SEWPCC Upgrading/Expansion
Conceptual Design Report

SECTION 9 - BNR Bioreactors

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9.0 BNR Bioreactor

9.1 PURPOSE OF UNIT PROCESS

The bioreactors provide biological treatment of the incoming primary effluent or any raw sewage that bypasses primary treatment directly to the bioreactors during high flows greater than 200 ML/d. Biological treatment facilitates oxidation of dissolved/particulate biodegradable constituents to stable end products (such as carbon dioxide and water); removes/incorporates suspended and non settleable colloidal solids into biological floc or biofilm and also provides nutrient removal (nitrogen and phosphorus).

The biological treatment proposed for the SEWPCC is based on the Integrated Fixed Film Activated Sludge process (IFAS) utilizing a free floating plastic media.

9.2 DESIGN BASIS (FLOWS AND LOADS)

The development of flows and loads for the proposed upgrade/expansion of the SEWPCC facility was presented earlier in the pre-design report. For the purpose of this report, the key flows and loadings on which the BNR bioreactors have been sized are summarized below.

Season	**Maximum Monthly Flows**			
Winter	70 ML/d			
Spring	111 ML/d			
Summer	132 ML/d			
Fall	92.3 ML/d			
Peak flows to BNR	175 ML/d (Summer) and 125 ML/d (Spring)			
Annual Average Flow	90.4 ML/d			
Design Loadings	**WINTER**	**SPRING**	**SUMMER**	**FALL**
BOD_5	13,650 kg/day (195 mg/L)	18,981 kg/day (171 mg/L)	15,708 kg/day (119 mg/L)	14,399 kg/day (156 mg/L)
TSS	10,290 kg/day (147 mg/L)	14,985 kg/day (135.7 mg/L)	12,936 kg/day (98 mg/L)	10,522 kg/day (114 mg/L)
TKN	3,200 kg/day (45.7 mg/L)	3,219 kg/day (28.7 mg/L)	3,036 kg/day (23 mg/L)	3,046 kg/day (33 mg/L)
NH3-N	2,310 kg/day (33 mg/L)	1,998 kg/day (18 mg/L)	2,112 kg/day (16 mg/L)	2,400 kg/day (26 mg/L)
Wastewater Temperature	13 deg C	10 deg C	16.7 deg C	16 deg C

9.3 PROPOSED BIOREACTOR DESIGN

As discussed in Section 4 – BNR Process Refinement and Section 5 – BNR Process Selection, the design of the proposed bioreactor is based on a 3-pass, 4-train high rate Modified Johannesburg (MJ) BNR process with biofilm carrier elements or IFAS media in the aerobic zones of the bioreactor. The biofilm carriers are retained within the aerobic zones by utilizing media retention screens. A mixed liquor recycle zone (with no media) is incorporated downstream of the last aerobic zone to facilitate internal recycle of mixed liquor to the first Anoxic zone (for denitrification).

As explained in Section 5, several types of media are available in the market, which will ultimately impact the bioreactor sizing and design. The Conceptual Design presented in this document is based on Anox Kaldness K3 media. The system design is based on both suspended MLSS kinetics and fixed film surface area loading rate (SALR) kinetics to meet the required organic removal and nitrification.

9.3.1 Existing Bioreactors

The SEWPCC currently uses a high purity oxygen (HPO) based high-rate activated sludge process. It was the first major treatment plant in North America to use HPO for secondary treatment process. HPO is produced by the pressure swing adsorption (PSA) system which is pumped into the bioreactors. Mixers located on the roof of the bioreactors vigorously agitate the mixed liquor, which causes the oxygen in the headspace (above the liquid surface) to dissolve into the wastewater. There are four (4) existing bioreactor trains with each train divided into three (3) stages. Reactors 3 and 4 are slightly larger than reactors 1 and 2.

For the proposed upgrade, the existing reactors 1 and 2 will be converted to pre-anoxic, anaerobic and anoxic zones of BNR train # 1. Similarly, the existing reactors 3 and 4 will be converted to the pre-anoxic, anaerobic and anoxic zones of BNR train # 2. The existing mixers, PSA system and its associated components will be decommissioned. From a staging perspective, the existing bioreactor modifications will be completed in a staged manner once the new bioreactors are constructed.

9.3.2 Influent Flow Distribution

The purpose of the bioreactor influent system is to convey a balanced flow of primary effluent (PE), return activated sludge (RAS) and any primary bypass flows to each of the four (4) proposed bioreactor trains. The existing system for the distribution of PE and RAS will be maintained in the expanded/upgraded system.

Effluent from the primary settling tanks collects in a primary effluent channel. Four existing 750 mm discharge pipes convey the effluent to the respective HPO reactors which are controlled by four PE motorized positioning valves designated by equipment nos. P401-FV1, P402-FV1, P407-HV1, and P408-FV1. Four manually controlled handvalves, P401-HV1, P402-HV1, P407-HV1, and P408-HV1, provide additional aid in the operation of this system. It is our understanding that these handvalves have not been exercised recently as none of the existing HPO bioreactor trains have been out of service. As the existing valves are fairly old butterfly valves, it is likely that a positive seal will not be achieved when they are closed. As such, we are including their replacement as part of the upgrade work. Flow through each of the discharge pipes is monitored by 500 mm diameter magnetic flow meters (four in total - see adjacent photo).

For the proposed upgrade, the pipes leading to HPO reactors 1 and 4 will be decommissioned (as existing reactors 1 and 4 will be incorporated into the proposed BNR train # 1 and 2 respectively). The PE channel will be extended to the south to allow construction of two similar systems for the new bioreactors 3 and 4. Also, the existing handvalves will be changed to a knife-gate style (from existing butterfly) and mounted on the vertical section of the 750 mm pipe to increase the accuracy of the flow-meter. In addition, a similar piping/valving system is proposed to allow equal splitting of the PE bypass directly to the respective BNR trains (see Figure 9.1). The size of this pipe is estimated to be 1200 mm, which will then be reduced to 1000 mm and finally to 750 mm as if feeds BNR train # 4.

RAS will be pumped as per current practice from the secondary clarifiers through a 750 mm header in Gallery 3, which will convey RAS to each of the proposed BNR bioreactors via one of four train lines. Each line contains a magnetic flowmeter and an automatic butterfly positioning valve to allow for accurate flow control to each of the four BNR bioreactors. Similar to the PE pipe, the following modifications are proposed:

- Provide two new entry points to proposed trains 3 and 4.
- Decommission existing RAS piping system for HPO trains 1 and 4.
- Replace 300 mm RAS pipe and valves with 450 mm for existing trains 2 and 3 that will be reused for BNR trains 1 and 2.

- Replace existing butterfly isolation valves with knife gate style valves.

The existing RAS header and piping system is shown in Figure 9.2.

