Technical Memoranda

Tomahawk Wastewater Treatment Facility Expansion
Project Definition Phase - Volume 2 of 3

JOHNSON COUNTY
KANSAS
Wastewater

Black & Veatch Project No. 185289
June 2016

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FINAL

TOMAHAWK WASTEWATER TREATMENT FACILITY

Project Definition Phase

Technical Memoranda

Volume No. 2

JCW NO. THM1-C026

PREPARED FOR

Johnson County Wastewater

20 JUNE 2016

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FINAL

TOMAHAWK CREEK WWTF PROJECT DEFINITION PHASE

Technical Memorandum 1

Existing and Future Flows and Loadings

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JOHNSON COUNTY KANSAS Wastewater

18 FEBRUARY 2016

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Acronyms and Abbreviations

Abbreviation	Meaning
A	
AA	Annual Average
AADF	Average Annual Daily Flow
ADF	Average Daily Flow
AFDM	Ash Free Dry Matter
AGS	Aerobic Granular Sludge
ALE	Alginate-like-exopolysaccharides
AL-E	Expected Aquatic Life Support
ANSI	American National Standards Institute
AQL	Warm Water Aquatic Life
AUX	Auxiliary
B	
B&V	Black & Veatch
BAF	Biological Aerated Filters
BFE	Base Flood Elevation
BFP	Belt Filter Press
BioMag	Biological Flocculation System from Siemens
Bio-P	Biological Phosphorous
BLDG	Building
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
BRIS	Blue River Interceptor Sewer
BRM	Blue River Main
C	
C	Hazen-Williams Equation Roughness Coefficient
C:Chl	Carbon to Chlorophyll Ratio
CA	Calcium
CANDO	Coupled Aerobic-anoxic Nitrous Decomposition Operation (Emerging)
CBOD	Carbonaceous Biochemical Oxygen Demand
$CBOD_5$	5-day Carbonaceous Biochemical Oxygen Demand
CEA	Cost Effective Analyses
CEAM	EPA's Center for Exposure Assessment Modeling
CEPT	Chemically Enhanced Primary Treatment
cf	Cubic Feet
CFD	Computational Fluid Dynamics
cfm	Cubic Feet per Minute
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CFUs	Colony Forming Units
CHP	Combined Heat and Power
CIPP	Cured-in-place Pipe
CLOMR	Conditional Letter of Map Revision
cm	Centimeters
CMF	Compressible Media Filters
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
COM	CoMag
CoMag	Chemical Flocculation System from Siemens
CR-B	Primary B Contact Recreation
CSBR	Continuous Sequencing Batch Reactor
CSOs	Combined Sewer Overflows
CT	Concentration Time
CWA	Clean Water Act
D	
D	Depth
DFM	Dry Weather Forcemain
DGC	Digester Gas Control Building
DIG	Digester
DISC	Disc Filters
DLSMB	Douglas L. Smith Middle Basin
DN	Down
DO	Dissolved Oxygen
DP	Dual Purpose
DS	Domestic Water Supply
dt	Dry Ton
DWF	Dry-weather Flow
DWS	Drinking Water Supply
E	
E. coli	Escherichia Coli
EA	Each
EFF	Effluent

Abbreviation	Meaning
EFHB	Excess Flow Holding Basin
EL	Elevation
ELA	Engineering, Legal, Administrative
ENR	Enhanced Nutrient Removal
EPA	Environmental Protection Agency
EPS	Extracellular Polymeric Substances
EQ	Equalization
F	
F/M	Food/Microorganism Ratio
FEMA	Federal Emergency Management Agency
Fe_3O_4	Non-abrasive Iron Ore, Magnetite
ff	Flocculated and Filtered
$ffCBOD_5$	Flocculated Filtered Carbonaceous Biochemical Oxygen Demand
ffCOD	Flocculated Filtered Chemical Oxygen Demand
ffTKN	Flocculated Filtered Total Kjeldahl Nitrogen
FG	Finish Grade
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FITOT	Fraction of Total Insolation
FL	Flow Line
floc	Flocculent
FM	Flow Meter
FP	Food Procurement
FSTE	Final Settling Tank Effluent
ft	Feet
FTE(s)	Full Time Equivalent(s)
G	
gal	Gallons
GAS	Granular Activated Sludge
GGE	Gallons of Gasoline Equivalent
GP	General Purpose
gpd	Gallons per Day
gpm	Gallons per minute
GR	Ground Water Recharge
H	
HB	Hallbrook Facility
HDD	Horizontal Directional Drilling

Abbreviation	Meaning
HEC-RAS	Hydraulic Engineering Center River Analysis System
HEX	Heat Exchanger
Hf	Friction Head
HI	Hydraulic Institute
HL	Head Loss
hp	Horsepower
hr	Hour
HRT	Hydraulic Retention Time
HVAC	Heating, Ventilation, Air Conditioning
HWE	Headworks Effluent
HWLA	High Water Level Alarm
Hypo	Hypochlorite
I	
I&C	Instrumentation and Controls
I/I	Inflow and Infiltration
IC	Internal Combustion
IFAS	Integrated Fixed-Film Activated Sludge
IMF	Interagency Metering Facility
in	Inches
IND	Industrial
INF	Influent
IP	Intellectual Property
IPS	Influent Pump Station
IR	Irrigation Use
IRR	Irrigation
IW	Industrial Water Supply Use
J	
JCW	Johnson County Wastewater
K	
kcf	Thousand Cubic Feet
KCMO	Kansas City, Missouri
KDHE	Kansas Department of Health and Environment
K_e	Light Extinction Coefficient
KU	University of Kansas
kWh	Kilowatt-hour
L	
L	Length, Liter
LBVSD	Little Blue Valley Sewer District

Abbreviation	Meaning
lb	Pound
lb/d	Pounds per Day
LF	Linear Feet
LIC	Lower Indian Creek
LOMR	Letter of Map Revision
LOX	Liquid Oxygen
LPON	Labile Particulate Organic Nitrogen
LPOP	Labile Particulate Organic Phosphorous
LS	Lump Sum
LWLA	Low Water Level Alarm
LWW	Livestock & Wildlife Watering
M	
m	Meter
MAD	Mesophilic Anaerobic Digestion
MARB	Mississippi-Atchafalaya River Basin
MBBR	Moving Bed Bioreactors
MBR	Membrane Bio-reactor
MCC	Motor Control Center
mg	Milligrams
Mg	Magnesium
MG	Million Gallons
mg/L	Milligrams per Liter
mgd	Million Gallons per Day
min	Minute, minimum
mJ	Millijoules
MLE	Modified Ludzack Ettinger
MLSS	Mixed Liquor Suspended Solids
MM	Maximum Month
mm	Millimeter
MMADF	Maximum Month Average Daily Flow
mmBtu	Million British Thermal Units
mpg	Miles per Gallon
MPN	Most Probable Number
N	
N	Nitrogen
NACWA	National Association of Clean Water Agencies
NaOH	Sodium Hydroxide (Caustic)
NCAC	New Century Air Center
NDMA	N-Nitrosodimethylamine
NFIP	National Flood Insurance Program
NH3-N	Total Ammonia
NOx-N	Nitrate + Nitrite
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NPV	Net Present Value
NTS	Not to Scale
O	
O&M	Operation and Maintenance
OCP	Overflow Control Plan
OMB	Office of Management and Budget
OUR	Oxygen Uptake Rate
P	
P	Phosphorous
PAOs	Phosphorous Accumulating Organisms
PC	Primary Clarifier
PD	Peak Day
PDF	Peak Daily Flow
PE	Primary Effluent
PFE	Primary Filtered Effluent
PFM	Peak Flow Forcemain
PHF	Peak Hour Flow
PIF	Peak Instantaneous Flow
PLC	Programmable Logic Controller
PO_4-P	Orthophosphate Phosphorous
ppd	Pounds per Day
pph	Pounds per Hour
PPI	Producer Price Index
ppy	Pounds per Year
PS	Pump Station
psf	Pounds per Square Foot
psi	Pounds per Square Inch
PWWF	Peak Wet-weather Flow
Q	
Q	Flow

Abbreviation	Meaning
R	
RAS	Return Activated Sludge
rbCOD	Rapidly Biodegradable Chemical Oxygen Demand
RDT	Rotating Drum Thickener
RECIRC	Recirculation
RIN	Renewable Identification Number
RM	River Mile
R&R	Repair and Replacement
RWW	Raw Wastewater
S	
SAB	USEPA Science Advisory Board
SBOD	Soluble Biochemical Oxygen Demand
SBR	Sequencing Batch Reactor
SCADA	Supervisory Control and Data Acquisition
SCE	Secondary Clarifier Effluent
scfm	Standard Cubic Feet per Minute
sCOD	Soluble Chemical Oxygen Demand
SCR	Secondary Contact Recreation
Sec	Second, Secondary
SF	Square Foot
SG	Specific Gravity
SLR	Solids Loading Rate
SMP	Stormwater Management Program, Shawnee Mission Park Pump Station
SND	Simultaneous Nitrification/ Denitrification
SOD	Sediment Oxygen Demand
SOR	Surface Overflow Rate
SOURs	Specific Oxygen Uptake Rates
SP	Single Purpose
S.P.S.	Sludge Pump Station
SRT	Sludge Retention Time
SS	Suspended Solids
SSOs	Sanitary Sewer Overflows
SSS	Separate Sewer System
sTP (GF)	Soluble Total Phosphorous (Glass Fiber Filtrate)
SVI	Sludge Volume Index
SWD	Side Water Depth

Abbreviation	Meaning
T	
TBL	Triple Bottom Line
$TBOD_5$	Total 5-day Biochemical Oxygen Demand
TDH	Total Dynamic Head
Temp	Temperature
TERT	Tertiary
TF	Trickling Filters
TFE	Tertiary Filter Effluent
THC	Tomahawk Creek
THM	Trihalomethanes
TIN	Total Inorganic Nitrogen
TKN	Total Kjeldahl Nitrogen
TM	Technical Memorandum
TMDL	Total Maximum Daily Loads
TN	Total Nitrogen
TOC	Top of Concrete
TP	Total Phosphorous
TPS	Thickened Primary Solids
TS	Total Solids
TSS	Total Suspended Solids
TWAS	Thickened Waste Activated Sludge
TYP	Typical
U	
µg/L	micrograms per Liter
UCT	University Cape Town
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultraviolet
UV LPHO	Ultraviolet Low Pressure, High Output
UV MPHO	Ultraviolet Medium Pressure, High Output
V	
VFA	Volatile Fatty Acids
VFAs	Volatile Fatty Acids (Speciated)
VFD	Variable Frequency Drive
VS	Volatile Solids
VSL	Volatile Solids Loading
VSr	Volatile Solids Reduction
VSS	Volatile Suspended Solids

Abbreviation	Meaning
W	
W	Width
WAS	Waste Activated Sludge
WASP	Water Quality Analysis Simulation Program
WBCR-A	Whole Body Contact Recreation – Category A
WBCR-B	Whole Body Contact Recreation – Category B
WFM	Wet Weather Forcemain
WL	Water Level
WK	Week
WS	Water Surface
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant
Y	
YR	Year

1 Executive Summary

1.1 BACKGROUND AND OBJECTIVES

In a previous study, the "Tomahawk Creek WWTP Process Improvements Pre-Design Study 2011 Update, HDR/CH2M HILL, October 2013", it was determined that the preferred path forward for JCW was to upgrade the Tomahawk Creek (THC) WWTF to a capacity sufficient to treat the full contribution of the tributary watershed in compliance with current and anticipated water quality requirements. The purpose of the current Project Definition Phase is to establish those regulatory requirements and determine the type, sizing, and configuration of the treatment facilities necessary to meet those requirements.

The purpose of this Technical Memorandum (TM) 1 is to determine the flow rates and waste loads under existing and future conditions that will serve as the basis for the process and hydraulic design of the treatment facilities.

1.2 DRY AND WET WEATHER DESIGN FLOWS

The THC WWTF receives gravity flows from the Lower Indian Creek (LIC) and Tomahawk Creek (THC) watersheds and pumped flow from the Dykes Branch watershed. A portion of the flow is treated at the WWTF while the remainder is conveyed to Kansas City, Missouri (KCMO) through the Linking Interceptor.

Existing dry weather flows were determined through evaluation of flow data from 2009 through 2013. This was an abnormally dry period, so the flows were normalized to a more historical representative basis through a rainfall vs flow correlation. The historical evaluation was then confirmed through hydraulic modeling by JCW's basin consultant, CH2M HILL. Similarly, existing wet weather flows were determined for various storm return intervals based on hydraulic modeling and review/extrapolation of historical data.

Currently, flows originating in parts of the City of Leawood flow by gravity across State Line Road at several locations into KCMO's collection system. An analysis was performed to determine if it would be cost effective to intercept this flow at State Line with pump stations and pump it to THC for treatment, thus avoiding the higher KCMO treatment cost. It was determined that it would, in fact, be cost effective to divert to THC from 3 of these locations.

Future flows were estimated based on factoring in future growth, cost effective infiltration and inflow (I & I) removal and applying a safety factor to account for unknowns and possible future redevelopment within the watershed.

The results of the existing and future flow evaluation are presented in Table 1-1.

Table 1-1: THC WWTF Design Flow Summary

FLOW COMPONENT	ADF (MGD)	MMADF (MGD)	PDF (MGD)	PEAK HOUR FLOW (MGD)		PEAK INSTANTANEOUS FLOW (MGD)	
				5-Yr Storm	10-Yr Storm	5-Yr Storm	10-Yr Storm
THC & LIC Basins	15.9 [1]	25.5[1]	100.3 [5]	166.8 [5]	189.9 [7]	167.7 [5]	190.5 [7]
Hallbrook	0.1 [2]	0.1 [4]	0.2 [6]	0.2 [6]	0.2 [6]	0.2 [6]	0.2 [6]
IMF 10/11	1.4 [3]	2.3 [4]	2.9 [6]	2.9 [6]	2.9 [6]	2.9 [6]	2.9 [6]
IMF 13/13A	1.0 [3]	1.6 [4]	2.0 [6]	2.0 [6]	2.0 [6]	2.0 [6]	2.0 [6]
Total	**18.4**	**29.5**	**105.4**	**171.9**	**195.0**	**172.8**	**195.6**
Recommended Design ADF = <u>19 mgd</u>							

Notes:

[1] Based on Average Annual Rainfall of 38.86 inches. Includes 4.57% growth based on Draft THC Service Area Existing Conditions Analysis TM (CH2M HILL, 2014).

[2] Based on 241 connections, at 300 gpd/connection.

[3] ADF at Leawood IMF sites provided by CH2M HILL.

[4] Based on 1.6 ratio of MMADF:ADF of 1.6.

[6] 5-year return interval with 23.2% I/I removal (hydraulic modeling provided by CH2M HILL and documented in Tomahawk WWTP Service Area – Storage Analysis TM).

[6] Peak flows limited to pump station capacities of twice ADF (2Q).

[7] 10-year return interval with 23.2% I/I removal (hydraulic modeling provided by CH2M HILL and documented in Tomahawk WWTP Service Area – Storage Analysis TM).

1.3 DRY AND WET WEATHER DESIGN LOADS

The analysis of historical loads used data provided by JCW extending from January 2011 through July 2014. This data spans a period of time when the area was in a drought so the recent historical data shows lower flows than projected in the sewer modeling analysis. The influent data at Tomahawk Creek WWTF is a grab sample collected between 8-9 am every morning. It was found that this data did not adequately portray typical domestic sewage as found at other JCW WWTFs so the data from Blue River Main WWTF was used as a surrogate. Blue River Main serves a similar watershed adjacent to Tomahawk Creek and the team agreed it would provide a reasonable set of influent characteristics for this evaluation.

The Blue River Main wastewater concentrations were used with the Tomahawk Creek flow data to develop influent loads. The flows and concentrations were adjusted from drought flows to more normal wet weather flows. While there is little growth in the service area, a number of sewers currently discharging to Kansas City, Missouri will be rerouted to Tomahawk Creek essentially acting as growth. Finally a 5.3 percent safety factor was applied to flows and loads to represent unknowns and possible redevelopment of some areas into higher density developments similar to the Mission Farms community just north of the plant site. The influent flows and loads developed for use in this evaluation are summarized in Table 1-2.

Table 1-2: Recommended Basis of Design

PARAMETER	ANNUAL AVERAGE		MM:AA	MAXIMUM MONTHLY AVERAGE		PD:AA	PEAK DAY	
Flow, mgd	19			28.7			105.4	
	mg/L	ppd		mg/L	ppd		mg/L	ppd
TSS	204	32,376	1.42	192	45,974	2.02	74.4	65,400
BOD	160	25,338	1.30	138	32,939	1.81	52.2	45,862
TKN	33.6	5,322	1.23	27.4	6,546	1.49	9.02	7,929
Ammonia	18.9	3,000	1.23	15.4	3,690	1.47	5.02	4,410
Total Phosphorus	4.05	642	1.26	3.39	809	1.67	1.22	1,073
Ortho-Phosphate	1.52	240	1.35	1.36	325	1.82	0.50	438

Historical primary clarifier performance was analyzed. TSS removal was estimated at 50 percent and BOD removal at 40 percent indicating a wastewater that is very fresh. This data was used to estimate future primary sludge production. Primary effluent quality was also estimated and used in a spreadsheet based activated sludge design program to obtain an estimate of WAS production at design conditions. The primary sludge and WAS solids projections for this evaluation are shown in Table 1-3.

Table 1-3: Biosolids Projections for Tomahawk Creek WWTF

	CONVENTIONAL PRIMARY TREATMENT		ADVANCED PRIMARY TREATMENT WITH COMAG TECHNOLOGY	
	Annual Average	Maximum Monthly Average	Annual Average	Maximum Monthly Average
Primary Sludge				
Quantity, ppd	16,188	22,987	29,139	41,377
Flow, mgd[1]	0.0485	0.0689	0.0873	0.1240
Thickened Waste Activated Sludge				
WAS Quantity, ppd	12,700	17,200	4,770	6,220
Flow, mgd[1]	0.0381	0.0516	0.0143	0.0186
Thickened Waste Activated Sludge (with carbon addition)				
Quantity, ppd	No supplemental carbon added		7,020	8,450
Flow, mgd[1]			0.0210	0.0253

	CONVENTIONAL PRIMARY TREATMENT	ADVANCED PRIMARY TREATMENT WITH COMAG TECHNOLOGY

Note:
[1] Assumed 4% total solids concentration.

1.4 SUMMARY OF RECOMMENDATIONS

It is recommended that the process and hydraulic design of the treatment facilities be based on the flows and loading presented in Tables 1-1, 1-2, and 1-3.

2 Introduction

2.1 BACKGROUND AND OBJECTIVES

The Tomahawk Creek (THC) WWTF was first constructed in 1955. Since then it has been modified numerous times, with the most recent major process modifications in 2009. Currently, THC treats about 7 mgd of flow per day while the total flow from the watershed averages about 15.2 mgd. Approximately 8 mgd of the influent flow, plus an additional 1 mgd waste stream from the treatment process is diverted to Kansas City, Missouri (KCMO) for treatment. On wet weather days most of the storm flow is diverted to KCMO.

The THC facility consists of flow diversion, influent pumping and screening, primary clarification (currently operated with ferric chloride addition for enhanced solids removal), rock trickling filters, shallow secondary clarifiers, chlorine disinfection and effluent dechlorination prior to discharge to Indian Creek. Primary and secondary sludges are discharged to the Diversion Structure for blending with the other diversion flows for discharge to KCMO. The site has anaerobic digesters that have been removed from service.

The hydraulic loading to the THC facility has been controlled to maximize nitrification through the trickling filters. At a base flow of 7 mgd through the THC WWTF, Johnson County Wastewater (JCW) has been able to meet effluent ammonia permit limits.

The site is located on a bend in Indian Creek. The bend is not natural; it is a relocation of the creek bed from its old path across the northern side of the site. Under high stream flow conditions, the stream still attempts to follow the old creek bed alignment. One of the major objectives of the project is not impact upstream water surface elevation because of new construction with the plant expansion.

The Kansas Department of Health and Environment (KDHE) will impose more stringent effluent permit limits on THC. The future permit limits will be based upon the new stream criteria for ammonia (lower effluent ammonia numerical limit) and new nutrient discharge limitations. The upgrade to nutrient removal will result in a major increase in the treatment plant footprint.

KCMO charges JCW for discharge of wastewater to the KCMO collection system. Given KCMO's recent consent decree agreement with EPA, it is anticipated that the KCMO rate structure will change and the rates for JCW will increase, making long term discharge of excess flow to KCMO not a viable option.

While the THC watershed is essentially built out, there is a little room for in-fill development, resulting in approximately a 4% increase in flow. The rest of the flow increases to the THC WWTF will involve disconnecting other selected flows from the KCMO system and diverting these flows to the THC WWTF for treatment.

The project objectives are as follows:

- Expand dry weather treatment capacity to eliminate the flow to KCMO.
- Modify the treatment processes to meet the future permit limits.

- Negotiate wet weather flow limits with KDHE.
- Design auxiliary treatment at the site to comply with the wet weather treatment limits.
- Design facilities such that upstream water surface levels in the stream are not impacted under flood conditions.
- Provide biosolids treatment either on the THC site or at the Douglas L. Smith Middle Basin (DLSMB) site (a Regional Treatment Approach).
- Design the new facilities to aesthetically blend into the area and provide effective odor control.

3 Existing and Future Flows Analysis

3.1 INTRODUCTION AND METHODS

Projections of future average and peak flows were developed to serve as a basis for evaluation and design of facilities at the THC WWTF. Three primary methodologies were used in this process:

- An analysis of historical flows and rainfall data was completed in order to develop estimated Average Daily Flow (ADF), Maximum Month Average Daily Flow (MMADF), and Peak Day Flow (PDF).
- Hydrographs of peak wet weather events were developed using hydraulic modeling to predict Peak Hour Flow (PHF) and Peak Instantaneous Flow (PIF) for the appropriate storm return interval.
- Cost Effective Analyses (CEA) were conducted to identify flows from outside the THC tributary area that are cost effective to divert to the THC WWTF for treatment.

The flow evaluation was a collaborative effort of the B&V/HDR team, and JCW's consultant for the tributary area collection system, CH2M HILL.

3.2 GENERAL

The THC WWTF, situated at the junction of Indian Creek and Tomahawk Creek, serves a tributary area comprised of the Lower Indian Creek (LIC) Basin and the THC WWTF Basin. In addition, flow is currently pumped to the WWTF from the Dyke's Branch Basin, via the Dyke's Branch Pump Station. Of the 15.2 mgd flow arriving at the WWTF, approximately 7 mgd is treated at the WWTF and the rest is diverted through a 72-inch Linking Interceptor to KCMO. Of the 7 mgd treated, approximately 1 mgd is returned to the KCMO flow via the gravity sludge drains. The exception to the above flow pattern is during extreme wet weather; when flows exceed approximately 80 – 90 mgd the wet weather lagoon at THC WWTF is activated.

JCW has several other locations in their collection system where flows cross over to KCMO for treatment. Several of these, specifically Interconnect Metering Facilities (IMF's) 10, 11, 12, 13, 13A, and the Hallbrook IMF are in reasonably close proximity to the THC WWTF. These IMF sites were evaluated to determine the cost effectiveness of diverting these flows to THC through pump stations and forcemains.

Figure 3-1shows the locations of the above referenced basins and facilities.

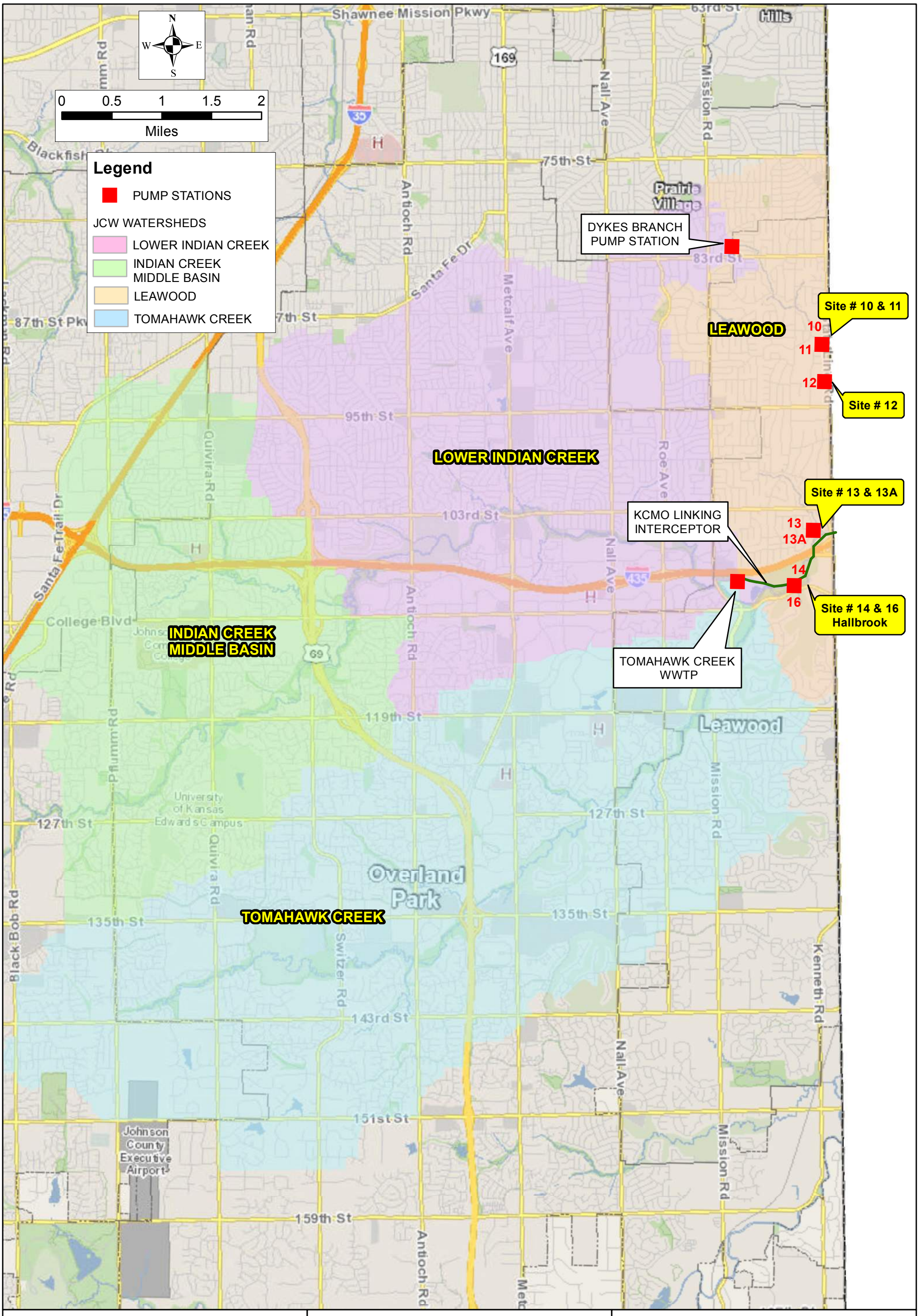

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Figure 3-1
Tomahawk and Leawood Service Area

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3.3 EXISTING DRY WEATHER FLOWS

An analysis of historical flow and rainfall data was completed in order to develop an estimate of the current Average Daily Flow (ADF) at the THC WWTF. Historical JCW flow data from 2009 and later was used as the basis of this analysis. This time period was chosen to account for previous improvement projects completed by JCW, which resulted in reduced flows to THC. In 2008, flow from the Blue River 8 Pump Station was re-routed, removing this flow from the THC service area. Improvements at the DLSMB WWTF were completed in 2009, eliminating the bypassing of peak flows during wet weather from DLSMB to THC.

Daily flow data provided by JCW was analyzed. This consisted of the following:

- Influent flows recorded at THC through the Influent Magnetic Flow Meter.
- By-pass flow to KCMO recorded at the flume located in the Diversion Structure.

Note that each of these flow measurements included an average of 1 mgd of sludge recirculation flow (the sludge flow is returned to the KCMO flow upstream of the flume). Therefore, 1 mgd was subtracted from the total daily flows to account for the "double counting" of the sludge flow.

Figure 3-2 presents the daily flow rates for each of the above flow components, as well as the total daily flows, from 2009 – 2013.

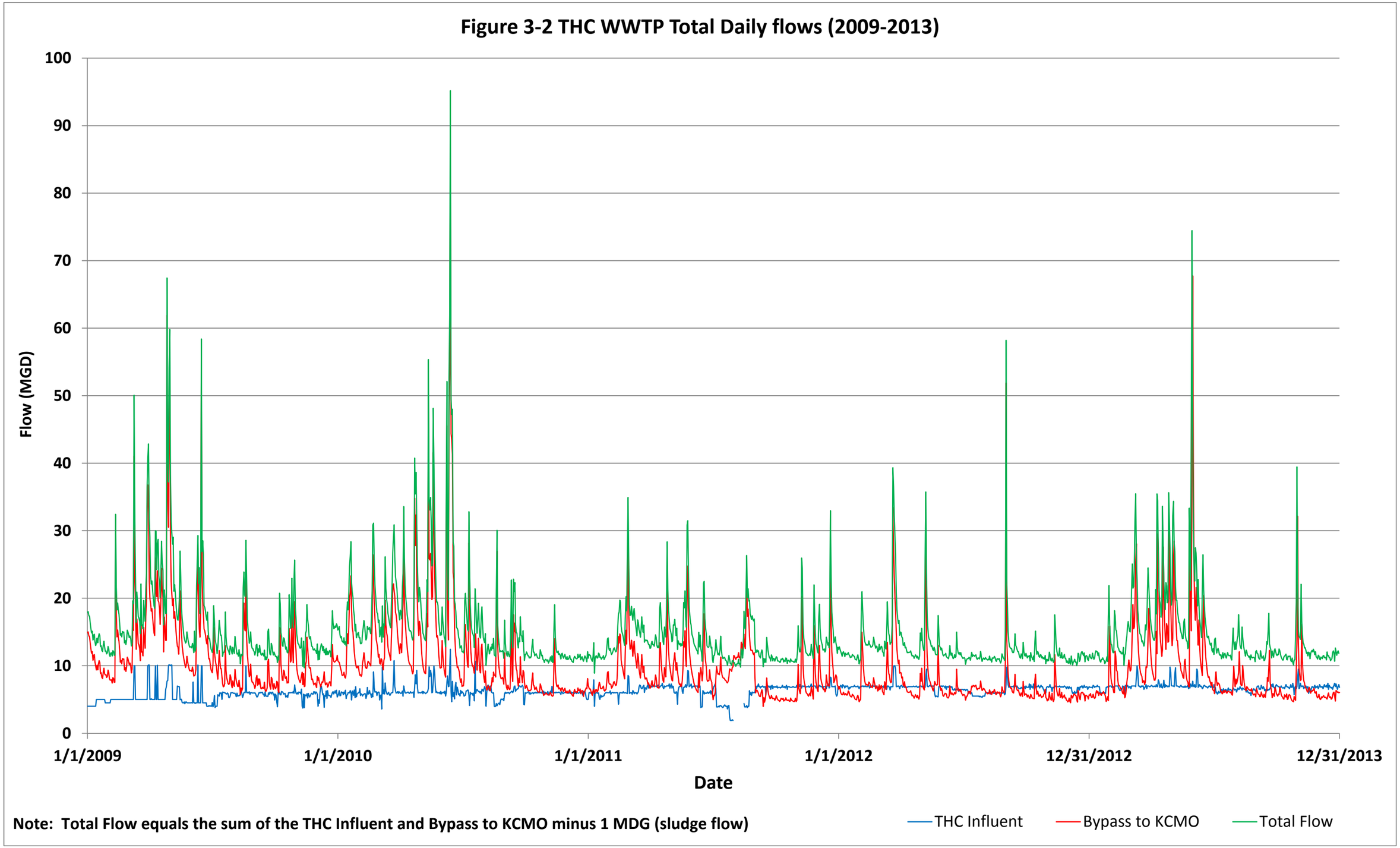
Figure 3-2 THC WWTP Total Daily flows (2009-2013)
Flow (MGD)
100
90
80
70
60
50
40
30
20
10
0
1/1/2009
1/1/2010
1/1/2011
1/1/2012
12/31/2012
12/31/2013
Date
Note: Total Flow equals the sum of the THC Influent and Bypass to KCMO minus 1 MDG (sludge flow)
THC Influent
Bypass to KCMO
Total Flow

During the review, it was noted that the ADF to THC was correlated closely to annual rainfall volumes. Therefore annual flows were analyzed in comparison to rainfall volumes, in order to determine the projected ADF to THC during a year with the average annual rainfall volume of 38.86 inches. Rainfall volumes can vary significantly over a service area as large as the THC service area. Annual rainfall totals were provided by CH2M HILL. These annual rainfall volumes represent the non-weighted average of 17 STORMWatch rain gauges located throughout the THC service area. These were provided to HDR in the Draft TM Tomahawk WWTF Service Area Prioritized Improvements – WWTF Flow Reference Material (dated January 29, 2015).

Table 3-1 presents a comparison of annual ADF and rainfalls to THC from 2009 to 2013.

Table 3-1: THC WWTF Annual Flow and Rainfall (2009 – 2013)

YEAR	ANNUAL RAINFALL TOTALS (IN)[1]	AVERAGE DAILY FLOW TO THC (MGD)[2]
2009	47.2	16.6
2010	47.0	17.1
2011	34.9	14.1
2012	26.7	12.7
2013	36.8	15.1
Average	38.5	15.1

Notes:
[1] Annual rainfall totals, provided by CH2M HILL, are the non-weighted averages of 17 STORMWatch Rain Gauges.
[2] Daily flow data recorded at flume to KCMO, plus the WWTF influent flow meter, minus the "double counted" recirculation flow.

Figure 3-3 presents the rainfall versus flow relationship and the ADF projection at the average annual rainfall of 38.86 inches.

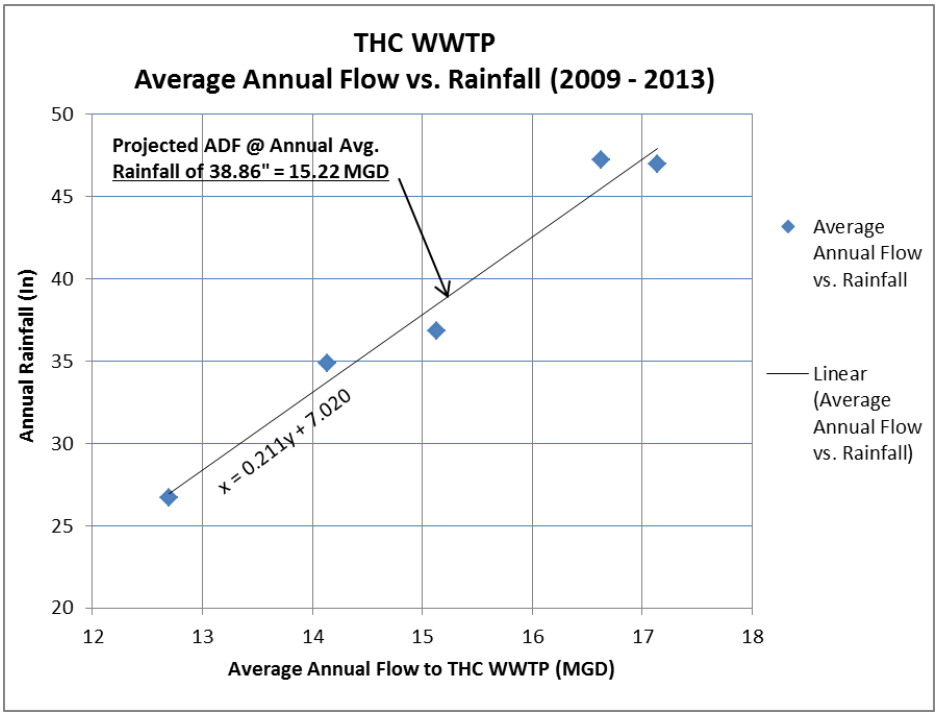

Figure 3-3: THC WWTF Average Annual Flow vs. Rainfall (2009 –2013)

The projected ADF at the average annual rainfall volume is 15.22 mgd. Note that this projection is based off a sample size of 5 years, and should be revisited before final design if recent flow data indicates an adjustment may be warranted.

The ADF figure of 15.22 mgd is comprised of wastewater production, infiltration, and inflow. The 2012 ADF of 12.7 mgd was recorded during a drought year, and thus represents a good estimate of the flow to THC during a dry weather, low groundwater year. The difference between this value and the projected ADF at average annual rainfall of 15.22 mgd is 2.52 mgd. This difference is attributed primarily to I/I in years wetter than 2012.

The diurnal peaking factor was also evaluated. Figure 3-4 shows instantaneous flow data for a selected dry weather period from August 2013. From this figure, the diurnal peaking factor was determined to be 1.4.

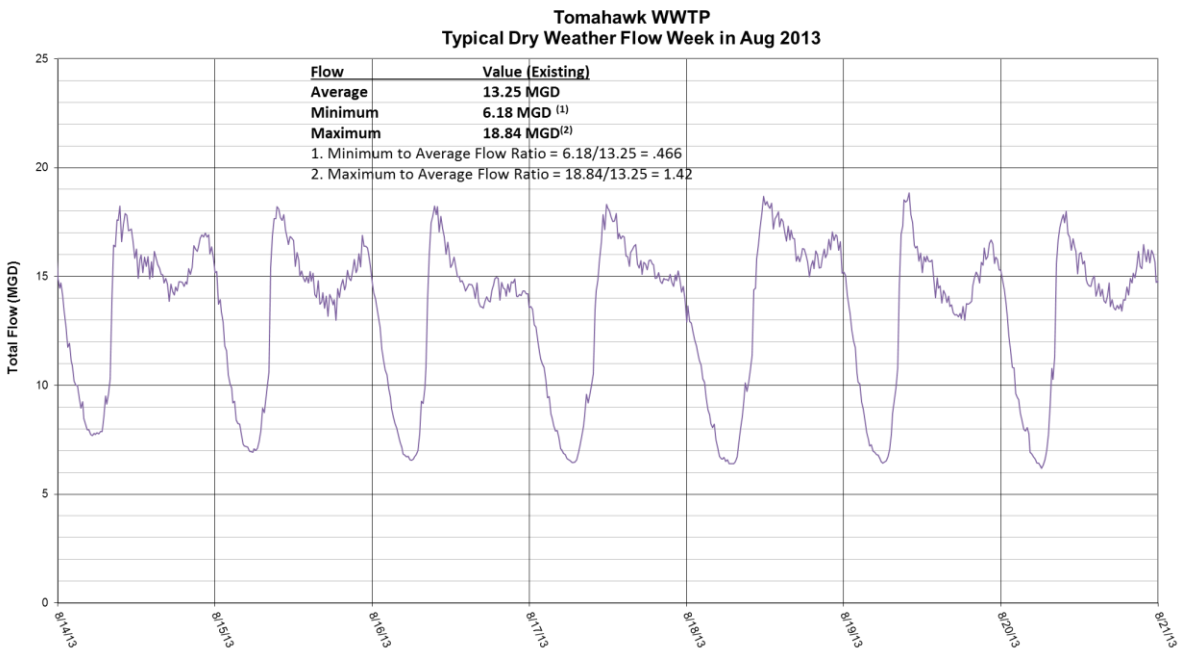

Figure 3-4: THC WWTF Typical Dry Weather Flow Pattern

Maximum Month Average Daily Flow (MMADF) and Peak Day Flow (PDF) were also evaluated for the Years 2009 – 2013. The MMADF was evaluated based on a running 30-day average, versus a calendar month basis. The MMADF: ADF ratio was then calculated. Table 3-2 presents the results of this evaluation.

Table 3-2: THC WWTF Maximum Month Average Day and Peak Day Flows (2009 –2013)

YEAR	ADF (MGD)	MMADF (MGD)	MMADF:ADF RATIO (MGD)	PDF (MGD)
2009	16.6	29.4	1.8	67.4
2010	17.1	30.3	1.8	95.2
2011	14.1	18.1	1.3	34.9
2012	12.7	18.0	1.4	58.2
2013	15.1	24.5	1.6	74.5
Average	15.1	24.1	1.6	66.0
Design-Basis	**15.22[1]**	**24.4[2]**	**1.6**	**95.2**

Notes:
[1] Based on average annual rainfall of 38.86 inches.
[2] Based on average ratio of MMADF: ADF of 1.6.

The 5-year average MMADF: ADF ratio was deemed appropriate for use in projecting MMADF for the average annual rainfall year. Note that as shown in Table 3-1, the 5-year average rainfall during this period was close to the average annual volume. The higher ratios in 2009 and 2010 were during wetter than average years, and the lower ratios in 2011 and 2012 were in drier than average years.

It should be noted that the above values are referring to hydraulic averages and peaks, and are not be confused with mass loading averages and peaks.

3.4 EXISTING WET WEATHER FLOWS

JCW's consultant for the tributary area collection system, CH2M HILL, developed and calibrated a hydraulic model of the THC WWTF service area collection system. This hydraulic model was used to predict peak wet weather flows to the THC WWTF. CH2M HILL documented the comprehensive results of the collection system modeling in the THC Service Area Draft Existing Conditions Analysis TM, completed in December of 2014. Modeling of specific design scenarios was also completed, in order to prepare a range of potential peak flows for evaluation by the B&V/HDR design team. The results of the scenarios modeled to date are documented in the following TMs:

- THC Service Area Prioritized Improvements – WWTF Flow Scenarios TM, completed in January of 2015 by CH2MHill.
- Tomahawk WWTP Service Area – Storage Analysis, completed in May of 2015 by CH2M Hill.

Existing conditions peak flow hydrographs were developed to predict peak flows to the THC WWTF. It was noted during the modeling effort that flow restrictions within the THC service area collection system, at the diversion structure to THC, and at the 72-inch Linking Interceptor to KCMO cause surcharging, which restricts the conveyance of flow downstream, thus reducing the peak modeled flows to the plant. Therefore, two types of hydrographs were developed to predict existing peak wet weather flows, as summarized below:

- Existing Conditions Model Hydrographs – these represent the existing system response to wet weather events, including surcharging from flow restrictions.
- Flow Analysis (Free Flow) Hydrographs – these represent the flows that would be generated in the sanitary system for an open sewer system with all flow restrictions removed.

Hydrographs were first developed to predict current peak wet weather flows. These hydrographs are presented in Figure 3-5, Figure 3-6, and Figure 3-7 for the 1-year, 5-year, and 10 year return interval, 24-hour design storms, respectively.

The existing conditions hydrographs were compared to metered peak flows at the plant as a verification check of the predicted modeled flows. It was noted that the peak flows predicted by the model generally matched up well with metered flows during storm events with wet antecedent conditions.

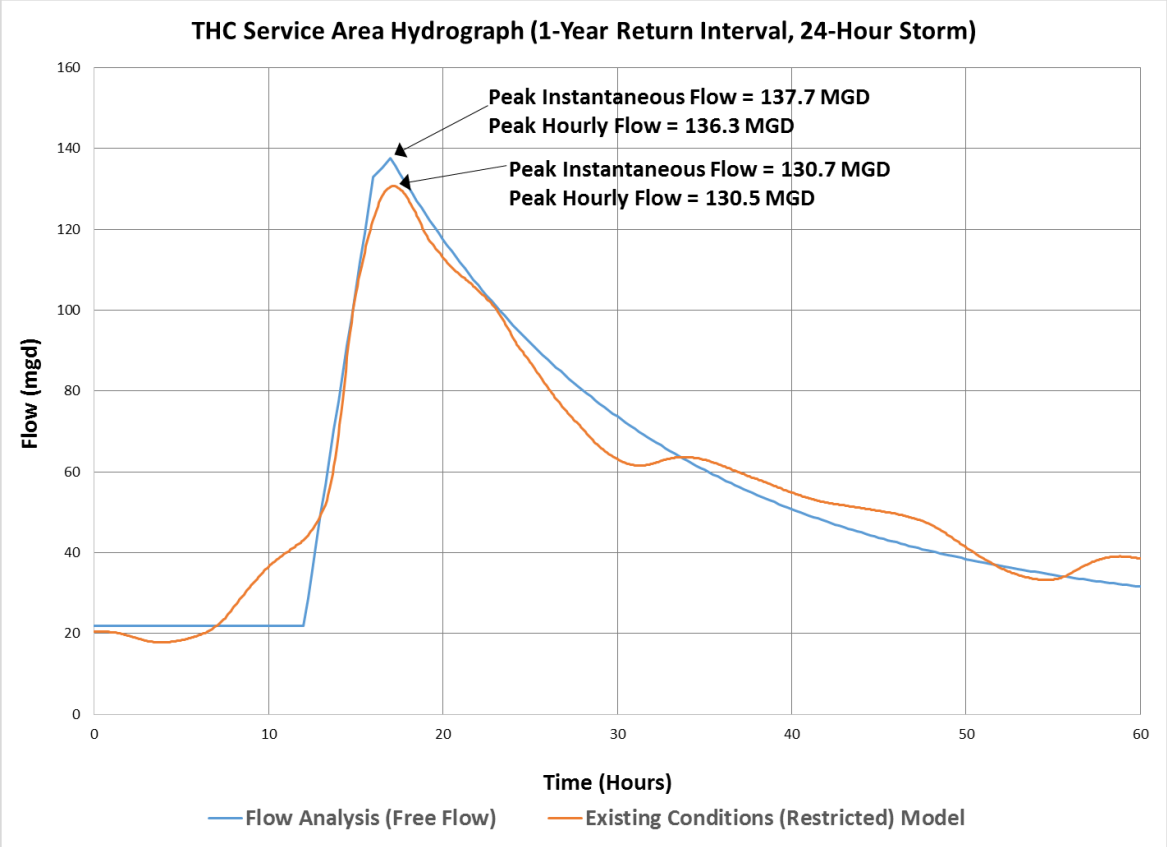

Figure 3-5: THC Service Area Hydrograph (1-Year Return Interval, 24-Hour Storm)

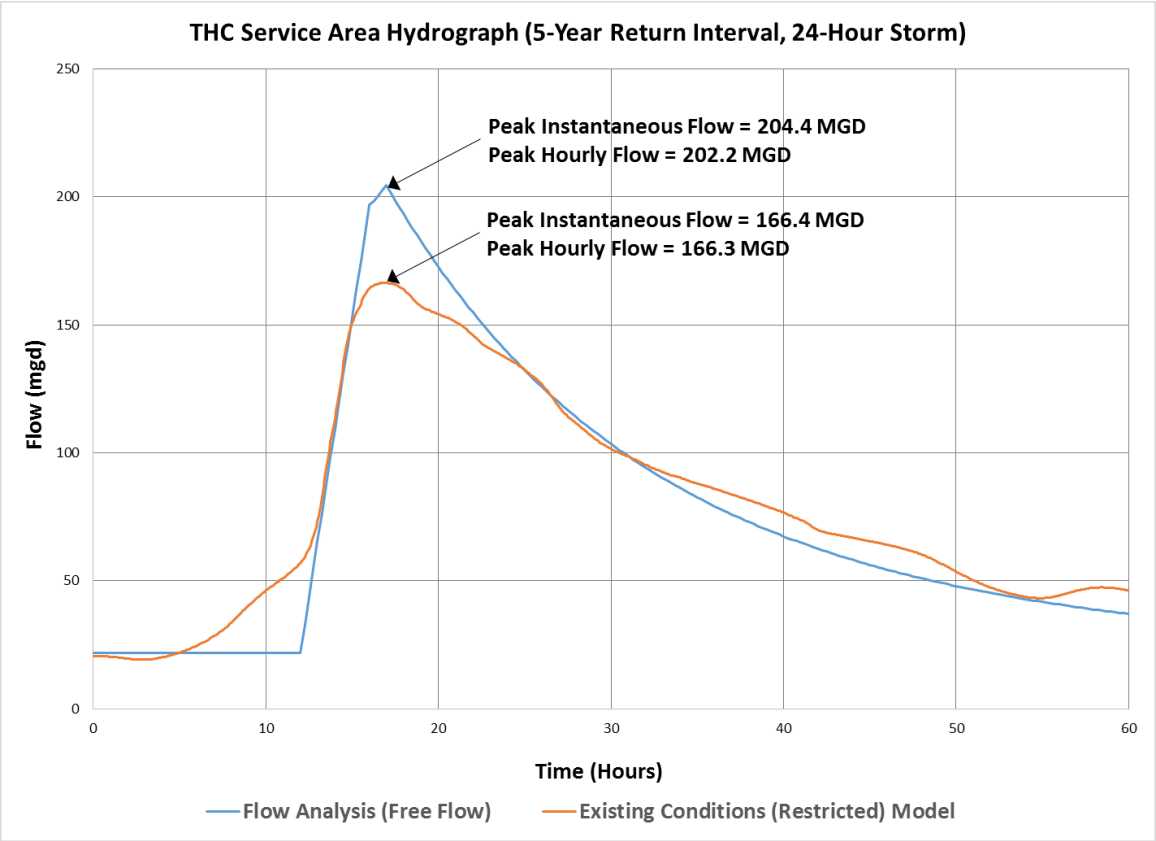

Figure 3-6: THC Service Area Hydrograph (5-Year Return Interval, 24-Hour Storm)

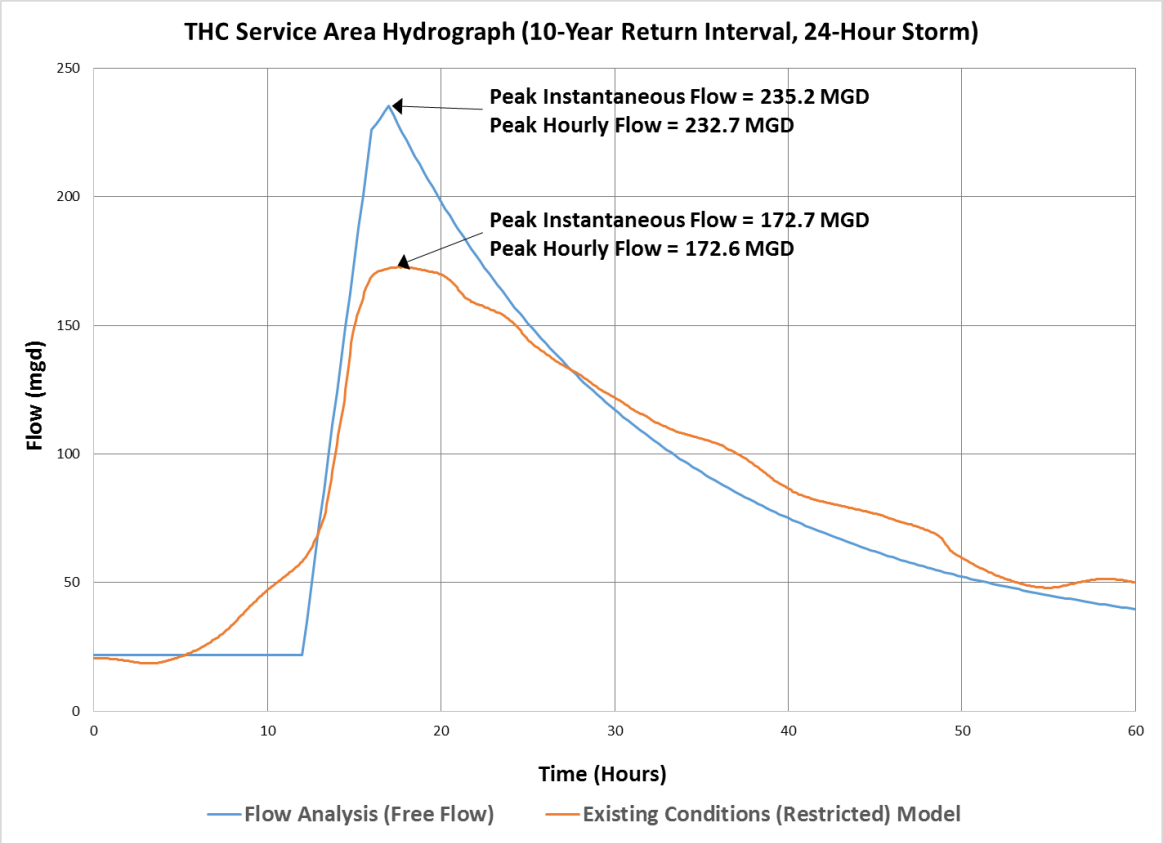

Figure 3-7: THC Service Area Hydrograph (10-Year Return Interval, 24-Hour Storm)

3.5 FUTURE DRY WEATHER FLOWS

A prior analysis of the watershed (Draft THC Existing Conditions Analysis TM, CH2M HILL, 2014) determined that 4.57% of the watershed is undeveloped. Existing flows were adjusted by this factor to arrive at the future flow projections from the Tomahawk Creek and Lower Indian Creek basins. The results are presented in Table 3-3.

Table 3-3: THC and LIC Basins Future Dry Weather Flow Projection Summary

FLOW COMPONENT	ADF (MGD)	MMADF (MGD)
THC & LIC Basins		
Existing	15.22[1]	24.35[1]
Future	0.7[2]	1.11[2]
Total	**15.92**	**25.46**

Notes:
[1] Based on Average Annual Rainfall of 38.86 inches.
[2] Includes 4.57% growth based on Draft THC Service Area Existing Conditions Analysis TM (CH2M HILL, 2014).

3.6 FUTURE WET WEATHER FLOWS

JCW plans to complete cost effective I/I removal efforts throughout the THC WWTF service area. Based on the results of the cost effective analysis, the cost effective I/I removal point in the THC WWTF service area is anticipated to be 23.2%. JCW also plans to construct relief sewers within the service area to carry the collection system's design 10-year storm event to meet JCW's level of service. This would eliminate the flow restrictions within the system discussed in Section 3.4.

CH2MHill completed hydraulic modeling of these future conditions, including the future growth within the watershed noted above. Hydrographs were developed to predict future peak wet weather flows to THC WWTF after construction of relief sewers and cost effective I/I removal efforts are completed. These hydrographs are presented in Figure 3-8, Figure 3-9, and Figure 3-10 for the 1-year, 5-year, and 10 year return interval, 24-hour design storms, respectively.

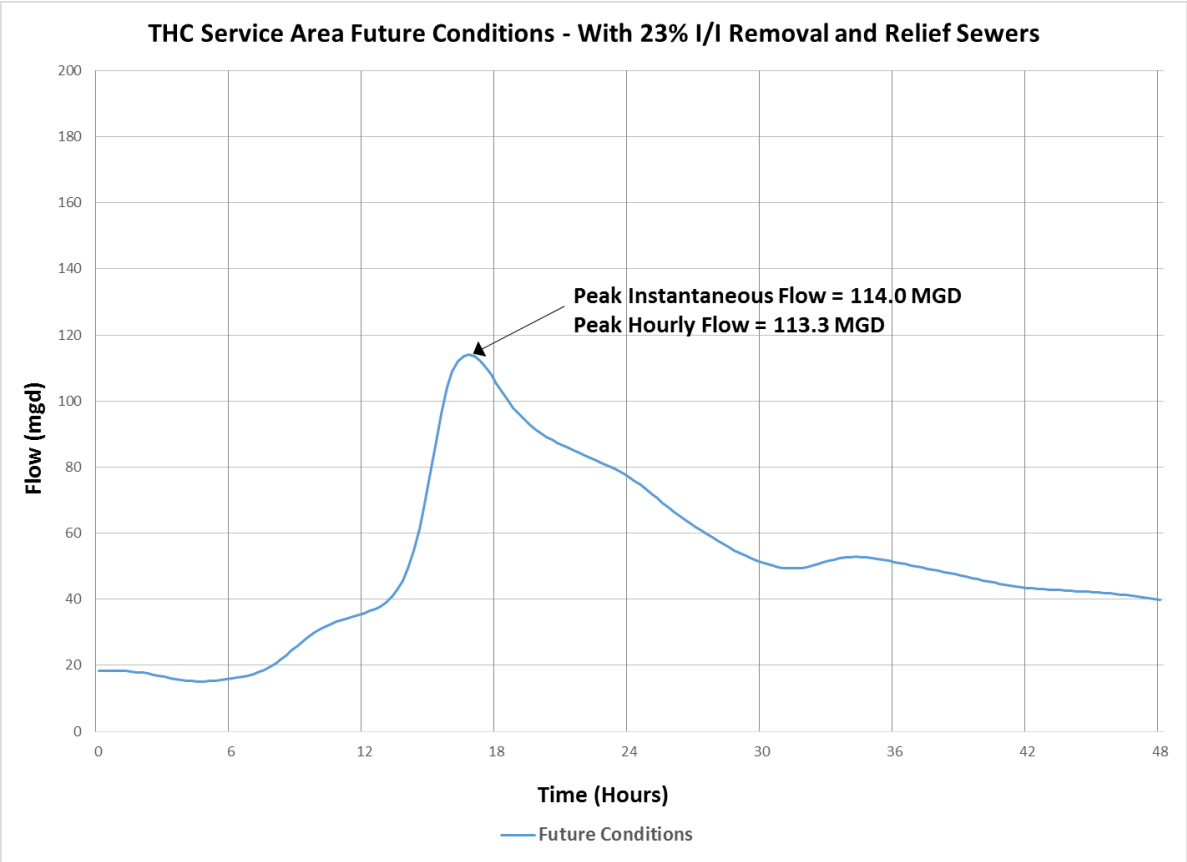

Figure 3-8: THC WWTF Service Area Future Conditions Hydrograph (1-Year Return Interval, 24-Hour Storm)

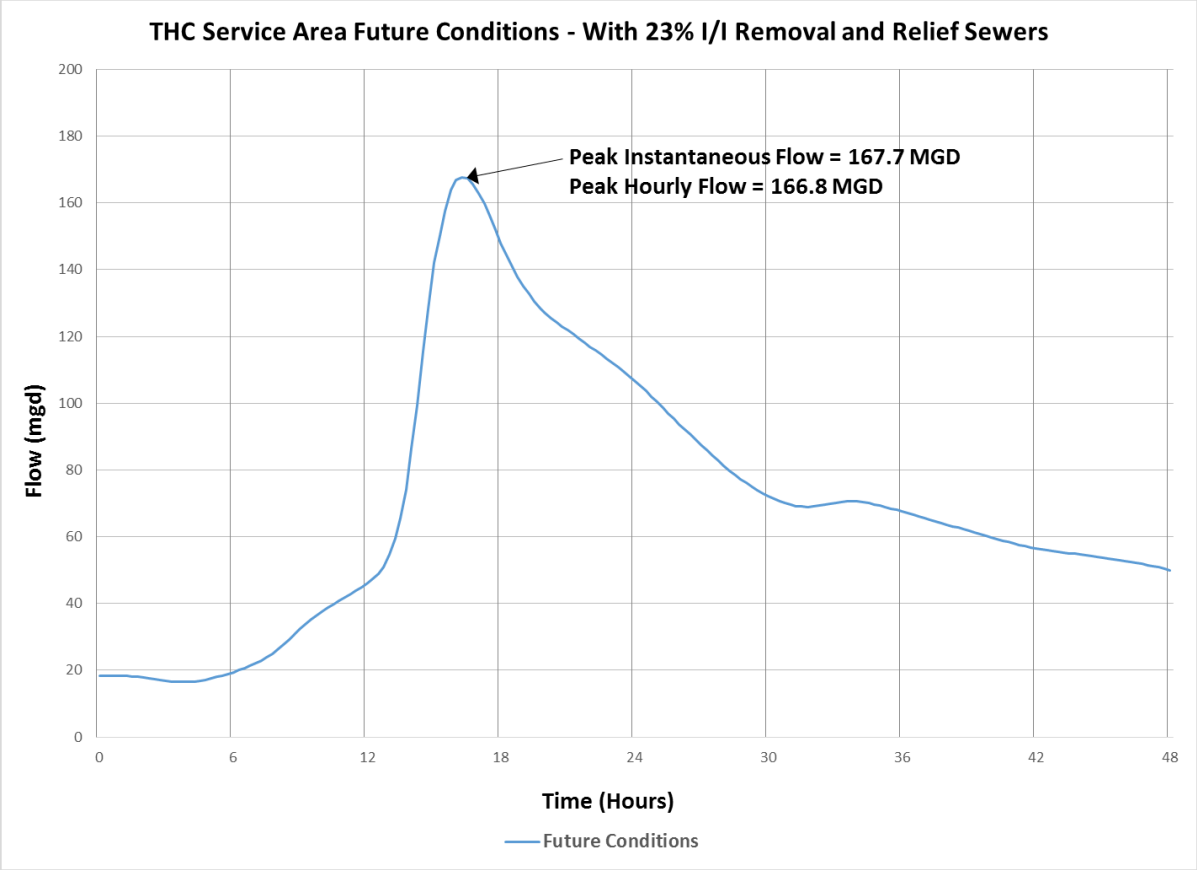

Figure 3-9: THC WWTF Service Area Future Conditions Hydrograph (5-Year Return Interval, 24-Hour Storm)

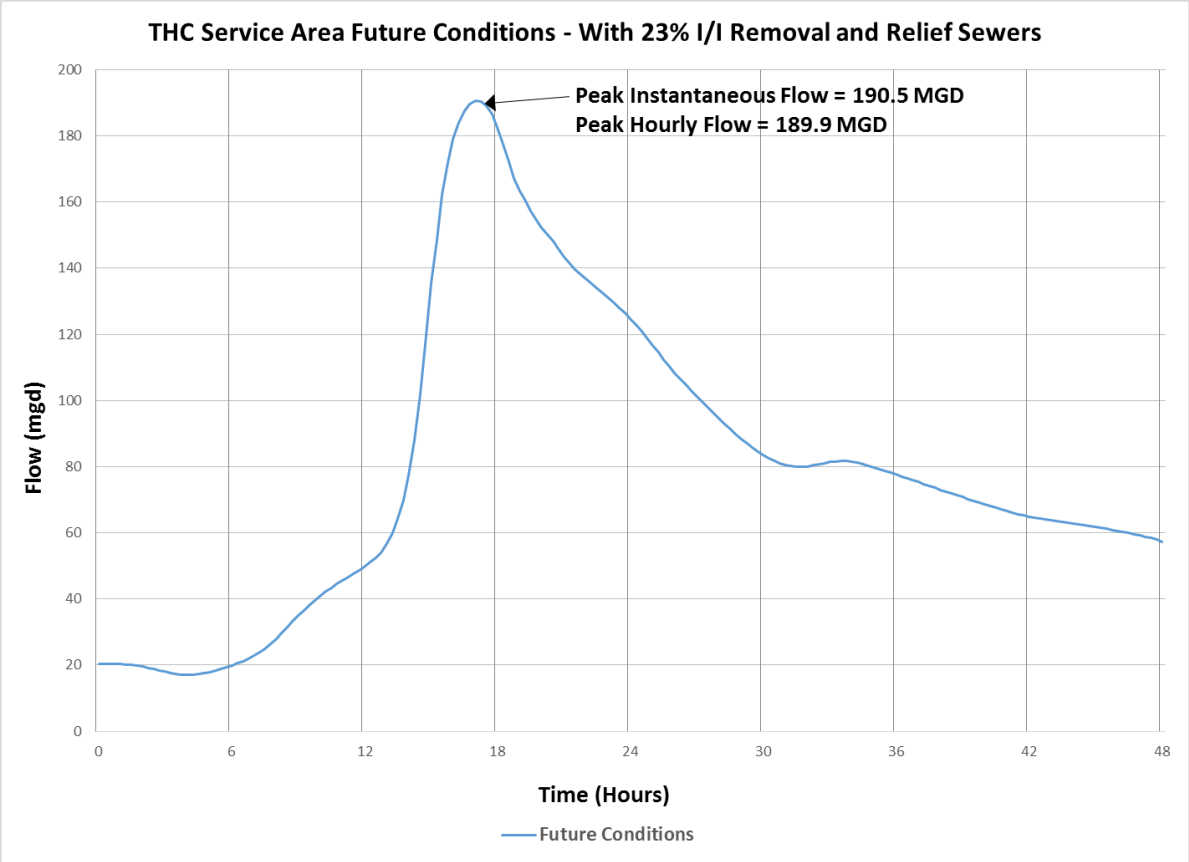

Figure 3-10: THC WWTF Service Area Future Conditions Hydrograph (10-Year Return Interval, 24-Hour Storm)

The flows presented in the hydrographs in this section are summarized below in Table 3-4.

Table 3-4: THC Service Area Peak Wet Weather Flow Summary

	FUTURE CONDITIONS – WITH 23% I/I REMOVAL & RELIEF SEWERS	
Return Interval	**Peak Hour Flow (MGD)**	**Peak Instantaneous Flow (MGD)**
1-Year Storm	113.3	114.0
5-Year Storm	166.8	167.7
10-Year Storm	189.9	190.5

3.7 FUTURE FLOW DIVERSIONS FROM KCMO BACK TO THC

Cost effective analyses (CEA's) were conducted with respect to diverting flows from outside the basin to THC WWTF for treatment. The analyses fell into two primary areas:

1. Flows from the Leawood Basin that currently are conveyed to KCMO by gravity - the cost of diverting and treating these flows at THC WWTF was compared to continuing with treatment by KCMO.

2. Dry weather flows that are currently pumped to THC by the Dykes Branch Pump Station through a dry weather forcemain that is nearing the end of its useful life. Alternatives for continued management of these flows include:

    a. Rehabilitate the dry weather forcemain and continue pumping to THC;

    b. Abandon the forcemain and divert the flows by gravity through the existing interceptor to KCMO;

    c. Abandon the forcemain and combine the flows with Leawood flows for subsequent pumping to THC.

3.8 LEAWOOD FLOW DIVERSION EVALUATION

Figure 3-11 on the following page shows the six Leawood IMF sites, and the preliminary pump station locations and forcemain routing that would be required to convey flows from these sites to the THC WWTF. Figure 3-12 through Figure 3-15 present maps of each preliminary pump station location at the IMF sites. It should be noted that Sites 10 and 11 are in close proximity and can thus be considered one site for the purposes of this evaluation. The same is true of Sites 13 and 13A.

