SHIP CHANNEL WASTEWATER RECLAMATION AND REUSE FEASIBILITY STUDY

FINAL REPORT

KBR

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Response to Texas Water Development Board Comments
Draft Final - Ship Channel Wastewater Reclamation and Reuse Feasibility Study
Contract No. 2003-483-505

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EXECUTIVE SUMMARY

This report examines the technical, environmental and economic feasibility of reclaiming municipal wastewater treatment plant effluent for reuse by industries along the Houston Ship Channel. The key findings of the report are:

- **The use of reclaimed wastewater for boiler feedwater makeup is considered technically feasible and could save the Houston Ship Channel industries 34 percent in costs, totaling up to nearly $33 million per year.**

- **Other project benefits include:**
  - **Provides up to 50 mgd of new water supply**
  - **Provides reliable, drought-proof water supply**
  - **Paid for by the water sales revenues from the industrial customers (no capital cost to City of Houston/Coastal Water Authority)**
  - **Is "revenue neutral" to City of Houston**
  - **Is environmentally sound (reduces salt load on Galveston Bay)**
  - **Can be implemented in less than 5 years**

- **This project should proceed to Phase 2 of engineering and development.**

Background

In Houston, the close proximity of a large population and a large industrial base provides a perfect opportunity for industrial reuse/reclamation of municipal and industrial wastewater effluent. The concentration of industries along the Houston Ship Channel currently uses approximately 100 million gallons per day (mgd) of raw surface water. This water is currently purchased from the City of Houston and transported to the users by the Coastal Water Authority (CWA). The industrial users then provide the water treatment required for cooling tower makeup, boiler makeup and process use to meet their demands.

The City of Houston operates three major wastewater treatment plants near the Ship Channel that can supply treated wastewater for reclamation and reuse.

The Trans-Texas Water Program and Senate Bill 1 Region H plans identified wastewater reclamation and reuse as a potential water management alternative for meeting projected water supply shortfalls in the Houston region. These studies report did not account for the industries' costs of treating the raw water to meet their requirements. When viewed from the perspective of the cost of treated water ready for use by each industry, the Ship Channel Wastewater Reuse/Reclamation Project appears economically feasible. Based on that premise, the Texas Water Development Board, the City of Houston, the Gulf Coast Waste Disposal Authority and the Coastal Water Authority cooperated to produce this feasibility study of wastewater reuse/reclamation for industrial supply along the Houston Ship Channel.

Results

This report includes nine Technical Memoranda, each addressing a separate technical, environmental or economic aspect of the project. The Technical Memoranda are attached to this report and their results are outlined in the Feasibility Study Report section of this document. The significant results of the work are summarized below:

1. **A reliable, sufficient supply of treated municipal wastewater is available for reclamation and reuse.** Based on analysis of a decade worth of records, the three City treatment plants can produce at least 73 million gallons per day (mgd) under worst-case conditions.
2. **There is an industrial market for reclaimed wastewater.** Ship Channel industries use about 40 mgd of boiler feedwater and another 11 mgd for other process needs. High-purity reclaimed wastewater could satisfy these demands.
3. **Sites for treatment and conveyance facilities are available.** An excellent site for the reclaimed water treatment plant has been located. Pipeline routes have been tentatively identified.
4. **No significant environmental issues have been identified.** The proposed treatment site is environmentally "clean" and careful route selection for pipelines can avoid any contamination.
5. **Pilot testing verified the reclaimed water treatment concept.** Testing of three vendors' equipment verified the ability of a combined ultrafiltration/reverse osmosis process to produce boiler feedwater suitable for intermediate-pressure boilers (up to at least 600 psi operating pressure).
6. **A conceptual treatment process flow diagram and treatment plant site layout have been developed.** Copies of both are included in this report.
7. **Treated reclaimed wastewater for boiler feed and process uses can be delivered to industries at or below their current costs of purchasing raw water and treating it themselves.** Treated reclaimed wastewater can be produced and delivered to Houston Ship Channel customers at estimated costs ranging from $2.18 per 1000 gallons (at a 60 mgd production rate) to $3.04 per 1000 gallons (at a 10 mgd production rate). Industries currently are estimated to pay in the range of $2.20 to $4.00 per 1000 gallons to purchase raw water and treat it themselves.
8. **Numerous funding options are available to the project sponsor.** Financing alternatives include private financing, TWDB loans, Bureau of Reclamation grants, municipal revenue bonds, commercial loans, VA/HUD State and Tribal Assistance Grant earmark and Section 219 Water Resources and Development Act funding.

9. **Turnkey and Design-Build project delivery methods should be considered.** A statistical analysis of project delivery methods showed turnkey and design-build strategies offering significant benefits to the project sponsor over the traditional design/bid/build approach.

10. **Supplying treated reclaimed municipal wastewater to industries for boiler feed and process uses is economically viable.** Depending on the financing method chosen and the project delivery strategy, Houston Ship Channel industries could save up to $33 million per year in water treatment costs.

11. **This project should proceed to Phase 2 of engineering and development.** The next phase of development will include environmental permitting, source water characterization, pursuit of project financing, public relations efforts, demonstration-scale pilot testing, property acquisition and project definition.

FINAL REPORT

1. Summary

This Technical Memo summarizes the results of the Ship Channel Wastewater Reclamation and Reuse Feasibility Study that are detailed in Technical Memos 1 through 9.

Significant findings include:

- **The use of Grade 1 Wastewater for cooling tower makeup presents technical concerns and, because of its cost, is not currently considered feasible.**
- **Use of Grade 2 Wastewater for boiler feedwater makeup is considered technically feasible and could save the Houston Ship Channel industries 34 percent in costs, totaling up to nearly $33 million per year.**

Identified project benefits include:

✓ Provides up to 50 mgd of new water supply

✓ Paid for by industry charges (no capital cost to City/CWA)

✓ Is "revenue neutral" to City

✓ Is environmentally sound (reduces salt load on Galveston Bay)

✓ Provides consistent, drought-proof water supply

✓ Can be implemented in less than 5 years

Based on these findings and benefits, it is recommended that the project proceed into Phase 2, to include application for federal funding.

2. Introduction

2.1 Background

The Houston region has a population base of 4.2 million which is forecast to increase to 5.6 million by 2020. Houston is also home to two-thirds of the U.S. petrochemical production and one-third of U.S. petroleum industries. This close proximity of a large population and a large industrial base provides a perfect opportunity for industrial reuse/reclamation of municipal and industrial wastewater effluent.

A concentration of industrial users along the HSC currently uses approximately 100 million gallons per day (mgd) of raw surface water for their operations. This water is currently purchased from the City of Houston and transported to the users by the Coastal Water

Authority (CWA). CWA distributes the raw water via its B-1 Pipeline to the HSC users. The industrial users then provide the water treatment required for cooling tower makeup, boiler makeup and process use to meet their demands.

The City operates three wastewater treatment plants in the vicinity of industries lining the Ship Channel: 69th Street and Sims North and South. And, the Gulf Coast Waste Disposal Authority (GCA) operates an industrial wastewater treatment plant in the same area. In total, these plants discharge an average of over 130 mgd and a minimum of approximately 84 mgd.

The Trans-Texas Water Program[1] identified wastewater reclamation and reuse as a potential water management alternative for meeting the year 2050 projected water supply shortfall for Southeast Texas. A further evaluation of one scenario of this alternative, reclamation and reuse of wastewater along the channel, was made in a subsequent report[2]. That study concluded that wastewater reclamation and reuse was technically and environmentally feasible, but not economically competitive with other raw water supply alternatives.

This latter report did not account for the cost of treating the raw water to meet the requirements of each user. When viewed from the perspective of the cost of treated water ready for use by each industry, the Ship Channel Wastewater Reuse/Reclamation Project appears economically feasible. Based on that premise, the City, GCA and CWA agreed to study the feasibility of wastewater reuse/reclamation for industrial supply along the HSC. The Texas Water Development Board (TWDB) provided a 50 percent Planning Grant for the project, and the City and GCA provided the remainder. Kellogg Brown & Root, Inc. (KBR) was selected to complete the Feasibility Study.