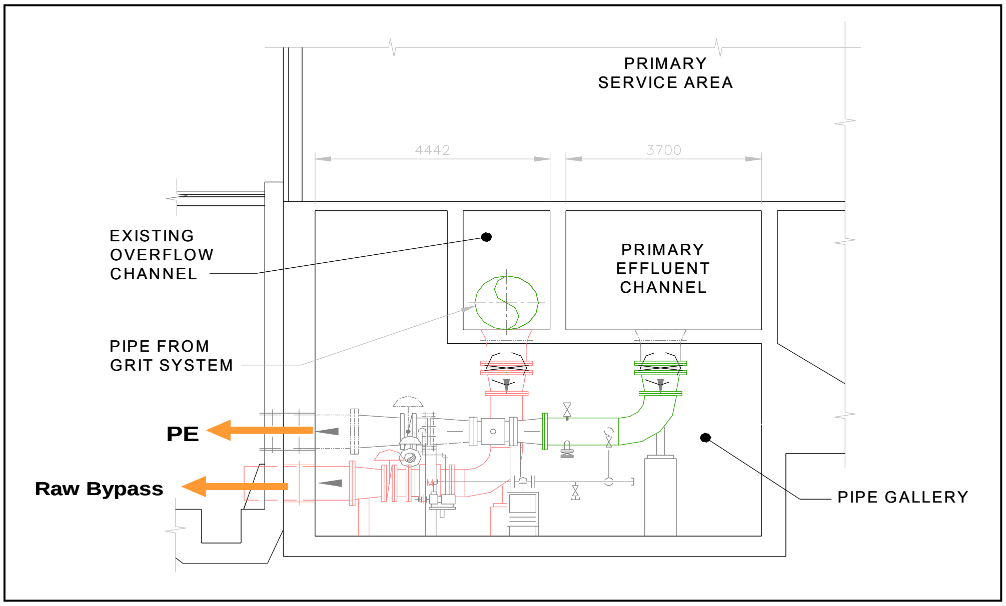


Figure 9.1: Bioreactor Influent Piping

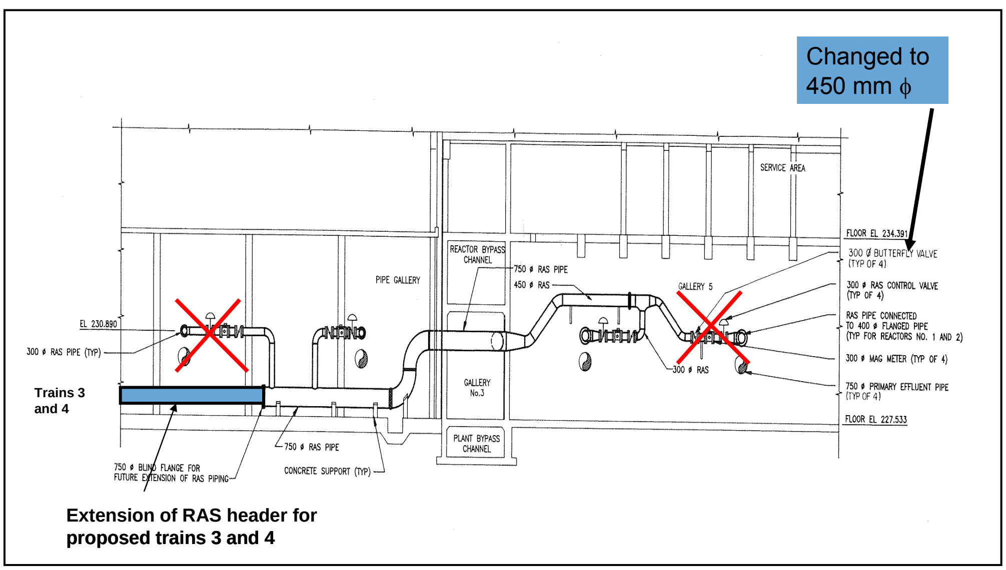


Figure 9.2: RAS Piping in Front of Bioreactor

9.3.3 Proposed BNR bioreactors

As presented in Section 5, a four train bioreactor system based on the MJP with IFAS media is proposed for the SEWPCC Upgrade/Expansion project. Each bioreactor train is a 3-pass configuration consisting of pre-anoxic, anaerobic, anoxic-1, anoxic-2, aerobic-1, aerobic-2 and a mixed liquor recycle zone in series. IFAS media is placed in aerobic-1 and aerobic-2 zones only. Mechanical mixing is provided in anoxic and anaerobic zones to maintain the biomass in suspension and provide a homogenous mixture of the biomass. A summary of the bioreactor design parameters is provided in Table. 9.1. The proposed bioreactor plans and sections are presented through Figures 9.3 to 9.6. The upper floor plans refer to the top of the bioreactor, primary effluent channel etc. The lower floor plan refers to the pipe galleries and bottom of the bioreactors.

Table 9.1 – Bioreactor Design Summary

Item	Unit	Design Value			
No. of Trains	Nos.	4			
Cells per bioreactor	Nos.	7			
Cell maximum SWD	m	4.5 m (existing), 5.5 m (new tanks)			
HRT @ AAF of 90.4 ML/d	hrs	6.9			
HRT @ Spring MMF of 111 ML/d	hrs	5.6			
% Fill of biofilm carrier elements	%	44 (aerobic-1), 60 (aerobic-2)			
System MLSS SRT, Spring	days	8.1			
System MLSS SRT, Summer	days	7.5			
System MLSS SRT, Winter	days	9.9			
Operating range of MLSS	mg/L	3200 ~ 4200			
Total Bioreactor Volume	m^3	26,100			
Volumes of zones		**Train 1**	**Train 2**	**Train 3**	**Train 4**
Pre anoxic	m^3	329	326	327	327
Anaerobic Zone	m^3	453	450	457	457
Anoxic Zone 1	m^3	1123	1298	825	825
Anoxic Zone 2	m^3	1119	1322	794	794
Aerobic Zone 1	m^3	1712	1712	1712	1712
Aerobic Zone 2	m^3	1712	1712	1712	1712
Mixed Liquor Recycle Zone	m^3	295	295	295	295
Total/train	m^3	**6743**	**7115**	**6122**	**6122**

Note: The existing HPO tanks are incorporated in the proposed BNR trains 1 and 2.

9.3.4 Reactor Mixing

Submersible low speed mixers are provided to keep the solids in the mixed liquor in suspension in the pre-anoxic, anaerobic, anoxic-1, anoxic-2 and the mixed liquor recycle zones of each of the bioreactor trains. Low speed mixers with a design energy gradient of 3 to 6 W/m³ will be provided. Low speed mixers with a speed of 600 rpm or less are preferred as they wear less and do not tend to shear floc. Since the aeration system in the IFAS zones is designed for both mixing and aeration, no dedicated mixers are provided in the aerobic zones. The submersible mixers will be mounted on a guide rail system with a portable, free-standing lifting davit and a stainless steel rope/chain. This allows the mixers to be either raised or lowered without emptying the tank contents.

A summary of the mixers in each of the bioreactor zones are summarized in Table 9.2.

Table 9.2 – Submersible Mixer Design Summary

Item	Train No.	Quantity	Design Value (kW)
Pre anoxic	1	1	1.7
Anaerobic Zone		1	3.2
Anoxic Zone 1		1	4.6
Anoxic Zone 1		1	3.2
Anoxic Zone 2		2	3.2
Mixed Liquor Recycle Zone		2	3.2
Pre anoxic	2	1	1.7
Anaerobic Zone		1	3.2
Anoxic Zone 1		1	4.6
Anoxic Zone 1		1	3.2
Anoxic Zone 2		2	3.5
Mixed Liquor Recycle Zone		2	3.2
Pre anoxic	3 and 4	1	1.7
Anaerobic Zone		1	3.2
Anoxic Zone 1		1	3.2
Anoxic Zone 1		1	3.2
Anoxic Zone 2		2	3.2
Mixed Liquor Recycle Zone		2	3.2

9.3.5 Mixed Liquor Recycle Pumping System

The nitrified recycle pump will be an axial flow propeller type mounted on guide rails. A spare pump will be provided and kept in spare parts inventory to enable repair with minimal downtime.

