WATER REUSE AND ENVIRONMENTAL CONSERVATION PROJECT

CONTRACT NO. EDH–I–00–08–00024–00 ORDER NO. 04

Aqaba Mechanical Wastewater Treatment Plant Preliminary Evaluation Report

July 2015

IMPLEMENTED BY AECOM

July 2015

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WATER REUSE AND ENVIRONMENTAL CONSERVATION PROJECT

CONTRACT NO. EDH–I–00–08–00024–00 ORDER NO. 04

AQABA MECHANICAL WASTEWATER TREATMENT PLANT PRELIMINARY EVALUATION REPORT

JULY 2015

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EXECUTIVE SUMMARY

Background

The Aqaba Water Company owns and maintains a 21,000 m^3/day Wastewater Treatment Plant (WWTP) in the northwest portion of Aqaba, Jordan. Aqaba is a fast growing area and this trend is expected to continue. Projected future population growth and associated wastewater flows; along with the impacts of seasonal variation for Aqaba; and its popularity as a tourist destination were considered in the "Aqaba Wastewater Collection System Master Plan", dated July 2010 (Master Plan).

This Preliminary Evaluation Report (PER) will evaluate the ability of the existing facility components to accept and process the additional flows predicted by the Master Plan in an effort to defer the inevitable treatment plant expansion. The key directives of this study are to accomplish the following:

- Assess the performance of the existing biological treatment system using the BioWin model to identify its potential capacity,
- Identify a short-term plan that will maximize the capacity of the current facilities with minimal investment while the AWC determines whether to upgrade this facility or construct an entirely new facility and ultimately abandon these facilities, and
- Evaluate alternatives that maximize the current infrastructure, and
- Make recommendations for expanding the WWTP to meet long-term expansion goals outlined in the Master Plan.

Major items of consideration in this evaluation include flow and hydraulics; future effluent reuse; BioWin wastewater treatment system modeling; biosolids management; odor control; plant staffing; schedule; and cost. Four distinct modeling scenarios (A, B1, B2, and C), described below, were evaluated at varying design flows. Each modeling scenario was evaluated with and without the addition of septage, annotated by a prefix of "1" and "2", respectively. Detailed descriptions of the modeling scenarios may be found in Section 4, while explanations of the upgrade alternatives are located in Section 9.

A Existing conditions, with provisions for denitrification filters;

B1 Extension of influent anoxic zone, with provisions for denitrification filters;

B2 Extension of influent anoxic zone, additional aeration, with provisions for denitrification filters;

C Addition of primary clarification upstream of biological process (as modified per B2), with provision for denitrification filters;

Findings and Recommendations

The long-term goal of the WWTP is to blend the septage loading at the headworks to improve the operating conditions of the Natural WWTP. Addition of septage at the Headworks:

- Improves the carbon loading to the biological process,
- Is beneficial for denitrification, and
- Does not significantly reduce the capacity of the biological system.

At current average flows of 10,500 m^3/d and peak flows during the past year reaching 14,000 m^3/d, the existing facilities are already approaching the hydraulic design limit of the

biological treatment capacity. Based on AECOM's modeling results, life cycle cost analysis and project future flows for the facility, it is recommended that Upgrade Option 2 (Alternative B2) as described in Section 4 be implemented. The following are some of the recommended actions based on Upgrade Option 2. Additional information regarding the recommendations can be found in Section 9.

1) Initiate recommended wastewater characterization sampling immediately;

2) Conduct a survey of the existing WWTP to assess infrastructure issues and possible O&M measures to be implemented.

3) Proceed with planning and design of improvements to existing oxidation channels to increase the influent anoxic zone;

4) Proceed with planning and design of improvements to provide an adjustable effluent weir to increase operational flexibility and additional aeration capacity.

5) Conduct additional BioWin modeling based on new data from the characterization sampling to confirm or modify design conditions for the recommended alternative;

6) Consider receiving septage to the Mechanical WWTP Headworks when the biological system performance is reviewed;

7) Proceed with planning and design of odor control improvements at the Headworks.

8) Proceed with design of a Mechanical WWTP upgrade plan.

These initial upgrades will increase the plant treatment capacity to 16,000 m^3/day at a cost of approximately $6.6 million USD including the required denitrification filters and associated tanks and equipment.

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1 INTRODUCTION

The USAID Water Reuse and Environmental Conservation Project works throughout Jordan in institutional capacity building, pollution prevention for industries, solid waste and wastewater management, and water reuse. The project goal is to protect and conserve scarce resources through regulation, education, and coordination with industry, local communities and the private sector. The project is implemented by AECOM and a team of international and Jordanian partner firms. This five-year project has four primary tasks:

- Task 1 – Institutional and Regulatory Strengthening
- Task 2 – Pollution Prevention and Industrial Water Management
- Task 3 – Disposal Sites Rehabilitation and Feasibility Studies
- Task 4 – Water Reuse for Community Livelihood Enhancement, including biosolids

As part of Task 2, this work is part of our integrated water resources management planning activities with a focus on finding ways to increase the amount and quality of reuse water available for irrigation and industry. This Preliminary Evaluation Report (PER) of the Aqaba Mechanical Wastewater Treatment Plant presents improvement recommendations for meeting future flow projections for wastewater treatment and effluent quality requirements to promote increased reuse by industry in the region.

1.1 Driving Factors-Existing and Future Conditions

The Aqaba Water Company owns and maintains a 21,000 m^3/day Wastewater Treatment Plant (WWTP) in the northwest portion of Aqaba, Jordan that includes a Natural WWTP constructed in 1994 with a design flow rate of 9,000 m^3/day and the Mechanical WWTP constructed in 2005 with a design capacity of 12,000 m^3/day. Aqaba is a fast growing area and this trend is expected to continue. Projected future population growth and associated wastewater flows have been documented in the "Aqaba Wastewater Collection System Master Plan" (Master Plan), dated July 2010. That report examined two future flow scenarios for the Mechanical WWTP: one with major new development in the Aqaba area (Scenario 1) and one without major new development in the Aqaba area (Scenario 2). These scenarios are summarized in the table below.

Table 1-1. Future Growth Scenarios

Description	Year 2010	Year 2020 Additional Flow	Year 2030 Additional Flow	Total Future Flow
Scenario 1 Average Daily Flows (m^3/d)	12,000	40,992	22,978	75,970
Scenario 2 Average Daily Flow (m^3/d)	12,000	17,000	14,475	43,475

Both future flow scenario predictions for the WWTP are heavily reliant on the rapid growth forecasts for Aqaba occurring as planned. This evaluation examines the impacts of both scenarios on the Aqaba WWTP and the next logical steps for upgrade and expansion of the Mechanical WWTP to address the increased flow from these scenarios; the capacity of the Natural WWTP is not intended to be increased from the rated 9,000 m^3/day flow. As recommended in the Master Plan, WWTP flows and forecasts for future development should be continually monitored, and adjusted if necessary, to provide an infrastructure expansion that meets the growth needs without over-investing.

The Master Plan also considered the impact of the seasonal variation for Aqaba as it is a popular tourist destination for many Jordanians and other nationalities. The results of the collection system influent flow analysis indicate that seasonal variation does have a considerable effect on flows in the Aqaba system with a variation in flow of up to 20 percent, which is considered to be the result of seasonal and tourist impact. In both future growth scenarios, it was concluded that expansion of the Aqaba WWTP would be required in order to adequately treat the predicted flows. The Master Plan proposed to upgrade the Mechanical WWTP using the same processes that are currently in place by installing additional units for each stage of the treatment process to meet the flow requirements.

As noted in Table 1-1, the future growth projections in the Master Plan reflect a long-range WWTP flow projection that extends well beyond Year 2030 as documented, considering current operating flows at the Mechanical WWTP at the Aqaba facility. If the Scenario 1 flows are realized future flows could exceed 75,000 m^3/d.

In consideration of the existing flows in comparison with the Master Plan Projections, a modified projection of future flows is depicted in Figure 1-1. The graph indicates the original Master Plan projections with a 5-year shift shown in the shaded flow range that reflects the fact that WWTP flows for 2015 are just reaching the 2010 design capacity.

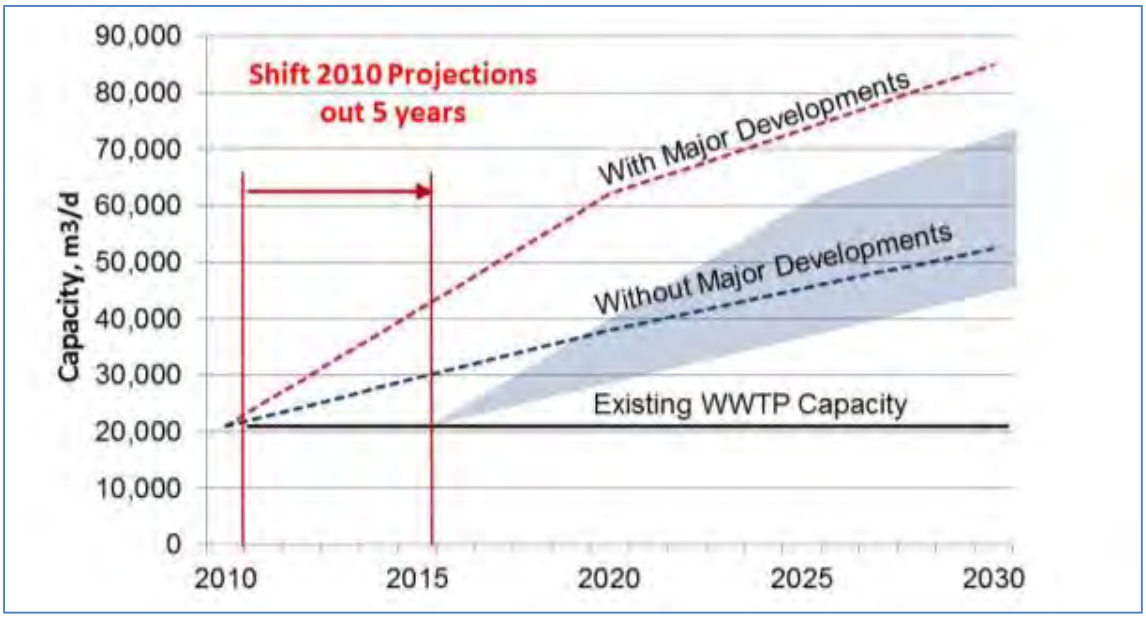

Figure 1-1. Master Plan Flow Projection With 5-Year Shift

This Preliminary Evaluation Report (PER) evaluates the ability of the existing facility components to accept and process additional flows predicted by the Master Plan in an effort to defer the inevitable treatment plant expansion. Several parameters were examined in order to determine the limiting factors for treatment at the facility, including:

- Hydraulic Capacity;
- Biological Process Limitation(s);
- Effluent Quality – Regulation and Customer Requirements; and
- Biosolids Processing - Process/Labor Capacity.

In order to draw these conclusions, AECOM has collected data including existing WWTP design documents, operations and maintenance reports, flow records, performed staff

interviews and site investigations, and reviewed complaint records. Data review and analysis included development of a BioWin model (a commercial wastewater modeling software) of the treatment facility.

1.2 Major Items of Consideration

The following is a summary of the sections of this PER and the information they present.

1.2.1 Section 2 - Flow and Hydraulics

This section summarizes the existing treatment process and capacity. It also summarizes the anticipated flow rates for the Mechanical WWTP and how it may be managed through the process treatment train. It considers the current operation of automated gates at the flow splitter box to “shave” the peak flows and direct them to the Natural WWTP, allowing flows to the Mechanical treatment train to be maintained more or less constant with minimal variation.

1.2.2 Section 3 - Future Effluent and Reuse Requirements

The proposed upgrades to the Aqaba WWTP consider the potential for more stringent effluent limitations in the future and must be designed with adequate capacity and/or expansion scalability to accommodate such effluent limitations as well as future effluent reuse considerations. As such, the evaluation of improvements considers whether, through expansion, chemical addition, or both, more stringent effluent limitations/reuse requirements are achievable.

1.2.3 Section 4 - BioWin Model

BioWin, a commercial wastewater modeling software produced by EnviroSim, was used to model the biological treatment process of the existing facility. Additional steady state model runs were performed to determine the effect of additional flow, changes in parameters, and additional process units. The objective is to determine if existing facilities will have to be modified and/or if new physical or biological processes are required to accommodate future flow and loading conditions.

1.2.4 Section 5 - Wastewater Treatment Technologies

Wastewater treatment technologies range significantly with respect to infrastructure and processes employed. A number of alternative technologies are available and considered in this section including Modified Ludzack-Ettinger (MLE) and denitrification filters to complement the existing oxidation channel activated sludge process. Natural treatment systems are also considered, including; constructed wetlands, aquaculture and other green technologies.

1.2.5 Section 6 - Biosolids Management

At present, all residuals from the wastewater treatment (biosolids) are dewatered through the use of drying beds without the aid of digestion, thickening and/or dewatering. This section conducts an evaluation of the existing solids handling practices and capabilities in light of the proposed modifications to the facility and its resulting impact on sludge quantity and quality. In consideration of the current limitation of the existing drying beds, alternatives are reviewed that include thickening and/or dewatering. From the many technologies available, the biosolids alternatives include: (a) thickening and dewatering; (b) high Solids, Heavy Duty Belt Filter Presses, (c) Centrifuges; (d) Rotary Presses; (e) Screw Presses, with disposition for Landfill disposal or beneficial reuse and/or energy recovery.

1.2.6 Section 7 - Odor Control

Nuisance odors, particularly those occurring near residential areas, can be an unwanted problem for the owner/operator of any wastewater facility. Current sources of odors at the Aqaba WWTP include the headworks, sludge drying beds and facultative ponds. Future development and associated wastewater flows will increase the loading to the WWTP and

related odor generating materials. With the same development expected to encroach on the WWTP property, mitigating nuisance odors is important for good neighbor relationships. Based on the operations of the existing Aqaba WWTP and the proposed modifications and upgrades, an evaluation of odor control techniques is conducted that may include use of chemical scrubbers, activated carbon systems, biofilters, and/or other odor management systems to meet the odor criteria acceptable to the Aqaba Water Supply as well as future neighbors. Process changes, such as adding biosolids digestion, may also be considered.

1.2.7 Section 8 - Project and Life-Cycle Costs

This section presents construction cost estimates for major process equipment and develops preliminary construction costs of the various alternatives that were evaluated to upgrade the Aqaba WWTP. Cost estimates are in spreadsheet format, itemized by distinct, biddable items of work. Construction costs are based upon values included in recent bid canvasses and schedules of values for similar types of construction including the existing Aqaba WWTP with adjustments for escalation as appropriate.

In evaluating alternatives, construction costs and operations and maintenance costs (O&M), including: labor; service contracts; fuel; power; chemicals; disposal costs; cleaning agents, etc. are assessed as well. Escalation of these costs over time must also be considered. O&M costs are put into terms of present worth for appropriate evaluation of alternatives.

Combining both construction and O&M costs, Life Cycle Cost Analyses (LCCAs) may sometimes influence decisions involving the selection of major equipment items with respect to the associated value of repairs, overhaul of major parts and/or replacement costs. This section includes the development of a LCCA to properly evaluate the cost of facilities and/or individual components modifications/upgrades. The cost of modifications, Capital and O&M, were determined as such costs influence the selection of the new facilities and/or the extent of modifications or additions to the existing facilities. The LCCA is used to evaluate the expected useful life costs of the various alternatives as part of the decision-making process.

Staffing levels at the Aqaba WWTP upgrade will change as new infrastructure is constructed to meet increased wastewater treatment capacity. The PER includes a review of the existing typical staffing level and identifies the need and time frame to increase operations and/or maintenance staff.

1.2.8 Section 9 - Findings and Recommendations

This section of the PER summarizes the conclusions drawn from the data analysis. It presents conceptual arrangements of the alternatives, and outlines a recommended plan for short and long-term implementation considering the current operating conditions and projected future flow projections. The recommendations include a summary of design criteria to be used for final design and target reuse quality.

1.2.9 Section 10 - Schedule

This section details a schedule to implement the necessary upgrades at the treatment plant. The schedule considerations include design, regulatory approvals, tendering, award, and construction assuming a conventional design-bid-build delivery method.

1.3 Reference Information

The following is a summary of the information utilized during the preparation of this PER.

- Aqaba Wastewater Collection System Master Plan, by MWH Arabtech Jardaneh, July 2010 (2010 Master Plan).
- The Hashemite Kingdom of Jordan Ministry of Water and Irrigation Water Authority of Jordan, Expansion of Aqaba Wastewater Facilities, As-Built Drawings, Montgomery Watson Arabtech Jardaneh and The Morganti Group, dated August 2005 (As-Built Drawings).
- Jordanian Institute of Standards and Metrology (JISM) by Technical Regulation No. 893/2006 titled “Water – Reclaimed Domestic Wastewater (JS 893)”
- Design of Municipal Wastewater Treatment Plants, MOP-8, 4th Edition as published by the Water Environment Foundation (WEF MOP 8).
- Monthly operations data recorded by Aqaba WWTP operators during the period of January 1, 2013 through December 31, 2014. A summary of this data is included in the Appendix.
- Process analytical data from grab samples obtained by Aqaba WWTP operators on January 20, 2015 and January 27, 2015, including: pH, Temperature, COD, TSS, Ammonia, BOD_5 TN, and Alkalinity for: Headworks Effluent (considered Mechanical WWTP Influent), Clarifier Effluent, Filter Effluent. The RAS was also sampled on those dates with TSS and VSS reported.

A summary of this data is included in the Appendix.

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2 FLOW AND HYDRAULICS

2.1 General

This section summarizes the existing treatment process and capacity. It also summarizes the anticipated flow rates for the Mechanical WWTP and how the flows may be managed. It is noted that automated gates at the flow splitter box control flows to the Mechanical WWTP based on urban reuse water demand. Refer to Figure 2-1. The gates are controlled to "shave" the peak flows and direct them to the natural treatment train, to normalize flows to the mechanical treatment train to be more or less constant.

Figure 2-1. Automated Gates at the Post-Headworks Flow Splitter Box

2.2 Process Description

The Aqaba Wastewater Treatment Plant features both a mechanical treatment process with oxidation diches, clarifiers, filters and UV disinfection and a "natural" treatment process featuring facultative and maturation ponds. The mechanical treatment process is rated at 12,000 m^3/day and the natural process is rated at 9,000 m^3/day. Influent enters the Headworks through a 1200 mm gravity sewer. However, the majority of the flow to this gravity sewer is contributed by pump stations.

No effluent is discharged to the nearby Red Sea. The effluent from the natural process is sent to evaporation ponds or agriculture (irrigation). Refer to Figure 2-2. The effluent from the mechanical process is sent to evaporation ponds, industrial users (for cooling water) and agriculture (including irrigation).

Figure 2-2. Natural Plant with City of Elat (Israel) in Background

This report focuses on the mechanical process at the Aqaba WWTP, which employs a secondary treatment process plus filtration to treat wastewater to the required standards. The following are detailed descriptions of the unit processes.

There are three levels of treatment employed in the WWTP to produce the high quality effluent and to stabilize the wastewater sludge prior to disposal. They are physical treatment, biological treatment and chemical treatment. Figure 2-3 presents a process flow diagram and hydraulic profile of the existing facility based on information compiled from the As- Built Drawings.

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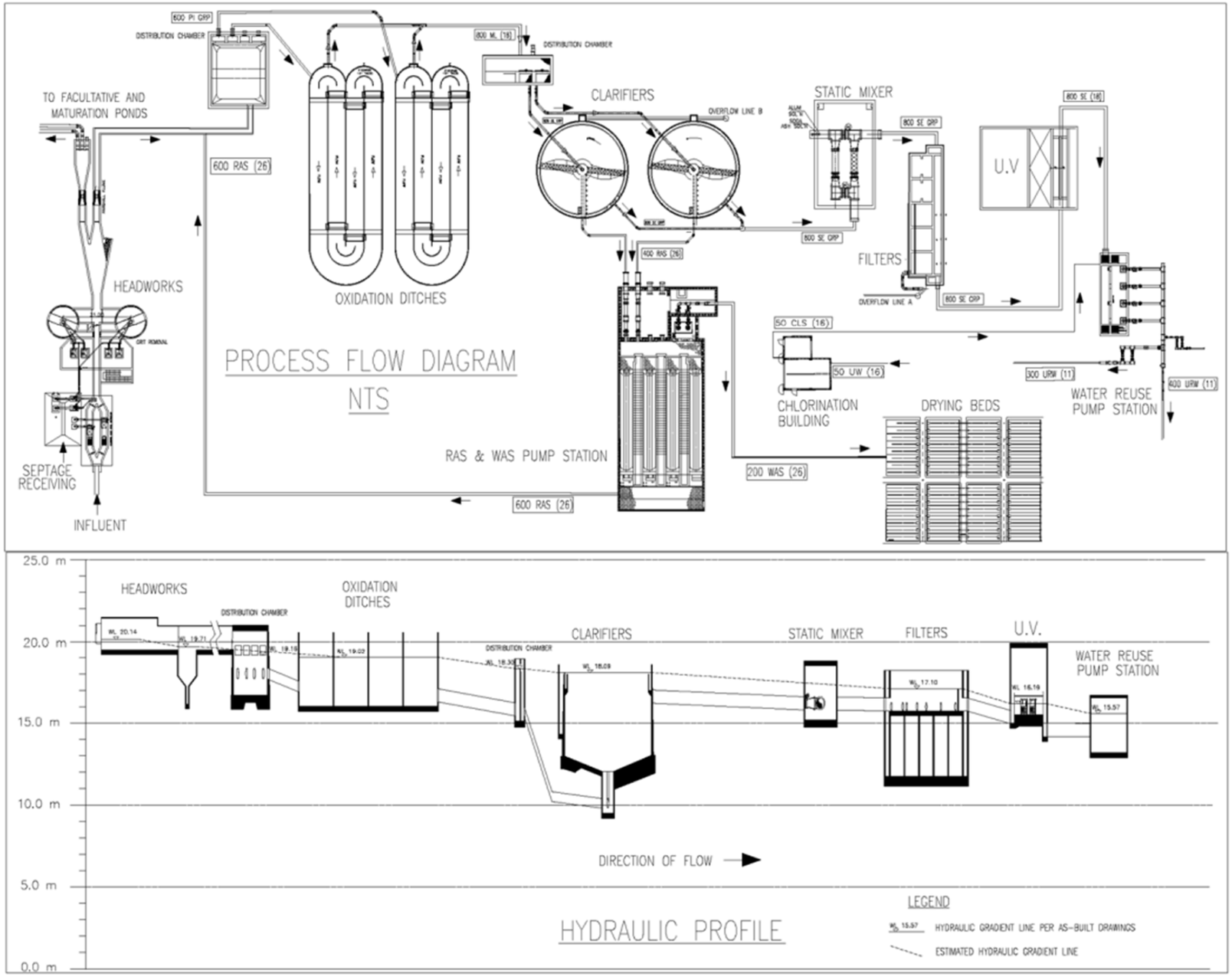

Figure 2-3. Existing Conditions Process Flow Diagram and Hydraulic Profile

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2.3 Physical Treatment Processes

Physical treatment is defined as the removal of impurities by mechanical means or by utilization of the physical properties of the waste to effect their removal. Physical processes include; screening, grit removal, sedimentation, filtration, gravity thickening of sludge and sludge dewatering.

2.3.1 Screening

The two coarse screens capture large objects in the influent wastewater. The coarse screens are followed by two mechanical fine screens, which capture finer solids as small as 9 mm. The mechanical fine screens automatically remove and convey screenings to waste containers. A photo of this equipment is shown as Figure 2-4.

Figure 2-4. Mechanical Fine Screens at Headworks

2.3.2 Grit Removal

The grit removal process removes the majority of the inorganic solids and certain relatively non-putrescible organics. Grit consists primarily of sand of various sizes, and a small fraction of other materials such as grain kernels, egg shells, seeds, fish scales and coffee grounds. The process relies on the fact that grit has a settling velocity substantially greater than that of organic putrescible solids. The grit chambers are designed to maintain the organics in suspension while creating a zone of settling for the grit. Grit removed is pumped to the grit classifiers which clean and mechanically convey the grit to dumpsters/roll off containers for disposal. Refer to Figure 2-5.

Figure 2-5. Grit Classifiers at Headworks

2.3.3 Biological Treatment Processes

From the Headworks channel, the sewage flows by gravity to the distribution chamber and into two Oxidation channels where biological treatment is provided. Refer to Figures 2-6 and 2-7. Mixing is supplemented by means of submerged turbine pumps. Mechanically driven brushes at the surface aerate the flow and propel it along the channel. The activated sludge process in the Oxidation channels uses a heterotrophic bacteria population to convert organic material in the wastewater to additional bacteria, which

Figure 2-6. Oxidation Channel Straightaways

are ultimately removed by physical process elements, e.g., sedimentation and filtration.

Complex biochemical reactions are involved in the utilization of the organic material for the growth and energy of the microorganisms. Enzymes in the wastewater help to convert the food to a form that can diffuse into the cells of the microorganisms. Intracellular enzymes then bring about oxidation, synthesis and energy reactions within the cells. This dynamic combination of wastewater and living microorganisms is called mixed liquor.

Figure 2-7. Oxidation Channel Curves and Aerators

In the extended aeration activated sludge process, the concentration of microorganisms in the oxidation channel, measured as mixed liquor suspended solids (MLSS), is typically maintained in a range between 1,500 and 3,500 mg/L. Hydraulic Retention time (HRT) in the aeration tank is proportional to flow, whereas solids retention time (SRT) is related to biomass concentration.

2.3.4 Secondary Clarification

The secondary clarifiers are used for separating the activated sludge from the mixed liquor. The biomass under aeration tends to form into clumps or floc. As the floc settles in the secondary clarifiers it traps smaller particles and further clarifies the secondary effluent. All settled sludge is removed to the RAS/WAS pumping station for recycling as return activated sludge (RAS) to the oxidation channels for further processing, or as waste activated sludge (WAS) to the drying beds for dewatering.

2.3.5 Filtration

Sand filters trap fine suspended material from the secondary effluent. The sand filters are also used to enhance the performance and reduce maintenance of the ultraviolet disinfection system. The effluent flows by gravity into and out of the filter system. The continuous backwash system releases the trapped solids from the sand media into the waste overflow which is ‘wasted’ to the Natural WWTP.

2.3.6 Ultraviolet Disinfection

The ultraviolet disinfection system is used for the inactivation/destruction of pathogenic organisms to prevent the spread of waterborne diseases to downstream users and the environment. UV lamps submerged in a channel provide ultraviolet radiation to inactivate bacteria and viruses in the treated flow. The system is paced by flow so that the system adjusts the lamp output in order to reduce energy use while achieving the required pathogen inactivation/destruction prior to gravity flow to the Water Reuse Pump Station.

2.3.7 Chemical Treatment Processes

Effluent from the UV process is chlorinated to control regrowth of bacteria in the reuse system. Because much of the effluent is reused for irrigation and cooling, bacterial growth must be controlled during the transit time between the WWTP and the end users in order to meet regulatory standards (JS 893) and prevent fouling of the end user's piping systems. Refer to Figure 2-8 regarding the existing chlorine storage and feed arrangement.

Figure 2-8. Chlorine Building with Chlorine Tanks and Feed System

2.3.8 Solids Processing

Solids processing involves the removal, processing, and disposal of screenings, grit, sludge, and scum. All of these materials are ultimately buried in the on-site landfill after processing as noted below:

- Screenings – Screening processing consists of the removal of rags from the wastewater using the mechanical screens located in the Headworks. The screenings are removed by an inclined mechanical screen that lifts and dewaters the material as it moves up and out of the channel. The screenings are dewatered through the screw compactors and deposited into containers. Screenings are sun-dried and buried on-site, co-mingled with dried sludge.
- Grit – Grit processing consists of the removal of sand like materials from the wastewater using the grit chambers located in the Headworks. Collected grit is mechanically conveyed and washed through the grit classifiers to dumpsters for subsequent disposal.
- Sludge – Sludge processing consists of Waste Activated Sludge (WAS) which is wasted daily by WAS pumps from the RAS/WAS pumping station to conventional sand drying beds. Dried biosolids ae buried on-site. Note that AWC has plans to add a gravity thickener in the near future.
- Scum – Scum is skimmed off the water surface at the Headworks, the oxidation channels, clarifiers and distribution chambers to collection pits at each point that flow by gravity to the WAS pumps to be directed to the sludge drying beds.
- Septage – Septage wastes from septic tank pump-outs are discharged by tanker to a manhole structure on the gravity sewer that drains to the facultative ponds. The existing Septage Receiving Station located east of the Headworks is not in use. All material received is directed to the Natural WWTP for treatment and is not directed to the Headworks for processing through the Mechanical WWTP as originally intended in the design. Septage becomes part of the biomass that is removed from the maturation ponds, as they are dredged periodically. These solids are also buried on site.

2.4 Initial Flows and Loadings

The Aqaba WWTP is designed to treat a combined average daily flow of 21,000 m^3/day. As noted previously, no effluent is discharged into the nearby Red Sea. The effluent from the natural process is conveyed to evaporation ponds or agriculture (irrigation). The effluent from the mechanical process is conveyed to evaporation ponds, industrial users (for cooling water) and agriculture. Table 2-1 provides the limits imposed by the current regulatory standards (JS 893) for irrigation uses where:

- Category A = Cooked Vegetables, Parks, Playgrounds and Sides of Roads within City Limits;
- Category B = Fruit Trees, Sides of Roads outside City Limits, and Landscape;
- Category C = Field Crops, Industrial Crops and Forest Trees; and
- Category D = Flowers.

Table 2-1. JS 893 Irrigation Discharge Limits

Parameter	Allowable Limits per End Use			
	Category A	Category B	Category C	Category D
Biological Oxygen Demand (mg/L)	30	200	300	15
Chemical Oxygen Demand (mg/L)	100	500	500	50
Dissolved Oxygen (mg/L)	>2	---	---	>2
Total suspended solids (mg/L)	50	200	300	15
pH (unit less)	6 to 9	6 to 9	6 to 9	6 to 9
Turbidity (mg/L)	10	---	---	5
Nitrate (mg/L)	30	45	70	45
Total Nitrogen (mg/L)	45	70	100	70
Escherishia Coli (MPN/100 ml)	100	1000	---	<1.1
Helminthes Eggs (one egg/L)	< or = 1	< or = 1	< or = 1	< or = 1

Table 2-2 provides the effluent quality originally offered by the Aqaba Water Company for industrial reuse customers. The major reclaimed water customer is the Jordan Phosphate Mines Company (JPMC), which uses up to 1.6 M m^3/year for cooling tower make-up water. The AWC has found that there is some flexibility in the effluent quality required by JPMC for cooling tower make up water compared to the effluent quality originally offered.

Table 2-2. Effluent Quality Promoted by Local Government to Attract Industrial Re-Use Customers

Parameter	Value
BOD (mg/L)	<5
TSS (mg/L)	<5
NH_3 (mg/L)	80
NO_3 (mg/L)	50
TKN (mg/L)	85
Dissolved Oxygen (mg/L)	1
Fecal Coliform (MPN/100 ml)	<= 2.2
Helminth Eggs (egg/L)	<1
TDS (mg/L)	<800

The Aqaba WWTP staff regularly samples and records certain influent, effluent and process water locations to monitor influent conditions and process performance. Table 2-3 shows the two-year average water quality and process information reported for the Aqaba WWTP from January 2013 through December 2014. This summary identifies the average value calculated over the two-year period based on the number of data points collected. As noted there are certain data that are sampled and/or reported on a more frequent schedule than others. The two-year data range for each parameter is identified by the minimum and maximum values reported.

Note that a few parameters are more consistent within narrow ranges such as pH, BOD and TSS, while most other parameters such as TDS and TN have a wide range of reported values, indicating less consistent measurements. Temperature and TDS have the least number of data points, and WWTP influent flow is the only data provided on a daily basis because it is monitored by a Parshall flume measurement device equipped with a transmitter for continuous recording.

There are also some noted irregularities with the data provided; for example the influent NH_4 and NO_3 values appear very high relative to expected wastewater influent characteristics, especially in comparison with influent BOD_5 and COD values. It was also found that the nitrogen related concentrations are reported in "ionic" form and not in the "as-nitrogen" form. BioWin modeling refers to the "nitrogen" form (only the weight of the nitrogen portion) which is typical when discussing scientific subjects such as nitrification/denitrification cycles. These issues are discussed in detail in Section 4 of this report related to the BioWin Modeling.

Table 2-3. Water Quality and Process Information Reported for 2013-2014

Parameter	Average Value	Minimum Value	Maximum Value	Number of Data Points
Mechanical Plant Influent[1] (m^3/day)	10,432	5,030	14,176	730
Influent BOD_5 (mg/L)	384	214	615	139
Effluent BOD_5 (mg/L)	6.25	1.65	16	139
Influent COD (mg/L)	796	448	1200	181
Effluent COD (mg/L)	27.4	9.8	86.8	180
Influent TSS (mg/L)	337	160	445	347
Effluent TSS (mg/L)	7	1.6	53.4	343
Influent VSS (mg/L)	279	130	600	121
Influent TDS (mg/L)	584	240	820	59
Effluent TDS (mg/L)	515	3	675	59
Influent NH_4 (mg/L)	90	7.8	152	199
Effluent NH_4 (mg/L)	6.2	0.02	79.9	199
Influent NO_3 (mg/L)	45.1	2.8	96	178
Effluent NO_3 (mg/L)	28.5	1.3	97	179
Influent TN (mg/L)	106.5	60	145	134
Effluent TN (mg/L)	12.4	1.6	52	134
Influent Temp. C	25.1	16.5	31.2	69
Effluent Temp. C	24.2	17	30.4	69
Effluent Turbidity (mg/L)	3	0.8	14	438
Influent pH	7.41	6.54	7.88	423
Effluent pH	7.03	5.72	8.68	423
Effluent Residual CL_2 (mg/L)	1.3	0	3.5	179

[1] All influent values are measured at the Headworks effluent channel.
[2] All effluent values are assumed to be measured after disinfection at the urban reuse water (URW) pump station wet well.

2.5 Design Flows

The existing collection system serving the City of Aqaba served by the Aqaba WWTP currently receives flow from 92 percent of the ASEZA area population. Small areas of development not connected to the sewer are served by on-site septic systems with leach

field disposal. The collection system includes 250 km of gravity sewers and 7 km of rising mains. Several pump stations serve various areas of the City that ultimately direct all flows through a 1200 mm gravity interceptor to the Aqaba WWTP which has a flow capacity of 21,000 m^3/d. All flows are directed to the inlet Headworks before being split to the Mechanical and Natural process trains, designed for a capacity of 12,000 m^3/d and 9,000 m^3/d, respectively.

Current design average daily flows and loadings are based upon the existing Aqaba WWTP reported performance data. The future wastewater flows and loadings are based on the Aqaba Wastewater Collection System Master Plan. In a typical wastewater collection, transmission and/or treatment system, the wastewater is composed of residential, commercial and industrial wastewater. Table 2-4 summarizes the wastewater flows and contributing allocations to the Aqaba WWTP identified in the 2010 Master Plan. Tables 2-5 and 2-6 show the range of possible flows, depending on the level of new development which may occur in Aqaba.

Table 2-4. Wastewater Flow Allocation

Catchment Type	2009 Average Flow (L/S)	Percent of Total
Airport	1.64	0.11
Commercial	27.6	1.87
Hotels	24.3	1.64
Industrial	10.5	0.71
Mixed Use	867.9	58.7
Residential	546.6	37.0

Table 2-5. Average Flows Scenario 1
Network Expansion and Investment Strategy with Major New Development

Description	2010 (m^3/day)	2020 (m^3/day)	2030 (m^3/day)
Average Daily Flow	12,000	53,000	76,000

Table 2-6. Average Flows Scenario 2
Network Expansion and Investment Strategy without Major New Development

Description	2010 (m^3/day)	2020 (m^3/day)	2030 (m^3/day)
Average Daily Flow	12,000	29,000	43,500

2.6 Peak Flows

Currently, the adjustable weirs in the flow splitter box are operated to shave peaks in influent flow through the Headworks to the Natural WWTP to minimize diurnal variations to the Mechanical WWTP and maintain a relatively constant flow condition. Based on review of the average monthly data provided there does appear to be a seasonal variation for the average daily flow, but specific diurnal patterns throughout the day are not quantified by the available data.

2.7 Wastewater Characteristics

Wastewater characteristics vary throughout the world. Domestic wastewater flows vary based on the water supply source, water consumption and site-specific conditions. For

wastewater treatment process design, determining the flow rate and mass loading variations are important in sizing certain unit processes. Unfortunately, there are no typical values for wastewater due to these variations. An adequate determination of wastewater characteristics is best made from existing sampling data (if available) or by gathering the data that is missing before designing the WWTP. For this evaluation, two years of influent loading data was provided by WWTP staff for the period January 2013 through December 2014 which is summarized in Table 2-7 for certain parameters as noted.

As required for proper operation of an activated sludge system, a portion of the settled solids from the clarifiers is recycled back to the splitter box feeding the oxidation channel tank as return activated sludge (RAS). The remaining waste activated sludge (WAS) is periodically pumped directly to the sludge drying beds for dewatering.

Table 2-7. Wastewater Waste Load Estimates for BOD_5, TSS, and TN

Description	Current Flow 10,400 m^3/d		Design Flow 12,000 m^3/d		Future Flow 76,000 m^3/d	
	mg/L	kg/day	mg/L	kg/day	mg/L	Kg/day
BOD_5	382	3,973	382	4,584	382	29,032
TSS	337	3,505	337	4,044	337	25,612
TKN	106	1,102	106	1,272	106	8,056

[1] *Current loading is based on 2013-2014 reported data from AWC for the Mechanical WWTP from the Headworks effluent channel.*

At the time this report was prepared, it was understood that the leachate from the sludge drying beds, as well as other waste side streams (filter back-wash, plant drains and septage) are directed to the Natural WWTP for treatment and not recycled to the Headworks which is more typical for a Mechanical WWTP design. As a result, these loadings are not sampled and thus excluded from the influent flow and quality data provided by the Operations staff.

As a footnote, after the design calculations were completed and this report drafted, it was learned that the filter backwash is actually returned to the Headworks. Although it was too late to incorporate this change, the next level of design will need to take this into consideration.

The Operations staff provided septage delivery volumes on a monthly basis for January 2014 through January 2015 which is summarized in Table 2-8. These quantities are assumed to represent a typical five year maintenance pumping frequency of the properties served by septic systems in the area.

Table 2-8. Waste Septage Quantities Discharged to Aqaba WWTP

Date	Monthly Quantities Cubic Meters
Jan 2014	1,906
Feb 2014	2,350
Mar 2014	2,703
Apr 2014	2,444
May 2014	1,735
Jun 2014	1,727
July 2014	1,662
Aug 2014	1,685
Sept 2014	1,622
Oct 2014	2,191
Nov 2014	1,856
Dec 2014	1,628
Jan 2015	2,917
Average	**2,033**

With no reported sampling data, septage waste load projections are based on wastewater industry references for recommended design values as presented in Table 2-9. In keeping with the current statistics, future waste flow and load estimates (Table 2-10) are based on an assumption that 10 percent of the population will continue to be served by septic systems because their locations are beyond the sewer infrastructure service areas.

Table 2-9. Septage Waste Load Estimates For BOD_5, TSS, and TN

Description	Waste Load at Average Flow [2] 2,033 m^3/month	
	mg/L	kg/day
BOD_5	7,000	468
TSS[1]	10,500	702
TKN	700	47

[1] *Concentration is 15,000 mg/L prior to 30% reduction in the headworks.*
[2] *Key References: EPA 832-F-99-068, Decentralized Systems Technology Fact Sheet Septage Treatment/Disposal, September 1999; EPA 625/1-80-012, Onsite Wastewater Treatment and Disposal Systems, October 1980; Lindeburg, M, Civil Engineering Reference Manual for the PE Review, Twelfth Edition, 2011, p.29-3, Table 29.3, Comparison of Typical Septage and Municipal Sewage*.

Table 2-10. Total Wastewater Waste Load Estimates (Septage and Sewage Flow) for BOD_5, TSS, and TKN

Description	Current Flow 10,400 m^3/d		Design Flow 12,000 m^3/d		Future Flow 76,000 m^3/d	
	mg/L	kg/day	mg/L	kg/day	mg/L	Kg/day
BOD5	424	4,441	419	5,052	388	29,488
TSS	402	4,206	393	4,746	346	26,296
TKN	110	1,149	109	1,319	107	8,132

The septage loading to the Mechanical WWTP varies slightly with increasing flow because the Natural WWTP is assumed to maintain a maximum capacity of 9,000 m^3/d.

3 FUTURE EFFLUENT AND REUSE REQUIREMENTS

3.1 Background

The Aqaba WWTP includes both mechanical and natural treatment process trains and is not allowed to discharge any flow to the Gulf of Aqaba. Reuse of effluent is the best use and highest objective of AWC. Figure 3-1 shows the reuse pump station at the Aqaba WWTP.

Figure 3-1. Urban Water Reuse Effluent Pump Station

There are a number of reuse distribution points from both processes as noted in Table 3-1, and what is not utilized by reuse customers is directed to the evaporation ponds. Future expansion of the facility has been documented in the "Aqaba Wastewater Collection System Master Plan" (Master Plan) dated July 2010. The Master Plan recommended that the facility upgrades be focused on the Mechanical WWTP, to continue to produce final effluent quality that will meet current and future limitations and reuse requirements. This will enable AWC to reclaim some of the costs associated with upgrading the plant by selling the effluent to private companies for beneficial reuse.

Table 3-1. Aqaba WWTP Effluent Distribution

Treatment Process	Distribution
Mechanical WWTP	Evaporation Ponds
	ASEZA – Irrigation
	Jordan Phosphate Mines (JPMC) – Cooling Systems
	Others – Miscellaneous Irrigation
Natural WWTP	Evaporation Ponds
	Agriculture - Irrigation

Each treatment train is maintained independently and the effluent is distributed to separate customers. Effluent from the natural treatment train is distributed to the Agricultural Reclaimed Water (ARW) network to a number of customers, primarily for agricultural irrigation use, many of which are seasonal. With a higher quality effluent produced by the mechanical process, effluent from the mechanical treatment train is distributed to the Urban Reclaimed Water (URW) network to a number of commercial customers including several farms (ASEZA) for irrigation and JPMC, a commercial customer, for cooling tower use; leaving some capacity available for new reclaimed wastewater customers.

3.2 Regulations

Reclaimed Wastewater is regulated by the Jordanian Institute of Standards and Metrology (JISM) by Technical Regulation No. 893/2006 titled "Water – Reclaimed Domestic Wastewater" (JS 893). The specification is divided into two main parts:

- Reclaimed water to be discharged to streams, wadis, or water bodies
- Reclaimed water for reuse

The reclaimed water for reuse is further divided into: reuse for the purpose of artificial recharge of groundwater aquifers (not for drinking water) and reclaimed water reuse for irrigation, which represents the majority of the customers of the Aqaba WWTP.

In accordance with the regulation, reclaimed water to be used for purposes other than those mentioned in this standard (such as cooling or fire extinguishing) requires that special standards or guidelines be applied in each case after conducting the necessary studies taking into consideration the health and environmental limitations. Current effluent quality data from the Mechanical WWTP are listed in comparison with the water quality criteria promoted by local government to attract potential industrial end users. It is understood that JPMC has not established standards for water quality requirements.

Table 3-2. Reuse Water Quality Promoted by Local Government

Test	Promotional Standard	Current WWTP Effluent[1]
Process Flow (m^3/d)	4,700	10,400 m^3/d
BOD (mg/L)	<5	6.3
TSS (mg/L)	<5	7
NH_3 (mg/L)	80	6.2
NO_3 (mg/L)	50	29
TKN (mg/L)	85	---
Dissolved Oxygen (mg/L)	1	---
Fecal Coliform (MPN/100 ml)	<= 2.2	---
Helminthes Eggs (one egg/L)	<1	---
TDS (mg/L)	<800	600

[1] WWTP performance values based on 2013 through 2014 monthly averages unless absent and unreported.

JPMC reclaimed water demand is 1,600,000 m^3/year 48 weeks per year, 7 days per week, 24 hours per day (plant shuts down 1 month per year for maintenance during which they accept no reclaimed water). Any waste side streams will be returned to the main WWTP by tanker truck.

TDS is a primary concern for JPMC because the water is used as make-up water for its cooling towers, where scaling can be a problem. Recent WWTP effluent quality average TDS is reported to be below 600 mg/L.

3.3 Future Effluent Requirements

As discussed, future WWTP flows are expected to increase based on significant growth in the region. In addition, the reclaimed wastewater regulation JS 893 is currently under review for modification. Future upgrades to the Aqaba WWTP, and specifically to the mechanical process treatment train, should address these changes to accommodate the future market for reclaimed water.

3.4 Existing Conditions

3.4.1 General

The current operations of the Aqaba WWTP include a number of practices that enhance the performance conditions of the Mechanical WWTP to provide high quality reuse water to its customers. The Mechanical WWTP is able to consistently produce Type A quality reclaimed water for its irrigation and farming reuse customers as well as JMPC as a commercial user.

When treated effluent flow exceeds the reuse demands (likely a seasonal condition) the effluent can be diverted to the Natural WWTP and ultimately to evaporation ponds; as discharges are not allowed to the local groundwater or nearby harbor. The diversion also serves to introduce clean water to the ponds for dilution.

3.4.2 Effluent Reuse Requirements

The reported data indicate that the Mechanical WWTP currently meets the effluent reuse quality requirements of JS 893 and its current customers.

3.4.3 Industrial Reuse

AWC could benefit from the favorable relationship with JPMC as a large volume customer by maintaining high water quality for cooling tower use. As reported by AWC, the current WWTP effluent quality summarized in Table 2-3 appears adequate, with a few exceptions noted for maximum values. For example, BOD_5 and TSS reported average values of 6 mg/L and 7 mg/L respectively and 2-year maximum values of 16 mg/L and 53 mg/L respectively, but fall short of the quality promoted to attract industrial end users.

3.5 Future Effluent and Reuse Requirements

With future development expected, the AWC is interested in developing more high quality reuse customers to offset the cost of the required WWTP expansion required to treat the additional wastewater generated. At this time, the information on the changes expected to JS 893, 2006 are not available, but the expectation is that there will be many reclamation opportunities for the current water quality from the Mechanical WWTP. In addition, there are customers of the ARW system served by the Natural WWTP that receive Type B quality (e.g., Airport) that are proposed to be supplied with Type A quality reclaimed water that the Natural WWTP cannot currently provide. With increased quality demands on the ARW system, it is assumed that the Mechanical WWTP will supply the water. In addition there are potential customers in the northern development referenced in the Master Plan that would seek Type A quality.

With Aqaba's economic growth trending higher than the average growth in the country due to the ASEZ status, there are several new resorts, housing and retail development under construction that could benefit from a high quality water reuse supply in the desert climate. Several of these developments are reported to be 'mega projects' that involve luxury hotels, with man-made canals, golf courses and similar high water use features. Maintaining consistent high quality WWTP effluent with a cost effective treatment process is important to provide a reliable product available to AWC customers. Table 3-3 provides a comparison of the current goals or standards for reuse quality and recommended future design target goals for effluent quality from the Mechanical WWTP.

The reuse standards per JS 893 are a combination of the most restrictive limits for each parameter for Categories A, B, and C reuse water quality. In meeting these limits, all other JS 893 requirements are met for fruit trees, field crop irrigation, and landscaping use. The limits for Flowers are more restrictive for a number of parameters related to human exposure because they are picked and distributed individually or in the form of bouquets for ornamental purposes with potential for direct contact by hand or by nose. Flower reuse

disinfection requirements to meet *E-coli* limits are so much more stringent than other reuse categories that AWC may not want to supply reuse to this type of customer.

