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SUBJECT: Western Wake Regional Wastewater Management Facilities
Western Wake Water Reclamation Facility
PER Technical Memorandum No. 15 – UV Disinfection Facilities and Post Aeration Facilities

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INTRODUCTION

Technical Memorandum (TM) No. 15 is one in a series of TMs being prepared for the Preliminary Engineering Report for the Western Wake Regional Wastewater Management Facilities project. Its purpose is to present the preliminary engineering information and data for proposed facilities at the Western Wake Water Reclamation Facility (WRF). This TM includes two sections as follows:

Section 1: UV disinfection facilities

Section 2: Post aeration facilities

SECTION 1: UV DISINFECTION FACILITIES

GENERAL PROCESS REQUIREMENTS

An ultraviolet (UV) disinfection facility will be provided to disinfect the final effluent from the Western Wake WRF. The installed UV equipment will meet the anticipated NPDES permit effluent limits for the plant. The UV equipment will be sized to provide adequate UV dose over the full range of projected flows at the plant, and the anticipated final effluent quality. Design flow rates are summarized in Table 15-1.

TABLE 15-1
DESIGN FLOW RATES

	PHASE 1	PHASE 2
Annual Average Flow (AAF), mgd	15.3	25.4
Maximum Monthly Flow (MMF), mgd	18	30
Peak Instantaneous Flow (PF), mgd	47.3	78.8

The UV disinfection equipment will be designed to treat the Phase 1 peak flow of 47.3 mgd. Additional channels will be added in the future to treat Phase 2 peak flows. An adequate UV dose must be selected to ensure that adequate intensity of UV energy at a wavelength of 254 nm is applied to the flow being treated. The UV equipment will be sized to provide a UV dose of 40,000 $\mu W\text{-}s/cm^2$, which is adequate to meet the anticipated NPDES permit limits for fecal coliforms:

- 200 organisms/100 mL (30-day geometric mean)
- 400 organisms /100 mL (7-day geometric mean)

If the plant is modified to provide off-site reuse water in the future, this will be accomplished by adding sodium hypochlorite downstream of the UV disinfection facility.

UV transmittance (UVT) and total suspended solids (TSS) concentration are effluent quality characteristics that impact the number of lamps required to provide the design UV dose. For preliminary design, equipment sizing is based on a UVT of 65%. This design UVT is consistent with the North Cary WRF design UVT of 65%, and the reported UVT at the Apex Middle Creek WWTP, which is greater than 70%. The design value for UVT will be confirmed with actual field data prior to completing detailed design. The treated plant effluent is expected to have low TSS concentrations due to the proposed installation of effluent filters. A maximum TSS concentration in the plant effluent of 10 mg/L was used for preliminary design of the UV equipment.

REGULATORY COMPLIANCE REQUIREMENTS

In addition to the NPDES permit requirements, the regulations in the North Carolina Administrative Code applying to wastewater treatment works (Section 15A NCAC 02H .0219(j)) will apply to the disinfection facilities, which primarily require that a standby power supply be provided.

ALTERNATIVES EVALUATION

Ultraviolet (UV) lamps are commonly used to disinfect wastewater. UV energy produced at a wavelength of 254 nm disables the reproduction capability of organisms including fecal coliforms. There are three standard types of UV disinfection systems used for disinfection of wastewater:

- Low-pressure/low-output (LPLO) lamp systems
- Low-pressure/high-output (LPHO) lamp systems
- Medium-pressure (MP) lamp systems

Low-pressure/low-output (LPLO) lamp systems, which require a large number of lamps and result in a large facility size, were not evaluated for the Western Wake WRF. LPHO and MP systems can both be provided with a reasonable number of lamps and are evaluated herein as Alternatives 1 and 2, respectively.

ALTERNATIVE 1: LOW-PRESSURE/HIGH-OUTPUT (LPHO) SYSTEM

The two prevalent LPHO systems are the TAK system by Wedeco UV Technologies, Inc. (Wedeco) and the UV3000 Plus system by Trojan UV Technologies, Inc. (Trojan). LPHO systems are installed in an open-channel arrangement, which means there is very low head loss through the lamps (< 2”). However, the LPHO systems require downstream level control in order to maintain a constant water level at the lamps, increasing the total head loss of the system. A disadvantage of the LPHO system when compared with the MP system is the higher number of lamps installed per unit of flow, which translates into higher maintenance costs due to replacing more lamps and ballasts. An advantage of the LPHO system when compared with the MP system is the lower installed power per unit of flow, which translates into lower power cost during normal operation.