In contrast to conventional axial flow pumps, recirculation pumps do not require expensive structures in the tank. The unit is lowered along a guide tube and connected by an automatic coupling system to the piping. The nitrified mixed liquor from the "mixed liquor recycle zone" is returned back to the front of the anoxic-1 zone of each bioreactor train for denitrification. The piping design includes an on-line magnetic flow meter, which will be physically located in the gallery at the back of the bioreactors. The pumps are provided with a variable frequency drive (VFD) to adjust flows in the range of 136 ML/d ~ 270 ML/d. This represents a flow range of 150% ~ 300% of the AAF of 90.4 ML/d. Each recycle pumps is rated at 15 kW or 20 hp.

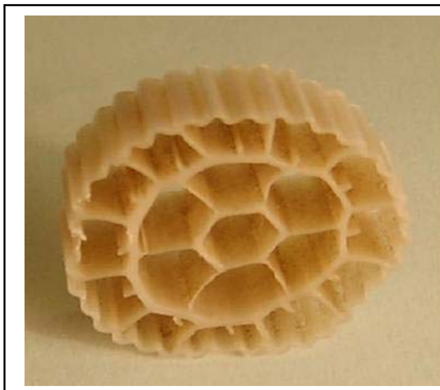
9.3.6 Biological Foam Control

Design detailing can assist in controlling foam in a wastewater treatment plant. Foam can be generated from filamentous organisms and it can also be generated from surfactants and other industrial waste discharges. Through design considerations foam can usually be controlled to manageable levels.

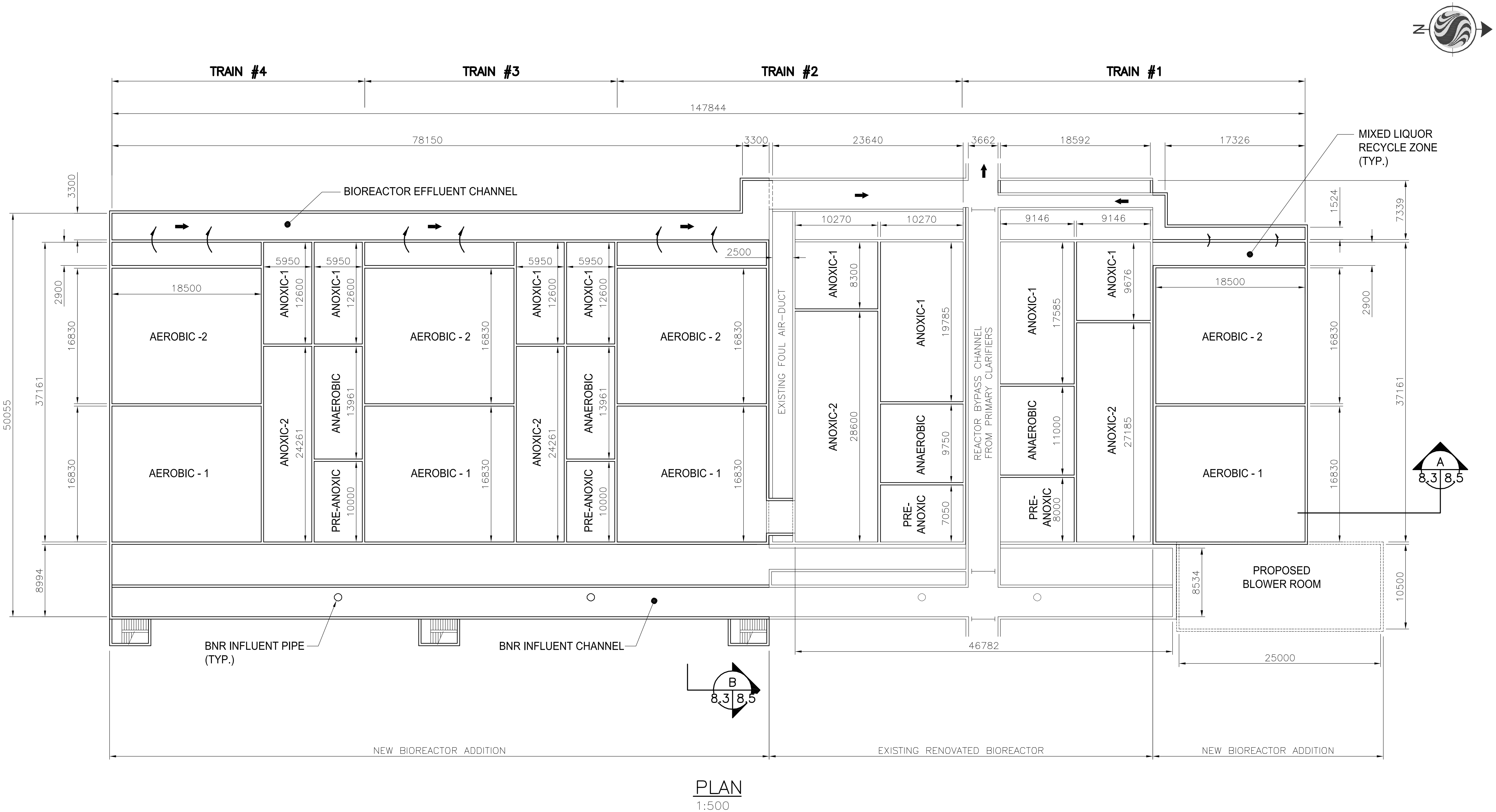
In the bioreactor design, the dividing walls will be designed to enable transport of foam and scum from the inlet to the aerobic-1 zone of the bioreactor without trapping the foam. Dividing walls will typically be slightly submerged to enable passage of foam except for the walls between aerobic-1, aerobic-2 and the mixed liquor recycle zone. For these walls, specially designed transfer screens located at the surface will allow the passage of scum to the mixed liquor recycle zone. Surface wasting will be designed for the mixed liquor recycle zone to enable removal of foam and scum to a wasting chamber. A non-potable water spray system will also be provided along the bioreactor to assist in scum break up.

9.3.7 Mixed Liquor Wasting

Mixed liquor will be wasted from the "mixed liquor recycle zone" continuously via a waste activated sludge (WAS) pump located in the pipe gallery at the end of each bioreactor. This method of wasting provides for better SRT control. WAS will be pumped directly to the DAFs for thickening. One WAS pump will be provided per bioreactor plus one spare.



Each WAS pump will be rated at 18.75 kW or 25 hp and will be capable of pumping 32 ~ 64 m^3/h of WAS.



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LOCATION APPROVED
UNDERGROUND STRUCTURES

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NOTE:
LOCATION OF UNDERGROUND STRUCTURES AS SHOWN ARE BASED ON THE BEST INFORMATION AVAILABLE BUT NO GUARANTEE IS GIVEN THAT ALL EXISTING UTILITIES ARE SHOWN OR THAT THE GIVEN LOCATIONS ARE EXACT. CONFIRMATION OF EXISTENCE AND EXACT LOCATION OF ALL SERVICES MUST BE OBTAINED FROM THE INDIVIDUAL UTILITIES BEFORE PROCEEDING WITH CONSTRUCTION.

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ELEV.

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Stantec Consulting Ltd.
905 Waverley Street, Winnipeg, Manitoba
Tel 204-489-5900 Fax 204-453-9012

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DATE 2008.07.17	DATE

ENGINEER'S SEAL

TENDER NO.

