Technical Support for Procurement and Project Management and Private Sector Participation to the Ministry of Water and Irrigation, Water Authority of Jordan and the Jordan Valley Authority

Support for Economic Growth and Institutional Reform:
General Business, Trade & Investment IQC

Aqaba Water Company Training Needs Assessment

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ACRONYMS

ASEZ	Aqaba Special Economic Zone
MWI	Ministry of Water and Irrigation
SOP	Standard Operating Procedure
TAPS	Technical Assistance for Private Sector Participation
UFW	Unaccounted-for-Water
WAJ	Water Authority of Jordan

EXECUTIVE SUMMARY

The water and wastewater utility operated by the Water Authority of Jordan (WAJ), and known as WAJ-Aqaba will be transformed into a decentralized and financially self-sufficient utility by February 2004.

In order to raise performance levels, this transformation will require significant changes to current operating practices, as well as a significant commitment to obtaining a better qualified staff, the retraining of existing personnel, and the implementation of more advanced" state-of-the-art" operation and maintenance techniques for existing and planned water and wastewater facilities.

This report describes the level of skills and equipment required for a modern, well operated utility. The TAPS consultants reviewed existing WAJ-Aqaba operating procedures and the need for additional formalized operating procedures.

In order to determine the level of training and preparedness of WAJ-Aqaba personnel to implement the utility transformation, the TAPS consultants prepared separate position-specific questionnaires for five general levels of job categories within WAJ-Aqaba: Technical Managers, Financial Managers, Technical Supervisor, Skilled Laborer, and Laborer. TAPS consultants interviewed a representative cross-section of WAJ-Aqaba employees, from management to laborers, using the prepared questionnaires, and tabulated the results. The blank and completed questionnaires have been included in this report.

As a result of the employee interviews and completed questionnaires, a training needs assessment was prepared. The assessment found an absence of formal written procedures within the utility, and a large need for more technical training across all worker classifications. The need for more financial training was also recognized. Higher salaries are also cited as necessary to attract and retain the quality of worker necessary to staff and operate an improved utility in the future.

As a result of the foregoing conclusions, the TAPS consultants prepared a series of standard operating procedures (SOPs) for operation and maintenance of the water and wastewater facilities. When translated into Arabic, these SOPs give the proper techniques for working safely in the facilities, for maintaining common facilities such as pumping stations, valves, and pipelines. These SOPs have been included in this report.

Lastly, a detailed training program was prepared for a range of employees, including technical management, financial managers, water specialists, wastewater specialists, mechanics, electricians, wastewater treatment plant operators.

A range of topics are proposed for the management staff including utility finance principles, water audits, procuring and managing contractors, and industrial pretreatment, among others. Proposed topics for operations staff include basic math and science for operators, safety, traffic control, pipeline maintenance, and operating biological wastewater processes, among others.

The specifics of these training courses are also included in this report.

SECTION I

INTRODUCTION

A. Background

The Technical Assistance for Private Sector Participation (TAPS) Project is currently assisting the Ministry of Water and Irrigation (MWI) in transforming the existing Aqaba water/wastewater utility into a "corporatized" entity operating within the Aqaba Special Economic Zone (ASEZ).

The process requires that the present utility operated by the Water Authority of Jordan (WAJ), and known as WAJ-Aqaba, be transformed into a separate and financially self-sufficient utility. In order to raise performance levels, this transformation will require significant changes to current operating practices, as well as a significant commitment to obtaining a better qualified staff, the retraining of existing personnel, and the implementation of more advanced" state-of-the-art" operation and maintenance techniques for existing and planned water and wastewater facilities.

B. Methodology Used

As part of its ongoing efforts, the TAPS consultants have:

- Reviewed existing WAJ-Aqaba operating procedures
- Assessed the need for additional formalized operating procedures
- Written formal operating procedures for translation into Arabic
- Prepared written questionnaires for five levels of workers within WAJ Aqaba
- Interviewed a representative cross-section of WAJ-Aqaba employees, from management to laborers, using the prepared questionnaires
- Tabulated the results of the questionnaires and prepared an assessment of needs for the future utility, including new hires and the retraining of existing WAJ-Aqaba staff
- Prepared an outline of training courses to be delivered to WAJ-Aqaba staff in preparation for the change to the new utility

The TAPS Consultants visited the utility in Aqaba to interview WAJ-Aqaba employees and to observe ongoing operations. The new wastewater treatment plant, now in the initial stages of construction, has been excluded from this analysis, as the construction specifications call for the contractor to:

- Provide extensive written instructions on plant operation
- Provide special staff to assist in the start-up and operation of the plant for the first year

Provide a comprehensive training program on the operation and maintenance of the plant's processes and equipment

The Consultants' findings and recommendations are described in subsequent Chapters in this Report.

SECTION II

TYPICAL UTILITY ACTIVITIES

This chapter is intended to briefly outline the general steps and procedures involved in successfully operating a water and wastewater utility, in order to provide a comprehensive understanding of, and to identify and address operational and training needs for WAJ-Aqaba.

A. Operation and Maintenance of Water Pipelines

WAJ-Aqaba provides water and wastewater services to its customers including residents, commercial and tourism companies, industries, and government agencies. Water is distributed to Aqaba from the Disi Wellfield through a series of pumping operations, storage tanks, and pipelines. Water distribution is dependent upon gravity from a series of pressure break tanks placed throughout the primary transmission lines.

Pressurized water from the primary transmission lines is further distributed to secondary distribution lines located in city streets, and then to individual customers through service connections and through a water meter.

Over time water meters wear out and tend to under-read the amount of water passing through them, resulting in under-billing. Along with leakage, under-recording water meters is the most significant source of unaccounted-for water (UFW).

The highest elevations in the water distribution network and changes of elevation are commonly equipped with air-release valves to bleed trapped air periodically from the pressurized line. The trapped air reduces the flow capacity of the pipeline.

The operation and maintenance of water pipelines generally consists of:

- Flushing lines to eliminate solids buildup
- Exercising isolation valves to ensure operation
- Exercising air-release valves to ensure that air is being released from the water pipeline
- Monitoring the pipelines for leakage
- Checking water meters for accuracy

B. Water Pumping, Including Well Pumps

The Aqaba water supply system originates with a series of pumps in the Disi Wellfield that lift the water into a series of tanks to flow toward Aqaba. Each tank “breaks” the pressure in the pipeline to atmospheric pressure, maintaining a pressure low enough to be carried safely without bursting the pipeline.

Pumps continually lift water into successive pressure break tanks until the water reaches the Aqaba distribution system under “normal” distribution pressures of 4—7 bar, or 415–690 kPa.

The pumps can be controlled manually or automatically through float switches mounted at different levels in the pressure break tanks.

Operating the pumps requires knowledge of hydraulics and a firm understanding of how pumps function. Failure to understand pumping principles can result in pump cavitation, leading to premature pump failure. This failure, potentially due to a lack of formal training at the utility, can also result in reduced pump output, higher electrical costs, and failure to serve the water demands of its customers.

In order to guarantee reliability, the pumping systems require weekly maintenance checks and monthly maintenance including greasing, alignment adjustment of pump shafts, and the replacement of pump packing.

C. Wastewater Collection System

Wastewater is collected from a portion of the water customers in Aqaba and is discharged by gravity to a sewer line usually located in the street or in a right-of-way. The sewer line is pitched to allow the wastewater to continue to flow by gravity at a velocity designed to keep solids from settling in the pipe. Manholes are provided approximately every 100 meters to allow access to the sewers for cleaning or flow monitoring.

Ultimately, the sewers can flow to a wastewater treatment plant, or to a wastewater pumping station if the treatment plant is located at a higher elevation, as is the case in Aqaba.

Normally, the wastewater collection system is maintained on a periodic basis, with a portion (5-10 percent) cleaned each year. The wastewater collection system does require occasional emergency maintenance, as blockages can occur. These blockages cause wastewater to back up into houses or overflow from manholes, causing unsightly and hazardous health conditions. Therefore, these incidents must be addressed immediately and properly.

First and foremost, maintenance of the wastewater collection system requires knowledge of the dangers of untreated wastewater: the potential for lethal hydrogen sulfide gas, bacteria and viruses that cause cholera, typhoid, and polio, among other diseases. Secondly, the operators must be aware of the slip hazards that accompany climbing into a manhole. Lastly, the operators must understand how to operate the “jet” trucks that are used to break blockages in sewer lines.

Failure to understand the principles of wastewater collection maintenance can lead to serious injury or death. Failure to understand how to properly operate the “jet” trucks may result in operator injury, or an inability to properly clean the sewer line, leading to otherwise preventable sewer backups and public health issues.

D. Wastewater Pumping Stations

The Aqaba wastewater pumping system consists of a series of six pumping stations:

- Al Hafayer Pumping Stations (3). These three pumping stations are located along the coastline. Each of these stations pumps to the Main Pumping Station. All are equipped with submersible pumps.

- Royal Pumping Station. Though this small pumping station is not operated by WAJ-Aqaba, it pumps to the Main Pumping Station.

- Pumping Station No. 2. This submersible pumping station is located in the port area and pumps to the Main Pumping Station.

- The Main Pumping Station. This pumping station receives most of the wastewater collected in Aqaba. This pump station receives gravity flow from the surrounding area, and all pumped flow from the Al Hafayer Pumping Stations, the Royal Pumping Station, and Pumping Station No. 2. The pumping station is a wet pit-dry-pit type of pumping station.

The pumps can be controlled manually or automatically through float switches mounted at different levels in the pumping station wet wells. All stations excluding the Main Pumping Station are submersible pumping stations, meaning the pumps and sealed motors are submerged in the wet well.

The Main Pumping Station is a so-called wet pit-dry pit station, meaning that the pumps and electric motors sit in a separate dry area, though connected to the wet well by pipes. The pipes carry the wastewater from the wet pit through to the dry pit, where it is pumped up to the wastewater treatment plant.

Submersible pumps have different maintenance requirements than dry pit pumps. Submersible pumps must be removed occasionally for maintenance while dry pit pumps are normally serviced in place. The electric motor in a submersible pump is close-coupled to the pump, while dry pit pumps usually have long shafts connecting the motor to the pump.

Operating the wastewater pumps requires knowledge of hydraulics and an understanding of how pumps function. Failure to understand pumping principles can result in pump cavitation, leading to premature pump failure – such is the casein the Main Pumping Station at present. Pump failure or lack of training at the utility can also result in reduced pump output, higher electrical costs, the inability to serve the wastewater demands of its customers, and possibly even leading to wastewater backups in the system.

The pumping systems require weekly maintenance checks and monthly maintenance including greasing, alignment adjustment of pump shafts, and replacement of pump packing.

E. Wastewater Treatment Plant

The existing wastewater treatment plant is a stabilization pond process that requires little operation and maintenance attention aside from a basic knowledge of pond microbiology, and simple steps taken to avoid toxicity and optimize performance.
This plant will be replaced as the primary treatment process by a new mechanical (activated sludge) wastewater treatment plant in 2005. The ponds will serve as polishing ponds to facilitate complete wastewater reuse. The new plant will be equipped with detailed operation

and maintenance manuals, procedures, and training materials, and will be excluded from this assessment. The assessment shall only include the existing stabilization pond.

