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Terminal Island Water Reclamation Plant Tertiary Filter Rehabilitation Final Preliminary Design Report CIP 5229

October 2013

REPORT

MWH®

BUILDING A BETTER WORLD

Terminal Island Water Reclamation Plant

Tertiary Filter Rehabilitation Final Preliminary Design Report
CIP 5229

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LIST OF ABBREVIATIONS

Abbreviation	Description
AMSL	Above Mean Sea Level
AWPF	Advanced Wastewater Purification Facility
City	City of Los Angeles
cfm	Cubic Feet per Minute
ft	Feet
gpm	Gallons per Minute
hr	Hours
icfm	Inlet Cubic Feet per Minute
mgd	Million Gallons per Day
MF	Microfiltration
NO_3-N	Nitrate Nitrogen
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Units
PD	Positive Displacement (a type of air blower)
P&ID	Process and Instrumentation Diagram
psi	Pounds per Square Inch
RO	Reverse Osmosis
sf	Square Foot
Study	CIP 5221 – December 2012 Tertiary Filter Rehabilitation Study
TIWRP	Terminal Island Water Reclamation Plant
TSS	Total Suspended Solids
WSE	Water Surface Elevation

Section 1
Introduction and Background

MWH prepared a report entitled “Terminal Island Water Reclamation Plant – Tertiary Filter Rehabilitation Study (CIP 5221)” in December 2012. This report (hereinafter referred to as the “Study”) investigated the cause of several operational and maintenance inefficiencies experienced at the Terminal Island Water Reclamation Plant (TIWRP) tertiary filters, and recommended the filters be rehabilitated to retain the ability to be operated as denitrifying filters. This Preliminary Design Report will lay out all of the required major elements of this rehabilitation and establish the design criteria that will be utilized for the detailed design. The recommended changes are discussed in detail in Section 3 and also listed below:

- Filter media replacement
- Filter underdrain rehabilitation
- Air scour blower replacement
- Air piping relocation
- Backwash supply pumps replacement
- Backwash waste effluent gates installation
- Filter effluent butterfly valve replacement
- Waste backwash butterfly valve replacement
- Replacement of valve and actuator controllers

BACKGROUND

The TIWRP is located in San Pedro, California and treats wastewater from over 130,000 people and 100 businesses in the Los Angeles Harbor area. The plant has a capacity of 30 million gallons per day (mgd) with a current average daily flow of 15 mgd. Most of the filtered effluent is discharged through an outfall into the Los Angeles Harbor. Further treatment by the Advanced Wastewater Purification Facility (AWPF) handles an annual average of approximately 4 mgd utilizing microfiltration (MF) and reverse osmosis (RO) for beneficial reuse. The process flow diagram of the TIWRP is shown below in **Figure 1-1**.

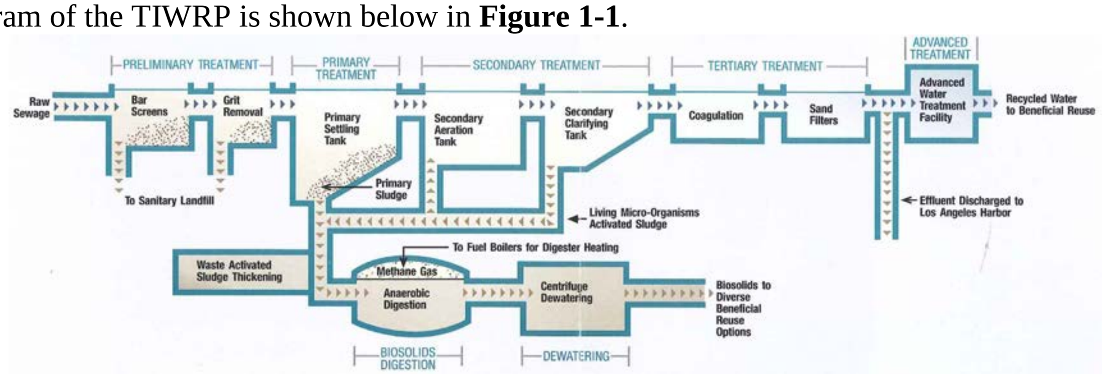


Figure 1-1: Process Flow Diagram for TIWRP

The existing tertiary filter system consists of 16 filter cells arranged into two banks of 8 filters each. Each cell has a filter area 60 ft long and 10 ft wide. The filters utilize tri-media beds, with the exception of Filter 3 which operates with a monomedia bed. The tri-media bed consists of (from upper to lower layers): 20 inches of anthracite, 16 inches of silica sand, and 6 inches of garnet, supported by 18 inches of graded support gravel.

During normal operation, flow is pumped approximately 22.5 ft vertically into a common influent channel by five filter influent pumps. The influent channel is “U” shaped with a bank of 8 filters on each side. Flow enters each filter through an influent slide gate and is directed along an influent trough that surrounds each filter. Secondary effluent flows over the weirs on the influent troughs and into the filter cell where it is filtered through the media. Filtered effluent then passes through the underdrain, to the effluent flume at the bottom of each filter cell, and out to one of two effluent channels. The two effluent channels are located between the two filter banks underneath the gallery. During operation, a minimum water surface elevation within the filters is maintained by weirs located on the north and south effluent channels. **Figure 1-2** shows the main features of the filters. **Figure 1-3** shows a plan layout of the main filter components.

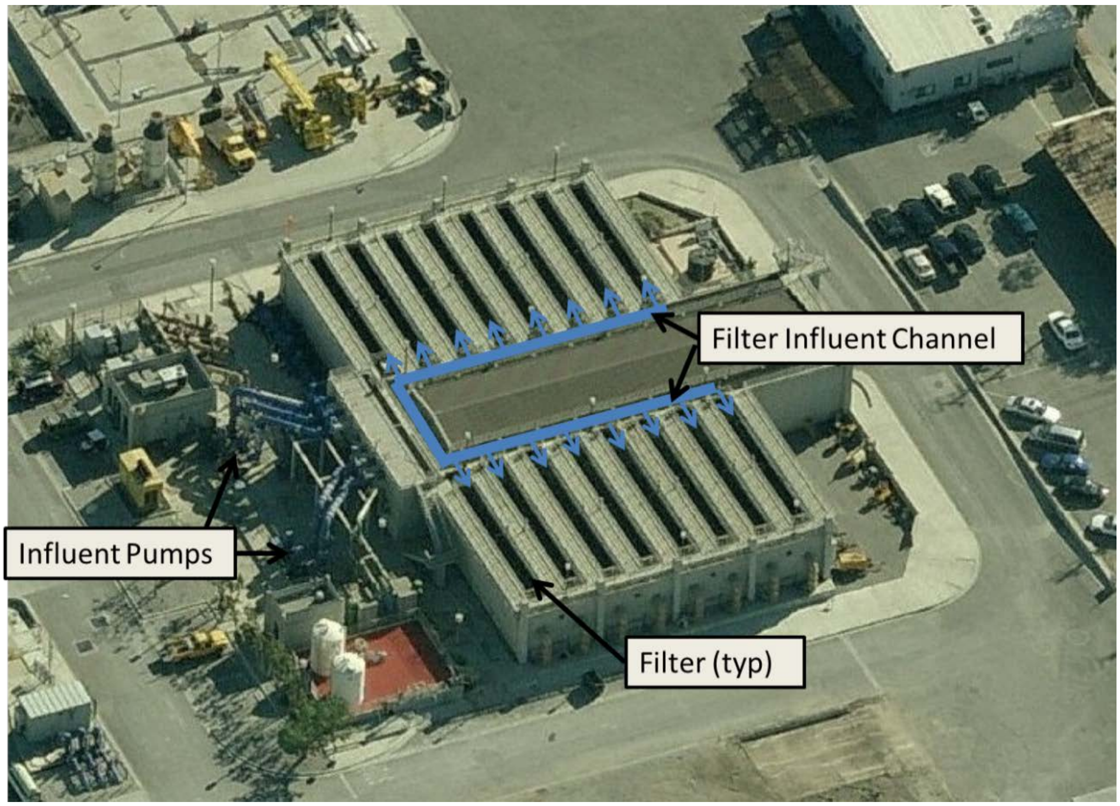


Figure 1-2: Main Features of the Existing Filters

PROPOSED PROCESS DESCRIPTION

Process Selection

The proposed rehabilitated process for tertiary treatment at the TIWRP is *denitrifying filtration*. The existing filters at the TIWRP were designed for optional denitrification, but have been operated as a conventional multi-media system for suspended solids removal. Problems have been encountered due to underdrain damage, media loss, and the failure of several mechanical components.

The filters will be rehabilitated and converted to deep-bed, gravity-flow filters with mono-media beds consisting of coarse sand. They will employ components of the Tetra® Denite system produced by Severn Trent Services. The rehabilitated filters will be designed to remove suspended solids as well as nitrate from the secondary effluent. CIP 5229 will not provide nitrate removal – this treatment feature may be added in the future if the City identifies the need to reduce effluent nitrate. In any case, the filters will be able to treat suspended solids effectively, whether or not concurrent denitrification is required.

Operation of the denitrifying filters will consist of the filtration and backwash cycles, in addition to a "bump" cycle for future denitrification.

Filtration Cycle

During the filtration cycle, water flows through the filters by gravity in the downward direction. Suspended solids are removed by depth filtration, and headloss through the filter bed increases as solids accumulate in the pore spaces. This causes the water level in the filter cell to rise.

As noted above, the filters can also be set up for nitrate removal in the future. This is done by the addition of a feedstock to the filter influent so that denitrifying anaerobic organisms grow as a biofilm on the filter media. These organisms remove nitrate by using it as an electron acceptor and reducing it to nitrogen gas, and they require the addition of an electron donor (typically methanol or acetic acid) to support their metabolic requirements.

Backwash Cycle

Compared to other granular media filters, denitrifying filters are backwashed at a lower velocity over a longer period of time. This backwash strategy removes solids that have accumulated in the filter, and also sloughs off some biomass without removing an excessive amount (since the ultimate design of this system is to permit denitrification via the biofilm growing on the media). Backwash consists of pumping water to flush the filter in the upflow direction, along with air scour.

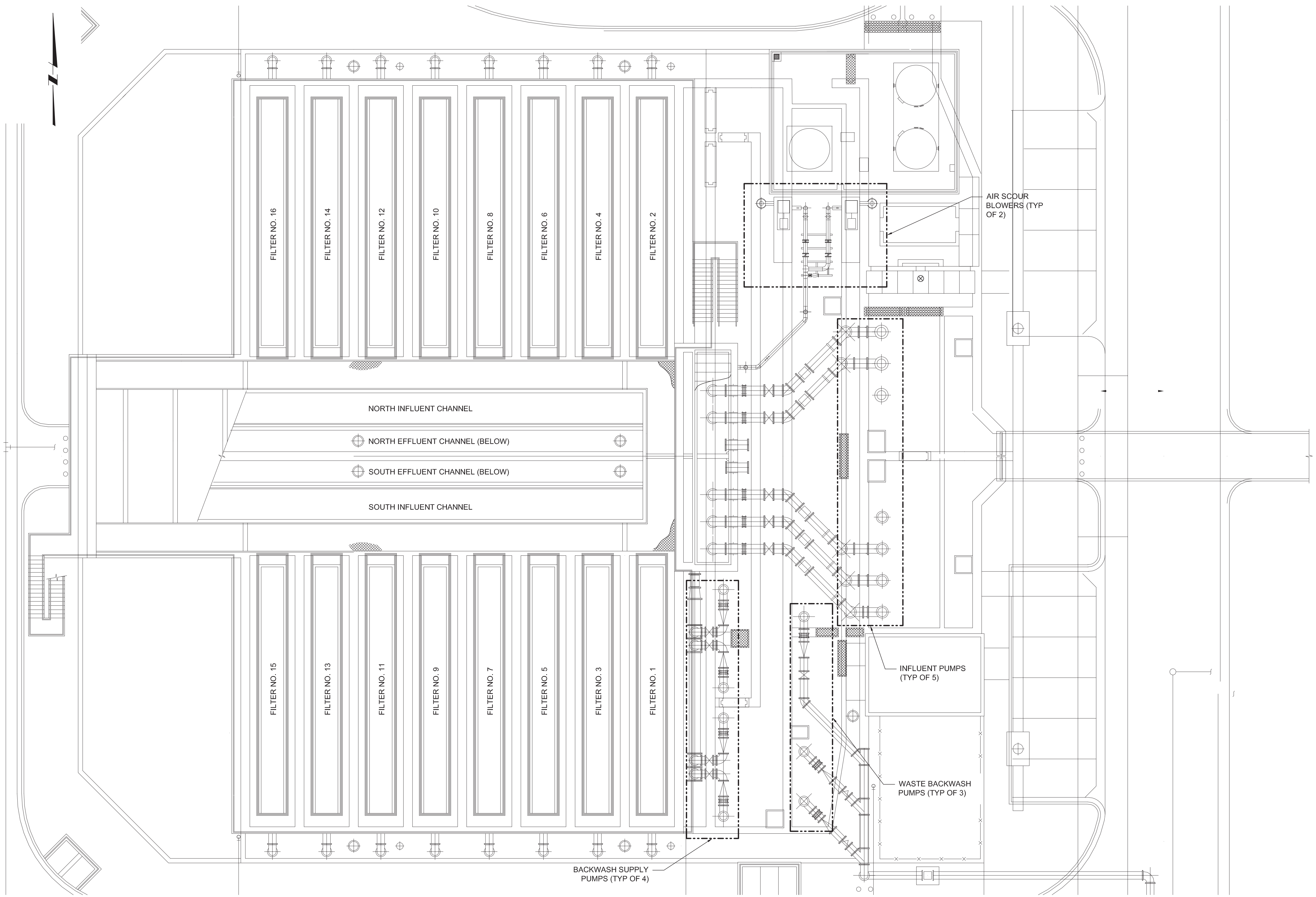
If the filters are operated mainly for suspended solids removal, they will be backwashed either when turbidity breakthrough is observed in the effluent, or when the water level in the filter box has risen to its highest point. This latter point is referred to as the terminal headloss. If the filters are operated for denitrification, the time between backwashes is often set by the desire to maintain a healthy growth rate in the biofilms, and backwash will often be done at regular intervals regardless of whether the terminal headloss has been reached. However, with high-turbidity influent, backwash may be required after a shorter time.

Bump Cycle

If the filters are used for denitrification, nitrogen gas will accumulate in the pore spaces as it is released by the denitrifying organisms during the filtration cycle. This will occupy a significant volume of the filter bed, decrease the capacity for TSS removal, and increase the headloss. The filter must be "bumped" periodically to remove this gas. This is done by briefly taking the filter out of service and flushing gently in the upflow direction.

Expected Effluent Quality

Denitrifying filters produce effluent with low turbidity and suspended solids content. Severn Trent product data indicates that <5 mg/L TSS is achievable, and <2 mg/L TSS is typical. In addition, if they are fed methanol and "bumped" to support denitrifying biomass, they can produce effluent with around 1 mg/L NO_3-N.



MWH®

TERMINAL ISLAND WATER RECLAMATION PLANT
TERTIARY FILTER REHABILITATION
PRELIMINARY DESIGN REPORT

LAYOUT OF
EXISTING FILTERS

FIGURE
1-3

Section 2
Design Requirements

INTRODUCTION

This Section summarizes the information that will serve as a basis for the final design. This includes the design criteria for the rehabilitated filtration system, and a list of major equipment. Lists of drawings and specifications for the final design package; preliminary Process and Instrumentation Diagrams (P&IDs); and an updated construction cost estimate are appended.

PROCESS DESIGN CRITERIA

Design Criteria Summary

The process design criteria for the TIWRP tertiary filters are provided in **Table 2-1**. Some of these parameters (as noted in **Table 2-1**) are based on published product data for the TETRA® Denite® system or the Severn-Trent proposal provided in the Study report. Other parameters are calculated as shown in **Appendix A**. Design criteria are grouped into six categories. Key assumptions and results associated with each category are summarized below.

1) *Influent.* The assumed flow and quality of the influent to the filters is based on data provided to MWH by the City during the Study. On average, the filters currently treat 15 mgd of flow with approximately 1.5 NTU turbidity and 8.5 mg/L NO_3-N. The design criteria conservatively assume maximum values for turbidity and nitrate, along with a target plant capacity of 30 mgd at average daily flow and a peak hour flow of 52 mgd (the observed peak hour flow during major rainfall event days in recent years).[1]

2) *Filter Configuration.* The existing dimensions of the filter cells are shown in **Table 2-1** and will remain unchanged during rehabilitation. During construction, it is assumed that the system will operate for some period of time with only one bank of filters, while the other bank is offline for gallery valve replacement. A single bank of eight filters with one filter out of service can treat a peak hourly flow of 30 mgd while maintaining a maximum filtration rate of 5 gpm/sf (see **Table 2-2**). This constraint will have to be taken into account for timing of major filter rehabilitation work. Section 4 describes the construction sequencing in detail.

3) *Media Configuration.* The selected media configuration is 72 inches of coarse sand media, with an effective size of 2 to 3 mm and a uniformity coefficient no greater than 1.4, as recommended for Denite® systems. This media should be clean quartz sand with high sphericity. The media will be supported by 18 inches of graded gravel and the existing TETRA® T-block underdrain. This media is typical for denitrifying filter

[1] The filters must treat the flow rate of secondary effluent that is produced; there is no opportunity for flow equalization between the secondary clarifiers and the filter influent pumps.

applications: because of its large grain size and high density, it only fluidizes at very high velocity and therefore protects biofilms in the bed from excessive scouring. It also balances solids removal capacity, headloss, and surface area for biofilm growth.

4) *Filtration Cycle.* The filters are sufficiently sized to handle the 30 mgd design capacity with one bank in service and one filter offline; they are also sufficient to handle the 52 mgd peak flow with both banks in service and up to four filters offline. Based on the design conditions, the filters are adequately sized for hydraulic surface loading, volumetric nitrate loading, and suspended solids removal capacity. Because of the low clean-bed headloss, the effluent valve position will be modulated to maintain the minimum water level at 15 ft above mean sea level (AMSL), so that the media is saturated at all times and at least 1.5 ft of submergence are maintained at all times.

5) *Backwash Cycle.* The filters will be backwashed at a low velocity (6 gpm/sf), which cleans the bed without fluidizing the media or disrupting the denitrifying biofilms. Two backwash pumps will be replaced to provide this lower flow rate, and the other two pumps will be left in place to allow for higher-velocity backwash if desired. In addition, air scour will be provided at a rate of 3 to 5 icfm/sf. The typical frequency of backwash for denitrifying filters is once per day, to maintain biofilm health. Backwash may be needed more frequently if influent TSS is high or less frequently if influent nitrate is low.

6) *Denite® Process.* Although this project will not provide for denitrification, future operation as denitrifying filters would require facilities to dose methanol as a carbon feedstock, in a range of about 25 to 40 mg/L. Alternative carbon sources such as glycerin are available, but methanol is often used for the Denite® process. Denitrification to nitrogen also would require periodic bumping of the filter at a velocity of 4.9 gpm/sf to remove accumulated gas. Typically, denitrifying filters are bumped every 2 hours.

Table 2-1: Process Design Criteria

PARAMETER	UNIT	DESIGN VALUE	SOURCE AND ASSUMPTIONS
1. Influent			
Flow Rate			
Average	mgd	15	Data from Study, Aug 2011 to Sep 2012
Plant Design Capacity	mgd	30	
Peak-Hour Capacity	mgd	52	
Water Quality			
Nitrate	mg/L as N	5.4 to 11	Data from Sep 2010 to Oct 2011
Turbidity	NTU	0.65 to 10	Data from Study, Aug 2011 to Sep 2012
Total Suspended Solids	mg/L	2.5 to 38	Estimated based on pilot data, Sep 2011
2. Filter Configuration			
Filter Cell Length	ft	60	Existing
Filter Cell Width	ft	10	Existing
Filter Cell Area	sf	600	Existing
Number of Filters	-	16	Existing
Minimum Filters Online	-	7	One filter bank in service with one filter offline

PARAMETER	UNIT	DESIGN VALUE	SOURCE AND ASSUMPTIONS
3. Media Configuration			
Filtration Media			
Media Type	-	TETRA #5 Sand	Recommended in Severn-Trent proposal
Specific Gravity	-	2.65	For silica sand media
Effective Size	mm	2 to 3	From TETRA® Denite® product literature
Uniformity	-	1.4	From TETRA® Denite® product literature
Bed Depth	in	72	Typical for denitrifying filters
Media Support System			
Underdrain	-	TETRA T-Block	Recommended in Severn-Trent proposal
Support Media Type	-	Gravel	Recommended in Severn-Trent proposal
Support Media Depth	in	18	Recommended in Severn-Trent proposal
4. Filtration Cycle			
Loading			
Hydraulic Loading Rate	gpm/sf	3 to 5	From TETRA® Denite® product literature
Nitrate Loading Rate	kg N/m^3-day	1.0 to 1.8	Calculated
Solids Capacity	kg TSS/m^3	2.67	From TETRA® Denite® product literature
Hydraulic Profile			
Minimum Water Level	ft AMSL	15	1.5 ft above top of media
Clean Bed Headloss	ft	0.2 to 0.3	Calculated
Terminal Headloss	ft	14.4 to 16.3	Calculated
5. Backwash Cycle			
Backwash Frequency	day	1	From Metcalf & Eddy, *Wastewater Engr.*
Backwash Water			
Flux	gpm/sf	5 to 6	From TETRA® Denite® product literature
Backwash Supply	mgd	4.3 to 5.2	Calculated
Bed Headloss	ft	0.3 to 32.6	Calculated
Bed Expansion	%	0	Calculated
Air Scour			
Flux	icfm/sf	3 to 5	From TETRA® Denite® product literature
Air Scour Rate	icfm	1800 to 3000	Calculated
Back Pressure	psi	9.1	Calculated
6. Denite® Process (applies to future denitrification operation only)			
Carbon Feedstock			
Feedstock Type	-	Methanol	Typical for denitrifying filters
Dosing Ratio	g / g NO_3^-	3.0 to 3.5	From Metcalf & Eddy, *Wastewater Engr.*
Feedstock Dose	mg/L	25 to 39	Calculated
Nitrogen Bump			
Bump Frequency	hr	2	From Metcalf & Eddy, *Wastewater Engr.*
Bump Velocity	gpm/sf	4.9	From Metcalf & Eddy, *Wastewater Engr.*
Bump Flow Rate	mgd	4.24	Calculated

Proposed Operating Window

The proposed "operating window" for the system was defined by calculating the filtration velocity with any number of filters online at the average, design, and peak flow rates. The results of this calculation are shown in **Table 2-2**. Note that there are a variety of possible configurations that will maintain the filtration velocity within the typical Denite® design range of 3 and 5 gpm/sf in all cases.

Table 2-2: Filter Operating Scenarios

Banks Online	Filters Online	Filtration Velocity (gpm/sf) Average (15 MGD)	Design (30 MGD)	Peak (52 MGD)
2	16	1.09	2.17	3.76
	15	1.16	2.31	4.01
	14	1.24	2.48	4.30
	13	1.34	2.67	4.63
	12	1.45	2.89	5.02
	11	1.58	3.16	5.47
	10	1.74	3.47	6.02
	9	1.93	3.86	6.69
1	8	2.17	4.34	7.52
	7	2.48	4.96	8.60
	6	2.89	5.79	10.03
	5	3.47	6.94	12.04
	4	4.34	8.68	15.05
	3	5.79	11.57	20.06
	2	8.68	17.36	30.09
	1	17.36	34.72	60.19

Ultimately, the number of filters to place online will depend on influent turbidity in addition to flow. The final operating strategy for the filters, considering hydraulic, (future) nitrate, and TSS loading, will be confirmed during the final design phase.

Backwash Velocity Selection

As a means of verifying the backwash rates that have been successfully operated for denitfication filters, MWH contacted a small sample of reference WWTPs that employ the Denite® filter design but are currently operating the systems as conventional filters for TSS removal (i.e. not utilizing the denitrification capability of the filter). After contacting the various WWTPs, it was confirmed that employing a backwash rate of approximately 6 gpm/sf has been successful to effectively clean the filter beds.

LIST OF MAJOR EQUIPMENT AND SIZING

Along with the improvements to the filtration process itself, rehabilitation of the TIWRP filter system will include the replacement of several items of mechanical equipment. Major equipment for this project is listed in **Table 2-3**.

New backwash pumps and blowers are required to provide the proper flow rates of water and air for the modified lower-velocity backwash. It is assumed that three pumps will be needed in a

1+2 configuration, each capable of providing 5.2 mgd of flow at up to 76 ft of head. Preliminary sizing calculations for the backwash pump are found in **Appendix B.** In addition, two positive-displacement (PD) air blowers will provided, each with a flow rate of 3,000 icfm at 9.1 psi.

Table 2-3: Mechanical Equipment List

ITEM	QTY	PARAMETERS	
Pumps and Blowers		**Flow**	**Head**
Vertical Turbine Backwash Supply Pumps	3	5.2 mgd	76 ft
Positive Displacement Air Scour Blowers	2	3000 icfm	9.1 psi
Valves		**Size (in)**	**Type**
Backwash Supply Isolation Valves	2	30	Butterfly
Filter Effluent Valves	16	18	Butterfly
Waste Backwash Valves	16	30	Butterfly
Air Piping Isolation Valves	16	10	Butterfly
Gates		**Length (ft)**	**Width (ft)**
Backwash Waste Effluent Gates	16	3	3

The valves listed in **Table 2-3** were identified during the Study as needing replacement, because they were leaking or incorrectly installed. The backwash effluent gates will be installed as a new feature to control flow into the backwash channels, replacing the existing butterfly valves that will be abandoned in place. The gates are better suited to this application: they experience less pressure given their placement in the backwash system, and they will not be prone to the significant leakage that plagued the butterfly valves.

LIST OF DRAWINGS

A list of drawing sheets that will be developed during the final design phase is shown in **Appendix C**.

LIST OF SPECIFICATIONS

A list of specification sections that will be developed during the final design phase is shown in **Appendix D**.

PRELIMINARY PROCESS AND INSTRUMENTATION DIAGRAMS

Preliminary P&IDs are found in **Appendix E**.

UPDATED CONSTRUCTION COST ESTIMATE

The Class "O" construction cost estimate developed during the Study has been refined to a Class "C" estimate, as shown in **Appendix F**.

Section 3
Elements of Design

INTRODUCTION

This Section describes the key elements of design for the rehabilitation of the TIWRP tertiary filters. **Table 3-1** summarizes these key elements and the rehabilitation tasks required to complete each one. Each element will be discussed further in this Section.

Table 3-1: Recommended Rehabilitation Items

Element of Design	Rehabilitation Tasks
New Filter Media	Remove existing multi-media and gravel, and place new sand media and gravel
Filter Underdrain Rehabilitation	Inspect and reinstall underdrain
Air Scour Blowers	Replace
Air Piping Relocation	Relocate existing air piping to exterior of structure and out of gallery
Backwash Supply Pumps	Resize and replace 3 of 4
Backwash Waste Effluent Gate	Add filter backwash effluent gate
Filter Effluent Butterfly Valves	Replace valves and actuators
Backwash Supply Valves	Replace valves and actuators
Backwash Supply Isolation Valves	Add one new valve each for North and South filter banks
Sample Pumps	Increase size of sample lines
Valve and Actuator Controllers	Replace all valve and actuator controllers

FILTER MEDIA REPLACEMENT

Fifteen of the filters have existing tri-media beds with between 10 to 24 inches of media, while one monomedia filter contains 58 inches of sand. During the Study, MWH measured the loss of media for all 16 filters. While a total of 42 inches of tri-media and 18 inches of graded gravel were originally present in each filter, an average media depth of 16 inches was observed in the field (see **Table 3-2**). The high media loss is most likely attributed to a combination of excessively high backwash rates and gravel/underdrain upsets that allow the media to exit the filter through the effluent piping. The media installed in the filters is not suitable for future denitrification service and needs to be removed and replaced to improve filter performance.

