US Army Corps
of Engineers
Afghanistan Engineer District

AED Design Requirements:
Package Waste Water Treatment Plants and Lagoons (Provisional)

Various Locations,
Afghanistan

September 2009 Version 1.2

TABLE OF CONTENTS

AED DESIGN REQUIREMENTS
FOR
PACKAGE PLANT
VARIOUS LOCATIONS,
AFGHANISTAN

Figure

Appendices

1. General

The purpose of this document is to provide wastewater treatment plant (WWTP) design requirements to Contractors for projects at medium-sized installations. It is a summary of requirements that should be provided in design submittals. References contained herein provide more specific design procedures and examples. Medium-sized installations are considered those requiring the design and construction of package plant for wastewater treatment for average daily waste water flow rates of between 60 cubic meter/day (15,000 gpd) and 378 cubic meter/day (100,000 gpd). Projects at small-sized installation with projected wastewater flows smaller than this range should be evaluated for onsite treatment systems such as septic/leach field disposal or self-contained lagoon systems. Septic and leach field systems are discussed in the USACE-AED Design Requirements Sanitary Sewer and Septic Tank System, 2009.

The contractor's design and construction shall comply with technical requirements contained herein. WWTP design involves several engineering disciplines including civil, mechanical, electrical and structural engineering. The designer shall have a minimum of 5 years experience with the design and construction of pre-engineered package wastewater treatment plants of the same magnitude and complexity as required in this project. The designer shall be responsible for providing (as demonstrated in shop submittals, Section 8) project experience in all the specialized disciplines and possess knowledge of the construction of package wastewater treatment plants as well as construction and industry standards for wastewater treatment plants.

2. Package Waste Water Plant

Treatment systems handling less than 378 cubic meters per day (100,000 gpd) are generally considered small package WWTP systems. For some packaged treatment systems, the principles of design are no different than larger plants with customized design but the choice of equipment will usually differ from that used in large plants. In addition, the level of redundancy for process components, and the types of containment systems may be dramatically different because package systems are pre-engineered and components may be constructed offsite. Packaged WWTPs must use larger safety factors for flow variation, altitude and temperature effects relative to total wastewater flows, and the lack of daily maintenance. Package WWTPs inherently have less operational flexibility; however, they are nonetheless capable of performing effectively and economically. Complete WWTPs can be obtained from various manufacturers. Some prefabricated plants may be capable of being relocated, depending on size and original construction. Most of these units are factory fabricated and shipped as complete units, ready for connections to piping and power. Small physical-chemical units have been developed as “add on" units to existing facilities to provide additional treatment efficiency. Shop submittals of package WWTP systems are a contract requirement.

Package plants are appropriate for forward operating bases (FOB) or small permanent installations such as ANP or ANA garrisons. These systems are designed to generally treat between 57,000 L/d (15,000 gpd) and 378,500 L/d (100,000 gpd), however larger capacities can be considered on a case by case basis. For MILCON projects beyond this flow range, the treatment processes used in the package WWTP may require HQDA (CEEC-EB) approval for Army projects and HQ USAF/LEEE approval for Air Force projects, with complete documentation and information to support the requested waiver. The wastewater treatment plant should be designed to achieve effluent quality standards as set forth in reference 1, unless superseded by subsequent host nation environmental guidance. In addition, the plant must be capable of being operated by few (no more than three) operating personnel, capable of being by-passed during operational failures, need a minimum of energy to provide treatment such that the plant can operate using standby power generation for a period of 48-hours. If the package plant design is supplementing the capacity of existing plants, criteria contained herein regarding flows and wastewater characteristics may be modified to conform to existing plant performance data provided the plant has been in operation long enough to have established that it is meeting effluent quality standards.

3. Site Selection

The major factors in the selection of suitable sites for treatment facilities include the following:

- Topography
- Availability of a suitable effluent discharge point
- Access to the plant for construction, operation, and maintenance
- Availability and acceptable location of sludge drying and disposal facilities
- Minimum separation distance between the wastewater plant and living quarters, dining facilities, and water wells of 30 meters
- Site locations shall be selected such that the WWTP is fully operational and functional during a 25-year flood.

The siting criteria for the package plant should consider protection requirements for drinking water sources. Sufficient space must be allocated not only for suitable arrangement of the initial units and associated plant piping but also to accommodate future expansion. The site will be selected so that an all-weather road is available or can be provided for access to the plant.

4. Treatment Requirements

Package WWTP for USACE-AED projects will generally be designed to provide secondary treatment consistent with the effluent quality requirements in reference 1. However other levels of treatment may be required depending upon the characteristics of the waste water. *Preliminary* treatment is defined as any physical or chemical process at the wastewater treatment plant that precedes primary treatment. Its function is mainly to protect subsequent treatment units and to minimize operational problems. *Primary* treatment is defined as physical or, at times, chemical treatment for the removal of settleable and floatable materials. *Secondary* wastewater treatment is defined as processes which use biological and, at times, chemical treatment to accomplish substantial removal of dissolved organics and colloidal materials that degrade receiving water and impair its use for other beneficial purposes. Disinfection of waste water to inactivate harmful microorganisms is considered a process that can be used in conjunction with both primary and secondary treatment processes. *Advanced* wastewater treatment is defined as that required to achieve pollutant reductions by methods other than those used in secondary and primary treatment (sedimentation, activated sludge, trickling filter, etc.). Before treatment plant design is begun, treatment requirements will be determined on the basis of meeting stream and effluent requirements.

Pretreatment of pollutants which may interfere with operation of a sewage treatment plant or pass through such a plant untreated may be required. Additionally, in many cases, pretreatment of industrial or maintenance facilities wastewater such as laundry waste water and water desalination treatment plant brine and back wash will be necessary to prevent adverse effects on the sewage treatment plant processes. Some types of industrial waste may be admitted to wastewater treatment plants, e.g., cooling tower discharges, boiler blowdown, vehicle washrack wastewater, swimming pool filter discharges, and aircraft wash wastes using biodegradable detergents. Flow of industrial wastewater may be reduced through process modification or wastewater recirculation. Adverse impacts on the treatment plant can be mitigated by reducing the concentration of those compounds such as bleach or disinfectants causing the problem. Table 1 is a listing of compounds which inhibit biological treatment processes. In some cases, the adverse impact may be caused by short-lived occurrences of either wastewater containing high concentrations of compounds or a wastewater flow rate much higher than the average daily flow. This situation, which is commonly called “slugs,” may, in some cases, be managed by including an equalization basin upstream of the treatment plant.