In order to determine an appropriate facility design for an LPHO system for the Western Wake WRF, the manufacturers provided preliminary equipment costs for the following arrangements to meet the current design flows:

- Two channels with two banks per channel
- Three channels with one bank per channel
- Three channels with two banks per channel

A three-channel system with two banks per channel is recommended for the LPHO alternative due to the flexibility that six total banks provides to treat lower flows (i.e., startup conditions and minimum flows) without using excess energy. The equipment cost for this type of system is closely related to the total number of lamps in the system. The number of lamps and associated equipment costs are very similar for the three LPHO arrangements; so equipment cost does not prohibit the facility from being designed with three channels and two banks per channel.

As discussed previously, the proposed peak flow capacity is 47.3 mgd. For a 3-channel system, each channel will treat up to 16 mgd. By adding two channels in the future, the UV facility would be expanded to a 5-channel system for a total facility capacity of 80 mgd, which is adequate for the Phase 2 peak flow. Table 15-2 summarizes the Phase 1 UV facility design characteristics for the Wedeco and Trojan LPHO systems.

TABLE 15-2
SUMMARY DATA FOR WEDECO AND TROJAN LPHO SYSTEMS

SYSTEM CHARACTERISTIC	WEDECO TAK SYSTEM	TROJAN UV3000 PLUS SYSTEM
Total Facility Capacity	48 mgd	48 mgd
Number of Channels	3	3
Total Number of Banks	6	6
Peak Flow Capacity per Bank	8 mgd	8 mgd
Lamp Turndown Capability	50%	60%
Minimum Turndown Flow Rate	4.0 mgd	4.8 mgd
Total Installed Power	130 kW	120 kW
Input Power per Lamp	360 W	250 W
Total Number of Lamps	360	480
Total Number of Ballasts	180	240

Table 15-2 demonstrates that Wedeco uses higher output lamps than Trojan, so the Wedeco system requires fewer lamps; however the total installed power demand is similar between the two systems. The primary difference between the two manufacturers' systems is that Trojan utilizes electronic ballasts that are mounted above the lamps and water surface elevation in each channel, while Wedeco utilizes electronic ballasts that are mounted in separate enclosures and must be cooled by air conditioning.

The preliminary installed equipment cost of either LPHO system is $1,100,000. This does not include the structural or electrical costs associated with building a UV disinfection facility. A preliminary UV facility cost is presented later in this memorandum.

ALTERNATIVE 2: MEDIUM-PRESSURE (MP) SYSTEM

The most prevalent MP system is the UV4000 Plus system by Trojan. This system is installed in a closed-conduit arrangement with a typical head loss of approximately 24". The MP system does not require downstream level control due to the closed-conduit arrangement; so the total system head loss is similar to an LPHO system. An advantage of the MP system compared with the LPHO system is the lower number of lamps installed per unit of flow. A disadvantage of the MP system is the higher power requirements per unit of flow.

Trojan provided preliminary equipment costs for the following arrangements to meet the current design flows:

- Two channels with two banks per channel
- Three channels with two banks per channel

The Phase 1 flow requirements can be met with the same total number of lamps in either a 2-channel or a 3-channel arrangement. However, a high portion of the equipment cost of an MP system is due to the support and mechanism components of the system, which makes a 2-channel system more economical than a 3-channel system. Considering that the current hydraulic peak flow (48 mgd) is 60 percent of the future hydraulic peak flow (80 mgd), it is recommended that the channels be sized so that only one additional channel is required in the future to expand the UV facility to meet the future hydraulic peak flow. By sizing the channels to treat 27 mgd each, the total capacity of the current 2-channel system would be 54 mgd and the total capacity of the future 3-channel system would be 81 mgd. Table 15-3 summarizes the Phase 1 UV facility design characteristics for the Trojan MP system.

TABLE 15-3
SUMMARY DATA FOR TROJAN MP SYSTEM

SYSTEM CHARACTERISTIC	TROJAN UV4000 PLUS SYSTEM
Total Facility Capacity	54 mgd
Number of Channels	2
Total Number of Banks	4
Peak Flow Capacity per Bank	13.5 mgd
Lamp Turndown Capability	60%
Minimum Turndown Flow Rate	8.1 mgd
Total Installed Power	512 kW
Input Power per Lamp	3,200 W
Total Number of Lamps	160
Total Number of Ballasts	80

The preliminary installed equipment cost of the Trojan UV4000 Plus system is $1,400,000. This does not include the structural or electrical costs associated with building a UV disinfection facility. A preliminary UV facility cost is presented later in this memorandum.