SECTION III

IDENTIFIED TRAINING NEEDS

A. Preparation of Questionnaires

Prior to determining the level of competency and expertise of current WAJ-Aqaba personnel, the TAPS consultants prepared separate questionnaires for five general levels of job categories within WAJ-Aqaba:

- Technical Manager
- Financial Manager
- Technical Supervisor
- Skilled Laborer
- Laborer

These blank questionnaires are shown in Annex A.

B. Results of the Questionnaires

The questionnaires worded in Arabic to a representative cross-section of WAJ-Aqaba employees by a TAPS consultant in Aqaba. Twenty-four employees were interviewed, representing approximately 9 percent of the existing 259-person staff. The responses to the questionnaires are reproduced in English in Annex B.

The responses by category numbered as follows:

- Technical Managers—5
- Financial Managers—4
- Technical Supervisors—3
- Skilled Laborers—3
- Laborers—9

C. Summary of Questionnaire Results by Job Category

The following is a category-by-category description of the results and interpretations of the questionnaire.

- **Technical Managers**
  All managers interviewed had earned bachelors' degrees (one Master's Degree) in various engineering disciplines. This is generally true of other managers interviewed on various topics over the span of the TAPS project. Of those questioned, many have been in their

positions less than five years. Outside of university training, most have received further formal training and coursework, as well as training on-the-job.

All of the technical managers felt that they could improve the quality of service to customers: primarily in reducing unaccounted-for water, improving customer relations, and increasing collections.

Most felt that proper equipment and training for both themselves and their subordinates were key needs. The need for more experienced technical supervisors (foremen) was noted, and better salaries were cited as the main incentive necessary to meet this need.

- **Financial Managers**

All managers interviewed had earned bachelors' degrees in finance or computer disciplines. This is generally true of other managers interviewed on various topics over the span of the TAPS project. Many have been in their positions less than five years, though most had significant utility experience. Supplemental to their university training, most have received further formal training or coursework, as well as training on-the-job.

All of the financial managers felt that they could improve the quality of service to customers: primarily in reducing unaccounted-for water, improving customer relations, and increasing invoicing and collection.

Most felt that proper equipment and training for both themselves and their subordinates were key needs. Computers and financial accounting programs were identified as major needs, as was additional financial and computer training.

- **Technical Supervisors**

All technical supervisors (nominally foremen) interviewed had earned high school or technical degrees in various technical disciplines. Many have been in their positions for a substantial period of time.

Aside from educational and/or on-the job training, most have not received further formal training or coursework.

Of those questioned most felt that proper equipment and training for both themselves and their subordinates were key needs. The technical supervisors all agreed that improved equipment and better trained workers were critical to increasing work performance. Increased salaries were cited as the main incentive necessary to meet this need.

- **Skilled Laborers**

These workers differentiated from common laborers, by measure of supplementary education and by particular categories of labor specialization including plumbers, leak detection specialists, and vehicle maintenance specialists. All skilled laborers interviewed had some degree of formal schooling.

While one skilled laborer questioned had been in his position for 15 years, others had been employed in their jobs less than five years.

Outside of their proper educations, most have received little formal training or course work, with the exception of on-the-job training. Most felt that proper equipment and training were key needs.

- **Laborers**

Laborers in Aqaba are often employed in unskilled positions such as that of a guard, driver, mechanic or helper. All laborers interviewed had little formal education and were unable to read or write. Many of the laborers had been in their jobs for about five years.

Most training has been on-the-job. All laborers interviewed felt that more experienced supervisors, more training and higher salaries were necessary to performing better and to improving their overall lives.

D. Overall Questionnaire Conclusions

A common conclusion in the above questionnaires and in previous field interviews by TAPS consultants is that more technical and financial training is a need perceived by all classes and categories of personnel in WAJ-Aqaba.

Higher salaries are also cited as necessary to attract and retain the quality of worker necessary to staff and operate an improved utility in the future.

SECTION IV

PROPOSED TECHNICAL TRAINING COURSES

A. General Approach

As discussed in the previous chapters, the lack of adequate training has been identified by all employees surveyed as a need to be resolved in the existing utility in Aqaba. Responding to this need, this chapter outlines specific training objectives, courses, duration and the target audience necessary to bring the utility up to Western standards. Note that the emphasis of this report is on technical training rather than on financial or personnel training. Financial and personnel training needs are addressed in other TAPS consultant reports, though do play an integral and supplemental role in the overall improvement and enhancement of the utility, and include:

- Additional equipment to assist the work force in performing their tasks more quickly and efficiently. This equipment would include computers, financial and maintenance software, safety equipment for confined space entry, and specialty tools to undertake necessary repairs
- Streamlined purchasing procedures to allow for more rapid repairs and better equipment performance
- Higher salaries and pay-for-performance incentives to attract and retain competent staff after they receive training
- Progressive personnel policies to allow for advancement to higher merit-based grade

B. Technical Training Course Objectives

The objectives of the course are to train WAJ-Aqaba staff:

- Improved public health and safety as a result of improved service and fewer overflows and service outages
- Improved safety for WAJ-Aqaba workers
- Methods to optimize operations and reduce operating costs
- Methods for prolonging the life of operating assets as a result of improved and timelier maintenance
- Improved financial condition of the utility as a result of lower costs and lower unaccounted-for water (UFW). Improved billing and collection procedures will be covered under financialtraining modules

C. Training Course Target Participants

The target participants include the appropriate staff of WAJ-Aqaba, particularly technical managers and technical supervisors. Depending upon the level of English-language capabilities, the training could be delivered in English, though preferably in Arabic. It is assumed that the appropriate courses - particularly safety, traffic control, and confined-space

entry would be delivered to both the skilled and unskilled laborers by the Technical Supervisors.

Training would initially use the aid of PowerPoint™ slides, with supplemental materials provided to accompany the presentations.

The training should also include Train the Trainer elements to ensure continuity of training after the initial courses are completed. All written materials must be prepared in both English and Arabic.

D. Training Course Topics and Duration

The proposed training course topics and duration are shown in Annex C.

E. Standard Operating Procedures (SOPs)

A series of Standard Operating Procedures have been prepared and are attached in Annex D. These SOPs would be used along with the training materials, in delivering the training courses.

ANNEX A

BLANK QUESTIONNAIRES

WAJ-Aqaba Personnel Questionnaire —Technical Managers

1. What is your position? _____
2. Describe your duties._____
3. What is your education level? _____
4. In what subject is your degree? _____
5. How many years have you worked at WAJ—Aqaba? _____
6. How many years have you worked at other utilities? _____
7. Total utility experience, years_____
8. How many years have you been in your present position? _____
9. What other departments have you worked in? _____
10. Other than your formal education, have you ever received training for your job?
    _____
11. Do you provide training of any kind for your subordinates? _____
12. If yes, what kind of training? _____
13. If yes, how long ago was the training given? _____
14. Are there areas of your job (safety, reduction of UFW, increase in hours of water service, reduction of leakage, etc.) that you could perform better?
    _____
15. What are those areas? _____
16. What would it take (more people, better equipment, more training, etc) to do a better job? _____
17. What is your biggest challenge in doing your job well? _____

WAJ-Aqaba Personnel Questionnaire —Financial Managers

1. What is your position? _____
2. Describe your duties._____
3. What is your education level? _____
4. In what subject is your degree? _____
5. How many years have you worked at WAJ—Aqaba? _____
6. How many years have you worked at other utilities? _____
7. Total utility experience, years_____
8. How many years have you been in your present position? _____
9. What other departments have you worked in? _____
10. Other than your formal education, have you ever received training for your job?
    _____
11. Do you provide training of any kind for your subordinates? _____
12. If yes, what kind of training? _____
13. If yes, how long ago was the training given? _____
14. Are there areas of your job (faster collection, increased revenues, reduced costs, etc.) that you could perform better? _____
15. What are those areas? _____
16. What would it take (more people, better equipment, more training, etc) to do a better job?
    _____
17. What is your biggest challenge in doing your job well? _____

WAJ-Aqaba Personnel Questionnaire —Technical Supervisor

1. What is your position? _____
2. Describe your duties._____
3. What is your education level? _____
4. If you have a degree, in what subject is your degree? _____
5. How many years have you worked at WAJ—Aqaba? _____
6. How many years have you worked at other utilities? _____
7. Total utility experience, years_____
8. How many years have you been in your present position? _____
9. What other departments have you worked in? _____
10. Other than your education, have you ever received training for your job? _____
11. Do you provide training of any kind for your subordinates? _____
12. If yes, what kind of training? _____
13. If yes, how long ago was the training given? _____
14. Are there areas in your job (safety, reduce UFW, increase hours of water service, reduce leakage, etc) that you could perform better? _____
15. What are those areas? _____
16. What would it take (more people, better equipment, more training, etc) to do a better job? _____
17. What is your biggest challenge in doing your job well? _____

WAJ-Aqaba Personnel Questionnaire —Skilled Laborer

1. What is your position? _____
2. Describe your duties._____
3. What is your education level? _____
4. If you have a degree, in what subject is your degree? _____
5. How many years have you worked at WAJ—Aqaba? _____
6. How many years have you worked at other utilities? _____
7. Total utility experience, years_____
8. How many years have you been in your present position? _____
9. What other departments have you worked in? _____
10. Other than your education, have you ever received training for your job? _____
11. Do you provide training of any kind for your subordinates? _____
12. If yes, what kind of training? _____
13. If yes, how long ago was the training given? _____
14. Are there areas in your job (finishing jobs quicker, or more safely, doing jobs you can't do now, etc) that you could perform better? _____
15. What are those areas? _____
16. What would it take (more help, better equipment, more training, etc) to do a better job? _____
17. What is your biggest challenge in doing your job well?_____

WAJ-Aqaba Personnel Questionnaire—Laborer

1. What is your position? _____
2. Describe your duties._____
3. What is your education level? _____
4. How many years have you worked at WAJ—Aqaba? _____
5. How many years have you worked at other utilities? _____
6. Total utility experience, years_____
7. How many years have you been in your present position? _____
8. What other departments have you worked in? _____
9. Other than your education, have you ever received training for your job? _____
10. Are there areas in your job (finishing jobs quicker, or more safely, doing jobs you can't do now, etc) that you could perform better? _____
11. What are those areas? _____
12. What would it take (more help, better equipment, more training, etc) to do a better job? _____
13. What is your biggest challenge in doing your job well? _____

ANNEX B

COMPLETED QUESTIONNAIRES

ANNEX C

PROPOSED TRAINING COURSES

Utility Management Workshop—8 Days

- Introduction to Utility Finance
- Conducting Water Audits
- Cash Flow Management, Billing and Collection Techniques
- Contracting for Construction
- Prequalification of Prospective Tenderers
- Evaluation, Negotiation and Award of Construction Tenders
- Administration of Construction Contracts
- Project Startup and Warranty Period
- Water Audit Case Study
- Construction Case Study
- Value Engineering Techniques in Project Design and Construction
- Industrial Pretreatment
- Case Studies (2)
- Group Exercises (2)