2.2 Initial Concept

The initial concept of the Ship Channel Reuse/Reclamation Project was to capture about 50 mgd of discharge from the City's 69th Street plant and distribute this effluent to industry for cooling tower makeup with minimal additional treatment. This effluent currently receives advanced secondary treatment, with mixed media sand filtration as the final process prior to disinfection, dechlorination and discharge. The final effluent from the 69th Street plant is low in biological activity, phosphorus, ammonia and suspended solids and is potentially suited for reuse as cooling tower makeup. In addition, it currently meets the requirements for Type I Reclaimed Water Use, as specified by the Texas Commission on Environmental Quality (TCEQ §210.32).

The other three treatment plants provide secondary treatment only. The initial concept was to collect these plant effluents, plus any unused portion from 69th Street, for conveyance to a new integrated membrane treatment facility (IMTF). The initial concept was for the IMTF to be located to minimize piping and pumping costs. In addition, the concept was that the IMTF would provide two stages of membrane treatment:

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1 *Phase I Report – Southeast Area*, Trans-Texas Water Program, Texas Water Development Board (March 1994).

2 *Wastewater Reclamation*, Trans-Texas Water Program, Texas Water Development Board (March 19, 1998).

- The first stage would include either a microfilter or an ultrafilter to reduce the particulate and organic content of the water.
- The second stage would utilize either a nanofilter membrane or a reverse osmosis membrane to desalt the wastewater.

The goal was that effluent from the second stage of processing would be suitable for makeup to steam generators operating at intermediate pressures - to at least 600 psig. Individual users would be responsible for providing treatment to a higher quality, if necessary.

2.3 Potential Benefits

Among the many potential benefits initially identified, implementation of the plan would release up to 50 mgd of raw surface water supply to the City to satisfy projected demands. The treated effluent supplied to industry would have low dissolved solids content and permit industries to minimize or even eliminate on-site water treatment processes currently required. Implementation of the project would also drought-proof the Ship Channel industries. And, these benefits would be realized at no cost to the City, since the expectation was that the project would be paid for by the channel industries while reducing the cost currently incurred by them to treat the raw Trinity River water.

3. Findings

The purpose of the Feasibility Study is to provide a more detailed assessment of the technical, economic, environmental, and institutional issues for reuse and reclamation of wastewater for industrial use along the Ship Channel.

The Feasibility Study was divided into several tasks to facilitate execution, budgeting, and tracking. These tasks are described in the following paragraphs, and the results are summarized.

3.1 Task 1 – Wastewater Effluent Quantity and Quality

The purposes of this task are to:

- Collect data on the quantity and quality of wastewater discharged from each of the treatment plants along the Ship Channel previously described.
- Identify additional parameters for analyses that may be necessary for design of the IMTF.

This task was anticipated to be accomplished by obtaining at least one year of data already recorded by each of the treatment plants and identifying data gaps that may exist (for instance, the silt density index of the wastewater is an essential design parameter that is not normally monitored in conjunction with wastewater plant operations).

Findings

- The minimum daily flow available from the four wastewater treatment plants included in this study—69th Street, Sims North, Sims South and the Washburn Tunnel plant—is 84 mgd and is based on a record period from 1995 to 2003 for the City plants and from 2000 to 2003 for the Washburn plant.
- Excluding the Washburn plant will reduce the minimum available flow to about 73 mgd.
- The secondary effluent will require further treatment for ammonia and nitrates to be useful as Grade 1 reclaimed cooling water.
- Extraction of wastewater return flow from the Houston Ship Channel would increase the potential amount of water available for reclamation to over 300 mgd, but in all likelihood would require desalting even prior to Grade 1 cooling water uses.
- There is insufficient information regarding the vertical and horizontal salinity distribution in the Houston Ship Channel and its tributaries to draw conclusions regarding the feasibility of extraction of Ship Channel water for treatment and Grade 2 reclaimed water use.

3.2 Task 2 – Industry Water Quality Requirements and Treatment Costs

The purposes of this task are to:

- Define the water quality requirements acceptable to each of the industries along the Ship Channel;
- Identify the quantity (current and projected), uses, and treatment of the water by each of the industries;
- Itemize the current costs for raw water and treatment; and,
- Estimate the costs/savings each industry would incur to treat the water expected from a wastewater reclamation facility.

This task was accomplished by supplementing information already obtained by KBR through the Trans-Texas Water Program and follow-on studies. It was intended that meetings would be scheduled with representatives from the various industries to discuss the required information. Prior to the meeting, a questionnaire was prepared and sent to the industries describing the requested information.

Findings

- Water Usage

  The total estimated water usage by the Ship Channel industries is nearly 94 mgd. Nearly 46 percent (43 mgd) of this is used for cooling (both once through and in cooling towers), and nearly 43 percent (40 mgd) is softened or demineralized, mostly for boiler feedwater.

The remainder (11 mgd) is for other uses, like washdown and direct process consumption.

Sixteen of the industries use more than 1 mgd (representing nearly 98 percent of the total), 4 use more than 5 mgd (representing over 59 percent of the total), and only 1 uses more than 20 mgd (nearly 22 percent of the total).

In general, water usage has been somewhat stable for the past several years – reduction by one industry has been offset by increase at another – and is expected to be somewhat the same for the foreseeable future.

- Water Quality Requirements

  The target water quality criteria for both cooling tower makeup and boiler feedwater makeup are reasonable. Meeting the criteria for intermediate pressure boilers will virtually eliminate the need for boiler feed water treatment in these boilers and tremendously reduce the treatment requirements for higher pressure boilers, although it is expected that most industries will keep these processes in operation as a polishing step.

- Current Costs

  In total, Ship Channel industries spend an estimated $65 million per year to purchase and treat water. Although, for most industries, this does not represent a major portion of their operating expenses, it is significant. The flow-weighted average cost is $1.80 per 1000 gallons (kgal).

  Reported costs to purchase and treat raw water for use as cooling tower makeup range from $0.52 to $1.15/kgal, across a wide range of makeup rates, where the lowest cost is for once-through cooling water that receives little or no treatment. The treatment costs consist of approximately $0.20/kgal for cooling tower chemicals and $0.11 for clarification ($0.38/kgal for clarification and lime softening). Applying the lowest cost for treatment of cooling tower makeup ($0.69/kgal) to those industries where exact costs were not obtained, the total annual cost for cooling tower makeup is $14.0 million, and the flow-weighted average cost is $0.90/kgal.

  Reported costs to purchase and treat (e.g., softening) raw water for use as low pressure boiler feedwater makeup range from $2.20 to $3.94/kgal, across a wide range of makeup rates. Applying the low cost to those industries where exact costs were not obtained, the total annual cost for low pressure boiler feedwater treatment is $18.2 million and the flow-weighted average cost is $2.34/kgal.

  Reported costs to purchase and treat raw water for use as high pressure boiler feedwater makeup (e.g., demineralization or reverse osmosis) range from $3.50 to $4.00/kgal. Applying the low cost to those industries where exact costs were not obtained, the total

annual cost for high pressure boiler feedwater treatment is $31.2 million and the flow-weighted average cost is $3.52/kgal.

Reported costs to purchase and treat raw water for other uses range from $0.39 to $0.50/kgal, indicating that this water is generally used with a minimal amount of treatment. Applying the low cost to those industries where exact costs were not obtained, the total annual cost for other uses is $1.45 million and the flow-weighted average cost is $0.39/kgal

- Projected Costs

The use of Grade 1 Wastewater for **cooling tower makeup** is not currently considered cost effective.

The primary cost savings associated with the use of Grade 2 Wastewater for makeup to **intermediate pressure boilers** are in terms of:

- Decreased water usage by virtue of reduced blowdown.
- Increased boiler efficiency due to reduced blowdown.
- Lower chemical usage due to higher quality feedwater.

