **Capital Costs and O&M Costs** were evaluated and compared to understand the true costs of various options and alternatives identified
- **Public perception** including the selection of publically accepted technologies and avoidance of adverse environmental and/or ecological impacts
- **Operation of downstream water treatment plants** including water quality goals, seasonal trends in customer demands, seasonal operating practices, planned process changes, unintended consequences, and the potential for management approaches to provide pre-treatment
- **Zebra mussel biology and ecology** including local growth and progression rates, water conditions favorable to zebra mussel settlement, and equipment and materials especially susceptible to fouling
- **Planned future improvements** to raw water handling facilities including opportunities for optimization of future projects for zebra mussel management
- **Current and potential future regulations** at the local, state and national level
- **Risk reduction** strategies that balance capital spending with minimizing future risks (e.g., capacity reductions due to fouling) such as selection of proven technologies and monitoring.

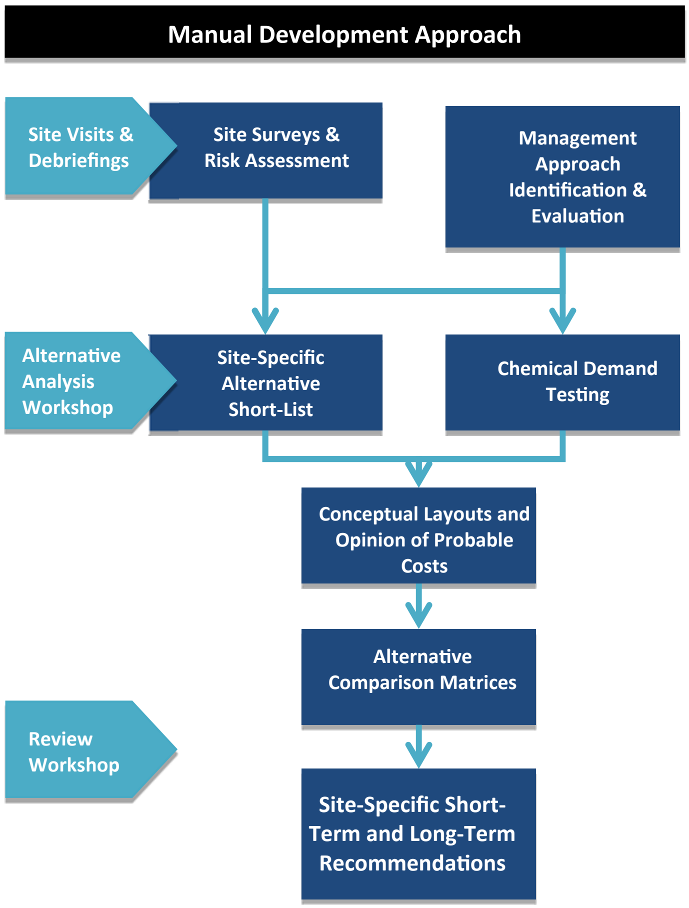
Forming the Right Team

To address the multi-dimensional O&M considerations, a multi-disciplinary team including an academic professor and a retired USACE expert brought a unique perspective to this evaluation – an understanding of the synergy of zebra mussel biology, potential unintended consequences, institutional knowledge of management approaches, and the engineering aspects of the system to be protected. The team also included a technical advisor with years of experience evaluating, designing and managing zebra mussels in the Great Lakes region. Additionally, numerous COD staff were involved throughout this project by participating in site visits and workshops and reviewing the Manual.

Manual Development Approach

Site surveys were conducted for both of the COD's two raw water systems. Site surveys included both desktop design document review and field visits, during which the team gained a greater understanding of what components are at most risk for fouling. Through site surveys, the team gained an understanding of how the systems are operated seasonally to meet customer demands and water quality goals, unique water quality and operational challenges of each intake, and what the potential impact of a mussel infestation at either intake would be on the system as a whole. A **risk assessment** was conducted to rank the overall relative risk to the raw water facilities and to provide information/notification of potential impacts. Lastly, a list of **potential future improvements**, including a summary of benefits and risks to future zebra mussel management, was developed .

In parallel, a review of zebra mussel **management approaches** was conducted, including both innovative and conventional technologies. Evaluations of alternatives were conducted for each site on a component-by-component basis while maintaining a system-wide approach that considered operational impacts to the downstream treatment plants and distributions system. During the **Alternatives Analysis Workshop**, COD staff ranked evaluation criteria and selected alternatives for further evaluation. **Chemical demand testing** was conducted to increase the accuracy of cost estimates and better understand the feasibility of implementation of the selected chemicals in the COD raw water systems.

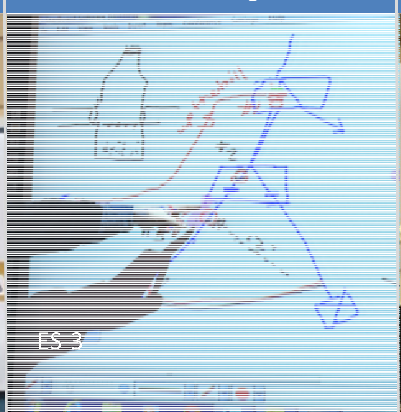


Conceptual layouts and costs were then developed for the top two preventative alternatives in addition to a reactive approach (i.e., physical removal and disposal), and **comparison matrices** were developed to compare the top alternatives. **Recommendations** for multi-barrier management approaches within both raw water systems were developed including the following:

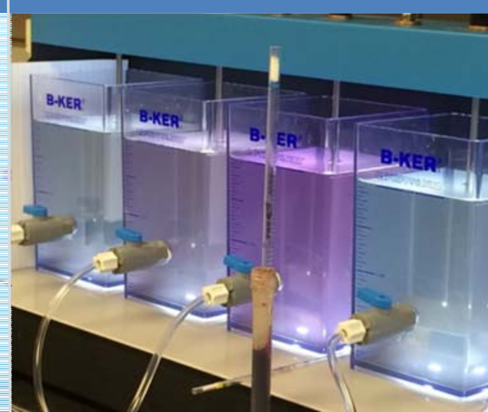
- Short and long-term capital improvements,
- Monitoring and inspection guidelines,
- Operations and maintenance guidelines, and
- Risk management approaches.