Table 3-3. Reuse Water Quality Requirements

Parameter	Irrigation Reuse Group A-C[1] per JS 893	Irrigation Reuse Group D[2] Flowers	Promoted for Industrial Use
Biological Oxygen Demand (mg/L)	30	15	<5
Chemical Oxygen Demand (mg/L)	100	50	-
Dissolved Oxygen (mg/L)	>2	>2	>1
Total Suspended Solids (mg/L)	50	15	<5
Total Dissolved Solids (mg/L)	1500	1500	<800
Total Nitrogen (mg/L)	45	70	-
Nitrate (mg/L)	30	45	50
Ammonia (mg/)L	-	-	80
TKN (mg/L)	-	-	85
Turbidity (NTU)	10	5	10
pH	6-9	6-9	6 - 9
Escherishia Coli (MPN/100 ml)	100	<1.1	100
Helminthes Eggs (one egg/L)	<= 1	<=1	<=1

[1]Standards include the most restrictive limit on each parameter based on Group A except Flowers
[2]The Flower Category requires low E.coli because of human contact risks

JS 893 does not specify requirements for industrial reuse as they are developed specifically in agreement between the user and the water supplier. As indicated in Table 3-2 the current WWTP effluent quality, is generally meeting these criteria with a few exceptions for maximum values, with consistently lower values for TDS (averaging 600 mg/L) compared with the Promotional Standard of 800 mg/L.

For reuse in cooling towers, the primary concerns include corrosion, scaling, fouling, and microbiological activity. This wide range of concerns makes it critical that the effluent reuse quality remain at a high standard for pH, alkalinity, solids content and BOD_5 among other parameters. Nitrogen can also be a concern with respect to algae growth in cooling towers and process piping.

3.6 Recommendations

As noted in Table 3-3, reuse quality requirements vary significantly and the strict limit on *E. coli* for Flower use would require a WWTP effluent that would be difficult to guarantee. This business category should not be a target reuse customer for AWC. However, the Mechanical WWTP should be able to reliably meet the JS 893 Reuse Groups A to C requirements with additional nitrogen removal through denitrification and proper operation and monitoring of the treatment process. The reuse water quality limits promoted by local government for BOD and TSS values <5 mg/L are not currently being met, but based on review of other cooling tower references, these limits may be relaxed for reuse as cooling tower make-up water.

Future effluent reuse goals should be developed based on the ability of the WWTP to produce the required effluent consistently and cost effectively.

4 BIOWIN MODEL

4.1 General

BioWin, a commercial wastewater modeling software produced by EnviroSim, was used to model the facility. The objective was to determine the operational flexibility within the existing facilities, if the existing facilities will have to be modified and/or if new physical or biological processes will be required for future flow conditions. Some of these alternative treatment processes are described in Section 5.

4.2 Historical Data

The Aqaba WWTP provided AECOM with two years (2013-2014) of influent/effluent record data, as well as some data from recent sampling of the intermediate processes. Limited data on the biological process was provided. Typically, when conducting an evaluation of a WWTP with a computer model, additional process stream sampling is used to supplement the wastewater data and to help calibrate the computer model. Due to the short time frame of the current evaluation, minimal additional process stream sampling was performed. Additional process stream sampling should be performed in the future to further refine the model.

4.3 Data Analysis

Prior to use in the process model, the data were examined for outliers or inconsistent values. Such outlying points can be attributed to the dynamic nature of wastewater treatment, the relatively short time frame of the wastewater sampling program, sample handling, data entry errors, and testing anomalies. It is important to eliminate erroneous data points before developing the model. Overall, less than 1 percent of the data points were deemed unreasonable and discarded. Data were discarded for two main reasons:

- Excessively high/low with respect to related data points (outliers); and
- Constituent elements that did not correlate. For example, the concentration of ammonia (a portion of total nitrogen) cannot be greater than the concentration of total nitrogen.

In situations where it was unclear which data point was erroneous, several data points may have been discarded.

Some data points were not discarded although their accuracy was questionable. For example, in the month of December 2013, a plant influent flow of 9,735 m^3/day, clarifier underflow of 9,362 m^3/day and WAS flow of 312 m^3/day were reported for 31 days in a row. Although this occurrence is unlikely, the flow data was used in the model as no other data was available. 23 separate days of zero WAS flow were also reported. It is unclear if this is an error or part of normal plant operations. It was noted that the MLVSS data was more consistent than is usually expected—the measurements were frequently exactly or very close to 75% of the associated MLSS measurements.

Additionally, it was noted that large blocks of headworks effluent TSS data appear to repeat as shown in Figure 4-1. It is unclear why this occurred. In the absence of any other information, these data were used in the model. Furthermore, significant variations in performance were reported for 2013 in comparison with 2014.

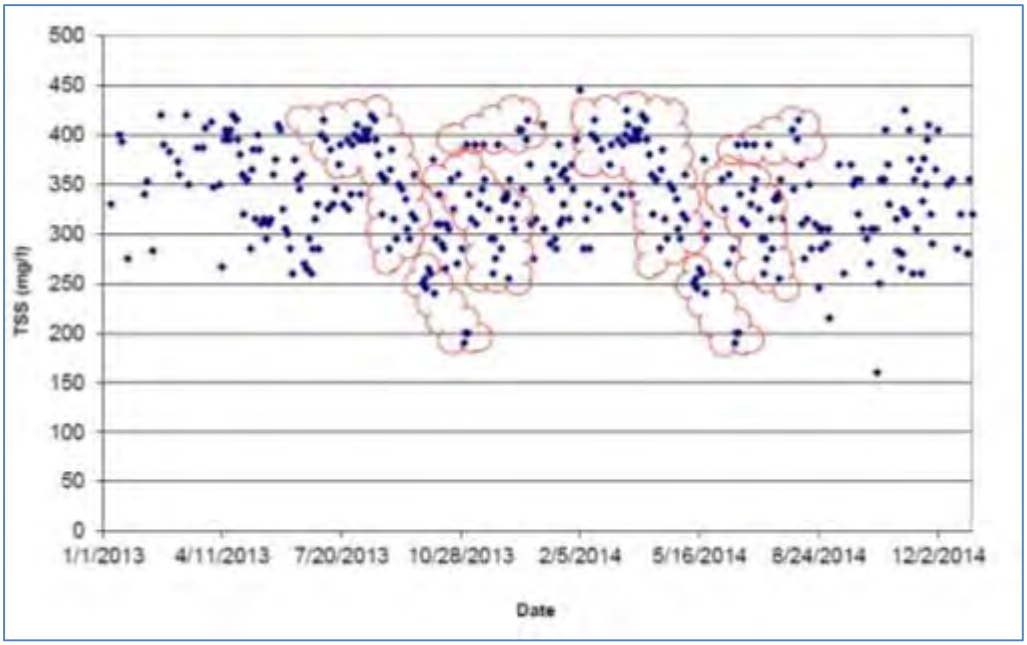

Figure 4-1. Headworks Effluent TSS Concentration, 2013-2014

Further data analysis noted that the influent nitrate data, which ranged from 2.8 mg/L to 96 mg/L, is unusually variable and inconsistent as shown in Figure 4-2. Usually, ammonia represents the bulk of nitrogen in the influent, and influent nitrates in wastewater are a very small fraction of TKN. The nitrate values were thus assumed to be reported in the ionic form of nitrate. These values were converted to nitrogen form of nitrate (NO_3-N) for the BioWin model by taking the reported ionic nitrate (NO_3) and dividing by 4.29 to adjust for the atomic weight, to calculate the concentration of nitrate as nitrogen (NO_3-N). Even with this conversion adjustment, the data does indicate a few inconsistencies remaining, as shown in Figure 4-3.

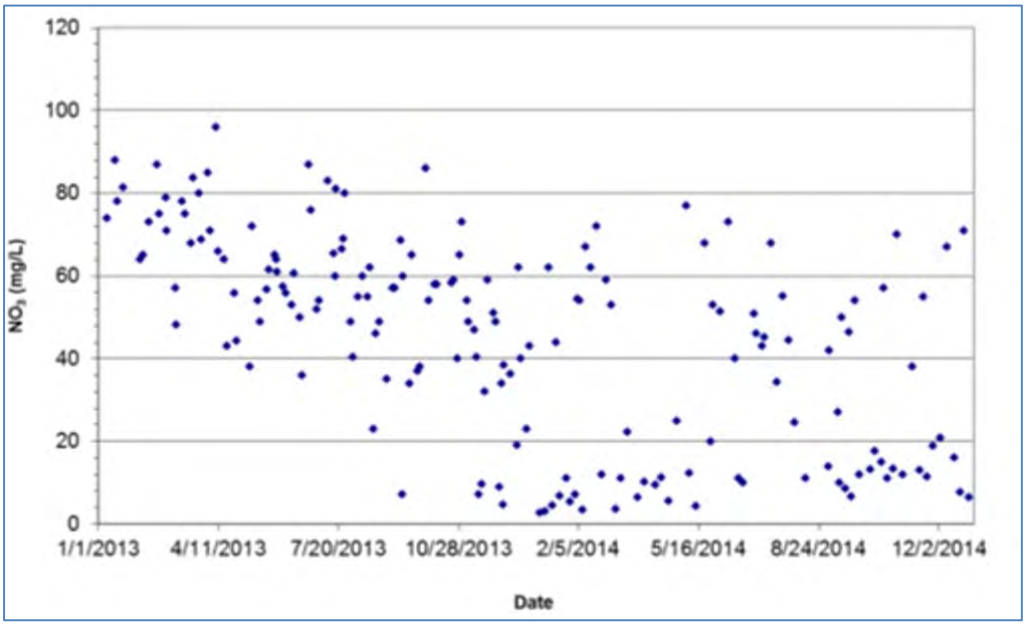

Figure 4-2. Headworks Effluent NO_3 Concentration without Adjustments, 2013-2014

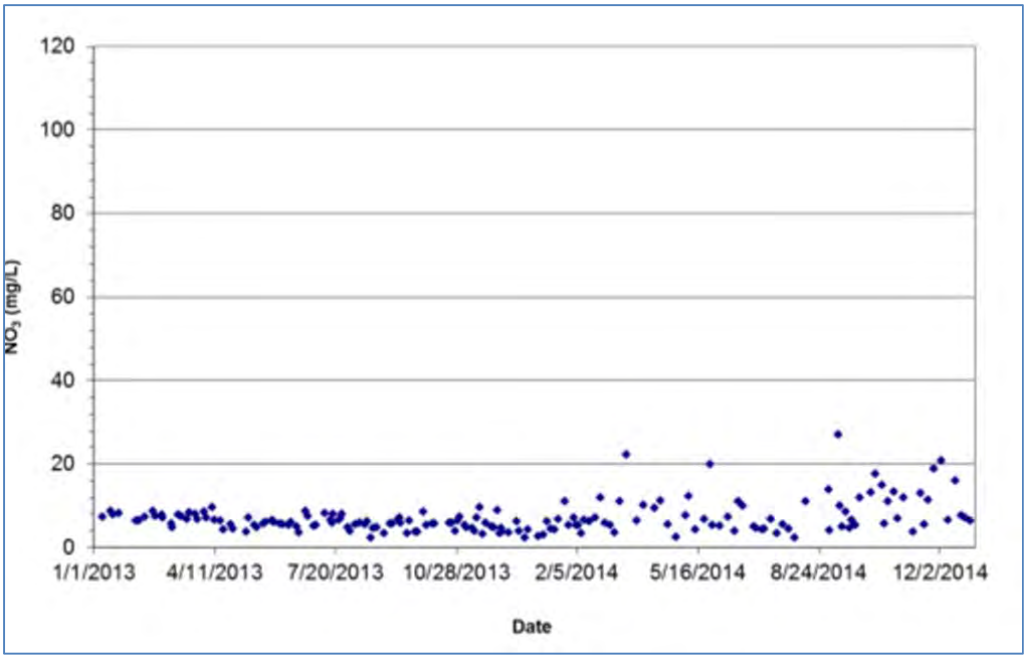

Figure 4-3. Headworks Effluent Adjusted NO_3 Concentration, 2013-2014

Data was provided for ammonia (NH_3) but not TKN (which is required as a BioWin model input). However, TKN was calculated based on the fact that NH_3 typically represents 2/3 of influent TKN in wastewater.

The raw data provided by the Aqaba WWTF operations staff is provided in Appendix A. All influent values are measured at the Headworks effluent channel. Plant effluent values are assumed to be measured after disinfection at the urban reuse water (URW) pump station. Adjusted average data is summarized in Table 4-1.

Table 4-1. Liquid Stream Process Data

Parameter	Monitoring/Sampling Location			
	Headworks Effluent	Plant Effluent	Oxidation channel 1	Oxidation channel 2
Flow (m^3/day)	10,432	--	--	--
BOD (mg/L)	382	6.25	--	--
COD (mg/L)	791	27.39	--	--
TSS (mg/L)	337	7.04	--	--
VSS (mg/L)	271	--	--	--
ISS (mg/L)	82	--	--	--
TDS (mg/L)	584	515	--	--
NH_4-N (mg/L)	71 (91)	4.8 (6.2)	--	--
NO_3 -N (mg/L)	10.2 (45)	6.4 (28.5)	--	--
TN (mg/L)	106	12.4	--	--
Temp. (C)	25.07	24.09	--	--
Turbidity (mg/L)	--	3	--	--
pH	7.41	7.04	--	--
Cl_2 (mg/L)	--	1.53	--	--

Parameter	Monitoring/Sampling Location			
	Headworks Effluent	Plant Effluent	Oxidation channel 1	Oxidation channel 2
MLSS (mg/L)	--	--	2,478	2,477
MLVSS (mg/L)	--	--	1,820	1,793

[1] BioWin refers to NO_3-N and NH_4-N in the model. The reported values in "ionic" form are included in parentheses for these parameters in comparison.

Table 4-2. Solid Stream Process Data

Solid Stream	Average Daily Flow (m^3/day)	Average TSS	Average TVSS
RAS	7,400	5,200	3,650
WAS	390	Not Measured (assumed same as RAS)	Not Measured (assumed same as RAS)

4.4 Process Model Calibration

This section describes the steps taken to calibrate the data to develop a process model of the existing plant.

4.4.1 Process Model Calibration

4.4.1.1 Process Flow Diagram

With the data from the wastewater characterization, a BioWin model of the existing secondary treatment process was successfully calibrated. The first step in this calibration was inputting the physical dimensions of the existing processes. These dimensions are displayed in Table 4-3.

Table 4-3. Existing Plant Physical Dimensions

Location	No.	Diameter, Each (M)	Length, Each (M)	Width, Each (M)	Depth, Each (M)	Total Area (M^2)	Total Volume (M^3)
Oxidation Channels	2	---	127.5	44.8	3.0	10,580*	31,740*
Existing Secondary Clarifiers	2	28	---	---	4.94	1,232	6,084

* Total area and volume for the two oxidation channels are as calculated by AECOM based on the provided record drawings. The oxidation channels are not rectangular (the ends are rounded) so calculating LxW LxWxD will not yield the total area or volume as calculated.

The oxidation channels were modeled as a series of anoxic and aerobic completely mixed bioreactors to better approximate the process. In addition to the physical dimensions of the processes, the measured operational parameters such as recycle and sludge flow rates were also input to the model. The process flow diagram from the model is displayed in Figure 4-4.

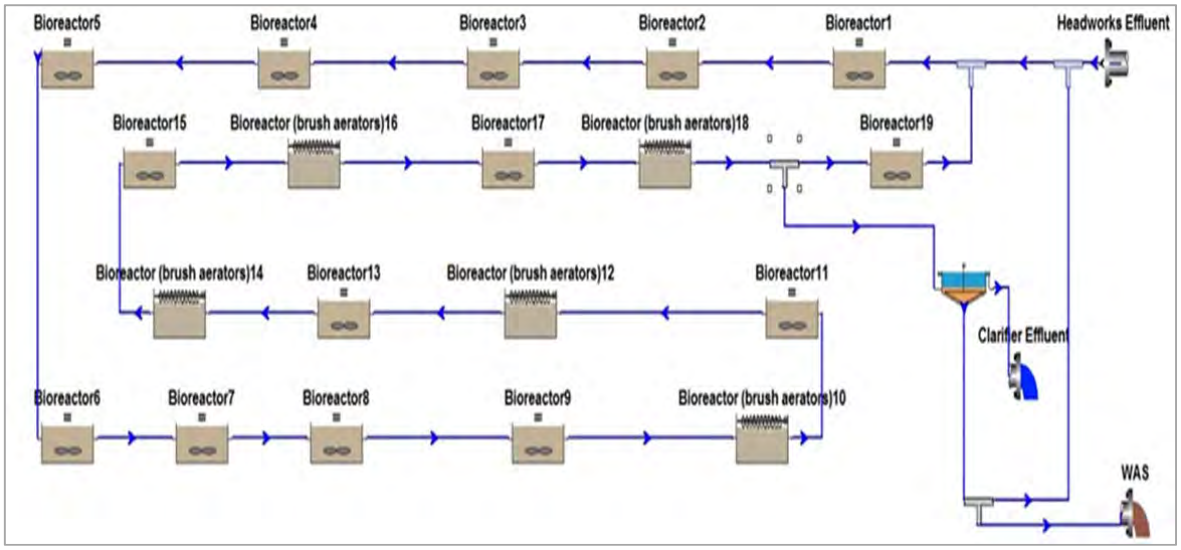

Figure 4-4. Process Flow Diagram

4.4.1.2 Calibration Process

The intent of the calibration process is to reach a state where the modeled results approximate the measured data. To do this, the model was dynamically calibrated using the data received based on the current design and operations with all side streams flowing to the natural process (lagoons). Data were not provided for all inputs for each of the 730 days modeled, and the BioWin model interpolated missing data points.

The model requires the following inputs:

- Headworks Effluent Flow
- Headworks Effluent COD
- Headworks Effluent TKN
- Headworks Effluent Total P
- Headworks Effluent Nitrate
- Headworks Effluent pH
- Headworks Effluent Alkalinity
- Headworks Effluent ISS
- Headworks Effluent Calcium
- Headworks Effluent Magnesium
- Headworks Effluent Dissolved Oxygen
- Process Temperature
- Oxidation channel Split Rate (the ratio of flow sent to the clarifiers vs. recirculated in the oxidation channels)
- Clarifier Effluent Underflow Rate (total flow of solids from the clarifiers, the total of RAS and WAS flow)
- WAS flow.

Data was provided for headworks effluent flow, COD, nitrate and pH. However, some of these data required modification, as described in Section 4.3. The data input and calibration process is described below.

Only 32 influent/effluent temperature data points were provided for the 2013-2014 period. The daily influent and effluent temperatures were averaged and used as inputs to the model. Temperatures were interpolated between data points.

No data were provided for headworks effluent Phosphorus, Calcium and Magnesium. These were left at the default levels BioWin assigns. Headworks effluent Inert Suspended Solids (ISS) is determined from the difference between TSS and VSS. In this case, however, there were relatively few days that had both TSS and VSS measurements. During the calibration, the default BioWin level for ISS was used as it resulted in a reasonable correlation to the measured TSS.

RAS and WAS flow rates were provided. Secondary clarifier underflow was set as sum of the RAS and WAS flow rates.

No data was provided for the rate of flow in the oxidation channels. Therefore, AECOM assumed (based on prior experience with brush aerator ditches) that the liquid in the oxidation channels would be moving at about 0.03 m/s. Using the cross sectional area of the oxidation channels, a volume of recirculating flow per day was calculated.

When the model was first run, the calculated concentration of MLSS was found to be inaccurate. In order to improve the calibration, the measured WAS flow volume per day was adjusted. It is not uncommon to adjust the WAS flow rate during model calibration. Often this is due to inaccurate WAS flow meter calibration. The model calibration was an iterative process. Table 4-4 summarizes the reduction factors used.

Table 4-4. Model Calibration - WAS Reduction Factors

Date Range	Reduction Factor
1/1/13-2/28/13	0.35
3/1/13-6/30/13	0.6
7/1/13-12/31/13	1.0
1/1/14-1/15/14	0.75
1/16/14-8/31/14	1.0
9/1/14-9/30/14	1.35
10/1/14-10/31/14	1.0
11/1/14-12/31/14	0.8

After the MLSS concentration was calibrated, attention was turned to the effluent ammonia. It was noted that the model was calculating periods of very low pH in the clarifier effluent. Periods of very low pH inhibit the biological process from metabolizing nitrogen sources. In order to calibrate ammonia, pH across the treatment process was adjusted by adjusting alkalinity. In an iterative process, alkalinity was adjusted to compensate for periods of low pH, and the effluent NH_4 began to calibrate to the observed values. Table4-5 summarizes the alkalinity values used.

Table 4-5. Model Calibration - Alkalinity Adjustments

Date Range	Alkalinity (mmol)
1/1/13-2/4/13	13
2/5/13-3/25/13	14
3/26/13-4/3/13	13
4/4/13-4/18/13	14
4/19/13-4/24/13	13
4/25/13-5/12/13	15

Date Range	Alkalinity (mmol)
5/13/13-6/12/13	13
6/13/13-7/2/13	15
7/3/13-11/15/13	12
11/16/13-11/29/13	13
11/30/13-12/16/13	14.5
12/17/13-12/31/13	13
1/1/14-2/26/14	7.2
2/27/14-3/13/14	8
3/14/14-8/6/14	7.2
8/7/14-8/14/14	8
8/15/14-12/31/14	7.2

4.4.1.3 Results

The results of the calibration process are shown in the graphs on the following pages as Figure 4-5.

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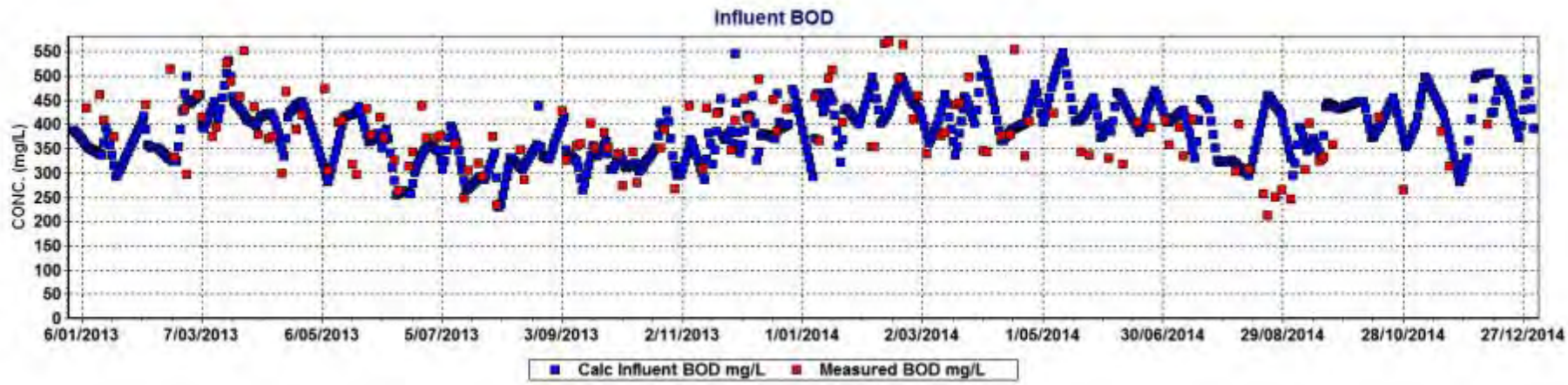


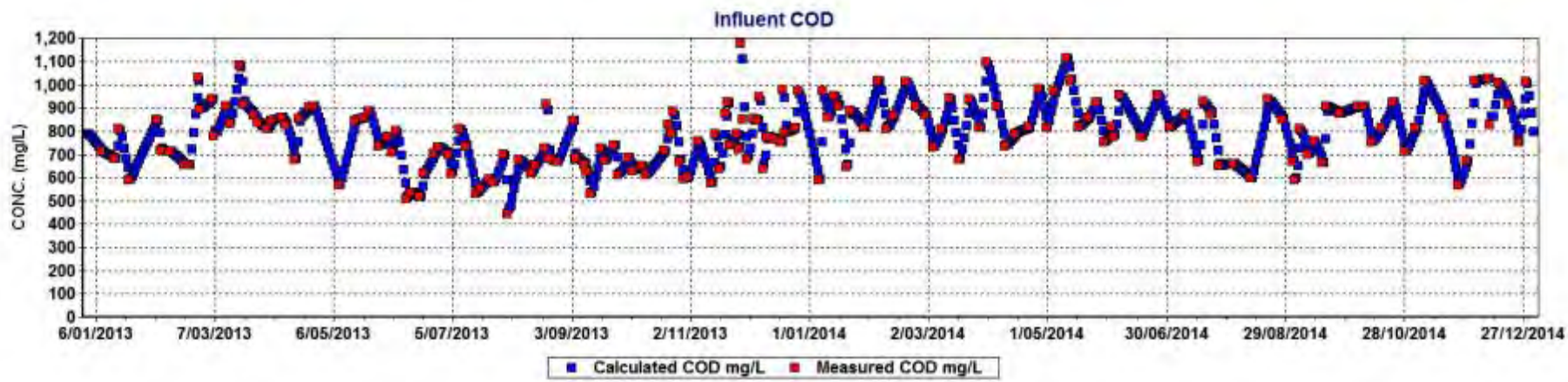
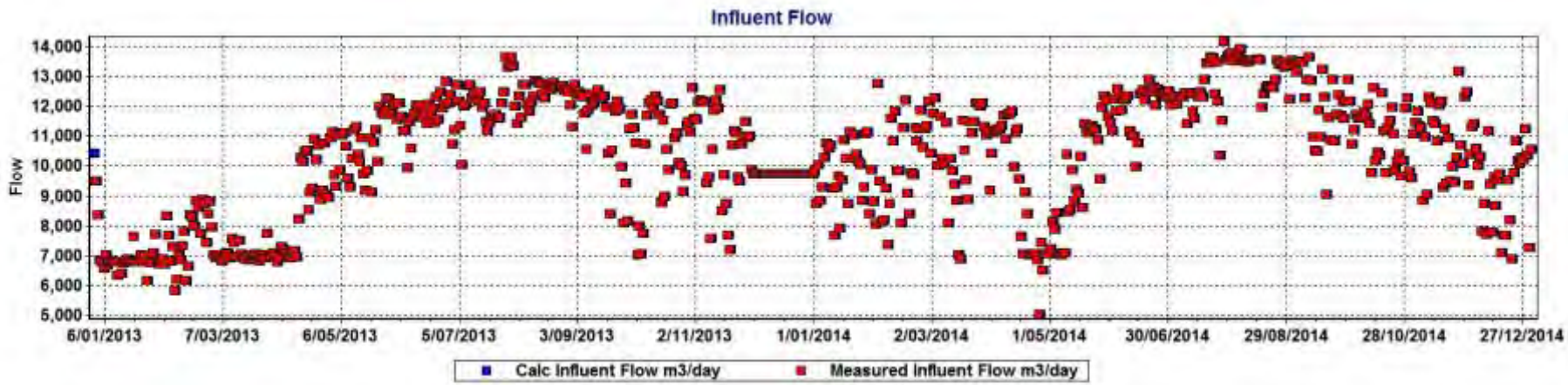
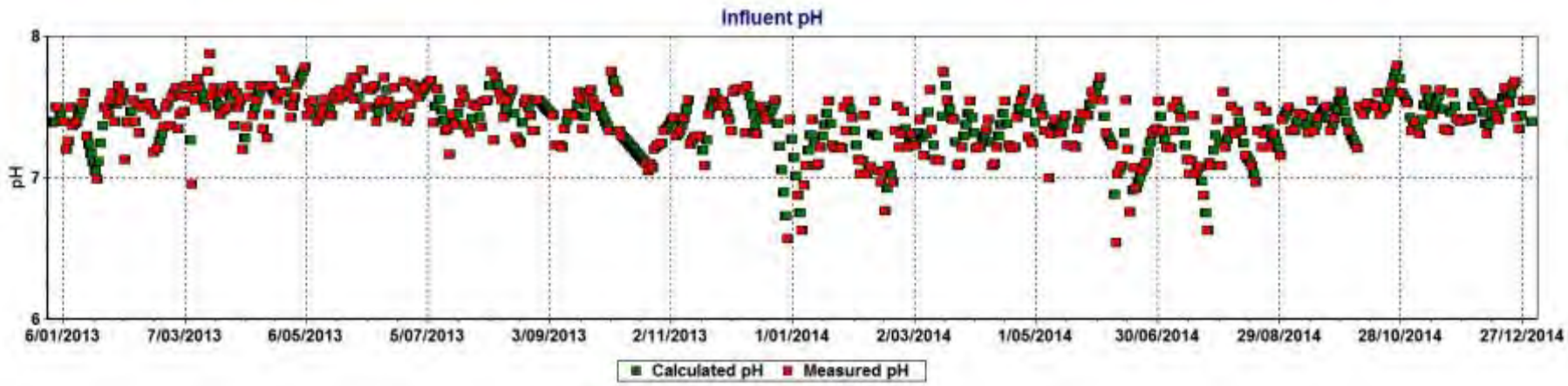
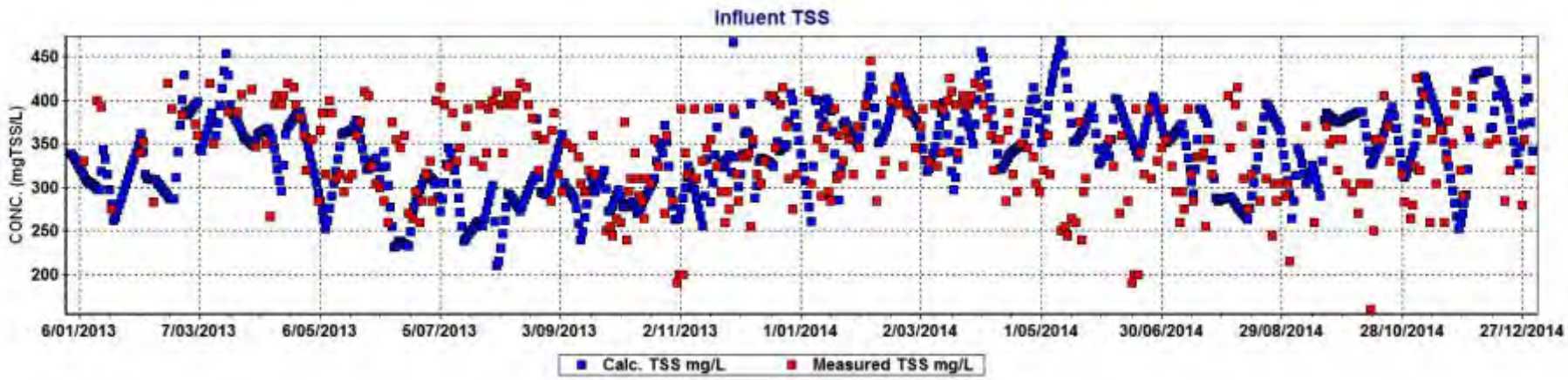


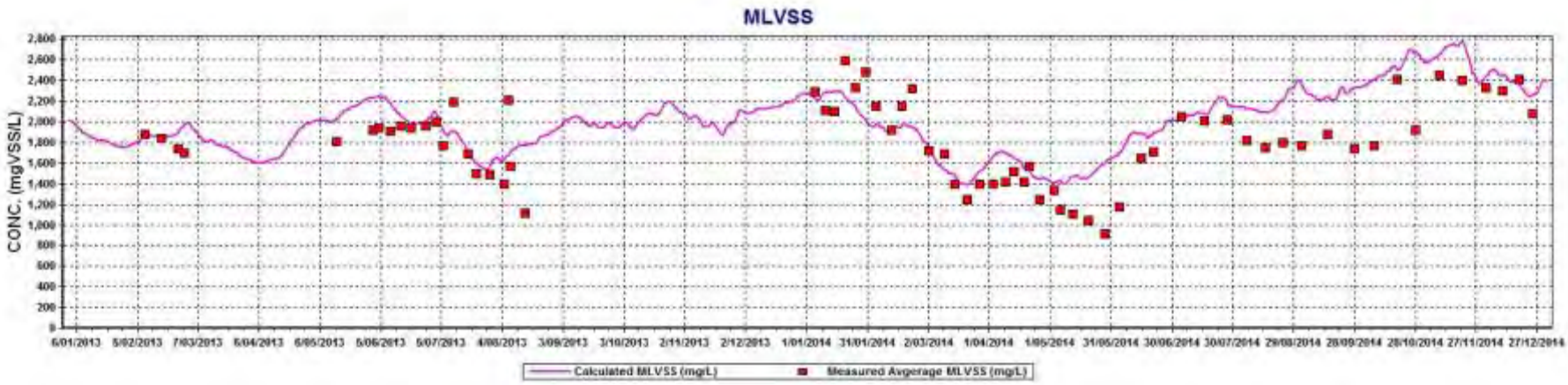
Figure 4-5. Calibration Process Results

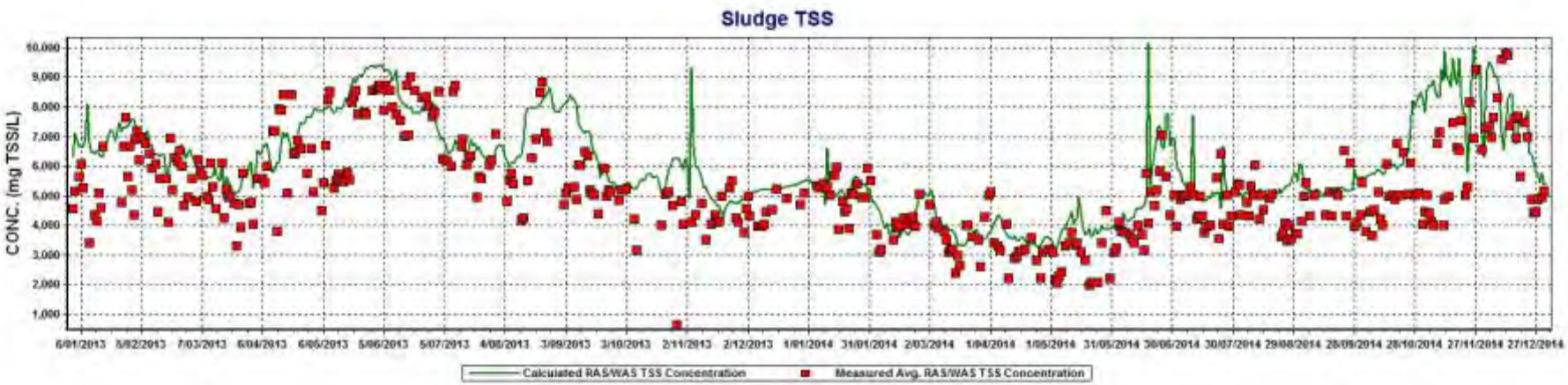

Influent Flow
Flow
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
6/01/2013
7/03/2013
6/05/2013
5/07/2013
3/09/2013
2/11/2013
1/01/2014
2/03/2014
1/05/2014
30/06/2014
29/08/2014
28/10/2014
27/12/2014
Calc Influent Flow m3/day
Measured Influent Flow m3/day

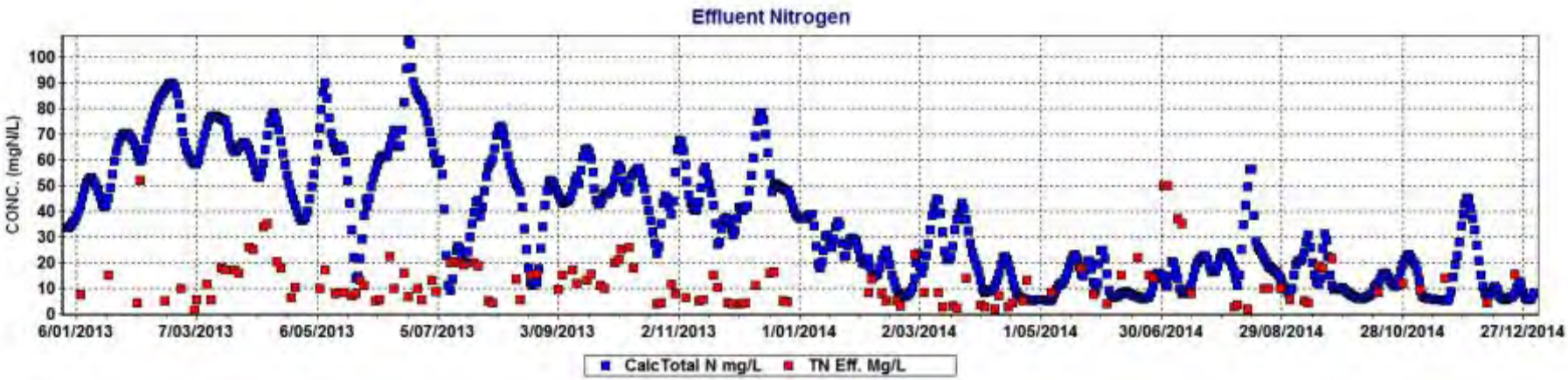

Influent pH
pH
8
7
6
6/01/2013
7/03/2013
6/05/2013
5/07/2013
3/09/2013
2/11/2013
1/01/2014
2/03/2014
1/05/2014
30/06/2014
29/08/2014
28/10/2014
27/12/2014
Calculated pH
Measured pH


Influent TSS
CONC. (mgTSS/L)
450
400
350
300
250
200
6/01/2013
7/03/2013
6/05/2013
5/07/2013
3/09/2013
2/11/2013
1/01/2014
2/03/2014
1/05/2014
30/06/2014
29/08/2014
28/10/2014
27/12/2014
Calc. TSS mg/L
Measured TSS mg/L

MLSS
CONC. (mgTSS/L)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
6/01/2013
7/03/2013
6/05/2013
5/07/2013
3/09/2013
2/11/2013
1/01/2014
2/03/2014
1/05/2014
30/06/2014
29/08/2014
28/10/2014
27/12/2014
Calculated Avg. MLSS
Measured Avg. MLSS (mg/l)


MLVSS
CONC. (mgVSS/L)
Calculated MLVSS (mg/L)
Measured Avgerage MLVSS (mg/L)


Sludge TSS
CONC. (mg TSS/L)
Calculated RAS/WAS TSS Concentration
Measured Avg. RAS/WAS TSS Concentration


Effluent Nitrogen
CONC. (mgN/L)
100
90
80
70
60
50
40
30
20
10
0
6/01/2013
7/03/2013
6/05/2013
5/07/2013
3/09/2013
2/11/2013
1/01/2014
2/03/2014
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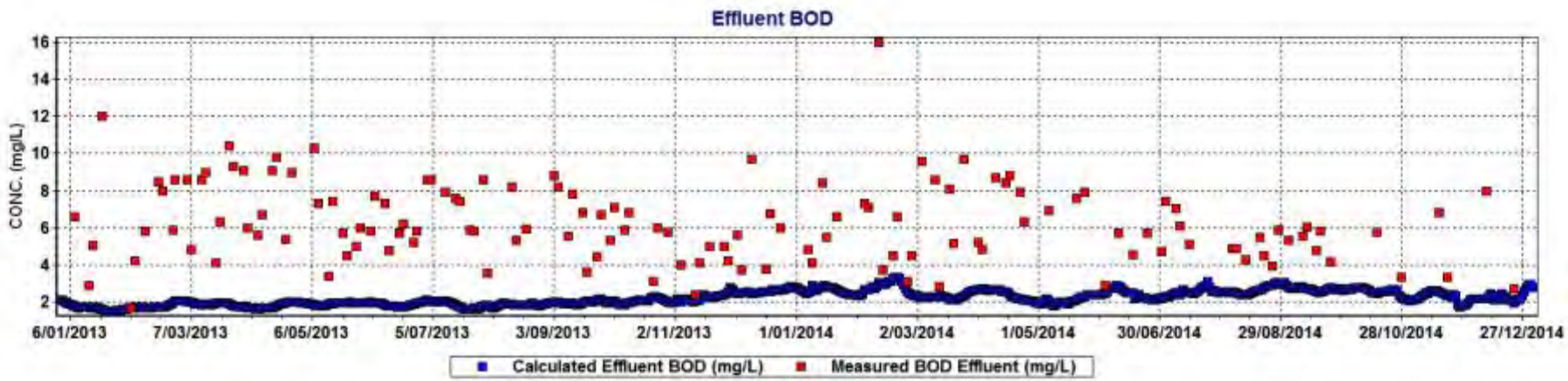
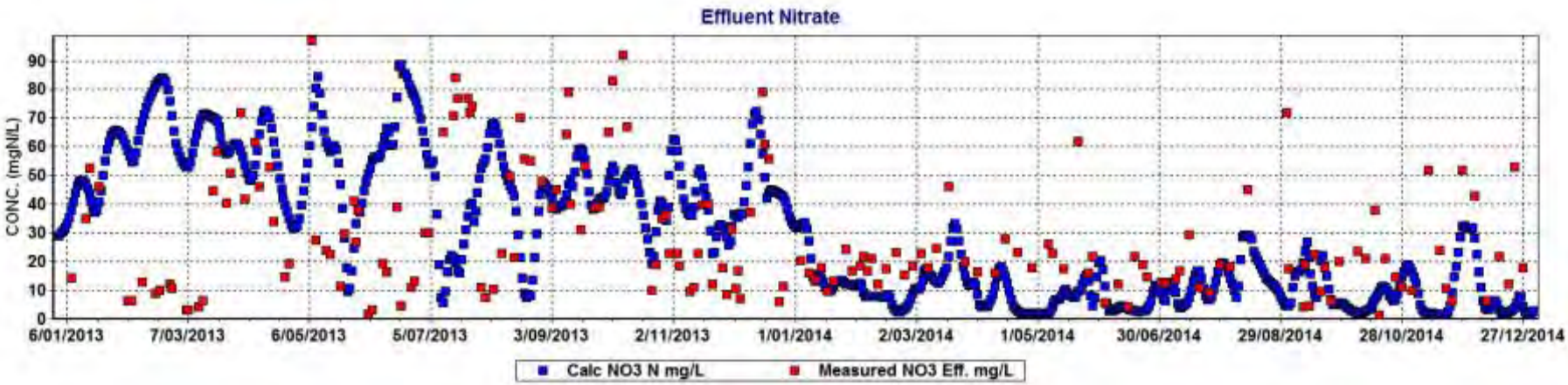
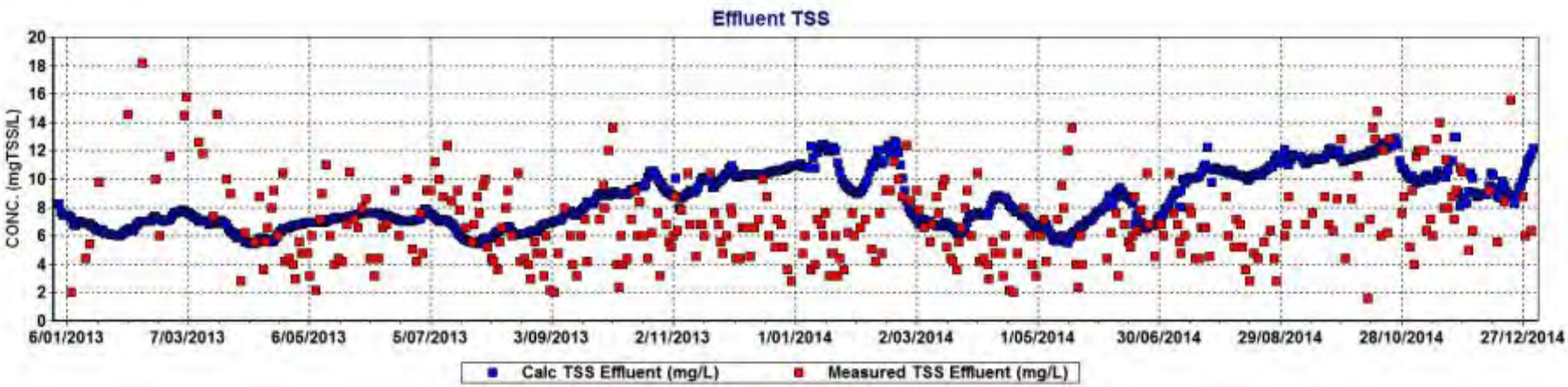
30/06/2014
29/08/2014
28/10/2014
27/12/2014
CalcTotal N mg/L
TN Eff. Mg/L


Effluent BOD
CONC. (mg/L)
16
14
12
10
8
6
4
2
6/01/2013
7/03/2013
6/05/2013
5/07/2013
3/09/2013
2/11/2013
1/01/2014
2/03/2014
1/05/2014
30/06/2014
29/08/2014
28/10/2014
27/12/2014
Calculated Effluent BOD (mg/L)
Measured BOD Effluent (mg/L)


Effluent Nitrate
CONC. (mgN/L)
90
80
70
60
50
40
30
20
10
0
6/01/2013
7/03/2013
6/05/2013
5/07/2013
3/09/2013
2/11/2013
1/01/2014
2/03/2014
1/05/2014
30/06/2014
29/08/2014
28/10/2014
27/12/2014
Calc NO3 N mg/L
Measured NO3 Eff. mg/L


Effluent TSS
CONC. (mgTSS/L)
20
18
16
14
12
10
8
6
4
2
0
6/01/2013
7/03/2013
6/05/2013
5/07/2013
3/09/2013
2/11/2013
1/01/2014
2/03/2014
1/05/2014
30/06/2014
29/08/2014
28/10/2014
27/12/2014
Calc TSS Effluent (mg/L)
Measured TSS Effluent (mg/L)

4.5 Model Configuration and Inputs

The calibrated model was used to simulate the performance of the oxidation channel activated sludge process as a steady state model.

4.5.1 Process Configuration

Plant capacity was evaluated as a function of effluent quality standards. In order to better understand what would be required for future flows and loads, model scenarios with additional oxidation channels and clarifiers (identically sized to the existing units) were run. Additional scenarios were run to evaluate the effect of adding or changing process units.

4.5.2 Headworks Effluent Flow and Load

The design flow rates to the secondary process were developed from the data provided by the Aqaba WWTF. Because no data regarding future loadings is available, future loadings were extrapolated from the current loadings. Since the operators at the Aqaba WWTP practice “peak shaving” by diverting maximum hourly flows to the natural treatment process, such peaks were not evaluated by the model.

AECOM compared the current loads at the Aqaba WWTP to several design standards, including “Wastewater Engineering Treatment and Reuse,” 4th Edition (Metcalf and Eddy). The per capita wastewater constituent loads for Aqaba were found to correspond to the published values for other arid Middle East locations, as shown in Table 4-6.

Table 4-6. Middle East Locations per Capita Wastewater Constituent Loads

Location/ Constituent	BOD (g/capita d)	TSS (g/capita d)	TKN (g/capita d)	TN (g/capita d)
Aqaba, Jordan	51	47	N/A	14
Egypt	27 to 41	41 to 68	8 to 14	N/A
Palestine (West Bank and Gaza Strip)	32 to 68	52 to 72	4 to 7	N/A
Turkey	27 to 50	41 to 68	8 to 14	N/A

The existing plant performance data was used to develop the pollutant mass loadings for the average day and max month scenarios. The average day loadings were assumed to be the average of the parameter data points. Per industry standard, max month loadings were assumed to be the top 91.7 percentile of the parameter data points (derived from ((365-30)/365) =0.917).

In the two series scenarios, loading was adjusted to model the effects of septage being added at the Headworks (instead of the natural plant). Based on input from referenced works, AECOM assumed that septage would have a TSS concentration of 15,000 mg/L, BOD of 7,000 mg/L, COD of 15,000 mg/L, and TKN of 700 mg/L. It was also assumed that 30% of TSS would be removed by the headworks grit removal process. The provided 2014 Aqaba plant data indicated that average septage flow is about 3,700 m^3/month. This information allowed AECOM to calculate the overall proportion of flow that septage would represent so that revised headworks effluent concentrations could be estimated that include septage. It was assumed for future flow scenarios that septage volumes would increase proportionally with plant influent flow. Table 4-7 displays the loading concentrations that were simulated in the alternative scenarios.

Table 4-7. Headworks Effluent Loading Concentrations

Parameter	Max Month, Without Septage, (1A-1C)	Max Month with Septage (2A-2C)
COD (mg/L)	977	1021
TKN (mg/L)	182	184
Total P (mg/L)	10	10
Nitrate-N (mg/L)	12	12
pH	7.41	7.41
Alkalinity mmol/L	12-16	12-16
ISS (mg/L)	25	32 (to simulate TSS of 437)
Calcium (mg/L)	80	80
Magnesium (mg/L)	15	15
DO (mg/L)	0	0

4.5.3 Model Parameters

Based on the very limited water temperature data provided for the WWTP, a temperature of 17 degrees Celsius was assumed as a conservative value for the steady-state computer modeling. This assumption is critical to the process calculations and represents a "worst case" biological process scenario. This assumed value should be revisited to reflect actual sustained cold-weather water temperatures to be recorded at the WWTP as part of a revised sampling and monitoring program given that typical low water temperatures experienced in other coastal areas of the Middle East are typically several degrees Celsius higher.