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

SOUTH END WATER POLLUTION CONTROL CENTRE

BIOREACTOR UPPER FLOOR PLAN

CITY DRAWING NUMBER: FIGURE 9.3

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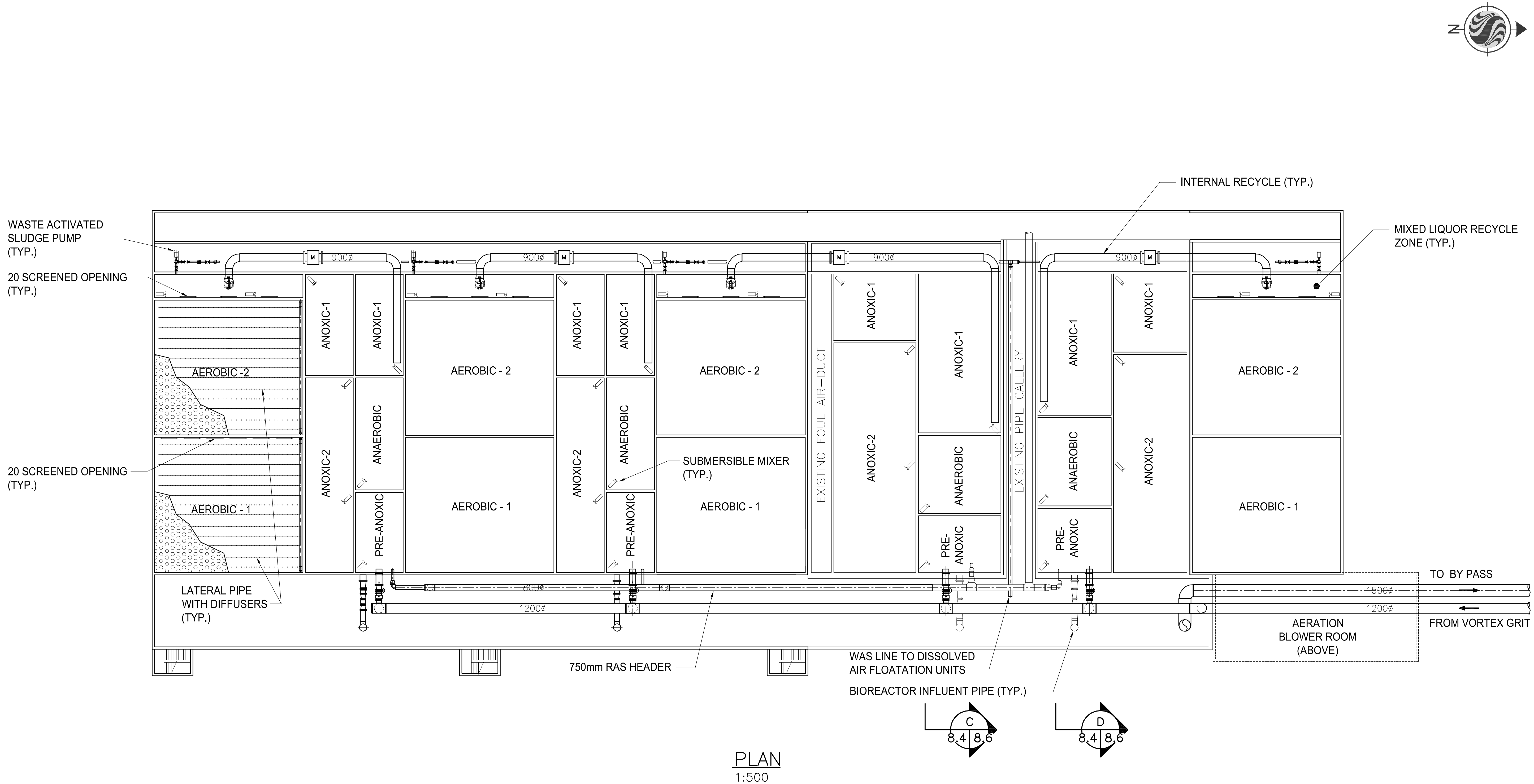

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WATER AND WASTE DEPARTMENT

SOUTH END WATER POLLUTION CONTROL CENTRE

BIOREACTOR LOWER FLOOR PLAN

CITY DRAWING NUMBER
FIGURE 9.4

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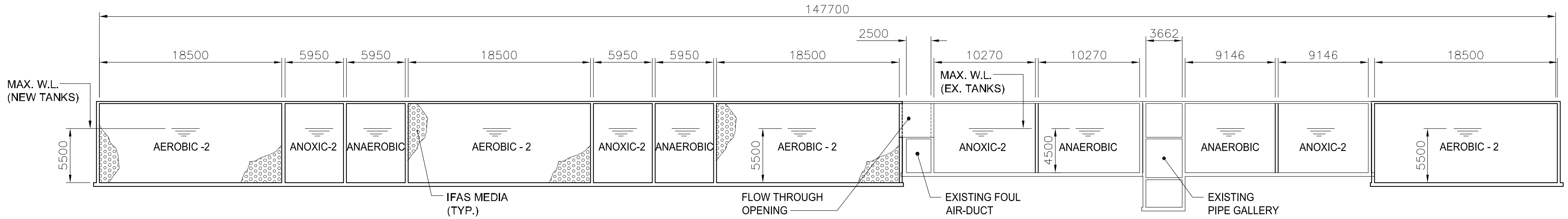

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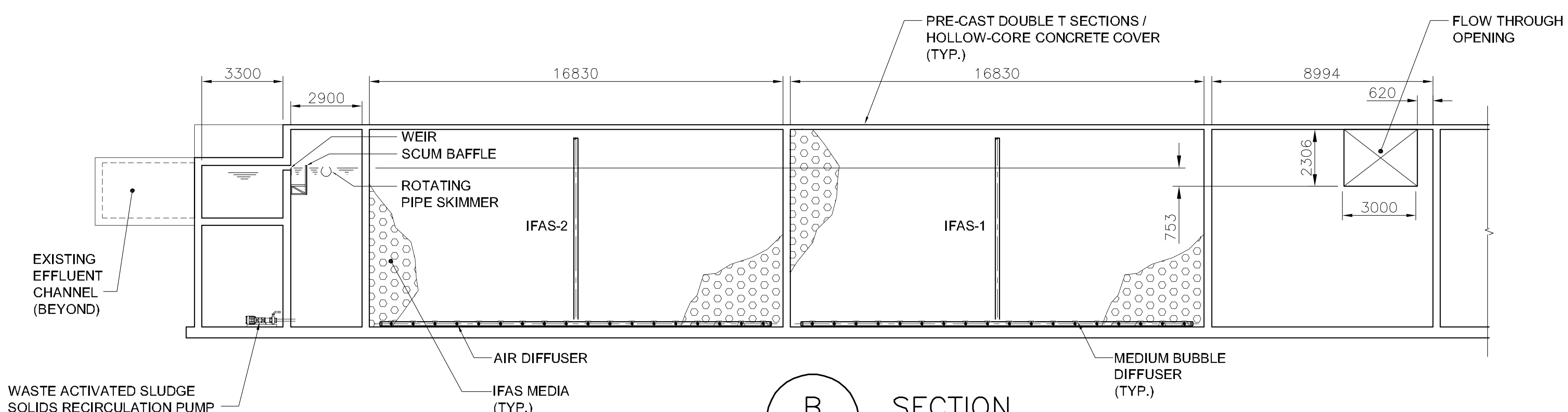

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SOUTH END WATER POLLUTION CONTROL CENTRE