PROPOSED FACILITIES

The UV Facility may be designed for medium pressure or low pressure/high output UV equipment, as both types would provide adequate disinfection. The type of UV equipment will be selected during final design. For the purposes of developing a UV Facility layout, the LPHO equipment is used. The LPHO UV facility would be designed to accommodate the Wedeco TAK system and the Trojan UV3000 Plus system. The facility would be designed with three channels and two banks per channel. The UV facility is shown in Figure 15-1 and would include the following equipment and characteristics:

- A common influent channel that receives flow from the effluent filters and distributes flow to the UV channels
- An automated (open/close) isolation valve to each UV channel
- Three UV channels with two UV banks per channel
- A level control weir gate at the end of each UV channel
- A common effluent channel to collect disinfected effluent
- An effluent flow measurement flume as described in TM No. 09, Hydraulic Design
- Hatches for access to UV lamps and other equipment and channels
- Hoisting equipment (either monorails or bridge crane) to facilitate lamp maintenance
- A lamp maintenance area to clean or replace lamps
- A separate building or enclosure to house electrical equipment and control panels

The UV facility will be located on the south side of the plant site, adjacent to the effluent filters.

ELECTRICAL REQUIREMENTS

The UV facility will be provided with 480V/three-phase power adequate to power the UV lamps and associated equipment. The total installed power will be 120 kW to 512 kW, depending on the selected UV equipment style and manufacturer. Electrical equipment will be located inside an electrical building or enclosure, as necessary. Wedeco requires additional electrical room space due to the requirement to air condition their ballast enclosures, as well as additional wiring and conduit between these ballast enclosures and the junction boxes at each UV bank. This wiring and conduit can be installed in the void area beneath the concrete slabs between the UV channels.

As mentioned previously in this TM, the UV facility will require standby power. Standby power alternatives are discussed in TM No. 23, Standby Power Facilities and Electrical Utility Service.

INSTRUMENTATION & CONTROLS

Both the medium pressure and the low pressure/high output UV systems would have a control panel that includes a PLC to provide automatic control of the UV system. This PLC will be interconnected with the other PLCs in the plant control system. The principal instruments that are utilized to control the UV facility include:

- UV transmittance (UVT) monitor
- Intensity sensors in each UV bank
- Conductivity probes to provide low liquid level indication in each channel
- Ultrasonic level sensors to provide a level setpoint in each channel (LPHO only)
- Automated effluent level control weir gates to maintain the level setpoint in each channel (LPHO only)
- Automated influent valves in each channel that open or close when UV channels are placed into or taken out of service
- Flow rate indication from the effluent flow measurement flume

Input and output commands are provided with the UV control PLC to provide automatic control of the UV equipment based on signals from the instruments and equipment listed above. There are two modes of operation available to control the UV system: “Flow Pacing” and “Dose Pacing”. Either mode of operation utilizes flow rate indicated from the effluent flow measurement device to modulate the number of banks and/or channels in service to modulate power to each bank. Also, with the LPHO system, either mode of operation utilizes the level control setpoint function provided by the automated weir gates and ultrasonic level sensors in each UV channel. “Dose Pacing” utilizes the full capability of the instruments installed with the UV system by modulating power (i.e., number of banks in service and percentage of bank power utilized) based on measured UV intensity within the bank(s) in service or using measured UVT. “Flow Pacing” also modulates the number of banks and power level based on flow, but uses an operator-input fixed UVT rather than an on-line input for UVT or lamp intensity.

ESTIMATED CAPITAL COST

Table 15-5 summarize the total estimated facility construction costs for the proposed UV disinfection system. The construction cost estimate is based on an LPHO system, and includes the various items proposed for the UV facility as described previously in this TM.

TABLE 15-5
ESTIMATED CAPITAL COST
UV DISINFECTION FACILITY

Sitework	$30,000
Structural	$400,000
Mechanical	$1,300,000
Electrical and Instrumentation	$250,000
Subtotal	**$1,980,000**
Construction Contingencies	$297,000
Engineering and Construction Services	$228,000
Legal and Financial	$125,000
Total Construction Cost	**$2,630,000**

SECTION 2: POST AERATION FACILITIES

GENERAL PROCESS REQUIREMENTS

A post aeration facility is required to raise the dissolved oxygen (DO) concentration of the final effluent from the Western Wake WRF prior to effluent pumping. Effluent flow from Holly Springs will discharge directly to the effluent pump station, with no additional post aeration, at the Western Wake WRF. The proposed facilities would provide adequate oxygen transfer to meet the anticipated NPDES permit limit for an effluent DO concentration of 6.0 mg/L. The projected effluent DO concentrations prior to post aeration are estimated to be as follows:

- 0.0 mg/L at or below the maximum month flow
- 2.0 mg/L at peak flows

ALTERNATIVES EVALUATION

Two standard methods for post aeration of plant effluent are cascade aeration and diffused air aeration. These alternatives are evaluated below on a present worth cost basis.