If all intermediate pressure boiler feedwater (21.3 mgd) is provided by Grade 2 Wastewater, the resulting average treated water cost would be approximately $1.74/kgal, compared to a current average cost of $2.34/kgal – a 26 percent decrease.

The primary cost savings associated with the use of Grade 2 Wastewater for makeup to **high pressure boilers** are in terms of:

- Decreased water usage by virtue of fewer demineralizer regenerations.
- Lower chemical usage by virtue of better feed water quality.

If all high pressure boiler feedwater (24.3 mgd) is provided by Grade 2 Wastewater, the resulting average treated water cost would be approximately $2.53/kgal, compared to a current average cost of $3.52/kgal – a 28 percent decrease.

It has been assumed that raw water from the CWA B-1 Line will continue to be utilized for **"Other" uses**. Therefore, the use of Grade 2 Wastewater has no expected cost impact.

The total demand for boiler feedwater makeup to channel industries is estimated at approximately 45.6 mgd. Assuming all of this is supplied by Grade 2 Wastewater, this is conservatively expected to save Ship Channel industries over $13 million per year, or an overall 21 percent reduction in the cost of water. The resulting weighted average cost of water is $1.43/kgal, compared to a current weighted average cost of $1.80/kgal.

3.3 Task 3 – IMTF Siting and Pipeline Routing Studies

The purposes of this task are to:

- Identify potential sites for a wastewater reclamation facility;
- Identify potential routings for required pipelines;
- Evaluate the alternative sites and routings; and,
- Recommend a preferable site and routing combination.

This was intended to be accomplished by establishing a set of criteria for evaluation of alternative sites and routings and ranking these criteria according to importance. Criteria were to include such items as location, access, and cost. Next, potential sites and routings were to be identified and evaluated against the respective criteria. The highest rated site and routings were to be recommended and presented to the project's sponsors for concurrence. The selected site and routings were to be used in the remaining analyses.

Findings

Of the twelve potential sites identified, the best site for the Integrated Membrane Treatment Facility (IMTF) is a 103-acre tract east of Allen-Genoa and about ¼-mile south of SH 225. The Port of Houston Authority owns the property. The land is vacant and is available for long-term lease.

Pipelines will constitute a substantial portion of the project cost. They will be needed to convey plant effluent to the IMTF for treatment and boiler feed water from the IMTF to the industrial customers. Lines will also be needed for carrying the IMTF waste streams to their disposal points. Tunnels will be mandatory where the lines cross railroads and SH 225; tunnels may also be used in lieu of open-cut construction for other segments. The routes identified below will apply equally well for both pipes and tunnels.

Six major corridors are needed to interconnect the proposed wastewater reclamation and reuse system. Their recommended routes are as follows:

- Treated Effluent Gravity Line from Sims South plant to Sims North plant: Use the Central Avenue ROW for the line between the two plants.
- Treated Effluent Force Main from Sims North to IMTF: Run this line east along Lawndale, then south on Allen-Genoa to the IMTF site.
- Treated Effluent Force Main from 69th Street plant to the IMTF: Route the line south from the plant, under Buffalo Bayou, then south along Wayside to the intersection with Harrisburg. Run the pipe east along Harrisburg to South 75th Street, then turn south on South 75th to Lawndale. Continue the line parallel to Lawndale to Allen-Genoa where the line would turn south, cross SH 225 and enter the IMTF site near the intersection of Allen-Genoa and Gober Street.
- Boiler Feed Water Distribution Lines from the IMTF to Industries: Practicality dictates running these lines within the existing CWA B-1 line right-of-way parallel to

the CWA line. CWA is in agreement with this concept. Additional ROW may be required at three identified bottlenecks along CWA's ROW.

- Ultrafiltration Backwash (process stream 19 on Figure 3) Force Main from IMTF to Sims North: This would run north along Allen-Genoa from the IMTF, under SH 225 and then west along Lawndale to the Sims North plant.
- Reverse Osmosis Concentrate (process stream16 on Figure 3) Line from IMTF to the Houston Ship Channel: A line from the IMTF to the Texas Genco power plant, running north on Scarborough from the IMTF, east on Lawndale and north on Light Company Road would be necessary.

3.4 Task 4 – Environmental Impacts

This Task includes the Phase 1 Environmental Analysis by includes HVJ Associates of the proposed Integrated Membrane Treatment Facility site and the potential pipeline routes to and from the IMTF. The site reconnaissance and Phase 1 environmental analysis were performed to identify the potential for soil and groundwater contamination and to document the existing environmental conditions. Permitting requirements for potential reject stream discharges to the Houston Ship Channel were also detailed.

The findings are based on the existing conditions on the date of the site visits and on available records. Certain indicators of the presence of hazardous materials may have been latent at the time of the site reconnaissance but may become observable later. No borings were made and no soil, sediment or groundwater sampling or chemical testing was conducted. Observable site conditions and readily available site histories were the sources of information.

Findings

In summary, it was determined that:

- There is no evident environmental contamination on the IMTF site.
- The IMTF site contains a small wetlands area that will have to be mitigated or avoided by onsite activities.
- Hydrocarbons, metals, PAHs and other compounds may contaminate portions of the evaluated route from the 69th Street Wastewater Treatment Plant to the IMTF site.
- Neighborhood impact will be significant along the evaluated route from the 69th Street Wastewater Treatment Plant to the IMTF site.
- No evident contamination was found along the proposed reclaimed water distribution pipeline route (i.e., the CWA B-1 line route).
- The required permits and approvals are listed in Table 1.

3.5 Task 5 – Pilot Testing

The objectives of the Pilot Testing Program were:

- Demonstrate that the proposed membrane systems will produce water meeting industrial user's water quality requirements for boiler makeup water for boilers operating up to 750 psig steaming pressure.
- Evaluate the need and compatibility of different coagulants and dosages with the source water and membrane systems to economically produce the desired product water.
- Demonstrate the turbidity and total organic carbon removal capabilities of the membrane systems.
- Establish achievable water recovery rates and estimate both the quantity and quality of residuals generated from the membrane processes.
- Evaluate the causes of any membrane fouling that may occur during pilot testing.
- Establish the requirements for an effective membrane cleaning regime including type and quantity of chemicals and determine minimum cleaning frequency.
- Identify the physical operating parameters (flux, recovery, pretreatment, cleaning strategy, etc.) that will provide a basis for the design and costs of the selected full-scale membrane system.

Pilot testing of the membrane processes using the actual effluents to be treated was used to establish basic design and operating criteria needed for the full-scale IMTF. The pilot testing provided hands-on experience and training prior to full-scale installation. KBR assisted in selection of the membranes to be tested during the pilot test, prepared the test protocol, monitored the testing and analyzed results.

City and GCA provided a number of services and assistance for this task, including:

- The water supplies for testing by the membrane pilot facilities (both),
- Sites for the pilot facilities, including power and other utilities necessary for operation of the pilot test equipment (both), and
- Analytical testing of the source, concentrate and permeate streams (City)

Findings

Performance of systems provided by Zenon Corporation and by Pall Corporation demonstrated the technical feasibility of an integrated ultrafiltration (UF) and reverse osmosis (RO) system to produce 750-psig boiler feedwater from municipal secondary wastewater effluent.
Specifically:

- Turbidity was reduced to less than 0.1 NTU by the UF systems.
- UF recovery rates exceeded 92%.
- UF operating flux was routinely greater than 35 gallons per square foot per day.

- No pre-UF coagulant was found to be necessary.
- One serious bio-fouling incident indicated the need to maintain a chlorine residual through the UF process and through any intermediate storage up to the inlet of the RO system.
- RO recovery rates were greater than 80%, yielding an overall integrated system recovery rate of about 74%.
- Total dissolved solids after RO treatment was consistently below 25 mg/L and total organic carbon was reduced to less than 1 mg/L.
- Aluminum removal by the integrated system was marginal for 750-psig boilers and will require further study.
- Membrane cleaning procedures using commonly available chemicals proved adequate to maintain/restore membrane permeabilities.
- Membrane cleaning frequencies and cleaning chemical consumption were reasonable.