Alternatives Analysis Workshop

Debriefings



Chemical Demand Testing



Risk Considerations

Key **risk review** considerations included:

- **Likelihood of infestation** - based on current water quality data (temperature, pH, Ca and DO) and location of current zebra mussel infestations
- **Potential impact to the COD** - considered both the susceptibility to fouling and risk to COD operations in the case of fouling

Risk Analysis Results

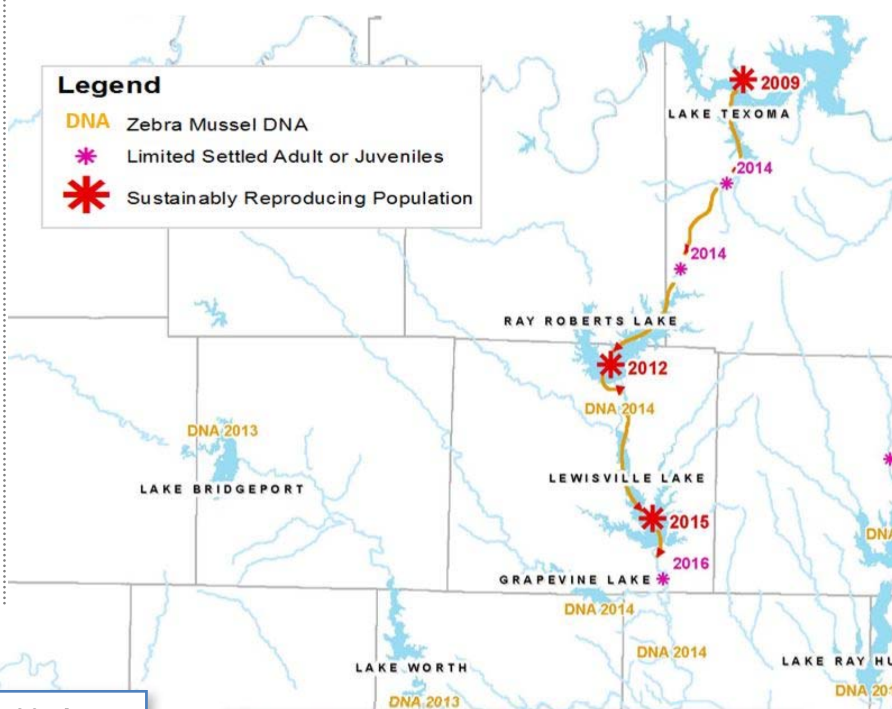
Site	Likelihood of Infestation	Potential Impact to COD	Overall Risk
LLWTP Intake	HIGH	HIGH	HIGH
RRWTP Intake	INFESTED	HIGH	EXTREMELY HIGH

Components with the Greatest Risk

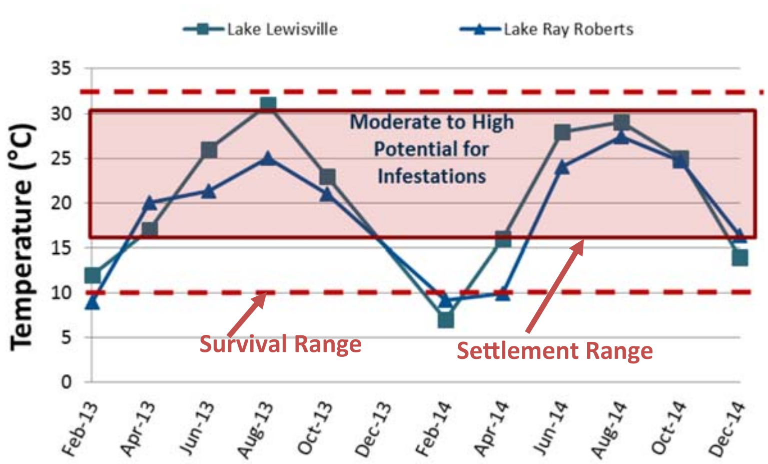
The following components were classified as the greatest risk for infestation:

Site	Component	Primary Reason
RRWTP Intake	Low point in 60-inch line	Shell accumulation
	Lagoon recycle line	Small diameter; potential headloss
	Fish strainer	Small openings; potential headloss
	Valves	Very susceptible to fouling
LLWTP Intake	Upper intake	No redundancy; only 36" diameter; favorable environment within the lake for settlement
	Bar screens	Small openings; potential headloss
	Solution water line for $KMnO_4$	Small diameter (1.5-inches); potential headloss
	Valves	Very susceptible to fouling
	Wet well	Shell accumulation; pump clogging

The team classified both of COD's raw water systems as high potential impact, meaning they are susceptible to fouling due to the presence of many hard surfaces with small openings (i.e. trash racks, gates, screens, pipelines) and would pose a significant risk to COD operations if flow was constricted. Both of COD's source waters were also classified as having a high likelihood of infestation due to water quality generally conducive to settlement. Thus, the LLWTP Intake was classified as high overall risk and the RRWTP Intake was classified as extremely high overall risk due to the prior infestation.

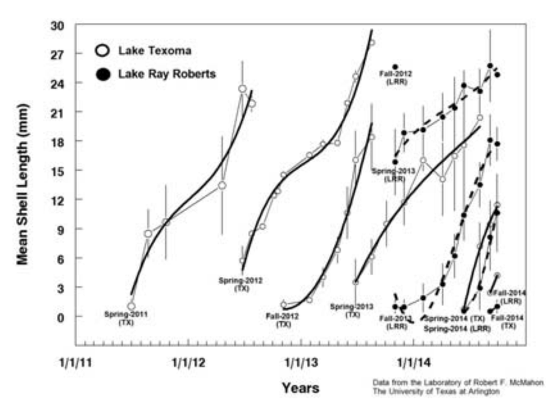


Temperature in COD Source Waters from 2013-2014



March – July and August–December are the most likely seasons, locally, for zebra mussel propagation.

Based on ongoing research conducted by project team member Dr. Bob McMahon, zebra mussel populations in North Texas exhibit more rapid growth, earlier maturity and shorter life spans compared to those in the Great Lakes region.



See Manual Section 2 for more information.

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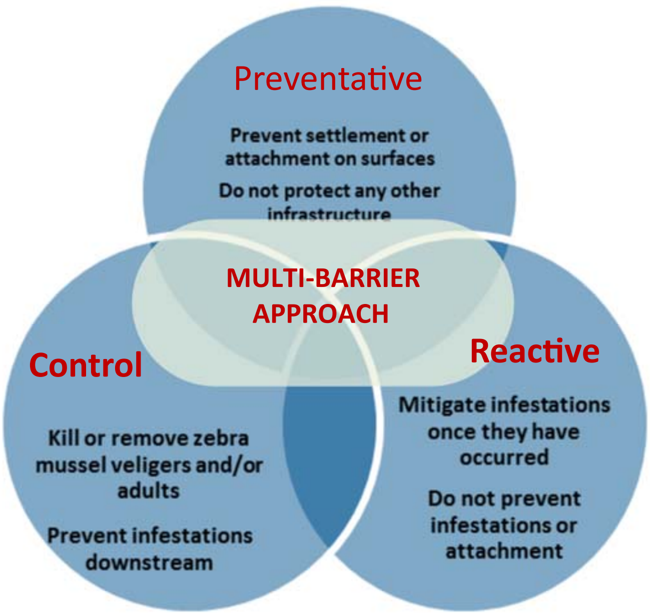
Management Approaches

A review was conducted to identify and evaluate zebra mussel management approaches, which would also be effective at controlling Asian clams. Mussel management approaches can be classified as preventative, control, reactive strategies, or a combination thereof. For example, a management approach might include an oxidant which can prevent settlement of veligers when low doses are maintained through the system (i.e. a preventative strategy) and kill adult mussels at a higher dose (i.e. a control strategy), as well as provisions for physical removal and disposal (i.e. a reactive strategy).



During the Alternatives Analysis Workshop, preventative, control and reactive strategies were discussed. Considerations related to feasibility of each potential management approach for COD, such as effectiveness and operational impacts, were derived from discussions with the technical advisors for this project, discussions with vendors, and a review of available literature, as well as the results of site visits and reviews to understand the design and operation of the COD facilities at risk for zebra mussel fouling. COD staff then scored each strategy based on the level of feasibility for implementation in the COD system.