Alternative 1: Cascade Aeration

In a cascade aeration structure, plant effluent flows down a series of steps, creating a highly turbulent flow pattern which provides for excellent oxygen transfer. Cascade aeration is the preferred means of providing post aeration at a treatment facility where the plant effluent flow discharges directly into a receiving stream and a natural fall in grade is available from the discharge point down to the water surface elevation in the receiving stream.

However, because the Western Wake WRF will not directly discharge into a receiving stream, it would be necessary to lower the effluent pump station to accommodate the cascade aeration structure in the hydraulic profile, resulting in additional effluent pumping costs. Preliminary evaluations indicate that the cascade aeration structure fall would need to be approximately 14 feet, thus increasing the effluent pump total dynamic head by an equivalent amount.

Alternative 2: Diffused Aeration

The second alternative would be to provide a diffused air post aeration basin. Membrane-type fine bubble diffusers would be installed in the basin to transfer oxygen to the plant effluent. It is possible to install diffusers in a basin that is being used for other purposes, such as the effluent filter clear well, and avoid the cost of a dedicated basin. Both options are considered in the following evaluation.

The centrifugal blowers provided for the BNR treatment process air requirements can provide the additional air needed for post aeration. Additional piping would be provided from the main air header to the post aeration facilities, along with the membrane diffusers in the basin. This alternative would add additional load to the aeration blowers and would result in increased power costs. Preliminary evaluations indicate that the air requirement at the peak flow will be approximately 1,500 scfm. The post aeration basin will be sized to provide adequate detention time for oxygen transfer and for installation of an adequate number of diffusers to meet the peak airflow requirements.

COST COMPARISON

Table 15-6 is a comparison of capital costs for the two alternatives assuming a dedicated post aeration basin is constructed.

TABLE 15-6
CAPITAL COST COMPARISON FOR
POST AERATION ALTERNATIVES

	ALTERNATIVE 1 CASCADE AERATION	ALTERNATIVE 2 DIFFUSED AERATION
Sitework	$25,000	$20,000
Structural	$310,000	$305,000
Mechanical	$35,000	$65,000
Electrical and Instrumentation	$10,000	$10,000
Subtotal	**$380,000**	**$400,000**
Construction Contingencies	$57,000	$60,000
Engineering and Construction Services	$43,700	$46,000
Legal and Financial	$24,035	$25,000
Total Construction Cost	**$507,735**	**$530,000**

If fine bubble diffusers are installed in the filter clear wells in lieu of constructing a separate basin, the capital cost for Alternative 2, diffused aeration, is estimated to be approximately $100,000.

PRESENT WORTH OF O&M COSTS

The parameters used for evaluating present worth costs are discussed in TM No. 32, Cost Estimating Methodology.

Power Requirements: Table 15-7 includes power costs for the following:

- Increase in pumping head at the effluent pump station to allow for the cascade aeration alternative
- Increase in aeration blower airflow for the diffused air post aeration alternative

Maintenance Requirements: The cascade aerator has minimal maintenance requirements. Maintenance for the post aeration basin would be associated primarily with the fine bubble diffusers.

Cost Comparison: Table 15-7 demonstrates the total present worth O&M costs of the two alternatives over a 20-year planning period.