Advanced treatment employs a number of different unit operations, including ponds, post-aeration, microstraining, filtration, carbon adsorption, membrane solids separation, and specific treatment processes such as phosphorus and nitrogen removal. Advanced wastewater treatment is capable of very high effectiveness and is used when necessary to meet strict effluent standards. Organics and suspended solids removal of over 90 percent is obtainable using various combinations of conventional and advanced wastewater treatment processes. Phosphorus levels of less than 1 milligram per liter and total nitrogen levels of 5.0 milligrams per liter or less can also be reached through advanced treatment.

Table 1. Materials Which Inhibit Biological Treatment Processes

Pollutant	Inhibiting or Toxic Concentration[1] mg/L		
	Aerobic Processes	Anaerobic Digestion	Nitrification
Copper	1.0	1.0	0.5
Zinc	5.0	5.0	0.5
Chromium (Hexavalent)	2.0	5.0	2.0
Chromium (Trivalent)	2.0	2,000[2]	*
Total Chromium	5.0	5.0	*
Nickel	1.0	2.0	0.5
Lead	0.1	*	0.5
Boron	1.0	*	*
Cadmium	*	0.02[2]	*
Silver	0.03	*	*
Vanadium	10	*	*
Sulfides (S^{-})	*	100[2]	*
Sulfates (SO_4^{-})	*	500	*
Ammonia	*	1,500[2]	*
Sodium (Ma^{+})	*	3,500	*
Potassium (K^{+})	*	2,500	*
Calcium (Ca^{++})	*	2,500	*
Magnesium (Mg^{++})	*	1,000	*
Acrylonitrite	*	5.0[2]	*
Benzene	*	50	*
Carbon Tetrachloride	*	10[2]	*
Chloroform	18.0	0.1[2]	*
Methylene Chloride	*	1.0	*
Pentachlorophenol	*	0.4	*
1, 1, 1 Trichloroethan	*	1.0[2]	*
Trichlorofluormethane	*	0.7	*
Trichlorofluorethane	*	5.0[2]	*
Cyanide (HCN)	*	1.0	2.0
Total Oil (Petroleum origin)[3]	50	50	50

* Insufficient data available to determine effect.

[1] Raw wastewater concentration unless otherwise indicated.

[2] Digester influent concentration only; lower values may be required for protection of other treatment processes as noted above under aerobic and nitrification processes.

[3] Petroleum–based oil concentration measured by API Method 733–58 for determining volatile and non–volatile oily materials. (The inhibitory level does not apply to animal or vegetable oil.)

5. Basic Design Considerations

The required treatment processes are determined by the influent characteristics, the effluent requirements, and the treatment processes that produce an acceptable effluent. Influent characteristics are best determined by laboratory testing of samples from an existing waste stream or from a similar waste stream; but they may be predicted on the basis of standard waste streams as stated in the contract technical requirements. Treatment capacity is based on the design population, effective multiplied by a Capacity Factor) which is a projected population obtained by analysis, per capita loading rates and other industrial or operational waste water loads. The effective population and per capita loading rates are given for each project in the contract technical requirements. The design population is determined by adding the total resident and 1/3 the non-resident populations and multiplying by the appropriate capacity factor taken from table 2 which allows for variations in the using population.

Table 2. Capacity Factors

Effective Population	Capacity Factor
under 5,000	1.50
5,000	1.50
10,000	1.25
20,000	1.15
30,000	1.10
40,000	1.05
50,000	1.00

The rates of sewage flow vary widely throughout the day. The design of process elements in a sewage treatment plant is based on the average daily flow. Transmission elements, such as conduits, siphons and distributor mechanisms, will be designed on the basis of an expected peak flow rate of two times the average rate or the peak hourly rate for a specific process or conveyance component given in Reference 3. For example secondary clarifiers will be designed for a peak hourly flow rate (i.e., 1.75 times the average daily rate). Consideration of the minimum rate of flow is necessary in the design of certain elements, such as grit chambers, measuring devices and dosing equipment; for this purpose, 40 percent of the average flow rate will be used. The average daily wastewater flow to be used in the design of new treatment plants will be computed by multiplying the design population by the per capita rates of flow. Unless already provided in the contract technical requirements, per capita wastewater flows can be determined from Table 3, and then adjusting for such factors as industrial wastewater flow and infiltration. Where shift personnel are engaged, the flow will be computed for the shift when most of the people are working. A check on sewage volumes could be to compare water consumption to the sewage estimate (neglecting infiltration, which will be considered subsequently). About 60 to 80 percent of the consumed water will reappear as sewage, the other 20-40 percent being lost to irrigation, wash-down, and points of use not connected to the sewer. If existing flow data are not available the wastewater flow fraction of water use shall be considered 80 percent.

Table 3. Per Capita Sewage Flows (1)

Installation	Per capita, liters/day (gal/day) (2)
U.S. bases	152 (40)
ANA/ANP and other host nation	125 (33)

Notes:
(1) Wastewater per capita rates in contract technical requirements shall take precedence over these values
(2) AED per capita sewage flows are defined as 80% of the per capita water allowance. For example the ANP and ANA per capita water allowance is 155 lpcd (41 gpcd). 80% of this number is reflected in Table 3 above as the per capita sewage flow.

If an existing wastewater stream exists at the project site, the wastewater at existing facilities will be analyzed to determine the characteristics and constituents as required. Analytical methods will be as given in Reference 2. For treatment facilities at new installations which will not generate any unusual waste, the characteristics shall shown in Table 4 unless specifically stated otherwise in the contract technical requirements or as determine by influent sampling and testing using Standard Methods (Reference 2).