All model runs were made at the "max month" loadings which is industry practice when designing wastewater treatment systems that are expected to maintain consistent effluent quality. The secondary clarifier overflow was paced at 75% of the Headworks effluent flow. In the scenarios that they were used, primary clarifiers were assumed to have underflow 1.5% of inflow and solids removal of 65%. Various models were run and solids retention time was graphed against effluent NH_3 in order to determine an ideal aerobic solids retention time. As Figure 4-6 shows, there is a break point (the "knee" of the curve) at which increasing aerobic solids retention time has diminishing benefits. The break point is set as the solids retention time in the BioWin Model. In this case, the breakpoint was found to be 11.5 days.

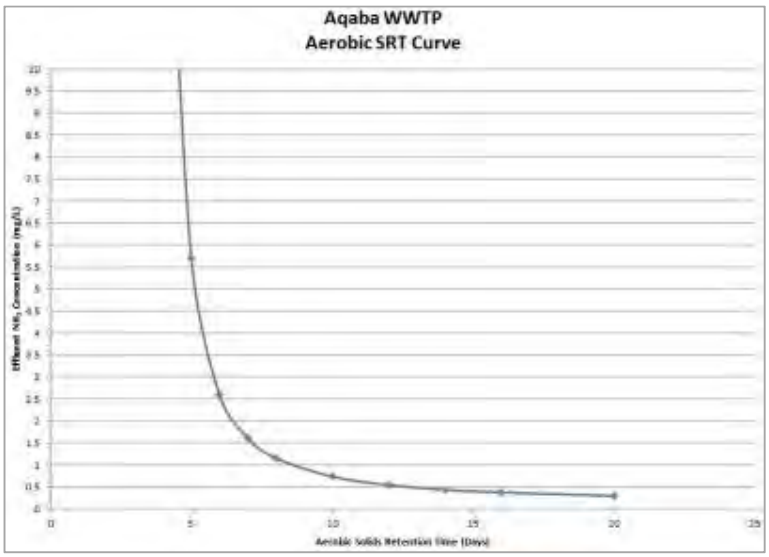


Figure 4-6. Aerobic SRT Curve

4.6 Model Runs

The purpose of developing the BioWin model was to evaluate the plant capacity as a function of different effluent quality standards. In addition, the Aqaba Wastewater Collection System Master Plan identified two scenarios for future system expansion and investment strategy. The model was used to determine if and how the existing facility would need to be changed in order to cope with the future expansion scenarios and what sort of operational flexibility exists at the facility now. To that end, four different unit process setups were evaluated against current operations (no septage to the mechanical plant) and an alternative operation scheme (septage to the mechanical plant). Once the capacities of the unit processes are modeled, the number of units needed for future flows can be determined multiplicatively.

4.6.1 Current Design and Operations with All Side Streams to Lagoons

- Model Run 1A No changes to the treatment process with the mechanical WWTP at the design flow of 12,000 m^3/day. This was found to be the existing mechanical facility's operational ceiling.

4.6.2 Projection of Plant Unit Capacity with All Side Streams to Lagoons

- Model Run 1B1 Move one aerator in each oxidation channel to create a larger anoxic zone in the oxidation channel. See Figure 4-7 for the proposed aerator relocation. Mechanical plant capacity was found to be 12,500 m^3/day.
- Model Run 1B2 Move one aerator in each oxidation channel as described for Run 1B1; add two more aerators to each oxidation channel for greater oxygen saturation. See Figure 4-7 for the proposed oxidation channel layout. Mechanical plant capacity was found to be 18,000 m^3/day.
- Model Run 1C Alternative that precedes the existing oxidation channel configuration described in 1B2 with two primary clarifiers (25 meters in diameter and 4.27 meters deep). Mechanical plant capacity was found to allow up to 37,000 m^3/day.

4.6.3 Current Design and Operations with Septage loading to Headworks

- Model Run 2A No changes to the treatment process. Mechanical plant capacity (including septage) was found to be 10,000 m^3/day.

4.6.4 Projection of Plant Unit Capacity with Septage loading to Headworks

- Model Run 2B1 Move one aerator in each oxidation channel to create a larger anoxic zone. See Figure 4-7 for the proposed aerator relocation. Mechanical plant capacity (including septage) was found to be 11,500 m^3/day.
- Model Run 2B2 Move one aerator in each oxidation channel as described for Run 2B1; add two more aerators to each oxidation channel for greater oxygen saturation. See Figure 4-7 for the proposed oxidation channel layout. Mechanical plant capacity (including septage) was found to be 16,500 m^3/day.
- Model Run 2C Retain oxidation channel configuration described in 2B2 and add two primary clarifiers (25 m diameter and 4.27 meters deep). Mechanical plant capacity (including septage) was found to be 34,000 m^3/day.

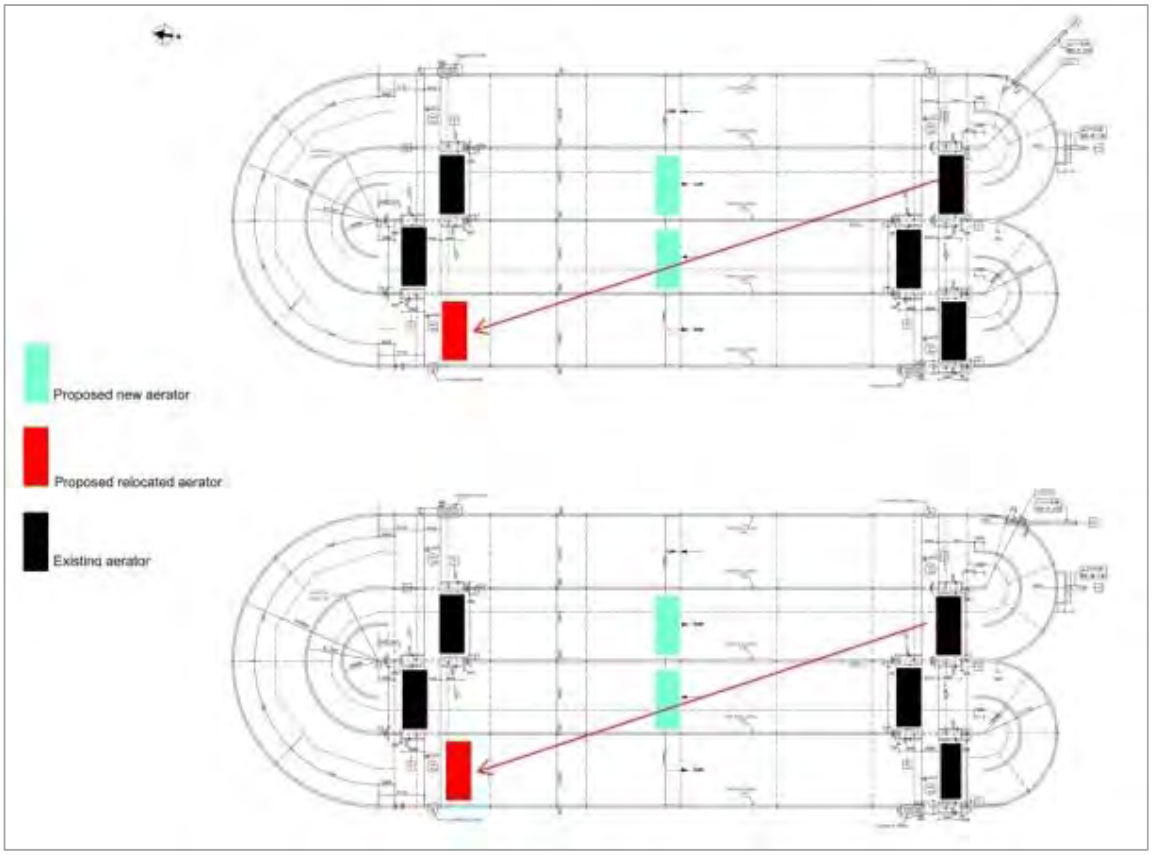


Figure 4-7. Proposed Aerator Layout

AECOM evaluated these Model Runs at the effluent quality limits shown in Table 4-8. Section 4.7 details the findings of the evaluation.

Table 4-8. Modeled Effluent Quality Limits

Parameter	WWTP Effluent Target
Biological Oxygen Demand, mg/L	10
Dissolved Oxygen, mg/L	>2
Total Suspended Solids , mg/L	10
TDS, mg/L	<800
Total Nitrogen, mg/L	45
Nitrate (NO_3-N), mg/L	30 (6.8)
Turbidity (NTU)	10
pH	6 - 9
E. Coli (MPN/100 ml)	100
Helminth Eggs (one egg/L)	<=1

4.7 Model Results & Findings

Table 4-9 summarizes the output (measured as secondary clarifier effluent) of the model runs of the biological process.

It should be noted that the concentrations of total nitrogen and nitrate are higher than the design effluent target. Due to what are believed to be high influent nitrogen loads in the form of Ammonia, overall nitrogen removal is carbon limited at the Aqaba WWTF. Though the measured average effluent nitrogen values as reported for the sampling period 2013-2014 appear to meet the end user requirements, there is a wide range of effluent values, including many exceedances in the daily measurements. This inconsistency is due to the partial nitrification and denitrification occurring in the existing process that can be difficult to manage.

To achieve consistent nitrogen removal, especially at increased flows, the biological process should be operated to fully nitrify. However, this change decreases the denitrification zones available in the oxidation channel, and requires the addition of a carbon source (such as methanol) for post denitrification.

Secondary clarifier effluent TSS is also slightly above the 10 mg/L target. Further polishing can be accomplished by the existing sand filters if necessary.

The results of the state point analysis for the scenarios evaluated indicate that the secondary clarifiers have sufficient capacity for the flows modeled.

As previously noted, the July 2010 Aqaba Wastewater Collection System Master Plan Report identified four scenarios related to future growth. The four scenarios are summarized below along with the required upgrades predicted by the BioWin Model.

4.7.1 Scenario 1 Network Expansion and Investment Strategy with Major New Development-Year 2020

Under this plan, treatment plant capacity would be increased from 21,000 m^3/day to 62,000 m^3/day and the mechanical WWTP would be upgraded from 12,000 m^3/day to 53,000 m^3/day by the year 2020.

4.7.2 Scenario 2 Network Expansion and Investment Strategy with Major New Development-Year 2030

Under this plan, treatment plant capacity would be increased from 21,000 m^3/day to 85,000 m^3/day and the mechanical WWTP would be upgraded from 12,000 m^3/day to 76,000 m^3/day by the year 2030.

4.7.3 Scenario 3 Network Expansion and Investment Strategy without Major New Investment-Year 2020

Under this plan, treatment plant capacity would be increased from 21,000 m^3/day to 38,000 m^3/day and the mechanical WWTP would be upgraded from 12,000 m^3/day to 29,000 m^3/day by the year 2030.

4.7.4 Scenario 4 Network Expansion and Investment Strategy without Major New Investment-Year 2030

Under this plan, treatment plant capacity would be increased from 21,000 m^3/day to 53,000 m^3/day and the mechanical WWTP would be upgraded from 12,000 m^3/day to 44,000 m^3/day by the year 2030.

The number of process units required to treat the flows described above for each operation scheme modeled is discussed in Section 8.

Table 4-9. Model Results in Mg/L (excluding pH)

	1A (12,000 m^3/day)	1B1 (12,500 m^3/day)	1B2 (18,000 m^3/day)	1C (37,000 m^3/day)	2A (10,000 m^3/day)	2B1 (11,500 m^3/day)	2B2 (15,500 m^3/day)	2C (34,000 m^3/day)
Ammonia-N	<1	<1	<1	<1	<1	<1	<1	<1
Nitrate-N	42	51	81	96	41	49	79	94
Total N	48	57	87	101	47	55	85	100
TSS	13	12	12	12	12	12	11	12
COD	67	65	66	66	67	67	67	68
BOD	3	3	4	5	3	3	4	5
pH*	7.63	6.70	7.07	7.07	7.64	7.54	7.29	6.65

**highly dependent on influent alkalinity*

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4.7.5 Limitations of the Model

Without a full wastewater characterization many assumptions were made in the creation of the BioWin model. For example, without measured oxygen levels reported from various points within the oxidation channel units, the amount of dissolved oxygen added by the aerators was assumed and the rate at which the dissolved oxygen was used by the biological process was assumed. The removal rates of the primary clarifiers for alternatives 1C and 2C were assumed. The concentrations of septage constituents were assumed. Some data with questionable accuracy was used as discussed in Sections 4.3 and 4.4.1.2. Ideally, the following data would be collected in order to further refine the model:

- Influent or effluent temperature data (daily)
- Influent and effluent COD or BOD (3-5 times per week)
- Influent TKN (3-5 times per week)
- Effluent NH_3 and NO_3 (3-5 times per week)
- DO concentration in oxidation channel (daily)
- Alkalinity (1-3 times per week)
- Side stream flow/concentration (if sent to the Headworks)
- Septage flow/concentration (if sent to the Headworks).

While this model is useful for planning purposes, it is recommended that a full wastewater characterization and further modeling based on this verified data be performed prior to any design or construction. In addition, it is recommended that limiting factors, such as effluent BOD, TSS, nitrogen, and TDS as well as mixed liquor suspended solids be monitored and recorded as flow gradually increases. This will show if the treatment process is corresponding to the assumptions within the model.

5 WASTEWATER TREATMENT TECHNOLOGIES

5.1 General

The existing Mechanical WWTP includes an oxidation channel which is a modified activated sludge biological treatment process typically designed for BOD5 removal and nitrification. The nitrification process converts influent ammonia to nitrite and nitrite to nitrate. Like most oxidation channel treatment systems the Aqaba WWTP includes “racetrack type” reactors with surface mounted brush rotors that are used to circulate the mixed liquor, provide oxygen transfer, and aerate the ditch. Flow to each oxidation channel is aerated and mixed with return sludge from the secondary clarifiers.

An oxidation channel may also be operated to achieve partial denitrification to further reduce total nitrogen by denitrifying nitrate in an anoxic condition. The Aqaba WWTP design includes constant speed motors on the brush aerators and a fixed weir which limits adjustments to the aeration capacity. Anoxic zones can be created by relying on the sharp oxygen drop between aerator locations and cycling the operation of the aerators on/off. Another way to provide some denitrification would be to create a dedicated anoxic zone with very low dissolved oxygen within the race track. The preferred location is where the influent and RAS enter the tank.

The main advantage of the oxidation channel is its simple operation, with minimal operational requirements and operation and maintenance costs. A number of additional treatment alternatives are available to supplement and/or improve the existing oxidation channel arrangement to provide enhanced nitrogen removal to meet the future flow needs for the facility and reuse quality effluent that is desired by the URW customers.

5.2 Modified Ludzack-Ettinger Process

One of the most common design modifications for enhanced nitrogen removal is known as the Modified Ludzack-Ettinger (MLE) process. In this process, an anoxic tank is added upstream of the ditch along with mixed liquor recirculation from the aerobic zone to the tank to achieve higher levels of denitrification. In the aerobic basin, nitrifying bacteria convert ammonia-nitrogen to nitrite-nitrogen and then to nitrate-nitrogen. In the anoxic zone, heterotrophic bacteria convert nitrate-nitrogen to nitrogen gas which is released to the atmosphere. Some mixed liquor from the aerobic basin is recirculated to the anoxic zone to provide a high-concentration of nitrate-nitrogen to the mixed liquor.

Several manufacturers have developed modifications to the oxidation channel design to remove nutrients in conditions cycled or phased between the anoxic and aerobic states. While the mechanics of operation differ by manufacturer, in general, the process consists of two separate aeration basins, the first anoxic and the second aerobic. Wastewater and return activated sludge (RAS) are introduced into the first reactor which operates under anoxic conditions. Mixed liquor then flows into the second reactor operating under aerobic conditions. The process is then reversed and the second reactor begins to operate under anoxic conditions.

5.3 Denitrification Filters

Denitrification filters have been utilized for wastewater treatment for a number of years. There are two main process configurations for denitrification filters commercially available, downflow and upflow continuous backwash filters. Downflow denitrification filters operate in a conventional filtration mode and consist of media and support gravel supported by an underdrain. Wastewater enters a downflow filter over weirs along the length of the filter bed on both sides. Filter effluent is conveyed from the bottom of the filter over a control weir into a clear well. Backwashing is required at regular intervals to clean the filter. Backwashing

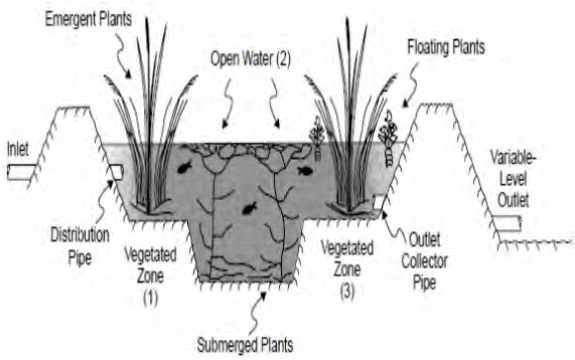
typically involves air scouring and backwashing with air and water. During the process, nitrate is metabolized to nitrogen gas, which becomes embedded in the filter media. Nitrogen-release cycles are needed to remove the nitrogen gas bubbles that accumulate. The piping for the filter influent and backwash is similar to that of conventional filters.

Upflow continuous-backwash filters differ in that influent wastewater flows upward through the filter, countercurrent to the movement of the sand bed. Wastewater enters the filter through the influent pipe (where methanol can be added), and then is transported downward through a supply pipe and distributors. The water moves up through the filter media and filtrate is discharged from the upper portion of the filter. The filter media travels slowly downward and is drawn into an airlift pipe in the center of the filter. Compressed air is introduced to the airlift, drawing sand upward and scouring it. At the top of the airlift, the media is returned to the filter bed.

Methanol is required as a carbon source for either type of filter, and usually dosed to the filter influent before it is divided among the filter cells. For denitrification, methanol is typically dispensed on the basis of the filter influent flow rate and the concentrations of nitrate in the influent and effluent, as measured by an online nutrient analyzer. There are several other natural wastewater treatment alternatives that could be considered exploratory for the region and applicable to specific reuse requirements.

5.4 Constructed Wetlands

Constructed wetlands provide several treatment mechanisms including settling, physical filtration, biological uptake, nitrification/ denitrification and other biochemical processes. They draw upon the performance of bacteria that thrive in aerobic and anaerobic zones in order to complete the processes of nitrification and denitrification. Constructed wetlands can be designed to accommodate both aerobic and anaerobic zones and associated treatment mechanisms. The aerobic zones in constructed wetlands are located either in the standing water (free surface wetlands) and/or around the root zone of plants (subsurface flow wetlands).



Source: US EPA 2000

Figure 5-2. Free Surface Water Wetlands

As oxygen is circulated down from the above-water aspects of plants to their roots, the process of nitrification occurs. The denitrification process in the adjacent anaerobic zones then transforms the nitrates into nitrogen gas and organic nitrogen. Subsurface wetlands contain more anaerobic treatment which allows greater removal of nitrogen and a lower nitrogen concentration in the effluent.

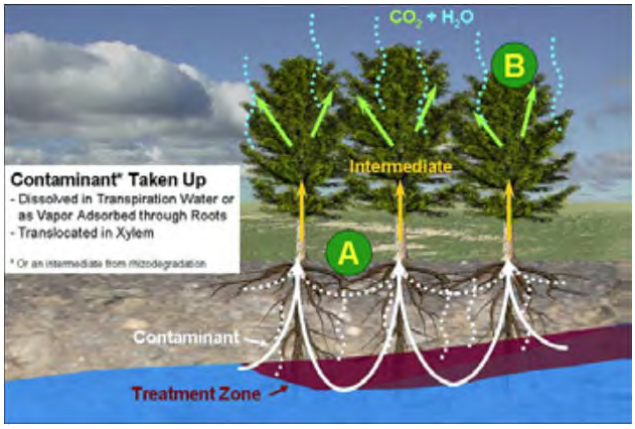
Source: John Todd Ecological Design, Inc.

Figure 5-1. Hydroponic Treatment

5.5 Hydroponic Treatment

Hydroponic treatment, (commercially known as Living- or Eco-Machines) is a

plant-based system that treats septic tank effluent or primary-treated wastewater. With hydroponic treatment, aeration and clarification chambers are combined with constructed wetlands to treat the influent. The wetlands are a series of chambers allowing for microbial communities to engage with and treat the wastewater. Plants are often suspended on racks with their root systems doing the work. Solids removal is generally onsite, after which water is pumped through the gravel filled cells (similar to subsurface wetlands).



Source: Interstate Regulatory Technology Council

Figure 5-3. Diagram of How Phytotechnologies Work

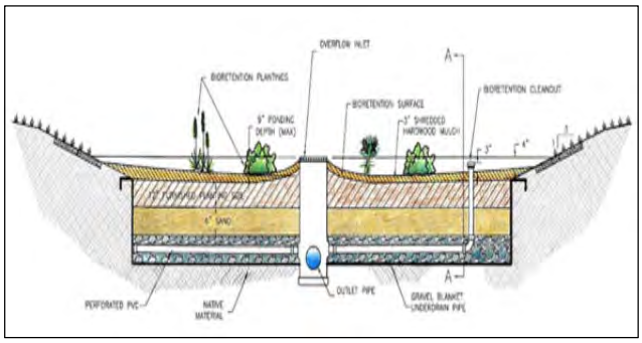
This process transfers more oxygen to the wastewater increasing the treatment capabilities of the system. For greater denitrification a sand or gravel filter with carbon source addition is added prior to discharge. The wetland effluent can be discharged into a water body or used for open space irrigation after treatment. The wetland effluent can also be discharged into a leach field or similar system for discharge to the groundwater. This technology can be used for wastewater effluent with primary, secondary, or advanced treatment.

5.6 Phytotechnologies

Phytotechnologies are plant technologies that can create buffers to intercept and uptake nutrients in the soil to intercept and uptake stormwater and groundwater through leaves and roots to control infiltration and cleanse runoff entering surface water lakes and ponds, or phytoirrigation, where after secondary treatment, wastewater effluent is irrigated onto plants to remove nutrients and other contaminants. See Figure 5-3.

5.6.1 Bioretention

Bioretention (Figure 5-4) is a technique that uses soils, plants, and microbes to treat stormwater. Smaller residential applications are shallow depressions filled with sandy soil topped with a thick layer of mulch and planted with dense native vegetation. Stormwater runoff is directed into the cell via piped or sheet flow. The runoff percolates through the soil media that acts as a filter. Microorganisms in the root zone provide a broad range of biochemical processes (including nitrification-denitrification) that break down a broad range of pollutants.



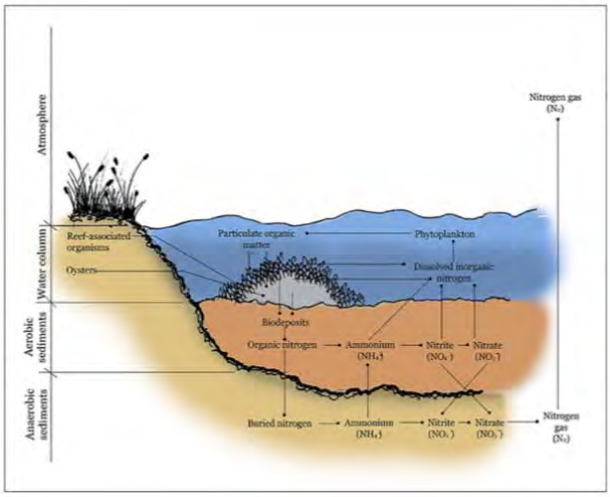
Source: Horsley Witten Group, Inc.

Figure 5-4. Diagram of a Bioretention System

5.6.2 Aquaculture and Shellfish Restoration

Aquaculture and shellfish restoration (Figure 5-5) has been found to positively impact water quality by filtering particulate organic matter, interest in using them to manage anthropogenic sources of nitrogen has recently surged. Additional co-benefits of oyster reefs may include habitat provision for juveniles and adults of commercially important fisheries (Coen et al. 2007), shoreline stabilization through reduced wave energy (Newell 2004), and increased removal of particulate matter, light penetration, and submerged aquatic vegetation growth

due to improvements in water clarity (Golden 2011). Some of these studies suggest variable results in terms of water quality benefits including light penetration.



Source: Adapted from Kellogg et al. 2013)

Figure 5-5. Denitrification and Nutrient Assimilation on a Restored Oyster Reef

5.6.3 Fertigation

Fertigation is the process of integrating fertilization and irrigation practices. Properly-designed and located irrigation wells can capture nutrient-enriched groundwater, for example down-gradient from high-density septic systems (that currently discharges to coastal embayments and ponds) and recycle it back to irrigated and fertilized turf grass areas (including golf courses, athletic fields and lawns). In this manner, nitrogen is recycled from a pollutant to a resource/fertilizer. This can significantly reduce nutrient loads to down-gradient surface waters and reduce fertilizer costs. These wells should be installed to target groundwater high in nitrates such as sewage disposal areas, golf courses and areas of dense development with septic systems.

6 BIOSOLIDS

6.1 General

Solids, or sewage sludge, removed from septic systems or wastewater treatment facilities are managed through means of disposal or recycling after treatment and/or dewatering. Disposal of solids involves either landfilling, with other municipal solid waste or separately, or incineration. Wastewater solids that are treated more extensively and processed for safe land application are called biosolids (an organic residual generated during the treatment of sewage sludge) and they are managed in several forms including liquid, cake, compost, and heat-dried granules. Recycling, or beneficial use of biosolids, includes land application on farm land, general use as gardening or landscaping fertilizer, and soil amendment after composing, heat-drying, or other advanced treatment. The following technologies or management strategies (Table 6-1) are utilized in solids processing:

Table 6-1. Technologies/Management Strategies Utilized In Solids Processing

Drying Beds	Commercial Disposal	Dewater and Landfill
Composting	Incineration	Lime Stabilization
Digestion	Thermal Drying	Drying and Gasification

6.2 Existing Conditions

Raw wastewater from the sewer collection system is delivered to the Headworks facilities at the Aqaba WWTP. Flows to the Mechanical WWTP are managed by use of automatic weir controls in the Parshall flume channel to divert peak flows to the Natural WWTP. Solids generated from the oxidation channel activated sludge process and are wasted daily to conventional sand drying beds. At present, solids processing consists of drying in open air drying beds, which is very popular where land is abundant and the site is away from development. The advantages of this system include its simple operation and reliability in the local climate conditions to produce dry solids with a low tech system. The beds quickly produce very dry cake, up to approximately 90 percent solids, that is landfilled on-site. However, collecting the dried sludge can be labor intensive.

At the Aqaba WWTP, the waste sludge does not receive any stabilizing treatment or dewatering before it is pumped to the drying beds. Drainage lines from the drying beds flow to the maturation pond for treatment. Periodically, other wastes diverted from the wastewater treatment processes to the Natural WWTP; including septage, screenings, grit and filter back-wash wastes are also landfilled on-site. Unfortunately, the drying bed operation and periodic contamination with these other wastes in the ponds have been a source of nuisance odors.

The existing sand drying beds are each 40m x 8m and arranged in 8 groups of 8 beds for a total of 64 units. With no stabilizing treatment or dewatering to reduce potential odors and disposal volume respectively, these beds will continue to be problematic with expanding development and increased sludge production from increased WWTP flows and treatment requirements. The Master Plan projected the addition of up to 184 sand drying beds in the same general unit configuration, consuming another 8,000 square meters of site area and likely generating more odors. Plant operators report that there is a plan to add a thickener; however, there is not a confirmed schedule when or if this plan will be realized.

6.3 Solids Management Strategies

This section presents a review of the available technologies to be considered to improve existing conditions and meet the future sludge management goals for the Aqaba WWTP and the developing region. The following is a summary of the well-established technologies

utilized to manage biosolids for more efficient disposal and beneficial use. Each summary includes a general description for each technology or strategy, applicable siting requirements, and a list of the siting requirements, advantages and disadvantages to consider.

6.3.1 Solar Drying Beds

Solar sludge drying is a process that utilizes the available energy in the sun to dry biosolids to levels greater than 75 to 90 percent dry solids without the use of supplemental fossil fuels. Solar drying (Figure 6-1) is essentially an improved drying bed enclosed inside a greenhouse that maximizes the readily available solar energy while protecting the biosolids from potential precipitation. In Jordan, this technology may not be needed for solids drying performance, but the enclosure concept could be considered from an odor control perspective.

Source: Parkson

Figure 6-1. Biosolids Active Solar Sludge Dryer

During the drying cycle, greenhouse conditions such as temperature, humidity and solar radiation are monitored to control the greenhouse. The greenhouse contains circulation fans and exhaust fans to provide convective drying and control of climatic conditions inside the greenhouse. The biosolids are periodically turned and aerated with varying devices depending on the manufacturer. In addition, low temperature waste heat can be used to enhance solar drying and reduce area requirements for the greenhouse. Advantages and disadvantages of biosolids active solar drying are summarized in Table 6-2.

There are numerous installations worldwide for solar drying. The process is reported to work well; however, there can be issues with odor in the greenhouse, especially for unstabilized sludge. Most odors are reported when the sludge is still moist enough so fermentation and biological activity occurs.

Table 6-2. Biosolids Active Solar Drying – Advantages and Disadvantages

Siting Requirements	Requires similar land area to existing drying beds
Advantages	Operation continues same dewatering and landfill method as currently utilized
	Allows for containment of and treatment of odorous air removed from greenhouse
Disadvantages	More costly than existing open air drying beds
	Requires power for air handling equipment
	Additional operation and maintenance costs for odor control system
	Must be blended with other materials or further processed for beneficial reuse

6.3.2 Composting

Composting is an aerobic process in which biodegradable material is decomposed by aerobic microorganisms in a controlled environment. The heat generated in composting

pasteurizes the product, significantly reducing pathogens. The heat generated also drives off water vapor, further dewatering the product and reducing reuse volume. Composting that is performed properly produces nuisance-free humus like material that can be used for soil amendment in farming.

All composting processes generally include the same basic steps. The dewatered sludge is mixed with an amendment and/or bulking agent to increase porosity of the mixture and provide a carbon source to improve the degradability of the compost. A rule of thumb for composting is to have a 30 to 1 ratio of carbon to nitrogen (mass basis). The resulting mixture is piled or placed in a vessel where microbial activity causes the temperature to rise starting the “active composting” period. The desired temperature required for optimal operation and end quality vary based on the method of composting and desired use of the end product. After the “active composting” period is complete, the material is cured and distributed. Advantages and disadvantages of composting are summarized in Table 6-3.

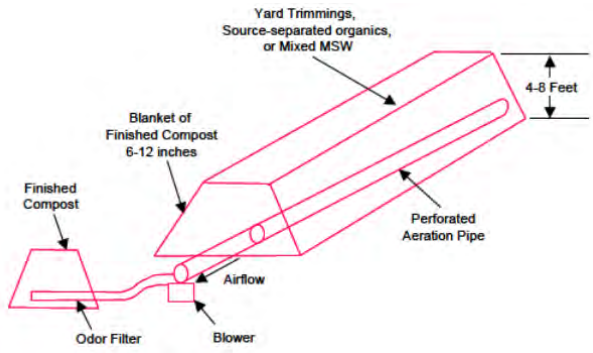
Table 6-3. Biosolids Composting – Advantages and Disadvantages

Siting Requirements	Requires a dewatering device and truck loading
	The area required for process depends on type of composting (windrow, aerated static pile or in vessel)
	Design and selection of an applicable composting site will depend on land area available, distance from neighbors and availability and source of amendment materials. If close to neighbors the system will likely need to be enclosed with odor control
Advantages	Produces a product marketable for beneficial use (soil amendment)
	Generally simple process that is relatively easy to operate and maintain
	Well proven technology
	Potential Income Source
	Minor Regulatory Requirements
Disadvantages	Relatively high operation and maintenance cost
	Many systems are labor intensive
	Reliance on demand for end product
	Market study needed to establish potential customers
	Sludge type assessment required
	Potential for strong odors and typically not well suited for raw primary sludge

In general, three types of composting are practiced: aerated static pile, windrow, and in-vessel as described below.

6.3.2.1 Aerated Static Pile Composting

In aerated static pile composting (Figure 6-2), the sludge and bulking agent is mixed and distributed in a long pile over a grid of air piping. The air for reaction is provided through the air piping to achieve the "active composting" period. The pile is typically covered with finished compost to provide insulation. After the "active composting" period is complete, the compost is moved to a separate curing pile for cooling. The bulking agent is typically screened and recycled in this method (US EPA).



Source: US EPA Biosolids Technology Fact Sheet

Figure 6-2. Biosolids Aerated Static Pile Composting

6.3.2.2 Windrow Composting

The compost mixture for windrow composting is prepared in a similar manner as it is for aerated static pile composting. The mixture, however, is spread into windrows and a mechanical turner device, as opposed to air grid piping, is used to periodically agitate the pile and provide a source of air to the compost material. See Figure 6-3. Once the "active composting" period is complete, the material is moved to a separate curing pile. The bulking agent is typically screened out and recycled. Windrow composting has a high potential to create odors (US EPA).

Source: US EPA Biosolids Technology Fact Sheet

Figure 6-3. Biosolids Windrow Composting

6.3.2.3 In-Vessel Composting

Unlike aerated static pile and windrow methods, in-vessel composting occurs inside an enclosed vessel or container (Figure 6-4). In-vessel composting systems are also typically more sophisticated then aerated static pile or windrow methods and contain a higher degree of control. The mechanical systems allow for control of the airflow, temperature, and oxygen concentration while also offering better containment of odors.

Due to the higher degree of process control, in-vessel systems typically can achieve composting at a faster rate yielding a smaller footprint. In vessel composting can be plug flow or complete mix type systems (US EPA).

Source: US EPA Biosolids Technology Fact Sheet

Figure 6-4. Biosolids In-Vessel Composting

6.3.3 Incineration

Incineration or advanced thermal oxidation is a combustion reaction that occurs in the presence of excess oxygen. Incineration is the most commonly used thermal conversion process practiced for sewage sludge today. Historically multiple hearth incineration has been the most common incineration technology employed for sewage sludge. However, the improved operation and reduced O&M costs associated with fluidized bed incineration makes the latter currently more in favor.

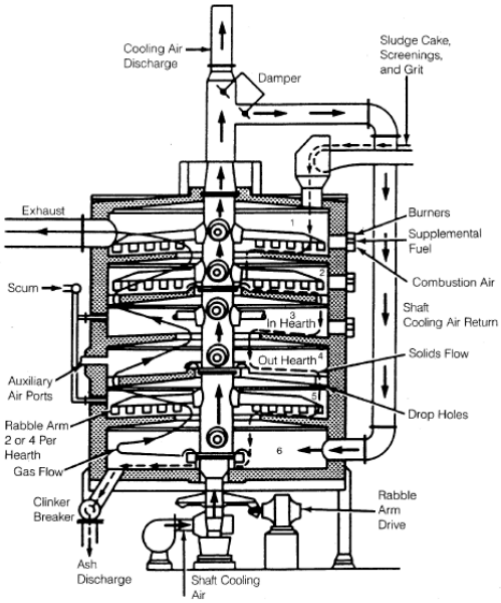
Incineration of sludge converts the waste into ash, flue gas, and heat. Flue gas treatment may be required by air permitting regulations and control limits for sewage sludge incinerators. In some cases, the heat generated by incineration can be recovered for electrical generation or other waste heat purposes. Advantages and disadvantages of incineration are summarized in Table 6-4.

Table 6-4. Biosolids Incineration – Advantages and Disadvantages

Siting Requirements	Requires a dewatering device and building to house the incineration equipment
	Incineration takes up a fairly small footprint when compared to other technologies. The will likely not be feasible in a non-attainment area
Advantages	Eliminates pathogens and toxic compounds
	Potential for energy recovery and electrical generation
	Significant volume reduction
	Byproduct is an inert sterile ash
	Small footprint
	Many vendors available
Disadvantages	High capital cost and operation and maintenance costs
	Significant air emission and regulatory requirements
	Requires highly skilled personnel to operate
	May require supplemental fossil fuel consumption depending on moisture content of solids feed
	Complex process with lots of instrumentation for air emissions control
	Potential for public opposition
	Requires ash disposal or beneficial use

6.3.3.1 Multiple Hearth Incineration

Multiple hearth incineration systems (Figure 6-5) consist of a refractory-lined, circular steel shell with several hearths. The center of the shell contains a rotating hollow cast iron shaft with rake (or rabble) arms mounted to it. Dewatered sludge fed onto the top hearth is raked slowly on alternating hearths to the outside circumference or to the center of the hearth in a series of spiral pattern paths. The solids are burned on the middle hearth, at temperatures over 900 degrees F. The remaining ash is cooled on the bottom zone prior to being discharged.



Source: US EPA Biosolids Technology Fact Sheet

Figure 6-5. Biosolids Multiple Hearth Incinerator

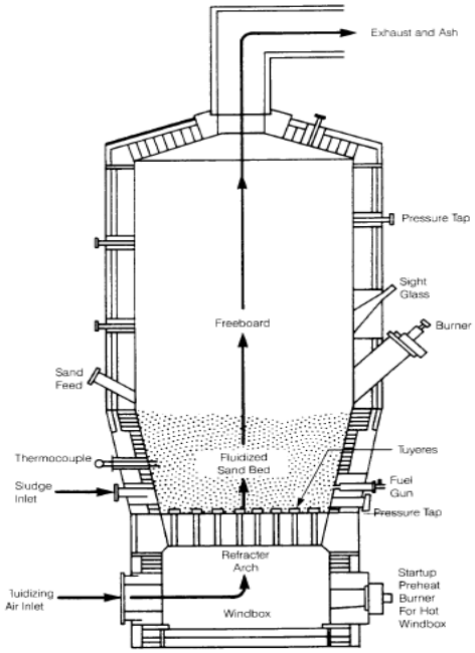
The solids burning on the middle hearths release heat which generates a flow of hot gases that rise countercurrent to the incoming sludge. This helps dry the sludge and improve combustion efficiency. Non-contact cooling air used to keep the rotating center shaft and rabble arms cool is introduced in the bottom of the hollow center shaft and is discharged through the hollow central shaft at the top of the unit. This pre-heated air can then be directed either to the lowest hearth or exhausted via either a dedicated stack or the downstream ductwork. The flue gases typically exit the upper hearths and are directed to the air pollution control equipment. The flue gas must be treated to meet air permitting requirements.

The rabble arms on the bottom hearth push the hot ash out of the system through a drop out port where it is transported to a containment area for further storage and processing.

The ancillary equipment associated with the multiple hearth incineration process include the biosolids feed system, air blowers, a number of burners (typically 12 to 20 per unit) located around the unit at various hearth levels, air pollution control system, induced draft fan, stack, ash conveyance and disposal system, and the general building services. Optional items would include any additional heat recovery and energy generation devices.

6.3.3.2 Fluidized Bed Incineration

Fluidized bed incinerators (Figure 6-6) consist of a vertically oriented outer shell constructed of steel and lined with refractory. Partially dewatered sludge is fed into the lower portion of the furnace on top of a bed of sand. Air at 3 to 5 pounds per square inch (psig) is injected through nozzles, known as tuyeres, simultaneously fluidizing the bed of hot sand and the incoming sludge. The fluidizing action creates turbulence and mixing to



Source: US EPA Biosolids Technology Fact Sheet

Figure 6-6. Biosolids Fluidized Bed Incinerator

allow for optimal combustion conditions while using less excess air than multiple hearth incinerators.

Combustion temperatures of 1,400 to 1,700 degrees F are maintained in the bed with residence times of approximately 2 to 5 seconds. The combustion reaction is separated into two zones, one within the bed and one in the freeboard area above the bed. In the fluidized bed, the water in the sludge evaporates simultaneously along with pyrolysis of the sludge. The combustible gas produced during the pyrolysis reaction is burned in the freeboard area just above the bed. The residual ash particles remaining after combustion along with some sand are carried out the top of the furnace thus requiring downstream removal. The resulting flue gas must be treated in accordance with the air permitting requirements. The fluidizing combustion air is typically preheated utilizing a large air to air heat exchanger (or air preheater) before being injected into the furnace which is known as a “hot windbox” design. If ambient air is used, it is known as a “cold windbox” design.

The ancillary equipment associated with the fluidized bed incinerator process include the biosolids feed system, high pressure fluidizing air blower, air preheater, air pollution control system, stack, ash conveyance and disposal system, sand makeup system, and the general building services. Optional items would include any additional heat recovery and energy generation devices.

6.3.4 Lime Stabilization

Lime stabilization involves addition of lime to biosolids in order to raise the pH to levels unfavorable for pathogen growth. The heat produced by the reaction of the lime with the water in the biosolids raises the pH and temperature of the biosolids sufficiently to comply with beneficial reuse requirements in accordance with US EPA’s regulations for pathogen destruction. The process converts sewage sludge into a stable product, improves the density and physical handling characteristics of the biosolids and offers a cost-effective, flexible, and environmentally protective alternative that promotes beneficial reuse. The lime stabilized biosolids provide a rich source of essential fertilizer to farmland, improve acidic soils, and are excellent for land reclamation and as soil substitute for landfill cover or as soil conditioner. Key features of lime stabilization are summarized in Table 6-5.

Table 6-5. Biosolids Lime Stabilization – Advantages and Disadvantages

Siting Requirements	Requires dewatering device
	Typically use additional mixing device such as a pug mill unless lime added prior to dewatering
	Requires building for processing and/or storage and loading facilities for hauling
Advantages	Simple to operate
	Can be designed to meet beneficial reuse requirements for pathogen and vector attraction reduction (US EPA 1994)
	Simple technology requiring few special skills for reliable operation
	Easy to construct of readily available parts
	Small land area required
	Flexible operation easily started and stopped
Disadvantages	The resulting product is not suitable for use on all soils
	Volume of final material is increased which increases transportation costs
	Odor and dust potential
	Potential for pathogen regrowth if the pH drops below 9.5 while the material is stored prior to use
	Plant available nitrogen and phosphorous content is reduced

6.4 Dewatering Technologies

Each of the strategies for solids management presented has its advantages and disadvantages, and requires require some level of pre-conditioning and/or dewatering prior to processing.

Dewatering is a physical separation process that involves a high level of moisture removal where typical solids concentrations of 12 to 30 percent are achieved, depending on sludge characteristics, dewatering device, and polymer usage. Dewatering can be the final stage of sludge and biosolids processing before hauling and disposition or it can be followed by another process such as drying or incineration. Dewatering is generally accomplished by technologies such as centrifuges, belt filter presses, rotary presses, and screw presses.

6.4.1 Centrifuge Dewatering

The basic type of centrifuge used for dewatering is a solid-bowl centrifuge which consists of a long bowl that is mounted horizontally and tapered at one end. See Figure 6-7. Sludge is introduced continuously into the spinning bowl of the unit, and the solids concentrate along the perimeter of the spinning bowl. An internal helical scroll, spinning at a slightly different speed, moves the accumulated sludge toward the tapered end where additional solids concentration occurs as the solids back up behind the lip at the discharge end of the unit. The dewatered material is discharged through a chute located at the bottom of the unit. Centrifuges operate as continuous feed units which remove solids by a scroll conveyor and discharge liquid over the weir. The conical-shaped bowl helps lift solids out of the liquid allowing them to dry on an inclined surface before being discharged.

Source: Centrisys
Figure 6-7. Biosolids Centrifuge Dewatering

Centrifuges feature relatively low operating labor costs, but power usage and maintenance requirements are relatively high. Centrifuges are high throughput machines and may require smaller footprint with a lower number of units than other dewatering technologies at medium to large plants. Similar to other dewatering equipment, polymer consumption varies with solids characteristics. Testing is generally recommended to confirm polymer dosages and feed rates, since these can vary considerably from location to location.

Centrifuges are high speed rotating machines that require careful maintenance and are not suitable for overhaul by inexperienced personnel. Centrifuges can be damaged if abrasive coarse materials are allowed to enter the unit. This requires the rotating scroll of the centrifuge to be returned to the manufacturer for overhaul and resurfacing that can be costly and time consuming. Because of the high throughput capacity, high power consumption and specialized maintenance requirements, centrifuges are typically most appropriate for medium to large size plants. There are numerous vendors who offer this technology including Westfalia, Alpha Laval, Centrysis, and Flottweg. Advantages and disadvantages of biosolids centrifuge dewatering are summarized in Table 6-6.

Table 6-6. Biosolids Centrifuge Dewatering – Advantages and Disadvantages

Advantages	Well-established/proven technology
	Good dewatering performance
	Small footprint
	Upsizes well for medium to large plants
	Can be automated
	Can be used for both thickening and dewatering
	Enclosed technology
	Little to no wash water requirements
Disadvantages	High electrical/energy consumption
	High speed machine
	Can require specialized maintenance by outside personnel
	Dewatered cake can be more odorous than low shear technologies

6.4.2 Belt Filter Press Dewatering

Belt filter presses (BFPs) are continuously fed sludge dewatering devices that use the principals of chemical conditioning, gravity drainage, and mechanically-applied pressure to dewater sludge. See Figure 6-8. Mechanical pressure is applied to sludge sandwiched between two tensioned belts, by passing those belts through varying diameter rollers.

Source: BDP Industries

Figure 6-8. Biosolids Belt Filter Press and Inclined Screw Conveyor

For a given belt tension, as the roller dimension decreases, increasing pressure is exerted to the sludge, removing more water. A BFP machine can be divided into three zones:

- Gravity zone, where free draining water is drained by gravity through a porous belt (similar to a gravity belt thickener);
- Wedge zone, where the solids are prepared for pressure application; and
- Pressure zone, where increasing pressure is applied to the conditioned solids as it moves through a series of rollers.

BFPs offer the flexibility to provide continuous operation, low operator labor, reasonable capital cost, ease and simplicity of maintenance, high solids throughput, moderate footprint; high solids capture rate, reasonable polymer consumption rate, high reliability and availability, and adaptability to changing process conditions. In recent years, there have been improvements in BFP designs to produce higher cake solids by changing the pressure, belt, or roller design.

Onsite odors during dewatering may be a problem, but can be controlled with good ventilation systems and chemicals to neutralize odor-causing compounds. Some companies design enclosed BFPs which provide odor containment similar to centrifuges. While this

minimizes on-site odor problems, it limits an operator's ability to monitor the process and perform cleaning and maintenance. BFPs require some operator attention if the feed solids vary in concentration or organic matter. Wastewater solids must be screened and/or ground to minimize the risk of sharp objects damaging the polyester belts. Automatic belt washing is provided and is continuous during normal operation. The entire machine needs to be cleaned at the end of each shift to prevent solids accumulation, which could reduce equipment service life and cause maintenance problems. This can be time consuming and requires large amounts of water. An automatic belt washing system can be configured to use plant effluent, which reduces operating costs.

The dewatered sludge from a BFP tend to be less odorous than dewatered sludge discharged from a centrifuge, especially if they are stored or stockpiled prior to further processing. Similar to other dewatering equipment, polymer consumption varies with sludge characteristics. Testing is generally recommended to confirm polymer dosages and feed rates, since these can vary considerably from location to location. There are numerous vendors who offer this technology including Ashbrook, BDP Industries, Andritz, Phoenix Process Equipment, and Komline Sanderson. Advantages and disadvantages of belt filter press dewatering of biosolids are summarized in Table 6-7.

Table 6-7. Belt Filter Press Biosolids Dewatering – Advantages and Disadvantages

Advantages	Well established/proven technology
	Moderate performance
	Low energy consumption
	Lower polymer consumption than other technologies
	Upsizes well for medium to large plants
Disadvantages	Higher labor requirements than some other dewatering technologies
	Requires large amount of wash water
	Open design can generate extensive odors
	Requires periodic replacement of belts
	Enclosed units are difficult to access for operation, would require building/enclosure for odor control

6.4.3 Rotary Press

The rotary press (Figure 6-9) dewaters sludge using rectangular channels that are formed between two parallel revolving stainless steel screens. The filtrate passes through the screens to the outer portion of the housing and drains out of the bottom of the unit. The flocculated solids continue to dewater and advance within the channel toward the discharge, which has an adjustable restricting gate that creates backpressure on the solids, further enhancing dewatering. The frictional force of the slow moving screens, coupled with the controlled

Source: Fournier
Figure 6-9. Biosolids Rotary Press

outlet restriction, creates an extrusion of dewatered cake.