Table 3-2: Existing Media Depth Summary

Filter	Average Media Depth (in)	Filter	Average Media Depth (in)
1	16	9	23
2	19	10	23
3*	58	11	23
4	19	12	19
5	24	13	13
6**	-7	14	11
7	15	15	10
8	17	16	16

*Monomedia filter
**Underdrain blocks exposed and overturned

Due to the fact that the rehabilitated filters are intended to be capable of operating as denitrifying filters in the future, the media selected will be based on the requirements of a denitrifying filter. For a denitrifying filter, 72 inches of coarse sand and 18 inches of support gravel are recommended for the rehabilitation (see Section 2). The sand would not normally need to be fluidized during backwash and would require a low backwash rate of 5 to 6 gpm/sf.

UNDERDRAIN REHABILITATION

The type of underdrain installed at the TIWRP is the TETRA® T-Block design, and it has experienced displacement (overturning) in several locations within the existing filters (see **Figure 3-1**).

Figure 3-1: TETRA T-Block (left) and Overturned Blocks (right) at Filter 6

Due to the fact that the rehabilitated filters are intended to retain their ability to operate as a Denite® system, a low flow non-fluidizing backwash is recommended for normal operations and the existing underdrain blocks are acceptable for this application. However, before the filters can be placed back into service, all the underdrain blocks must be inspected and reinstalled properly. During the rehabilitation of the filters, all filter cells will be completely excavated to allow for the underdrain blocks to be inspected and reinstalled properly. Due to the nature of the concretefilled underdrain blocks, the purchase of new underdrain blocks is anticipated to be minimal, as it is unlikely that any are damaged beyond repair.

The upsets that have been seen with the existing underdrain blocks can be attributed to a combination of high backwash flows, air entrainment and media loss. All of the aforementioned causes of the overturning of the underdrain blocks will be eliminated with the rehabilitation of the filter structure and modifications to the backwash routine. The manufacturer of the underdrain blocks, Severn Trent Services, may provide a 10 year warranty for the operation of the underdrain blocks so long as the backwash operation and media selection conform to their intended design criteria.

AIR SCOUR BLOWER REPLACEMENT

There are currently two (2) Gardner-Denver Sutorbilt positive-displacement blowers operating at the TIWRP (3370 scfm at 12 psig; approximate motor hp 250). During field investigations it was observed that even though the existing air piping goosenecks above the expected high water level in the filters, water is still able to reach the blowers. During the first backwash run of the day, water was observed in the field being released from the blowers via a vent stack. Discussions with plant staff have indicated that the blowers have experienced severe corrosion due to water reaching the blower discharge point. Blowers require replacement. **Figure 3-2** shows water being released from the blower vent stack beyond the gooseneck.

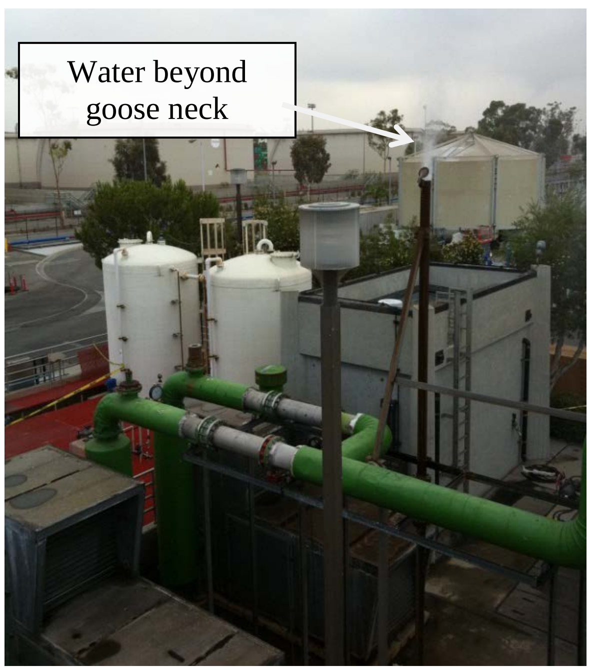


Figure 3-2: Air Blowers Releasing Water

The existing air scour blowers will be replaced with new positive displacement blowers sized to deliver 5 icfm/sf against minimum of 9.1 psi of back pressure (see Section 2). Actual blower pressure rating will match 12 psig of the existing units. The locations of the air scour blowers are also shown in **Figure 3-3**.

AIR PIPING RELOCATION

The current air piping routing consists of a 10-inch header that serves the entire filter structure. The 10-inch air header branches off into each individual filter cell with a dedicated butterfly valve to feed air to each filter. The individual air piping butterfly valves are located below grade at an elevation below the water level in the filters (see **Figure 3-4**). A constant backpressure of 2 to 15.5 ft of water is observed on the air piping butterfly valves, with different fluids on each side of the valve (air and water). It has been observed in the field by the City and MWH that the air piping butterfly valves were leaking during both backwash and normal operation.

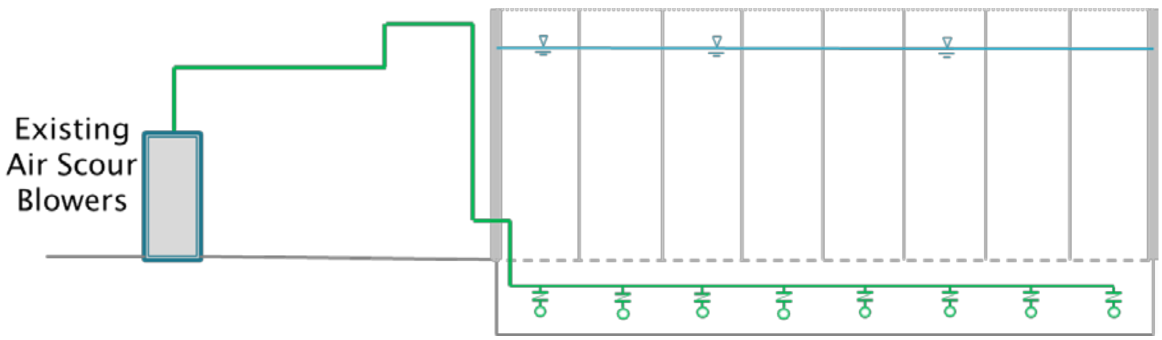


Figure 3-4: Relative Elevations of the Existing Air Scour System

For rehabilitation, the air piping should be removed from the filter gallery and routed around the exterior of the filter structure (see **Figure 3-5**). The individual filter air piping would branch off from the exterior piping, then either penetrate through the filter wall or be routed over the handrail. In either case, the air pipe downcomer will penetrate through the media to connect to existing air piping in the underdrain. Individual butterfly valves for isolation would be installed at each filter branch at an accessible level. Moving the air piping to the exterior of the filter structure will allow for the individual air valves to be operated above the hydraulic grade line, relieving the valves of having to hold seal against a significant head of water on one side and air on the other. The existing below-grade air header will be demolished (see **Figures 3-5** and **3-6**).

BACKWASH SUPPLY PUMPS

Existing Backwash Supply Pumps

There are four existing backwash supply pumps of the vertical turbine type operating at the TIWRP. Each backwash sequence consists of a single backwash pump operating for 3 minutes (approximately 11.3 gpm/sf) and two backwash pumps in operation for 12 minutes (24.5 gpm/sf). However, the intended backwash rate for the operation of a denitrifying filter is approximately 5-6 gpm/sf (see Section 2). Due to the large difference between the existing and proposed backwash supply pump capacities, some of the backwash supply pumps will need to be resized and replaced to allow for efficient operation at 6 gpm/sf (the existing Simflo pump curves are not rated for operation in the 3,600 gpm range that is the basis for new pumps).

Proposed Backwash Supply Pumps

Since the new backwash velocity will be 6 gpm/sf, the new vertical-turbine backwash pumps should be sized to deliver this amount of backwash supply water to a single filter with only one pump in service. Sizing data for these pumps is found in **Table 2-3**.

In summary, three of the four backwash pumps will be replaced so as to be capable of supplying the required 6 gpm/sf backwash flow for a single backwash with a single pump, a backup pump and one pump out of service. Locations of the backwash supply pumps are shown on **Figure 3-3**.

BACKWASH WASTE EFFLUENT GATES

Each filter has a dedicated 30-inch backwash waste butterfly valve located on the exterior of the filter structure. Observations by the City and MWH in the field confirmed that many of the valves were experiencing at least some leakage, with several valves experiencing extensive leakage. Based on data received from the City during the Study, it was determined that an average of 19% of the total filter flow was being recycled back to the front of the plant, attributable in part to this leakage, far beyond the normal design of 2% to 3%. The TIWRP operations staff attempted to minimize the leakage by replacing gearboxes to provide extra torque in an attempt to close the valves more tightly. Discussions with the operations staff indicated that the valves were consistently not seating properly due to fibrous material that would prevent a tight seal. Rehabilitation or replacement of the backwash waste effluent butterfly valves would not necessarily result in increased performance due to the potential for the same problem to build up again.

As a result of the location of the butterfly valves and the extensive work already done by the TIWRP staff to attempt to assure that they seal as tight as possible, the backwash waste butterfly valves will be removed and replaced with a spool piece. Effluent backwash water slide gates, similar to the influent gates, will be installed on the filter wall at the backwash waste opening to block flow from entering the waste line during normal operation. **Figure 3-7** shows the locations of the proposed backwash waste effluent gates. The addition of the backwash waste effluent gates will significantly reduce the total flow being sent back to the head of the plant.

FILTER EFFLUENT BUTTERFLY VALVE REPLACEMENT

Each filter has a dedicated 18-inch filter effluent butterfly valve that is located below grade in the filter gallery (See **Figure 3-6,** Section B). Because significant leakage through the closed effluent butterfly valves has been observed, the valves should be replaced. **Figure 3-6** shows the locations of the filter effluent butterfly valves that are to be replaced.

During the Study, the plant staff attempted to drain several filters to collect core samples of the media. To drain a filter, all valves were closed, with the exception of the 6-inch drain valve). After 24 hours, several filters were still draining. It was later concluded that the filter effluent butterfly valve was leaking water into the filter at the same rate at which it was draining out through the 6-inch drain valve, making drainage of the filter cell impossible. It was also observed that under certain conditions, entrained air from the air scour blowers would leak through the closed filter effluent butterfly valve and exit into the effluent channel, sometimes leaking through with enough force to raise the manhole cover over the effluent channel (see **Figure 3-8**).

Figure 3-8: Air Leaking through Filter Effluent Butterfly Valve during Backwash

In addition to the valves being replaced, the motorized actuators should be replaced. Because of the low elevation of the filter effluent weir (6.5 ft AMSL) and the low clean-bed headloss (0.1 to 0.3 ft with coarse media), these effluent valves will be very important to prevent the filter media from dewatering during normal filtration operation. In order to keep the media beds saturated, a minimum water elevation of 16 ft AMSL is recommended in each filter cell (see Section 2). The valves actuators will operate based on feedback control from the ultrasonic water level transmitters in each filter cell, to throttle the valve such that this minimum water level is maintained. This will take place at the beginning of each filtration cycle, until sufficient headloss has accumulated in the filter bed to keep the water surface elevation above 16 ft AMSL with the valve fully open.

BACKWASH SUPPLY VALVES

Each filter cell has a dedicated 30-inch backwash supply valve (see **Figure 3-6**). Although it is likely that the valves are experiencing some leakage, replacing the valves with the intention of minimizing the leaking of the valves is not required for performance improvement that would result from this replacement.

However, the backwash supply valves were installed in 1994 and are expected to be reaching the end of their expected lives. Replacement of the valves in the future would require the filter structure to be shut down in phases (similar to the requirements of this project) and would require a significant amount of mechanical work in the filter gallery. Due to the fact that the valve is expected to reach the end of its expected life relatively soon and would require a significant amount of mechanical work to replace it was confirmed that the valve should be replaced as part of this rehabilitation.

BACKWASH SUPPLY ISOLATION VALVES

The backwash supply pumps currently discharge into a single 30-inch backwash supply header that serves all 16 filters. The 30-inch backwash supply header branches off into two parallel headers, each serving one bank of the filter structure. Each filter cell has a dedicated backwash supply butterfly valve that isolates the filter cell from the backwash supply header. In order to isolate half of the backwash supply header from the filter structure, and not just an individual filter cell, two backwash supply isolation valves must be installed. The location of the proposed backwash supply isolation valve can be seen on **Figure 3-6.** Further discussion regarding the steps required to install the backwash supply isolation valves is provided in Section 4.

SAMPLE PUMPS

Each filter cell currently has a 1/4-inch sample tap into the filter effluent pipe to allow the measurement of the effluent turbidity for each filter cell. However, it was acknowledged during site investigation that the turbidity tap would frequently clog with debris, making measurement of turbidity on individual filter cells impossible without entering into the filter gallery or using a portable pump. Because of the limited space provided in the filter gallery, obtaining regular turbidity readings for individual filter cells remains a time consuming tasks that requires operations staff to enter into a confined space. **Figure 3-9** shows the current layout of the existing 1/4-inch turbidity sample port.

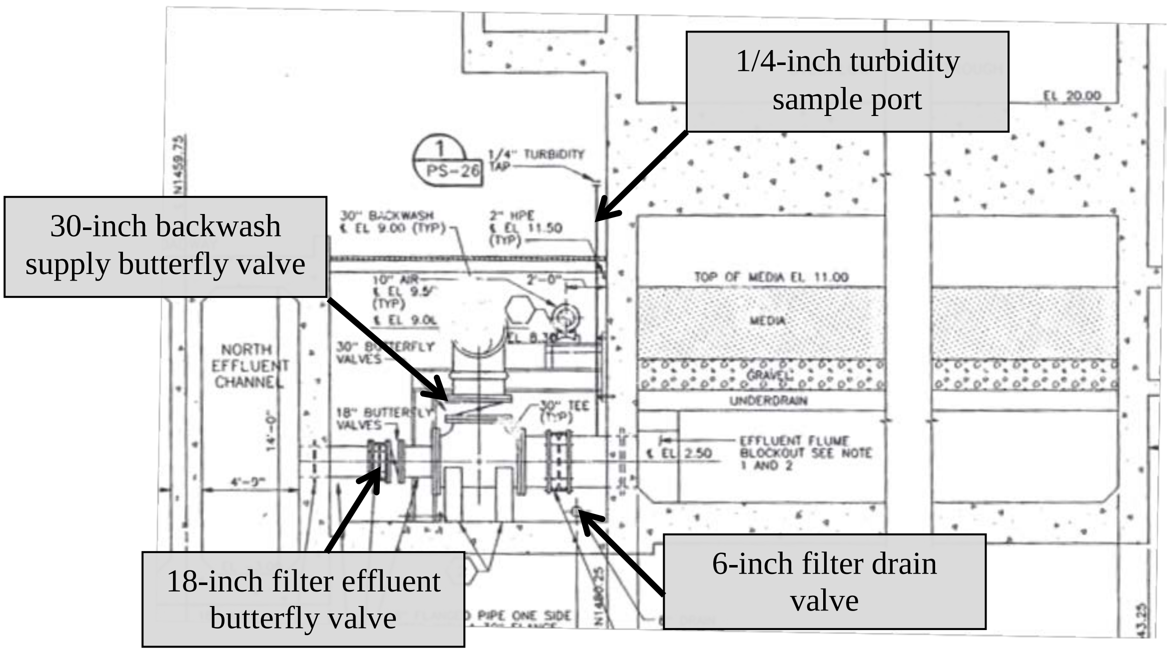


Figure 3-9: Location of Turbidity Sample Port and Relevant Valves

To provide a more reliable and efficient method of obtaining samples from individual filters, the sample ports for each filter will be increased to ¾" diameter. The increased sample port size should eliminate the biological clogging of the filter sample port.

VALVE AND ACTUATOR CONTROLS

All of the existing valve and actuators are currently controlled through Pakscan, which utilized a proprietary control signal to each element. The City has indicated that a new control system is preferred for the filter structure that utilizes an open source control system that is more easily manipulated by plant staff. To accomplish this, the Consultant will provide new valve and actuator controller boxes to provide communication throughout the structure. **Figure 3-10** below shows the general configuration of the new valve and actuator controller boxes.

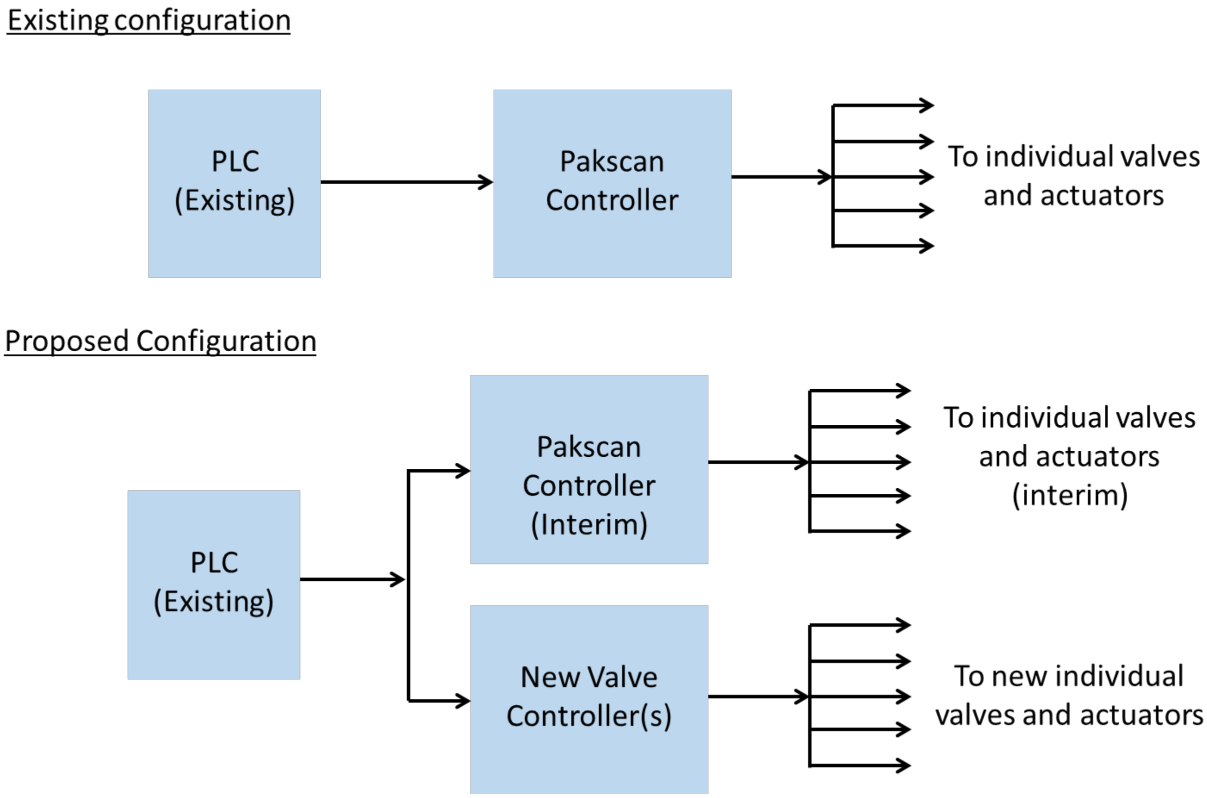
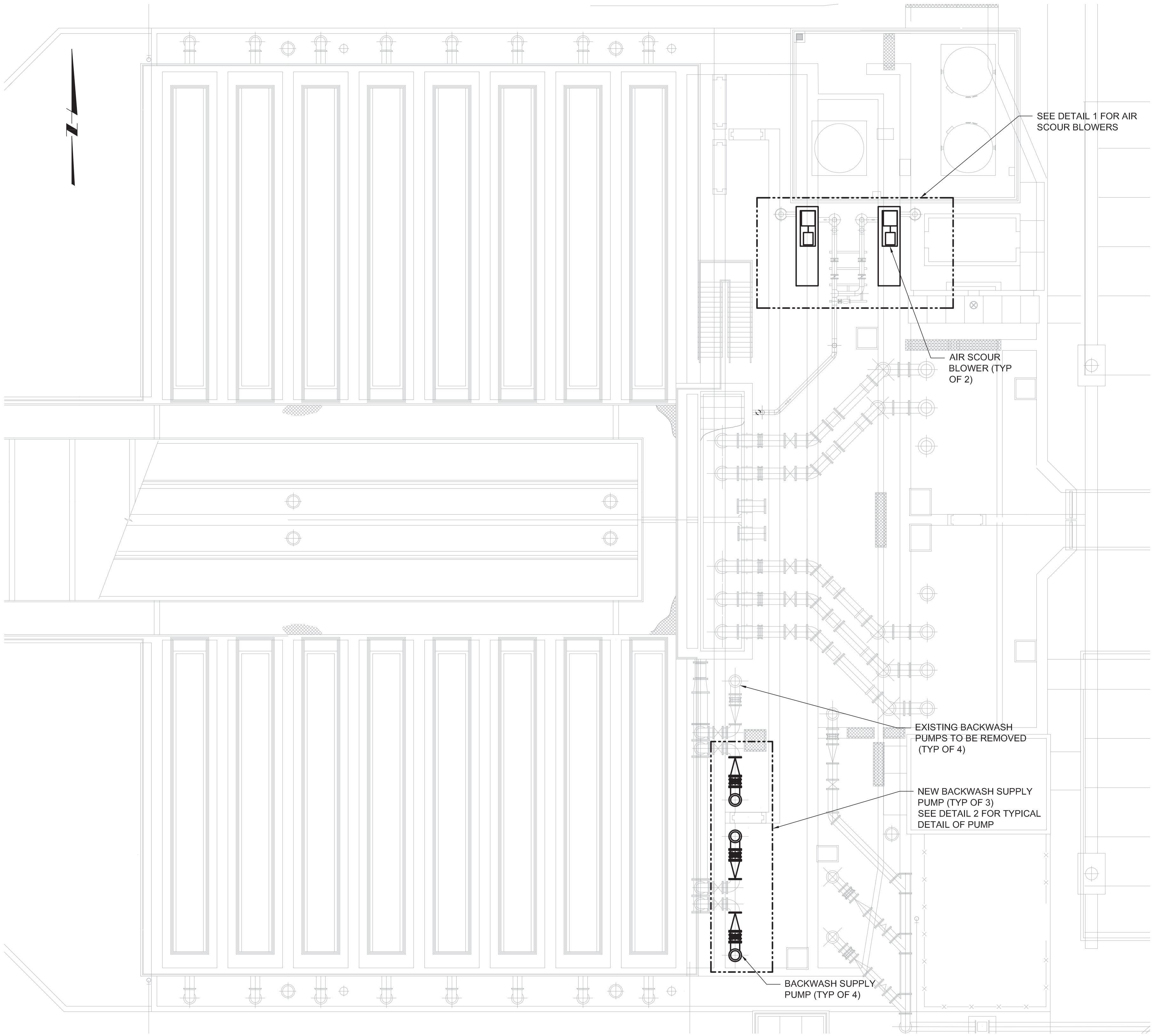
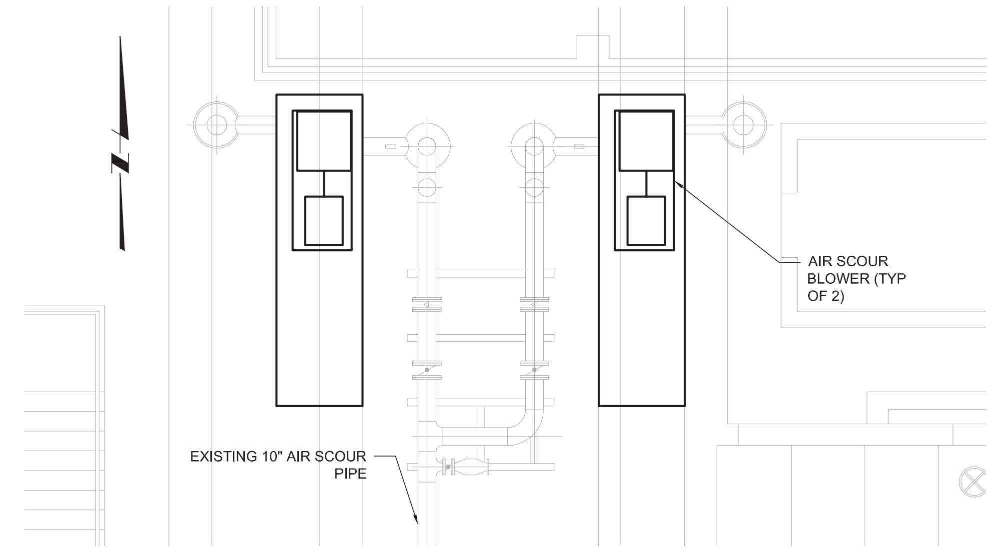


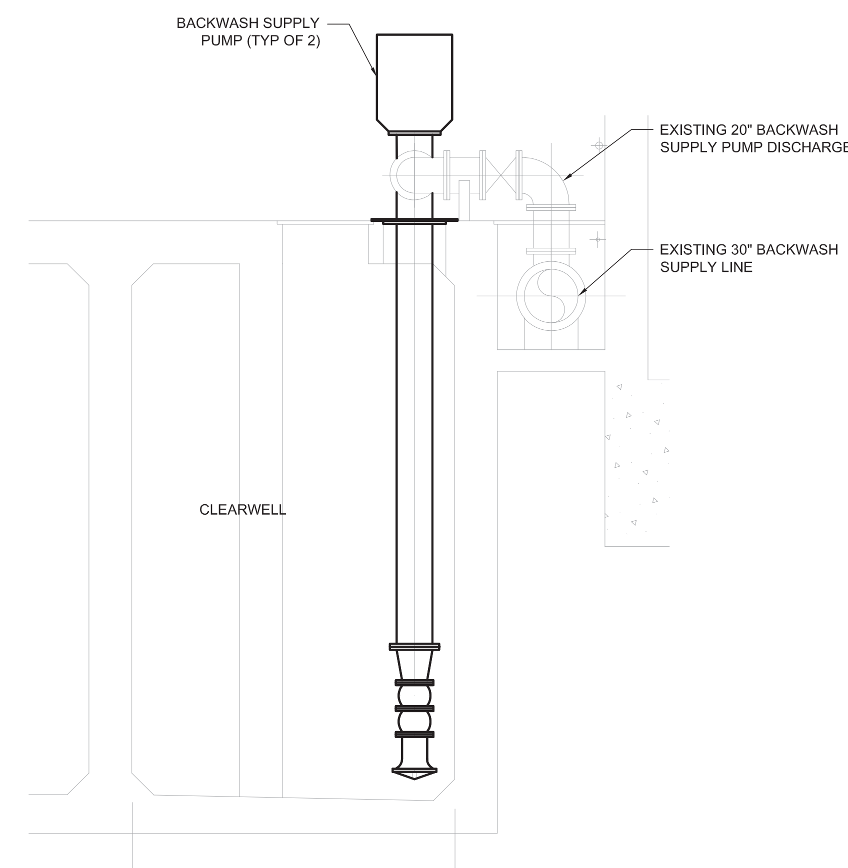
Figure 3-10: Existing and Proposed Diagram of Valve and Actuator Controls

To accomplish the replacement of the communication system, all existing valves and actuators, including those not being replaced as part of this project, must be wired with new control wires and programmed in the PLC. The PLC, which contains all of the logic for the operation of the filter structure, will then communicate with the new valve controller box to open and close the various elements as required. It is important to note, that throughout the phased rehabilitation of the filter structure, the PLC must be reprogrammed by the Contractor each time a new set of valves is rewired for the proposed control configuration. The reprogramming will allow the PLC to communicate with the appropriate controller (Pakscan for old elements and new valve controllers for rehabilitated elements). It is estimated that the Contractor will reprogram the PLC 6 times, although the exact number of times the PLC will be required to be reprogrammed will be contingent upon the construction sequence utilized by the Contractor.