TABLE 15-7
COMPARISON OF PRESENT WORTH O&M COSTS FOR CASCADE AND DIFFUSED AIR POST AERATION

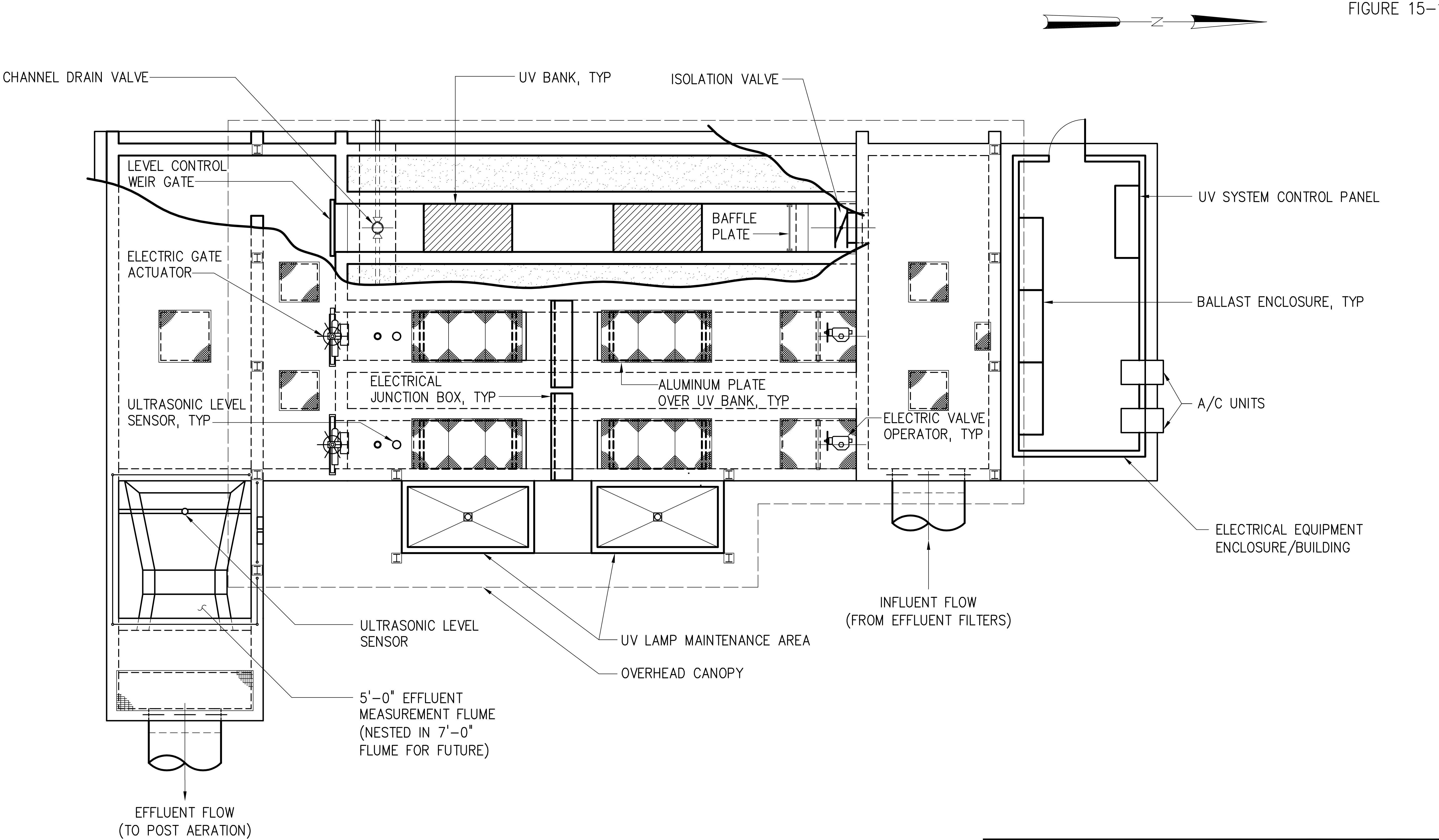
Item	Cascade	Diffused Air
Power Costs		
Additional Horsepower per mgd	3.5 HP/mgd	3.2 HP/mgd
Present Worth of Power Costs	**$359,000**	**$317,000**
Annual Equipment Maintenance Costs	--	$1,600
Present Worth of Maintenance Costs	**--**	**$25,000**
Total Present Worth O&M Cost	**$359,000**	**$342,000**

Recommendations

There is not a significant difference in operating costs for the two alternatives, as demonstrated by the present worth evaluation. Therefore, the selection should be based upon capital costs, operator preference and siting considerations. The evaluation demonstrates that cascade aeration and a new post aeration basin with diffusers have similar capital costs. However, because the effluent pump station operating level is 14 feet lower under the cascade aeration option, the station must be either located at a lower elevation on the site or the station must be significantly deeper and more costly. If the station is sited at a lower location, convenience of access would be impacted and the cost of additional grading, roadway, and piping would increase the overall capital cost of the cascade aeration alternative. Also, the capital cost of the effluent pump station would increase if the station must be deeper at a different site location.

Because the capital costs of the two alternatives are not significantly different, it is recommended that the diffused aeration alternative be selected. The option of installing diffusers in the effluent filter clear well rather than having a separate post aeration basin should be evaluated further during detailed design.

FIGURE 15-1



PLAN

1/8"=1'-0"

CDM / HAZEN AND SAWYER

WESTERN WAKE REGIONAL
WASTEWATER MANAGEMENT FACILITIES

UV DISINFECTION FACILITIES