The rotary press is a continuous dewatering process; therefore, ancillary equipment is similar to that required for BFP or centrifuge systems. Polymer conditioning is necessary for proper dewatering with a rotary press. Rotary presses are relatively quiet and make efficient use of floor space. They are available in several sizes with single or multiple channel arrangements. Another feature of the rotary press is the ability to add new chamber units to the same machine at a future date, when needed. Similar to other dewatering equipment, polymer consumption varies with the sludge characteristics. Testing is generally recommended to confirm polymer dosages and feed rates, since these can vary considerably from location to location. Rotary press dewatering is a relatively new dewatering technology but is becoming more established in the industry. Advantages and disadvantages of rotary press biosolids dewatering are summarized in Table 6-8.

Table 6-8. Rotary Press Biosolids Dewatering – Advantages and Disadvantages

Advantages	Moderate performance
	Low energy consumption
	Low maintenance requirement
	Easily Automated
	Enclosed technology reduces odors
	Low wash water requirements
Disadvantages	Capacity is limited and may requirement multiple trains for medium to large plants
	Does not work well on thin sludge's or sludge's low in fiber

6.4.4 Screw Press Dewatering

Screw presses dewater solids by using one or more rotating screws that are installed within perforated screen troughs. This allows gravity drainage of water (filtrate) through the screen at the beginning of the inlet end of the unit. As the solids are conveyed along the unit, the frictional forces create gradually increasing pressure that is caused by the outlet restriction weir, producing dewatered cake that is discharged from the end of the unit. The screw press (Figure 6-10) contains a helical screw inside a cylinder formed from perforated sheets, longitudinal bars, or a series of rings. To increase pressure as sludge passes through the press, the distance between the cylinder and screw decreases. This can be achieved by having a cone-shaped cylinder, increasing the diameter of the screw shaft, or by reducing the pitch of the screw flight or windings.

Source: Huber Technology
Figure 6-10. Biosolids Inclined Screw Press

Similar to other dewatering equipment, polymer consumption varies with solids characteristics. Testing is generally recommended to confirm polymer dosage and feed rates, since these can vary considerably from location to location. Screw Press dewatering is a relatively new dewatering technology but is becoming more established in the industry

with more than 100 installations worldwide. There are several manufacturers that provide screw press systems including Huber, Fukoku Kogyo Company (FKC), PW Tech, Schwing, and BDP Industries. Advantages and disadvantages of biosolids screw press dewatering are summarized in Table 6-9.

Table 6-9. Biosolids Screw Press Dewatering – Advantages and Disadvantages

Advantages	Moderate performance
	Low energy consumption
	Low maintenance requirement
	Easily Automated
	Enclosed technology reduces odors
	Low wash water requirements
Disadvantages	Capacity is limited and may require multiple trains for medium to large plants
	Many design variations with individual vendor units making competitive bidding more challenging

6.4.5 Disc Thickener

A disc thickener is a compact, enclosed rotating filter that separates flocculated sludge from the filtrate through a slowly rotating filter disc covered with a stainless steel filter cloth. The unit (Figure 6-11) is slightly inclined with the filtrate outlet located at the bottom of the slope for a gravity discharge.

Source: Huber Technology
Figure 6-11. Biosolids Disc Thickener

A baffle plate distributes the influent waste sludge across the filter radius and the fluid accumulation on the low side of the sloped disc creates a low hydrostatic pressure for filtrate to drain through below.

A scraper pushes the thickened sludge from the disc surface as the disc rotates to the sludge discharge area and the filter cloth is cleaned from below so the solids are washed back into the sludge and the filtrate water remains clear. This allows filtrate water to be reused as wash water in lieu of a separate utility water feed. The arrangement is compact and makes it suitable for retrofit to existing facilities. The thickening results can meet an 85 percent reduction and a solids concentration of over 6 percent solids. Advantages and disadvantages of a biosolids disc thickener are summarized in Table 6-10.

Table 6-10. Biosolids Disc Thickener – Advantages and Disadvantages

Advantages	Enclosed process contains odors and protects operators from aerosols
	Easy access for inspection, operation, and maintenance
	Low O&M costs and operator attention
	Low polymer consumption
	Wash water demand less than 5 percent
	Adjustable throughput, polymer dose and filter rotation speed to meet thickening needs
	Automatic control
Disadvantages	Polymer use may vary with WAS characteristics
	Thickening performance less than other mechanical thickening alternatives
	Limited size selection available; 20 m^3/h and 40 m^3/h units

6.4.6 Gravity Belt Thickener

Gravity belt thickeners (GBT) have a history of reliable operation and many models have been redesigned for an enclosed operation in response to the need to reduce odor control costs. See Figure 6-12. By totally enclosing the GBT, the volume of foul air to be ventilated and treated is greatly reduced in comparison to an open GBT that is installed inside a building. The stainless steel enclosure encompasses the feed distribution assembly, gravity deck, filtrate collection pan and thickened cake discharge. All belt drive, bearings and other components are mounted outside the enclosure for ease of maintenance. Unit sizes available range from 0.5 meter to 4 meters. Advantages and disadvantages of a biosolids gravity belt thickener are summarized in Table 6-11.

Source: BDP Industries

Figure 6-12. Biosolids Totally Enclosed GBT

Table 6-11. Biosolids Gravity Belt Thickener – Advantages and Disadvantages

Advantages	Reliable established technology
	Many unit sizes and suppliers available
	Enclosed system minimizes release of foul odors
	Can allow for unattended operation for extended periods
	Easy access for inspection, operation, and maintenance
Disadvantages	May be considered old technology
	Large unit footprint
	Requires more wash water than other thickening alternatives
	Odor control more difficult than other alternatives

6.4.7 Rotary Drum Thickener

The rotary drum thickener (Figure 6-13) utilizes a multi-zone drum cylinder for dewatering that includes different size mesh media to adjust capture efficiency as the sludge moves along the length of the rolling cylinder. Finer mesh is used in the feed with downstream zones of increasing mesh size to enhance water removal from the thicker sludge material.

Source: Parkson
Figure 6-13. Biosolids Rotary Drum Thickener

The internal drum components include roll bars, split augers, flights and detention ports. The detention time in each zone can be changed by adjusting the ports on the zone rings. As the unit rotates, the roll bars in each zone flip sludge for additional water removal. Various suppliers are available with a range of filtration media including wedge wire, and perforated plates. Most units are equipped with a self-cleaning spray header running the length of the drum that can utilize filtrate to reduce utility water requirements.

Various floc development tank arrangements are available, including those with tangential inlet/outlet design intended to minimize floc disturbance and reduce polymer consumption. Thickening performance on an inlet sludge range of 0.5 percent to 1.5 percent solids can be increased in the range of 5 percent to 8 percent. A high solids capture rate of 98 percent is reported with a cleaner filtrate and reduced re-treatment through the WWTP. Advantages and disadvantages of a biosolids rotary drum thickener are summarized in Table 6-12.

Table 6-12. Biosolids Rotary Drum Thickener – Advantages and Disadvantages

Advantages	Low polymer usage and O&M cost
	High capture rate and high quality filtrate
	Compact footprint with large panels for access
	Range of unit sizes available
	Lends itself to outside installation
	Odor control easily installed because unit is completely enclosed
Disadvantages	Should be flushed before maintenance to reduce odor release when panels removed

6.5 Existing Conditions

6.5.1 General

The current operations of the Aqaba WWTP include a number of solids management practices that favor the performance conditions of the Mechanical WWTP while diverting septage wastes for processing at the Natural WWTP. The existing Mechanical WWTP is designed around a very simple activated sludge process that is performing well and generally meeting the effluent requirements at the current flows based on performance data reported by AWC and summarized in Table 3-2. The solids generated from the current process are limited to waste activated sludge (WAS) which are dewatered on the sludge drying beds. The screenings and grit removed at the Headworks are buried in the on-site landfill.

Figure 6-14. Sludge Drying Beds

6.5.2 Sludge Drying Beds

The sludge drying beds (Figure 6-14) are performing well as expected in this location, but are approaching maximum capacity.

6.5.3 Disposal

On-site landfill disposal (Figure 6-15) appears to be the favored approach and no problems have been reported with this practice at the site.

Figure 6-15. Dried Sludge Landfilling and Burying

6.6 Alternatives

6.6.1 General

A number of biosolids management alternatives are available that could be considered should future development expansion (encroachment) warrant such investment. Many of these alternatives focus on beneficial reuse of the biosolids or energy recover from their processing.

6.6.2 Sludge Drying Beds

Immediate improvements to consider for the current operation include:

- Thickening WAS to reduce the drying time on the beds.
- The AWC has recently completed design of a new gravity sludge thickener for the WAS sludge to be constructed in the vicinity of the existing drying beds. The tanks will be covered for odor control with the air treated through use of biofilters. The arrangement can accommodate a second tank for future installation.

- As discussed above, alternatives to the planned gravity thickeners including the; drum thickener and disc thickener could be readily installed with minimal infrastructure and could be expandable to meet future WWTP flows/solids generated.

6.6.3 Disposal

On-site disposal is clearly the least costly alternative for the Aqaba WWTP. At this time, it does not appear that Aqaba has a significant interest or demand for biosolids reuse in lieu of on-site disposal. However, should the WWTP expansion and/or development encroachment limit the on-site disposal access or public acceptance, alternative disposal locations should focus on customer beneficial use. Off-site delivery of any biosolids reuse will require some form of dewatering that will require capital and O&M investment

6.7 Recommendations

As future growth projections are realized, the AWC should consider the capacity of the existing service area for both effluent reuse and biosolids reuse potential.

7 ODOR CONTROL

7.1 General

Odors related to wastewater facilities are caused by a wide variety of conditions. In collection systems, these factors include relatively low wastewater flows to pump stations through long transmission mains during initial years of operation that occur because the pump volumes were designed for future, greater flows. This results in long detention times and increased opportunity for “off-gas” release and odor generation, as well as increase in corrosion. Similarly, oversized pumps, wet wells, and force mains can also contribute to odor problems. Odors may also be a result of industrial or unusual wastewater discharges into the collection system. At treatment facilities, odors are a normal occurrence when dealing with sludge and when processing raw sewage and septage wastes.

Treatment facilities need to be a good neighbor by treating the air as well as the wastewater. As sludge is concentrated during processing, and more and more sewage processing operations become enclosed, the need for odor control and odor treatment may become necessary.

Odor control measures range from simple modification of operation and maintenance procedures, to implementation of pretreatment programs, to installation of high capacity multi-stage odor scrubbing equipment. Each odor situation has its own unique characteristics, which must be evaluated prior to implementing an odor control program in order to develop and implement a cost-effective and efficient odor and noise abatement solution.

A number of odor control systems are included below with key considerations noted.

7.1.1 Biofilter

A traditional biofilter is a biological treatment process used to remove contaminants and consists of an in-ground construction (Figure 7-1) or prefabricated system with a low profile that allows the foul air to pass through the media. Biofilters remove odors by capturing the odor-causing compounds from an air source in a porous media bed made with natural or synthetic media. The contaminants are removed by microorganisms that feed on the organic materials. The beds can be open to the environment, covered, or totally enclosed. The land area required for installation can be large as the surface area is directly related to the airflow treated and the need to provide 45 to 60 second detention time.

Figure 7-1. Odor Control Biofilter

The biofilters must be kept moist for optimal performance which results in a significant water use and the need to manage the leachate from the bed. Performance inhibitors include short-circuiting, pH depression and high temperatures. Biofilters may not be appropriate for very strong odors and a concentration of ammonia greater than 35 ppm in the foul air stream may cause a toxic accumulation of ammonium in the media, leading to reduced efficiencies. Advantages and disadvantages of a biofilter for odor control are summarized in Table 6-13.

Table 7-1. Biofilter for Odor Control – Advantages and Disadvantages

Advantages	Effective for H_2S Removal and Removal of Volatile Organic Compounds
	Relatively simple operation
Disadvantages	Space Required is Typically Large
	Must maintain even moisture distribution in media (no dry spots)
	Media Replacement and Disposal Required Periodically
	Fan Noise

7.1.2 Trickling Biofilters

A trickling biofilter is similar to the traditional biofilter described in Section 7.1.1, in that it uses a biological treatment process to remove contaminants, but it sits above ground and requires a much smaller footprint.

Source: BIOREM
Figure 7-2. Odor Control via Biological Trickling Filter

Trickling biofilters (Figure 7-2) utilize an acid resistant inorganic substrate such as porous lava rock or an engineered media to capture odor causing compounds from an air source. By utilizing this type of media, pretreatment of the air source is eliminated as is the need for replacement of degraded media. As with the traditional biofilters, the contaminants are removed by microorganisms that feed on the organic materials. The media in trickling biofilters is stacked, thereby allowing for the same surface of area of media to be provided with a smaller footprint.

As with the traditional biofilters, the media in the trickling biofilters must be kept moist for optimal performance. However, unlike the traditional biofilters, that can use a significant amount of water and require leachate management, the trickling biofilter utilizes a water recirculation system. These units may be used for demanding applications with high concentrations of H_2S or other water soluble compounds. Advantages and disadvantages of a biological trickling filter for odor control are summarized in Table 6-14.

Table 7-2. Biological Trickling Filter for Odor Control – Advantages and Disadvantages

Advantages	Effective for H_2S Removal and Removal of Volatile Organic Compounds
	Relatively simple operation
	Smaller Foot print
	No pre-treatment of air required
	Minimal water use- self-contained units and recirculated water*
Disadvantages	Media weight may limit depth of filter bed that can be installed
	Fan noise
	Larger fans needed to force air through the filter bed.
	Minimal leachate produced.

*Some manufactured units uses a once through water flow rather than recirculation of water.

7.1.3 Chemical Addition

Packed-Tower Wet Scrubbers utilize a containment vessel equipped with an air inlet, packing bed, packing irrigation system, and air outlet. A scrubbing solution sump may be integrated in the vessel, or may be located remotely. The basis for wet scrubbing is the absorption of the contaminant molecules into the scrubbing solution by the intimate contact with the foul air. This causes a mass transfer in the bed region as the scrubbing solution is recirculated through the vessel. Oxidation reduction potential (ORP) or pH can be continually monitored and adjusted to optimize effectiveness. Advantages and disadvantages of a packed-tower wet chemical scrubber for odor control are summarized in Table 6-15.

Table 7-3. Packed-tower Wet Chemical Scrubber for Odor Control – Advantages and Disadvantages

Advantages	Chemical injection to liquid
	Typical chemicals used; sodium hypochlorite, calcium nitrate, ferric chloride, potassium permanganate, hydrogen peroxide, ozone
	Can be used in force mains
	Typically no water required
Disadvantages	Less effective than treatment of exhaust air
	Chemical containment required
	Relatively simple operation

7.1.4 Chemically Treated Activated Carbon

Activated carbon adsorption is effective for treating low level foul air emissions from WWTPs such as hydrogen sulfide, reduced sulfur compounds, and VOCs. Granular activated carbon (GAC) is an extremely effective adsorbent because its characteristics include high surface area per unit weight, an intricate pore structure, and a primarily hydrophobic surface. See Figure 7-3.

Source: Calgon Carbon

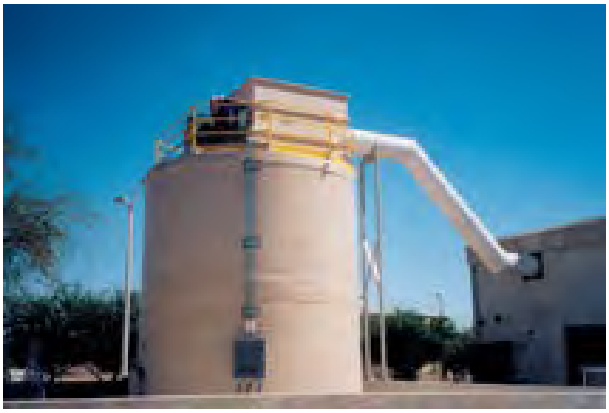
Figure 7-3. Odor Control via Chemically Treated Activated Carbon

Bituminous coal and coconut shells are the most widely used materials for manufacturing GAC because of their durable physical properties and excellent porosity. For VOC removal, coconut shell GAC is preferred. Whereas alkali-impregnated bituminous coal carbons are commonly used to remove H2S and other reduced sulfur compounds. The NaOH or KOH impregnation increases the low adsorption capacity of H_2S from 3 to 5 percent by weight for virgin carbon to approximately 25 percent by weight for impregnated carbon. For simultaneous H_2S and VOC removals, a mixed bed of media with a layer of impregnated GAC and a layer of coconut shell-based GAC can be used effectively. The activated carbon media must be replaced or regenerated periodically for consistent long-term performance. Advantages and disadvantages of chemically-treated activated carbon for odor control are summarized in Table 7-16.

Table 7-4. Chemically-treated Activated Carbon for Odor Control – Advantages and Disadvantages	
Advantages	Effective for H_2S removal and removal of Volatile Organic Compounds
	Vessel suitable for Indoor or Outdoor service
	Above ground installation required
	Typically no water use
Disadvantages	Carbon media replacement – may require treatment as a special waste
	Media can be subject to spontaneous combustion if fan is shut off
	Fan Noise in outdoor installations

7.1.5 Mist Chamber Chemical Scrubber

Fine-mist or fog scrubbers treat odor by bringing the foul air in contact with 10 micron-sized droplets of scrubber solution created using special atomizers. Usually compressed air is used to create the mist of controlled dilute chemical solution. The atomization is a continuous process with the air and droplets flowing concurrently with no recirculation of liquid effluent. See Figure 7-4.



Source: Evoqua Water Technologies
Figure 7-4. Odor Control via Mist Chamber Chemical Scrubber

The chemical feed rate is controlled by sensing exhaust, liquid effluent or inlet parameters. The two principals of mist treatment include diffusion and reaction of water-soluble contaminants, and adsorption of non-water soluble compounds. Advantages and disadvantages of a mist chamber chemical scrubber for odor control are summarized in Table 6-17.

Table 7-5. Mist-chamber Chemical Scrubber for Odor Control – Advantages and Disadvantages

Advantages	Effective for H_2S Removal
	Vessel suitable for Indoor or Outdoor service
Disadvantages	Not effective for Removal of Volatile Organic Compounds
	Waste chemical disposal required
	Continuous water use required
	Chemical containment required
	Fan noise in outdoor installations

7.1.6 Packed Bed Chemical Scrubber

Packed-bed systems utilize a high surface area plastic media in the bed to promote droplet and film contact within the chamber as a shower of scrubbing liquid is applied over the bed. The foul air is ventilated through the plastic media counter-current to the liquid flow and the arrangement can be either horizontal or vertical. See Figure 7-5.

Source: AECOM
Figure 7-5. Odor Control via Packed Bed Chemical Scrubber

The advantage of a packed scrubber is that the concentration of the scrubbing solution can be varied in response to fluctuating odor levels. These units are typically the least costly method for treating high intensity odors and can be arranged with multiple stages to improve odor treatment effectiveness.

Multi-stage scrubbers can remove a wide range of odor causing compounds and have a history of reliability in a range of applications. Multi-stage scrubbers are typically applied when odor intensity is high and a large volume of air must be treated. There are several types of wet scrubbers including; packed bed, mist and venture type. All are designed to maximize the contact between the odorous compounds of the foul air stream and a 'scrubbing' chemical solution. The compounds are absorbed and then oxidized by the chemicals in the reaction. Advantages and disadvantages of a packed-bed chemical scrubber for odor control are summarized in Table 7-18.

Table 7-6. Packed-bed Chemical Scrubber for Odor Control – Advantages and Disadvantages

Advantages	Effective for H_2S Removal and Removal of Volatile Organic Compounds
	Can be installed outdoors in locations not subject to freezing temperatures
Disadvantages	Chemical containment required
	Continuous water use
	Waste chemical disposal required
	Fan noise in outdoor installations

7.2 Existing Conditions

7.2.1 General

There are a number of odor issues currently reported in the Aqaba Wastewater Treatment Plant that need to be addressed with any upgrade to the facility. These are identified as follows:

- Headworks;
- Sludge Drying Beds; and
- Lagoons.

7.2.2 Headworks

There is no odor control at the Headworks facilities. The main trunk sewer feeding the WWTP is reportedly oversized for the existing flow and is suspect of generating a hydrogen sulfide release as it enters the open influent channel. See Figure 7-6 and 7-7.

Source: Engicon 2015

Figure 7-6. Model of Headworks Layout

Measurements were taken by plant operations staff at various times over a 3-day period to measure gaseous sulfide levels at the receiving manhole at the Headworks. The measurements ranged from 21 to 75 ppmV as noted in Table 7-1 below:

Table 7-7. Gaseous Hydrogen Sulfide at WWTP Headworks

Date	Time	H_2S (ppmV)
9/4/2014	09:00	40
	17:00	24
	01:00	60
9/5/2014	09:00	35
	17:00	21
	01:00	75
9/6/2014	09:00	35
	17:00	21
	01:00	67

Source: Engicon 2015

Figure 7-7. Mechanical Plant Open Channel from Parshall Flume to Distribution Chamber

7.2.3 Sludge Drying Beds

Sludge is wasted directly from the oxidation channel to the open sand drying beds with no pre-conditioning or thickening. The drying beds function well, but are operating at full capacity. The open sludge drying beds achieve significant dewatering of the WAS from 0.5-1% solids to about 70% solids for landfilling on-site. Unfortunately they are also one of the primary sources for odors at the WWTP and can host nuisance flies. With continual sludge wasting and application to the beds, the odors and nuisance conditions will remain an issue.

Source: Engicon 2015

Figure 7-8. Sludge Drying Beds

The existing drying beds (Figure 7-8) are approaching their capacity and the AWC is planning to install a gravity thickener system intended to increase the feed solids to the beds and therefore reduce the dewatering time and bed area required for existing sludge quantities. These improved conditions may also result in a reduction in odor emissions from the beds. The new gravity thickener and related chemical feed system will be constructed in the vicinity of the existing drying beds with provisions for a future second unit. The gravity thickener will be covered and equipped with an odor control biofilter system to treat the odorous air from inside the tank.

7.2.4 Lagoons

The lagoons (Figure 7-9) are reported to produce seasonal odor issues, likely related to the water level during certain times as the process is not managed except for periodic dredging. In addition, the accumulation of solids from direct septage disposal without pre-treatment, and several side streams directed from the Mechanical WWTP are significantly increasing the potential for odorous conditions.

Source: Engicon 2015

Figure 7-9. Natural Plant Lagoons

7.3 Alternatives

7.3.1 General

A number of odor control techniques are presented in Section 7.1 with varying levels of investment and performance. Considering the familiarity AWC has with biofilters for controlling odors at pumping stations, the same could be considered where practical at the WWTP and one is currently being planned in association with new gravity thickeners for WAS sludge. Biofilters are simple to operate and mainly require moist conditions for proper operation. With the existing plant utility water system located throughout the WWTP site, biofilters could be utilized at many locations where site area permits.

7.3.2 Headworks

The hydrogen sulfide release in the Headworks is likely caused by upstream conditions in the large influent sewer sized for future flows. High sulfide conditions in sewers can cause problems with concrete corrosion and may be best addressed at the upstream pumping station that handles a significant portion of the influent flow discharged to the interceptor sewer. If a local solution is necessary, odor control using a traditional biofilters, trickling biofilters, or a small chemical scrubber could be considered. The inlet channel of the Headworks is covered where the influent sewer connects and is the recommended location for the exhaust fan to be connected.

7.3.3 Sludge Drying Beds

The AWC has recently completed design and is currently tendering a contract for construction of a new gravity sludge thickener for the WAS sludge to be located east of the No. 1 sludge drying beds. The proposed gravity thickener is designed to be covered and equipped with an odor control biofilter system to treat the odorous air contained under the tank dome. With provisions planned for a second gravity thickener in the future, it is likely that this system may be expanded to meet future sludge thickening, conditioning and odor control requirements related to the processing of WAS prior to dewatering.

Future considerations include enclosing the drying beds if odors become problematic.

7.3.4 Lagoons

Odors from the lagoons could be reduced by maintaining water levels and more frequent dredging of solids to reduce the potential for odor releases. The septage disposal station and the practice of accepting raw septage directly to the pond is likely a significant source of odors which could be eliminated by utilizing the septage receiving tank at the Mechanical WWTP. The septage receiving facility is equipped with wash-down water to clean out the tank as necessary and the waste is directly piped to the influent sewer manhole ahead of the Headworks. The septage would then be combined with influent wastewater flows for pretreatment through the screens and grit chamber before discharging to the Natural WWTP. Figure 7-10 provides an indication of the problems in the lagoons.

Source: Engicon 2015

Figure 7-10. Floating Solids in the Natural Plant Lagoons

8 PROJECT AND LIFE-CYCLE COSTS

8.1 Development of Project Costs

As part of the development of this document, order-of-magnitude estimates were developed for the various alternatives of the proposed upgrades to the Aqaba Wastewater Treatment Facility. The costs for the alternatives obviously vary with the specific design considerations and layout configuration ultimately selected. Nonetheless, it is possible to put together an estimate that can be used for Life Cycle Cost Analysis to determine of the most cost effective alternative.

The costs presented are planning level costs and should be refined as additional informational details are identified and/or determined. This refinement to the project scope includes types of process equipment, type of mechanical systems, redundancy and site security, and types of control systems. In addition, project constraints, project schedule, and overall project complexity will impact project costs. It is recommended that planning level project costs be updated just prior to appropriation of funding for design and construction.

The planning level project costs are preliminary in nature and contain construction cost, construction contingencies, administrative, legal, construction engineering, environmental and regulatory permitting. The Class 4 opinion of probable construction costs were developed in accordance with “AACE International Recommended Practice No. 18R-97 - Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries” as prepared by the Association for the Advancement of Cost Estimating (AACE) International dated February 2, 2005. Refer to Table 8-1 for the AACE International Cost Estimating classification system.

AECOM has no control over costs of labor, materials, competitive bidding environments and procedures, unidentified field conditions, financial and/or market conditions or other factors likely to affect the opinion of probable project costs.

Planning level costs were referenced primarily from the existing Aqaba Wastewater Treatment Plant (WWTP) original contract construction costs. These contract construction costs originally presented the capital costs in the year 2000 in US Dollars (USD). The Engineering News Record (ENR) Construction cost index of 6221 for the year 2000 was used to present these costs in then-current USD. The ENR cost index of 9972 for January 2015 was then used to inflate the capital costs to 2015 USD. Refer to Table 8-2 for a “menu” of planning level project cost components and Tables 8-3, 8-4 and 8-5 for the planning level project costs for Alternative 2B1, Alternative 2B2, and Alternative 2C respectively for the 32,000 m^3/d upgrade cost comparison.

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Table 8-1. AACE International Cost Estimating Classification System

Estimate Class	Primary Classification	Secondary Classification			
	Level of Project Definition[1]	End Usage[2]	Methodology[3]	Expected Accuracy Range[4]	Preparation Effort[5]
5	0 to 2 percent	Concept Screening	Capacity Factored, Parametric Models, Judgment or Analogy	L: -20 to -50 percent H: +30 to +100 percent	1
4	1 to 15 percent	Study or Feasibility	Equipment Factored or Parametric Models	L: -15 to -30 percent H: +20 to +50 percent	2 to 4
3	10 to 40 percent	Budget Authorization or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10 to -20 percent H: +10 to +30 percent	3 to 10
2	30 to 70 percent	Control or Bid Tender	Detailed Unit Cost with Forced Detailed Take-off	L: -5 to -15 percent H: +50 to +20 percent	4 to 20
1	50 to 100 percent	Check Estimate or Bid Tender	Detailed Unit Cost with Detailed Take-off	L: -3 to -10 percent H: +3 to +5 percent	5 to 100

Notes:

1 Expressed as percent of Complete Definition

2 Typical Purpose of Estimate

3 Typical Estimating Method

4 Variation of Low and High Ranges. The state of process technology and availability of applicable reference costs data affect the range market. The +/- value represents percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50 percent level of confidence) for given scope.

5 Typical Degree of Effort Relative to Least Cost Index of 1. If the range index value of “1” represents 0.005 percent of project costs, then an index value of “100” represents 0.5 percent. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.

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Table 8-2. Menu of Planning-Level Project Costs

Description	Unit	Unit Cost
Construction		
Relocate Existing Aerators	Pair	$100,000
Add Adjustable Weir Gates	Pair	$100,000
Install Additional Aerators	Pair	$200,000
Denitrifying Filter (3,000 m^3/d) including Backwash Water Storage	Each	$480,000
Oxidation Channels	Each	$1,840,000
Secondary Clarifier	Each	$550,000
GRP Piping	Linear meter	$620
Covered Primary Clarifier	Each	$950,000
Sludge Pumping Station	Each	$830,000
Sludge Thickeners	Each	$2,000,000
Sludge Digesters	Each	$800,000
UV Disinfection	Each	$1,130,000
Odor Control	Each	$1,070,000
Contractor Overhead and Profit (OH&P)	Percent	21 percent
Project Services (Includes the following)	Percent	25 percent
Design Engineering	Percent	10 percent
Construction Engineering	Percent	12 percent
Administrative Costs/Financing	Percent	3 percent
Contingency	Percent	30 percent

Table 8-3. Planning-Level Project Costs for Alternative 2B1 at 32,000 m^3/d

Description	Quantity	Unit	Unit Cost	Estimated Costs	
				Initial (16,000 m3/d)	Expansion (32,000 m^3/d)
Relocate Aerators	2	Pair	$100,000	$200,000	$0
Add Adjustable Weir	6	Each	$100,000	$300,000	$300,000
Denitrifying Filters	10	Each	$650,000	$2,600,000	$3,900,000
Oxidation Channels	4	Each	$1,840,000	$0	$7,360,000
Secondary Clarifiers	4	Each	$550,000	$0	$2,200,000
GRP Piping	400	Lin. meter	$620	$0	$248,000
Construction Subtotal				**$3,100,000**	**$14,000,000**
Contractor OH & P	1	Percent	21%	$650,000	$2,940,000
Construction Contract Subtotal				**$3,800,000**	**$16,900,000**
Project Services	1	Percent	25%	$950,000	$4,200,000
Project Subtotal				**$4,800,000**	**$21,100,000**
Contingency	1	Percent	30%	$1,400,000	$6,300,000
Estimated Project Cost				**$6,200,000**	**$27,400,000**

Note: Cost totals rounded to $100,000.

Table 8-4. Planning-Level Project Costs for Alternative 2B2 at 32,000 m^3/d

Description	Quantity	Unit	Unit Cost	Estimated Costs	
				Initial (16,000 m^3/d)	Expansion (32,000 m^3/d)
Relocate Aerators	2	Pair	$100,000	$200,000	$0
Add Adjustable Weir	4	Each	$100,000	$200,000	$200,000
Add Aerators	4	Pair	$200,000	$400,000	$400,000
Denitrifying Filters	10	Each	$650,000	$2,600,000	$3,900,000
Oxidation Channels	2	Each	$1,840,000	$0	$3,680,000
Secondary Clarifiers	2	Each	$550,000	$0	$1,100,000
GRP Piping	200	Lin. meter	$620	$0	$124,000
Construction Subtotal				**$3,400,000**	**$9,404,000**
Contractor OH & P	1	Percent	21%	$700,000	$1,996,000
Construction Contract Subtotal				**$4,100,000**	**$11,400,000**
Project Services[1]	1	Percent	25%	$1,000,000	$2,800,000
Project Subtotal				**$5,100,000**	**$14,200,000**
Contingency	1	Percent	30%	$1,500,000	$4,300,000
Estimated Project Cost				**$6,600,000**	**$18,500,000**

Note: Cost totals rounded to $100,000.

Table 8-5. Planning-Level Project Costs for Alternative 2C at 32,000 m^3/d

Description	Quantity	Unit	Unit Cost	Estimated Costs	
				Initial (16,000 m^3/d)	Expansion (32,000 m^3/d)
Relocate Aerators	2	Pair	$100,000	$200,000	$0
Add Adjustable Weir	2	Each	$100,000	$100,000	$100,000
Add Aerators	2	Pair	$200,000	$200,000	$200,000
Denitrifying Filters	10	Each	$650,000	$2,600,000	$3,900,000
Primary Clarifier	2	Each	$550,000	$0	$1,100,000
Primary Sludge PS	1	Each	$800,000	$0	$800,000
Gravity Thickener	1	Each	$2,200,000	$0	$2,200,000
Primary Digesters	1	Each	$800,000	$0	$800,000
Odor Control System	1	Each	$1,100,000	$0	$1,100,000
GRP Piping	600	Lin. meter	$620	$0	$372,000
Construction Subtotal				**$3,100,000**	**$10,600,000**
Contractor OH & P	1	Percent	21%	$650,000	$2,200,000
Construction Contract Subtotal				**$3,800,000**	**$12,800,000**
Project Services[1]	1	Percent	25%	$950,000	$3,200,000
Project Subtotal				**$4,800,000**	**$16,000,000**
Contingency	1	Percent	30%	$1,400,000	$4,800,000
Estimated Project Cost				**$6,200,000**	**$20,800,000**

Note: Cost totals rounded to $100,000.

8.2 Life Cycle Cost Analysis

Life Cycle costs were evaluated for several model run results at design flows representing the existing infrastructure with minor modifications and with the addition of primary clarification. The analysis assumes a 20-year planning horizon and four percent discount rate, and all costs are presented in US dollars. Construction components germane to the potential upgrade scenarios were selected for cost comparisons. The priced Bill of Quantities from the original Aqaba Mechanical WWTP Plant construction was used as a reference in developing estimated costs where possible. Where component costs were not included in that original project, unit prices were developed based on recent construction bids for a similar project (2009) or obtained as current estimates from vendors. These unit costs were then adjusted for inflation to reflect the approximate cost for the component in January 2015 using construction cost index values from Engineering News Record (ENR) tables as listed in Table 8-6. A contingency of 30% was added to those values for use in the life-cycle analysis.

Table 8-6. ENR Cost Adjustment Indices

Index Date	ENR Cost Index
2000	6221
2009	8570
January 2015	9972

Life cycle costs were analyzed for three upgrade options. As described in previous sections, 2B1 would increase plant capacity by including septage in the treatment volume and moving aerators in the oxidation channels to increase the anoxic zone; 2B2 includes installation of two additional floating aerators in each oxidation channel in addition to the upgrades in 2B1, further increasing the capacity of each treatment train; and 2C greatly increases capacity by adding primary clarification to the 2B2 upgrades. For the purpose of simplifying this discussion and presentation, the proposed upgrades associated with BioWin model runs 2B1, 2B2, and 2C will be referred to as Upgrade Options 1, 2 and 3 respectively.

The life cycle cost calculations are presented in Appendix A. For each component, basic information has been compiled:

- The approximate useful life of the component,
- The cost basis used (including the original value, the year that value was estimated, escalation of that cost to current-year dollars, and addition of a contingency factor), and
- The number of units needed for each assembled treatment unit.

For the purpose of comparison of the alternatives based on a Life Cycle Cost Analysis (LCCA), a design flow condition of 32,000 m^3/d to the Mechanical WWTP was selected. As noted in Section 4, the BioWin modeling for the activated sludge process estimated the following corresponding capacities for the Scenario runs as outlined in Table 8-7.

Table 8-7. Summary of Upgrade Options for Expansion Up to 32,000 m^3/day

Option	BioWin Model Run	Alternative Details	Design Flow (m^3/day)	Flow per Train (m^3/day)	Number of Trains Required[1]
1	2B1	• Move aerators for anoxic zone • Add Adjustable Weir in Oxidation channel • Add Denitrification Filters[2] • Demolish existing filters	12,000	6,000	6
2	2B2	• Move aerators for anoxic zone • Add Adjustable Weir in Oxidation channel • Provide additional aeration • Add Denitrification Filters[2] • Demolish existing filters	16,000	8,000	4
3	2C	• Move aerators for anoxic zone • Add Adjustable Weir in Oxidation channel • Provide additional aeration • Add Denitrification Filters[2] • Demolish existing filters • Add primary clarifier to each existing train • Add Primary Sludge processing (thickener, pumping) • Add Odor Control for new Primary and Sludge Processing Tanks	32,000	16,000	2

[1] Number of trains required to provide a total combined capacity equal to or greater than 32,000 m^3/d. A treatment train refers to an Oxidation channel, Final Settling Tank and related piping/structures. Currently there are two (2) treatment trains

[2] Addition of denitrification filters is based on average design flow at 3,000 m3/d/ unit. Includes lift station, backwash water storage, chemical feed system and storage

The life cycle cost analysis was based on the following elements:

Number of Trains required: As flow through the treatment system increases, additional treatment trains must be added.

Upgrade Cost: This column includes the cost to install the necessary number of each component for the proposed model run/flow combination.

Annualized O&M Costs: A base rate of one percent of the installed cost was used for all components. Additional maintenance cost was added to all mechanical equipment components equivalent to the annualized value of a major rehabilitation every ten years that would cost approximately one third of the installation cost. Denitrification filters also include additional maintenance costs for methanol use, at $21 USD per 1,000 cubic meters per day (80 USD per day per mgd) of flow.

Present Value (PV) O&M Costs: The present value of the annualized O&M estimates was calculated by treating the annual costs as annuity payments. This value represents the amount of money to be invested now, earning an average of three percent per year, in order to have the annualized O&M costs available each year.

Present Value (PV) Replacement Estimate: This calculation estimates the amount of money to be invested now, earning an average of three percent, to accumulate the necessary funds to replace each component at the end of its useful life. Because some of the equipment is projected to last beyond the planning horizon and some will require replacement one or more times within the planning horizon, the present value calculation uses the effective interest rate for the actual replacement period. This value includes investment toward replacing equipment such as concrete tanks that are expected to last well beyond the planning horizon.

Present Value (PV) Life Cycle Cost sums the upgrade cost, the present value O&M costs, and the present value replacement estimate. The resulting value represents the amount to be invested now, earning an average of three percent per year, in order to have the funds necessary each year for installation of new and replacement equipment and ongoing maintenance of the upgrades.

It is important to recognize that the upgrade cycles for each alternative were estimated as sequential events. Therefore, the upgrade value for the 12,000 m^3/day design flow should be combined with the upgrade value for the 32,000 m^3/day design flow to find the total 20-year cost to achieve the upper flow volume. This analysis assumes that both upgrades will be completed at the same time, but separate calculations were generated to facilitate changes to the timing of the second upgrade as plans are refined. The results of the analysis are summarized in Table 8-8:

Table 8-8. Comparison of Present Value Life Cycle Costs for Expansion Options

Option	Upgrade Description	Estimated Capacity	Present Value Life Cycle Cost in USD
1	• Move aerators for influent anoxic zone • Add Denitrification Filters- 4 Units • Demolish existing filters	12,000 m^3/day	$ 7,400,000
	• Add Oxidation Channels – 4 New with influent anoxic zone • Add Final Settling Tanks – 4 New • Add Denitrification Filters – 6 New	Increase to 36,000 m^3/day	$ 30,300,000
		Total Cost at 36,000 m^3/day	**$ 37,700,000**
2	• Move aerators for influent anoxic zone • Provide Additional Aeration • Add Denitrification Filters- 4 units • Demolish existing filters	16,000 m^3/day	$ 8,300,000
	• Add Oxidation Channels – 2 New with influent anoxic zone o Adjustable effluent weir • Add Final Settling Tanks – 2 New • Add Denitrification Filters – 6 New	Increase to 32,000 m^3/day	$ 22,500,000
		Total Cost at 32,000 m^3/day	**$ 30,800,000**

Option	Upgrade Description	Estimated Capacity	Present Value Life Cycle Cost in USD
3	• Move aerators for influent anoxic zone • Provide additional aeration • Add Denitrification Filters- 4 New • Demolish existing filters	16,000 m^3/day	$ 8,300,000
	• Add primary clarifier to each existing train (2) • Add Primary Sludge processing (thickener, pumping) • Add Odor Control for new Primary and Sludge Processing Tanks • Add Denitrification Filters- 6 New	Increase to 32,000 m^3/day	$ 28,800,000
		Total Cost at 32,000 m^3/day	**$ 37,000,000**

Note: Costs rounded to $100,000.

Another consideration in upgrading a wastewater treatment facility is the capacity for existing staff to adequately maintain additional and different equipment. Based on standard projections for a plant of this size and configuration, it is likely that a staffing increase of 10% to 30% will be required, depending on which upgrades are constructed.

9 FINDINGS AND RECOMMENDATIONS

9.1 Introduction

The key directives of this study were to 1) verify the capacity of the existing biological treatment system using the BioWin model in an effort to identify its potential capacity, 2) to identify a short-term plan that will maximize the capacity of the current facilities with minimal investment while the AWC determines whether to upgrade this facility or construct an entirely new facility and ultimately abandon these facilities, and 3) to evaluate alternatives that maximize the current infrastructure and make recommendations for expanding the WWTP to meet long-term expansion goals outlined in the 2010 Master Plan report to the year 2030 and beyond.

9.2 Findings

As outlined in the BioWin modeling and analysis description in Section 4, a number of scenarios were analyzed for comparison among alternative designs and expanded capacity opportunities. The BioWin modeling reveals that the high influent ammonia nitrogen levels (>100 mg/L) and substandard BOD:TKN ratios in the biological process are limiting the nitrogen removal in the secondary treatment system. The model results also indicate that all alternative scenarios will require the addition of a post denitrification process prior to effluent disinfection and distribution to meet the JS 893 water reuse standards for Group A and JPMC industrial use. In general these limits include total nitrogen of 45 mg/L and a Nitrate-N limit of 30 mg/L which are exceeded in all BioWin modeling scenarios as indicated by the high nitrate and total nitrogen as shown in Table 4-9.

9.2.1 Scenario 1A: Existing Conditions

The results confirmed that the existing biological process has an operating capacity of 12,000 m^3/d, as currently functioning.

9.2.2 Scenario 1B1: Extend Influent Anoxic Zone

The findings also indicate that the operating capacity can be increased slightly to 12,500 m^3/d by relocating one of the existing brush aerators in each tank to another location to create an extended influent anoxic zone. An option for modifying the existing arrangement would be to relocate where incoming wastewater enters into the oxidation channel to a point further downstream of the existing influent point. For future tank construction the relocated aerator (or influent feed point) would not represent a cost difference.

9.2.3 Scenario 1B2: Extend Influent Anoxic Zone and Add Aeration

This scenario was modeled to determine the ability to increase the capacity of the existing biological process arrangement by providing additional aeration at two locations to supplement the brush aerators. This scenario also includes the extended anoxic zone created in scenario 1B1 above. As indicated, with the added modifications, the process capacity is substantially increased to 18,000 m^3/d.

9.2.4 Scenario 1BC: Provide Primary Clarification Upstream of Biological Process

This scenario was modeled as an alternate arrangement to further maximize the capacity of the existing biological process arrangement including the previous scenario modifications to the oxidation channel. This alternative potentially increases the biological process capacity up to 37,000 m^3/d, but the increased flow through the existing infrastructure introduces some hydraulic considerations.

To address odor issues and enhance conditions in the Natural WWTP, the BioWin program was modeled with the same cumulative process change scenarios as described in the Scenario 1-series above with the addition of septage loading. As noted previously in

Section 2, the acceptance of septage loads at the receiving station was intended by the facility design, and should be considered to improve conditions, especially in the Natural WWTP. In general, the added load affects the capacity for each scenario, but not significantly considering that the scenario models use maximum month loadings to provide a conservative design basis in each condition.

9.2.5 Scenario 2A: Existing Conditions with Septage Loading

The addition of septage loading reduces the existing biological process capacity to 10,000 m^3/d.

9.2.6 Scenario 2B1: Extend Influent Anoxic Zone with Septage Loading

With this change, the existing biological process has a capacity of 11,500 m^3/d which is approaching the design rating of 12,000 m^3/d.

9.2.7 Scenario 2B2: Extend Influent Anoxic Zone and Add Aeration with Septage Loading

This scenario was modeled to determine the ability to increase the capacity of the existing biological process arrangement by providing additional aeration at two general locations to supplement the brush aerators. As indicated, the process capacity is substantially increased to 16,000 m^3/d.

9.2.8 Scenario 1BC: Provide Primary Clarification Upstream of Biological Process

This scenario was modeled as an alternate arrangement to maximize the capacity of the existing biological process arrangement. This alternative shows to increase the biological process capacity up to 34,000 m^3/d, but the increased flow through the existing infrastructure does introduce some hydraulic considerations.

For all the above described scenarios, the proposed oxidation channel and clarifier arrangement reflects the existing design and appropriately sized denitrification filters and chemical feed facilities that would be added.

It should be noted that post denitrification filters can produce nitrites if the process is not allowed to completely denitrify. The presence of nitrites can drastically increase chlorine demand (up to 4-fold). The Mechanical WWTP is designed with UV disinfection rated at 24,000 m^3/d. It has recently been reported that the UV units are not in service and that chlorine is being used for disinfection. Given that nitrites significantly increase chlorine demand, it is recommended that use of the UV disinfection system be reconsidered.

9.3 Alternatives Considered

The long-term goal is to accept liquid septage at the headworks to improve operating conditions in the Natural WWTP. The findings confirm that the addition of septage at the headworks improves the carbon loading to the biological process, which is beneficial for denitrification, and does not significantly reduce the capacity of the biological system. The alternatives considered for review reflect that approach for long-term planning at the Mechanical WWTP. A summary of the details and the advantages/disadvantages is presented in Table 9-1.

- Upgrade Option 1 (Alternative 2B1) reflects minimal change to the existing infrastructure and presents the Master Plan approach to future upgrades. As presented in the comparative life cycle cost analysis (LCCA), this alternative would be the highest cost impact to the AWC for upgrades beyond the current design flow conditions.

- Upgrade Option 2 (Alternative 2B2) including additional aeration which provides a significant increase in biological treatment capacity, is the most cost effective in the LCCA for the comparative flow of 32,000 m^3/d as it reduces the number of oxidation channels required. This option also has the lowest cost per unit flow for the additional treatment capacity provided.

- Upgrade Option 3 (Alternative 2C) is not significantly higher than Option 2 with respect to capital costs, but the additional operational costs related to sludge management increase the long-term cost impact. This option which includes the addition of primary clarifiers and related sludge pumping and odor control requirements was rejected based on the noted disadvantages, the high cost impact reflected in the life cycle cost analysis (LCCA) as presented in Section 9, and the significant changes imposed on the existing WWTP operations.

A revised process flow schematic and future flow expansion details for upgrade options considered is provided in Figures 9-1 through 9-3.