DETAIL 1



DETAIL 2

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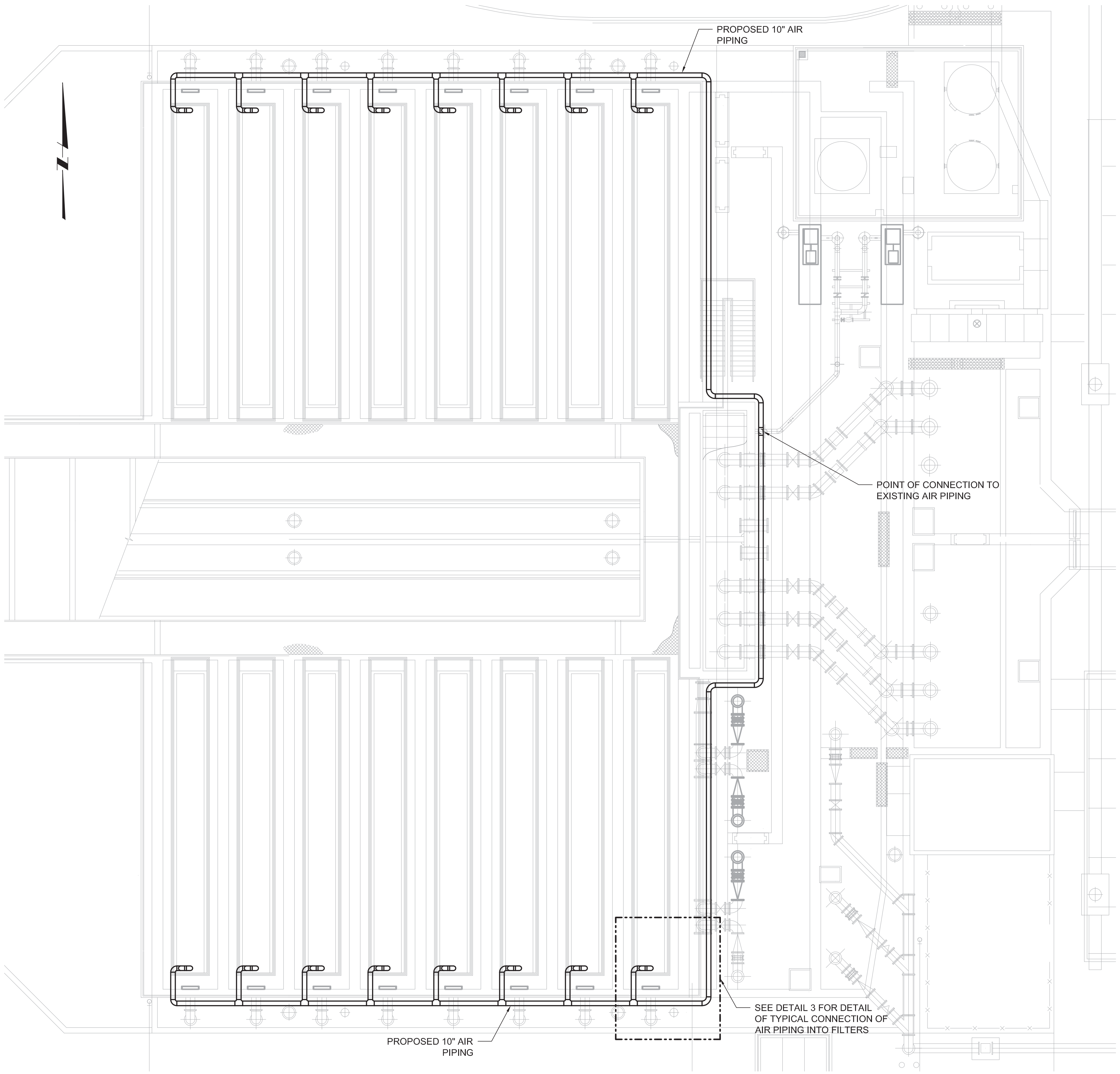
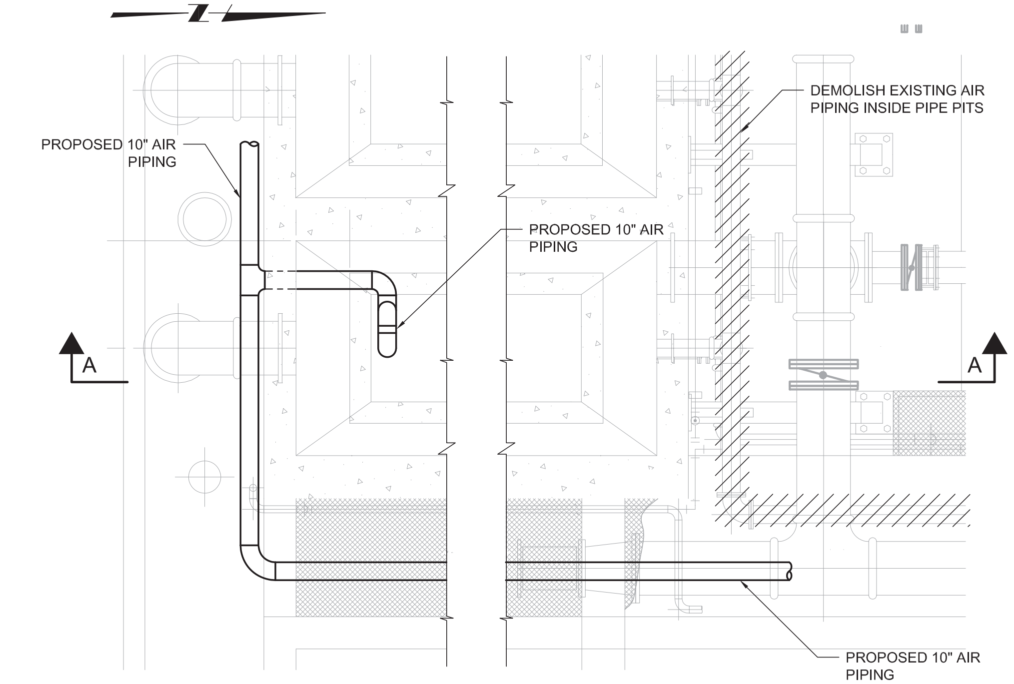
TERMINAL ISLAND WATER RECLAMATION PLANT
TERTIARY FILTER REHABILITATION
PRELIMINARY DESIGN REPORT

BLOWER AND BACKWASH PUMP REPLACEMENT

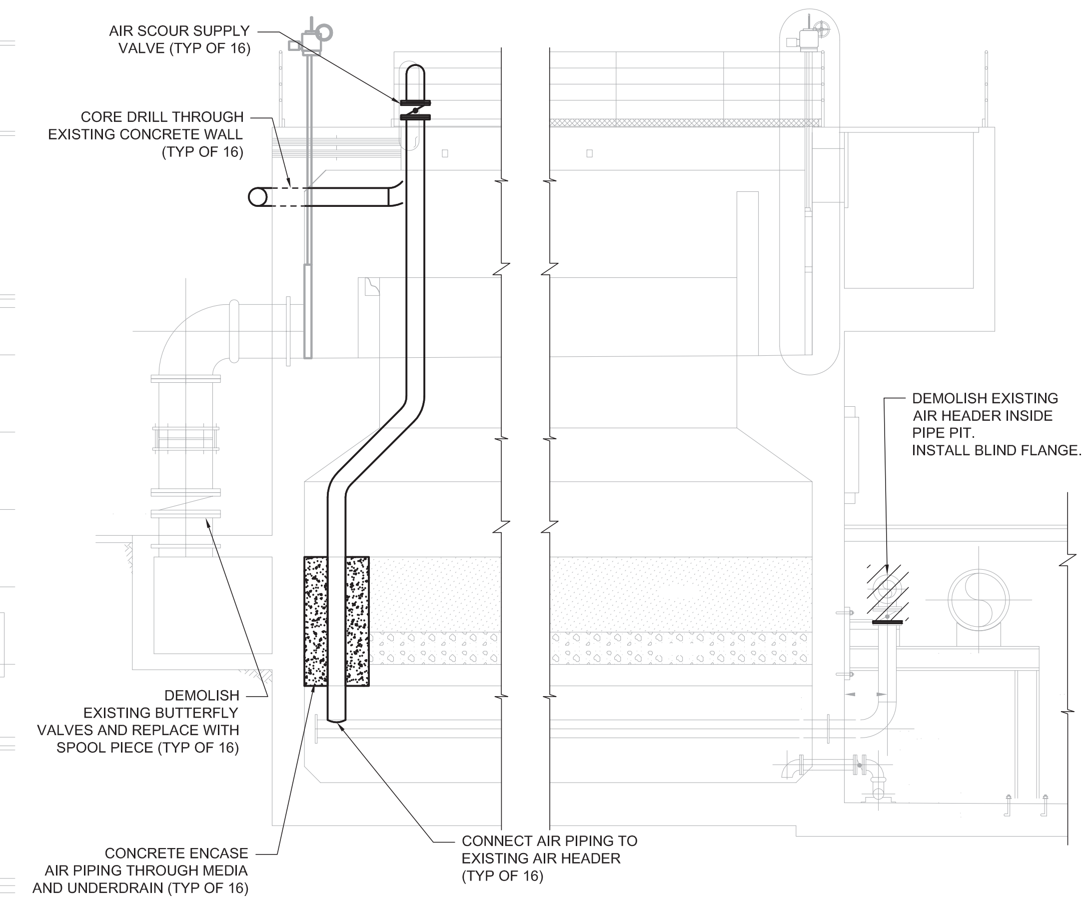
FIGURE 3-3



PLAN



DETAIL 3



SECTION A

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TERMINAL ISLAND WATER RECLAMATION PLANT
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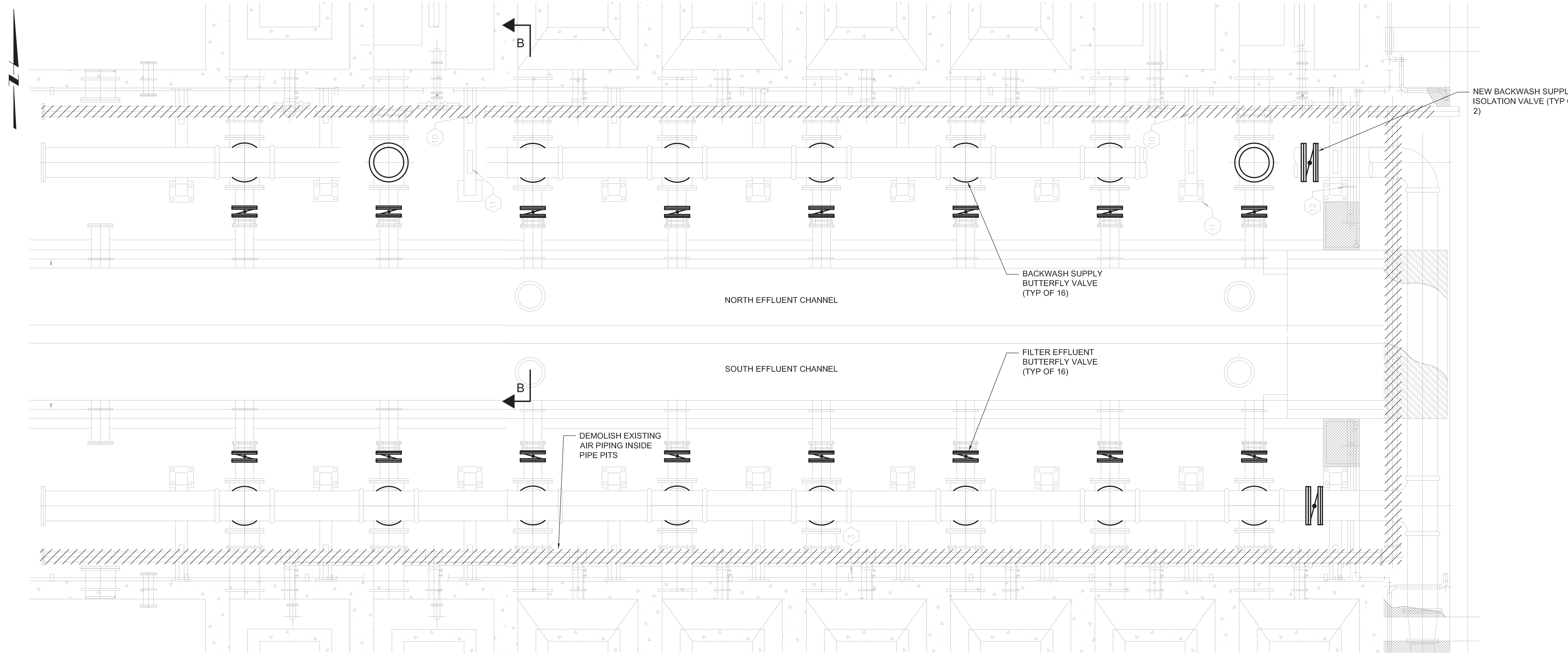
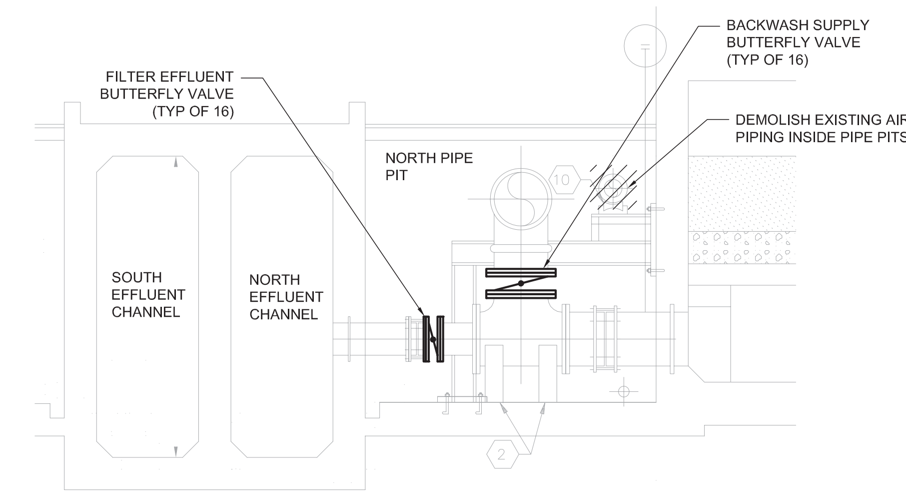
AIR PIPING RELOCATION

FIGURE

3-5



PLAN VIEW AT EL. 21.50



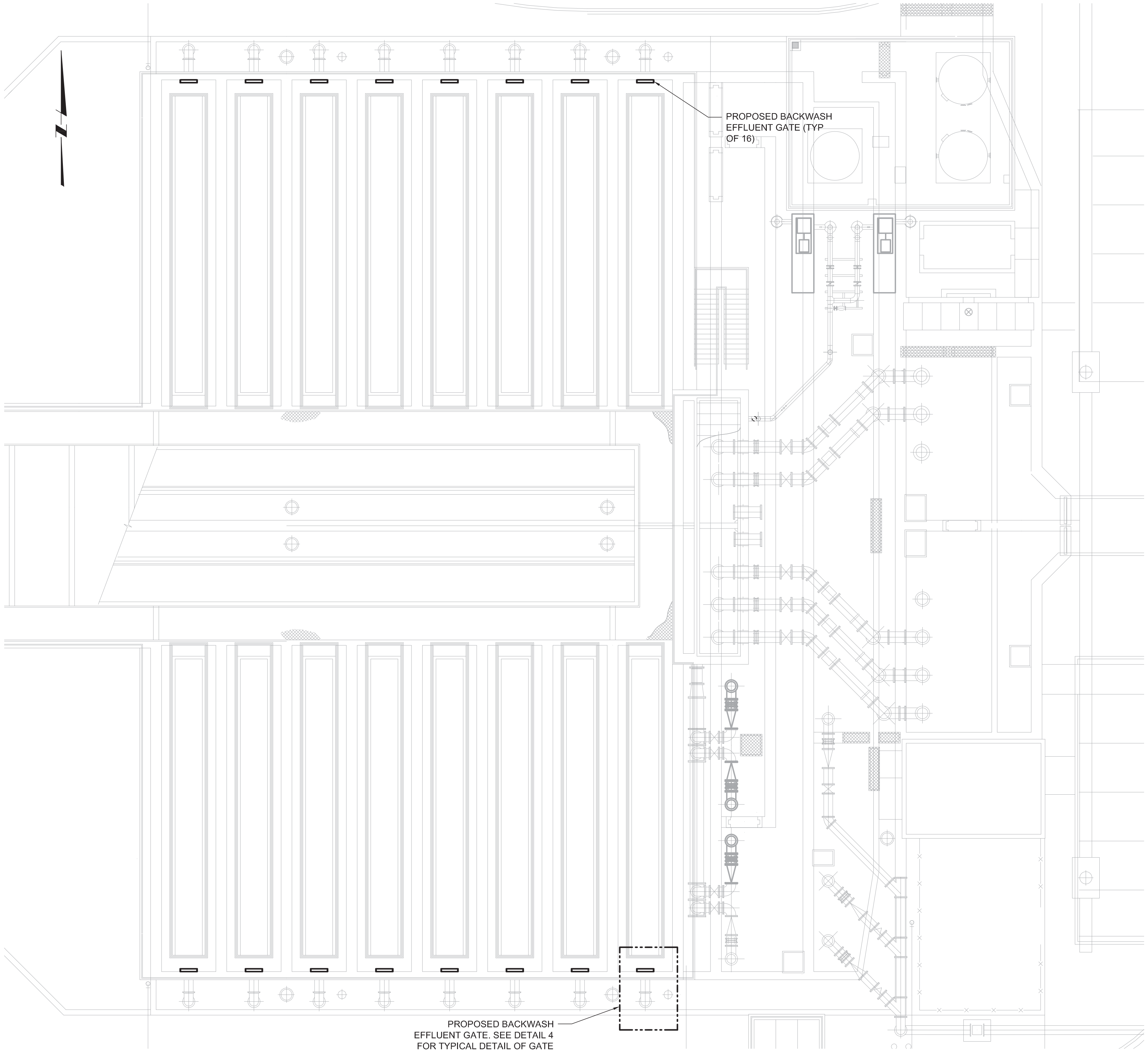
SECTION B

MWH

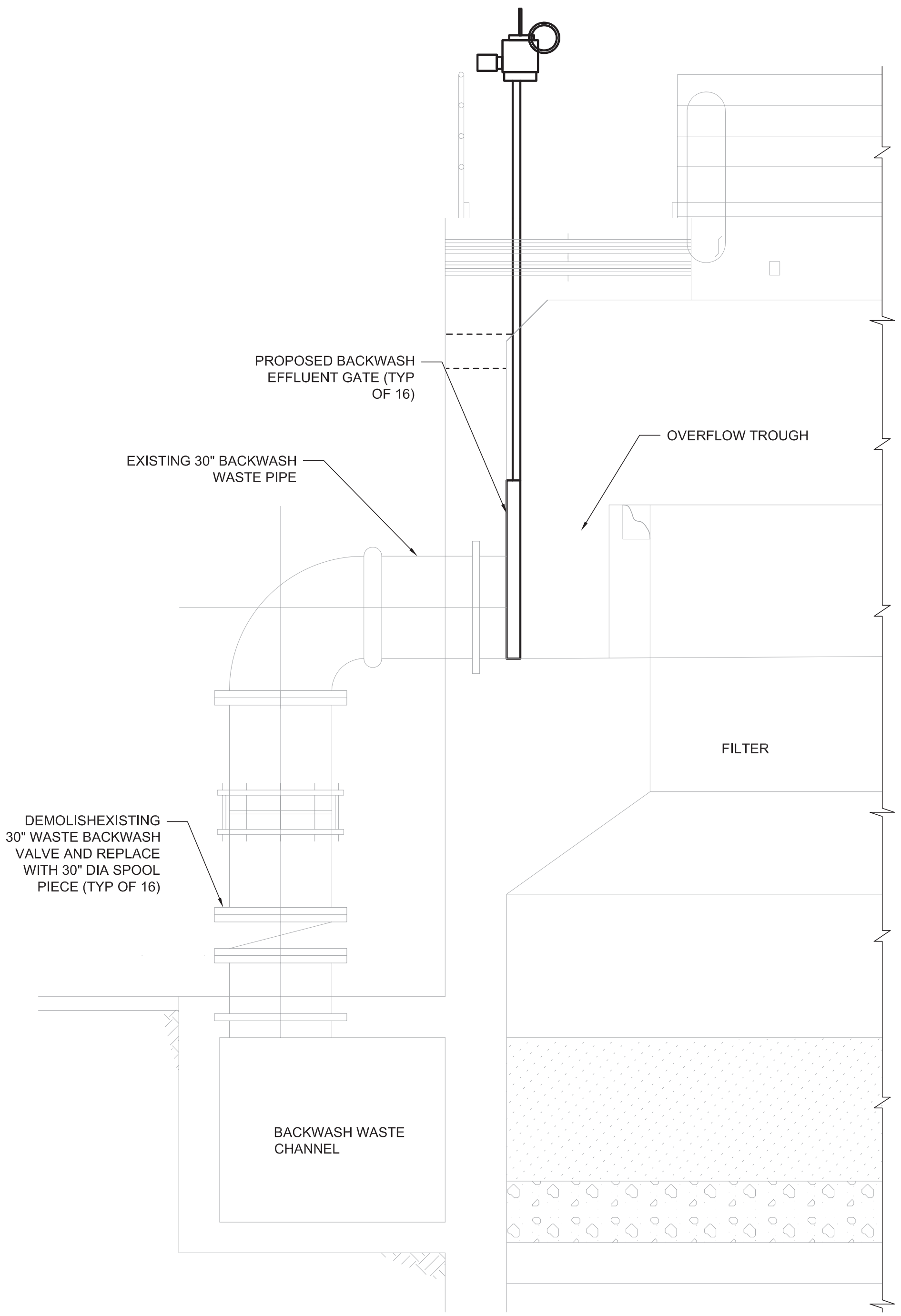
TERMINAL ISLAND WATER RECLAMATION PLANT
TERTIARY FILTER REHABILITATION
PRELIMINARY DESIGN REPORT

BUTTERFLY VALVES REPLACEMENT

FIGURE
3-6



PLAN



DETAIL 4

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TERTIARY FILTER REHABILITATION
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BACKWASH EFFLUENT GATES

FIGURE

3-7

Section 4
Construction Sequence

INTRODUCTION

A key aspect of the successful rehabilitation of the TIWRP tertiary filters is the proper sequencing of the construction activities to allow for the continued operation of the filters. A detailed discussion of the proposed construction sequence is presented in this Section.

As noted in Section 2, with only one bank of filters online and one filter in that bank out of service, the maximum flow the filter facility can treat is 30 mgd while maintaining 5gpm/sf. This assumes 7 of 8 filters are available. If fewer filters are available, the corresponding capacity is lessened.

For this reason, when the filter rehabilitation work requires shutdown of half the filters, arrangements must be made for times when the flow to the filters exceeds this capacity, and these arrangements must comply with regulatory requirements associated with discharge or recycled water end use. The construction sequence is intended to minimize the required shutdown of half of the filter structure. However, shutting down half of the filter structure for four to five weeks (each half) is unavoidable without a significant amount of extra work (described in detail in this Section).

CAPACITY AND REGULATORY CONSTRAINTS

The TIWRP currently discharges treated municipal effluent and a brine waste stream from the AWPF to the Los Angeles Harbor. The discharge to the Los Angeles Harbor is governed by the requirements of the National Pollution Discharge Elimination System (NPDES) permit R4-2010-0071. The TIWRP also provides treated effluent from the AWPF for beneficial reuse as permitted under Order No. R4-2003-0134 and Order No. R4-2003-0025.

In order to rehabilitate the filter structure, the filters undergoing rehabilitation must be placed offline. Placing filter cells offline may affect the performance of the remaining filters in service at high flows. This Section summarizes the capacity of the filter structures during rehabilitation and the regulatory constraints for placing filters offline.

Flow and Water Quality Considerations

Data from the TIWRP Filter Rehabilitation Study was used to estimate how frequently the flow to the filters would exceed the 30 mgd capacity of one filter bank (**Table 2-2**). Over the period from August 1, 2011 to September 27, 2012, the filter influent flow rate was averaged over one-hour intervals and is plotted in **Figure 4-1.** There were 19 measurements (0.2%) exceeding 30 mgd and ranging as high as 37 mgd. However, these instantaneous increases in flow were rarely long-lasting – flows greater than 30 mgd were never recorded in back-to-back intervals. Winter and spring appear to be the seasons with somewhat higher frequency of over 30 mgd events.