Upon completion of chemical demand testing (conducted in April and June of 2015) and further evaluation of copper alternatives, COD staff further narrowed the short-list of chemical alternatives by selecting the top two most feasible chemicals for further evaluation. The short-list of alternatives included metal alloys, sodium permanganate, copper ion generation systems and physical removal using divers or by dewatering pipelines. An evaluation of disposal methods was also completed and landfilling was recommended.

Preventative Strategies	Control Strategies	Reactive Strategies
• Molluscicides (see below) • Metal Alloy Materials of Construction or Coatings • Foul-Release Coatings • Anti-Fouling Coatings • Maintenance of High Velocities	• Molluscicides (see below) • Strainers and Screens • Biological Treatment • Bank or Sand Filtration • UV Light • Acoustics • Electric Shock / High Voltage • Electric / Low Voltage Electric Magnetism • Copper Ion Generation Systems	• Physical Removal: ✓ Physical Scraping and Power Washing with Divers ✓ Pipe Pigging ✓ Physical Scraping and Power Washing of Dewatered Pipes • Oxygen Deprivation • Dewatering / Desiccation • Thermal Exposure
Molluscicides Evaluated as Preventative & Control Strategies		**Disposal**
Oxidants: • Chlorine (Hypochlorite and Chlorine gas) • Chloramines • Chlorine Dioxide • Sodium Permanganate • Potassium Permanganate • Hydrogen Peroxide • Ozone • Bromine • Peracetic Acid	**Non-Oxidants:** • Cationic Polymer • Quaternary & Polyquaternary Ammonium Compounds (e.g. Bulab 6002, Calgon, Veligon) • Aromatic Hydrocarbons (e.g. Mexel 432, Bulab 6009) • Endothall (e.g. EVAC) • Potassium Compounds (e.g. potash, potassium chloride) • Copper Sulfate	• Landfill • On-Site Burial • Leave-in-Place • Composting • Other Beneficial Uses

Key:
- Alternatives Selected for Further Evaluation
- Alternatives Selected for Detailed Comparison with Quantitative and Qualitative Evaluation Criteria

Evaluation Criteria:

- Life Cycle Cost (Capital &Operations & Maintenance)
- Effectiveness for Zebra Mussel Control
- Ease of Operation & Maintenance & Operational Flexibility
- Impact to Downstream Water Quality & Water Treatment Plant
- Impact to Environment / Ecology
- Implementability
- Health & Safety
- Status in the Industry / Record of Performance
- Public acceptability

See Manual Section 3.1 for more information.

Operations & Maintenance Guidelines

A multi-barrier zebra mussel management approach should include enhancing daily operational activities, improving designs to ease maintenance activities, optimizing chemical dosing strategies, and initiating programs to manage future risks.

See Manual Section 3.2 for more information.

Operational and Maintenance Enhancements

O&M enhancements that will optimize zebra mussel management are outlined below. These are not intended to be stand-alone approaches to managing zebra mussels. However, they are good practices that give operators a second level of management. For example, if a trash rack were being reconstructed in stainless steel to allow for application of a metal alloy coating, the reconstruction could include increased opening sizes to prevent clogging with mussels and a means for removing the trash racks for cleaning and coating replacement.

Operational Enhancements

- Operate all moving equipment frequently
- Clean trash racks and screens frequently
- Isolate and dewater components during shutdowns or maintenance to desiccate any attached mussels
- Clean silt away from gates and screens to allow operation and rakes to fully clean components
- Alternate pipeline use when parallel pipelines are available to allow for oxygen deprivation (may require flushing anoxic water)

Maintenance Enhancements

- Include redundant or oversized pipelines
- Replace stationary screens with travelling screens
- Design trash racks with 6 inch or greater openings
- Design removable bar screens and trash racks to ease cleaning
- Include pressure washing or pigging stations
- Allow for isolation of components (e.g. replace any leaky or non-functioning gates)

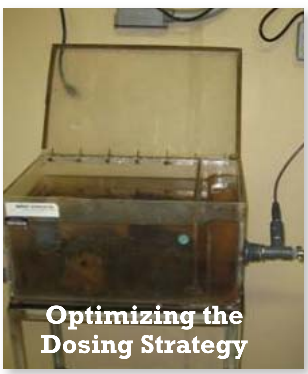
Operations & Maintenance Guidelines

Chemical Dosing Strategies

Dosing strategies to manage zebra mussels using chemicals in raw water systems include prevention (i.e. continuous or semi-continuous treatment) and control / reaction approaches (end-of-settlement season or periodic treatment). Determining which approach to use depends on specifics of the facility's raw water system, the level of management required and the management approach selected. Regardless of the dosing strategy, a **biological monitoring program** should be implemented as a feedback mechanism to allow for adjustments in timing and dosing of the chemical. Specific chemical dosing recommendations for the copper ion generation system and sodium permanganate are provided.

Copper Ion Generation Dosing Strategy

Copper ion generation technology produces positively charged copper ions which are toxic to mussels and aluminum hydroxide floc which coat pipe surfaces and immobilize veligers. The following dosing strategies should be implemented.



Optimizing the Dosing Strategy

- **Optimize the Dose –** The manufacturers recommend copper and aluminum doses of approximately 5 and 0.05 ppb (during settlement) and 2 and 0.02 ppb (during non-settlement seasons), respectively. Conductivity, temperature and total suspended solids data should be provided to the system PLC to improve accuracy of the calculated dose, and mussel settlement should be evaluated at the farthest point in the system requiring protection to optimize the dose.

- **Optimize the Dosing Frequency –** The manufacturer recommends a continuous dosing strategy; idling of the cells without flow is not recommended.

- **Monitor for Settlement –** Application of the higher chemical dose to prevent mussel settlement need only occur during months when mussel veliger larvae are present in the water column, which is approximately 4-5 months of the year compared to the 8 months of the year when the temperature is favorable for settlement.

Sodium Permanganate Dosing Strategy

The molluscicidal properties of sodium permanganate centers on its capacity to oxidize biological organic compounds in living cells, leading to loss of function and eventually death. The following dosing strategies should be implemented.

Optimizing Chemical Residual

- **Optimize the Dose –** A target permanganate residual of approximately 0.25 mg/L must be maintained throughout the entire system to effectively protect against zebra mussel fouling. Demand of the local water quality was considered in order to determine approximate chemical doses required for COD source waters. However, the required dose will change throughout the year as the water quality changes and should be monitored by measuring the chemical residual and monitoring for mussel settlement at the farthest point in the system requiring protection.

- **Optimize the Dosing Frequency –** It is recommended, based on previous project experience, that COD begin by applying a semi-continuous dosing strategy (e.g. 30 minutes on and 90 minutes off) to balance mitigation of zebra mussel veliger settlement with minimizing chemical costs. Continuous dosing may have added value if a consistent influent water quality to the plant or pre-oxidation is desired. The dosing strategy should be optimized after start-up by monitoring the chemical residual and using biological monitoring techniques.

- **Monitor for Settlement –** Application of the higher chemical dose to prevent mussel settlement need only occur during months when mussel veliger larvae are present in the water column, which is approximately 4-5 months of the year, compared to the 8 months of the year when the temperature is favorable for settlement.