Water Pipeline Module —5 Days

- Basic Math and Science For Operators
- Unaccounted-For Water and Leakage Detection
- Valve Operation and Maintenance
- Water Meters
- Traffic Control and Safety
- Case Studies (2)
- Group Exercises (2)

Wastewater Pipeline Module—5 Days

- Basic Math and Science For Operators
- Wastewater Hazards
- Infiltration and Inflow
- Valve Operation and Maintenance
- Traffic Control and Safety
- Jet Truck Operation and Maintenance
- Case Studies (2)
- Group Exercises (2)

Wastewater Pumping Station Module —5 Days

- Principles of Pumping and Hydraulics
- Well Pump Operation & Maintenance
- Submersible Pump Operation & Maintenance
- Dry Pit Pump Operation & Maintenance
- Storage Tank and Wet Well Maintenance

- Setting of Level Controls
- Maintenance of Level Controls and Pump Station Appurtenances
- Maintenance of Valves

Wastewater Treatment Module—5 Days

- Basic Math and Science For Operators
- Wastewater Hazards
- Basic Wastewater Microbiology and Pond Operation

ANNEX D

STANDARD OPERATING PROCEDURES

I. PIPELINE MAINTENANCE AND REPAIR STANDARD OPERATING PROCEDURE

A. General

The water and wastewater pipe network represents a substantial portion of the assets of the Aqaba utility. While the current numbers are imprecise and changing regularly, the most recent asset tabulation of pipelines indicated more than 500 kilometers of water pipelines, and over 160 kilometers of wastewater pipelines.

While pipelines represent a major capital investment, proper pipeline design should minimize normal preventive maintenance. Pipeline design usually involves sizing the pipeline to produce velocities of 1—2 meters-per-second in order to keep any solids in suspension. Properly sized and constructed, most pipelines will require only periodic cleaning.

However, the wastewater collection system is subject to blockages and broken lines due to settlement. These blockages and leaks represent a threat to public health, and must be handled immediately.

The water distribution network is also subject to leakage and broken lines. These leaks can be a public health threat, but their larger effect is economic: water usage that cannot be billed, or possible flooding and damage to streets and nearby property. These must also be addressed promptly.

B. Wastewater Collection System Maintenance

The Aqaba utility owns two jet-cleaning trucks for cleaning sewer lines to prevent blockage, or to clean sewers that are already blocked. The jet trucks are designed for cleaning sanitary and storm sewer, conduits, culverts and drainpipes of varying diameters. When cleaning a sewer line the unit is placed directly over a manhole.

Each jet truck has a high pressure hose, equipped with a special self propelling high velocity jet nozzle which is fed directly into the sewer pipe.

High-pressure water, up to 170 bar (17,000 kPa) at 250 liters of water per minute, will push the nozzle up the sewer through the clogged materials relieving the stoppage and washing back any loose debris to be removed. As the hose is withdrawn, the sewer is further cleaned by means of the rear jets in the nozzle that discharge a high velocity stream of water.

It is recommended that, to prevent blockages from occurring, the entire wastewater collection system be cleaned over time. A ten-year cycle is often cited as effective in minimizing blockages in properly designed sewers. In Aqaba, this would represent 16—20 kilometers to be cleaned per year. Western standards for operating a jet truck indicate that 0.75 kilometers per day can be cleaned by a truck and 2-man crew.

Assuming an equipment availability of 50% (allowing for equipment repair and maintenance, and travel time), a single truck could clean almost 100 kilometers per year, or more than half of the system.

C. Sewer Cleaning Procedure. The following procedure is recommended for cleaning of sewer lines:

- Identify line segments for cleaning.
- Prepare a work order with the necessary information for activity (pipe location, manhole numbers, etc.).
- Assign a cleaning crew to perform the work.
- Upon arrival at the site, park all vehicles in a way so traffic is not obstructed.
- Fill jet truck with water from the nearest fire hydrant.
- Locate manholes to be opened to clean the line segment.
- Follow all precautions regarding traffic safety and manhole entry (See Confined Spaces SOP).
- Setup cleaning equipment at the operating manhole. All sewers should be cleaned from *upstream manhole to downstream manhole* whenever possible.
- Select the proper nozzle for the debris to be removed and the pipe size to be cleaned.
- If necessary, use a rake to remove debris from the operating manhole. The sewer to be cleaned should be relatively free of grease, excess solids, and other obstructions to provide easy passage for the nozzle and hose.
- Use extreme caution if the nozzle is to be inserted into a submerged manhole. The nozzle could hit an unseen obstruction and deflect upward through the water and out of the manhole. This could cause injury to persons close to the manhole.
- Perform the cleaning operation in a step-by-step manner, if sewer section is heavily loaded with debris. This may be done by first cleaning 10—40 meters; then 40—80 meters, etc. When the return of the cleaning tool fails to bring additional debris to the manhole, the line is clean.

- When obstructions in the line prevent passage of the cleaning tool through the line, attempt to clean the line in reverse: downstream to upstream. Use lower pressure and speed when operating in the reverse direction.

D. Manhole Inspection

It is recommended that all sewer manholes be inspected on a recurring basis for cracks, infiltration of groundwater, and missing covers, typically at least once every 5 years. Assuming typical manhole spacing of approximately 100 meters, Aqaba would have 1,600—2,000 manholes. This would require inspection of 325—400 manholes per year.

Note: Follow confined entry procedures if the manhole is entered. Table 1 showing the types of gases encountered in sewers and wastewater treatment plants has been reproduced from the Confined Space SOP, and added to the back of this SOP for convenience.

Each manhole inspection should include:

- Manhole location
- Cover
- Ring and frame
- Manhole cone
- Manhole riser
- Manhole shelf or bench
- Channel level of flow
- Type and amount of debris in manhole.

Any noted deficiencies should be addressed in follow-up maintenance.

E. Water Distribution System Maintenance

Water distribution system maintenance consists mostly of exercising valves, checking and calibrating water meters, and checking for major leaks.

Table I (a)

COMMON DANGEROUS GASES ENCOUNTERED IN SEWERS AND AT WASTEWATER TREATMENT PLANTS

Name of Gas	Chemical Formula	Specific Gravity of Vapor Density(2) (air=1)	Explosive Range (% by volume in air) Lower Limit	Upper Limit	Common Properties (percentages below are % in air by volume)	Physiological Effects (percentages below are % in air by volume)	Most Common Sources in Sewers	Simplest and Cheapest Safe Method of Testing (3)	Max. Safe 60-minute exposure, % by volume (4)	Max. Safe 8-hour Exposure, % by volume (4)
Oxygen (in air)	O_2	1.11	Not flammable		Colorless, odorless, tasteless, non-poisonous gas. Supports combustion.	Normal air contains 30.9% of O_2. Man tolerates down to 12%; below 5% to 7% likely to be fatal	Oxygen depletion from poor ventilation & absorption or chemical consumption of available O_2	Oxygen deficiency indicator	--	--
Gasoline	C_3H_{12} to C_9H_{20}	3.0 to 4.0	1.3	7.0	Colorless, odor noticeable in 0.03%; flammable, explosive	Anesthetic effects when inhaled; 2.3% rapidly fatal; 1.1% to 2.2% dangerous for even short exposure	Leaking storage tanks, discharges from garages and commercial or home dry cleaning operations	1)Combustible gas indicator; 2)Oxygen deficiency indicator for concentration over 0.3%	0.4 to 0.7	0.10

Carbon Monoxide	CO	0.97	12.5	7.42	Colorless, odorless, non-irritating, tasteless; flammable; explosive	Hemoglobin of blood has strong affinity for gas, causing oxygen starvation; 0.2% to 0.25% causes unconsciousness in 30 min.	Manufactured fuel gas	CO ampoules	0.04	0.01
Hydrogen	H_2	0.07	4.0	74.2	Colorless, odorless, tasteless, non-poisonous; flammable, explosive; propagates flame rapidly; very dangerous	Acts mechanically to deprive tissues of oxygen; does not support life; a simple asphyxiant	Manufactured fuel gas	Combustible gas indicator	--	--

Table I (a) (Continued)

COMMON DANGEROUS GASES ENCOUNTERED IN SEWERS AND AT WASTEWATER TREATMENT PLANTS

	Chemical Formula	Specific Gravity of Vapor Density(2) air=1)	Explosive Range (% by volume in air) Lower Limit	Upper Limit	Common Properties (percentages below are % in air by volume)	Physiological Effects (percentages below are % in air by volume)	Most Common Sources in Sewers	Simplest and Cheapest Safe Method of Testing (3)	Max. Safe 60-minute exposure, % by volume (4)	Max. Safe 8-hour Exposure, % by volume (4)
Name of Gas										
Methane	CH_4	0.55	5.0	15.0	Colorless, tasteless, non-poisonous gas; supports combustion	Normal air contains 30.9% O_2; man tolerates down to 12%; below 5% to 7% likely to be fatal	Oxygen depletion from poor ventilation & adsorption or chemical consumption of available O_2	1)Combustible gas indicator; 2)Oxygen deficiency indicator	--	--
Hydrogen Sulfide	H2S	1.19	4.3	46.0	Rotten egg odor in small concentrations, but sense of smell rapidly impaired; odor not evident at high concentrations; colorless; flammable, explosive; poisonous	Death within a few minutes at 0.2%; paralyzes respiratory center	Petroleum fumes from blasting; sewer gas	1)H_2S ampoules; 2)5% by weight lead acetate solution	0.02 to 0.03	0.0002

Carbon Dioxide	CO2	1.53	Non flammable	Colorless, odorless, nonflammable; not generally present in dangerous amounts unless there is already a deficiency of oxygen	10% cannot be endured for more than a few minutes; acts on nerves of respiration	Leaves from carbonaceous strata; sewer gas	Oxygen deficiency indicator	4.06 to 6.0	0.5
Nitrogen	N_2	0.97	Non flammable	Colorless, tasteless, odorless; non-poisonous; principal constituent of air (about 79%)	See hydrogen	Leaves from some rock strata; sewer gas	Oxygen deficiency indicator	--	--

Table I (a) (Continued)

COMMON DANGEROUS GASES ENCOUNTERED IN SEWERS AND AT WASTEWATER TREATMENT PLANTS

Name of Gas	Chemical Formula	Specific Gravity of Vapor Density(2) (air=1)	Explosive Range (% by volume in air) Lower Limit	Upper Limit	Common Properties (percentages below are % in air by volume)	Physiological Effects (percentages below are % in air by volume)	Most Common Sources in Sewers	Simplest and Cheapest Safe Method of Testing (3)	Max. Safe 60-minute exposure, % by volume (4)	Max. Safe 8-hour Exposure, % by volume (4)
Ethane	C_2H_4	1.05	3.1	15.0	Colorless; tasteless; odorless; non-poisonous; flammable; explosive	See hydrogen	Natural gas	Combustible gas indicator	--	--
Chlorine	Cl_2	2.5	Nonflammable; nonexplosive		Greenish yellow gas or amber color liquid under pressure; highly irritating and penetrating odor; highly corrosive in presence of moisture	Respiratory irritant; irritating to eyes and mucous membranes; 30 ppm nausea; 40-60 ppm dangerous in 30 minutes; 1,000 ppm likely to be fatal in a few breaths	Leaking pipe connection; over dosage	Odor, strong ammonia on grab gives off w hite fumes	0.0004	0.0001

(1)From “Water and Sewage Works,” Van Kleeck, August 1953.