3.6 Task 6 - Conceptual Planning and Design

The purpose of this task is to prepare a conceptual design package for review by the stakeholders and for use in preparing cost estimates. Included in this task were modeling of the effluent flow and industrial water demand to optimize the size of the reclamation plant, preparation of design criteria, and conceptual design, including site plan, layout of major equipment, list of major equipment, material balances, process flow diagrams, and operational philosophy.

Findings

- Grade 1 Wastewater

  The reuse of Grade 1 Wastewater presents technical issues and, because of estimated costs (see Section 3.7), is not currently considered feasible.

- Grade 2 Wastewater

  The conceptual Flow Diagram for the IMTF is provided on Figure 3 and the conceptual Site Layout is presented on Figure 4.

  Modeled results indicate constituent concentrations below guidelines for intermediate pressure boilers, so the reclamation of Grade 2 Wastewater is considered technically feasible.

  To provide a reliable source of water, the IMTF has to be designed for 24-hour-per-day operation, 365 days per year. Adequate redundancy must be provided to assure reliable operation.

3.7 Task 7 – Estimated Costs

The purpose of this task is to provide budget estimates of the capital and operating and maintenance costs for the project. Based on the conceptual design, costs to construct, operate, and maintain the reclamation plant will be estimated.

Findings

- Grade 1 Wastewater Costs

  Because the minimum estimated cost for Grade 1 Wastewater ($0.48/kgal), including the "revenue neutral" charge ($0.22/kgal), is greater than the current cost of raw water ($0.385/kgal), and because the quality is inferior, the reuse of Grade 1 Wastewater is not currently considered economically feasible.

  Without the "revenue neutral" charge, Grade 1 Wastewater reuse could be economically feasible. Even with the "revenue neutral" charge, the cost of Grade 1 Wastewater is comparable to other water supply options being considered for the region.

- Grade 2 Wastewater

  The Ship Channel industries' costs to purchase raw Trinity River water and treat it to a quality equivalent to Grade 2 Wastewater currently range between $2.20 and $4.00 per 1000 gallons. As indicated on Figure 1, the total produced water cost for Grade 2 Wastewater, including the "revenue neutral" charge ($0.22/kgal), ranges from $2.18 per 1000 gallons, at a production rate of 60 mgd, to $3.04 per 1000 gallons, at a production rate of 10 mgd. As indicated on Figure 2, the estimated capital costs range from $60.5 million at a production rate of 20 mgd, to $254.3 million at a production rate of 60 mgd.

  Based on the unit costs, the reclamation of Grade 2 Wastewater is currently considered economically feasible, especially at production rates of 20 mgd and above.

3.8 Task 8 – Financial and Legal Structuring

The purpose of this task is to identify alternative mechanisms for structuring the project and recommend the preferable combination of choices. Previously identified financing alternatives include private financing, financing by government entities (including the Texas Water Development Board and the Bureau of Reclamation), issuance of municipal revenue bonds, and commercial loans. Previously identified structuring alternatives include public ownership, private ownership, a public/private partnership, and a qualified management contract.

Findings

- Funding Alternatives

  The following multiple-approach strategy for project funding is recommended:

  - Seek to have Houston Ship Channel Reuse/Reclamation project authorized and appropriated under the Bureau of Reclamation's Title 16 account.
  - Pursue a State and Tribal Assistance Grant earmark in the next VA/HUD Appropriations Bill.
  - Pursue a Section 219 Water Resources Development Act authorization and appropriation.

  While this broad approach is recommended initially, the authorization process and certainly the Energy and Water appropriations process may narrow the possibilities to one account.

  To support these efforts, it is recommended that the City's lobbyist, Patton Boggs, continue to engage the relevant Committees. This should include aggressive communication and support efforts. In addition, Patton Boggs can prepare Title 16 authorization legislation, secure sponsors for the authorization legislation and prepare the necessary correspondence to ensure that a hearing is held on the bill. Patton Boggs would also submit the necessary request to the Senate Environment and Public Works Committee to have the project included in the WRDA reauthorization bill. To be successful, Patton Boggs should work with the Congressional delegation and key members of the authorizing Committees to ensure that the legislation moves forward.

- Project Structuring

  The allocation of risks is a major factor in selecting a project delivery approach, and process risk is considered the major risk for this project since the technology, although proven, requires a high degree of operational skill.

  Traditional and alternative delivery approaches were considered and evaluated using *Project Delivery and Contract Strategy Selection* (PDCS), by the Construction Industry Institute at the University of Texas at Austin.

A statistical analysis of the seven Selection Factors that were considered the most important from the 20 available was performed. With seven Selection Factors, there are 5040 permutations. Assigning a range of Preference Scores (a rating based on the relative importance) to these permutations produces the following results:

- Turnkey delivery (which includes startup) is rated No. 1 over 93 percent of the time.
- Design-Build or EPC delivery is rated No. 1 the remaining nearly 7 percent of the time.

3.9 Task 9 – Economic Evaluation

The purpose of this task is to combine the financial aspects of the project, including capital cost, operation and maintenance costs, and financing costs, to provide an economic assessment of the viability of the project.

Findings

Federal funding offers the single greatest cost benefit to the project over other funding alternatives. Title 16 funding through the Bureau of Reclamation appears to be easier to obtain and less bureaucratic to implement than Section 219 funding through the Corps of Engineers. For the local share, issuance of municipal bonds provides the greatest cost advantage.

These funding assumptions provide the following overall impacts on the cost effectiveness of the project:

- The estimated average cost industry incurs to purchase and treat raw Trinity River water for use in boilers is $2.97/kgal.
- The estimated average unit cost to purchase and use Grade 2 Wastewater, including projected cost savings and the normal financing assumption (6 percent for 30 years) ranges from $3.00/kgal at a production rate of 20 mgd to $2.16/kgal at a production rate of 45 mgd.
- The estimated unit cost to purchase and use Grade 2 Wastewater, including the projected cost savings discussed in Technical Memo 2-Industrial Water Quality/Quantity Requirements, plus a Title 16 grant, and using municipal bonds to finance the local share (4.45 percent for 30 years) ranges from $2.68/kgal at a production rate of 20 mgd to $1.96/kgal at a production rate of 45 mgd.

For this last scenario, use of Grade 2 Wastewater for boiler feedwater makeup could save the channel industries 34 percent in costs, totaling up to nearly $33 million per year.

4. Benefits

As discussed in the previous paragraphs, the Ship Channel Reclamation project is environmentally sound, technically feasible, and would save industry up to 34 percent in operating costs. In addition, the following benefits would be realized:

- ✓ Up to 50 mgd of new water supply at no cost.
- ✓ "Revenue neutral" to City.
- ✓ Drought-proof water supply to industry.
- ✓ Consistent water quality to industry.
- ✓ Eligible for State and Federal funding.
- ✓ Implementable in less than 5 years.

5. Follow-On Phases

Since this Feasibility Study indicates that the reclamation of Grade 2 Wastewater for boiler feedwater makeup project is technically and economically feasible. Therefore, it is recommended that the Project proceed into Phase 2 to include the following tasks (a detailed description of each task is included in the Appendix):

- Task 1 – Environmental Permitting/Coordination
- Task 2 – Source Water Characterization
- Task 3 – Project Financing / Structuring
- Task 4 – Public Relations
- Task 5 – Pilot Testing
- Task 6 – Property Acquisition
- Task 7 – Project Definition

The cost for these Phase 2 activities is conceptually estimated at $3.1 million.