BIOREACTOR SECTIONS - I

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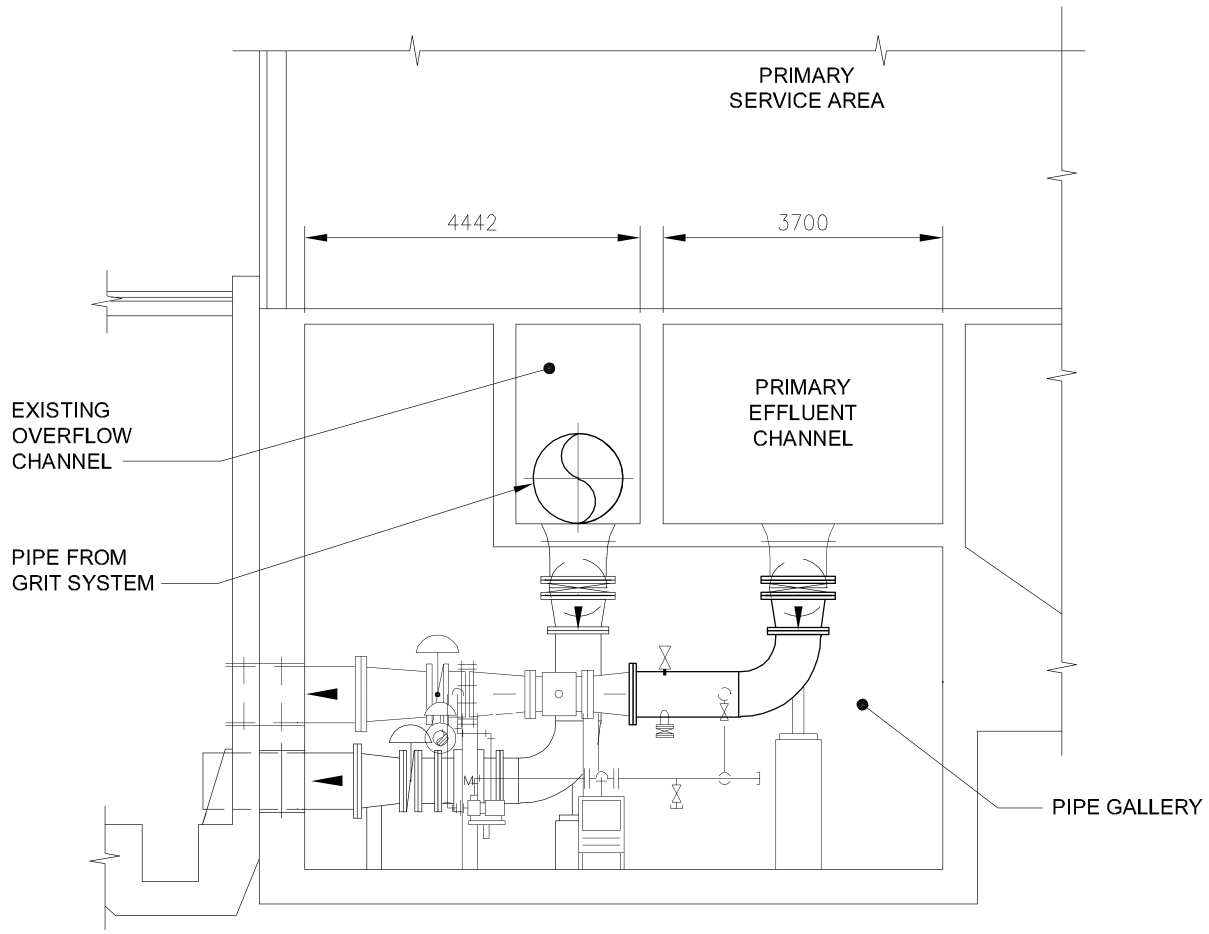

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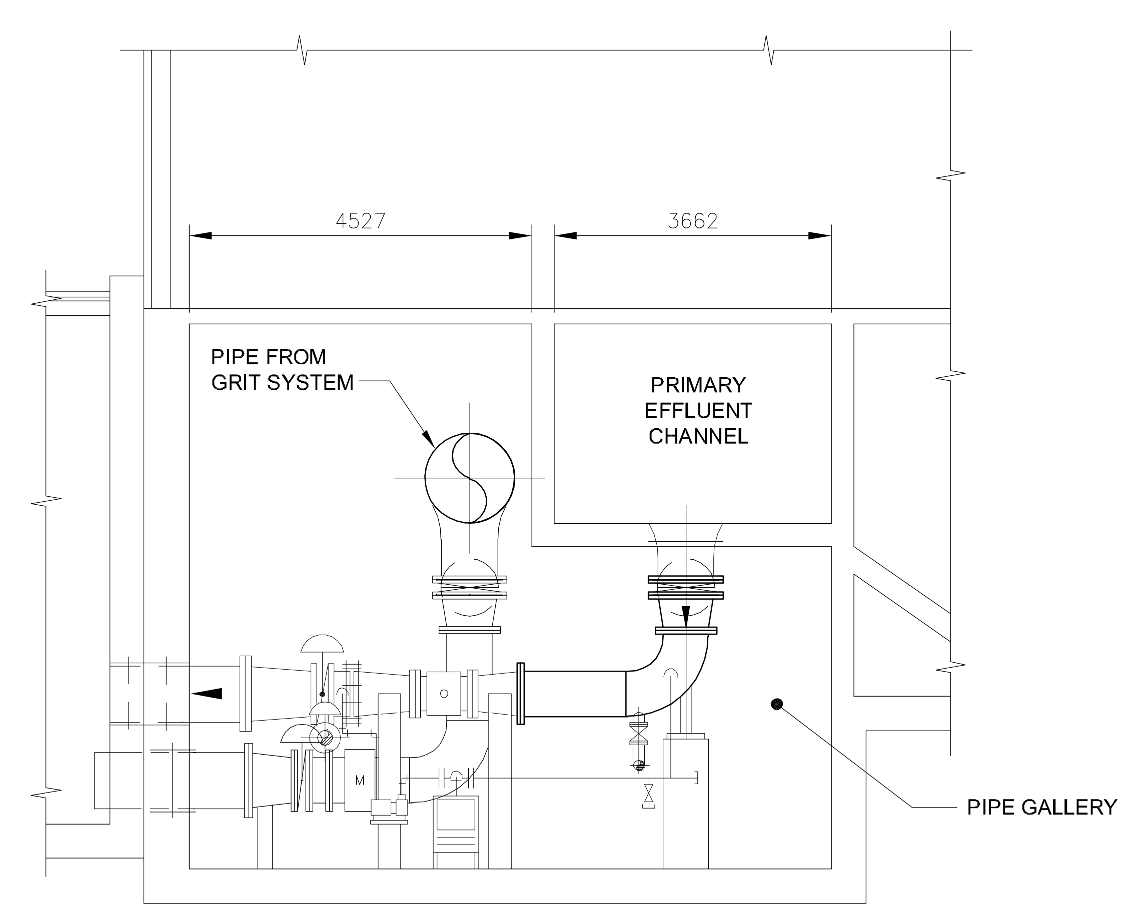

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BIOREACTOR SECTIONS - 2

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FIGURE 9.6

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9.3.8 IFAS Media

One of the key elements of the proposed IFAS BNR system for the SEWPCC is the use of a biomass carrier elements or IFAS media. The IFAS media is proprietary to respective equipment vendors. As stated earlier, for the purpose of this memorandum, the design is based around Anox-Kaldness's K3 type media (see attached photo).