Table 4. Assumed Wastewater Influent Characteristics Flows

Parameter	Concentration, mg/l unless noted
pH	7 to 7.5 (standard units)
temperature	20 to 22 degrees celsius
BOD_5	400[1]
Total suspended solids	400
Total nitrogen	80
Ammonia nitrogen	15
Oils and grease	100
Phosphorous	15
Chloride	100
Hardness	200

Notes: BOD_5 shall be the greater number based on 400 mg/l or based on 0.09 kg/capita-day (0.2 lb/capita-day)

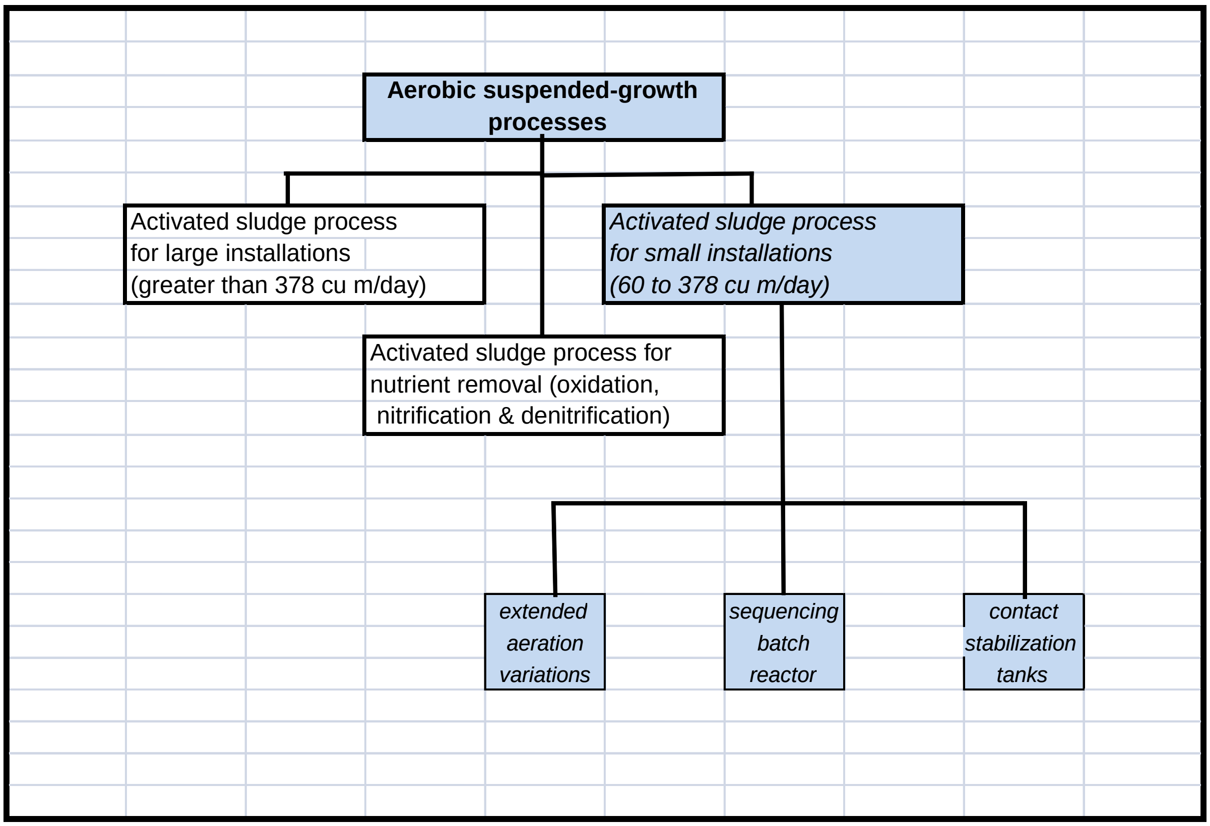
Concentrations are presented above in milligrams per liter; which is equivalent to parts per million (ppm). These values represent an average waste and therefore should be used only where detailed analysis is not available. When the water supply analysis for the installation is known, the above analysis will be modified to reflect the normal changes to constituents in water as it arrives at the wastewater treatment plant. Industrial waste loadings can also be characterized to a large extent by normal sewage parameters. However; industrial waste contains contaminants not generally found in domestic sewage and is more variable than domestic sewage in terms of pH, biochemical oxygen demand, chemical oxygen demand, oil and grease, and suspended solids. Each industrial wastewater must be characterized individually to determine any and all effects of treatment processes.

6. Selection of Treatment Process

Packaged WWTPs combine the different levels of treatment described in the previous section into a single treatment train. The secondary treatment process in the treatment train may consist of trickling filter plants, rotating biological discs, membrane bioreactors, physical-chemical technology, or an aerobic suspended growth (activated sludge) biological treatment process. Physical-chemical systems also have the flexibility to operate in an on-off mode which is not possible with biological systems. However, they are often costly to operate, require skilled attention, and produce large amounts of sludge and are not the preferred treatment type of USACE-AED projects which often require training of Afghan nationals for the operation and maintenance in remote locations. Membrane bioreactors (MBR) which are now common in the U.S. at small package WWTP installations, use low pressure micro or ultra filtration membranes and eliminate the need for secondary clarification and filtration. The membranes are usually suspended in an aerated tank. The main advantage of MBRs is that they overcome the poor settling of sludge that can occur in convention activated sludge processes.

Pre-engineered package WWTP's used at USACE-AED projects are predominantly aerobic suspended growth (activated sludge) biological treatment processes. Although many variations of the activated sludge process exist, the three which have been most successful for USACE-AED projects are extended aeration, sequencing batch reactor and contact stabilization plants. Figure 1 lists processes applicable to USACE-AED projects including the three named previously.

Figure 1 Classification Sketch of Activated Sludge Variations



Large WWTPs for installations that anticipate average daily flow greater than 378 cubic meter/day (100,000 gpd) are better suited to complete mix or plug flow activated sludge processes that are only considered to be subsets of the activated sludge process on the left side of the above figure.

Table 5 describes the differences between the three types of activated sludge processes highlighted in Figure 1. Note variations of other activated sludge process may be selected for pre-engineered wastewater package plants but the highlighted variations have already been approved and provided successful operation at USACE-AED projects.

Table 5. Description of Activated Sludge Processes for Use at Medium-Size Installations

Process	Description
Extended aeration	A plug flow process that operates for a relatively longer aeration time at lower loading rates resulting in the biochemical degradation of the organic matter as well as d the heterotrophic bacteria in the reaction. Hydraulic residence times are typically 18 to 36 hours and biological loading rates are 64 to 190 kg BOD_5/m^3-day (5 to 15 lb BOD_5 / 10^3- ft^3-day).
Sequencing batch reactor	A fill and draw type biological reactor involving one or two complete mix reactors in which all the steps of the activated sludge process occurs. A separate secondary sedimentation tank is not required, but typically two reactors are required for sequencing. Hydraulic residence times are typically 12 to 50 hours and biological loading rates are 64 to 190 kg BOD_5/m^3-day (5 to 15 lb BOD_5 / 10^3- ft^3-day).
Contact stabilization	Two tanks or compartments are used to mix the influent with the activated sludge; during treatment, the mixed liquid is settled in a secondary settling tank and return sludge is aerated in a separate reaeration basin to stabilize organic matter. Hydraulic residence times are typically 4 to 8 hours and biological loading rates are 765 to 950 kg BOD_5/m^3-day (60 to 75 lb BOD_5 / 10^3- ft^3-day).