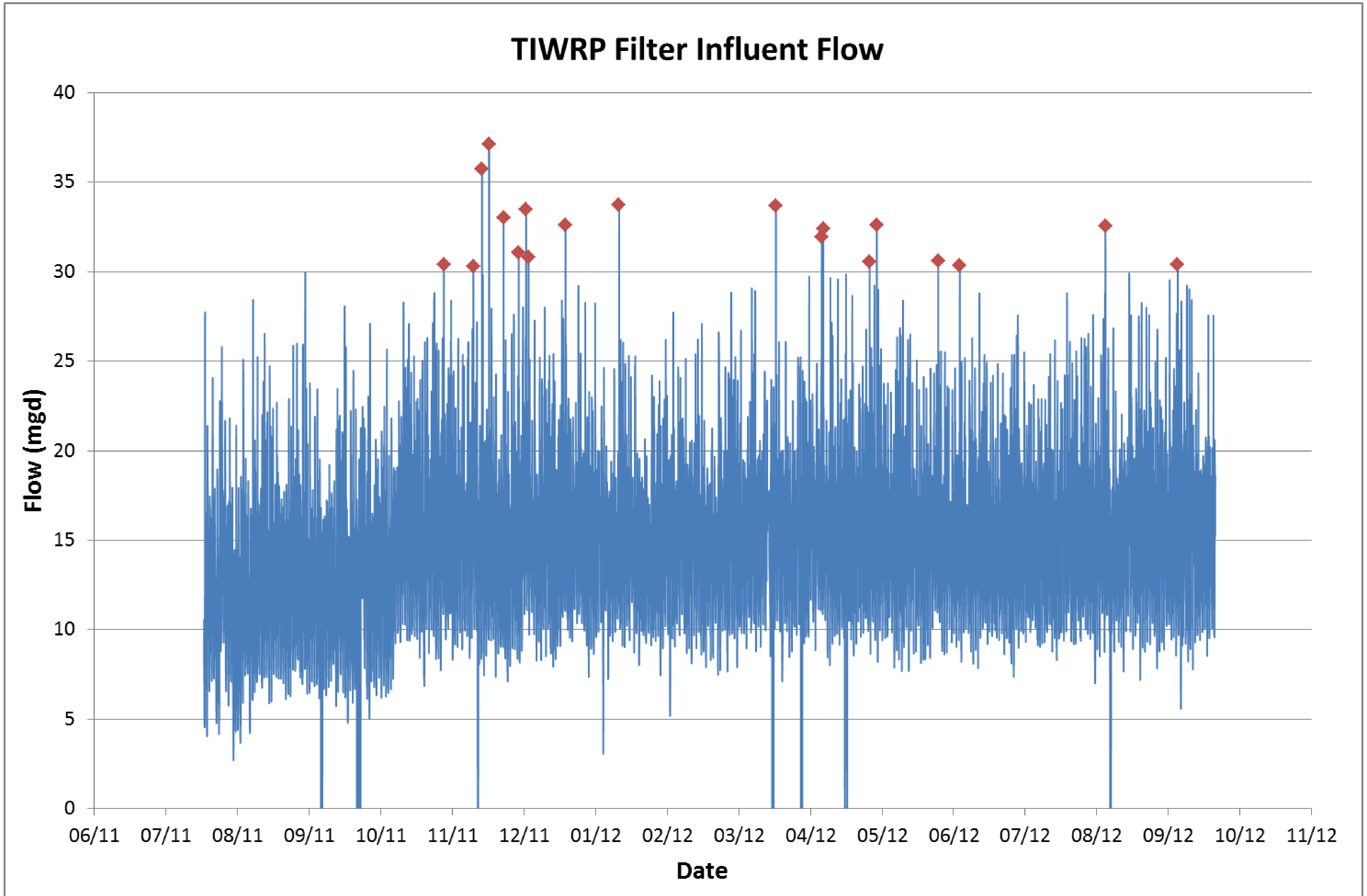


Figure 4-1: Graph of Influent Flow to the TIWRP Filters from 8/1/11 to 9/27/12. Averaged over one-hour periods, with points exceeding 30 mgd marked in red.

Another consideration is the quality of the water to be treated. During the time period of the study data, the influent turbidity exceeded the required average effluent limit of 2 NTU only 12% of the time during the period noted above, and the 75-minute peak limit of 5 NTU only 0.5% of the time. Even if part of the flow were to be bypassed around the filters, it would be possible to meet the effluent limits under most cases given the typically low influent turbidity.

Discharge to the Los Angeles Harbor

A portion of tertiary treated wastewater from the TIWRP that is discharged into the Los Angeles Harbor is governed by the requirements of the NPDES permit R4-2010-0071. Monitoring data for discharge into the Los Angeles Harbor is collected at the effluent sampling station (EFF-001) which samples combined flow of the tertiary-treated wastewater and brine waste generated at the AWPF. The NPDES permit states that the final effluent turbidity at EFF-001 must not exceed the following criteria:

a) A daily average of 2 NTU
b) 5 NTU more than 5 percent of the time (i.e. for a period 72 minutes per day)
c) 10 NTU at any time

The NPDES permit does not specifically mandate a maximum flow rate that is permitted for each filter cell.

An option for the operation of the filter cells under the NPDES permit is to continue to send all flow into the online filter cells with no bypass. This would result in filtration rates as high as 8.6 gpm/sf (7 filters online at the 52 mgd peak flow). However, high flow rates will attenuate somewhat inside the filter cells, and high flow events are infrequent and of short duration as described above. The highest hourly average flow over the period of the filter study data was only 37 mgd (6 gpm/sf with 7 filters online). Furthermore, as noted, the NPDES permit only limits the allowable effluent quality, and does not mandate a maximum hydraulic loading rate through the filters.

Recycled Water Requirements

The product water from the AWPF system is permitted for groundwater injection under Order No. R4-2003-0134. The City also provides recycled water from the AWPF that meets and/or exceeds Title 22 standards.

The California Code of Regulations, Title 22, Division 4 Environmental Health defines "filtered wastewater" as oxidized wastewater that meets either (a) **or** (b) below:

(a) Has been coagulated and passed through natural undisturbed soils or a bed of filter media pursuant to the following:

(1) At a rate that does not exceed 5 gallons per minute per square foot of surface area in mono, dual or mixed media gravity, upflow or pressure filtration systems, or does not exceed 2 gallons per minute per square

foot of surface area in traveling bridge automatic backwash filters; and

(2) So that the turbidity of the filtered wastewater does not exceed any of the following:

(A) An average of 2 NTU within a 24-hour period;
(B) 5 NTU more than 5 percent of the time within a 24-hour period; and
(C) 10 NTU at any time.

(b) Has been passed through a microfiltration, ultrafiltration, nanofiltration, or reverse osmosis membrane so that the turbidity of the filtered wastewater does not exceed any of the following:

(1) 0.2 NTU more than 5 percent of the time within a 24-hour period; and
(2) 0.5 NTU at any time.

Although the filtration rate will be greater than 5 gpm/sf under high flow conditions (greater than 30 mgd), the treated water that will eventually go to beneficial use will first pass through the AWPF. The AWPF consists of microfiltration and reverse osmosis, and therefore will meet the requirements of (b) above to be considered filtered wastewater.

Order R4-2003-0134 further defines the following requirements for the AWPF influent:

For purposes of this Order, the AWTF includes microfiltration, reverse osmosis, lime stabilization, and chlorination. The influent to the AWTF shall be tertiary treated effluent that meets the following characteristics:

The influent shall, at all times, be adequately oxidized. The influent shall be considered adequately oxidized when it meets the following characteristics:

1. *The monthly average Biochemical Oxygen Demand value (BOD_5 20C) does not exceed 15 mg/L. Compliance shall be determined monthly using the average of the analytical results of all 24-hour composite samples taken at least weekly during the month.*

2. *The monthly average Total Suspended Solids (TSS) concentration does not exceed 15 mg/L. Compliance shall be determined monthly using the average of the analytical results of all 24-hour composite samples taken daily during the month.*

With half of the filter cells being out of service, the monthly average BOD and TSS are not anticipated to be affected.

Recommended Operation during Rehabilitation

Considering the average influent turbidity of approximately 1.5 NTU, the infrequent occurrences of the flow rates greater than 30 mgd, and the regulatory requirements discussed above, it is recommended to operate the filters during rehabilitation by pumping all flow into the online filter cells. The filters may be taken offline one bank at a time for the replacement of the filter effluent valves and backwash supply valves, and the plant will operate by passing all flow through the online filter cells in the other bank during this time. For the full rehabilitation of the filters, four filters will be placed offline at a time, with the remaining filters remaining in service. The required downtime for half of a filter structure and sequence of construction is described in detail in the "Construction Sequence" portion of this section.

CONSTRUCTION SEQUENCE

The sequence of construction activities is a key component of the filter rehabilitation. The construction sequence described in this Section has been developed with the following constraints:

- The amount of time with 8 filters being placed out of service is minimized
- No more than 4 filters should be placed offline at a time for a significant period of time
- All valve and gate actuator communication systems will be replaced (per Section 3)
- North half of the filters to be rehabilitated first (South half equally viable option)

The general steps that must be followed and the order in which they must be executed are illustrated in **Figure 4-2**. Each step identified in **Figure 4-2** is described in detail in this Section.

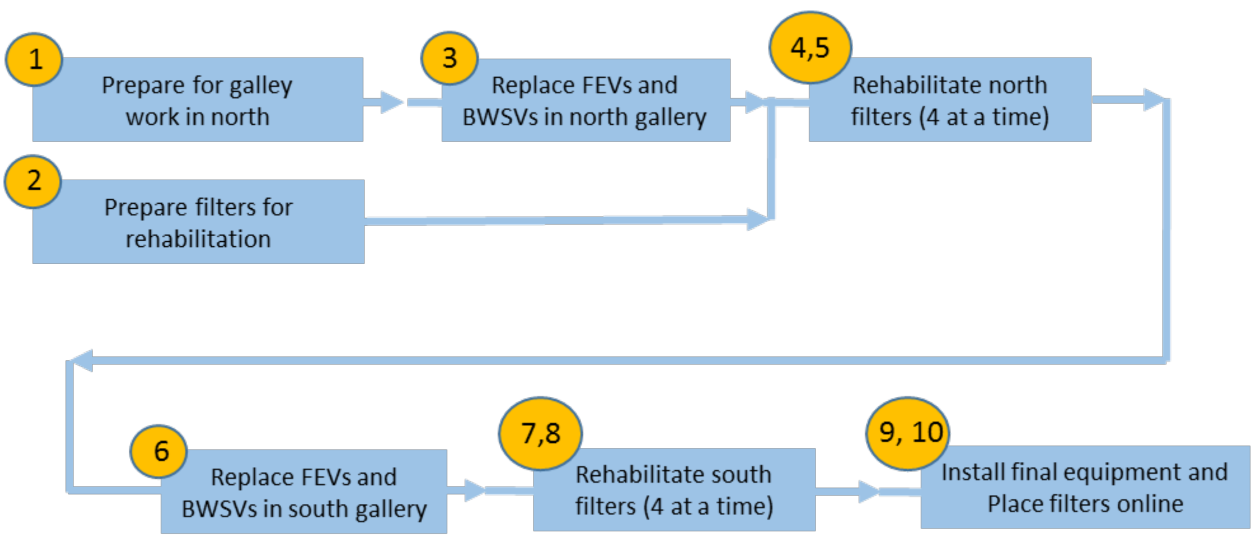


Figure 4-2: General Sequence of Construction

Steps 3 and 6 shown in **Figure 4-2** require that eight filters be placed offline for the duration of the task, which is estimated to be approximately four to five weeks. Although the time eight filters are taken offline can be minimized, it is unavoidable for the replacement of the filter effluent valves and backwash supply valves. **Figure 4-3** illustrates why placing less than eight filters offline at a time is required.

To minimize the amount of time that eight filters are placed offline, only the filter effluent valve and backwash supply valve will be replaced during the shutdown, that is, no rehabilitation inside the filter cell will take place. After the gallery valves are replaced, then it will be possible to rehabilitate the inside of the filters (expected to take approximately 6-7 weeks) 4 at a time.

A more detailed breakdown of the specific activities and estimated lengths of each activity that each of the general steps requires is shown in detail in **Figure 4-4** attached at the end of this section.

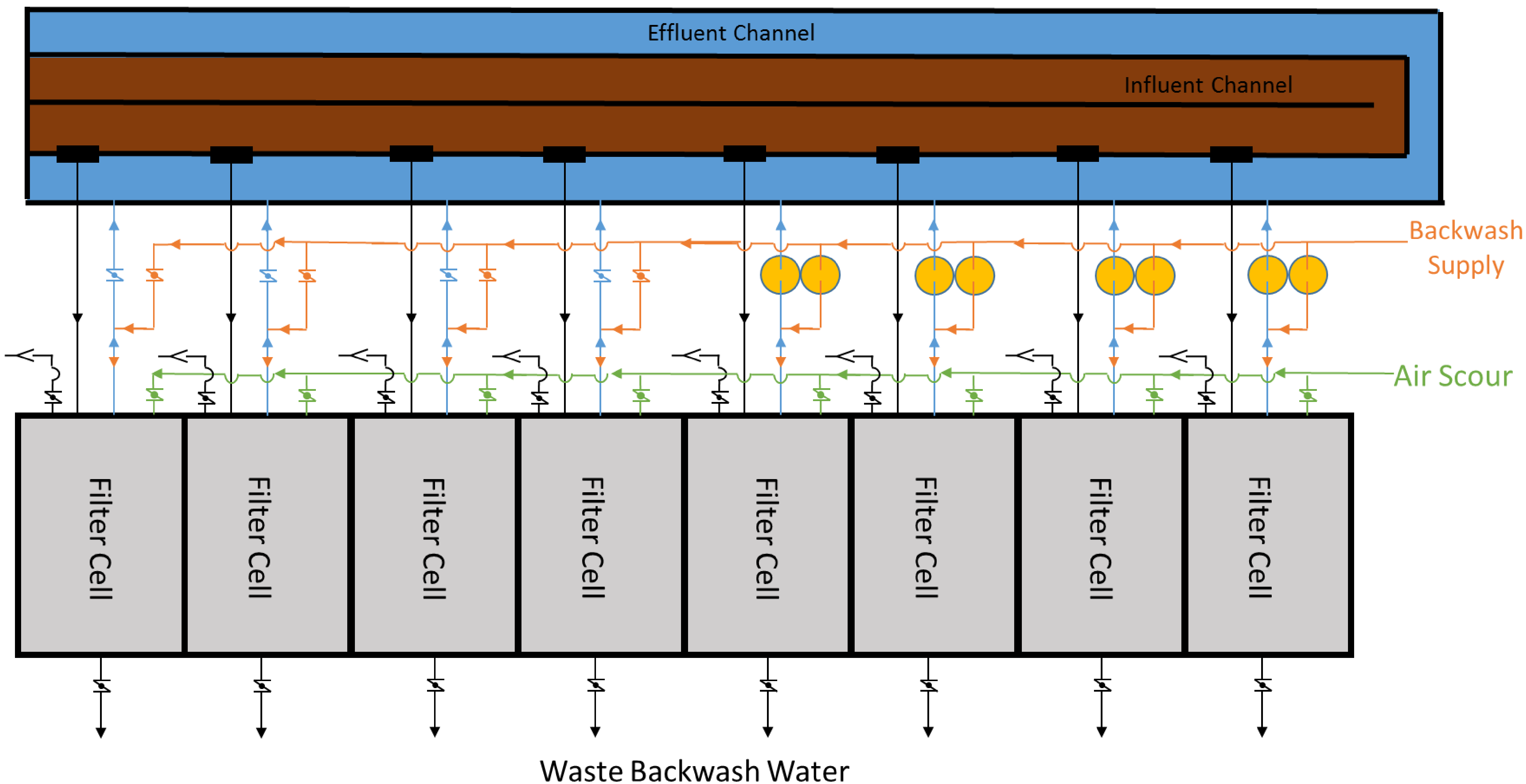


Figure 4-3: Eight Filters Required to be Out of Service

This figure illustrates why a minimum of eight filters must be placed out of service in order to replace the filter effluent valves and backwash supply valves. The figure shows the filter effluent valves and backwash supply valves for four filters removed, these valves are highlighted in yellow. If only these four valves are intended to be rehabilitated, it would be impossible for backwash supply to reach the downstream valves, with respect to the backwash supply header. During the rehabilitation of the filter effluent butterfly valves and backwash supply valves, all eight filters must be placed out of service. The time that eight filters must be placed offline will be constrained in the Contract Documents for CIP 5229.

The general layout of the filter structure and relevant valves, pumps, and gates are shown below in **Figure 4-5**. Discussions of the steps identified in **Figure 4-2** are further described in this section.

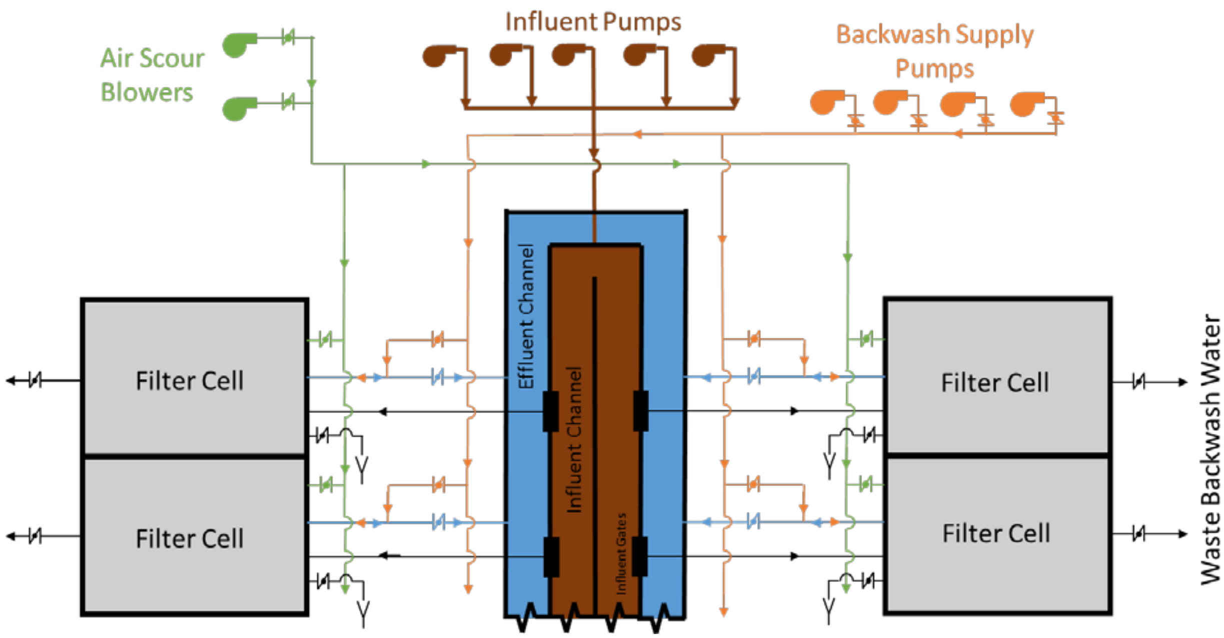


Figure 4-5: Relevant Pumps, Valves, and Gates at the TIWRP Tertiary Filters.

1. **<u>Prepare for Gallery Work in North Filters</u>**

This step is intended to assure that all required preparatory work is performed for the removal of the filter effluent valves and backwash supply valves for the north half of the filters (if the south half is the preferred initial filter bank to take out of service, there is no constraint – either half may be rehabilitated first). In order to allow for the filter structure to be placed offline in phases (i.e. to allow for half of the filter structure to remain in operation while the filter effluent valves and backwash supply valves are replaced on the other half of the structure), two backwash supply isolation valves must be installed. The installation of the backwash supply isolation valves will allow for the backwash supply pumps to serve the online filter cells, while the filter cells undergoing rehabilitation are completely isolated from the operating filters. **Figure 4-6** and **3-6** shows the general location of the additional backwash supply isolation valves. Additional steps that are also required for the preparation of the replacement of the gallery valves are:

- Obtain all equipment necessary for shutdown of filter cells including all valves and actuators
- Install new control conduit for all valves and actuators.
- Install and commission valve controller box.

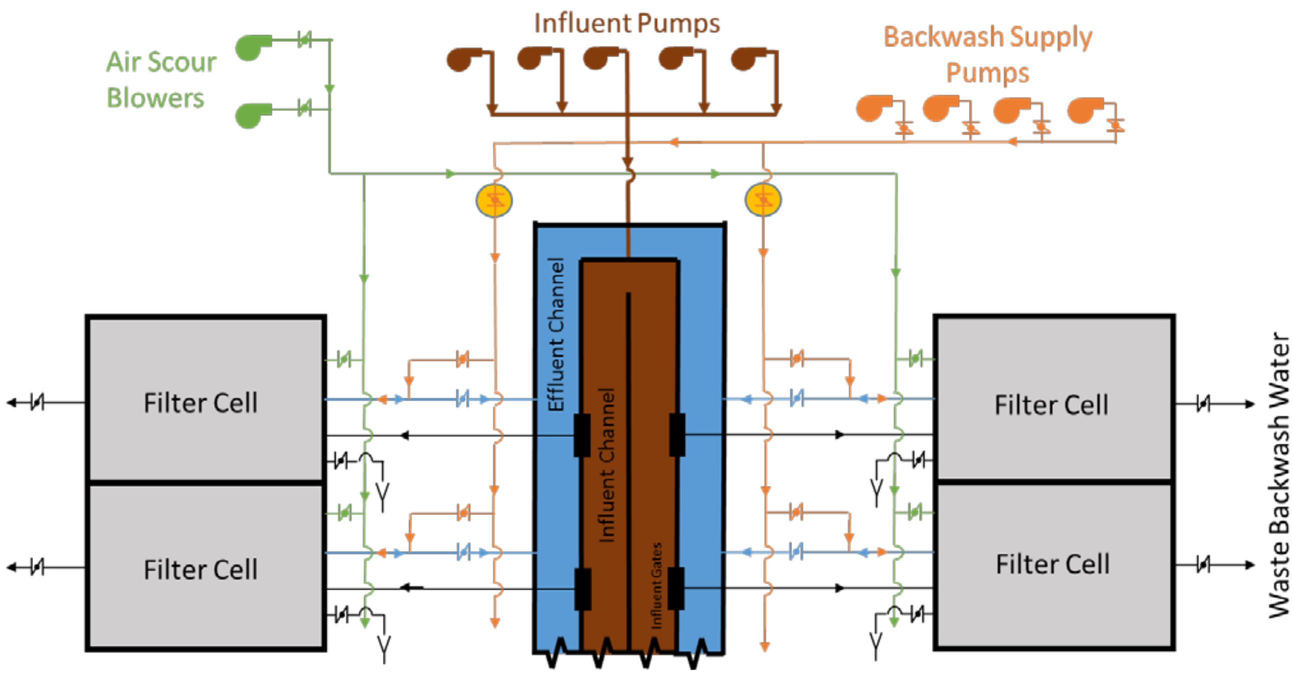


Figure 4-6: Installation of Backwash Isolation Valves (Step 1).

2. **Prepare Filters for Rehabilitation**

In parallel with steps 1 and 3, preparatory work must be performed to the filters before rehabilitation work inside the filters can begin. The steps involved in the preparation of the filters for rehabilitation is detailed in **Figure 4-4**. The major steps that need to be completed before step 4 can commence are the following:

- Remove two existing backwash supply pumps
- Obtain and install two new backwash supply pumps
- Install exterior air piping

3. **Replace Gallery Valves in North Filter**

After step 1 is complete, the north half of the filter structure may be shut down to allow for the filter effluent valves and backwash supply butterfly valves to be replaced. The replacement of the valves will consist of the following main steps:

- Isolate north half of filters (see **Figure 4-4**)
- Remove and replace filter effluent valves and backwash supply valves
- Connect new actuator to new communication system (see Section 3)
- Update PLC programming for newly installed actuators (see Section 3)
- Commission newly installed valves and actuators

4. **Rehabilitation of 4 Filters (2, 4, 6, and 8)**

When step 3 is complete, then the newly installed filter effluent and backwash supply valves are expected to be capable of isolating individual filters for rehabilitation. Due to potential limitations in the capacity of the existing filters, the rehabilitation of the filters will be limited to four at a time. TIWRP will have up to 12 filter cells available during this phase of construction. The general steps that will be required for the rehabilitation of the filters are shown in **Figure 4-7** (also see **Figure 4-4**).

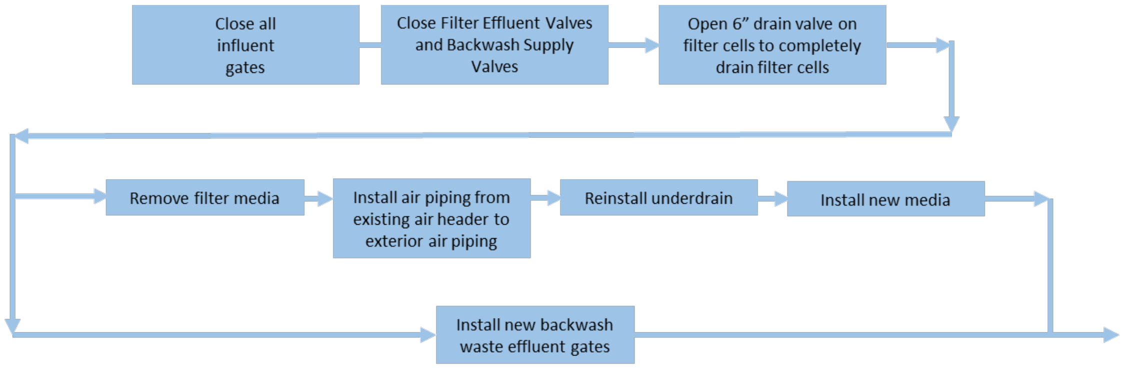


Figure 4-7: Steps for Rehabilitation of Filters (Step 4)

5. Rehabilitate Filters 10, 12, 14, and 16

The rehabilitation of filters 10, 12, 14, and 16 will follow the same general steps as step 4.

6. Replace Gallery Valves in South Half of Filters

Shutdown of the south half of the filters will follow the same general steps as identified in step 3.

7. Rehabilitate filters 1, 3, 5, and 7

The rehabilitation of filters 1, 3, 5, and 7 will follow the same general steps as step 4.

8. Rehabilitate filters 9, 11, 13, and 15

The rehabilitation of filters 9, 11, 13 and 15 will follow the same general steps as step 4.

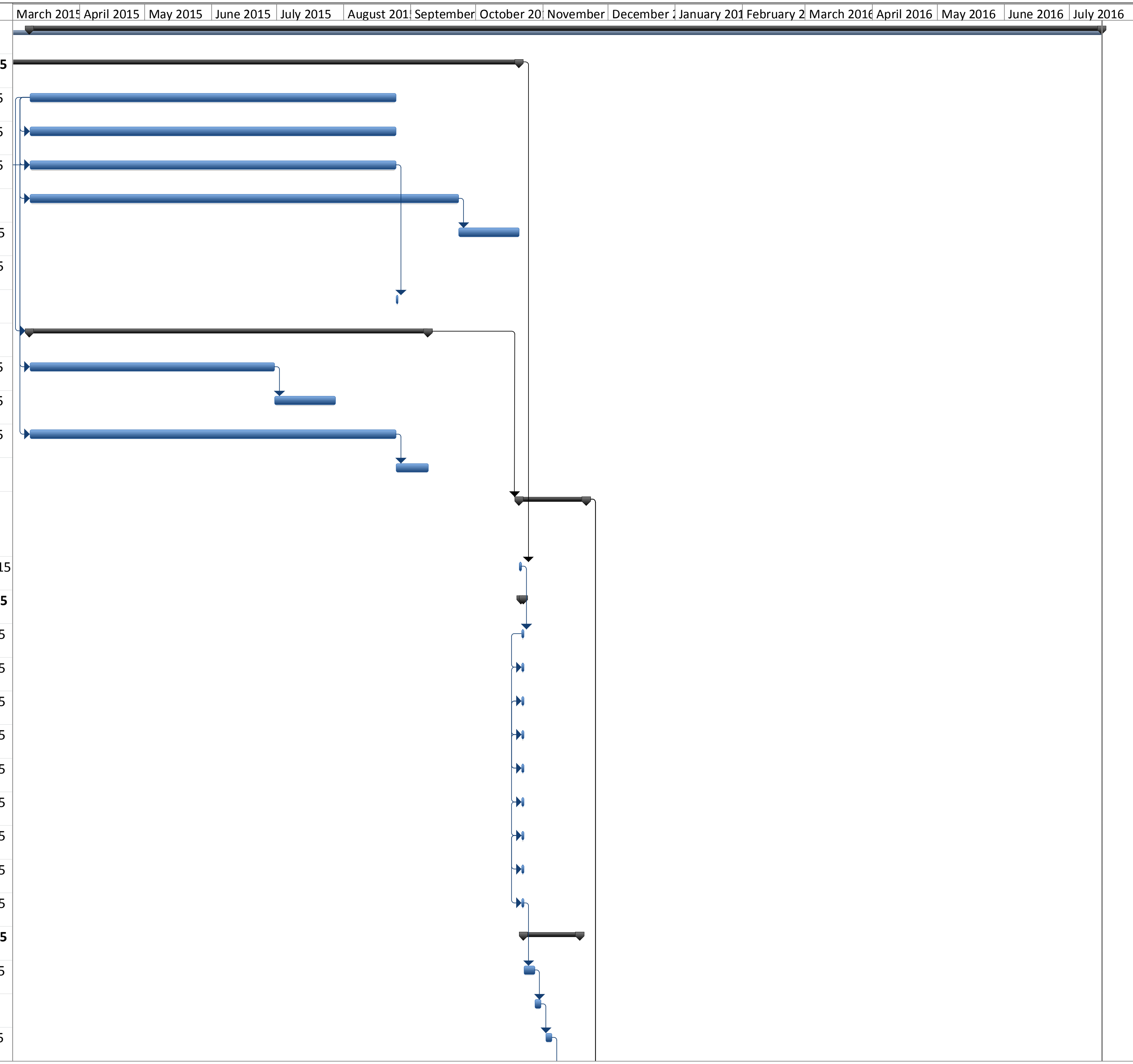
9. Install Final Equipment

After all filters have been rehabilitated, the final pieces of equipment may be installed. The final pieces of equipment to install are the following:

- Removal of two remaining backwash supply pumps
- Install one additional backwash supply pump
- Remove and replace two air scour blowers

Once these final pieces of equipment are installed and commissioned, the rehabilitation of the filters is complete.