(2)Cases with a specific gravity less than 1.0 are lighter than air; those more than 1.0 are heavier than air.

(3)The first method given is the preferable testing procedure.

(4)One percent equals 10,000 ppm (parts per million).

II. VALVE AND METER OPERATION AND MAINTENANCE STANDARD OPERATING PROCEDURES

A. General

Valves are the controlling devices placed in the piping system to stop or regulate the flow of water or wastewater. There are specific valves that are more suitable for certain jobs than others. This SOP will discuss the function and characteristics of valves and how to operate and maintain them so they work properly when required.

This SOP also includes standard maintenance and calibration practices for water meters. While a number of studies have been performed on the optimum period to repair and calibrate water meters, 10 years is a commonly accepted standard. This means that 10% of all meters should be removed, checked, repaired, and calibrated each year.

B. Valve Functions

The following are typical valve functions in water and wastewater service:

- **Isolation**—allows equipment to be shut off or isolated from other equipment.
- **Directional**—allows the water or wastewater to flow in one direction, but not the reverse.
- **Air-Release**—allows trapped air in water lines to be released to the atmosphere at the high points of water lines
- **Control**—allows pressure or flow in the pipeline to be regulated as desired.

C. Valves Types

In Aqaba, the following valves are present:

- Gate valves
- Globe valves
- Check valves
- Air-release valves
- Plug valves
- Butterfly valves

Table II (a) shows the characteristics and typical usage for each valve used in the Aqaba water and wastewater utility. Valves that are used in water but not wastewater are more subject to plugging due to the solids present in wastewater. These types of valves should never be installed in wastewater pumping stations or pipelines.

Table II (a)

Typical Valve Characteristics and Functions in Water and Wastewater

Valve Type	**Service**	Valve Function	Location
Gate	Water/Wastewater	Shutoff or isolation	Pumping stations
Globe	Water	Control or shutoff	Water service shutoff
Check	Water/Wastewater	Stop flow in one direction	Pumping stations
Air-release	Water	Allows air to bleed from pipeline at high points	At high points in distribution systems and on pump volutes
Plug	Wastewater	Shutoff or isolation	Pumping stations and treatment plant
Butterfly	Water/Wastewater	Control or shutoff	Pumping station discharge lines

D. Common Valve Operation

General operation procedures for all of the valves are listed below:

- Open valve fully. When at stop, reverse and close valve one half turn. This prevents the packing from becoming compressed.
- Operate all large valves (> 200 mm) at least yearly to ensure proper operation.
- Inspect valve stem packing for leaks. Tighten as needed.
- If the valve has a rising stem, keep stem threads clean and lubricated.
- Close valves slowly in pressure lines to prevent water hammer.
- If a valve will not close by using the normal operator, check for cause. Donot use a large wrench to force the valve open or closed.

E. Gate Valve and Globe Valve Operation and Maintenance

The maintenance requirements for gate valves and globe valves are similar, and are shown in Table II (b).

Table II (b)
Maintenance Practices for Gate Valves and Globe Valves

Task	Suggested Frequency
Replace packing	Annual
Operate inactive valves	6 Months
Lubricate gearing on valve operator	Annual
Lubricate rising-stem threads	6 Months
Reface leaky gate valve seats	Annual

F. Check Valve Operation and Maintenance

The purpose of a check valve is to prevent backflow through a pipe and/or pump after the pump stops pumping. Table II (c) is a listing of maintenance requirements for check valves.

Table II (c)
Maintenance Practices for Check Valves

Task	Suggested Frequency
Open valves to observe general condition	Annual
Inspect valve disc facing	Annual
Check pin wear	Annual

G. Air-Release Valve Operation and Maintenance

Air-release valves are used to release built-up air in pipelines. This air reduces the amount of water that can be delivered, and increases the cost of pumping to the distribution system.

Table II (d) is a listing of operation and maintenance requirements for automatic air-release valves. Table II (e) is a listing of operation and maintenance requirements for manual air-release valves.

Table II (d)
Operation and Maintenance Practices for Automatic Air-Release Valves

Task	Suggested Frequency
Close small valve between water line and air-release valve.	Annual
Drain water from air-release valve	Annual
Backwash air-release valve with pressurized water to clean out valve	Annual
Drain water out of valve. Close drain valves	Annual
Open small valve between water line and air-release valve and return to service	Annual

Table II (e)
Operation and Maintenance Practices for Manual Air-Release Valves

Task	Suggested Frequency
Open air-release valve slowly allowing air to be released.	Monthly
Continue opening valve until approximately half open, to allow for rapid closure	Monthly
When all air has been removed from the line, water will appear at valve. When this happens, close the valve.	Monthly

H. Plug Valve Operation and Maintenance

Plug valves are often used to isolate tanks or pumps in wastewater treatment plants and pumping stations. The maintenance requirements for plug valves are shown in Table II (f).

Table II (f)
Maintenance Practices for Plug Valves

Task	Suggested Frequency
Lubricate gearing on valve operator	Annual
Open valve to observe general condition	Annual
Inspect plug coating and valve seats. Replace as necessary	Annual

I. Butterfly Valve Operation and Maintenance

Butterfly valves are used on the discharge lines of many water and wastewater pumps to adjust or throttle the flow from the pump. The maintenance requirements for butterfly valves are shown in Table II (g).

Table II (g)
Maintenance Practices for Butterfly Valves

Task	Suggested Frequency
Lubricate gearing on valve operator	Annual
Open valve to observe general condition	Annual
Inspect valve disc facing and seat. Replace or reface as necessary.	Annual

J. Water Meter Operation and Maintenance

Maintenance of water meters is critical to the financial health of the Aqaba utility. Poorly performing meters usually under-read the actual usage, resulting in lower revenues to the utility. Therefore, maintenance and calibration of water meters becomes one of the most important maintenance tasks in the utility.

Water meters have a number of moving parts that can cause problems. The maintenance and calibration requirements for water meters consist mainly of dismantling the meter, inspecting the parts for wear, and replacing worn or corroded parts. The maintenance and calibration requirements for water meters are summarized in Table II (h).

Table II (h)
Maintenance Practices and Calibration for Water Meters

Task	Suggested Frequency
Remove meter from service and take to shop	10% Per Year
Test meter for accuracy	10% Per Year
Dismantle meter	10% Per Year
Inspect parts for wear and corrosion	10% Per Year
Replace defective parts	10% Per Year
Clean all parts to be used in the meter	10% Per Year
Assure the parts move properly	10% Per Year
Retest meter for accuracy	10% Per Year

III. CONFINED SPACES AND CONFINED SPACE ENTRY STANDARD OPERATING PROCEDURE

A. General

A "confined space" is defined as follows:

- It has adequate size and configuration to allow operator access.
- It has limited means of access (entrance) or egress (exit).
- It is not designed for continuous operator occupancy.

The General Manager or his designee should inspect all water and wastewater facilities within Aqaba to determine those spaces and areas that would fit this description. When in doubt, assume an area is a confined space and use confined-space procedures.

B. Elements of a Confined-Space Entry Program

The General Manager is responsible for establishing a confined-space entry program for the utility. However, AWC must provide support for the program in the form of budgets for confined-space training, safety equipment, and backup personnel.

A combined space entry program should include the following elements:

- **A Written Confined-Space Entry Policy.** The U.S.-based Water Environment Federation suggests the following policy statement be included:
    - *"In any instance of a confined-space entry, the intent of management is that the most appropriate and safe confined space working procedures are to be followed. In this intent, management's support by the availability of personal safety equipment and a*
    - *Standardized procedure to ensure the safety of its employees shall not be compromised by any responsible or assigned supervisory representative."*
- **A Permit Application and Entry Procedures.** Entry to a confined space should be by written permit only. A suggested permit form is included at the end of this SOP. The General Manager is responsible for establishing the permit procedures. This may be

done in conjunction with other agencies within Aqaba such as the Fire Department, which may have similar programs. All completed permits should be kept on file for at least one year.

- **Training Program.** All employees should receive training related to confined-space entry including:

  A. Potential hazards in confined space entry
  B. Permitting and entry procedures
  C. Emergency first-aid
  D. Use and maintenance of emergency equipment

- **Confined Space Entry Equipment.** The following is a partial list of suggested equipment:

  A. Multiple-gas detectors to detect the presence of toxic or combustible gases or oxygen-deficient atmospheres

  B. Substance-specific detectors for hydrogen sulfide, carbon monoxide, carbon dioxide and explosive gases

  C. Retrieval systems including safety-harnesses and at least 15 meters of 18 mm manila rope or 13 mm polypropylene rope. A tripod and winch are also recommended for sewer manholes and the pump station wet wells

  D. Explosion-proof lighting

  E. Protective clothing including hardhat with chinstrap, rubber boots, rubber or chemical-resistant clothing and gloves and eye protection

  F. Standard railings and barriers to prevent unauthorized or accidental entry and injury to a confined space

  G. Spark-proof equipment for use in potentially-explosive atmospheres

  H. Self-contained breathing apparatus (SCBA)

  I. Ventilation blowers designed for use in potentially-explosive atmospheres

  J. Two-way radios

  K. Proper ladders

  L. A complete first-aid kit

M. Fire extinguishers

Confined Space Entry Checklist. Attached at the end of the SOP is a suggested checklist for confined space entry that should be completely filled out before entry.

NOTE: The first rule of confined space entry is to avoid entry if an alternate means of clearing, testing or monitoring of the space is available.

C. Hazardous Gases in Confined Spaces

The air within confined spaces such as the wastewater pumping station wet wells, tanks, and manholes can be deficient in oxygen, or can contain noxious or toxic gases. Normal air contains about 21 percent oxygen by volume.

Any atmosphere containing less than 13 percent is dangerous to human beings and is termed "oxygen deficient." Such a situation may occur in any confined space if another gas displaces the oxygen. Oxygen deficiency may also occur in a confined space, such as a basement, where sludges or other organic material may have spilled.

An oxygen-deficiency indicator should be used to measure the amount of oxygen in an area. A portable air blower can be used to restore adequate ventilation. The discharge hose should extend well into the structure, the blower allowed to run for a while, and the atmosphere retested before anyone attempts an entrance.

Noxious and toxic gases or vapors may also exist in enclosed areas. The following are some of the more common hazardous situations found in the wastewater treatment plant:

- Gas emitted by wastewater or sludge is explosive when mixed with certain proportions of air, can be asphyxiating and is sometimes toxic. Methane is the main constituent of such gas mixtures and accounts for 60 to 70 percent of their volume. It is odorless and colorless and cannot be detected without testing equipment.