Design procedures for these processes are contained in references 4 and 5. The designer shall consider the affect of high temperature and elevation at the project in the calculation of aeration requirement for secondary treatment and accordingly size the air diffusers blowers or mechanical mixers with adequate size motors for the project site conditions.

A typical system consists of the following components.

- Influent manhole that receives and conveys raw wastewater flows to a lift station or headwork where there the wastewater receives comminution and hydraulic energy potential needed to transport the flow through the entire plant (except as provided by recirculation pumps)
- Headwork to provide coarse screening, primary sedimentation and flow measurement
- Flow equalization to store peak flows and recycled activated sludge
- Aeration basin with air diffusers or mechanical aerators with return activated sludge pump capability
- Secondary sedimentation including waste sludge collection and pumping to sludge drying facility
- Sludge drying beds
- Chorine contact chamber for effluent disinfection
- Effluent gravity or pumping system to convey the effluent flow to the proposed outfall location at the receiving surface water point
- Emergency bypass pipe and valve system

Package WWTP systems need to provide safety factors such as equalization basins, generous loading capacity and aeration capacity, and emergency bypass provisions because they do not have the parallel trains required in Reference 3 for permanent WWTP facilities. Parallel components may be required depending upon the size of the package WWTP and the safety factors used in design.

The basis of design for the package WWTP shall be completely documented using the submittal process. Submittal can be through the project design submittal process or using ENG FORM 4025, Transmittal of Shop Drawings, Equipment Data, Material, Samples, or Manufacturer's Certificates of Compliance, however 100% final design submittal shall include all submittal information to provide a single set of documents for future reference. Section 8 describes the submittal requirements.

The major design and operational issues that affect package plants are summarized in Table 6. The design shall provide explanations of how these issues will be mitigated by the proposed system.

Table 6. Types of Design and Operational Issues at Package WWTP

Issue	Discussion
Hydraulic shock loads	Provide equalization tank
Large fluctuations in BOD loading	Provide equalization tank and pump equipment necessary for recirculation
Small flows that are do not self clean conduits and channels	Provide adequate water service to allow washing channels and lift stations
Positive sludge return provisions that allow an extended aeration system to meet all normal requirements	Pump capacity for recirculation ratio of up to 3:1
Adequate provisions for scum or froth and grease removal from the secondary clarifier	Provide scum collection facilities and pumping equipment to return the scum and froth to the equalization tank
Denitrification in final clarifier that results in solids discharge in the effluent	Overflow rates limited to 24 to 33 m^3/m^2 – day 600 to 800 gal/ft^2 – day
Adequate removal and storage of waste sludge	Provide holding tank for sludge storage (may be combined with equalization)
Provision to adjust to large and rapid temperature changes	Size aeration facilities for expected high temperature at project site using site climatic data given in mechanical section of RFP technical requirements
Adequate air supply rate	Adjust air supply rate for altitude and temperature extremes anticipated at project site using site climatic data given in mechanical section of RFP technical requirements

The performance of most package WWTPs can be improved by sizing facilities with using conservative design parameters and providing sufficient storage for handling side stream flows.

7. Lagoon Treatment Systems

Lagoon wastewater systems are earthen basins that are engineered for BOD and total suspended solids removal similar to package WWTPs; however, they are sized such that the biological loading rate is lower than traditional aerobic suspended growth processes such as in pre-engineered package WWTP plants. In addition BOD is removed by sedimentation. These systems are capable of providing effluent quality that meets the technical requirements, however, they are affected by climate conditions and shock loading and require conservative design factors. They provide significant removal of pathogens as a result of natural die-off, sedimentation, and adsorption.

The design requirements include embankment design, impermeable layer or liner design, erosion control design both for the embankment and outlet features, and hydraulic design for pipe lines and lift stations (if needed). These design requirements are considered in other design guides and Unified Facility Criteria (UFC). The information presented in this section demonstrates the type of design information required for project submittal of WWTPs involving lagoons. The information may need to be expanded or adapted for the specific project site.

Two types of lagoons are applicable to USACE-AED projects that are described in Table 7.

Table 7. Description of Lagoon Treatment Systems for Use at Medium-Size Installations

Type of lagoon	Description
Facultative	The surface zone is aerobic as a result of wind shear mixing, but the subsurface zone may be anaerobic or even anoxic. Hydraulic residence times are typically 25 to 180 days and biological loading rates are 64 to 190 kg BOD_5/cu m-day (20 to 60 lb BOD_5 / ac-day). Hydraulic depths are typically 1.5 to 2 meters.
Aerated Partial-Mix	Surface aeration using mechanical equipment produces a surface aerobic zone that ranges in depth depending upon the amount and efficiency of oxygen transferred and the lagoon depth Hydraulic residence times are typically 5 to 20 days and biological loading rates are 64 to 190 kg BOD_5/cu m-day (5 to 15 lb BOD_5 / 10^3- ft^3-day). Hydraulic depths are typically 3 to 5 meters.

The principal advantage of aerated lagoons is that they require less land area and because they are smaller they may be more economical considering lining and covers. They are more expensive to construct and operate and maintain, and the construction of liners that do not fail and are capable of enduring the weight of maintenance vehicles requires more experience. Liner design is a specialized engineering topic and not discussed in this design guide.

The principle design concept for facultative lagoons is to provide sufficient detention time and low organic loading that the surface layer of the lagoon remains aerobic. However these lagoons are subject to wind mixing and thermal turnover at times of the year that can create odors.

Pretreatment of influent for lagoons shall be designed to minimize floatables, scum, and large objects from being transported in to the lagoons. Bar screens are used in combination with primary sedimentation to remove rags, large objects and grit.

Design procedures for facultative lagoons shall be based on area biological loading rates shown in Table 8.