ID	Task	Task Name	Duration	Start	Finish
1		**TIWRP Filter Rehabilitation**	**347 days**	**Mon 3/9/15**	**Fri 7/15/16**
2		**1. Prepare for Gallery Work in North Filter**	**173 days**	**Wed 2/18/15**	**Tue 10/20/15**
3		Obtain filter effluent valve	6 mons	Mon 3/9/15	Mon 8/24/15
4		Obtain backwash supply valve	6 mons	Mon 3/9/15	Mon 8/24/15
5		Obtain backwash supply isolation valve	6 mons	Mon 3/9/15	Mon 8/24/15
6		Obtain and install valve controller boxes	7 mons	Mon 3/9/15	Tue 9/22/15
7		Install control conduit and wires	1 mon	Wed 9/23/15	Tue 10/20/15
8		Backwash all filters in south gallery	1 day	Wed 2/18/15	Wed 2/18/15
9		Install backwash isolation valve	1 day	Tue 8/25/15	Tue 8/25/15
10		**2. Prepare Filters for Rehabilitation**	**130 days**	**Mon 3/9/15**	**Tue 9/8/15**
11		Obtain air piping and valves	4 mons	Mon 3/9/15	Mon 6/29/15
12		Install exterior air piping, including valves	20 days	Tue 6/30/15	Mon 7/27/15
13		Obtain backwash supply pumps	6 mons	Mon 3/9/15	Mon 8/24/15
14		Replace two BWS pumps	10 days	Tue 8/25/15	Tue 9/8/15
15		**3. Replace Gallery Valves in North Gallery (8 Filters in Service)**	**23 days**	**Wed 10/21/15**	**Fri 11/20/15**
16		Confirm all required equipment is onsite	1 day	Wed 10/21/15	Wed 10/21/15
17		**Isolate North Half of Filters**	**1 day**	**Thu 10/22/15**	**Thu 10/22/15**
18		Close influent gates	1 day	Thu 10/22/15	Thu 10/22/15
19		Close filter effluent valves	1 day	Thu 10/22/15	Thu 10/22/15
20		Close backwash supply isolation valve	1 day	Thu 10/22/15	Thu 10/22/15
21		Close backwash supply valves	1 day	Thu 10/22/15	Thu 10/22/15
22		Open 6" drain valves to allow for filters to drain	1 day	Thu 10/22/15	Thu 10/22/15
23		Remove blind flange at end of BWS header	1 day	Thu 10/22/15	Thu 10/22/15
24		Allow BWS Header to drain, gallery sump pump on	1 day	Thu 10/22/15	Thu 10/22/15
25		Install bulkhead in north effluent channel	1 day	Thu 10/22/15	Thu 10/22/15
26		Temporary sump in north filter effluent channel	1 day	Thu 10/22/15	Thu 10/22/15
27		**Replace Valves in Gallery (Two Shifts)**	**18 days**	**Fri 10/23/15**	**Tue 11/17/15**
28		Remove filter effluent valve	3 days	Fri 10/23/15	Tue 10/27/15
29		Remove tee	3 days	Wed 10/28/15	Fri 10/30/15
30		Remove backwash supply valve	3 days	Mon 11/2/15	Wed 11/4/15



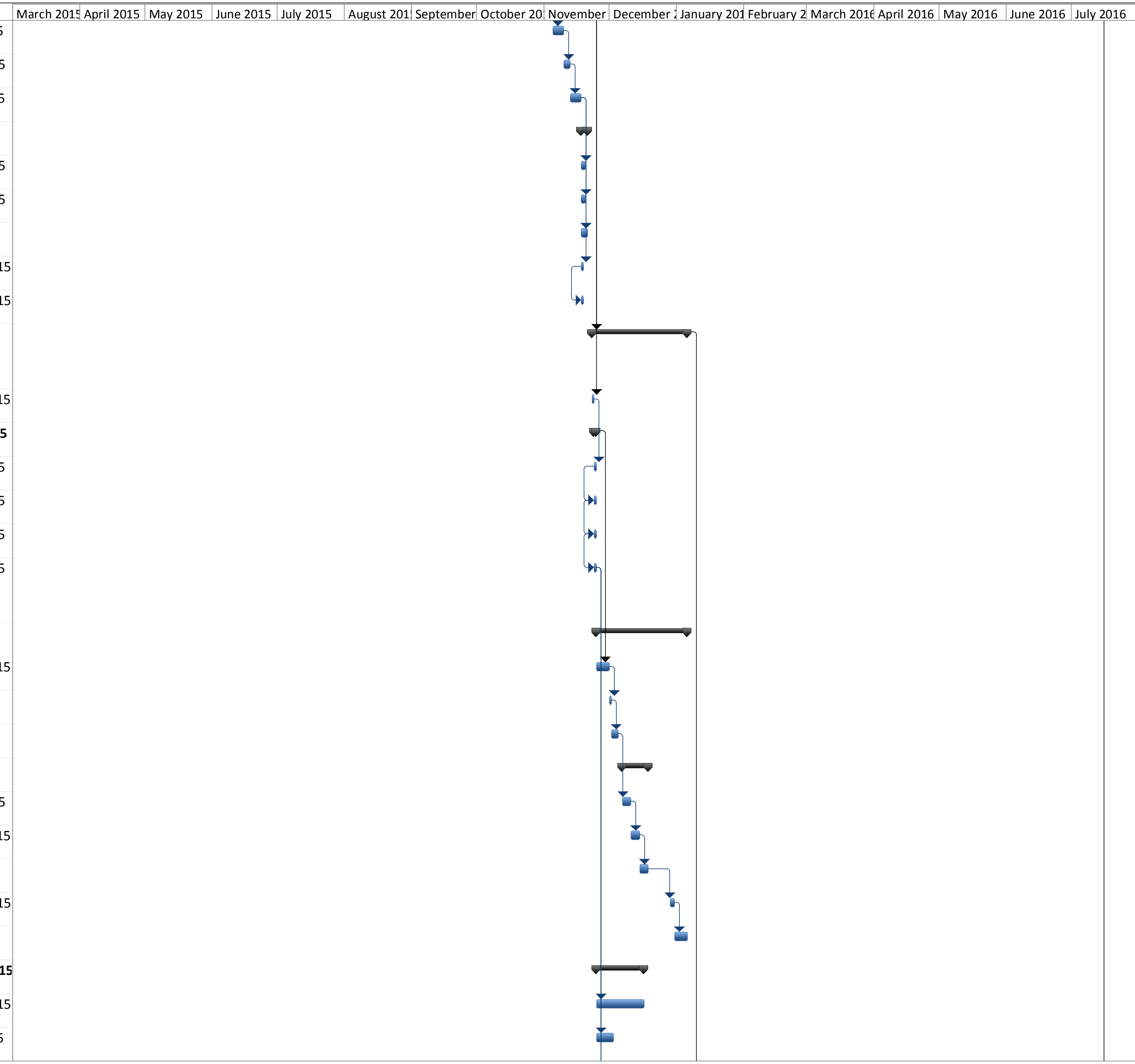
Project: TIWRP
Date: Tue 10/29/13

Task		Summary		External Milestone		Inactive Summary		Manual Summary Rollup		Finish-only	
Split		Project Summary		Inactive Task		Manual Task		Manual Summary		Deadline	
Milestone		External Tasks		Inactive Milestone		Duration-only		Start-only		Progress	

TIWRP-PDR
Construction Sequence

Figure 4-4: Construction Sequence

ID	Task	Task Name	Duration	Start	Finish
31		Install new backwash supply valve	3 days	Thu 11/5/15	Mon 11/9/15
32		Reinstall tee	3 days	Tue 11/10/15	Thu 11/12/15
33		Install new filter effluent valve	3 days	Fri 11/13/15	Tue 11/17/15
34		**New Communications**	**3 days**	**Wed 11/18/15**	**Fri 11/20/15**
35		Connect new actuators to new communications system	2 days	Wed 11/18/15	Thu 11/19/15
36		Install new PLC programming	2 days	Wed 11/18/15	Thu 11/19/15
37		Commission new valves and actuators	3 days	Wed 11/18/15	Fri 11/20/15
38		Reinstall blind flange on BWS header	1 day	Wed 11/18/15	Wed 11/18/15
39		Open backwash supply isolation valve	1 day	Wed 11/18/15	Wed 11/18/15
40		**4. Rehabilitation of 4 Filters (2,4,6,8), 12 Existing Filters in Service**	**29 days**	**Mon 11/23/15**	**Tue 1/5/16**
41		Confirm valves and equipment are on site	1 day	Mon 11/23/15	Mon 11/23/15
42		**Isolate Filter to Allow Workers to Enter Filter**	**1 day**	**Tue 11/24/15**	**Tue 11/24/15**
43		Close applicable influent gates	1 day	Tue 11/24/15	Tue 11/24/15
44		Close applicable filter effluent valves	1 day	Tue 11/24/15	Tue 11/24/15
45		Close applicable backwash Supply Valves	1 day	Tue 11/24/15	Tue 11/24/15
46		Open applicable 6" drain valves to allow for filters to drain	1 day	Tue 11/24/15	Tue 11/24/15
47		**Work to be performed inside the filters**	**27 days**	**Wed 11/25/15**	**Tue 1/5/16**
48		Remove existing filter media	3 days	Wed 11/25/15	Mon 11/30/15
49		Inspect existing underdrain	1 day	Tue 12/1/15	Tue 12/1/15
50		Remove any media or debris located in the filter gullet	3 days	Wed 12/2/15	Fri 12/4/15
51		**Install New Air Piping**	**10 days**	**Mon 12/7/15**	**Fri 12/18/15**
52		Connect exterior air piping to existing air header	4 days	Mon 12/7/15	Thu 12/10/15
53		Blind flange existing air supply valve to filter	2 days	Fri 12/11/15	Mon 12/14/15
54		Form and pour concrete encasement of new air piping	4 days	Tue 12/15/15	Fri 12/18/15
55		Properly install underdrain	2 days	Tue 12/29/15	Wed 12/30/15
56		Install new media and gravel	3 days	Thu 12/31/15	Tue 1/5/16
57		**Installation of Waste Backwash Gates**	**15 days**	**Wed 11/25/15**	**Wed 12/16/15**
58		Install new waste backwash gates (incl commissioning)	15 days	Wed 11/25/15	Wed 12/16/15
59		Replace existing waste backwash valves with spool	5 days	Wed 11/25/15	Wed 12/2/15



Project: TIWRP
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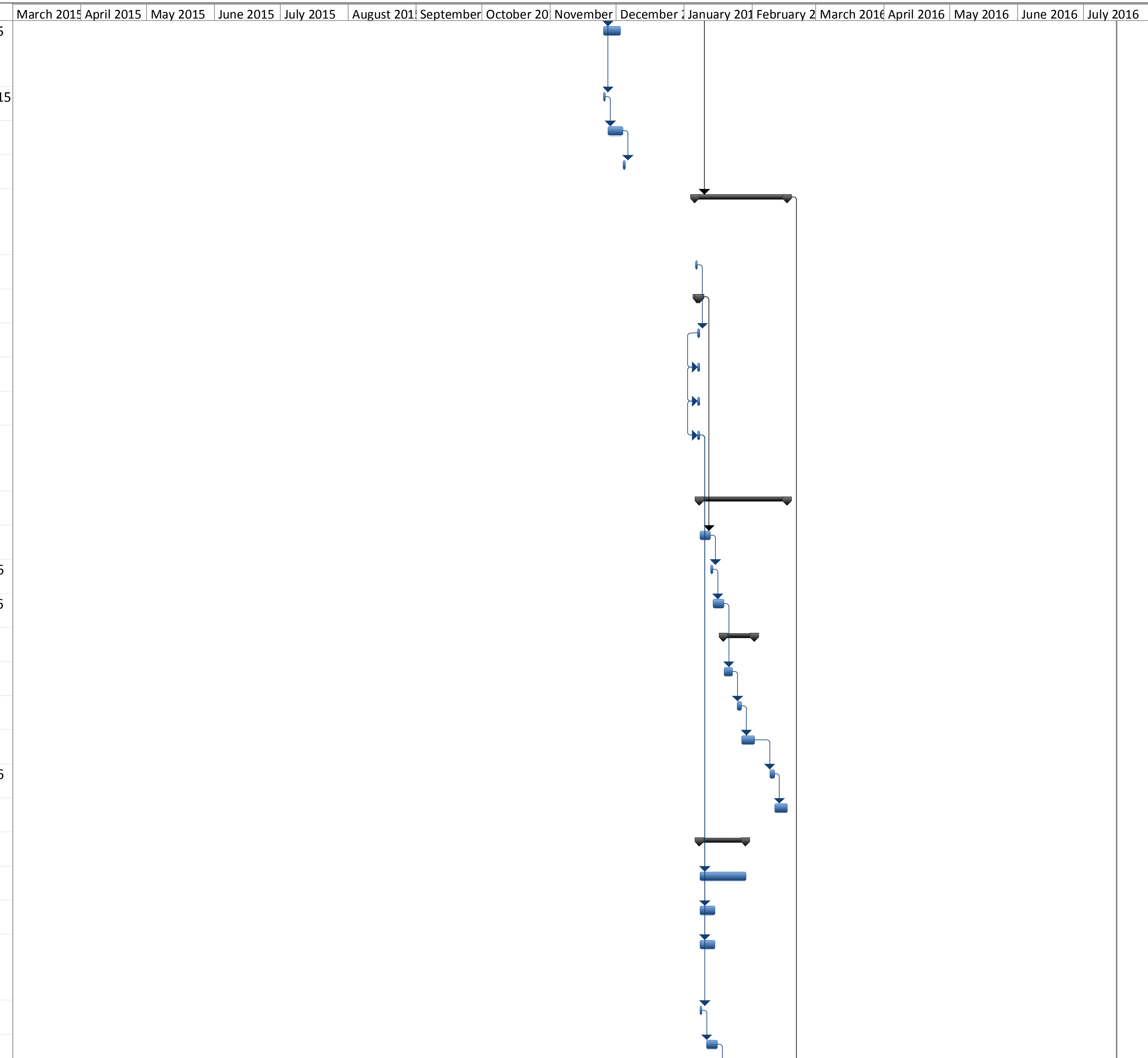
Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Deadline
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Progress

TIWRP-PDR
Construction Sequence

Figure 4-4: Construction Sequence

ID	Task Name	Duration	Start	Finish
60	Connect existing influent gate actuators to new communications	5 days	Wed 11/25/15	Wed 12/2/15
61	Install PLC programming for rehabilitated filters	1 day	Wed 11/25/15	Wed 11/25/15
62	Commissioning	5 days	Fri 11/27/15	Thu 12/3/15
63	Connect air piping to blowers	1 day	Fri 12/4/15	Fri 12/4/15
64	**5. Rehabilitation of 4 Filters (10,12,14,16), 4 Rehabilitated Filters in Sevice, 8 Existing Filters in Service**	**29 days**	**Wed 1/6/16**	**Tue 2/16/16**
65	Confirm valves and equipment are on site	1 day	Wed 1/6/16	Wed 1/6/16
66	**Isolate Filter to Allow Workers to Enter Filter**	**1 day**	**Thu 1/7/16**	**Thu 1/7/16**
67	Close applicable influent gates	1 day	Thu 1/7/16	Thu 1/7/16
68	Close applicable filter effluent valves	1 day	Thu 1/7/16	Thu 1/7/16
69	Close applicable backwash Supply Valves	1 day	Thu 1/7/16	Thu 1/7/16
70	Open applicable 6" drain valves to allow for filters to drain	1 day	Thu 1/7/16	Thu 1/7/16
71	**Work to be performed inside the filters**	**27 days**	**Fri 1/8/16**	**Tue 2/16/16**
72	Remove existing filter media	3 days	Fri 1/8/16	Tue 1/12/16
73	Inspect existing underdrain	1 day	Wed 1/13/16	Wed 1/13/16
74	Remove any media or debris located in the filter gullet	3 days	Thu 1/14/16	Mon 1/18/16
75	**Install New Air Piping**	**10 days**	**Tue 1/19/16**	**Mon 2/1/16**
76	Connect exterior air piping to existing air header	4 days	Tue 1/19/16	Fri 1/22/16
77	Blind flange existing air supply valve to filter	2 days	Mon 1/25/16	Tue 1/26/16
78	Form and pour concrete encasement of new air piping	4 days	Wed 1/27/16	Mon 2/1/16
79	Properly install underdrain	2 days	Tue 2/9/16	Wed 2/10/16
80	Install new media and gravel	3 days	Thu 2/11/16	Tue 2/16/16
81	**Installation of Waste Backwash Gates**	**15 days**	**Fri 1/8/16**	**Thu 1/28/16**
82	Install new waste backwash gates (incl commissioning)	15 days	Fri 1/8/16	Thu 1/28/16
83	Replace existing waste backwash valves with spool	5 days	Fri 1/8/16	Thu 1/14/16
84	Connect existing influent gate actuators to new communications	5 days	Fri 1/8/16	Thu 1/14/16
85	Install PLC programming for rehabilitated filters	1 day	Fri 1/8/16	Fri 1/8/16
86	Commissioning	5 days	Mon 1/11/16	Fri 1/15/16



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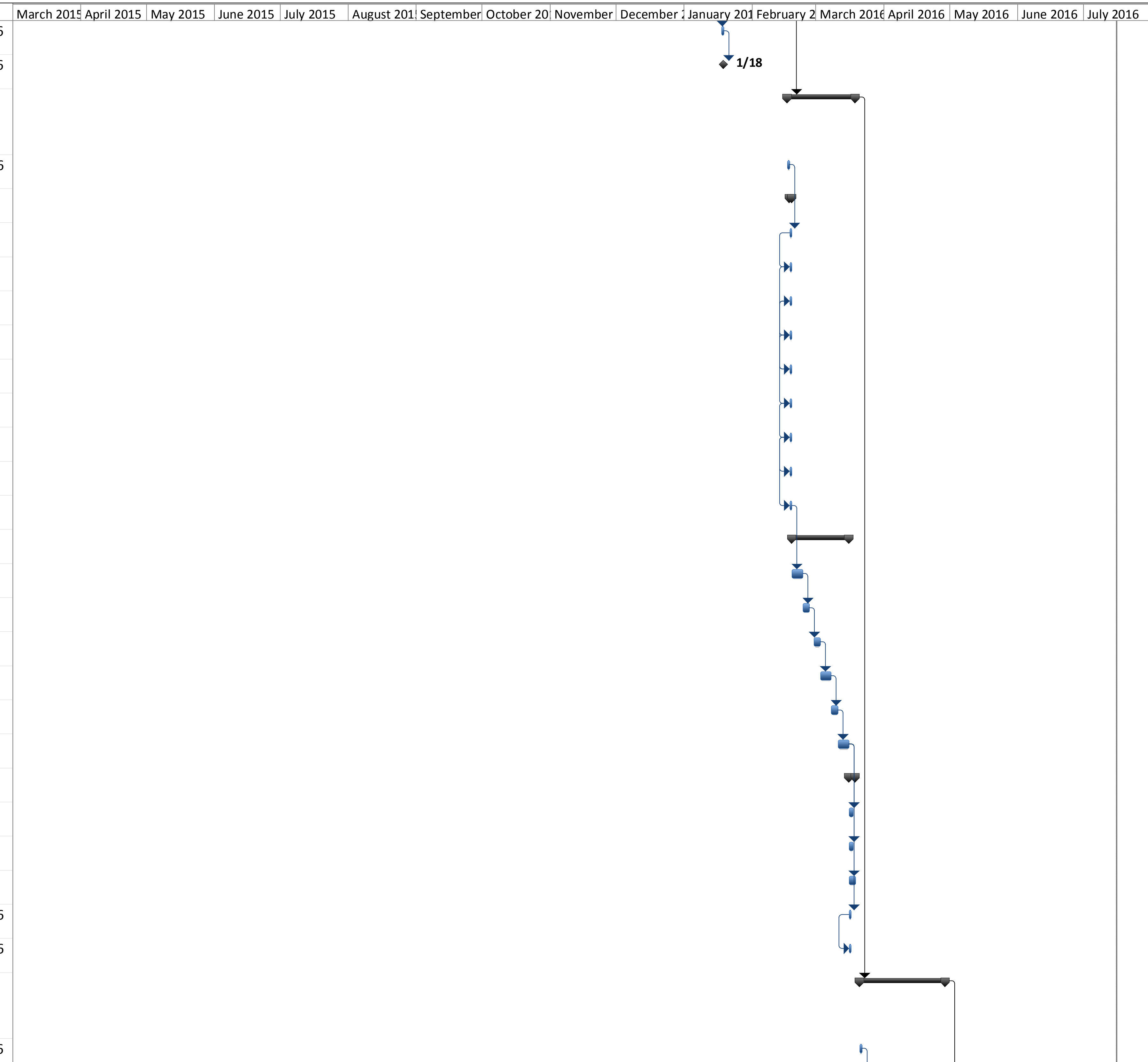
Task, Split, Milestone, Summary, Project Summary, External Tasks, External Milestone, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, Deadline, Progress

TIWRP-PDR
Construction Sequence

Figure 4-4: Construction Sequence

ID		Task	Task Name	Duration	Start	Finish
87			Connect air piping to blowers	1 day	Mon 1/18/16	Mon 1/18/16
88			8 Filters Rehabilitated	0 days	Mon 1/18/16	Mon 1/18/16
89			**6. Replace Gallery Valves in South Gallery (8 Filters in Service)**	**23 days**	**Wed 2/17/16**	**Fri 3/18/16**
90			Confirm all required equipment is onsite	1 day	Wed 2/17/16	Wed 2/17/16
91			**Isolate South Half of Filters**	**1 day**	**Thu 2/18/16**	**Thu 2/18/16**
92			Close influent gates	1 day	Thu 2/18/16	Thu 2/18/16
93			Close filter effluent valves	1 day	Thu 2/18/16	Thu 2/18/16
94			Close backwash supply isolation valve	1 day	Thu 2/18/16	Thu 2/18/16
95			Close backwash supply valves	1 day	Thu 2/18/16	Thu 2/18/16
96			Open 6" drain valves to allow for filters to drain	1 day	Thu 2/18/16	Thu 2/18/16
97			Remove blind flange at end of BWS header	1 day	Thu 2/18/16	Thu 2/18/16
98			Allow BWS Header to drain, gallery sump pump on	1 day	Thu 2/18/16	Thu 2/18/16
99			Install bulkhead in north effluent channel	1 day	Thu 2/18/16	Thu 2/18/16
100			Temporary sump in north filter effluent channel	1 day	Thu 2/18/16	Thu 2/18/16
101			**Replace Valves in Gallery (Two Shifts)**	**18 days**	**Fri 2/19/16**	**Tue 3/15/16**
102			Remove filter effluent valve	3 days	Fri 2/19/16	Tue 2/23/16
103			Remove tee	3 days	Wed 2/24/16	Fri 2/26/16
104			Remove backwash supply valve	3 days	Mon 2/29/16	Wed 3/2/16
105			Install new backwash supply valve	3 days	Thu 3/3/16	Mon 3/7/16
106			Reinstall tee	3 days	Tue 3/8/16	Thu 3/10/16
107			Install new filter effluent valve	3 days	Fri 3/11/16	Tue 3/15/16
108			**New Communications**	**3 days**	**Wed 3/16/16**	**Fri 3/18/16**
109			Connect new actuators to new communications system	2 days	Wed 3/16/16	Thu 3/17/16
110			Install new PLC programming	2 days	Wed 3/16/16	Thu 3/17/16
111			Commission new valves and actuators	3 days	Wed 3/16/16	Fri 3/18/16
112			Reinstall blind flange on BWS header	1 day	Wed 3/16/16	Wed 3/16/16
113			Open backwash supply isolation valve	1 day	Wed 3/16/16	Wed 3/16/16
114			**7. Rehabilitation of 4 Filters (1,3,5,7), 8 Rehabilitated Filters in Service, 4 Existing Filters in Service**	**29 days**	**Mon 3/21/16**	**Thu 4/28/16**
115			Confirm valves and equipment are on site	1 day	Mon 3/21/16	Mon 3/21/16