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Table 9-1. Comparison of Upgrade Options Considered

Option	Description	Max Flow (m^3/day)	Advantages	Disadvantages
1	• Move aerators for influent anoxic zone • Add Adjustable Weir in Oxidation channel • Add Denitrification Filters and demolish existing filters	12,000	• Anoxic zone improves capacity for existing condition • Allows phasing in 6,000 m^3/d increments per the Master Plan	• Limits capacity increments for future upgrade phases
2	• Move aerators for influent anoxic zone • Add Adjustable Weir in Oxidation channel • Provide additional aeration • Add Denitrification Filters and demolish existing filters	16,000	• Allows phasing in 8,000 m^3/d increments • Continues existing sludge management program • Most cost effective for future upgrades	• Upgrade capacity increments are not same as original design
3	• Move aerators for anoxic zone • Add Adjustable Weir in Oxidation channel • Provide additional aeration • Add Denitrification Filters and demolish existing filters • Add covered primary clarifier to each existing train • Add Primary Sludge processing (thickener, pumping) • Add Odor Control for new Primary and Sludge Processing Tanks	32,000	• Allows phasing in 16,000 m^3/d increments • No new oxidation channels or final settling tanks required • Allows phased improvements • Highest capacity realized for exiting biological treatment infrastructure	• Primary sludge processing requires odor control and tank covers • Flows greater than 24,000 m^3/d will require upsizing of other unit processes • Primary settling reduces carbon available for biological process

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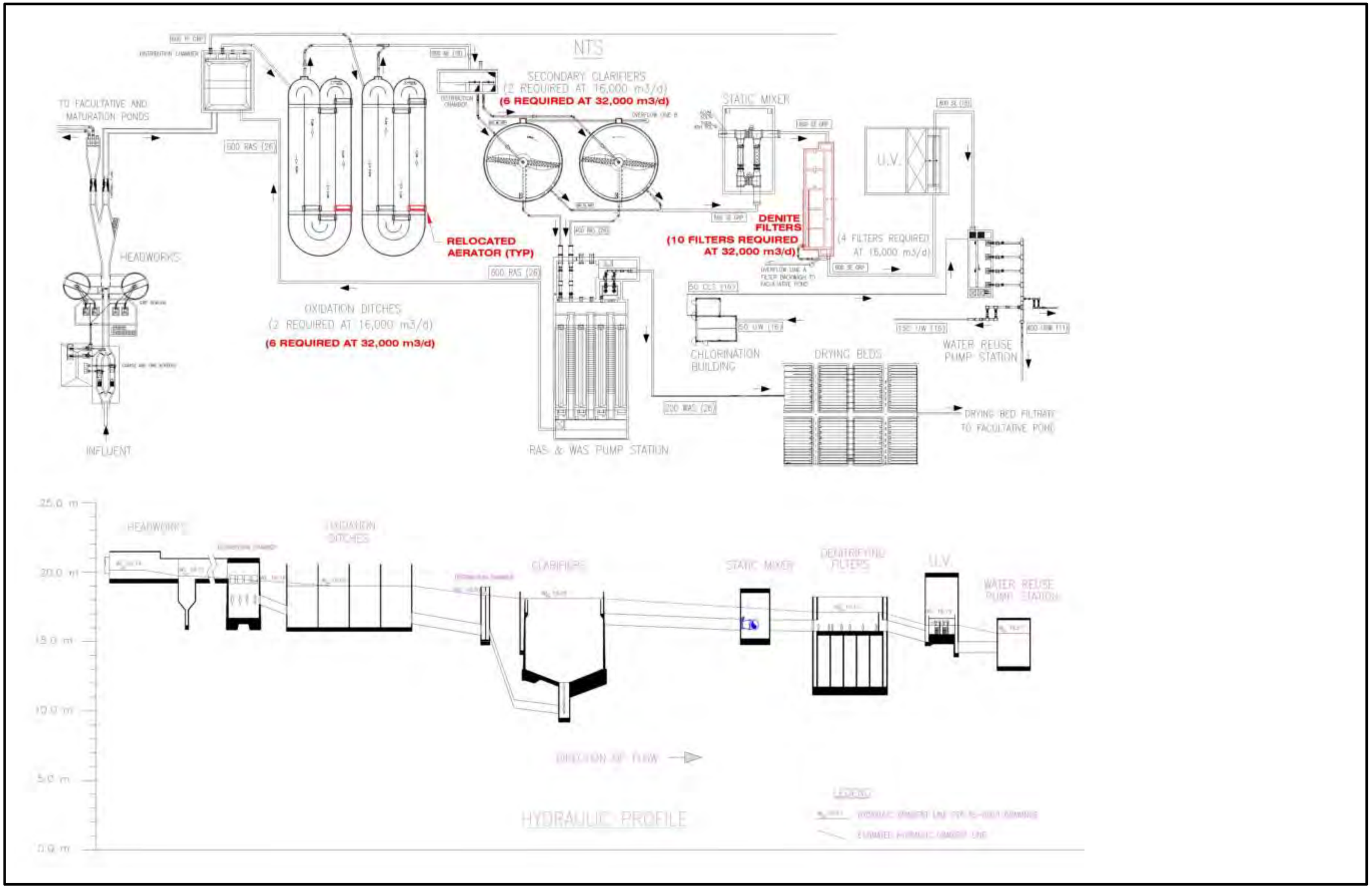

Figure 9-1. Option 1 (Scenario 2B1) Process Flow Diagram and Estimated Hydraulic Profile

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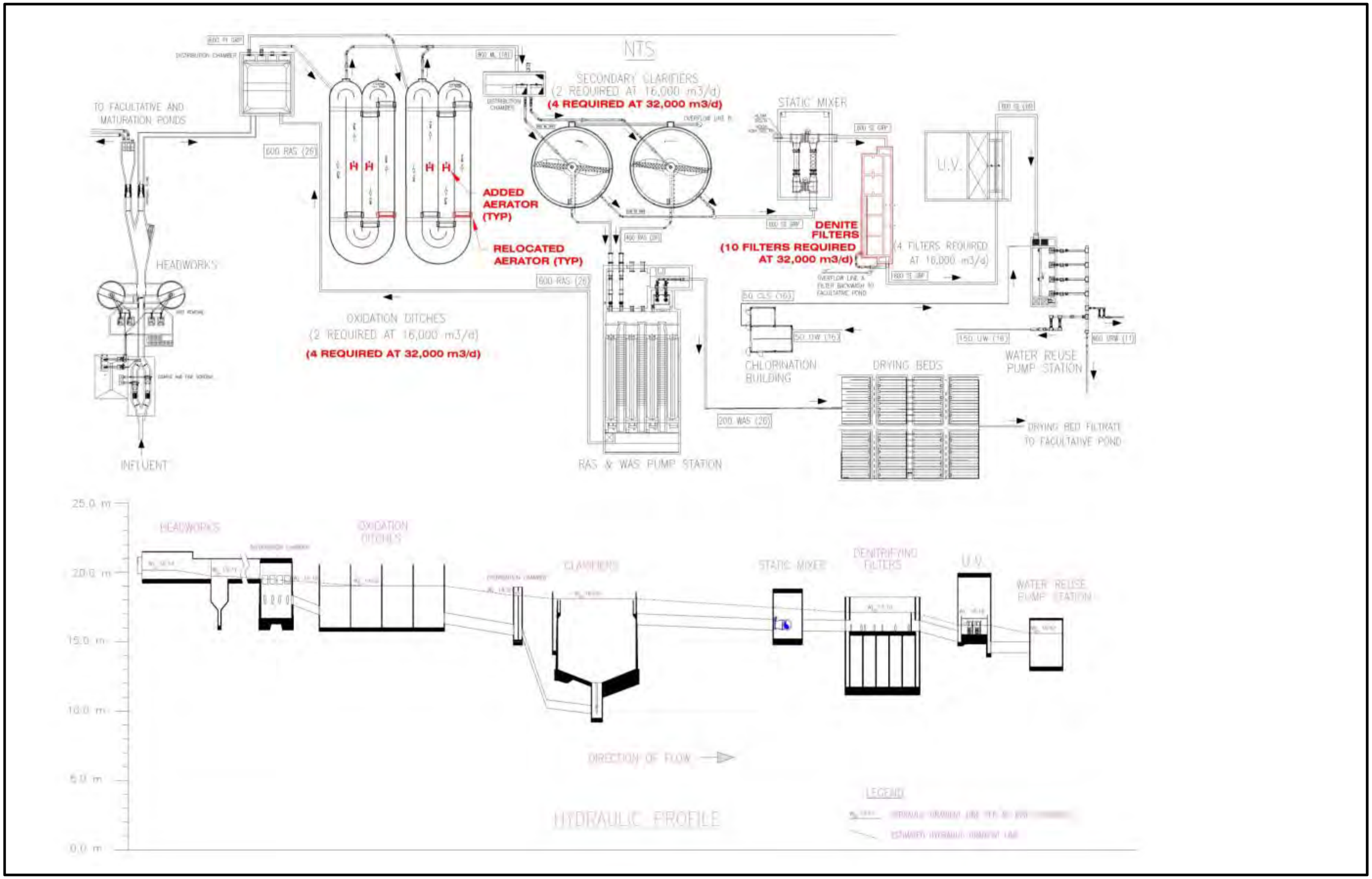

Figure 9-2. Option 2 (Scenario 2B2) Process Flow Diagram and Estimated Hydraulic Profile

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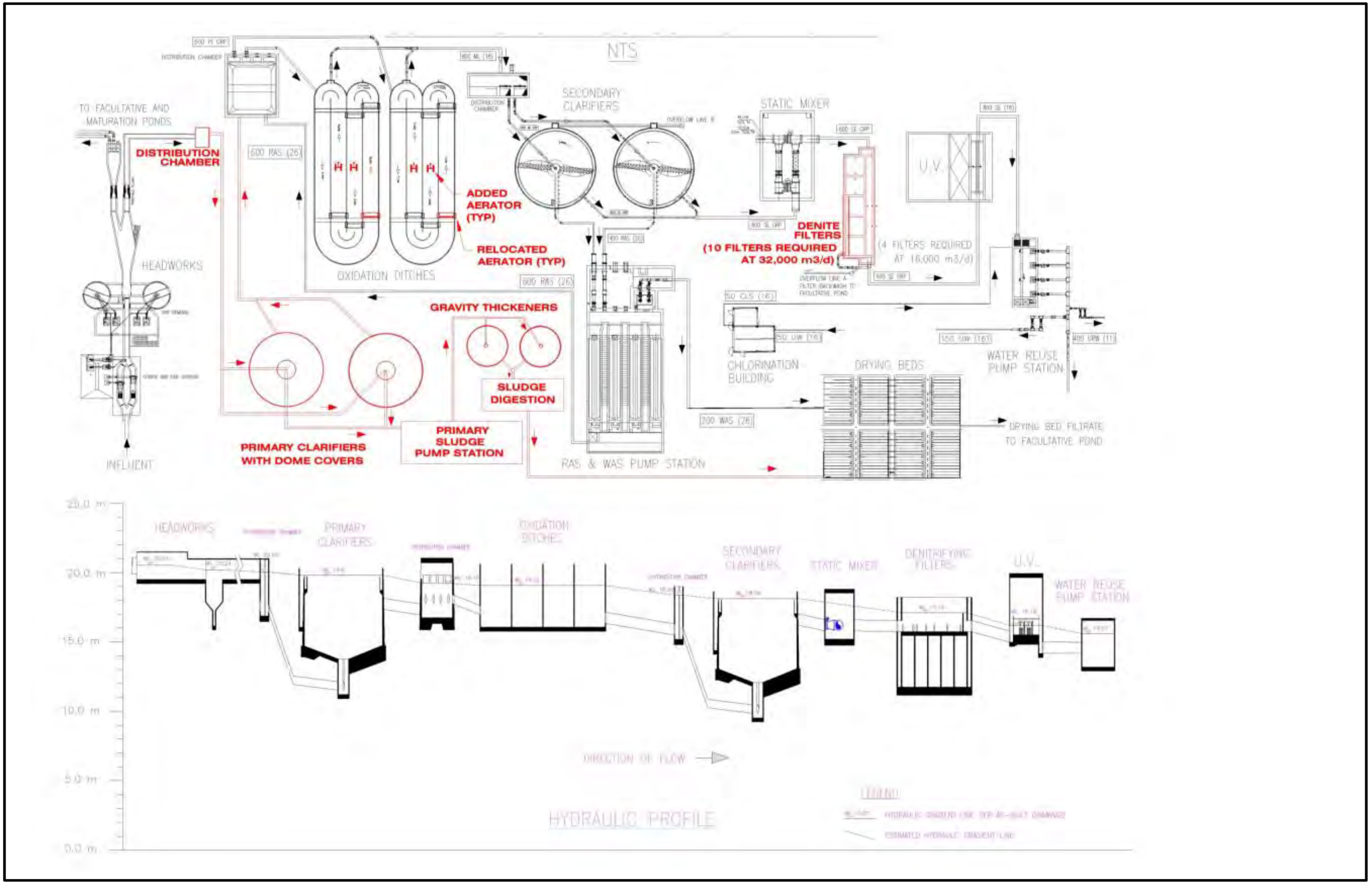

Figure 9-3. Option 3 (Scenario 2C) Process Flow Diagram and Estimated Hydraulic Profile

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9.4 Recommended Plan

At current average flows of 10,500 m^3/d and peak flows during the past year reaching 14,000 m^3/d, the existing facilities are already approaching the hydraulic design limit of the biological treatment capacity. The following actions are based on the recommended Upgrade Option 2 (Alternative 2B2):

1) Initiate recommended wastewater characterization sampling immediately. The nitrogen data reported by the AWC includes a number of anomalies with respect to high concentrations of Ammonia and Nitrate in the raw wastewater influent. As a result, the biological process modeling calculated very high nitrification requirements without adequate conditions for biological denitrification. Due to the very high nitrate concentrations generated from the biological process and the low limit for nitrate in the JS 893 reuse standard, post denitrification filters that utilize methanol are required.

2) Conduct a survey of the existing WWTP to assess infrastructure issues and possible O&M measures to be implemented. The facility has been in operation for approximately 10 years and some recent equipment repairs have been reported, including brush aerator refurbishing, turbine mixer issues, UV equipment, and effluent filters out of service that warrant a complete survey be performed to assess critical process equipment.

3) Proceed with planning and design of improvements to existing oxidation channels to increase the influent anoxic zone to improve nitrogen reduction in the biological process. This will require some engineering and planning to verify the structural requirements for associated brush relocation, or relocation of the influent feed pipe and its discharge location.

4) Proceed with planning and design of improvements to provide an adjustable effluent weir to increase operational flexibility and potential aeration capacity. The 50kW brush aerators are currently drawing between 36 and 44 kW at the current fixed weir elevation. Adjustable weirs will allow the operators to increase the aeration capacity in the oxidation channels.

5) Conduct additional BioWin modeling based on new data from the characterization sampling to confirm or modify design conditions for the recommended alternative. This task is recommended due to the nitrogen anomalies mentioned in this report that resulted in high nitrogen loadings modeled in BioWin for this report that resulted in very high nitrate concentrations from the biological process to the proposed denitrification filters. This is highlighted to emphasize the need for further investigation at the next stage of design after AWC gathers and provides more historical data on all influent Nitrogen compounds.

6) Consider receiving septage to the Mechanical WWTP Headworks when the biological system performance is reviewed.

7) Proceed with planning and design of odor control improvements at the Headworks to address current odors from the influent sewer and existing processes that also consider loading from the septage receiving facility.

8) Proceed with design of a Mechanical WWTP upgrade plan for flows up to 24,000 m^3/d. As presented in the 2010 Master Plan, all of the WWTP process infrastructure is rated for 24,000 m^3/d except for the Biological Process (rated at

12,000m^3/d) and the Headworks (rated at 48,000 m^3/d). The recommended Phase 2 upgrades include the addition of one oxidation channel and secondary clarifier arrangement for biological treatment to bring the Mechanical WWTP capacity to 24,000 m^3/d. Any increases in capacity greater than 24,000 m^3/d will require a more thorough engineering review to determine the best way to increase the capacity of all the other plant processes in addition to the Biological Process.

The new oxidation channel would be designed and specified with the adjustable weir gates and other aeration efficiency enhancements as part of the recommended modifications to the existing channels. The three phases of this plan include the following improvements to the Mechanical WWTP:

- Phase 1 – Initial aeration modifications and construction of denitrification filter(s) to treat up to 16,000 m^3/d.
- Phase 2 – Construction of a new single biological treatment train (oxidation channel and secondary clarifier) and denitrification filter(s) to provide an additional capacity of 8,000 m^3/d for a total of 24,000 m^3/d. This would be completed by the year 2019 to meet shifted projected future flows as indicated in Figure 9-4.
- Future – Planning and design of biological process improvements and denitrification facilities beyond 24,000 m^3/d will also require upgrades to other WWTP infrastructure that have a reported capacity limit of 24,000 m^3/d. These include the RAS/WAS pumping station, the UV disinfection and turbine mixers as well as solids handling systems, and pipe distribution systems throughout the WWTP.

Figure 9-4. Mechanical WWTP Upgrade Plan to Meet Future Flow Demands

A summary of the related infrastructure costs for expansion up to a recommended capacity of 24,000 m^3/d is presented in Table 9-2. A site plan is presented below in Figure 9-5 that shows the phased implementation of the recommended plan improvements for the biological treatment process and conceptual arrangement for the new denitrification filters to treat future flows of 32,000 m^3/d as presented in the Master Plan. However, as noted previously,

any future upgrades beyond 24,000 m^3/d must also include increasing the capacity of other unit processes not shown in the figure which requires a more comprehensive evaluation.

Table 9-2. Project Costs for Recommended Option 2 Expansion Up to 24,000 m^3/d

Description	Quantity	Unit	Unit Cost	Estimated Costs	
				Initial	Expansion
Construction					
Relocate aerators	2	Pair	$100,000	$200,000	$0
Add adjustable weirs	3	Each	$100,000	$200,000	$100,000
Add aerators	3	Pair	$200,000	$400,000	$200,000
Denitrifying Filters	8	Each	$650,000	$2,600,000	$2,600,000
Oxidation channels	1	Each	$1,840,000	$0	$1,840,000
Secondary clarifiers	1	Each	$550,000	$0	$550,000
GRP Piping	100	Lin. meter	$620	$0	$62,000
Construction Subtotal				**$3,400,000**	**$5,400,000**
Contractor OH & P	1	Percent	21%	$700,000	$1,134,000
Construction Contract Subtotal				**$4,100,000**	**$6,500,000**
Project Services	1	Percent	25%	$1,000,000	$1,600,000
Construction and Services Subtotal				**$5,100,000**	**$8,100,000**
Contingency	1	Percent	30%	$1,500,000	$2,400,000
Estimated Project Cost				**$6,600,000**	**$10,500,000**

Note: Totals rounded to $100,000.

Figure 9-5. Option 2 Recommended Phased Improvements

9.5 Recommended Wastewater Characterization Sampling

As noted in this report, process sampling and data reporting issues; including frequency, accuracy, consistency and/or reliability have contributed to the difficulties experienced in using the BioWin modeling program in evaluating the existing biological process. This modeling also affects other process recommendations and related solids processing. The end result is the development of conservative recommendations based on a lack of confidence to predict future performance for the process. Calculations are only as reliable as the input values used in the equations.

In an effort to improve this evaluation and further refine these recommendations, it is advised that the AWC begin a comprehensive process monitoring and sampling program that includes contracting with a certified testing laboratory. The outside lab should conduct independent sampling and laboratory analyses with results compared in parallel to the same performed by the Operations staff. Process data monitoring is critical to maintaining consistent WWTP performance, reliable operations, and provides a basis for future process upgrades in response to changing needs. After a sufficient period of time (several months), the existing process BioWin modeling should be updated based on the new data collected with greater confidence and allow a more accurate design with less conservatism and contingencies that can escalate project costs.

Recommendations regarding process operations and performance sampling necessary for future modeling include the following:

1. Influent and Effluent Sampling

   Flow proportional composite samples for the influent (at the Headworks channel) and effluent (at the UV effluent channel) will give the most accurate data on WWTP influent loading and overall process performance. Sampling for the following parameters is recommended at the frequency noted:

   - Influent or effluent temperature data (daily);
   - Influent and effluent COD or BOD (3-5 times per week);
   - Influent TKN (3-5 times per week);
   - Influent Alkalinity (1-3 times per week); and
   - Influent and Effluent NH_3 and NO_3 (3-5 times per week).

2. Dissolved Oxygen measurements
   Daily measurements along the oxidation channel will provide a dissolved oxygen profile. The most popular method for measurements is with a dissolved oxygen meter and sensor. Several of the dissolved oxygen sensor technologies are available in a smart sensor platform with a digital output. Suggested locations are; just before the aerators, just after the aerators, and two equally spaced locations in between. Measurements should be just below the water surface by dipping a probe along the outside edges of the tank that are accessible to the operators. Measurements were recently provided once weekly from January to April 2015 for each oxidation channel and were very helpful. It is recommended that this practice continue.

3. TSS and VSS analysis of RAS/WAS
   Analyzing the RAS/WAS for TSS and VSS on a regular basis will be useful and relevant to the waste sludge processing and odor control processes. Data received to date on these characteristics was apparently estimated at 70 or 75% of TSS. Grab

samples taken from the influent flow to the RAS/WAS pumping station on a daily basis would be appropriate for this profiling.

4. Septage Testing
   The characteristics of septage can be highly variable and can impact WWTP influent loading, especially if commercial or industrial properties are served by septic systems. Grab samples (1/week for 4-6 weeks) from a mixed location at the receiving tank would be helpful to characterize the TSS, COD and TKN loading on the WWTP process. If the sampling results are consistent during the initial sampling period, the frequency could be reduced to 1/month. Currently the septage is discharged to the Natural WWTP. If the septage receiving facility located east of the Headworks were utilized, the septage would be introduced upstream of the Headworks and thus benefit from screening and grit removal before biological treatment.

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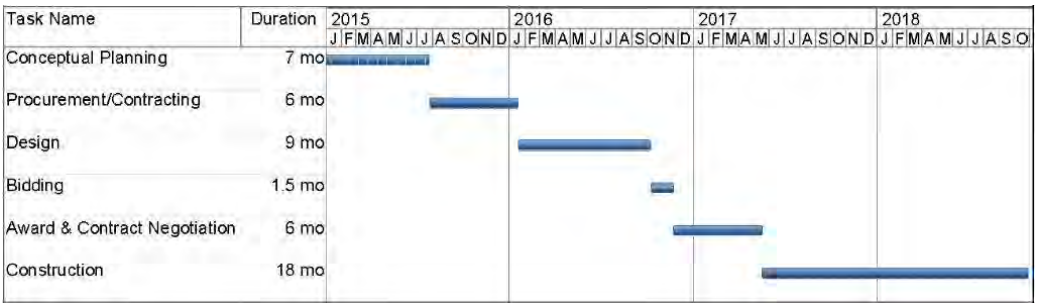
10 SCHEDULE

An approximate schedule for plant upgrades has been developed for preliminary planning purposes. This Preliminary Evaluation Report is included in the Preliminary Design phase. Design of the upgrades will take less than a year. This process may require survey and/or soil borings to update detailed information on site conditions. Bidding, contract award and contract negotiation typically can take six to eight months, followed by one to two years for construction of upgrades. This sequence is shown graphically below.

Figure 10-1. Approximate Project Schedule



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GLOSSARY OF WASTEWATER TERMS AND ACRONYMS

A

Absorb - To take in.

Accretion - A gradual increase in land area adjacent to a river.

Acid Rain - The acidic rainfall which results when rain combines with sulfur oxides emissions from combustion of fossil fuels.

Activated Carbon Adsorption - The process of pollutants moving out of water and attaching on to activated carbon.

Activated Sludge - Term given to a method of wastewater treatment that uses aerobic and facultative bacteria in suspension to remove wastes. Activated sludge is a popular method of treatment, and dozens of variations on the basic process exist.

Adhesion - The molecular attraction asserted between the surfaces of bodies in contact. Compare cohesion.

ADF - Average Daily Flow.

Adsorption - The adhesion of a substance to the surface of a solid or liquid. Adsorption is often used to extract pollutants by causing them to be attached to such adsorbents as activated carbon or silica gel. Hydrophobic, or water-repulsing adsorbents, are used to extract oil from waterways in oil spills.

Aeration - The mixing or turbulent exposure of water to air and oxygen to dissipate volatile contaminants and other pollutants into the air.

Aeration Basins - Provide the conditions necessary (food, air and water) for the decomposition of organic waste. This process is often referred to as activated sludge to indicate the "activation" of microorganisms for organic decomposition and removal.

Aerobic - Wastewater treatment depending on oxygen for bacterial breakdown of waste.

Aerobic Bacteria – Bacteria that require the presence of free or dissolved oxygen in their environment for survival and reproduction.

Alkalinity - The measurement of constituents in a water supply which determine alkaline conditions. The alkalinity of water is a measure of its capacity to neutralize acids.

Anaerobic - Wastewater treatment in which bacteria breakdown waste without using oxygen.

Anaerobic Bacteria - Bacteria that live and reproduce in an environment that contains no free or dissolved oxygen. They get their required oxygen by breaking down chemical compounds that contain oxygen such as sulfate (SO_4) or nitrate (NO_3).

Aquatic - Growing in, living in, or frequenting water.

Aquifer - A geologic formation that will yield water to a well in sufficient quantities to make the production of water from this formation feasible for beneficial use; permeable layers of underground rock or sand that hold or transmit groundwater below the water table.

ARW – Agricultural reclaimed water; treated wastewater to a level compliant with regulations and end user requirements per JS 893.

ASEZA – Aqaba Special Economic Zone Authority setup principally to encourage multiple investment opportunities in a multi sector development zone of Aqaba.

AWC – Aqaba Water Company

B

Backwashing - Reversing the flow of water through a filter or membrane to clean and remove deposits.

Bar Screen -Preliminary treatment apparatus used to remove large pieces of trash, sticks and rags from raw wastewater.

Barrage - Any artificial obstruction placed in water to increase water level or divert it, typically to control peak flow for later release.

Beneficial Use - The economical reuse of treated wastewater in place of potable or raw water, or biosolids in place of manufactured commercial fertilizers including the following uses as allowed by permit: irrigation for farming and landscaping, industrial uses, use of biosolids to improve soil properties, plant productivity, and reduce dependence on inorganic fertilizers, and other applications as permitted.

Bioaccumulation - Uptake and retention of substances by an organism from its surrounding medium (usually water) and from food.

Bio-monitoring - A test used to evaluate the relative potency of a chemical by comparing its effect on a living organism with the effect of a standard population on the same type of organism.

Bioremediation -A process that uses living organisms to remove pollutants.

Biosolids - A nutrient-rich organic material resulting from the treatment of domestic wastewater. Biosolids contain nitrogen and phosphorus along with other supplementary nutrients in smaller doses, such as potassium, sulfur, magnesium, calcium, copper and zinc. Soil that is lacking in these substances can be reclaimed with biosolids use. The application of biosolids to land improves soil properties and plant productivity, and reduces dependence on inorganic fertilizers.

Black Water - Wastewater from toilet, latrine, and privy flushing, and sinks used for food preparation or disposal of chemical or chemical-biological ingredients.

Blinds - Water samples containing a chemical of known concentration given a fictitious company name and slipped into the sample flow of the lab to test the impartiality of the lab staff.

Blow-down - The water drawn from boiler systems and cold water basins of cooling towers to prevent the buildup of solids.

Boiling Point - The temperature at which a liquid boils. It is the temperature at which the vapor pressure of a liquid equals the pressure on its surface. If the pressure of the liquid varies, the actual boiling point varies. For water it is 100 degrees Celsius.

BOD (Biochemical Oxygen Demand) - A measure of the amount of oxygen required to neutralize organic wastes.

Brine - Highly salty and heavily mineralized water containing heavy metal and organic contaminants.

Buoyancy - The tendency of a body to float or rise when immersed in a fluid; the power of a fluid to exert an upward force on a body placed in it.

C

Calcium Carbonate - C_ACO_3 - a white precipitate that forms in water lines, water heaters and boilers in hard water areas; also known as scale.

Calorie - Amount of energy required to raise the temperature of 1 gram of water 1 degree Celsius.

Carbonates - The collective term for the natural inorganic chemical compounds related to carbon dioxide that exist in natural waterways.

CFU - Colony forming units.

Chlorination - The addition of chlorine to water or sewage for the purpose of disinfection or other biological or chemical results.

Chlorine Demand - The difference between the amount of chlorine added to water, sewage, or industrial wastes and the amount of residual chlorine remaining at the end of a specific contact period.

Chute Spillway - The overall structure which allows water to drop rapidly through an open channel without causing erosion. Usually constructed near the edge of dams.

Circulate - To move in a circle, circuit or orbit; to flow without obstruction; to follow a course that returns to the starting point.

Cistern -A tank used to collect rainwater runoff from the roof of a house or building.

Coagulation - In water treatment, the use of chemicals to make suspended solids gather or group together into small flocs.

COD (Chemical Oxygen Demand) - The COD test measures the chemical oxidant required to break down organics. COD is an indicator of the concentration of organics in water. The COD test can be completed in a few hours and is frequently substituted for BOD. COD levels are usually greater than BOD for a given wastewater.

Cohesion - A molecular attraction by which the particles of a body are united throughout the mass whether like or unlike.

Cold Vapor - Method to test water for the presence of mercury.

Coliform Bacteria - Non-Pathogenic microorganisms used in testing water to indicate the potential presence of pathogenic bacteria.

Colloids - Finely divided solids which will not settle but which may be removed by coagulation or biochemical action.

Composite Sample, Weighted - A sample composed of two or more portions collected at specific times and added together in volumes related to the flow at time of collection.

Concentration - Amount of a chemical or pollutant in a particular volume or weight of air, water, soil, or other medium.

Condensation - The change of state from a gas to a liquid.

Confluent Growth - In coliform testing, abundant or overflowing bacterial growth which makes accurate measurement difficult or impossible.

Conservation - To protect from loss and waste. Conservation of water may mean to save or store water for later use.

Contamination - The introduction into water of sewage or other foreign matter that will render the water unfit for its intended use.

Critical Low Flow - Low flow conditions below which some standards do not apply. The impacts of permitted discharges are analyzed at critical low-flow.

D

Deionized Water - Water free of inorganic chemicals.

Deposit - Something dropped or left behind by moving water, such as sand or mud.

Desalination - The process of salt removal from sea or brackish water.

Detention Time - Time a theoretical particle/water drop will remain in a tank or basin. The product of capacity divided by flow.

Detection Limit - The lowest level that can be determined by a specific analytical procedure or test method.

Diatomaceous - Consisting of or abounding in diatoms, a class of unicellular or colonial algae having a silicified cell wall that persists as a skeleton after death.

Diluting Water - Distilled water that has been stabilized, buffered, and aerated. Used in the BOD test.

Discharge - The volume of water that passes a given point within a given period of time. It is an all-inclusive outflow term, describing a variety of flows such as from a pipe to a stream, or from a stream to a lake or ocean.

Disinfection - The killing of the larger portion of the harmful and objectionable bacteria in the sewage. Usually accomplished by introduction of chlorine, but more and more facilities are using exposure to ultraviolet radiation, which renders the bacteria sterile.

Disinfection Byproducts - Halogenated organic chemicals formed when water is disinfected.

Dissolve - The process by which solid particles mix molecule by molecule with a liquid and appear to become part of the liquid.

Dissolved Oxygen (DO) - The amount of free oxygen available in water or other liquid solution for use by bacteria. Measured in ppm (parts per million) or mg/L (milligrams per liter).

Dissolved Solids - Inorganic material contained in water or wastes. Excessive dissolved solids make water unsuitable for drinking or industrial uses.

Distillation - Water treatment method where water is boiled to steam and condensed in a separate reservoir. Contaminants with higher boiling points than water do not vaporize and remain in the boiling flask.

Distilled Water - Water that has been treated by boiling and condensation to remove solids, inorganics, and some organic chemicals.

Diversion - To remove water from a water body. Diversions may be used to protect bottomland from hillside runoff, divert water away from active gullies, or protect buildings from runoff.

Domestic Wastewater - The liquid wastes generated by residences, commercial, and institutional facilities.

Drainage Area - The area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into the stream above the specified location.

Duplicates - Two separate samples with separate containers taken at the same time at the same place.

E

Effluent - Any substance, particularly a liquid that enters the environment from a point source. Generally refers to wastewater from a sewage treatment or industrial plant.

Enteric Viruses - A category of viruses related to human excreta found in waterways.

Environment - Aggregate of external conditions that influence the life of an individual organism or population.

Erosion - The wearing away of the land surface by wind, water, ice or other geologic agents. Erosion occurs naturally from weather or runoff but is often intensified by human land use practices.

F

Facultative Bacteria -Bacteria that function equally well whether free or dissolved oxygen is available in their environment or not.

Fecal Coliform - The portion of the coliform bacteria group which is present in the intestinal tracts and feces of warm-blooded animals. A common pollutant in water.

Fermentation, Anaerobic - Process in which carbohydrates are converted in the absence of oxygen to hydrocarbons (such as methane).

Filter - A device used to remove solids from a mixture or to separate materials. Materials are frequently separated from water using filters.

Filtration - The mechanical process which removes particulate matter by separating water from solid material, usually by passing it through sand.

Flocculation - Large scale treatment process involving gentle stirring whereby small particles in flocs are collected into larger particles so their weight causes them to settle to the bottom of the treatment tank.

Flora - Plant population of a region.

Flow - The rate of water discharged from a source expressed in volume with respect to time.

Flow Augmentation - The addition of water to meet flow needs.

Freezing - The change of a liquid into a solid as temperature decreases. For water, the freezing point is 32 degrees Fahrenheit or 0 degrees Celsius.

Fresh Water - Water containing less than 1,000 parts per million (ppm) of dissolved solids of any type.

Frost - A covering of minute ice crystals on a cold surface.

G

Geohydrology - A term which denotes the branch of hydrology relating to subsurface or subterranean waters; that is, to all waters below the surface.

Grab Sample - A sample taken at a given place and time.

Granular Activated Carbon - Pure carbon heated to promote "active" sites which can adsorb pollutants. Used in some home water treatment systems to remove certain organic chemicals and radon.

Gravity Sewer - Sewer line that uses a declining grade to induce the flow of wastewater. This is the most common type of sewer line in existence.

Grey Water - Wastewaters from clothes washing machines, showers, bathtubs, hand washing, lavatories and sinks that is are not used for disposal of chemical or chemical-biological ingredients.

Groundwater - Water within the earth that supplies wells and springs; water in the zone of saturation where all openings in rocks and soil are filled, the upper surface of which forms the water table.

Groundwater Recharge - The inflow to a ground water reservoir.

Groundwater Runoff - The portion of runoff which has passed into the ground, has become ground water, and has been discharged into a stream channel as spring or seepage water.

H

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ha (Hectare) – Area representing 1,000 square meters

Hard Water - Water containing a high level of calcium, magnesium, and other minerals. Hard water reduces the cleansing power of soap and produces scale in hot water lines and appliances.

Hardness (Water) - Condition caused by dissolved salts of calcium, magnesium, and iron, such as bicarbonates, carbonates, sulfates, chlorides, and nitrates.

Head - The pressure of a fluid owing to its elevation, usually expressed in meters or feet of head or in pounds per square centimeter or inch, since a measure of fluid pressure is the height of a fluid column above a given or known point.

Heavy Water - Water in which the majority of hydrogen atoms are the deuterium isotope.

Hp - Horsepower is a common term regarding electrical power.

Hydrograph - A chart that measures the amount of water flowing past a point as a function of time.

Hydrologic Cycle - Natural pathway water follows as it changes between liquid, solid, and gaseous states; biogeochemical cycle that moves and recycles water in various forms through the ecosphere. Also called the water cycle.

Hydrologic Unit - A geographic area representing part or all of a surface drainage basin or distinct hydrologic feature.

Hydrometer - An instrument used to measure the density of a liquid.

Hydrostatic Head - A measure of pressure at a given point in a liquid in terms of the vertical height of a column of the same liquid which would produce the same pressure.

Hydrostatic Pressure - Pressure exerted by or existing within a liquid at rest with respect to adjacent bodies.

I

Ice - The solid form of water.

Impermeable - Material that does not permit fluids to pass through.

Impervious - The quality or state of being impermeable; resisting penetration by water or plant roots. Impervious ground cover like concrete and asphalt affects quantity and quality of runoff.

Indicator Organisms - Microorganisms, such as coliforms, whose presence is indicative of pollution or of more harmful microorganism.

Indicator Tests - Tests for a specific contaminant, group of contaminants, or constituent which signals the presence of something else (e.g., coliforms indicate the presence of pathogenic bacteria).

Infiltration - The groundwater that enters a sewer system through such means as defective pipes, pipe joints, or porous manhole walls. Infiltration does not include inflow, however, "Rainfall Induced Infiltration" (RII) of groundwater may occur during and for a short period after rainfall events and have similar characteristics to Inflow.

Inflow - Storm water that enters a sewer system directly through a connection such as roof leaders; basements, foundations, a yard drains; catch basins, etc.

I/I - The total quantity of water in a sewer system from both infiltration and inflow, not distinguished as to source.

Influent - The commercial and residential waste materials carried in water via underground pipes to the water pollution control facility; (also referred to as wastewater or sewage).

Interbasin Transfer - The physical transfer of water from one watershed to another.

ISS – Inert suspended solids portion of TSS.

J

JPMC – Jordan Phosphate Mines Company

K

None

L

Laboratory Water - Purified water used in the laboratory as a basis for making up solutions or making dilutions. Water devoid of interfering substances.

Lag Time - The time from the center of a unit storm to the peak discharge or center of volume of the corresponding unit hydrograph.

Lagoon - A shallow pond where sunlight, bacterial action, and oxygen work to purify wastewater. Lagoons are typically used for the storage of wastewaters, sludges, liquid wastes, or spent nuclear fuel.

Lake - An inland body of water, usually fresh water, formed by glaciers, river drainage etc. Usually larger than a pool or pond.

Leachate - Water containing contaminants which drains from a disposal site such as a landfill or dump.

Leaching - Extraction or flushing out of dissolved or suspended materials from the soil, solid waste, or another medium by water or other liquids as they percolate down through the medium to groundwater.

Lift Station - An assembly of a wet well, a level control, and one or more pumps designed to take the flow from a gravity sewer system and boost it over a hill or up some other grade where the installation of gravity sewer lines is impossible or impractical.

Limiting Factor - Factor such as temperature, light, water, or a chemical that limits the existence, growth, abundance, or distribution of an organism.

Liquid - A state of matter, neither gas nor solid, that flows and takes the shape of its container.

M

Marsh - An area periodically inundated by water, generally treeless, and often characterized by grasses, cattails, and other monocotyledons.

MCL - Maximum Contaminant Level - The maximum level of a contaminant allowed in water by regulation. Typically based on health effects and currently available treatment methods.

Median Stream Flow - The rate of discharge of a stream for which there are equal numbers of greater and lesser flow occurrences during a specified period.

Melting - The changing of a solid into a liquid.

Melt Water - Water that comes from the melting ice of a glacier or a snow bank.

Method Blank - Laboratory grade water taken through the entire analytical procedure to determine if samples are being accidentally contaminated by chemicals in the lab.

Micrograms per Liter (µg/L) - One thousand micrograms per liter is equivalent to 1 milligram per liter. This measure is equivalent to parts per billion (ppb)

Migration - The movement of oil, gas, contaminants, water, or other liquids through porous and permeable rock.

mg/L - Milligrams per Liter which is equivalent to parts per million (ppm).

Minimum Streamflow - The specific amount of water reserved to support aquatic life, to minimize pollution, or for recreation. It is subject to the priority system and does not affect water rights established prior to its institution.

Mixed Liquor - Term used to describe the mixture of wastewater with activated sludge in a wastewater treatment facility.

Municipal Sewage - Sewage from a community which may be composed of domestic sewage, industrial wastes or both.

N

Natural flow - The rate of water movement past a specified point on a natural stream. The flow comes from a drainage area in which there has been no stream diversion caused by storage, import, export, return flow, or change in consumptive use caused by man-controlled modifications to land use. Natural flow rarely occurs in a developed country.

Natural Resource - Any form of matter or energy obtained from the environment that meets human needs.

Nitrogen - A nutrient that can cause an overabundance of bacteria and algae when high amounts are present, leading to a depletion of oxygen and fish kills. Several forms occur in water, including ammonia, nitrate, nitrite or elemental nitrogen. High levels of nitrogen in water are usually caused by agricultural runoff or improperly operating wastewater treatment facilities.

Non-consumptive Use - Using water in a way that does not reduce the supply. Examples include hunting, fishing, boating, water-skiing, swimming, and some power production.

Non-contact Recreation - Recreational pursuits not involving a significant risk of water ingestion, including fishing, commercial and recreational boating, and limited body contact incidental to shoreline activity.

Nonporous - Something which does not allow water to pass through it.

Nonpoint Source - Source of pollution in which wastes are not released at one specific, identifiable point but from a number of points that are spread out and difficult to identify and control.

Nonpotable - Not suitable for drinking.

Nonthreshold pollutant - Substance or condition harmful to a particular organism at any level or concentration.

NPDES Permit - Permit issued under the National Pollutant Discharge Elimination System for companies discharging pollutants directly into the waters of the United States.

NTU - Nephlometric turbidity units.

Nutrient - As a pollutant, any element or compound, such as phosphorous or nitrogen, that fuels abnormally high organic growth in aquatic ecosystems.

O

Organic Chemicals - Chemicals containing carbon.

Outfall - The place where a wastewater treatment facility discharges treated water into the environment.

Overflow - A discharge of untreated wastewater from the collection system.

Oxygen Demanding Waste - Organic water pollutants that are usually degraded by bacteria if there is sufficient dissolved oxygen (DO) in the water.

OSWDS - On-site Waste Disposal Systems

P

PPB (Parts per Billion) - A measurement of concentration; number of parts in one billion parts of a solid, liquid, or gaseous mixture. Equivalent to micrograms per liter (µg/L).

PPM (Parts per Million) - A measurement of concentration; number of parts of a chemical found in one million parts of a solid, liquid, or gaseous mixture. Equivalent to milligrams per liter (mg/L).

Pathogens - Bacteria or other things (viruses, et. al) that cause disease in a host.

Peak Flow - In a wastewater treatment plant, the highest flow expected to be encountered under any operational conditions, including periods of high rainfall and prolonged periods of wet weather.

Percolation - The movement of water through the subsurface soil layers, usually continuing downward to the groundwater or water table reservoirs.

Permeability - The ability of a water bearing material to transmit water. It is measured by the quantity of water passing through a unit cross section, in a unit time, under 100 percent hydraulic gradient.

pH - The logarithm of the reciprocal (negative log) of the hydrogen ion concentration (hydrogen ion activity) in moles per liter that describes the intensity of the acid or basic (alkaline) conditions of a solution. The pH scale is from 0 to 14, with the neutral point at 7.0. Values lower than 7.0 indicate the presence of acids and greater than 7.0 the presence of alkalis (bases).

Phosphorous - A nutrient that can cause an overabundance of bacteria and algae when high amounts are present, leading to a depletion of oxygen and fish kills. High levels of phosphorous in water are usually caused by agricultural runoff or improperly operating wastewater treatment facilities.

Plug - Cement, grout, or other material used to fill and seal a hole drilled for a water well.

Point Source - Source of pollution that involves discharge of wastes from an identifiable point, such as a smokestack or wastewater treatment facility.

Pollution - Undesirable change in the physical, chemical, or biological characteristics of the air, water, or land that can harmfully affect the health, survival, or activities of human or other living organisms.

Pond - A body of water usually smaller than a lake and larger than a pool either naturally or artificially confined.

Porous - Something which allows water to pass through it.

Potable - Suitable, safe, or prepared for drinking.

Precipitate - A solid which has come out of an aqueous solution. (ex., iron from groundwater precipitates to a rust colored solid when exposed to air).

Preservative - A chemical added to a water sample to keep it stable and prevent compounds in it from changing to other forms or to prevent microorganism densities from changing prior to analysis.

Primary Treatment - Mechanical treatment in which large solids are screened out and suspended solids in the sewage settle out as sludge.

Pump - A device which moves, compresses, or alters the pressure of a fluid, such as water or air, being conveyed through a natural or artificial channel.

Pumped Hydroelectric Storage - Storing water for future use in generating electricity. Excess electrical energy produced during a period of low demand is used to pump water up to a reservoir. When demand is high, the water is released to operate a hydroelectric generator.

Purge - To force a gas through a water sample to liberate volatile chemicals or other gases from the water so their level can be measured.

Purgeable Organics - volatile organic chemicals which can be forced out of the water sample with relative ease through purging.

Q

R

Rain - Water drops which fall to the earth from the air.

Rain Gage - Any instrument used for recording and measuring time, distribution, and the amount of rainfall.

RAS – Return Activated Sludge; residuals from biological process settled in the clarifiers that are returned to the influent of the biological process to provide ‘food’ for enhance treatment.

Raw Wastewater - Wastewater that has not been treated by any means at all.

Receiving Waters - A river, ocean, stream, or other watercourse into which wastewater or treated effluent is discharged.

Recharge - Water entering an underground aquifer through faults, fractures, or direct absorption.

Recharge Zone - The area where a formation allows available water to enter the aquifer.

Reclaimed Water - Domestic wastewater that is under the direct control of a wastewater treatment facility owner/operator and end user which has been treated to a quality suitable for a beneficial use.

Reservoir - A pond, lake, tank, or basin (natural or human made) where water is collected and used for storage. Large bodies of groundwater are called groundwater reservoirs; water behind a dam is also called a reservoir of water.

Residual Chlorine - The available chlorine which remains in solution after the demand has been satisfied.

Reverse Osmosis - A water treatment method whereby water is forced through a semipermeable membrane which filters out impurities.

Rising Main - also known as a force main, a line that carries pumped wastewater from a lift station to a point where other pumps or gravity can take over.

River Basin - The area drained by a river and its tributaries.

Runoff - Surface water entering rivers, freshwater lakes, or reservoirs.

S

Saline Water - Water containing more than 1,000 parts per million (ppm) of dissolved salts of any type.

Salinity - Amount of dissolved salts in a given volume of water.

Sanitary Landfill - Landfill that is lined with plastic or concrete or located in clay-rich soils to prevent hazardous substances from leaching into the environment.

Sanitary Sewer - A pipe intended to carry only domestic, commercial and/or industrial wastewaters.

Saturation - The condition of a liquid when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.

Seal - The impermeable material, such as cement grout bentonite, or puddling clay placed in the annular space between the borehole wall and the casing of a water well to prevent the down hole movement of surface water or the vertical mixing of artesian waters.

Secondary Treatment - Biological step in most waste treatment systems, in which bacteria break down the organic parts of sewage wastes; usually accomplished by bringing the sewage and bacteria together in trickling filters or in the activated sludge process.

Sedimentation - A large scale water treatment process where heavy solids settle out to the bottom of the treatment tank after flocculation.

Separate Sewer - A sewer system that carries only sanitary sewage, not stormwater runoff. When a sewer is constructed this way, wastewater treatment plants can be sized to treat sanitary wastes only and all of the water entering the plant receives complete treatment at all times.

Septage - The materials derived from subsurface wastewater disposal systems in areas not serviced by public sewer. The mixture of liquid and solid wastes originating in septic tanks that is periodically pumped from the tanks and transported to a wastewater treatment facility.

Septic - A condition produced by the presence of anaerobic bacteria. Severe septic conditions are revealed by black, odorous water with little or no dissolved oxygen present.

Septic Tank - Underground receptacle for wastewater from a building. The bacteria in the sewage decompose the organic wastes, and the sludge settles to the bottom of the tank. The effluent flows out of the tank into the ground through drains.

Settleable Solids - In sewage, suspended solids that will settle when the sewage is brought to a quiet state for a reasonable length of time, usually two hours.

Siltation - The deposition of finely divided soil and rock particles upon the bottom of stream and river beds and reservoirs.

Sludge - Solid matter that settles to the bottom of sedimentation tanks in a sewage treatment plant and must be disposed of by digestion or other methods or recycled to the land.

Solute - Any substance derived from the atmosphere, vegetation, soil, or rock that is dissolved in water.

Soil Erosion - The processes by which soil is removed from one place by forces such as wind, water, waves, glaciers, and construction activity and eventually deposited at some new place.

Specific Heat - The amount of heat required to raise the temperature of a kilogram of a substance by 1 degree Celsius.

Spillway - The channel or passageway around or over a dam through which excess water is diverted.

Standard Solution - Any solution in which the concentration is known.

Stormwater Discharge - Precipitation that does not infiltrate into the ground or evaporate due to impervious land surfaces but instead flows onto adjacent land or water areas and is routed into drain/sewer systems.

Stream - A general term for a body of flowing water.

Surface Water - Water in streams, rivers, natural lakes, wetlands, and reservoirs constructed by humans.

T

Tertiary Treatment - Removal from wastewater of traces or organic chemicals and dissolved solids that remain after primary treatment and secondary treatment.

TDS - **Total Dissolved Solids** - The sum or all inorganic and organic particulate material. TDS is an indicator test used for wastewater analysis and is also a measure of the mineral content of bottled water and groundwater. There is a relationship between TDS and conductivity.

Toxicity Reduction Evaluation (TRE) - A study conducted to determine the source(s) of toxicity in a discharge effluent so that these sources can be controlled sufficiently to allow a discharger to comply with their permit limits.

Toxicity Test - The means to determine the toxicity of a chemical or an effluent using living organisms. A toxicity test measures the degree of response of an exposed test organism to a specified chemical or effluent.

TSS (Total Suspended Solids) - Components in influent or septage that result in particle deposition in receiving waters.

U

Ultraviolet Disinfection (UV) - A disinfection method in which final wastewater effluent is exposed to ultraviolet light to kill pathogens and microorganisms.

Underdrain - A concealed drain with openings through which the water enters when the water table reaches the level of the drain.

Underflow - Movement of water through subsurface material.

Upflow - An upward flow.

URW – Urban Reclaimed Water- Treated wastewater to a level compliant with regulations and end user requirements per JS 893.

V

None

W

Wadi - The bed or valley of a stream that is usually dry except during the rainy season and that often forms an oasis.

Wastewater - Water containing waste including grey water, black water or water contaminated by waste contact, including process generated flows and contaminated rainfall runoff.