TABLE

Table 1

Wastewater Reclamation / Reuse Permits
Houston Ship Channel

Required Permit / Approval	Responsible Agency	Required for Reclamation Plant?	Required for Pipelines?	Required for HSC Intake?	Required for Outfall?	Comments
Use of Reclaimed Water Notification	TCEQ	Yes				Section 210
TPDES Industrial Wastewater Discharge Permit	TCEQ	TBD			TBD	
Source Water Assessment	TCEQ	TBD				Probably not required since not potable use.
Certificate of Convenience and Necessity	TCEQ	TBD	TBD	No	No	
Local Permits / Approvals (Land Use, Building, etc.)	Houston, Pasadena, Deer Park	Yes	Yes	TBD	TBD	
§316(b) of the Clean Water Act (cooling water intakes)				No		Only required for cooling water intakes, but the provisions should be considered.
Section 10 of the Rivers and Harbors Act of 1899 (structures or work in, under, over or otherwise affecting the navigable capacity of U.S. waters - USACE)	USACE	No	TBD	TBD	TBD	
Section 401 of the Clean Water Act (discharge into a navigable waterways)		TBD	TBD	TBD	TBD	Acquired by the USACE from the TCEQ as part of the Section 404 permitting process
Section 404 of the Clean Water Act (discharge of dredge or fill material into a navigable waterways, including wetlands)	USACE	TBD	TBD	TBD	TBD	
Bridge Modifications	Coast Guard		TBD	TBD	TBD	
Coastal Zone Management	General Land Office	TBD	TBD	TBD	TBD	Acquired by the USACE from the GLO as part of the Section 404 permitting process
Railroad Crossings	Texas Railroad Commission		Yes			
Pipeline Crossings	Private Utilities and Pipeline Owners		Yes			
State Hwy Crossings	TXDOT		Yes			
Bayou Crossings	HCFCD		Yes			

FIGURES

Figure 1: Estimated Produced Water Unit Costs - Grade 2 Wastewater

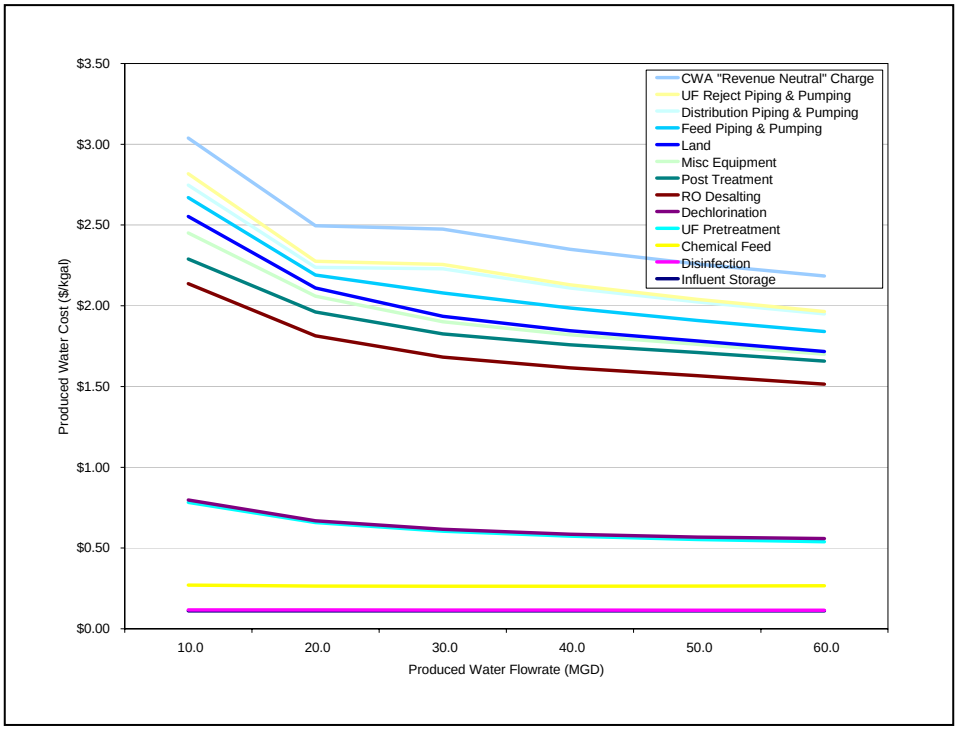
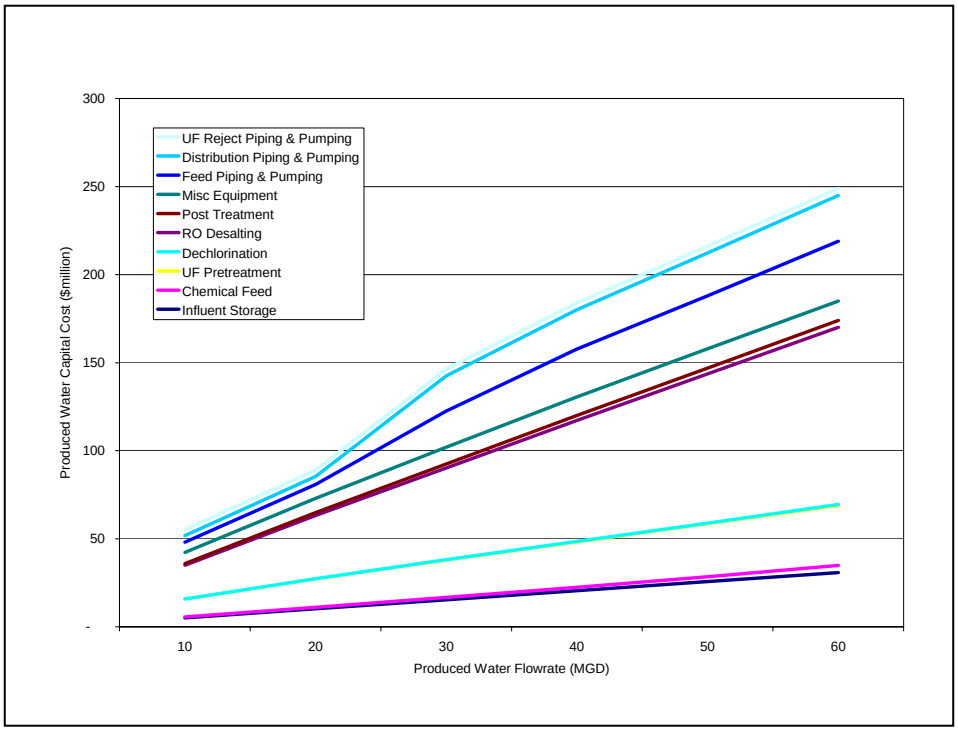
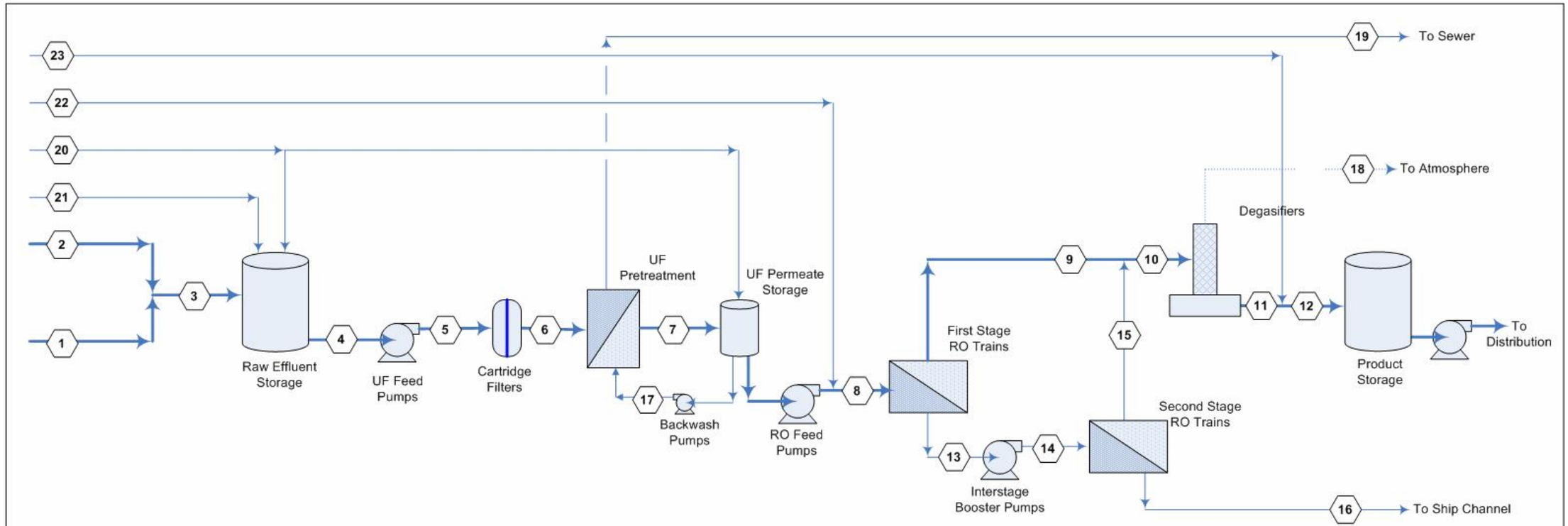