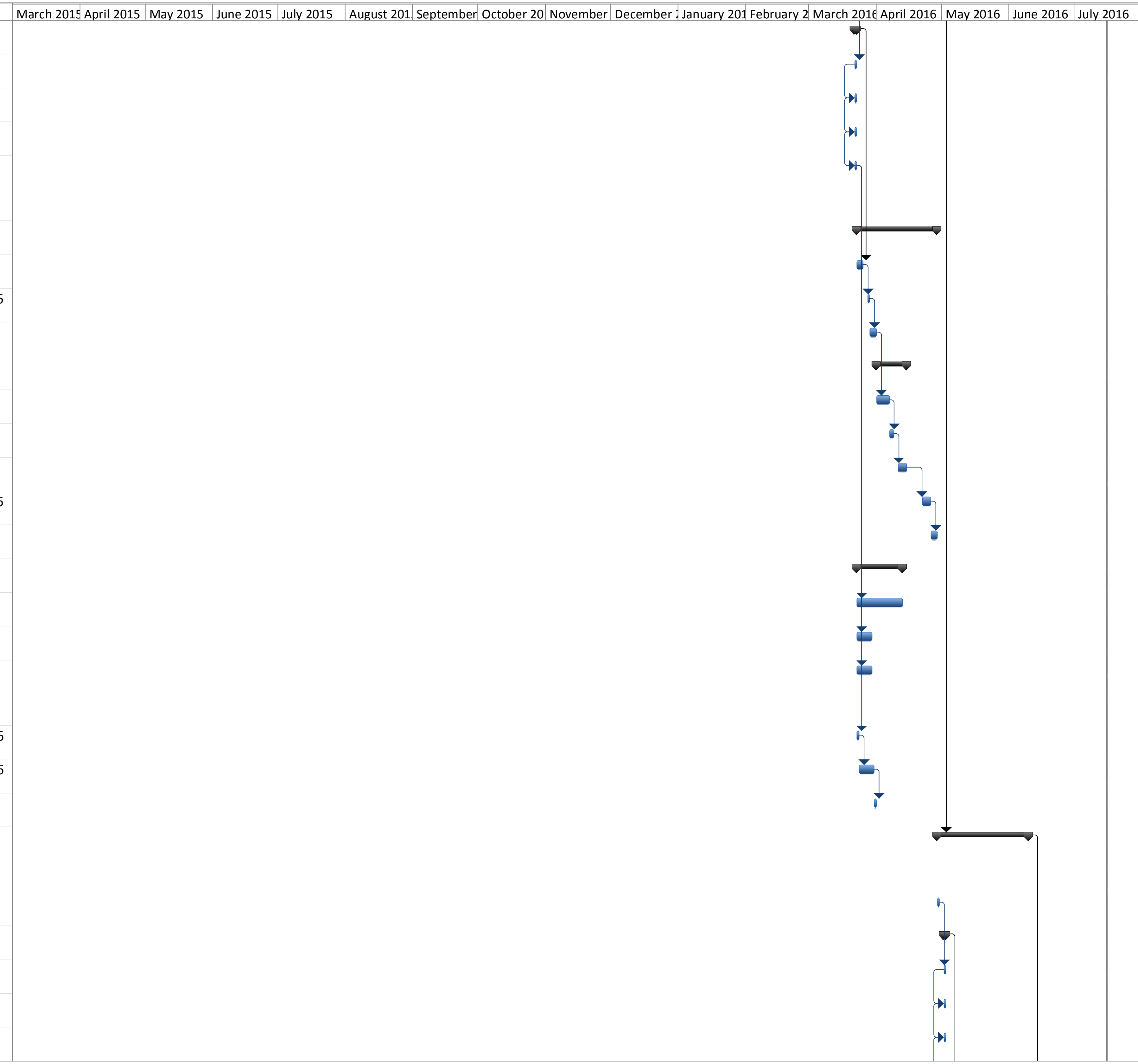
Project: TIWRP
Date: Tue 10/29/13

Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Deadline
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Progress

TIWRP-PDR
Construction Sequence

Figure 4-4: Construction Sequence

ID	Task	Task Name	Duration	Start	Finish
116		**Isolate Filter to Allow Workers to Enter Filter**	**1 day**	**Tue 3/22/16**	**Tue 3/22/16**
117		Close applicable influent gates	1 day	Tue 3/22/16	Tue 3/22/16
118		Close applicable filter effluent valves	1 day	Tue 3/22/16	Tue 3/22/16
119		Close applicable backwash Supply Valves	1 day	Tue 3/22/16	Tue 3/22/16
120		Open applicable 6" drain valves to allow for filters to drain	1 day	Tue 3/22/16	Tue 3/22/16
121		**Work to be performed inside the filters**	**27 days**	**Wed 3/23/16**	**Thu 4/28/16**
122		Remove existing filter media	3 days	Wed 3/23/16	Fri 3/25/16
123		Inspect existing underdrain	1 day	Mon 3/28/16	Mon 3/28/16
124		Remove any media or debris located in the filter gullet	3 days	Tue 3/29/16	Thu 3/31/16
125		**Install New Air Piping**	**10 days**	**Fri 4/1/16**	**Thu 4/14/16**
126		Connect exterior air piping to existing air header	4 days	Fri 4/1/16	Wed 4/6/16
127		Blind flange existing air supply valve to filter	2 days	Thu 4/7/16	Fri 4/8/16
128		Form and pour concrete encasement of new air piping	4 days	Mon 4/11/16	Thu 4/14/16
129		Properly install underdrain	2 days	Fri 4/22/16	Mon 4/25/16
130		Install new media and gravel	3 days	Tue 4/26/16	Thu 4/28/16
131		**Installation of Waste Backwash Gates**	**15 days**	**Wed 3/23/16**	**Tue 4/12/16**
132		Install new waste backwash gates (incl commissioning)	15 days	Wed 3/23/16	Tue 4/12/16
133		Replace existing waste backwash valves with spool	5 days	Wed 3/23/16	Tue 3/29/16
134		Connect existing influent gate actuators to new communications	5 days	Wed 3/23/16	Tue 3/29/16
135		Install PLC programming for rehabilitated filters	1 day	Wed 3/23/16	Wed 3/23/16
136		Commissioning	5 days	Thu 3/24/16	Wed 3/30/16
137		Connect air piping to blowers	1 day	Thu 3/31/16	Thu 3/31/16
138		**8. Rehabilitation of 4 Filters (9, 11, 13, 15), 12 Rehabilitated Filters in Service**	**29 days**	**Fri 4/29/16**	**Thu 6/9/16**
139		Confirm valves and equipment are on site	1 day	Fri 4/29/16	Fri 4/29/16
140		**Isolate Filter to Allow Workers to Enter Filter**	**1 day**	**Mon 5/2/16**	**Mon 5/2/16**
141		Close applicable influent gates	1 day	Mon 5/2/16	Mon 5/2/16
142		Close applicable filter effluent valves	1 day	Mon 5/2/16	Mon 5/2/16
143		Close applicable backwash Supply Valves	1 day	Mon 5/2/16	Mon 5/2/16

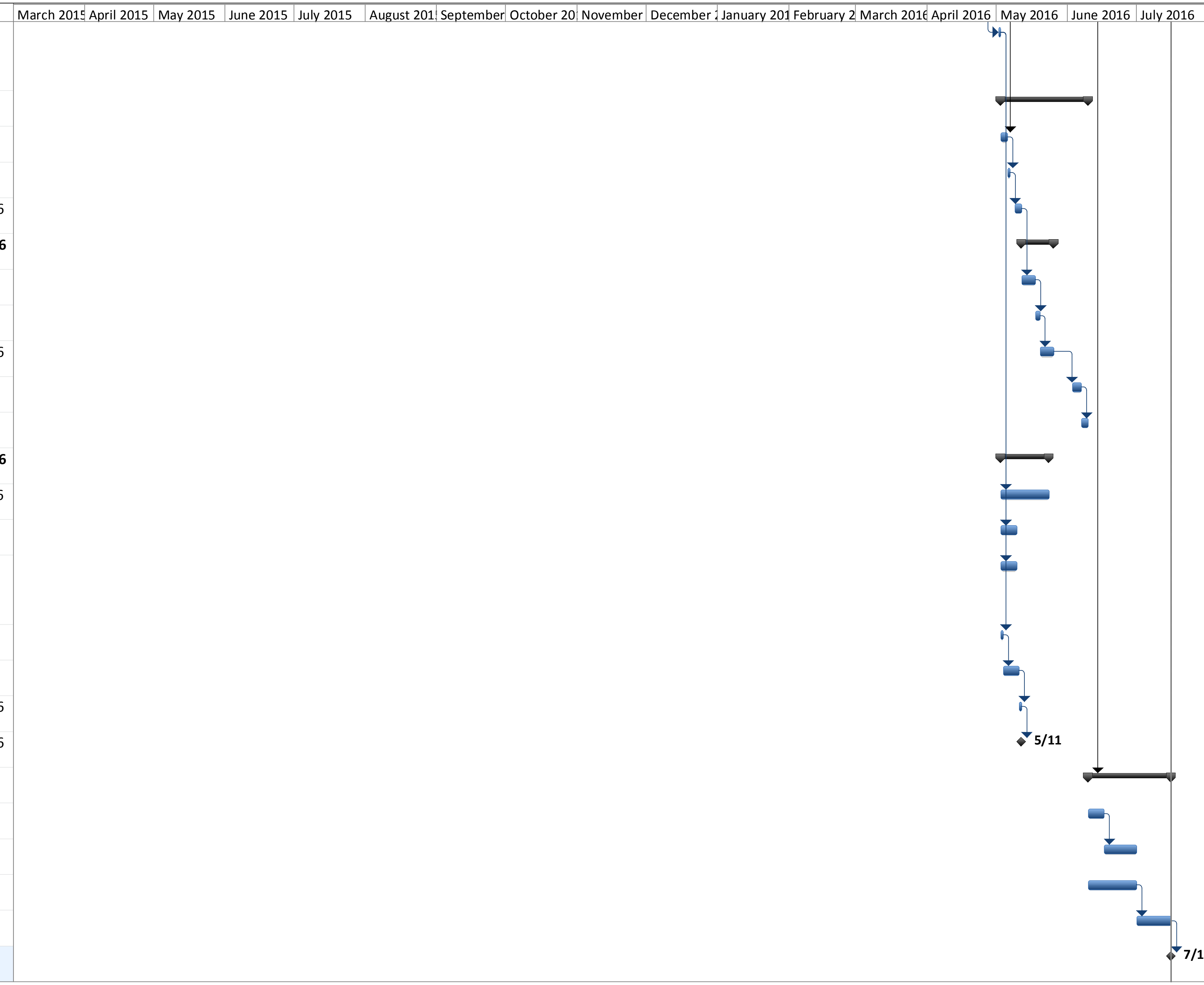


Project: TIWRP
Date: Tue 10/29/13

Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Deadline
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Progress

Figure 4-4: Construction Sequence

ID	Task Mode	Task Name	Duration	Start	Finish
144		Open applicable 6" drain valves to allow for filters to drain	1 day	Mon 5/2/16	Mon 5/2/16
145		**Work to be performed inside the filters**	**27 days**	**Tue 5/3/16**	**Thu 6/9/16**
146		Remove existing filter media	3 days	Tue 5/3/16	Thu 5/5/16
147		Inspect existing underdrain	1 day	Fri 5/6/16	Fri 5/6/16
148		Remove any media or debris located in the filter gullet	3 days	Mon 5/9/16	Wed 5/11/16
149		**Install New Air Piping**	**10 days**	**Thu 5/12/16**	**Wed 5/25/16**
150		Connect exterior air piping to existing air header	4 days	Thu 5/12/16	Tue 5/17/16
151		Blind flange existing air supply valve to filter	2 days	Wed 5/18/16	Thu 5/19/16
152		Form and pour concrete encasement of new air piping	4 days	Fri 5/20/16	Wed 5/25/16
153		Properly install underdrain	2 days	Fri 6/3/16	Mon 6/6/16
154		Install new media and gravel	3 days	Tue 6/7/16	Thu 6/9/16
155		**Installation of Waste Backwash Gates**	**15 days**	**Tue 5/3/16**	**Mon 5/23/16**
156		Install new waste backwash gates (incl commissioning)	15 days	Tue 5/3/16	Mon 5/23/16
157		Replace existing waste backwash valves with spool	5 days	Tue 5/3/16	Mon 5/9/16
158		Connect existing influent gate actuators to new communications	5 days	Tue 5/3/16	Mon 5/9/16
159		Install PLC programming for rehabilitated filters	1 day	Tue 5/3/16	Tue 5/3/16
160		Commissioning	5 days	Wed 5/4/16	Tue 5/10/16
161		Connect air piping to blowers	1 day	Wed 5/11/16	Wed 5/11/16
162		Rehabilitated 16 filters	0 days	Wed 5/11/16	Wed 5/11/16
163		**9. Install Final Equipment**	**25 days**	**Fri 6/10/16**	**Fri 7/15/16**
164		Remove two remaining backwash supply pumps	5 days	Fri 6/10/16	Thu 6/16/16
165		Install one additional backwash supply pump	10 days	Fri 6/17/16	Thu 6/30/16
166		Remove and replace air scour blowers	15 days	Fri 6/10/16	Thu 6/30/16
167		Commission new equipment	10 days	Fri 7/1/16	Fri 7/15/16
168		Rehabilitation Complete	0 days	Fri 7/15/16	Fri 7/15/16



Project: TIWRP
Date: Tue 10/29/13

Task		Summary		External Milestone		Inactive Summary		Manual Summary Rollup		Finish-only	
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Milestone		External Tasks		Inactive Milestone		Duration-only		Start-only		Progress	

TIWRP-PDR
Construction Sequence

Figure 4-4: Construction Sequence

Appendix A

Design Criteria Supporting Information

Calcs by: MJA 10/31/13
Check by: SJM 10/31/13

1. Influent

Flow Rate Data:

$Q_{FilterAvg} := 15mgd$ — Average flow, from filter rehab study report

$Q_{FilterDesign} := 30mgd$ — Design capacity of the TIWRP

$Q_{FilterPeak} := 52mgd$ — Peak flow rate, from filter rehab study report

Water Quality Data:

$NO_{3.Influent} := \begin{pmatrix} 8.5 \\ 11 \end{pmatrix} \frac{mg}{L}$ — Average and maximum nitrate (mg/L as NO_3-N), from plant data

$T_{Influent} := \begin{pmatrix} 1.5 \\ 10 \end{pmatrix} \cdot NTU$ — Average and maximum filter influent turbidity, from filter rehab study report data

$TSS_f := 3.8 \frac{mg}{L \cdot NTU}$ — Conversion factor from NTU to TSS, from Aqua MiniDisk filter pilot test data

Estimate Influent Suspended Solids:

$TSS(Turb) := TSS_f \cdot Turb$

$$TSS_{Influent} := TSS\left(T_{Influent}\right) = \begin{pmatrix} 5.7 \\ 38 \end{pmatrix} \cdot \frac{mg}{L}$$

2. Filter Configuration

Number and Arrangement of Filters:

$N_{Filters} := 16$ — Total number of filter boxes

$N_{FiltersBank} := 8$ — Filter boxes in each bank

$N_{FiltersMin} := 7$ — Minimum number of filters, assuming one bank in service with one filter offline.

Filter Geometry:

$L_{Filter} := 60ft$ — Length of filter active area

$W_{Filter} := 10ft$ — Width of filter active area

Calculate Filter Area:

$A_{Filter} := L_{Filter} \cdot W_{Filter}$

$A_{Filter} = 600 \cdot ft^2$

3. Media Configuration

Assumed Media Characteristics:

$d_{Media} := 2.5mm$

Size and uniformity based on Tetra product data

$UC_{Media} := 1.4$

$SG_{Media} := 2.65$ — Assumed specific gravity for silica sand media

$\varepsilon_{Media} := 0.4$ — Porosity from Tetra product data

Select the Bed Depth:

$D_{Bed} := 6ft$ — Recommended depth from Tetra product data

4. Filtration Cycle

Check the Filtration Velocity:

$$V_{Filtration}(Q, N) := \frac{Q}{A_{Filter} \cdot N}$$

$$V_{Filtration}\left(Q_{FilterDesign}, N_{FiltersMin}\right) = 4.96 \cdot \frac{gpm}{ft^2}$$

$$V_{Filtration}\left(Q_{FilterPeak}, N_{Filters} - 4\right) = 5.02 \cdot \frac{gpm}{ft^2}$$

$V_{FiltrationRange} := \begin{pmatrix} 3 \\ 5 \end{pmatrix} \frac{gpm}{ft^2}$

Recommended low and high filtration velocity based on Tetra product data for warm areas.

CONCLUDE: one filter bank (with one filter offline) is sufficiently sized to handle the design flow. Both filter banks (with four filters offline) are sufficient for the peak flow.

Check the Nitrate Loading:

$$NO_{3.Loading}(Q, N) := \frac{NO_{3.Influent} \cdot Q}{N \cdot A_{Filter} \cdot D_{Bed}}$$

$$NO_{3.Loading}\left(Q_{FilterDesign}, N_{FiltersMin}\right) = \begin{pmatrix} 1.35 \\ 1.75 \end{pmatrix} \cdot \frac{kg}{m^3 \cdot day}$$

$$NO_{3.Loading}\left(Q_{FilterPeak}, N_{Filters} - 4\right) = \begin{pmatrix} 1.37 \\ 1.77 \end{pmatrix} \cdot \frac{kg}{m^3 \cdot day}$$

$NO_{3.LoadingMax} := 1.8 \frac{kg}{m^3 \cdot day}$

Recommended maximum nitrate loading based on Metcalf & Eddy, *Wastewater Engineering,* 4th ed.

CONCLUDE: one filter bank (with one filter offline) is sufficiently sized to handle the design flow. Both filter banks (with four filters offline) are sufficient for the peak flow.

Check the TSS Loading:

$$TSS_{Loading}(TSS, Q, N) := 1day \cdot \frac{TSS \cdot Q}{N \cdot A_{Filter} \cdot D_{Bed}}$$

$$TSS_{Loading}\left(TSS_{Influent}, Q_{FilterDesign}, N_{FiltersMin}\right) = \begin{pmatrix} 0.91 \\ 6.05 \end{pmatrix} \frac{kg}{m^3}$$

$$TSS_{Loading}\left(TSS_{Influent}, Q_{FilterPeak}, N_{Filters} - 1\right) = \begin{pmatrix} 0.73 \\ 4.89 \end{pmatrix} \frac{kg}{m^3}$$

$$TSS_{Loading}\left(TSS_{Influent}, Q_{FilterAvg}, N_{FiltersMin}\right) = \begin{pmatrix} 0.45 \\ 3.02 \end{pmatrix} \frac{kg}{m^3}$$

$TSS_{LoadingMax} := 2.67 \frac{kg}{m^3}$

Recommended maximum TSS loading based on Tetra product data (1 lb TSS per square foot of bed)

CONCLUDE: Under normal conditions, the predicted TSS capacity will not be exceeded with 1 backwash per day. With high turbidity influent, breakthrough may occur and more frequent backwash may be required.

Estimate the Clean-bed Headloss:

$k_{CK} := 5$

Typical Carman-Kozeny coefficient

$\nu_{Water} := 1\,\frac{mm^2}{s}$

$$HL_{CleanBed}\left(V_{Filtration}\right) := \frac{36\cdot k_{CK}\cdot \nu_{Water}}{g}\cdot\left[\frac{\left(1-\varepsilon_{Media}\right)^2}{\varepsilon_{Media}{}^3}\right]\cdot\left(\frac{D_{Bed}}{d_{Media}{}^2}\right)\cdot V_{Filtration}$$

$$HL_{CleanBed}\left(V_{FiltrationRange}\right) = \begin{pmatrix} 0.2 \\ 0.3 \end{pmatrix}\cdot ft$$

Estimate the Terminal Headloss:

$Z_{BackwashWeir} := 24.0ft$

Existing backwash weir elevation

$HW_{Effluent} := \begin{pmatrix} 7.7 \\ 9.6 \end{pmatrix} ft$

Minimum and maximum water surface elevation in the effluent channel

$HL_{Terminal} := Z_{BackwashWeir} - HW_{Effluent}$

$$HL_{Terminal} = \begin{pmatrix} 16.3 \\ 14.4 \end{pmatrix}\cdot ft$$

5. Backwash Cycle

Backwash Velocity and Flow Rate:

$V_{BackwashRange} := \begin{pmatrix} 5 \\ 6 \end{pmatrix}\frac{gpm}{ft^2}$

Recommended backwash velocity from Tetra product data

$Q_{Backwash} := V_{BackwashRange}\cdot A_{Filter}$

$$Q_{Backwash} = \begin{pmatrix} 4.32 \\ 5.18 \end{pmatrix}\cdot mgd$$

Extent of Media Fluidization:

$$e_{Media} := \frac{\varepsilon_{Media}}{1-\varepsilon_{Media}} = 0.67$$

Media void ratio

$$i_{CR} := \frac{SG_{Media}-1}{1+e_{Media}} = 0.99$$

Critical hydraulic gradient and hydraulic conductivity

$$K_{Media} := \frac{g \cdot d_{Media}^{\;2}}{36 \cdot k_{CK} \cdot \nu_{Water}} \cdot \left[\frac{\varepsilon_{Media}^{\;3}}{\left(1-\varepsilon_{Media}\right)^2}\right] = 60.53 \cdot \frac{mm}{s}$$

$$V_{Fluidization} := K_{Media} \cdot i_{CR}$$

The filter media will fluidize at the velocity that produces the critical hydraulic gradient.

$$V_{Fluidization} = 88.25 \cdot \frac{gpm}{ft^2}$$

CONCLUDE: because of its coarse nature, the media will not fluidize at the given backwash velocity. The backwash headloss will be estimated based on the terminal headloss of the filtration cycle, scaled by the ratio of the backwash velocity to the filtration velocity.

Backwash Headloss:

- Assume that media does not fluidize, as shown above, so the backwash flow will be through a settled bed and headloss will scale linearly with velocity.
- Assume that at the beginning of backwash, headloss will be attributable both to the media itself and to the solids entrained in the pore space.
- Assume as a worst-case scenario a filtration cycle run at the minimum velocity, leading to the maximum terminal headloss.
- The backwash head is then estimated by scaling the terminal headloss of 16.3 ft at 3 gpm/sf to the maximum backwash rate of 6 gpm/sf.

$$HL_{BW.Media.Max} := \max\left(HL_{Terminal}\right) \cdot \frac{\max\left(V_{BackwashRange}\right)}{\min\left(V_{FiltrationRange}\right)}$$

$$HL_{BW.Media.Max} = 32.6\,ft$$

- Once the filter has been cleaned, the headloss during backwash can be approximated with the Carman-Kozeny model, similar to the clean-bed headloss.
- The minimum backwash headloss would be observed under this clean-bed condition at the lowest backwash velocity.

$$HL_{BW.Media.Min} := HL_{CleanBed}\left(\min\left(V_{BackwashRange}\right)\right)$$

$$HL_{BW.Media.Min} = 0.34 \cdot ft$$

Air Scour Velocity and Flow Rate:

$$V_{AirScourRange} := \begin{pmatrix} 3 \\ 5 \end{pmatrix} \cdot \frac{cfm}{ft^2}$$

Recommended air scour velocity, from Tetra product data

$$Q_{AirScour} := V_{AirScourRange} \cdot A_{Filter}$$

$$Q_{AirScour} = \begin{pmatrix} 1800 \\ 3000 \end{pmatrix} \cdot cfm$$

Required Air Pressure:

$$Z_{AirInlet} := 3ft$$

Height of air inlet to the filter, located below the underdrain.

$$P_{Air} := \rho_{Water} \cdot g \cdot \left(Z_{BackwashWeir} - Z_{AirInlet}\right)$$

$$P_{Air} = 9.1 \cdot psi$$

6. Biological Process

Methanol Dosing:

$$Ratio_{MeOH} := \begin{pmatrix} 3.0 \\ 3.2 \\ 3.5 \end{pmatrix}$$

Dosing ratio of methanol to nitrate nitrogen.
Low, average, and high values from Metcalf & Eddy.

$$Dose_{MeOH.Avg} := NO_{3.Influent_0} \cdot Ratio_{MeOH}$$

$$Dose_{MeOH.High} := NO_{3.Influent_1} \cdot Ratio_{MeOH}$$

$$Dose_{MeOH.Avg} = \begin{pmatrix} 25.5 \\ 27.2 \\ 29.75 \end{pmatrix} \cdot \frac{mg}{L} \qquad Dose_{MeOH.High} = \begin{pmatrix} 33 \\ 35.2 \\ 38.5 \end{pmatrix} \cdot \frac{mg}{L}$$

Gas Removal Bumping:

$$V_{Bump} := 12 \frac{m}{hr} = 4.91 \cdot \frac{gpm}{ft^2}$$

Recommended bump velocity from Metcalf & Eddy

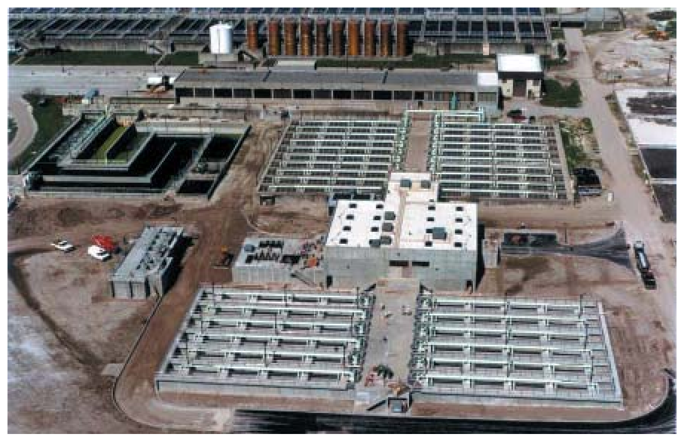
$$Q_{Bump} := V_{Bump} \cdot A_{Filter}$$

$$Q_{Bump} = 4.24 \cdot mgd$$

TETRA® Denite®
DeepBed™ DENITRIFICATION

The TETRA® Denite® system integrates well with other plant treatment processes to provide superior total nitrogen (TN) and phosphorous removal.

Severn Trent Services offers the TETRA® Denite® System, a practical process for the removal of nitrate-nitrogen (NO_3-N) and suspended solids (SS) in a single treatment step. Denite is a fixed-film biological denitrification process that also serves as a deep bed filtration system capable of removing suspended solids to virtually any final effluent requirement. Denite is used as the final treatment step in the total nitrogen removal process to help each facility meet stringent TN discharge limits of 3 mg/l.



For more information on TETRA® Denite® Systems visit **www.severntrentservices.com**

SEVERN TRENT SERVICES

UNDERSTANDING
A VALUABLE RESOURCE

WE UNDERSTAND DENITRIFICATION

Denite® Process Description

Biological denitrification processes can be of the fixed-film or suspended growth type. The TETRA Denite system requires one-tenth of the space used with suspended growth systems, greatly facilitating expansion or retrofitting requirements. With Denite, the denitrification process and the filtration process are combined in a single system and provide superior process synergy. NO_3-N is converted to nitrogen gas and captured within the media bed along with suspended solids and biomass formed from the denitrification reaction. The Denite gravity filter system operates in a downflow mode to maintain excellent suspended solids removal, thus avoiding the necessity for clarifiers or additional effluent polishing filters.

The specially sized and shaped granular media used in the fixed-film biological reactors is an excellent support medium for denitrifying bacteria and the deep bed environment is conducive to efficient NO_3-N and solids removal. The specific surface of the 2-3 mm sand is high, 300 square feet per cubic foot. A 4-6 foot depth of media is used that prevents short-circuiting and premature solids breakthrough. The contact between wastewater and biomass is excellent and hydraulic short-circuiting is negligible even during plant upsets.

The media allows for heavy capture of solids of at least 1.0 pound of solids per square foot of filter surface area before backwashing is required. The high solids capture permits operating for extended periods of time and easily handles peak flow periods or plant upsets.

As solids are captured increasing the head loss in the filters, a backwash is required to remove the solids. Because of the heavy loading capacity and media depth, DeepBed™ vessels require heavy-duty backwashing. Concurrent backwash air and water are used during the backwash cycle. The solids slurry removed from the filter media are typically returned to the upstream biological process. Due to the filters high solids loading capacity, the percent of return is less than 4% (<2% typical) of the plant's forward flow.

During the denitrification reaction, nitrogen gas accumulates in the media bed and wastewater is forced to flow around the gas bubbles in the media voids. This reduces the apparent size of the media and also improves the biomass contact and filtration efficiency. The effect of the gas bubbles increases head loss and requires periodic removal in between backwashes. Removing a reactor from service and applying backwash water for a short period of time accomplish this. This nitrogen release cycle, or bump, releases the entrapped nitrogen gas into the atmosphere, reducing the head loss. The TETRA SpeedBump® technology is utilized to conduct a complete system bump cycle without stopping flow to the reactors.