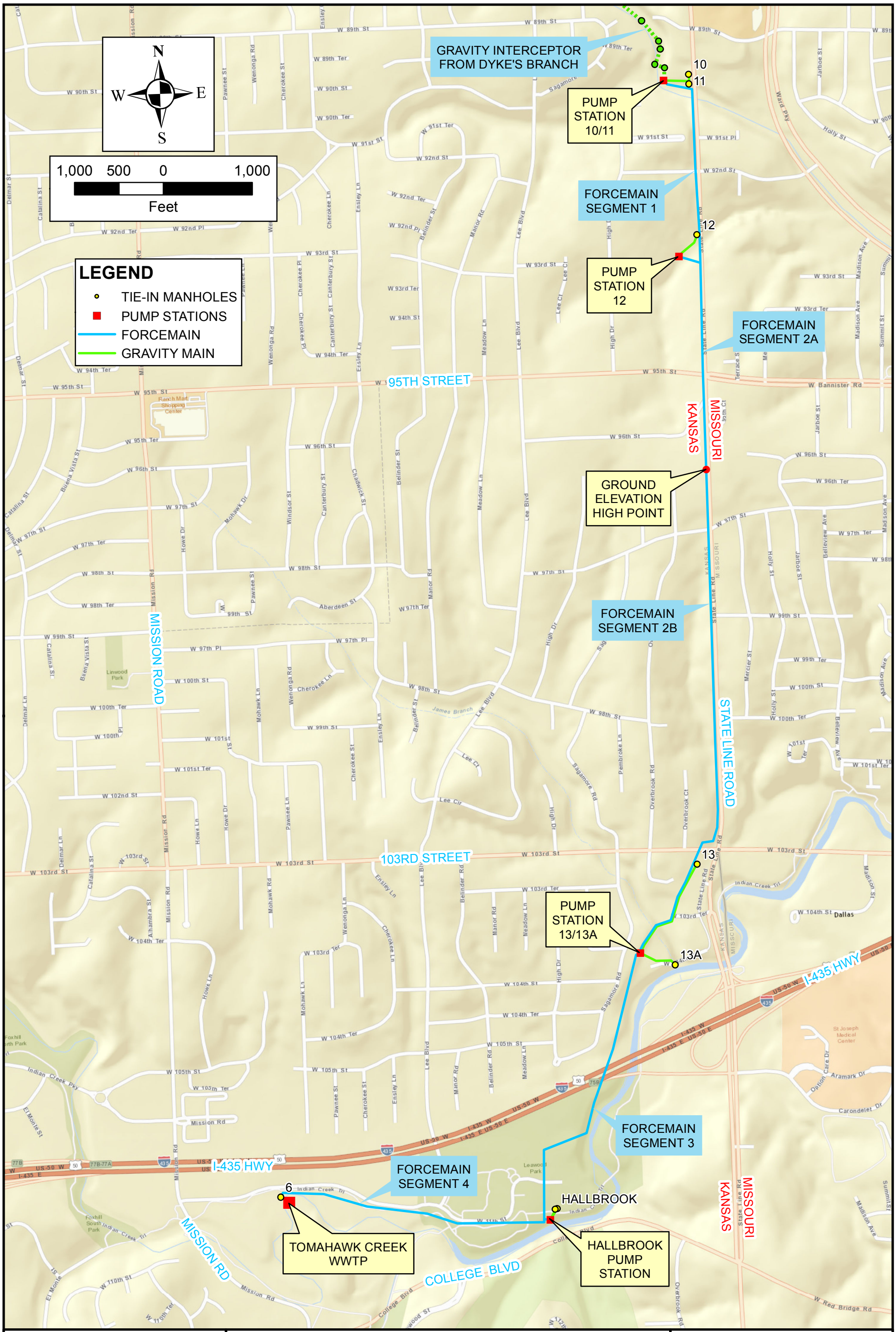

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FIGURE 3-11
LEAWOOD IMF SITES, PRELIMINARY PUMP STATION LOCATION AND FORCEMAIN ROUTING

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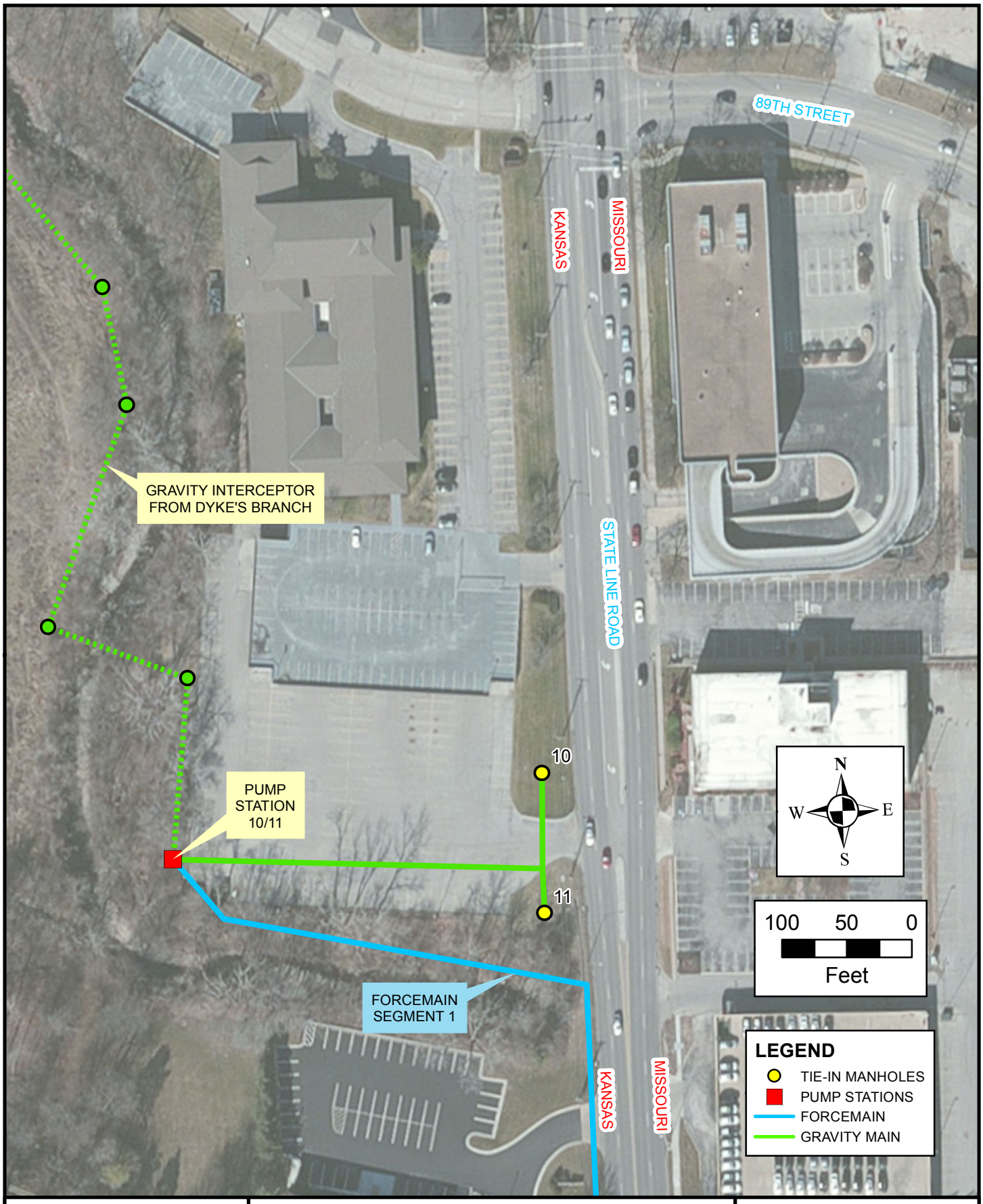

JOHNSON COUNTY KANSAS Wastewater

FIGURE 3-12
PUMP STATION SITE AT IMF 10 AND IMF 11

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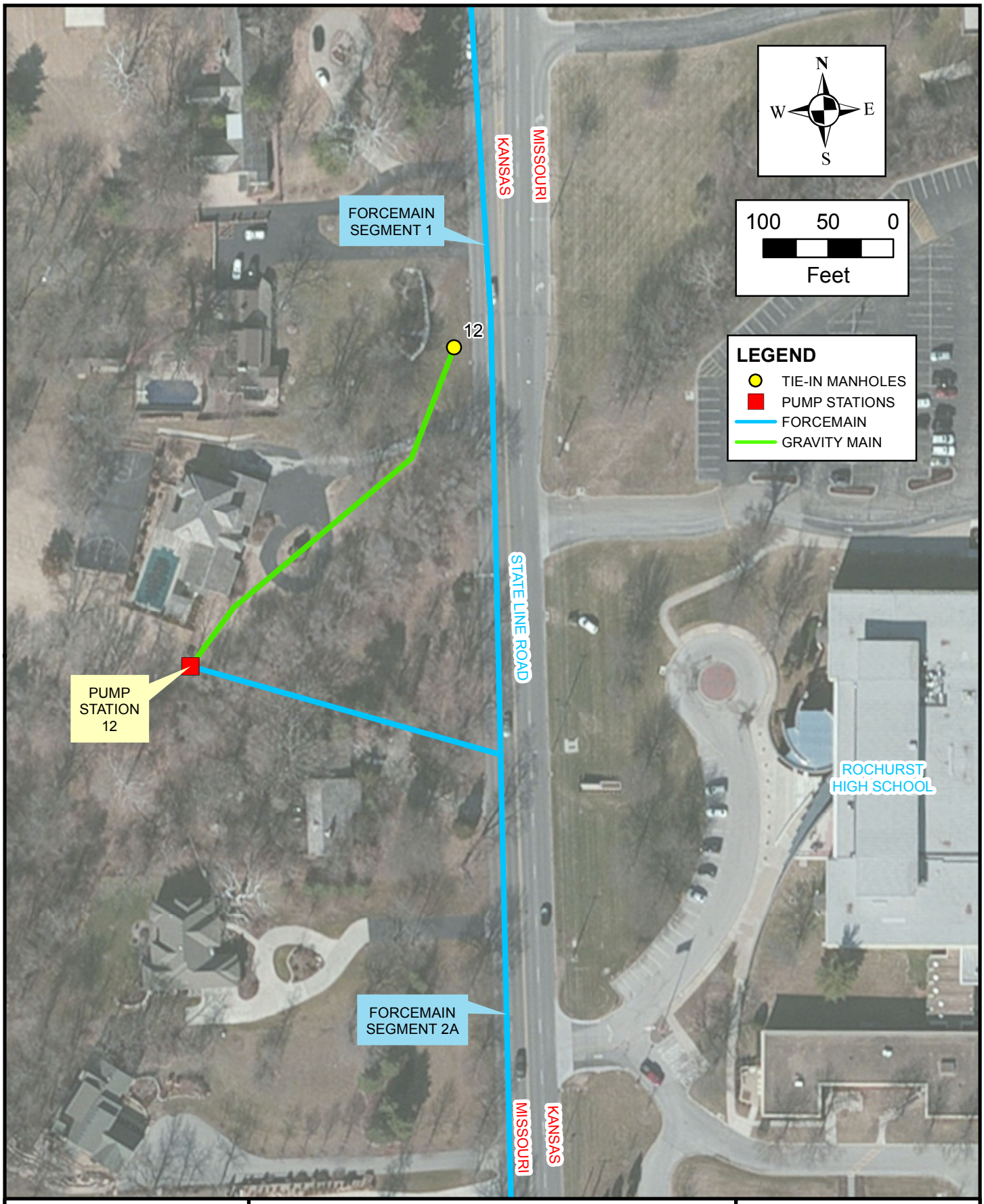

JOHNSON COUNTY KANSAS Wastewater

FIGURE 3-13
PUMP STATION SITE AT IMF 12

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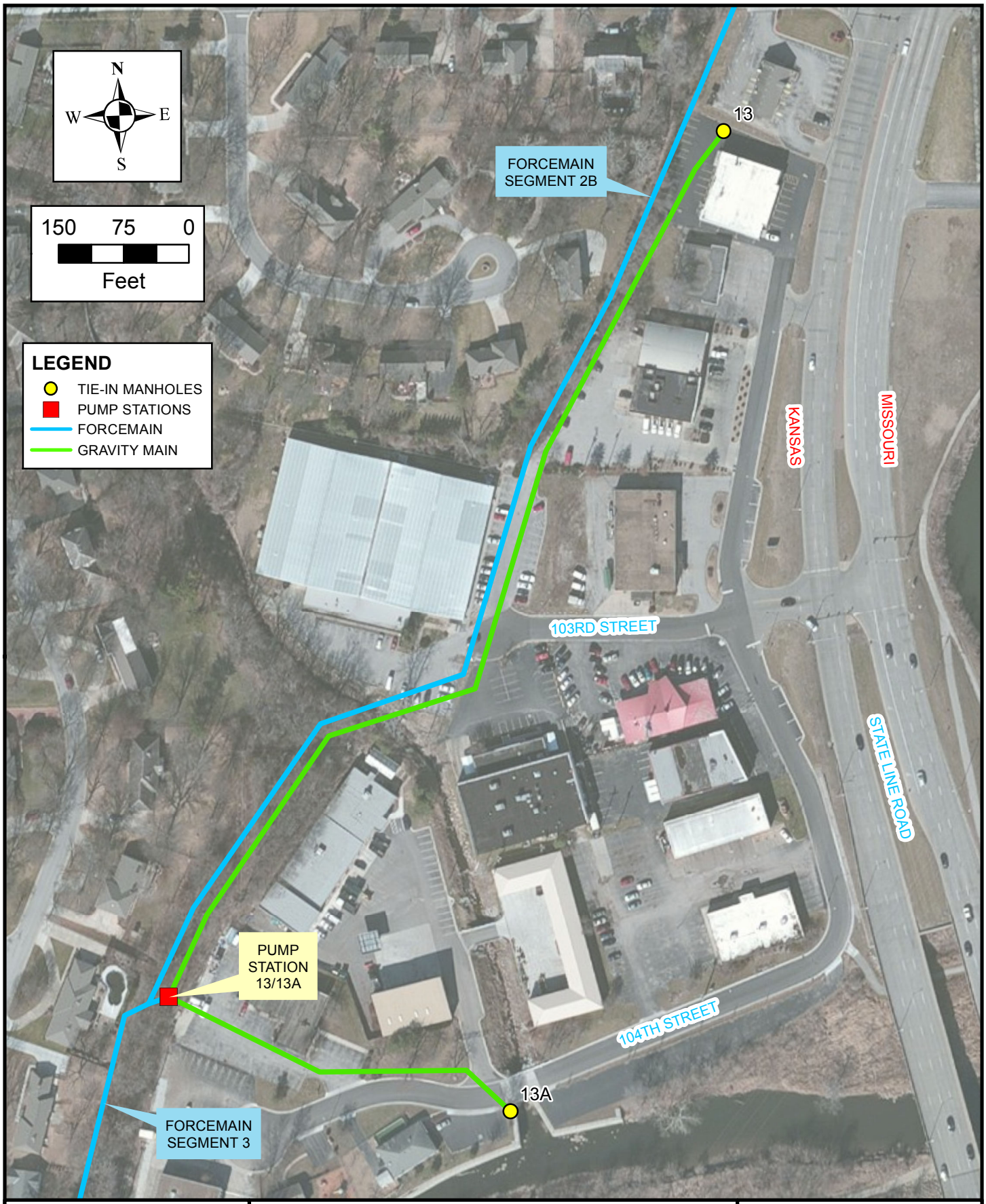

JOHNSON COUNTY KANSAS Wastewater

FIGURE 3-14
PUMP STATION AT IMF 13 AND IMF 13A

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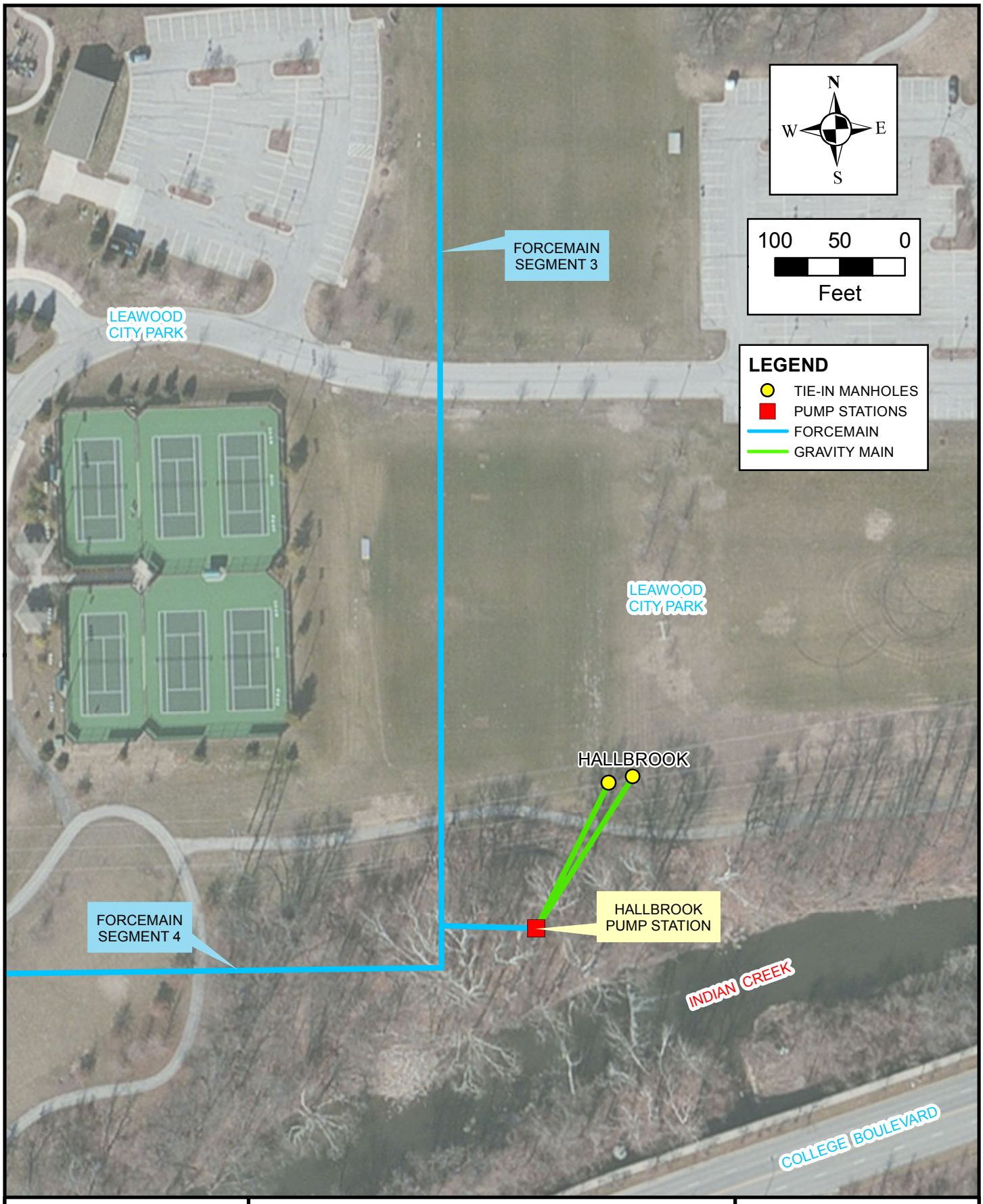

JOHNSON COUNTY KANSAS Wastewater

FIGURE 3-15
PUMP STATION SITE AT HALLBROOK IMF

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Each of the IMF sites experiences significant levels of I/I. JCW will continue to pursue cost effective I/I removal. However, to avoid the high costs and site impacts of large wet weather pumping facilities, it may be preferable to size the facilities for dry weather diurnal flows, and to allow the peak wet weather flows to continue by gravity to KCMO for treatment. Therefore each of the sites was evaluated based on diverting two times the annual ADF (2Q) to THC WWTF for treatment. The ADF values, with the exception of Hallbrook, were provided by CH2M HILL based on hydraulic modeling of the Leawood Watershed. These values are summarized below in Table 3-5.

Table 3-5: ADF Values for Leawood IMF Sites

IMF SITE ID	ADF (MGD)	PUMP STATION CAPACITY (MGD)
10	0.07	2.88 (PS 10/11)
11	1.37	
12	0.16	0.32
13	0.36	1.96 (PS 13/13A)
13A	0.62	
Hallbrook[1]	0.07	0.14

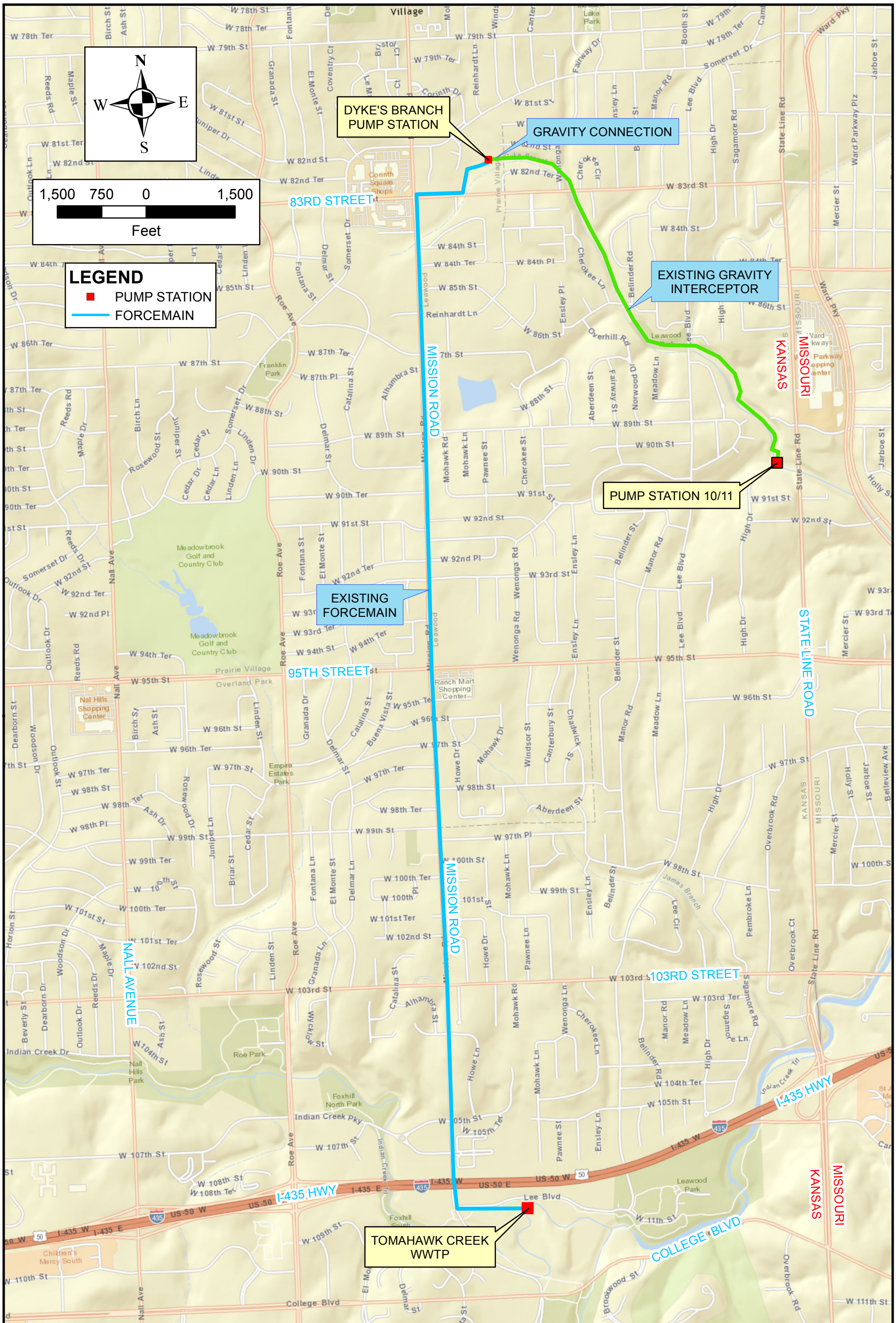
Notes:
[1] Hallbrook IMF is not metered. Flows were calculated based on 241 connections at 300 gpd/connection.

Six possible combinations of IMF's were evaluated, from 13/13A only with a single pump station, to all six served by four total pump stations. This was initially completed without considering the impact of combining these flows with diverted dry weather flows from Dyke's Branch Pump Station. Facility sizing and conceptual cost estimates, both capital and annual O&M, are included in Appendix A.

3.8.1 DYKE'S BRANCH FLOW DIVERSION EVALUATION

Figure 3-16 on the following page shows the routing of the existing Dyke's Branch Dry Weather Forcemain, which currently diverts flow from the Dyke's Branch Basin to THC. The Dry Weather Forcemain is nearing the end of its serviceable life and must be rehabilitated if it is to continue in service. An alternative would be to divert the dry weather flow, which averages 0.8 mgd, to KCMO for treatment. A third alternative would be to convey the flow by gravity to Leawood Pump Station 10/11 and provide additional capacity in that pump station. Facility sizing and conceptual cost estimates, both capital and annual O&M, are included in Appendix B.

It should be noted that a parallel forcemain conveys wet weather flow from Dyke's Branch to THC (the wet weather forcemain is believed by JCW to have significantly more useful life remaining than the dry weather forcemain).



JOHNSON COUNTY KANSAS Wastewater

FIGURE 3-16
DYKE'S BRANCH PUMP STATION AND FORCEMAIN ROUTING

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3.8.2 COST EFFECTIVE ANALYSIS (CEA)

As previously noted, the Leawood alternatives were first evaluated without considering the impact of combining the dry weather flow from Dyke's Branch. Once the optimum Leawood plan was identified, the impact of upsizing to accommodate Dyke's Branch dry weather flow was compared to the other two Dyke's Branch alternatives.

A 20-year life cycle cost analysis was performed for the six Leawood alternatives. In order to account for the KCMO cost of treatment, it was necessary to estimate the annual flow volume to KCMO. Since only dry weather flows would be diverted to THC, the remaining wet weather flow would continue to KCMO. Since the wet weather flows would continue to be treated by KCMO under all alternatives, this component can be omitted from the comparative analysis. It was determined by CH2M Hill (reference "Tomahawk Service Area Prioritized Improvements – WWTP Flow Reference Materials", 1/29/15) and confirmed by B&V/HDR through review of historical flow data, that about 95 - 96% of the annual flow falls within the 2Q range. To be conservative, this analysis assumed that 90% of the annual flow will be diverted to THC, with 10% continuing to KCMO for treatment.

To provide a sensitivity analysis of the impact of future KCMO rate increases on the CEA, four rate increase scenarios were evaluated:

1. Full KCMO Overflow Control Program (OCP) Rates/Inflation Post OCP - this scenario used the schedule of annual revenue increases provided to JCW by KCMO through 2021, with increases matching the rate of inflation of 1.9% per year thereafter.

2. Full OCP Rates/National Association of Clean Water Agencies (NACWA) Average Post OCP – this is the same as Scenario 1, but the historical annual average rate increase for wastewater utilities (from Years 2001 through 2011, determined during the THC Pre-Design Study) of 2.8% beyond inflation was used for the Post OCP period. With the inflation rate of 1.9% used in this study, this equates to an annual rate increase of 4.7%.

3. Reduced OCP Rates/Inflation Post OCP – this is the same as Scenario 1, but the OCP rates are reduced to reflect that in 2014, the actual increase was slightly less than the revenue requirement/rate increase schedule previously provided by KCMO.

4. Reduced OCP Rates/NACWA Average Post OCP – this is the same as Scenario 3, but with the Post OCP rate increases set at 4.7% per year.

Appendix A includes the rate schedules for each of these scenarios. Appendix A also includes the 20 year Net Present Value (NPV) calculations for each of the Leawood alternatives.

A summary of the parameters used in the economic analysis is as follows**:**

- Inflation = 1.9% (Nominal Discount Rate (3.1%) – Net Discount Rate (1.2%))
- NACWA Average Annual Rate Increase = 2.8% + Inflation (1.9%) = 4.7%
- Full OCP rates are 11.9% for years 2016-2020 and 8% for year 2021
- Reduced OCP rates are 9.9% for years 2016-2020 and 8% for year 2021

Table 3-6 presents a summary of the NPV for each of the Leawood alternatives compared to the four KCMO treatment scenarios.

Table 3-6: Leawood Flow Conveyance Alternatives – Life Cycle Cost Analysis

NET PRESENT VALUE (NPV) SUMMARY OF FINANCIAL SCENARIOS						
		Treatment at THC WWTP	Treatment at KCMO			
			Full OCP Rates		Reduced OCP Rates	
Alternative	Included IMF Sites		Inflation Post OCP[1]	NACWA Average Post OCP[2]	Inflation Post OCP[3]	NACWA Average Post OCP[4]
L1	13/13A	$14,100,000	$32,300,000	$40,800,000	$29,500,000	$37,300,000
L2	13/13A & HB	$16,000,000	$34,600,000	$43,700,000	$31,600,000	$40,000,000
L3	10/11 & 13/13A	$36,200,000	$79,800,000	$100,800,000	$72,900,000	$92,100,000
L4	10/11, 13/13A, & HB	$38,200,000	$82,100,000	$103,700,000	$75,000,000	$94,800,000
L5	10/11, 12, & 13/13A	$39,400,000	$82,100,000	$103,700,000	$75,000,000	$94,800,000
L6	10/11, 12, 13/13A, & HB	$41,300,000	$84,400,000	$106,700,000	$77,100,000	$97,500,000

Note:
NPV comparison is for conveyance and treatment for flows up to 2Q for each site only. Assumes 90% of annual flow volume falls in the 2Q and remaining 10% is sent to KCMO for treatment.

KCMO Rate Increase Scenarios
[1] Full OCP rates with post-OCP increases at inflation.
[2] Full OCP rates with post-OCP increases at NACWA annual average rate increase plus inflation.
[3] Reduced OCP rates with post-OCP increases at inflation.
[4] Reduced OCP rates with post-OCP increases at NACWA annual average rate increase plus inflation.

For all alternatives under all scenarios, it is significantly more cost effective to divert the 2Q flows to THC than to continue to send them to KCMO for treatment. Note that although diversion of flow from Site 12 is cost effective, site specific conditions preclude construction of a pump station at that site without significant property owner impacts. It is therefore recommended that the THC WWTF be sized to accommodate diverted flows from Leawood IMF sites 10/11, 13/13A, and Hallbrook (Alternative L4). The following flows shown in Table 3-7 should be added to the future flows determined in Section 3.5 and 3.6.

Table 3-7: Leawood IMF Site Design Flows Diverted to THC WWTF

IMF SITE	ADF (MGD)	PEAK HOUR FLOW = PUMP STATION CAPACITY (MGD)
10/11	1.44	2.88
13/13A	0.98	1.96
Hallbrook	0.07	0.14
Total	2.49	4.98

3.8.3 DYKE'S BRANCH DRY WEATHER FLOW ANALYSIS

Alternative DB1 consists of rehabilitating the dry weather forcemain. Alternative DB2 consists of adding a small length of connecting sewer at the Dyke's Branch Pump Station, flow control provisions at that location, and upsizing of Pump Station 10/11 and the forcemain from there to the WWTF. Because Alternative DB2 requires an incremental increase to the sizing of Pump Station 10/11 and the forcemain, the costs of the two Dyke's Branch alternatives must be evaluated in conjunction with the recommended Leawood alternative, Alternative L4. Specifically, the Alternative DB1 costs and the Alternative L4 cost will be combined, and the combined total compared to DB 2 which includes Alternative L4 with an upsized Pump Station 10/11 to convey the diverted Dyke's Branch flow.

Table 3-8 presents an NPV comparison of the two Dyke's Branch improvement alternatives to sending the flow to KCMO under the four KCMO rate scenarios. The table also contains a comparison of the NPV costs for the Dyke's Branch alternatives in conjunction with Leawood Alternative L4. Sizing and conceptual cost estimates for these alternatives are presented in Appendix B.

Table 3-8: Dyke's Branch Flow Conveyance Alternatives – Life Cycle Cost Analysis

NET PRESENT VALUE (NPV) SUMMARY OF FINANCIAL SCENARIOS						
ALTERNATIVE	INCLUDED IMF SITES	TREATMENT AT THC WWTP	TREATMENT AT KCMO			
			FULL OCP RATES		Reduced OCP Rates	
			INFLATION POST OCP[1]	NACWA AVERAGE POST OCP[2]	Inflation Post OCP[3]	NACWA Average Post OCP [4]
Incremental Cost for Dyke's Branch Only						
DB1 (FM Rehab)	-	$13,300,000	$29,300,000	$37,000,000	$26,800,000	$33,800,000
DB2 (L4 with Upsized PS 10/11)[5]	-	$10,600,000	$29,300,000	$37,000,000	$26,800,000	$33,800,000
Combined Cost for Dyke's Branch and Leawood (Alternative L4)						
DB1 & L4	10/11, 13/13A, & HB	$51,500,000	$111,400,000	$140,800,000	$101,800,000	$128,600,000
DB2 (Upsized L4)[5]	10/11, 13/13A, & HB	$48,800,000	$111,400,000	$140,800,000	$101,800,000	$128,600,000

Note:
NPV comparison is for conveyance and treatment for flows up to 2Q for each site only. Assumes 90% of annual flow volume falls in the 2Q and remaining 10% is sent to KCMO for treatment.

KCMO Rate Increase Scenarios
[1] Full OCP rates with post-OCP increases at inflation
[2] Full OCP rates with post-OCP increases at NACWA annual average rate increase plus inflation
[3] Reduced OCP rates with post-OCP increases at inflation
[4] Reduced OCP rates with post-OCP increases at NACWA annual average rate increase plus inflation
[5] Includes incremental cost increase to Leawood Alternative 4 due to increased size of Pump Station 10/11 and forcemain.

For both alternatives under all scenarios, it is significantly more cost effective to continue to treat the Dyke's Branch flows at THC than to send them to KCMO for treatment. From Table 3-8, the preferred Dyke's Branch conveyance alternative is Alternative DB2, conveying the flow by gravity to Leawood Pump Station 10/11 and providing additional capacity in that pump station.

3.9 DESIGN FLOW PROJECTIONS

Design flow projections based on the following future design conditions are presented in Table 3-9:

- 4.57% future growth within the THC service area
- Cost effective I/I removal of 23.2% within the THC service
- Construction of relief sewers to carry the 10-year storm event to meet JCW's 10-year collection system level of service
- Flow diversions to THC from the Leawood IMF Sites 10, 11, 13, 13A, and Hallbrook.
- Continued treatment of all Dyke's Branch flows at THC, with dry weather flows rerouted to Pump Station 10/11 in Leawood, then pumped to THC.

Table 3-9: THC WWTF Future Flow Projection Summary

FLOW COMPONENT	ADF (MGD)	MMADF (MGD)	PDF (MGD)	PEAK HOUR FLOW (MGD)		PEAK INSTANTANEOUS FLOW (MGD)	
				5-Yr Storm	10-Yr Storm	5-Yr Storm	10-Yr Storm
THC & LIC Basins	15.9 [1]	25.5[1]	100.3 [5]	166.8 [5]	189.9 [7]	167.7 [5]	190.5 [7]
Hallbrook	0.1 [2]	0.1 [4]	0.2 [6]	0.2 [6]	0.2 [6]	0.2 [6]	0.2 [6]
IMF 10/11	1.4 [3]	2.3 [4]	2.9 [6]	2.9 [6]	2.9 [6]	2.9 [6]	2.9 [6]
IMF 13/13A	1.0 [3]	1.6 [4]	2.0 [6]	2.0 [6]	2.0 [6]	2.0 [6]	2.0 [6]
Total	**18.4**	**29.5**	**105.4**	**171.9**	**195.0**	**172.8**	**195.6**
Recommended Design ADF = <u>19 mgd</u>							

Notes:

[1] Based on Average Annual Rainfall of 38.86 inches. Includes 4.57% growth based on Draft THC Service Area Existing Conditions Analysis TM (CH2M HILL, 2014).

[2] Based on 241 connections, at 300 gpd/connection.

[3] ADF at Leawood IMF sites provided by CH2M HILL.

[4] Based on 1.6 ratio of MMADF:ADF of 1.6.

[6] 5-year return interval with 23.2% I/I removal (hydraulic modeling provided by CH2M HILL and documented in Tomahawk WWTP Service Area – Storage Analysis TM).

[6] Peak flows limited to pump station capacities of twice ADF (2Q).

[7] 10-year return interval with 23.2% I/I removal (hydraulic modeling provided by CH2M HILL and documented in Tomahawk WWTP Service Area – Storage Analysis TM).

The total ADF determined for future conditions is approximately 18.4 mgd. A safety factor was added to increase the recommended design flow for THC to 19.0 mgd. This factor accounts for future unknowns in the service area. These unknowns include potential conversion of residential/ commercial areas into high density housing developments, like the Mission Farms Development immediately north of the THC site, across Interstate 435. One of the recent trends in urban development is to design multi-story structures with commercial property occupying the ground floor and lofts or apartments in the upper stories. While future plans for similar developments in the watershed are not yet defined, a 3.2 percent safety factor for unknown growth (a 0.6 mgd annual average capacity allowance) has been built into the future flow projection to provide THC with some ability to accommodate potential future flow changes.

4 Existing and Projected Future Loads

4.1 BACKGROUND, OBJECTIVE, AND SCOPE

Daily plant influent data for the Tomahawk Creek (THC) WWTF was analyzed and was compared to the Blue River Main (BRM) WWTF to develop the basis of design for the primary and secondary process design. This section describes the analysis for the development of loads and concentration for the design basis.

4.2 EXISTING THC INFLUENT DATA REVIEW

The daily plant operating data from January 2011 through September 2014 for THC WWTF was evaluated to develop the annual average, maximum monthly average and peak day mass influent loads and concentrations. Daily flow data was used with daily pollutant concentrations to calculate the daily influent mass loads. The annual average, maximum month and peak day flow data that was developed in Section 3 was used with the corresponding annual average, maximum month and peak day pollutant loads to estimate the influent concentrations.

Table 4-1 presents the influent mass loads and concentration observed at THC. The average BOD and TSS concentration measured at the plant were lower than the typical domestic wastewater (200 mg/L BOD and 200 mg/L TSS), while the TKN concentration (47 mg/L TKN in Table 4-1 versus 40 mg/L TKN in typical domestic wastewater) was higher. Grab samples are collected at the THC influent downstream of the diversion structure. Grab samples are collected in the morning typically between 8-9 AM, which might not be representative of a daily composite sample. The influent total phosphorus was comparable to the typical concentration observed for domestic wastewater.

Table 4-1: Current Flows and Loads- Monthly Plant Operating Data (Jan 2011 through end of Sept 2014)

PARAMETER	ANNUAL AVERAGE		MM:AA	MAXIMUM MONTHLY AVERAGE		PD:AA	PEAK DAY	
Flow, mgd	13.8*			20.8			70.4	
	mg/L	ppd		mg/L	ppd		mg/L	ppd
TSS	155	17,800	1.44	148	25,700	2.84	87	50,700
BOD	154	17,800	1.37	141	24,500	2.33	71	41,400
TKN	47	5,400	1.34	42	7,220	1.58	15	8,530
Ammonia	29	3,340	1.24	24	4,160	1.73	9.9	5,790
Total Phosphorus	4.9	560	1.25	4.1	700	1.70	1.6	960

Note:
*The annual average flow for this table is derived from plant data spanning Jan 2011 – Sept 2014 instead of 2009-2013 data set used for **Figure 3-2**.

Figure 4-1 and Figure 4-2present the daily average pollutant concentration at the WWTF over the analysis period.

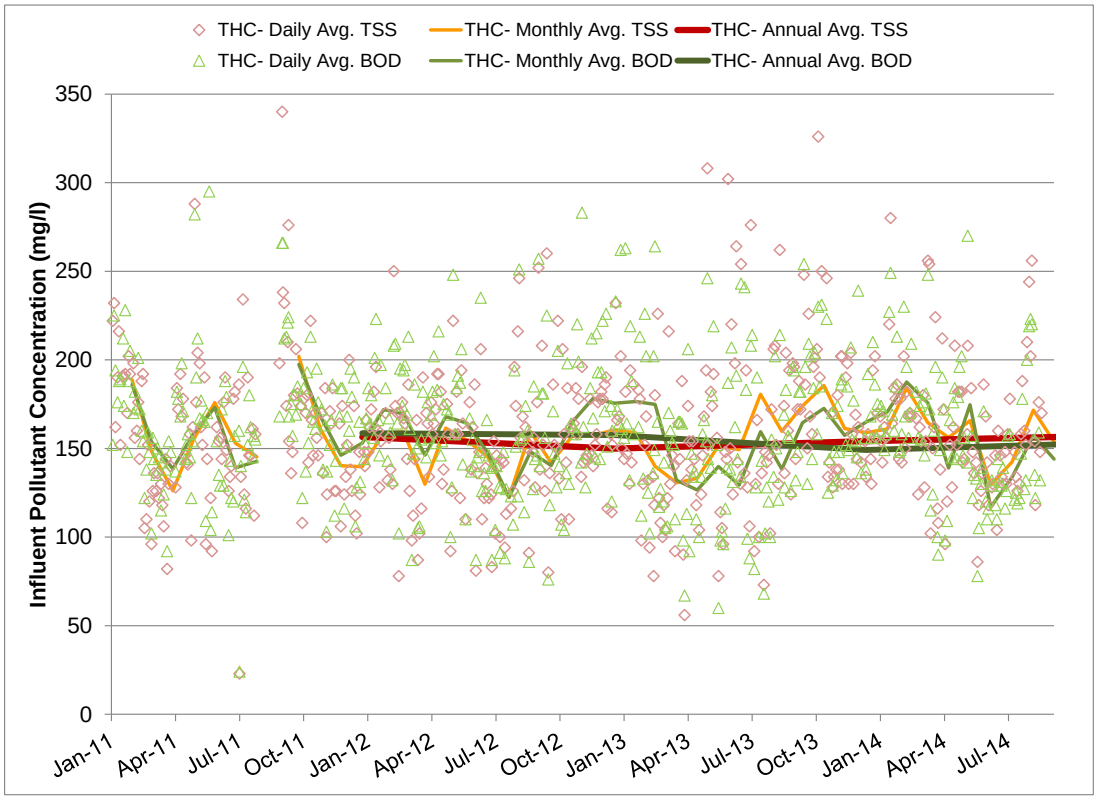


Figure 4-1: Daily Influent BOD and TSS Concentration to Tomahawk Creek WWTF

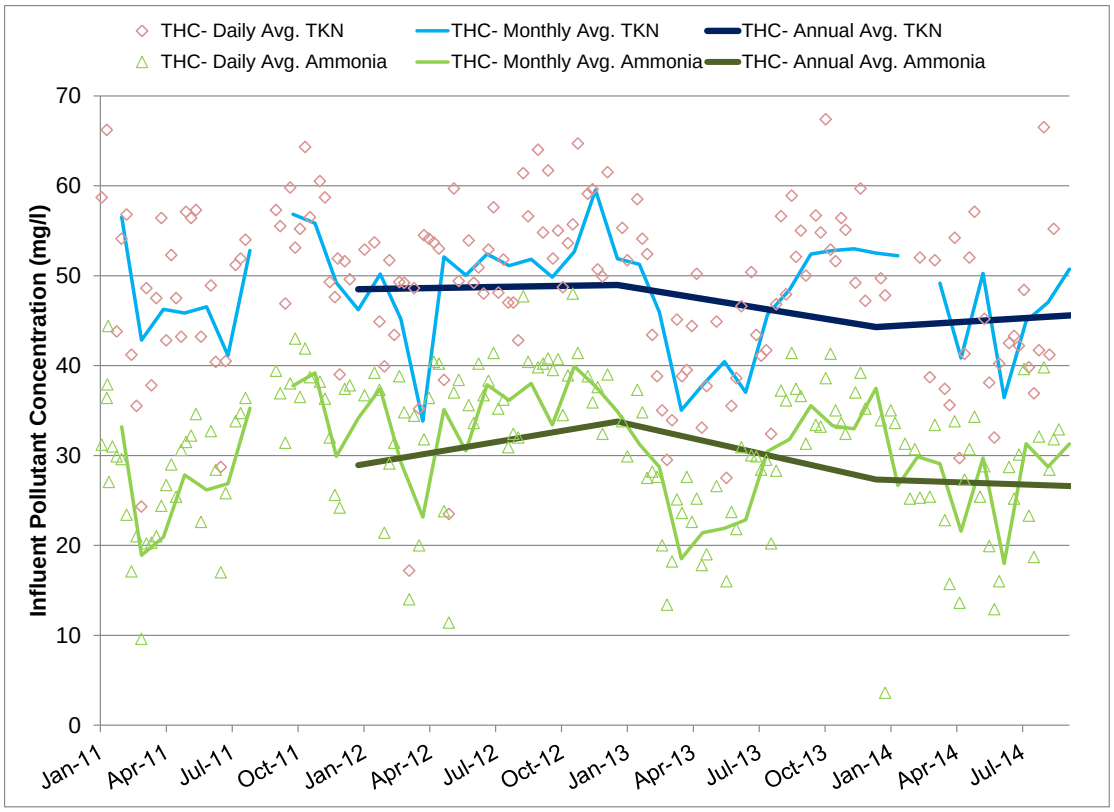


Figure 4-2: Daily Influent BOD and TSS Concentration to Tomahawk Creek WWTF

The plots for TSS and BOD concentration superimposed over each other for almost the entire analysis period, showing that the influent BOD and TSS concentrations are essentially the same. In comparison, the influent TSS concentrations at other treatment facilities in Johnson County are usually higher than the BOD concentration. In contrast to the other treatment facilities, the TKN concentration of THC influent is significantly higher than the TKN concentration at other JCW facilities.

The daily influent grab samples at the facility are collected between 8:00 and 9:00 AM. This time typically coincides with the diurnal peaks for ammonia and TKN, which explains the elevated influent concentrations. However, in the absence of the full diurnal TKN or ammonia profiles, it is difficult to validate this assumption.

Additionally, lower influent BOD and TSS concentrations during this period indicate that there could be issues with the solids settling in the influent sewer or diversion structure, upstream of the sampling location. JCW staff indicated that during the diurnal low flow periods at night, there is no bypass flow to KCMO. Primary and secondary clarifier solids are continuously discharged upstream of the KCMO Parshall flume and the total flow of waste sludge is estimated at approximately 1 mgd. As a result, the plant solids that are typically combined upstream of the KCMO bypass weir do not flow over the weir. Normally this infusion of waste sludge into the influent would elevate the incoming BOD and TSS concentrations. However, that is not the case and since the diversion structure is hydraulically designed for wet weather flows, the large channels must be providing

retention time for the influent solids and any recycle sludge to settle in the sewer line/ diversion structure upstream of the grab sampling location.

Because of these issues with the influent concentrations, it is recommended that the THC WWTF data be compared to other treatment facilities within Johnson County. The following section describes the data comparison to BRM WWTF influent data. It is also recommended that additional sampling be performed upstream of the diversion structure to obtain more representative daily composite information.

4.3 COMPARISON TO BLUE RIVER MAIN DATA

To validate the daily influent data at the THC WWTF, it was compared to the influent data at the Blue River Main WWTF. This facility was selected as both the treatment facilities serve a similar socio-economic watershed, with no significant industrial component. Table 4-2 summarizes the influent pollutant concentration at both the treatment facilities.

Table 4-2: Comparison of Tomahawk Creek WWTF and Blue River Main Data

	TOMAHAWK CREEK WWTF		BLUE RIVER MAIN WWTF		TYPICAL DOMESTIC WASTEWATER
	Annual Average	Maximum Monthly Average	Annual Average	Maximum Monthly Average	Median Values
Flow, mgd	13.8	20.8	5.0	7.5	
BOD, mg/L	154	141	181	192	200
TSS, mg/L	155	148	235	243	200
Ammonia, mg/L	29	24	21	19	25
TKN, mg/L	47	42	38	34	40
TP, mg/L	4.9	4.1	4.6	5.1	5

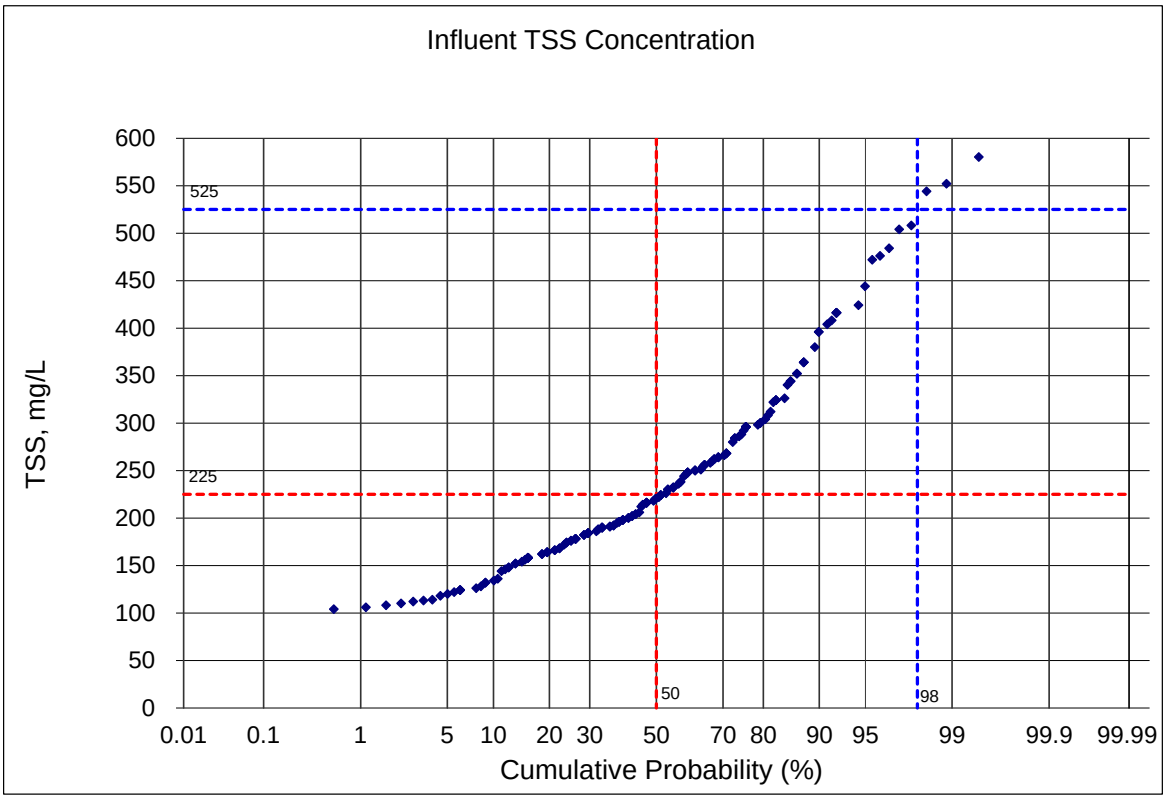
The data for the BRM WWTF was generated using the preliminary analysis of their influent data. The TSS concentration at this plant is higher than the BOD concentration, which trends with the other facilities in the region. Also, the BOD and TSS concentration of the influent wastewater at this plant was significantly higher than the Tomahawk Creek WWTF influent while the ammonia and TKN concentration were lower. This further validates the observation of the JCW personnel that the THC grab sample is picking up the diurnal ammonia peaks but is misrepresenting the BOD and TSS loads as some of it settles upstream of the sampling location.

As adequate data is not available on the representative samples at THC WWTF, it was concluded to use the influent wastewater characteristics of the BRM WWTF until longer term THC influent sampling can be collected. The following section describes the detailed analysis that was carried out on the BRM WWTF data.

4.4 EXISTING BRM INFLUENT DATA REVIEW

The operational data for Blue River Main WWTF was analyzed further to determine the influent wastewater characteristics that could be used as an alternative to THC WWTF. A probability chart of the influent TSS concentration is presented in Figure 4-3. The markers on the chart indicate the daily TSS data while the dotted lines represent the data that was at or below that value. For instance, the point of intersection of the two blue dotted lines indicate the TSS concentration at which ninety-eight percent of the data is at or below that value. In this case ninety-eight percent of the time the influent TSS concentration was below 525 mg/L.

Figure 4-3: Probability Chart for Influent TSS Concentration at BRM WWTF



Given the recent drought conditions, 20xx to 20xx, it is necessary to also examine the probability chart for the influent mass loading for TSS, Figure 4-4. The influent mass load data shows two daily data points that are significantly affecting the definition of the maximum month loads. We recommend that these two circled points be dropped from the analysis.

Figure 4-4: Probability Chart for Influent TSS Mass Loads at BRM WWTF

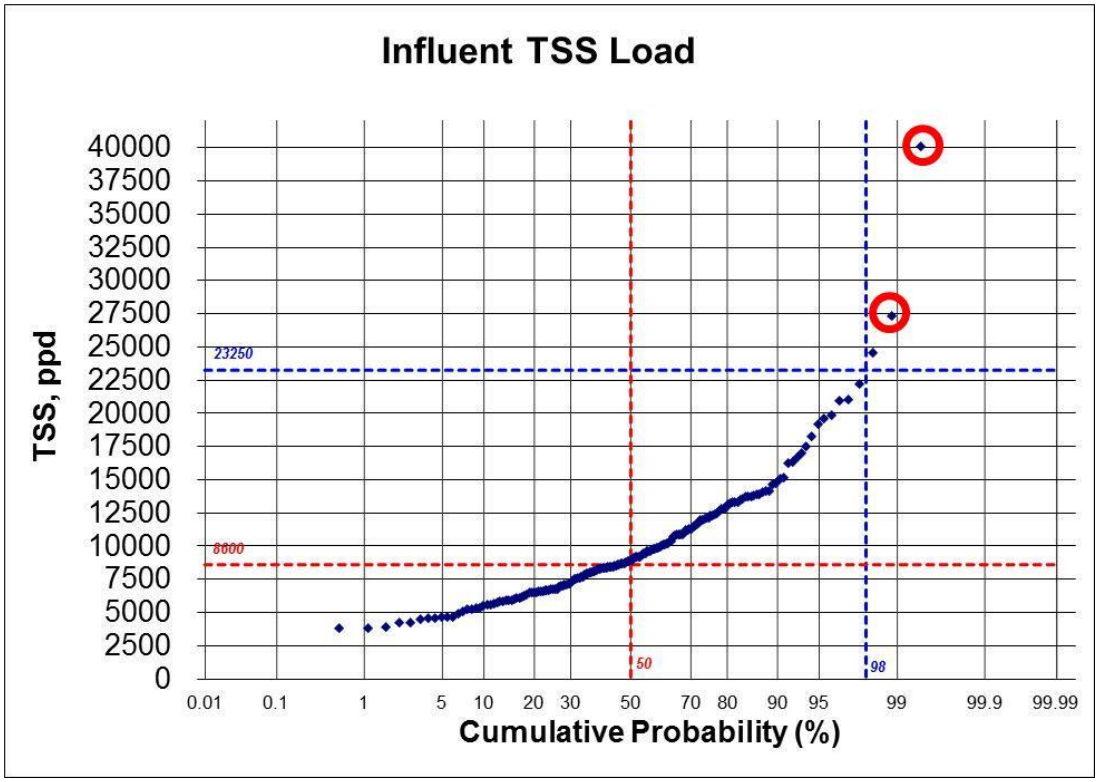


Figure 4-4 suggests that the average the influent TSS at BRM is 225 mg/L, which is significantly higher than the value estimated for THC WWTF. Table 4-3 presents the annual average, maximum monthly average and peak day values from BRM WWTF historical data. This table is generated by truncating the values above 98th percentile of the data. The probability plots of the other data showed no significant outliers.

Table 4-3: Influent Wastewater Characteristics at Blue River Main WWTF

PARAMETER	ANNUAL AVERAGE		MM:AA	MAXIMUM MONTHLY AVERAGE		PD:AA	PEAK DAY	
Flow, mgd	5.0			7.4			16.2	
	mg/L	ppd		mg/L	ppd		mg/L	ppd
TSS	228	9,525	1.52	235	14,481	2.47	174	23,534
BOD	180	7,548	1.59	195	11,997	2.18	122	16,441
TKN	37.8	1,583	1.36	35	2,150	1.63	19.2	2,586
Ammonia	21.3	892	1.31	19	1,168	1.67	11	1,490
Total Phosphorus	4.6	191	1.66	5.17	318	2.07	2.94	396
Ortho-Phosphate	1.71	72	1.47	1.72	106	2.17	1.16	156

4.5 SAMPLING PLAN

As a result of the discrepancy between the THC influent grab samples and the BRM composite influent data, a separate sampling effort was started in December 2014. Composite samplers were installed on the Tomahawk Creek and Indian Creek interceptors, immediately upstream of the diversion box. The initial results from sampling at these two locations showed much higher than expected concentrations for BOD and TSS (BOD nd TSS concentrations over 350 mg/L). After discussion with JCW, it was postulated that at night low flow conditions, sludge wasted to the diversion structure was backing up in the channels and affecting the composite samples.

The sampler location is being changed to an upstream manhole on each interceptor. The new location must have a sewer invert that is higher than the elevation of the diversion structure Parshall flume throat to ensure that waste primary and secondary sludge cannot back up in the channels at low flow conditions and contaminate the composite samples. Data from this second sample characterization effort will not be available in time to affect the development of influent wastewater characteristics for this conceptual process comparison, but will be available before the start of detailed design.

At the beginning of the design phase, detailed BioWin modeling will be performed on the selected alternative. In order to perform this modeling, special sampling must be performed at THC. A sampling plan has been developed to collect the information necessary to support the modeling effort. The sampling plan describes four (4) sampling events to be performed under winter, spring, summer and fall weather conditions to define how the influent characteristics vary seasonally. It is recommended that the special sampling for developing modeling characteristic information be performed in early November 2015, January 2016 and March/ April 2016 (depending on severity or mildness of the winter and before the spring rains begin) and July 2016. The sampling plan also describes collection of diurnal profile information and wet weather pollutant profile information. The sampling plan details are presented in Appendix B.

4.6 DEVELOPMENT OF FUTURE FLOWS AND LOADS

The flows developed in Section 3 and the influent wastewater concentrations for Blue River Main WWTF were used to develop revised influent loads at Tomahawk Creek WWTF. Table 4-4 presents the recommended future flows and loads for use in this evaluation. The derivation of the flows and loads is presented in Appendix D.

Table 4-4: Recommended Basis of Design

PARAMETER	ANNUAL AVERAGE		MM:AA	MAXIMUM MONTHLY AVERAGE		PD:AA	PEAK DAY	
Flow, mgd	19			28.7			105.4	
	mg/L	ppd		mg/L	ppd		mg/L	ppd
TSS	204	32,376	1.42	192	45,974	2.02	74.4	65,400
BOD	160	25,338	1.30	138	32,939	1.81	52.2	45,862
TKN	33.6	5,322	1.23	27.4	6,546	1.49	9.02	7,929
Ammonia	18.9	3,000	1.23	15.4	3,690	1.47	5.02	4,410
Total Phosphorus	4.05	642	1.26	3.39	809	1.67	1.22	1,073
Ortho-Phosphate	1.52	240	1.35	1.36	325	1.82	0.50	438

4.7 PRIMARY CLARIFIER PERFORMANCE

Figure 4-5 presents the existing primary clarifier performance at THC WWTF. Both BOD and TSS removal efficiencies at the treatment plant ranged between five and fifty percent. As this data was not adequate to develop typical removal efficiencies across the primary clarifiers, additional data was requested from JCW personnel.

Figure 4-5: Primary Clarifier Performance at THC WWTF

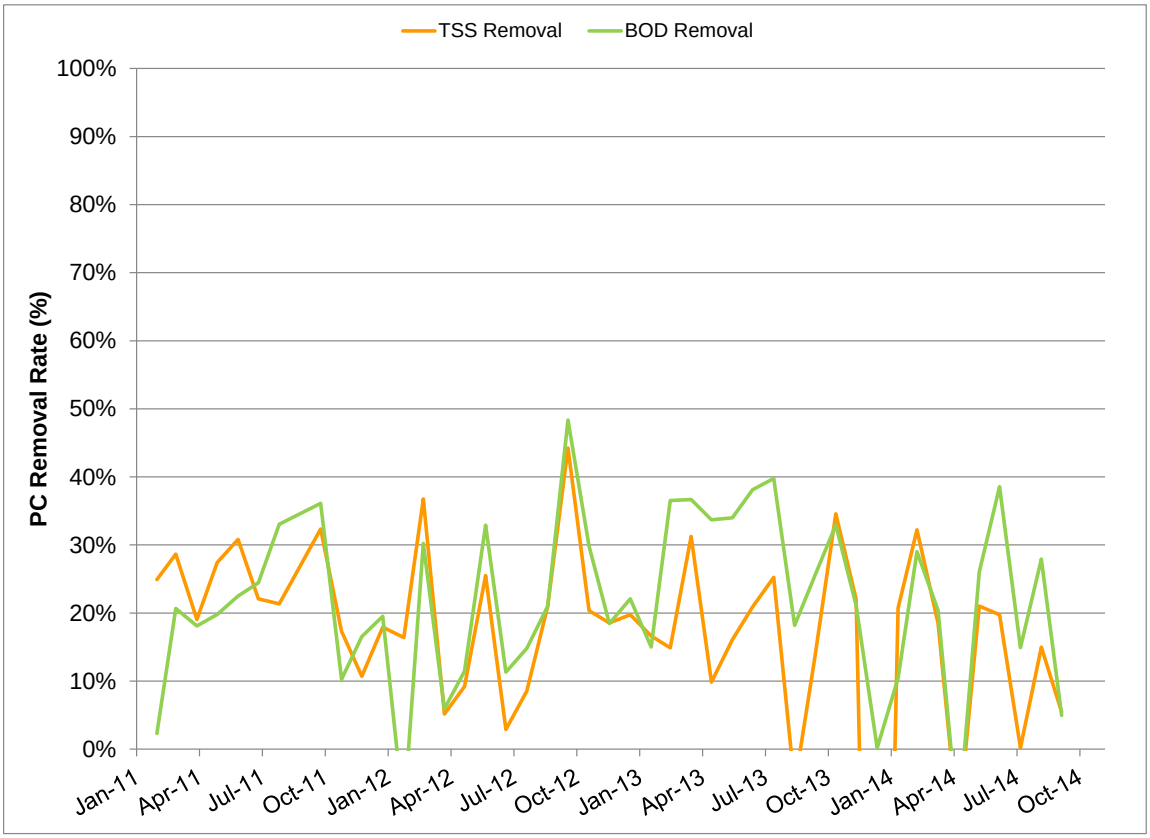
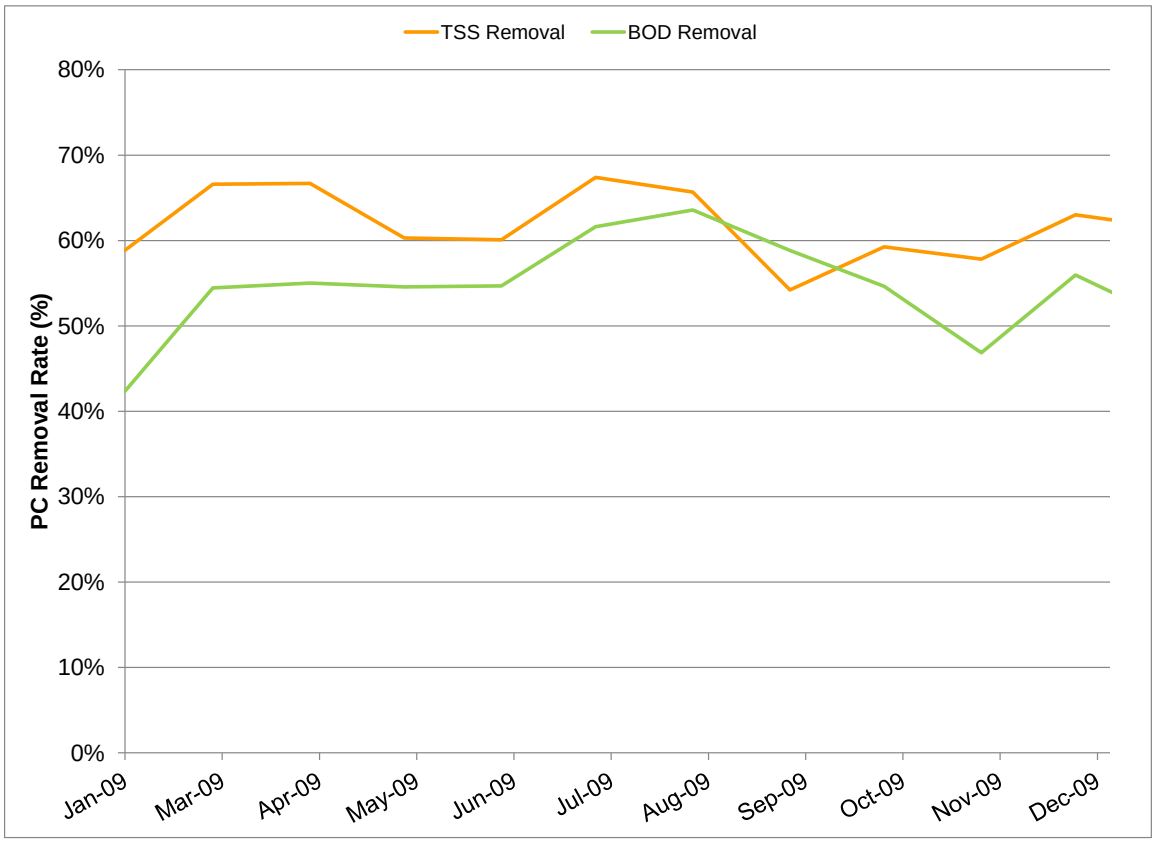


Figure 4-6 presents the BOD and TSS removal across the primary clarifiers during the year 2009. This data was collected as a part of the CEPT study at the facility. Based on this information and B&V experience, an average TSS removal efficiency of 50% was used across the primary clarifiers.

During this study, the facility also tracked soluble BOD concentration in March 2009. With the assumption that the soluble BOD fraction will remain constant at the facility, the total BOD removal across the primary clarifier was calculated as 40%.

During this analysis it was found that the trickling filter recycle stream from the effluent of the trickling filters was returned not to the influent of the trickling filters but to the influent of the primary clarifiers. The higher hydraulic loading and unknown contribution of BOD and TSS from this recycle stream complicated the primary clarifier performance analysis and resulted in the low removal efficiencies shown in Figure 4-5 and Figure 4-6. Therefore, primary clarifier removal performance was assumed to be 50 percent TSS and 40 percent BOD removal under non-CEPT operation based upon Black & Veatch experience.

Figure 4-6: Primary Clarifier Performance at THC WWTF During 2009



5 Solids Projections and Primary Effluent Quality Projections

5.1 BACKGROUND, OBJECTIVE, AND SCOPE

The following two treatment technologies for primary clarification are analyzed for THC WWTF:

- Conventional primary clarification- Tomahawk Creek WWTF currently uses conventional circular clarifiers with CEPT for primary treatment. For the analysis it was assumed that these clarifiers would be operated without CEPT and in this mode of operation fifty percent TSS removal can be achieved across primary treatment.
- Advanced primary clarification- CoMag technology will be considered at Tomahawk Creek WWTF as an advanced treatment option. With this technology it was assumed that the primary treatment has around ninety removal efficiency.

The following four alternatives will be evaluated for secondary treatment of wastewater at THC WWTF:

- BioMag technology
- IFAS technology
- MBR technology
- Granular Activated Sludge technology

The standard Black & Veatch activated sludge model was used to predict the amount of Waste Activated Sludge (WAS) generated by these different treatment technologies. The amount of WAS predicted by the model for the different alternatives is about the same and is discussed in the following section, along with primary sludge predictions.

5.2 PROJECTIONS

Biosolids projections presented in Table 5-1 includes primary sludge and WAS solids produced at Tomahawk Creek WWTF. The solids projection is divided into two groups, based on the primary treatment technology described in the above section.

Following are the assumptions that were used to develop the solids quantities:

- Conventional primary treatment can remove up to 50% of primary influent solids while the CoMag treatment can get up to 90%
- Primary sludge can thicken up to 4% total solids concentration
- WAS is thickened using mechanical thickeners and can get up to 4% total solids
- An external carbon source is required for denitrification with advanced primary treatment with CoMag technology

Table 5-1: Biosolids Projections for Tomahawk Creek WWTF

	CONVENTIONAL PRIMARY TREATMENT		ADVANCED PRIMARY TREATMENT WITH COMAG TECHNOLOGY	
	Annual Average	Maximum Monthly Average	Annual Average	Maximum Monthly Average
Primary Sludge				
Quantity, ppd	16,188	22,987	29,139	41,377
Flow, mgd[1]	0.0485	0.0689	0.0873	0.1240
Thickened Waste Activated Sludge				
WAS Quantity, ppd	12,700	17,200	4,770	6,220
Flow, mgd[1]	0.0381	0.0516	0.0143	0.0186
Thickened Waste Activated Sludge (with carbon addition)				
Quantity, ppd	No supplemental carbon added		7,020	8,450
Flow, mgd[1]			0.0210	0.0253

Note:
[1] Assumed 4% total solids concentration.

These projected solids quantities are used to evaluate biosolids handling facilities and analyze treatment alternatives.

6 Summary of Findings and Recommendations

This section includes a summary of findings and recommendations. Section 6.1 presents a summary of the findings of the existing and future design flows analysis, detailed in Section 3. Sections 6.2 through 6.4 summarize the findings of the existing and future loads analysis, detailed in Section 4 and Section 5. Note that the design flows defined in Section 6.1 are hydraulic design flows, while the flows defined in Section 6.2 through 6.4 are process design flows that are dependent on the waste load characteristics of the wastewater.

6.1 DRY AND WET WEATHER DESIGN FLOWS

The THC WWTF, situated at the junction of Indian Creek and Tomahawk Creek, serves a tributary area comprised of the Lower Indian Creek and Tomahawk Creek basins. In addition, flow is currently pumped to the WWTF from the Dyke's Branch Basin, via the Dyke's Branch Pump Station.

Projections of future average and peak flows were developed to serve as a basis for evaluation and design of facilities at the THC WWTF. It was determined that during an average rainfall year, the current ADF is 15.2 MGD.

Similarly, existing wet weather flows were determined for various storm return intervals based on hydraulic modeling and review/extrapolation of historical data. Future flows were estimated based on factoring in future growth, cost effective I & I removal, and applying a safety factor to account for unknowns and possible future redevelopment within the watershed.

JCW has several other locations in their collection system where flows cross over to KCMO for treatment. Several of these, specifically Interconnect Metering Facilities (IMF's) 10, 11, 12, 13, 13A, and the Hallbrook IMF are in reasonably close proximity to the THC WWTF. An analysis was performed to determine if it would be cost effective to intercept this flow at State Line with pump stations and pump it to THC for treatment, thus avoiding the higher KCMO treatment cost. It was determined that it would, in fact, be cost effective to divert flow to THC from 3 of these locations.

An additional analysis was completed to evaluate options for managing flows from the Dykes Branch Pump Station. The Dry Weather Forcemain is nearing the end of its serviceable life and must be rehabilitated if it is to continue in service. It was determined that the most cost effective Dyke's Branch conveyance alternative was to abandon the dry weather forcemain, convey the flow by gravity to Leawood Pump Station 10/11, and provide additional capacity in that pump station for the additional flow from Dyke's Branch.

The results of the existing and future flow evaluation are summarized in Table 6-1.

Table 6-1: THC WWTF Design Flow Summary

FLOW COMPONENT	ADF (MGD)	MMADF (MGD)	PDF (MGD)	PEAK HOUR FLOW (MGD)		PEAK INSTANTANEOUS FLOW (MGD)	
				5-Yr Storm	10-Yr Storm	5-Yr Storm	10-Yr Storm
THC & LIC Basins	15.9 [1]	25.5[1]	100.3 [5]	166.8 [5]	189.9 [7]	167.7 [5]	190.5 [7]
Hallbrook	0.1 [2]	0.1 [4]	0.2 [6]	0.2 [6]	0.2 [6]	0.2 [6]	0.2 [6]
IMF 10/11	1.4 [3]	2.3 [4]	2.9 [6]	2.9 [6]	2.9 [6]	2.9 [6]	2.9 [6]
IMF 13/13A	1.0 [3]	1.6 [4]	2.0 [6]	2.0 [6]	2.0 [6]	2.0 [6]	2.0 [6]
Total	**18.4**	**29.5**	**105.4**	**171.9**	**195.0**	**172.8**	**195.6**
Recommended Design ADF = <u>19 mgd</u>							

Notes:

[1] Based on Average Annual Rainfall of 38.86 inches. Includes 4.57% growth based on Draft THC Service Area Existing Conditions Analysis TM (CH2M HILL, 2014).

[2] Based on 241 connections, at 300 gpd/connection.

[3] ADF at Leawood IMF sites provided by CH2M HILL.

[4] Based on 1.6 ratio of MMADF:ADF of 1.6.

[6] 5-year return interval with 23.2% I/I removal (hydraulic modeling provided by CH2M HILL and documented in Tomahawk WWTP Service Area – Storage Analysis TM).

[6] Peak flows limited to pump station capacities of twice ADF (2Q).

[7] 10-year return interval with 23.2% I/I removal (hydraulic modeling provided by CH2M HILL and documented in Tomahawk WWTP Service Area – Storage Analysis TM).

6.2 FLOWS AND WASTE CHARACTERISTICS

The basis of design developed for Tomahawk Creek WWTF is summarized in Table 6-2. The flows presented include growth in the watershed and contribution from flows currently discharged to KCMO for treatment relocated and sent to THC for treatment. It also includes a flow correction from drought conditions to more normal rainfall conditions as this affects the amount of daily infiltration and a safety factor for growth, as described in Sections 3 and 4.

The concentration values presented in the table are based on the influent the data from the Blue River Main WWTF and modified for the growth and flows diverted to THC for treatment as described in Section 3.

Table 6-2: Basis of Design

PARAMETER	ANNUAL AVERAGE		MM:AA	MAXIMUM MONTHLY AVERAGE		PD:AA	PEAK DAY	
Flow, mgd	19			28.7			105.4	
	mg/L	ppd		mg/L	ppd		mg/L	ppd
TSS	204	32,376	1.42	192	45,974	2.02	74.4	65,400
BOD	160	25,338	1.30	138	32,939	1.81	52.2	45,862
TKN	33.6	5,322	1.23	27.4	6,546	1.49	9.02	7,929
Ammonia	18.9	3,000	1.23	15.4	3,690	1.47	5.02	4,410
Total Phosphorus	4.05	642	1.26	3.39	809	1.67	1.22	1,073
Ortho-Phosphate	1.52	240	1.35	1.36	325	1.82	0.50	438

In order to validate these concentrations, it is recommended that THC WWTF perform daily composite sample collection in place of the grab samples. It is further recommended that the treatment plant move the current sampling location to a point where the sewer invert elevation is higher than the diversion structure weir elevation. Relocating the sampling point should resolve the issues with sludge solids interfering with the sample quality during low flow periods.

6.3 PRIMARY EFFLUENT CHARACTERISTICS

Based on the different primary treatment alternatives, two different primary effluent concentrations were developed. These values are presented in

Table 6-3. Additional side stream loads that will be added to the primary effluent from the biosolids treatment facilities are also included in these numbers in Table 6-4.

Following assumptions are made to develop the primary effluent characteristics:

- Based on the discussion in Section 4.7, primary clarifier TSS and BOD removal efficiencies for the conventional treatment alternative are 50% and 40% respectively
- Primary clarifier TSS and BOD removal efficiencies for the advanced treatment (CoMag) alternative are 90% and 70% respectively
- The soluble BOD fraction in the plant influent is 20%
- TKN and TP has 50% particulate inert fraction that will be removed in primary clarifiers

Table 6-3: Primary Effluent Characteristics

	CONVENTIONAL PRIMARY TREATMENT				ADVANCED PRIMARY TREATMENT WITH COMAG			
	Annual Average		Maximum Monthly Average		Annual Average		Maximum Monthly Average	
	ppd	mg/L	ppd	mg/L	ppd	mg/L	ppd	mg/L
TSS	16,188	102	22,987	96	3,238	20	4,597	19
BOD	15,203	96	19,674	83	7,095	45	9,223	39
VSS	14,259	90	20,248	85	2,852	18	4,050	17
TKN	4,741	29.9	5,832	24.4	4,277	27	5,261	22
Ammonia	3,000	18.9	3,690	15.4	3,000	18.9	3,690	15.4
TP	542	3.4	688	2.9	462	2.9	591	2.5

Table 6-4: Primary Effluent Characteristics With an Allowance for Sidestream Return Loads

	CONVENTIONAL PRIMARY TREATMENT				ADVANCED PRIMARY TREATMENT WITH COMAG			
	Annual Average		Maximum Monthly Average		Annual Average		Maximum Monthly Average	
	ppd	mg/L	ppd	mg/L	ppd	mg/L	ppd	mg/L
TSS	16,579	104	23,525	98	3,665	23	5,196	22
BOD	15,592	98	20,229	85	7,527	47	9,827	41
VSS	14,277	90	20,271	85	2,855	18	4,054	17
TKN	5,638	35.5	7,069	29.6	5,299	33.4	6,692	28
Ammonia	3,888	24.5	4,925	20.6	4,015	25.3	5,120	21.4
TP	913	5.8	1,202	5.0	885	5.6	1,186	5.0

The primary effluent flows and loads summarized in this section are used to size the secondary treatment alternatives

6.4 BIOSOLIDS QUANTITIES

Biosolids projections presented in Table 6-5 includes primary sludge and WAS solids for both conventional and advanced primary treatment options. These projected solids quantities are used to evaluate biosolids handling facilities and analyze treatment alternatives.