Figure 2: Estimated Produced Water Capital Costs – Grade 2 Wastewater





Line	Description	Production = 10 MGD			Production = 20 MGD			Production = 30 MGD			Production = 40 MGD			Production = 50 MGD			Production = 60 MGD			Pressure (psi)	pH	TSS (mg/L)	TDS (mg/L)
		Flow			Flow			Flow			Flow			Flow			Flow						
		(MGD)	gpm (max)	gpm (avg)	(MGD)	gpm (max)	gpm (avg)	(MGD)	gpm (max)	gpm (avg)	(MGD)	gpm (max)	gpm (avg)	(MGD)	gpm (max)	gpm (avg)	(MGD)	gpm (max)	gpm (avg)				
1	Raw Effluent from Sims	13.90	12,063	9,650	27.79	24,125	19,300	27.79	24,125	19,300	27.79	24,125	19,300	27.79	24,125	19,300	27.79	24,125	19,300		7.0	7.0	
2	Raw Effluent from 69th Street	-	-	-	-	-	-	13.90	12,063	9,650	27.79	24,125	19,300	41.69	36,188	28,950	55.58	48,250	38,600		7.0	7.0	
3	Combined Influent to IMTF	13.90	12,063	9,650	27.79	24,125	19,300	41.69	36,188	28,950	55.58	48,250	38,600	69.48	60,313	48,250	83.38	72,375	57,900		7.0	7.0	755
4	Pretreated Influent to IMTF	13.90	12,063	9,650	27.79	24,125	19,300	41.69	36,188	28,950	55.58	48,250	38,600	69.48	60,313	48,250	83.38	72,375	57,900			7.0	755
5	Cartridge Filter Feed	13.90	12,063	9,650	27.79	24,125	19,300	41.69	36,188	28,950	55.58	48,250	38,600	69.48	60,313	48,250	83.38	72,375	57,900	15.15		7.0	755
6	UF Feed	13.90	12,063	9,650	27.79	24,125	19,300	41.69	36,188	28,950	55.58	48,250	38,600	69.48	60,313	48,250	83.38	72,375	57,900	15.00		7.0	755
7	UF Permeate	12.50	10,851	8,681	25.00	21,701	17,361	37.50	32,552	26,042	50.00	43,403	34,722	62.50	54,253	43,403	75.00	65,104	52,083	2.00		-	755
8	RO First Stage Feed	12.50	10,851	8,681	25.00	21,701	17,361	37.50	32,552	26,042	50.00	43,403	34,722	62.50	54,253	43,403	75.00	65,104	52,083	92.50	5.5	-	755
9	RO First Stage Permeate	6.48	5,621	4,493	12.95	11,241	8,986	19.43	16,862	13,479	25.90	22,483	17,972	32.38	28,103	22,465	38.85	33,724	26,958	4.00		-	9.3
10	RO Combined Permeate	10.00	8,684	6,944	20.01	17,369	13,888	30.01	26,053	20,832	40.02	34,738	27,776	50.02	43,422	34,720	60.03	52,106	41,664	4.00		-	15.4
11	Degassed Permeate	10.00	8,684	6,944	20.01	17,369	13,888	30.01	26,053	20,832	40.02	34,738	27,776	50.02	43,422	34,720	60.03	52,106	41,664	2.00	6.00	-	15.4
12	pH Adjusted Permeate	10.00	8,684	6,944	20.01	17,369	13,888	30.01	26,053	20,832	40.02	34,738	27,776	50.02	43,422	34,720	60.03	52,106	41,664	2.00	6.50	-	15.4
13	RO First Stage Concentrate	6.03	5,234	4,187	12.06	10,468	8,374	18.09	15,701	12,561	24.12	20,935	16,748	30.15	26,169	20,935	36.18	31,403	25,122	80.80		-	1,555
14	RO Second Stage Feed	6.03	5,234	4,187	12.06	10,468	8,374	18.09	15,701	12,561	24.12	20,935	16,748	30.15	26,169	20,935	36.18	31,403	25,122	110.80		-	1,555
15	RO Second Stage Permeate	3.53	3,064	2,451	7.06	6,128	4,902	10.59	9,191	7,353	14.12	12,255	9,804	17.65	15,319	12,255	21.18	18,383	14,706	4.00		-	26.6
16	RO Second Stage Concentrate	2.50	2,170	1,736	5.00	4,340	3,472	7.50	6,510	5,208	10.00	8,680	6,944	12.50	10,850	8,680	15.00	13,020	10,416	98.10		-	3,714
17	UF Permeate for Backwash	1.09	1,920	759	2.19	1,898	1,518	3.28	2,846	2,277	4.37	3,795	3,036	5.47	4,744	3,795	6.56	5,693	4,554	35.00		-	755
18	Degassifier Discharge (CO_2)																					-	
19	UF Backwash	1.09	1,920	759	2.19	1,898	1,518	3.28	2,846	2,277	4.37	3,795	3,036	5.47	4,744	3,795	6.56	5,693	4,554	-		77.0	755
20	Chemical Feed (H_2SO_4, Coagulant, & Antiscalant)																						
21	Chemical Feed (Disinfectant)																						
22	Chemical Feed (Dechlorination)																						
23	Chemical Feed (NaOH & Disinfectant)																						