Operations & Maintenance Guidelines

Risk Management Strategies

Both of the COD's raw water intakes are currently at risk for future zebra mussel infestations if preventative measures are not in place as the RRWTP has already experienced a zebra mussel infestation and a heavy settlement of zebra mussels was identified this year in the Elm Fork arm of Lake Lewisville. However, considering that the long-term density of zebra mussels in either of these source waters is unknown combined with the short zebra mussel life spans (approximately one year), fast growth rates and two settlement seasons per year observed in North Texas, it may be difficult to get a permanent chemical feed system designed, bid and constructed before another severe infestation in one of the COD raw water systems. Other utilities in the past have balanced capital investment with risk of reduced hydraulic capacity or public confidence by developing a number of risk management strategies.

1. **Implement a robust monitoring program –** Expanding upon the current COD raw water monitoring program is recommended to allow for more accurate estimates of how quickly and frequently management measures are required (i.e. to act as an early warning system in optimizing the selected management approach). Monitoring methods used by other utilities include: information gathering / collaboration, water quality monitoring (e.g. pH, temperature and calcium), veliger monitoring with plankton nets, substrate samplers, direct site inspections and control validation with sidestream bioboxes.

2. **Design permanent chemical systems but do not construct –** "Pre-designing" systems reduces the implementation time by six months to a year, which is critical given that zebra mussel infestations have been noted to occur in less than 1.5 years. The frequently cited downside of this approach is the risk that the designs will lose viability over time if changes are made to the facilities. However, pre-designing the systems in advance allows for thoughtful input by operations personnel in a non-emergency situation, while designing after an infestation will naturally prioritize response speed over operational input.

3. **Interim chemical systems –** Temporary chemical feed systems might include piping routed overland with temporary secondary containment from the back of the container on a truck or from rented tanks and could include temporary diffuser systems. Temporary systems can be installed quickly to provide some degree of protection during the design and construction of permanent facilities. Pre-designing these systems along-side permanent designs would allow for optimization of capital expenditures (i.e. identification of equipment which could be reused in permanent systems). An interim chemical system, as discussed here, would also provide the opportunity to implement demonstration testing (additional data on oxidant demand and the effectiveness of the chemical dosed in this source water).

4. **On-call contracts –** On-call contracts allow for rapid mobilization of contractor forces and can be bid ahead of a zebra mussel infestation on an annual or multi-year basis. On-call contracts can be prepared separately, or in combination, for monitoring, inspection and cleaning services. On-call contracts should provide the detail necessary to allow lump sum bidding of the services listed above at a subset of or at all of the facilities and would put the winning contractor on standby to perform those services within a predetermined period of time after being notified of the need for the services.

Exhibit 3

LLWTP Overview

The LLWTP is the largest of the two COD water treatment plants. The plant was originally constructed in 1957 but has been upgraded several times in 1964, 1972 and 1988 to the current capacity of 30 MGD. Average flows are approximately 8.4 MGD while minimum flows are approximately 5 MGD. A major improvements project just finished construction in 2015 that included addition of ozone and biologically active filtration to the treatment plant.

The LLWTP Intake provides water from Lake Lewisville to the wet well through two 36" prestressed concrete cylinder pipe (PCCP) raw water lines with bar screens, also referred to as the lower and upper intakes, located at elevations of 480 ft and 505 ft, respectively. From the RWPS, which includes an existing potassium permanganate storage and feed system and four vertical enclosed-line pumps, water is pumped to the LLWTP through two parallel concrete raw water lines (one 27-inch and one 30-inch). The total distance from Lake Lewisville to the LLWTP is approximately 8.6 miles.

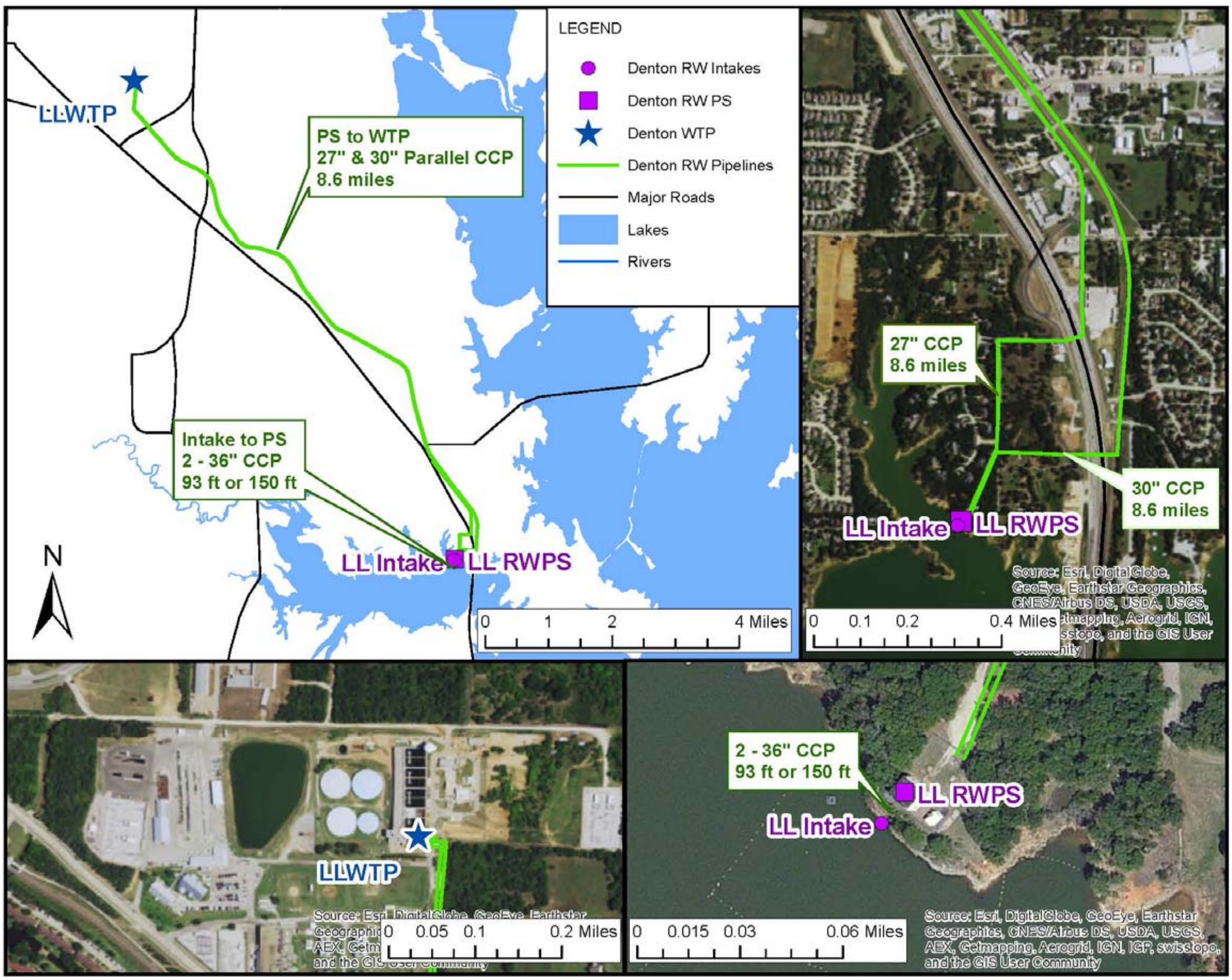
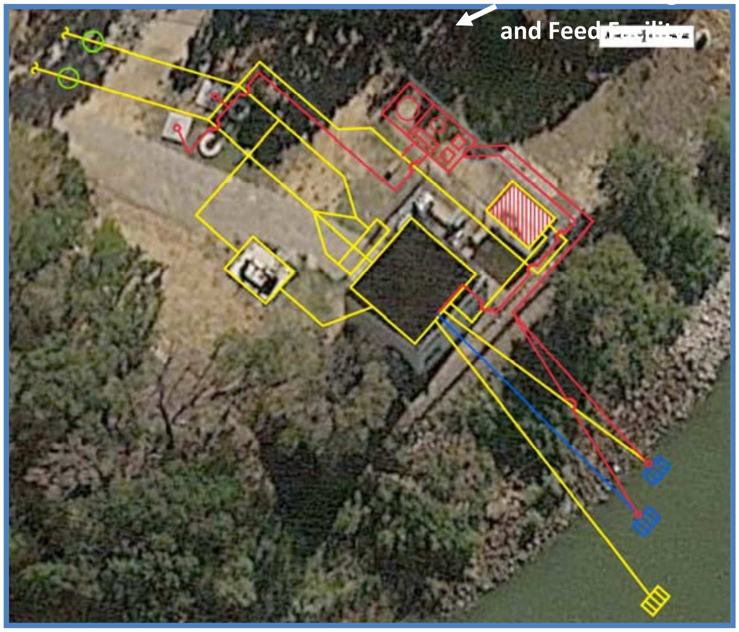