WAJ – Water Authority of Jordan

WAS – Waste Activated Sludge; Residuals from biological process tanks that are settled in the clarifiers and removed as waste product, or sludge.

Water - The liquid that is an odorless, tasteless, colorless, very slightly compressible liquid.

Water Cycle - Natural pathway water follows as it changes between liquid, solid, and gaseous states; biogeochemical cycle that moves and recycles water in various forms through the ecosphere, also called the hydrologic cycle.

Water Pollution - Degradation of a body of water by a substance or condition to such a degree that the water fails to meet specified standards or cannot be used for a specific purpose.

Water Table - Level at which the ground becomes saturated with water. The surface of an unconfined aquifer which fluctuates due to seasonal precipitation.

Water Table Aquifer - An aquifer confined only by atmospheric pressure (water levels will not rise in the well above the confining bed).

Watershed - Land area from which water drains toward a common watercourse in a natural basin.

WWTF - Wastewater Treatment Facility

WWTP (WwTP) – Wastewater Treatment Plant

Wetland - Area that is regularly wet or flooded and has a water table that stands at or above the land surface for at least part of the year, such as a bog, pond, fen, estuary, or marsh.

Whole-Effluent Toxicity - The aggregate toxic effect of an effluent measured directly by a toxicity test.

X

None

Y

Yield - Tthe quantity of water expressed either as a continuous rate of flow (cubic feet per second, etc.) or as a volume per unit of time. It can be collected for a given use, or uses, from surface or groundwater sources on a watershed.

Z

Zone of Aeration - A region in the Earth above the water table. Water in the zone of aeration is under atmospheric pressure and will not flow into a well.

Zone of Saturation - The space below the water table in which all the interstices (pore spaces) are filled with water. Water in the zone of saturation is called groundwater.

Appendix – Data and Calculations

- Aqaba Mechanical WWTP Operations Data 2013-2014
- Aqaba Mechanical WWTP MLSS Data 2013-2014
- Aqaba Mechanical WWTP Life Cycle Cost Analysis

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Aqaba Mechanical WWTP Operations Data 2013-2014

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Aquaba Mechanical WWTF
Operational Data 2013-2014

DATE	Mech Plant Inf. m3/d	BOD5 mg/l	BOD5 Eff. mg/l	BOD5 inf. kg/d	COD inf. mg/L	COD Eff. Mg/l	COD inf. kg/d	TSS inf. mg/L	TSS Eff. Mg/L	TSS inf. kg/d	VSS mg/L	VSS kg/D	ISS mg/L	TDS Inf. Mg/L	TDS Inf. Kg/D	TDS Eff. Mg/L	NH4 Inf. Mg/L	Adjusted NH4 Inf mg/L (factor of 1.29)	Calc. TKN (NH4/0.66) mg/L	Adjusted Calc TKN (adjusted NH4/0.66) mg/L	NH4 Inf. Kg/D	NH4 Eff. Mg/L	NO3 Inf. Mg/L	Adjusted NO3 Inf. Mg/L (factor of 10)	Adjusted NO3 Inf. Mg/L (factor of 4.42)	NO3 inf. Kg/D	MeasuredNO3 Eff. Mg/L	Adjusted NO3 Eff. Mg/L (factor of 4.42)	Measured TN inf. mg/L	Calc TN (calc TKN+NO3) Mg/L	TN Eff. Mg/L	TN inf.kg/d	Org. N. inf. Mg/L	Org. N. Eff. Mg/L	Inf. TEMP c	Eff. Temp. C	Avg. Temp. C.	Eff. Turb. Mg/L	Inf. P.H unit	Eff. P.H.	Eff. Res. CL2	COD/BOD	COD/TSS	COD/TN	BOD/TSS	VSS/TSS
1/1/2013	9495																																														
1/2/2013	8372																																					3.29	7.5	6.6							
1/3/2013	6852																																					1.5	7.5	7.1							
1/4/2013	6797																																														
1/5/2013	6574																																					1.2	7.4	6.7							
1/6/2013	7009																																					1.42	7.4	6.7							
1/7/2013	6690																																					1.5	7.2	6.7							
1/8/2013	6800	434	6.6	2951	715	26.4	4862	330	2	2244	302	2054	28	639	4345	574	102	79.20	155	120	694	1.6	74	7.4	16.72	50	14.4	3.25	109	162	7.4	741			20.9	19.4	20.15	0.98	7.26	7.1		1.65	2.17	6.56	1.32	0.92
1/9/2013	6833																																					2.08	7.5	6.2							
1/10/2013	6800																																					4.87	7.37	7.27							
1/11/2013	6783																																														
1/12/2013	6326																																					1.99	7.4	6.2							
1/13/2013	6778																																					3.45									
1/14/2013	6401																																					3.34									
1/15/2013	6750	463	2.9	3125	685	10	4624	400	4.4	2700	346	2336	54	605	4084	562	74	57.46	112	87	500	0.2	88	8.8	19.88	59	35	7.91		121					19.7	17	18.35	1.87	7.53	6.49	2	1.48	1.71		1.16	0.87
1/16/2013	6814																																					3.11	7.6	6.68							
1/17/2013	6886	409	5.05	2816	813	18.6	5598	393	5.4	2706	373	2568	20	543	3739	556	78	60.57	118	92	537	0.2	78	7.8	17.62	54	52.5	11.86		126					20.5	17.1	18.8	2.46	7.3	6.91	3	1.99	2.07		1.04	0.95
1/18/2013	6810																																														
1/19/2013	6810																																														
1/20/2013	7650																																														
1/21/2013	6790																																														
1/22/2013	6790	375	12	2546	592	20	4020	275	9.8	1867	280	1901		607	4122	537	104	80.75	158	122	706	0.2	81.5	8.15	18.41	55	46	10.39	133	166	15	903			21.8	20.6	21.2	3.92	6.99	6.68	3	1.58	2.15	4.45	1.36	1.02
1/23/2013	6800																																														
1/24/2013	7040																																														
1/25/2013	6800																																														
1/26/2013	6990																																					4.88	7.5	7.5							
1/27/2013	6170																																					2.85	7.5	7.2							
1/28/2013	6790																																					3.11	7.45	6.95							
1/29/2013	6760																																					3.1	7.55	6.9							
1/30/2013	7100																																					2.97	7.6	7.43							
1/31/2013	7700																																					2.87	7.4	7.6							
2/1/2013	6850																																														
2/2/2013	6710																																					2.08	7.65	7.07							
2/3/2013	6830																																					2.58	7.54	7							
2/4/2013	6890																																					2.04	7.6	7.4							
2/5/2013	6710		1.65		853	34.6	5724	340	14.6	2281	327	2194	13	600	4026	560	99	76.87	150	116	664	1.4	64	6.4	14.46	43	6.6	1.49	115	156	4.5	772			21.4	19.2	20.3	3.4	7.13	7.09	0.1		2.51	7.42		0.96
2/6/2013	8320																																					3.35	7.4	7.53							
2/7/2013	7670	441	4.2	3382	720	53	5522	353	53.4	2708	320	2454	33	767	5883	535	120	93.18	182	141	920	39	65	6.5	14.68	50	6.6	1.49	122	188	52	936			20.8	18.4	19.6	14	7.39	7.25		1.63	2.04	5.90	1.25	0.91
2/8/2013	6820																																														
2/9/2013	7290																																					3.23	7.55	7.58							
2/10/2013	5810																																					4.35	7.4	7.48							
2/11/2013	6200																																					5.88	7.52	6.35							
2/12/2013	7030		5.8		715	23.2	5026	283	18.2	1989	260	1828	23	650	4570	594	119	92.40	180	140	837	0.2	73	7.3	16.49	51	12.8	2.89		188					20.7	19	19.85	5.56	7.32	6.51	1.5		2.53			0.92
2/13/2013	6850																																					6.43	7.64	7.5							
2/14/2013	7340																																					3.79	7.5	7.58							
2/15/2013	7810																																														
2/16/2013	6180																																														
2/17/2013	6640																																					5.2	7.53	7.2							
2/18/2013	8350																																					2.72	7.48	8.08							
2/19/2013	8310	516	8.45	4288	659	19.2	5476	420	10	3490	397	3299	23	685	5692	600	116	90.07	176	136	964	0.2	87	8.7	19.65	72	9.1	2.06	125	184	5	1039			20.5	18.8	19.65	4.17	7.18	6.62	2.5	1.28	1.57	5.27	1.23	0.95
2/20/2013	8000																																					9.22	7.45	6.74							
2/21/2013	8830	333	8	2940	660	20.1	5828	390	6	3444	375	3311	15	650	5740	580	114	88.52	173	134	1007	0.2	75	7.5	16.94	66	10	2.26		180					20.6	19.1	19.85	3	7.21	6.8	1	1.98	1.69		0.85	0.96
2/22/2013	8590																																														
2/23/2013	7740																																					3.41									
2/24/2013	8870																																					3.56	7.36	6.68							
2/25/2013	8740																																					2.47	7.5	6.8							
2/26/2013	7440	433	5.9	3222	1032	36.5	7678	383	11.6	2850	340	2530	43	580	4315	578	115	89.30	174	135	856	3.5	79	7.9	17.85	59	12	2.71		182					21.7	20.2	20.95	5.04	7.53	7.12	0.2	2.38	2.69		1.13	0.89
2/27/2013	8410	298	8.6	2506	896	35	7535							530	4457	583	112	86.97	170	132	942	2.95	71	7.1	16.04	60	10.8	2.44	115	177	9.9	967						4.7	7.37	8.06	0.1	3.01		7.79		
2/28/2013	8820																																					6.82	7.57	6.45							
3/1/2013	7950																																														
3/2/2013	7020																																					2.55	7.64	6.8							
3/3/2013	6920																																					3.92	7.35	6.1							
3/4/2013	7020																																					5.55	7.45	5.72							
3/5/2013	6910	462	8.6	3192	941	30.1	6502	373	14.5	2577				640	4422	520																						2.4	7.58	7.22		2.04	2.52		1.24	
3/6/2013	6820				781	27.9	5326	360	15.8	2455							120	93.18	182	141	818	0.2	57	5.7	12.88	39	3.1	0.70	119	188	1.55	812			22	20.9	21.45	4.95	7.47	7.08	0.8		2.17	6.56		
3/7/2013	6910	416	4.8	2875							347	2398					126	97.84	191	148	871	0.2	48.2	4.82	10.89	33	3.1	0.70	122	196	5.4	843						5.45	7.65	7.55	0.2					
3/8/2013	7100																																						7.57	7.7							
3/9/2013	7070																																					3.77									
3/10/2013	6910																																					2.61	6.96	7.09							
3/11/2013	7580																																					4.98	7.63	6.55							
3/12/2013	7420	375	8.6	2783	912	41	6767	420	12.6	3116	333	2471	87				133	103.27	202	156	987	8	78	7.8	17.62	58	4.43	1.00	131	209	11.5	972						4.7	7.55	6.35		2.43	2.17	6.96	0.89	0.79
3/13/2013	6960																																					3.98	7.7	6.25	0.2						
3/14/2013	6970	395.6	9	2757	837	35.8	5834	350	11.8	2440							120	93.18	182	141	836	1.37	75	7.5	16.94	52	6.6	1.49	122	189	5.7	850						3.5	7.64	6.9		2.12	2.39	6.86	1.13	
3/15/2013	7510																																								0.2					
3/16/2013	7060																																														
3/17/2013	6930																																					3.25	7.5	8.68							
3/18/2013	6900																																					3.49	7.75	7.4							
3/19/2013	7000	527	4.1	3689	1088	30.7	7616		7.4		343	2401		543	3801	582	142	110.26	215	167	994	0.2	68	6.8	15.36	48	44.6	10.08	145	222	17.9	1015			24.1	22.2	23.15	3.12	7.88	7.12	2	2.06		7.50		
3/20/2013	6860																																					3.05	7.58	6.9							
3/21/2013	6870	490	6.3	3366	920	30	6320	387	14.6	2659							108	83.86	164	127	742	0.8	83.8	8.38	18.93	58	58.5	13.22	118	172	17	811						2.28	7.64	6.95	2	1.88	2.38	7.80	1.27	
3/22/2013	7030																																														
3/23/2013	7070																																														
3/24/2013	6970																																					2.93	7.45	6.9							
3/25/2013	6810																																					3.54	7.6	6.78							
3/26/2013	7040	457	10.4	3217	869	40	6118	387	10	2724	360	2534	27				122	94.73	185	144	859	5.71	80	8	18.07	56	40.6	9.17	128	193	17.1	901						4.8	7.48	7.3		1.90	2.25	6.79	1.18	0.93
3/27/2013	6920																																					3.3	7.64	6.5							
3/28/2013	6920	553	9.3	3827	838	32.1	5799	407	9	2816							118	91.62	179	139	817	1.5	68.9	6.89	15.56	48	51	11.52	138	186	15.8	955						3.5	7.5	6.9		1.52	2.06	6.07	1.36	
3/29/2013	7750																																														
3/30/2013	7010																																					3.24	7.65	6.55							
3/31/2013	6970																																					3.18	7.37	6.99							
4/1/2013	7090																																					1.78	7.6	7.35							
4/2/2013	7000	437	9.1	3059	812	28.5	5684	413	2.8	2891							95	73.77	144	112	665	0.2	85	8.5	19.20	60	72	16.27	110	152	26	770						1.7	7.5	7.5	>3.5	1.86	1.97	7.38	1.06	
4/3/2013	6790																																					1.72	7.55	7.35							
4/4/2013	6930	380	6	2633	849	38.2	5884	347	6.2	2405	343	2377	4	666	4615	625	98	76.10	148	115	679	0.26	71	7.1	16.04	49	42	9.49	112	156	25	776			26.4	24.9	25.65	2.17	7.2	6.91		2.23	2.45	7.58	1.10	0.99
4/5/2013	7310																																														
4/6/2013	7180																																					1.5	7.36	6.9							
4/7/2013	7080																																					1.84	7.57	7.25							
4/8/2013	7020																																					1.66	7.65	7.33							
4/9/2013	7080	371	5.6	2627	864	20.6	6117	350	5.6	2478	330	2336	20				140	108.71	212	165	991	11	96	9.6	21.69	68	61.6	13.92	137	222	34	970						1.54	7.44	7.2		2.33	2.47	6.31	1.06	0.94
4/10/2013	6930																																								0.2					
4/11/2013	7120	376	6.7	2677	832	24	5924	266.6	8.8	1898							129	100.17	195	152	918	12	66	6.6	14.91	47	46	10.39	130	202	35	926			26.3	22.1	24.2	1.75	7.55	7.1	0.2	2.21	3.12	6.40	1.41	
4/12/2013	7170																																														
4/13/2013	6960							395	3.6	2749	310	2158	85																									1.66	7.65	6.98							0.78
4/14/2013	8220							405	5.6	3329																												1.75	7.35	6.95							
4/15/2013	10300							400	6.6	4120																												1.86	7.64	6.92							
4/16/2013	10140	299	9.1	3032	680	32	6895							573	5810	595	91	70.66	138	107	923	0.2	64	6.4	14.46	65	53	11.97	101	144	20.5	1024						3.02	7.28	7.05		2.27		6.73		
4/17/2013	10480							395	8	4140																												3.5	7.45	6.98							
4/18/2013	10540	468	9.8	4933	859	15.7	9054	405	9.2	4269							102	79.20	155	120	1075	2.7	43	4.3	9.71	45	34	7.68	101	159	18	1065						2.84	7.65	6.95		1.84	2.12	8.50	1.16	
4/19/2013	8530																																														
4/20/2013	9130							420	6	3835																																					
4/21/2013	9270																																					2.35	7.55	7.24							
4/22/2013	10910																																					2.47	7.6	7.3							
4/23/2013	10230	390	5.4	3990	904	21	9248	415	10.4	4245	307	3141	108				102	79.20	155	120	1043	0.45							134		6.5	1371						2.33	7.76	7.43		2.32	2.18	6.75	0.94	0.74
4/24/2013	10690							395	4.2	4223													55.8	5.58	12.61	60	14.6	3.30										3.5	7.6	7.41							
4/25/2013	8890				912	21.9	8108																						105		10.5	933						3.16	7.7	7.45				8.69		
4/26/2013	9200	420	9	3864				380	4.4	3496													44.3	4.43	10.01	41	19.4	4.38																		1.11	
4/27/2013	10760																103	79.98	156	121	1108	0.2																									
4/28/2013	9070							360	4	3265																												4.05	7.43	7.7							

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DATE	Mech Plant Inf. m3/d	BOD5 mg/l	BOD5 Eff. mg/l	BOD5 inf. kg/d	COD inf. mg/L	COD Eff. Mg/l	COD inf. kg/d	TSS inf. mg/L	TSS Eff. Mg/L	TSS inf. kg/d	VSS mg/L	VSS kg/D	ISS mg/L	TDS Inf. Mg/L	TDS Inf. Kg/D	TDS Eff. Mg/L	NH4 Inf. Mg/L	Adjusted NH4 Inf mg/L (factor of 1.29)	Calc. TKN (NH4/0.66) mg/L	Adjusted Calc TKN (adjusted NH4/0.66) mg/L	NH4 Inf. Kg/D	NH4 Eff. Mg/L	NO3 Inf. Mg/L	Adjusted NO3 Inf. Mg/L (factor of 10)	Adjusted NO3 Inf. Mg/L (factor of 4.42)	NO3 inf. Kg/D	MeasuredNO3 Eff. Mg/L	Adjusted NO3 Eff. Mg/L (factor of 4.42)	Measured TN inf. mg/L	Calc TN (calc TKN+NO3) Mg/L	TN Eff. Mg/L	TN inf.kg/d	Org. N. inf. Mg/L	Org. N. Eff. Mg/L	Inf. TEMP c	Eff. Temp. C	Avg. Temp. C.	Eff. Turb. Mg/L	Inf. P.H unit	Eff. P.H.	Eff. Res. CL2	COD/BOD	COD/TSS	COD/TN	BOD/TSS	VSS/TSS
4/29/2013	8940							320	3	2861																												3.2	7.51	7.65						
4/30/2013	10960																																					4.98	7.57	6.95						
5/1/2013	11160							355	5.6	3962																												1.84	7.66	7.53						
5/2/2013	9700							355	4.8	3444																												1.9								
5/3/2013	9340																																														
5/4/2013	11040																																					1.86								
5/5/2013	9870							285	4.8	2813																												3.27	7.78	7.34						
5/6/2013	11030							365	3.2	4026																												2.2	7.44	7.26						
5/7/2013	11100	474	10.3	5261				385	6	4274	247	2742	138	527	5850	531	128	99.39	194	151	1421	0.2	38	3.8	8.58	42	97	21.91	125	198	10	1388			27	26.5	26.75	1.94	7.53	7.45					1.23	0.64
5/8/2013	10670				570	69.6	6082										128	99.39	194	151	1366	0.2																1.6	7.48	6.97						
5/9/2013	9600	307	7.3	2947				315	2.2	3024	257	2467	58				87	67.55	132	102	835	0.39	72	7.2	16.27	69	27.5	6.21		139								2.7	7.55	7					0.97	0.82
5/10/2013	9300																												133		17	1237														
5/11/2013	10250							400	7.2	4100																												2.4	7.4	6.72						
5/12/2013	11220							385	9	4320																												1.88								
5/13/2013	11330																																					1.86	7.44	6.63						
5/14/2013	10410	406	3.4	4226				310	11	3227	220	2290	90				109	84.64	165	128	1135	0.2	54	5.4	12.20	56	24	5.42		171								1.25	7.49	7.33					1.31	0.71
5/15/2013	10160																												118		8	1199						1.65	7.56	7.35						
5/16/2013	10950	410	7.4	4490	850	17	9308	315	6	3449	306	3351	9				126	97.84	191	148	1380	0.2	49	4.9	11.07	54	22.5	5.08		196								2.97				2.07	2.70		1.30	0.97
5/17/2013	9730																																														
5/18/2013	9200							295	4	2714																												3.77	7.44	6.9						
5/19/2013	9840																												125		8.5	1230						3.82	7.57	6.92						
5/20/2013	10930							310	4.4	3388																												3.56	7.6	7.55						
5/21/2013	9130	318	5.7	2903	860	18.5	7852				347	3168		567	5177	559	77.2	59.94	117	91	705	0.2	56.7	5.67	12.81	52	11.3	2.55		123					28.2	28.4	28.3	2.72	7.55	7.2		2.70				
5/22/2013	10790							315	4.2	3399																												1.53	7.62	7.08						
5/23/2013	11210	298	4.5	3341	890	13.5	9977				256	2870					64.9	50.39	98	76	728	0.31	61.6	6.16	13.92	69	29.7	6.71	85	104	7.1	953						2.35	7.57	6.88		2.99		10.47		
5/24/2013	10160							360	6.8	3658							93	72.21	141	109	945	0.2																									
5/25/2013	12000																												98		8.1	1176															
5/26/2013	11790							375	10.5	4421																												3.68	7.6	6.85						
5/27/2013	11730																												115		13	1349						3.7	7.66	6.94						
5/28/2013	11860	433	5	5135	740	15.7	8776	410	7.2	4863	266	3155	144				116	90.07	176	136	1376	0.2	65	6.5	14.68	77	41	9.26		182								2.68	7.71	6.99		1.71	1.80		1.06	0.65
5/29/2013	12280																77.1	59.87	117	91	947	0.16	64	6.4	14.46	79	27	6.10	115	123	11	1412						2.85	7.56	6.88						
5/30/2013	12240	380	6	4651				405	6.6	4957	307	3758	98				111	86.19	168	131	1359	0.303	61	6.1	13.78	75	38	8.58		174								3.6	7.7	7.33					0.94	0.76
5/31/2013	11740																																														
6/1/2013	12050							325	8	3916																												1.66	7.44	7.16						
6/2/2013	12120				780	18.9	9454																															2.49	7.76	7.14						
6/3/2013	11550							305	8.6	3523																												2.84	7.5	6.9						
6/4/2013	12100	415	5.8	5022	712	23.7	8615				280	3388		523	6328	494	113	87.74	171	133	1367	1.3	57.5	5.75	12.99	70	1.7	0.38	120	177	5	1452			28.7	28.3	28.5	2.66	7.64	6.95		1.72		5.93		
6/5/2013	11660							300	4.4	3498																												1.89	7.5	7.33						
6/6/2013	11200	374	7.7	4189	803	24.8	8994				280	3136		516	5779	574	113	87.74	171	133	1266	2.3	55.8	5.58	12.61	62	3.1	0.70	125	177	5.6	1400						1.68	7.62	7.45		2.15		6.42		
6/7/2013	11200							285	3.2	3192																																					
6/8/2013	9960																																					1.45	7.65	7.51						
6/9/2013	11500							260	4.4	2990																												1.56	7.4	7.48						
6/10/2013	10610																																					2.5								
6/11/2013	11630	327	7.3	3803	513	15.3	5966	375	6.6	4361		0		540	6280	575	104	80.75	158	122	1210	6.7	53	5.3	11.97	62	19.4	4.38	125	163	22.2	1454			26.7	25.5	26.1	2.12	7.53	6.92		1.57	1.37	4.10	0.87	
6/12/2013	11780																																					2.08	7.55	6.92						
6/13/2013	12040	264	4.75	3179	540	19.6	6502	355	6.8	4274	240	2890	115				78	60.57	118	92	939	1.9	60.6	6.06	13.69	73	16.4	3.70	128	124	10	1541						3.04	7.71	6.86		2.05	1.52	4.22	0.74	0.68
6/14/2013	11990																																														
6/15/2013	12050							345		4157																												4.21	7.54	7.23						
6/16/2013	11640																																					3.98								
6/17/2013	11790							360	9.2	4244																													7.43	6.99						
6/18/2013	11430	314	5.7	3589	523	15	5978				227	2595		627	7167	570	152	118.03	230	179	1737	0.2	50	5	11.30	57	39	8.81	140	235	16	1600			30	29.6	29.8	5.12	7.64	7.2		1.67		3.74		
6/19/2013	12070							270	6	3259																												1.71	7.45	7.88						
6/20/2013	11650	345	6.2	4019	621	19.5	7235				247	2878					111	86.19	168	131	1293	0.2	36	3.6	8.13	42	4.8	1.08	123	172	6.6	1433						1.65	7.51	7.62		1.80		5.05		
6/21/2013	11940							265		3164																																					
6/22/2013	11470																																					2.8	7.5	7.31						
6/23/2013	12310							295	10	3631																												2.45	7.68	7.12						
6/24/2013	11550																																					2.79	7.4	7.18						
6/25/2013	12490	439	5.2	5483	705	16.9	8805	260		3247	253	3160	7				115	89.30	174	135	1436	0.2	87	8.7	19.65	109	11	2.48	130	183	9.8	1624						3.2	7.43	7.23		1.61	2.71	5.42	1.69	0.97
6/26/2013	11950							285	5.1	3406																												2.9	7.52	7.09						
6/27/2013	12090	374	5.8	4522	735	20.5	8886				303	3663					112	86.97	170	132	1354	0.173	76	7.6	17.17	92	13.3	3.00	119	177	5.4	1439						3.07	7.66	7.2		1.97		6.18		
6/28/2013	12820							315	4.2	4038																																					
6/29/2013	12120																																					1.58	7.63	7.25						
6/30/2013	12400							330	7.6	4092																												6.18	7.57	7.28						
7/1/2013	10730							285	4.8	3058				586	6288	542																															
7/2/2013	11210	374	8.6	4193	703	24.4	7881				425	4764					95	73.77	144	112	1065	0.24	52	5.2	11.75	58	30	6.78	125	149	13	1401							7.62	6.86		1.88		5.62		
7/3/2013	12720							400	9.2	5088																									26.2	25.8	26	3.04	7.64	6.95						
7/4/2013	12170	378	8.6	4600	619	21	7533				227	2763					102	79.20	155	120	1241	0.24	54	5.4	12.20	66	30	6.78	102	160	8.9	1241										1.64		6.07		
7/5/2013	11370							415	9.2	4719																																					
7/6/2013	10060																																					2.26	7.69	7.09						
7/7/2013	12010							395	11.2	4744							42	32.61	64	49	504	2.5																2.02	7.39	7.07						
7/8/2013	12080				815	19	9845																																								
7/9/2013	12700							325	10	4128																												1.9	7.63	7.3						
7/10/2013	12740																																														
7/11/2013	12270	360	7.9	4417	739	21.3	9068	385	8.8	4724	233	2859	152				91	70.66	138	107	1117	0.36	83	8.3	18.75	102	65	14.68	100	146	20	1227						3.6				2.05	1.92	7.39	0.94	0.61
7/12/2013	12430																																														
7/13/2013	12480							330	12.4	4118																												3.2	7.33	6.9						
7/14/2013	12170																																					2.09	7.35	6.76						
7/15/2013	12500							345	8.5	4313				513	6413	596																						5.23	7.17	6.92						
7/16/2013	11990	249	7.6	2986	533	22.6	6391				130	1559					55	42.71	83	65	659	0.2	65.5	6.55	14.80	79	71	16.04	65	90	20	779			31	30.4	30.7	5	7.45	7.01		2.14		8.20		
7/17/2013	12110																56	43.48	85	66	678	0.19	60	6	13.55	73	84	18.98		91																
7/18/2013	11480	306	7.45	3513	557	24.1	6394	370	9.2	4248	180	2066	190				74	57.46	112	87	850	0.134	81	8.1	18.30	93	77	17.39	79	120	19.3	907						4.05	7.38	7.12		1.82	1.51	7.05	0.83	0.49
7/19/2013	11180							390	7.8	4360																																					
7/20/2013	11470																																					5.67	7.53	7.09						
7/21/2013	11660																																					7.95	7.62	6.71						
7/22/2013	11650							330	6.6	3845																												4.93	7.57	6.93						
7/23/2013	11730	320	5.9	3754	597	21.5	7003				280	3284					87	67.55	132	102	1021	0.139	66.5	6.65	15.02	78	77	17.39	89	138	19.9	1044						4.04	7.38	7.29		1.87		6.71		
7/24/2013	11600												0				45.3	35.17	69	53	525	0.7	69	6.9	15.59	80	72	16.27		76																
7/25/2013	11640	294	5.85	3422	583	23.5	6786	395	5.6	4598	200	2328	195				90.4	70.19	137	106	1052	0.266	80	8	18.07	93	74	16.72	101	145	18.9	1176						5.23	7.32	7.05		1.98	1.48	5.77	0.74	0.51
7/26/2013	12110							325	6.8	3936																																					
7/27/2013	12490																																					2.76	7.52	6.89						
7/28/2013	13650							340	8.8	4641																																					
7/29/2013	13300							390	7.6	5187																												3.55	7.51	6.99						
7/30/2013	13470	375	8.6	5051	701	28.2	9442				230	3098					103	79.98	156	121	1387	0.526	49	4.9	11.07	66	11	2.48	115	161	5	1549										1.87		6.10		
7/31/2013	13660							400	9.6	5464																												3.04	7.36	7.05						
8/1/2013	13360	234	3.55	3126	448	21.6	5985		10								101	78.42	153	119	1349	0.48	40.3	4.03	9.10	54	7.5	1.69	102	157	4.5	1363						3.09	7.54	6.99		1.91		4.39		
8/2/2013	12020							410	5.2	4928																																					
8/3/2013	11410																																					3.11	7.55	7.09						
8/4/2013	12360							395	4.4	4882																																					
8/5/2013	11640							340	4.2	3958													55	5.5	12.42	64	10.5	2.37										3.76	7.75	7.62						
8/6/2013	12720																																					3.95	7.27	6.88						
8/7/2013	12730				680	15.7	8656	395	3.6	5028																												3.95	7.72	6.88			1.72			
8/8/2013	12080							405	5.6	4892																																					
8/9/2013	11840							400	6.6	4736													60	6	13.55	71	23	5.20										4.09	7.6	7.12						
8/10/2013	12150																																					3.33	7.55	7.2						
8/11/2013	12350							395	8	4878																												3.05	7.43	7.03						
8/12/2013	12870							405	9.2	5212																																					
8/13/2013	12790	348	8.2	4451	624	25.9	7981				210	2686		543	6945	632	86	66.78	130	101	1100	0.26	55	5.5	12.42	70	49.6	11.20	89	136	13.4	1138			31.2	28.5	29.85	2.18	7.55	6.98		1.79		7.01		
8/14/2013	12810							420	6	5380																																					
8/15/2013	12780	287	5.3	3668	659	27.5	8422				278	3553					65	50.47	98	76	831	0.2	62	6.2	14.01	79	21.3	4.81	60	105	5.5	767						2.15	7.62	7.14		2.30		10.98		
8/16/2013	12430																																														
8/17/2013	12290							415	10.4	5100																												1.73	7.29	6.92						
8/18/2013	12690							395	4.2	5013							60.2	46.74	91	71	764	1.4	23	2.3	5.20	29	70	15.81		94																
8/19/2013	12780																																					8.33	7.25	6.96						
8/20/2013	12560		5.95		731	17.3	9181	380	4.4	4773	183	2298	197				75	58.24	114	88	942	0.2	46	4.6	10.39	58	56	12.65	80	118	15	1005											1.92	9.14		0.48
8/21/2013	12790				920	18.7	11767																															5.33	7.53	6.87						
8/22/2013	12680				685	20	8686	360	4	4565							85	66.00	129	100	1078	0.2																4.38	7.56	7.22			1.90			
8/23/2013	12640							320	3	4045													49	4.9	11.07	62	55	12.42	89		15.5	1125														
8/24/2013	12660																																					1.91	7.44	7.2						

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DATE	Mech Plant Inf. m3/d	BOD5 mg/l	BOD5 Eff. mg/l	BOD5 inf. kg/d	COD inf. mg/L	COD Eff. Mg/l	COD inf. kg/d	TSS inf. mg/L	TSS Eff. Mg/L	TSS inf. kg/d	VSS mg/L	VSS kg/D	ISS mg/L	TDS Inf. Mg/L	TDS Inf. Kg/D	TDS Eff. Mg/L	NH4 Inf. Mg/L	Adjusted NH4 Inf mg/L (factor of 1.29)	Calc. TKN (NH4/0.66) mg/L	Adjusted Calc TKN (adjusted NH4/0.66) mg/L	NH4 Inf. Kg/D	NH4 Eff. Mg/L	NO3 Inf. Mg/L	Adjusted NO3 Inf. Mg/L (factor of 10)	Adjusted NO3 Inf. Mg/L (factor of 4.42)	NO3 inf. Kg/D	MeasuredNO3 Eff. Mg/L	Adjusted NO3 Eff. Mg/L (factor of 4.42)	Measured TN inf. mg/L	Calc TN (calc TKN+NO3) Mg/L	TN Eff. Mg/L	TN inf.kg/d	Org. N. inf. Mg/L	Org. N. Eff. Mg/L	Inf. TEMP c	Eff. Temp. C	Avg. Temp. C.	Eff. Turb. Mg/L	Inf. P.H unit	Eff. P.H.	Eff. Res. CL2	COD/BOD	COD/TSS	COD/TN	BOD/TSS	VSS/TSS
8/25/2013	12630							355	5.6	4484							104	80.75	158	122	1314	0.2															1.97	7.33	6.59						
8/26/2013	12700				670	30.3	8509	355	4.8	4509																											2.01	7.33	6.45			1.89			
8/27/2013	12510																																				2	7.55	6.45						
8/28/2013	12600																																				2	7.55	6.66						
8/29/2013	12500							285	4.8	3563							102	79.20	155	120	1275	0.2	35	3.5	7.91	44	48	10.84		158																
8/30/2013	12030							365	3.2	4391																																				
8/31/2013	11310							385	6	4354																																				
9/1/2013	12720																																													
9/2/2013	12380							315	2.2	3900																											1.91								
9/3/2013	12480	428	8.8	5341	850	14.5	10608				296	3694		650	8112	563	102	79.20	155	120	1273	0.2	57	5.7	12.88	71	38.8	8.77	109	160	9.5	1360			30.5	30.1	30.3	2.35			1.99		7.80		
9/4/2013	12400				680	25	8432	295	2	3658																												7.44	6.92			2.31			
9/5/2013	12310	328	8.2	4038	690	28.3	8494				400	4924					93	72.21	141	109	1145	0.2	57	5.7	12.88	70	45	10.17	105	147	15	1293						3.18	7.23	6.98		2.10		6.57		
9/6/2013	11770							350	4.8	4120																																				
9/7/2013	10570																																				3.18	7.23	6.99						
9/8/2013	11870																																													
9/9/2013	12430				660	31.5	8204	345	8	4288																											2.14	7.22	6.78			1.91			
9/10/2013	12040	357	5.54	4298	629	31	7573				333	4009					101	78.42	153	119	1216	0.2	68.7	6.87	15.52	83	64.3	14.53	107	160	17	1288						2.88	7.35	6.99		1.76		5.88		
9/11/2013	12120																70.3	54.59	107	83	852	3	7.2	7.2	1.63	87	79	17.85		114																
9/12/2013	12280	360	7.8	4421	533	22.7	6545	335	6	4114	370	4544					101	78.42	153	119	1240	0.2	60	6	13.55	74	40	9.04	102	159	12	1253			28.8	28.3	28.55	2.82	7.46	6.92		1.48	1.59	5.23	1.07	1.10
9/13/2013	12550							305	4	3828																																				
9/14/2013	12280																																													
9/15/2013	12300							295	3.2	3629																											2.84	7.44	7.07						
9/16/2013	12350																																													
9/17/2013	11990	404	6.84	4844	730	16.5	8753	320	6	3837				580	6954	564	102	79.20	155	120	1223	0.2	34	3.4	7.68	41	31	7.00	105	158	13	1259						0.93	7.61	7.11		1.81	2.28	6.95	1.26	
9/18/2013	10420																																				0.82	7.56	7.2						
9/19/2013	8400	352	3.6	2957	677	21.8	5687	360	7.2	3024	393	3301					77.5	60.18	117	91	651	0.078	65	6.5	14.68	55	53.5	12.09	85	124	15.5	714						1.33	7.35	7.22		1.92	1.88	7.96	0.98	1.09
9/20/2013	10520							315	4.2	3314																																				
9/21/2013	11960																																													
9/22/2013	11850																																				2.35	7.6	7.46						
9/23/2013	12180																																				2.18	7.62	6.98						
9/24/2013	11910	385	4.46	4585	744	29.5	8861				340	4049					102	79.20	155	120	1215	0.02	37	3.7	8.36	44	38.5	8.70	95	158	11	1131						2.08	7.55	6.99		1.93		7.83		
9/25/2013	9990																																				2	7.5	6.65						
9/26/2013	8100	353	6.7	2859	613	26.4	4965	250	7.2	2025	250	2025	0				90	69.88	136	106	729	0.246	38	3.8	8.58	31	38.9	8.79	98	140	10	794										1.74	2.45	6.26	1.41	1.00
9/27/2013	9420																																				2.06	7.51	6.95						
9/28/2013	8160							255	9.6	2081																																				
9/29/2013	11270							245	8	2761																																				
9/30/2013	11730																																													
10/1/2013	11300	340	5.3	3842	688	17.4	7774	265	12	2995							102	79.20	155	120	1153	0.132	86	8.6	19.43	97	65	14.68	115	163	20	1300										2.02	2.60	5.98	1.28	
10/2/2013	10779																																				1.5	7.33	6.51						
10/3/2013	7020	274	7.1	1923	632	13.6	4437	260	13.6	1825				610	4282	605	77.4	60.10	117	91	543	4	54	5.4	12.20	38	83	18.75	102	123	21	716			29.5	28.9	29.2	2.75	7.75	7		2.31	2.43	6.20	1.05	
10/4/2013	8001										237	1896																	96		25	768														
10/5/2013	7050							375	4	2644																											1.64	7.63	6.69						
10/6/2013	7760							240	2.4	1862																											1.66	7.61	6.90						
10/7/2013	10750							295	6	3171							100	77.65	152	118	1075	0.04															2.08	7.33	6.99						
10/8/2013	11690	345	5.87	4033	653	26.3	7634	310	4	3624							90	69.88	136	106	1052	0.196	58	5.8	13.10	68	92	20.78	96	142	26	1122						1.26	7.3	6.98		1.89	2.11	6.80	1.11	
10/9/2013	12120																																													
10/10/2013	12200	280	6.84	3416	616	24.5	7515	340	4.4	4148				320	3904	552	94	72.99	142	111	1147	0.284	58	5.8	13.10	71	67	15.14	102	148	18	1244										2.20	1.81	6.04	0.82	
10/11/2013	11926							310		3697	280	3339	30																																	0.90
10/12/2013	12339							290	7.2	3578																																				
10/13/2013	12198																																													
10/14/2013	11724							285	9.2	3341																																				
10/15/2013	8783							265	6	2327																																				
10/16/2013	11517							310	8.4	3570																																				
10/17/2013	8999																																			28.8	28.5	28.65								
10/18/2013	10560							305	6	3221																																				
10/19/2013	9879				720	14	7113																																							
10/20/2013	12073							355	4.4	4286							68	52.80	103	80	821	3.1															1.82	7.1	6.65						
10/21/2013	12102				830	28.1	10045																														2	7.05	6.99						
10/22/2013	10940	353	3.1	3862	805	25.9	8807	325	6.2	3556	265	2899	60				116	90.07	176	136	1269	0.02	58.4	5.84	13.19	64	10	2.26	115	182	4	1258						2.5	7.1	6.8		2.28	2.48	7.00	1.09	0.82
10/23/2013	11101				790	32.5	8770																														1.88	7.07	6.96						
10/24/2013	10119	391	6	3957	888	16	8986										114	88.52	173	134	1154	0.17	59	5.9	13.33	60	19	4.29	113	179	4.2	1143						1.31	7.2	6.82		2.27		7.86		
10/25/2013	10000							270	7.6	2700																																				
10/26/2013	9170							360	3.2	3301																											2.14	7.23	6.77						
10/27/2013	9721				670	9.8	6513										75.8	58.86	115	89	737	1.7	40	4	9.04	39	35.0	7.91		119																
10/28/2013	11351																																				1.26	7.25	6.45						
10/29/2013	11483	269	5.74	3089	596	17	6844	285	6.8	3273	210	2411	75				116	90.07	176	136	1332	0.157	65	6.5	14.68	75	36	8.13	120	182	11.5	1378						2.15	7.33	6.72		2.22	2.09	4.97	0.94	0.74
10/30/2013	11158																																													
10/31/2013	12634				605	21	7644	190	5.6	2400							103	79.98	156	121	1301	0.167	73	7.3	16.49	92	23	5.20	113	163	8	1428											3.18	5.35		
11/1/2013	11582							200	5.2	2316																																				
11/2/2013	11546							390	6	4503																																				
11/3/2013	12146							200	8.8	2429																									27.7	26.8	27.25	3.08	7.43	6.93						
11/4/2013	12223							340	6.4	4156							84.5	65.61	128	99	1033	2.35	54	5.4	12.20	66	23	5.20		133								2.33	7.3	6.71						
11/5/2013	12190	440	4	5364	758	18	9240							340	4145	4.6	88	68.33	133	104	1073	0.154	49	4.9	11.07	60	18.6	4.20	95	138	6.5	1158						2.09			1.5	1.72		7.98		
11/6/2013	12156							315	7.8	3829	233	2832	82																								1.09	7.33	7.08	2.5					0.74
11/7/2013	9420																																							2						
11/8/2013	9630																																				1.22	7.42	7.05	1.5						
11/9/2013	7560							390	10.4	2948																																				
11/10/2013	10561							310	6.8	3274							88	68.33	133	104	929	0.02	47	4.7	10.62	50	9.7	2.19		138							1.82	7.55	6.76						
11/11/2013	11889																																				2	7.24	6.71						
11/12/2013	12221	311	2.4	3801	580	30	7088							333	4070	4.6	101	78.42	153	119	1234	0.171	40.3	4.03	9.10	49	11.07	2.50	103	157	5	1259									1.5	1.86		5.63		
11/13/2013	11926							330	4.6	3936	231	2755	99																						25.5	24.5	25	3.02	7.29	6.91						0.70
11/14/2013	12551	434	4.1	5447	792	30	9940							293	3677	5.2	93.3	72.45	141	110	1171	4.9	7.2	7.2	1.63	90	23	5.20	95	149	5.5	1192									2	1.82		8.34		
11/15/2013	8490							345	6.8	2929																																				
11/16/2013	9712				640	17.5	6216	390	6.8	3788													9.7	9.7	2.19	94	39.9	9.01									1.7	7.3	6.3			1.64			
11/17/2013	8756							355	6	3108																																				
11/18/2013	7683																																				3.21	7.09	6.45	2					
11/19/2013	7213	425	5	3066	880	19.5	6347							293	2113	2.8	58.9	45.73	89	69	425	2	32	3.2	7.23	23	40	9.04	100	92	15	721									3.5	2.07		8.80		
11/20/2013	10720				930	60	9970	325	10.4	3484	225	2412	100				103	79.98	156	121	1104	0.077															1.08	7.45	6.88			2.86			0.69
11/21/2013	11189				741	21.5	8291							240	2685	2.8	98	76.10	148	115	1097	0.164	59	5.9	13.33	66	12	2.71	98	154	10.3	1097									1.5			7.56		
11/22/2013	11133							295	7.6	3284																																				
11/23/2013	9649																																				1.2	7.6	6.82						
11/24/2013	9506							260	6.8	2472																																				
11/25/2013	10752				790	17.1	8494	295	5.6	3172																											3.09	7.51	6.8	2.5		2.68			
11/26/2013	10963	348	5	3815	726	29	7959	275	4.8	3015				253	2774	4.8	81.6	63.36	124	96	895	4.3	51	5.1	11.52	56	18	4.07	110	129	4.5	1206						2.03				2.09	2.64	6.60	1.27	
11/27/2013	11484				1180	52	13551										107	83.08	162	126	1229	0.055															1.59	7.54	7.01						
11/28/2013	10947	410	4.2	4488	853	30	9338	390	6	4269	275	3010	115	333	3645	3							49	4.9	11.07	54	8.7	1.97	102		4	1117						1.65	7.51	6.91	2	2.08	2.19	8.36	1.05	0.71
11/29/2013	11020																																							3.5						
11/30/2013	9882				680	19.7	6720	315	8	3113							103	79.98	156	121	1018	0.21															1.02	7.41	6.81			2.16			
12/1/2013	9735							285	7.6	2775							80	62.12	121	94	779	3.7	9	9	2.03	88	31	7.00		130							2.33	7.33	6.71						
12/2/2013	9735																																		23.4	22.1	22.75	1.8	7.61	6.92						
12/3/2013	9735	454	5.6	4420	859	28.5	8363	335	4.4	3261				737	7175	644	113	87.74	171	133	1100	0.02	34	3.4	7.68	33	10.6	2.39	107	175	4	1042						1.21			2.5	1.89	2.56	8.03	1.36	
12/4/2013	9735																93	72.21	141	109	905	3.8	4.6	4.6	1.04	45	17	3.84		146							1.09	7.63	7.05						
12/5/2013	9735	413	3.7	4021	847	29	8246	335	4.4	3261							134	104.05	203	158	1305	0.29	38.5	3.85	8.70	37	7.08	1.60	128	207	4.3	1246										2.05	2.53	6.62	1.23	
12/6/2013	9735				950	33.2	9248	340	6.6	3310																																	2.79			
12/7/2013	9735							255	6.6	2482																											2.46	7.62	7.08						
12/8/2013	9735				640	20.2	6231	355	6.6	3456	266	2590	89																								3.18	7.32	7.5			1.80			0.75
12/9/2013	9735																																				3.09	7.65	7.22	2.5					
12/10/2013	9735	493	9.7	4799	779	28	7584	315	4.6	3067							132	102.50	200	155	1285	0.107	36.3	3.63	8.20	35	37.2	8.40	129	204	11.3	1256									2.5	1.58	2.47	6.04	1.57	
12/11/2013	9735																																													
12/12/2013	9735							305	6.6	2969																																				
12/13/2013	9735																																													
12/14/2013	9735				770	71	7496	330	7.2	3213	250	2434	80																								3.2	7.31	6.99	2.5		2.33			0.76
12/15/2013	9735																																													
12/16/2013	9735							405	10	3943							72.5	56.29	110	85	706	3.8	19		4.29		79	17.85							18.9	17.6	18.25	3.05	7.51	6.92	<0.5					
12/17/2013	9735	452	3.76	4400	755	16	7350							707	6883	643	122	94.73	185	144	1188	0.066	62	6.2	14.01	60	61	13.78	129	191	16	1256						0.91			3.5	1.67		5.85		
12/18/2013	9735				980		9540	405	8.8	3943	286	2784	119																								3.09	7.44	7.08	2.5		2.42			0.71
12/19/2013	9735	386	6.74	3758	797	21.5	7759	345	6	3359							103	79.98	156	121	1003	0.11	40	4	9.04	39	56	12.65	106	160	16.5	1032						4.01	7.41	6.98	2.5	2.06	2.31	7.52	1.12	
12/20/2013	9735																																													