- Hydrogen sulfide has an odor similar to rotten eggs and can be easily detected by smell in small concentrations. However, in strong concentrations, it causes impairment or temporary loss of sense of smell and may cause suffocation before one realizes what is happening.
- Gasoline and other flammable and volatile substances find their way into the sewer systems from time to time. Such materials pose a serious fire and/or explosion hazard in sewers, wet wells, or wherever there is an open surface of wastewater.

- Materials releasing toxic gases may also enter the sewer occasionally and could cause personnel hazards in the previously mentioned areas.
- If confined-space pre-entry tests show noxious gases or an oxygen deficiency, the structure should be thoroughly ventilated and retested until the tests prove negative.

Table IV (a) is a summary of the gases commonly found in sewers and wastewater treatment plants, along with the characteristics, detection methods, and dangerous levels of each

IV. SAFETY STANDARD OPERATING PROCEDURE

A. General

The safety procedures in this Standard Operating Procedure (SOP) include the water production facilities at Disi, pressure break tanks, disinfection facilities, and distribution network including piping, valves and other appurtenances. This SOP also includes the wastewater collection system, pumping stations, and new wastewater treatment and sludge treatment facilities north of the City of Aqaba.

The operation of water and wastewater facilities can be dangerous, if proper safety procedures are not followed. Physical injuries and body infections are continuous threats. Confined space entry should be a major concern in Aqaba. Explosions and asphyxiation from gases or oxygen deficiency are constant hazards. Lifting injuries and slipping injuries are the most frequent type of injuries in the water and wastewater profession.

Safety measures for operation and maintenance of the facilities in Aqaba will be effective if hazards are known and if proper safety precautions are followed. Personnel should be aware of hazards, preventive measures, and emergency procedures. Any accidents or injuries which occur should be immediately investigated and recorded. Safety meetings, formal and informal, should be held on a regular basis, and safety equipment must be maintained and tested routinely. It is desirable that all employees become safety-conscious and develop a personal concern in preventing accidents at their plant, or in the other water/wastewater facilities.

The phone numbers of several physicians, the nearest hospital, the police and fire stations, and one or more ambulance services should be prominently posted in each building and pumping station.

B. Safety Responsibilities

- **Management**

The General Manager of AWC has the key responsibility for safety within the utility. Through his managers and foremen, the General Manager has direct control of the work being done by the other workers and it is his responsibility to set work patterns and implement a safety program. This can be done by instructing employees on safe working habits and reviewing their work for compliance to established safety regulations. The General Manager should also conduct periodic safety inspections covering the facilities and equipment throughout the Aqaba utility.

- **Staff**

All employees have a responsibility to themselves, their families and their jobs to do everything they can to prevent personal injuries. This can be done by following established safety regulations and using proper safety equipment in daily work routine. Human error is the most significant cause of accidents, and it is the employee's responsibility to perform his job safely.

C. Safety Program

- **General**

A safety program is necessary for any utility, and this is especially true in water and wastewater utilities. The purpose of this safety program should be to define the principles under which the work within the plant is to be done, and to make AWC employees aware of safe working procedures.

- **Safety Education and Training**

Perhaps the most essential element of a good safety program is some form of safety training. The purpose of safety training is to stress the importance of safety to the plant employees. This safety training can be accomplished through safety manuals, safety meetings, and safety posters placed in strategic areas in treatment plants, pumping stations, and buildings, along with a safety suggestion program.

A safety suggestion program is an especially valuable means of acquiring safety training, since it not only provides a means of securing many worthwhile ideas for more effective safe work practices, but it also encourages the plant employees to think about safety. For this reason, several blank pages should be added at the end of this SOP for any "Safety Notes" which plant personnel may wish to make from their observations about plant safety.

D. Occupational Hazards

General

The hazards commonly associated with operating a water and wastewater utility may be classified into the following broad categories:

- Bacterial and Viral
- Mechanical and Physical

  - General
  - Hoisting Equipment
  - Pressure Vessels
- Electrical
- Ultraviolet Disinfection
- Chemical and Gaseous
  - Chlorine
  - Polymer
- Plant Laboratory

E. Bacterial and Viral

Constant caution is necessary to prevent infection by the bacteria and viruses present in sewage. Workers are continually exposed to such waterborne diseases as typhoid fever, amoebic dysentery, and infectious hepatitis. Tetanus and skin diseases must also be guarded against. The local health department should be requested to notify plant personnel when cases of waterborne diseases are encountered.

Some of the more basic, if not obvious, rules of safety are as follows:

- Personal cleanliness is a necessity. Personnel must make a habit of frequently and thoroughly washing with soap and hot water, especially before meals and before leaving the plant.

- Wastewater and sludge on hands contaminates doorknobs and fixtures. Dirty clothing or careless hand washing may spread infection beyond the wastewater plant area.

- Emergency first aid must be promptly given to all minor cuts or injuries. A 2% tincture of iodine or tincture of Merthiolate solution should be immediately applied to any wound or cut. Major injuries must be treated by a physician at once. All staff should have first aid training.

- Rubber gloves should be worn when handling sludge, wastewater or similar materials. Special precautions should be taken to prevent wastewater from coming in contact with open cuts or other injuries. Fingers must be kept out of the nose, mouth and eyes at all times.

- Drinking water from any source other than regular drinking fountains must be prohibited. Hands should be thoroughly washed before using the drinking fountains.

- Personnel should have typhoid and tetanus inoculations followed by booster shots at the appropriate intervals.

- There should be no smoking in sewers or in other areas in the vicinity of wastewater or sludge. It is impossible to avoid contamination of the ends of cigars, cigarettes or pipes.

- Cross-connection inspections (contaminated water connected to potable water lines) should be conducted frequently to prevent any accidental occurrence resulting in exposure of an operator to waterborne disease.

F. Mechanical and Physical

General

Some of the general safety precautions to take against mechanical and physical hazards follow:

- Care must be taken when repairing or performing maintenance on automatic or remote-controlled equipment to ensure that power is shut off so that equipment cannot be started. Local lock-out switches at the equipment motors should be off and marked with red tags. Where this procedure is impossible, power should be shut off at the motor control center or lighting panel as appropriate and the breaker marked with a red tag. The red tag should read: "WORKMAN IS WORKING ON LINE" and be signed by the workman. The tag should be removed only by the person whose name is on the tag.

- If possible, lubrication or adjustments should not be made on machinery in operation. If such services must be performed on operating machinery, a second man must be present and stationed at the stop-start switch.

- Belt guards must be kept in place.

- Floors and stairways must be kept clean, dry, and free of grease, oil and ice to prevent slipping.

- Tools must be picked up and manhole covers or hatch covers kept closed. If it is necessary for openings to be uncovered, they must be protected with guards and warning signals.

- Cleaning fluids with flash points below 38 degrees C should not be used.

- Hard hats should be worn by personnel working in areas where tools or other heavy items may be dropped from above.

- One of the most common injuries results from improperly lifting objects. All personnel should become familiar with correct lifting techniques and should use hoists and power equipment wherever possible.

- Life preservers with throw lines should be attached to railings around open tanks in the wastewater treatment plant.

- Tools to be used in an empty tank should be lowered in a pail on a rope and removed in the same way.

- While washing floors, all personnel should wear rubber boots with good, treaded soles and heels.

- When an extension ladder is used to enter an empty tank, the ladder should be lashed to a handrail.

- Clothes must not be hung on electrical disconnect handles, light switches or control panel knobs.

- A safety belt with a short rope and safety snap should be used by personnel when leaning out through the railings over any tank.

- Fire prevention is an important part of every safety program. Flammable materials should be kept in approved safety cans. Oily rags should be stored outdoors in a covered bin.

- Permanent warning signs should be placed at all hazardous locations and should be supplemented by temporary signs during emergency operation.

- Sharp projections or locations of low headroom should be padded and identified by being either marked clearly or painted with a contrasting color.

- Employees working in noisy areas for prolonged periods should wear ear-protecting devices.

Hoisting Equipment

Only experienced personnel should be permitted to use the hoisting equipment. The following safety precautions should be taken with hoists:

- Never pick up a load beyond the rated capacity appearing on the hoist.
- Never carry personnel on the hook or the load.
- Never lift a load with the hoist until all personnel are clear.
- Never use the hoist rope or chain as a sling.
- Do not allow unqualified personnel to operate the hoist.
- Do not transport a load over personnel.
- Do not use the chain or rope as a ground for welding.
- Never touch a welding electrode to the chain or rope.
- Do not leave a load suspended in the air for extended or unattended periods.
- Center the hoist unit over the load before lifting. Avoid side pull.
- Be sure the sling is properly seated in the saddle of the hook.
- Make sure a load clears neighboring stockpiles or machinery before moving.
- Avoid plugging, excessive inching, and quick reversals of load.
- Avoid swinging the load or load hook when traveling the hoist.
- Check limit devices and braking mechanism daily for proper function. Check the wire rope or chain daily for improper seating, twisting, kinking, wear, or other defects before operating the hoist.

- Be sure that the power supply is disconnected before performing maintenance and repair procedures.

- Do not operate a hoist if it is functioning improperly.

- Do not use the limit clutch to stop the loaded hook in the down direction. It is primarily a backup device.

Pressure Vessels

Pressurized fluids in pressure vessels can seriously injure persons if suddenly discharged. Therefore, proper safety procedures must be followed when dealing with pressure vessels:

- Pressures and temperatures should be monitored. Surging pressures or abnormally high temperatures must not be ignored.

- Piping and pressure vessels should never be operated at pressures exceeding their rated capacity.

- Before inspecting or cleaning pipes and vessels, associated piping and vessels should be completely depressurized and all vents, drains, nozzles, etc., should be left open to relieve any pressure.

- Large vessels should be well ventilated and completely isolated before persons enter. Persons entering a vessel should have safety lines tended by others outside.

G. Electrical

- Electrical maintenance and repairs should be performed only by licensed, qualified electricians. This includes virtually all electrical work to be done at the Aqaba water and wastewater facilities.

- Only electrical tools and lights having 3-wire grounded extension cords should be used.

- All persons should become familiar with the types of electrical accidents, how to administer first aid and CPR (cardiopulmonary resuscitation) and how to rescue another person without endangering themselves.

- Rubber mats should be placed on the floors in front of switchgear when work is being done on this equipment.

- When work is to be done on equipment controlled by a switch located at some distance from the equipment, the switch should be tagged with a red card to prevent others from closing the circuit.

- Consider all electrical circuits to be dangerous. Contact with even low-voltage wiring has caused workmen to fall from ladders and scaffolds.

- Treat dead circuits as though they were alive; an accident can result from the negligent closure of the circuit by another person.

Note: Ultraviolet Disinfection

Ultraviolet disinfection is basically a safe process. However, ultraviolet power supplies are high voltage, requiring the adherence to electrical safety codes. Particular attention should be paid to electrical wiring, groundings, and waterproofing.