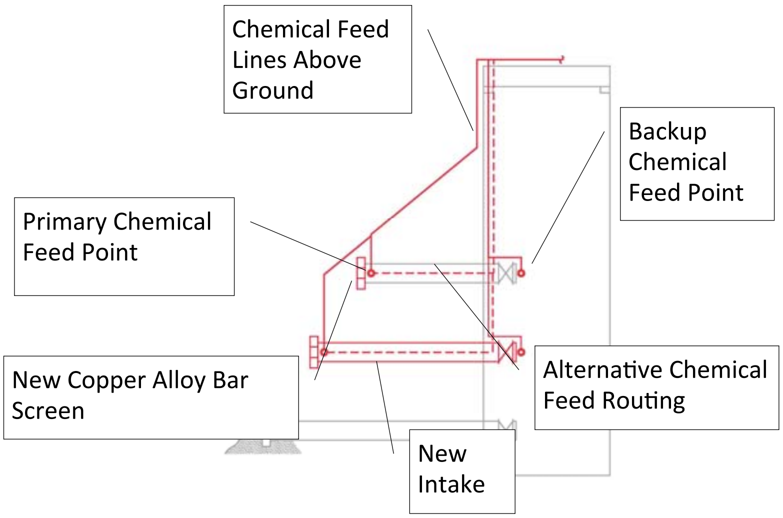
Exhibit 3

LLWTP Capital, Operations and Maintenance Recommendations

Primary recommendations include rebuilding the upper intake bar screen in copper alloy along with a redesign to make the screen removable, and adding chemical immediately after the bar screen to protect all downstream components including the RWPS. Chemical facilities will be located to the north-east of the existing permanganate building. Two-chemical systems using common piping and feed system components provide redundancy without a significant increase in cost, and are common in zebra mussel management strategies employed in the Great Lakes region. The ability to utilize an alternate system to reduce the impact of system limitations or when the primary system is not operating due to maintenance, will provide the LLWTP with a robust preventative zebra mussel management strategy. Additional commendations include manway installations, operating pumps and valves frequently, and risk management strategies (e.g. monitoring and inspections).

Probable Costs	Recommendations
Probable **Capital Improvement** Cost: $ 2,360,000	• Rebuild bar screen in copper alloy • Install a copper ion system (based upon plant flow) • Install a sodium permanganate storage and feed system (based on design dose of 5.5 mg/L) • Minor manway improvements for physical removal and disposal access especially at pipeline low points
Probable **Engineering and Construction Administration** Fee: $ 480,000	
Probable Annual **Operations & Maintenance** Cost: $ 99,000—$ 147,000	• Light physical removal and disposal, as required (e.g. bar screen power washing) • During settlement season, feed copper ions at a dose of 5 ppb copper (2 ppb year-round) or sodium permanganate at an average dose of 3.5 mg/L (range of 1.5-5.5 mg/L) • Operate pumps and valves frequently • Isolate and dewater structures (e.g. wet well) during plant shutdowns (lower water level if dewatering not possible) • Alternate pipeline use, when possible
Risk Management Recommendations	• Increase monitoring to include additional water quality, substrate sampler and veliger monitoring at minimum • Visually inspect debris from the bar screen(s). Also visually inspect any dewatered surfaces during maintenance activities • Develop a plan for interim chemical feed using the existing potassium permanganate system • Implement on-call contracts, begin regulatory coordination and develop new SOPs





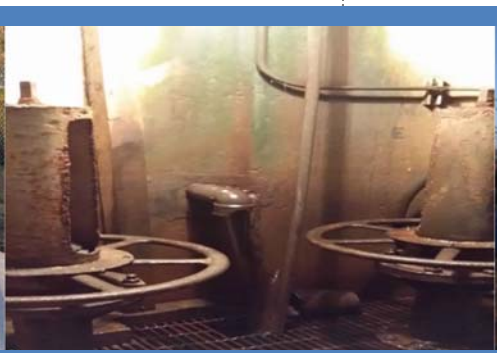


Exhibit 3

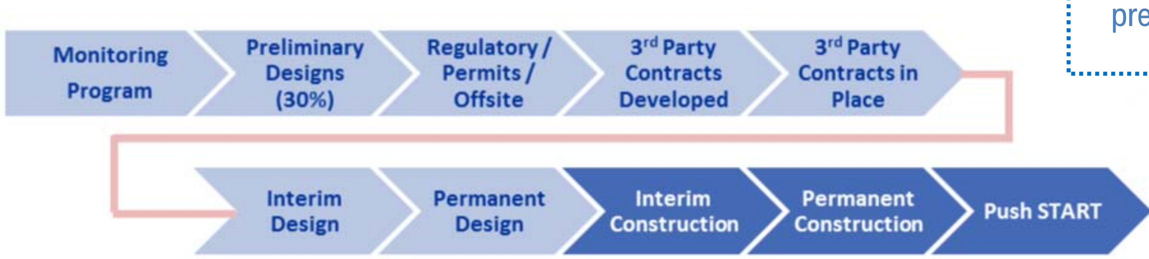
LLWTP Recommended Next Steps

The previous RRWTP raw water system zebra mussel infestation and recent heavy juvenile zebra mussel settlement in Lake Lewisville lead to the recommendation that the COD proceed proactively with actions to better prepare for future zebra mussel infestations of the LLWTP raw water system. As the LLWTP raw water facilities are susceptible to fouling, and zebra mussel infestations would pose significant risk to COD operations, a proactive program to manage risk is recommended for immediate implementation. Key recommendations include:

- Applying monitoring and inspection techniques to input information into the decision-making process;
- Developing a multi-barrier approach to zebra mussel management; and
- Optimizing O&M activities, which can significantly reduce future impacts with minimal capital investment.