Suspended Solids Removal

The removal of suspended solids from wastewater effluent also lowers BOD since each mg/l of TSS contains 0.4-0.5 mg/l of BOD. Effluent suspended solids also contain nitrogen, phosphorous, and heavy metals. The removal of these solids often decreases 1 mg/l or more of these materials. With proper chemical treatment, effluent total phosphorous concentrations <0.3 mg/l are consistently achieved. Denite filters can easily meet <2 NTU or < 5 mg/l TSS (<2 mg/l TSS typical). Table 1 demonstrates the final effluent quality reported by the City for the Howard Curren AWTP in Tampa, Florida during the period of 1980-2001 where the Denite system is operating.

Nitrogen Removal

The denitrification reaction is time-dependent, and the time required for a specific removal efficiency varies according to the temperature of the wastewater being treated. In practice, filtration rates of 1-3 gpm/ft^2 are designed for water temperatures down to 8 degrees Celsius and 2-5 gpm/ft^2 in warmer waters. Table 2 demonstrates the Denite system's capability to denitrify to low NO_3-N concentrations at low wastewater temperatures. Table 1 demonstrates the consistency of yearly Denite operations for NO_3-N and SS removal.

Table 1: Howard Curren AWTP – Tampa, FL (100 MGD)

Period	MGD	BOD (mg/l)	SS (mg/l)	TN (mg/l)	TKN (mg/l)	NH_3-N (mg/l)	NOx-N (mg/l)
1980-1988	51.3	3.4	2.8	2.8	1.7	0.17	1.06
1989-1998	55.5	2.4	1.6	2.4	1.56	0.18	0.87
1999	50.45	2.6	0.9	2.52	1.46	0.13	1.01
2000	48.5	3.1	0.7	2.24	1.29	0.14	0.95
2001	49.7	2.3	0.8	2.28	1.21	0.15	1.06
Average	51.0	2.76	1.4	2.4	1.5	0.15	0.99

Table 2. Cold Weather Performance Data – Northeast US (Monthly Averages)

	MGD	Wastewater Temperature degrees C	Influent NO_3-N mg/l	Effluent NO_3-N mg/l
Nov 2003	1.01	14.9	11.56	0.45
Dec 2003	1.77	11.6	8.25	0.47
Jan 2004*	1.13	8.5	10.91	0.48
ADF Design	1.0	8	13	0.5
Peak-Day Design	2.36	8	11	0.5

* 15 days were measured <8 degrees C with average effluent NO_3-N of 0.45 mg/l @ 1.09 MGD

WE UNDERSTAND DENITRIFICATION

Denite® System Components and Specifications

- **Filter Vessel:** concrete or steel, round or rectangular-usually 18-20 feet deep with free board.
- **Filter Bottom:** Nozzleless design; stainless steel air headers and pipe laterals; plastic jacketed 5000 psi concrete T Block underdrains.
- **Filter Media:** monomedia granular sand with 2-3 mm effective size at depths of 4-to-6 feet.
- **Support Layers:** gravel in five layers totaling 18 inches deep in a reverse graded fashion.
- **Filter Controls:** consist of split flow influent over Curvilinear Weir™ blocks and standpipe effluent control. The mode is a uniform rate with open or closed valves.
- **Backwash Air:** distributed across the entire area of the filter bottom, supplied by a positive displacement blower at a rate of 3-5 icfm/ft²
- **Backwash Water:** supplied at a rate of 5-6 gpm/ft² with a low head centrifugal pump. The head loss across the filter bottom is 4.0 inches water column.
- **Filter Valves:** pneumatic or electric control valves with double acting cylinders. Isolation valves can be included.
- **Chemical Feed Systems:** includes a methanol storage and feed system with TetraPace™ automatic dosing control. This can be used for other chemical feeds as well.
- **Instrumentation:** PLC with human machine interface and multiple screens included. Also includes outputs for a centralized computer control and/or SCADA system. It also includes flow meters, analyzers, level switches, local panels and system alarms.
- **Filter Operation:** automatic with manual overrides. Backwashing and bumping are time based.
- **Head Requirement:** typically 6-8 feet of water but can be more or less depending on the specific application.
- **System Integration:** works well with other treatment plant processes such as overall nitrogen removal, phosphorous removal and virus removal.

650.0001.2 OCT/11

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SEVERN TRENT SERVICES

Appendix B

Backwash Supply Pump Calculations

General Information

Project Name	TIWRP Filter Rehab Design
Project Location	Los Angeles, CA
MWH Project No.	10503240

Revision History

	By	Date	Checked By	Date Checked
Rev 1	mja	6-Sep-13		
Rev 2	mja	16-Sep-13	pfw	25-Sep-13
Rev 3	mja	30-Oct-13		
Rev 4	mja/pfw	31-Oct-13	pfw	31-Oct-13

Fluid Characteristics

Type:	Water	
Temperature:	70	°F

	Manual	Computed	
Density		62.29	lbm/ft³
Kinematic Viscosity		1.06E-05	ft²/s
Vapor Pressure Head		0.80	ft

System Parameters

Design Flow	3,600.0	gpm	600 sf x 6 gpm/sf
Pump Centerline Elevation	-10.1	ft	
Minimum NPSHr Safety Margin	10	ft	
Friction Loss Calculation Method	Hazen-Williams		
H-W C Factor Correction in Accordance	TRUE		
with AWWA M11	TRUE		

Design Ranges

	Minimum	Maximum	Units	
System Flow	0.0	5,000.0	gpm	
Suction Flow Velocity	0.0	5.0	fps	
Discharge Flow Velocity	0.0	6.0	fps	
Suction Reservoir Fluid Elev	-8.5	9.0	ft	Min/max WSE
Discharge Reservoir Fluid Elev	24.0	24.0	ft	Backwash weir

Suction Piping Network

TIWRP Filter Rehab Design

Los Angeles, CA

MWH

Rev 4 / 31-Oct-2013, PSET version 2010-10-28

Segment		Pipe Information						Minor Losses				Flow	Custom Overrides			Calculated Values									
# / Station	Description	Pipe Material	Pipe Schedule	Pipe Diameter (Nominal)	Segment Length	Lining	Lining Thickness	Fitting Type	Minor Loss Parameter A	Minor Loss Parameter B	Number of Fittings	Flow Ratio	Pipe Inner Diameter	Hazen Williams C	ε (absolute roughness)	Effective Pipe I.D.	Effective Flow	Velocity (line)	Effective Hazen-Williams C	ε (absolute roughness)	K (Minor Loss Coef)	ΔH (friction) ∑ = 0.0	Velocity (fitting)	ΔH (minor) ∑ = 0.5	Total Headloss ∑ = 0.0
				in	ft		in					%	in	-	ft	in	gpm	fps	ft	ft		ft	fps	ft	ft
1	Suction Inlet	Steel ANSI B36.10 and B36.19	40	16	2	Asphaltic		Pipe, Entrance, Inward Projecting			1	100%				15.000	3600	6.536	100	0.0004	0.780	0.03	6.536	0.52	0.03

Discharge Piping Network
TIWRP Filter Rehab Design
Los Angeles, CA

MWH
Rev 4 / 31-Oct-2013, PSET version 2010-10-28

Segment		Pipe Information						Minor Losses				Flow	Custom Overrides			Calculated Values									
# / Station	Description	Pipe Material	Pipe Schedule	Pipe Diameter (Nominal) in	Segment Length ft	Lining	Lining Thickness in	Fitting Type	Minor Loss Parameter A	Minor Loss Parameter B	Number of Fittings	Flow Ratio %	Pipe Inner Diameter in	Hazen Williams C -	ε (absolute roughness) ft	Effective Pipe I.D. in	Effective Flow gpm	Velocity (line) fps	Effective Hazen-Williams C ft	ε (absolute roughness) ft	K (Minor Loss Coef)	ΔH (friction) ∑ = 34.3 ft	Velocity (fitting) fps	ΔH (minor) ∑ = 2.8 ft	Total Headloss ∑ = 38.4 ft
1	16" Pump Column	Steel ANSI B36.10 and B36.19	40	16	25	Asphaltic		No Minor Losses				100%				12.063	3600	10.106	100	0.0004	0.000	1.08	10.106	0.00	1.08
2	16" Bend	Steel ANSI B36.10 and B36.19	40	16				Pipe, Standard Tee, Flow Through Branch			1	100%				12.063	3600	10.106	102	0.00015	0.776	0.00	10.106	1.23	1.23
3	16" x 20" Expansion	Steel ANSI B36.10 and B36.19	40	16				Pipe, Enlargement	0	20	1	100%				15.000	3600	6.536	102	0.00015	0.330	0.00	4.812	0.12	0.12
4	20" Discharge Piping	Steel ANSI B36.10 and B36.19	40	20	17	Asphaltic		No Minor Losses				100%				18.812	3600	4.155	100	0.0004	0.000	0.08	4.155	0.00	0.08
5	20" Elbows	Steel ANSI B36.10 and B36.19	40	20				Pipe, Bend, Flanged or Butt-welded, r/d=1.5			2	100%				18.812	3600	4.155	103	0.00015	0.166	0.00	4.155	0.09	0.09
6	20" Check Valve	Steel ANSI B36.10 and B36.19	40	20				Valve, Check, Swing, Flanged			1	100%				18.812	3600	4.155	103	0.00015	1.200	0.00	4.155	0.32	0.32
7	20" Gate Valve	Steel ANSI B36.10 and B36.19	40	20				Valve, Gate, Full Port			1	100%				18.812	3600	4.155	103	0.00015	0.095	0.00	4.155	0.03	0.03
8	30" x 30" x 20" Tee	Steel ANSI B36.10 and B36.19	40	20				Pipe, Enlargement	90	30	1	100%				18.812	3600	4.155	103	0.00015	2.381	0.00	3.208	0.38	0.38
9	30" Discharge Piping	Steel ANSI B36.10 and B36.19	30	30	172	Asphaltic		No Minor Losses				100%				28.750	3600	1.779	100	0.0004	0.000	0.11	1.779	0.00	0.11
10	30" Elbows	Steel ANSI B36.10 and B36.19	30	30				Pipe, Bend, Flanged or Butt-welded, r/d=1.5			1	100%				28.750	3600	1.779	105	0.00015	0.154	0.00	1.779	0.01	0.01
11	30" Tees - Line Flow	Steel ANSI B36.10 and B36.19	30	30				Pipe, Standard Tee, Flow Through Run			11	100%				28.750	3600	1.779	105	0.00015	0.219	0.00	1.779	0.12	0.12
12	30" Tees - Branch Flow	Steel ANSI B36.10 and B36.19	30	30				Pipe, Standard Tee, Flow Through Branch			2	100%				28.750	3600	1.779	105	0.00015	0.658	0.00	1.779	0.06	0.06
13	30" Butterfly Valve	Steel ANSI B36.10 and B36.19	30	30				Custom, Manually Specified K	0.35		2	100%		100		28.750	3600	1.779	100	0.00015	0.350	0.00	1.779	0.03	0.03
14	30" Pipe Exit	Steel ANSI B36.10 and B36.19	30	30				Pipe, Exit, Sharp-Edged			1	100%				28.750	3600	1.779	105	0.00015	1.000	0.00	1.779	0.05	1.83
15	Underdrain	Custom	Custom	Custom				Custom, Differential Pressure	0.145		1	100%					3600							0.33	0.33
16	Loaded Filter Media	Custom	Custom	Custom				Custom, Differential Pressure	16.3	3	1	100%					3600	0.013				32.60			32.60
17	Clean Filter Media	Custom	Custom	Custom				Custom, Differential Pressure	30.211		1	100%					3600	0.013				0.40			

Pump Catalog Data

Catalog	Existing - Simflo SR24C
Model	86154F396
Impeller	SR24C
Impeller Dia.	23.50 in
Speed	1160 rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency
85.0	0.0	80.0		0.0%
53.0	6,000.0	109.0	19.8	73.6%
51.0	6,500.0	110.0	22.0	76.0%
49.0	7,000.0	110.0	24.0	78.7%
47.0	7,500.0	110.0	26.5	80.9%
43.0	8,000.0	110.0	29.0	78.9%
38.0	8,500.0	110.0	32.0	74.1%

Catalog	FlowServe
Model	18ENH
Impeller	
Impeller Dia.	14.46 in
Speed	1180 rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency
98.0	0.0		12.0	-
82.0	1,000.0	60.0	12.0	34.5%
71.0	2,000.0	55.2	13.0	64.9%
65.0	3,000.0	63.2	14.0	77.9%
61.5	3,600.0	67.8	15.0	82.4%
58.0	4,000.0	69.4	17.0	84.3%
44.0	5,000.0	74.1	35.0	74.9%
40.0	5,200.0	75.1	45.0	69.9%

Catalog	
Model	
Impeller	
Impeller Dia.	in
Speed	rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency

Catalog	
Model	
Impeller	
Impeller Dia.	in
Speed	rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency

Catalog	
Model	
Impeller	
Impeller Dia.	in
Speed	rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency

Catalog	
Model	
Impeller	
Impeller Dia.	in
Speed	rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency

Pump Configuration Alternatives

Pump	Existing - Simflo SR24C
Composite	Do not use
Graph	Hide
Stages	1 #
Pumps	1 #
Impeller	23.5 in
Speed	100%
Description	Existing - Simflo SR24C (1160 rpm, imp ø=23.5in, 1 stage)
Catalog Imp. ø	23.50 in
Catalog Max Head	85 ft
Max Head	85 ft
Speed	1,160 rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency
85	-	80	-	-
80	938	85	3	22%
75	1,875	89	6	40%
70	2,813	94	9	53%
65	3,750	98	12	63%
60	4,688	103	15	69%
55	5,625	107	19	73%
50	6,750	110	23	77%
45	7,750	110	28	80%
40	8,300	110	31	76%
35	8,500	110	32	68%
30	8,500	110	32	58%
25	8,500	110	32	49%
20	8,500	110	32	39%
15	8,500	110	32	29%

Pump	FlowServe
Composite	Use
Graph	Show
Stages	1 #
Pumps	1 #
Impeller	14.46 in
Speed	100%
Description	FlowServe (1180 rpm, imp ø=14.46in, 1 stage)
Catalog Imp. ø	14.46 in
Catalog Max Head	98 ft
Max Head	98 ft
Speed	1,180 rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency
98	-	-	12	-
92	371	22	12	39%
86	741	44	12	36%
80	1,162	59	12	40%
74	1,701	57	13	56%
68	2,440	59	13	72%
62	3,441	67	15	81%
57	4,107	70	19	84%
51	4,531	72	27	80%
45	4,954	74	34	75%
39	5,200	75	45	68%
33	5,200	75	45	57%
27	5,200	75	45	47%
21	5,200	75	45	37%
15	5,200	75	45	26%

Pump	FlowServe
Composite	Do not use
Graph	Show
Stages	1 #
Pumps	1 #
Impeller	14.46 in
Speed	63%
Description	FlowServe (743.4 rpm, imp ø=14.46in, 1 stage)
Catalog Imp. ø	14.46 in
Catalog Max Head	98 ft
Max Head	39 ft
Speed	743 rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency
39	-	-	5	-
37	169	4	5	39%
35	339	8	5	38%
34	508	12	5	36%
32	699	15	5	38%
30	945	14	5	50%
29	1,191	14	5	62%
27	1,586	15	5	73%
25	2,042	16	6	80%
24	2,427	17	6	84%
22	2,655	18	8	83%
20	2,849	18	10	80%
18	3,042	18	13	77%
17	3,210	19	16	73%
15	3,276	19	18	66%

Pump	None
Composite	Do not use
Graph	Hide
Stages	1 #
Pumps	1 #
Impeller	in
Speed	
Description	
Catalog Imp. ø	- in
Catalog Max Head	- ft
Max Head	- ft
Speed	- rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
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-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-

Pump	None
Composite	Do not use
Graph	Hide
Stages	1 #
Pumps	1 #
Impeller	in
Speed	
Description	
Catalog Imp. ø	- in
Catalog Max Head	- ft
Max Head	- ft
Speed	- rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
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-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-

Pump	None
Composite	Do not use
Graph	Hide
Stages	1 #
Pumps	1 #
Impeller	in
Speed	
Description	
Catalog Imp. ø	- in
Catalog Max Head	- ft
Max Head	- ft
Speed	- rpm

Head ft	Flow gpm	Bowl hp	NPSHr ft	Efficiency
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-

System Curves

TIWRP Filter Rehab Design

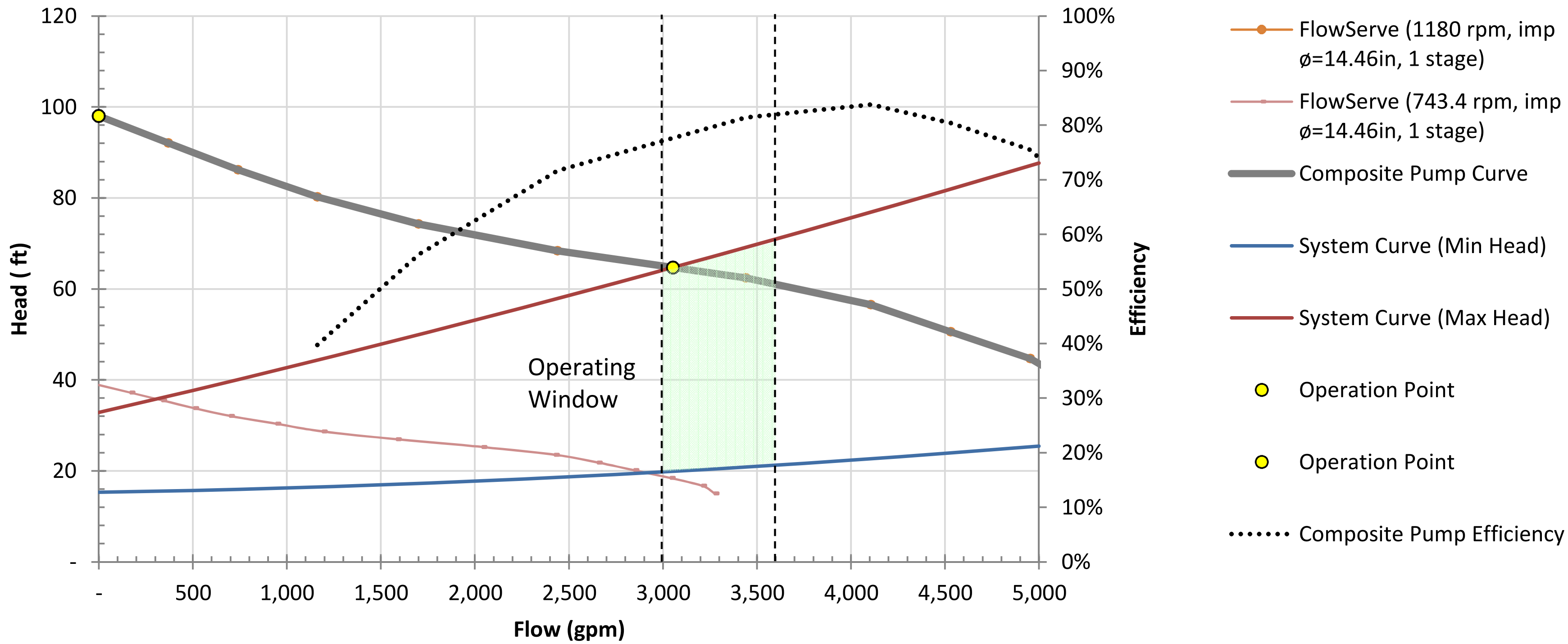
Los Angeles, CA

Rev 4 / 31-Oct-2013, PSET version 2010-10-28

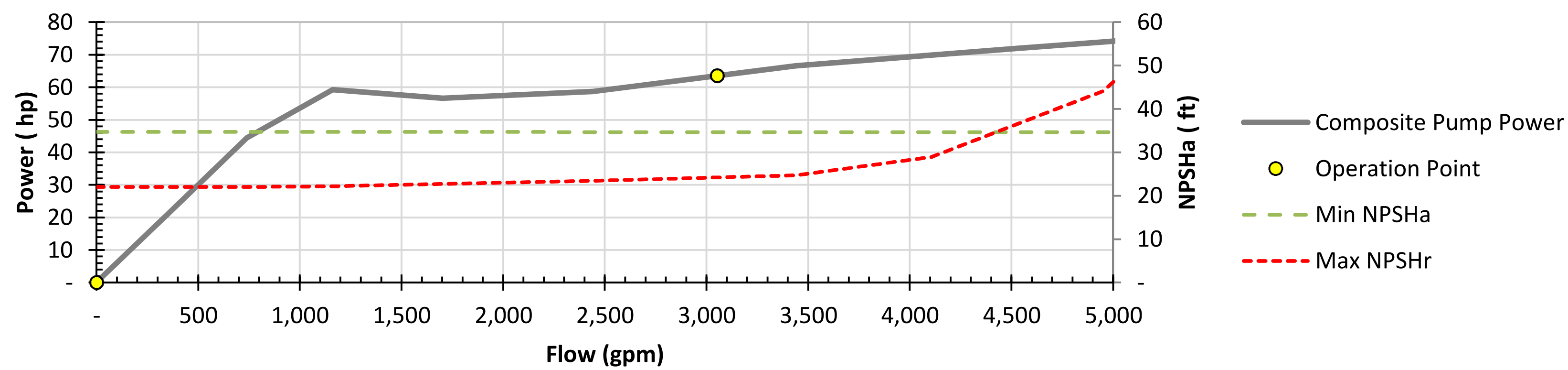
Calculated System Curves			
Flow	Min Suction NPSHa	Min System Head	Max System Head
gpm	ft	ft	ft
-	34.7	15.3	32.8
500	34.7	15.7	37.7
1,000	34.7	16.2	42.7
1,500	34.7	16.9	47.8
2,000	34.7	17.7	53.1
2,500	34.7	18.7	58.5
3,000	34.7	19.8	64.1
3,500	34.7	21.0	69.8
4,000	34.7	22.4	75.6
4,500	34.6	23.8	81.6
5,000	34.6	25.5	87.7

Calculated Composite Pump Curve				
Head	Flow Flow	Bowl Power	Max NPSHr	Bowl Efficiency
ft	gpm	hp	ft	%
98	-	-	22.0	
92	371	22	22.0	
86	741	44	22.0	
80	1,162	59	22.2	40%
74	1,701	57	22.7	56%
68	2,440	59	23.4	72%
62	3,441	67	24.7	81%
57	4,107	70	28.9	84%
51	4,531	72	36.6	80%
45	4,954	74	44.2	75%
39	5,200	75	55.0	68%
33	5,200	75	55.0	57%
27	5,200	75	55.0	47%
21	5,200	75	55.0	37%
15	5,200	75	55.0	26%

Calculated Operation Points		
Minimum System Head		
Flow	0	gpm
Head	98	ft
Power	0	hp
Max NPSHr	22	ft
Min NPSHa	34.7	ft
NPSH Margin	12.7	ft
Efficiency	-	
Maximum System Head		
Flow	3,054	gpm
Head	65	ft
Power	64	hp
Max NPSHr	24.2	ft
Min NPSHa	34.7	ft
NPSH Margin	10.4	ft
Efficiency	78%	
Maximum Flow		
Flow	5000	gpm
Head	44	ft
Power	74	hp
Max NPSHr	46.2	ft
Min NPSHa	34.6	ft
NPSH Margin	-11.6	ft
Efficiency	74%	



Head (ft)
Efficiency
Flow (gpm)
Operating Window
FlowServe (1180 rpm, imp ø=14.46in, 1 stage)
FlowServe (743.4 rpm, imp ø=14.46in, 1 stage)
Composite Pump Curve
System Curve (Min Head)
System Curve (Max Head)
Operation Point
Operation Point
Composite Pump Efficiency



Power (hp)
NPSHa (ft)
Flow (gpm)
Composite Pump Power
Operation Point
Min NPSHa
Max NPSHr

Appendix C

List of Drawings

Appendix C: List of Drawings
CIP 5229 - PDR

	Dwg No.	Drawing Title
General	R-1	Cover Sheet, Site Location, Vicinity Map, Meets & Bounds
	R-2	Drawing Index
	R-3	General Notes (City Standard Plan)
	FS-1	System layout flow diagram
Process Inst	PI-1	Filter,Typical (Waste BW Gate, Effl vlvs, etc.)
	PI-2	Backwash Pumps & Air Scour Blowers
	PI-3	Loop No. Tables
	PI-4	Filter Gallery (sample pumps, drain pumps)
Process drawings	0-PD-1	Mechanical Symbols
	0-PD-2	Standard Abbreviations and Notes
	0-PD-3	Mechanical Standard Details (1)
	0-PD-4	Mechanical Standard Details (2)
	PD-1	Overall Key Plan
	PD-2	Demolition Plan 1 - Backwash Pumps Plan and Blowers Plan
	PD-3	Demolition Plan 2 - Backwash Pumps and Blowers Sections
	PD-4	Demolition Plan 2 - Backwash Supply Pump Section
	PD-5	Demolition Plan 3 - Gallery Plan
	PD-6	Demolition Plan 4 - Gallery Sections
	PD-7	East Facilities Plan 1
	PD-8	East Facilities Plan 2
	PD-9	Backwash Supply Pumps Section
	PD-10	Replace Air Blowers and Discharge Piping
	PD-11	Air Piping Plan
	PD-12	Filter Gallery Plan - E
	PD-13	Filter Gallery Plan - W
	PD-14	Filter Section
Electrical	O-E-1	Abbreviations and General Notes
	O-E-2	Symbol List
	O-E-3	Electrical Symbols, Instrumentation and Devices Designations
	O-E-4	Electrical Standard Details
	E-1	Unit Substation Single Line Diagram
	E-2	Single Line Diagram, Load Schedule, Notes - 1
	E-3	Panel Schedules
	E-4	Electrical Site Plan, Overall
	E-5	Electrical Site Plan, Air Scour
	E-6	Electrical Site Plan, Backwash Pump
	E-7	Electrical Site Plan, Gallery
	E-8	Electrical Demo Plan - 1
	E-9	Electrical Demo Plan - 2
	E-10	Electrical Demo Plan - 3

Electrical	E-11	Electrical Plan - Backwash Pumps & Air Scour Blowers
	E-12	Electrical Plan - Gallery E
	E-13	Electrical Plan - Gallery W
	E-14	Schematic Diagrams - 1
	E-15	Schematic Diagrams - 2
	E-16	Schematic Diagrams - 3
	E-17	Schematic Diagrams - 4
	E-18	Instrumentation Block Diagram - 1
	E-19	Instrumentation Block Diagram - 2
	E-20	Instrumentation Block Diagram - 3
Instrumentation	O-I-1	Instrumentation Symbols and Abbrev - 1
	O-I-2	Instrumentation Symbols and Abbrev - 2
	O-I-3	Instrumentation Symbols and Abbrev - 3
	O-I-4	Instrumentation Abberviations
	O-I-5	Instrumentation Installation Details
	I-1	Instrumentation Loop Diagram - 1
	I-2	Instrumentation Loop Diagram - 2
	I-3	Instrumentation Loop Diagram - 3