Table 6-5: Biosolids Projections for Tomahawk Creek WWTF

	CONVENTIONAL PRIMARY TREATMENT		ADVANCED PRIMARY TREATMENT WITH COMAG TECHNOLOGY	
	Annual Average	Maximum Monthly Average	Annual Average	Maximum Monthly Average
Primary Sludge				
Quantity, ppd	16,188	22,987	29,139	41,377
Flow, mgd[1]	0.0485	0.0689	0.0873	0.1240
Thickened Waste Activated Sludge				
WAS Quantity, ppd	12,700	17,200	4,770	6,220
Flow, mgd[1]	0.0381	0.0516	0.0143	0.0186
Thickened Waste Activated Sludge (with carbon addition)				
Quantity, ppd	No supplemental carbon added		7,020	8,450
Flow, mgd[1]			0.0210	0.0253

Note:
[1] Assumed 4% total solids concentration.

APPENDIX A

LEAWOOD FLOW CONVEYANCE EVALUATION CAPITAL AND NET PRESENT VALUE COST CALCULATIONS

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A. 8 Life Cycle Cost Analysis - Reduced OCP Rates & NACWA Average Post OCP

A. 1

Life Cycle Cost Analysis Summary

Leawood Flow Conveyance Alternatives - Life Cycle Cost Analysis

		Net Present Value (NPV) Summary of Financial Scenarios				
			Treatment at KCMO			
			Full OCP Rates		Reduced OCP Rates	
Alternative	Included Sites	Treatment at THC WWTP	Inflation Post OCP (1)	NACWA Average Post OCP (2)	Inflation Post OCP (3)	NACWA Average Post OCP (4)
L1	13/13A	$14,100,000	$32,300,000	$40,800,000	$29,500,000	$37,300,000
L2	13/13A & HB	$16,000,000	$34,600,000	$43,700,000	$31,600,000	$40,000,000
L3	10/11 & 13/13A	$36,200,000	$79,800,000	$100,800,000	$72,900,000	$92,100,000
L4	10/11, 13/13A, & HB	$38,200,000	$82,100,000	$103,700,000	$75,000,000	$94,800,000
L5	10/11, 12, & 13/13A	$39,400,000	$82,100,000	$103,700,000	$75,000,000	$94,800,000
L6	10/11, 12, 13/13A, & HB	$41,300,000	$84,400,000	$106,700,000	$77,100,000	$97,500,000

Note: NPV comparison is for conveyance and treatment for flows up to 2Q for each site only. Assumes 90% of of annual flow volume falls in the 2Q and remaining 10% is sent to KCMO for treatment.

KCMO Rate Increase Scenarios

(1) Full OCP rates with post-OCP increases at inflation

(2) Full OCP rates with post-OCP increases at NACWA annual average rate increase plus inflation

(3) Reduced OCP rates with post-OCP increases at inflation

(4) Reduced OCP rates with post-OCP increases at NACWA annual average rate increase plus inflation

Economic Analysis Assumptions

NACWA Average Annual Rate Increase = 2.8%

Inflation = 1.9% (Nominal Discount Rate (3.1%) - Net discount Rate (1.2%))

Full OCP rates are 11.9% for years 2015-2020 and 8% for year 2021

Reduced OCP rates are 9.9% for years 2015-2020 and 8% for year 2021

A. 2

Flow Conveyance Evaluation Assumptions

Leawood Flow Conveyance Evaluation Assumptions

Design Flow Assumption

- Average Annual Daily Flow (AADF) data at IMF sites provided by CH2MHill except for Hallbrook. Hallbrook flows are calculated based on 241 connections at 300 gpd/connection.
- Pump station capacities are two times the AADF (2Q) for each pump station.
- Comparative analysis is for conveyance and treatment for all flows up to 2Q for each site only. Wet weather flows above 2Q are assumed to continue to be sent to KCMO for all IMF sites for all alternatives.
    - Flows up to 2Q are assumed to include 90% of the annual average flow volume; the remaining 10% of flow volume is assumed to be wet weather flow sent to KCMO for treatment. The basis for this assumption is an analysis of Site 13/13A by CH2MHill which indicates that flows above 2Q constitute 4% of the annual average flow volume for a typical year. A conservative wet weather flow volume of 10% was used for this preliminary study.

Cost Estimate Assumptions

- Cost estimates and Net Present Values (NPV) shown in 2015 dollars.
- Basis of pump station cost estimates – JCW Shawnee Mission Park pump station costs, inflated to 2015 dollars, scaled to appropriate pump station size.
- Pump station factors used to estimate capital costs:
    - Structure Size – physical size of the pump station based on size and quantity of pumps
    - Hydraulic Capacity – based on total pump station capacity
    - Electrical Requirement – based on pump horsepower requirements
- Incremental costs for treatment of increased flow to THC were assumed to be 50% of the Capital and O&M costs/MGD established in the THC WWTP Improvements Pre Design Study.

Life Cycle Cost Economic Analysis Assumptions

- Economic Analysis Criteria (OMB Circular A-94 Appendix C, December 2014 for 20-year planning Horizon):
    - Nominal Discount Rate: 3.1%
    - Net Discount Rate: 1.2%
    - Inflation: 1.9%

KCMO Rate Scenarios Evaluated:

- Full OCP Rates
  - 11.9% for years 2015-2020
  - 8% for year 2021
- Reduced OCP Rates
  - 9.9% for years 2015-2020
  - 8% for year 2021
- Post OCP Rate Increases (after 2021):
  - Evaluated at National Association of Clean Water Agencies (NACWA) average annual rate increase of 2.8% above inflation, based on the 10 year average rate increase identified in the 2011 NACA Service Charge Index.
  - Also evaluated with annual rate increase equal to inflation.

A. 3

Hydraulic Calculations

Force Main Hydraulics

Alternative	Force Main Segment	Flow (MGD) (1)	Diameter (in)	Length (ft)	Hf (ft) (2)
L1	3	1.96	12	3300	17.29
(13/13A)	4	1.96	12	3300	17.29
L2	3	1.96	12	3300	17.29
(13/13A & HB)	4	2.10	12	3300	19.64
L3	1	2.88	16	2200	5.79
(10/11 & 13/13A)	2A	2.88	16	2400	6.32
	2B	2.88	16	6100	16.06
	3	4.84	20	3300	7.67
	4	4.84	20	3300	7.67
L4	1	2.88	16	2200	5.79
(10/11, 13/13A, & HB)	2A	2.88	16	2400	6.32
	2B	2.88	16	6100	16.06
	3	4.84	20	3300	7.67
	4	4.98	20	3300	8.08
L5	1	2.88	16	2200	5.79
(10/11, 12, & 13/13A)	2A	3.2	16	2400	7.68
	2B	3.2	16	6100	19.52
	3	5.16	20	3300	8.63
	4	5.16	20	3300	8.63
L6	1	2.88	16	2200	5.79
(10/11, 12, 13/13A, & HB)	2A	3.2	16	2400	7.68
	2B	3.2	16	6100	19.52
	3	5.16	20	3300	8.63
	4	5.3	20	3300	9.07

Notes:

(1) Hydraulic Calculation is based on two times the Average Annual Daily Flow (AADF)

(2) Friction Head is calculated using the Hazen Williams equation with a C = 120

Pump Station Sizing

Alternative	Pump Station	Hf (ft)	Hs (ft)[1][2]	TDH	Capacity (gpm)	Calculated HP	Pump Information Motor Size	Pump Information Quantity
L1	13/13A	34.6	27	62	1361	32.6	25	3
L2 (13/13A & HB)	13/13A	36.9	27	64	1361	33.9	25	3
	HB	19.6	26	46	97	1.8	5	2
L3 (10/11 & 13/13A)	10/11	12.1	121	133	2000	103.5	75	3
	13/13A	15.3	27	42	1361	22.4	15	3
L4 (10/11, 13/13A, & HB)	10/11	12.1	121	133	2000	103.5	75	3
	13/13A	15.7	27	43	1361	22.7	25	3
	HB	8.1	26	34	97	1.3	5	2
L5 (10/11, 12, & 13/13A)	10/11	13.5	101	114	2000	89	75	3
	12	7.7	94	102	222	8.8	10	2
	13/13A	17.3	27	44	1361	23.5	25	3
L6 (10/11, 12, 13/13A, & HB)	10/11	13.5	121	134	2000	104.5	75	3
	12	7.7	94	102	222	8.8	10	2
	13/13A	17.7	27	45	1361	23.7	25	3
	HB	9.1	26	35	97	1.4	5	2

[1] 20 feet added due to pump station depth

[2] Elevation High Point Governs Static Head for Pump Stations 10/11 and 12

A. 4

Cost Estimates

Basis of Cost Estimate and Assumptions

JCW -Shawnee Mission Park Pump Station (SMP)
Year 2006
2 Submersible Pumps
Capacity 97 gpm
Low TDH
Cost $317,442
Inflation 3%

Hallbrook Pump Station

Year 2015
2- 5 HP Submersible Pumps
Capacity 97 gpm
Low TDH

Time adjustment for	9	years	$317,442	x	$(1.03)^9$	≈	$420,000
					Flow Meter		$15,000
					Bypass connection		$15,000
							$450,000
					Contingency	25%	$112,500
					Engineering Fee	25%	$112,500
							$700,000

(Rounded to nearest one hundred thousand)

Pump Station 13/13A

Year 2015
3- 25 HP Submersible Pumps
Capacity 1361 gpm
Low TDH
** Hallbrook Pump Station estimated cost used as base for scaling 13/13A estimated cost** $700,000

Adjustments to Base Cost	Size Factor (1)	Economy of Scale (2)	% of Cost (3)	Cost (4)
Structure Size	1.5	1.22	45%	$385,795
Hydraulic Capacity	14	3.75	35%	$917,718
Electrical Requirements	7.5	2.74	20%	$383,406
				$1,700,000

Notes:
(1) Structure Size Factor is based on theratio of footprint, or physical size, of the pump station primarily due to pump quantity.
Hydraulic Capacity Size Factor is a ratio of the pump station capacities.
Electrical Requirements Size Factor is a ratio of pump horse power.
(2) Economy of Scale multiplier is the square root of the Size Factor.
(3) % of Cost is the Engineer's assumed percentage of the overall pump station cost of each component of the station.
(4) Component cost is calculated by multiplying the base pump station cost by the Economy of Scale and the % of Cost.

Pump Station 12

Year 2015
2 - 10 HP Submersible Pumps
Capacity 222 gpm
Low TDH
** Hallbrook Pump Station estimated cost used as base for scaling 12 estimated cost** $700,000

Adjustments to Base Cost	Size Factor	Economy of Scale	% of Cost	Cost
Structure Size	1	1.00	45%	$315,000
Hydraulic Capacity	2	1.51	35%	$370,829
Electrical Requirements	2	1.41	20%	$197,990
				$900,000

Note:
See Pump Station 13/13A for explanation of Scale Factors, Economy of Scale and % of Cost.

Pump Station 10/11

Year 2015
3 - 75 HP Submersible Pumps
Capacity 2000 gpm
Low TDH
Pump Station 13/13A estimated cost used as base for scaling 10/11 estimated cost $1,700,000

Adjustments to Base Cost	Size Factor	Economy of Scale	% of Cost	Cost
Structure Size	1	1.00	45%	$765,000
Hydraulic Capacity	1.5	1.21	35%	$721,278
Electrical Requirements	3	1.73	20%	$588,897
				$2,100,000
			Odor Control Station	$300,000
				$2,400,000

Note:
See Pump Station 13/13A for explanation of Scale Factors, Economy of Scale and % of Cost.

Alternative L1 -13/13A Only

Capital Cost	Quantity	Unit	Unit Cost	Cost
Pump Station				
13/13A	1	EA	$1,700,000	$1,700,000
Force Main				
12"	6600	LF	$150	$990,000
Gravity Sewer				
24" Diameter	1300	LF	$360	$468,000
30" Diameter	450	LF	$450	$202,500
			Conveyance Subtotal	$3,360,500
Incremental Treatment Cost (1)	0.98	MGD	$5,347,000	$5,240,100
			Total Capital	**$8,600,600**

O&M-Annual	Quantity	Unit	Unit Cost	Cost
Pump Station				
13/13A	5%	Capital / Year	$1,700,000	$85,000
Force Main	6600	LF	$1.00	$6,600.00
Gravity Sewer	1750	LF	$1.00	$1,750
			Conveyance Subtotal	$93,350
Incremental Treatment Cost (1)	0.882	MGD	$288,000	$254,016
			Total O&M	**$347,366**

Notes:
(1) Incremental Treatment Cost is assumed to be 50% of the Capital and O&M Cost/MGD established in the THC WWTP Improvements Pre Design Study

Alternative L2 - 13/13A Hallbrook

Capital Cost	Quantity	Unit	Unit Cost	Cost
Pump Station				
13/13A	1	EA	$1,700,000	$1,700,000
HB	1	EA	$700,000	$700,000
Force Main				
12"	6600	LF	$150	$990,000
Gravity Sewer				
24" Diameter	1300	LF	$360	$468,000
30" Diameter	450	LF	$450	$202,500
			Conveyance Subtotal	$4,060,500
Incremental Treatment Cost (1)	1.05	MGD	$5,347,000	$5,614,350
	`		**Total Capital**	**$9,674,850**

O&M-Annual	Quantity	Unit	Unit Cost	Cost
Pump Station				
13/13A	5%	Capital / Year	$1,700,000	$85,000
HB	5%	Capital / Year	$700,000	$35,000
Force Main	6600	LF	$1.00	$6,600
Gravity Sewer	1750	LF	$1.00	$1,750
			Conveyance Subtotal	$128,350
Incremental Treatment Cost (1)	0.945	MGD	$288,000	$272,160
			Total O&M	**$400,600**

Notes:

(1) Incremental Treatment Cost is assumed to be 50% of the Capital and O&M Cost/MGD established in the THC WWTP Improvements Pre Design Study

Alternative L3 - 10/11 & 13/13A

Capital Cost	Quantity	Unit	Unit Cost	Cost
Pump Station				
10/11	1	EA	$2,400,000	$2,400,000
13/13A	1	EA	$1,700,000	$1,700,000
Force Main				
16" Diameter	10700	LF	$200	$2,140,000
20" Diameter	6600	LF	$250	$1,650,000
Gravity Sewer				
18" Diameter	400	LF	$270	$108,000
24" Diameter	1300	LF	$360	$468,000
30" Diameter	450	LF	$450	$202,500
			Subtotal Conveyance	$8,668,500
Incremental Treatment Cost (1)	2.42	MGD	$5,347,000	$12,939,740
			Total Capital	**$21,608,300**

O&M-Annual	Quantity	Unit	Unit Cost	Cost
Pump Station				
10/11	5%	Capital / Year	$2,400,000	$120,000
13/13A	5%	Capital / Year	$1,700,000	$85,000
Odor Control Chemicals	26353	GAL	$2.71	$71,417
Force Main	17300	LF	$1.00	$17,300
Gravity Sewer	2150	LF	$1.00	$2,150
			Conveyance Subtotal	$295,900
Incremental Treatment Cost (1)	2.178	MGD	$288,000	$627,264
			Total O&M	**$923,200**

Notes:

(1) Incremental Treatment Cost is assumed to be 50% of the Capital and O&M Cost/MGD established in the THC WWTP Improvements Pre Design Study

Alternative L4 - 10/11, 13/13A, & Hallbrook

Capital Cost	Quantity	Unit	Unit Cost	Cost
Pump Station				
10/11	1	EA	$2,400,000	$2,400,000
13/13A	1	EA	$1,700,000	$1,700,000
HB	1	EA	$700,000	$700,000
Force Main				
16" Diameter	10700	LF	$200	$2,140,000
20" Diameter	6600	LF	$250	$1,650,000
Gravity Sewer				
18" Diameter	400	LF	$270	$108,000
24" Diameter	1300	LF	$360	$468,000
30" Diameter	450	LF	$450	$202,500
			Conveyance Subtotal	$9,368,500
Incremental Treatment Cost (1)	2.49	MGD	$5,347,000	$13,314,030
			Total Capital	**$22,682,600**

O&M-Annual	Quantity	Unit	Unit Cost	Cost
Pump Station				
10/11	5%	Capital / Year	$2,400,000	$120,000
13/13A	5%	Capital / Year	$1,700,000	$85,000
HB	5%	Capital / Year	$700,000	$35,000
Odor Control Chemicals	26353	GAL	$2.71	$71,417
Force Main	17300	LF	$1.00	$17,300
Gravity Sewer	2150	LF	$1.00	$2,150
			Conveyance Subtotal	$330,900
Incremental Treatment Cost (1)	2.241	MGD	$288,000	$645,408
			Total O&M	**$976,400**

Notes:

(1) Incremental Treatment Cost is assumed to be 50% of the Capital and O&M Cost/MGD established in the THC WWTP Improvements Pre Design Study

Alternative L5 - 10/11, 12, 13/13A

Capital Cost	Quantity	Unit	Unit Cost	Cost
Pump Station				
10/11	1	EA	$2,400,000	$2,400,000
12	1	EA	$900,000	$900,000
13/13A	1	EA	$1,700,000	$1,700,000
Force Main				
16" Diameter	10700	LF	$200	$2,140,000
20" Diameter	6600	LF	$250	$1,650,000
Gravity Sewer				
18" Diameter	400	LF	$270	$108,000
8" Diameter	350	LF	$120	$42,000
24" Diameter	1300	LF	$360	$468,000
30" Diameter	450	LF	$450	$202,500
			Conveyance Subtotal	$9,610,500
Incremental Treatment Cost (1)	2.58	MGD	$5,347,000	$13,795,260
			Total Capital	**$23,405,800**

O&M-Annual	Quantity	Unit	Unit Cost	Cost
Pump Station				
10/11	5%	Capital / Year	$2,400,000	$120,000
12	5%	Capital / Year	$900,000	$45,000
13/13A	5%	Capital / Year	$1,700,000	$85,000
Odor Control Chemicals	26353	GAL	$2.71	$71,417
Force Main	17300	LF	$1.00	$17,300
Gravity Sewer	2500	LF	$1.00	$2,500
			Conveyance Subtotal	$341,300
Incremental Treatment Cost (1)	2.322	LF	$288,000	$668,736
			Total O&M	**$1,010,100**

Notes:

(1) Incremental Treatment Cost is assumed to be 50% of the Capital and O&M Cost/MGD established in the THC WWTP Improvements Pre Design Study

Alternative L6 - 10/11, 12, 13/13A, & Hallbrook

Capital Cost	Quantity	Unit	Unit Cost	Cost
Pump Station				
10/11	1	EA	$2,400,000	$2,400,000
12	1	EA	$900,000	$900,000
13/13A	1	EA	$1,700,000	$1,700,000
HB	1	EA	$700,000	$700,000
Force Main				
16" Diameter	10700	LF	$200	$2,140,000
20" Diameter	6600	LF	$250	$1,650,000
Gravity Sewer				
18" Diameter	400	LF	$270	$108,000
8" Diameter	350	LF	$120	$42,000
24" Diameter	1300	LF	$360	$468,000
30" Diameter	450	LF	$450	$202,500
			Conveyance Subtotal	$10,310,500
Incremental Treatment Cost (1)	2.65	MGD	$5,347,000	$14,169,550
			Total Capital	**$24,480,100**

O&M-Annual	Quantity	Unit	Unit Cost	Cost
Pump Station				
10/11	5%	Capital / Year	$2,400,000	$120,000
12	5%	Capital / Year	$900,000	$45,000
13/13A	5%	Capital / Year	$1,700,000	$85,000
HB	5%	Capital / Year	$700,000	$35,000
Odor Control Chemicals	26353	GAL	$2.71	$71,417
Force Main	17300	LF	$1.00	$17,300
Gravity Sewer	2500	LF	$1.00	$2,500
			Conveyance Subtotal	$376,300
Incremental Treatment Cost (1)	2.385	MGD	$288,000	$686,880
			Total O&M	**$1,063,180**

Notes:

(1) Incremental Treatment Cost is assumed to be 50% of the Capital and O&M Cost/MGD established in the THC WWTP Improvements Pre Design Study

A. 5

Life Cycle Cost Analysis - Full OCP Rates & Inflation Post OCP

Full OCP & Inflation Post OCP

Alternative	Included Sites	Convey/Treatment & THC			Treatment at KCMO NPV*	Difference in NPV
		Capital NPV	O&M NPV	Total NPV		
L1	13/13A	$8,200,000	$5,900,000	$14,100,000	$32,300,000	$18,200,000
L2	13/13A & HB	$9,200,000	$6,800,000	$16,000,000	$34,600,000	$18,600,000
L3	10/11 & 13/13A	$20,600,000	$15,600,000	$36,200,000	$79,800,000	$43,600,000
L4	10/11, 13/13A, & HB	$21,600,000	$16,500,000	$38,200,000	$82,100,000	$43,900,000
L5	10/11, 12, & 13/13A	$22,300,000	$17,100,000	$39,400,000	$82,100,000	$42,700,000
L6	10/11, 12, 13/13A, & HB	$23,400,000	$18,000,000	$41,300,000	$84,400,000	$43,100,000

*KCMO Rates to Increase per OCP Schedule through 2021:

2015	4.4%
2016	11.9%
2017	11.9%
2018	11.9%
2019	11.9%
2020	11.9%
2021	8.0%

After 2021, Annual Rate Increase is 1.9% (Inflation)

Economic Analysis Criteria

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%
Term:	20 years

Alternative L1 (Site 13 and 13A) - Full OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$9,273,112	$8,600,600																				
NPV of Capital Costs		$8,207,121																				
O&M Costs																						
Total, O&M Costs		$347,366	$381,644	$388,895	$396,284	$403,813	$411,486	$419,304	$427,271	$435,389	$443,661	$452,091	$460,681	$469,434	$478,353	$487,442	$496,703	$506,140	$515,757	$525,556	$535,542	$545,717
NPV of O&M Cost		$5,875,996	$327,616	$323,803	$320,034	$316,309	$312,627	$308,989	$305,392	$301,838	$298,325	$294,852	$291,420	$288,029	$284,676	$281,363	$278,088	$274,851	$271,652	$268,490	$265,365	$262,277

NPV Summary

Capital Cost @ THC	$8,207,121
O&M @ THC	$5,875,996
Total NPV	**$14,083,117**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$1,986,580	$2,145,506	$2,186,271	$2,227,810	$2,270,139	$2,313,271	$2,357,223	$2,402,011	$2,447,649	$2,494,154	$2,541,543	$2,589,832	$2,639,039	$2,689,181	$2,740,275	$2,792,341	$2,845,395	$2,899,458	$2,954,547	$3,010,684
NPV of O&M Cost		$32,315,368	$1,705,347	$1,786,396	$1,765,604	$1,745,054	$1,724,743	$1,704,668	$1,684,827	$1,665,217	$1,645,836	$1,626,679	$1,607,746	$1,589,033	$1,570,538	$1,552,259	$1,534,192	$1,516,335	$1,498,686	$1,481,242	$1,464,002	$1,446,962

NPV Summary

O&M @ KCMO	$32,315,368
Total NPV	**$32,315,368**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L2 (Site 13/13A, and HB) - Full OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$10,431,361	$9,674,850																				
NPV of Capital Costs		$9,232,224																				
O&M Costs																						
Total, O&M Costs		$400,600	$440,131	$448,493	$457,015	$465,698	$474,546	$483,563	$492,750	$502,113	$511,653	$521,374	$531,280	$541,375	$551,661	$562,142	$572,823	$583,707	$594,797	$606,098	$617,614	$629,349
NPV of O&M Cost		$6,776,495	$377,823	$373,426	$369,079	$364,783	$360,538	$356,341	$352,194	$348,095	$344,043	$340,039	$336,081	$332,169	$328,303	$324,482	$320,705	$316,972	$313,283	$309,637	$306,033	$302,471

NPV Summary

Capital Cost @ THC	$9,232,224
O&M @ THC	$6,776,495
Total NPV	**$16,008,719**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs			$2,128,479	$2,298,757	$2,342,433	$2,386,940	$2,432,291	$2,478,505	$2,525,596	$2,573,583	$2,622,481	$2,672,308	$2,723,082	$2,774,820	$2,827,542	$2,881,265	$2,936,009	$2,991,794	$3,048,638	$3,106,562	$3,165,586	$3,225,733
NPV of O&M Cost		$34,623,608	$1,827,157	$1,913,996	$1,891,719	$1,869,701	$1,847,939	$1,826,430	$1,805,172	$1,784,162	$1,763,395	$1,742,871	$1,722,585	$1,702,536	$1,682,720	$1,663,134	$1,643,777	$1,624,644	$1,605,735	$1,587,045	$1,568,573	$1,550,317

NPV Summary

O&M @ KCMO	$34,623,608
Total NPV	**$34,623,608**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L3 (Site 13/13A and 10/11) - Full OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$23,297,930	$21,608,300																				
NPV of Capital Costs		$20,619,716																				
O&M Costs																						
Total, O&M Costs		$923,200	$1,014,301	$1,033,572	$1,053,210	$1,073,221	$1,093,612	$1,114,391	$1,135,565	$1,157,140	$1,179,126	$1,201,529	$1,224,358	$1,247,621	$1,271,326	$1,295,481	$1,320,095	$1,345,177	$1,370,735	$1,396,779	$1,423,318	$1,450,361
NPV of O&M Cost		$15,616,726	$870,710	$860,575	$850,559	$840,659	$830,875	$821,204	$811,646	$802,199	$792,862	$783,634	$774,513	$765,498	$756,588	$747,782	$739,079	$730,476	$721,974	$713,571	$705,266	$697,057

NPV Summary

Capital Cost @ THC	$20,619,716
O&M @ THC	$15,616,726
Total NPV	**$36,236,442**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$4,905,636	$5,298,087	$5,398,751	$5,501,327	$5,605,852	$5,712,364	$5,820,899	$5,931,496	$6,044,194	$6,159,034	$6,276,055	$6,395,300	$6,516,811	$6,640,631	$6,766,803	$6,895,372	$7,026,384	$7,159,885	$7,295,923	$7,434,546
NPV of O&M Cost		$79,799,174	$4,211,163	$4,411,305	$4,359,961	$4,309,215	$4,259,059	$4,209,487	$4,160,492	$4,112,067	$4,064,206	$4,016,902	$3,970,149	$3,923,940	$3,878,268	$3,833,128	$3,788,514	$3,744,419	$3,700,837	$3,657,762	$3,615,188	$3,573,111

NPV Summary

O&M @ KCMO	$79,799,174
Total NPV	**$79,799,174**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L4 (Site 13/13A, 10/11, & HB) - Full OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$24,456,233	$22,682,600																				
NPV of Capital Costs		$21,644,866																				
O&M Costs																						
Total, O&M Costs		$976,400	$1,072,750	$1,093,133	$1,113,902	$1,135,066	$1,156,633	$1,178,609	$1,201,002	$1,223,821	$1,247,074	$1,270,768	$1,294,913	$1,319,516	$1,344,587	$1,370,134	$1,396,167	$1,422,694	$1,449,725	$1,477,270	$1,505,338	$1,533,939
NPV of O&M Cost		$16,516,650	$920,885	$910,167	$899,573	$889,103	$878,754	$868,526	$858,417	$848,426	$838,551	$828,791	$819,145	$809,610	$800,187	$790,874	$781,669	$772,571	$763,578	$754,691	$745,907	$737,225

NPV Summary

Capital Cost @ THC	$21,644,866
O&M @ THC	$16,516,650
Total NPV	**$38,161,516**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$5,047,535	$5,451,338	$5,554,913	$5,660,457	$5,768,005	$5,877,597	$5,989,272	$6,103,068	$6,219,026	$6,337,188	$6,457,594	$6,580,288	$6,705,314	$6,832,715	$6,962,537	$7,094,825	$7,229,626	$7,366,989	$7,506,962	$7,649,594
NPV of O&M Cost		$82,107,414	$4,332,973	$4,538,905	$4,486,076	$4,433,862	$4,382,255	$4,331,249	$4,280,837	$4,231,012	$4,181,766	$4,133,094	$4,084,988	$4,037,442	$3,990,449	$3,944,004	$3,898,099	$3,852,728	$3,807,886	$3,763,565	$3,719,760	$3,676,465

NPV Summary

O&M @ KCMO	$82,107,414
Total NPV	**$82,107,414**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L5 (Site 13/13A, 10/11, & 12) - Full OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$25,235,983	$23,405,800																				
NPV of Capital Costs		$22,334,980																				
O&M Costs																						
Total, O&M Costs		$1,010,100	$1,109,776	$1,130,862	$1,152,348	$1,174,243	$1,196,553	$1,219,288	$1,242,454	$1,266,061	$1,290,116	$1,314,628	$1,339,606	$1,365,059	$1,390,995	$1,417,424	$1,444,355	$1,471,797	$1,499,762	$1,528,257	$1,557,294	$1,586,883
NPV of O&M Cost		$17,086,714	$952,669	$941,581	$930,621	$919,790	$909,084	$898,503	$888,045	$877,709	$867,493	$857,396	$847,417	$837,554	$827,805	$818,170	$808,647	$799,235	$789,933	$780,739	$771,652	$762,670

NPV Summary

Capital Cost @ THC	$22,334,980
O&M @ THC	$17,086,714
Total NPV	**$39,421,694**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$5,047,535	$5,451,338	$5,554,913	$5,660,457	$5,768,005	$5,877,597	$5,989,272	$6,103,068	$6,219,026	$6,337,188	$6,457,594	$6,580,288	$6,705,314	$6,832,715	$6,962,537	$7,094,825	$7,229,626	$7,366,989	$7,506,962	$7,649,594
NPV of O&M Cost		$82,107,414	$4,332,973	$4,538,905	$4,486,076	$4,433,862	$4,382,255	$4,331,249	$4,280,837	$4,231,012	$4,181,766	$4,133,094	$4,084,988	$4,037,442	$3,990,449	$3,944,004	$3,898,099	$3,852,728	$3,807,886	$3,763,565	$3,719,760	$3,676,465

NPV Summary

O&M @ KCMO	$82,107,414
Total NPV	**$82,107,414**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L6 (Site 13/13A, 10/11, 12, & HB) -Full OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$26,394,286	$24,480,100																				
NPV of Capital Costs		$23,360,130																				
O&M Costs																						
Total, O&M Costs		$1,063,180	$1,168,094	$1,190,288	$1,212,903	$1,235,948	$1,259,431	$1,283,360	$1,307,744	$1,332,591	$1,357,911	$1,383,711	$1,410,001	$1,436,791	$1,464,091	$1,491,908	$1,520,254	$1,549,139	$1,578,573	$1,608,566	$1,639,129	$1,670,272
NPV of O&M Cost		$17,984,608	$1,002,731	$991,060	$979,525	$968,124	$956,856	$945,719	$934,711	$923,832	$913,079	$902,452	$891,948	$881,567	$871,306	$861,165	$851,141	$841,235	$831,443	$821,766	$812,201	$802,748

NPV Summary

Capital Cost @ THC	$23,360,130
O&M @ THC	$17,984,608
Total NPV	**$41,344,739**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$5,189,434	$5,604,588	$5,711,075	$5,819,586	$5,930,158	$6,042,831	$6,157,645	$6,274,640	$6,393,858	$6,515,341	$6,639,133	$6,765,277	$6,893,817	$7,024,799	$7,158,270	$7,294,278	$7,432,869	$7,574,093	$7,718,001	$7,864,643
NPV of O&M Cost		$84,415,655	$4,454,784	$4,666,505	$4,612,191	$4,558,508	$4,505,451	$4,453,011	$4,401,182	$4,349,956	$4,299,326	$4,249,285	$4,199,827	$4,150,944	$4,102,631	$4,054,879	$4,007,684	$3,961,038	$3,914,935	$3,869,368	$3,824,332	$3,779,819

NPV Summary

O&M @ KCMO	$84,415,655
Total NPV	**$84,415,655**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

A. 6

Life Cycle Cost Analysis - Full OCP Rates & NACWA Average Post OCP

Full OCP & NACWA Average Post OCP

Alternative	Included Sites	Convey/Treatment & THC			Treatment at KCMO NPV*	Difference in NPV
		Capital NPV	O&M NPV	Total NPV		
L1	13/13A	$8,200,000	$5,900,000	$14,100,000	$40,800,000	$26,700,000
L2	13/13A & HB	$9,200,000	$6,800,000	$16,000,000	$43,700,000	$27,700,000
L3	10/11 & 13/13A	$20,600,000	$15,600,000	$36,200,000	$100,800,000	$64,600,000
L4	10/11, 13/13A, & HB	$21,600,000	$16,500,000	$38,200,000	$103,700,000	$65,500,000
L5	10/11, 12, & 13/13A	$22,300,000	$17,100,000	$39,400,000	$103,700,000	$64,300,000
L6	10/11, 12, 13/13A, & HI	$23,400,000	$18,000,000	$41,300,000	$106,700,000	$65,400,000

*KCMO Rates to Increase per OCP Schedule through 2021:

2015	4.4%
2016	11.9%
2017	11.9%
2018	11.9%
2019	11.9%
2020	11.9%
2021	8.0%

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%

After 2021, Annual Rate Increase is 4.7% (2.8% (NACWA Average Rate Increase) + 1.9% (Inflation))

Economic Analysis Criteria

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%
Term:	20 years

Alternative L1 (Site 13 and 13A) - Full OCP & NACWA Average Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$9,273,112	$8,600,600																				
NPV of Capital Costs		$8,207,121																				
O&M Costs																						
Total, O&M Costs		$347,366	$381,644	$388,895	$396,284	$403,813	$411,486	$419,304	$427,271	$435,389	$443,661	$452,091	$460,681	$469,434	$478,353	$487,442	$496,703	$506,140	$515,757	$525,556	$535,542	$545,717
NPV of O&M Cost		$5,875,996	$327,616	$323,803	$320,034	$316,309	$312,627	$308,989	$305,392	$301,838	$298,325	$294,852	$291,420	$288,029	$284,676	$281,363	$278,088	$274,851	$271,652	$268,490	$265,365	$262,277

NPV Summary

Capital Cost @ THC	$8,207,121
O&M @ THC	$5,875,996
Total NPV	**$14,083,117**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$1,986,580	$2,145,506	$2,246,345	$2,351,923	$2,462,464	$2,578,200	$2,699,375	$2,826,246	$2,959,079	$3,098,156	$3,243,769	$3,396,226	$3,555,849	$3,722,974	$3,897,954	$4,081,158	$4,272,972	$4,473,802	$4,684,070	$4,904,222
NPV of O&M Cost		$40,831,521	$1,705,347	$1,786,396	$1,814,119	$1,842,272	$1,870,863	$1,899,896	$1,929,381	$1,959,323	$1,989,729	$2,020,608	$2,051,965	$2,083,809	$2,116,148	$2,148,988	$2,182,338	$2,216,206	$2,250,599	$2,285,526	$2,320,994	$2,357,014

NPV Summary

O&M @ KCMO	$40,831,521
Total NPV	**$40,831,521**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L2 (Site 13/13A, and HB) - Full OCP & NACWA Average Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$10,431,361	$9,674,850																				
NPV of Capital Costs		$9,232,224																				
O&M Costs																						
Total, O&M Costs		$400,600	$440,131	$448,493	$457,015	$465,698	$474,546	$483,563	$492,750	$502,113	$511,653	$521,374	$531,280	$541,375	$551,661	$562,142	$572,823	$583,707	$594,797	$606,098	$617,614	$629,349
NPV of O&M Cost		$6,776,495	$377,823	$373,426	$369,079	$364,783	$360,538	$356,341	$352,194	$348,095	$344,043	$340,039	$336,081	$332,169	$328,303	$324,482	$320,705	$316,972	$313,283	$309,637	$306,033	$302,471

NPV Summary

Capital Cost @ THC	$9,232,224
O&M @ THC	$6,776,495
Total NPV	**$16,008,719**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs			$2,128,479	$2,298,757	$2,406,798	$2,519,918	$2,638,354	$2,762,357	$2,892,188	$3,028,120	$3,170,442	$3,319,453	$3,475,467	$3,638,814	$3,809,838	$3,988,901	$4,176,379	$4,372,669	$4,578,184	$4,793,359	$5,018,647	$5,254,523
NPV of O&M Cost		$43,748,058	$1,827,157	$1,913,996	$1,943,699	$1,973,863	$2,004,496	$2,035,603	$2,067,194	$2,099,274	$2,131,853	$2,164,937	$2,198,534	$2,232,653	$2,267,301	$2,302,487	$2,338,219	$2,374,506	$2,411,356	$2,448,777	$2,486,780	$2,525,372

NPV Summary

O&M @ KCMO	$43,748,058
Total NPV	**$43,748,058**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L3 (Site 13/13A and 10/11) - Full OCP & NACWA Average Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$23,297,930	$21,608,300																				
NPV of Capital Costs		$20,619,716																				
O&M Costs																						
Total, O&M Costs		$923,200	$1,014,301	$1,033,572	$1,053,210	$1,073,221	$1,093,612	$1,114,391	$1,135,565	$1,157,140	$1,179,126	$1,201,529	$1,224,358	$1,247,621	$1,271,326	$1,295,481	$1,320,095	$1,345,177	$1,370,735	$1,396,779	$1,423,318	$1,450,361
NPV of O&M Cost		$15,616,726	$870,710	$860,575	$850,559	$840,659	$830,875	$821,204	$811,646	$802,199	$792,862	$783,634	$774,513	$765,498	$756,588	$747,782	$739,079	$730,476	$721,974	$713,571	$705,266	$697,057

NPV Summary

Capital Cost @ THC	$20,619,716
O&M @ THC	$15,616,726
Total NPV	**$36,236,442**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$4,905,636	$5,298,087	$5,547,097	$5,807,811	$6,080,778	$6,366,575	$6,665,804	$6,979,096	$7,307,114	$7,650,548	$8,010,124	$8,386,600	$8,780,770	$9,193,466	$9,625,559	$10,077,961	$10,551,625	$11,047,551	$11,566,786	$12,110,425
NPV of O&M Cost		##########	$4,211,163	$4,411,305	$4,479,764	$4,549,285	$4,619,885	$4,691,581	$4,764,389	$4,838,327	$4,913,413	$4,989,663	$5,067,098	$5,145,733	$5,225,590	$5,306,685	$5,389,039	$5,472,671	$5,557,601	$5,643,849	$5,731,435	$5,820,381

NPV Summary

O&M @ KCMO	$100,828,857
Total NPV	**$100,828,857**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L4 (Site 13/13A, 10/11, & HB) - Full OCP & NACWA Average Post OCP

Base Year for Cost Estimate = 2015
First Year of Operation = 2020
Mid-Point of Construction = 2019

Nominal Discount Rate: 3.10% (1)
Net Discount Rate: 1.20%
Inflation: 1.90%

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$24,456,233	$22,682,600																				
NPV of Capital Costs		$21,644,866																				
O&M Costs																						
Total, O&M Costs		$976,400	$1,072,750	$1,093,133	$1,113,902	$1,135,066	$1,156,633	$1,178,609	$1,201,002	$1,223,821	$1,247,074	$1,270,768	$1,294,913	$1,319,516	$1,344,587	$1,370,134	$1,396,167	$1,422,694	$1,449,725	$1,477,270	$1,505,338	$1,533,939
NPV of O&M Cost		$16,516,650	$920,885	$910,167	$899,573	$889,103	$878,754	$868,526	$858,417	$848,426	$838,551	$828,791	$819,145	$809,610	$800,187	$790,874	$781,669	$772,571	$763,578	$754,691	$745,907	$737,225

NPV Summary

Capital Cost @ THC	$21,644,866
O&M @ THC	$16,516,650
Total NPV	**$38,161,516**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$5,047,535	$5,451,338	$5,707,551	$5,975,806	$6,256,668	$6,550,732	$6,858,616	$7,180,971	$7,518,477	$7,871,845	$8,241,822	$8,629,188	$9,034,759	$9,459,393	$9,903,985	$10,369,472	$10,856,837	$11,367,108	$11,901,362	$12,460,727
NPV of O&M Cost		##########	$4,332,973	$4,538,905	$4,609,344	$4,680,876	$4,753,518	$4,827,288	$4,902,202	$4,978,279	$5,055,536	$5,133,993	$5,213,667	$5,294,577	$5,376,743	$5,460,184	$5,544,920	$5,630,972	$5,718,358	$5,807,101	$5,897,221	$5,988,739

NPV Summary

O&M @ KCMO	$103,745,394
Total NPV	**$103,745,394**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L5 (Site 13/13A, 10/11, & 12) - Full OCP & NACWA Average Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$25,235,983	$23,405,800																				
NPV of Capital Costs		$22,334,980																				
O&M Costs																						
Total, O&M Costs		$1,010,100	$1,109,776	$1,130,862	$1,152,348	$1,174,243	$1,196,553	$1,219,288	$1,242,454	$1,266,061	$1,290,116	$1,314,628	$1,339,606	$1,365,059	$1,390,995	$1,417,424	$1,444,355	$1,471,797	$1,499,762	$1,528,257	$1,557,294	$1,586,883
NPV of O&M Cost		$17,086,714	$952,669	$941,581	$930,621	$919,790	$909,084	$898,503	$888,045	$877,709	$867,493	$857,396	$847,417	$837,554	$827,805	$818,170	$808,647	$799,235	$789,933	$780,739	$771,652	$762,670

NPV Summary

Capital Cost @ THC	$22,334,980
O&M @ THC	$17,086,714
Total NPV	**$39,421,694**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$5,047,535	$5,451,338	$5,707,551	$5,975,806	$6,256,668	$6,550,732	$6,858,616	$7,180,971	$7,518,477	$7,871,845	$8,241,822	$8,629,188	$9,034,759	$9,459,393	$9,903,985	$10,369,472	$10,856,837	$11,367,108	$11,901,362	$12,460,727
NPV of O&M Cost		##########	$4,332,973	$4,538,905	$4,609,344	$4,680,876	$4,753,518	$4,827,288	$4,902,202	$4,978,279	$5,055,536	$5,133,993	$5,213,667	$5,294,577	$5,376,743	$5,460,184	$5,544,920	$5,630,972	$5,718,358	$5,807,101	$5,897,221	$5,988,739

NPV Summary

O&M @ KCMO	$103,745,394
Total NPV	**$103,745,394**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L6 (Site 13/13A, 10/11, 12, & HB) - Full OCP & NACWA Average Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$26,394,286	$24,480,100																				
NPV of Capital Costs		$23,360,130																				
O&M Costs																						
Total, O&M Costs		$1,063,180	$1,168,094	$1,190,288	$1,212,903	$1,235,948	$1,259,431	$1,283,360	$1,307,744	$1,332,591	$1,357,911	$1,383,711	$1,410,001	$1,436,791	$1,464,091	$1,491,908	$1,520,254	$1,549,139	$1,578,573	$1,608,566	$1,639,129	$1,670,272
NPV of O&M Cost		$17,984,608	$1,002,731	$991,060	$979,525	$968,124	$956,856	$945,719	$934,711	$923,832	$913,079	$902,452	$891,948	$881,567	$871,306	$861,165	$851,141	$841,235	$831,443	$821,766	$812,201	$802,748

NPV Summary

Capital Cost @ THC	$23,360,130
O&M @ THC	$17,984,608
Total NPV	**$41,344,739**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$5,189,434	$5,604,588	$5,868,004	$6,143,800	$6,432,559	$6,734,889	$7,051,429	$7,382,846	$7,729,840	$8,093,142	$8,473,520	$8,871,775	$9,288,749	$9,725,320	$10,182,410	$10,660,983	$11,162,049	$11,686,666	$12,235,939	$12,811,028
NPV of O&M Cost		##########	$4,454,784	$4,666,505	$4,738,924	$4,812,467	$4,887,151	$4,962,994	$5,040,015	$5,118,230	$5,197,660	$5,278,322	$5,360,235	$5,443,420	$5,527,896	$5,613,683	$5,700,802	$5,789,272	$5,879,115	$5,970,353	$6,063,006	$6,157,097

NPV Summary

O&M @ KCMO	$106,661,932
Total NPV	**$106,661,932**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

A. 7

Life Cycle Cost Analysis - Reduced OCP Rates & Inflation Post OCP

Reduced OCP & Inflation Post OCP

Alternative	Included Sites	Convey/Treatment & THC			Treatment at KCMO NPV*	Difference in NPV
		Capital NPV	O&M NPV	Total NPV		
L1	13/13A	$8,200,000	$5,900,000	$14,100,000	$29,500,000	$15,400,000
L2	13/13A & HB	$9,200,000	$6,800,000	$16,000,000	$31,600,000	$15,600,000
L3	10/11 & 13/13A	$20,600,000	$15,600,000	$36,200,000	$72,900,000	$36,700,000
L4	10/11, 13/13A, & HB	$21,600,000	$16,500,000	$38,200,000	$75,000,000	$36,800,000
L5	10/11, 12, & 13/13A	$22,300,000	$17,100,000	$39,400,000	$75,000,000	$35,600,000
L6	10/11, 12, 13/13A, & HB	$23,400,000	$18,000,000	$41,300,000	$77,100,000	$35,800,000

*KCMO Rates to Increase per OCP Schedule through 2021:

2015	4.4%
2016	9.9%
2017	9.9%
2018	9.9%
2019	9.9%
2020	9.9%
2021	8.0%

After 2021, Annual Rate Increase is 1.9% (Inflation)

Economic Analysis Criteria

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%
Term:	20 years

Alternative L1 (Site 13 and 13A) - Reduced OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$9,273,112	$8,600,600																				
NPV of Capital Costs		$8,207,121																				
O&M Costs																						
Total, O&M Costs		$347,366	$381,644	$388,895	$396,284	$403,813	$411,486	$419,304	$427,271	$435,389	$443,661	$452,091	$460,681	$469,434	$478,353	$487,442	$496,703	$506,140	$515,757	$525,556	$535,542	$545,717
NPV of O&M Cost		$5,875,996	$327,616	$323,803	$320,034	$316,309	$312,627	$308,989	$305,392	$301,838	$298,325	$294,852	$291,420	$288,029	$284,676	$281,363	$278,088	$274,851	$271,652	$268,490	$265,365	$262,277

NPV Summary

Capital Cost @ THC	$8,207,121
O&M @ THC	$5,875,996
Total NPV	**$14,083,117**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$1,815,282	$1,960,505	$1,997,754	$2,035,711	$2,074,390	$2,113,803	$2,153,966	$2,194,891	$2,236,594	$2,279,089	$2,322,392	$2,366,517	$2,411,481	$2,457,299	$2,503,988	$2,551,564	$2,600,043	$2,649,444	$2,699,784	$2,751,080
NPV of O&M Cost		$29,528,891	$1,558,299	$1,632,360	$1,613,360	$1,594,582	$1,576,023	$1,557,679	$1,539,549	$1,521,630	$1,503,919	$1,486,415	$1,469,114	$1,452,015	$1,435,115	$1,418,411	$1,401,902	$1,385,585	$1,369,458	$1,353,518	$1,337,765	$1,322,194

NPV Summary

O&M @ KCMO	$29,528,891
Total NPV	**$29,528,891**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L2 (Site 13/13A, and HB) - Reduced OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$10,431,361	$9,674,850																				
NPV of Capital Costs		$9,232,224																				
O&M Costs																						
Total, O&M Costs		$400,600	$440,131	$448,493	$457,015	$465,698	$474,546	$483,563	$492,750	$502,113	$511,653	$521,374	$531,280	$541,375	$551,661	$562,142	$572,823	$583,707	$594,797	$606,098	$617,614	$629,349
NPV of O&M Cost		$6,776,495	$377,823	$373,426	$369,079	$364,783	$360,538	$356,341	$352,194	$348,095	$344,043	$340,039	$336,081	$332,169	$328,303	$324,482	$320,705	$316,972	$313,283	$309,637	$306,033	$302,471

NPV Summary

Capital Cost @ THC	$9,232,224
O&M @ THC	$6,776,495
Total NPV	**$16,008,719**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs			$1,944,945	$2,100,541	$2,140,451	$2,181,119	$2,222,561	$2,264,789	$2,307,820	$2,351,669	$2,396,351	$2,441,881	$2,488,277	$2,535,554	$2,583,730	$2,632,821	$2,682,844	$2,733,818	$2,785,761	$2,838,690	$2,892,625	$2,947,585
NPV of O&M Cost		$31,638,097	$1,669,606	$1,748,957	$1,728,600	$1,708,481	$1,688,596	$1,668,942	$1,649,517	$1,630,318	$1,611,342	$1,592,587	$1,574,051	$1,555,730	$1,537,623	$1,519,726	$1,502,038	$1,484,555	$1,467,276	$1,450,198	$1,433,319	$1,416,636

NPV Summary

O&M @ KCMO	$31,638,097
Total NPV	**$31,638,097**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L3 (Site 13/13A and 10/11) - Reduced OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital and O&M Costs																						
Total, Capital Costs	$23,297,930	$21,608,300																				
NPV of Capital Costs		$20,619,716																				
O&M Costs																						
Total, O&M Costs		$923,200	$1,014,301	$1,033,572	$1,053,210	$1,073,221	$1,093,612	$1,114,391	$1,135,565	$1,157,140	$1,179,126	$1,201,529	$1,224,358	$1,247,621	$1,271,326	$1,295,481	$1,320,095	$1,345,177	$1,370,735	$1,396,779	$1,423,318	$1,450,361
NPV of O&M Cost		$15,616,726	$870,710	$860,575	$850,559	$840,659	$830,875	$821,204	$811,646	$802,199	$792,862	$783,634	$774,513	$765,498	$756,588	$747,782	$739,079	$730,476	$721,974	$713,571	$705,266	$697,057

NPV Summary

Capital Cost @ THC	$20,619,716
O&M @ THC	$15,616,726
Total NPV	**$36,236,442**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$4,482,635	$4,841,246	$4,933,230	$5,026,961	$5,122,473	$5,219,800	$5,318,976	$5,420,037	$5,523,018	$5,627,955	$5,734,886	$5,843,849	$5,954,882	$6,068,025	$6,183,317	$6,300,800	$6,420,516	$6,542,505	$6,666,813	$6,793,482
NPV of O&M Cost		$72,918,281	$3,848,044	$4,030,929	$3,984,012	$3,937,642	$3,891,811	$3,846,513	$3,801,743	$3,757,494	$3,713,760	$3,670,534	$3,627,812	$3,585,588	$3,543,854	$3,502,607	$3,461,839	$3,421,546	$3,381,722	$3,342,362	$3,303,459	$3,265,010

NPV Summary

O&M @ KCMO	$72,918,281
Total NPV	**$72,918,281**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L4 (Site 13/13A, 10/11, & HB) - Reduced OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital and O&M Costs																						
Total, Capital Costs	$24,456,233	$22,682,600																				
NPV of Capital Costs		$21,644,866																				
O&M Costs																						
Total, O&M Costs		$976,400	$1,072,750	$1,093,133	$1,113,902	$1,135,066	$1,156,633	$1,178,609	$1,201,002	$1,223,821	$1,247,074	$1,270,768	$1,294,913	$1,319,516	$1,344,587	$1,370,134	$1,396,167	$1,422,694	$1,449,725	$1,477,270	$1,505,338	$1,533,939
NPV of O&M Cost		$16,516,650	$920,885	$910,167	$899,573	$889,103	$878,754	$868,526	$858,417	$848,426	$838,551	$828,791	$819,145	$809,610	$800,187	$790,874	$781,669	$772,571	$763,578	$754,691	$745,907	$737,225

NPV Summary

Capital Cost @ THC	$21,644,866
O&M @ THC	$16,516,650
Total NPV	**$38,161,516**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$4,612,298	$4,981,282	$5,075,926	$5,172,369	$5,270,644	$5,370,786	$5,472,831	$5,576,815	$5,682,774	$5,790,747	$5,900,771	$6,012,886	$6,127,131	$6,243,546	$6,362,174	$6,483,055	$6,606,233	$6,731,751	$6,859,655	$6,989,988
NPV of O&M Cost		$75,027,488	$3,959,351	$4,147,526	$4,099,252	$4,051,540	$4,004,384	$3,957,776	$3,911,711	$3,866,182	$3,821,182	$3,776,707	$3,732,749	$3,689,303	$3,646,362	$3,603,922	$3,561,975	$3,520,517	$3,479,541	$3,439,042	$3,399,014	$3,359,452

NPV Summary

O&M @ KCMO	$75,027,488
Total NPV	**$75,027,488**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L5 (Site 13/13A, 10/11, & 12) - Reduced OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$25,235,983	$23,405,800																				
NPV of Capital Costs		$22,334,980																				
O&M Costs																						
Total, O&M Costs		$1,010,100	$1,109,776	$1,130,862	$1,152,348	$1,174,243	$1,196,553	$1,219,288	$1,242,454	$1,266,061	$1,290,116	$1,314,628	$1,339,606	$1,365,059	$1,390,995	$1,417,424	$1,444,355	$1,471,797	$1,499,762	$1,528,257	$1,557,294	$1,586,883
NPV of O&M Cost		$17,086,714	$952,669	$941,581	$930,621	$919,790	$909,084	$898,503	$888,045	$877,709	$867,493	$857,396	$847,417	$837,554	$827,805	$818,170	$808,647	$799,235	$789,933	$780,739	$771,652	$762,670

NPV Summary

Capital Cost @ THC	$22,334,980
O&M @ THC	$17,086,714
Total NPV	**$39,421,694**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$4,612,298	$4,981,282	$5,075,926	$5,172,369	$5,270,644	$5,370,786	$5,472,831	$5,576,815	$5,682,774	$5,790,747	$5,900,771	$6,012,886	$6,127,131	$6,243,546	$6,362,174	$6,483,055	$6,606,233	$6,731,751	$6,859,655	$6,989,988
NPV of O&M Cost		$75,027,488	$3,959,351	$4,147,526	$4,099,252	$4,051,540	$4,004,384	$3,957,776	$3,911,711	$3,866,182	$3,821,182	$3,776,707	$3,732,749	$3,689,303	$3,646,362	$3,603,922	$3,561,975	$3,520,517	$3,479,541	$3,439,042	$3,399,014	$3,359,452

NPV Summary

O&M @ KCMO	$75,027,488
Total NPV	**$75,027,488**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L6 (Site 13/13A, 10/11, 12, & HB) - Reduced OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$26,394,286	$24,480,100																				
NPV of Capital Costs		$23,360,130																				
O&M Costs																						
Total, O&M Costs		$1,063,180	$1,168,094	$1,190,288	$1,212,903	$1,235,948	$1,259,431	$1,283,360	$1,307,744	$1,332,591	$1,357,911	$1,383,711	$1,410,001	$1,436,791	$1,464,091	$1,491,908	$1,520,254	$1,549,139	$1,578,573	$1,608,566	$1,639,129	$1,670,272
NPV of O&M Cost		$17,984,608	$1,002,731	$991,060	$979,525	$968,124	$956,856	$945,719	$934,711	$923,832	$913,079	$902,452	$891,948	$881,567	$871,306	$861,165	$851,141	$841,235	$831,443	$821,766	$812,201	$802,748

NPV Summary

Capital Cost @ THC	$23,360,130
O&M @ THC	$17,984,608
Total NPV	**$41,344,739**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$4,741,961	$5,121,318	$5,218,623	$5,317,777	$5,418,815	$5,521,772	$5,626,686	$5,733,593	$5,842,531	$5,953,539	$6,066,656	$6,181,923	$6,299,379	$6,419,068	$6,541,030	$6,665,309	$6,791,950	$6,920,997	$7,052,496	$7,186,494
NPV of O&M Cost		$77,136,694	$4,070,658	$4,264,123	$4,214,492	$4,165,439	$4,116,957	$4,069,039	$4,021,678	$3,974,869	$3,928,605	$3,882,879	$3,837,686	$3,793,018	$3,748,871	$3,705,237	$3,662,111	$3,619,487	$3,577,359	$3,535,721	$3,494,569	$3,453,895

NPV Summary

O&M @ KCMO	$77,136,694
Total NPV	**$77,136,694**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

A. 8

Life Cycle Cost Analysis - Reduced OCP Rates & NACWA Average Post OCP

Reduced OCP & NACWA Average Post OCP

Alternative	Included Sites	Convey/Treatment & THC			Treatment at KCMO NPV*	Difference in NPV
		Capital NPV	O&M NPV	Total NPV		
L1	13/13A	$8,200,000	$5,900,000	$14,100,000	$37,300,000	$23,200,000
L2	13/13A & HB	$9,200,000	$6,800,000	$16,000,000	$40,000,000	$24,000,000
L3	10/11 & 13/13A	$20,600,000	$15,600,000	$36,200,000	$92,100,000	$55,900,000
L4	10/11, 13/13A, & HB	$21,600,000	$16,500,000	$38,200,000	$94,800,000	$56,600,000
L5	10/11, 12, & 13/13A	$22,300,000	$17,100,000	$39,400,000	$94,800,000	$55,400,000
L6	10/11, 12, 13/13A, & HB	$23,400,000	$18,000,000	$41,300,000	$97,500,000	$56,200,000

*KCMO Rates to Increase per OCP Schedule through 2021:

2015	4.4%
2016	9.9%
2017	9.9%
2018	9.9%
2019	9.9%
2020	9.9%
2021	8.0%

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%

After 2021, Annual Rate Increase is 4.7% (2.8% (NACWA Average Rate Increase) + 1.9% (Inflation))

Economic Analysis Criteria

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%
Term:	20 years

Alternative L1 (Site 13 and 13A) - Reduced OCP & NACWA Average Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$9,273,112	$8,600,600																				
NPV of Capital Costs		$8,207,121																				
O&M Costs																						
Total, O&M Costs		$347,366	$381,644	$388,895	$396,284	$403,813	$411,486	$419,304	$427,271	$435,389	$443,661	$452,091	$460,681	$469,434	$478,353	$487,442	$496,703	$506,140	$515,757	$525,556	$535,542	$545,717
NPV of O&M Cost		$5,875,996	$327,616	$323,803	$320,034	$316,309	$312,627	$308,989	$305,392	$301,838	$298,325	$294,852	$291,420	$288,029	$284,676	$281,363	$278,088	$274,851	$271,652	$268,490	$265,365	$262,277

NPV Summary

Capital Cost @ THC	$8,207,121
O&M @ THC	$5,875,996
Total NPV	**$14,083,117**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$1,815,282	$1,960,505	$2,052,648	$2,149,123	$2,250,131	$2,355,888	$2,466,614	$2,582,545	$2,703,925	$2,831,009	$2,964,067	$3,103,378	$3,249,237	$3,401,951	$3,561,843	$3,729,249	$3,904,524	$4,088,036	$4,280,174	$4,481,342
NPV of O&M Cost		$37,310,716	$1,558,299	$1,632,360	$1,657,692	$1,683,418	$1,709,543	$1,736,073	$1,763,015	$1,790,375	$1,818,159	$1,846,375	$1,875,029	$1,904,127	$1,933,677	$1,963,686	$1,994,160	$2,025,108	$2,056,535	$2,088,450	$2,120,861	$2,153,774

NPV Summary

O&M @ KCMO	$37,310,716
Total NPV	**$37,310,716**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L2 (Site 13/13A, and HB) - Reduced OCP & NACWA Average Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	Start Year 2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$10,431,361	$9,674,850																				
NPV of Capital Costs		$9,232,224																				
O&M Costs																						
Total, O&M Costs		$400,600	$440,131	$448,493	$457,015	$465,698	$474,546	$483,563	$492,750	$502,113	$511,653	$521,374	$531,280	$541,375	$551,661	$562,142	$572,823	$583,707	$594,797	$606,098	$617,614	$629,349
NPV of O&M Cost		$6,776,495	$377,823	$373,426	$369,079	$364,783	$360,538	$356,341	$352,194	$348,095	$344,043	$340,039	$336,081	$332,169	$328,303	$324,482	$320,705	$316,972	$313,283	$309,637	$306,033	$302,471

NPV Summary

Capital Cost @ THC	$9,232,224
O&M @ THC	$6,776,495
Total NPV	**$16,008,719**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
KCMO Treatment																						
O&M Costs																						
Total, O&M Costs			$1,944,945	$2,100,541	$2,199,266	$2,302,631	$2,410,855	$2,524,165	$2,642,801	$2,767,013	$2,897,062	$3,033,224	$3,175,786	$3,325,048	$3,481,325	$3,644,947	$3,816,260	$3,995,624	$4,183,418	$4,380,039	$4,585,901	$4,801,438
NPV of O&M Cost		$39,975,767	$1,669,606	$1,748,957	$1,776,099	$1,803,662	$1,831,653	$1,860,078	$1,888,944	$1,918,259	$1,948,028	$1,978,259	$2,008,960	$2,040,137	$2,071,797	$2,103,949	$2,136,600	$2,169,758	$2,203,430	$2,237,625	$2,272,351	$2,307,615

NPV Summary

O&M @ KCMO	$39,975,767
Total NPV	**$39,975,767**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L3 (Site 13/13A and 10/11) - Reduced OCP & NACWA Average Post OCP

Base Year for Cost Estimate = 2015
First Year of Operation = 2020
Mid-Point of Constru 2019

Nominal Discount Rate: 3.10% (1)
Net Discount Rate: 1.20%
Inflation: 1.90%

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	Start Year 2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$23,297,930	$21,608,300																				
NPV of Capital Costs		$20,619,716																				
O&M Costs																						
Total, O&M Costs		$923,200	$1,014,301	$1,033,572	$1,053,210	$1,073,221	$1,093,612	$1,114,391	$1,135,565	$1,157,140	$1,179,126	$1,201,529	$1,224,358	$1,247,621	$1,271,326	$1,295,481	$1,320,095	$1,345,177	$1,370,735	$1,396,779	$1,423,318	$1,450,361
NPV of O&M Cost		$15,616,726	$870,710	$860,575	$850,559	$840,659	$830,875	$821,204	$811,646	$802,199	$792,862	$783,634	$774,513	$765,498	$756,588	$747,782	$739,079	$730,476	$721,974	$713,571	$705,266	$697,057

NPV Summary

Capital Cost @ THC	$20,619,716
O&M @ THC	$15,616,726
Total NPV	**$36,236,442**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$4,482,635	$4,841,246	$5,068,784	$5,307,017	$5,556,447	$5,817,600	$6,091,027	$6,377,306	$6,677,039	$6,990,860	$7,319,430	$7,663,443	$8,023,625	$8,400,736	$8,795,570	$9,208,962	$9,641,783	$10,094,947	$10,569,410	$11,066,172
NPV of O&M Cost		$92,134,625	$3,848,044	$4,030,929	$4,093,485	$4,157,011	$4,221,523	$4,287,037	$4,353,567	$4,421,130	$4,489,741	$4,559,417	$4,630,174	$4,702,029	$4,775,000	$4,849,102	$4,924,355	$5,000,776	$5,078,382	$5,157,193	$5,237,227	$5,318,503

NPV Summary

O&M @ KCMO	$92,134,625
Total NPV	**$92,134,625**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L4 (Site 13/13A, 10/11, & HB) - Reduced OCP & NACWA Average Post OCP

Base Year for Cost Estimate = 2015
First Year of Operation = 2020
Mid-Point of Construction = 2019

Nominal Discount Rate: 3.10% (1)
Net Discount Rate: 1.20%
Inflation: 1.90%

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$24,456,233	$22,682,600																				
NPV of Capital Costs		$21,644,866																				
O&M Costs																						
Total, O&M Costs		$976,400	$1,072,750	$1,093,133	$1,113,902	$1,135,066	$1,156,633	$1,178,609	$1,201,002	$1,223,821	$1,247,074	$1,270,768	$1,294,913	$1,319,516	$1,344,587	$1,370,134	$1,396,167	$1,422,694	$1,449,725	$1,477,270	$1,505,338	$1,533,939
NPV of O&M Cost		$16,516,650	$920,885	$910,167	$899,573	$889,103	$878,754	$868,526	$858,417	$848,426	$838,551	$828,791	$819,145	$809,610	$800,187	$790,874	$781,669	$772,571	$763,578	$754,691	$745,907	$737,225

NPV Summary

Capital Cost @ THC	$21,644,866
O&M @ THC	$16,516,650
Total NPV	**$38,161,516**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$4,612,298	$4,981,282	$5,215,402	$5,460,526	$5,717,171	$5,985,878	$6,267,214	$6,561,773	$6,870,177	$7,193,075	$7,531,149	$7,885,113	$8,255,714	$8,643,732	$9,049,988	$9,475,337	$9,920,678	$10,386,950	$10,875,136	$11,386,268
NPV of O&M Cost		$94,799,677	$3,959,351	$4,147,526	$4,211,891	$4,277,255	$4,343,634	$4,411,042	$4,479,497	$4,549,014	$4,619,609	$4,691,301	$4,764,105	$4,838,038	$4,913,119	$4,989,366	$5,066,795	$5,145,426	$5,225,278	$5,306,368	$5,388,717	$5,472,344

NPV Summary

O&M @ KCMO	$94,799,677
Total NPV	**$94,799,677**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L5 (Site 13/13A, 10/11, & 12) - Reduced OCP & NACWA Average Post OCP

Base Year for Cost Estimate = 2015
First Year of Operation = 2020
Mid-Point of Construction = 2019

Nominal Discount Rate: 3.10% (1)
Net Discount Rate: 1.20%
Inflation: 1.90%

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$25,235,983	$23,405,800																				
NPV of Capital Costs		$22,334,980																				
O&M Costs																						
Total, O&M Costs		$1,010,100	$1,109,776	$1,130,862	$1,152,348	$1,174,243	$1,196,553	$1,219,288	$1,242,454	$1,266,061	$1,290,116	$1,314,628	$1,339,606	$1,365,059	$1,390,995	$1,417,424	$1,444,355	$1,471,797	$1,499,762	$1,528,257	$1,557,294	$1,586,883
NPV of O&M Cost		$17,086,714	$952,669	$941,581	$930,621	$919,790	$909,084	$898,503	$888,045	$877,709	$867,493	$857,396	$847,417	$837,554	$827,805	$818,170	$808,647	$799,235	$789,933	$780,739	$771,652	$762,670

NPV Summary

Capital Cost @ THC	$22,334,980
O&M @ THC	$17,086,714
Total NPV	**$39,421,694**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$4,612,298	$4,981,282	$5,215,402	$5,460,526	$5,717,171	$5,985,878	$6,267,214	$6,561,773	$6,870,177	$7,193,075	$7,531,149	$7,885,113	$8,255,714	$8,643,732	$9,049,988	$9,475,337	$9,920,678	$10,386,950	$10,875,136	$11,386,268
NPV of O&M Cost		$94,799,677	$3,959,351	$4,147,526	$4,211,891	$4,277,255	$4,343,634	$4,411,042	$4,479,497	$4,549,014	$4,619,609	$4,691,301	$4,764,105	$4,838,038	$4,913,119	$4,989,366	$5,066,795	$5,145,426	$5,225,278	$5,306,368	$5,388,717	$5,472,344

NPV Summary

O&M @ KCMO	$94,799,677
Total NPV	**$94,799,677**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative L6 (Site 13/13A, 10/11, 12, & HB) - Reduced OCP & NACWA Average Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$26,394,286	$24,480,100																				
NPV of Capital Costs		$23,360,130																				
O&M Costs																						
Total, O&M Costs		$1,063,180	$1,168,094	$1,190,288	$1,212,903	$1,235,948	$1,259,431	$1,283,360	$1,307,744	$1,332,591	$1,357,911	$1,383,711	$1,410,001	$1,436,791	$1,464,091	$1,491,908	$1,520,254	$1,549,139	$1,578,573	$1,608,566	$1,639,129	$1,670,272
NPV of O&M Cost		$17,984,608	$1,002,731	$991,060	$979,525	$968,124	$956,856	$945,719	$934,711	$923,832	$913,079	$902,452	$891,948	$881,567	$871,306	$861,165	$851,141	$841,235	$831,443	$821,766	$812,201	$802,748

NPV Summary

Capital Cost @ THC	$23,360,130
O&M @ THC	$17,984,608
Total NPV	**$41,344,739**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$4,741,961	$5,121,318	$5,362,020	$5,614,035	$5,877,894	$6,154,156	$6,443,401	$6,746,241	$7,063,314	$7,395,290	$7,742,868	$8,106,783	$8,487,802	$8,886,729	$9,304,405	$9,741,712	$10,199,572	$10,678,952	$11,180,863	$11,706,364
NPV of O&M Cost		$97,464,728	$4,070,658	$4,264,123	$4,330,298	$4,397,499	$4,465,744	$4,535,047	$4,605,426	$4,676,897	$4,749,478	$4,823,185	$4,898,035	$4,974,047	$5,051,239	$5,129,629	$5,209,235	$5,290,077	$5,372,173	$5,455,543	$5,540,207	$5,626,185

NPV Summary

O&M @ KCMO	$97,464,728
Total NPV	**$97,464,728**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

APPENDIX B

DYKE'S BRANCH FLOW CONVEYANCE EVALUATION CAPITAL AND NET PRESENT VALUE COST CALCULATIONS

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B. 1

Life Cycle Cost Analysis Summary

Dykes Branch Dry Weather Conveyance Alternatives - Life Cycle Cost Analysis

		Net Present Value (NPV) Summary of Financial Scenarios				
			Treatment at KCMO			
			Full OCP Rates		Reduced OCP Rates	
Alternative	Included IMF Sites	Treatment at THC WWTP	Inflation Post OCP (1)	NACWA Average Post OCP (2)	Inflation Post OCP (3)	NACWA Average Post OCP (4)
Incremental Cost for Dyke's Branch Only						
DB1 (FM Rehab)	--	$13,300,000	$29,300,000	$37,000,000	$26,800,000	$33,800,000
DB2 & L4 Upsized 10/11 (5)	--	$10,600,000	$29,300,000	$37,000,000	$26,800,000	$33,800,000
Combined Cost for Dyke's Branch and Leawood (Alternative L4)						
DB1 & L4	10/11, 13/13A, & HB	$51,500,000	$111,400,000	$140,800,000	$101,800,000	$128,600,000
DB2 & L4 Upsized 10/11 (5)	10/11, 13/13A, & HB	$48,800,000	$111,400,000	$140,800,000	$101,800,000	$128,600,000

Note: NPV comparison is for conveyance and treatment for flows up to 2Q for each site only. Assumes 90% of annual flow volume falls in the 2Q and remaining 10% is sent to KCMO for treatment

KCMO Rate Increase Scenarios

(1) Full OCP rates with post-OCP increases at inflation

(2) Full OCP rates with post-OCP increases at NACWA annual average rate increase plus inflation

(3) Reduced OCP rates with post-OCP increases at inflation

(4) Reduced OCP rates with post-OCP increases at NACWA annual average rate increase plus inflation

(5) Includes incremental cost increase to Leawood Alternative 4 due to increased size of Pump Station 10/11 and forcemain.