However, the recommended capital improvements do not need to be constructed immediately. There are a number of proactive actions COD can initiate to prepare for potential future infestations of the LLWTP Intake without spending capital funds prematurely. Develop a response plan to initiate further steps to provide zebra mussel protection (e.g. confirm the trigger for constructing interim and permanent improvements).

> There are a number of proactive actions the COD can initiate to prepare for potential future infestations without spending excessive capital prematurely.



Key:
- Short-Term Action Items
- Initiate Upon Mussel Observance

Group activities during workshops highlighted the need to balance future risks by sufficiently preparing but not over-preparing for a mussel infestation. The timeline above summarizes recommendations for the timing of completion of each preparation stage.

Develop and Initiate a Response or Strategic Plan:

Develop a Zebra Mussel Monitoring SOP

Increased biological monitoring should begin immediately to maximize the amount of time to respond and prevent future potential infestations. Consider hiring and/or training staff members to perform zebra mussel monitoring (i.e. veliger, settlement and adult identification) at both intake locations. Update the monitoring plan annually based upon a review of trended data collected through the monitoring effort. Following implementation of any molluscicides, the SOP should provide procedures for modifying the site's monitoring program for chemical feed optimization including the use of chemical residual monitors and bioboxes in the intake and at the point farthest downstream in the system where protection is required.

[See Manual Sections 4.3.1.1 & 4.3.2.1]

Begin Regulatory Coordination

Zebra mussel management will require coordination with multiple regulatory agencies throughout the planning, design, and construction phases of the project. Which agencies are involved depends on the selected zebra mussel management approach and the application, but the following regulatory focus items should be addressed in the near term:

- Send design documents for new chemical improvements to TCEQ for review and approval
- Make arrangements with TPWD and US FWS for native mussel surveys, if required
- Coordinate with USACE on required permits and follow up on the new easement agreement

[See Manual Sections 2.6 & 4.3.2.2]

Exhibit 3

LLWTP Recommended Next Steps

Develop On-Call Contracts for Physical Removal and Disposal

It is recommended that COD proactively develop an on-call contract for cleaning and disposal of mussels. On-call contracts generally require the contractor to coordinate disposal in accordance with all regulations. Develop on-call contracts (or price agreements) for inspecting facilities for zebra mussels and cleaning mussel infestations from facilities. On-call contracts should include detailed drawings and specifications that consider the lessons learned from the RRWTP zebra mussel cleaning event .

[See Manual Sections 2.4, 3.2.3.4 & 4.3.2.3]

Assess Acceptable Impacts and Evaluate Access

Consider potential hydraulic losses due to zebra mussels and/or Asian clams, potential disposal efforts associated with disposal of shells and evaluate access points for physical removal of shells.

- Determine the level of allowable reduced hydraulic capacity before cleaning is necessary
- Consider the maximum volume of mussels that should be allowed to accumulate before removal
- Consider executing inspection on-call contracts including CCTV assessments
- Evaluate locations for maintenance access points for zebra mussel and/or Asian clam removal, especially at low points

[See Manual Section 4.3.2.4]

Coordinate Disposal

Based on a review of the alternatives, landfilling is recommended to minimize capital costs and future risks associated with alternative disposal approaches. It is assumed that the COD landfill, which was used to dispose of mussels from the RRWTP raw water system, will be used for the LLWTP. If a different landfill will be used, there may be additional testing and regulatory requirements. Verify that testing completed previously with mussel samples from Lake Ray Roberts is sufficient for approval of future mussels removed from the LLWTP raw water system, and review easement and access agreements to ensure ability to access all raw water lines in the case that physical removal is required.

[See Manual Sections 2.4, 3.2.3.4 & 4.3.2.5]

Develop an Interim Chemical Feed Plan

Develop a plan for using the existing potassium permanganate system to provide some level of zebra mussel management in the case that an infestation occurs before a permanent system is constructed. Detailed recommendations for increasing the permanganate feed are provided in section 4.3.1.2 and recommendations for increased monitoring and inspections are provided in section 4.3.1.1. The interim design should include the necessary monitoring equipment (e.g. residual monitors and bioboxes) to optimize the chemical dose and frequency required. Consider completing additional testing of a higher chemical dose in coordination with the recommended increased monitoring (i.e. manganese, ORP and pH profiles) prior to an infestation to troubleshoot any downstream consequences (e.g. increased turbidity or colored water).

[See Manual Sections 4.3.1.1, 4.3.1.2 & 4.3.2.6]

Develop New Chemical System Design Documents

As settled zebra mussels have been identified in Lake Lewisville, begin development of design documents for the selected alternative. If construction will be completed immediately, complete 100% design documents. Otherwise, 60 or 90% design documents could be developed to minimize the time to complete design prior to future construction without sacrificing the value of designs decreasing as they sit on the shelf. The design should balance dual-water quality benefits with downstream treatment challenges and include developing chemical dosing SOPs, protection of all small diameter pipelines, and redundancy of equipment.

[See Manual Sections 4.2.1, 4.3.1 & 4.3.2.7]

Develop a Manganese SOP

With sodium permanganate (or potassium permanganate for interim feed) implementation, a manganese standard operating procedure (SOP) should be developed. If not properly monitored and managed, permanganate can result in increased manganese concentrations (potentially above the 0.05 mg/L MCL) in the treatment stream, which in turn can lead to colored water events. It should be noted that although development of a manganese management procedure is recommended, many utilities (e.g. City of Oregon, OH, City of Toledo, OH and City of Raleigh, NC) have used permanganate doses of 2-4 mg/L without any noticeable resulting manganese water quality impacts.

[See Manual Sections 4.3.1.1 & 4.3.2.8]

Monitor Copper and Aluminum

Copper removal via downstream processes should be verified to ensure compliance with regulations and assess impacts on distribution system copper and lead control, understanding that regulations generally become more stringent over time. Aluminum should also be monitored and assessed. Due to the limited information available and limited full-scale municipal installations for zebra mussel control, a sidestream biobox pilot study could be performed prior to installation of a copper ion alternative to verify efficacy in COD source waters. Additionally a performance guarantee of zebra mussel settlement prevention could be requested from the manufacturer.

[See Manual Section 4.3.2.9]

RRWTP Overview

The RRWTP is the smaller of the two COD water treatment plants. The plant was constructed in 2002 while the raw water infrastructure was completed in 1983 and the second valve vault added in 1997. Most recently, in 2014, manways were installed in the raw water line to allow access for cleaning and disposal of zebra mussels. The plant has a current capacity of 20 MGD, average flows of approximately 9.9 MGD and minimum flows of approximately 5 MGD. If future demands increase, the capacity of the RRWTP will be increased to 50 and ultimately 100 MGD.