TITLE		REVISIONS			
October 2004	NTS				

Figure 3 Conceptual Flow Diagram Grade 2 Wastewater

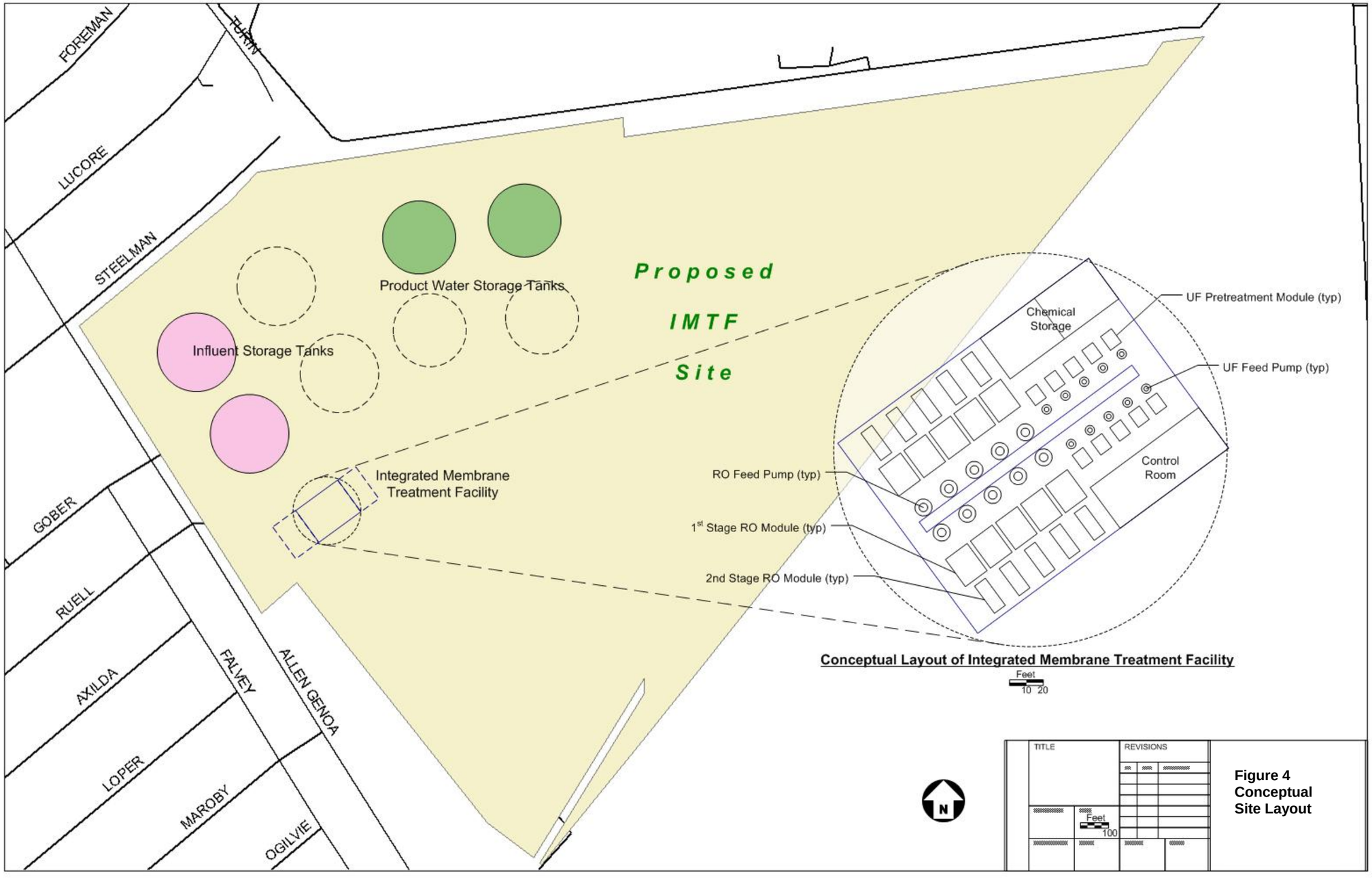


Figure 4
Conceptual
Site Layout

Appendix

Conceptual Scope of Work

Phase 2 - Ship Channel Wastewater Reuse/Reclamation

Introduction

Wastewater reclamation and reuse for industrial water supply will be important strategies in helping the Houston region meet the increasing demand for water supply,[3] including the projected 2050 water supply shortfall for Southeast Texas. The regional need for water was affirmed with the adoption of the 2002 State Water Plan by the Texas Water Development Board. The Department of Interior's "*Water 2025 Preventing Crises and Conflict in the West*" has also identified the Houston region as one where existing water supplies are expected to be inadequate to meet demands for farms, ranches, cities, recreation and the environment.

The Trans-Texas Water Program first identified wastewater reclamation and reuse as a water management alternative for meeting the projected water supply shortfall for Southeast Texas. A further evaluation of one scenario of this alternative, reclamation and reuse of wastewater along the Houston Ship Channel, was made in a subsequent report.[4] The Ship Channel Wastewater Reuse/Reclamation Feasibility Study is providing a more detailed assessment of the technical, economic, environmental, and institutional issues for reuse and reclamation of wastewater for use along the Houston Ship Channel.

A grouping of industrial users along the Ship Channel currently requires approximately 100 MGD of untreated surface water for their operations. The City of Houston (City) operates three wastewater treatment plants in the vicinity of these industries, and the Gulf Coast Waste Disposal Authority (GCA) operates an industrial wastewater treatment plant in the same area. Finding of the Feasibility Study include:

- The direct reuse of wastewater for industrial cooling tower makeup is currently not considered feasible. However, this water source is potentially more cost effective than other sources being considered, including Luce Bayou and Allen's Creek Reservoir.
- The Ship Channel Reclamation Project would capture discharge from the City of Houston's (City's) 69th Street and Sims North and South wastewater treatment plants for further treatment in an advanced, integrated membrane treatment facility to produce up to 50-60 MGD of process and boiler makeup water. A variation of this concept involves pumping water directly from the Houston Ship Channel for treatment in the new membrane treatment facility. This concept would potentially be less costly and provide more water to serve additional industries.

The many benefits of the project include:

- Effective use of a valuable resource.

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3 *Phase I Report – Southeast Area*, Trans-Texas Water Program, Texas Water Development Board (March 1994).

4 *Wastewater Reclamation*, Trans-Texas Water Program, Texas Water Development Board (March 19, 1998).

- Release of up to 50-60 MGD of raw surface water supply to the City and surrounding region to help meet projected demands.
- Minimization or, in some cases, elimination of industry on-site water treatment processes and associated costs.
- Drought-proofing of the Ship Channel industrial users.
- Cost savings to the Ship Channel industrial users.
- Reduction of the salt load to the Ship Channel and Galveston Bay.

Purpose

The purpose of Phase 2 of the project is to build upon the work being completed under Phase 1. This continuation would include beginning the process of obtaining necessary permits and approvals; obtaining water quality data on the Ship Channel; moving the financing/structuring public outreach and property/right-of-way tasks forward; performing pilot testing on Ship Channel water; and performing demonstration treatment testing.

Scope of Work

Phase 2 of the project has been divided into several tasks to facilitate execution, budgeting, and tracking. These tasks are described in the following paragraphs.

Task 1 – Environmental Permitting / Coordination

The Phase 1-Feasibility Study involved:

- Defining the environmental issues and regulatory requirements;
- Identifying potential environmental impacts from a wastewater reclamation plant;
- Assessing the magnitude of the environmental impacts; and,
- Defining design considerations that must be implemented to eliminate or mitigate any unacceptable impacts.

This task will continue the Phase 1 environmental work and begin the actual environmental permitting process, including preparation of EIA/EIS documentation and TPDES, Coast Guard, and Corps of Engineers (Section 10, 401 and 404), and Section 316b permit application documents, as required, as well as Ship Channel water rights documentation. This will require regular meetings with the responsible agencies, both before and after submittal of the applications, to verify requirements and expedite review and approval, and dispersion and water quality modeling in support of the permit process.

Task 2 – Source Water Characterization

The Phase 1-Feasibility Study involved:

- Collecting data on the quantity and quality of wastewater discharged from each of the treatment plants along the Ship Channel; and,
- Identifying additional parameters for analyses that may be necessary for design of the Integrated Membrane Treatment Facility (IMTF).

The expectation at that time was that pump stations and pipelines would feed directly from the wastewater treatment plants to the IMTF. A new concept is to pump at least some of the water directly out of the Houston Ship Channel. Although there is a concern regarding the acceptability of this water, particularly from a salinity standpoint, there appears to be the likelihood that fresh water is available in certain parts of the Ship Channel, at least during high flow periods. Therefore, there is a need to define the quality of the water in the vicinity of the anticipated intake(s) to properly assess its suitability for treatment. Biweekly samples from the Ship Channel at varying depths will be obtained and analyzed under this task.

Task 3 – Project Financing / Structuring

The Phase 1-Feasibility Study involved identifying alternative mechanisms for structuring the project and recommending the preferable combination of choices.

This task will continue this process and:

- Provide the coordination and documentation necessary to obtain project funding, including federal funding authorization and appropriations for both Phase 2 and construction, as well as investigating additional State funding sources.
- Begin the necessary steps to implement the recommended project delivery method.