Economic Analysis Assumptions

NACWA Average Annual Rate Increase = 2.8%

Inflation = 1.9% (Nominal Discount Rate (3.1%) - Net discount Rate (1.2%))

Full OCP rates are 11.9% for years 2015-2020 and 8% for year 2021

Reduced OCP rates are 9.9% for years 2015-2020 and 8% for year 2021

B. 2

Flow Conveyance Evaluation Assumptions

Dyke's Branch Flow Conveyance Evaluation Assumptions

Design Flow Assumption

- Average Annual Daily Flow (AADF) data at IMF sites provided by CH2MHill except for Hallbrook. Hallbrook flows are calculated based on 241 connections at 300 gpd/connection.
- Pump station capacities are two times the AADF (2Q) for each pump station.
- Comparative analysis is for conveyance and treatment for all flows up to 2Q for each site only. Wet weather flows above 2Q are assumed to continue to be sent to KCMO for all IMF sites for all alternatives.
    - Flows up to 2Q are assumed to include 90% of the annual average flow volume; the remaining 10% of flow volume is assumed to be wet weather flow sent to KCMO for treatment. The basis for this assumption is an analysis of Site 13/13A by CH2MHill which indicates that flows above 2Q constitute 4% of the annual average flow volume for a typical year. A conservative wet weather flow volume of 10% was used for this preliminary study.

  Rehabilitation of Dyke's Branch forcemain is also assumed to result in the conveyance of 90% of the annual flow volume to THC for treatment. Wet weather flows are assumed to continue to be conveyed to THC for treatment through the separate wet weather forcemain.

Cost Estimate Assumptions

- Cost estimates and Net Present Values (NPV) shown in 2015 dollars.
- Basis of pump station cost estimates – JCW Shawnee Mission Park pump station costs, inflated to 2015 dollars, scaled to appropriate pump station size.
- Pump station factors used to estimate capital costs:
    - Structure Size – physical size of the pump station based on size and quantity of pumps
    - Hydraulic Capacity – based on total pump station capacity
    - Electrical Requirement – based on pump horsepower requirements
- Incremental costs for treatment of increased flow to THC were assumed to be 50% of the Capital and O&M costs/MGD established in the THC WWTP Improvements Pre Design Study.
- Estimated capital costs for Dyke's Branch forcemain rehabilitation (Alternative DB1) assumed no engineering fees (Owner will perform rehabilitation of forcemain) and no capital improvements to the Dyke's Branch pump station.
- Estimated capital costs for Dyke's Branch gravity sewer extension (Alternative DB2) includes capital improvements with in the Dyke's Branch Pump Station to direct dry weather flow through the gravity sewer. This assumption does not include engineering fees.

Life Cycle Cost Economic Analysis Assumptions

- Economic Analysis Criteria (OMB Circular A-94 Appendix C, December 2014 for 20-year planning Horizon):
    - Nominal Discount Rate: 3.1%
    - Net Discount Rate: 1.2%
    - Inflation: 1.9%

KCMO Rate Scenarios Evaluated:

- Full OCP Rates
    - 11.9% for years 2015-2020
    - 8% for year 2021
- Reduced OCP Rates
    - 9.9% for years 2015-2020
    - 8% for year 2021
- Post OCP Rate Increases (after 2021):
    - Evaluated at National Association of Clean Water Agencies (NACWA) average annual rate increase of 2.8% above inflation, based on the 10 year average rate increase identified in the 2011 NACA Service Charge Index.
    - Also evaluated with annual rate increase equal to inflation.

B. 3

Hydraulic Calculations

Force Main Hydraulics

Alternative	Force Main Segment	Flow (MGD) (1)	Diameter (in)	Length (ft)	Hf (ft) (2)
L4 & DB2	1	4.48	20	2200	4.43
(DB, 10/11, 13/13A, & HB)	2A	4.48	20	2400	4.83
	2B	4.48	20	6100	12.28
	3	6.44	24	3300	5.36
	4	6.58	24	3300	5.57

Notes:

(1) Hydraulic Calculation is based on two times the Average Annual Daily Flow (AADF)

(2) Friction Head is calculated using the Hazen Williams equation with a C = 120

Pump Station Sizing

Alternative	Pump Station	Hf (ft)	Hs (ft)[1][2]	TDH	Capacity (gpm)	Calculated HP	Pump Information	
							Motor Size	Quantity
L4-DB2 (DB, 10/11, 13/13A, & HB)	10/11	9.3	121	130	3111	157.5	100	3
	13/13A	10.9	27	38	1361	20.1	25	3
	HB	5.6	26	32	97	1.2	5	2

[1] 20 feet added due to pump station depth

[2] Elevation High Point Governs Static Head for Pump Stations 10/11 and 12

B. 4

Cost Estimates

Pump Station 10/11- With DB2 Flow

Year 2015
3 - 100 HP Submersible Pumps
Capacity 3111 gpm
Low TDH
13/13A Capacit 1361 gpm
Pump Station 13/13A estimated cost used as base for scaling 10/11 estimated cost $1,700,000

	Size Factor	Economy of Scale	% of Cost	Cost
Adjustments to Base Cost	1.5	1.22	45%	$936,930
Structure Size	2.3	1.51	35%	$899,592
Hydraulic Capacity	4	2.00	20%	$680,000
Electrical Requirements				
				$2,500,000
			Odor Control Station	$300,000
				$2,800,000

Note:
See Appendix A - Pump Station 13/13A for explanation of Scale Factors, Economy of Scale and % of Cost.

Alternative DB1 & L4 - 10/11, 13/13A, & Hallbrook

Capital Cost	Quantity	Unit	Unit Cost	Cost
Pump Station				
10/11	1	EA	$2,400,000	$2,400,000
13/13A	1	EA	$1,700,000	$1,700,000
HB	1	EA	$700,000	$700,000
Force Main				
16" Diameter	10700	LF	$200	$2,140,000
20" Diameter	6600	LF	$250	$1,650,000
Rehabilitation-CIPP (3)	18650	LF	$200	$3,730,000
Gravity Sewer				
18" Diameter	400	LF	$270	$108,000
24" Diameter	1300	LF	$360	$468,000
30" Diameter	450	LF	$450	$202,500
			Conveyance Subtotal	$13,098,500
Incremental Treatment Cost (1)	3.29	MGD	$5,347,000	$17,591,630
			Total Capital (2)	**$30,690,200**

O&M-Annual	Quantity	Unit	Unit Cost	Cost
Pump Station				
Dykes Branch	1	LS	$85,000	$85,000
10/11	5%	Capital / Year	$2,400,000	$120,000
13/13A	5%	Capital / Year	$1,700,000	$85,000
HB	5%	Capital / Year	$700,000	$35,000
Odor Control Chemicals	26353	GAL	$2.71	$71,417
Force Main	35950	LF	$1.00	$35,950
Gravity Sewer	2150	LF	$1.00	$2,150
			Conveyance Subtotal	$434,600
Incremental Treatment Cost (1)	3.04	MGD	$288,000	$875,808
			Total O&M	**$1,310,500**

Notes:

(1) Incremental Treatment Cost is assumed to be 50% of the Capital and O&M Cost/MGD established in the THC WWTP Improvements Pre Design Study

(2) Total Capital Costs does not include any capital improvements at the Dykes Branch Pump Station

(3) Assumes rehabilitation will be performed by Owner, therefore no Engineering consulting fees have been included

Alternative DB2 & L4 - DB, 10/11, 13/13A, & Hallbrook.

Capital Cost	Quantity	Unit	Unit Cost	Cost
Pump Station				
10/11/DB	1	EA	$2,800,000	$2,800,000
13/13A	1	EA	$1,700,000	$1,700,000
HB	1	EA	$700,000	$700,000
Dry Weather Diversion Structure	1	LS	$25,000	$25,000
Force Main				
20" Diameter	10700	LF	$250	$2,675,000
24" Diameter	6600	LF	$350	$2,310,000
Gravity Sewer				
12" Diameter	300	LF	$120	$36,000
18" Diameter	400	LF	$270	$108,000
24" Diameter	1300	LF	$360	$468,000
30" Diameter	450	LF	$450	$202,500
			Conveyance Subtotal	$11,024,500
Incremental Treatment Cost (1)	3.29	MGD	$5,347,000	$17,591,630
			Total Capital	**$28,616,200**

O&M-Annual	Quantity	Unit	Unit Cost	Cost
Pump Station				
10/11/DB	5%	Capital / Year	$2,800,000	$140,000
13/13A	5%	Capital / Year	$1,700,000	$85,000
HB	5%	Capital / Year	$700,000	$35,000
Odor Control Chemicals	40989.5	GAL	$2.71	$111,082
Force Main	17300	LF	$1.00	$17,300
Gravity Sewer	2450	LF	$1.00	$2,450
			Conveyance Subtotal	$390,900
Incremental Treatment Cost (1)	3.04	MGD	$288,000	$875,808
			Total O&M	**$1,266,800**

Notes:

(1) Incremental Treatment Cost is assumed to be 50% of the Capital and O&M Cost/MGD established in the THC WWTP Improvements Pre Design Study

B. 5

Life Cycle Cost Analysis - Full OCP Rates & Inflation Post OCP

Full OCP & Inflation Post OCP

Alternative	Included Sites	Convey/Treatment & THC			Treatment at KCMO NPV*	Difference in NPV
		Capital NPV	O&M NPV	Total NPV		
DB1 & L4	10/11, 13/13A, & HB	$29,300,000	$22,200,000	$51,500,000	$111,400,000	$59,900,000
DB2 & L4 (Upsized)	10/11, 13/13A, & HB	$27,300,000	$21,400,000	$48,700,000	$111,400,000	$62,700,000

*KCMO Rates to Increase per OCP Schedule through 2021:

2015	4.4%
2016	11.9%
2017	11.9%
2018	11.9%
2019	11.9%
2020	11.9%
2021	8.0%

After 2021, Annual Rate Increase is 1.9% (Inflation)

Economic Analysis Criteria

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%
Term:	20 years

Alternative DB1 & L4 (DB and Sites 13/13A, 10/11, & HB) - Full OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$33,089,976	$30,690,200																				
NPV of Capital Costs		$29,286,117																				
O&M Costs																						
Total, O&M Costs		$1,310,500	$1,439,819	$1,467,176	$1,495,052	$1,523,458	$1,552,404	$1,581,899	$1,611,956	$1,642,583	$1,673,792	$1,705,594	$1,738,000	$1,771,022	$1,804,671	$1,838,960	$1,873,900	$1,909,505	$1,945,785	$1,982,755	$2,020,427	$2,058,816
NPV of O&M Cost		$22,168,240	$1,235,989	$1,221,603	$1,207,385	$1,193,332	$1,179,442	$1,165,715	$1,152,147	$1,138,737	$1,125,483	$1,112,383	$1,099,436	$1,086,639	$1,073,991	$1,061,491	$1,049,136	$1,036,925	$1,024,856	$1,012,928	$1,001,138	$989,486

NPV Summary

Capital Cost @ THC	$29,286,117
O&M @ THC	$22,168,240
Total NPV	**$51,454,357**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$6,849,422	$7,397,375	$7,537,926	$7,681,146	$7,827,088	$7,975,803	$8,127,343	$8,281,762	$8,439,116	$8,599,459	$8,762,849	$8,929,343	$9,099,000	$9,271,881	$9,448,047	$9,627,560	$9,810,484	$9,996,883	$10,186,824	$10,380,373
NPV of O&M Cost		$111,418,405	$5,879,773	$6,159,219	$6,087,531	$6,016,677	$5,946,648	$5,877,434	$5,809,025	$5,741,413	$5,674,587	$5,608,540	$5,543,261	$5,478,742	$5,414,974	$5,351,948	$5,289,656	$5,228,088	$5,167,238	$5,107,095	$5,047,653	$4,988,902

NPV Summary

O&M @ KCMO	$111,418,405
Total NPV	**$111,418,405**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative DB2 & L4 (DB and Sites 13/13A, 10/11, & HB) - Full OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$30,853,803	$28,616,200																				
NPV of Capital Costs		$27,307,003																				
O&M Costs																						
Total, O&M Costs		$1,266,800	$1,391,807	$1,418,251	$1,445,198	$1,472,657	$1,500,637	$1,529,149	$1,558,203	$1,587,809	$1,617,977	$1,648,719	$1,680,045	$1,711,965	$1,744,493	$1,777,638	$1,811,413	$1,845,830	$1,880,901	$1,916,638	$1,953,054	$1,990,162
NPV of O&M Cost		$21,429,017	$1,194,774	$1,180,867	$1,167,123	$1,153,539	$1,140,113	$1,126,843	$1,113,727	$1,100,764	$1,087,952	$1,075,289	$1,062,774	$1,050,404	$1,038,178	$1,026,095	$1,014,152	$1,002,348	$990,681	$979,151	$967,754	$956,490

NPV Summary

Capital Cost @ THC	$27,307,003
O&M @ THC	$21,429,017
Total NPV	**$48,736,020**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$6,849,422	$7,397,375	$7,537,926	$7,681,146	$7,827,088	$7,975,803	$8,127,343	$8,281,762	$8,439,116	$8,599,459	$8,762,849	$8,929,343	$9,099,000	$9,271,881	$9,448,047	$9,627,560	$9,810,484	$9,996,883	$10,186,824	$10,380,373
NPV of O&M Cost		$111,418,405	$5,879,773	$6,159,219	$6,087,531	$6,016,677	$5,946,648	$5,877,434	$5,809,025	$5,741,413	$5,674,587	$5,608,540	$5,543,261	$5,478,742	$5,414,974	$5,351,948	$5,289,656	$5,228,088	$5,167,238	$5,107,095	$5,047,653	$4,988,902

NPV Summary

O&M @ KCMO	$111,418,405
Total NPV	**$111,418,405**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

B. 6

Life Cycle Cost Analysis - Full OCP Rates & NACWA Average Post OCP

Full OCP & NACWA Average Post OCP

Alternative	Included Sites	Convey/Treatment & THC			Treatment at KCMO NPV*	Difference in NPV
		Capital NPV	O&M NPV	Total NPV		
DB1 & L4	10/11, 13/13A, & HB	$29,300,000	$22,200,000	$51,500,000	$140,800,000	$89,300,000
DB2 & L4 (Upsized)	10/11, 13/13A, & HB	$27,300,000	$21,400,000	$48,740,000	$140,800,000	$92,060,000

*KCMO Rates to Increase per OCP Schedule through 2021:

2015	4.4%
2016	11.9%
2017	11.9%
2018	11.9%
2019	11.9%
2020	11.9%
2021	8.0%

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%

After 2021, Annual Rate Increase is 4.7% (2.8% (NACWA Average Rate Increase) + 1.9% (Inflation))

Economic Analysis Criteria

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%
Term:	20 years

Alternative DB1 & L4 (DB and Sites 13/13A, 10/11, & HB) - Full OCP & NACWA Average Post OCP

Base Year for Cost Estimate = 2015
First Year of Operation = 2020
Mid-Point of Construction = 2019

Nominal Discount Rate: 3.10% (1)
Net Discount Rate: 1.20%
Inflation: 1.90%

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	Start Year 2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$33,089,976	$30,690,200																				
NPV of Capital Costs		$29,286,117																				
O&M Costs																						
Total, O&M Costs		$1,310,500	$1,439,819	$1,467,176	$1,495,052	$1,523,458	$1,552,404	$1,581,899	$1,611,956	$1,642,583	$1,673,792	$1,705,594	$1,738,000	$1,771,022	$1,804,671	$1,838,960	$1,873,900	$1,909,505	$1,945,785	$1,982,755	$2,020,427	$2,058,816
NPV of O&M Cost		$22,168,240	$1,235,989	$1,221,603	$1,207,385	$1,193,332	$1,179,442	$1,165,715	$1,152,147	$1,138,737	$1,125,483	$1,112,383	$1,099,436	$1,086,639	$1,073,991	$1,061,491	$1,049,136	$1,036,925	$1,024,856	$1,012,928	$1,001,138	$989,486

NPV Summary

Capital Cost @ THC	$29,286,117
O&M @ THC	$22,168,240
Total NPV	**$51,454,357**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$6,849,422	$7,397,375	$7,745,052	$8,109,069	$8,490,196	$8,889,235	$9,307,029	$9,744,459	$10,202,449	$10,681,964	$11,184,016	$11,709,665	$12,260,019	$12,836,240	$13,439,544	$14,071,202	$14,732,549	$15,424,978	$16,149,952	$16,909,000
NPV of O&M Cost		$140,780,787	$5,879,773	$6,159,219	$6,254,804	$6,351,871	$6,450,446	$6,550,549	$6,652,207	$6,755,442	$6,860,279	$6,966,743	$7,074,859	$7,184,654	$7,296,152	$7,409,380	$7,524,365	$7,641,135	$7,759,718	$7,880,140	$8,002,431	$8,126,620

NPV Summary

O&M @ KCMO	$140,780,787
Total NPV	**$140,780,787**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative DB2 & L4 (DB and Sites 13/13A, 10/11, & HB) - Full OCP & NACWA Average Post OCP

Base Year for Cost Estimate = 2015
First Year of Operation = 2020
Mid-Point of Construction = 2019

Nominal Discount Rate: 3.10% (1)
Net Discount Rate: 1.20%
Inflation: 1.90%

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$30,853,803	$28,616,200																				
NPV of Capital Costs		$27,307,003																				
O&M Costs																						
Total, O&M Costs		$1,266,800	$1,391,807	$1,418,251	$1,445,198	$1,472,657	$1,500,637	$1,529,149	$1,558,203	$1,587,809	$1,617,977	$1,648,719	$1,680,045	$1,711,965	$1,744,493	$1,777,638	$1,811,413	$1,845,830	$1,880,901	$1,916,638	$1,953,054	$1,990,162
NPV of O&M Cost		$21,429,017	$1,194,774	$1,180,867	$1,167,123	$1,153,539	$1,140,113	$1,126,843	$1,113,727	$1,100,764	$1,087,952	$1,075,289	$1,062,774	$1,050,404	$1,038,178	$1,026,095	$1,014,152	$1,002,348	$990,681	$979,151	$967,754	$956,490

NPV Summary

Capital Cost @ THC	$27,307,003
O&M @ THC	$21,429,017
Total NPV	**$48,736,020**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$6,849,422	$7,397,375	$7,745,052	$8,109,069	$8,490,196	$8,889,235	$9,307,029	$9,744,459	$10,202,449	$10,681,964	$11,184,016	$11,709,665	$12,260,019	$12,836,240	$13,439,544	$14,071,202	$14,732,549	$15,424,978	$16,149,952	$16,909,000
NPV of O&M Cost		$140,780,787	$5,879,773	$6,159,219	$6,254,804	$6,351,871	$6,450,446	$6,550,549	$6,652,207	$6,755,442	$6,860,279	$6,966,743	$7,074,859	$7,184,654	$7,296,152	$7,409,380	$7,524,365	$7,641,135	$7,759,718	$7,880,140	$8,002,431	$8,126,620

NPV Summary

O&M @ KCMO	$140,780,787
Total NPV	**$140,780,787**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

B. 7

Life Cycle Cost Analysis - Reduced OCP Rates & Inflation Post OCP

Reduced OCP & Inflation Post OCP

Alternative	Included Sites	Convey/Treatment & THC			Treatment at KCMO NPV*	Difference in NPV
		Capital NPV	O&M NPV	Total NPV		
DB1 & L4	10/11, 13/13A, & HB	$29,300,000	$22,200,000	$51,500,000	$101,800,000	$50,300,000
DB2 & L4 (Upsized)	10/11, 13/13A, & HB	$27,300,000	$21,400,000	$48,700,000	$101,800,000	$53,100,000

*KCMO Rates to Increase per OCP Schedule through 2021:

2015	4.4%
2016	9.9%
2017	9.9%
2018	9.9%
2019	9.9%
2020	9.9%
2021	8.0%

After 2021, Annual Rate Increase is 1.9% (Inflation)

Economic Analysis Criteria

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%
Term:	20 years

Alternative DB1 & L4 (DB and Sites 13/13A, 10/11, & HB) - Reduced OCP & Inflation Post OCP

Base Year for Cost Estimate = 2015
First Year of Operation = 2020
Mid-Point of Construction = 2019

Nominal Discount Rate: 3.10% (1)
Net Discount Rate: 1.20%
Inflation: 1.90%

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital and O&M Costs																						
Total, Capital Costs	$33,089,976	$30,690,200																				
NPV of Capital Costs		$29,286,117																				
O&M Costs																						
Total, O&M Costs		$1,310,500	$1,439,819	$1,467,176	$1,495,052	$1,523,458	$1,552,404	$1,581,899	$1,611,956	$1,642,583	$1,673,792	$1,705,594	$1,738,000	$1,771,022	$1,804,671	$1,838,960	$1,873,900	$1,909,505	$1,945,785	$1,982,755	$2,020,427	$2,058,816
NPV of O&M Cost		$22,168,240	$1,235,989	$1,221,603	$1,207,385	$1,193,332	$1,179,442	$1,165,715	$1,152,147	$1,138,737	$1,125,483	$1,112,383	$1,099,436	$1,086,639	$1,073,991	$1,061,491	$1,049,136	$1,036,925	$1,024,856	$1,012,928	$1,001,138	$989,486

NPV Summary

Capital Cost @ THC	$29,286,117
O&M @ THC	$22,168,240
Total NPV	**$51,454,357**

KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$6,258,812	$6,759,517	$6,887,948	$7,018,819	$7,152,177	$7,288,068	$7,426,541	$7,567,646	$7,711,431	$7,857,948	$8,007,249	$8,159,387	$8,314,415	$8,472,389	$8,633,365	$8,797,398	$8,964,549	$9,134,875	$9,308,438	$9,485,298
NPV of O&M Cost		$101,811,062	$5,372,774	$5,628,124	$5,562,618	$5,497,873	$5,433,883	$5,370,637	$5,308,127	$5,246,345	$5,185,281	$5,124,929	$5,065,279	$5,006,323	$4,948,054	$4,890,462	$4,833,541	$4,777,283	$4,721,679	$4,666,723	$4,612,406	$4,558,721

NPV Summary

O&M @ KCMO	$101,811,062
Total NPV	**$101,811,062**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative DB2 & L4 (DB and Sites 13/13A, 10/11, & HB) - Reduced OCP & Inflation Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital and O&M Costs																						
Total, Capital Costs	$30,853,803	$28,616,200																				
NPV of Capital Costs		$27,307,003																				
O&M Costs																						
Total, O&M Costs		$1,266,800	$1,391,807	$1,418,251	$1,445,198	$1,472,657	$1,500,637	$1,529,149	$1,558,203	$1,587,809	$1,617,977	$1,648,719	$1,680,045	$1,711,965	$1,744,493	$1,777,638	$1,811,413	$1,845,830	$1,880,901	$1,916,638	$1,953,054	$1,990,162
NPV of O&M Cost		$21,429,017	$1,194,774	$1,180,867	$1,167,123	$1,153,539	$1,140,113	$1,126,843	$1,113,727	$1,100,764	$1,087,952	$1,075,289	$1,062,774	$1,050,404	$1,038,178	$1,026,095	$1,014,152	$1,002,348	$990,681	$979,151	$967,754	$956,490

NPV Summary

Capital Cost @ THC	$27,307,003
O&M @ THC	$21,429,017
Total NPV	**$48,736,020**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$6,258,812	$6,759,517	$6,887,948	$7,018,819	$7,152,177	$7,288,068	$7,426,541	$7,567,646	$7,711,431	$7,857,948	$8,007,249	$8,159,387	$8,314,415	$8,472,389	$8,633,365	$8,797,398	$8,964,549	$9,134,875	$9,308,438	$9,485,298
NPV of O&M Cost		$101,811,062	$5,372,774	$5,628,124	$5,562,618	$5,497,873	$5,433,883	$5,370,637	$5,308,127	$5,246,345	$5,185,281	$5,124,929	$5,065,279	$5,006,323	$4,948,054	$4,890,462	$4,833,541	$4,777,283	$4,721,679	$4,666,723	$4,612,406	$4,558,721

NPV Summary

O&M @ KCMO	$101,811,062
Total NPV	**$101,811,062**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

B. 8

Life Cycle Cost Analysis - Reduced OCP Rates & NACWA Average Post OCP

Reduced OCP & NACWA Average Post OCP

Alternative	Included Sites	Convey/Treatment & THC			Treatment at KCMO NPV*	Difference in NPV
		Capital NPV	O&M NPV	Total NPV		
DB1 & L4	10/11, 13/13A, & HB	$29,300,000	$22,200,000	$51,500,000	$128,600,000	$77,100,000
DB2 & L4 (Upsized)	10/11, 13/13A, & HB	$27,300,000	$21,400,000	$48,700,000	$128,600,000	$79,900,000

*KCMO Rates to Increase per OCP Schedule through 2021:

2015	4.4%
2016	9.9%
2017	9.9%
2018	9.9%
2019	9.9%
2020	9.9%
2021	8.0%

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%

After 2021, Annual Rate Increase is 4.7% (2.8% (NACWA Average Rate Increase) + 1.9% (Inflation))

Economic Analysis Criteria

Nominal Discount Rate:	3.10%
Net Discount Rate:	1.20%
Inflation:	1.90%
Term:	20 years

Alternative DB1 & L4 (DB and Sites 13/13A, 10/11, & HB) - Reduced OCP & NACWA Average Post OCP

Base Year for Cost Estimate = **2015**
First Year of Operation = **2020**
Mid-Point of Construction = **2019**

Nominal Discount Rate: **3.10%** (1)
Net Discount Rate: **1.20%**
Inflation: **1.90%**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Conveyance and THC Treatment																						
Capital Costs																						
Total, Capital Costs	$33,089,976	$30,690,200																				
NPV of Capital Costs		$29,286,117																				
O&M Costs																						
Total, O&M Costs		$1,310,500	$1,439,819	$1,467,176	$1,495,052	$1,523,458	$1,552,404	$1,581,899	$1,611,956	$1,642,583	$1,673,792	$1,705,594	$1,738,000	$1,771,022	$1,804,671	$1,838,960	$1,873,900	$1,909,505	$1,945,785	$1,982,755	$2,020,427	$2,058,816
NPV of O&M Cost		$22,168,240	$1,235,989	$1,221,603	$1,207,385	$1,193,332	$1,179,442	$1,165,715	$1,152,147	$1,138,737	$1,125,483	$1,112,383	$1,099,436	$1,086,639	$1,073,991	$1,061,491	$1,049,136	$1,036,925	$1,024,856	$1,012,928	$1,001,138	$989,486

NPV Summary

Capital Cost @ THC	$29,286,117
O&M @ THC	$22,168,240
Total NPV	**$51,454,357**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
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O&M Costs																						
Total, O&M Costs		-	$6,258,812	$6,759,517	$7,077,215	$7,409,844	$7,758,106	$8,122,737	$8,504,506	$8,904,218	$9,322,716	$9,760,884	$10,219,645	$10,699,969	$11,202,867	$11,729,402	$12,280,684	$12,857,876	$13,462,196	$14,094,919	$14,757,381	$15,450,977
NPV of O&M Cost		$128,641,596	$5,372,774	$5,628,124	$5,715,467	$5,804,165	$5,894,239	$5,985,711	$6,078,603	$6,172,936	$6,268,734	$6,366,017	$6,464,811	$6,565,138	$6,667,022	$6,770,487	$6,875,557	$6,982,259	$7,090,616	$7,200,654	$7,312,401	$7,425,881

NPV Summary

O&M @ KCMO	$128,641,596
Total NPV	**$128,641,596**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

Alternative DB2 & L4 (DB and Sites 13/13A, 10/11, & HB) - Reduced OCP & NACWA Average Post OCP

Base Year for Cost Estimate = 2015
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Nominal Discount Rate: 3.10% (1)
Net Discount Rate: 1.20%
Inflation: 1.90%

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
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NPV Summary

Capital Cost @ THC	$27,307,003
O&M @ THC	$21,429,017
Total NPV	**$48,736,020**

Project Element	Capital Cost (In Mid-Point of Construction Year Dollars)	Cost (2015 Dollars)	2020 (Start Year)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
KCMO Treatment																						
O&M Costs																						
Total, O&M Costs		-	$6,258,812	$6,759,517	$7,077,215	$7,409,844	$7,758,106	$8,122,737	$8,504,506	$8,904,218	$9,322,716	$9,760,884	$10,219,645	$10,699,969	$11,202,867	$11,729,402	$12,280,684	$12,857,876	$13,462,196	$14,094,919	$14,757,381	$15,450,977
NPV of O&M Cost		$128,641,596	$5,372,774	$5,628,124	$5,715,467	$5,804,165	$5,894,239	$5,985,711	$6,078,603	$6,172,936	$6,268,734	$6,366,017	$6,464,811	$6,565,138	$6,667,022	$6,770,487	$6,875,557	$6,982,259	$7,090,616	$7,200,654	$7,312,401	$7,425,881

NPV Summary

O&M @ KCMO	$128,641,596
Total NPV	**$128,641,596**

(1) Economic Evaluation Criteria from OMB Circular No. A-94 Appendix C (Revised 2014) for 20 year evaluation period

APPENDIX C

SAMPLING PLAN

FINAL

TOMAHAWK CREEK WWTP CHARACTERIZATION SAMPLING PLAN

JCW NO. THM1-C026

PREPARED FOR

JOHNSON COUNTY KANSAS Wastewater

28 JANUARY 2015

HDR

BLACK & VEATCH Building a world of difference.

B&V PROJECT 185289

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1 TOMAHAWK CREEK WWTP CHARACTERIZATION SAMPLING PLAN

The objective of this memorandum is to outline the sampling plan to characterize the influent wastewater to the Tomahawk Creek Wastewater Treatment Plant (WWTP). The wastewater characteristics will be used to develop a process model using the BioWIN process simulator to evaluate the selected process technology for the expanded Tomahawk Creek WWTP. The level of evaluation and scope of the BioWIN modeling effort will be developed after a treatment technology is selected. However, for any treatment technology, the model is highly dependent on accurate characterization of the Tomahawk Creek influent wastewater. This sampling plan outlines (1) the goals of this special sampling campaign, (2) sampling locations, (3) analytical tests and sampling protocol, (4) study participants and responsibilities.

1.1 SPECIAL SAMPLING GOALS

The goals of the sampling plan are to establish the design influent wastewater characteristics for the Tomahawk Creek WWTP expansion and upgrade project and evaluate potential influences on in-stream water quality. Special sampling is required to characterize the influent to the WWTP under the following scenarios:

- Seasonal dry weather conditions
- Diurnal seasonal dry weather conditions
- Wet weather conditions

The wastewater characteristics in conjunction with historical flow data will be used in a BioWIN model to simulate the selected treatment technology for the Tomahawk Creek WWTP expansion project.

1.2 SAMPLING LOCATIONS

Figure 1 shows two sampling locations within the treatment plant that were identified to develop the wastewater characteristics: (1) the raw influent to the primary settling tanks before any sidestream, trickling filter recirculation or chemical addition and (2) the final settling tank effluent before chemical addition and disinfection.

Black & Veatch and JCW staff needs to coordinate on the influent sample collection. The current sampling effort is yielding influent wastewater concentrations of BOD and TSS much higher than the historical grab sample data and higher than experienced at other local JCW WWTPs. Sampling from the two influent interceptors will probably remain a requirement with those samples blended together to make a single composite for analysis. These details and others must be coordinated prior to beginning this influent characterization study.

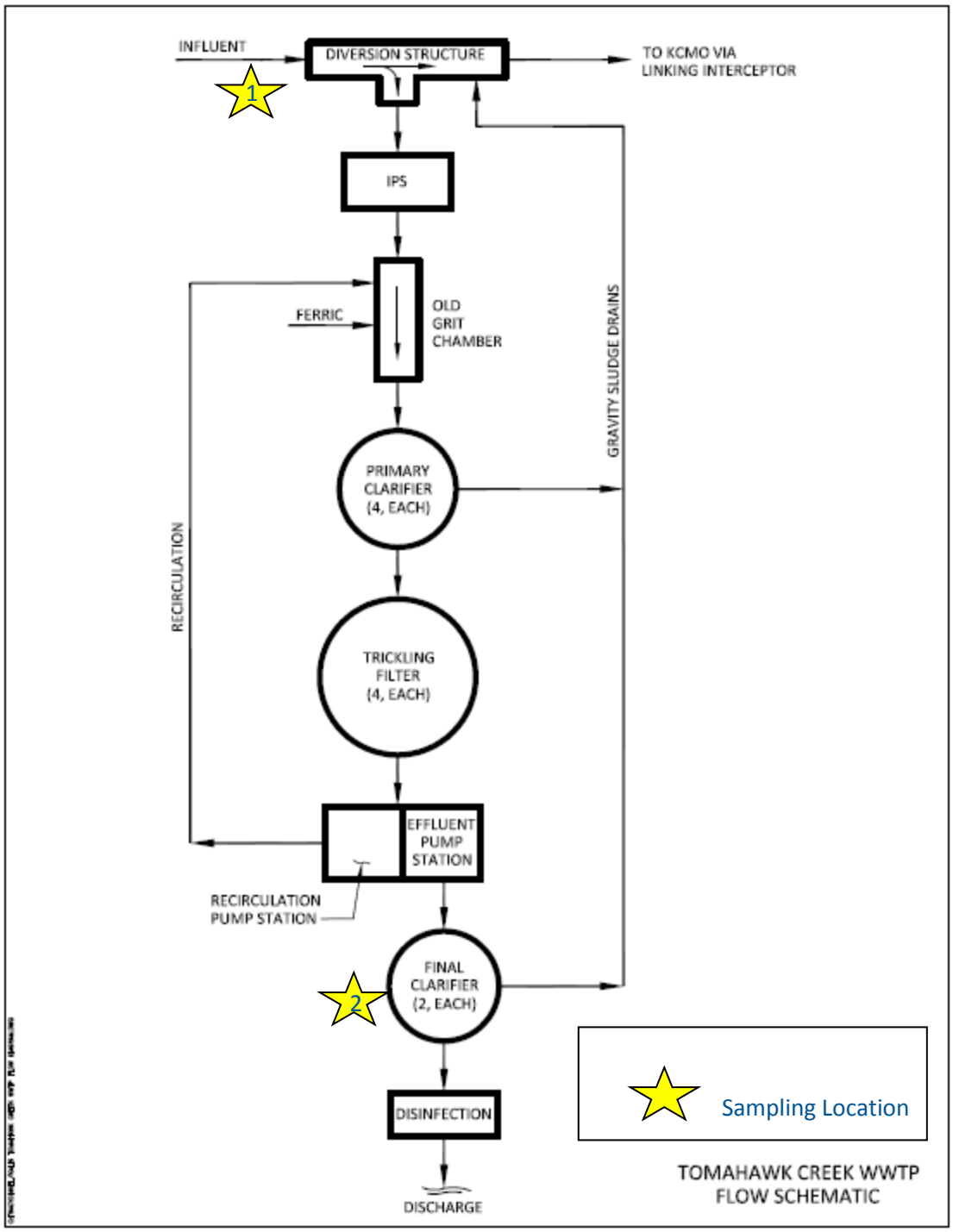

Figure 1-1: Sampling Point Locations

1. Raw wastewater (RWW) influent to primary clarifiers
   - RWW without any sidestream, recycle flows or chemical addition
2. Final settling tank effluent (FSTE)
   - FSTE before chemical addition and disinfection

1.3 ANALYTICAL TESTS FOR INFLUENT CHARACTERIZATION AND SAMPLING

Table 1 shows the analytical parameters for the sampling campaign. Although the trickling filter does not fully biodegrade all colloidal material, it is assumed that much of the readily biodegradable COD, BOD and TKN are consumed and, therefore, the floculated and filtered (ff) test will be performed on the plant influent and effluent. The ffCOD, ffBOD, ffTKN, ammonia, nitrite + nitrate will be measured in the plant effluent before disinfection, while all other parameters will be measured in the raw influent for all samples.

Since the current Tomahawk Creek WWTP secondary treatment process uses tricking filters (TF), many wastewater constituents are not removed to the extent that they are with conventional activated sludge systems. Wastewater characteristics that cannot be developed through direct sampling of the effluent may be derived from previous studies on other activated sludge treatment plants in the area that are assumed to have similar wastewater characteristics. Alternatively an activated sludge bench test bioassay can be performed for more comprehensive wastewater characterization to determine the non-biodegradable components of nitrogen and phosphorous.

The bench test bioassay will consist of collecting a MLSS sample from either Blue River Main or Douglas L. Smith Middle Basin and washing that MLSS to remove soluble contaminants unique to those two WWTPs. The washed MLSS will be added to a sample of Tomahawk Creek WWTP primary effluent and the mixture will be aerated for up to two days to ensure that complete nitrification has occurred. The solids will be allowed to settle and the supernatant will be analyzed for ffCOD, ffBOD, ffTKN, ammonia, ortho phosphorus and soluble total phosphorus.

Table 1-1: Sampling Parameters

Sampling and Analytical Requirements for Wastewater Characterization

Treatment Facility:
Tomahawk Creek WWTP

	Sampling point		
	1	2	
Sample Parameters	**Raw Influent to Primary Clarifiers**	**Final Clarifier Effluent**	
	Daily	Daily	**LEGEND:**
Flow	x		
TSS	x		Total suspended solids
VSS	x		Volatile suspended solids
COD	x		Total COD
ffCOD[2]	x	x	"Flocculated filtered" COD as per test
$TBOD_5$	x		Total 5-day BOD (uninhibited)
$ffCBOD_5$	x	x	"Flocculated filtered" soluble Carbonaceous 5-day BOD
TKN	x		Total TKN
ffTKN	x	x	"Flocculated filtered" Soluble TKN
NH3-N	x	x	Total ammonia
NOx-N	x	x	Nitrate + nitrite
TP	x		Total P
sTP (GF)	x		Soluble TP (glass fiber filtrate)
PO4-P	x		Orthophosphate P
VFAs[2]	x		Volatile fatty acids (speciated)
Alkalinity	x		Alkalinity (as CaCO3)
pH	x		pH, SU
Temp	x		Temperature, deg C
Ca	x		Calcium, mg/L
Mg	x		Magnesium, mg/L

Notes:
1. **Use flow proportioned composite samplers**
2. **Refer to Appendix**

The sampling campaign is broken down into three parts; each of the three parts will be performed four times coinciding with the four seasons to capture the seasonal variability in the wastewater characteristics.

- Two weeks of daily composite samples collected every 15-20 minutes in a single large bottle (1 sample per day for 14 days = 14 samples total)
- Two nonconsecutive days of 24-hour discrete samples, each 24-hour set should be collected every 1-hour in individual bottles then manually combined into 2-hour composite samples (12 samples per day for 2 days = 24 samples total)
- One 24 hour discrete samples during a wet weather event collected every 1-hour in individual bottles (24 samples total)

1.4 LONG TERM INFLUENT CHARACTERIZATION

In addition to the 4 two week characterization events, a long term sampling effort is needed to develop typical influent wastewater characteristics. The current sampling locations seem to have an elevation that allows sludge flow to back up to the sampling point at night. A new sampling location is needed for each influent interceptor far enough upstream such that the sewer bottom elevation is higher than the overflow weir to Kansas City Missouri. By moving this far upstream, interference in sampling from a backup of primary and secondary sludge should not occur at nighttime low flow conditions. Because of the location, composite samples must be time weighted.

This sampling effort must start soon and extend for a year or until such time that the plant design begins. The wastewater influent data being used in the conceptual process evaluation is JCW Blue River Main data. A Tomahawk Creek WWTP influent database is needed to ensure that the JCW Blue River main data is either representative of Tomahawk Creek WWTP influent quality or to define a correction factor to use to adjust Blue River main data to be representative of Tomahawk Creek WWTP influent wastewater.

1.5 STUDY PARTICIPANTS AND RESPONSIBILITIES

Roles and responsibilities of the participants in this study are briefly described in the following paragraphs.

- **Black & Veatch (B&V)** – B&V shall act as the primary investigator in this study and shall provide study oversight, and evaluate data collected from the study.
- **Johnson County Wastewater (JCW)** – JCW shall coordinate field sampling and laboratory analytical services for the study and provide laboratory analytical services for the study.

Contact information for study participants is provided in Table 2.

Table 1-2: Contact Information

Organization	Contact	Phone	E-mail
B&V	Roland Jezek	917-327-9069	JezekR@BV.com
B&V	Ed Kobylinski	913-458-3370	KobylinskiEA@BV.com
JCW	Tony Holt	913-722-3633	Tony.Holt@JCW.org

Appendix A: Special Sampling Notes Page

INTENSIVE SAMPLING PROGRAM FOR WASTEWATER CHARACTERIZATION ANALYSIS

INTRODUCTION

An intensive sampling program will be conducted at the plant with the main objectives of providing information on:
1. Influent wastewater characteristics; for example, the division of influent organic material into biodegradable and unbiodegradable fractions, the fraction of the influent TKN in the form of ammonia, etc.
2. The form of the diurnal influent flow and concentration patterns (COD, TKN, TP etc.).
3. Characterizing performance of the system.

Data from the sampling program will be utilized, in conjunction with historical plant data, to calibrate the biological process model for the plant.

OVERALL PROGRAM

The intensive sampling program should be conducted over a two week period, and involves two main components:
1. Collection and analysis of daily composite or grab samples at a number of locations for a number of days defined in the spreadsheet.
2. Collection and analysis of twelve to twenty four (12-24) grab samples at 1-hour to 2-hour intervals (i.e. diurnal sampling) at a number of locations for a number of days defined in the spreadsheet.

The sampling program should be scheduled during a period where major disruptions in plant operation (e.g. taking units on/off line) are not envisaged.

SPECIFIC PROGRAM

The spreadsheet Table identifies sample locations and analyses required.

The latest edition of Standard Methods for the Examination of Water & Wastewater (APHA/AWWA/WEF) should be used for all analyses where possible. Specific notes are provided below for analyses requiring additional or special guidance

SPECIFIC NOTES ON ANALYSIS METHODS

ffCOD (and ffTKN):
Influent readily biodegradable COD concentration (RBCOD) will be indirectly measured using the ffCOD (flocculated and filtered COD) method (analogous to the Mamais et al. (1993) method for ffCOD, but modified according to Wentzel et al. (2000)). The method is based on a physical separation, which involves pre-flocculation of the sample followed by filtration. It is assumed that the flocculation step removes the colloidal material, resulting in a filtrate that contains only "truly soluble" material. The procedure is outlined briefly below:
¨ Preparation of samples can be carried out in 250 mL beakers, mounted on a laboratory magnetic stirrer; or can be carried out on a jar test gang stirrer, with six simultaneous stirrers. If using the standard jar test apparatus, then larger sample volumes than 250 mL would be used - say, 1-liter samples. (In this case the alum dosage would be increased to 10 mL in 1-liter);
¨ 1 mL of 50 g/L aluminum sulfate ($Al_2(SO_4)_3.15H_2O$)solution is added to 100 mL of wastewater (or 10 mL in 1-liter);
¨ The sample is then stirred rapidly (approx. 200 rpm on the jar test apparatus) for approximately 2 minutes;
¨ The sample is then stirred slowly (approx. 10 rpm on the jar test apparatus) for 15 minutes;
¨ The sample is then allowed to settle (approximately 15 minutes), and a sample of the clear liquid supernatant is withdrawn;
¨ The supernatant sample is filtered using a glass fiber GF/C (Whatmans) filter, and the filtrate COD and TKN are analyzed.

Important Note: Samples for ALL filtered and floc-filtered samples SHOULD NOT BE PRESERVED BEFORE FILTERING. Preservation should only occur AFTER filtration or floc-filtration.

Blending of samples:
Samples for COD (total) should be thoroughly homogenized in a high-speed blender prior to analysis.

MLSS and MLVSS Measurements
Avoid using too small sample volumes for filtering samples. At least 50 mL, and preferably 100 mL samples should be used. Take care to not allow residual solids on the sides of the Buchner funnel after filtering. Take care to "wipe" solids from the funnel with the filter paper. Allow sufficient time for drying (MLSS) and burning (MLVSS). 2 hours drying and 1 hour burning is often sufficient and may avoid the re-weighing, re dry/burn, re-weigh etc. as recommended in Standard Methods.

VFAs
VFA analysis will need to be conducted off-site since gas chromatography (GC) is required to isolate and quantify the individual short-chained molecules (acetic acid, propionic acid, butyric acid, isobutyric acid, valeric acid, and isovaleric acid).

Method
No standard method exists for the determination of VFA's in domestic wastewaters. Standard Methods for the Examination of Water and Wastewater 2005 does contain a gas chromatographic method 5560 D. for VFA concentration measurements of digested sludge samples. This method will need to be adapted for wastewater samples. Titration methods have also been used to monitor VFA levels in anerobic digesters. However, these methods are not sensitive enough for low VFA levels observed in most municipal wastewaters and should not be used.

A good reference for VFA measurement using GC is, "Development of a headspace solid-phase microextraction procedure for the determination of free volatile fatty acids in waste waters", Journal of Chromatography A, 873 (2000) 107–115, M. Abalos , J.M. Bayona , J. Pawliszyn (2000), which contains a description of a method using solid-phase micro-extraction, along with a general discussion and references to other measurement techniques. Another good reference is Chapter 10 from WERF Report 99-WWF-3 published in 2003 "Methods for Wastewater Characterization in Activated Sludge Modelling".

The EPA has published several methods for measuring organic chemicals in water (such as EPA 8015B and EPA 624) using GC, including methods for volatile organics. These methods are not specifically designed for VFA measurement and should not be used.

There are not many laboratories that conduct VFA analysis for wastewater, but Black & Veatch has received very good results from the following company:

Minnesota Valley Testing Laboratories, Inc.
1126 N. Front Street
New Ulm, MN 56073
1-800-782-3557 (contact: Mike Wierima)

Sampling
Ideally, the wastewater sample should be filtered as quickly as possible, using pressure filtration (never vacuum filtration which may draw off the volatile acids), and stored in a sealed container at 4°C or less. Some investigators have gone as far as freezing samples to preserve them to ensure that the VFA's remain in the sample. This will probably be impractical on most sites and unnecessary unless the accuracy of measurement is extremely critical (say for research-level investigation of VFA's).

Reporting
The results from the VFA analysis should be expressed both as individual acids and as total VFA (sum of the individual acids). Concentrations of acids should be expressed as mg/L of COD.

APPENDIX D

DEVELOPMENT OF FUTURE FLOWS AND LOADS

D. Development of Future Flows and Loads

The flows developed inTM1 Section 3 and the influent wastewater concentrations for Blue River Main WWTF were used to develop revised influent loads at Tomahawk Creek WWTF. Table D-1 presents the revised loads. The loads were calculated by using the THC flow data and the pollutant concentrations from TM1 Table 4-3.

Table D-1: THC Flow and Concentrations from the Analysis of Blue River Main WWTF Influent Characteristics

PARAMETER	ANNUAL AVERAGE		MM:AA	MAXIMUM MONTHLY AVERAGE		PD:AA	PEAK DAY	
Flow, mgd	13.8			20.8			70.4	
	mg/L	ppd		mg/L	ppd		mg/L	ppd
TSS	230	26,471	1.42	217	27,589	2.02	91.1	53,472
BOD	180	20,717	1.30	155	26,932	1.81	63.9	37,497
TKN	37.8	4,351	1.23	30.9	5,352	1.49	11.0	6,483
Ammonia	21.3	2,453	1.23	17.4	3,017	1.47	6.14	3,606
Total Phosphorus	4.6	525	1.26	3.8	662	1.67	1.49	877
Ortho-Phosphate	1.7	197	1.35	1.5	265	1.82	0.61	358

The flows and loads developed in the table above were increased by approximately sixteen percent (Table 3-9) to accommodate growth in the Tomahawk Creek and LIC basins. Based on the information supplied by HDR Inc., this percentage factor also includes the load increase from flow diverted from discharge to KCMO. These flow increases are discussed in further detail in Section 3. Table D-2defines the flows and loads with sixteen percent increase at the same concentration as provided in Table D-1.

Table D-2: Watershed and Diversion of Selected Flows from KCMO to THC (New Loads to THC)

PARAMETER	ANNUAL AVERAGE		MM:AA	MAXIMUM MONTHLY AVERAGE		PD:AA	PEAK DAY	
Flow, mgd	16.03			24.2			81.8	
	mg/L	ppd		mg/L	ppd		mg/L	ppd
TSS	230	30,747	1.42	217	43,660	2.02	91.1	62,108
BOD	180	24,063	1.30	155	31,281	1.81	63.9	43,553
TKN	37.8	5,054	1.23	30.9	6,216	1.49	11.0	7,530
Ammonia	21.3	2,849	1.23	17.4	3,505	1.47	6.14	4,188
Total Phosphorus	4.6	610	1.26	3.8	769	1.67	1.49	1,019
Ortho-Phosphate	1.7	228	1.35	1.5	308	1.82	0.61	416

Keeping the loads to the plant same as those developed in Table D-2, the flows were increased by approximately twelve percent to account for increased I & I to adjust from a drought basis to a more normal annual rainfall basis. As a result the plant influent concentrations were decreased slightly as shown in Table D-3.

Table D-3: Revised Flows and Loads from Increased I & I

PARAMETER	ANNUAL AVERAGE		MM:AA	MAXIMUM MONTHLY AVERAGE		PD:AA	PEAK DAY	
Flow, mgd	18.05			27.21			92.08	
	mg/L	ppd		mg/L	ppd		mg/L	ppd
TSS	204	30,747	1.42	192	43,660	2.02	80.9	62,108
BOD	160	24,063	1.30	138	31,281	1.81	56.7	43,553
TKN	33.6	5,054	1.23	27.4	6,216	1.49	9.8	7,530
Ammonia	18.9	2,849	1.23	15.4	3,505	1.47	5.5	4,188
Total Phosphorus	4.05	610	1.26	3.39	769	1.67	1.33	1,019
Ortho-Phosphate	1.52	228	1.35	1.36	308	1.82	0.54	416

A 5.3% safety factor was added on to these revised flows and loads shown in Table D-3, as discussed in Section 3, to develop the basis of design for THC WWTF and is summarized in

Table **D-4**. The mass loads and flows in Table D-3 were increased, resulting in a 19 mgd annual average flow as the basis for design of the new THC facilities. The increase in flow from 18 to 19 mgd is a 1 mgd capacity to handle unknown flow and load increases that have, as of this date, not yet been identified.

Table D-4: Basis of Design

PARAMETER	ANNUAL AVERAGE		MM:AA	MAXIMUM MONTHLY AVERAGE		PD:AA	PEAK DAY	
Flow, mgd	19			28.7			105.4[1]	
	mg/L	ppd		mg/L	ppd		mg/L	ppd
TSS	204	32,376	1.42	192	45,974	2.02	80.9	65,400
BOD	160	25,338	1.30	138	32,939	1.81	56.7	45,862
TKN	33.6	5,322	1.23	27.4	6,546	1.49	9.81	7,929
Ammonia	18.9	3,000	1.23	15.4	3,690	1.47	5.45	4,410
Total Phosphorus	4.05	642	1.26	3.39	809	1.67	1.33	1,073
Ortho-Phosphate	1.52	240	1.35	1.36	325	1.82	0.54	438

Note:

[1] There is a difference in the peak day flows. From the historical data analysis the peak day is 97.1 mgd. From the sewershed modeling the peak day flow is 105.4 mgd. The larger of the two values is shown in this table. The peak day mass loads remain as predicted from the historical data.

FINAL

TOMAHAWK CREEK WWTF REGULATORY STRATEGY

Technical Memorandum 2

JCW NO. THM1-C026

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PREPARED FOR

JOHNSON COUNTY KANSAS Wastewater

Johnson County Wastewater

17 MAY 2016

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HDR

B&V PROJECT 185289

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Acronyms and Abbreviations

Abbreviation	Meaning
A	
AA	Annual Average
AADF	Average Annual Daily Flow
ADF	Average Daily Flow
AFDM	Ash Free Dry Matter
AGS	Aerobic Granular Sludge
ALE	Alginate-like-exopolysaccharides
AL-E	Expected Aquatic Life Support
ANSI	American National Standards Institute
AQL	Warm Water Aquatic Life
AUX	Auxiliary
B	
B&V	Black & Veatch
BAF	Biological Aerated Filters
BFE	Base Flood Elevation
BFP	Belt Filter Press
BioMag	Biological Flocculation System from Siemens
Bio-P	Biological Phosphorous
BLDG	Building
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
BRIS	Blue River Interceptor Sewer
BRM	Blue River Main
C	
C	Hazen-Williams Equation Roughness Coefficient
C:Chl	Carbon to Chlorophyll Ratio
CA	Calcium
CANDO	Coupled Aerobic-anoxic Nitrous Decomposition Operation (Emerging)
CBOD	Carbonaceous Biochemical Oxygen Demand
$CBOD_5$	5-day Carbonaceous Biochemical Oxygen Demand
CEA	Cost Effective Analyses
CEPT	Chemically Enhanced Primary Treatment
cf	Cubic Feet
CFD	Computational Fluid Dynamics
cfm	Cubic Feet per Minute
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CFUs	Colony Forming Units
CHP	Combined Heat and Power
CIPP	Cured-in-place Pipe
CLOMR	Conditional Letter of Map Revision
cm	Centimeters
CMF	Compressible Media Filters
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
COM	CoMag
CoMag	Chemical Flocculation System from Siemens
CR-B	Primary B Contact Recreation
CSBR	Continuous Sequencing Batch Reactor
CSOs	Combined Sewer Overflows
CT	Concentration Time
CWA	Clean Water Act
D	
D	Depth
DFM	Dry Weather Forcemain
DGC	Digester Gas Control Building
DIG	Digester
DISC	Disc Filters
DLSMB	Douglas L. Smith Middle Basin
DN	Down
DO	Dissolved Oxygen
DP	Dual Purpose
DS	Domestic Water Supply
dt	Dry Ton
DWF	Dry-weather Flow
DWS	Drinking Water Supply
E	
E. coli	Escherichia Coli
EA	Each
EFF	Effluent
EFHB	Excess Flow Holding Basin

Abbreviation	Meaning
EL	Elevation
ELA	Engineering, Legal, Administrative
ENR	Enhanced Nutrient Removal
EPA	Environmental Protection Agency
EPS	Extracellular Polymeric Substances
EQ	Equalization
F	
F/M	Food/Microorganism Ratio
FEMA	Federal Emergency Management Agency
Fe_3O_4	Non-abrasive Iron Ore, Magnetite
ff	Flocculated and Filtered
$ffCBOD_5$	Flocculated Filtered Carbonaceous Biochemical Oxygen Demand
ffCOD	Flocculated Filtered Chemical Oxygen Demand
ffTKN	Flocculated Filtered Total Kjeldahl Nitrogen
FG	Finish Grade
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FITOT	Fraction of Total Insolation
FL	Flow Line
floc	Flocculent
FM	Flow Meter
FP	Food Procurement
FSTE	Final Settling Tank Effluent
ft	Feet
FTE(s)	Full Time Equivalent(s)
G	
gal	Gallons
GAS	Granular Activated Sludge
GGE	Gallons of Gasoline Equivalent
GP	General Purpose
gpd	Gallons per Day
gpm	Gallons per minute
GR	Ground Water Recharge

Abbreviation	Meaning
H	
HB	Hallbrook Facility
HDD	Horizontal Directional Drilling
HEC-RAS	Hydraulic Engineering Center River Analysis System
HEX	Heat Exchanger
Hf	Friction Head
HI	Hydraulic Institute
HL	Head Loss
hp	Horsepower
hr	Hour
HRT	Hydraulic Retention Time
HVAC	Heating, Ventilation, Air Conditioning
HWE	Headworks Effluent
HWLA	High Water Level Alarm
Hypo	Hypochlorite
I	
I&C	Instrumentation and Controls
I/I	Inflow and Infiltration
IC	Internal Combustion
IFAS	Integrated Fixed-Film Activated Sludge
IMF	Interagency Metering Facility
in	Inches
IND	Industrial
INF	Influent
IP	Intellectual Property
IPS	Influent Pump Station
IR	Irrigation Use
IRR	Irrigation
IW	Industrial Water Supply Use
J	
JCW	Johnson County Wastewater
K	
kcf	Thousand Cubic Feet
KCMO	Kansas City, Missouri
KDHE	Kansas Department of Health and Environment
K_e	Light Extinction Coefficient
KU	University of Kansas

Abbreviation	Meaning
kWh	Kilowatt-hour
L	
L	Length, Liter
LBVSD	Little Blue Valley Sewer District
lb	Pound
lb/d	Pounds per Day
LF	Linear Feet
LIC	Lower Indian Creek
LOMR	Letter of Map Revision
LOX	Liquid Oxygen
LPON	Labile Particulate Organic Nitrogen
LPOP	Labile Particulate Organic Phosphorous
LS	Lump Sum
LWLA	Low Water Level Alarm
LWW	Livestock & Wildlife Watering
M	
m	Meter
MAD	Mesophilic Anaerobic Digestion
MARB	Mississippi-Atchafalaya River Basin
MBBR	Moving Bed Bioreactors
MBR	Membrane Bio-reactor
MCC	Motor Control Center
mg	Milligrams
Mg	Magnesium
MG	Million Gallons
mg/L	Milligrams per Liter
mgd	Million Gallons per Day
min	Minute, minimum
mJ	Millijoules
MLE	Modified Ludzack Ettinger
MLSS	Mixed Liquor Suspended Solids
MM	Maximum Month
mm	Millimeter
MMADF	Maximum Month Average Daily Flow
mmBtu	Million British Thermal Units
mpg	Miles per Gallon
MPN	Most Probable Number
N	
N	Nitrogen

Abbreviation	Meaning
NACWA	National Association of Clean Water Agencies
NaOH	Sodium Hydroxide (Caustic)
NCAC	New Century Air Center
NDMA	N-Nitrosodimethylamine
NFIP	National Flood Insurance Program
NH3-N	Total Ammonia
NOx-N	Nitrate + Nitrite
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NPV	Net Present Value
NTS	Not to Scale
O	
O&M	Operation and Maintenance
OCP	Overflow Control Plan
OMB	Office of Management and Budget
OUR	Oxygen Uptake Rate
P	
P	Phosphorous
PAOs	Phosphorous Accumulating Organisms
PC	Primary Clarifier
PD	Peak Day
PDF	Peak Daily Flow
PE	Primary Effluent
PFE	Primary Filtered Effluent
PFM	Peak Flow Forcemain
PHF	Peak Hour Flow
PIF	Peak Instantaneous Flow
PLC	Programmable Logic Controller
PO_4-P	Orthophosphate Phosphorous
ppd	Pounds per Day
pph	Pounds per Hour
PPI	Producer Price Index
ppy	Pounds per Year
PS	Pump Station
psf	Pounds per Square Foot
psi	Pounds per Square Inch
PWWF	Peak Wet-weather Flow

Abbreviation	Meaning
Q	
Q	Flow
R	
RAS	Return Activated Sludge
rbCOD	Rapidly Biodegradable Chemical Oxygen Demand
RDT	Rotating Drum Thickener
RECIRC	Recirculation
RIN	Renewable Identification Number
RM	River Mile
R&R	Repair and Replacement
RWW	Raw Wastewater
S	
SAB	USEPA Science Advisory Board
SBOD	Soluble Biochemical Oxygen Demand
SBR	Sequencing Batch Reactor
SCADA	Supervisory Control and Data Acquisition
SCE	Secondary Clarifier Effluent
scfm	Standard Cubic Feet per Minute
sCOD	Soluble Chemical Oxygen Demand
SCR	Secondary Contact Recreation
Sec	Second, Secondary
SF	Square Foot
SG	Specific Gravity
SLR	Solids Loading Rate
SMP	Stormwater Management Program, Shawnee Mission Park Pump Station
SND	Simultaneous Nitrification/ Denitrification
SOD	Sediment Oxygen Demand
SOR	Surface Overflow Rate
SOURs	Specific Oxygen Uptake Rates
SP	Single Purpose
S.P.S.	Sludge Pump Station
SRT	Sludge Retention Time
SS	Suspended Solids
SSOs	Sanitary Sewer Overflows
SSS	Separate Sewer System
sTP (GF)	Soluble Total Phosphorous (Glass Fiber Filtrate)
SVI	Sludge Volume Index
SWD	Side Water Depth
T	
TBL	Triple Bottom Line
$TBOD_5$	Total 5-day Biochemical Oxygen Demand
TDH	Total Dynamic Head
Temp	Temperature
TERT	Tertiary
TF	Trickling Filters
TFE	Tertiary Filter Effluent
THC	Tomahawk Creek
THM	Trihalomethanes
TIN	Total Inorganic Nitrogen
TKN	Total Kjeldahl Nitrogen
TM	Technical Memorandum
TMDL	Total Maximum Daily Loads
TN	Total Nitrogen
TOC	Top of Concrete
TP	Total Phosphorous
TPS	Thickened Primary Solids
TS	Total Solids
TSS	Total Suspended Solids
TWAS	Thickened Waste Activated Sludge
TYP	Typical
U	
µg/L	micrograms per Liter
UCT	University Cape Town
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultraviolet
UV LPHO	Ultraviolet Low Pressure, High Output
UV MPHO	Ultraviolet Medium Pressure, High Output
V	
VFA	Volatile Fatty Acids
VFAs	Volatile Fatty Acids (Speciated)
VFD	Variable Frequency Drive

Abbreviation	Meaning
VS	Volatile Solids
VSL	Volatile Solids Loading
VSr	Volatile Solids Reduction
VSS	Volatile Suspended Solids
W	
W	Width
WAS	Waste Activated Sludge
WASP	Water Quality Analysis Simulation Program
WBCR-A	Whole Body Contact Recreation –Category A
WBCR-B	Whole Body Contact Recreation –Category B
WFM	Wet Weather Forcemain
WL	Water Level
WK	Week
WS	Water Surface
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant
Y	
YR	Year

1 Executive Summary

1.1 BACKGROUND AND OBJECTIVES

The 2013 Pre-Design Study for the Tomahawk Creek (THC) Wastewater Treatment Facility (WWTF) concluded that the facility should be upgraded to a 19 mgd nutrient removal facility with auxiliary treatment for peak wet weather flows. From late 2014 through 2015, Johnson County Wastewater (JCW) and the consulting team held several meetings with Kansas Department of Health and Environment (KDHE) officials and developed a regulatory strategy for the proposed facility.

The strategy is delineated in the three documents that are presented in this Technical Memorandum 2, specifically:

1. Antidegradation Review, dated October 15, 2015, which presents an alternative analysis which demonstrates that a 19 mgd Enhanced Nutrient Removal (ENR1) Facility with Auxiliary Treatment for peak wet weather flows provides the best combination of practicability, treatment effectiveness, and cost effectiveness.

2. Draft NPDES Permit, which identifies auxiliary treatment as a key component of the facility description and operating strategy, and includes discharge limits for Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), Ammonia, total phosphorus, and nitrate/nitrite that are reasonable and achievable.

3. Consent Decree, which sets forth an implementation schedule and provides JCW with a means to continue to operate their wet weather lagoon until the new facility is complete.

1.2 SUMMARY AND RECOMMENDATIONS

The regulatory strategy outlined in the three documents presented in this Technical Memorandum (TM) supports the implementation of a 19 mgd Enhanced Nutrient Removal Facility with Auxiliary Treatment for peak wet weather flows, provides for discharge limits that are reasonable and technologically achievable, and provides a means within the regulatory framework which enables JCW to utilize their peak weather lagoon while the new WWTF is being constructed.

It is recommended that JCW proceed with implementation of the project as soon as the permit is issued and the Consent Order is executed.

2 Introduction

2.1 BACKGROUND AND OBJECTIVES

The 2013 Pre-Design Study for the THC WWTF concluded that the facility should be upgraded to a 19 mgd nutrient removal facility with auxiliary treatment for peak wet weather flows. From late 2014 through 2015, JCW and the consulting team held several meetings with KDHE officials and developed a regulatory strategy for the proposed facility.

The purpose of the strategy is to provide for responsible environmental stewardship and compliance with State and Federal regulations and policies during and after construction of the new facility. The results of this effort are reflected in three documents:

1. THC WWTF, Project Definition Phase, Antidegradation Review, dated October 15, 2015.
2. Draft Kansas Water Pollution Control Permit M-MO27-OO03 (NPDES Permit).
3. Draft Consent Order, Case No. 15-E-39 BOW.

This process culminated in a meeting in November, 2015 with USEPA, Region 7 and KDHE at JCW's offices. Some comments were obtained, a consensus was reached, and the draft documents were modified accordingly. Each of these documents is included in the appendix to this TM.

The purpose of TM 2 Regulatory Strategy is to present a summary of the strategy outlined in these three documents and a recommended path forward.

3 Antidegradation Review

3.1 RECEIVING STREAM

The THC WWTF discharges to Indian Creek 1.3 miles upstream of the Kansas/Missouri border and 4.7 miles from its confluence with the Blue River. The entire reach is subject to use designations for aquatic life and primary contact reaeration, as well as other uses. Multiple 303(d) listing impairments and TMDLs have been identified for Indian Creek, including Total Phosphorus, Chloride, *E. coli*, and Nitrate.

3.2 ALTERNATIVE ANALYSIS

The purpose of the Antidegradation analysis is to demonstrate that the facility expansion is necessary and to identify the least impacting, cost effective, treatment method for the expanded facility. This is accomplished through an alternative analysis.

Initially, 16 different alternatives were identified. Those consisted of combinations of facility capacity, with flow exceeding that capacity being sent to Kansas City, Missouri (KCMO) for treatment, treatment level with respect to total nitrogen (TN) and total phosphorus (TP), and wet weather management approaches. These were screened for practicability, and all but eight were discarded or impractical. The retained alternatives were as follows:

- **10.2-BNR**: Alternative 10.2-BNR represents a 10 MGD BNR facility that would convey the balance of the dry weather flow and all of the wet weather flows to KCMO. Some storage would also be required at THC WWTP to reduce wet weather peaks and avoid exceeding the capacity of the KCMO interceptor.

- **19.1-BNR**: Alternative 19.1-BNR represents a 19 MGD BNR facility that would treat all flows at the THC WWTF with wet weather flows greater than 57 MGD treated through an advanced high-rate treatment systems, such as ballasted flocculation or compressible media filtration (further referred to as auxiliary treatment). Auxiliary treatment flows are combined with flows for BNR prior to discharge.

- **19.1-ENR1**: Alternative 19.1-ENR1 represents a 19 MGD ENR facility (enhanced phosphorus removal) that would treat all flows at the THC WWTF with wet weather flows greater than 57 MGD treated through an auxiliary treatment system. Auxiliary treatment flows are combined with flows for ENR prior to discharge.

- **19.1-ENR2**: Alternative 19.1-ENR2 represents a 19 MGD ENR facility (enhanced phosphorus and nitrogen removal) that would treat all flows at the THC WWTF with wet weather flows greater than 57 MGD treated through an auxiliary treatment system. Auxiliary treatment flows are combined with flows for ENR prior to discharge.

- **19.3-BNR**: Alternative 19.3-BNR represents a 19 MGD BNR facility that would store wet weather flows greater than 57 MGD at the THC WWTF.

- **19.3-ENR1**: Alternative 19.3-ENR1 represents a 19 MGD ENR facility (enhanced phosphorus removal) that would store wet weather flows greater than 57 MGD at the THCWWTF.

- **19.3-ENR2**: Alternative 19.3-ENR2 represents a 19 MGD ENR (enhanced phosphorus and nitrogen removal) facility that would store wet weather flows greater than 57 MGD at the THC WWTF.

- **0.2**: Alternative 0.2 assumes all flows would be conveyed to the KCMO system and includes wet weather storage at the KCMO 87th Street Pump Station as well as some storage at the THC WWTF to reduce wet weather peaks to avoid exceeding the capacity of the KCMO interceptor.

In the above list, the 0, 10, and 19 refer to the average day treatment capacity of the facility. Biological Nutrient Removal (BNR), Enhanced Nutrient Removal (ENR1), and ENR2 refer to the degree of TN and TP removal:

- BNR = 10.0 mg/L TN, 1.0 mg/L TP
- ENR1 = 10 mg/L TN, 0.5 mg/L TP
- ENR2 = 5.0 mg/L TN, 0.5 mg/L TP

A Near-Field analysis was performed which focused on water quality in Indian Creek. The extent of growth of periphyton algae was taken as representative of stream health. Two periphyton models were developed, one representing critical low flow conditions based on the drought year of 2012, and the other representing typical rainfall year flows based on 2001 consistent with the rainfall approach used in the KCMO Long Term Control Plan. The Antidegradation Report, as well as details of the model development, calibration, and results can be found in Appendix A.

A Far-Field analysis was also performed which focused on impacts to the Missouri and Mississippi Rivers and the Gulf of Mexico. A key component of this analysis was the contrast between the higher level of tertiary treatment at THC versus secondary treatment at KCMO's Blue River WWTF in terms of the level of ammonia, TN, and TP discharged to the downstream waters.

A cost effectiveness analysis was then performed. The Net Present Value (NPV) was determined for each alternative. These are shown in Table 3-1. The alternatives were then compared based on the incremental pollutant removal cost, i.e., the cost difference of one alternative over another per pound of pollutant removed. These comparisons are show in Tables 3-2 and 3-3. This approach allowed the "knee of the curve" to be identified, the point at which further removal of the given pollutant was no longer cost effective.

Table 3-1 20-Year Present Worth Cost of Treatment Alternatives for the Tomahawk WWTP

ALTERNATIVE	20-YEAR NET PRESENT WORTH COSTS			
	Net Present Value of Capital	Net Present Value of O&M	Total Net Present Value	Percent of Lowest Cost Alternative
19.1-BNR	$260,467,000	$201,955,000	$462,422,000	100%
19.1-ENR1	$278,325,000	$207,737,000	$486,062,000	105%
19.1-ENR2	$288,270,000	$214,116,000	$502,386,000	109%
19.3-BNR	$440,131,000	$189,554,000	$629,685,000	136%
19.3-ENR1	$457,989,000	$195,335,000	$653,324,000	141%
19.3-ENR2	$467,934,000	$201,714,000	$669,648,000	145%
10.2-BNR	$232,750,000	$480,290,000	$713,040,000	154%
0.2	$168,333,000	$776,693,000	$945,026,000	204%

Assumptions:

1. All costs in 2015 dollars.
2. Mid Point of Construction is 2019
3. Normal Discount Rate = 3.1%, Inflation = 1.9%, Net Discount Rate = 1.2%
4. In the 10 MGD and 0 MGD alternatives, the O&M figures include KCMO treatment charges, which in turn include cost recovery for storage.

Table 3-2 Cost per Pound of Additional Pollutant Removal in Indian Creek Relative to Base Case Alternative 19.1-BNR

	$CBOD_5$ ($/LB)	TSS ($/LB)	NH3N ($/LB)	TP ($/LB)	TN ($/LB)
19.1-ENR1 relative to 19.1-BNR	$7.0	$3.5	NC	$42	NC
19.1-ENR2 relative to 19.1-BNR	$11.8	$5.9	NC	$71	$7
10.2-BNR relative to 19.1-BNR	$84	$59	$1,282	$535	$54
0.2 relative to 19.1-BNR	$68	$46	$1,451	$418	$42

Note:
NC – Not calculable (i.e., there is no difference in pollutant loadings so the denominator is zero).