Table 8. Area BOD_5 Design Loading of Facultative Lagoon Treatment Systems

Average winter temperature, ^{o}C	Kg/ha-day	Lb/ac-day
Greater than 15	45-90	40-80
0-15	22-45	20-40
Less than 0	11-22	10-20

Notes: Source – reference 6

Design procedures for aerated partial mix lagoons shall be based on hydraulic detention times shown calculated using the following equation:

t= (n/k)*((Co/Cn)^(1/n)-1)) Eq. 1

where t= hydraulic detention time, days
n= number of equal sized cells
k= BOD removal constant rate, per day
Co= influent BOD concentration to first cell in series, mg/l
Cn= effluent BOD concentration from cell n, mg/l

The BOD removal rate used in 0.276 day^{-1} based on reference 7. The rate constant is adjusted for the design temperature using the following equation:

k_2/k_{20}=theta^(T_2-T_{20}) Eq. 2

where k_2= BOD removal rate constant at T_2
k_{20}= BOD removal rate constant at T_{20}
T_{20}= 20^o C
T_2= average winter temperature ^{o} C

The lagoon area is calculated as the design flow multiplied by the hydraulic detention time divided by the hydraulic depth of the lagoons. In the example below, average winter temperatures were used in equation (2) to compute hydraulic detention times from equation (1) to size three lagoon systems, each containing "n" lagoons in sequence, in 3 locations at 4 different design flow rates. In every case the lagoon hydraulic depth is 3 meters. Results are provided in Table 9. The table shows the size for each lagoon for the number of cells shown in the left column.

Table 9. Partial-Mix Aerated Lagoon Treatment Systems

	DESIGN FLOW RATE, cubic meters/day											
	61			**120**			**340**			**680**		
	Lagoon size, hectare			Lagoon size, hectare			Lagoon size, hectare			Lagoon size, hectare		
number of cells, n	Kandahar	Kunduz	Kabul	Kandahar	Kunduz	Kabul	Kandahar	Kunduz	Kabul	Kandahar	Kunduz	Kabul
1	0.30	0.28	0.38	0.60	0.56	0.74	1.70	1.58	2.10	3.40	3.17	4.20
2	0.11	0.10	0.14	0.22	0.20	0.27	0.62	0.58	0.77	1.24	1.16	1.54
3	0.08	0.08	0.10	0.16	0.15	0.20	0.46	0.43	0.57	0.92	0.86	1.14

Notes: Basis of calculations shown in reference 6

Reference 6 provides the basis for the size calculations and can be used for sizing lagoons with various depths at other locations. Appendix A provides climate conditions for various locations in Afghanistan. Aeration system shall be designed for the maximum summer temperatures at the altitude of the project region.

Aeration requirements partial-mix lagoons can be met by floating mechanical aerators. The key to successful aeration is to meet the oxygen demand of the wastewater and to apply the aeration in the upper portion allowing the lower portion to remain quiescent to enhance sedimentation and anaerobic decomposition.

The oxygen transfer rate at standard temperature (20^o C) and one atmosphere pressure can be calculated from the following equation

$$SOTR = AOTR/[(beta*Cs_{TH}-C_L)/C_{s20})]*(1.024^{\wedge(T-20)})*alpha \qquad \text{Eq. 3}$$

Where AOTR = actual oxygen transfer rate required under field conditions, kg/h
SOTR = standard oxygen transfer rate at 20^o C standard conditions, kg/h
beta = salinity-surface tension correction factor, assumed = 0.95
Cs_{TH} = dissolved oxygen saturation concentration in clean water at temperature T and altitude H
C_L = operating dissolved oxygen concentration, typically 2 mg/L
C_{S20} = dissolved oxygen saturation concentration in clean water at 20^o C shown in Appendix B
T = wastewater temperature, ^{o} C
H = altitude, meter
alpha = oxygen transfer correction factor for wastewater, typically 0.6 (unit-less)

Mechanical aeration shall be designed for the average high summer temperature and the project site altitude. Appendix A provides outside climate conditions and altitude information at various locations in Afghanistan. Higher temperatures and altitudes increase the mechanical energy required for oxygen transfer because of the lower oxygen solubility at higher temperature and lower oxygen content of less dense air (at higher altitudes). Table 10 presents three examples of the type of information required for aerated lagoon design submittals.

Table 10. Partial-Mix Aerated Lagoon Aeration Requirements

Field condition - project	Kandahar	Kunduz	Kabul
elevation, m	1010	432	1790
elevation, ft	3314	1417	5876
summer high, o C	41	39	34
summer high, o F	106	102	93
AOTR, kg/day	730	720	760
SOTR, kg/day	2200	2000	2260
total aerator, kw	48	43	49
CsTH, mg/l	5.7	6.2	5.6

Mechanical aerators are rated in terms of their standard oxygen transfer rate (SOTR) at standard conditions of temperature and pressure. This rate shall be estimated by using Eq.3 adjusting the AOTR for field conditions at the project site.

8. System Submittals

All of the information about the design process and plant selection should be included within the design for review by USACE-AED. Package WWTP shop submittals by the contractor shall include the following:

1. Wastewater treatment plant site plan. The plan shall identify required setbacks, buried utilities (other than sewer) and potential points of connection to the existing electrical distribution system (existing on the compound). The set back requirements for the wastewater treatment plant site shown on a drawing to identify the buildable footprint. Setback requirements shall be obtained from applicable technical criteria listed in Section 01015.
2. Prepare a summary of basis of design report to include the following
   Design average daily loading for the wastewater treatment plant based on the design

equivalent population (See Section 01010) to be used as the basis for wastewater loading. Provide the design peak hourly flow rates for the lift station and head works of the plant. The anticipated waste loading in terms of biochemical oxygen demand (BOD_5) and total suspended solids (TSS) loading shall be shown for the plant based on wastewater characteristics in the Section 01015.