The storage, handling, and disposal of the expendable components should also be considered from the standpoint of safety. Storage of lamps, quartz sleeves, and ballasts should be in a separate dry area. Adequate shelving should be designed to store the materials such that they are protected from breakage, and are easily and safely accessed. Used lamps, quartz sleeves, and ballasts which are to be discarded should be repackaged and overpacked for safe disposal.

Personnel safety training should address and require strict adherence to personal protection from excessive UV radiation. A lamp battery does not present a hazard while submerged and operational; the water absorbency will sufficiently reduce the radiation. However, these lamp batteries should not be operated while in a dewatered and dry state. If it is necessary to engage a system without shields in place (or with the lamp battery exposed) it is absolutely necessary that the proper protective gear be worn by all personnel in the area and that adequate warning signals be active during these operations to warn anyone entering the area. This will also apply during the routine lamp monitoring tasks discussed earlier.

The skin and eyes readily absorb UV radiation and are particularly vulnerable to injury. Sunburn (erythema) is a common example, although this effect is most pronounced with UV light between wavelengths 285 and 300 nanometers. Absorption by the mucous membranes of the eyes and eyelids can cause conjunctivitis (commonly referred to as "welders flash"). The

injury becomes apparent 6 to 12 hours after exposure; although painful and incapacitating, the damage is usually temporary.

Personnel protection must include plastic goggles (wrap around), or face-shields. These must be rated to absorb the UV spectral lines. Protective clothing should be worn to prevent exposure to the hands, arms, and face.

H. CHEMICAL and GASEOUS

Table IV (a) lists common dangerous gases encountered in wastewater sewers and at the wastewater treatment facilities.

Chlorine

The water from Disi uses chlorine gas for disinfection. Chlorine gas is an extremely active chemical that is very toxic and corrosive in moist atmospheres. As a result, chlorine must be handled cautiously. The following suggested rules will help to prevent accidents or, if an accident occurs, to minimize the damage:

- All employees should be fully informed concerning the safe handling of chlorine and the repairing of leaks, and should be responsible for proper handling of chlorine containers, for maintenance of chlorination equipment, and for inspection and care of the self-contained breathing apparatus. All employees should be instructed in the principles of safely handling chlorine and procedures to follow in case of an emergency.

- Do not drop chlorine containers or allow them to strike against each other, as it may damage the fusible plugs or other container parts and allow chlorine gas to escape.

- Do not heat or store chlorine containers where the temperature might exceed 52 degrees C (such as adjacent to steam lines), as the fusible plug will soften or melt and allow the chlorine within the container to discharge to the atmosphere.

- Chlorine gas, as drawn from containers, is dry and noncorrosive to metals. In combination with moisture, however, chlorine will attack all but the noble metals (gold, silver, platinum, etc.) and a few other materials. Liquid chlorine will attack both hard and soft rubber. Chlorine in the atmosphere, even in small amounts, is particularly damaging to metal objects and electrical equipment.

- Connections between gas headers and chlorine containers should be carefully inspected at regular intervals and should be replaced promptly when defects are found.

- The flexible connections between the chlorine containers and the manifold should be replaced yearly. Deterioration on the inside of these pipes can be extensive and may not be readily noticed. Any small pinhole will increase in size very rapidly.

- Plastic-coated gloves should be worn by personnel changing containers or making connections.

- When a chlorine container is being connected to the headers, it is important to eliminate bending stresses at the ends of unions of the flexible-tube connectors.

- When piping on containers is connected, or when it is necessary to break a connection and recouple it, a new lead or fiber washer must be used.

- Never connect a full container to a header with other containers until the temperatures of all containers are approximately the same. Chlorine would tend to flow from the warmer to the cooler container and cause it to overfill. Bursting pressures could develop as the temperature of the cool, overfilled container increases.

- Keep the valve-protection caps on containers except when they are in use. Caps include both the small cap on the valve outlet and the large cap enclosing the entire valve assembly.

- Close the valve on a container as soon as it is empty and replace the protective caps.

- All lines used for chlorine must be perfectly dry. All oil and grease must be thoroughly removed with trichloroethylene rather than water.

- When shutting off the flow of liquid chlorine, be careful not to leave the line full with the valves closed at both ends, as the line may warm up and burst because of the resulting increased pressure. The container valve should be shut first and the line allowed to empty by continued usage. The downstream valve may then be closed.

- After full chlorine containers have been installed, all joints must be checked for leaks.

- Do not start up a chlorinator or turn on a container unless self-contained breathing apparatus is on hand in the chlorine area.

- The slightest leaks of chlorine gas must be given immediate attention. Leaks may be located by passing an opened bottle of commercial strength (26 degree Baume) ammonia solution along the pipelines and fittings. If chlorine leaks are present, white fumes will appear at the mouth of the bottle. (The ammonia solution should not be allowed to enter any fittings.)

NOTE:Household ammonia is not strong enough for this purpose.

- Inaccessible locations may be conveniently leak-checked by tying a cloth saturated with ammonia solution to the end of a long pole.

- An uncapped bottle of commercial strength ammonia left on the floor of a chlorine area will indicate a leak without entering the room.

- Chlorine valves should be opened only one turn so that they may be closed quickly in case of emergency.

- Self-contained breathing apparatus must be used if personnel must enter the chlorine area to repair a leak. The breathing apparatus should not be stored in an area likely to be affected by a chlorine leak.

- If chlorine use were ever contemplated, the plant should obtain an emergency repair kit for 68-kilogram cylinders. Drills should be held at frequent intervals to review the use of the kits and the emergency procedures to be followed in the event of a leak.

- Local fire and police departments should be instructed in emergency procedures and should participate in the drills at the plant.

- When a leak is detected, the emergency procedures include the following:

    - Authorized employees should ensure that the ventilating system is operating in the area involved if the leak is within a building.

    - Personnel without breathing apparatus in areas lower in elevation or downwind of the chlorine leak should leave those locations, and go to areas higher in elevation and upwind of the leak.

- Designated employees should use the self-contained breathing apparatus and investigate the source and severity of the leak, locating the point of leakage with ammonia as previously described.

- Notify the police and fire departments of the emergency.

- Never put water on a leak, as water will always make the situation worse.

- If the leak is downstream of the valve on the container or tank, turn off that valve before repairing the leak.

- If the leak is in a fusible plug on a one-tonne container, lessen the flow by reducing the pressure. Pressure can be reduced by increasing the rate of chlorine feed to the treatment plant to the maximum, turning off any other containers connected to the header and rotating the ton container until only gaseous chlorine can escape. Liquid chlorine will cool as it changes to gas, thereby reducing pressure and causing the gas to discharge at a lower rate. The container may also be insulated with rags or similar material to decrease the amount of heat transferred to the container from the room.

- Chlorine gas may be readily absorbed in solutions of either caustic soda or soda ash. One kilogram of chlorine will require 1.25 kilograms of caustic soda or 3 kilograms of soda ash. Solutions should be prepared by using 100 liters of water to dissolve either 30 kilograms of caustic soda (sodium hydroxide) or 36 kilograms of soda ash (sodium carbonate). The chlorine should be passed into the solution near the bottom of the container or caustic soda or soda ash through an iron pipe or weighted rubber hose.

- One person should never work on a leak alone. Someone should always observe him and be equipped to go to his aid if necessary.

- If the leak is large, plans for large-scale evacuation of nearby populated areas should be readied for implementation, if necessary.

- Never be ashamed to call for help in a chlorine emergency.

Polymer

Reasonable care should be used when handling or preparing polymer. Precautions should be taken to avoid contact of polymer with the skin surface. Skin exposed to polymer should be immediately flushed with water.

I. PLANT LABORATORY

Only experienced or well-instructed personnel should be permitted to work in the utility's laboratory. The laboratory and its equipment should be used only for its intended purpose.

The following safety precautions should be taken in the laboratory:

- Store all strong acids and alkalies in clearly marked bottles where they can be conveniently reached without climbing.
- Use rubber bulbs on pipettes.
- Keep lab tables clear when not in use.
- Wear protective gloves, aprons, and goggles when handling hazardous materials.
- Use water-soluble jellies when making glass-to-hose or other similar connections.
- Keep labware clean.
- Discard any chemicals that cannot be identified.

J. FIRE FIGHTING EQUIPMENT

Plant personnel should know the exact locations of all extinguishers and should be thoroughly familiar with their use. The extinguishers should be checked periodically for operability and charge as recommended by the local fire department.

K. FIRST AID EQUIPMENT

First aid kits are provided throughout the treatment plant. The cabinets and kits should be kept well supplied, neat, clean, and in order. Items in the kit should be replaced before the supply is exhausted to ensure their availability when needed.

Personnel should be familiar with first aid procedures. In case of serious injuries, a doctor should be called or the injured person taken to a hospital by ambulance.

L. ACCIDENT REPORTS

Any injury, however slight, must be reported to the General Manager by means of a standard form. A suggested accident report form is attached to this procedure.

After an accident has occurred, an injury investigation (formal or informal) should be made to find the cause of the injury and to take steps to prevent a recurrence. If plant personnel are allowed to play a role in determining the cause of an injury, overall safety-consciousness is likely to increase. Copies of accident reports should be made available to all employees for their review, in the hope that they will adjust their work habits to avoid similar injuries.

M. SAFETY REFERENCES

Further safety references are included at the end of this SOP. These references should be kept at the utility administration building, or at the new wastewater treatment plant and updated as revisions become available.

SUGGESTED ACCIDENT REPORT FORM

Accident classification _____

Date of report _____ Person reporting _____

Name and title of injured _____

Occupation _____ Age _____

_____ On duty

_____ Off duty

Date of injury _____ Time _____ am/pm _____ Visitor

Place of injury _____

Name/address/phone
of doctor, if seen _____

Administrant of first aid, if any _____

Description of accident: _____

Type of injury: _____ Fatal _____ Permanent _____ Temporary Nondisabling

Describe cause of accident: _____

_____

Was injured acting in regular line of duty? _____ Yes _____ No

What other persons were involved? _____

What was this person(s)' role in the accident? _____

Did defective equipment or unsafe conditions contribute to accident? _____

If yes, how?