Aquaba Mechanical WWTF
Operational Data 2013-2014

DATE	Mech Plant Inf. m3/d	BOD5 mg/l	BOD5 Eff. mg/l	BOD5 inf. kg/d	COD inf. mg/L	COD Eff. Mg/l	COD inf. kg/d	TSS inf. mg/L	TSS Eff. Mg/L	TSS inf. kg/d	VSS mg/L	VSS kg/D	ISS mg/L	TDS Inf. Mg/L	TDS Inf. Kg/D	TDS Eff. Mg/L	NH4 Inf. Mg/L	Adjusted NH4 Inf mg/L (factor of 1.29)	Calc. TKN (NH4/0.66) mg/L	Adjusted Calc TKN (adjusted NH4/0.66) mg/L	NH4 Inf. Kg/D	NH4 Eff. Mg/L	NO3 Inf. Mg/L	Adjusted NO3 Inf. Mg/L (factor of 10)	Adjusted NO3 Inf. Mg/L (factor of 4.42)	NO3 inf. Kg/D	MeasuredNO3 Eff. Mg/L	Adjusted NO3 Eff. Mg/L (factor of 4.42)	Measured TN inf. mg/L	Calc TN (calc TKN+NO3) Mg/L	TN Eff. Mg/L	TN inf.kg/d	Org. N. inf. Mg/L	Org. N. Eff. Mg/L	Inf. TEMP c	Eff. Temp. C	Avg. Temp. C.	Eff. Turb. Mg/L	Inf. P.H unit	Eff. P.H.	Eff. Res. CL2	COD/BOD	COD/TSS	COD/TN	BOD/TSS	VSS/TSS
12/21/2013	9735																																														
12/22/2013	9735							395	5.2	3845																																					
12/23/2013	9735							415	7.2	4040																												2.1	7.55	7.03						
12/24/2013	9735	433	6	4215	816	37.5	7944										104	80.75	158	122	1012	0.14	23	2.3	5.20	22	6.2	1.40	105	160	5	1022										1.88		7.77		
12/25/2013	9735							370	6.8	3602																																					
12/26/2013	9735				976	20.5	9502	310	5.2	3018	217	2113	93				106	82.31	161	125	1032	0.15	43	4.3	9.71	42	11.3	2.55	109	165	4.8	1061											3.15	8.95		0.70
12/27/2013	9735																																														
12/28/2013	9735							275	3.6	2677																										16.5	17.4	16.95									
12/29/2013	9735																																					1.69	6.57	7.48	<0.5					
12/30/2013	9735							315	2.8	3067																												5.72	7.41	6.72						
12/31/2013	9735																																														
1/1/2014	9845																																														
1/2/2014	8733																																														
1/3/2014	10061																																					2.08	6.88	6.9	<0.5					
1/4/2014	8835																87.5	67.94	133	103	773	5	2.8	2.8	0.63	25	20.5	4.63		135							3									
1/5/2014	9306				590	29.4	5491	410	4.8	3815																												1.47	6.63	6.59	1.5		1.44			
1/6/2014	10281							305	6	3136							87	67.55	132	102	894	7													21.3	22.5	21.9	1.03	6.95	6.7						
1/7/2014	10770	458	4.8	4933	975	22.5	10501				290	3123																										4.02	7.09	6.71		2.13				
1/8/2014	10585																77.3	60.02	117	91	818	3.5	3	3	0.68	32	16	3.61		120							4.5			<0.5					
1/9/2014	10711	368	4.1	3942				355	3.6	3802																																			1.04	
1/10/2014	9253				860	34.2	7958																															4.6	7.41	6.89	1					
1/11/2014	7668							290	4	2224													62	6.2	14.01	48	14.1	3.19																		
1/12/2014	9282							345	7.2	3202							123	95.51	186	145	1142	7.9																5.12	7.09	6.6						
1/13/2014	9663				955	28.8	9228																															3.6	7.1	6.99	0.5					
1/14/2014	7913	495	8.4	3917				370	6.8	2928	237	1875	133				95.4	74.08	145	112	755	7	4.5	4.5	1.02	36	18	4.07		149					19.8	19.5	19.65	1.09	7.22	6.98					1.34	0.64
1/15/2014	9531				910	36.4	8673	295	6	2812																												2.08			<0.5		3.08				
1/16/2014	10880	512	5.5	5571				285	7.6	3101																																			1.80	
1/17/2014	10258																116	90.07	176	136	1190	9.6	44	4.4	9.94	45	9.5	2.15		180																	
1/18/2014	8744							390	3.2	3410																												2.03	7.54	6.71						
1/19/2014	11167				650	35.2	7259	310	4.8	3462																																2.10				
1/20/2014	10254							360	4.8	3691							72.3	56.14	110	85	741	17.5	6.8	6.8	1.54	70	13.3	3.00		116							1.29	7.23	6.88	1.5					
1/21/2014	11050	406	6.6	4486	893	34.4	9868	315	6	3481																												4.41	7.21	7.06		2.20	2.83		1.29	
1/22/2014	10380							330	3.2	3425	285	2958	45																																		0.86
1/23/2014	10140							365	4.4	3701							111	86.19	168	131	1126	35													21.1	20.4	20.75	4.02	7.22	7.01	<0.5					
1/24/2014	10060																																														
1/25/2014	8830							355	3.6	3135																												2.55	7.21	6.92						
1/26/2014	9297																97.3	75.55	147	114	905	36	11	11	2.48	102	24.5	5.53		158							4.49	7.5	6.95	1					
1/27/2014	11076							315	6.2	3489																												4.04	7.33	6.91						
1/28/2014	11143				816	33.2	9093																															3.98	7.54	6.99						
1/29/2014	8397							370	7.6	3107							87.7	68.10	133	103	736	6.9	5.4	5.4	1.22	45	17	3.84		138										<0.5						
1/30/2014	9880							345	6	3409																												5.42	7.43	7.52						
1/31/2014	8801																																														
2/1/2014	8046																																														
2/2/2014	12782							395	6.6	5049							102	79.20	155	120	1304	14	7.1	7.1	1.60	91	18.5	4.18		162							7.02	7.13	7.67	1					
2/3/2014	9493																																					4.18	7.03	7.61						
2/4/2014	8114	355	7.29	2880	1020	48.9	8276				280	2272		675	5477	610							54.4	5.44	12.29	44	22	4.97	107		8.2	868			21	20.6	20.8	1.88	7.12	6.91	0.3	2.87		9.53		
2/5/2014	8184							445	7.2	3642																												2.15	7.44	6.93						
2/6/2014	9262	355	7.1	3288							280	2593											54	5.4	12.20	50	17	3.84	107		13.7	991						3.11	7.03	7.12	0.2					
2/7/2014	7375																																														
2/8/2014	8759				815	32	7139	285	5.1	2496							96	74.54	145	113	841	12.3	3.4	3.4	0.77	30	21	4.74		149							2.1	7.08	6.97			2.86			
2/9/2014	11583																																														
2/10/2014	10844							315	4.2	3416																												3.11	7.54	7						
2/11/2014	11853	568	16	6733							230	2726					103	79.98	156	121	1221	3	67	6.7	15.14	79	12	2.71	108	163	8	1280	-2	-7							0.2					
2/12/2014	9827				870	35.1	8549	330	7.6	3243																												2.51	7.05	7.21			2.64			
2/13/2014	9840	572	3.72	5628					4.8																				107		5.2	1053						3.06	6.97	7.51	0.2					
2/14/2014	8104																																					1.11	7.04	7.56						
2/15/2014	11289							400	9.2	4516							82.3	63.90	125	97	929	41	62	6.2	14.01	70	17.4	3.93		131							2.01	6.77	7.04						
2/16/2014	12225																																														
2/17/2014	9096							415	9.2	3775												5.8																1.97	7.09	7.33						
2/18/2014	8407	496	4.48	4170	1016	40	8542				386	3245		743	6246	622													110		5	925			23.2	21.9	22.55	1.08				2.05		9.24		
2/19/2014	9791							395	11.2	3867																												5.66	6.97	7.01	0.2					
2/20/2014	9691	566	6.6	5485							307	2975					64.5	50.08	98	76	625	9.2	72	7.2	16.27	70	23.1	5.22	103	105	3.1	998	31	-29				4.41	7.33	7.09						
2/21/2014	11280							325	10	3666																												3.09	7.51	6.98	0.2					
2/22/2014	10847																																					6.21	7.22	6.87						
2/23/2014	11237				910	39	10226	385	8.8	4326																												2.2	7.31	7.41			2.36			
2/24/2014	11880																82.5	64.06	125	97	980	6.8	12	12	2.71	143	15.5	3.50		137							3.13	7.47	7.51						
2/25/2014	10633	412	3.1	4381					12.4	0		0																												<0.5					
2/26/2014	11268																																					4.19	7.22	7.24						
2/27/2014	11341	460	4.5	5217				345	8.5	3913	310	3516	35				118	91.62	179	139	1338	19.4							113		23	1282													1.33	0.90
2/28/2014	12172				870	23	10590										75	58.24	114	88	913	4	59	5.9	13.33	72	18.5	4.18		120							2.1	7.31	6.98						
3/1/2014	10414																																					4.06								
3/2/2014	11770							370	9.2	4355																												3.5	7.23	7.09						
3/3/2014	12277							390	7.8	4788																												2.09								
3/4/2014	10000	339	9.6	3390	732	21	7320				343	3430		768	7680	648	103	79.98	156	121	1030	5.1	53	5.3	11.97	53	23	5.20	120	161	8.2	1200	12	-20	23.2	22.2	22.7	1.98	7.41	7.17		2.16		6.10		
3/5/2014	9999																																							<0.5						
3/6/2014	11663							330	6.6	3849																												1.35	7.16	7.3						
3/7/2014	10273																																														
3/8/2014	10087				814	18.4	8211										120	93.18	182	141	1210	4	3.6	3.6	0.81	36	18	4.07		185																
3/9/2014	11451							395	5.6	4523																												5.13	7.62	7.33	1.5					
3/10/2014	8079							325	6.8	2626																												4.15	7.34	6.97						
3/11/2014	10251	377	8.6	3865							283	2901																	113		8.2	1158									<0.5					
3/12/2014	9853				944	25.6	9301	340	8.8	3350							83	64.45	126	98	818	3.8	11	11	2.48	108	24.7	5.58		137							3.16	7.13	7.22			2.78			
3/13/2014	9413	385	2.84	3624				390	7.6	3671	307	2890	83																122		2.6	1148													0.99	0.79
3/14/2014	8860																																					3.34	7.12	7.14	1					
3/15/2014	7008							400	9.6	2803																																				
3/16/2014	6898							425	10	2932																												4.09	7.75	6.91	<0.5					
3/17/2014	11526				680	18	7838	410	5.2	4726																																1.66				
3/18/2014	10532	442	8.1	4655										603	6351	575	81.5	63.28	123	96	858	5.2	22.3	22.3	5.04	235	46	10.39	122	146	3	1285	18	-48				4.11	7.55	7.13	0.2					
3/19/2014	9519							395	4.4	3760																																				
3/20/2014	8865	445	5.17	3945				340	4.2	3014		0																	132		2.5	1170						2.79	7.42	7.09						
3/21/2014	11477																104	80.75	158	122	1194	4.2																	7.41	6.89	2.5						
3/22/2014	11113				940	22.3	10446	395	3.6	4390																												3.31					2.38			
3/23/2014	11485							405	5.6	4651																													7.09	6.6						
3/24/2014	12110							400	6.6	4844																												2.88	7.1	6.99	1.5					
3/25/2014	12110	499	9.7	6043							273	3306																	100		14	1211			24.1	23.3	23.7		7.22	6.98	0.2					
3/26/2014	12000							395	8	4740							92.5	71.82	140	109	1110	3.1	6.4	6.4	1.45	77	19.9	4.50		147							3.56								
3/27/2014	12110				816	45.1	9882	405	9.2	4905																																2.01				
3/28/2014	11320																																														
3/29/2014	11040							420	6	4637																												1.05	7.54	6.71`	1.5					
3/30/2014	11190																																														
3/31/2014	9200				1100	51.4	10120																																								
4/1/2014	10430	347	5.2	3619				415	10.4	4328	220	2295	195				84.2	65.38	128	99	878	9.6	10.1	10.1	2.28	105	16.5	3.73	121	138	3.6	1262	27	-23				4.42	7.21	7.06	1.5				0.84	0.53
4/2/2014	11100							395	4.2	4385																																				
4/3/2014	11180	344	4.8	3846							340	3801																	116		2.8	1297						2.66	7.22	7.01	2					
4/4/2014	11270							380	4.4	4283																																				
4/5/2014	11270				910	23.5	10256																																								
4/6/2014	11350							360	4	4086																												7.73	7.34	7.75	<0.5					
4/7/2014	11710							320	3	3747																												3.64	7.41	6.89						
4/8/2014	10900										260	2834		550	5995	563													100		2.1	1090			25.7	28.4	27.05				1					
4/9/2014	11720				740	26.4	8673	355	5.6	4161																												2.21	7.09	6.6	1.5		2.08			
4/10/2014	11760	378	8.7	4445				355	4.8	4175	253	2975	102				83.2	64.60	126	98	978	6.8	9.5	9.5	2.15	112	16	3.61	112	136	7.2	1317	19	-16					7.1	6.99					1.06	0.71
4/11/2014	11830																																					5.01	7.22	6.98	1					
4/12/2014	9980																																														
4/13/2014	11100							285	4.8	3164																												2.98								
4/14/2014	11250				790	29.5	8888	365	3.2	4106																																2.16				
4/15/2014	9580	379	8.4	3631				385	6	3688	217	2079	168				65.4	50.78	99	77	627	5.2	11.2	11.2	2.53	107	28	6.33	98	110	2.8	939	21	-30				1.77	7.54	6.71`	1				0.98	0.56
4/16/2014	7630																																					1.92								
4/17/2014	7050	555	8.8	3913				315	2.2	2221	203	1431	112																105		4.5	740						3.07	7.23	6.88	1.5				1.76	0.64

Aquaba Mechanical WWTF
Operational Data 2013-2014

DATE	Mech Plant Inf. m3/d	BOD5 mg/l	BOD5 Eff. mg/l	BOD5 inf. kg/d	COD inf. mg/L	COD Eff. Mg/l	COD inf. kg/d	TSS inf. mg/L	TSS Eff. Mg/L	TSS inf. kg/d	VSS mg/L	VSS kg/D	ISS mg/L	TDS Inf. Mg/L	TDS Inf. Kg/D	TDS Eff. Mg/L	NH4 Inf. Mg/L	Adjusted NH4 Inf mg/L (factor of 1.29)	Calc. TKN (NH4/0.66) mg/L	Adjusted Calc TKN (adjusted NH4/0.66) mg/L	NH4 Inf. Kg/D	NH4 Eff. Mg/L	NO3 Inf. Mg/L	Adjusted NO3 Inf. Mg/L (factor of 10)	Adjusted NO3 Inf. Mg/L (factor of 4.42)	NO3 inf. Kg/D	MeasuredNO3 Eff. Mg/L	Adjusted NO3 Eff. Mg/L (factor of 4.42)	Measured TN inf. mg/L	Calc TN (calc TKN+NO3) Mg/L	TN Eff. Mg/L	TN inf.kg/d	Org. N. inf. Mg/L	Org. N. Eff. Mg/L	Inf. TEMP c	Eff. Temp. C	Avg. Temp. C.	Eff. Turb. Mg/L	Inf. P.H unit	Eff. P.H.	Eff. Res. CL2	COD/BOD	COD/TSS	COD/TN	BOD/TSS	VSS/TSS
4/18/2014	9130																																						7.21	7.06						
4/19/2014	8400							295	2	2478																												3.01		<0.5					
4/20/2014	7040																																						7.22	7.01						
4/21/2014	7050				820	41.3	5781	350	4.8	2468							59.9	46.51	91	70	422	6	5.5	5.5	1.24	39	23.2	5.24		96								6	7.43	6.72			2.34			
4/22/2014	7050	335	7.9	2362										593	4181	573													107		5	754						4.06		0					
4/23/2014	7050																																					3.55	7.55	6.98						
4/24/2014	6850	407	6.33	2788				345	8	2363																			109		13	747			26.6	25.2	25.9	1.98		0.2				1.18	
4/25/2014	5030																																						7.62	7.14						
4/26/2014	7450				986	35	7346																															3.05							
4/27/2014	6500							335	6	2178																													7.29	6.92	0.3					
4/28/2014	7060							305	4	2153							63.1	49.00	96	74	445	4.2	25	2.5	5.65	18	18	4.07		98								4.1							
4/29/2014	7050																																					1.09	7.25	6.96	<0.5					
4/30/2014	7060				816	32.5	5761	295	3.2	2083																																	2.77			
5/1/2014	7230																																					2.76	7.53	6.87						
5/2/2014	8130							320	6	2602																												2.65	7.56	7.22	1.5					
5/3/2014	7900																52.8	41.00	80	62	417	3.1																2.09							
5/4/2014	8450				975	45.7	8239	360	7.2	3042																												1.33	7.44	7.2	2		2.71			
5/5/2014	7050							315	4.2	2221																													7.33	6.59						
5/6/2014	7040	424	6.92	2985							406	2858		677	4766	635	92	71.44	139	108	648	0.6	77	7.7	17.39	54	26	5.87	100	147	8.5	704	0	-18	27.6	26.7	27.15	3.09	7.33	6.45	0.5					
5/7/2014	7080																																					3.11	7	6.45						
5/8/2014	7100																93.3	72.45	141	110	662	6.7	12.4	12.4	2.80	88	22.8	5.15		154									7.31	6.9	1.5					
5/9/2014	10380																																					2.98							
5/10/2014	8470				1120	66.4	9486																															1.87	7.41	6.87	2					
5/11/2014	8547							250	7.2	2137																												1.74							
5/12/2014	9883				1020	65	10081																																		<0.5					
5/13/2014	8804							255	9.6	2245																												3.88	7.32	6.91						
5/14/2014	9226							245	8	2260							112	86.97	170	132	1033	8.8	4.4	4.4	0.99	41	17.5	3.95		174								1.54							
5/15/2014	9080																																					4.21	7.44	6.92	1.5					
5/16/2014	10330				820	18	8471	265	12	2737																													7.23	6.98			3.09			
5/17/2014	8620																																					3.09							
5/18/2014	11420							260	13.6	2969																													7.23	6.99	<0.5					
5/19/2014	11220																																					3.01							
5/20/2014	11120	344	7.6	3825				375	4	4170	233	2591	142	820	9118	675	77.3	60.02	117	91	860	12													27.7	26.8	27.25	1.8	7.22	6.78	1				0.92	0.62
5/21/2014	11320				860	14	9735	240	2.4	2717													68	6.8	15.36	77	62	14.01	109		18	1234							7.35	6.99			3.58	7.89		
5/22/2014	11350							295	6	3348							102	79.20	155	120	1158	0.4																4.4		1					
5/23/2014	11250							310	4	3488																													7.46	6.92						
5/24/2014	11230	338	7.92	3796																																		3.7		<0.5					
5/25/2014	10860				930	16	10100																																							
5/26/2014	9560																55.6	43.17	84	65	532	4.5	20	20	4.52	191	16	3.61		104								2.13	7.44	7.07						
5/27/2014	11959										200	2392																	106		7.4	1268									0.7					
5/28/2014	12356																103	79.98	156	121	1273	0.4	53	5.3	11.97	65	22	4.97		161								3.32	7.61	7.11						
5/29/2014	12206				755	18.9	9216																															2.08	7.56	7.2						
5/30/2014	11683																																													
5/31/2014	11473																																													
6/1/2014	11200																																					3.21	7.71	7.13	<0.5					
6/2/2014	12263				820	23	10056																																7.55	6.96						
6/3/2014	11850	331	2.9	3922	779	18	9231				183	2169		647	7667	641	54	41.93	82	64	640	1.43	51.4	5.14	11.61	61	5.8	1.31	61	87	3.9	723	2	-3	28	27.7	27.85					2.35		12.77		
6/4/2014	12609							355	4.4	4476																												3.34	7.32	6.98	2.5					
6/5/2014	12369																																													
6/6/2014	11858				960	26.7	11384	325	6.2	3854																																2.95			
6/7/2014	12206																																					2.09	7.23	6.88	1.5					
6/8/2014	12242																																								<0.5					
6/9/2014	12365							270	7.6	3339																												3.18	6.54	7.33						
6/10/2014	11176	318	5.7	3554		86.8	13411	360	3.2	4023	270	3018	90				84	65.22	127	99	939	10.4	73	7.3	16.49	82	12	2.71	95	135	15.2	1062	4	-7				2.21	7.03	6.91	<0.5				0.88	0.75
6/11/2014	11015																																													
6/12/2014	11015																																					2.49	7.09	7.19	1.5					
6/13/2014	9995							285	6.8	2849																																				
6/14/2014	10775																																					3.01	7.55	7.91	1					
6/15/2014	12426							190	5.6	2361							62.2	48.30	94	73	773	10.3	40	4	9.04	50	4.4	0.99		98								2.02	7.2	7.03	<0.5					
6/16/2014	12408							200	5.2	2482																												3.87	6.76	7.03						
6/17/2014	12557	405	4.56	5086	779	24	9782	390	6	4897	170	2135	220	553	6944	595																			29.6	28.3	28.95					1.92	2.00		1.04	0.44
6/18/2014	12228							200	8.8	2446							53.4	41.46	81	63	653	13.4	11	11	2.48	135	22	4.97	131	92	22	1602	67	-13				2.11	7.07	7.19	2.5					
6/19/2014	12509							340	6.4	4253																												3.47	6.93	7.17						
6/20/2014	12891																																								2					
6/21/2014	12479							315	7.8	3931																																				
6/22/2014	12664																63.5	49.31	96	75	804	18	10	10	2.26	127	19	4.29		106								4.27	7.05	7.2	1.5					
6/23/2014	12029																																													
6/24/2014	12582	395	5.7	4970				390	10.4	4907	260	3271	130														14.5	3.28	105		15	1321						5.12	7.11	7.2	<0.5				1.01	0.67
6/25/2014	12467				960	33	11968	310	6.8	3865							103	79.98	156	121	1284	14.5																				3.10				
6/26/2014	12341										320	3949																	106		14	1308								<0.5					
6/27/2014	12438																																					3.11	7.32	7.12						
6/28/2014	12307							330	4.6	4061																															2					
6/29/2014	12317																																					2.19	7.35	6.99						
6/30/2014	12519							345	6.8	4319																												3.08	7.54	6.97	1.5					
7/1/2014	12032	410	4.69	4933	820	23.6	9866	390	6.8	4692	337	4055	53	720	8663	636	77	59.79	117	91	926	49	50.9	5.09	11.50	61	13	2.94	85	122	50	1023	3	-12	29.3	29.2	29.25					2.00	2.10	9.65	1.05	0.86
7/2/2014	12266							355	6	4354																												2.21	7.33	7.08						
7/3/2014	12326	358	7.45	4413													106	82.31	161	125	1307	49.5	46	4.6	10.39	57	12.7	2.87	107	165	50	1319	-4	-12											
7/4/2014	12078																																					4.02	7.22	7.01						
7/5/2014	12354							325	10.4	4015																															<0.5					
7/6/2014	12328																																					2.55	7.21	6.92						
7/7/2014	12334							295	7.6	3639																												4.49	7.5	6.95	2.5					
7/8/2014	12466	395	7.05	4924							168	2094					67	52.02	102	79	835	36	43	4.3	9.71	54	13.9	3.14	72	106	37	898	1	-13				4.04	7.33	6.91	1.5					
7/9/2014	11423				877	27.4	10018	260	6.8	2970																												3.98	7.54	6.99			3.37			
7/10/2014	12441	336	6.1	4180				295	5.6	3670	230	2861	65				76	59.01	115	89	946	29	45.2	4.52	10.21	56	16.8	3.80	73	120	35	908	-8	-11										1.14	0.78
7/11/2014	12421							275	4.8	3416																												5.42	7.43	7.52	2					
7/12/2014	11842																																													
7/13/2014	11594							390	6	4522																																				
7/14/2014	12437													777	9664	622																						4.02	7.13	7.12	<0.5					
7/15/2014	12324	411	5.08	5065	670.4	26.6	8262	315	8	3882	238	2933	77				76	59.01	115	89	937	0.32	68	6.8	15.36	84	29.4	6.64	83	122	8	1023	0	-22	27.3	27.4	27.35	4.18	7.03	7.26		1.63	2.13	8.08	1.30	0.76
7/16/2014	12485							285	7.6	3558																												2.88	7.12	6.91	2.5					
7/17/2014	12307																																					2.15	7.44	6.93	2.5					
7/18/2014	12905				932	30.04	12027	335	4.4	4323																												3.11	7.03	7.09			2.78			
7/19/2014	13458																																													
7/20/2014	13442							335	4.4	4503							108	83.86	164	127	1452	50	34.4	3.44	7.77	46	11.2	2.53		167								2.1	7.08	6.97	1.5					
7/21/2014	13654							340	6.6	4642																															1.5					
7/22/2014	13623				877	34.4	11947	255	6.6	3474																												2.08	6.88	6.9			3.44			
7/23/2014	12407							355	6.6	4404																															2.5					
7/24/2014	13495																					7.6																1.47	6.63	6.59						
7/25/2014	12176							315	4.6	3835													55.1	5.51	12.45	67	9.4	2.12										1.03	7.11	6.7	2.5					
7/26/2014	10376				654	25.7	6786																															4.02	7.09	6.71	1.5					
7/27/2014	11538																																													
7/28/2014	14176																77.3	60.02	117	91	1096	0.65																			2.5					
7/29/2014	13558																																					4.6	7.41	6.89	2.5					
7/30/2014	13708																						44.4	4.44	10.03	61	18.9	4.27																		
7/31/2014	13760																																					5.12	7.09	6.6	<0.5					
8/1/2014	13793																																					3.6	7.61	6.99						
8/2/2014	13524				665	31.3	8993	405	8.8	5477																												1.09	7.22	6.98			1.64			
8/3/2014	13781							345	6	4754																																				
8/4/2014	13645																65	50.47	98	76	887	6.6	24.5	2.45	5.53	33	18.3	4.13		101								2.12	7.33	7.09	2.5					
8/5/2014	13930	303	4.9	4221							157	2187					54	41.93	82	64	752	0.07							65		2.9	905						3.09	7.51	6.98	2.5					
8/6/2014	13576							395	5.2	5363																												6.21	7.33	6.87						
8/7/2014	13531	402	4.86	5439				415	7.2	5615	217	2936	198				87	67.55	132	102	1177	0.07							90		3.5	1218						2.2	7.31	7.41	1.5				0.97	0.52
8/8/2014	13528																																					3.13	7.47	7.05						
8/9/2014	13481							370	6.8	4988																																				
8/10/2014	13563							310	5.2	4205																												3.18	7.33	6.91	<0.5					
8/11/2014	13555				600	18.9	8133																																							
8/12/2014	13552	309	4.3	4188				275	3.6	3727	190	2575	85	487	6600	595	113	87.74	171	133	1531	0.02							88		2.1	1193						3.34	7.16	6.77	<0.5				1.12	0.69
8/13/2014	13567																50.8	39.45	77	60	689	6.7	11	11	2.48	149	45	10.17		88																	

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DATE	Mech Plant Inf. m3/d	BOD5 mg/l	BOD5 Eff. mg/l	BOD5 inf. kg/d	COD inf. mg/L	COD Eff. Mg/l	COD inf. kg/d	TSS inf. mg/L	TSS Eff. Mg/L	TSS inf. kg/d	VSS mg/L	VSS kg/D	ISS mg/L	TDS Inf. Mg/L	TDS Inf. Kg/D	TDS Eff. Mg/L	NH4 Inf. Mg/L	Adjusted NH4 Inf mg/L (factor of 1.29)	Calc. TKN (NH4/0.66) mg/L	Adjusted Calc TKN (adjusted NH4/0.66) mg/L	NH4 Inf. Kg/D	NH4 Eff. Mg/L	NO3 Inf. Mg/L	Adjusted NO3 Inf. Mg/L (factor of 10)	Adjusted NO3 Inf. Mg/L (factor of 4.42)	NO3 inf. Kg/D	MeasuredNO3 Eff. Mg/L	Adjusted NO3 Eff. Mg/L (factor of 4.42)	Measured TN inf. mg/L	Calc TN (calc TKN+NO3) Mg/L	TN Eff. Mg/L	TN inf.kg/d	Org. N. inf. Mg/L	Org. N. Eff. Mg/L	Inf. TEMP c	Eff. Temp. C	Avg. Temp. C.	Eff. Turb. Mg/L	Inf. P.H unit	Eff. P.H.	Eff. Res. CL2	COD/BOD	COD/TSS	COD/TN	BOD/TSS	VSS/TSS
8/14/2014	13575							315	2.8	4276																															1.5					
8/15/2014	13542																76	59.01	115	89	1029	0.73																1.97	7.09	7.33	2					
8/16/2014	11968							350	4.8	4189																																					
8/17/2014	12428																																					2.66	6.97	7.01	<0.5					
8/18/2014	12621							285	4.4	3597																												4.55	7.33	7.09						
8/19/2014	12709	257	5.48	3266							150	1906																										3.09	7.51	6.98	0.5					
8/20/2014	12652				940	19.6	11893																						111		10	1404						6.21	7.22	6.87	0.5			8.47		
8/21/2014	12619	214	4.5	2700				310	5.6	3912	176	2221	134				88	68.33	133	104	1110	4.5															2.2	7.31	7.41					0.69	0.57
8/22/2014	12634																												81		10	1023						3.13	7.47	7.51	<0.5					
8/23/2014	12915																																														
8/24/2014	13574							245	6.4	3326																												3.19	7.22	7.24						
8/25/2014	13420	251	3.94	3368				305		4093																															2.5				0.82	
8/26/2014	13444							285	4.4	3832	197	2648	88				79.9	62.04	121	94	1074	0.35															2.1	7.31	6.98						0.69
8/27/2014	13319				855	17.7	11388	305	2.8	4062																																		2.80			
8/28/2014	13476	266	5.86	3585							173	2331		777	10471	628													85		10	1145									1					
8/29/2014	13399																																					1.35	7.16	7.3						
8/30/2014	12242																																					1.98	7.41	7.17	<0.5					
8/31/2014	13560							290	6	3932																																					
9/1/2014	13456				670	19.7	9016	305	6.8	4104							57.4	44.57	87	68	772	3.4	14	14	3.16	188	72	16.27		101													2.20			
9/2/2014	13354	246	5.35	3285	590	18.7	7879	215	8.8	2871	197	2631	18				75	58.24	114	88	1002	0.46	42	4.2	9.49	56	17.4	3.93	80	118	5.5	1068	1	-12				2.14	7.5	7.1	0.8	2.40	2.74	7.38	1.14	0.92
9/3/2014	13158																																						7.33	7.08							
9/4/2014	13535																																														
9/5/2014	13483				815	33	10989																															4.33	7.34	6.99	1					
9/6/2014	13472																75	58.24	114	88	1010	0.46																								
9/7/2014	12286																																						7.46	7.12	<0.5					
9/8/2014	12900																																														
9/9/2014	13656	308	5.55	4206	701	22.7	9573				317	4329		757	10338	541	76	59.01	115	89	1038	3.2	27	27	6.10	369	4.4	0.99	75	142	5.2	1024	-28	-2	23.2	23.1	23.15	3.12				2.28		9.35		
9/10/2014	12861							370	6.8	4759							63.5	49.31	96	75	817	10	10	10	2.26	129	19	4.29		106									7.44	6.98							
9/11/2014	10982	404	6.07	4437							164	1801																	79		4.35	868															
9/12/2014	10530				760	19.9	8003										70	54.35	106	82	737	3.2	50	5	11.30	53	4.63	1.05		111									3.08	7.32	6.97	2.5					
9/13/2014	10509																																														
9/14/2014	11870							260	7.6	3086																													7.54	6.99							
9/15/2014	10988																65	50.47	98	76	714	14.2	8.6	8.6	1.94	94	22.5	5.08		107									7.33	7.07	<0.5						
9/16/2014	13250	325	4.75	4306	666	19.7	8825				227	3008					101	78.42	153	119	1338	19.3							94		18.7	1246						1.11				2.05		7.09		
9/17/2014	12307																																						7.43	7.09	1.5						
9/18/2014	9065	334	5.8	3028	912	37.3	8267				217	1967					106	82.31	161	125	961	19.7	46.5	4.65	10.50	42	9.7	2.19	106	165	17.9	961	-5	-12								2.73		8.60		
9/19/2014	11623																																					3.06								
9/20/2014	10885							370	8.8	4027							77.3	60.02	117	91	841	5.6	6.7	6.7	1.51	73	18	4.07		124																	
9/21/2014	12921																																						7.51	6.97	1						
9/22/2014	10840							350	6.8	3794																												2.43									
9/23/2014	11743	359	4.19	4216							198	2325		593	6964	575	81.6	63.36	124	96	958	21	54	5.4	12.20	63	6.3	1.42	89	129	21.7	1045	2	-6	29.5	28.8	29.15		7.33	6.95	2.5						
9/24/2014	12392							355	6.4	4399																																					
9/25/2014	11704				880	32.2	10300																																7.42	7.07							
9/26/2014	12155							320	8.6	3890							80.9	62.82	123	95	983	8.7								123								3.76			<0.5					
9/27/2014	11587																						12	12	2.71	139	19.9	4.50																			
9/28/2014	12175							355	12.8	4322	285	3470	70																						28.9	27.5	28.2		7.61	7.04	1.5					0.80
9/29/2014	12907																																														
9/30/2014	12184							305	4.4	3716																																					
10/1/2014	10748																																														
10/2/2014	11227																																					3.04	7.33	6.95	1					
10/3/2014	11721							295	8.6	3458																															<0.5					
10/4/2014	11610				910	24.4	10565				305	3541																							29.6	28.8	29.2	4.15								
10/5/2014	11610																54.3	42.16	82	64	630	10.7																								
10/6/2014	11610							270	10.2	3135													13.2	13.2	2.98	153	23.6	5.33										3.16	7.21	7.01	2.5					
10/7/2014	11807				912	30.5	10768	305	6.6	3601																													7.51	6.98				2.99			
10/8/2014	11664																																					3.34								
10/9/2014	12070																																						7.45	6.98	<0.5						
10/10/2014	11437																						17.7	17.7	4.00	202	21.2	4.79										4.09								
10/11/2014	9773				754	19	7369	305	1.6	2981	275	2688	30																						27.4	26.6	27		7.53	7.05			2.47			0.90
10/12/2014	12626							160	7.2	2020																												4.11									
10/13/2014	10201																																								2.5						
10/14/2014	10458							250	13.6	2615																																					
10/15/2014	10354							355	12.8	3676							75	58.24	114	88	777	9.5	15	15	3.39	155	38	8.58		129									7.51	7.11							
10/16/2014	12451	416	5.75	5180	819	29	10197		14.8		237	2951		627	7807	568													95		8.3	1183			25	24.3	24.65		7.6	7.83	0.3	1.97		8.62		
10/17/2014	11173																85	66.00	129	100	950	8.5	57	5.7	12.88	64	1.27	0.29		134									7.45	7.01							
10/18/2014	9761							355	6	3465																																					
10/19/2014	11302							405	12	4577																															1.5						
10/20/2014	11527																77.3	60.02	117	91	891	29.5	11	11	2.48	127	21	4.74		128									7.5	6.97							
10/21/2014	11959							370	6.2	4425																																					
10/22/2014	11097				930	21	10320	330	12.8	3662																																	2.82			
10/23/2014	9849																																						7.66	7.02	1.5						
10/24/2014	10167																																														
10/25/2014	10387																89.9	69.81	136	106	934	11.5	13.3	13.3	3.00	138	14.5	3.28		150											<0.5						
10/26/2014	9669																																						7.8	7.71							
10/27/2014	10204										263	2684																							26.1	24.9	25.5									
10/28/2014	11924	267	3.33	3184	717	29.4	8550	315	7.6	3756				623	7429	548	81	62.90	123	95	966	7.9	70	7	15.81	83	11	2.48	97	130	12.1	1157	9	-7				7.6	7.54	0.3	2.69	2.28	7.39	0.85	
10/29/2014	12291							283	8.8	3478																																					
10/30/2014	9823																																														
10/31/2014	9608																																						7.53	7.5	2.5						
11/1/2014	11078							265	5.2	2936																																					
11/2/2014	11460				816	23.5	9351	280	9.2	3209												79.9	12	12	2.71	138	10	2.26											7.33	6.95			2.91			
11/3/2014	11844							325	4	3849																												2.76			<0.5						
11/4/2014	11352							425	11.6	4825																												2.65	7.4	6.98							
11/5/2014	11282							320	12	3610																												2.09									
11/6/2014	8860							320	12	2835				633	5608	538													105		9.6	930						1.33	7.31	7.09	0.3						
11/7/2014	10964				1020	30.5	11183																																								
11/8/2014	9063							405	12	3671																												3.09									
11/9/2014	12315							375	6.4	4618																												3.11	7.62	6.98	1						
11/10/2014	12128																58.8	45.66	89	69	713	5.2	38	3.8	8.58	46	52	11.75		93																	
11/11/2014	11515							260	7.2	2994																												2.98									
11/12/2014	11429							355	6	4057																												1.87	7.45	6.97	1						
11/13/2014	10840																																					1.74									
11/14/2014	12059							305	12.8	3678																									26.1	24.4	25.25				<0.5						
11/15/2014	12195													503	6134	539																						3.88									
11/16/2014	9282	387	6.84	3592	856	35	7945	365	14	3388	350	3249	15										13	13	2.94	121	24	5.42										1.54	7.62	7.41		2.21	2.35		1.06	0.96
11/17/2014	11249																																					4.21									
11/18/2014	9436							260	8	2453							48.8	37.89	74	57	460	9.3							83		13.8	783							7.35	7.34	0.2						
11/19/2014	10945							333	11.4	3645	290	3174	43										55	5.5	12.42	60	10.8	2.44							24.6	23.9	24.25	3.09								0.87
11/20/2014	9509	315	3.36	2995		30.5		376	8	3575							99	76.87	150	116	941	5.5																	7.33	7.08					0.84	
11/21/2014	9987																																					3.01									
11/22/2014	9453							350	8.8	3309							74	57.46	112	87	700	14.2	11.5	11.5	2.60	109	6.4	1.45										1.8	7.6	7.2	2.5					
11/23/2014	10306							395	7.2	4071																																					
11/24/2014	13169				570	70	7506	410	9.2	5399																												4.4	7.42	7.09			1.39				
11/25/2014	10699																																								<0.5						
11/26/2014	10101							320	10.8	3232							87.7	68.10	133	103	886	6.5																	7.4	6.98							
11/27/2014	12314							290	10.5	3571													18.8	18.8	4.25	232	52	11.75																			
11/28/2014	12507				677	18.9	8467																																								
11/29/2014	9369																																					1.2	7.41	7.05	2.5						
11/30/2014	10381							365	5	3789																												1.42									
12/1/2014	11314																81.8	63.52	124	96	925	7																1.5	7.42	6.98	1.5						
12/2/2014	11432				1020	27.8	11661	405	6.4	4630																												0.98					2.52				
12/3/2014	10610																						20.9	20.9	4.72	222	43	9.71										2.08	7.6	7.1	1						
12/4/2014	10014																																					4.87									
12/5/2014	10308																77.3	60.02	117	91	797	14																			<0.5						
12/6/2014	7822																																					1.99	7.54	7.23							
12/7/2014	8759																																					3.45			1						
12/8/2014	7722																																					3.34									
12/9/2014	11177	400	8	4471	1030	32.2	11512				300	3353					80.9	62.82	123	95	904	29.9	67	6.7	15.14	75	6.6	1.49	98	129	4.4	1095	10	-32	24.9	23.2	24.05	1.87	7.31	7.11	1	2.58		10.51		

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DATE	Mech Plant Inf. m3/d	BOD5 mg/l	BOD5 Eff. mg/l	BOD5 inf. kg/d	COD inf. mg/L	COD Eff. Mg/l	COD inf. kg/d	TSS inf. mg/L	TSS Eff. Mg/L	TSS inf. kg/d	VSS mg/L	VSS kg/D	ISS mg/L	TDS Inf. Mg/L	TDS Inf. Kg/D	TDS Eff. Mg/L	NH4 Inf. Mg/L	Adjusted NH4 Inf mg/L (factor of 1.29)	Calc. TKN (NH4/0.66) mg/L	Adjusted Calc TKN (adjusted NH4/0.66) mg/L	NH4 Inf. Kg/D	NH4 Eff. Mg/L	NO3 Inf. Mg/L	Adjusted NO3 Inf. Mg/L (factor of 10)	Adjusted NO3 Inf. Mg/L (factor of 4.42)	NO3 inf. Kg/D	MeasuredNO3 Eff. Mg/L	Adjusted NO3 Eff. Mg/L (factor of 4.42)	Measured TN inf. mg/L	Calc TN (calc TKN+NO3) Mg/L	TN Eff. Mg/L	TN inf.kg/d	Org. N. inf. Mg/L	Org. N. Eff. Mg/L	Inf. TEMP c	Eff. Temp. C	Avg. Temp. C.	Eff. Turb. Mg/L	Inf. P.H unit	Eff. P.H.	Eff. Res. CL2	COD/BOD	COD/TSS	COD/TN	BOD/TSS	VSS/TSS
12/10/2014	9395				829	24.5	7788	350	9.2	3288							89	69.11	135	105	836	12															3.11				2.37			
12/11/2014	7789													697	5429	578																					2.46			1.5				
12/12/2014	9628																																					7.52	6.95						
12/13/2014	8691																																							1					
12/14/2014	9536				1011	22	9641	355	5.6	3385																												7.44	6.98			2.85			
12/15/2014	9745																54.5	42.32	83	64	531	10.6	16	16	3.61	156	22	4.97		99								7.41	6.99						
12/16/2014	7083																																				3.92			1.5				
12/17/2014	7679.5																																												
12/18/2014	7679.5							285	8.4	2189																												7.64	6.88						
12/19/2014	9535				918	14.6	8753																																						
12/20/2014	8188																						7.7	7.7	1.74	63	12	2.71									4.88	7.53	7.08	2.5				
12/21/2014	6884							320	15.6	2203							76.6	59.48	116	90	527	12															2.85							
12/22/2014	9758																																				3.11	7.66	7.05						
12/23/2014	10828		2.73			18					300	3248		740	8013	652	81	62.90	123	95	877	0.02	71	7.1	16.04	77	53	11.97	93	130	15.5	1007	5	-38	22.2	21.2	21.7	3.1	7.68	6.78	3					
12/24/2014	10189				756	26.1	7703																														2.97	7.43	7.01						
12/25/2014	10100																56.7	44.03	86	67	573	13.3																7.35	7.09	2.5						
12/26/2014	10287																																												
12/27/2014	10237							280	8.8	2866													6.5	6.5	1.47	67	18	4.07										7.54	6.78	2.5					
12/28/2014	11267				1016	27.8	11447	355	6	4000																																2.86				
12/29/2014	10370																55.8	43.33	85	66	579	11.7																7.55	7.21	2					
12/30/2014	7263																																					7.55	6.99	1.5					
12/31/2014	10560							320	6.4	3379																																			
Average	10431.65	382.39	6.25	3936.09	791.14	27.39	8318.04	336.85	7.04	3608.01	271.26	2755.09	82.02	584.27		515.42	91.00	70.66	137.88	107.06	958.91	6.19	45.06	7.05	10.18	74.25	28.53	6.44	106.46	146.38	12.40	1107.73	8.11	-17.08	25.07	24.09	24.58	3.00	7.41	7.04	1.53	2.02	2.34	7.12	1.12	0.78
Min	5030.00	214.00	1.65	1923.48	448.00	9.80	4019.68	160.00	1.60	0.00	130.00	0.00	0.00				42.00	32.61	63.64	49.41	417.12	0.02	2.80	2.30	0.63	17.65	1.27	0.29	60.00	75.54	1.55	704.00			16.50				6.54			1.28	1.37	3.74	0.69	
Max	14176.00	572.00	16.00	6732.50	1180.00	86.80	13551.12	445.00	53.40	5615.37	425.00	4924.00	220.00				152.00	118.03	230.30	178.83	1737.36	79.90	96.00	27.00	21.69	368.71	97.00	21.91	145.00	235.30	52.00	1623.70			31.20				7.88			3.01	3.58	12.77	1.80	
Count	730	135	139	135	178	180	179	343	343	344	116	119	64				196	196	196	196	196	199	178	177	178	177	179	179	134	154	134	134	23	23	57	57	57		423			90	104	87	75	
91.70%	12735	493	9	5212	977	40	10644	405	11	4750	355	3707	185	759	8214	641	120	93	182	141		18	77	12	17	136	65	14.79	130	189	23	1404	28	-5	30	29	29	5	8	7	3	2	3	9	1	1
8.30%	7000	281	4	2822	597	16	5776	262	4	2434	183	1905	13	331	3728	5	59	46	89	69	627	0	7	4	2	38	7	1.49	81	100	4	770	-5	-33	21	19	20	1	7	7	0	2	2	5	1	1

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DATE	MLSS (oxi 1)	MLSS (oxi 2)	Avg. MLSS	MLVSS (oxi 1)	MLVSS (oxi 2)	Avg. MLVSS	RAS	
	TSS mg/L	TSS mg/L	TSS mg/L	VSS mg/L	VSS mg/L	VSS mg/L	TSS mg/L	VSS mg/L
1/1/2013								
1/2/2013	1990	2225	2107.5				4580	3206
1/3/2013	2110	2215	2162.5				5170	
1/4/2013								
1/5/2013	2220	2095	2157.5				5650	
1/6/2013	1935	1855	1895				6080	4560
1/7/2013	2055	2130	2092.5				5260	
1/8/2013	1676	1760	1718					
1/9/2013								
1/10/2013	1930	2080	2005				3430	2400
1/11/2013								
1/12/2013								
1/13/2013	1870	1900	1885				4350	
1/14/2013	1470	1425	1447.5				4140	2890
1/15/2013	2210	2080	2145				5100	
1/16/2013	2020	1935	1977.5				4620	
1/17/2013	2110	2045	2077.5				6680	5010
1/18/2013								
1/19/2013								
1/20/2013								
1/21/2013								
1/22/2013	2135	2445	2290					
1/23/2013								
1/24/2013								
1/25/2013								
1/26/2013	2010	1810	1910				4770	3350
1/27/2013	1830	1925	1877.5				6680	
1/28/2013	2140	2115	2127.5				7660	
1/29/2013	2115	2080	2097.5				5670	4250
1/30/2013	2050	2260	2155				6660	
1/31/2013	2165	2285	2225				5190	
2/1/2013	2450	2450	2450				4350	3150
2/2/2013	2270	2215	2242.5				6900	
2/3/2013	2195	2080	2137.5				7190	
2/4/2013	2055	2325	2190				6200	
2/5/2013	2390	2550	2470				6990	
2/6/2013								
2/7/2013	2730	2494	2612				6790	
2/8/2013								
2/9/2013	2470	2485	2477.5	1870	1880	1875	6440	4810
2/10/2013	2330	2445	2387.5				5930	
2/11/2013								
2/12/2013	2630	2620	2625				6080	4390
2/13/2013	2430	2550	2490				4480	
2/14/2013	2445	2630	2537.5				5580	
2/15/2013								
2/16/2013								
2/17/2013	2355	2545	2450	1765	1920	1842.5	5570	4130
2/18/2013	2595	2500	2547.5				4111	
2/19/2013	2650	2530	2590				6950	5200
2/20/2013	2435	2385	2410				5190	
2/21/2013	2415	2440	2427.5				6280	4710
2/22/2013								
2/23/2013	2325	2500	2412.5				6190	4570
2/24/2013	2475	2480	2477.5				6530	
2/25/2013	2340	2330	2335	1725	1760	1742.5	6010	4470
2/26/2013	2415	2440	2427.5				4690	
2/27/2013	2555	2655	2605					
2/28/2013	2335	2155	2245	1745	1655	1700	4950	3735
3/1/2013								
3/2/2013	2195	2445	2320				5570	
3/3/2013								
3/4/2013	2320	2345	2332.5				4830	
3/5/2013	2225	2610	2417.5				6230	4350
3/6/2013	2355	2700	2527.5				5870	
3/7/2013	2115	2415	2265				5690	
3/8/2013								
3/9/2013	2135	2320	2227.5				4990	3740