The K3 media measures 25 mm in diameter and 9 mm in length. The K3 media has a specific area of 500 m^2/m^3 and a specific volume of 0.095 m^3/m^3. For the SEWPCC project, it is estimated that a total of 7,101 m^3 of K3 media will be required. This equates to a total effective surface area of 3,550,500 m^2 for biofilm growth. The media can be simply unloaded to the respective tanks following start-up as shown in the adjacent picture.

9.3.9 IFAS Screens

Each of the aerobic zones of the bioreactor trains are provided with an engineered media retention screen assembly to retain the IFAS media or carrier elements within the reactors. Similar to the IFAS media, the screens are a proprietary design and are unique to the system vendor. For the SEWPCC project, a total of 20 screens are provided per aerobic zone (i.e. 40 screens per bioreactor for a total of 160 screens for the entire system). Each screen is 400 mm in diameter with 5 mm openings and is constructed of 304L stainless steel. The screen system has been designed to handle the peak flow rate of 175 ML/d plus recycle streams. The headloss at peak flow is estimated at 50 mm per reactor. A typical screen assembly is illustrated in Figure 9.7 below.

Figure 9.7: Typical Media Retention Screen Assembly

9.4 PHOSPHORUS TRIMMING

The SEWPCC will be equipped with a back up alum feed system, which is used in the event of process failure or on occasion when the phosphorus levels must be trimmed to meet the licence limit of ≤ 1 mg/L. This system will enable feeding alum solution directly to the bioreactor effluent channel prior to entry to the secondary clarifiers. The discussion of the chemical storage and feed system is provided in Section 8 - Primary Treatment.

9.5 BLOWERS AND AERATION SYSTEM

An air supply system consisting of blowers, air piping, air diffusers, monitoring and control equipment is needed to provide sufficient oxygen to the mixed liquor and maintain mixing in the aerobic zones.

9.5.1 Blowers

Aeration blowers are the center of the aeration process. Aeration blowers consume upwards of 60% of the total power used in a wastewater treatment plant (WWTP). Variable air flow rate to the process and ease of blower turndown are features necessary to maintain proper oxygen concentration in the process and make the BNR process work. Maintaining the proper oxygen concentration saves energy and aids the process.

The blowers must have appropriate turn down capability to match the blower air flow rate to the process air demand for the full range of loads from the Year 2013 to the Year 2031. Moreover, the blower system must have uniform and continuous air turndown over the entire plant air flow range.

For WWTPs with similar size capacities to the SEWPCC, either multi-stage or single-stage centrifugal blowers are commonly used. Positive displacement blowers are typically used for small WWTPs. The centrifugal style blower is usually a single impeller or a multi stage impeller design. The multistage blowers come in a horizontal split-case or vertically split-case configuration.

Both multistage and single stage centrifugal blowers offer single point control though inlet valve guide vanes or variable speed control. Only single point control is available on multistage blowers. Variable speed control offers a method for capacity reduction with fewer inlet losses than throttling but the turn down range is compromised in a constant pressure wastewater application. Throttling of a multistage blower is limited and is usually through the use of a throttling butterfly valve on the blower discharge. Multistage blower efficiency decreases when throttling to a lower air flow. Care must be exercised when throttling a blower to avoid creation of a surge condition. A surge condition has the potential to seriously damage the impellers.

For the purpose of this memorandum a single-stage blower system with integrally geared compressor and a dual-point control was utilized. However, other types of blowers such as the high speed turbine (HST) utilizing magnetic bearing (e.g. ABS Group) or air bearing (e.g.

Neuros Co. Ltd.) will be evaluated during detailed design. The dual point control technology consists of automatically adjustable inlet guide vanes (IGV). IGV control the output with a minimum loss of efficiency by monitoring the operating variables that affect horsepower consumption and increases the stable operating range. Automatic adjustable diffuser vanes control the capacity on the discharge side of the impeller and maximize efficiency and turndown. The overall turn down capability is reported in the range of 100% down to 40% with minimal loss in efficiency. This range is particularly suitable for the flexible operation of the BNR process and the potential energy savings. The final blower selection will be reviewed as part of the Detail Design stage. The design airflows for the proposed SEWPCC expansion/upgrade are summarized in the following table.

Table 9.3 – Design Air Flows

2013 – Air Flow Requirements (Nm^3/hr)			
Minimum hour	**Minimum day**	**Maximum month**	**Peak day**
7,200	20,385	33,157	37,276
2031 – Air Flow Requirements (Nm3/hr)			
13,979	24,806	41,780	45,567

To meet the above range of air flows, a total of four (4) single-stage blowers are proposed with 3-duty and one stand-by. Each blower has a maximum throughput of 15,190 Nm3/hr at 8.3 psig and is equipped with a 400 hp high-efficiency motor. The turn-down capability of each blower is estimated down to 6,100 Nm3/hr. The proposed blower system is equipped with a Master Control Panel (MCP), which brings blowers on-line or off-line as required based on the dissolved oxygen set points in the bioreactor aerobic zones.

Individual air flows to the bioreactor aerobic zones are controlled by motorized air control valves, which will modulate to maintain dissolved oxygen set points. The MCP controls the delivery of the required air volumes thereby minimizing system power costs. In addition, the MCP operates multiple blowers in parallel or cascade control mode. In cascade control mode, air flow from one blower only is modulated while holding others in either a maximum, minimum or a stopped mode.

9.5.2 Blower Sound Attenuation

The blowers would be equipped with inlet and outlet silencers to reduce blower noise. Additionally, the blower building will incorporate a sound attenuation design to minimize noise impacts.

9.5.3 Blower Local Control Panel

A local control panel (LCP) is provided with each blower to monitor inlet temperature, oil temperature, blower gearbox vibration, motor current, low oil pressure, surge conditions, differential pressure across the blower. The panel will monitor and control the position of the inlet and outlet guide vanes for efficiency optimization.

9.5.4 Blower Room

The blower room will be constructed adjacent the north west end of the existing primary settling tank and adjacent the proposed Bioreactor Train No. 1. An air intake plenum room will be constructed to potentially reduce the amount of dust and snow entering the blower filter and to reduce frosting of the filter. Outside air will enter the plenum through roof mounted penthouse louvers. An access door is provided to the air intake plenum to periodically remove accumulated dust or snow.

The floor plan of the blower room showing the general arrangement of the proposed four (4) blowers is shown in Figure 9.8. The room has been designed to expand to a five (5) blower set-up in the future.

9.5.5 Blower Discharge Piping

Centrifugal blowers cannot start against head pressure in a pipe so each blower discharge will be equipped with a motorized air relief valve (blow off valve) and a motorized discharge butterfly valve to discharge air from the discharge pipe during start up. The relief valve allows the blower to come up to speed and achieve maximum discharge pressure. Each blower discharge line will have a check valve.