Table 3-3 Cost per Pound of Additional Pollutant Removal in Indian Creek for Storage Relative to Auxiliary Treatment

	$CBOD_5$ ($/LB)	TSS ($/LB)	NH3N ($/LB)	TP ($/LB)	TN ($/LB)
19.3-BNR relative to 19.1-BNR	$626	$1,252	$1,602	$12,523	$1,968
19.3-ENR1 relative to 19.1-ENR1	$551	$810	$1,602	$8,611	$1,968
19.3-ENR2 relative to 19.1-ENR2	$551	$810	$1,602	$8,611	$1,148

3.3 CONCLUSIONS AND RECOMMENDATIONS

The final analysis focused on three key comparisons and the incremental costs and benefits of each:

- Treatment capacity at THC WWTF versus full or partial conveyance to KCMO
- Auxiliary peak wet weather treatment versus storage
- Comparison of level of nutrient removal (BNR vs ENR1 vs ENR2)

It was concluded the Alternative 19.1 ENR1 with Auxiliary Treatment provides the best combination of practicability, treatment effectiveness, and cost effectiveness.

4 National Pollutant Discharge Elimination System (NPDES) Permit

Based on the findings of the Antidegradation Review, KDHE proceeded with drafting of an NPDES permit. The draft permit is included in Appendix B.

The essence of the permit is contained in the Facility Description, key Discharge Limits, and Supplemental Condition No. 6, as follows:

4.1 FACILITY DESCRIPTION

- Mechanical Bar Screens
- Grit Removal
- Primary Sedimentation
- BNR Activated Sludge Treatment Basins
- Final Sedimentation
- Anaerobic Digestion
- Tertiary Pump Station
- Dual Purpose Filters
- UV Disinfection
- Chlorination
- Dechlorination
- Effluent Cascade Aeration
- Dry Weather Design Flow = 19 MGD
- Peak Instantaneous Hydraulic Design Flow through Activated Sludge System = 57 MGD
- Peak Instantaneous Hydraulic Design Flow through Facility = 172 MGD

4.2 DISCHARGE LIMITS

Outfall 001A1 (EDMR code: EFF001A1) – Effluent at Sampling Point. Discharge limits are presented in Table 4-1.

Table 4-1 Discharge Limits

PARAMETER	INTERIM	FINAL
Biological Oxygen Demand		
January-June and September-December		
Weekly Average-mg/L	30	30
Monthly Average-mg/L	20	20
July and August		
Weekly Average-mg/L	25	25
Monthly Average-mg/L	15	15
Total Suspended Solids		
Weekly Average-mg/L	45	45
Monthly Average-mg/L	30	30
Ammonia-mg/L (as N)		
January		
Daily Maximum		7.0
Monthly Average	10.7	2.0
February		
Daily Maximum		10
Monthly Average	8.7	1.7
March		
Daily Maximum		10.0
Monthly Average	7.3	2.0
April		
Daily Maximum		11.8
Monthly Average	8.1	1.3
May		
Daily Maximum		8.4
Monthly Average	6.1	1.3
June		
Daily Maximum		7.8
Monthly Average	4.6	0.9
July		
Daily Maximum		6.6
Monthly Average	3.2	0.6

PARAMETER	INTERIM	FINAL
August		
Daily Maximum		8.8
Monthly Average	3.2	0.6
September		
Daily Maximum		8.7
Monthly Average	4.3	0.9
October		
Daily Maximum		11.6
Monthly Average	6.5	1.5
November		
Daily Maximum		10.0
Monthly Average	10.4	1.8
December		
Daily Maximum		7.0
Monthly Average	13.6	2.3
***E.Coli*-Colonies/100ml**		
Monthly Geometric Average	262	262
Weekly Geometric Average	4348	4348
Total Residual Chlorine - µ/l	21.00	17.0
Dissolved Oxygen-mg/L (Minimum)		
Weekly Average	6.0	6.0
Nitrate (NO3) + Nitrite (NO2) as N- mg/L		
Annual Rolling Average	Calculate	10
Total Phosphorus (as P)		
Annual Rolling Average – mg/L	Not Required	Calculate
Annual Rolling Average – lbs/day	Not Required	79.2

The limits for Nitrate + Nitrite, and for Total Phosphorus are based on the Antidegradation Review. The ammonia limits are based on wasteload allocation calculations, default KDHE mixing allowances, representative pH and temperature measurements, and USEPA's 2013 recommended

ammonia criteria. The daily maximum ammonia limits were derived based on pH mixing modeling at the zone of initial dilution.

4.3 SUPPLEMENTAL CONDITION NO. 6

Supplemental Condition No. 6, quoted below, provides further definition as to how auxiliary treatment is provided for in the permit:

"6. For the Final Limits applicable to the Expanded Facility after the new construction is placed into service, a portion of the peak wet weather influent flow shall be split directly to filtration and disinfection once flow has been maximized through the activated sludge treatment units at a level which does not cause a washout of activated sludge biomass or other process upsets (see Expanded Facility Description design flow thresholds). The use of the auxiliary wet weather flow treatment configuration is not an in-plant diversion and not subject to Standard Conditions 7, 8, and 9".

5 Consent Order

JCW proposes to demolish the majority of the existing WWTF and send all dry weather flow to KCMO while the new facility is being constructed. However, peak wet weather flow exceeding the capacity of the Linking Interceptor will still need to be pumped to the existing wet weather lagoon. It will either be stored in the lagoon and bled back to the Linking Interceptor after the storm passes, or, if the storage capacity of the lagoon is exceeded, discharged through existing Outfall 002.

The draft permit requires that existing Outfall 002 be permanently abandoned both in terms of the proposed Interim and Final discharge limits. A primary feature of the Consent Order is to provide a means by which JCW can continue to use the peak flow lagoon while the new WWTF is being constructed, without being subjected to fines and penalties.

The Consent Order also includes a provision by which JCW must perform an Auxiliary Treatment Performance Study after the new facilities have been place in service.

Finally, the Consent Order provides a compliance schedule for design and construction of the new facility, since the implementation process is expected to take longer than the standard five year period covered under the NPDES permit.

6 Summary and Recommendations

The regulatory strategy outlined in three documents presented in this TM supports the implementation of a 19 mgd Enhanced Nutrient Removal Facility with Auxiliary Treatment for peak wet weather flows, provides for discharge limits that are reasonable and achievable, and provides a means within the regulatory framework which enables JCW to utilize their peak weather lagoon while the new WWTF is being constructed.

It is recommended that JCW proceed with implementation of the project as soon as the permit is issued and the Consent Order is executed.

APPENDIX A

ANTIDEGRADATION REVIEW

TOMAHAWK CREEK WWTF PROJECT DEFINITION PHASE

Antidegradation Review

JCW NO. THM1-C026

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PREPARED FOR

JOHNSON COUNTY KANSAS

Wastewater

15 OCTOBER 2015

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B&V PROJECT 185289

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APPENDICES

Appendix A - Water Quality Model Documentation

1 Executive Summary

A 2013 pre-design study for the Tomahawk Wastewater Treatment Facility (WWTF) commissioned by Johnson County Wastewater (JCW) concluded that the plant should be upgraded to the full tributary area capacity, providing for a 19 million gallon per day (MGD) nutrient removal facility with auxiliary treatment for peak wet weather flows. Based on these recommendations, JCW commissioned Black & Veatch (B&V)/HDR to initiate the Project Definition Phase of the Tomahawk WWTF expansion project to further refine the analysis of the wastewater treatment and management alternatives. As part of this phase, the project team was tasked with addressing Federal and State antidegradation review requirements for the plant upgrade.

Antidegradation policies and regulations provide protections that are critical to the fulfillment of the Clean Water Act (CWA) objective to restore and *maintain* the chemical, physical, and biological integrity of the nation's waters. Regulations provide for three levels or tiers of water quality protection. The first tier (Tier 1) protects water quality for existing uses and is typically applied to impaired waters. The second tier (Tier 2) protects high quality waters. The third tier (Tier 3) protects Outstanding National Resource Waters. For purposes of this report, receiving waters to the Tomahawk WWTF (i.e., Indian Creek, Blue River and the Missouri River) are considered Tier 2.

The intent of Tier 2 protections is to maintain and protect high quality waters and prohibit any degradation without a demonstration that lowering water quality is necessary and important. To satisfy these requirements, an alternatives analysis was conducted on sixteen different treatment alternatives to identify the least degrading option that is most practicable and cost-effective. Cost-effectiveness is an important consideration recognized by both the Kansas Department of Natural Resources (KDHE) and the U.S. Environmental Protection Agency (USEPA) as environmental benefits of many least degrading alternatives are not commensurate with the additional costs. JCW must also weigh Tomahawk WWTF alternatives against competing resource demands from other wastewater collection and treatment projects which total approximately $2 billion in capital investments over the next 25 years, not including the increased operational costs associated with many of these capital projects.

The alternatives analysis included a variety of wet weather treatment strategies including flow conveyance to the Kansas City, Missouri (KCMO) system, advanced high-rate treatment systems, such as ballasted flocculation (further referred to as auxiliary treatment), and storage. Additionally, three levels of nutrient removal were evaluated for the expanded plant including biological nutrient removal (BNR) and two levels of enhanced nutrient removal (ENR1 and ENR2). BNR is capable of achieving total phosphorus (TP) and total nitrogen (TN) effluent goals of 1 mg/L and 10 mg/L, respectively, on an average annual basis. The corresponding TP and TN effluent goals for ENR1 are 0.5 mg/L and 10 mg/L, respectively, and for ENR2 are 0.5 mg/L and 5 mg/L, respectively.

Water quality impacts were assessed for each practicable alternative in both the near-field (i.e., Indian Creek) and the far-field (i.e., the Missouri River and the Gulf of Mexico). The near-field analysis was conducted using a one-dimensional (cross-sectional average) hydrodynamic and water quality model consisting of two time-variable components: 1) a hydraulic model (CE-QUAL-RIV1), and 2) a water quality model (Peri-WASP). The model simulated the instream benthic algal (i.e., periphyton) response to help evaluate the influence of different wastewater

management and treatment scenarios on eutrophication in Indian Creek during both drought conditions (as represented by the Year 2012) and typical rainfall conditions (as represented by the Year 2001). For purposes of evaluating typical rainfall conditions, the model was linked to the P8 watershed runoff model.

Results of the modeling demonstrate that benthic algal levels are largely insensitive to nutrient levels from the Tomahawk WWTF, showing that nutrient removal beyond BNR provides no additional benefits in the near-field. The model also demonstrated that benthic levels decrease with increasing flow. Therefore, benthic algae levels appear to increase in Indian Creek as flow is diverted to KCMO. In addition, predicted near-field water quality conditions did not meaningfully differ between wet weather management and treatment alternatives.

Water quality in the far-field (i.e., Missouri River and Gulf of Mexico) was evaluated in terms of annual pollutant loading. Annual pollutant loadings were greatest for alternatives that included a flow diversion to KCMO. Flow diversions to KCMO result in overall larger loadings due to higher treatment levels at the Tomahawk WWTF relative to the existing treatment capabilities at the KCMO Blue River WWTP. The far-field analysis also demonstrated that differences in pollutant loadings between auxiliary treatment and storage are minimal. With respect to the baseline alternative (i.e., existing conditions), all alternatives (with the exception of 100% diversion to KCMO) result in pollutant loading reductions in the far-field. Nutrient reductions in the far-field range from 64-82% for TP and 44-72% for TN for the 19 MGD BNR, ENR1, and ENR2 alternatives.

Cost-effectiveness was next evaluated based on environmental benefits and economic costs. Alternatives that include a flow diversion to KCMO represent the most expensive and most degrading alternatives; therefore, are the least cost-effective. Alternatives that include storage at Tomahawk WWTF are also not cost-effective relative to auxiliary treatment. The minimal benefits of storage relative to auxiliary treatment are not commensurate to the increase in cost. Relative to auxiliary treatment, storage costs range from $551 to $12,523 per additional pound of pollutant removal depending on the pollutant and treatment level.

The most cost-effective nutrient removal technology is ENR1. Relative to BNR, ENR1 costs approximately 6% more but result in significantly greater reductions in phosphorus, carbonaceous oxygen demand, and total suspended solids. Phosphorus is likely the most limiting nutrient in the near-field and should be prioritized for removal. The next level of nutrient removal, ENR2, costs approximately 9% more than BNR and results in half the level of nitrogen loading. However, ENR2 requires supplemental carbon sources like methanol, which raises safety and environmental concerns about its storage, handling, and use and it provides no benefit in the near-field with respect to benthic algae levels.

Based on results of the antidegradation review, a 19 MGD ENR1 facility with auxiliary treatment for peak wet weather flows is proposed for the Tomahawk WWTF. A 19 MGD ENR1 facility with auxiliary treatment provides many benefits and advantages including the following:

- Relative to existing conditions, the proposed alternative will reduce benthic algae levels in Indian Creek.
- Relative to existing conditions, the proposed alternative will result in an 82% reduction in total phosphorus and a 44% reduction in total nitrogen to the Missouri River.

- Auxiliary treatment is significantly more practicable and cost-effective than providing storage at the Tomahawk WWTF, which has an incremental total phosphorus removal cost of over $8,000 pound. The auxiliary treatment alternative also reduces the risk of untreated wet weather discharges compared to the storage alternative.
- Expanding the Tomahawk WWTF will provide benefits in terms of reduced flows to the KCMO system, which has significant capacity issues.
- Relative to existing conditions, the proposed alternative results in improved water quality conditions in both the near-field and far-field; thereby satisfying the primary objective of antidegradation.

Anticipated water quality improvements due to Alternative 19 MGD ENR1 facility surpass antidegradation requirements. While BNR would also satisfy antidegradation requirements, as it results in no further degradation, JCW is willing to consider an additional level of phosphorus removal through ENR1, which provides the greatest potential for near-field benefits. Any additional level of nutrient removal (e.g., ENR2) is not required through antidegradation and raises environmental and safety concerns (e.g., storage and handling of methanol).

Results of this antidegradation review direct JCW to expand the Tomahawk WWTF to 19 MGD with upgrades including ENR1 and auxiliary treatment, using advanced high-rate treatment processes. Any alternative that involves diverting flow to the KCMO system is more degrading to water quality and is not cost-effective. Similarly, water quality benefits associated with storage in lieu of auxiliary treatment are marginal, not commensurate with cost, and do not justify the risk of a potential untreated discharge during extreme wet weather events.

2 Introduction

In 2013, HDR/CH2M finalized the "Updates to Process Improvements Pre-Design Study" commissioned by Johnson County Wastewater (JCW) for the Tomahawk Wastewater Treatment Plant (WWTP), which recommended upgrades and expansion of the facility. The study found that extensive rehabilitation was required to maintain National Pollutant Discharge Elimination System (NPDES) permit compliance and long-term treatment reliability. Needed rehabilitation was identified for multiple components of the facility, including the biosolids facilities, odor control facility, and the influent pump station. The study also found that expansion of the Tomahawk WWTF to treat the majority of flows tributary to the facility was the most cost-effective and viable wastewater management alternative for JCW. Based on these recommendations, JCW commissioned Black & Veatch (B&V)/HDR to initiate the Project Definition Phase of the Tomahawk WWTF expansion project to further refine the analysis of the expansion alternative. Critical to this phase is investigating the regulatory pathway for the expansion alternative. The Kansas Department of Health and Environment (KDHE) has indicated that complying with the Kansas Antidegradation Policy (KDHE, 2001) is critical for regulatory approval if JCW is to proceed with the 2013 expansion recommendations. The intent of Kansas Antidegradation Policy is to limit discharges and other activities that will negatively impact water quality.

Implementation of antidegradation regulations focuses on protecting those waters that have a higher quality than needed to maintain designated uses (i.e., Tier 2 waters). Per KDHE (2011) guidance, "*[d]ischarges to Tier 2 waters are required to minimally impact the water unless minimally impacting alternatives are too costly, and there are important economic or social reasons for allowing the discharge*". Therefore, in order to allow a new or expanded discharge into a Tier 2 water, the potential permittee must demonstrate the importance and necessity of the proposed project. The necessity of a project is demonstrated through an alternatives analysis designed to identify the least impacting, cost-effective treatment method.

The objective of this report is to satisfy all antidegradation requirements by demonstrating the proposed project is important, necessary, and ultimately non-degrading. Although limited degradation is allowed where the necessity and importance is demonstrated, this project likely is non-degrading, which should represent the ultimate goal of implementation of the antidegradation policy. This antidegradation review report includes the following remaining sections:

- Facility Background
- Receiving Streams
- Alternatives Analysis
- Social and Economic Importance
- Proposed Alternative
- Degradation Evaluation

3 Facility Background

The Tomahawk WWTF treats wastewater from the Tomahawk Creek watershed, the Indian Creek watershed downstream of the Douglas L. Smith Middle Basin WWTP (Lower Indian Creek), and a portion of the Dykes Branch sub-watershed (**Figure 1**). The WWTF treats only a portion of the flow arriving at the plant, the balance being diverted to the City of Kansas City, MO (KCMO) wastewater collection and treatment system. Wastewater flows through the KCMO

system by gravity until reaching the 87th Street Pump Station. This station, located near Prospect Avenue at the Blue River, delivers flow to the Blue River Interceptor System (BRIS), which conveys the wastewater for ultimate treatment at the KCMO Blue River WWTP.

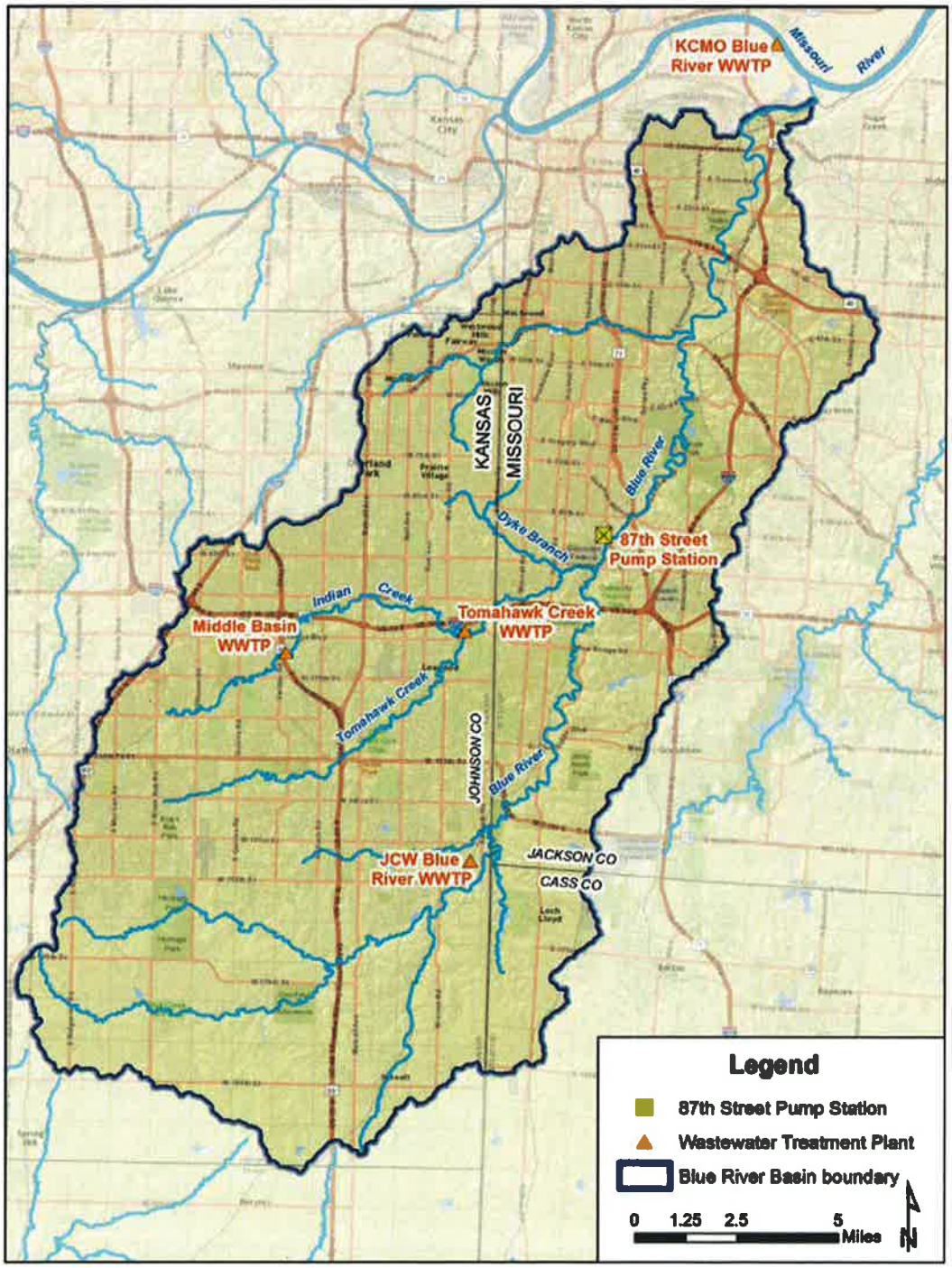

Figure 1. Blue River Basin and Key Wastewater Facilities

The existing facilities at the Tomahawk WWTF consist of bar screening, primary and final clarification, trickling filters, chlorination and dechlorination, and a peak flow holding basin. The WWTF has a 10 million gallon per day (MGD) hydraulic rated capacity, but is currently limited to approximately 7 MGD to maintain water quality-based effluent limitations, primarily ammonia and carbonaceous biochemical oxygen demand (CBOD).

In 2006, the Tomahawk WWTF came under regulatory scrutiny due to difficulties in meeting its CBOD limits and an Administrative Order of Compliance was issued by KDHE. In addition, a provision of the plant's NPDES permit, issued in 2005, required JCW to conduct a study by October 1, 2008 to assess the cost and feasibility for incorporating nutrient removal under KDHE's Nutrient Reduction Plan. To satisfy these requirements, JCW commissioned HDR/CH2M to prepare the "Tomahawk Creek WWTP Process Improvements Pre-Design Study."

The 2006 Study concluded that, based on the information available at the time, the best approach would be to upgrade the Tomahawk WWTF plant to treat 10 MGD, and convey the remaining service area flow to KCMO.

However, due to uncertainty with future KCMO rate increases and the timing for incorporation of nutrient removal into the NPDES permit, JCW decided to proceed with an interim project to address the CBOD compliance issue. Then JCW planned to revisit the long-term improvements when more definitive information was available with respect to these uncertainties. The Interim Process Improvements Project, which included automated trickling filter drives, chemically enhanced primary treatment (CEPT) for dry weather flows, sludge conveyance facilities, and various flow control improvements, was undertaken and completed in 2008.

Since that time, a number of developments have occurred:

- KCMO has completed its Overflow Control Plan (OCP) and entered into a Consent Decree that incorporated the OCP control measures with the U.S. Environmental Protection Agency (USEPA) and the U.S. Department of Justice. Although several details are not finalized, the level and timing of the anticipated rate increases for conveyance and treatment of JCW wastewater flows are now better understood.

- On September 30, 2009, KDHE placed the draft NPDES permit renewal for the Tomahawk WWTF on public notice. The draft permit stipulated that discharges from the wet weather lagoon (i.e., peak flow holding basin) be classified and reported as a bypass rather than permitted discharges (as had been the case prior to this reissuance).

- On November 2, 2009, USEPA issued an objection to the permit. Within the objection, USEPA requested that the draft permit be revised to prohibit wet weather transfers to KCMO unless there is documented adequate capacity within the system to transport or store such transfers without contributing to sanitary sewer overflows (SSOs) within the KCMO system. KDHE subsequently advised USEPA that it could not issue the permit with the requested modification in that it would leave JCW with no viable alternative nor time to evaluate and implement one.

Pursuant to these developments, JCW commissioned an update to the 2006 Pre-Design Study. The Process Improvements Pre-Design Study Update was completed by HDR and CH2M in 2013. The Update concluded that the best approach is to expand the Tomahawk WWTF to the full

tributary area capacity, providing for a 19 MGD nutrient removal facility with auxiliary treatment for peak wet weather flows.

The KCMO OCP referenced above includes control measures to address sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs) from the Blue River South Basin (including flows from JCW tributary to the 87th Street Pumping Station). Planned improvements to the separate sewer system (SSS) in the Blue River South Basin include a 45% reduction in inflow and infiltration (I/I) by 2030 and construction of wet weather storage capacity at the 87th Street Pump Station by December 31, 2024. Although the OCP calls for a total storage volume of 68 MG, this volume may increase or decrease depending upon flows from JCW. The outcome of this report and regulatory acceptance will help dictate the final storage capacity.

In addition to the Tomahawk WWTF, JCW faces competing resource demands from other sewer design and construction projects throughout the County. Collectively, JCW operates a total treatment capacity of 63.87 MGD, which provides sanitary sewer services to over 500,000 people. Above ground assets include six major treatment plants, one small lagoon, and 31 pump stations. JCW also manages more than 2,200 miles of sewer line, including approximately 56,000 manholes, approximately 23 miles of active low-pressure sewers, and 42 miles of active force mains.

To maintain and service its existing sanitary sewer system, JCW currently anticipates approximately $2 billion in capital expenditures over the next 25 years. Fifty percent of the projected expenditures are for treatment facility asset renewal, expansions, and upgrades. Forty percent is planned for collection system asset renewal, I/I removal, and capacity enhancement. The remaining ten percent of the 25-year projection is planned for collection system expansion to accommodate growth in the County. With an overall objective of having reliable and sustainable wastewater networks with the capacity to support the entire service area, it is important that upgrades to the Tomahawk WWTF do not compromise JCW's ability to make other equally or more important improvements elsewhere.

4 Receiving Streams

The Tomahawk WWTF discharges to Indian Creek approximately 1.3 miles upstream from the Missouri/Kansas border and 4.7 miles from the Blue River (**Figure 1**). Indian Creek is classified as a General Purpose (GP) water within Kansas and a Class C (i.e., intermittent flow) water within Missouri. The Blue River flows in a northeasterly direction through the Kansas City metropolitan area and enters the Missouri River at River Mile 357 approximately 21.5 miles downstream from the confluence with Indian Creek. Blue River and the Missouri River are classified by Missouri as Class P (i.e., permanent flow) waters.

Flow diverted from the Tomahawk WWTF is ultimately treated at the KCMO Blue River WWTP, which discharges to the Missouri River near the Blue River confluence.

4.1 USE DESIGNATIONS

Designated uses are an important component of water quality standards that are used to establish water quality goals. Consistent with the "fishable/swimmable" goals identified in Section 101(a)(2) of the Clean Water Act (CWA), state designated uses for all waterbody segments located between the Tomahawk WWTF and the Missouri River include aquatic life and primary contact recreation. The State designated uses for the Tomahawk WWTF receiving waters are identified below in **Table 1**.

Table 1. Receiving Waterbodies and Use Designations

Waterbody	Segment	Designated Uses
Indian Creek (Kansas)	10300101-32	AL-E, CR-B, DS, FP, GR, IW, IR, L
Indian Creek (Missouri)	0420	AQL, WBCR-A, SCR, LWW, IND
Blue River	0419	AQL, WBCR-A, SCR, LWW
Blue River	0418	AQL, WBCR-B, SCR, LWW, IND
Blue River	0417	AQL, WBCR-B, SCR, LWW
Missouri River	0356	AQL, WBCR-B, SCR, LWW, DWS, IND, IRR

Notes: Kansas Use Categories: Expected Aquatic Life Support (AL-E), Primary B Contact Recreation (CR-B), Domestic Water Supply (DS), Food Procurement (FP), Ground Water Recharge (GR), Industrial Water Supply Use (IW), Irrigation Use (IR), Livestock Watering Use (L)
Missouri Use Categories: Irrigation (IRR), Warm Water Aquatic Life (AQL), Livestock & Wildlife Watering (LWW), Whole Body Contact Recreation – Category A (WBCR-A), Whole Body Contact Recreation – Category B (WBCR-B), Secondary Contact Recreation (SCR), Drinking Water Supply (DWS), Industrial (IND)

4.2 CLEAN WATER ACT IMPAIRMENTS

Under section 303(d) of the CWA, states are required to identify all waterbodies not meeting water quality standards. Water quality standards define the water quality goal by designating beneficial uses and setting narrative and numeric criteria to protect those uses. Waterbodies that do not attain water quality standards are placed on a 303(d) list and require the development of a Total Maximum Daily Loads (TMDL). The TMDL allocates pollutant loads to point and non-point sources such that the waterbody will meet water quality standards for that particular pollutant.

Multiple 303(d) impairments and TMDLs have been identified for Indian Creek, Blue River, and the Missouri River as shown below in **Table 2.**

Table 2. Receiving Waterbody Clean Water Act 303(d) Impairments

Waterbody	Segment(s)	Pollutant	Category
Indian Creek (Kansas)	10300101-32	Total Phosphorus	5
		Chloride	5
		E. coli	4a
		Nitrate	4a
Indian Creek (Missouri)	0420	Chloride	5
		E. coli	5
Blue River	0417, 0418, 0419	*E. coli*	5
		Chlordane	4a
Missouri River	0356	*E. coli*	5
		Chlordane	4a
		PCBs	4a

Notes: Category 4: Available data and/or information indicate that at least one designated use is not being supported or is threatened, but a TMDL is not needed. (4a: TMDL has been developed for water, 4b: NPDES permits addressed impairment, 4c: Pollution (typically insufficient hydrology or habitat) is causing impairment)
Category 5: Available data and/or information indicate that least one designated use is not being supported or is threatened, and a TMDL is needed.

4.3 ANTIDEGRADATION TIER LEVEL

The Kansas Antidegradation Policy (KDHE, 2001) provides the following three tiers for maintaining and protecting water quality and designated uses:

1. *"The first tier (Tier 1) provides a "floor" which protects existing uses. Water quality must be preserved to protect and maintain those existing uses. Activities that would lower water quality below levels necessary to maintain existing uses are prohibited."*

2. *"The second tier (Tier 2) provides protection of high quality waters where water quality exceeds the criteria associated with the assigned designated uses. Limited water quality degradation is allowed in high quality waters where the degradation is necessary to accommodate important social or economic development, but only if designated uses are still maintained and the highest statutory and regulatory requirements for all point sources of pollution and all cost effective and reasonable best management practices for nonpoint sources of pollution are achieved. Public participation is required before allowing a lowering of water quality."*

3. *"The third tier (Tier 3) provides special protections for Outstanding Resource Waters, such as those waters in National and State Parks, wildlife refuges, outstanding fisheries, and other waters of unique recreational or ecological value. Although activities that may create temporary reductions in water quality are allowed, any activities that would permanently lower water quality of these surface waters is forbidden."*

For purposes of this antidegradation review, all receiving waterbodies are assumed Tier 2. Although existing impairments potentially suggest Tier 1, JCW is committed to identifying the least impacting, most cost-effective treatment alternative.

5 Alternatives Analysis

A primary requirement of antidegradation is that there must be must be a demonstration that the lowering of water quality is "necessary". A demonstration of necessity consists of an alternatives analysis as discussed in USEPA's final federal water quality standards rulemaking (80 FR 51048):

> *"Before allowing any lowering of high water quality, pursuant to (a)(2) of this section, the State shall find, after an **analysis of alternatives** (emphasis added), that such a lowering is necessary to accommodate important economic or social development in the area in which the waters are located. The analysis of alternatives shall evaluate a range of practicable alternatives that would prevent or lesson the degradation associated with the proposed activity."*

The alternatives analysis does not mandate implementation of the least degrading alternative, regardless of cost. This fact is illustrated in USEPA's proposed rule, which states that "*this evaluation would include a consideration of any non-degrading or minimally degrading **cost-effective** (emphasis added) pollution prevention alternatives . . .*" (78 FR 54529). Cost considerations are also included in Kansas guidance, which states the purpose of the alternatives analysis is to "*identify the least impacting, **cost-effective** (emphasis added) treatment method for a new or expanded discharge*" (KDHE, 2011).

Identifying the most cost-effective alternative also provides JCW greater capacity to address more critical environmental projects needed throughout their system. JCW anticipates approximately $2 billion in capital resource expenditures over the next 25 years. Requiring treatment levels beyond what is cost-effective will hinder JCW's ability to address other critical needs including I/I removal, collection system renewal, and upgrades at other treatment facilities.

In addition to being cost-effective, USEPA recognizes that alternatives must be practicable. USEPA defines "practicable" in the final federal water quality standards as meaning *"technologically possible, able to be put into practice, and economically viable"* (80 FR 51047).

Based on USEPA and Kansas guidance, a range of alternatives are presented below along with considerations for practicability, implementation, near- and far-field water quality impacts, and cost-effectiveness.

5.1 POTENTIAL ALTERNATIVES

Potential alternatives selected for the alternatives analysis were adapted from Technical Memorandum (TM) No. 6 – Combined Dry and Wet Weather Flow Alternative Selection, which was completed as part of the pre-design study update (HDR and CH2MHill, 2013). While components for the basic alternatives were maintained, the expected peak hour flow, termed peak wet weather flow (PWWF) was increased from 135 to 172 MGD based on more recent flow analyses. Additionally, the eight alternatives considered in the pre-design study update were supplemented with eight additional alternatives based on baseline conditions (i.e., existing system), three levels of nutrient removal, and elimination of wet weather flows through I/I control were included for a total of 16 alternatives.

The three levels of nutrient removal under evaluation include biological nutrient removal (BNR) and two levels of enhanced nutrient removal (ENR1 and ENR2) as described below.

- BNR represents the minimum level of treatment necessary to comply with KDHE's Surface Water Nutrient Reduction Plan (2004a). The plan calls for plants in excess of 1 MGD to achieve a goal of 8 mg/L for total nitrogen (TN) and 1.5 mg/L for total phosphorus (TP) on an average annual basis. However, alternative annual average goals of 1 mg/L TP and 10 mg/L TN have more recently been accepted by KDHE and are proposed here for BNR alternatives.
- ENR1 is considered equivalent to achieving a TN goal of 10 mg/L and a TP goal of 0.5 mg/L. Additional TP removal is through chemical addition (e.g., alum or ferric) and filtration.
- ENR2 is considered equivalent to achieving a TN goal of 5 mg/L and a TP goal of 0.5 mg/L. Additional TN removal is through additional denitrification capacity and addition of supplemental carbon sources (e.g., methanol).

It should be noted that ENR1 and ENR2 were only evaluated for the 19 MGD alternatives. Evaluation beyond BNR is not required for the 10 MGD alternatives because the current facility is already rated as a 10 MGD facility. Should JCW elect to upgrade the existing facility without expanding the design flow, antidegradation would not apply and there would be no regulatory need to evaluate ENR1 or ENR2.

A description of each alternative is provided for below and corresponding flow routing scenarios are summarized in **Table 3**:

Baseline: The baseline alterative represents the existing trickling filter facility. Although rated for a hydraulic design flow of 10 MGD with a peak flow rate of 45 MGD, the existing facility currently conveys all flows above approximately 7 MGD to the KCMO system, except during wet weather events when the capacity of the interceptor to KCMO is reached and the peak flow lagoon is activated.

10.1-BNR: Alternative 10.1-BNR represents a 10 MGD BNR facility with the balance of the dry weather flow being conveyed to KCMO. During wet weather events, the wet weather flows would be treated through an auxiliary treatment system, eliminating the need for JCW-dedicated storage at the KCMO 87th Street Pump Station.

10.2-BNR: Alternative 10.2-BNR represents a 10 MGD BNR facility that would convey the balance of the dry weather flow and all of the wet weather flows to KCMO. Some storage would also be required at Tomahawk to reduce wet weather peaks and avoid exceeding the capacity of the KCMO interceptor.

19.1-BNR: Alternative 19.1-BNR represents a 19 MGD BNR facility that would treat all flows at the Tomahawk WWTF with wet weather flows greater than 57 MGD treated through an advanced high-rate treatment systems, such as ballasted flocculation or compressible media filtration (further referred to as auxiliary treatment). Auxiliary treatment flows are combined with flows for BNR prior to discharge.

19.1-ENR1: Alternative 19.1-ENR1 represents a 19 MGD ENR facility (enhanced phosphorus removal) that would treat all flows at the Tomahawk WWTF with wet weather flows greater than 57 MGD treated through an auxiliary treatment system. Auxiliary treatment flows are combined with flows from ENR prior to discharge.

19.1-ENR2: Alternative 19.1-ENR2 represents a 19 MGD ENR facility (enhanced phosphorus and nitrogen removal) that would treat all flows at the Tomahawk WWTF with wet weather flows greater than 57 MGD treated through an auxiliary treatment system. Auxiliary treatment flows are combined with flows from ENR prior to discharge.

19.2-BNR: Alternative 19.2-BNR represents a 19 MGD BNR facility that would convey wet weather flows greater than 57 MGD to the KCMO system. Some storage would also be required at the Tomahawk WWTF to reduce wet weather peaks and avoid exceeding the capacity of the KCMO interceptor.

19.2-ENR1: Alternative 19.2-ENR1 represents a 19 MGD ENR (enhanced phosphorus removal) facility that would convey wet weather flows greater than 57 MGD to the KCMO system. Some storage would also be required at the Tomahawk WWTF to reduce wet weather peaks and avoid exceeding the capacity of the KCMO interceptor.

19.2-ENR2: Alternative 19.2-ENR2 represents a 19 MGD ENR facility (enhanced phosphorus and nitrogen removal) that would convey wet weather flows greater than 57 MGD to the KCMO system. Some storage would also be required at the Tomahawk WWTF to reduce wet weather peaks and avoid exceeding the capacity of the KCMO interceptor.

19.3-BNR: Alternative 19.3-BNR represents a 19 MGD BNR facility that would store wet weather flows greater than 57 MGD at the Tomahawk WWTF.

19.3-ENR1: Alternative 19.3-ENR1 represents a 19 MGD ENR facility (enhanced phosphorus removal) that would store wet weather flows greater than 57 MGD at the Tomahawk WWTF.

19.3-ENR2: Alternative 19.3-ENR2 represents a 19 MGD ENR (enhanced phosphorus and nitrogen removal) facility that would store wet weather flows greater than 57 MGD at the Tomahawk WWTF.

0.1: Alternative 0.1 assumes dry weather flows would be conveyed to the KCMO system and wet weather flows would receive auxiliary treatment at the Tomahawk WWTF.

0.2: Alternative 0.2 assumes all flows would be conveyed to the KCMO system and includes wet weather storage at the KCMO 87th Street Pump Station as well as some storage at the Tomahawk WWTF to reduce wet weather peaks to avoid exceeding the capacity of the KCMO interceptor.

0.3: Alternative 0.3 assumes all flows would be conveyed to the KCMO system and includes wet weather storage at the Tomahawk WWTF and a small amount of storage at the KCMO 87th Street Pump Station.

I/I Reduction: The inflow and infiltration (I/I) reduction alternative presumes that wet weather flows would be reduced below the secondary treatment hydraulic capacity of 57 MGD at the Tomahawk WWTF.

Table 3. Treatment Alternatives for the Proposed Tomahawk WWTF

Alternative	Description	Tomahawk WWTF Flows (MGD)				KCMO Conveyance Flows (MGD)[1]		
		DWF	PWWF		Auxiliary	DWF	PWWF	THC Storage
			Direct	THC Storage				
Baseline	Existing Facility	7	--	--	--	12	135	50
		(0-7)	--	--	--	(7-19)	(85-104)	(104-172)
10.1-BNR	10 MGD with Auxiliary Treatment	10	10	--	97	10	27	
		(0-10)	(20-30)	--	(57-172)	(10-20)	(30-57)	
10.2-BNR	10 MGD with KCMO Conveyance	10	10	--	--	10	97	27
		(0-10)	(20-30)	--	--	(10-20)	(57-172)	(30-57)
19.1-BNR, 19.1-ENR1, 19.1-ENR2	19 MGD BNR, ENR & ENR2 with Auxiliary Treatment	19	38		97	--	--	--
		(0-19)	(38-57)		(57-172)	--	--	
19.2-BNR, 19.2-ENR1, 19.2-ENR2	19 MGD BNR, ENR & ENR2 with KCMO Conveyance	19	38		--	--	97	--
		(0-19)	19-57		--	--	(57-172)	--
19.3-BNR, 19.3-ENR1, 19.3-ENR2	19 MGD BNR, ENR & ENR2 with THC Storage	19	38	97	--	--	--	--
		(0-19)	(19-57)	(57-172)	--	--	--	
0.1	0 MGD with Auxiliary Treatment	--	--	--	97	19	19	19
		--	--	--	(57-172)	(0-19)	(19-38)	(38-57)
0.2	0 MGD with THC and KCMO Storage	--	--	--	--	19	97	38
		--	--	--	--	(0-19)	(19-38, 76-172)	(38-76)
0.3	0 MGD with THC Storage	--	--	--	--	19	19	116
		--	--	--	--	(0-19)	(19-38)	(38-172)
I/I Reduction	Reduction of wet weather flows to secondary treatment capacity through I/I controls	19 (0-19)	38 (19-57)	--	--	--	--	--

Notes: Flows in parentheses represent the range in which the treatment or storage component of each of the alternatives would be implemented.
DWF – Dry weather flow
PWWF – Peak wet weather flow
[1] Total hydraulic flow to KCMO limited to 97 MGD interceptor capacity.

5.2 PRACTICABILITY

Potential alternatives were evaluated for practicability based on the following definition from USEPA's finalized updates to federal water quality standards regulations:

> *"Practicable, in the context of §131.12(a)(2)(ii), means technologically possible, able to be put into practice, and economically viable."*

Based on this evaluation, at least eight of the sixteen alternatives are considered impracticable and warrant no further consideration. Rationale for each impracticable option is provided as follows:

- Baseline (Existing Facility): The existing facility is included within this report to evaluate anticipated water quality improvements relative to existing conditions, but is not considered a viable alternative. The existing facility is not capable of meeting future mussels-based ammonia limits.

- 10.1-BNR (10 MGD with Auxiliary Treatment): While auxiliary treatment was originally investigated for the 10 MGD alternative due to limited capacity in the linking interceptor to transport high peak flows to the KCMO system, the concept of only treating part of the dry weather flow and all of the wet weather flow at the Tomahawk WWTF is less logical and less desirable from a water quality standpoint than treating all flow, dry and wet, at the Tomahawk WWTF. If JCW is to construct a new 10 MGD facility, Alternative 10.2-BNR is the more practicable alternative.

- 19.2- BNR (19 MGD BNR with KCMO Conveyance): For Alternative 19.2-BNR, all dry weather flow would be treated at Tomahawk WWTF and only approximately 1% of the total annual flow would be conveyed to the KCMO system. KCMO acceptance of infrequent peak flows is unlikely since this would drive significant capital investments and these flows would occur when the KCMO system is most challenged.

- 19.2-ENR1 (19 MGD ENR with KCMO Conveyance): The same rationale applied to Alternatives 19.2-ENR1 applies to Alternative 19.1-BNR. The only difference with this option is the level of nutrient treatment.

- 19.2-ENR2 (19 MGD ENR with KCMO Conveyance): The same rationale applied to Alternatives 19.2-ENR2 applies to Alternative 19.1-BNR. The only difference with this option is the level of nutrient treatment.

- 0.1 (0 MGD with Auxiliary Treatment): Similar to the rationale for Alternative 10.1-BNR, it is impracticable to treat wet weather flow at the Tomahawk WWTF while sending all dry weather flow to the KCMO system. It also presents challenges from an operational standpoint. If dry weather flows are conveyed to the KCMO system, Alternative 0.2 is the more practicable alternative.

- 0.3 (0 MGD with THC Storage): The Tomahawk WWTF site is surrounded by residential and commercial development and streamway corridors to the east, south, and west. To the north and northeast lie highly developed parks, owned by both the County and the City of Leawood, which are heavily utilized for youth soccer, baseball,

softball, and aquatic activities. The parks are the only adjacent open areas where storage could physically be constructed; however, obtaining the space would be politically unfavorable and result in a protracted land acquisition schedule. If dry weather flows are conveyed to the KCMO system, Alternative 0.2 is the more practicable alternative.

- I/I Reduction (Elimination of Wet Weather Flows through I/I Controls): To reduce the total flow from 172 MGD to the 57 MGD capacity of the biological treatment facility would require over 80% I/I removal. Studies, including JCW's recent Pilot I/I Study, have consistently shown that I/I reduction beyond 20-30% for systems like that tributary to the Tomahawk WWTF is not cost effective.

Although most alternatives with Tomahawk WWTF storage were retained as practicable, it should be noted that, as explained above, there are serious practicability issues associated with these alternatives. The storage facility required for Alternative 0.2 would be constructed at the Johnson County owned soccer field located to the north of the Tomahawk WWTF. Alternatives 0.3 (already determined to be impracticable) and 19.3 (BNR, ENR1 and ENR2) would require additional storage constructed at the City of Leawood owned soccer fields to the east. Although technically feasible, it is unclear if JCW could acquire these properties for purposes of storage without a protracted legal battle.

5.3 IMPLEMENTATION CONSIDERATIONS

Alternatives that involve constructing additional storage capacity at the 87th Street Pump Station (i.e., all except 19.1 and 19.3) will not be fully implemented until 2030. The current KCMO OCP calls for completion of additional storage at the 87th Street Pump Station by December 31, 2024. However, the additional storage volume is based upon the wastewater flows expected in the Year 2030, following completion of recommended I/I reduction work in the Blue River South Basin. The potential expansion of the Tomahawk WWTF is scheduled for completion in early 2022. Therefore, Alternatives 19.1 and 19.3 (BNR, ENR1 and ENR2) would result in the equivalent level of reduction in SSOs approximately 8 years ahead of any other practicable alternative.

5.4 WATER QUALITY IMPACTS

Water quality impacts associated with each alternative were evaluated for both the near-field (i.e., Indian Creek) and the far-field (i.e., Missouri River and ultimately the Gulf of Mexico). The primary purpose of the near- and far-field analyses was to evaluate relative differences between alternatives for assessing wastewater management strategies. Both the near-field and far-field analyses were based on pollutant loading assumptions derived from anticipated long-term average effluent concentrations and JCW flow projections. The long-term average effluent concentrations were estimated from facility effluent data and literature sources along with best professional judgment (**Table 4**). Estimated effluent concentrations are not intended to be representative of permit limits, but rather represent long-term average concentrations for purposes of the alternatives analysis. The JCW flow projections were derived from the compilation of Tomahawk WWTF influent flows and KCMO diversion flows.

Table 4. Estimated Long-Term Average Effluent Concentrations Used for Modeling Water Quality Impacts (Table values are not intended to be representative of permit limits.)

Parameter	Units	Existing (Baseline)	BNR	ENR1	ENR2	Auxiliary	KC Blue River WWTP
Dissolved Oxygen	mg/L	6.0	6.0	6.0	6.0	6.0	--
$CBOD_5$ (total)	mg/L	14	6	3	3	28	20
$CBOD_5$ (soluble)	mg/L	7	3	2	2	25	--
$CBOD_5$ (particulate)	mg/L	7	3	1	1	3	--
Total Suspended Solids	mg/L	15	9	3	3	20	29
Non-Volatile Suspended Solids	mg/L	3	2	0.6	0.6	5	--
Volatile Suspended Solids	mg/L	12	7	2.4	2.4	15	--
Total Nitrogen	mg/L	18	10	10	5	17	18
Organic Nitrogen (soluble)	mg/L	3	2	2	2	7	--
NO_3+NO_2-N	mg/L	11	8	8	3	1	--
NH_3-N	mg/L	4	0.2	0.2	0.2	8.8	15
Total Phosphorus	mg/L	2.6	1.0	0.5	0.5	2.1	2.9
Organic P (soluble)	mg/L	0.05	0.05	0.05	0.05	0.05	--
PO_4-P	mg/L	1.3	0.7	0.4	0.4	0.9	--

Notes: BNR applies to Alternatives 10.2-BNR, 19.1-BNR and 19.3-BNR. ENR applies to Alternatives 19.1-ENR1, 19.1-ENR2, 19.3-ENR1, and 19.3-ENR2. Auxiliary applies to Alternatives 19.1-BNR, 19.1-ENR1, and 19.1-ENR2. Auxiliary flows are combined with flows from secondary treatment (i.e., BNR, ENR1, and ENR2) prior to discharge. The KC Blue River WWTP applies to Alternatives 10.2-BNR and 0.2.

5.4.1. Bacteria

All alternatives under evaluation, including auxiliary treatment, will provide equivalent levels of disinfection that will meet seasonal bacteria criteria. Therefore, all alternatives are considered equivalent with regards to bacteria and no further analysis is provided in this antidegradation report.

5.4.2. Near-Field Analysis

The near-field (i.e., Indian Creek) analysis considered both impacts to instream pollutant concentrations and benthic algal response. Benthic algal response was modeled to evaluate the relative influence of different wastewater management and treatment scenarios on eutrophication in Indian Creek. For purposes of conducting the alternatives analysis, the relative difference in benthic algae levels is considered of greater importance than the magnitude of benthic algae levels, for which there is no criterion. The method used to assess water quality impacts in the near-field and results are described below.

Near-Field Modeling Method

Two periphyton models of Indian Creek were developed to help evaluate each of the nine alternatives. One of the two models was developed to simulate water quality impacts during critical low-flow conditions as represented by the Year 2012 (hereinafter referred to as the 2012 model). The Year 2012 was selected because it represents a conservative scenario as it was a relatively low-flow year. Additionally, the most significant amount of USGS water quality data available for model calibration was from the Year 2012. This model year should be

considered very conservative as the 2012 annual rainfall ranks in the 7th percentile over the past 30 years, and these dry weather conditions should amplify potential eutrophication impacts from continuous wasteloads within Indian Creek.

The second periphyton model was developed to simulate water quality impacts during a typical rainfall year as represented by the Year 2001 (hereinafter referred to as the 2001 model). The Year 2001 was selected in part based on a precipitation evaluation conducted in support of the Long-Term Control Plan for the City of Kansas City, Missouri. This evaluation considered rainfall amounts, inter-event time, and peak intensity recurrence analysis. Additional assessment of local rain gage data and historical Indian Creek flows corroborated the selection of 2001 as a typical rainfall year.

The 2001 and 2012 modeling framework included a hydraulic model (CE-QUAL-RIV1) and a periphyton model (PeriWASP) of Indian Creek beginning just upstream from USGS gaging station at 119th Street (River Mile [RM] 13) and ending at the USGS gaging station at the stateline (RM .35) for a total model length of 9.5 miles (Figure 2). Both these models are 1-dimensional and time-variable. The hydraulic model provides time-varying creek geometry as a function of creek flow to the periphyton model; and the periphyton model provides time-varying calculation of various water quality parameters using the creek transport information calculated with the hydraulic model. The periphyton model was chosen for its ability to simulate algal response in dynamic flow, which is considered a key driver in controlling algal levels. As flow (and hence shear stress) increases, sloughing and bed-scouring contribute to loss of algal biomass.

The modeling framework used for the 2001 model also included the P8 watershed runoff model, since comprehensive hydrologic and water quality data inputs were not available, unlike for 2012. P8 is an urban catchment model for predicting the generation of pollutants resulting from stormwater runoff in urban watersheds. The model computes pollutant loads and concentrations by simulating runoff volumes for both pervious and impervious areas. Runoff volume was simulated based on 2001 rainfall data from the Corporate Woods gaging station, which is located in the middle portion of the Indian Creek Basin. Relative to other nearby rain gages, the Corporate Woods station best matched the long-term average rainfall in Kansas City. P8 model output was used as input into the CE-QUAL-RIV1/PeriWASP model. For the 2012 model, real-time flow data at multiple gaging stations and average baseflow and wet weather water quality data were used as inputs into the CE-QUAL-RIV1/PeriWASP model.

Data used to develop, calibrate, and validate the 2001 and 2012 water quality models were obtained from multiple sources including the following:

- USGS gage station data (**Table 5** and **Figure 2**)
  - 2012 monthly nutrient and periphyton data
  - 2012 continuous flow, dissolved oxygen, turbidity, solar radiation (available light) and temperature data
  - Creek geometry data
- 2014 USGS and B&V synoptic data
  - Spatial variation in nutrient and BOD concentrations
  - Tributary data to define non-point source inputs
  - $CBOD_{20}$ data to determine ultimate oxygen demand in creek and effluent
  - Pool/riffle/run information from USGS

- JCW effluent data
  - Effluent data from Middle Basin WWTP and Tomahawk WWTF
- Past studies on Indian Creek
  - Past creek geometry, travel time and reaeration studies

Table 5. USGS Gage Stations Used for Calibrating the Indian Creek Water Quality Model

Site Identifier	Site Name	USGS Station Number	Distance from Middle Basin WWTP (mi.)	Distance from Tomahawk WWTF (mi.)
119th	Indian C at 119th Street	385446094430700	1.5 above	8.1 above
College	Indian C at College Blvd	385520094420000	0.6 below	6.2 above
Marty	Indian C at Overland Park	06893300	3.2 below	3.6 above
Mission Farms	Indian C at Indian C Pkwy	385608094380300	5.9 below	0.9 above
Tomahawk	Tomahawk C nr Overland Park	06893350	Not Applicable	1.7 above
State Line	Indian C at State Line Rd	06893390	8.1 below	1.4 below

Complete model documentation is included in Appendix A.

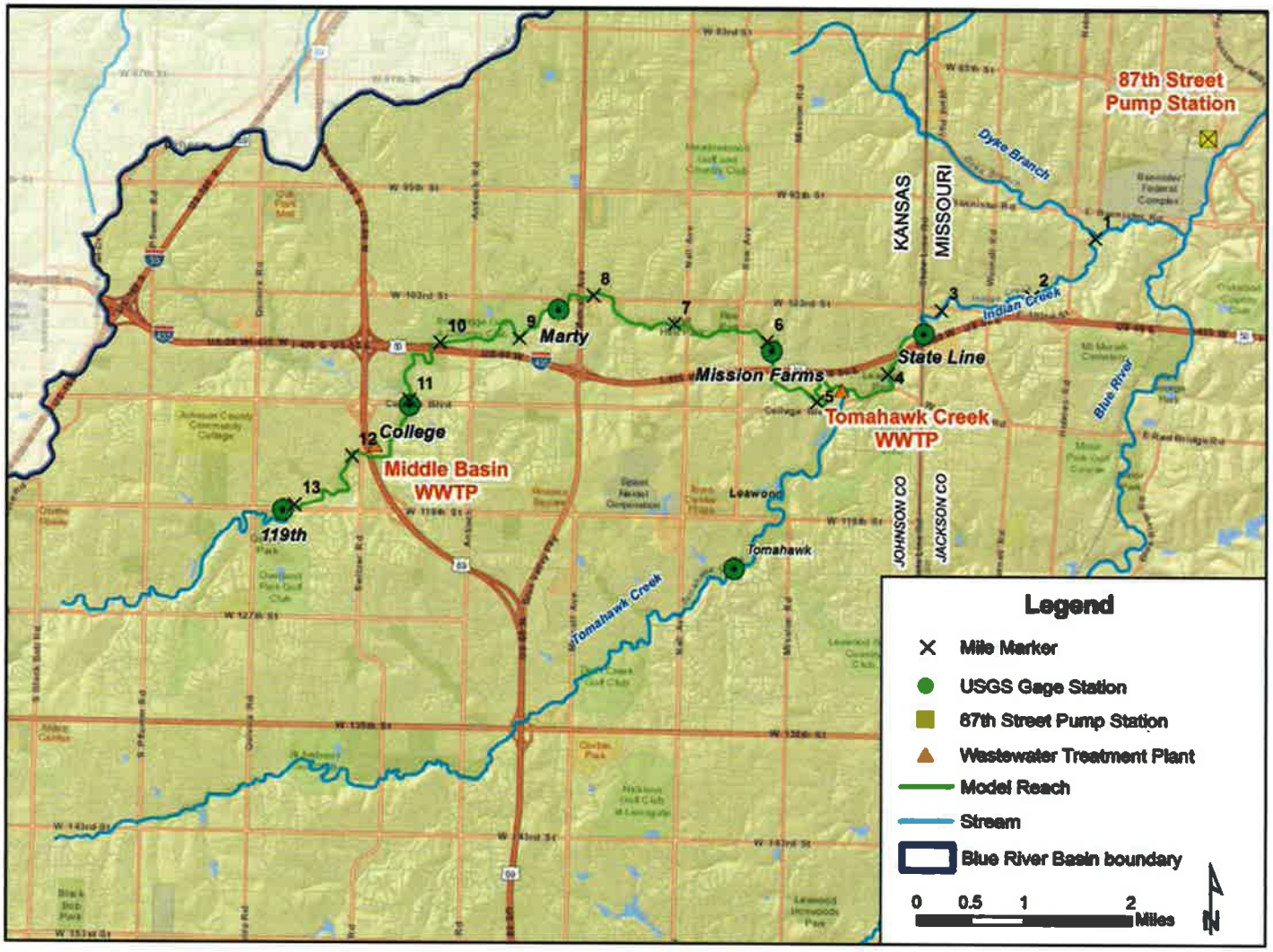

Figure 2. Water Quality Model Reach and Sampling Stations

Near-Field Water Quality Modeling Results

Results of the 2001 and 2012 water quality model demonstrate that the annual reach-average pollutant concentrations and benthic algal biomass improve relative to baseline conditions for all alternatives, with the exception of Alternative 0.2 (**Table 6**). Algal biomass is considered the most meaningful water quality measure in Indian Creek since it is the key response variable to nutrient discharges. Furthermore, benthic algal biomass was selected as the primary metric for algal production as this community dominates within Indian Creek compared to phytoplankton (USGS 2014). Alternative 0.2 results in the lowest reach average concentrations of TP, TN, ammonia, and $CBOD_5$, but actually the highest benthic algae levels due to physical factors as discussed below.

Table 6. Reach Annual -Average Concentrations

Alternative	Benthic Algae (mg Chl a /m²)		TP (mg/L)		TN (mg/L)		Ammonia-N (mg/L)		$CBOD_5$ (mg/L)	
	2001	2012	2001	2012	2001	2012	2001	2012	2001	2012
Baseline	27	58	1.2	1.1	11.4	9.7	1.48	1.33	6.9	6.5
10.2-BNR	23	53	0.7	0.6	8.8	7.4	0.12	0.09	4.7	4.1
19.1-BNR	15	42	0.8	0.7	9.0	7.9	0.13	0.11	4.9	4.5
19.1-ENR1	15	41	0.5	0.4	9.0	7.9	0.13	0.11	3.3	3.0
19.1-ENR2	15	41	0.5	0.4	6.1	5.1	0.13	0.11	3.3	3.0
19.3-BNR	15	42	0.8	0.7	9.0	7.9	0.13	0.11	4.9	4.5
19.3-ENR1	15	41	0.5	0.4	9.0	7.9	0.13	0.11	3.3	3.0
19.3-ENR2	15	41	0.5	0.4	6.1	5.1	0.13	0.11	3.3	3.0
0.2	34	68	0.4	0.3	7.4	5.0	0.05	0.03	3.6	2.8

Notes: Values calculated as the median of the annual reach averages for the model reach segment extending from the Tomahawk WWTF to State Line for all parameters except benthic algae. Benthic algae levels were averaged over the growing season (i.e., May – September). $CBOD_5$ values assume a $CBOD_U$ to $CBOD_5$ ratio of 3.

Relative to the 2001 typical year model run, reach average benthic algal levels for the 2012 critical low-flow model run more than doubled (**Table 6**). The increase in biomass is predicted despite a decrease in nutrient levels. This suggests that physical factors, and not nutrients, are driving benthic algal levels in Indian Creek. The role of physical factors is further demonstrated in **Table 6** by the fact that benthic levels are inversely proportional to effluent flow (i.e., the lower the design flow the greater the benthic algae biomass). Additionally, the instream responses for the six 19 MGD alternatives are indistinguishable, suggesting neither wet weather treatment strategy (i.e., storage vs. auxiliary) nor level of nutrient removal appreciably impact benthic algae levels. Collectively, these results suggest that benthic algal biomass within the modeled stream segment is controlled by physical factors rather than nutrient limitations.

Longitudinal plots for both the 2001 and 2012 model runs depict an increasing trend in benthic algae levels downstream of the Tomahawk WWTF for all alternatives (**Figure 3**). This trend corresponds with decreasing levels of tree canopy shade in the downstream direction, suggesting that algal biomass is light limited rather than nutrient limited. In comparison, as shown in **Figure 4**, downstream TP levels remain relatively flat and benthic algae levels do not appear related to TP levels (i.e., higher benthic algae levels do not correspond to higher TP levels). This further suggests that nutrients are not the primary limiting growth factor in Indian Creek.

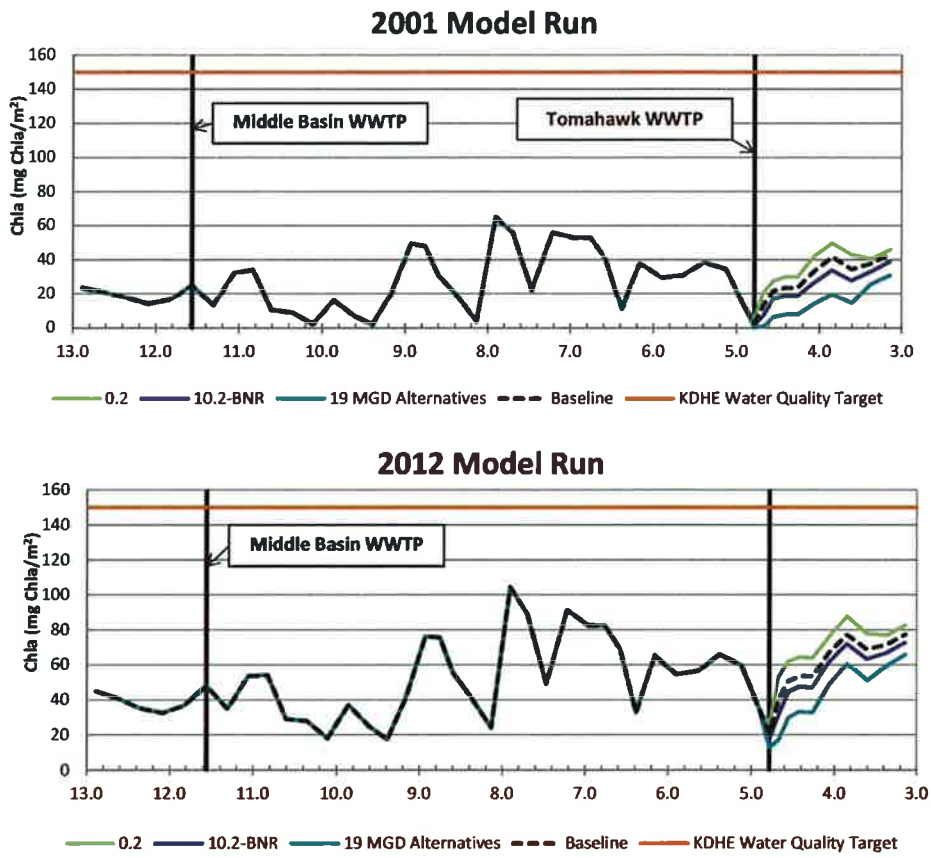

Figure 3. Longitudinal Plots of Growing Season (May – September) Median Benthic Chlorophyll *a* Concentrations (2001 and 2012 Models). (Note: 19 MGD Alternatives [i.e., 19.1-BNR, 19.1-ENR1, 19.1-ENR2, 19.3-BNR, 19.3-ENR1 and 19.3-ENR2] are represented as one single line since differences in model output were indistinguishable.)

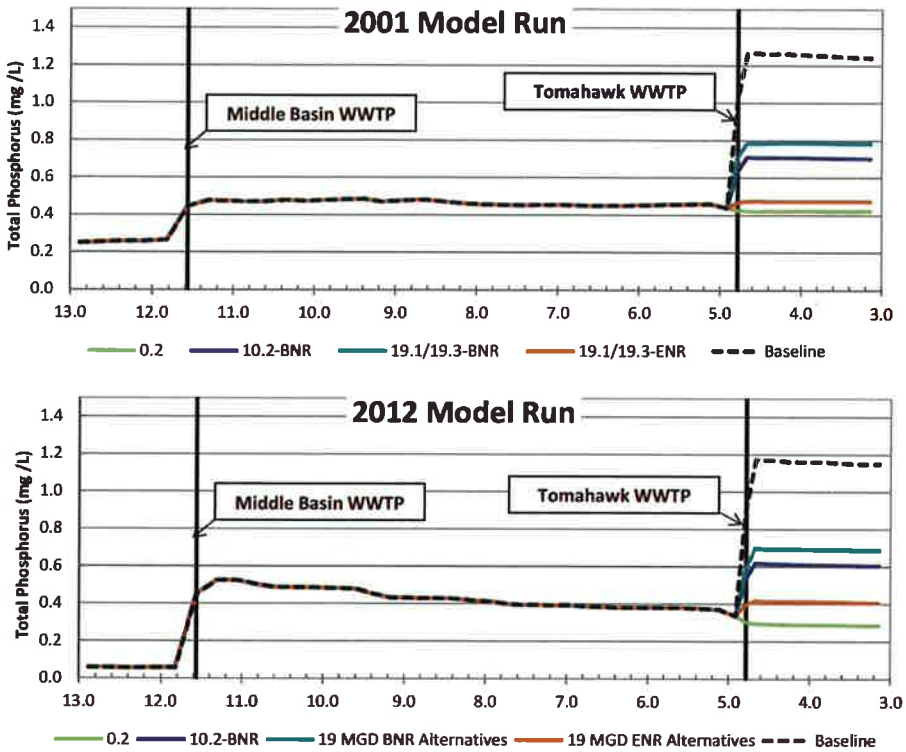

Figure 4. Longitudinal Plots of Annual Median Total Phosphorus for Wastewater Management and Treatment Alternatives Under Evaluation (2001 and 2012 Models). (Note: 19 MGD BNR Alternatives [i.e., 19.1-BNR and 19.3-BNR] and 19 MGD ENR Alternatives [i.e., 19.1-ENR1, 19.1-ENR2, 19.3-ENR1, and 19.3-ENR2] are each represented as one single line since differences in model output were indistinguishable.)

Seasonal depictions of benthic algae further illustrate the relationship of stream hydraulics to benthic algae levels in Indian Creek. As modeled for the baseline alternative at State Line, benthic algae levels precipitously drop following peak flow events, most noticeably in the spring and late summer (**Figure 5**). This demonstrates that sloughing and bed-scouring are critical drivers in regulating benthic algae levels in Indian Creek. USGS (2014) similarly found that average weekly flows in excess of 50 cubic feet per second (cfs) typically resulted in scouring of the benthic algae community at the State Line sampling site. Conversely, **Figure 5** illustrates that algae levels are greatest during the summer when flows are relatively low and stable.

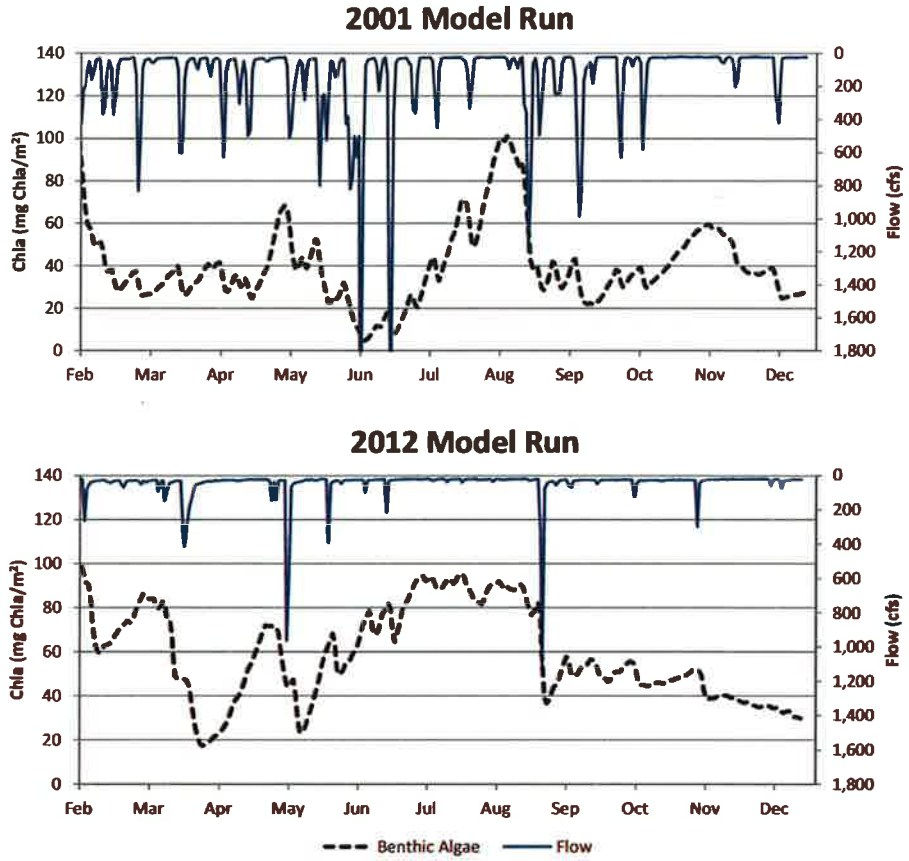

Figure 5. Seasonal Variation of Benthic Chlorophyll *a* at State Line for Baseline Alternative (2001 and 2012 Models)

Water quality modeling results also demonstrate that on a monthly average basis, KDHE's water quality target for benthic algae of 150 mg Chl a/m² are protected by all the alternatives during the peak growing season as defined by the months of May through September (**Figure 6**). Although not a water quality criterion, KDHE has referenced 150 mg Chl a/m² as an acceptable condition in TMDLs based on studies conducted by Suplee (2009) and others. The 2012 model results depict a very conservative (worst case) condition with respect to algal production during the summer growing season. The persistent drought that occurred in the summer of 2012, resulted in minimal benthic algae scouring compared to more typical years. The 2001 model, which is representative of typical year rainfall conditions, simulated lower benthic algae levels when depicted as a geometric mean. However, maximum daily average benthic algae levels appear similar between the 2001 and 2012 models.

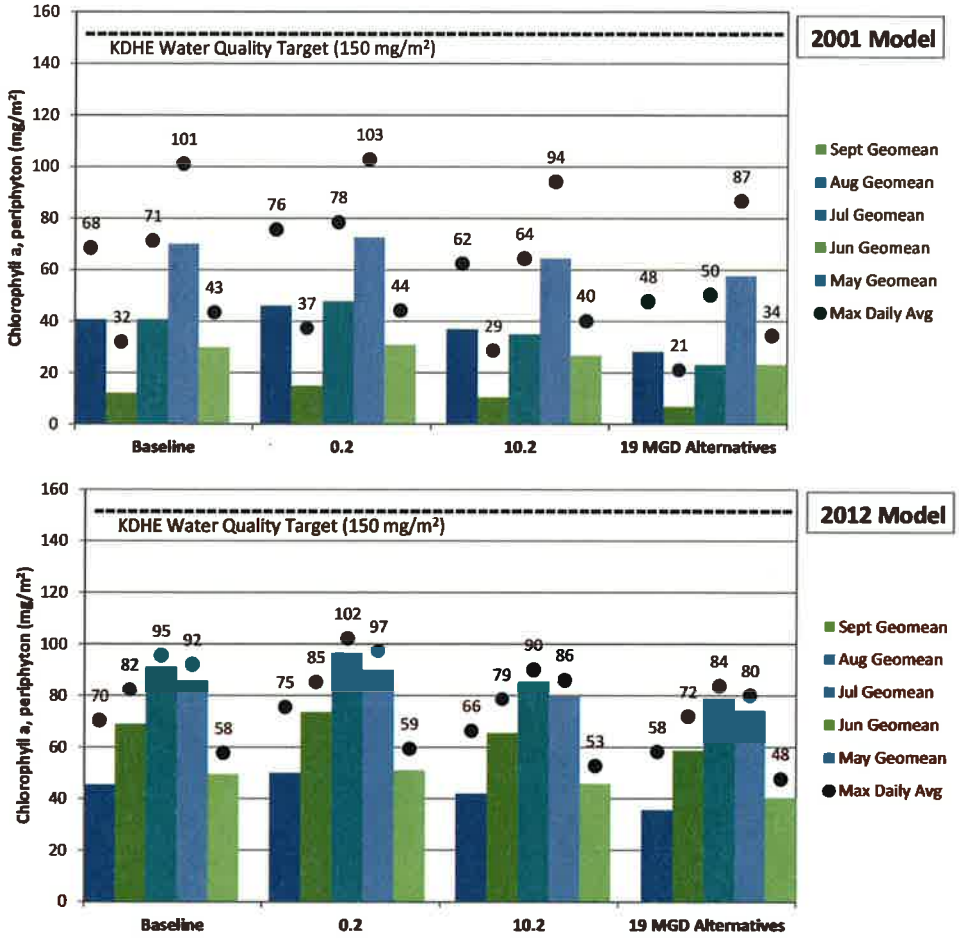

Figure 6. Summary of Daily Average Benthic Algae Levels at State Line (May – September) for the 2001 and 2012 Models. (Note: The 19 MGD Alternatives are collectively represented as one set of bars since differences in model output were indistinguishable. The bars represent the monthly geometric mean and the dots represent the monthly maximum. Results based on the 2012 model.)