3. Prepare a treatment train diagram that includes process modules: lift station pumping and flow metering, headwork processes (e.g. grit, trash and scum removal), equalization chamber, primary treatment processes (e.g. sedimentation and aeration), secondary treatment process including aeration and secondary clarification, sludge and scum recirculation systems, effluent chlorination and outfall system, sludge holding/digestion and disposal. All process component tankage shall be above ground steel tank. The biological treatment process shall be activated sludge with extended aeration. The general dimensions of each module shall be specified based on the design capacity requirements of each module shall be shown. The lift station pumps, wet well, hatches, and pump controls, inlet bar screen, distribution weirs and pipe sizes, pump capacity and power requirements, the aeration equipment (diffusers, piping, and blower), and froth control equipment requirements shall be stated. Actual oxygen transfer rates used in the sizing of aeration equipment based on site elevation and high summer temperature range shall be shown. Return ratio ranges for sludge recirculation shall be estimated. Provide pipe and pump capacities on sludge recycling and wasting and calculated sludge storage and disposal volumes required. Show all emergency bypass piping and valve locations.
4. Provide catalogue information for the proposed lift station and treatment plant equipment. Include information on manufactured steel tanks. Information shall include material standards for field welding of tanks, piping, valves, pumps, pump control equipment, bolts, gaskets, electrical enclosures, central systems control panels, motors and generators, aerators, air piping, blowers, bar screens, handrails, access ladders and service walkway gratings. Provide an access ladder anti-climb gate a minimum of 4 feet above the ladder base to secure the plan from unauthorized entry. Include product coating and lining, and cathodic protection specifications for applicable equipment.
5. Electrical feeds to the waste water treatment plant shall be sized to limit the voltage drop to a total of 5% from the separately derived electrical system to the piece of equipment that is being powered. All breakers, cables and equipment shall be installed and sized in accordance with the latest edition of the National Electrical Code. A layout plan of all the electrical equipment that includes location of the motor control centers, pumps, panels and grounding shall be submitted. The contractors shall also submit panel schedules, motor control center (MCC) layout (with MCC equipment sizes), cable sizes, and electrical equipment sizes and ratings. The contractor shall provide all calculations to show how the equipment was sized.
6. An evaluation of the sludge disposal options and recommendation of the preferred disposal option. The proposed sludge disposal equipment/process requirements shall be shown on a plan drawing.
7. Complete the checklist shown in Table 11 summarizing design parameters, and reference to the drawings where the features are shown. Clearly show dimensions and numbers of each component.

Table 11. Summary of WWTP Design Parameters to be Included in Submittal

Parameter	Design Value	Units	Source or Equation[1] (with supporting calculations shown)	Construction Drawing and Catalogue Reference Number
Average daily flow (ADF)		m^3/d		
Peak hour flow (PHF)		m^3/hr		
Equalization storage volume [7]		m^3		
Biological loading (BOD_5) [2]		kg BOD_5 /day		
Primary Reactor Volumetric organic loading rate, $L_{organic}$		kg/ BOD_5 /10^3 m^3 –day [3]		
Mixed Liquor Suspended Solids (MLSS)		mg/L		
Food:Microorganism Mass (FM) ratio		kg BOD_5 /MLVSS-day		
Site conditions; high and low temperature range; altitude (see section 01015)				
Mechanical aerator or differ system actual oxygen transfer rate (AOTR) under field conditions temperature and atmospheric pressure (altitude) at project site		kg O_2 /h		
Standard oxygen transfer rate (SOTR) under standard pressure and temperature conditions per manufacturer[4]		kg O_2 /h		
Number and power requirements of each aerator or diffuser blower system for each treatment unit (indicate standby units)		kW/number		
Estimate of annual energy required based on ADF		kWh		
Secondary clarifier overflow rate		m^3/ m^2 -day		
Disinfection chamber volumetric hydraulic residence time		minutes [5]		
Sludge storage volume		m^3		
Sludge drying bed loading rate (if applicable)		m^2/person-month [6]		
Effluent channel peak flow capacity		m^3/sec		
Panel schedules, motor control center (MCC) layout (with MCC equipment sizes), cable sizes, and electrical equipment sizes and ratings		varies		

Notes:
1. Documentation for sources shall cite name and date of standard, data collection, or if an equation, all parameter symbols shall be defined used in the equation
2. if process provides nitrogenous oxygen demand removal, include this loading
3. if other basis for reactor sizing is used such as mean cell residence time or F/M ratio provide, appropriate units
4. provide documentation from equipment manufacturer of aerator or diffuser system
5. minimum 30 minute contact time
6. only open beds are permitted
7. Equalization storage shall be adequate for flow variation over 24-hour period as shown in Appendix C

The lagoon system submittals shall include the additional following information in addition to Table 11 data:

1. Liner or impervious layer design for the pond including plan and elevation drawings showing liner/layer thickness, anchoring for synthetic line, side slope, liner/layer bedding preparation, pond cover layer protection, access route for equipment entry into pond for maintenance, synthetic layer specifications and details of pipe penetrations through liner/layer.
2. Mechanical aeration equipment design and specifications.
3. Size of conveyance channel or pipes and invert elevations at each pond.

All submittals shall include the WWTP proposed start-up testing and training program in including operation and maintenance manuals. When the wastewater system construction nears completion and all units are operative, the contractor shall commence a commissioning and startup procedure for the treatment system. The treatment system includes all lift stations, force main, gravity sewers, treatment plant units and associated equipment, sludge holding and digestion, septage dump pad, and laboratory building. The contractor will operate the treatment facility for a trial period of two months performing all daily and weekly operation and maintenance (O&M) tasks recommended by the equipment manufacturer. The contractor shall utilize services of qualified operators; including the use of at least two Afghan Nationals that the contractor shall train. During the routine O&M, the contractor shall perform all sampling and testing necessary to ensure proper daily operations in achieving the required effluent standards. The contractor shall maintain a log that includes records of daily O&M activities, e.g. repairs, inflow measurement, aeration cycles, effluent cycling, waste and return sludge pumping, and sludge drying. The contractor shall also maintain and operate the sludge disposal operation during the trial period.

Project submittal shall include markup UFGS specification 44 41 13 Prefabricated Biochemical Wastewater Treatment Plant. The specification paragraph 1.2.1 “Extended Aeration Plant Design” shall be changed to Activated Sludge Plant Design Type [extended aeration], [contact stabilization], [sequencing batch reactor]”. Strike out the inapplicable type. Appendix D contains a list of the specific strike-out topics to be edited by the designer.

9. As-Builts

Upon completion of installing the package wastewater treatment plant, the contractor shall submit editable CAD format As-Built drawings. The drawing shall show the final product as it was installed in the field, with the exact dimensions, locations, materials used and any other changes made to the original drawings. Refer to Contract Sections 01335 and 01780A of the specific project for additional details.