Appendix D

Specification List

Appendix D: Specification List
CIP 5229 PDR

- **00 General Conditions**
  - 00001 Cover
  - 00010 General Conditions
- **01 General Requirements**
  - 01000 Master General Requirements Cover
  - 01022 Environmental Procedures
  - 01050 Table of Contents
  - 01100 Summary
  - 01111 Abbreviations and Reference Standards
  - 01112 Description of Work
  - 01113 Divisions of Technical Sections of Project Manual
  - 01114 Issuance of Drawings and the Project Manual
  - 01115 Mandatory Provisions
  - 01116 Electronic Document Control
  - 01120 Interface / Coordination Requirements
  - 01140 Contractor’s Use of the Premises
  - 01150 Storage of Materials and Equipment
  - 01200 Price and Payment Procedures
  - 01211 Allowance for Equipment Substitutions for Compatibility Purposes
  - 01212 Fixed Cash Allowance Items
  - 01230 Alternatives
  - 01251 Change Order Requests
  - 01252 Construction Incentive Change Proposal
  - 01253 Differing Site Condition
  - 01254 Change Orders
  - 01255 Price Reduction for Defective Cost or Pricing Data
  - 01270 Measurement of Quantities for Unit Price Work
  - 01291 Notice to Withhold and/or Stop Notice
  - 01292 Payments
  - 01298 Schedule of Values / Contract Price Breakdown
  - 01300 Administrative Requirements
  - 01311 Preconstruction Safety Conference
  - 01312 Project Meetings
  - 01313 Work by City or Others
  - 01321 Contractor's Construction Schedule and Reports
  - 01322 Construction Progress Photography
  - 01323 Construction Status Reports
  - 01330 Shop Drawings / Submittals
  - 01350 Audit and Access to Records
  - 01351 Escrow Bid Documents
  - 01352 Disputes Review Board
  - 01353 Opportunity to Partner
  - 01400 Quality Requirements

- 01410 Regulatory Requirements
- 01411 Confined Space Entry
- 01412 Enhanced Electrical Safety Policy
- 01420 Units of Measure
- 01421 Symbols
- 01430 Manufacturer's Field Service
- 01451 Approval of Electrical Equipment
- 01452 Inspection of the Work
- 01453 Sampling, Testing And Fabrication Inspection
- 01454 Weighing and Metering Equipment
- 01455 Calibration of Testing Equipment
- 01500 Temporary Facilities and Controls
- 01561 Environmental Control
- 01562 Environmental Mitigation
- 01563 Pollution Control -Sewage Spill Prevention and Response Requirements
- 01571 Stormwater Pollution Control Measures for Construction Activities
- 01572 Construction and Demolition Waste Management
- 01573 Excavation Shoring, Forms and Falsework
- 01581 Project Signs
- 01600 Product Requirements
- 01611 Guaranty / Warranty
- 01630 Substitutions and "Or Equal" Submittal
- 01700 Execution Requirements
- 01711 Site Investigation
- 01712 Subsurface Data
- 01721 Mobilization
- 01722 Surveying
- 01723 Right of Way
- 01731 Cutting and Patching
- 01732 Additional Potholing
- 01740 Removal, Cleanup and Demobilization
- 01750 Startup Assistance
- 01770 Project Closeout
- 01781 Spare Parts
- 01782 Technical Manuals
- 01783 Record Drawings and Records Project Manual
- 01800 Facility Operation
- 01810 Fundamental Commissioning Requirements
- 01813 Prefunctional Checklists
- 01820 Operations and Maintenance Training
- 01900 Facility Decommissioning

- **02 Site Work**
    - 02220 Site Demolition
    - 02225 Lead Based Paint Removal
    - 02230 Asbestos Removal

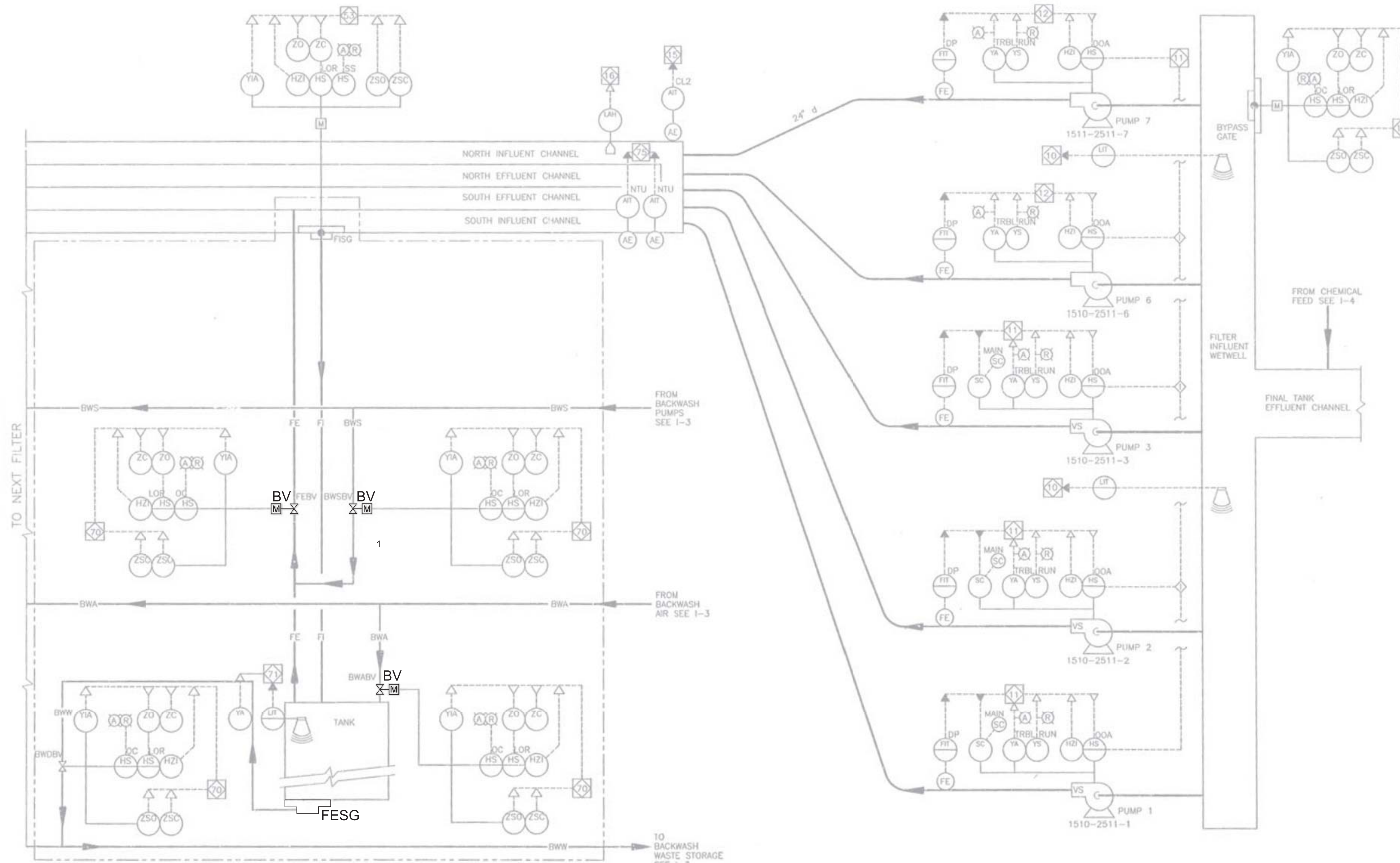
- **03 Concrete**
  - 03310 Cast-In-Place Concrete.
  - 03315 Grout
  - 03740 Concrete Repair
- **05 Metals**
  - 05035 Anodic Finish Coatings
  - 05500 Miscellaneous Metalwork
  - 05520 Handrails and Railings
- **07 Thermal and Moisture Protection**
  - 07900 Joint Sealants
- **08 Doors and Windows**
- **09 Finishes**
  - 09800 Protective Coating
- **10 Specialties**
- **11 Equipment**
  - 11000 Equipment General Provisions
  - 11300 Pumps, General
  - 11430 Vertical Turbine Pumps
  - 11450 Positive Displacement Air Blowers
  - 11490 Submersible Sump Pumps
  - 11805 Hydraulic Gates and Valves, General
  - 11815 Slide/Stop Gates
- **12 Furnishings**
- **13 Special Construction**
  - 13220 Filter Underdrain Rehabilitation
  - 13221 Filter Materials (Gravel & Media)
- **14 Conveying Systems**
- **15 Mechanical**
  - 15170 Air Transmission and Air Distribution Systems
  - 15270 Mechanical Systems Commissioning
  - 15280 Mechanical Testing Requirements
  - 15320 Electrical Requirements for Mechanical Equipment
  - 15340 Hangers and Supports
  - 15350 Pipe Expansion Joints
  - 15380 Motors and Drives
  - 15610 Piping, General
  - 15615 Treatment Plant Valves, General
  - 15620 Pipe System Testing
  - 15710 Mortar-Lined Mortar-Coated Carbon Steel Pipe, Fittings and Valves
  - 15720 Steel Pipe - Fabricated Specials
  - 15730 Carbon Steel Pipe, Fittings and Valves
  - 15740 Stainless Steel Pipe, Fittings and Valves
  - 15770 Treatment Plant Pipe Supports And Mechanical Joint Restraints
  - 15780 Treatment Plant Piping Identification Systems
  - 15790 Treatment Plant Pipe and Equipment Insulation
  - 15830 Miscellaneous Valves

- **16 Electrical**
  - 16010 Wastewater Facilities General Electrical Requirements
  - 16030 Wastewater Facilities Electrical Testing Requirements
  - 16100 Basic Materials and Methods
  - 16115 Conduits and Raceways
  - 16140 Cable Trays
  - 16150 Conductors, 600 Volts and Below
  - 16170 Cabinets and Enclosures
  - 16180 Wiring Devices
  - 16190 Electrical Identification
  - 16200 Motor Control Centers
  - 16210 Switches, Disconnect and Safety
  - 16240 Medium Voltage Switchgear
  - 16250 Electrical Service and Distribution
  - 16260 Surge Arresters
  - 16270 Service and Distribution Switchboard
  - 16280 Short Circuit and Coordination Report
  - 16300 Wastewater Facilities Grounding Systems
  - 16310 Variable Frequency Drive Units
  - 16320 Transformers
  - 16330 Panelboards
  - 16340 Low Voltage Motor Control
  - 16490 Electric Motors
  - 16520 Electric Heat Tracing
  - 16550 Contactors, Relays and Time Switches
- **17 Instrumentation and Control**
  - 17100 Meters, General
  - 17200 Rotameters
  - 17300 Gages
  - 17400 Process Instrumentation and Control
  - 17410 Distributed Control Systems
  - 17420 Supervisory Control and Data Acquisition Systems
- **Referenced Vendors**
  - 1 Referenced Vendors List
- **Miscellaneous Forms**
  - Form 1 Project Specifications Approval Form
  - Form 2 Line Summary
  - Form 3 Final Specification Approval
  - Form 4 Dacum Chart
  - Form 5 Job and Task Analysis Worksheet
  - Form 6 Development of Project Specifications
  - Form 7 Specification Directory Tree
  - Form 8 Special Plan Accommodations (SPA)
  - Form 9 Suggested Revision to Wastewater Master Specifications
  - Form 10 Procedures and Sign Off Log for Electrical Intertie with the Plant
  - Form 11 Equipment Summary Data Forms

- Form 12 Electrical Summary Data Form
- Form 13 Pump Summary Data Form
- Form 14 Equipment Maintenance Summary Forms
- Form 15 Request for Special Plant Accommodations (RESPA)
- Form 16 Authorization for Work in Restricted Area
- Form 17 Construction Water Supply Schematics

Appendix E

Preliminary P&IDs



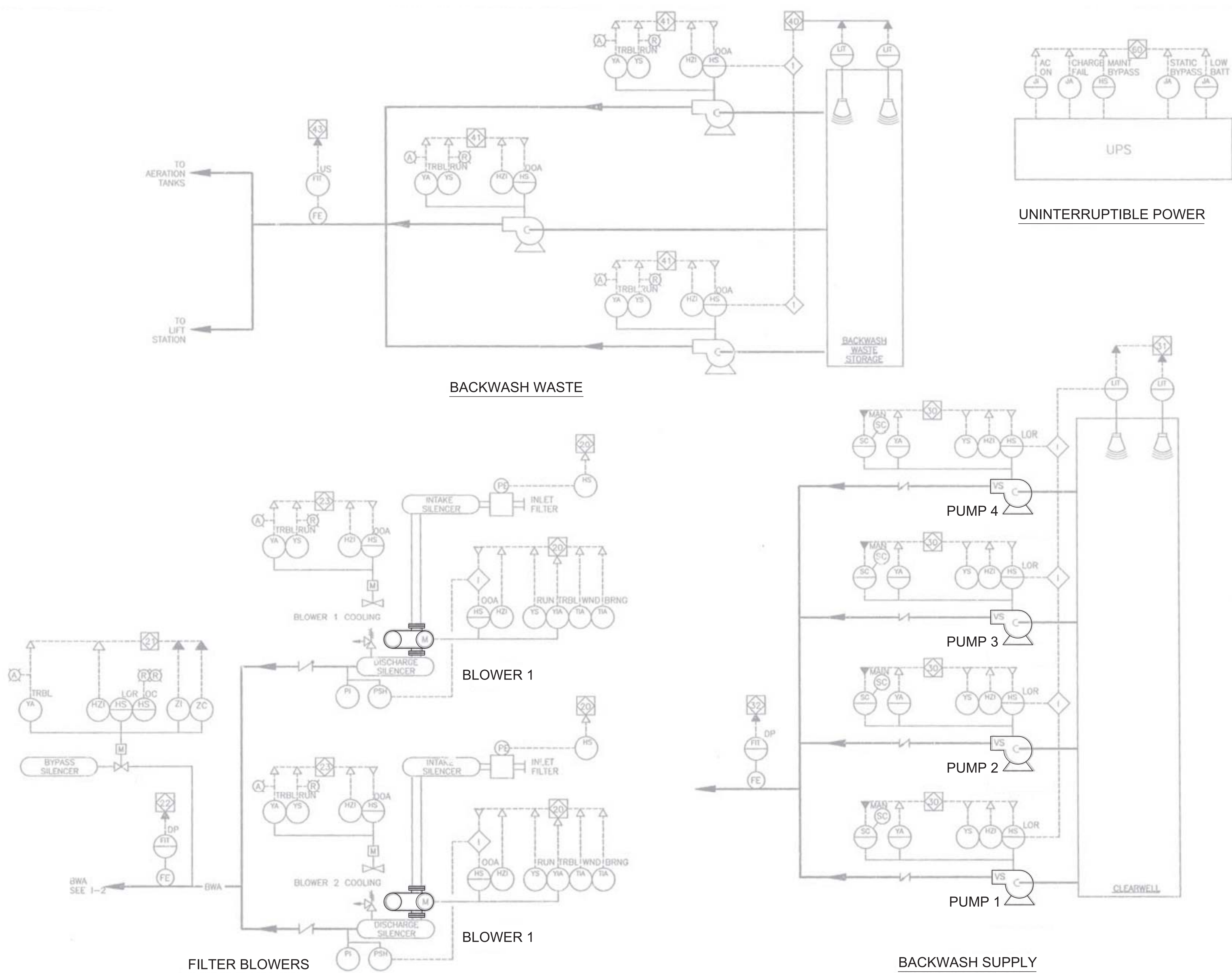
FILTER NO. 1: TYPICAL EACH FILTER TANK

MWH®

TERMINAL ISLAND WATER RECLAMATION PLANT
TERTIARY FILTER REHABILITATION
DRAFT PRELIMINARY DESIGN REPORT

PROCESS & INSTRUMENTATION
DIAGRAM I-2

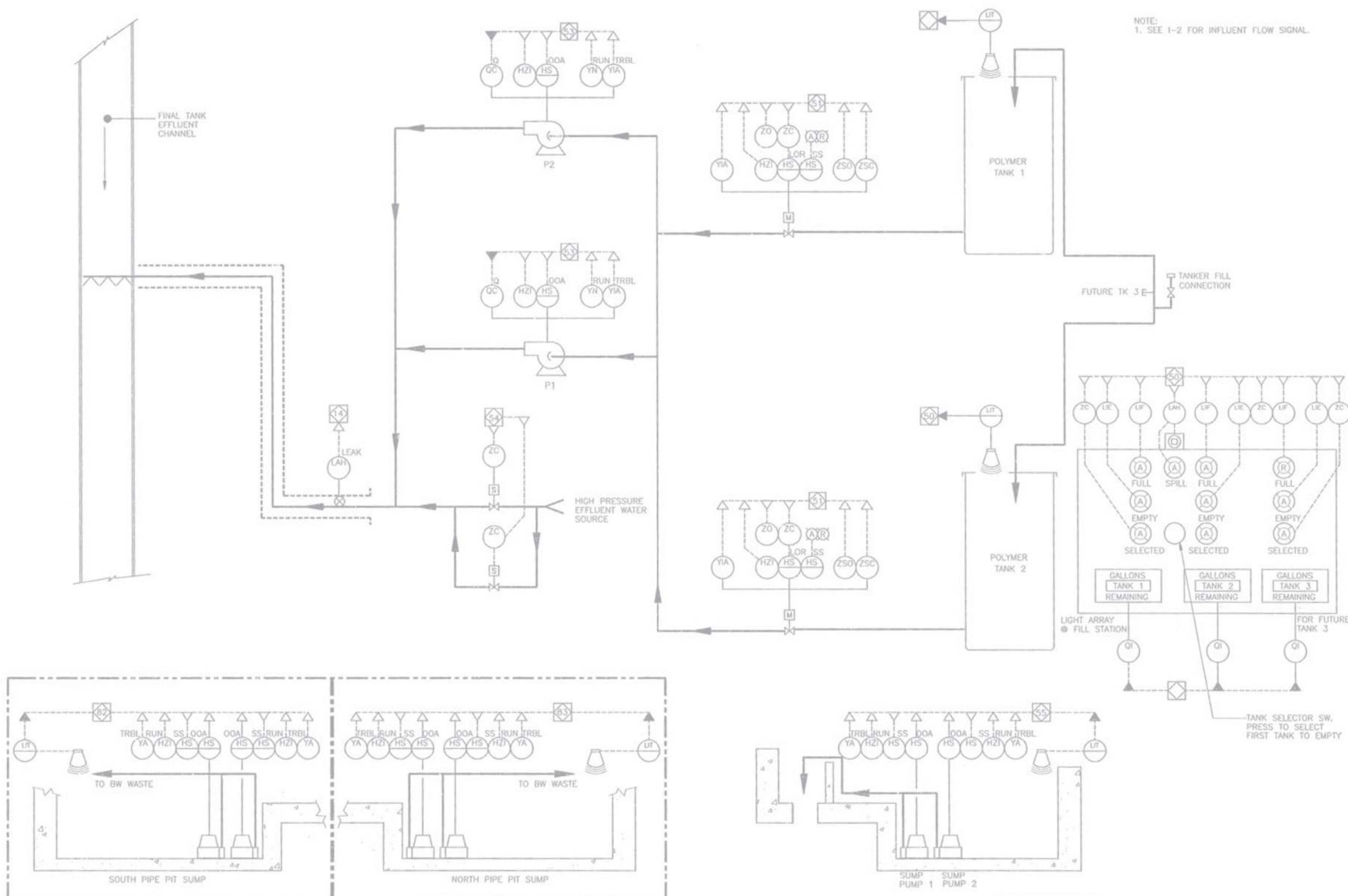
FIGURE
I-2



TERMINAL ISLAND WATER RECLAMATION PLANT
TERTIARY FILTER REHABILITATION
DRAFT PRELIMINARY DESIGN REPORT

PROCESS & INSTRUMENTATION DIAGRAM I-3

FIGURE
I-3



PIPE PIT SUMP AREA

POLYMER CONTAINMENT AREA

MWH®	TERMINAL ISLAND WATER RECLAMATION PLANT TERTIARY FILTER REHABILITATION DRAFT PRELIMINARY DESIGN REPORT	PROCESS & INSTRUMENTATION DIAGRAM I-4	FIGURE I-4

Appendix F

Construction Cost Estimate

BUREAU OF ENGINEERING
ENVIRONMENTAL ENGINEERING DIVISION (EED)
PROJECT CONSTRUCTION COST ESTIMATE

Project Title: TIWRP CIP 5229 - **Rehabiliation** of Existing Filters

Scope: Rehabilitation of Existing Filters - Denitrfying Option

Work Order: N/A

Client Dept.: BOE

Project Manager: Paul Wallace

Project Engineer: Sarah Munger

Type of Estimate: ☐ Class "A" ☐ Class "B" ☑ Class "C" ☐ Class "O"

Item	Description	Unit	Quantity	Unit Price	Item Total
1	New Filter Media	CY	2,666	200	533,200
2	Removal & Disposal of Existing Filter Media	CY	1,800	42	75,600
3	Backwash Supply Pumps	EA	3	100,000	300,000
4	Air Scour Blowers, New	EA	2	85,000	170,000
5	Air Piping, New, 10"	LF	560	456	255,200
6	Air Piping, New, 10" (Header)	LF	480	159	76,160
7	Demolition of Existing Air Piping	LS	1	40,320	40,320
8	Backwash Trough Effluent Gates, Frame & Actuator	EA	16	20,000	320,000
9	Installation of Effluent Slide Gates Frames & Actuator	EA	16	6,750	108,000
10	Effluent Butterfly Valves, New, 18"	EA	16	15,000	240,000
11	Sample Pumps, New	EA	0	0	0
12	Filter Gallery Labor and Construction Equipment	LS	1	140,800	140,800
13	Backwash Supply Isolation Valves, New, 30" (Labor & Material)	EA	2	25,000	50,000
14	PLC & Valve Controller Programming	LS	1	50,400	50,400
15	Backwash Supply Butterfly Valve, New, 30"	EA	16	30,000	480,000
16	Electrical & Instrumentation	LS	1	567,936	567,936
	Subtotal (1)				**$ 3,407,616**

Mobilization - 0% to 7% of Subtotal (1) - 7%	238,534
Permits - 2% to 5% of Subtotal (1) - 0.5%	17,039
Allowances - 5% of Subtotal (1) - 5%	170,381
Subtotal (2)	**$ 3,833,570**
Estimating Contingency - 10% to 50% of Subtotal (2) - 30%	1,150,071
Subtotal (3)	**$ 4,983,641**
Escalation - 3% per year of Subtotal (3) - 2 years	299,019
Subtotal (4)	**$ 5,282,660**
Construction Contingency - 5% to 20% of Subtotal (4) - 5%	264,133
Total Estimated Project Construction Cost	**$ 5,550,000**
Project Right of Way Estimated Cost	

Assumptions: Each filter assumed to have 24" of existing filter media

Prepared by:	Richard Warsinger	Date:	10-29-12
Checked by:	Behjat Zanjani	Date:	10-30-12
Approved by:	James Borchardt	Date:	12-06-12
Updated by:	Michael Adelman/Patrick Stahl	Date:	09-16-13
Updated by:	Paul Wallace/ Patrick Stahl	Date:	10-25-13
Client Approval:		Date:	

			Unit	Quantity	Unit Price	Total
1	**NEW FILTER MEDIA**					
	New Filter Media - Sand	(133 CY x 16 ea)	CY	2,133	200.00	426,600
	New Support Gravel	(33 CY x 16 ea)	CY	533	200.00	106,600
					SUBTOTAL 1	**$ 533,200**
2	**REMOVAL & DISPOSAL OF EXISTING FILTER MEDIA**					
	Media Removal & Disposal	(111 CY x 16 ea)	CY	1,800	42.00	75,600
					SUBTOTAL 2	**$ 75,600**
3	**BACKWASH SUPPLY PUMPS**					
	Replace Backwash Pumps		EA	3	100,000.00	300,000
	(Includes pipe modifications, removal and installation)					-
					SUBTOTAL 3	**$ 300,000**
4	**AIR SCOUR BLOWERS, NEW**					
	Blowers (including removal and installation)		EA	2	85,000.00	170,000
					SUBTOTAL 4	**$ 170,000**
5	**AIR PIPING, NEW, 10"**					
	Air Piping, New, 10" (including installation)		LF	560	150.00	84,000
	Removal and Installation, Air		EA	16	1,200.00	19,200
	Air Valves and Actuator, 10"		EA	16	9,500.00	152,000
					SUBTOTAL 5	**$ 255,200**
6	**AIR PIPING, NEW, 10" (HEADER)**					
	Air Piping, New, 10" (including installation)		LF	480	150.00	72,000
	Core Drill for Air Piping		EA	16	260.00	4,160
					SUBTOTAL 6	**$ 76,160**
7	**DEMOLITION OF EXISTING AIR PIPING**					
	Demolition of Existing Air Piping		LF	840	48.00	40,320
					SUBTOTAL 7	**$ 40,320**
8	**BACKWASH TROUGH EFFLUENT GATES, FRAME & ACTUATOR**					
	Overflow Trough Effluent Gates, Frame & Actuator, 3'x3'		EA	16	20,000.00	320,000
	(Stainless Steel Slide Gate)					-
	(Quote provided by Golden Harvest, Kerry Hays, 559-734-9778)					-
					SUBTOTAL 8	**$ 320,000**
9	**INSTALLATION OF EFFLUENT SLIDE GATES FRAMES & ACTUATOR**					
	Installation of Effluent Slide Gates Frames & Actuator		EA	16	4,500.00	72,000
	Demo existing BWW valves		EA	16	500.00	8,000
	Spool piece		EA	16	1,000.00	16,000
	Core Drill Hole for Slide Gate Rod		EA	16	750.00	12,000
					SUBTOTAL 9	**$ 108,000**

		Unit	Quantity	Unit Price	Total
10	**EFFLUENT BUTTERFLY VALVES, NEW, 18"**				
	Removal and Installation	EA	0	1,500.00	-
	Butterfly Valves and Actuator, New, 18"	EA	16	15,000.00	240,000
					-
				SUBTOTAL 10	**$ 240,000**
11	**SAMPLE PUMPS, NEW**				
	Peristaltic Sample Pumps	EA	0	1,000.00	-
				SUBTOTAL 11	**$ -**
12	**FILTER GALLERY LABOR AND CONSTRUCTION EQUIPMENT**				
	Equipment Rental	LS	1	32,000.00	32,000
	Total Labor for Isolation	LS	1	108,800.00	108,800
				SUBTOTAL 12	**$ 140,800**
13	**BACKWASH SUPPLY ISOLATION VALVES, NEW, 30" (LABOR & MATERIAL)**				
	Removal and Installation of BWS Valves	EA	2	5,000.00	10,000
	Butterfly Valves and Actuator, New, 30"	EA	2	20,000.00	40,000
				SUBTOTAL 13	**$ 50,000**
14	**PLC and Valve Controller Programming**				
	PLC and Valve Controller Programming	LS	1	50,400.00	50,400
				SUBTOTAL 14	**$ 50,400**
15	**30" BACKWASH SUPPLY BUTTERFLY VALVES**				
	Remove and Installation	EA	0	2,200.00	-
	Butterfly Valves and Actuator, New, 30"	EA	16	30,000.00	480,000
					-
				SUBTOTAL 15	**$ 480,000**
16	**ELECTRICAL & INSTRUMENTATION**				
	Electrical and Instrumentation Allowance	LS	1	567,936.00	567,936
	(20% of total for other items)				
				SUBTOTAL 16	**$ 567,936**

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