Boxplots were used to assess the distribution of daily average benthic algae levels at State Line during the growing season, as depicted by the months of May through September (**Figure 7**). The boxplots demonstrate there are little to no differences between the 19 MGD alternatives. The similarity in distribution suggests that neither differences between wet weather treatment strategy (i.e., auxiliary treatment and storage) nor between treatment level (i.e., BNR, ENR1 and ENR2) have any meaningful impact on benthic algae levels. However, as previously discussed, the boxplot comparison does show that benthic algae levels (maximums, medians, and range) decrease with increasing design flow.

The boxplots also suggest that the overall range of daily average benthic algae levels remains relatively constant regardless of climate patterns. Although daily average algae levels are higher for the 2012 critical low-flow model run, maximum levels are relatively consistent with

the 2001 typical year model run. This suggests that benthic algae levels remain higher longer during critical low-flow periods, but generally do not exceed maximum values observed during more typical rainfall years.

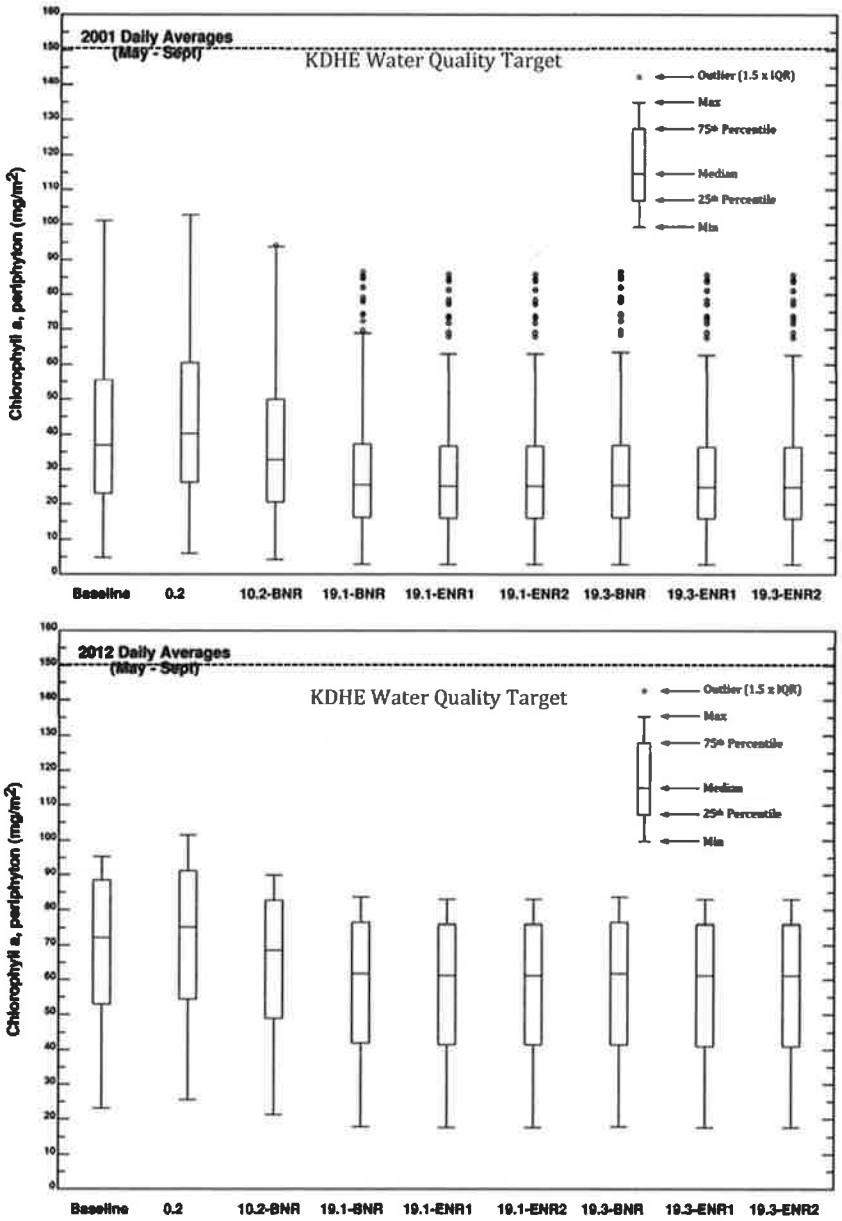

Figure 7. Distribution of Daily Average Benthic Algae Levels at State Line (2001 and 2012 Models)

Boxplot analyses for the 2012 model run demonstrate that instream nutrient concentrations are closely linked to effluent quality (**Figures 8-9**). Alternative 0.2, which does not include a THC discharge to Indian Creek results in the lowest instream nutrient concentrations in the near-field. However, the 19 MGD alternatives are nearly comparable to Alternative 0.2 and result in significantly lower instream concentrations relative to baseline conditions due to a higher

effluent quality. With respect to the 19 MGD alternatives, ENR1 and ENR2 result in significantly lower instream TP levels than BNR, but differences between auxiliary treatment and storage of wet weather flows are generally negligible for all parameters. This demonstrates that the storage and secondary treatment of wet weather flows in excess of 57 MGD does not result in any meaningful water quality improvements relative to auxiliary treatment. With the exception of the baseline alternative, the 2012 model also predicts all alternatives will meet instream ammonia criteria based on USEPA's 2013 recommendations (USEPA 2013) (**Figure 10**).

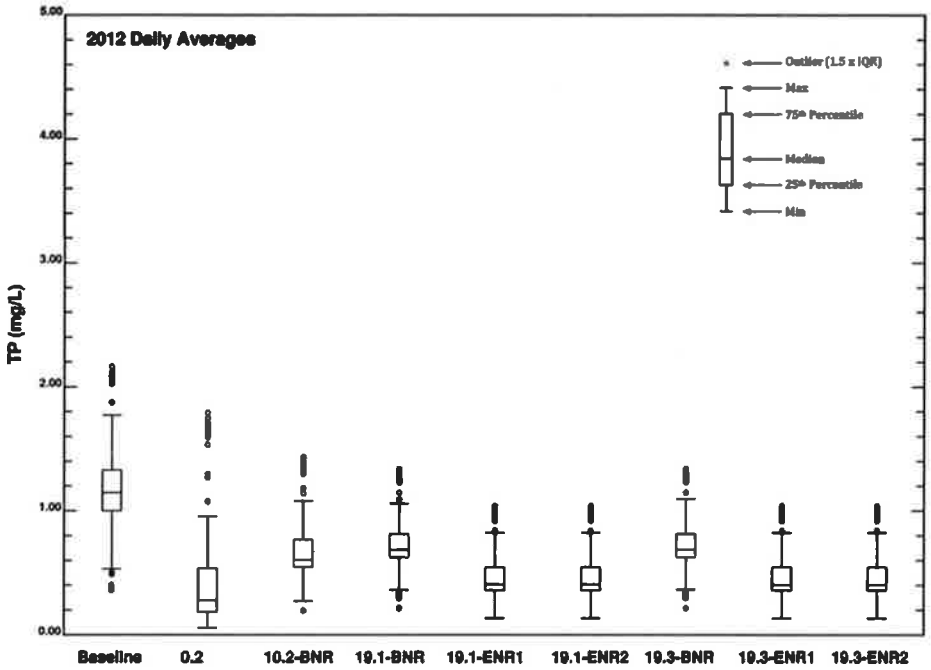

Figure 8. Distribution of Daily Average Total Phosphorus Levels at State Line

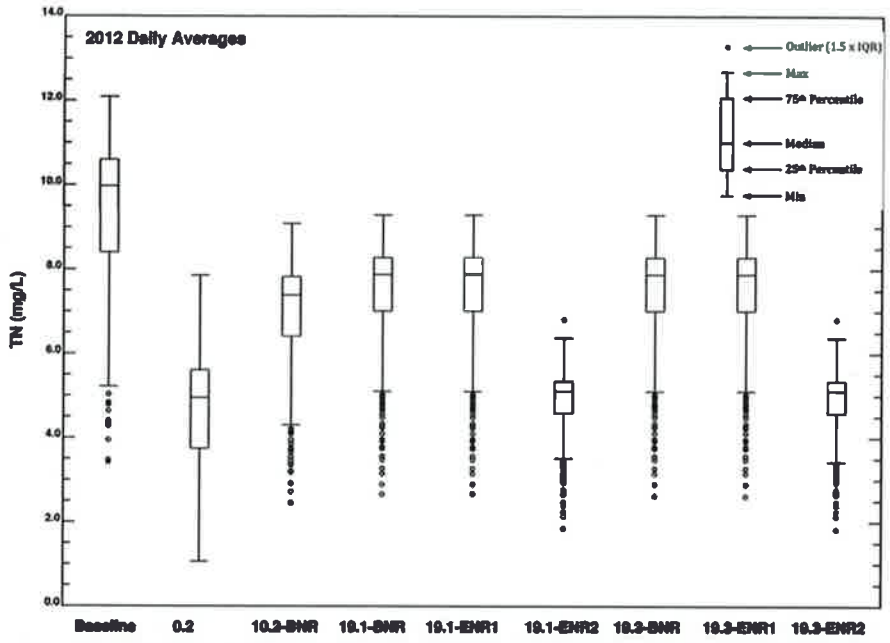

Figure 9. Distribution of Daily Average Total Nitrogen Levels at State Line

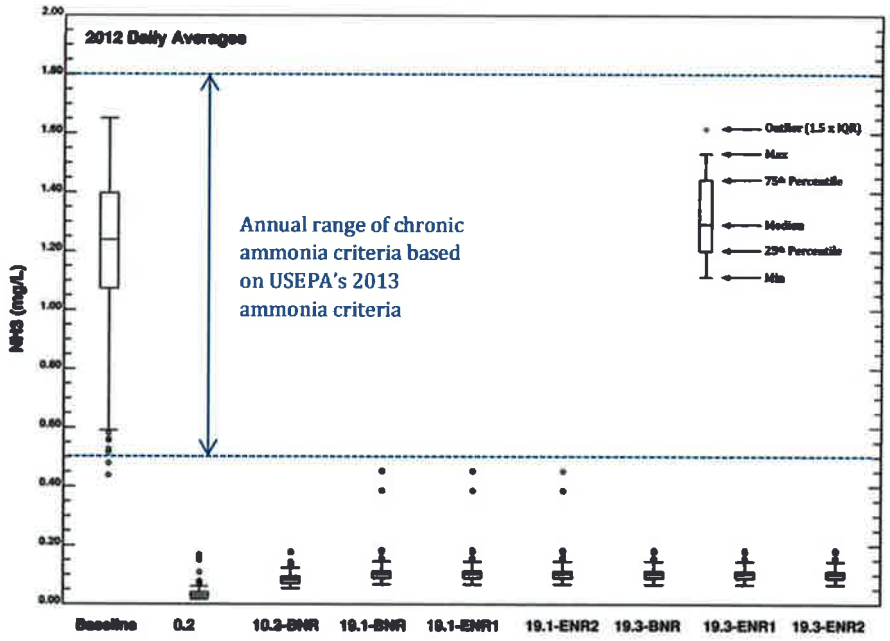

Figure 10. Distribution of Daily Average Ammonia Levels at State Line (Note: Individual data points and outliers are more appropriately compared to acute criteria rather than chronic criteria, which are applied as 30-day averages. Acute criteria values exceed the range presented in this graph.)

5.4.3. Far-Field Analysis

Whereas instream pollutant concentrations and algal response are critical for assessing near-field impacts, pollutant loading is considered a better indicator of far-field impacts. This is particularly true for nutrients, where approximately 90% of nutrients in the Missouri River are delivered to the Gulf of Mexico (Alexander et al., 2008). Therefore, far-field impacts of alternative treatment options were evaluated in terms of annual pollutant loadings to the Missouri River, which is a major river within the Mississippi-Atchafalaya River Basin (MARB). The method used to assess water quality loading in the far-field and results are described below.

Far-Field Modeling Method

Annual pollutant loadings to the Missouri River were calculated using a mass-balance spreadsheet model for 5-day carbonaceous biochemical oxygen demand ($CBOD_5$), total suspended solids (TSS), ammonia (NH3N), total phosphorus (TP), and total nitrogen (TN). Total loadings to the Missouri River were calculated for each alternative as the sum of incremental pollutant loadings from the Tomahawk WWTF (secondary and auxiliary treatment) and that portion of the KC Blue River WWTP attributable to the Tomahawk service area. Total loadings do not take into account pollutant decay or other instream processes that would reduce contributions to the Missouri River attributable to the Tomahawk WWTF. Therefore, alternatives with a direct discharge to Indian Creek are depicted as having a larger impact on the Missouri River than likely occurs. While important to consider, this ultimately does not impact the interpretation of alternatives evaluation results.

The mass-balance spreadsheet model calculated annual pollutant loadings from estimated long-term average effluent concentrations (**Table 4**) and estimated annual flow volumes. Estimated annual flow volumes were derived from JCW flow data collected between September 2009 through 2014 (**Table 7**). The JCW flow data were increased by a factor of approximately 1.2 to account for some growth as well as the likely future diversion of additional flows from small adjacent sub-watersheds by pumping, as is currently done with the previously mentioned Dyke's Branch watershed. This projection established a design average flow of 19 MGD. For modeling purposes, flows were partitioned between potential treatment scenarios based on the flow routing scheme previously presented in **Table 3**. One hundred percent of flows diverted to the KCMO system are assumed treated by the KCMO Blue River WWTP. Although not modeled, in actuality, a small percentage of flows diverted to the KCMO Blue River WWTP will likely be discharged directly to the Blue River during CSO events.

Table 7. Total Annual Flow Volumes and Diversions Used for Estimating Pollutant Loading

Alternative	Annual Discharge Volume to Tomahawk WWTF (MG)		Annual Discharge Volume to KC Blue River WWTP (MG)	Diversions to Auxiliary or KCMO Conveyance	
	Secondary	Auxiliary		Percent of Flow Diverted	Percent of Time Diverted
Baseline	2,380	0	4,462	65.2%	95.9%
10.2-BNR	4,112	0	2,730	39.9%	83.8%
19.1 (BNR, ENR1 and ENR2)	6,769	73	0	1.1%	0.7%
19.3 (BNR, ENR1 and ENR2)	6,842	0	0	0%	0%
0.2	0	0	6,842	100%	100%

Notes: Estimated annual flow volumes were derived from the following datasets collected between September 2009 and September 2014: 1) influent flows to Tomahawk WWTF, and 2) diverted flows to KCMO. Flows from the two datasets were combined and increased by a factor of approximately 1.2 to account for growth and consolidation, resulting in a design average flow of 19 MGD.
MG – Million gallons

Far-Field Modeling Results

Incremental results of the far-field analysis demonstrate that pollutant loadings from diversions to the KC Blue River WWTP dominate pollutant loadings to the Missouri River relative to loadings from secondary treatment and auxiliary treatment (**Table 8** and **Figure 11**). Conversely, pollutant loadings from auxiliary treatment represent a small fraction of the overall loadings relative to other loading sources (**Figure 11**). This suggests that alternatives that include diversions to the KC Blue River WWTP result in significantly greater impacts to the Missouri River and impacts due to auxiliary treatment are negligible.

Total pollutant loadings to the Missouri River (i.e., sum of the incremental pollutant loadings) are greatest for Alternatives Baseline, 0.2, and 10.2-BNR (**Table 9**). Total loadings to the Missouri River are approximately one-half to over an order of magnitude smaller for alternatives that do not include any diversion to the KC Blue River WWTP (i.e., Alternatives 19.1-BNR, 19.1-ENR1, 19.1-ENR2, 19.3-BNR, 19.3-ENR1, and 19.3-ENR2). With respect to the 19 MGD alternatives, there are significant differences between BNR and the ENR alternatives (i.e., ENR1 and ENR2). Relative to BNR, the ENR alternatives result in half or less of the loadings for $CBOD_5$, TSS, and TP. The ENR2 alternatives result in approximately half the TN loading than the BNR alternatives. With respect to wet weather treatment strategy, there is relatively no difference in loading between the auxiliary treatment and storage wet weather alternatives (e.g., less than a 3% difference between 19.1-ENR1 and 19.3-ENR1 for TP).

Relative to Baseline, all other alternatives with the exception of 0.2 result in significant pollutant loading reductions to the Missouri River (**Figure 12**). For example, ammonia loading reductions are close to 100% and nutrient loading reductions range from 44% to 82%. Conversely, Alternative 0.2 (i.e., 100% conveyance to the KCMO system) results in the greatest pollutant loading to the Missouri River. Effectively, the more wastewater that is diverted to KCMO, the higher the pollutant loading is to the Missouri River due to the lower effluent quality from the KCMO Blue River WWTP.

Table 8. Annual Pollutant Loadings by Treatment Facility and Process

Alternative	$CBOD_5$ (ppy)	TSS (ppy)	Ammonia-N (ppy)	TP (ppy)	TN (ppy)
Tomahawk WWTF Loading from Secondary Treatment to Indian Creek					
Baseline	277,899	297,749	79,400	51,610	357,298
10.2-BNR	205,746	308,619	6,858	34,291	342,910
19.1-BNR	338,717	508,075	11,291	56,453	564,528
19.1-ENR1	169,358	169,358	11,291	28,226	564,528
19.1-ENR2	169,358	169,358	11,291	28,226	282,264
19.3-BNR	342,357	513,536	11,412	57,060	570,596
19.3-ENR1	171,179	171,179	11,412	28,530	570,596
19.3-ENR2	171,179	171,179	11,412	28,530	285,298
0.2	0	0	0	0	0
Tomahawk WWTF Loading from Auxiliary Treatment to Indian Creek					
Baseline	0	0	0	0	0
10.2-BNR	0	0	0	0	0
19.1-BNR	16,995	12,139	5,341	1,275	10,318
19.1-ENR1	16,995	12,139	5,341	1,275	10,318
19.1-ENR2	16,995	12,139	5,341	1,275	10,318
19.3-BNR	0	0	0	0	0
19.3-ENR1	0	0	0	0	0
19.3-ENR2	0	0	0	0	0
0.2	0	0	0	0	0
KCMO Blue River WWTF Loading to the Missouri River					
Baseline	744,193	1,079,080	558,145	107,908	669,774
10.2-BNR	455,372	660,289	341,529	66,029	409,834
19.1-BNR	0	0	0	0	0
19.1-ENR1	0	0	0	0	0
19.1-ENR2	0	0	0	0	0
19.3-BNR	0	0	0	0	0
19.3-ENR1	0	0	0	0	0
19.3-ENR2	0	0	0	0	0
0.2	1,141,191	1,654,727	855,893	165,473	1,027,072

Note: ppy – pounds per year

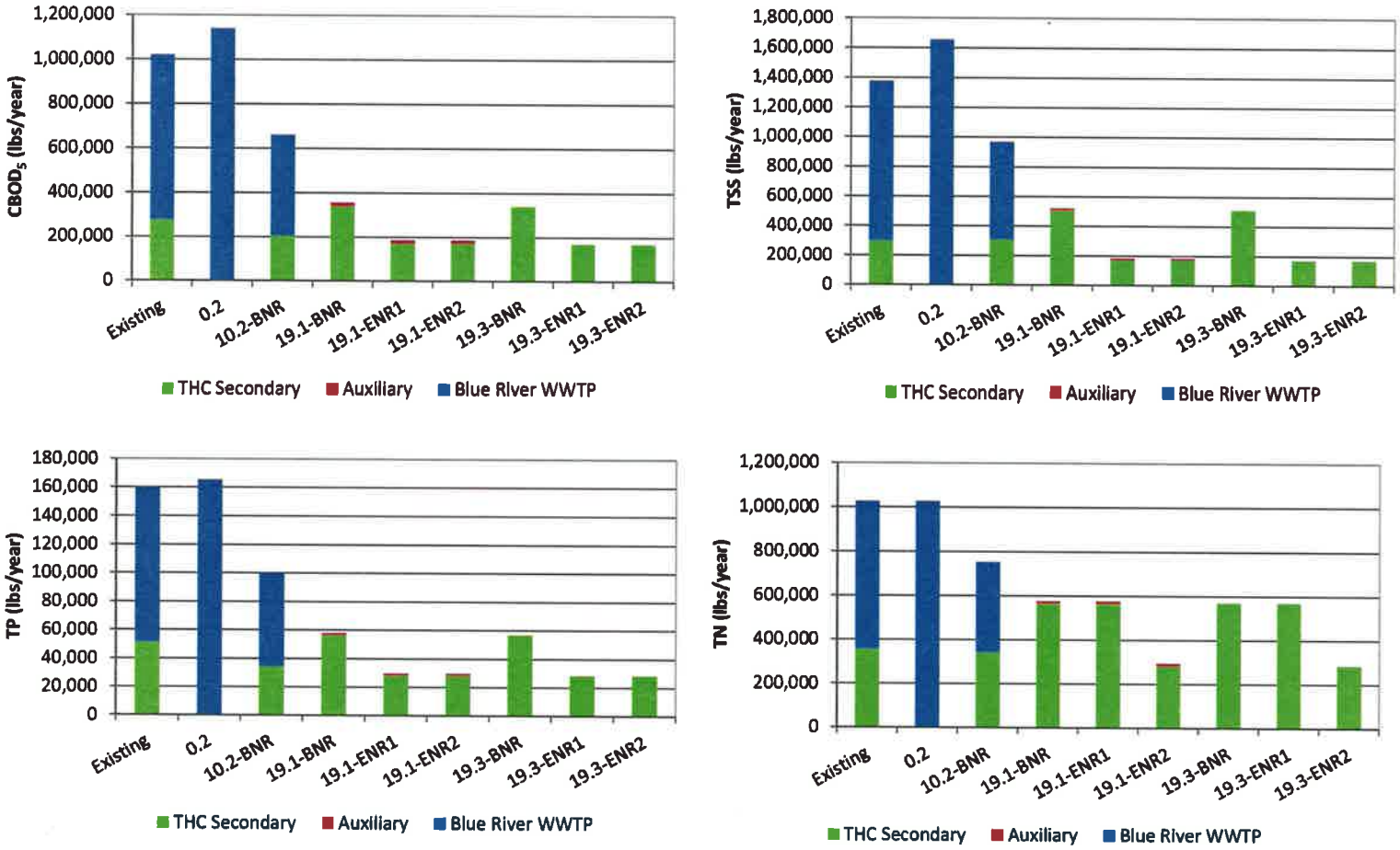

Figure 11. Stacked Bar Graphs of Annual Pollutant Loadings for Each Alternative and by Source

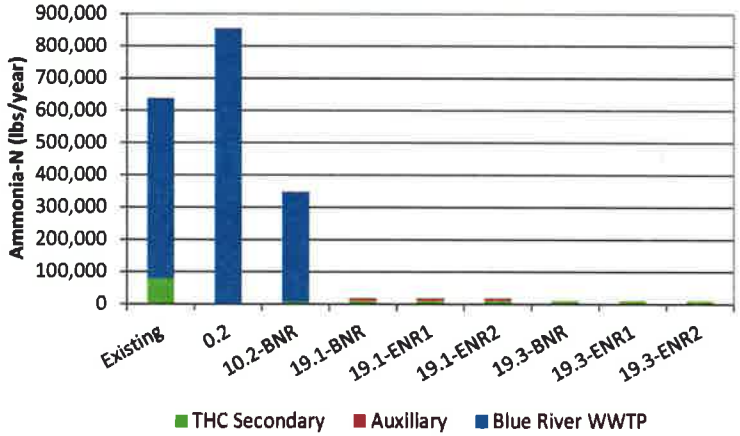

Figure 11 (continued). Stacked Bar Graphs of Annual Pollutant Loadings for Each Alternative and by Source

Table 9. Total Annual Pollutant Loadings to the Missouri River

Alternative	$CBOD_5$ (ppy)	TSS (ppy)	Ammonia-N (ppy)	TP (ppy)	TN (ppy)
Baseline	1,022,092	1,376,829	637,544	159,518	1,027,072
10.2-BNR	661,117	968,908	348,387	100,320	752,744
19.1-BNR	355,712	520,214	16,632	57,727	574,846
19.1-ENR1	186,353	181,498	16,632	29,501	574,846
19.1-ENR2	186,353	181,498	16,632	29,501	292,582
19.3-BNR	342,357	513,536	11,412	57,060	570,596
19.3-ENR1	171,179	171,179	11,412	28,530	570,596
19.3-ENR2	171,179	171,179	11,412	28,530	285,298
0.2	1,141,191	1,654,727	855,893	165,473	1,027,072

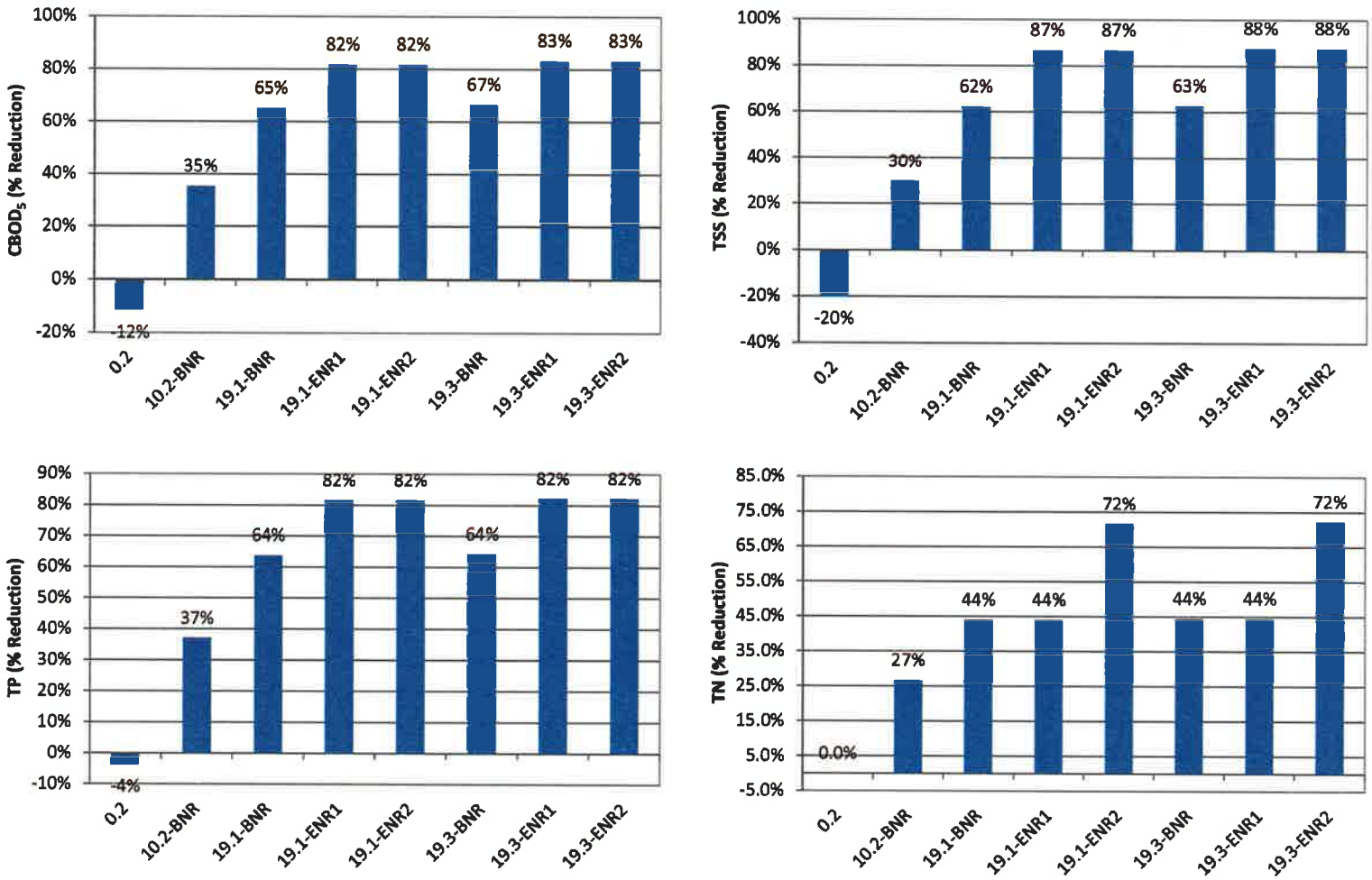

Figure 12. Pollutant Loading Reductions to the Missouri River Relative to the Baseline Alternative.

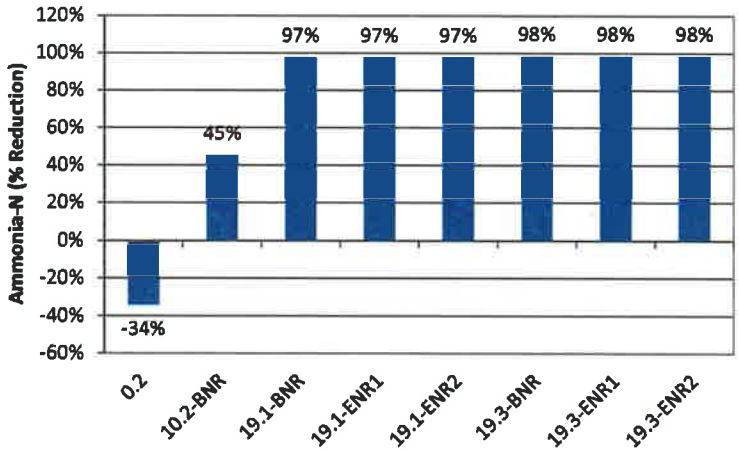

Figure 12 (continued). Pollutant Loading Reductions to the Missouri River Relative to the Alternative Baseline.

5.5 COST-EFFECTIVENESS

A cost-effectiveness analysis was conducted based on the 20-year present worth costs and estimated pollutant loadings for each alternative. Costs were adapted from the Life Cycle Cost analyses presented in the TM No. 6 – Combined Dry and Wet Weather Flow Alternative Selection (HDR and CH2MHill, 2013) to match the alternatives currently under evaluation. Costs based on TM No. 6 were adjusted to 2015 dollars based on a net discount rate (nominal discount rate less inflation) of 1.2%. Results of cost-effectiveness analyses are discussed below.

5.5.1. Relative Cost Differences

Costs were first evaluated relative to Alternative 19.1-BNR, which represents the base cost alternative (i.e., the least expensive alternative capable of meeting regulatory requirements). Relative to Alternative 19.1-BNR, other alternatives cost between 105% and 204% of the base cost (**Table 10**).

Table 10. 20-Year Present Worth Cost of Treatment Alternatives for the Tomahawk WWTF

Alternative	20-Year Net Present Worth Costs			
	Net Present Value of Capital	Net Present Value of O&M	Total Net Present Value	Percent of Lowest Cost Alternative
19.1-BNR	$260,467,000	$201,955,000	$462,422,000	100%
19.1-ENR1	$278,325,000	$207,737,000	$486,062,000	105%
19.1-ENR2	$288,270,000	$214,116,000	$502,386,000	109%
19.3-BNR	$440,131,000	$189,554,000	$629,685,000	136%
19.3-ENR1	$457,989,000	$195,335,000	$653,324,000	141%
19.3-ENR2	$467,934,000	$201,714,000	$669,648,000	145%
10.2-BNR	$232,750,000	$480,290,000	$713,040,000	154%
0.2	$168,333,000	$776,693,000	$945,026,000	204%

Assumptions:

1. All costs in 2015 dollars.
2. Mid Point of Construction is 2019
3. Normal Discount Rate = 3.1%, Inflation = 1.9%, Net Discount Rate = 1.2%
4. In the 10 MGD and 0 MGD alternatives, the O&M figures include KCMO treatment charges, which in turn include cost recovery for storage.

5.5.2. Incremental Pollutant Removal Costs Relative to Base Cost

Cost-effectiveness was evaluated based on the incremental pollutant removal costs with respect to the base cost alternative (i.e., cost of additional pollutant removal beyond Alternative 19.1-BNR). Alternatives that include storage at Tomahawk WWTF (i.e., 19.3-BNR, 19.3-ENR1, and 19.3-ENR2) are evaluated separately in the subsequent section relative to corresponding alternatives with auxiliary treatment (i.e., 19.1-BNR, 19.1-ENR1, and 19.1-ENR2). For purposes of this evaluation, pollutant removal is with respect to the near-field (i.e., Indian Creek) and was calculated in dollars per pound as follows:

$$\text{Dollars per pound} = \frac{(\text{Cost}_{\text{Alt X}}) - (\text{Cost}_{\text{Alt 19.1-BNR}})}{\left([\text{Total Annual Pounds}_{\text{Alt 19.1-BNR}}] - [\text{Total Annual Pounds}_{\text{Alt X}}]\right) \times 20 \text{ Years}}$$

where, "Alt X" is the alternative under evaluation.

On a dollars per pound basis, Alternative 19.1-ENR1 is the most cost-effective alternative relative to 19.1-BNR (**Table 11**). The additional unit process (filtration) used along with an iron or aluminum coagulant will not only effectively reduce phosphorus, but will also result in enhanced solids removal to reduce $CBOD_5$ and TSS. The incremental pollutant removal costs for

Alternative 19.1-ENR1 are approximately $7 for $CBOD_5$ and less than $4 for TSS as compared to the next most cost-effective alternative (i.e., 19.1-ENR2), which has an incremental pollutant removal cost of approximately $12 for $CBOD_5$ and $6 for TSS. With respect to TP, incremental removal costs for 19.1-ENR1 are approximately $42 per pound as compared to $71 for Alternative 19.1-ENR2. With respect to TN, Alternative 19.1-ENR2 is the most cost-effective alternative. However, Alternative 19.1-ENR2 provides no additional environmental benefit in the near-field relative to 19.1-ENR1 and does not provide the added benefit of removing multiple pollutants, such as $CBOD_5$ and TSS.

While Alternative 19.1-ENR2 will result in an overall reduction in TN loading in the far-field, this does not outweigh the costs or environmental and operational issues associated with enhanced nitrogen removal. Enhanced nitrogen removal associated with ENR2 will require the addition of supplemental carbon sources (e.g., methanol). Methanol is a Class 1B flammable liquid that is toxic to humans and the environment if exposure and releases occur. Therefore, enhanced nitrogen removal raises concerns about safe storage, handling, and use of methanol. Additionally, methanol delivery creates increased trucking requirements; thereby, increasing the overall carbon footprint and the disruption to nearby residents and plant operations.

Table 11. Cost per Pound of Additional Pollutant Removal in Indian Creek Relative to Base Case Alternative 19.1-BNR

	$CBOD_5$ ($/lb)	TSS ($/lb)	NH3N ($/lb)	TP ($/lb)	TN ($/lb)
19.1-ENR1 relative to 19.1-BNR	$7.0	$3.5	NC	$42	NC
19.1-ENR2 relative to 19.1-BNR	$11.8	$5.9	NC	$71	$7
10.2-BNR relative to 19.1-BNR	$84	$59	$1,282	$535	$54
0.2 relative to 19.1-BNR	$68	$46	$1,451	$418	$42

Notes: NC – Not calculable (i.e., there is no difference in pollutant loadings so the denominator is zero).

5.5.3. Incremental Pollutant Removal Costs of Storage Relative to Auxiliary Treatment

To evaluate the cost effectiveness of storage, incremental pollutant removal costs were evaluated relative to the auxiliary treatment alternatives with corresponding levels of treatment (e.g., 19.3-ENR1 relative to 19.1-ENR1). As shown in **Table 12**, results of this analysis indicate significant incremental pollutant removal costs for storage (i.e., ranging from $551 to $12,523 per pound depending on the pollutant and treatment level). This is due to the fact that pollutant reductions due to storage relative to auxiliary treatment are negligible, but costs are significantly greater. Therefore, storage at the Tomahawk WWTF in lieu of auxiliary treatment is not cost-effective.

Table 12. Cost per Pound of Additional Pollutant Removal in Indian Creek for Storage Relative to Auxiliary Treatment

	$CBOD_5$ ($/lb)	TSS ($/lb)	NH3N ($/lb)	TP ($/lb)	TN ($/lb)
19.3-BNR relative to 19.1-BNR	$626	$1,252	$1,602	$12,523	$1,968
19.3-ENR1 relative to 19.1-ENR1	$551	$810	$1,602	$8,611	$1,968
19.3-ENR2 relative to 19.1-ENR2	$551	$810	$1,602	$8,611	$1,148

5.5.4. System Wide Cost Considerations

While the focus of this cost analysis is primarily on the Tomahawk WWTF and its receiving waters, selection of a treatment alternative at the Tomahawk WWTF will have a direct impact

on JCW's ability to address other environmental improvement opportunities. JCW's resources are limited and they already anticipate $2 billion in capital expenditures over the next 25 years. Selection of alternatives with only marginal benefits at greater cost represents a lost opportunity to address more critical needs elsewhere. Although a detailed analysis was not performed, the additional costs associated with storage and ENR2 would likely have greater environmental benefit if spent elsewhere in the system.

6 Social and Economic Importance

Federal antidegradation regulations and the Kansas Antidegradation Policy prohibit any degradation of high quality waters unless it is necessary to accommodate important social or economic development. KDHE recommends utilizing USEPA's 1995 "Interim Economic Guidance for Water Quality Standards" for demonstrating importance, but acknowledges that this document is outdated and suggests other mechanisms may be used (KDHE, 2011).

Typically, a demonstration of "importance" is made by showing that positive changes in economic indicators would be prevented unless lower water quality is allowed to accommodate growth. While approximately 95% of the Tomahawk WWTF service area is currently developed, additional community growth is expected with full build out of the service area within 20 years. Adequate wastewater management will be needed to serve this additional growth. Although accommodating growth is important, the primary motivation for these wastewater system upgrades is providing adequate long-term capacity in the most cost-effective, environmentally beneficial manner JCW anticipates approximately $2 billion in capital improvements over the next 25 years, of which the proposed upgrades to the Tomahawk WWTF is just one component. Identifying the most cost-effective solutions with respect to the entire system is important for maximizing environmental benefits. More environmentally beneficial strategies will provide additional ecosystem services such as water quality benefits that will ultimately yield social benefits. The most ideal alternative would be both environmentally beneficial and cost-effective.

7 Proposed Alternative

Alternative 19.1-ENR1 (19 MGD ENR1 with Auxiliary Treatment for Wet Weather Flows) is proposed based on consideration of the environmental benefits to the receiving waters and cost-effectiveness. The following discussion summarizes why Alternative 19.1-ENR1 is the least impacting and most cost-effective practicable wastewater management and treatment option.

7.1 VIABILITY OF 100 PERCENT CONVEYANCE TO KCMO

Alternative 0.2 (Complete conveyance to the KCMO system and Tomahawk WWTF and KCMO storage) is not a viable option based on environmental, social, and cost considerations. In the near-field (i.e., Indian Creek) Alternative 0.2 will result in the elimination of the existing pollutant loading from the Tomahawk WWTF, but is not expected to result in any significant environmental benefits. In fact, although instream nutrient levels may marginally improve, benthic algae levels would actually increase due to less sloughing and bed-scouring (see Section 5.4.1).

In the far-field (i.e., Missouri River) Alternative 0.2 will result in the highest pollutant loadings of any alternative (**Table 9**). As Alternative 0.2 effectively conveys all wastewater downstream to the KCMO Blue River WWTP, pollutant loadings to the Missouri River will increase,

particularly with respect to ammonia, TP, and TN. Alternative 0.2 also presents the greatest risk with regards to SSOs and CSOs as all other alternatives reduce flows to the hydraulically-challenged KCMO system.

In addition to having the highest overall pollutant loadings, Alternative 0.2 is not cost effective as it is nearly twice the cost of Alternative 19.1-BNR. On a dollars per pound basis, Alternative 0.2 costs $418 per pound of additional TP removal and $42 per pound of additional TN removal in the near-field (**Table 11**). With respect to the Missouri River, Alternative 0.2 would have a negative cost-benefit because it results in a higher pollutant loading in the far-field. Therefore, Alternative 0.2 is eliminated as an alternative.

7.2 COMPARISON OF TOMAHAWK WWTF CAPACITY (10 MGD VS. 19 MGD)

Alternative 10.2-BNR was compared to Alternative 19.1-BNR to assess what, if any, advantage a 10 MGD facility provided relative to a 19 MGD facility. Relative to Alternative 19.1-BNR, Alternative 10.2-BNR is more degrading and less cost-effective. In the near-field (i.e., Indian Creek) Alternative 10.2-BNR will result in lower pollutant loadings than Alternative 19.1-BNR, but is not expected to result in any significant environmental benefits. As demonstrated in Section 5.4.1, algae levels in Indian Creek are relatively insensitive to the nutrient loadings as Indian Creek is not nutrient limited. Additionally, lower flows associated with Alternative 10.2-BNR are expected to result in higher benthic algae levels due to less sloughing and bed-scouring.

The primary environmental benefit of Alternative 19.1-BNR relative to 10.2-BNR is that an additional 2.7 billion gallons of wastewater will receive advanced treatment annually. The 9 MGD differential in flow would otherwise receive a lower current level of treatment at the KCMO Blue River WWTP or potentially contribute to SSOs and CSOs. With the additional treatment capacity at the Tomahawk WWTF, pollutant loadings will decrease to the Missouri River relative to Alternative 10.2-BNR. For example, the annual TP loading from 19.1-BNR is approximately 60% of the annual loading from Alternative 10.2-BNR (**Table 9**).

Aside from higher pollutant loadings in the far-field, Alternative 10.2-BNR is not cost-effective in the near-field. Alternative 10.2-BNR is 154% of the base cost (i.e., Alternative 19.1-BNR), but pollutant reductions in the near-field are not commensurate with the additional cost. Relative to Alternative 19.1-BNR, Alternative 10.2-BNR costs $54 per additional pound of TN removal and $535 per additional pound of TP removal (**Table 11**). Therefore, Alternative 10.2-BNR is eliminated as an alternative.

7.3 COMPARISON OF WET WEATHER MANAGEMENT ALTERNATIVES (AUXILIARY TREATMENT VS. STORAGE)

Having excluded alternatives with flow diversions to KCMO, the two remaining wet weather strategies under consideration are auxiliary treatment (19.1-BNR, 19.1-ENR1, and 19.1-ENR2) and storage (19.3-BNR, 19.3-ENR1, and 19.3-ENR2) of wet weather flows beyond the 57 MGD secondary treatment capacity. The primary difference between these two strategies is the treatment of flows above 57 MGD, i.e., through a high-rate auxiliary treatment system or through secondary treatment after being stored for a period of time. In either case, flows above 57 MGD represent a small fraction of the total annual flow volume and are infrequent as summarized below:

- Auxiliary flow represents approximately 1.1% of the total average annual flow volume (**Table 7**).
- The frequency of wet weather flow events triggering the use of auxiliary treatment system is estimated at approximately 3 times per year based upon typical year event-based hydraulic modeling taking into account future conditions.
- The estimated frequency of auxiliary treatment ranged from 1 to 6 times per year based on an analysis of 2010-2014 flows adjusted for future conditions, averaging 3 times per year. This analysis of a wide range of hydrologic conditions corroborates the typical year hydraulic modeling results.

The relatively small frequency of potential diversions to auxiliary treatment combined with the overall effectiveness of auxiliary treatment demonstrates that storage in lieu of auxiliary treatment provides no meaningful benefits. This is thoroughly evaluated in Sections 5.4.1 and 5.4.2, which show that pollutant loadings and instream water quality negligibly differ between auxiliary treatment and storage. For example, there is only an approximately 1% difference in annual TP loading to the Missouri River between Alternatives 19.1-BNR and 19.3-BNR and impacts on benthic algae in Indian Creek are indiscernible regardless of wet weather treatment strategy (i.e., auxiliary treatment and storage).

While the benefits of storage relative to wet weather auxiliary treatment are marginal, the difference in cost is significant. The additional cost of storage relative to wet weather auxiliary treatment is approximately $167 million. On a dollars per pound basis, the incremental cost of going from wet weather auxiliary treatment to storage ranges from $551 to $12,523 depending on the pollutant and treatment level (**Figure 13**). The additional costs of storage will also have a direct impact on JCW's ability to address more critical environmental improvement opportunities throughout their system.

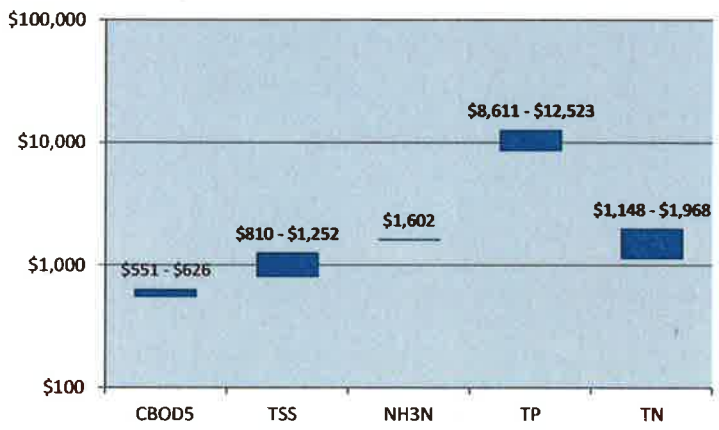

Figure 13. Range of Costs per Pound for Additional Pollutant Removal in Indian Creek for Storage Relative to Auxiliary Treatment (Adapted from Table 12)

In addition to not being cost-effective, there are practicability issues with storing wet weather flows at the Tomahawk WWTF. As previously discussed, Alternatives 19.3-BNR, 19.3-ENR1, and 19.3-ENR2 would require additional storage constructed at the Johnson County and Leawood

owned sports facilities to the north and east of the WWTF. This alternative would result in a significant financial and social impact to Leawood citizens. These sports facilities represent one of Leawood's greatest annual revenue generators and would significantly impact City services if these were taken out of service on even a temporary basis. It is also unclear whether JCW could acquire these lands for the purpose of storage without a protracted legal battle. Storage also presents additional risk as its finite capacity could be exceeded, particularly during back-to-back large storms, resulting in a bypass. Therefore, based on negligible benefits, cost considerations, the lack of readily available land, and risk of bypassing, storage is eliminated as a viable option.

7.4 COMPARISON OF ADVANCED TREATMENT ALTERATIVES (BNR VS. ENR)

Alternatives 19.1-BNR, 19.1-ENR1, and 19.1-ENR2 result in significant water quality improvements relative to current conditions in the near and far-field. However, Alternatives 19.1-ENR1 and 19.1-ENR2 yield additional pollutant removal beyond Alternative 19.1-BNR. In particular, Alternatives 19.1-ENR1 and 19.1-ENR2 result in half the loading of TP as compared to 19.1-BNR. Alternative 19.1-ENR2 also results in half the loading of TN as compared to 19.1-BNR. Although water quality modeling demonstrates that reductions in nutrient loading has no impact in the near-field (i.e., Indian Creek), nutrient reductions may have an impact in the far-field (i.e., the Missouri River and ultimately the Gulf of Mexico).

Findings by Alexander et al. (2008) suggest that roughly 50 to 75% of stream nutrients from the Tomahawk WWTF reaches the Gulf of Mexico. Based on this level of reduction, Alternatives 19.1-ENR1 and 19.1-ENR2 will result in an overall reduction of TP delivered to the Gulf of Mexico of approximately 14,000 to 21,000 pounds per year relative to Alternative 19.1-BNR. Alternative 19.1-ENR2 will result in an overall reduction of TN delivered to the Gulf of Mexico of approximately 141,132 to 211,698 pounds per year relative to Alternatives 19.1-BNR and 19.1-ENR1. While such reductions represent an insignficantly small fraction of total loading to the Gulf of Mexico, it would help address USEPA's recommendations regarding the hypoxic zone in the Gulf of Mexico.

The USEPA Science Advisory Board (SAB) recommends a dual nutrient strategy targeting at least a 45% reduction in riverine TN and TP flux to reduce the size of the hypoxic zone and improve water quality in the MARB (USEPA, 2008). Relative to Baseline (i.e., existing conditions), all three alternatives (i.e., 19.1-BNR, 19.1-ENR1, and 19.1-ENR2) approximately meet or surpass USEPA's nutrient reduction goal (**Figure 14**) and are essentially non-degrading. Therefore, requiring nutrient reductions beyond 19.1-BNR exceeds antidegradation requirements and creates an equity issue, whereby the Tomahawk WWTF would effectively be responsible for addressing nutrient reductions from other sources.

Nutrient reductions beyond BNR should make sense economically, environmentally and from an operational standpoint. While the Indian Creek water quality modeling does not suggest near-field algal reductions with ENR1 or ENR2, enhanced phosphorus removal provides the greatest potential for creating near-field water quality benefits and reduces multiple pollutants (i.e., $CBOD_5$ and TSS). While Alternative 19.1-ENR2 would result in further nitrogen load reductions, this alternative would require the addition of supplemental carbon sources like methanol, which is toxic to humans and the environment if exposure and releases occur. Use of methanol raises safety concerns and creates increased trucking requirements, which increases the overall carbon footprint, impacts nearby property owners, and potentially creates logistical issues for

plant operators. Based upon these considerations, JCW is willing to consider going beyond antidegradation requirements and considers Alternative 19.1-ENR1 viable.

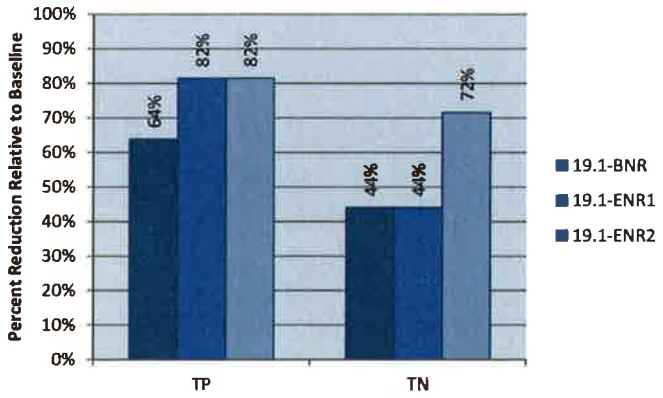

Figure 14. Nutrient Reductions to the Missouri River Relative to Existing Conditions (Note: USEPA is targeting a 45% reduction in nutrients to the hypoxic zone)

8 Degradation Evaluation

Results of the water quality model in Section 5.4.1 demonstrate that antidegradation requirements are effectively met with Alternative 19.1-BNR as it will result in either water quality improvements or no additional degradation. However, JCW is willing to consider Alternative 19.1-ENR1, as the additional phosphorus removal was determined to be practicable and cost-effective. Alternative 19.1-ENR1 will improve water quality in Indian Creek relative to existing conditions. Notably, average annual TP concentrations downstream of the Tomahawk WWTF will decrease from 1.2 mg/L to 0.4 mg/L and average annual ammonia levels will decrease from 1.5 mg/L to 0.1 mg/L. Total nitrogen loading will remain relatively unchanged in the near-field and will be reduced in the far-field relative to baseline conditions. Potentially of greater significance, benthic algae levels are expected to decrease as a result of physical factors with increased flow.

In the far-field (i.e., Missouri River), Alternative 19.1-ENR1 will result in decreased loadings for $CBOD_5$, TSS, ammonia, TP, and TN (**Figure 11**). Notably, TP and TN loading to the Missouri River will be reduced by 82% and 44%, respectively. Reductions in pollutant loadings are attributable to the fact that approximately 4.5 billion gallons of wastewater will receive advanced treatment at the Tomahawk WWTF, that otherwise would have been diverted to KCMO.

Based on results summarized above, Alternative 19.1-ENR1 exceeds treatment levels necessary to satisfy antidegradation requirements as it will result in water quality improvements in both the near- and far-field. The proposed expansion of the Tomahawk WWTF is non-degrading; therefore, no additional treatment beyond 19.1-ENR1 is required to satisfy antidegradation requirements.

9 Conclusion

Proposed treatment Alternative 19.1-ENR1 (19 MGD ENR1 with auxiliary treatment of wet weather flows) meets all state and federal antidegradation regulations as it is necessary, important, and ultimately non-degrading. The necessity of Alternative 19.1-ENR1 is based on results of the alternatives analysis, which finds it provides the best combination of practicability, treatment effectiveness, and cost-effectiveness. Other alternatives are either more degrading, not practicable, or only have marginal benefits that are not commensurate with cost or other non-economic concerns (e.g., lack of suitable land, carbon footprint, and safety).

Expanding capacity at Tomahawk WWTF is important for multiple reasons. Not only will expansion help accommodate population growth in the service area, but it will provide more cost-effective and environmentally beneficial wastewater management strategies. JCW anticipates approximately $2 billion in capital expenditures over the next 25 years. Cost-effective measures taken to upgrade and expand the Tomahawk WWTF will result in a greater capacity to address other environmental improvement opportunities throughout JCW's system. Additionally, expansion is also important for addressing KCMO's current capacity issues.

In addition to being both necessary and important, the proposed expansion of the Tomahawk WWTF is ultimately non-degrading and exceeds minimum antidegradation requirements. While Alternative 19.1-BNR is also non-degrading and thereby satisfies antidegradation requirements, JCW is willing to consider Alternative 19.1-ENR1, which provides for an additional level of phosphorus removal. Therefore, Alternative 19.1-ENR1 not only meets, but exceeds the intent of antidegradation (i.e., existing water quality will not be degraded) and any additional treatment (e.g., Alternative 19.1-ENR2) is unjustified through antidegradation. Furthermore, use of enhanced nitrogen removal raises concerns about safe storage, handling, and use of methanol. However, flexibilities to add ENR2 facilities in the future will be incorporated into the facility design (e.g., footprint and headloss considerations).

Results of this antidegradation review direct JCW to expand the Tomahawk WWTF to 19 MGD with upgrades including ENR1 and auxiliary treatment, using advanced high-rate treatment processes. Any alternative that involves diverting flow to the KCMO system is more degrading to water quality and is not cost-effective. Similarly, water quality benefits associated with storage in lieu of auxiliary treatment are marginal, not commensurate with cost, and do not justify the risk of a bypass during extreme wet weather events. Furthermore, additional costs associated with storage limits JCW's ability to address more critical and cost-effective improvements elsewhere within its system.

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APPENDIX A

WATER QUALITY MODELING DOCUMENTATION

Technical Memorandum

Date:	Tuesday, October 06, 2015
Project:	Johnson County Wastewater Tomahawk Creek WWTF Expansion
To:	Trent Stober (HDR) John Christiansen (HDR)
From:	Andrew Thuman (HDR) Yuki Tanimoto (HDR) Carmen Santos (HDR) Thomas Gallagher (HDR)
Subject:	Indian Creek Periphyton Model

A periphyton model of Indian Creek was developed as part of the Johnson County Wastewater (JCW) Tomahawk Creek wastewater treatment facility (WWTF) expansion and associated permitting. The modeling framework included a hydraulic model (CE-QUAL-RIV1) and a periphyton model (PeriWASP) of the creek beginning just upstream from the USGS gaging station at 119th Street (River Mile [RM] 13) and ending at the USGS gaging station at the Stateline (RM 3.5) for a total modeled length of 9.5 miles (see Figure 2). RM 0 in Indian Creek is the confluence with the Blue River. The models include both the JCW Middle Basin and Tomahawk Creek WWTFs. Both of these models are 1-dimensional and time-variable. The hydraulic model provides time-varying creek geometry as a function of creek flow to the periphyton model; and the periphyton model provides time-varying calculation of various water quality parameters using the creek transport information calculated with the hydraulic model. Additional details on the development and calibration/validation of these two models is presented below.

In addition, a watershed model (P8) was developed by Black & Veatch (B&V) to provide rainfall driven runoff and nonpoint source water quality from the surrounding watershed for an average hydrologic rainfall year. This average hydrologic rainfall year was used to complete water quality projections with the periphyton model for various Tomahawk Creek WWTF discharge scenarios. The P8 model and typical rainfall year analyses are presented in Section 6.

The main purpose of developing a periphyton model of Indian Creek was to relate nutrients to periphyton growth to assess proposed wastewater treatment upgrades at the JCW Tomahawk Creek WWTF. Nutrient reductions are part of the proposed upgrades at the WWTF and, therefore, the model developed includes the ability to relate instream nutrient concentrations to periphyton growth as a function of available light, algal sloughing, algal grazing and water transport in the creek. In addition, the interactions between organic and inorganic nitrogen and phosphorus are included in the model along with BOD and dissolved oxygen (DO).

1. Hydraulic Model (CE-QUAL-RIV1)

CE-QUAL-RIV1 is a one-dimensional (cross-sectionally averaged) hydraulic model that calculates flows, depths, velocities, water surface elevations and other hydraulic characteristics of the modeled water body. The hydrodynamic model solves the St. Venant equations as the governing flow

equations using the widely accepted four-point implicit finite difference numerical scheme. CE-QUAL-RIV1 is capable of simulating multiple branches, and in-stream hydraulic control structures such as run-of-the-river dams, waterway locks and dams, and re-regulation dams. Each branch is further subdivided into nodes or cross-sections. The shape of the cross-section can be specified using simple geometric equations or look-up tables. Boundary information (upstream, tributary or point source inputs) can be assigned as time-varying. The boundary conditions for the model can be either flows or stages at the upstream boundary, or flows stages or a rating curve at the downstream boundary.

CE-QUAL-RIV1 was designed to simulate flows in river systems under highly unsteady flow conditions. In order to do so, the hydraulic model is based on the full (non-linear) flow equations. The basic equations solved are those for the: conservation of momentum, a statement that the time rate of change of momentum of a volume of water plus the net rate of efflux of momentum through that volume is equal to the net force acting upon it; and continuity, a statement of the conservation of water mass, which includes a term for lateral inflows. The net forces in the momentum equation include the forces due to: gravity acting upon the water mass; friction applied by the river bottom and channel sides; and pressure force due to the water slope. In addition to these major forces, there are also some minor forces included in the equations solved. These minor forces allow simulation of the impacts of channel constrictions, such as due to bridges, through a constriction coefficient, and non-uniformities in velocities across the width of the river, such as in bends, using a momentum correction coefficient.

2. Periphyton Model (PeriWASP)

The periphyton model is based on a modified version of WASP3 as distributed by EPA's Center for Exposure Assessment Modeling (CEAM) before being superseded by subsequent release versions of WASP. The PeriWASP model uses the time-variable hydraulic transport calculated with the CE-QUAL-RIV1 model. The model segmentation used in the periphyton model includes water column segments and segments representing periphyton attached to the surface of the substrate. Advection occurs through the water column segments as the creek flows downstream, while there is no advective flow through the periphyton segments. Mass transfer in and out of the periphyton segments is controlled by a transfer coefficient (length per time) between the overlying water column segment and the periphyton segment.

The periphyton model contains 19 state variables representing attached algal biomass (tracked as algal carbon); algal internal cell nitrogen and phosphorus; organic and inorganic forms of nitrogen and phosphorus; dissolved oxygen (DO); biochemical oxygen demand (BOD); and a conservative tracer. The state variables are listed in Table 1 and a schematic of the kinetic interactions are presented in Figure 1. In Figure 1, the labile/refractory particulate and dissolved organic forms of nitrogen and phosphorus are shown as a single state variable for illustrative purposes.

The complexity of the revised kinetic framework comes from the representation of the factors controlling the periphyton biomass and the complexity of the organic nitrogen and phosphorus systems, which is included to properly represent the recycle of nutrients associated with the decay of detrital algal cells. The accumulation of algal biomass is controlled by the balance between growth and loss terms. Growth is represented by a maximum growth rate which is modified by terms describing the effect of temperature and limitations (if any) imposed by ambient light and nutrient conditions. The model includes variable cell stoichiometry and represents the uptake of nutrients

into the cell separately from growth. Nutrient limitation for growth is a function of internal cell nitrogen and phosphorus. Loss mechanisms include endogenous respiration, death or grazing by higher trophic levels, and sloughing due to the shear stress imposed by water flowing past the periphyton. Benthic algal photosynthetic oxygen production is calculated as the product of the specific growth rate, the oxygen to carbon ratio, and periphyton biomass (as carbon). The specific growth rate includes the effect of temperature and limitations due to light and nutrients. The light limitation includes both the variation in incident solar radiation during the day as well as the attenuation of light through the water column and self shading by the periphyton biomass. The light attenuation through the water column can be estimated from measurements of turbidity. The nutrient limitation is calculated by the more limiting of the Michaelis-Menton expressions for internal cell nitrogen and phosphorus. Oxygen consumption due to benthic algal respiration is computed as the product of a respiration rate, an oxygen to carbon ratio, and periphyton biomass (as carbon). The benthic algal biomass, which affects the photosynthetic oxygen production and consumption due to respiration, changes throughout the time-variable simulation in response to the balance between accumulation and loss terms. A detailed discussion of the complete periphyton model kinetics can be found in the report *Development and Calibration of the Jackson River Periphyton Model* (HydroQual, 2003).

Table 1. Periphyton Model State Variables

Constituent	Abbreviation
Dissolved Oxygen	DO
Point Source Dissolved Carbonaceous BOD	DBOD
Point Source Particulate Carbonaceous BOD	PBOD
Upstream & Periphyton Carbonaceous BOD	MatBOD
Labile Particulate Organic Phosphorus	LPOP
Refractory Particulate Organic Phosphorus	RPOP
Labile Dissolved Organic Phosphorus	LDOP
Refractory Dissolved Organic Phosphorus	RDOP
Orthophosphate Phosphorus	PO4
Labile Particulate Organic Nitrogen	LPON
Refractory Particulate Organic Nitrogen	RPON
Labile Dissolved Organic Nitrogen	LDON
Refractory Dissolved Organic Nitrogen	RDON
Total Ammonia as Nitrogen	NH4
Nitrite + Nitrate Nitrogen	NO23

Table 1. Periphyton Model State Variables	
Constituent	**Abbreviation**
Periphyton Biomass as Carbon	CALGAE
Periphyton Internal Cell Nitrogen	ICN
Periphyton Internal Cell Phosphorus	ICP
Algal Exudate	ALGEX
Conservative Tracer	TRACER

3. Model Development and Calibration Inputs for Indian Creek

The Indian Creek periphyton model was developed to assess the water quality changes associated with planned upgrades at the JCW Tomahawk Creek WWTF. The model was developed with water quality data collected by the USGS in 2012 and additional data collected in 2014 as part of this effort. The year 2012 was used for time-variable calibration of the model to the observed data as this year represented a relatively low-flow period. Although 2012 was generally a low-flow year, the hydrograph did include periods of flashy wet-weather flow. The May-September growing season average flow at the USGS Marty gage in 2012 represented the 27th percentile for the period from 1986-2014. In addition, the data collected in 2014 were used to validate the model using the model calibration coefficients to further assess the validity of the periphyton model of Indian Creek. The hydrology in 2014 was wetter than in 2012 with more high flow events, which provided a good test of the model periphyton sloughing relationships and wet weather loading conditions. In 2014, the May-September growing season average flow at the USGS Marty gage roughly represented the 33rd percentile for the period from 1986-2014.

Available data in 2012 included: monthly nutrient and periphyton data; continuous flow, DO, turbidity and temperature data from the USGS; effluent data from the JCW Douglas L. Smith Middle Basin (Middle Basin) and Tomahawk Creek WWTFs. The 2014 data included additional USGS and project specific information on the spatial variation in creek nutrient and BOD levels; tributary data for defining nonpoint source (NPS) inputs; CBOD20 data to determine the ultimate oxygen demand in the creek and effluent; pool/riffle/run information in the creek from the USGS. There are five USGS gages in the creek at 119th Street, College Road, Overland Park (Marty), Mission Farms and Stateline that provided creek flow and geometry information. In addition, there is a USGS gage on Tomahawk Creek. Figure 2 presents the locations of these USGS gages and Figure 3 presents the locations of the 2014 monitoring locations used for model validation. Increased daily DO swings at the Stateline station as compared to the upstream stations is observed in these data and is considered primarily due to decreasing tree cover, widening and slowing of the creek, and the presence of *Cladophora* that were identified but not measured in the lower reach of the creek as periphyton levels at the Stateline station are similar to the upstream stations.

3.1. Creek Physical Characteristics

Figure 4 presents the creek drainage area, width, water elevation and percent tree cover as a function of distance. The widening of the creek in the downstream direction was assigned in the model geometry as was the decreasing tree cover in the downstream direction. This was an important factor in representing the algal biomass and DO levels in the creek as discussed in the model calibration section. Creek water depths were adjusted to reflect the observed data at the USGS gages, including the measured creek water velocities.

3.2. Time-Variable Model Inputs

There are a number of time-variable model inputs assigned in the periphyton model besides the time-varying upstream creek flow, tributary flows and WWTF loads. These other time-variable inputs include: maximum algal growth rate; carbon to chlorophyll ratio (C:Chl); and slope of the photosynthesis-light curve. The model inputs used for these parameters are presented in Tables 2 through 4. A discussion of these model inputs is also provided in each table.

Table 2. Algal Maximum Growth Rate

Month	Growth Rate (1/day)
January, February, March	1.5
May, June, July, August	2.0
October, November, December	1.5

Growth rates were interpolated in April and September to give a smooth transition. Growth rates were held constant in the temperature ranges experienced by the model.

Table 3. Algal Carbon to Chlorophyll Ratio

Month	C:Chl
January, February	30
May – December	60

Ratio was interpolated in March-April as a transitional period. These values were the result of calibrating the model to DO data (chlorophyll-a measurements for the last three months of the year were unavailable).

Table 4. Slope of Photosynthesis-Light Curve (I_k)

Month	I_k
January	65
February	94

Table 4. Slope of Photosynthesis-Light Curve (I_k)	
Month	**I_k**
March	123
April	146
May	171
June	187
July	186
August	157
September	135
October	90
November	73
December	51
Slopes were assigned to better represent photo-adaptation of periphyton to allow for more primary productivity when total insolation is limited in the winter. These values were computed as 0.24 of the average daily insolation for a given month. The scale factor was derived by fitting the I_k value for the summer months to a value of 186, which was determined by a previous study.	

3.3. Spatially Variable Model Inputs

Tree Shading

Shading of the creek by riparian trees was calculated by the *Shade* program developed by Greg Pelletier of the Department of Ecology, State of Washington, available at http://www.ecy.wa.gov/programs/eap/models.html/. The program calculates the fraction of insolation striking the water surface at a specific hour of the day, which can be numerically integrated to yield the total insolation received at the water surface on a daily basis, due to topography and tree shading. The ratio of this number to the total insolation that the stream would see without any tree cover was introduced to the periphyton model. This ratio is referred to as the fraction of total insolation (FITOT) and varies from 1 (no tree cover) to 0 (full tree cover). Over the year, FITOT was given a seasonal trend, as trees do not maintain leaves year-round (see Table 5). During the months of March-April the fraction of FITOT was increased to simulate the leaves growing and the months of September-October were decreased to simulate the leaves falling off. Spatially, every segment received a FITOT number based on a review of aerial photographs (see Figure 5) for the summer season (May-August) that was modified temporally based on the inputs in Table 5. Preliminary model runs based on the outputs from *Shade* induced a light limitation near the College station that led to under computing the biomass, thus the FITOT for these segments were increased to allow for more light. Also, the FITOT for the segments closest to the upstream boundary of the model had to be relaxed for stability issues.

Table 5. Tree Cover (Shading)	
Month	**Fraction of Total Sunlight (FITOT)**
January, February	1
May, June, July, August	See Figure 5
November, December	1
Shading was interpolated in March-April and September-October to give a smooth transition between seasons.	

Cladophora

Near the USGS Stateline gage, the DO production and consumption due to photosynthesis and respiration were scaled by a factor of 1.8 to simulate the effects of *Cladophora* on DO levels. The consequent uptake of nutrients by the *pseudo-Chladophora* is not represented in the present modeling kinetics. In addition, the *Cladophora* was also given a seasonal trend as presented in Table 6.

Table 6. Seasonal Cladophora Factor	
Month	**Fraction of Scale Factor**
January, February	0
April, May, June, July, August	1
October November, December	0
The scale factor value was interpolated during the months of March and September to simulate the appearance and disappearance of *Cladophora* from the stream gradually.	

Light Extinction

Light extinction is calculated as a function of the creek flow. This relationship was empirically derived from flow and turbidity data from the five Indian Creek USGS gages, then relating the turbidity to a light extinction coefficient, K_e (1/m). The equation used is:

$$K_e = 0.3 + 0.05 \times [aQ^b] + K_{eshade}.$$

Values for *a* and *b* are assigned spatially in the model based on the observed turbidity-flow relationships at the USGS gages. K_{eshade} represents the light extinction due to periphyton biomass self-shading.

Fraction Rock

Preliminary model calibration runs suggested that the overall biomass calculated was too high in segments upstream of the Marty Gage. The periphyton biomass in the model is assumed to inhabit

the rocks at the bottom the channel, which is assigned as fraction of the bottom area in the model. By reducing this number, we were able to scale down the diurnal DO swings to better fit the data without sacrificing the amount of biomass calculated. Reducing the fraction rock was also used to simulate possible pools that exist in the creek channel where the periphyton would not accumulate. The USGS synoptic data from July 2014 indicated the presence of pools in some regions, which justified our use of the fraction rock to control periphyton growth.

3.4. Other Water Quality Model Inputs

Atmospheric Reaeration

Atmospheric reaeration was calculated using the Tsivoglou and Neal formulation:

$$k_2 = \begin{Bmatrix} 0.11\frac{dD}{dt}; Q < 10\ cfs \\ 0.054\frac{dD}{dt}; Q > 25\ cfs \end{Bmatrix}$$

For flows in between 10 and 25 cfs, the escape coefficient (i.e., 0.11 or 0.054) was linearly interpolated.

Sediment Oxygen Demand (SOD)

The SOD for all model segments was assigned an estimated background value of 1 $gO_2/m^2/day$, at 20°C.