Task 4 – Public Education and Outreach

The Phase 1-Feasibility Study involved considerable interaction with the industries to explain the project and obtain information regarding water demand, usages, and minimum water quality for each use. This task will continue that work and expand it to include interface with the various environmental, civic and industrial groups who may be interested in the project. Most importantly, it will involve working with the Ship Channel industries to obtain Letters of Interest upon which the scope of the project will be based, and Memoranda of Understanding, which will form the bases of the long-term contracts upon which the project will be funded.

Task 5 – Pilot Testing

The Phase 1-Feasibility Study involved pilot testing of the effluent from the City and GCA wastewater treatment plants. This task will provide demonstration testing (e.g., higher production than pilot testing) of those effluents to provide up to one year of additional data to industries regarding quality and reliability, and, if its suitability as a source is determined, provide pilot testing of the Ship Channel water in view of that alternative. In addition, this task will include pilot testing of a cooling tower to demonstrate operation on wastewater effluent for future use in determining the technical feasibility of reuse for cooling tower makeup.

Task 6 – Property Acquisition

The Phase 1-Feasibility Study involved:

- Identifying potential sites for a wastewater reclamation facility;
- Identifying potential routings for required pipelines;
- Evaluating the alternative sites and routings; and,
- Recommending a preferable site and routing combination.

This task allows right-of-way to be optioned, leased or purchased for the IMTF and the recommended pipeline routes. Included in this task will be boundary surveying to facilitate the acquisition of property.

Task 7 – Project Definition

The Phase 1-Feasibility Study involved preparing a conceptual design package including modeling of the effluent flow and industrial water demand, preparation of design criteria, and conceptual design, including site plan, layout of major equipment, list of major equipment, material balances, process flow diagrams, and operational philosophy. And, Task 7 involves providing estimated capital and operating and maintenance costs.

This task will build upon that information to provide a higher level of detail, including:

- Performance of topographic surveys for use in the final design.
- Performance of soil testing and preparation of Geotechnical Design Criteria.
- Preparation of design criteria for major project components.
- Completion of a Constructability Analysis.
- Preparation of Utility Flow Diagrams.
- Preparation of Process Control Philosophy and Logic Diagrams.
- Preparation of Piping and Instrumentation Diagrams.
- Compilation of a Project Definition Report.

Estimated Costs

Preliminary estimated costs for the outlined tasks associated with Phase 2 of the Wastewater Reuse/Reclamation project are summarized in the following table.

Task	Estimated Cost
Task 1 – Environmental Permitting / Coordination	$362,000
Task 2 – Source Water Characterization	$71,000
Task 3 – Project Financing / Structuring	$185,000
Task 4 – Public Relations	$126,000
Task 5 – Pilot Testing	$1,427,000
Task 6 – Property Acquisition	$432,000
Task 7 – Project Definition	$517,000
	$3,120,000

Response to TWDB Comments

Response to Texas Water Development Board Comments
Draft Final - Ship Channel Wastewater Reclamation and Reuse Feasibility Study
Contract No. 2003-483-505

1. **The Task 10 Feasibility Study Report is the primary study report and should be presented before the Technical Memoranda.**

   Response: The Feasibility Study Report will precede the Technical Memoranda in the final submittal.

2. **Include an Executive Summary;**

   Response: An Executive Summary will be included in the final submittal.

3. **Task 2, Section 5.5.5, final paragraph – Explain the reason for the 17 percent reduction from a cost of $1.94/kgal.**

   Response: The referenced paragraph is misleading and incorrect. The last three paragraphs of the referenced section should be replaced with the following:

   In addition, fewer chemicals for boiler feedwater treatment would be required because the water would be higher quality. Grade 2 Wastewater will have considerably less TDS (25 to 60 times less) than existing intermediate pressure feedwater. Therefore, it could reasonably be expected that proportionately less chemicals would be required. Assuming only 50 percent less chemical addition implies that chemicals would cost something on the order of $0.20/kgal less.

   Finally, with higher quality water, the time between softener regenerations would be reduced. However, since this primarily affects chemical costs, the impact on the total cost has been assumed to be negligible.

   If all intermediate pressure boiler feedwater (21.3 MGD) is provided by Grade 2 Wastewater, the resulting average treated water cost would be approximately $1.74/kgal, compared to a current average cost of $2.34/kgal – a 26 percent decrease.

4. **The quantity of new water supply (benefits) is reported as up to 100 mgd in Section 2.3 of Task 10, up to 50 mgd in Section 4 of Task 10, and 84 mgd in Task 1. The report should clarify the conditions under which the different amounts will be available.**

   Response: Section 2.3 in Task 10 has been revised to 50 mgd. The 84 mgd referenced in the Task 1 Technical Memo is the reliable flow ("yield") obtainable from all four wastewater plants potentially supplying the water for this project. The equivalent reliable flow from only the three City of Houston wastewater treatment plants is 73 mgd. Production of 50 mgd of treated Grade 2 wastewater requires about 70 mgd of secondary

effluent. Concentrate streams from the ultrafiltration and reverse osmosis processes account for the remaining flow.

5. **Task 10 Section 3.1, findings, bullet 4 Explain why 300 mgd is available via indirect reuse. Additionally, in Task 3 Indirect Reuse Option, paragraph 1, availability is said to double for indirect reuse, which would be either 100 mgd or 200 mgd.**

   Response: The 300 mgd is the total of all flow discharged into the Houston Ship Channel and is the amount conceptually available for reuse. The wording in technical Memorandum 3 has been revised to indicate 300 mgd is potentially available under the indirect reuse option.

6. **Use consistent baseline conditions, or explain the conditions clearly, when mentioning costs throughout the report. Presenting the various costs relative to a consistent measure would be one method of addressing this issue. Minimize the number of times that costs are presented under varying conditions.**

   Response: Although it is not clear, all costs are in terms of 2004 dollars. This will be made clear in the final submittal.

7. **The assumption that the project can receive tax-exempt financing is critical to the price of water. Clarify which aspects of the project qualify for this exemption.**

   Response: The assumption that the project can receive tax-exempt financing is based on the premise that the project will be financed either in whole or in part with municipal revenue bonds or private activity bonds, either of which are tax-exempt. The potential for use of private activity bonds is enhanced by proposed legislation that would raise or remove the cap on this type of financing.

8. **The report conservatively assumes that the success of the project relies on its ability to provide treated water to the industry at a competitive price that recovers the cost of building and operating the systems. Consider including the benefits to the City of Houston of having the current industrial supply freed for municipal use, namely the pre-existing. lake, raw water delivery, and much of the treatment facilities and distribution.**

   Response: Technical Memo 10 states that, in addition to being environmentally sound, technically feasible, and saving industry up to 34 percent in operating costs, the following benefits would be realized:

   - ✓ *Up to 50 mgd of new water supply at no cost.*
   - ✓ *"Revenue neutral" to City.*
   - ✓ *Drought-proof water supply to industry.*
   - ✓ *Consistent water quality to industry.*
   - ✓ *Eligible for State and Federal funding.*
   - ✓ *Implementable in less than 5 years.*

Other potential benefits mentioned in the comment (e.g., pre-existing lake, treatment facilities and distribution) are not applicable since the current water supplied to the industries does not flow through Lake Livingston or Lake Houston, is not treated, and is not distributed in the same systems used for municipal supply.

9. **Task 7, Page 4 – Consider presenting the impact of reducing the Revenue Neutral Charge. Over time other City customers will begin using the original supply and offset the lost revenue. The report states:** ***The estimate produced water cost for Grade 1 Wastewater includes the $0.22 per 100 gallons "revenue neutral" charge. Without the "revenue neutral" charge, Grade 1 Wastewater reuse would be potentially cost effective, at least for the selected alternative.***

   Response: The issue of reducing the "revenue neutral" charge over time was considered during preparation of the report and the decision was made not to include it. The first issue was to determine a period of time over which to reduce it. However, it became clear that, no matter what this period, the initial cost would be more than the industries are currently paying, so the perception was that it would be difficult to generate interest. This issue becomes academic when the costs of other sources of water supply exceed the cost of the Grade 1 Wastewater with the "revenue neutral" charge.