Witnesses to accident: _____

_____

SUGGESTED ACCIDENT REPORT FORM (Continued)

Corrective action taken: _____

_____

What steps have been taken to prevent future accidents? _____

_____

Recommendations: _____

_____

Cost of accident: $_____

Cost of accident computation to be filled in on administration copy:

Compensation	JD_____
Medical	JD
Public liability	JD_____
Property loss	JD_____
Time off job	JD_____
Other	JD_____
TOTAL COST	JD_____

RECOMMENDED REFERENCE MATERIAL ON SAFETY

Water Environment Federation:

MOP No. 1, "Safety in Wastewater Works"
MOP No. 4, "Chlorination of Wastewater"
MOP No. 11:
"Operations of Wastewater Treatment Plants"
"Wastewater Treatment Plant Operator Training Course I"
"Wastewater Treatment Plant Operator Training Course II"
"How to Promote Safety in Water Pollution Control Operation"
"Confined Space Entry"

State of New York, Health Education Service:

"Manual of Instruction for Sewage Treatment Plant Operators"

Fisher Scientific Company:

"Laboratory Safety Manual"

Ontario Water Resources Commission:

"Safety Regulations for Plant Operators"

American Red Cross:

"Standard First Aid and Personal Safety"

American National Standard Requirements for Confined Spaces. ANSI Z117.1

OSHA (1993) "Permit-Required Confined Spaces (Permit Spaces)" U.S. Code of Federal Regulations, Title 29, 29 CFR 1910.146

National Electric Code

National Fire Code

TABLE IV (a)
COMMON DANGEROUS GASES ENCOUNTERED IN SEWERS AND AT WASTEWATER TREATMENT PLANTS

	Chemical Formula	Specific Gravity of Vapor Density (2) (air=1)	Explosive Range (% by volume in air) Lower Limit	Upper Limit	Common Properties (percentages below are % in air by volume)	Physiological Effects (percentages below are % in air by volume)	Most Common Sources in Sewers	Simplest and Cheapest Safe Method of Testing (3)	Max. Safe 60-minute exposure, % by volume (4)	Max. Safe 8-hour Exposure, % by volume (4)
Name of Gas										
Oxygen (in air)	O_2	1.11	Not flammable		Colorless, odorless, tasteless, non-poisonous gas. Supports combustion.	Normal air contains 30.9% of O_2. Man tolerates down to 12%; below 5% to 7% likely to be fatal	Oxygen depletion from poor ventilation & absorption or chemical consumption of available O_2	Oxygen deficiency indicator	--	--
Gasoline	C_3H_{12} to C_9H_{20}	3.0 to 4.0	1.3	7.0	Colorless, odor noticeable in 0.03%; flammable, explosive	Anesthetic effects when inhaled; 2.3% rapidly fatal; 1.1% to 2.2% dangerous for even short exposure	Leaking storage tanks, discharges from garages and commercial or home dry cleaning operations	1)Combustible gas indicator; 2)Oxygen deficiency indicator for concentration over 0.3%	0.4 to 0.7	0.10

Carbon Monoxide	CO	0.97	12.5	7.42	Colorless, odorless, non-irritating, tasteless; flammable; explosive	Hemoglobin of blood has strong affinity for gas, causing oxygen starvation; 0.2% to 0.25% causes unconsciousness in 30 min.	Manufactured fuel gas	CO ampoules	0.04	0.01
Hydrogen	H_2	0.07	4.0	74.2	Colorless, odorless, tasteless, non-poisonous; flammable, explosive; propagates flame rapidly; very dangerous	Acts mechanically to deprive tissues of oxygen; does not support life; a simple asphyxiant	Manufactured fuel gas	Combustible gas indicator	--	--

TABLE IV (a) (Continued)

COMMON DANGEROUS GASES ENCOUNTERED IN SEWERS AND AT WASTEWATER TREATMENT PLANTS

	Chemical Formula	Specific Gravity of Vapor Density (2) Air=1)	Explosive Range (% by volume in air) Lower Limit	Upper Limit	Common Properties (percentages below are % in air by volume)	Physiological Effects (percentages below are % in air by volume)	Most Common Sources in Sewers	Simplest and Cheapest Safe Method of Testing (3)	Max. Safe 60-minute exposure, % by volume (4)	Max. Safe 8-hour Exposure, % by volume (4)
Name of Gas										
Methane	CH_4	0.55	5.0	15.0	Colorless, tasteless, non-poisonous gas; supports combustion	Normal air contains 30.9% O_2; man tolerates down to 12%; below 5% to 7% likely to be fatal	Oxygen depletion from poor ventilation & adsorption or chemical consumption of available O_2	1) Combustible gas indicator; 2) Oxygen deficiency indicator	--	--
Hydrogen Sulfide	H2S	1.19	4.3	46.0	Rotten egg odor in small concentrations, but sense of smell rapidly impaired; odor not evident at high concentrations; colorless; flammable, explosive; poisonous	Death within a few minutes at 0.2%; paralyzes respiratory center	Petroleum fumes from blasting; sewer gas	1) H_2S ampoules; 2)5% by weight lead acetate solution	0.02 to 0.03	0.0002

Carbon Dioxide	CO2	1.53	Non flammable	Colorless, odorless, nonflammable; not generally present in dangerous amounts unless there is already a deficiency of oxygen	10% cannot be endured for more than a few minutes; acts on nerves of respiration	Leaves from carbonaceous strata; sewer gas	Oxygen deficiency indicator	4.06 to 6.0	0.5
Nitrogen	N_2	0.97	Non flammable	Colorless, tasteless, odorless; non-poisonous; principal constituent of air (about 79%)	See hydrogen	Leaves from some rock strata; sewer gas	Oxygen deficiency indicator	--	--

TABLE IV (a) (Continued)

COMMON DANGEROUS GASES ENCOUNTERED IN SEWERS AND AT WASTEWATER TREATMENT PLANTS

	Chemical Formula	Specific Gravity of Vapor Density(2) (air=1)	Explosive Range (% by volume in air) Lower Limit	Upper Limit	Common Properties (percentages below are % in air by volume)	Physiological Effects (percentages below are % in air by volume)	Most Common Sources in Sewers	Simplest and Cheapest Safe Method of Testing (3)	Max. Safe 60-minute exposure, % by volume (4)	Max. Safe 8-hour Exposure, % by volume (4)
Name of Gas										
Ethane	C_2H_4	1.05	3.1	15.0	Colorless; tasteless; odorless; non-poisonous; flammable; explosive	See hydrogen	Natural gas	Combustible gas indicator	--	--
Chlorine	Cl_2	2.5	Nonflammable; nonexplosive		Greenish yellow gas or amber color liquid under pressure; highly irritating and penetrating odor; highly corrosive in presence of moisture	Respiratory irritant; irritating to eyes and mucous membranes; 30 ppm nausea; 40-60 ppm dangerous in 30 minutes; 1,000 ppm likely to be fatal in a few breaths	Leaking pipe connection; over dosage	Odor, strong ammonia on grab gives off white fumes	0.0004	0.0001

(1)From “Water and Sewage Works,” Van Kleeck, August 1953.

(2)Cases with a specific gravity less than 1.0 are lighter than air; those more than 1.0 are heavier than air.

(3)The first method given is the preferable testing procedure.

(4)One percent equals 10,000 ppm (parts per million).

V. PUMP OPERATION AND MAINTENANCE

STANDARD OPERATING PROCEDURE

A. General

Incoming potable water from Disi enters the pressure break tanks and storage reservoirs where it is stored until sufficient volume has accumulated. Level controllers turn on the water pumps to pump the water into the primary transmission main. When the tank level is low, the water pumps shut off.

Wastewater enters the pumping station wet wells by gravity from the Aqaba collection system. The wastewater it is stored in the wet well until sufficient volume has accumulated. The wastewater pumps are operated on high level to pump the wastewater into the station's force main and then to the wastewater treatment plant.

B. Basic Procedures

Operations personnel should be aware of some basic operation and maintenance procedures of pumping stations and pumping facilities in the Aqaba water and wastewater facilities. These basic procedures relate to most of the pumping units within the utility and include:

- The general up-keep of the pumps and pumping stations on a regular basis is of critical importance. It is easier to keep the buildings clean and neat than to let them deteriorate and then try to clean up after they've been allowed to run down.

- All areas of the buildings, particularly those building areas and process units that come into contact with wastewater must be thoroughly cleaned at least once or twice a week.

- Maintain constant alertness for unusual sounds and/or noises, and for reduced equipment performance. These signs are good indicators of problems. Early identification of trouble will, in almost all cases, minimize repair costs and prolong the life of the equipment.

- A fundamental and critical part of the periodic maintenance schedule must be preventive maintenance including, but not limited to such things as equipment lubrication. A typical Preventive Maintenance Schedule is presented at the end of this SOP.

C. General Maintenance Requirements

Proper equipment preventive maintenance is essential in order for the equipment to function properly for long periods of time and for the equipment warranties to remain in force.

Operating personnel must become very familiar with the maintenance procedures contained in this SOP, and also provided in literature supplied by the manufacturers of the various pieces of equipment. Shop drawings and manufacturer's literature and instructions for equipment in must be kept in an organized fashion and in a readily accessible file.

All equipment requires maintenance. Some require frequent and extensive maintenance; others require less frequent and less extensive maintenance. Detailed maintenance requirements are contained in this SOP and supplemented by additional information in the manufacturer's literature. If that information is misplaced from the file, it must be replaced by contacting the appropriate manufacturer's representative to obtain a replacement copy of that literature.

D. Normal Operation

Before water or wastewater flow is directed into a pumping station during initial start-up, each inlet valve or gate must be checked to see that the valves or gates are properly seated.

Because some of the valves and/or gates in the stations are intended to be normally open or normally closed and are intended to remain opened or closed for extremely long periods of time, it is important to exercise the valves and/or gates at regular intervals to insure that they will operate properly required to be moved.

The valves and/or gates should be exercised at least once a month by partially closing the unit at a point in time when the flow into the station will not be restricted or backed-up by partially closing the gates and when both wet wells are not otherwise shut-down for other maintenance.

E. Electrical Controls

All electrical controls are pre-wired and connected to the terminal strip in the Motor Control Center (MCC). All troubleshooting should be done by a qualified electrician and in accordance with the schematic wiring diagram provided with the manufacturer's literature.

F. Initial Pump Start-Up

Before water or wastewater flow is pumped by any pump during initial start-up of a station, or during normal operation after the pump(s) have been shut down for repairs, each pumping unit must be checked to see that the pump, motor and connecting drive shaft assembly is in proper working order and is ready to be started.

In addition, for those pumps with water seals—the horizontal pumps, make sure water is flowing to the seal when the pump is operating.

The following should be done before operating:

- Check the pump, shafting, and pump motor for proper installation according to the manufacturer's requirements.
- Check the suction and discharge piping and valves for proper installation and operation.
    - Check suction and discharge valves to make sure that the proper valves are open and those that should be closed are closed.
    - Check and tighten all flange bolts.
- The pump bearings must be lubricated according to the manufacturer's recommendations.
- Check shaft rotation - pump shaft must turn without any binding or rubbing. Only uniform frictional drag of the bearings and the stuffing box should be detected when manually turning the shaft.

- Check the direction of rotation of the motor before it is coupled to the pump. The rotational direction is clearly indicated on the exterior of the pump frame.

- Lubricating lines carrying liquid to the stuffing box must be checked before starting the pump to ensure that liquid is flowing. Both mechanical seals and packing require lubrication for continuous service.

- Check the seal water system in the horizontal pumps for proper operation according to the manufacturer's recommendations.

- The pump must be completely primed before beginning operation.

- Check the pump motor and pump drive assembly according to the manufacturer's recommendations including:

    - Check motor and control device connections for agreement with the wiring diagrams.

    - Check that the voltage, phase, and power supply frequency agree with motor nameplate data.