10. References

1. Overseas Environmental Baseline Guidance Document, Department of Defense, 2007
2. Standard Methods for the Examination of Water and Wastewater, American Public Health Association (APHA) publication, current edition.
3. UFC 3-240-09FA Domestic Wastewater Treatment, 2004
4. Small and Decentralized Wastewater Management Systems, Crites and Tchobanoglous, Metcalf & Eddy, McGraw- Hill, 1998
5. Wastewater Engineering Treatment and Reuse, Metcalf & Eddy, McGraw- Hill, 2003
6. US EPA. Municipal Wastewater Stabilization Ponds – Design Manual, EPA-625/1-83-015, 1983
7. Report of the Wastewater Committee of the Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers. Ten State Standards for Wastewater Facilities. 2004

Appendix A - Outside Design Climate Conditions

Bagram Area			**Darualaman Area**	
Latitude:	35.0 deg North		**Latitude:**	34.42 deg North
Longitude:	69.0 deg East		**Longitude:**	69.11 deg East
Elevation:	1490 M (4888 Ft)		**Elevation:**	1737 M (5700 Ft)
Summer Temp:	DB: 35^{o} C (95^{o} F)		**Summer Temp:**	DB: 34^{o} C (93^{o} F)
	WB: 18.6 ^{o}C (66 ^{o}F)			WB: 15.6 ^{o}C (60 ^{o}F)
Winter Temp:	-12.8 ^{o}C (9 ^{o}F)		**Winter Temp:**	-8 ^{o}C (18 ^{o}F)
Daily Range:	18.3 ^{o}C (33 ^{o}F)		**Daily Range:**	8 ^{o}C (15 ^{o}F)
Farah Area			**Gardez Area**	
Latitude:	32.22 deg North		**Latitude:**	33.6 deg North
Longitude:	62.11 deg East		**Longitude:**	69.22 deg East
Elevation:	700 M (2297 Ft)		**Elevation:**	1737 M (7710 Ft)
Summer Temp:	DB: 41.1^{o} C (106^{o} F)		**Summer Temp:**	DB: 29^{o} C (84^{o} F)
	WB: 22.5 ^{o}C (72.5 ^{o}F)			WB: 12.2 ^{o}C (54 ^{o}F)
Winter Temp:	1.6 ^{o}C (35 ^{o}F)		**Winter Temp:**	-10 ^{o}C (14 ^{o}F)
Daily Range:	unknown		**Daily Range:**	unknown
Ghanzni/Khair Kot Area			**Herat Area**	
Latitude:	33 deg North		**Latitude:**	34.22deg North
Longitude:	68 deg East		**Longitude:**	62.22 deg East
Elevation:	2183 M (7162 Ft)		**Elevation:**	964 M (3163 Ft)
Summer Temp:	DB: 30.5^{o} C (87^{o} F)		**Summer Temp:**	DB: 38^{o} C (100^{o} F)
	WB: 15.6 ^{o}C (60 ^{o}F)			WB: 20 ^{o}C (68 ^{o}F)
Winter Temp:	-7.2 ^{o}C (19 ^{o}F)		**Winter Temp:**	-6 ^{o}C (21 ^{o}F)
Daily Range:	unknown		**Daily Range:**	9 ^{o}C (17 ^{o}F)
Jalalabad Area			**Kabul Area**	
Latitude:	34 deg North		**Latitude:**	34.31deg North
Longitude:	70 deg East		**Longitude:**	69.12 deg East
Elevation:	580 M (1903 Ft)		**Elevation:**	1800 M (5900 Ft)
Summer Temp:	DB: 39.6^{o} C (103^{o} F)		**Summer Temp:**	DB: 19^{o} C (68^{o} F)
	WB: 25.6 ^{o}C (78 ^{o}F)			
Winter Temp:	4.6 ^{o}C (40 ^{o}F)		**Winter Temp:**	-5 ^{o}C (42 ^{o}F)
Daily Range:	unknown		**Daily Range:**	11 ^{o}C (20 ^{o}F)

Appendix B - Solubility of Oxygen in Fresh Water

Temperature °C	Temperature °F	Saturation DO mg/l	$1.035^{(T-20)}$	Temperature °C	Temperature °F	Saturation DO mg/l	$1.035^{(T-20)}$
0	32	14.6	.503	21	69.8	9.0	1.035
1	33.8	14.2	.520	22	71.6	8.8	1.071
2	35.6	13.8	.538	23	73.4	8.7	1.109
3	37.4	13.5	.557	24	75.2	8.5	1.148
4	39.2	13.1	.577	25	77.0	8.4	1.188
5	41.0	12.8	.597	26	78.8	8.2	1.229
6	42.8	12.5	.618	27	80.6	8.2	1.272
7	44.6	12.2	.639	28	82.4	7.9	1.317
8	46.4	11.9	.662	29	84.2	7.8	1.363
9	48.2	11.6	.685	30	86.0	7.6	1.411
10	50.0	11.3	.709	31	87.8	7.5	1.460
11	51.8	11.1	.734	32	89.6	7.4	1.511
12	53.6	10.8	.759	33	91.4	7.3	1.564
13	55.4	10.6	.786	34	93.2	7.2	1.619
14	57.1	10.4	.814	35	95.0	7.1	1.675
15	59.0	10.2	.842	36	96.8	7.0	1.739
16	60.8	10.0	.871	37	98.6	6.9	1.795
17	62.6	9.7	.902	38	100.4	6.8	1.858
18	64.4	9.5	.934	39	102.2	6.7	1.923
19	66.2	9.4	.966	40	104.0	6.6	1.990
20	68.0	9.2	1.000				

Temperature effect on $E_t = E_{20}$. (T−20)

[1] To be used for calculating oxygen transfer capability.

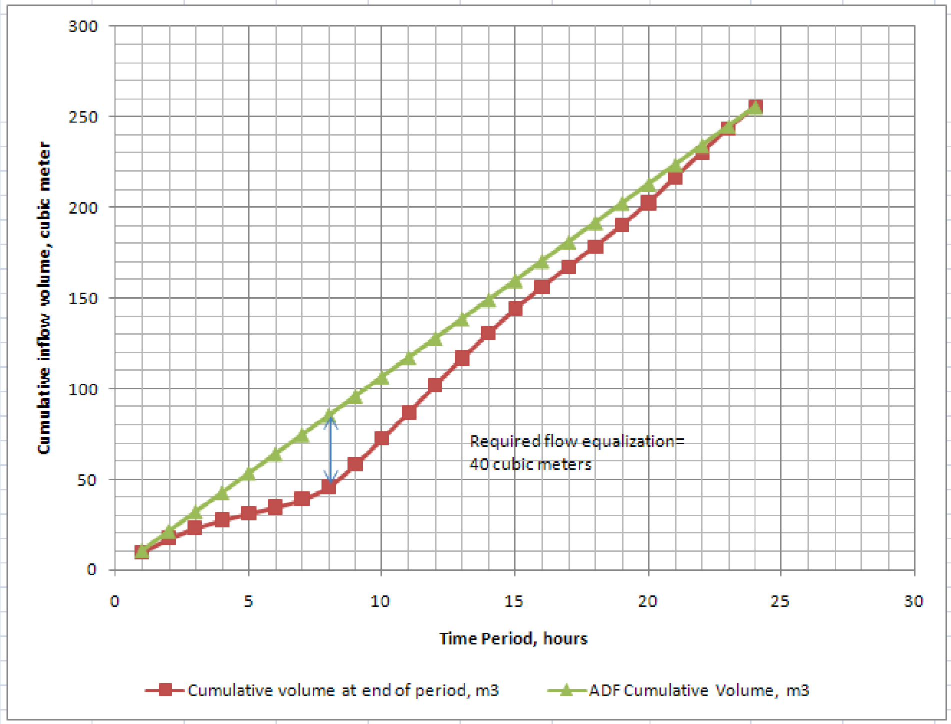
[2] To be used for trickling filter design utilizing Howland Formula.