Tributary Inputs

Tributary flows were based on the USGS Tomahawk Creek gage data and drainage area ratios. The tributary nutrient concentrations were based on the Black and Veatch 2014 sampling of two wet-weather, and two dry-weather sampling events. Wet-weather in the model was defined as when the flow at the Marty gage exceeded 100 cfs and was interpolated between 20 and 100 cfs. The concentrations inputs are presented in the Table 7 and were

Table 7. Tributary Concentrations used for Model Input

Parameter	Concentration (mg/L)	
	Dry-Weather	Wet-Weather
Organic P	0.01-0.02	0.18-0.70
Orthophosphate	0.01-0.05	0.06-0.07
Organic N	0.16-0.70	1.4
Ammonia	0.04-0.05	0.04-0.05
Nitrite + Nitrate	0.31-0.60	0.60-0.65
CBOD	5-6	20-25

Table 7. Tributary Concentrations used for Model Input		
Parameter	Concentration (mg/L)	
	Dry-Weather	Wet-Weather
DO	Saturation	Saturation
Organic N and P data were split as follows: 50% particulate, 50% dissolved 50% refractory, 50% labile		

WWTF Loads

Effluent flow and concentrations for the two JCW WWTFs that discharge to the creek were based on the data received from JCW and for some parameters were slightly adjusted to reflect instream data and data from the USGS synoptic study. The data available were either reported daily (flow), 2-3 times per week (BOD) or weekly (nutrients).

Algal Derived Detritus Hydrolysis

The hydrolysis rate of algal derived detritus was set at 0.1 (1/day) to reach a higher equilibrium value of the ash free dry matter (AFDM) in order to induce more algal self shading. This rate was adjusted as part of the model calibration.

Algal Photorespiration

The algal respiration rate is expressed as:

$$resp = 0.03 + 0.25 * (\mu)$$

where μ is the ambient growth rate, which is a function of the light regime and available nutrients.

Algal Sloughing

Sloughing is expressed as

$$k_{slough} = 0.05 + 0.0005(\frac{V}{\bar{V}})^3$$

where $\bar{V}$ is the long-term average velocity for the segment, this value was assigned as 1 ft/s based on available data in the creek.

4. Model Calibration Results

The Indian Creek periphyton model was calibrated in two steps. First the hydraulic model (CE-QUAL-RIV1) was setup and run using measured flow and geometry relationships (i.e., depth vs. flow) based on data from the USGS gages; and then the periphyton model (PeriWASP) was calibrated to measured periphyton chl-a, DO, PO4, NH4 and NO23 data at the USGS gages using the CE-QUAL-RIV1 calculated creek transport. The adjustment of certain periphyton model parameters and coefficients (within acceptable ranges) was completed, as discussed in Section 3, to achieve the best fit of model output to observed data. An adjustment to the reported JCW Middle

Basin WWTF effluent NO23 concentrations was necessary to match the observed creek data. This did not impact the model calculated periphyton chl-a or DO levels because algal growth and the associated DO effects are not limited downstream by creek nutrient concentrations.

Figures 6 through 10 present the periphyton model-data comparisons at the USGS 119th Street, College Road, Marty, Mission Farms and Stateline gages for daily average PO4, NO23, periphyton chl-a and DO. Overall, the periphyton model reasonably reproduces the observed data given the data available for developing the model. The observed nutrient levels are reproduced fairly well by the model and show the increases along the creek due to the two JCW WWTF discharges in addition to the variation during the year due to the flashy hydrograph and nonpoint source loads. The periphyton model generally captures the observed periphyton levels in the creek including the higher values observed during cooler winter period from January through March. During the summer (growing season) time period, the average periphyton levels are reasonably reproduced by the model. For DO, the periphyton model reproduces the observed daily average and diurnal DO swings well in the creek including the increased DO swings observed at the Stateline location.

There was limited information on the geometry of the creek for setting up the hydraulic model and calculating the creek transport to drive the periphyton model. In addition since nutrient levels in the creek are above algal growth limiting values, the light available at the creek surface is very important and was based on the best information available (i.e., aerial photographs, topographic maps and available geometry data from the USGS gages). Finally, the creek substrate area (fraction rock) and creek characteristics (i.e., pool/riffle/run) are also important factors affecting periphyton growth in the creek. All of these factors are included in the model and were estimated with the best data and information available at the time of model development. Future enhancements to the Indian Creek periphyton model should include: better geometry data along the entire length of the creek; additional creek substrate information; and better estimates of tree shading in the creek.

5. Model Validation

In order to test the model with a different dataset, the calibrated model was validated to available Indian Creek data from 2014. In 2014, creek nutrient, dissolved oxygen and periphyton data was available from the USGS (dry event – 7/23) and from B&V sampling (2 dry events – 9/16 and 10/8; 2 wet events – 10/9 and 10/13). Unlike 2012, there were more limited USGS flow data available in 2014 (2 gages) as well as diurnal DO data. Based on the available data, the periphyton model was setup for the time period from July-October 2014.

The same model coefficients developed for the 2012 calibration period were used for the 2014 validation period with the only differences being the upstream, tributary and WWTF flows and loads observed in 2014. In addition creek temperature, solar radiation and fraction daylight were modified to reflect the 2014 validation time period.

The model validation results are presented in two formats: spatial concentration profiles along the length of the creek; and concentration vs. time figures. Figures 11-15 present the spatial profiles and Figures 16-20 present the time-series figures. The figures present model output as solid lines (daily range as shaded region) and observed data as the circles (mean and range when available).

Overall, the periphyton model reproduced the observed data well along the length of the creek and also with respect to the July-October validation time period. The 7/23 survey experienced rapidly

decreasing nutrient concentrations in the downstream direction that was not observed in the other 3 surveys in September and October. Given that this was a dry event with relatively stable low flows, a time-variable Middle Basin WWTF load appears to have caused the rapid nutrient decrease in the downstream direction (i.e., there were lower WWTF nutrient loads prior to the survey date that affected the downstream creek concentrations and higher WWTF loads on the survey date).

During the September and October surveys, sampling typically occurred in the mid to late morning when DO levels are just beginning to increase due to daytime algal photosynthesis. Therefore, the observed grab sample DO data from these surveys is either less than or near the modeled daily average or closer to the calculated daily minimum DO levels. In addition, the observed July periphyton levels were more variable along the length of the creek as compared to the September and October surveys; and the model tended to over-predict the observed periphyton levels in July but generally reproduced the data in September and October. Given that the only changes to the model for the validation period are the external model inputs (e.g., tributary and WWTF loads), the model validation to the observed 2014 data is considered acceptable.

Considering the available data for developing, calibrating and validating the Indian Creek periphyton model along with the reasonable calibration and validation of the model to observed data, the model is considered suitable for assessing loading changes on the relative magnitude of changes to nutrients, DO and periphyton biomass in the creek.

6. Watershed Model

The concentration and loading of pollutants resulting from nonpoint sources are difficult to measure due to the diffuse and intermittent nature of stormwater runoff. A watershed runoff model, P8, was selected to estimate runoff volume, pollutant loads, and pollutant event mean concentrations in tributaries to Indian Creek during selected years.

6.1. Model Description

P8 is an urban catchment model for predicting the generation of pollutants resulting from stormwater runoff in urban watersheds. The model was initially developed by William W. Walker for the Narragansett Bay Commission (Providence, Rhode Island) in 1990. It has since been updated and newer versions include additional features. Mass-balance calculations are performed on a system defined by the user, which consists of watersheds (nonpoint source areas), devices (transport, storage, and treatment areas), particulate classes and water quality components.

The P8 model was selected since minimal site-specific input data are required to generate predictions of runoff quality. Input data required include precipitation data, watershed area, percent impervious area, pervious area curve number and depression storage. The model uses algorithms derived from other urban runoff models, such as SWMM, STORM, HSPF, TR-20 and D3RM, to manipulate input data and calculate runoff and pollutant loads.

The model computes pollutant loads and concentrations by simulating runoff volumes for both pervious and impervious areas. Runoff from pervious areas is computed by applying a watershed curve number, which is based on soil types and vegetative cover, to the Soil Conservation Service (SCS) curve number technique. Runoff from impervious areas is assumed to begin after cumulative storm precipitation exceeds depression storage. Watershed runoff volumes were generated using local hourly precipitation data.

The model also computes particulate loads and concentrations for both pervious and impervious areas, summing the results. An empirical equation, similar to the sediment rating model in SWMM is used to calculate pollutant concentrations in runoff from pervious areas. The model assumes that impervious surface is the primary source of stormwater pollutants. The effects of land use are included in the model through impervious area and soil type. Pollutant loads from impervious areas are computed based on particulate accumulation, washoff, and fixed runoff concentration, which are input to an exponential washoff relationship similar to that included in SWMM. Median values for pollutant event mean concentrations measured during the National Urban Runoff Program (NURP) study are used as default values in the model. These can be calibrated with site-specific data. Of the many pollutants monitored during the NURP study, the concentrations of total Kjeldahl nitrogen (TKN) and total phosphorus (TP) are of interest in this evaluation. The NURP median event mean concentrations for TKN and TP were 1.5 mg/L and 0.33 mg/L, respectively.

6.2. Model Configuration

The Indian Creek watershed comprises many smaller drainage areas. A total of 11 sub-basins were modeled as presented in Figure 21. The primary input parameters for the model are precipitation data and watershed characteristics including, watershed area, impervious fraction, pervious area curve number, and time of concentration. Impervious area was based on information in a report by USGS (2014). The SCS curve number is a measure of soil permeability. Guidance on selecting curve numbers is provided in the P8 model. Higher curve numbers represent less permeable soils. Information on soil type in the watershed was derived from the Johnson County Automated Mapping System (AIMS). The time of concentration (TOC) is defined as the time required for runoff to travel from the hydraulically most distant part of the watershed to the watershed outlet. The time of concentration was computed using the SCS TR-55 model.

6.3. Flow Calibration Process

Initial model runs were made using the input data presented above and precipitation data for two years, 2012 and 2014. Results of the model were compared to daily measured streamflow data obtained by USGS at the Marty and State Line gaging stations. Because the gaging stations are downstream from the two WWTFs, effluent discharge volumes were subtracted from the measured streamflow prior to making the comparison with model results. Calibration factors included curve numbers, time of concentration and runoff coefficients.

The P8 model does not perform flow routing as would be expected from hydraulic models. Without consideration of a time of concentration all runoff generated each hour by rainfall would immediately be directed from the watershed to Indian Creek. Specifying a time of concentration will generate a hydrograph over a longer period of time, however, it is not the same as flow routing. Therefore, the flow calibration was done on a daily basis rather than an hourly basis.

Average daily wastewater discharge from the Douglas L. Smith Middle Basin (Middle Basin) WWTF was subtracted from the daily flows measured at the Marty gaging station to determine watershed runoff flows. These values were compared to runoff flows predicted by the P8 model considering only the sub-basins entering Indian Creek upstream of the Marty gage. The average daily wastewater discharge from the Tomahawk Creek WWTF and the flows measured at the Marty gage were subtracted from the flows measured at the State Line gaging station to determine watershed runoff that enters Indian Creek between the two USGS gaging stations. These values were

compared to runoff flows predicted by the P8 model for sub-basins entering Indian Creek between the two gaging stations.

The P8 model predicts runoff from impervious and pervious areas. There is an option in the model to include an aquifer which would allow flow that infiltrates through pervious areas to flow back into Indian Creek. However, the model assumes that virtually all of the flow, minus some lost to evapotranspiration, is returned to the creek and that none is directed to a deep aquifer. Using this option resulted in flows that were much higher than the measured flows and, therefore, the aquifer option was not used. Without the aquifer, some shallow baseflow or interflow is not represented in the model. When comparing the measured to simulated flows, both the annual average flow and flows during storm events were considered. Results of the flow calibration for the years 2012 and 2014 are shown on Table 8.

Table 8. P8 Model Flow Calibration Results

USGS Gage	2012 Flow (cfs)		2014 Flow (cfs)	
	Measured	Calculated	Measured	Calculated
Marty				
Annual Average	19.7	23.5	26.1	26.6
Storm Flow	49.2	60.9	50.6	53.6
Stateline				
Annual Average	41.7	39.4	55.4	44.4
Storm Flow	80.8	100.8	88.1	83.4
Total				
Annual Average	61.7	62.9	81.5	71.0
Storm Flow	158.7	161.7	138.7	137.0

On an annual basis, there was good agreement between the measured and predicted flows. For individual storm events, at times the model over predicted or under predicted flows. That is likely because of the uneven rainfall distribution across the watershed. The model uses one rainfall distribution for the entire watershed.

6.4. Nutrient Calibration Process

The P8 model simulates particulate buildup and washoff from impervious surfaces. Particulates are distributed into 5 particle size classes. Water quality components are defined based on their weight distributions across the size classes and the dissolved fraction. Default values for particle classes and water quality components are defined based on the EPA's NURP data.

The nutrient data collected during the field surveys conducted for this project were used to calibrate the model for TKN and TP. The P8 model predicts flows, pollutant loads and pollutant concentrations on an hourly basis, an event basis, or for the entire period of simulation. Because the model does not perform flow routing, it should not be expected that concentrations predicted by the model for a specified time interval would match the concentrations measured at that time. Therefore, nutrient concentrations were calibrated on an event mean concentration (EMC) basis and not by matching concentrations at a specific time.

Measured EMCs for TKN and TP were determined using a flow-weighted average using the measured flow during the time interval represented by the sample. Only those locations not affected by the WWTF discharges were used in this analysis. Those locations included the area upstream of the Middle Basin WWTF, Tomahawk Creek and Dykes Branch. Sampler problems experienced at the upstream location limited the available data for calibration at that location. In addition, the samples collected during the April 25, 2015 survey had very high concentrations of TSS indicating erosion of the stream banks. Because the watershed model is being used to simulate nonpoint sources of nutrients from the watershed these data were not used in the calibration process.

The goal for the nutrient calibration was to achieve the best overall match between the measured values while limiting under prediction of concentrations. A comparison of measured and predicted EMCs indicated that the default values for TP should be modified. The water quality component file was revised such that the EMC for TP was set to 0.25 mg/L while the EMC for TKN remained at 1.5 mg/L. The P8 model was run using the calibrated water quality component to determine the predicted EMCs for each of the sampling events. Table 9 lists the measured and predicted EMCs for each of the sampling events. Differences are expressed as percentage of measured value. Negative values indicate an under prediction while positive values are an over prediction of the measured value.

Table 9. Comparison of Measured and Calculated EMCs for TKN and TP

Date	Location	TP (mg/L)			TKN (mg/L)		
		Measured	Calculated	% Diff.	Measured	Calculated	% Diff.
10/9/14	Tomahawk Crk	0.255	0.262	2.7	1.44	1.56	8.3
	Dykes Branch	0.217	0.261	20.5	1.27	1.56	22.9
10/14/14	Upstream	0.189	0.225	19.3	1.49	1.37	-7.7
	Tomahawk Crk	0.321	0.216	-32.8	1.88	1.33	-29.5
	Dykes Branch	0.188	0.218	15.9	1.14	1.32	15.0
Average		0.234	0.236	1.0	1.44	1.43	-1.2

6.5. Typical Year Rainfall

As part of their Long Term Control Work Plan, the City of Kansas City, Missouri evaluated precipitation data to define the typical year for rainfall. The evaluation considered rainfall amounts, inter-event time, and peak intensity recurrence analysis. They also considered the full year versus the recreational season and resulting streamflow from rain. Based on the analysis of historical data the year 2001 was selected as the "typical year".

Indian Creek was also modeled for the typical year using rainfall data from 2001. There are many rain gages in the Indian Creek watershed that could be used to drive the watershed model. To determine the most appropriate gaging station two issues were considered: which station had rainfall data that best matched the typical year for the Kansas City Metro area; and how that compared to the stations' long-term averages. Rainfall information was obtained from the StormWatch system for three sites with long-term records located in approximately the middle portion of the Indian Creek Basin. The data were used to calculate annual averages and overall averages for rainfall.

For the year 2001, the data from the Corporate Woods location best matched the long-term average rainfall in the Kansas City and gave the best match to the station's long-term average, indicating that 2001 is a typical year for the site in terms of rainfall amount. Therefore, the Corporate Woods rainfall data was selected to drive the watershed model. This decision was based on the rainfall analysis conducted by Kansas City, Missouri, the similarity of the 2001 rainfall to the long-term average in the metro area, and the comparison of 2001 rainfall to the 25 year average at the site.

6.6. Watershed Nutrient Loads for the Typical Year

The calibrated model was run using rainfall for 2001 which was considered to be a typical year. All factors except the rainfall record remained the same from the calibration runs previously completed. A check on the flows indicated that the model under-predicted flows to the Marty gage. The flow at the Marty gage represent about one-third of the flow for the Indian Creek watershed. There were no other flow gages installed in the watershed at that time so it is not known how the rest of the watershed responded to the rainfall. It is possible that the rain gage selected was not representative of that portion of the watershed at that time. However, the purpose in evaluating a typical year is to determine how the watershed would respond to a typical year of rainfall. For 2001, the model predicted there would be about 0.9 cfs of stream discharge per inch of rainfall; this is equivalent to the long-term average for the site.

Outputs for 2001 included hourly values of flow and nutrient concentrations and loads for each of the watersheds. These were then used as inputs to the Indian Creek periphyton model for completing water quality projections.

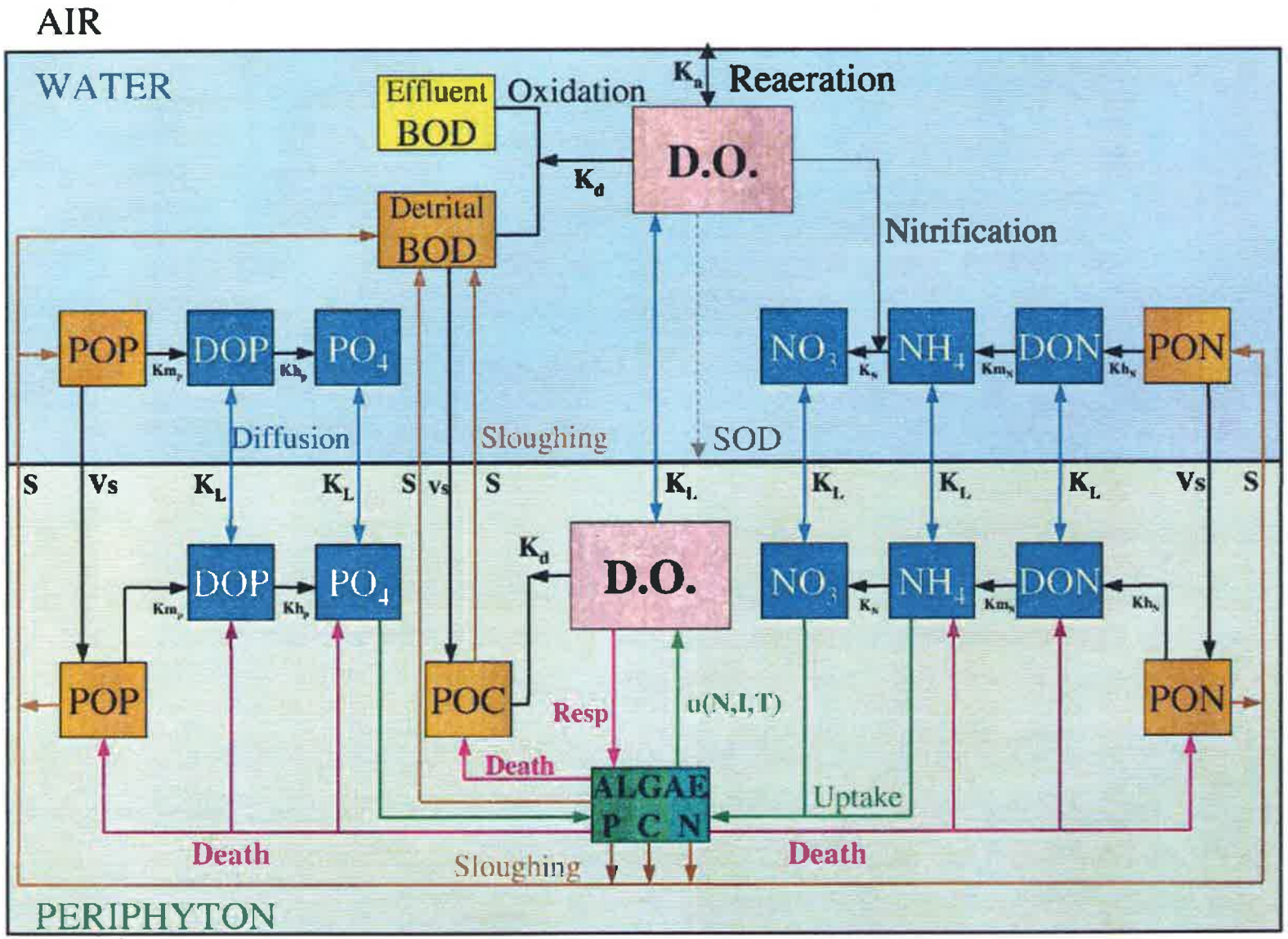


Figure 1. Schematic of the Periphyton Model (PeriWASP) Kinetic Structure

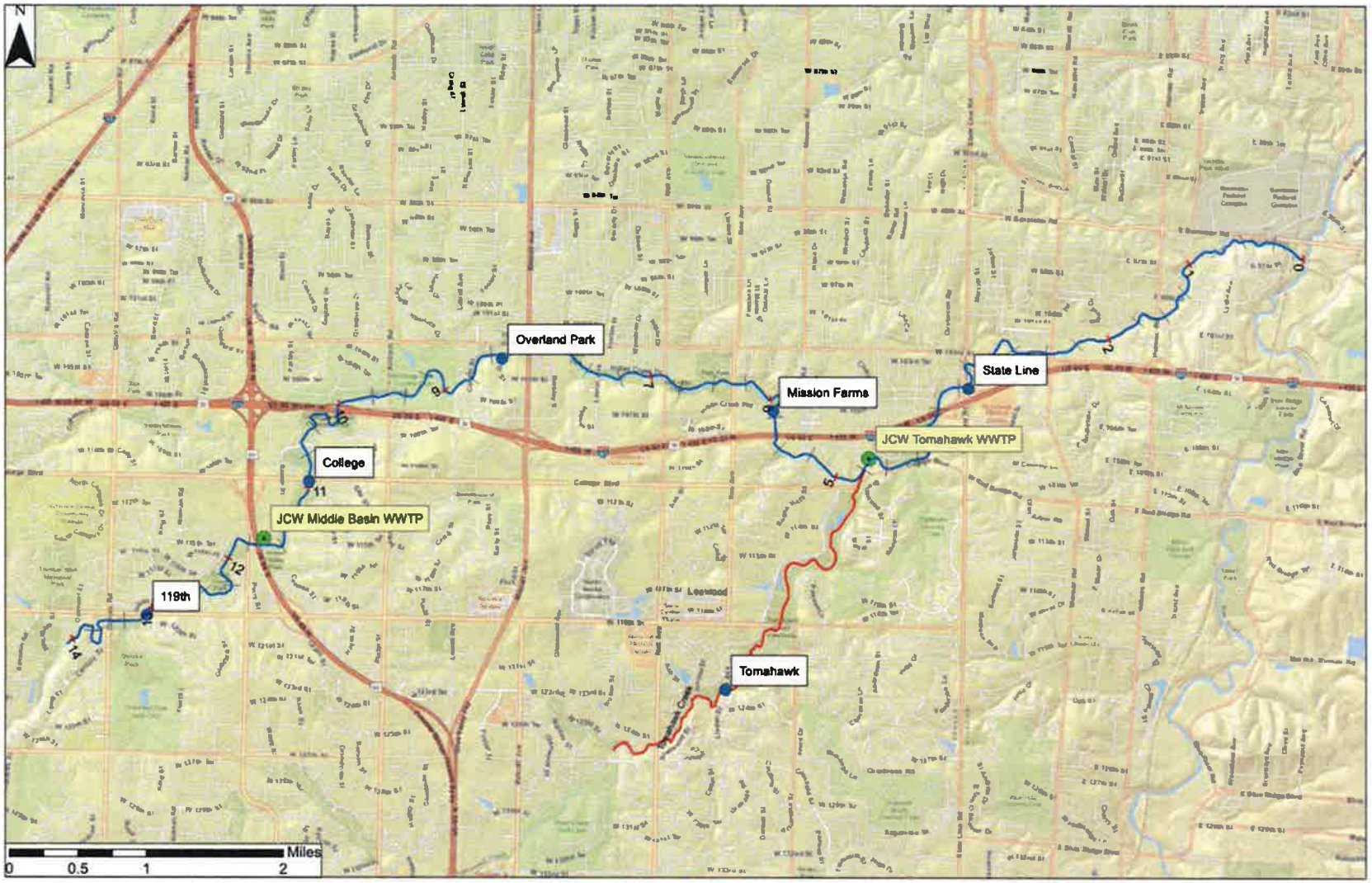


Figure 2. Indian Creek Study Area and Model Segmentation

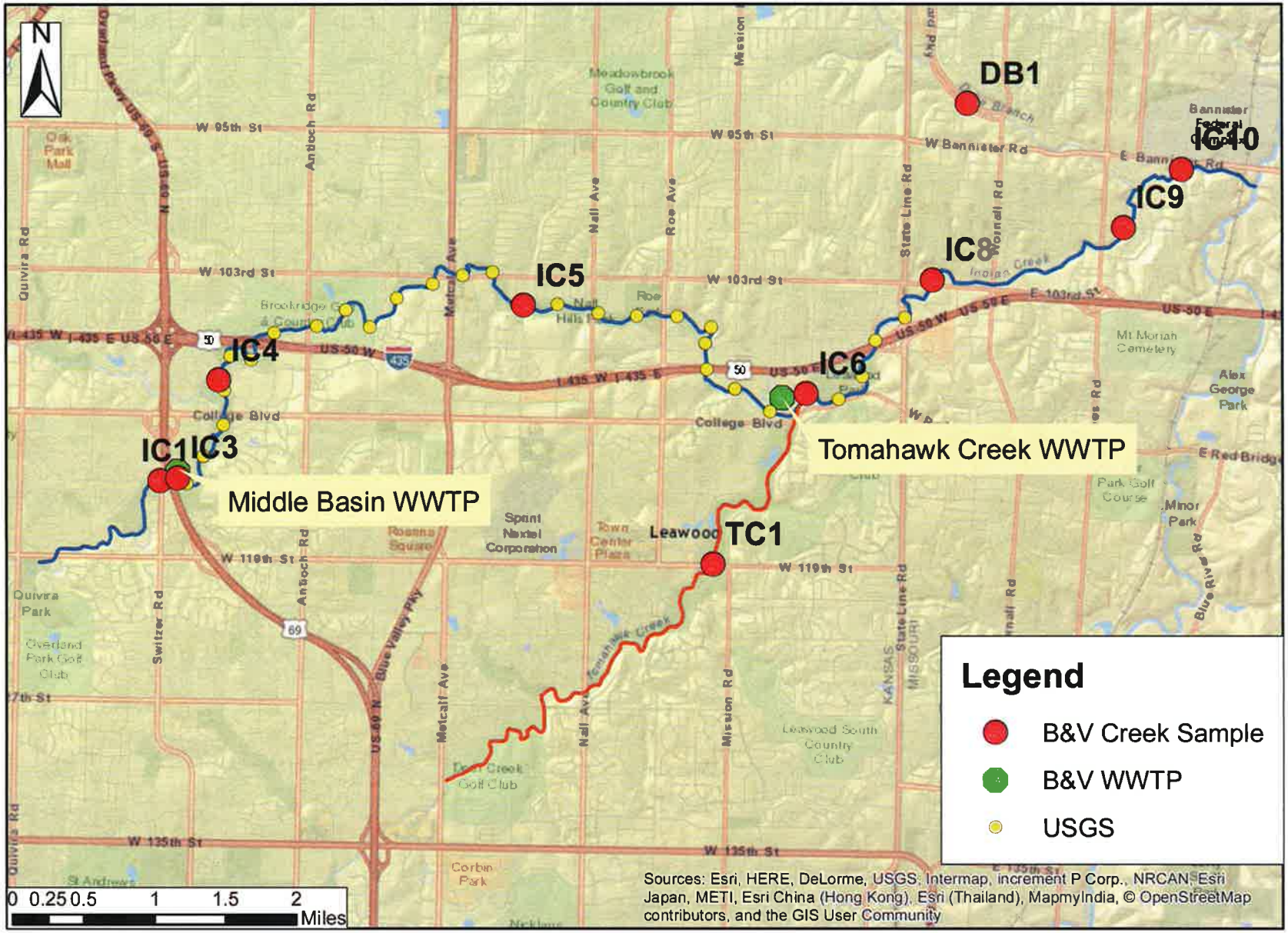


Figure 3. 2014 Indian Creek Sampling Locations (B&V and USGS)

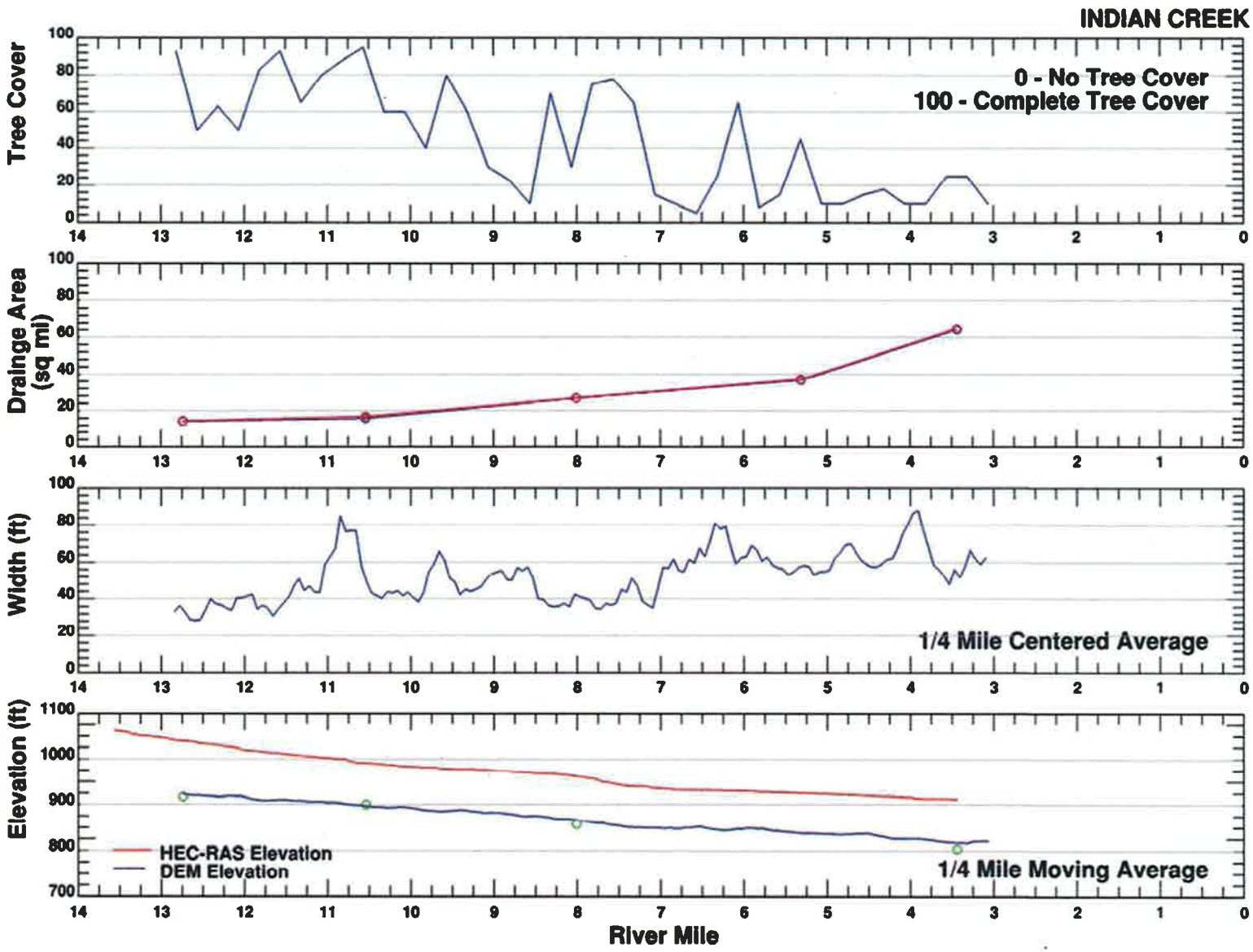


Figure 4. Indian Creek Physical Characteristics

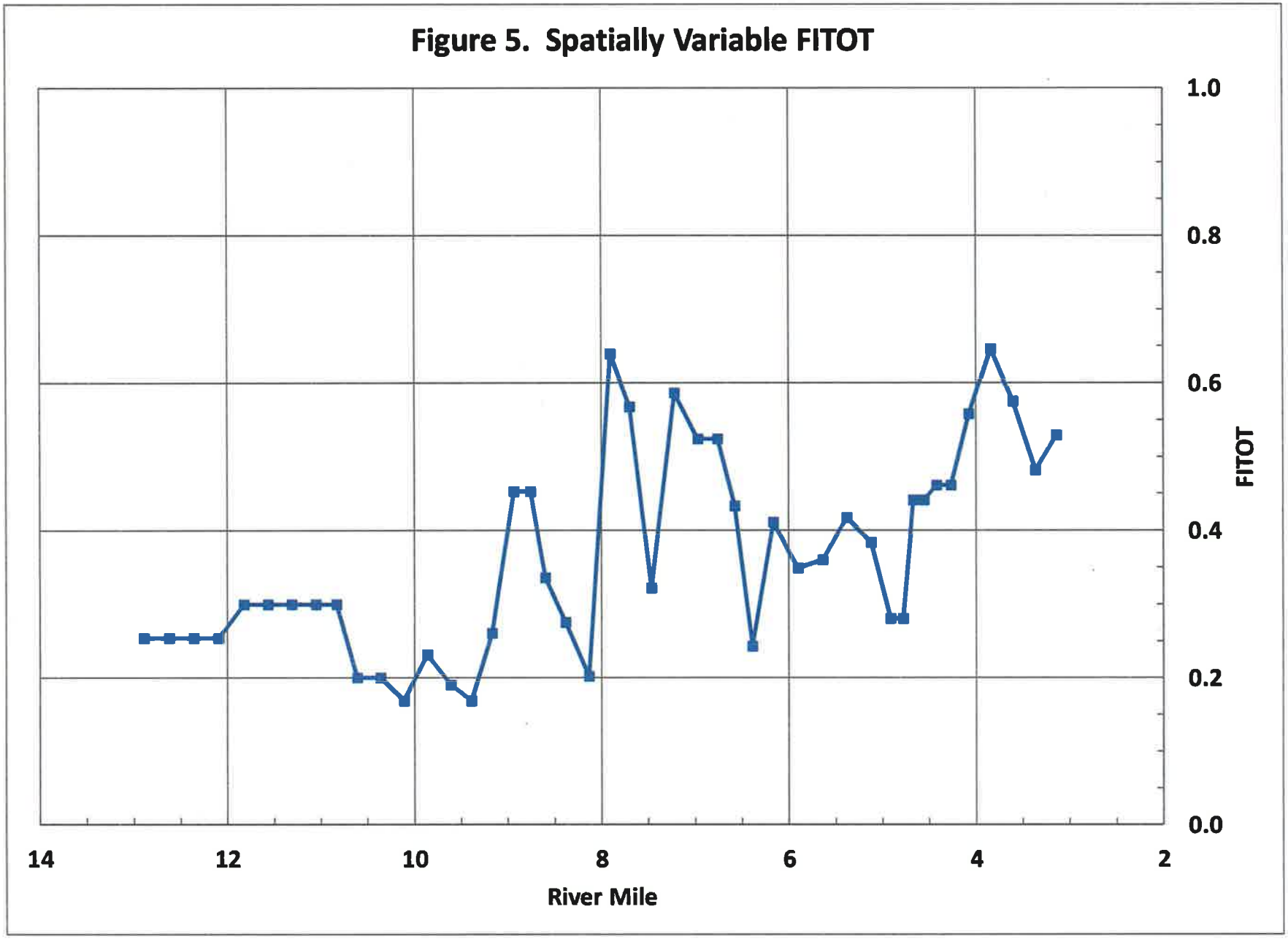


Figure 5. Spatially Variable FITOT
1.0
0.8
0.6
0.4
0.2
0.0
FITOT
14
12
10
8
6
4
2
River Mile

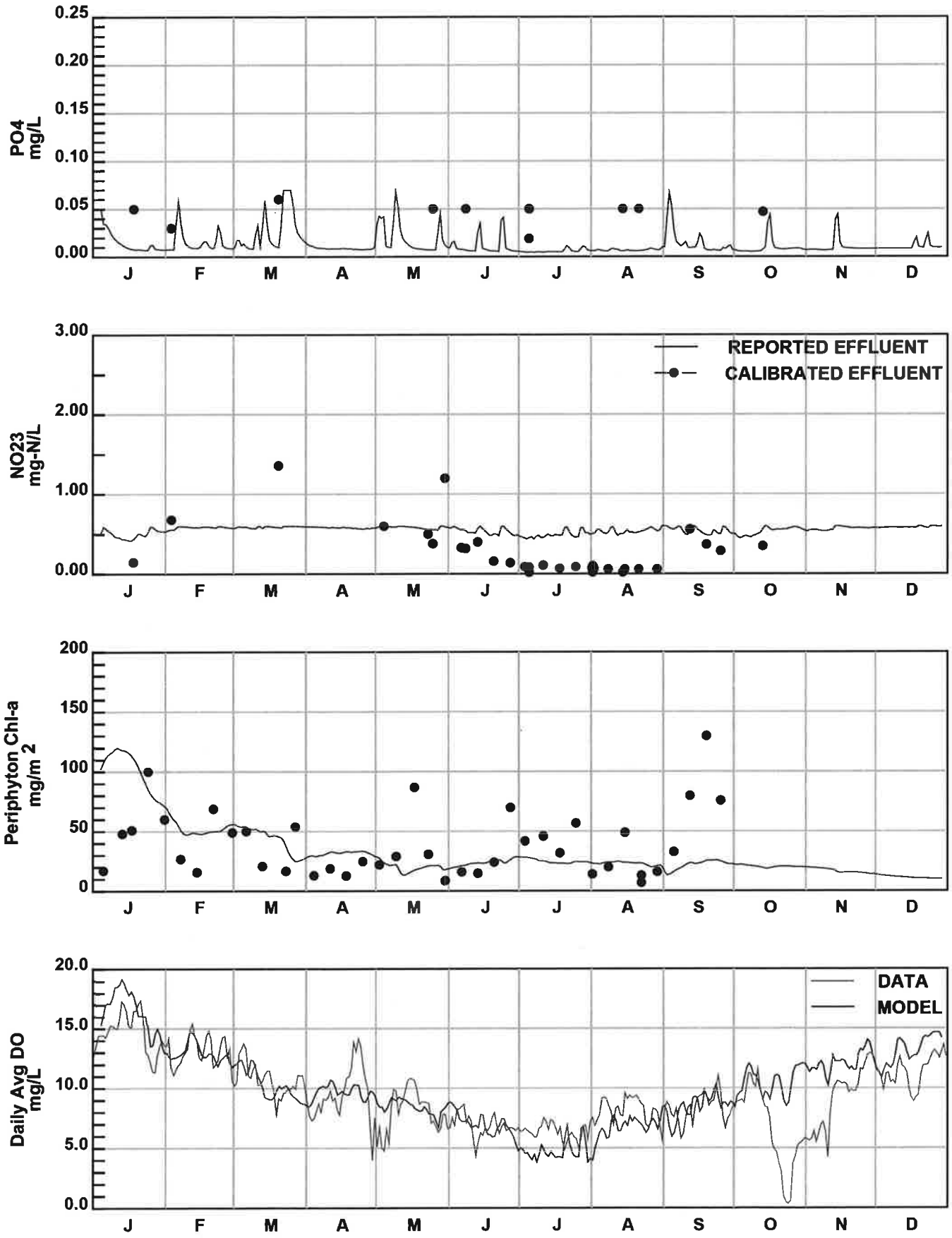


Figure 6. Indian Creek Periphyton Model Calibration to 2012 Data at 119th St.

DATE: 9/04/2015 TIME: 12: 5:14

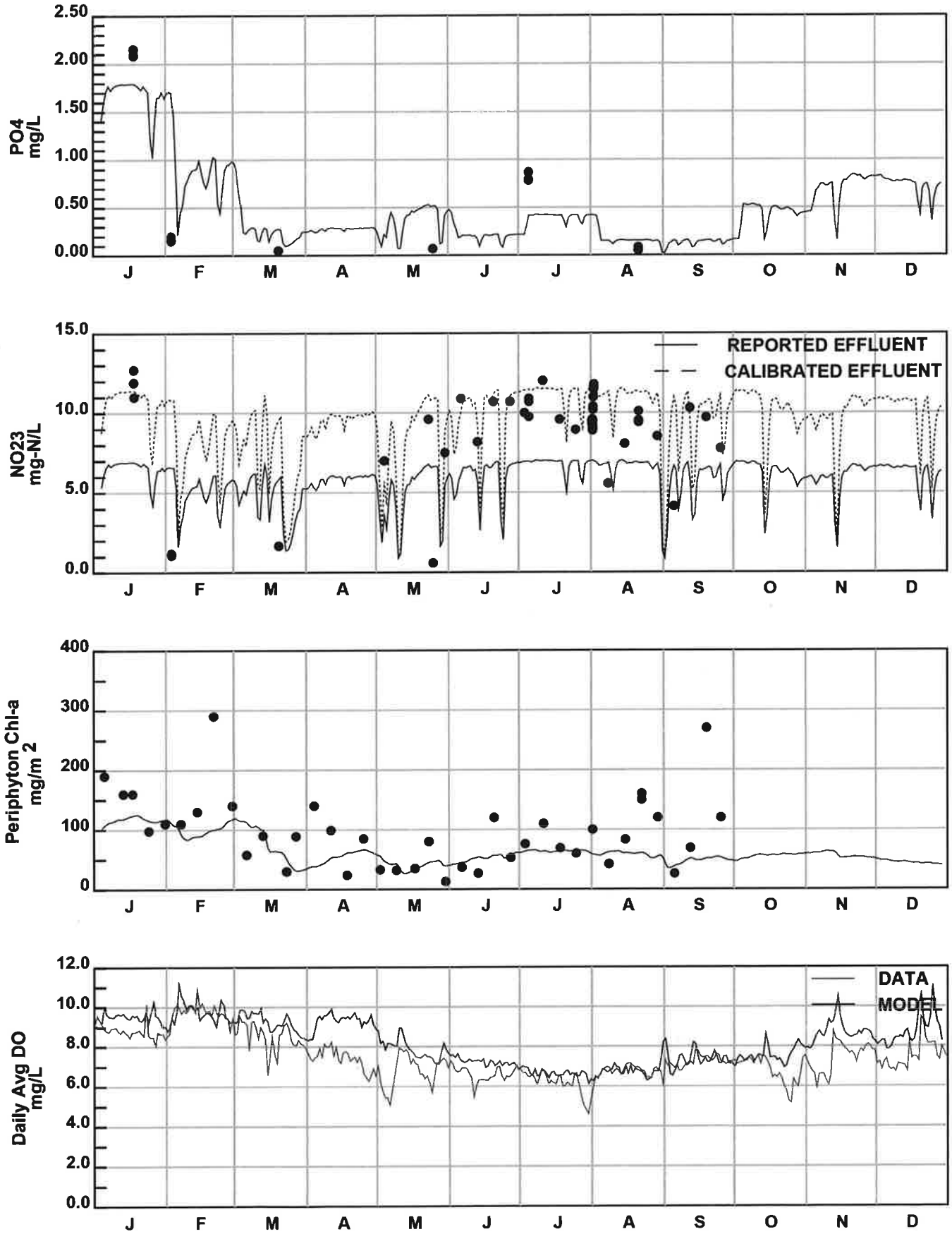


Figure 7. Indian Creek Periphyton Model Calibration to 2012 Data at College

DATE: 9/04/2015 TIME: 12: 5:14

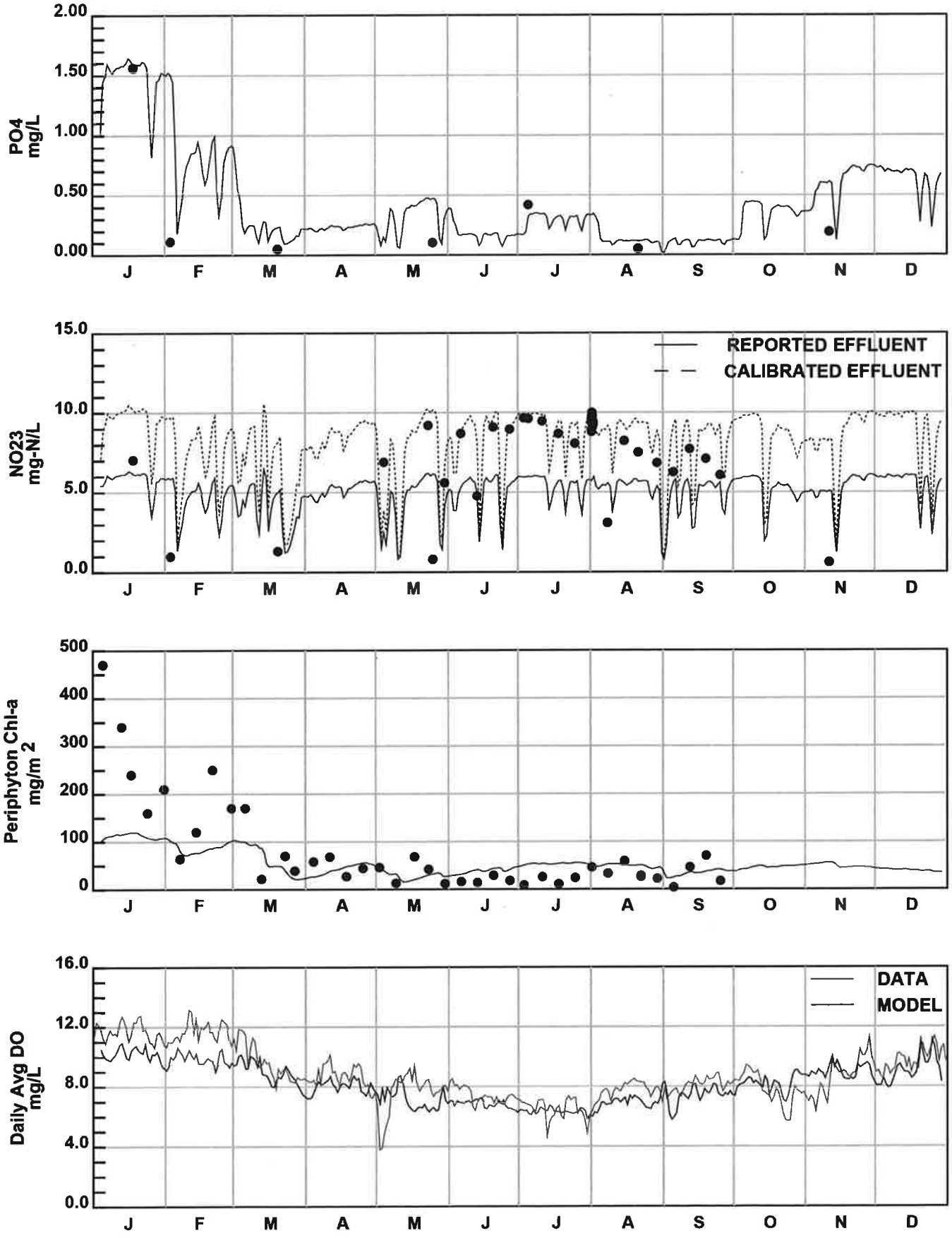


Figure 8. Indian Creek Periphyton Model Calibration to 2012 Data at Marty

DATE: 9/04/2015 TIME: 12: 5:14

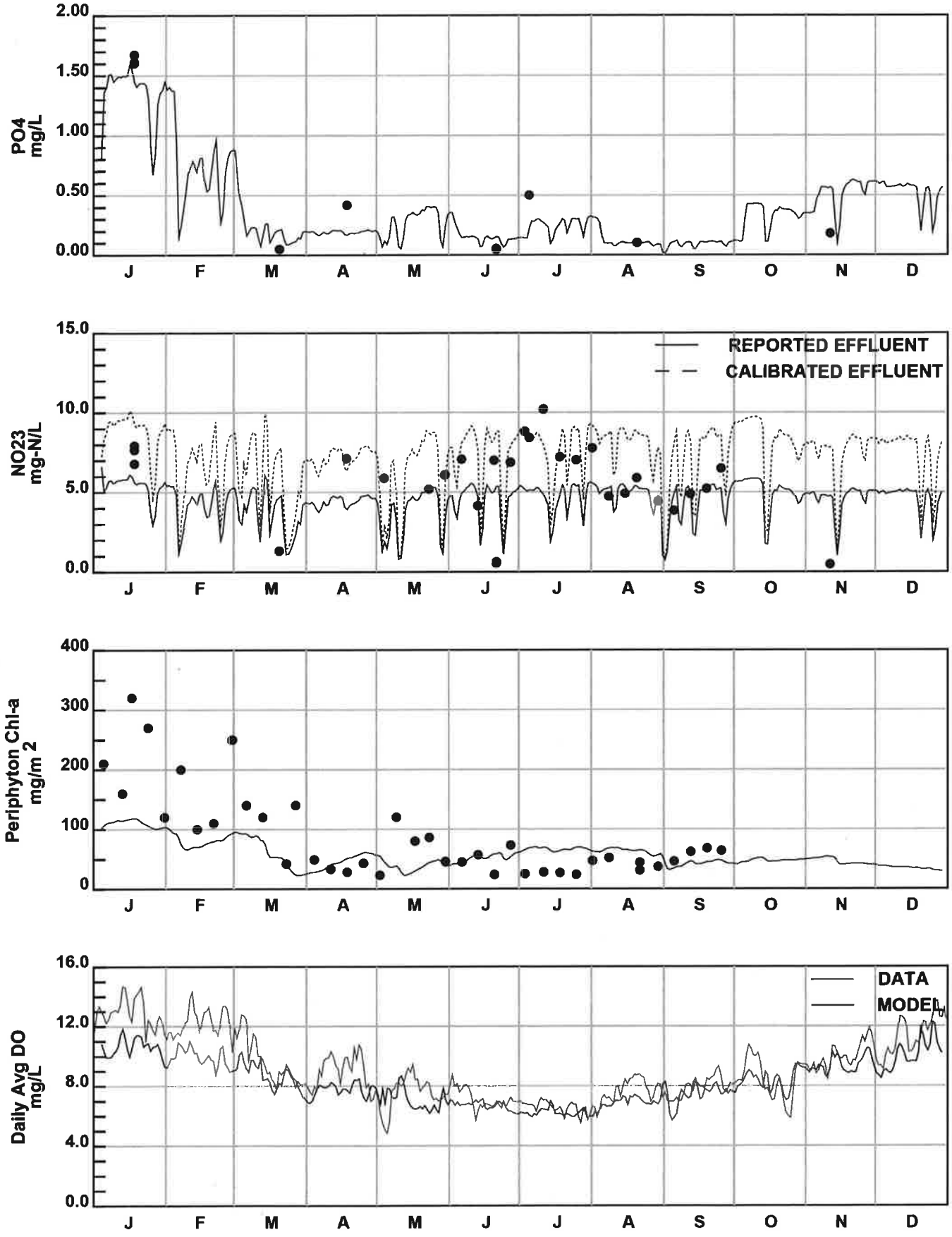


Figure 9. Indian Creek Periphyton Model Calibration to 2012 Data at Mission Farms