    - Check insulation resistance according to manufacturer's recommendations.

    - Check all foundation, base and coupling bolts to assure proper tightness.

    - Check oil-lubricated bearings to verify that the bearing housings have been properly filled.

    - Check to ensure that all protective devices are connected and properly operating.

    - Start motor and monitor to assure that no unusual condition develops.

- Manually start the pump at minimum speed and bring the unit up to operating speed and temperature. Check all systems for leaks, pressure gauge readings and pressure switches. Shut-down the unit and re-check the pump and motor, the gear and drive shaft alignment.

- Listen for unusual noise; watch for excessive vibration.

G. Normal Pump Operation (AUTO)

For normal operation, the pumps should be set in the "AUTO" (or Automatic) mode. With the pumps in AUTO, the pumps will start and operate to match the incoming flow. To do this, the pumps operate off level in the storage tank or wet well.

As water or wastewater level increases beyond a set point, the level control causes the pump to operate. If the level continues to rise to a second set point, a second pump starts, and so on. The pumps will effectively match the flow entering the station.

While in normal mode of operation, the valves controlling flow to each pump are placed in the fully-open position.

H. Alternate Pump Operation (MANUAL)

Both the water and wastewater pumps can be placed in the MANUAL mode of operation.

In the MANUAL mode, the pumps must be started and stopped manually, based on operator decision. Level control is not provided in the MANUAL mode of operation.

In this operating mode, the operator must be present at all times to monitor the liquid level, and to adjust the number of pumps on line as the need arises.

I. Emergency Operation

If an emergency condition develops at the facility that affects or is caused by one of the pumps, the following procedures must be carried out IMMEDIATELY to avoid flooding and to ensure continuous operation of the facility:

- Remove malfunctioning pumps from their "On-Line" positions. Start other pumps. This is automatically performed when the pumps are operating under the AUTO mode of operation, but conditions, at times, may require the operator to adjust the order of pump-start by manually changing the mode of operation at the Pump Control Panel.

- Should a malfunction occur within the pumping system control panel, the operator must take over MANUAL control of the pumping system until the control panel malfunction has been corrected.

J. Equipment Exercising

To ensure that each pump receives the same amount of usage and to ensure that the pumps are well maintained and operable at all times, the pump operating sequence should be changed periodically. This is accomplished at the Pump Control Panel by selecting the pump operating sequence.

K. Level Controls

The pumping systems use a level control system using mercury float switches and constant- speed pumps to vary the flow rate and maintain a relatively constant liquid level in the storage tank or wet well.

The major components of the Level Control System are:

- Mercury float and switch assemblies
- Pump discharge pressure transmitter and pump discharge flow meter
- Constant-speed pump controllers

The following sections describe operation of the individual pumping system components.

Mercury Float and Switch Measurement The wet well level is controlled by a series of mercury floats and switches hung at different levels within the wet well. These switches turn on pumps as a rising wet well level reaches each switch. As the pumped flow begins to exceed the flow of the incoming water or wastewater, the wet well level begins to drop. As the water level drops below a mercury switch, the switch will cause a pump to shut down. As the level continues to drop, the

next switch is reached; another pump is shut down, and so on. When the level begins to rise again, the cycle is repeated.
The operation of the mercury switches should be checked periodically; these systems are very reliable and require little maintenance.

Pump Discharge Pressure and Flow: The pump discharge pressure transmitter is located on the common pipeline before it leaves the station. The pressure transmitter measures water transmission line or wastewater force main discharge pressure and transmits an electrical signal to the pump control panel which is proportional to discharge pressure.

There are also individual discharge pressure gauges on each pump. The pressure gauge readings can be compared with the pressure transmitter indicator.

Each main pump discharge line is equipped with a flow meter that measures total pumped flow.

TROUBLESHOOTING GUIDE PUMPS

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
1. Pump does not pump liquid at required delivery rate	1a. Pump not properly primed 1b. Impeller defective 1c. Obstruction in pump 1d. Suction and/or discharge line plugged/blocked	1a. Shut pump down, check water level in pump 1b. Shut pump down, check impeller 1c. Shut pump down, inspect inside pump 1d. Shut pump down, inspect suction and discharge piping	1a. Re-prime pump 1b. Replace, if found damaged or worn 1c. Remove obstruction 1d. Remove obstructions
2. Pump loses prime after starting	2a. Leak in suction line 2b. Pump and/or suction pipe not completely filled with liquid or has air pockets	2a. Inspect suction piping/joints 2b. Shut pump down, inspect inside pump & piping	2a. Replace gaskets, tighten bolts, replace defective piping 2b. Open air release valve and re-prime pump
3. Pump draws excessive electrical power	3a. Motor speed too high 3b. Obstruction in pump 3c. Distorted pump casing 3d. Mechanical failure of critical parts 3e. Packing improperly installed	3a. Shut pump down, check speed 3b. Shut pump down, inspect pump 3c. Shut pump down, inspect alignment 3d. Shut pump down, inspect pump 3e. Shut pump down, inspect packing	3a. Consult manufacturer 3b. Remove obstructions 3c. Replace damaged or misaligned parts 3d. Replace damaged or misaligned parts 3e. Remove and install new packing

TROUBLESHOOTING GUIDE PUMPS

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
4. Pump vibrates and produces excessive noise	4a. Pump or suction piping not completely filled with liquid	4a. Shut pump down; inspect pump and piping	4a. Open air release valve and re-prime pump. Bleed off all air.
	4b. Pump operating at very low end of pumping range	4b. Check amperage at Motor Control Center	4b. Consult manufacturer
	4c. Obstruction in pump	4c. Shut pump down; inspect pump	4c. Dismantle pump; remove obstructions
	4d. Bearings worn	4d. Check bearings	4d. Replace, if necessary
	4e. Impeller damaged	4e. Inspect impeller	4e. Replace if vanes are worn or damaged
	4f. Shafting out of alignment	4f. Shut pump down; inspect pump, bearings, impeller, etc.	4f. Refer to SHAFTING Troubleshooting Guide
	4g. Mechanical failure of critical pump parts		4g. Replace all damaged components

TROUBLESHOOTING GUIDE PUMPS

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
5. Pump overheats and/or seizes up	5a. Pump looses prime	5a. Shut down pump; check for air leaks	5a. Repair air leaks; re-prime pump
	5b. Pump operating at very low capacity	5b. Shut down pump; check MCC	5b. Consult with manufacturer
	5c. Rotating part rubbing against stationary part of pump	5c. Shut down pump; check pump	5c. Adjust/realign parts as necessary
	5d. Bearings worn	5d. Check bearings	5d. Replace, if necessary
	5e. Impeller damaged	5e. Inspect impeller	5e. Replace if vanes are worn or damaged
	5f. Shafting out of alignment	5f. Shut pump down; inspect pump, bearings, impeller, etc.	5f. Refer to SHAFTING Troubleshooting Guide
	5g. Mechanical failure of critical pump parts		5g. Replace all damaged components
6. Stuffing box leaks excessively	6a. Seal cage improperly located in stuffing box preventing sealing water from forming a seal	6a. Check placement of seal cage	6a. Remove and replace in proper location
	6b. Packing improperly installed	6b. Check packing seal	6b. Remove and install new packing
	6c. Shaft or shaft sleeves worn or scored at packing	6c. Check shaft and shaft sleeves	6c. Replace if necessary
	6d. Shaft running off-center due to worn bearings or mis-alignment	6d. Check shaft alignment and condition of bearings	6d. Re-align shaft and replace bearings if necessary

TROUBLESHOOTING GUIDE PUMP SHAFTS

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
1. Bearing failure	1a. Universal joints not lubricated or improperly lubricated before startup	1a. Examine joints	1a. Replace joints if questionable
	1b. Improper maintenance schedule	1b. Check for proper lubrication	1b. Lubricate according to manufacturer's recommendations
	1c. U-joint coupling under-specified	1c. Check for proper sizing	1c. Replace U-joint coupling if necessary
	1d. Brinelled cross (needle bearing indentations)	1d. Inspect lubrication	1d. Replace joint
2. Drive shaft twisted	2a. Torque overload or tight universal joints; U-joint coupling	2a. Inspect U-joints coupling	2a. Replace U-joints coupling
	2b. U-joint coupling undersized	2b. Verify proper sizing with manufacturer	2b. Consult manufacturer; have them replace U-joint
	2c. Resonance failure at critical speed	2c. Shut down pump and motor	2c. Consult manufacturer
3. Flange slipping off shaft	3a. Set screw tightened improperly	3a. Check set screw	3a. Tighten as necessary
	3b. Weight limitation exceeded for stock bored flanges	3b. Check set screw	3b. Add additional set screw or
	3c. Shaft diameter undersized	3c. Check set screw	3c. Replace set screw with interference fit bore flange/locking collar

TROUBLESHOOTING GUIDE PUMP SHAFTS

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
4. Unusual / excessive vibration	4a. Operating too close to "critical" or "half-critical" speed resonance	4a - 4j. Shut down and inspect	4a. Contact manufacturer; change speed, change tube sizing
	4b. Operating at forcing frequency exciting another component		4b. Contact shafting manufacturer
	4c. Non-rigid floors/unsteady bearing supports		4c. Contact manufacturer to reinforce and/or perform structural analyses
	4d. Driver/driven components out of balance		4d. Contact shafting manufacturer
	4e. Bent shafting		4e. Shafting must be returned to manufacturer
	4f. Pump noise		4f. Contact shafting manufacturer
			4g. Disassemble and align yoke
	4g. Ears not in phase		4h. Check for burrs or grit and reseat
	4h. Flange faces not seated		4i. Contact shafting manufacturer
	4i. Operating speed with torsional vibration mode		4j. Align and adjust; shim as necessary
	4j. Drive and drive shafts/companion flange not parallel to with 1 degree		

TROUBLESHOOTING GUIDE PUMP SHAFTS (Continued)

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
4. (Continued) Unusual/excessive vibration	4k. Driver and driven shaft runout	4k. Shut-down and inspect	4k. Contact shafting manufacturer
	4l. Flange face or pilot runout exceeding 0.005 inches	4l. Shut down and check fit	4l. Contact shafting manufacturer
	4m. Steady bearing inner face not secured to shafting	4m. Shut down and check set screw	4m. Tighten set screw
	4n. Steady bearing not self-aligning	4n. Shut down and inspect	4n. Replace bearing
	4o. Bearings elsewhere in system failed	4o. Shut down and inspect	4o. Contact shafting manufacturer
	4p. Maximum joint acceleration exceeded	4p. Shut down and inspect	4p. Reduce angle and/or speed
	4q. Universal joint dry or brinelled	4q. Shut down and inspect	4q. Replace damaged parts
	4r. System resonance/vibration	4r. Shut down	4r. Contact shafting manufacturer
	4s. Excessive radial movement at the slip yoke or binding movement	4s. Shut down	4s. Contact shafting manufacturer
	4t. Companion flange or other U-joint fastener loose	4t. Shut down and inspect	4t. Secure/tighten fastener