Appendix C – Determination of Equalization Storage for Package WWTP

EQUALIZATION BASIN STORAGE VOLUME

Hydraulic loading	255,588	L/day
	255.6	cu m/day
	0.003	cum m/sec

Fraction of ADF	Interval	Time Period	Average flow rate in time period, m^3/sec	Cumulative volume at end of period, m^3	ADF Cumulative Volume, m^3
0.895	1	M-1	0.003	10	11
0.716	2	1-2	0.002	17	21
0.537	3	2-3	0.002	23	32
0.423	4	3-4	0.001	27	43
0.342	5	4-5	0.001	31	53
0.325	6	5-6	0.001	34	64
0.391	7	6-7	0.001	39	75
0.667	8	7-8	0.002	46	85
1.155	9	8-9	0.003	58	96
1.334	10	9-10	0.004	72	106
1.383	11	10-11	0.004	87	117
1.399	12	11-N	0.004	102	128
1.383	13	N-1	0.004	117	138
1.318	14	1-2	0.004	131	149
1.253	15	2-3	0.004	144	160
1.139	16	3-4	0.003	156	170
1.058	17	4-5	0.003	167	181
1.058	18	5-6	0.003	179	192
1.074	19	6-7	0.003	190	202
1.188	20	7-8	0.004	203	213
1.302	21	8-9	0.004	217	224
1.302	22	9-10	0.004	230	234
1.237	23	10-11	0.004	244	245
1.123	24	11-M	0.003	256	256
Average daily flow from design above			**0.003**		



Appendix D – Summary of Markup Pages for UFGS 44 41 13 – Prefabricated Biochemical Wastewater Treatment Plant

Topic	Page	Edit Options	Comments	References
Paragraph 1.2.1 Extended Aeration	4	"Extended Aeration Plant Design" shall be changed to Activated Sludge Plant"		
Paragraph 1.2.1 Activated Sludge Plant	4	Insert Select Design Type: [extended aeration], [contact stabilization], [sequencing batch reactor] – strike others		USACE –AED Package Wastewater Treatment Plant Design Requirements, 2009
Paragraph 1.2.1 Activated Sludge Plant	5	Insert design and peak flow rates for plant (L/day) in brackets	Select peak flow as 2.5 times average day flow	UFC 3 240-09fa
Paragraph 1.2.1 Activated Sludge Plant	5	Insert 400 mg/L for BOD_5 and 400 mg/L for TSS; Insert 92.5 % for removal		Effluent standards shall meet requirements in "Overseas Environmental Baseline Guidance Document", Department of Defense, 2007
Paragraph 1.2.1 Activated Sludge Plant	5	Strike last sentence in paragraph concerning seismic design		
Paragraph 1.2.1.1 Aeration Zone	5	Insert minimum wastewater depth and freeboard; insert influent pipe diameter		
Paragraph 1.2.1.2 Sludge Settling Zone	5-6	Insert surface loading rate at average daily flow rate and surface loading rate at peak hourly flow rate; edit scum baffle height		
Paragraph 1.2.1.3 Sludge Holding Zone	6	Insert sludge holding capacity		
Paragraph 1.2.1.4 Chlorination Zone		Insert chlorination zone effluent pipe diameter		
Paragraph 1.2.2	6-8	Delete in entirety		
Paragraph 1.3 Submittals	8	Insert USACE-AED-EC in bracket after "G"		
Paragraph 1.6 Extra Materials	10	Insert one month in bracket		
Paragraph 2.4 Sewage Shredder	13	Indicate zone; add batch reactor plant		
Paragraph 2.4.3 Sewage Shredder Motor and mounting	14	Insert motor voltage, phase and change 60 to 50 Hz		
Paragraph 2.5.1 Blower Capacity	14	Inset blower capacity SCFM and pressure kPA		
Paragraph 2.5.2 Blower Drive	15	Insert blower, rpm, motor voltage and phase; revise 60 to 50 Hz		
Paragraph 2.5.5 Blower Drive	15	Insert pressure relief valve set-point pressure		

Notes: 1. Other than deletions/edits shown in this table the standard specification 44 41 13 shall be retained in its entirety

Appendix D – Summary of Markup Pages for UFGS 44 41 13 – Prefabricated Biochemical Wastewater Treatment Plant (Continued)

Topic	Page	Edit Options	Comments	References
Paragraph 2.6.1 Air Diffusion Performance and Design requirements	16	Insert 3 cubic meters of air per 100 cubic meters of tank volume		
Paragraph 2.6.2 Air Diffusion Piping and Valves	16	Select piping material and state number of separate diffusers per tank		
Paragraph 2.7.1 Sludge and Scum Piping and Valves	17	Select zone for sludge recirculation; for batch reactor indicate sludge storage		
Paragraph 2.7.2 Sludge and Scum Air lift Pumps	17	Insert sludge draw or recirculation percent; add frequency		
Paragraph 2.9.1 Gas Chlorinator	19-20	Delete paragraph and all subparagraphs	Use calcium hypochlorite solution chlorinator, paragraph 2.10	
17Paragraph 2.10.2 Calcium Hypochlorite Chlorination System Metering Pump	21	Select type of metering pump, motor enclosure, motor voltage, phase, and change 60 to 50 Hz		
Paragraph 2.11 Sewage Pumps	22	Select final effluent as required		
Paragraph 2.11.1 Sewage Pumps	22	Select motor enclosure		
Paragraph 2.12 Flow meter and Control	22-23	Delete all but one applicable paragraph leaving one paragraph as flow metering method		
Paragraph 3.5.2 Welding	25-26	Delete paragraph and subparagraphs		
Paragraph 8 Field training	27	Insert hours of training	As per contract technical requirements or minimum per manufacturer's recommendation; whichever greater	

Notes: 1. Other than deletions/edits shown in this table the standard specification 44 41 13 shall be retained in its entirety