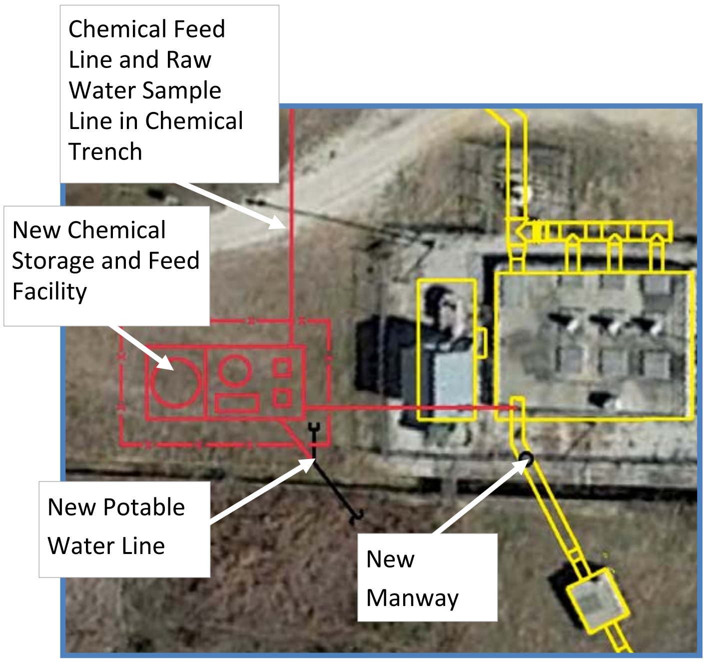
The raw water system consists of the USACE-owned dam outlet structure (i.e. the RRWTP Intake), a 60-inch raw water pipeline to the raw water pump station (RWPS) that is currently bypassed, and a 42-inch pipeline to the plant. The COD also owns a hydroelectric power plant that is connected to the raw water system but is no longer functioning. The total distance from Lake Ray Roberts to the RRWTP is approximately 1 mile.

Exhibit 3

RRWTP Capital, Operations and Maintenance Recommendations

Primary recommendations include improvements to the raw water pipelines to provide additional access and adding a chemical feed point in valve vault 1 to protect all downstream components including the RWPS. Due to environmental releases through the USACE structure into the Elm Fork of the Trinity River, chemical cannot be applied any farther upstream. Chemical facilities will be located to the north-west of the RWPS. Two-chemical systems using common piping and feed system components provide redundancy without a significant increase in cost. The ability to utilize an alternate system will serve as a key aspect of the RRWTP's zebra mussel management strategy. Additional recommendations include operating pumps and valves frequently and risk management strategies (e.g. monitoring and inspections at USACE pipe outlet).

Probable Costs	Recommendations
Probable **Capital Improvement** Cost: $ 2,180,000	• Improve the raw water pipelines with additional access points and valves • Install a copper ion system based upon plant flow • Install a sodium permanganate storage and feed system (based on a design dose of 2.5 mg/L) • Minor manway improvements for physical removal and disposal access especially at pipeline low points
Probable **Engineering and Construction Administration** Fee: $ 440,000	
Probable Annual **Operations & Maintenance** Cost: $ 98,000—$ 119,000	• Light physical removal and disposal, as required (e.g. low point downstream of USACE outlet) • During settlement season, feed copper ions at a 5 ppb dose (2 ppb during non-settlement season) or feed sodium permanganate at an average dose of 1.5 mg/L (range of 0.5-2.5 mg/L) • Operate pumps (if operational) and valves frequently • Isolate and dewater structures (e.g. pipelines) during plant shutdowns (lower water level if dewatering not possible)
Risk Management Recommendations	• Increase monitoring to include additional water quality, substrate sampler and veliger monitoring at minimum • Visually inspect debris from the pipelines or USACE Outlet. Also visually inspect any dewatered surfaces during maintenance activities • Continue developing the plan for interim chemical feed using sodium permanganate totes • Implement on-call contracts, begin regulatory coordination and develop new SOPs



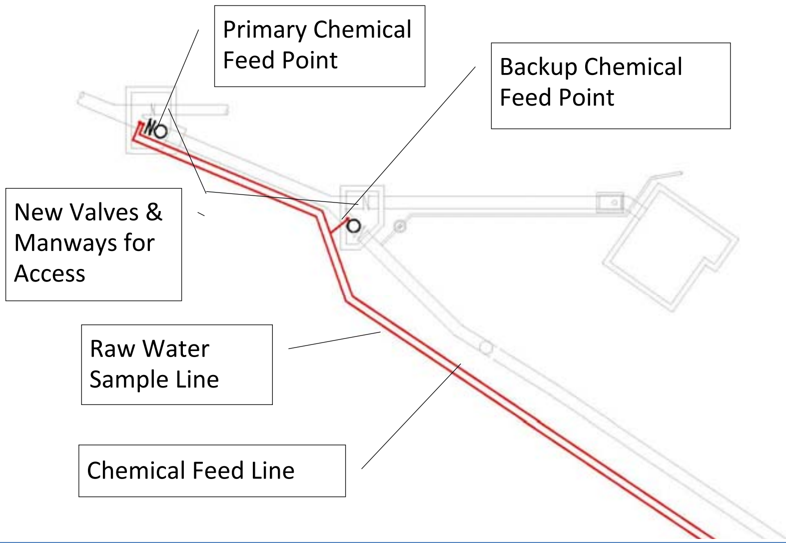





Exhibit 3

RRWTP Recommended Next Steps

Lessons learned from the previous RRWTP raw water system zebra mussel infestation lead to the recommendation that the COD proceed proactively with actions to better prepare for future zebra mussel infestations of the RRWTP raw water system. As the RRWTP raw water facilities are susceptible to fouling, and zebra mussel infestations would pose significant risk to COD operations, a proactive program to manage risk is recommended for immediate implementation. Key recommendations include:

- Applying monitoring and inspection techniques to input information into the decision-making process;
- Developing a multi-barrier approach to zebra mussel management; and
- Optimizing O&M activities, which can significantly reduce future impacts with minimal capital investment.

In addition to designing and constructing the selected capital improvements ASAP, there are a number of proactive actions COD can initiate to prepare for potential future infestations of the RRWTP Intake. Develop a response plan to initiate further steps to provide zebra mussel protection (e.g. confirm the trigger for constructing interim and permanent improvements). The response plan should include:

- Implement the next steps recommended in this section,
- Revise budgets in the Capital Improvements Plan (CIP) to account for increased annual costs to manage zebra mussels,
- Begin designs and subsequent construction of permanent systems,
- Begin implementation of the interim sodium permanganate system to minimize future infestation of 42” pipeline,
- Make plans for physical removal and disposal at least every two years,
- During future projects, include zebra mussel management approaches during design and construction, and
- Update the response or strategic plan annually based upon updated data from monitoring.

Develop and Initiate a Response or Strategic Plan:

Develop a Zebra Mussel Monitoring SOP

Increased biological monitoring should begin immediately to maximize the amount of time to respond and prevent future potential infestations. Consider hiring and/or training staff members to perform zebra mussel monitoring (i.e. veliger, settlement and adult identification) at both intake locations. Update the monitoring plan annually based upon a review of trended data collected through the monitoring effort. Following implementation of any molluscicides, the SOP should provide procedures for modifying the site’s monitoring program for chemical feed optimization including the use of chemical residual monitors and bioboxes in the intake and at the point farthest downstream in the system where protection is required.