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DATE	MLSS (oxi 1)	MLSS (oxi 2)	Avg. MLSS	MLVSS (oxi 1)	MLVSS (oxi 2)	Avg. MLVSS	RAS	
	TSS mg/L	TSS mg/L	TSS mg/L	VSS mg/L	VSS mg/L	VSS mg/L	TSS mg/L	VSS mg/L
3/10/2013	2435	2240	2337.5				4870	
3/11/2013		2575	2575				6100	
3/12/2013	2315	2615	2465				5300	
3/13/2013								
3/14/2013	2545	2655	2600				4570	3200
3/15/2013								
3/16/2013								
3/17/2013	2195	2010	2102.5				6100	
3/18/2013	2135	2035	2085				4250	
3/19/2013	2195	2195	2195				5230	3900
3/20/2013	1850	2170	2010				4970	
3/21/2013	2035	2300	2167.5				4950	3460
3/22/2013								
3/23/2013	1945	1975	1960				4730	
3/24/2013	1930	1775	1852.5				3300	
3/25/2013	2010	1805	1907.5				4700	
3/26/2013	1830	1870	1850				3930	
3/27/2013	1690	1695	1692.5				5750	4310
3/28/2013	1695	1685	1690					
3/29/2013								
3/30/2013	1785	1670	1727.5				4740	
3/31/2013	1945	1690	1817.5				4780	
4/1/2013	1890	1775	1832.5				4030	2800
4/2/2013	2135	2025	2080					
4/3/2013	1360	1705	1532.5				5580	
4/4/2013	2105	2080	2092.5					
4/5/2013								
4/6/2013	2017	2045	2031				5600	4200
4/7/2013	2140	2280	2210				5450	
4/8/2013	2210	2050	2130				6020	
4/9/2013	2100	1820	1960					
4/10/2013								
4/11/2013	1840	1700	1770				7210	5407
4/12/2013	1950	1760	1855				7200	
4/13/2013	2010	1720	1865				3800	
4/14/2013	1860	1530	1695				7930	5947
4/15/2013	1950	1630	1790				7900	
4/16/2013	1905	1660	1782.5				8420	6300
4/17/2013								
4/18/2013	2135	1915	2025				5080	
4/19/2013								
4/20/2013	1940	2150	2045				8420	6315
4/21/2013	2025	1760	1892.5				6440	
4/22/2013	2200	2250	2225				6450	4830
4/23/2013	2585	2280	2432.5				6880	
4/24/2013	2450	2250	2350					
4/25/2013	2220	2410	2315				6590	4600
4/26/2013								
4/27/2013								
4/28/2013	2135	2365	2250				5750	4025
4/29/2013	2135	2360	2247.5					
4/30/2013	2195	2360	2277.5				6600	4950
5/1/2013	2280	2190	2235				5140	
5/2/2013								
5/3/2013								
5/4/2013								
5/5/2013	2570	2390	2480				4500	
5/6/2013	2695	2165	2430				5440	
5/7/2013	2505	2770	2637.5				6690	
5/8/2013	2215	2170	2192.5				8240	
5/9/2013	2210	2165	2187.5				8540	
5/10/2013								
5/11/2013		2370	2370				5270	
5/12/2013							5500	
5/13/2013	2650	2545	2597.5				5740	
5/14/2013	2575	2410	2492.5	1760	1865	1812.5	5540	4100
5/15/2013	2560	2440	2500				5620	
5/16/2013	2600	2510	2555				5480	

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DATE	MLSS (oxi 1)	MLSS (oxi 2)	Avg. MLSS	MLVSS (oxi 1)	MLVSS (oxi 2)	Avg. MLVSS	RAS	
	TSS mg/L	TSS mg/L	TSS mg/L	VSS mg/L	VSS mg/L	VSS mg/L	TSS mg/L	VSS mg/L
5/17/2013								
5/18/2013	2810	2745	2777.5				5810	
5/19/2013	2575	2410	2492.5				5540	
5/20/2013	2590	2900	2745				8160	
5/21/2013	2750	2800	2775				8340	
5/22/2013	2715	2905	2810				8570	
5/23/2013	2750	2815	2782.5				7760	
5/24/2013								
5/25/2013								
5/26/2013							7840	
5/27/2013	2750	2815	2782.5				7760	
5/28/2013								
5/29/2013	2720	2780	2750					
5/30/2013	2710	2800	2755				8560	
5/31/2013								
6/1/2013	2700	2780	2740	1890	1946	1918	8600	
6/2/2013	2760	2820	2790				8700	
6/3/2013	2850	2805	2827.5				8740	
6/4/2013	2800	2750	2775	1960	1925	1942.5	8600	
6/5/2013	3070	2975	3022.5				7880	
6/6/2013	3200	3000	3100				8750	
6/7/2013								
6/8/2013	3250	3330	3290				8560	
6/9/2013	2625	2895	2760				8000	
6/10/2013	2650	2850	2750	1835	1985	1910		
6/11/2013	2660	2860	2760				7760	
6/12/2013								
6/13/2013	2850	2620	2735				7540	
6/14/2013								
6/15/2013	2905	2710	2807.5	2035	1895	1965	7033	
6/16/2013	3000	2850	2925				8750	
6/17/2013	2895	2705	2800				7040	
6/18/2013	2750	2885	2817.5				9010	
6/19/2013	2700	2905	2802.5					
6/20/2013	2770	2800	2785	1930	1960	1945	8560	
6/21/2013								
6/22/2013	2700	2620	2660					
6/23/2013								
6/24/2013	2750	2715	2732.5				8330	
6/25/2013	2840	2700	2770					
6/26/2013							8350	
6/27/2013	2805	2750	2777.5	2020	1900	1960	8050	
6/28/2013								
6/29/2013	2565	2715	2640				7680	
6/30/2013	2490	2505	2497.5				7840	
7/1/2013								
7/2/2013	2955	2755	2855	2068	1925	1996.5	8530	
7/3/2013								
7/4/2013							6250	
7/5/2013								
7/6/2013	2650	2410	2530	1855	1687	1771	6170	
7/7/2013								
7/8/2013							6000	
7/9/2013	2445	2575	2510				8530	
7/10/2013	2990	2870	2930				8750	
7/11/2013	3000	2850	2925	2250	2135	2192.5		
7/12/2013								
7/13/2013							6660	
7/14/2013	2285	2320	2302.5				6920	
7/15/2013	2045	2225	2135					
7/16/2013							6050	
7/17/2013	2295	2315	2305				6280	
7/18/2013	2675	2150	2412.5	1875	1505	1690	6350	
7/19/2013	2295	2315	2305					
7/20/2013								
7/21/2013							4960	
7/22/2013	2115	2170	2142.5	1480	1520	1500	5650	
7/23/2013	1630	1905	1767.5				5600	

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DATE	MLSS (oxi 1)	MLSS (oxi 2)	Avg. MLSS	MLVSS (oxi 1)	MLVSS (oxi 2)	Avg. MLVSS	RAS	
	TSS mg/L	TSS mg/L	TSS mg/L	VSS mg/L	VSS mg/L	VSS mg/L	TSS mg/L	VSS mg/L
7/24/2013								
7/25/2013								
7/26/2013								
7/27/2013	2050	2100	2075				6040	
7/28/2013	2040	2070	2055				6200	
7/29/2013	2100	2150	2125	1470	1505	1487.5		
7/30/2013							7080	
7/31/2013	1725	1730	1727.5					
8/1/2013	1750	1770	1760					
8/2/2013								
8/3/2013	1890	1880	1885					
8/4/2013								
8/5/2013	1880	1845	1862.5	1410	1380	1395	4800	
8/6/2013	2250	2150	2200				5500	
8/7/2013	2315	2210	2262.5		2210	2210	5750	
8/8/2013	2295	2200	2247.5	1606	1540	1573	5400	
8/9/2013								
8/10/2013								
8/11/2013								
8/12/2013	1670	2080	1875				4200	
8/13/2013	1735	2130	1932.5				4250	
8/14/2013								
8/15/2013	1870	2150	2010	1300	940	1120	5505	
8/16/2013								
8/17/2013	2330	2240	2285				6290	
8/18/2013								
8/19/2013	2110	1965	2037.5				6930	
8/20/2013								
8/21/2013	2150	2050	2100				8500	
8/22/2013	2145	2130	2137.5				8830	
8/23/2013								
8/24/2013	2160	2240	2200				7140	
8/25/2013	2120	2210	2165				6860	
8/26/2013								
8/27/2013								
8/28/2013								
8/29/2013								
8/30/2013								
8/31/2013								
9/1/2013								
9/2/2013	2250	2645	2447.5				4710	
9/3/2013	2225	2305	2265				5100	
9/4/2013	2225	2350	2287.5				5270	
9/5/2013								
9/6/2013								
9/7/2013	2705	2300	2502.5				5320	
9/8/2013	2405	2180	2292.5				4900	
9/9/2013	2490	2705	2597.5				6050	
9/10/2013	2495	2680	2587.5				6040	
9/11/2013								
9/12/2013	2490	2705	2597.5				6500	
9/13/2013								
9/14/2013	2295	2315	2305				6350	
9/15/2013	2715	2290	2502.5				5190	
9/16/2013	2230	2345	2287.5				5080	
9/17/2013	2555	2650	2602.5				5010	
9/18/2013								
9/19/2013	2515	2595	2555				4380	
9/20/2013								
9/21/2013								
9/22/2013	2565	2330	2447.5				5950	
9/23/2013	2490	2275	2382.5				5000	
9/24/2013	2410	2485	2447.5				5200	
9/25/2013	2430	2455	2442.5				5130	
9/26/2013								
9/27/2013								
9/28/2013								
9/29/2013	2405	2520	2462.5				4860	

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DATE	MLSS (oxi 1)	MLSS (oxi 2)	Avg. MLSS	MLVSS (oxi 1)	MLVSS (oxi 2)	Avg. MLVSS	RAS	
	TSS mg/L	TSS mg/L	TSS mg/L	VSS mg/L	VSS mg/L	VSS mg/L	TSS mg/L	VSS mg/L
9/30/2013	2410	2485	2447.5				5200	
10/1/2013	2790	2760	2775					
10/2/2013								
10/3/2013	2930	3075	3002.5				5225	
10/4/2013								
10/5/2013								
10/6/2013								
10/7/2013	2675	2450	2562.5				4205	
10/8/2013	2430	2400	2415				3180	
10/9/2013	2540	2845	2692.5					
10/10/2013	2596	2770	2683					
10/11/2013								
10/12/2013								
10/13/2013								
10/14/2013								
10/15/2013								
10/16/2013								
10/17/2013								
10/18/2013								
10/19/2013								
10/20/2013	2595	2840	2717.5				4020	
10/21/2013	2945	3125	3035					
10/22/2013	3125	3170	3147.5				5075	
10/23/2013								
10/24/2013	2870	3005	2937.5				5130	
10/25/2013								
10/26/2013	2970	2835	2902.5				4690	
10/27/2013								
10/28/2013	2720	2650	2685				650	
10/29/2013								
10/30/2013	2420	2700	2560				4820	
10/31/2013	2270	2340	2305				4050	
11/1/2013								
11/2/2013								
11/3/2013								
11/4/2013	2695	2460	2577.5				4100	
11/5/2013	3145	2980	3062.5					
11/6/2013	2900	2980	2940				4350	
11/7/2013								
11/8/2013								
11/9/2013	2570	2785	2677.5				4740	
11/10/2013								
11/11/2013	2815	2910	2862.5				3520	
11/12/2013	2590	3255	2922.5					
11/13/2013	2975	2835	2905					
11/14/2013	2975	2940	2957.5				4040	
11/15/2013								
11/16/2013	2900	2980	2940				4350	
11/17/2013	2820	2740	2780				4120	
11/18/2013	2855	2800	2827.5				4140	
11/19/2013	2810	2850	2830				5000	
11/20/2013								
11/21/2013	2666	2850	2758					
11/22/2013								
11/23/2013	2875	2810	2842.5				5280	
11/24/2013	2950	2835	2892.5				5500	
11/25/2013	3040	2635	2837.5					
11/26/2013	2835	2910	2872.5				4260	
11/27/2013	2820	2740	2780				4120	
11/28/2013	2960	3285	3122.5					
11/29/2013								
11/30/2013	2755	2985	2870				3760	
12/1/2013	2800	2665	2732.5				4560	
12/2/2013	2825	3090	2957.5				5000	
12/3/2013	2975	2900	2937.5				4310	
12/4/2013								
12/5/2013								
12/6/2013								

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DATE	MLSS (oxi 1)	MLSS (oxi 2)	Avg. MLSS	MLVSS (oxi 1)	MLVSS (oxi 2)	Avg. MLVSS	RAS	
	TSS mg/L	TSS mg/L	TSS mg/L	VSS mg/L	VSS mg/L	VSS mg/L	TSS mg/L	VSS mg/L
12/7/2013	3065	2940	3002.5				3980	
12/8/2013								
12/9/2013	3075	3090	3082.5				3960	
12/10/2013	2820	2550	2685				4050	
12/11/2013	2985	3035	3010				4450	
12/12/2013								
12/13/2013								
12/14/2013	2810	2985	2897.5				4530	
12/15/2013								
12/16/2013	2775	2895	2835				5240	
12/17/2013	2995	2930	2962.5					
12/18/2013								
12/19/2013	2615	2935	2775					
12/20/2013								
12/21/2013	2810	2910	2860				4920	
12/22/2013								
12/23/2013								
12/24/2013	3315	3165	3240					
12/25/2013								
12/26/2013	3350	3250	3300					
12/27/2013								
12/28/2013	2925	2870	2897.5				4700	
12/29/2013								
12/30/2013	2810	2920	2865				5100	
12/31/2013								
1/1/2014								
1/2/2014								
1/3/2014								
1/4/2014								
1/5/2014	3325	3220	3272.5	2327	2254	2290.5	5350	3745
1/6/2014	2940	3145	3042.5				5270	
1/7/2014								
1/8/2014	3105	3220	3162.5				5400	
1/9/2014								
1/10/2014	3110	3005	3057.5	2115	2100	2107.5	5310	3717
1/11/2014								
1/12/2014	3055	3005	3030				5040	
1/13/2014								
1/14/2014	3040	3060	3050				5690	
1/15/2014	3035	2980	3007.5	2120	2080	2100	5970	4460
1/16/2014	3030	3010	3020				3860	
1/17/2014								
1/18/2014	3205	3190	3197.5				4820	
1/19/2014	3090	3165	3127.5				4480	
1/20/2014	3440	3470	3455	2580	2600	2590	4580	3430
1/21/2014	3165	2965	3065				3920	
1/22/2014	3250	3345	3297.5				5110	
1/23/2014	3055	3065	3060				5070	
1/24/2014								
1/25/2014	3150	3085	3117.5	2360	2300	2330	5400	4050
1/26/2014								
1/27/2014	2960	3015	2987.5				4960	
1/28/2014								
1/29/2014	2900	2975	2937.5				4950	
1/30/2014	3335	3300	3317.5	2500	2470	2485	5950	4460
1/31/2014								
2/1/2014	3210	3105	3157.5				5515	
2/2/2014								
2/3/2014	3120	2990	3055					
2/4/2014	2885	2905	2895	2150	2160	2155	3710	2780
2/5/2014	2795	2725	2760				3100	
2/6/2014	2815	2850	2832.5				3220	
2/7/2014								
2/8/2014								
2/9/2014								
2/10/2014								
2/11/2014								
2/12/2014	2505	3005	2755	1750	2100	1925	3520	2460

Aqaba Mechanical WWTP
MLSS Data 2013-2014

DATE	MLSS (oxi 1)	MLSS (oxi 2)	Avg. MLSS	MLVSS (oxi 1)	MLVSS (oxi 2)	Avg. MLVSS	RAS	
	TSS mg/L	TSS mg/L	TSS mg/L	VSS mg/L	VSS mg/L	VSS mg/L	TSS mg/L	VSS mg/L
2/13/2014	2870	3020	2945				4120	
2/14/2014	2995	3115	3055				3900	
2/15/2014	3045	2995	3020				4015	
2/16/2014	2990	2985	2987.5					
2/17/2014	2860	3100	2980	2140	2170	2155	4270	2900
2/18/2014								
2/19/2014	3010	3520	3265				4060	
2/20/2014	3100	3250	3175				4265	
2/21/2014								
2/22/2014	3090	3115	3102.5	2310	2330	2320	4300	3200
2/23/2014	3030	2825	2927.5				3980	
2/24/2014								
2/25/2014	2690	2665	2677.5				5060	
2/26/2014								
2/27/2014	2510	2400	2455					
2/28/2014	2505	2390	2447.5					
3/1/2014								
3/2/2014	2470	2135	2302.5	1852	1579	1715.5	4700	3384
3/3/2014								
3/4/2014	2310	2205	2257.5				4005	
3/5/2014							4105	
3/6/2014	2420	2315	2367.5				3910	
3/7/2014								
3/8/2014								
3/9/2014	2405	2285	2345				3800	
3/10/2014	2310	2230	2270	1732	1650	1691	3510	2530
3/11/2014							3105	
3/12/2014	1965	1965	1965				3200	
3/13/2014	1755	1830	1792.5				3200	
3/14/2014								
3/15/2014	1845	1960	1902.5	1380	1420	1400	2400	1680
3/16/2014	1780	1880	1830				3005	
3/17/2014	1880	1935	1907.5				2660	
3/18/2014								
3/19/2014								
3/20/2014	1730	1890	1810				4000	
3/21/2014	1820	1750	1785	1270	1220	1245	4005	3000
3/22/2014								
3/23/2014	1705	1910	1807.5				3630	
3/24/2014	1700	1880	1790					
3/25/2014								
3/26/2014	1685	1760	1722.5				3530	
3/27/2014	1840	1890	1865	1380	1420	1400	2620	1960
3/28/2014	1910	1750	1830					
3/29/2014							4305	
3/30/2014	1905	1900	1902.5					
3/31/2014							5020	
4/1/2014	1700	1935	1817.5				5120	
4/2/2014	1790	1910	1850					
4/3/2014	1820	1915	1867.5	1365	1430	1397.5	3420	2560
4/4/2014								
4/5/2014	1860	1690	1775				3320	
4/6/2014	1845	1885	1865				3170	
4/7/2014								
4/8/2014	1818	1875	1846.5					
4/9/2014	1870	1930	1900	1400	1445	1422.5	4050	3030
4/10/2014	1970	1950	1960				2210	
4/11/2014								
4/12/2014								
4/13/2014	2160	2005	2082.5	1630	1403	1516.5	2880	2160
4/14/2014	1810	1955	1882.5				2950	
4/15/2014	1975	2003	1989				3150	
4/16/2014	2010	1890	1950				3120	
4/17/2014								
4/18/2014	1985	1810	1897.5	1488	1357	1422.5	3210	2407
4/19/2014								
4/20/2014								
4/21/2014	2130	2050	2090	1597	1537	1567	3600	2520

Aqaba Mechanical WWTP
MLSS Data 2013-2014

DATE	MLSS (oxi 1)	MLSS (oxi 2)	Avg. MLSS	MLVSS (oxi 1)	MLVSS (oxi 2)	Avg. MLVSS	RAS	
	TSS mg/L	TSS mg/L	TSS mg/L	VSS mg/L	VSS mg/L	VSS mg/L	TSS mg/L	VSS mg/L
4/22/2014								
4/23/2014	1930	1875	1902.5					
4/24/2014	1840	1870	1855				2830	
4/25/2014								
4/26/2014	1655	1790	1722.5	1241	1250	1245.5	2240	1680
4/27/2014	1745	1965	1855				3100	
4/28/2014	1650	1845	1747.5					
4/29/2014								
4/30/2014	1660	1705	1682.5				3210	
5/1/2014								
5/2/2014	1770	1550	1660				3105	
5/3/2014	1905	1675	1790	1430	1250	1340	2200	1650
5/4/2014	1815	1600	1707.5				2040	
5/5/2014	1870	1550	1710				2310	
5/6/2014	1660	1430	1545	1245	1050	1147.5	2450	1830
5/7/2014								
5/8/2014	1675	1440	1557.5				3315	
5/9/2014								
5/10/2014	1545	1605	1575				3405	
5/11/2014	1655	1620	1637.5				3770	
5/12/2014	1430	1545	1487.5	1070	1150	1110		
5/13/2014	1695	1655	1675				3350	2510
5/14/2014	1325	1330	1327.5				3420	
5/15/2014	1220	1310	1265					
5/16/2014	1425	1510	1467.5				3110	
5/17/2014								
5/18/2014	1205	1440	1322.5				2810	2100
5/19/2014								
5/20/2014	1425	1575	1500	998	1102	1050	1980	
5/21/2014	1685	1385	1535				2100	
5/22/2014	1650	1420	1535				2100	
5/23/2014	1430	1545	1487.5					
5/24/2014	1320	1415	1367.5				2100	
5/25/2014								
5/26/2014	1320	1405	1362.5				3420	
5/27/2014								
5/28/2014	1210	1220	1215	907	915	911	4505	
5/29/2014	1350	1320	1335					
5/30/2014							2220	
5/31/2014	1540	1440	1490					
6/1/2014	1575	1390	1482.5				3105	
6/2/2014	1660	1450	1555				3225	
6/3/2014								
6/4/2014	1750	1605	1677.5	1225	1123	1174	4105	
6/5/2014							3815	
6/6/2014	1805	1980	1892.5					
6/7/2014							3765	
6/8/2014	1905	2030	1967.5					
6/9/2014	2215	2050	2132.5				3710	
6/10/2014	1820	2080	1950				3550	
6/11/2014							3420	
6/12/2014								
6/13/2014							4005	
6/14/2014								
6/15/2014	2370	2350	2360	1656	1645	1650.5	3700	
6/16/2014	2115	2080	2097.5				3170	
6/17/2014	2260	2575	2417.5				5770	
6/18/2014	2385	2315	2350				4070	
6/19/2014	2570	2410	2490				5140	
6/20/2014	2475	2395	2435					
6/21/2014	2340	2300	2320	1705	1720	1712.5	4675	
6/22/2014							5202	
6/23/2014	2540	2210	2375					
6/24/2014	2675	2655	2665				5820	
6/25/2014	2245	2795	2520				7040	
6/26/2014								
6/27/2014	2805	2620	2712.5				5660	
6/28/2014								

Aqaba Mechanical WWTP
MLSS Data 2013-2014

DATE	MLSS (oxi 1)	MLSS (oxi 2)	Avg. MLSS	MLVSS (oxi 1)	MLVSS (oxi 2)	Avg. MLVSS	RAS	
	TSS mg/L	TSS mg/L	TSS mg/L	VSS mg/L	VSS mg/L	VSS mg/L	TSS mg/L	VSS mg/L
6/29/2014	2660	2800	2730				4370	
6/30/2014	2750	2700	2725					
7/1/2014	2675	2655	2665				5009	
7/2/2014	2490	2480	2485				3980	
7/3/2014								
7/4/2014							4875	
7/5/2014	2225	3250	2737.5	1668	2437	2052.5	5030	
7/6/2014	2540	2420	2480				4980	
7/7/2014	2880	2715	2797.5					
7/8/2014							5010	
7/9/2014	2930	2505	2717.5				5290	
7/10/2014	2805	2700	2752.5				5025	
7/11/2014	2940	2650	2795					
7/12/2014							4220	
7/13/2014	2810	2650	2730				4335	
7/14/2014							4980	
7/15/2014	2900	2750	2825				4320	
7/16/2014	2660	2705	2682.5	1988	2028	2008	3775	
7/17/2014	2870	2640	2755				3980	
7/18/2014								
7/19/2014	2910	2805	2857.5				4020	
7/20/2014	2890	2740	2815					
7/21/2014								
7/22/2014	2900	2825	2862.5				5630	
7/23/2014							3570	
7/24/2014	2850	2810	2830				6440	
7/25/2014	2750	2980	2865				4050	
7/26/2014								
7/27/2014	2760	2820	2790	2070	1974	2022	5010	
7/28/2014	2620	2805	2712.5				3980	
7/29/2014							4320	
7/30/2014	2700	2750	2725					
7/31/2014							5120	
8/1/2014	2605	2450	2527.5				5410	
8/2/2014	2715	2500	2607.5				5360	
8/3/2014	2750	2700	2725				4370	
8/4/2014	2605	2650	2627.5					
8/5/2014								
8/6/2014	2555	2650	2602.5	1788	1850	1819	4780	
8/7/2014	2750	2695	2722.5				4330	
8/8/2014	2745	2610	2677.5				5350	
8/9/2014	2605	2555	2580				5020	
8/10/2014	2425	2095	2260				6025	
8/11/2014								
8/12/2014	2200	2290	2245				4220	
8/13/2014	2305	2315	2310				5035	
8/14/2014	2410	2305	2357.5				4550	
8/15/2014	2410	2295	2352.5	1805	1700	1752.5		
8/16/2014	2510	2305	2407.5					
8/17/2014	2490	2545	2517.5				4910	
8/18/2014	2495	2615	2555				5050	
8/19/2014								
8/20/2014								
8/21/2014								
8/22/2014								
8/23/2014							3610	
8/24/2014	2665	2485	2575	1865	1725	1795	3760	
8/25/2014	2495	2285	2390				4080	
8/26/2014	2405	2375	2390				3470	
8/27/2014	2520	2595	2557.5				4020	
8/28/2014	2610	2600	2605				3540	

Aqaba Mechanical WWTP
MLSS Data 2013-2014

DATE	MLSS (oxi 1)	MLSS (oxi 2)	Avg. MLSS	MLVSS (oxi 1)	MLVSS (oxi 2)	Avg. MLVSS	RAS	
	TSS mg/L	TSS mg/L	TSS mg/L	VSS mg/L	VSS mg/L	VSS mg/L	TSS mg/L	VSS mg/L
8/29/2014								
8/30/2014	2395	2410	2402.5				3720	
8/31/2014	2405	2375	2390				3740	
9/1/2014								
9/2/2014	2370	2525	2447.5	1777	1760	1768.5	4140	
9/3/2014	2330	2610	2470				4975	
9/4/2014	2315	2415	2365				5445	
9/5/2014	2450	2505	2477.5					
9/6/2014	2540	2460	2500				4335	
9/7/2014								
9/8/2014	2605	2555	2580				5020	
9/9/2014								
9/10/2014								
9/11/2014								
9/12/2014								
9/13/2014								
9/14/2014	2730	2580	2655				4360	
9/15/2014	2660	2450	2555	1905	1855	1880		
9/16/2014	2595	2395	2495				5125	
9/17/2014	2810	2640	2725				4320	
9/18/2014	2705	2565	2635				5125	
9/19/2014							5100	
9/20/2014	2605	2555	2580				5020	
9/21/2014	2715	2605	2660					
9/22/2014	2590	2485	2537.5					
9/23/2014	2465	2385	2425				6540	
9/24/2014							4320	
9/25/2014	2395	2450	2422.5					
9/26/2014	2315	2560	2437.5				6105	
9/27/2014	2345	2605	2475					
9/28/2014	2490	2480	2485	1740	1730	1735	3980	
9/29/2014	2410	2550	2480				4125	
9/30/2014								
10/1/2014	2495	2355	2425				4360	
10/2/2014	2550	2480	2515				5430	
10/3/2014	2520	2600	2560					
10/4/2014							3810	
10/5/2014	2360	2440	2400					
10/6/2014							4450	
10/7/2014	2410	2340	2375				3675	
10/8/2014	2410	2310	2360	1805	1735	1770	4520	
10/9/2014								
10/10/2014	2200	2340	2270				5120	
10/11/2014	2200	2290	2245				4220	
10/12/2014	2600	2930	2765				4005	
10/13/2014								
10/14/2014	2530	2540	2535				6060	
10/15/2014	2990	2980	2985				4980	
10/16/2014								
10/17/2014	2940	2810	2875				5020	
10/18/2014	2815	2845	2830				4890	
10/19/2014	3425	3225	3325	2580	2255	2417.5	6790	
10/20/2014								
10/21/2014	2605	2555	2580				5020	
10/22/2014	3295	2720	3007.5				6460	
10/23/2014								
10/24/2014	3120	2870	2995					
10/25/2014							5060	
10/26/2014	2810	2650	2730				6100	
10/27/2014	2705	2415	2560					
10/28/2014	2605	2520	2562.5	1955	1890	1922.5	5010	
10/29/2014								
10/30/2014	2600	2540	2570				5100	
10/31/2014								
11/1/2014	2520	2595	2557.5				4060	
11/2/2014	2510	2455	2482.5				4480	
11/3/2014	2850	2870	2860				5020	
11/4/2014	2650	3520	3085				4420	

Aqaba Mechanical WWTP
MLSS Data 2013-2014

DATE	MLSS (oxi 1)	MLSS (oxi 2)	Avg. MLSS	MLVSS (oxi 1)	MLVSS (oxi 2)	Avg. MLVSS	RAS	
	TSS mg/L	TSS mg/L	TSS mg/L	VSS mg/L	VSS mg/L	VSS mg/L	TSS mg/L	VSS mg/L
11/5/2014	2640	2525	2582.5				4160	
11/6/2014	2430	2525	2477.5				4020	
11/7/2014								
11/8/2014	3425	3225	3325				6790	
11/9/2014	3365	3180	3272.5	2525	2385	2455	7170	
11/10/2014								
11/11/2014	2600	2930	2765				4005	
11/12/2014	2815	2845	2830				4890	
11/13/2014								
11/14/2014	2990	2980	2985				4980	
11/15/2014	3200	3005	3102.5					
11/16/2014	3500	3605	3552.5				7490	
11/17/2014								
11/18/2014	3230	3080	3155				6640	
11/19/2014	3220	3100	3160				6545	
11/20/2014	3400	3020	3210	2550	2265	2407.5	7540	
11/21/2014								
11/22/2014	3105	3005	3055				5020	
11/23/2014	3160	3145	3152.5				5290	
11/24/2014	3410	3850	3630				8170	
11/25/2014								
11/26/2014	3275	3445	3360				6960	
11/27/2014	3205	2815	3010				9250	
11/28/2014								
11/29/2014								
11/30/2014	3295	3365	3330				6555	
12/1/2014	3445	3115	3280					
12/2/2014	3200	3450	3325	2240	2415	2327.5	7300	
12/3/2014								
12/4/2014	3100	3210	3155				7320	
12/5/2014	3205	3090	3147.5				6980	
12/6/2014	3190	3310	3250				7650	
12/7/2014	3210	3145	3177.5					
12/8/2014	3090	3120	3105				8330	
12/9/2014								
12/10/2014	3190	3020	3105	2340	2265	2302.5	9600	
12/11/2014	3210	3250	3230					
12/12/2014	3230	3415	3322.5				9810	
12/13/2014	3220	3305	3262.5				9745	
12/14/2014	3415	3465	3440				7370	
12/15/2014								
12/16/2014	3260	3080	3170				7600	
12/17/2014							6965	
12/18/2014	3305	3110	3207.5	2485	2335	2410	7670	
12/19/2014	3050	3130	3090				5665	
12/20/2014								
12/21/2014	3280	3305	3292.5				7460	
12/22/2014	3220	3130	3175					
12/23/2014	3190	3040	3115				6980	
12/24/2014								
12/25/2014	2980	2960	2970	2086	2075	2080.5	4900	
12/26/2014	2875	2895	2885				4435	
12/27/2014	3005	2980	2992.5				4480	
12/28/2014	2815	2845	2830				4890	
12/29/2014								
12/30/2014	2870	2810	2840				4965	
12/31/2014	2925	2870	2897.5				5170	
Average	2478.06	2477.23	2477.64	1820.06	1793.34	1809.57	5218.66	3646.00
Min	1205	1220						
Max	3500	3850						
Count	476	478						

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Aqaba Mechanical WWTP Life Cycle Cost Analysis

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Aqaba Mechanical WWTF
20-Year Life Cycle Cost Analysis

Planning Horizon: 20 years
Discount Rate: 4%
O&M Factor: 1%
Contingency: 30% updated 7-09-15

Item	Component information								Model Run 2B1 at 12,000 m3/day						Model Run 2B1 at 32,000 m3/day (7 Treatment Trains)					
	Est Useful Life (years)	Unit Cost (USD)	Number per Assembly	Assembly Cost (USD)	Year of Unit Price	2015 Estimated Price per Assembly (USD)	30% Contingency (USD)	2015 Est Total per Assembly with Contingency (USD)	Number of Assemblies Required	Upgrade Cost (2015 USD)	Annualized O&M Costs (USD)	PV O&M Costs (USD)	PV Replacement Estimate (USD)	PV Life Cycle Cost (USD)	Quantity Required	Upgrade Cost (2015 USD)	Annualized O&M Costs (USD)	PV O&M Costs (USD)	PV Replacement Estimate (USD)	PV Life Cycle Cost (USD)
Primary Clarifier																				
Civil	50	207000	1	$207,000	2000	$332,000	$ 99,600	$ 431,000	0	$ -	$ -	$ -	$ -	$ -	0	$ -	$ -	$ -	$ -	$ -
Sludge Collection Mechanisms	25	131000	2	262,000	2000	420,000	126,000	546,000	0	-	-	-	-	-	0	-	-	-	-	-
Electrical	20	5000	1	5,000	2000	8,000	2,400	10,000	0	-	-	-	-	-	0	-	-	-	-	-
Domed Cover	50	250,000	1	250,000	2015	250,000	75,000	325,000	0	-	-	-	-	-	0	-	-	-	-	-
Oxidation Ditches (1 ditch)																				
Civil	50	653,000	1	653,000	2000	1,047,000	314,100	1,361,000	0	-	-	-	-	-	4	5,444,000	54,000	734,000	306,000	6,484,000
Brush Aerators	25	31,000	10	310,000	2000	497,000	149,100	646,000	0	-	-	-	-	-	4	2,584,000	112,000	1,522,000	775,000	4,881,000
Submersible Mixers	25	10,000	12	120,000	2000	192,000	57,600	250,000	0	-	-	-	-	-	4	1,000,000	43,000	584,000	300,000	1,884,000
Other Mechanical	25	10,000	1	10,000	2000	16,000	4,800	21,000	0	-	-	-	-	-	4	84,000	4,000	54,000	25,000	163,000
Electrical	20	56,000	1	56,000	2000	90,000	27,000	117,000	0	-	-	-	-	-	4	468,000	5,000	68,000	214,000	750,000
Move Brush Aerator (existing tanks only)	25	100,000	1	100,000	2015	100,000	30,000	130,000	1	130,000	6,000	82,000	39,000	251,000	0	-	-	-	-	-
Floating Supplementary Aerators																				
Floating Aerators (cost is for 2 units)	25	143,000	1	143,000	2015	143,000	42,900	186,000	0	-	-	-	-	-	0	-	-	-	-	-
Electrical	20	57,000	1	57,000	2015	57,000	17,100	74,000	0	-	-	-	-	-	0	-	-	-	-	-
Secondary Clarifiers (1 clarifier)																				
Civil	50	207,000	1	207,000	2000	332,000	99,600	431,000	0	-	-	-	-	-	4	1,724,000	17,000	231,000	97,000	2,052,000
Sludge Collection Mechanisms	25	66,000	2	132,000	2000	212,000	63,600	275,000	0	-	-	-	-	-	4	1,100,000	48,000	652,000	330,000	2,082,000
Electrical	20	5,000	1	5,000	2000	8,000	2,400	10,000	0	-	-	-	-	-	4	40,000	-	-	18,000	58,000
GRP Pipe (100 m of 800mm)	25	39,000	1	39,000	2000	63,000	18,900	81,000	0	-	-	-	-	-	4	324,000	14,000	190,000	97,000	611,000
RAS & WAS Pump Station																				
Civil	50	107,000	1	107,000	2000	172,000	51,600	223,000	0	-	-	-	-	-	0	-	-	-	-	-
Inclined Screw Pump	25	78,000	3	234,000	2000	375,000	112,500	488,000	0	-	-	-	-	-	0	-	-	-	-	-
WAS Submersible Pump	25	19,000	2	38,000	2000	61,000	18,300	79,000	0	-	-	-	-	-	0	-	-	-	-	-
Other Mechanical	25	87,000	1	87,000	2000	139,000	41,700	181,000	0	-	-	-	-	-	0	-	-	-	-	-
Electrical	20	50,000	1	50,000	2000	80,000	24,000	104,000	0	-	-	-	-	-	0	-	-	-	-	-
Sludge Handling																				
Gravity Sludge Thickener	25	1,371,000	1	1,371,000	2000	2,198,000	659,400	2,857,000	0	-	-	-	-	-	0	-	-	-	-	-
Primary Sludge Digestion	25	500,000	1	500,000	2000	801,000	240,300	1,042,000	0	-	-	-	-	-	0	-	-	-	-	-
Odor Control System	25	665,000	1	665,000	2000	1,066,000	319,800	1,386,000	0	-	-	-	-	-	0	-	-	-	-	-
Denitrifying Filters & Backwash Tanks																				
Civil	50	134,000	1	134,000	2015	134,000	40,200	174,000	4	696,000	7,000	95,000	39,000	830,000	6	1,044,000	10,000	136,000	59,000	1,239,000
Down Flow Denite Filter (per 4/15 Quote)	25	480,000	1	480,000	2015	480,000	144,000	624,000	4	2,496,000	201,000	2,732,000	749,000	5,977,000	6	3,744,000	355,000	4,825,000	1,124,000	9,693,000
Electrical	20	36,000	1	36,000	2015	36,000	10,800	47,000	4	188,000	2,000	27,000	86,000	301,000	6	282,000	3,000	41,000	129,000	452,000
								Subtotals		**$3,510,000**	**$216,000**	**$2,936,000**	**$913,000**	**$7,359,000**		**$17,838,000**	**$665,000**	**$9,037,000**	**$3,474,000**	**$30,349,000**

Aqaba Mechanical WWTF
20-Year Life Cycle Cost Analysis

Planning Horizon: 20 years
Discount Rate: 4%
O&M Factor: 1%
Contingency: 30% updated 7-09-15

Item	Component information								Model Run 2B2 at 12,000 m3/day						Model Run 2B2 at 32,000 m3/day (4 Treatment Trains)					
	Est Useful Life (years)	Unit Cost (USD)	Number per Assembly	Assembly Cost (USD)	Year of Unit Price	2015 Estimated Price per Assembly (USD)	30% Contingency (USD)	2015 Est Total per Assembly with Contingency (USD)	Quantity Required	Upgrade Cost (2015 USD)	Annualized O&M Costs (USD)	PV O&M Costs (USD)	PV Replacement Estimate (USD)	PV Life Cycle Cost (USD)	Quantity Required	Upgrade Cost (2015 USD)	Annualized O&M Costs (USD)	PV O&M Costs (USD)	PV Replacement Estimate (USD)	PV Life Cycle Cost (USD)
Primary Clarifier																				
Civil	50	207000	1	$207,000	2000	$332,000	$ 99,600	$ 431,000	0	$ -	$ -	$ -	$ -	$ -	0	$ -	$ -	$ -	$ -	$ -
Sludge Collection Mechanisms	25	131000	2	262,000	2000	420,000	126,000	546,000	0	-	-	-	-	-	0	-	-	-	-	-
Electrical	20	5000	1	5,000	2000	8,000	2,400	10,000	0	-	-	-	-	-	0	-	-	-	-	-
Domed Cover	50	250,000	1	250,000	2015	250,000	75,000	325,000	0	-	-	-	-	-	0	-	-	-	-	-
Oxidation Ditches (1 ditch)																				
Civil	50	653,000	1	653,000	2000	1,047,000	314,100	1,361,000	0	-	-	-	-	-	2	2,722,000	27,000	367,000	153,000	3,242,000
Brush Aerators	25	31,000	10	310,000	2000	497,000	149,100	646,000	0	-	-	-	-	-	2	1,292,000	56,000	761,000	388,000	2,441,000
Submersible Mixers	25	10,000	12	120,000	2000	192,000	57,600	250,000	0	-	-	-	-	-	2	500,000	22,000	299,000	150,000	949,000
Other Mechanical	25	10,000	1	10,000	2000	16,000	4,800	21,000	0	-	-	-	-	-	2	42,000	2,000	27,000	13,000	82,000
Electrical	20	56,000	1	56,000	2000	90,000	27,000	117,000	0	-	-	-	-	-	2	234,000	2,000	27,000	107,000	368,000
Move Brush Aerator (existing tanks only)	25	100,000	1	100,000	2015	100,000	30,000	130,000	1	130,000	6,000	82,000	39,000	251,000	0	-	-	-	-	-
Floating Supplementary Aerators																				
Floating Aerators (cost is for 2 units)	25	143,000	1	143,000	2015	143,000	42,900	186,000	2	372,000	16,000	217,000	112,000	701,000	2	372,000	16,000	217,000	112,000	701,000
Electrical	20	57,000	1	57,000	2015	57,000	17,100	74,000	2	148,000	1,000	14,000	68,000	230,000	2	148,000	1,000	14,000	68,000	230,000
Secondary Clarifiers (1 clarifier)																				
Civil	50	207,000	1	207,000	2000	332,000	99,600	431,000	0	-	-	-	-	-	2	862,000	9,000	122,000	49,000	1,033,000
Sludge Collection Mechanisms	25	66,000	2	132,000	2000	212,000	63,600	275,000	0	-	-	-	-	-	2	550,000	24,000	326,000	165,000	1,041,000
Electrical	20	5,000	1	5,000	2000	8,000	2,400	10,000	0	-	-	-	-	-	2	20,000	-	-	9,000	29,000
GRP Pipe (100 m of 800mm)	25	39,000	1	39,000	2000	63,000	18,900	81,000	0	-	-	-	-	-	2	162,000	7,000	95,000	49,000	306,000
RAS & WAS Pump Station																				
Civil	50	107,000	1	107,000	2000	172,000	51,600	223,000	0	-	-	-	-	-	0	-	-	-	-	-
Inclined Screw Pump	25	78,000	3	234,000	2000	375,000	112,500	488,000	0	-	-	-	-	-	0	-	-	-	-	-
WAS Submersible Pump	25	19,000	2	38,000	2000	61,000	18,300	79,000	0	-	-	-	-	-	0	-	-	-	-	-
Other Mechanical	25	87,000	1	87,000	2000	139,000	41,700	181,000	0	-	-	-	-	-	0	-	-	-	-	-
Electrical	20	50,000	1	50,000	2000	80,000	24,000	104,000	0	-	-	-	-	-	0	-	-	-	-	-
Sludge Handling																				
Gravity Sludge Thickener	25	1,371,000	1	1,371,000	2000	2,198,000	659,400	2,857,000	0	-	-	-	-	-	0	-	-	-	-	-
Primary Sludge Digestion	25	500,000	1	500,000	2000	801,000	240,300	1,042,000	0	-	-	-	-	-	0	-	-	-	-	-
Odor Control System	25	665,000	1	665,000	2000	1,066,000	319,800	1,386,000	0	-	-	-	-	-	0	-	-	-	-	-
Denitrifying Filters & Backwash Tanks																				
Civil	50	134,000	1	134,000	2015	134,000	40,200	174,000	4	696,000	7,000	95,000	39,000	830,000	6	1,044,000	10,000	136,000	59,000	1,239,000
Down Flow Denite Filter (per 4/15 Quote)	25	480,000	1	480,000	2015	480,000	144,000	624,000	4	2,496,000	201,000	2,732,000	749,000	5,977,000	6	3,744,000	409,000	5,558,000	1,124,000	#########
Electrical	20	36,000	1	36,000	2015	36,000	10,800	47,000	4	188,000	2,000	27,000	86,000	301,000	6	282,000	3,000	41,000	129,000	452,000
								Subtotals		**$4,030,000**	**$233,000**	**$3,167,000**	**$1,093,000**	**$8,290,000**		**$11,974,000**	**$588,000**	**$7,990,000**	**$2,575,000**	**$22,539,000**

Aqaba Mechanical WWTF
20-Year Life Cycle Cost Analysis

Planning Horizon: 20 years
Discount Rate: 4%
O&M Factor: 1%
Contingency: 30% updated 7-09-15

Item	Component information								Model Run 2C at 12,000 m3/day						Model Run 2C at 32,000 m3/day (2 Treatment Trains)					
	Est Useful Life (years)	Unit Cost (USD)	Number per Assembly	Assembly Cost (USD)	Year of Unit Price	2015 Estimated Price per Assembly (USD)	30% Contingency (USD)	2015 Est Total per Assembly with Contingency (USD)	Quantity Required	Upgrade Cost (2015 USD)	Annualized O&M Costs (USD)	PV O&M Costs (USD)	PV Replacement Estimate (USD)	PV Life Cycle Cost (USD)	Quantity Required	Upgrade Cost (2015 USD)	Annualized O&M Costs (USD)	PV O&M Costs (USD)	PV Replacement Estimate (USD)	PV Life Cycle Cost (USD)
Primary Clarifier																				
Civil	50	207000	1	$207,000	2000	$332,000	$ 99,600	$ 431,000	0	$ -	$ -	$ -	$ -	$ -	2	$ 862,000	$ 9,000	$ 122,000	$ 49,000	$ 1,033,000
Sludge Collection Mechanisms	25	131000	2	262,000	2000	420,000	126,000	546,000	0	-	-	-	-	-	2	1,092,000	47,000	639,000	328,000	2,059,000
Electrical	20	5000	1	5,000	2000	8,000	2,400	10,000	0	-	-	-	-	-	2	20,000	-	-	9,000	29,000
Domed Cover	50	250,000	1	250,000	2015	250,000	75,000	325,000	0	-	-	-	-	-	2	650,000	7,000	95,000	37,000	782,000
Oxidation Ditches (1 ditch)																				
Civil	50	653,000	1	653,000	2000	1,047,000	314,100	1,361,000	0	-	-	-	-	-	0	-	-	-	-	-
Brush Aerators	25	31,000	10	310,000	2000	497,000	149,100	646,000	0	-	-	-	-	-	0	-	-	-	-	-
Submersible Mixers	25	10,000	12	120,000	2000	192,000	57,600	250,000	0	-	-	-	-	-	0	-	-	-	-	-
Other Mechanical	25	10,000	1	10,000	2000	16,000	4,800	21,000	0	-	-	-	-	-	0	-	-	-	-	-
Electrical	20	56,000	1	56,000	2000	90,000	27,000	117,000	0	-	-	-	-	-	0	-	-	-	-	-
Move Brush Aerator (existing tanks only)	25	100,000	1	100,000	2015	100,000	30,000	130,000	1	130,000	6,000	82,000	39,000	251,000	0	-	-	-	-	-
Floating Supplementary Aerators																				
Floating Aerators (cost is for 2 units)	25	143,000	1	143,000	2015	143,000	42,900	186,000	2	372,000	16,000	217,000	112,000	701,000	0	-	-	-	-	-
Electrical	20	57,000	1	57,000	2015	57,000	17,100	74,000	2	148,000	1,000	14,000	68,000	230,000	0	-	-	-	-	-
Secondary Clarifiers (1 clarifier)																				
Civil	50	207,000	1	207,000	2000	332,000	99,600	431,000	0	-	-	-	-	-	0	-	-	-	-	-
Sludge Collection Mechanisms	25	66,000	2	132,000	2000	212,000	63,600	275,000	0	-	-	-	-	-	0	-	-	-	-	-
Electrical	20	5,000	1	5,000	2000	8,000	2,400	10,000	0	-	-	-	-	-	0	-	-	-	-	-
GRP Pipe (100 m of 800mm)	25	39,000	1	39,000	2000	63,000	18,900	81,000	0	-	-	-	-	-	6	486,000	21,000	285,000	146,000	917,000
RAS & WAS Pump Station																				
Civil	50	107,000	1	107,000	2000	172,000	51,600	223,000	0	-	-	-	-	-	1	223,000	2,000	27,000	13,000	263,000
Inclined Screw Pump	25	78,000	3	234,000	2000	375,000	112,500	488,000	0	-	-	-	-	-	1	488,000	21,000	285,000	146,000	919,000
WAS Submersible Pump	25	19,000	2	38,000	2000	61,000	18,300	79,000	0	-	-	-	-	-	1	79,000	3,000	41,000	24,000	144,000
Other Mechanical	25	87,000	1	87,000	2000	139,000	41,700	181,000	0	-	-	-	-	-	1	181,000	8,000	109,000	54,000	344,000
Electrical	20	50,000	1	50,000	2000	80,000	24,000	104,000	0	-	-	-	-	-	1	104,000	1,000	14,000	47,000	165,000
Sludge Handling																				
Gravity Sludge Thickener	25	1,371,000	1	1,371,000	2000	2,198,000	659,400	2,857,000	0	-	-	-	-	-	1	2,857,000	124,000	1,685,000	857,000	5,399,000
Primary Sludge Digestion	25	500,000	1	500,000	2000	801,000	240,300	1,042,000	0	-	-	-	-	-	1	1,042,000	45,000	612,000	313,000	1,967,000
Odor Control System	25	665,000	1	665,000	2000	1,066,000	319,800	1,386,000	0	-	-	-	-	-	1	1,386,000	60,000	815,000	416,000	2,617,000
Denitrifying Filters & Backwash Tanks																				
Civil	50	134,000	1	134,000	2015	134,000	40,200	174,000	4	696,000	7,000	95,000	39,000	830,000	6	1,044,000	10,000	136,000	59,000	1,239,000
Down Flow Denite Filter (per 4/15 Quote)	25	480,000	1	480,000	2015	480,000	144,000	624,000	4	2,496,000	201,000	2,732,000	749,000	5,977,000	6	3,744,000	409,000	5,558,000	1,124,000	10,426,000
Electrical	20	36,000	1	36,000	2015	36,000	10,800	47,000	4	188,000	2,000	27,000	86,000	301,000	6	282,000	3,000	41,000	129,000	452,000
								Subtotals		**$4,030,000**	**$233,000**	**$3,167,000**	**$1,093,000**	**$8,290,000**		**$14,540,000**	**$770,000**	**$10,464,000**	**$3,751,000**	**$28,755,000**