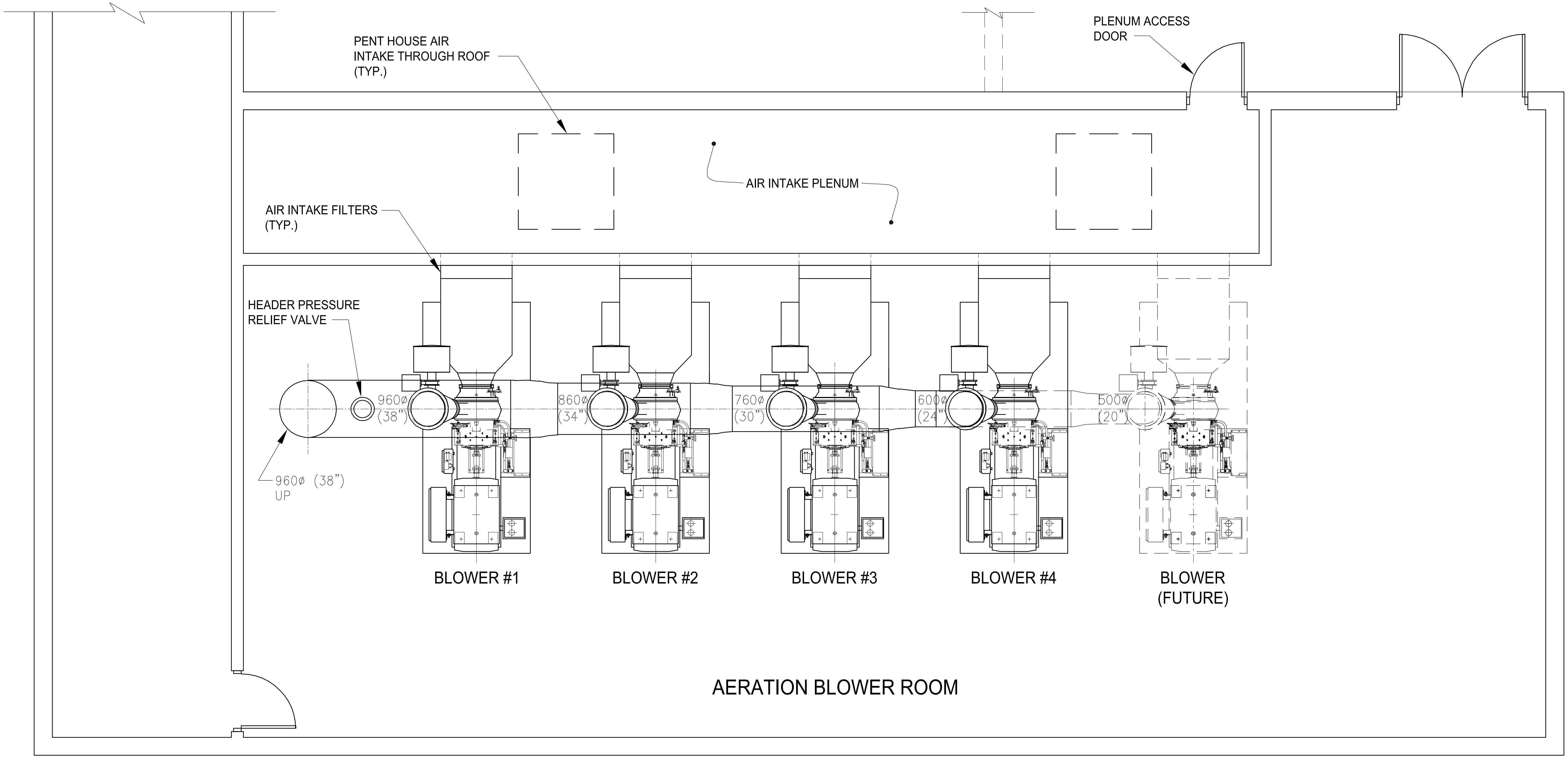
9.5.6 Aeration Piping

The blower discharge air header piping is shown in Figure 9.8. The internal pipe pressure at the discharge of a blower is approximately 28 mm of water (11 inches of water). A schedule 10 stainless steel pipe will be used to supply air to the process. The header will have an automatic and motorized air relief valve to relieve line pressure during blower start up and over pressure events.

The air piping will be increased progressively from 500 mm (20 inches) to 950 mm (38 inches). A plan showing proposed air headers to individual bioreactor trains and aerobic zones is shown in Figure 9.9.

9.5.7 Air Diffuser System

The air diffuser system comprises of a site specific, engineered medium bubble aeration system in 304L stainless steel including header and lateral piping within the aerobic zones of the proposed bioreactors.



LOCATION APPROVED
UNDERGROUND STRUCTURES

SUPV. U/C STRUCTURES COMMITTEE — DATE

NOTE:
LOCATION OF UNDERGROUND STRUCTURES AS SHOWN ARE BASED ON THE BEST INFORMATION AVAILABLE BUT NO GUARANTEE IS GIVEN THAT ALL EXISTING UTILITIES ARE SHOWN OR THAT THE GIVEN LOCATIONS ARE EXACT. CONFIRMATION OF EXISTENCE AND EXACT LOCATION OF ALL SERVICES MUST BE OBTAINED FROM THE INDIVIDUAL UTILITIES BEFORE PROCEEDING WITH CONSTRUCTION.

B.M.
ELEV.

NO.	REVISIONS	DATE	BY

Stantec Consulting Ltd.
905 Waverley Street, Winnipeg, Manitoba
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CHECKED BY
DRAWN BY
APPROVED BY
HOR. SCALE: AS NOTED
VERTICAL:
RELEASED FOR CONSTRUCTION:
DATE 2008.07.17
DATE

ENGINEER'S SEAL

TENDER NO.

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

SOUTH END WATER POLLUTION CONTROL CENTRE

BLOWER ROOM

CITY DRAWING NUMBER
FIGURE 9.8

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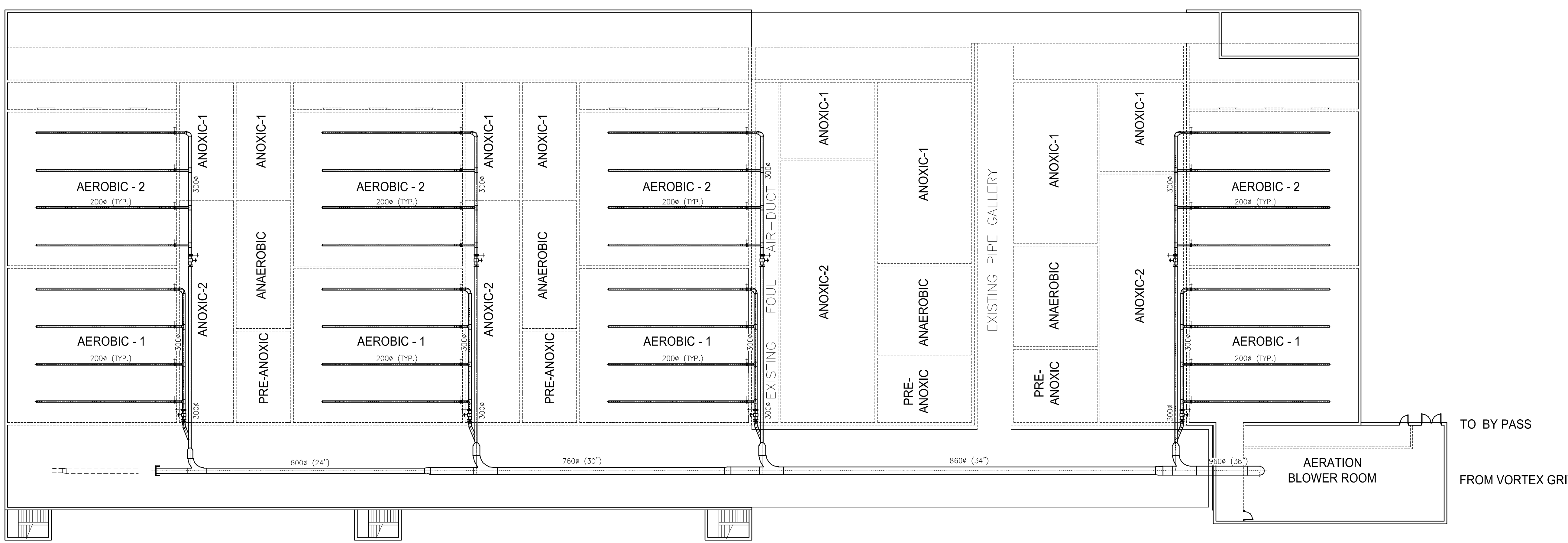

PLAN
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LOCATION APPROVED
UNDERGROUND STRUCTURES

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THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

SOUTH END WATER POLLUTION CONTROL CENTRE

BIOREACTOR REACTOR AERATION PIPING PLAN

CITY DRAWING NUMBER FIGURE 9.9 | SHEET | OF

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Based on the conceptual design, a total of eight aeration grids complete with drop pipes will be provided in each of the aerobic zones for a total of sixty-four (64) aeration grids for the entire treatment system. The system includes supports for the aeration grid systems, manifolds and drop pipes into the reactors.