[See Manual Sections 5.3.1.1 & 5.3.3.1]

Begin Regulatory Coordination

Zebra mussel management will require coordination with multiple regulatory agencies throughout the planning, design, and construction phases of the project. Which agencies are involved depends on the selected zebra mussel management approach and the application, but the following regulatory focus items should be addressed in the near term:

- Send design documents for new chemical improvements to TCEQ for review and approval
- Make arrangements with TPWD and US FWS for native mussel surveys, if required
- Coordinate with USACE on required permits and follow up on the new easement agreement

[See Manual Sections 2.6 & 5.3.3.2]

Exhibit 3

RRWTP Recommended Next Steps

Develop On-Call Contracts for Physical Removal and Disposal

It is recommended that COD proactively develop an on-call contract for cleaning and disposal of mussels. On-call contracts generally require the contractor to coordinate disposal in accordance with all regulations. Develop on-call contracts (or price agreements) for inspecting facilities for zebra mussels and cleaning mussel infestations from facilities. On-call contracts should include detailed drawings and specifications that consider the lessons learned from the RRWTP zebra mussel cleaning event .

[See Manual Sections 2.4, 3.2.3.4 & 5.3.3.3]

Assess Acceptable Impacts and Evaluate Access

Consider potential hydraulic losses due to zebra mussels and/or Asian clams, potential disposal efforts associated with and evaluate access points for physical removal of shells.

- Determine the level of allowable reduced hydraulic capacity before cleaning is necessary
- Consider the maximum volume of mussels that should be allowed to accumulate before removal
- Consider executing inspection on-call contracts including CCTV assessments

[See Manual Section 5.3.3.4]

Implement the Interim Chemical Feed Plan

Implement the interim chemical feed system as described in section 5.3.1.2. Concurrently, implement the recommendations for increased monitoring and inspections provided in section 5.3.1.1. The interim design should include the necessary monitoring equipment (e.g. residual monitors and bioboxes) to optimize the chemical dose and frequency required.

[See Manual Sections 5.3.1.1, 5.3.1.2 & 5.3.3.5]

Develop New Chemical System Design Documents

Complete development of design documents for the selected alternative. The design should balance dual-water quality benefits with downstream treatment challenges and include developing chemical dosing SOPs, protection of all small diameter pipelines, and redundancy of equipment.

[See Manual Sections 5.2.1, 5.3.1 & 5.3.3.6]

Develop a Manganese SOP

If sodium permanganate is implemented, a manganese standard operating procedure (SOP) should be developed. If not properly monitored and managed, permanganate can result in increased manganese concentrations (potentially above the 0.05 mg/L MCL) in the treatment stream, which in turn can lead to colored water events. It should be noted that although development of a manganese management procedure is recommended, many utilities (e.g. City of Oregon, OH, City of Toledo, OH and City of Raleigh, NC) have used permanganate doses of 2-4 mg/L without any noticeable resulting manganese water quality impacts.

[See Manual Sections 5.3.1.1 & 5.3.3.7]

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Copper removal via downstream processes should be verified to ensure compliance with regulations and assess impacts on distribution system copper and lead control, understanding that regulations generally become more stringent over time. Aluminum should also be monitored and assessed. Due to the limited information available and limited full-scale municipal installations for zebra mussel control, a sidestream biobox pilot study could be performed prior to installation of a copper ion alternative to verify efficacy in COD source waters. Additionally a performance guarantee of zebra mussel settlement prevention could be requested from the manufacturer.

[See Manual Section 5.3.3.8]

MEMORANDUM

Arcadis U.S., Inc.
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To:
Mamun Yusuf, P.E.
Project Manager, City of Denton

Copies:
File

From:
Gail Charles, PE

City Project No:
5643

Date:
June 3, 2016

Arcadis Project No.:
05673009.0000

Subject:
Phasing of Improvements for Zebra Mussel Management

INTRODUCTION

It is our understanding that budget constraints limit the amount of funding allocated for zebra mussel management improvements to $4,000,000 during CIP year 2017. Phasing of improvements as described below would allow design, construction and installation of key improvements to be accomplished as part of the 2017 CIP, with completion of the remaining improvements recommended in the Control, Operation and Maintenance Manual (Manual) for Zebra Mussels timed based upon the results of on-site monitoring.

PHASING OF IMPROVEMENTS:

Observations reported by Dr. Robert McMahon suggest that the population of zebra mussels in Lake Ray Roberts has “crashed”, as it did in both Lake Texoma and Lake Belton, and that it is uncertain as to whether a resurgence (and timing of it) will rival what occurred before the recent cleaning project was completed. Therefore, we recommend a phased approach to implementing the permanent facilities recommended in the Manual, based upon the results of monitoring by outside agencies and the City. Enhanced in-house monitoring is recommended moving forward, and a cost estimate for field and laboratory zebra mussel monitoring is provided at the end of this memorandum for consideration. Arcadis, in conjunction with Dr. McMahon, is currently conducting a similar training program for City of Dallas staff.

We recommend design and installation of the sodium permanganate system at the Lake Lewisville Water Treatment Plant (LLWTP) under the current (2017) CIP cycle as it can be used to replace the existing, labor-intensive, potassium permanganate system for pipeline maintenance and pre-oxidation, and also be used to manage zebra mussels, as necessary. The design should include provisions (e.g., building space, piping connections, vendor coordination, etc.) for the future installation of the copper ion system during the following CIP cycle or when zebra mussel indicators are observed. Note that the copper ion chemical storage and feed systems are available as turnkey skids which could be connected to the pumps and piping installed as part of the 2017 CIP design and construction effort.

While at the Ray Roberts Water Treatment Plant (RRWTP), access improvements have been made that will ease physical removal efforts in the future, we recommend that proposed improvements to the raw water line be included as part of the 2017 CIP to allow easier access along with addition of a new water line for future cleaning events . In addition, we recommend that the temporary sodium permanganate system recently installed be utilized while design of permanent chemical feed systems takes place during the 2017 CIP cycle. Installation of permanent chemical feed facilities should be slated for inclusion in the 2018 CIP, contingent upon the degree of infestation observed in the coming year.

COST BREAKDOWN:

2017 CIP

LLWTP

Permanent Sodium Permanganate Feed System with Provisions for Future Copper Ion Skid:

Capital[1]	$2,060,000
Design and Construction Admin	$ 440,000

RRWTP

Permanent Sodium Permanganate and Copper Ion Feed Systems Design	$ 200,000
Raw water line improvements and new water line for ease of cleaning	
Capital	$ 750,000
Design and Construction Admin	$ 150,000

Staff Training on Monitoring Techniques led by Arcadis

Interactive Field and Laboratory Training on Veliger and Adult Mussel Identification[2]	$ 20,000
Total	**$3,620,000**

[1] The capital cost could be further reduced by approximately $730,000 if the mid-level intake was constructed under another contract.

[2] Costs of Monitoring Equipment Including Microscope Not Included

2018 CIP

LLWTP

Copper Ion Skid Installation

Capital	$ 300,000
Engineering Support	$ 50,000

RRWTP

Permanent Sodium Permanganate and Copper Ion Feed Systems

	Capital	$1,430,000
	Construction Admin	$ 130,000
Total		**$1,910,000**