A typical example of the proposed medium bubble aeration system is shown in Figure 9.10.

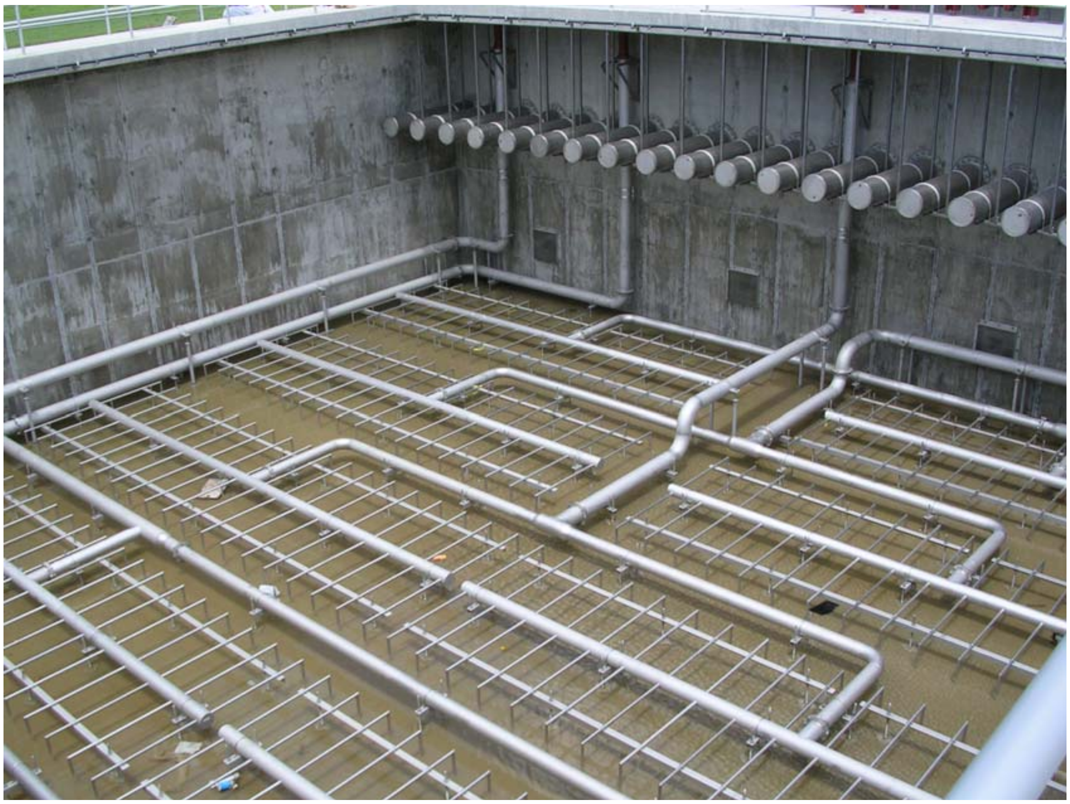

Figure 9.10: Typical Medium Bubble Diffuser Grid

9.6 BNR PROCESS CONTROL

Several process control measures are proposed for the bioreactor system. These includes the following:

- SRT control via direct wasting of the MLSS from the mixed liquor recycle zone.
- ORP control: Oxygen Reduction Potential (ORP) probes are proposed in the anaerobic and anoxic-1 zones of the bioreactor. To ensure a proper anaerobic and reducing environment for the phosphorus accumulating organisms (PAOs), an ORP sensor should be installed in each anaerobic zone. The PAOs breakdown polyphosphates and release orthophosphates under a strongly reducing environment. The target ORP value should be less than -150 mV.

The second set of ORP sensors will be installed in the first anoxic zone. This anoxic zone is responsible for the majority of the denitrification taking place, and it is necessary to ensure a fairly neutral environment. Like most anoxic zones, ORP values should be maintained between -100 and 100 mV. This target ORP value will ensure that an appropriate amount of mixed liquor is recycled back via the internal nitrate recycle for the biomass present. As with most wastewater installations, the ORP sensor will be installed in the middle of the basin, approximately 1/4 of the depth of the basin.

- Internal Nitrate recycle: The internal nitrate recycle pump will be set at 150% ~ 300% of the AAF of 90.4 ML/d to optimize denitrification and control the amount of oxygen recycled back to the front-end of the anoxic zone-1. As a rule of thumb, an NO_2^{-1}/NO_3^{-1} level of 0.5 ~ 0.75 mg/L will be maintained at the effluent end of the anoxic-2 cell of the proposed bioreactor system.

- DO control: The BNR process must have the appropriate dissolved oxygen (DO) control to achieve the treatment objectives. The two aerobic (IFAS) zones of each bioreactor train require precise dissolved oxygen levels and thus precise air flow control. To achieve an aeration system with sufficient wide range of air capacity and control to match the air requirements to the biological process air needs, control valves, instrumentation and software are required. It is proposed that each IFAS aerobic zone be monitored with DO probe and analyzer (eight total). Based on the DO readings, a thermal dispersion flow meter and analyzer will monitor the air supply to each IFAS aerobic zone and position an electric basin flow control valve located on the lateral air supply to each zone (eight total). The valve will be opened and closed to match the selected DO set points for the zone. All information is sent to a process air MCP. The MCP integrates the entire aeration system and direct overall operation using a programmable logic controller (PLC). The MCP would collect the DO, flow rate and valve position from each IFAS basin (eight total) and provide information, through software, to the blower LCP to control the air flow from the blowers. The MCP would provide information to the plant's DCS for monitoring of the system.

- On-line Nutrient Analyzer: Real time effluent quality monitoring for ammonia-N, NO_2^{-1}/NO_3^{-1} and ortho-P levels will be provided for effluent leaving the individual bioreactor trains. A sample pump dedicated for each of the 4 bioreactor train will sequentially deliver approximately a 4.5~9.0 m^3/hour mixed liquor sample from the "mixed liquor recycle zone" to an on-line filter for a period of time such that it fully flushes the sample line and accumulates fresh filtrate for analysis. The sampling sequence will be controlled via a "sample sequence controller". Analysis is performed on the filtrate in the central Nutrient Analyzer and the results are sent to the plant Supervising and Control and Data Acquisition (SCADA) system for information and appropriate action (e.g. WAS control, alum feed for phosphorus trimming etc.). While the analyzer performs an analysis, the sequencer begins to flush a new sample location so that the overall cycle time is minimized.