DATE: 9/04/2015 TIME: 12: 5:14

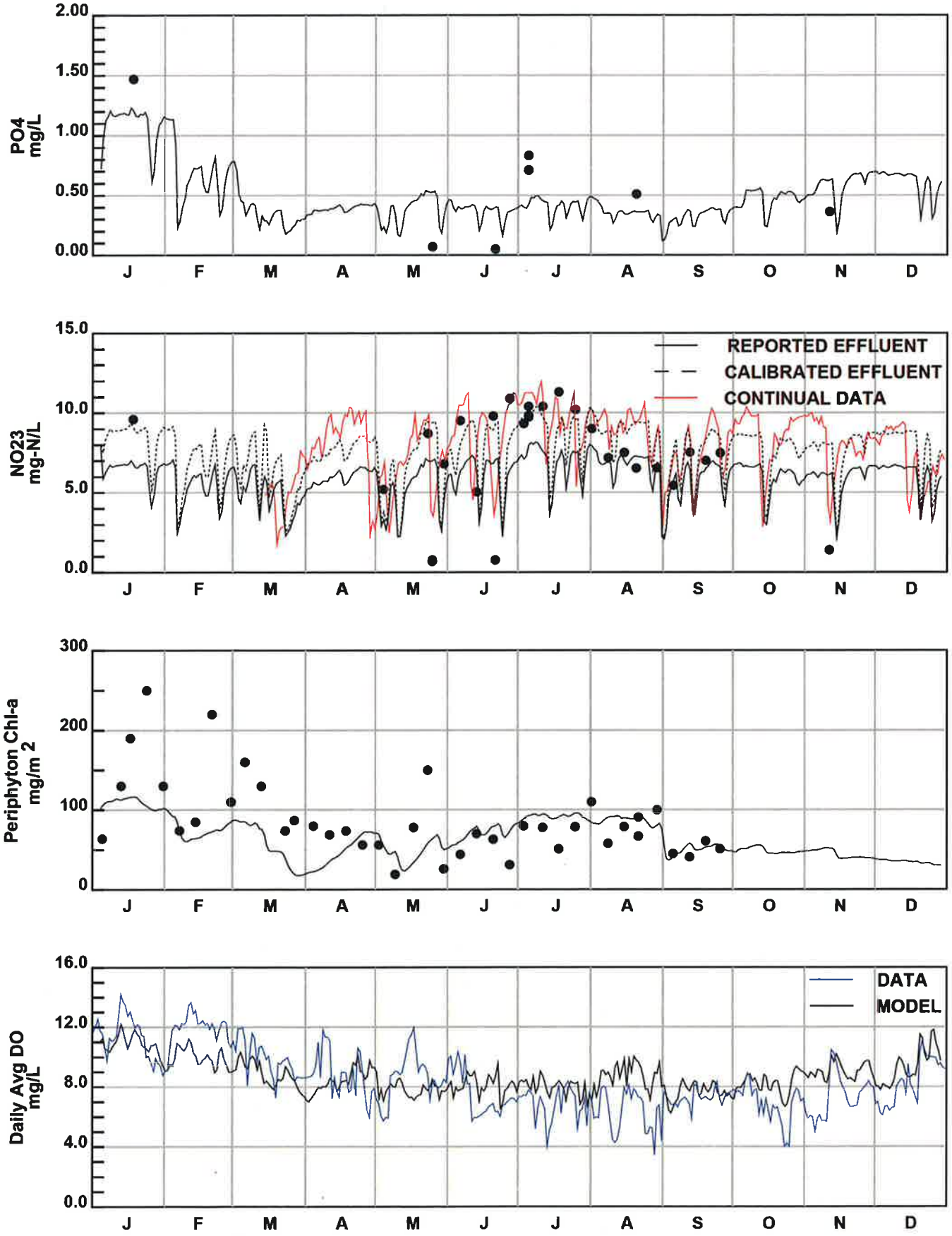


Figure 10. Indian Creek Periphyton Model Calibration to 2012 Data at Stateline

DATE: 9/04/2015 TIME: 12: 5:14

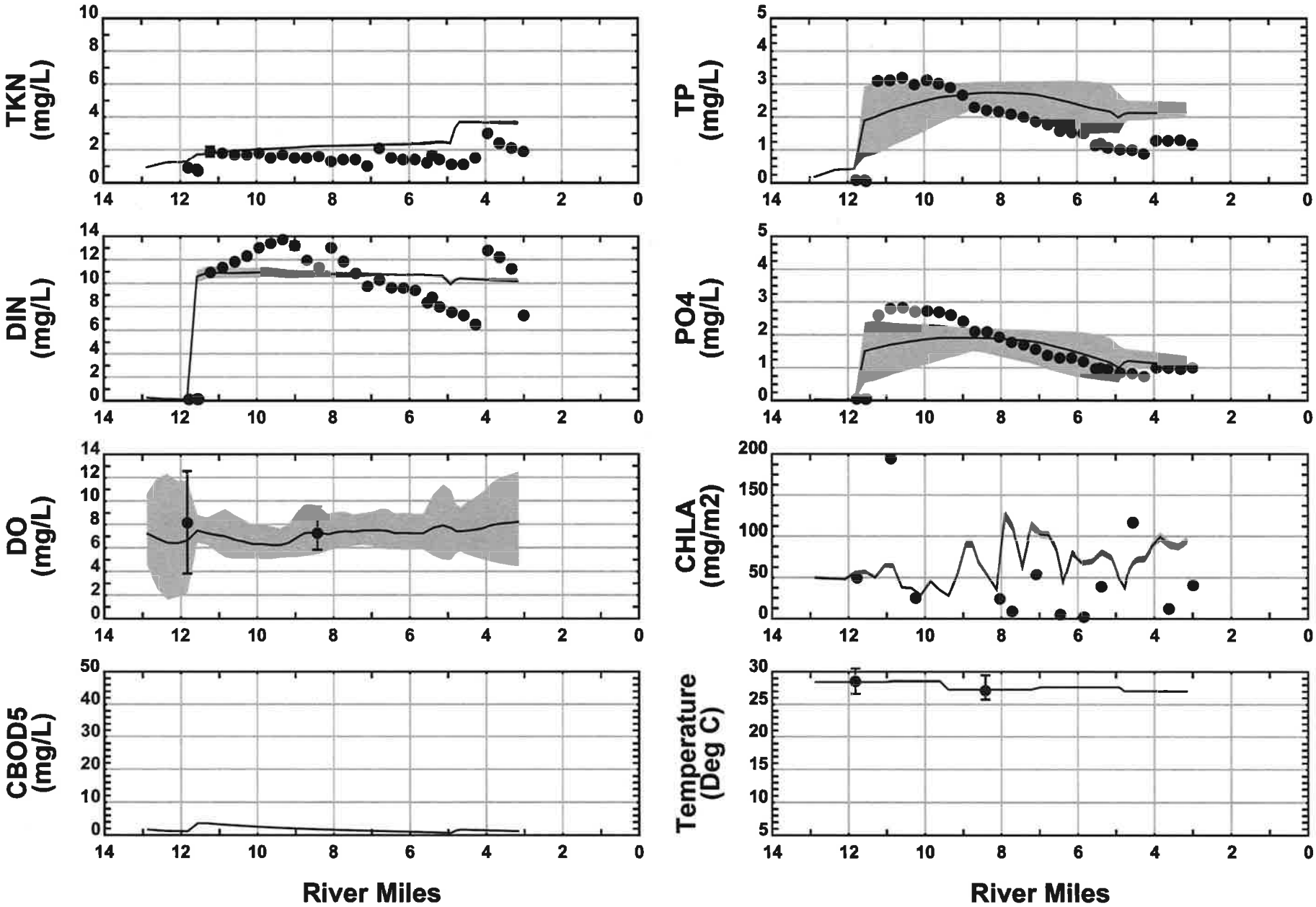


Figure 11. Model Validation Results for 7/23/2014

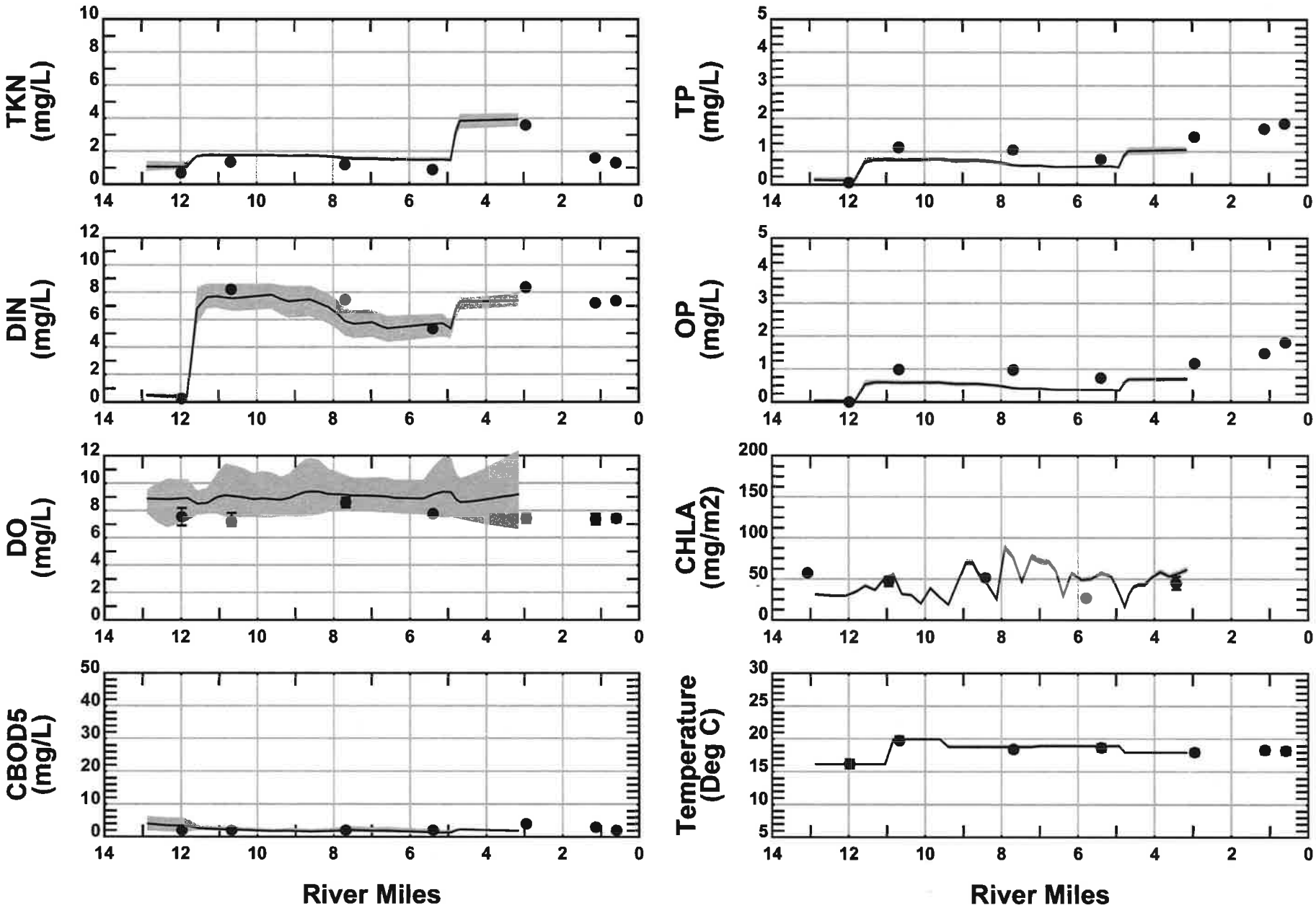


Figure 12. Model Validation Results for 9/16/2014

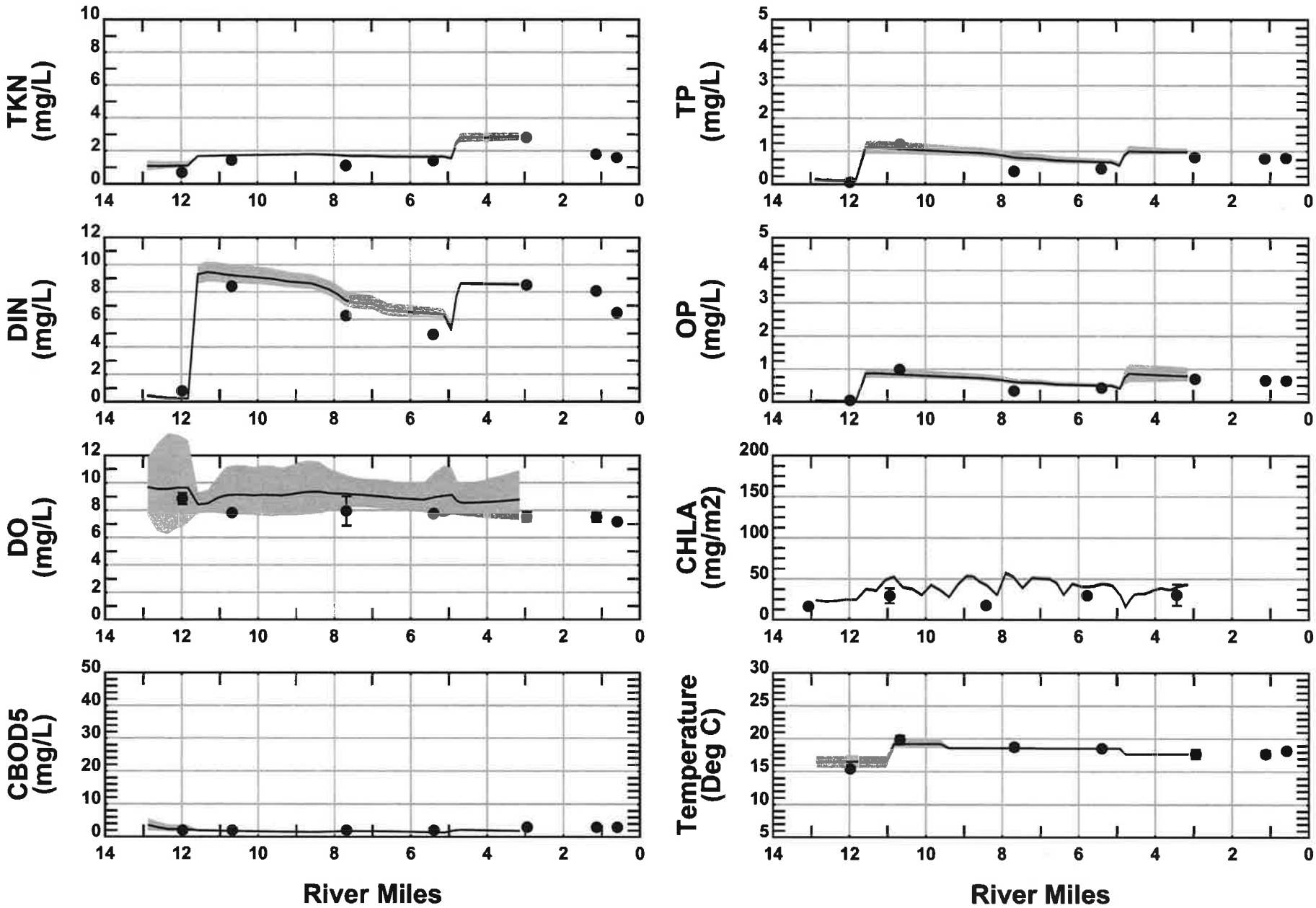


Figure 13. Model Validation Results for 10/8/2014

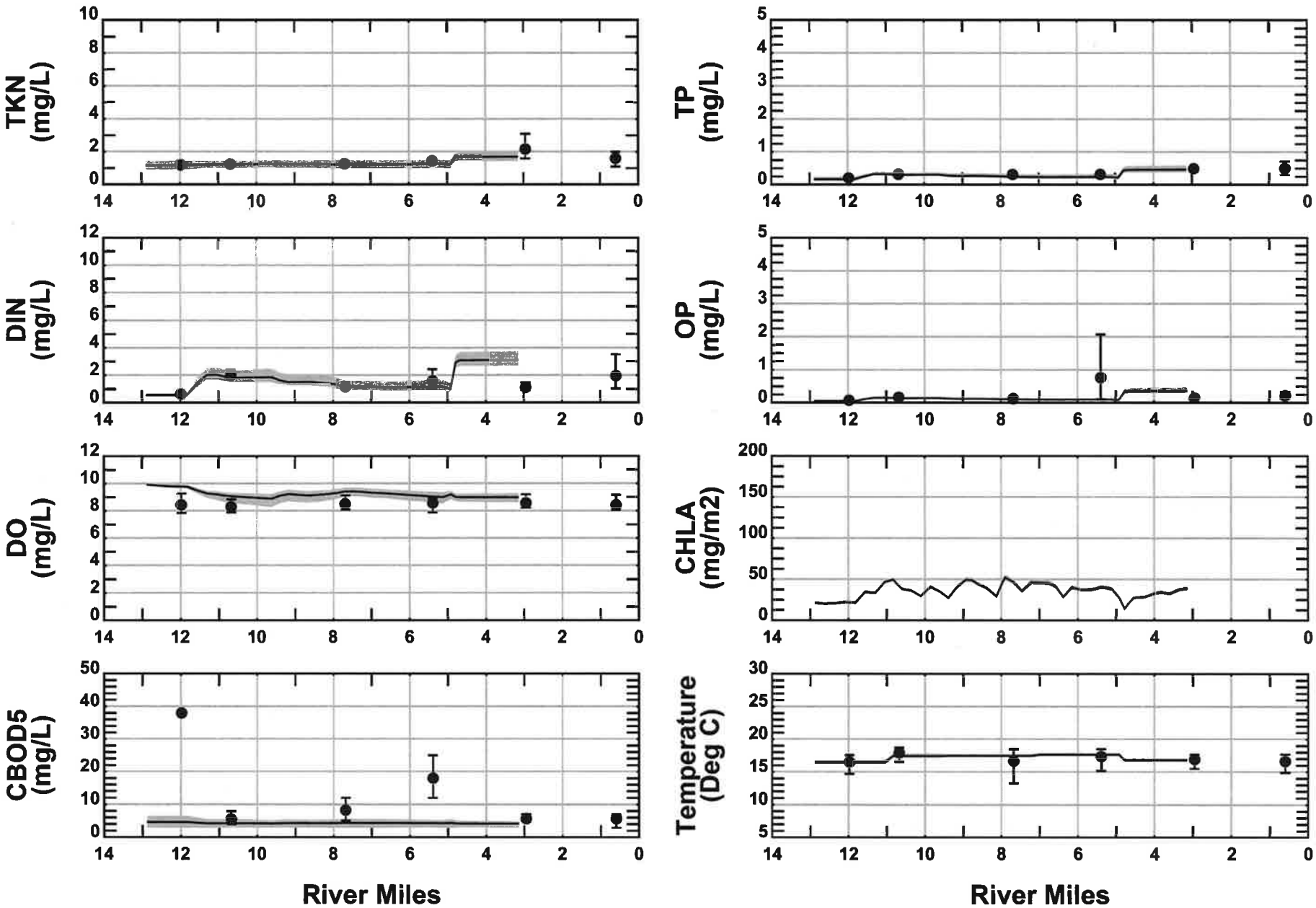


Figure 14. Model Validation Results for 10/10/2014

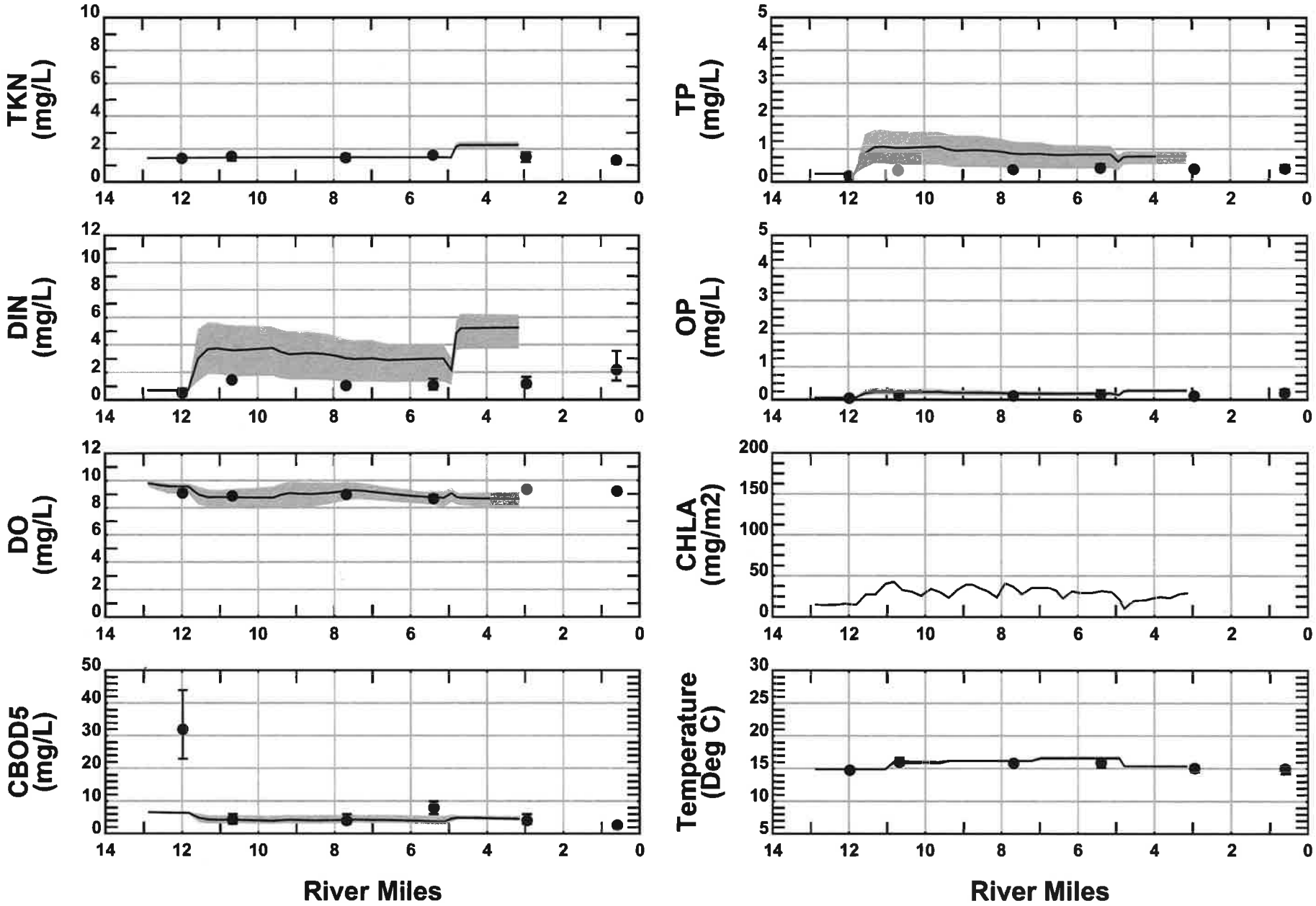


Figure 15. Model Validation Results for 10/13/2014

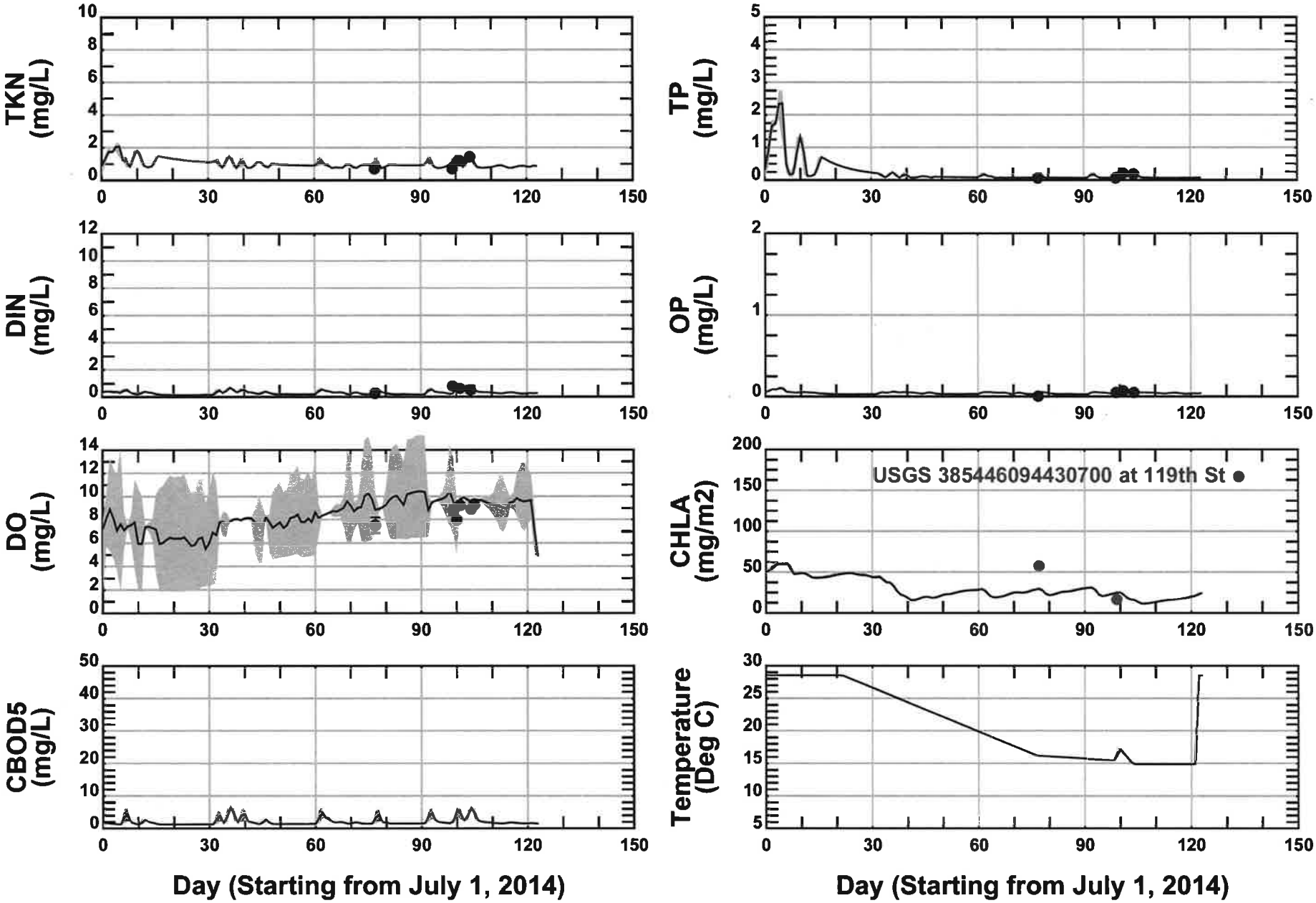


Figure 16. Model Validation Results for Station IC1

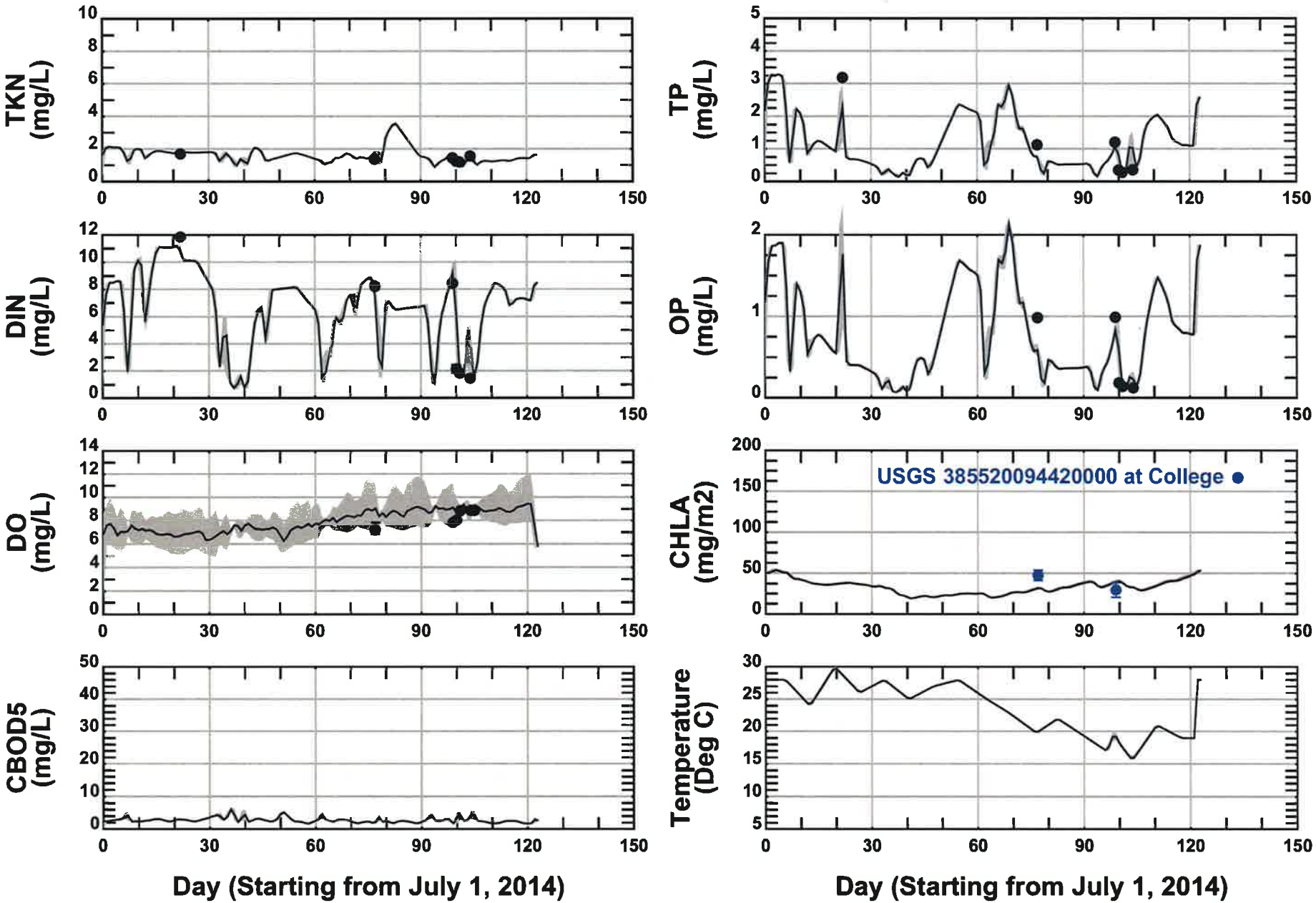


Figure 17. Model Validation Results for Station IC4

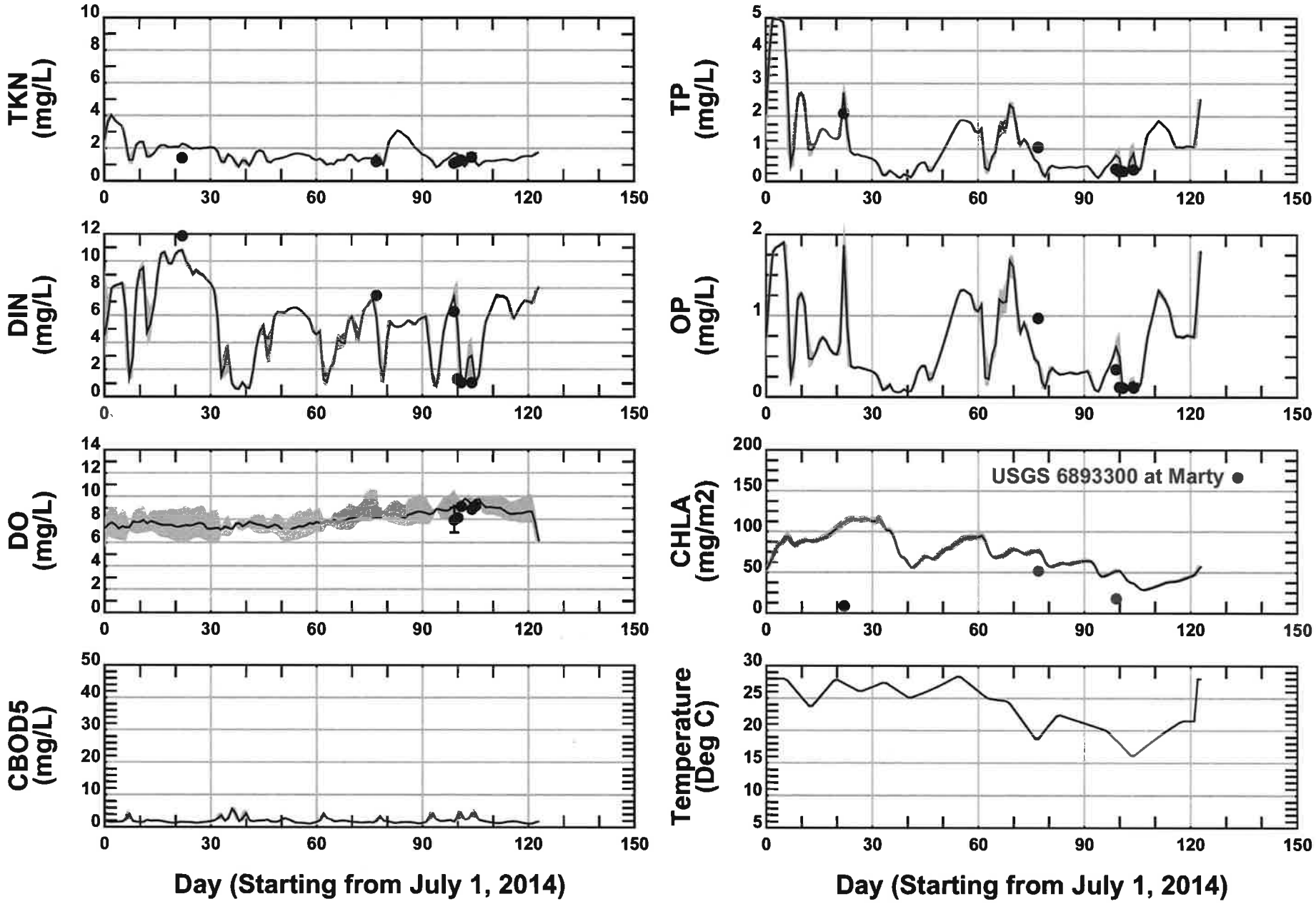


Figure 18. Model Validation Results for Station IC5

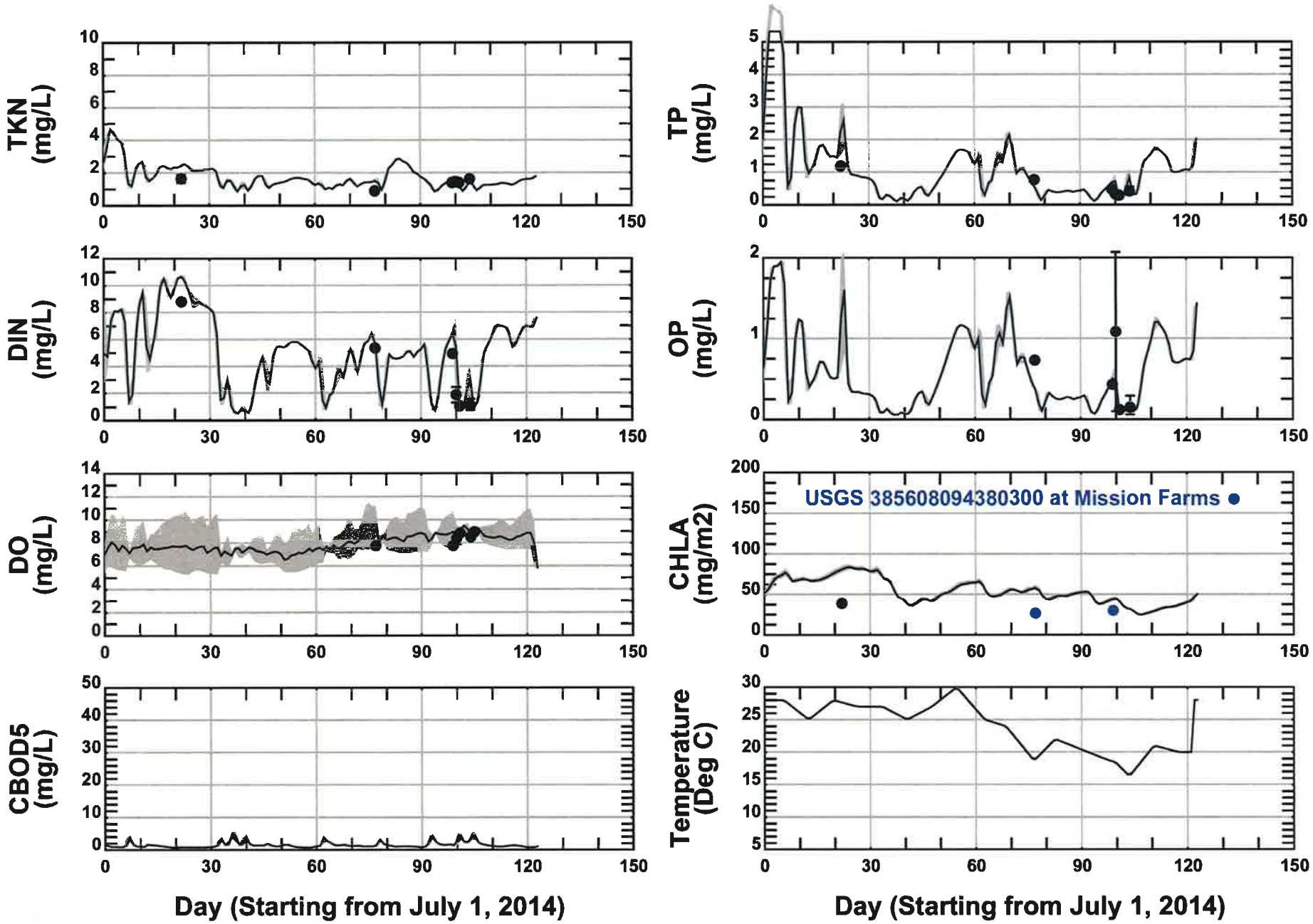


Figure 19. Model Validation Results for Station IC6

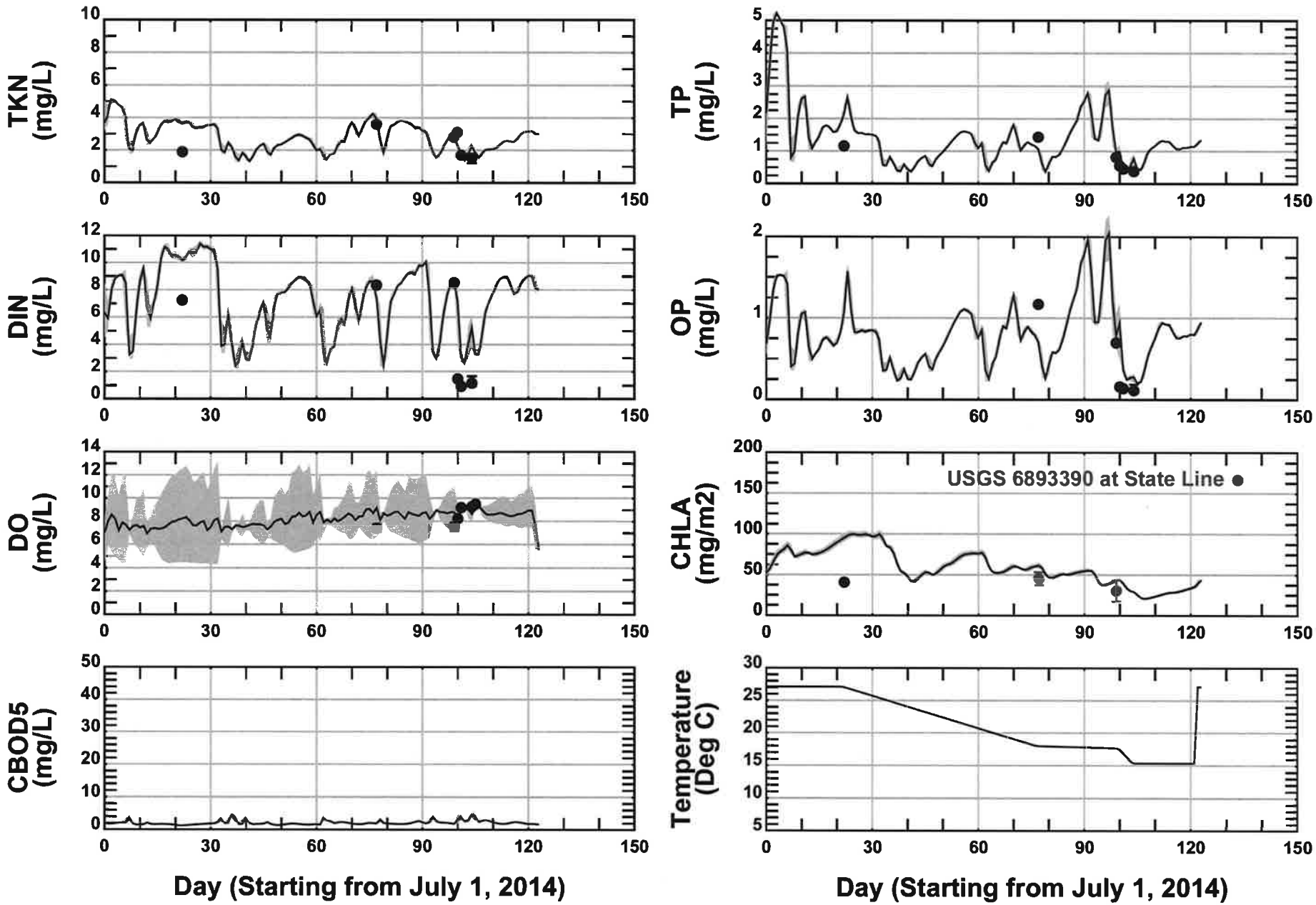


Figure 20. Model Validation Results for Station IC8

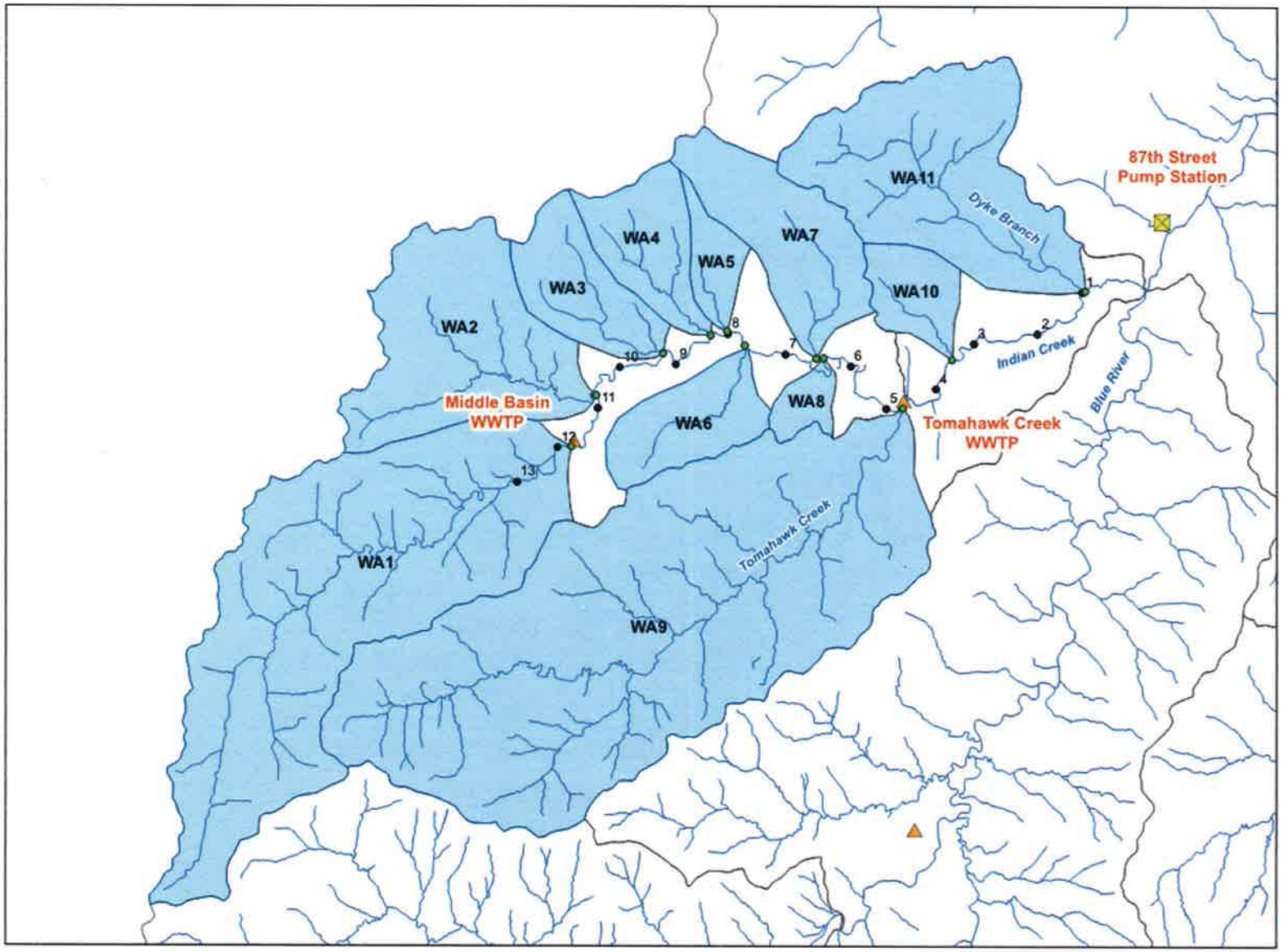
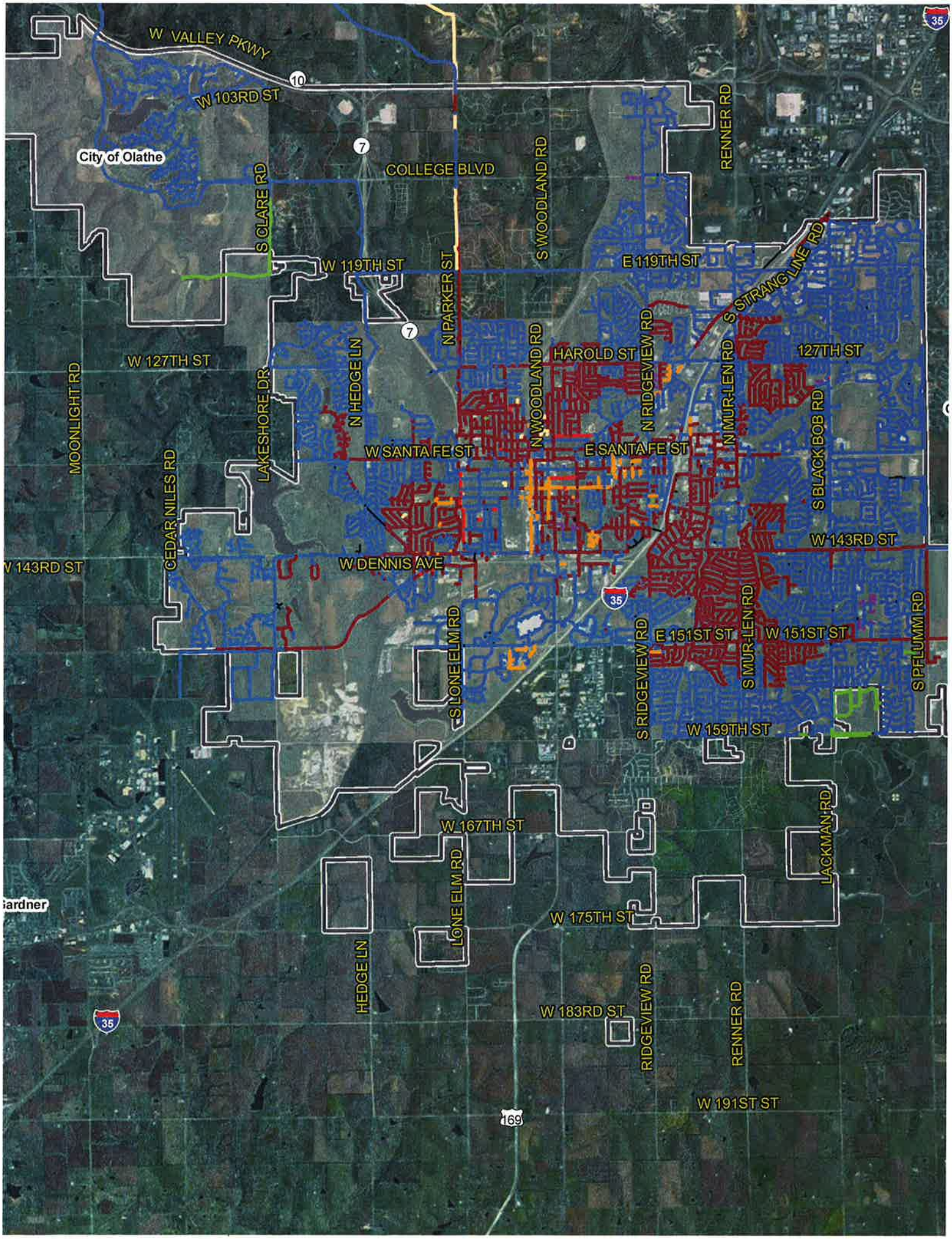


Figure 21. Indian Creek Watershed P8 Model Sub-basins


W VALLEY PKWY
W 103RD ST
City of Olathe
COLLEGE BLVD
S CLARE RD
S WOODLAND RD
RENNER RD
W 119TH ST
E 119TH ST
S STRANG LINE RD
N PARKER ST
N HEDGE LN
N WOODLAND RD
HAROLD ST
N RIDGEVIEW RD
N MUR-LEN RD
127TH ST
W 127TH ST
MOONLIGHT RD
LAKESHORE DR
W SANTA FE ST
E SANTA FE ST
S BLACK BOB RD
CEDAR NILES RD
W 143RD ST
W DENNIS AVE
S LONE ELM RD
E 151ST ST
W 151ST ST
S MUR-LEN RD
S PFLUMM RD
S RIDGEVIEW RD
W 159TH ST
W 167TH ST
LACKMAN RD
LONE ELM RD
W 175TH ST
HEDGE LN
W 183RD ST
RIDGEVIEW RD
RENNER RD
W 191ST ST
Gardner

APPENDIX B

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT

Technical Services Section
Bureau of Water
1000 SW Jackson St., Suite 420
Topeka, KS 66612-1367

Kansas

Phone: 785-296-2856
Fax: 785-296-0086
SShoresM@kdheks.gov
www.kdhe.ks.gov

Susan Mosier, MD, Secretary
Department of Health & Environment
Sam Brownback, Governor

February 9, 2016

Johnson County Wastewater
Environmental Manager
11811 S. Sunset Dr., Suite 2500
Olathe, KS 66061

RE: Kansas Public Notice No. KS-NQ-16- 15
Kansas Water Pollution Control
Permit No. M-MO27-OO03
Tomahawk Creek WTF

Dear Permittee:

The enclosed public notice and draft permit pertain to the referenced pending Kansas Water Pollution Control Permit and Authorization to Discharge under the National Pollutant Discharge Elimination System (NPDES).

Regulations require this department to issue a public notice to inform interested persons of the agency's intent to issue a Kansas/Federal Water Pollution Control Permit. The notice allows a 30-day period for comment by the applicant or other interested parties. If response to the notice indicates significant interest, a public hearing may be held. Please post the draft permit and the public notice in a conspicuous public place in your place of business (if a private business) or other public building (if a governmental entity) until the Comments Due Date identified in the public notice.

Also, please note that if the permit requires routine monitoring and reporting, the table under section A will contain a new term called "EDMR code". This term stands for Electronic Discharge Monitoring Report and is an addition to the permits to allow all permittees, in the future, to report the discharge monitoring report data electronically instead of on paper.

Any comments you have regarding the proposed permit should be sent to this office. If you have any questions, please contact me at (785)296-2856.

Sincerely,

Shelly Shores-Miller
Permits & Compliance

NE - District
RG- Permit File

Kansas Permit No.: M-MO27-0003
Federal Permit No.: KS0100846

KANSAS WATER POLLUTION CONTROL PERMIT AND AUTHORIZATION TO DISCHARGE UNDER THE NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

Pursuant to the Provisions of Kansas Statutes Annotated 65-164 and 65-165, the Federal Water Pollution Control Act as amended, (33 U.S.C. 1251 et seq; the "Act"),

Owner:	Johnson County Wastewater
Owner's Address:	11811 S. Sunset Drive Suite 2500 Olathe, Kansas 66061-7061
Facility Name:	Tomahawk Creek Wastewater Treatment Facility
Facility Location:	SW¼, Section 10, Township 13S, Range 25E Johnson County, Kansas Lat: 38.92997 Long: -94.62425
Receiving Stream & Basin:	Blue River (MO) via Indian Creek & Missouri River Basin

is authorized to discharge from the wastewater treatment facility described herein, in accordance with effluent limits and monitoring requirements as set forth herein.

This permit is effective _____, supersedes the previously issued water pollution control permit M-MO27-0001, and expires _____.

EXISTING FACILITY DESCRIPTION:

001A1 Discharge

1. Mechanical Bar Screens
2. Grit Removal
3. Primary Sedimentation
4. Trickling Filter
5. Final Sedimentation
6. Chlorination
7. Dechlorination
8. Hydraulic Design Flow = 10.0 MGD

007A -Influent to KCMO Interceptor Line for Treatment at KCMO Blue River WWTF

Peak Flow Holding Basin

1. Screens
2. Peak Flow Pump Station
3. Disinfection

EXPANDED FACILITY DESCRIPTION:

001A1 Discharge*

1. Mechanical Bar Screens
2. Grit Removal
3. Primary Sedimentation
4. BNR Activated Sludge Treatment Basins
5. Final Sedimentation
6. Anaerobic Digestion
7. Tertiary Pump Station
8. Dual Purpose Filters
9. Disinfection
10. Effluent Cascade Aeration
11. Dry Weather Design Flow = 19 MGD
12. Peak Instantaneous Hydraulic Design Flow through Activated Sludge System = 57 MGD
13. Peak Instantaneous Hydraulic Design Flow through Facility = 172 MGD

*Discharge Location 007A will no longer be active in the expanded facility.

_____
Secretary, Kansas Department of Health and Environment

_____
Date

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A. LIMITS AND MONITORING REQUIREMENTS

The permittee is authorized to discharge from outfall(s) with serial number(s) as specified in this permit. The effluent limits shall become effective on the dates specified herein. Such discharges shall be controlled, limited, and monitored by the permittee as specified. There shall be no discharge of floating solids or visible foam in other than trace amounts.

Monitoring reports shall be submitted on or before the 28th day of the following month. In the event no discharge occurs, written notification is still required.

Parameter	Interim Limits	Final Limits	Measurement Frequency	Sample Type
Monitoring Location 001AG (EDMR code: INF001AG) - Influent to Treatment Plant				
BOD(5-Day)-mg/l	Monitor	Monitor	3/Week	24 Hour Composite
Total Suspended Solids - mg/l	Monitor	Monitor	3/Week	24 Hour Composite
Total Phosphorus (as P)-mg/l	Monitor	Monitor	3/Week	24 Hour Composite
Total Kjeldahl Nitrogen(as N)-mg/l	Monitor	Monitor	3/Week	24 Hour Composite
Flow to Treatment Plant - MGD	Monitor	Monitor	Daily	Meter
Outfall 001A1 (EDMR code: EFF001A1) - Effluent at Sampling Point				
Biochemical Oxygen Demand (5-day)*	3/Week	24-Hour		
January-June and September-December				Composite
Weekly Average-mg/l	30	30		
Monthly Average-mg/l	20	20		
July and August				
Weekly Average-mg/l	25	25		
Monthly Average-mg/l	15	15		
Total Suspended Solids*			3/Week	24-Hour
Weekly Average-mg/l	45	45		Composite
Monthly Average-mg/l	30	30		
pH - Standard Units	6.0-9.0	6.0-9.0	3/Week	Grab

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A. EFFLUENT LIMITS AND MONITORING REQUIREMENTS (continued)

Parameter	Interim Limits	Final Limits	Measurement Frequency	Sample Type
Ammonia-mg/l (as N)			3/Week	24-Hour Composite
January				
Daily Maximum		7.0		
Monthly Average	10.7	2.0		
February				
Daily Maximum		10.0		
Monthly Average	8.7	1.7		
March				
Daily Maximum		10.0		
Monthly Average	7.3	2.0		
April				
Daily Maximum		11.8		
Monthly Average	8.1	1.3		
May				
Daily Maximum		8.4		
Monthly Average	6.1	1.3		
June				
Daily Maximum		7.8		
Monthly Average	4.6	0.9		
July				
Daily Maximum		6.6		
Monthly Average	3.2	0.6		
August				
Daily Maximum		8.8		
Monthly Average	3.2	0.6		
September				
Daily Maximum		8.7		
Monthly Average	4.3	0.9		
October				
Daily Maximum		11.6		
Monthly Average	6.5	1.5		
November				
Daily Maximum		10.0		
Monthly Average	10.4	1.8		
December				
Daily Maximum		7.0		
Monthly Average	13.6	2.3		
E.Coli-Colonies/100ml			3/Week	Grab
Monthly Geometric Average	262	262		
Weekly Geometric Average	4348	4348		
Total Residual Chlorine - µg/l **	21.0	17.0	Daily (when used)	Grab

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A. EFFLUENT LIMITS AND MONITORING REQUIREMENTS (continued)

Parameter	Interim Limits	Final Limits	Measurement Frequency	Sample Type
Dissolved Oxygen-mg/l (Minimum) Weekly Average	6.0	6.0	3/Week	Grab
Temperature, Deg. C	Monitor	Monitor	3/Week	Grab
Total Phosphorus (as P)-mg/l	Monitor	Monitor	Twice Monthly	24-Hour Composite
Total Phosphorus (as P)-lbs/day	Calculate	Calculate	Twice Monthly	Calculate
Nitrate(NO3) + Nitrite(NO2) as N - mg/l*** Monthly Average	Monitor	Monitor	Twice Monthly	24-Hour Composite
Nitrate(NO3) + Nitrite(NO2) as N- mg/l Annual Rolling Average****	Calculate	10	Twice Monthly	Calculate
Total Kjeldahl Nitrogen(TKN) as N-mg/l***	Monitor	Monitor	Twice Monthly	24-Hour Composite
Total Nitrogen as N - mg/l**** (TKN + NO3 + NO2)	Calculate	Calculate	Twice Monthly	Calculate
Total Nitrogen as N - lbs/day (TKN + NO3 + NO2)	Calculate	Calculate	Twice Monthly	Calculate
Whole Effluent Toxicity - See Supplemental Conditions F.1.				
Priority Pollutant Scan - See Supplemental Conditions F.2.				
Flow to Receiving Stream - MGD	Monitor	Monitor	Daily	Meter
BNR/Anti-Deg Based Calculations 001T1 (EDMR code: 001T1) - BNR/Anti-Deg Based Calculations at Effluent				
Total Phosphorus (as P) ****			Monthly	Calculate
Annual Rolling Average - mg/l	Not Required	Calculate		
Annual Rolling Average - lbs/day	Not Required	79.2		
Monitoring Location 007A1 [EDMR Code: KCMO007A1] - Raw Sewage to Blue River (MO) WWTF via KCMO Interceptor Line				
Flow - MGD	Monitor	Not Applicable	Daily (When Used)	Meter

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A. EFFLUENT LIMITS AND MONITORING REQUIREMENTS (continued)

Parameter	Interim & Final Limits	Measurement Frequency	Sample Type
Monitoring Location Receiving Stream Sampling Pt. 005A5 - Indian Creek [EDMR Code: ICUS005A5] - Upstream of Outfall 001A			
Dissolved Oxygen- mg/l	Monitor	Weekly	Grab
Temperature- Deg. C	Monitor	Weekly	Grab
Ammonia (as N)-mg/l	Monitor	Weekly	Grab
pH - Standard Units	Monitor	Weekly	Grab
Monitoring Location Receiving Stream Sampling Pt. 006A6 - Indian Creek [EDMR Code: ICDS006A6] - Downstream of Outfall 001A near State Line			
Dissolved Oxygen-mg/l	Monitor	Weekly	Grab
Temperature-Deg.C	Monitor	Weekly	Grab
Ammonia (as N)-mg/l	Monitor	Weekly	Grab
Nitrate(NO3) + Nitrite(NO2) as N - mg/l	Monitor	Weekly	Grab
pH - Standard Units	Monitor	Weekly	Grab
Stream Flow - cfs	See Supplemental Condition 5	USGS Station	Reading

Footnotes

* Minimum removal of 85% required for Biochemical Oxygen Demand (5-Day) and Total Suspended Solids based on monthly average influent and effluent concentrations. If the Inhibited BOD test procedure is used to measure Biochemical Oxygen Demand, effluent limits are 5 mg/l less than listed.

** This test is required only if disinfection is by chlorination. Permittee shall conduct testing for total residual chlorine according to the methods prescribed in 40 CFR Part 136. The current acceptable quantification level for total chlorine in wastewater is 100 µg/l. Test results in excess of the quantification level are violations of the permit limits.

*** Permittee shall sample these monitoring locations on the same day and calculate the total nitrogen only when both TKN and NO3+NO2 test values are available. The Minimum Reportable Limit (MRL) for TKN is 1 mg/l and for NO3+NO2 is 0.1 mg/l. Values less than the MRL shall be reported using the less than sign (<) with the MRL value but for purposes of calculating and reporting the total nitrogen result, less than values shall be defaulted to zero and the result reported without the less than sign.

**** The values for parameters shown as "Calculate" will be calculated by the eDMR program. The values cannot be entered into the eDMR program by the permittee. Reporting of these values is not required until KDHE provides the eDMR program to do the calculations. In addition to these calculated values, the permittee will see monthly average values (shown as the parameter short name followed by the letters MA) calculated and displayed in the raw data tables. The monthly average parameter short names and (parameter codes) will be T-P MA (KS665) in mg/l and lbs/day and NO3NO2 MA (KS630) in mg/l.

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Footnotes - CONTINUED

The monthly averages are required intermediary calculated values used for purposes of calculating the annual rolling averages and are shown for purposes of checking those calculations.

The total phosphorus annual average load limit of 79.2 lbs/day and nitrate plus nitrite annual average limit of 10 mg/l shall be effective 12 months after completion of Section D. Schedule of Compliance. Also, see Section E. Supplemental Conditions (Nutrient Removal).

B. STANDARD CONDITIONS

In addition to the specified conditions stated herein, the permittee shall comply with the attached Standard Conditions dated August 1, 2010.

C. PRETREATMENT PROGRAM

The permittee shall implement and administer the Pretreatment Program in accordance with the General Pretreatment Regulations 40 CFR Part 403, their approved pretreatment program, and all program modifications approved by the Kansas Department of Health and Environment and the Environmental Protection Agency.

D. SCHEDULE OF COMPLIANCE

Within 1 year following the substantial completion of the project addressed in the Consent Order 15-E-39 BOW, the permittee shall achieve compliance with the final permit limits.

E. SUPPLEMENTAL CONDITIONS

1. Nutrient Removal: The permittee is pursuing a construction project to upgrade the biological process to improve nitrification and provide denitrification and to provide for phosphorus removal. The upgraded facility shall be operated to optimize the level of nutrient removal with the intent of achieving the following goals as annual average goals:

	Goal
Total Nitrogen (as N) - mg/l	10.0
Total Phosphorus (as P) - mg/l	0.5

These goals are not to be considered as limits for this permit. KDHE reserves the right to re-open this permit to impose limits for nutrients pursuant to Kansas law after such criteria or a TMDL limiting nutrients is adopted in the Kansas Surface Water Quality Standards.

2. The sludge produced at this facility is subject to the 40 CFR Part 503 Sludge Regulations.

3. The effluent limits and monitoring requirements for outfall 001A1 listed in this permit are subject to change if water quality criteria violations in Indian Creek can be attributed to the treatment plant effluent.

4. For the Interim Limits applicable to the Existing Facility, wastewater flow rates which would cause permit limits to be exceeded are to be routed to the Blue River (KCMO) treatment facility via Monitoring Location 007A1.

5. For the Interim Limits applicable to the Existing Facility, the Permittee shall provide daily stream flow readings from the USGS station on Indian Creek at State Line Road when the Peak Flow Holding Basin is discharging and weekly at all other times.

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E. SUPPLEMENTAL CONDITIONS - continued

6. For the Final Limits applicable to the Expanded Facility after the new construction is placed into service, a portion of the peak wet-weather influent flow shall be spilt directly to filtration and disinfection once flow has been maximized through the activated sludge treatment units at a level which does not cause a washout of activated sludge biomass or other process upsets (see Expanded Facility Description design flow thresholds). The use of the axillary wet weather flow treatment configuration is not an in-plant diversion and not subject to Standard Conditions 7, 8, and 9.

7. The Permittee shall renew the permit in accordance with Standard Condition 26, unless a later date (not to exceed the expiration date of the permit) has been approved by the Department pursuant to 40 CFR 122.21(d)(1).

F. BIOMONITORING AND PRIORITY POLLUTANTS

1. Whole Effluent Toxicity:

a. Chronic Whole Effluent Toxicity (WET) testing on a 24-hr composite sample of the effluent shall be conducted once in calendar year 2015 and annually thereafter. The 25% Inhibition Concentration, IC25, shall be equal to or greater than 50% effluent as an Interim Limit and 62% as a Final Limit. The test procedures shall use the seven day static renewal test method in accordance with the EPA document, Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, fourth edition, October 2002 using test organisms *Pimephales promelas* (fathead minnow) and *Ceriodaphnia dubia* (water flea) within a dilution series containing 0%, 25%, 50%, 75%, and 100% effluent. KDHE reserves the right to increase or decrease testing frequency based upon compliance history and toxicity testing results.

b. If the WET test results indicate the IC25 is equal to or greater than 50% effluent as an Interim Limit and 62% as a Final Limit, the effluent has passed the toxicity test and a copy of the test report shall be due with the next scheduled Discharge Monitoring Report.

c. If the WET test results indicate the IC25 is less than 50% effluent as an Interim Limit and 62% as a Final Limit, the effluent has failed the toxicity test and the permittee shall immediately notify KDHE by telephone at (785) 296-5517 and submit to KDHE a copy of the test report within five days of receipt of the information. KDHE reserves the right to require the permittee to take such actions as are reasonable to identify and remedy any identified or predicted toxic conditions in the receiving stream outside of the mixing zone which is caused by the permittee's effluent.

d. Permittee shall also test a portion of one of same effluent samples used for the WET test for the following parameters (required minimum reportable detection levels are in parenthesis):

Antimony (10 µg/L)*
Arsenic (10 µg/L)*
Beryllium (5 µg/L)*
Cadmium (2 µg/L)*
Chromium (10 µg/L)*
Copper (10 µg/L)*
Lead (5 µg/L)*
Mercury (0.2 µg/L-Cold Vapor Method))
Nickel (10 µg/L)*
Selenium (5 µg/L)*
Silver (2 µg/L)*
Thallium (10 µg/L)*
Zinc (20 µg/L)*
Ammonia as "N" (0.2mg/l)
Total Hardness as CaCO3 mg/l
pH

* Parameter shall be tested and reported as "total recoverable" metals.

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e. The permittee shall coordinate sampling for this test with other requirements of this permit. The permittee shall use a laboratory approved by KDHE for Whole Effluent Toxicity testing.

2. Permittee shall conduct a Priority Pollutant Scan on the effluent at 001A1 during typical plant operations for the parameters listed in Table I, Priority Pollutant Scan, on the following pages. The Priority Pollutant Scan shall be conducted within 18 months of the expiration date of this permit and the results reported to KDHE prior to 6 months of the expiration date of this permit.

   Sample type shall be 24-hour composite except for Volatiles which shall be a grab sample. See Supplemental Condition F.1.d. for minimum detection limits for certain metals in the Priority Pollutant Scan.

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Table I - Priority Pollutant Scan*

Metals (µg/l)
- Total Antimony
- Total Beryllium
- Total Cadmium
- Total Chromium
- Total Copper
- Total Lead
- Total Mercury
- Total Nickel
- Total Selenium
- Total Silver
- Total Thallium
- Total Zinc

Pesticides (µg/l)
- Aldrin
- Alpha-BHC**
- Beta-BHC**
- Gamma-BHC**
- Delta-BHC**
- Chlordane
- 4,4-DDT
- 4,4-DDD
- 4,4-DDE
- Dieldrin
- Alpha-endosulfan
- Beta-endosulfan
- Endosulfan sulfate
- Endrin
- Endrin aldehyde
- Heptachlor
- Heptachlor epoxide
- Toxaphene

Polychlorinated Biphenyls (µg/l)
- PCB-1242
- PCB-1254
- PCB-1221
- PCB-1232
- PCB-1248
- PCB-1260
- PCB-1016

Base/Neutral (µg/l)
- Acenaphthene
- Acenaphthylene
- Anthracene
- Benzidine
- Benzo(a) anthracene
- Benzo(a)pyrene
- Benzo (k) fluoranthene
- Benzo (ghi) perylene
- Benzo (b) fluoranthene
- Bis(2-chloroethoxy)methane
- Bis(2-chloroethyl)ether
- Bis(2-ethylhexyl)phthalate
- Bis(2-chloroisopropyl) ether
- 1,2-diphenylhydrazine
- Fluoranthene
- Fluorene
- Nitrobenzene
- N-nitrosodimethylamine
- N-nitrosodi-n-propylamine
- N-nitrosodiphenylamine
- Phenanthrene
- Pyrene
- 1,2,4-trichlorobenzene
- 4-bromophenyl phenyl ether
- Butyl benzyl phthalate
- 2-chloronaphthalene
- 4-chlorophenyl phenyl ether
- Chrysene
- Dibenzo(a,h) anthracene
- 1,2-dichlorobenzene
- 1,3-dichlorobenzene
- 1,4-dichlorobenzene
- 3,3-dichlorobenzidine
- Dimethyl phthalate
- Diethyl phthalate
- Di-n-butyl phthalate
- 2,4-dinitrotoluene
- 2,6-dinitrotoluene
- Di-n-octyl phthalate
- Hexachlorobenzene
- Hexachlorobutadiene
- Hexachlorocyclopentadiene
- Hexachloroethane
- Indeno (1,2,3-cd) pyrene
- Naphthalene
- Isophorone

Acid Compounds (µg/l)
- 2-chlorophenol
- 2,4-dichlorophenol
- 2,4-dimethylphenol
- 2,4-dinitrophenol
- 2-nitrophenol
- 4-nitrophenol
- Parachlorometa cresol
- Pentachlorophenol
- Phenol
- 4,6-dinitro-o-cresol
- 2,4,6-trichlorophenol

Volatiles (µg/l)
- Acrolein
- Acrylonitrile
- Benzene
- Bromoform
- Carbon Tetrachloride
- Chlorobenzene
- Chlorodibromomethane
- Chloroethane
- 2-chloroethylvinyl ether
- Chloroform
- Dichlorobromomethane
- 1,1-dichloroethane
- 1,2-dichloroethane
- 1,1-dichloroethylene
- 1,2-dichloropropane
- 1,3-dichloropropylene
- Ethylbenzene
- Methyl bromide
- Methyl chloride
- Methylene chloride
- 1,1,2,2-tetrachloroethane
- Tetrachloroethylene
- Toluene
- 1,2 trans-dichloroethylene
- 1,1,1-trichloroethane
- 1,1,2-trichloroethane
- Trichloroethylene
- Vinyl chloride

Miscellaneous
- Total Cyanide (mg/l)***
- ~~Asbestos (cnt/l)~~
- ~~2,3,7,8-TCDD (Dioxin) (µg/l)~~

* Testing not required for pollutants with a strike-through.

** Scientific name is hexachlorocyclohexane

*** The total cyanide analysis must include preliminary treatment of the sample to avoid NO_2^- interference. See Standard Methods for the Examination of Water and Wastewater, 22nd Edition, 4500-CN^- B. Preliminary Treatment of Samples.

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STANDARD CONDITIONS FOR
KANSAS WATER POLLUTION CONTROL AND
NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMITS

1. Representative Sampling and Discharge Monitoring Report Submittals:

A. Samples and measurements taken as required herein shall be representative of the quality and quantity of the monitored discharge. Test results shall be recorded for the day the samples were taken. If sampling for a parameter was conducted across more than one calendar day, the test results may be recorded for the day sampling was started or ended. All samples shall be taken at the locations designated in this permit, and unless specified, at the outfall/monitoring location(s) before the wastewater joins or is diluted by any other water or substance.

B. Monitoring results shall be recorded and reported on forms acceptable to the Division and postmarked no later than the 28th day of the month following the completed reporting period. Signed and certified copies of these, prepared in accordance with KAR 28-16-59, and all other reports required herein, may be FAXed to 785.296.0086, e-mailed as scanned attachments to dmr4kdhe@kdheks.gov , or sent by U.S. mail to:

Kansas Department of Health & Environment
Bureau of Water-Technical Services Section
1000 SW Jackson Street, Suite 420
Topeka, KS 66612-1367

2. Definitions:

A. Unless otherwise specifically defined in this permit, the following definitions apply:

1. The "Daily Maximum" is the total discharge by weight or average concentration, measurement taken, or value calculated during a 24-hour period. The parameter, pH, is limited as a range between and including the values shown.

2. The "Weekly Average" is the arithmetic mean of the value of test results from samples collected, measurements taken or values calculated during four monitoring periods in each month consisting of calendar days 1-7, 8-14, 15-21 and 22 through the end of the month.

3. The "Monthly Average", other than for E. coli bacteria, is the arithmetic mean of the value of test results from samples collected, measurements taken or values calculated during a calendar month. The monthly average is determined by the summation of all calculated values or measured test results divided by the number of calculated values or test results reported for that parameter during the calendar month. The monthly average for E. coli bacteria is the geometric average of the value of the test results from samples collected in a calendar month. The geometric average can be calculated by using a scientific calculator to multiply all the E. coli test results together and then taking the nth root of the product where n is the number of test results. Non-detect values shall be reported using the less than symbol (<) and the minimum detection or reportable value. To calculate average values, non-detects shall be defaulted to zero (or one for geometric averages). Greater than values shall be reported using the greater than symbol (>) and the reported value. To calculate average values, the greater than reported value shall be used in the averaging calculation.

B. A "grab sample" is an individual sample collected in less than 15 minutes. A "composite sample" is a combination of individual samples in which the volume of each individual sample is proportional to the flow, or the sample frequency is proportioned to the flow rate over the sample period, or the sample frequency is proportional to time.

C. The terms "Director", "Division", and "Department" refer to the Director, Division of Environment, Kansas Department of Health and Environment, respectively.

D. "Severe property damage" means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of an in-plant diversion. Severe property damage does not mean economic loss caused by delays in production.

E. "Bypass" means the intentional diversion of waste streams from any portion of the treatment facility.

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3. Schedule of Compliance: No later than 14 calendar days following each date identified in the "Schedule of Compliance," the permittee shall submit via mail, e-mail or fax per paragraph 1.B above, either a report of progress or, in the case of specific action being required by identified dates, a written notice of compliance or noncompliance. In the latter case, the notice shall include the cause of noncompliance, any remedial actions taken, and the probability of meeting the next scheduled requirements, or, if there are no more scheduled requirements, when such noncompliance will be corrected.

4. Test Procedures: All analyses required by this permit shall conform to the requirements of 40 CFR Part 136, unless otherwise specified, and shall be conducted in a laboratory accredited by the Department. For each measurement or sample, the permittee shall record the exact place, date, and time of measuring/sampling; the date and time of the analyses, the analytical techniques or methods used, minimum detection or reportable level, and the individual(s) who performed the measuring/sampling and analysis and, the results. If the permittee monitors any pollutant at the location(s) designated herein more frequently than required by this permit, using approved procedures, the results shall be included in the Discharge Monitoring Report form required in 1.B. above. Such increased frequencies shall also be indicated.

5. Change in Discharge: All discharges authorized herein shall be consistent with the permit requirements. The discharge of any pollutant not authorized by this permit or of any pollutant identified in this permit more frequently than or at a level in excess of that authorized shall constitute a violation of this permit. Any anticipated facility expansions, production or flow increases, or production or wastewater treatment system modifications which result in a new, different, or increased discharge of pollutants shall be reported to the Division at least one hundred eighty (180) days before such change.

6. Facilities Operation: The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with the requirements of this permit and Kansas and Federal law. Proper operation and maintenance also include adequate laboratory controls and appropriate quality assurance procedures. This provision requires the operation of back-up or auxiliary facilities or similar systems which are installed by a permittee only when the operation is necessary to achieve compliance with the requirements of this permit. The permittee shall take all necessary steps to minimize or prevent any adverse impact to human health or the environment resulting from noncompliance with any effluent limits specified in this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the noncomplying discharge. When necessary to maintain compliance with the permit requirements, the permittee shall halt or reduce those activities under its control which generate wastewater routed to this facility.

7. Incidents:

"Collection System Diversion" means the diversion of wastewater from any portion of the collection system.

"In-Plant Diversion" means routing the wastewater around any treatment unit in the treatment facility through which it would normally flow.

"In-Plant Flow Through" means an incident in which the wastewater continues to be routed through the equipment even though full treatment is not being accomplished because of equipment failure for any reason.

"Spill" means any discharge of wastewater, sludge or other materials from the treatment facility other than effluent or as more specifically described by other "Incidents" terms.

"Upset" means an exceptional incident in which there is unintentional and temporary noncompliance or anticipated noncompliance with permit effluent limits because of factors beyond the reasonable control of the permittee, as described by 40 C.F.R. 122.41(n).

8. Diversions not Exceeding Limits: The permittee may allow any diversion to occur which does not cause effluent limits to be exceeded, but only if it also is for essential maintenance to assure efficient operation. Such diversions are not subject to the Incident Reporting requirements shown below.

9. Prohibition of an In-Plant Diversion: Any in-plant diversion from facilities necessary to maintain compliance with this permit is prohibited, except: (a) where the in-plant diversion was unavoidable to prevent loss of life, personal injury, or severe property damage; (b) where there were no feasible alternatives to the in-plant diversion, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime and (c) the permittee submitted a notice as required in the Incident Reporting paragraph below. The Director may approve an anticipated in-plant diversion, after considering its adverse effects, if the Director determines that it will meet the three conditions listed above.

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10. Incident Reporting: The permittee shall report any unanticipated collection system diversion, in-plant diversion, in-plant flow through occurrences, spill, upset or any violation of a permitted daily maximum limit within 24 hours from the time the permittee became aware of the incident. A written submission shall be provided within 5 days of the time the permittee became aware of the incident. The written submission shall contain a description of the noncompliance and its cause, the period of noncompliance, including exact dates and times; and if the noncompliance has not been corrected, the anticipated time it is expected to continue; and steps taken or planned to reduce, eliminate, and prevent recurrence of the noncompliance. An Incident Report form is available at www.kdheks.gov/water/tech.html.

For an anticipated incident or any planned changes or activities in the permitted facility that may result in noncompliance with the permit requirements, the permittee shall submit written notice, if possible, at least ten days before the date of the event.

For other noncompliance, the above information shall be provided with the next Discharge Monitoring Report.

11. Removed Substances: Solids, sludges, filter backwash, or other pollutants removed in the course of treatment of water shall be utilized or disposed of in a manner acceptable to the Division.

12. Power Failures: The permittee shall provide an alternative power source sufficient to operate the wastewater control facilities or otherwise control pollution and all discharges upon the loss of the primary source of power to the wastewater control facilities.

13. Right of Entry: The permittee shall allow authorized representatives of the Division of Environment or the Environmental Protection Agency upon the presentation of credentials, to enter upon the permittee's premises where an effluent source is located, or in which are located any records required by this permit, and at reasonable times, to have access to and copy any records required by this permit, to inspect any facilities, monitoring equipment or monitoring method required in this permit, and to sample any influents to, discharges from or materials in the wastewater facilities.

14. Transfer of Ownership: The permittee shall notify the succeeding owner or controlling person of the existence of this permit by certified letter, a copy of which shall be forwarded to the Division. The succeeding owner shall secure a new permit. This permit is not transferable to any person except after notice and approval by the Director. The Director may require modification or revocation and reissuance of the permit to change the name of the permittee and incorporate such other requirements as may be necessary.

15. Records Retention: Unless otherwise specified, all records and information resulting from the monitoring activities required by this permit, including all records of analyses and calibration and maintenance of instruments and recordings from continuous monitoring instruments, shall be retained for a minimum of 3 years, or longer if requested by the Division. Biosolids/sludge records and information are required to be kept for a minimum of 5 years or longer if requested by the Division. Groundwater monitoring data, including background samples results, shall be kept for the life of the facility regardless of ownership.

16. Availability of Records: Except for data determined to be confidential under 33 USC Section 1318, all reports prepared in accordance with the terms of this permit shall be available for public inspection at the offices of the Department. Effluent data shall not be considered confidential. Knowingly making any false statement on any such report or tampering with equipment to falsify data may result in the imposition of criminal penalties as provided for in 33 USC Section 1319 and KSA 65-170c.

17. Permit Modifications and Terminations: As provided by KAR 28-16-62, after notice and opportunity for a hearing, this permit may be modified, suspended or revoked or terminated in whole or in part during its term for cause as provided, but not limited to those set forth in KAR 28-16-62 and KAR 28-16-28b through g. The permittee shall furnish to the Director, within a reasonable amount of time, any information which the Director may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit or to determine compliance with this permit. The permittee shall also furnish upon request, copies of all records required to be kept by this permit. The filing of a request by the permittee for a permit modification, revocation and reissuance, or termination, or a notification of planned changes or anticipated noncompliance does not stay any permit condition.

18. Toxic Pollutants: Notwithstanding paragraph 17 above, if a toxic effluent standard or prohibition (including any schedule of compliance specified at such effluent standards) is established under 33 USC Section 1317(a) for a toxic pollutant which is present in the discharge and such standard or prohibition is more stringent than any limitation for such pollutant in this permit, this permit shall be revised or modified in accordance with the toxic effluent standard or prohibition. Nothing in this permit relieves the permittee from complying with federal toxic effluent standards as promulgated pursuant to 33 USC Section 1317.

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19. Administrative, Civil and Criminal Liability: The permittee shall comply with all requirements of this permit. Except as authorized in paragraph 9 above, nothing in this permit shall be construed to relieve the permittee from administrative, civil or criminal penalties for noncompliance as provided for in KSA 65-161 et seq., and 33 USC Section 1319.

20. Oil and Hazardous Substance Liability: Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities or penalties to which the permittee is or may be subject to under 33 USC Section 1321 or KSA 65-164 et seq. A municipal permittee shall promptly notify the Division by telephone upon discovering crude oil or any petroleum derivative in its sewer system or wastewater treatment facilities.

21. Industrial Users: A municipal permittee shall require any industrial user of the treatment works to comply with 33 USC Section 1317, 1318 and any industrial user of storm sewers to comply with 33 USC Section 1308.

22. Property Rights: The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights nor any infringements of or violation of federal, state or local laws or regulations.

23. Operator Certification: The permittee shall, if required, ensure the wastewater facilities are under the supervision of an operator certified by the Department. If the permittee does not have a certified operator or loses its certified operator, appropriate steps shall be taken to obtain a certified operator as required by KAR 28-16-30 et seq.

24. Severability: The provisions of this permit are severable. If any provision of this permit or any circumstance is held invalid, the application of such provision to other circumstances and the remainder of the permit shall not be affected thereby.

25. Removal from Service: The permittee shall inform the Division at least three months before a pumping station, treatment unit, or any other part of the treatment facility permitted by this permit is to be removed from service and shall make arrangements acceptable to the Division to decommission the facility or part of the facility being removed from service such that the public health and waters of the state are protected.

26. Duty to Reapply: A permit holder wishing to continue any activity regulated by this permit after the expiration date, must apply for a new permit at least 180 days prior to expiration of the permit.

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State of Kansas
Department of Health and Environment

Public Notice Concerning Kansas / Federal
Water Pollution Control Permits and Applications

State of Kansas
Department of Health and Environment
Division of Environment-Bureau of Water
1000 SW Jackson St., Suite 420
Topeka, Kansas 66612-1367
Telephone: (785) 296-6432 - Ag Permits
(785) 296-5517 - All Others

Public Notice No. KS-AG-16-024/028
KS-AG-R-16-006
KS-Q-16-015

Beginning Date: February 11, 2016
Comments Due: March 12, 2016

In accordance with Kansas Administrative Regulations 28-16-57 through 63, 28-18-1 through 17, 28-18a-1 through 33, 28-16-150 through 154, 28-46-7, and the authority vested with the State by the administrator of the U.S. Environmental Protection Agency, various draft water pollution control documents (permits, notices to revoke and reissue, notices to terminate) have been prepared and/or permit applications have been received for discharges to waters of the United States and the state of Kansas for the class of discharges described below.

The proposed actions concerning the draft documents are based on staff review, applying the appropriate standards, regulations and effluent limitations of the state of Kansas and the Environmental Protection Agency. The final action will result in a Federal National Pollutant Discharge Elimination System Authorization and/or a Kansas Water Pollution Control permit being issued, subject to certain conditions, revocation and reissuance of the designated permit or termination of the designated permit.

****

Public Notice No. KS-AG-16-024/028
Pending Permits for Confined Feeding Facilities

Name And Address of Applicant	Legal Description	Receiving Water
Terry Farwell Farwell Farms #2 2980 State Highway 63 Seneca, KS 66538	NW/4 of Section 11 T01S, R12E Nemaha County	Missouri River Basin

Kansas Permit No.: A-MONM-S047

This is a renewal permit for an existing facility for a maximum capacity of 990 head (396 animal units) of swine more than 55 pounds. There is no change in the permitted animal units.

Allan R. Williams 2415 29th Terrace Vermillion, KS 66544	NW/4 of Section 35 T04S, R10E Marshall County	Big Blue River Basin

Kansas Permit No.: A-BBMS-S041

This is a renewal permit for an existing facility with a maximum capacity of 100 head (40 animal units) of swine more than 55 pounds and 400 head (40 animal units) of swine 55 pounds or less. There is no change in the permitted animal units.

Ben Leibbrandt Leibbrandt Farms 2030 Road 11 St. Francis, KS 67756	SW/4 of Section 30 T02S, R40W Cheyenne County	Upper Republican River Basin

Kansas Permit No.: A-URCN-S011

This is a renewal permit for an existing facility with a maximum capacity of 125 head (12 animal units) of swine weighing less than 55 pounds, and 400 head (160 animal units) of swine weighing more than 55 pounds. There is no change in the permitted animal units.

Osborne Industries, Inc. Osborne Industries Demonstration Farm 1372 C 671 Drive Osborne, KS 67473	SW/4 of Section 14 T08S, R13W Osborne County	Solomon River Basin

Kansas Permit No.: A-SOOB-S011

This is a renewal permit for an existing facility with a maximum capacity of 2,078 head (831.2 animal units) of swine more than 55 pounds, and 1,250 head (125 animal units) of swine 55 pounds or less, for a total of 3,328 head (956.2 animal units) of swine. There is no change in the permitted animal units.

Kendall Martens KM Feeders 2240 Avenue P Lyons, KS 67554	NW/4 of Section 22 T20S, R07W Rice County	Lower Arkansas River Basin

Kansas Permit No.: A-ARRC-C001 Federal Permit No.: KS0080730

This is a re-issuance permit for an existing facility for 6,000 head (6,000 animal units) of cattle weighing greater than 700 pounds. This facility has an approved Nutrient Management Plan on file with KDHE.

Public Notice No. KS-AG-R-16-006
Per Kansas Statutes Annotated 65-171d, the following Registration(s) have been received for proposed confined feeding facilities:

Name And Address of Registrant	Legal Description	County
Daniel J. Unruh 147 A Road Burns, KS 66840	SW/4 of Section 36 T22S, R05E	Chase

****

Public Notice No. KS-Q-16-015
The requirements of the draft permit public noticed below are pursuant to the Kansas Surface Water Quality Standards, K.A.R. 28-16-28 (b-g), and Federal Surface Water Criteria.

NAME AND ADDRESS OF APPLICANT	RECEIVING STREAM	TYPE OF DISCHARGE
Johnson County Wastewater 11811 S. Sunset Drive, Suite 2500 Olathe, KS 66061	Blue River (MO) via Indian Creek	Treated Domestic Wastewater

Kansas Permit No. M-MO27-OO03 Federal Permit No. KS0100846
Legal Description: SW¼, S10, T13S, R25E, Johnson County, KS

Facility Name: Tomahawk Creek Wastewater Treatment Facility

The proposed action is to issue a new Kansas/NPDES Water Pollution Control permit for an existing facility. This facility is being upgraded and expanded to alleviate effluent flow to Kansas City, Missouri and to meet water quality criteria requirements per an anti-degradation study. The existing facility is a mechanical treatment plant consisting of a mechanical bar screen, grit removal, primary sedimentation, trickling filters, secondary sedimentation, chlorine disinfection, and dechlorination. Higher rates of raw sewage flow are diverted to the Kansas City, Missouri Blue River Wastewater Treatment Facility by way of an interceptor sewer line. Any peak flow above the combined capacity of the existing wastewater treatment facility and the KCMO interceptor is treated with peak flow screening, peak flow pump station, chlorine disinfection, and a peak flow storage/treatment lagoon. Sludge produced by this facility is conveyed with the diverted raw sewage flow to KCMO. The proposed permit contains limits for biochemical oxygen demand, total suspended solids, ammonia, E. coli, total residual chlorine, dissolved oxygen, total phosphorus, nitrate + nitrite, whole effluent toxicity, and pH, as well as monitoring for temperature, total Kjeldahl nitrogen, total nitrogen, priority pollutants, and flow. Contained in the permit is a schedule of compliance requiring the permittee to achieve compliance with final permit limits with one year of the completion of the upgraded project.

****

Persons wishing to comment on or object to the draft documents and/or permit applications must submit their comments in writing to the Kansas Department of Health and Environment if they wish to have the comments or objections considered in the decision making process. Comments or objections should be submitted to the attention of Livestock Waste Management Section for agricultural related draft documents or applications, or to the permit clerk for all other permits, at the Kansas Department of Health and Environment, Division of Environment, Bureau of Water, 1000 SW Jackson St., Suite 420, Topeka, Kansas 66612-1367.

All comments regarding the draft documents or application notices received on or before ***March 12, 2016***, will be considered in the formulation of final determinations regarding this public notice. Please refer to the appropriate Kansas document number (KS-AG-16-024/028, KS-AG-R-16-006, KS-Q-16-015) and name of the applicant/permittee when preparing comments.

After review of any comments received during the public notice period, the Secretary of Health and Environment will issue a determination regarding final agency action on each draft document/ application. If response to any draft document / application indicates significant public interest, a public hearing may be held in conformance with K.A.R. 28-16-61 (28-46-21 for UIC).

All draft documents / application and the supporting information including any comments received are on file and may be inspected at the offices of the Kansas Department of Health and Environment, Bureau of Water, 1000 SW Jackson St., Suite 420, Topeka, Kansas. These documents are available upon request at the copying cost assessed by KDHE. Application information and components of plans and specifications for all new and expanding swine facilities are available on the Internet at http://www.kdheks.gov/feedlots. Division of Environment offices are open from 8 a.m. to 5 p.m., Monday through Friday, excluding holidays.

APPENDIX C

CONSENT ORDER

STATE OF KANSAS
DEPARTMENT OF HEALTH AND ENVIRONMENT

In the Matter of: JOHNSON COUNTY WASTEWATER - TOMAHAWK CREEK M.S.D. NO. 1 11811 S. SUNSET DR. SUITE 2500 OLATHE, KANSAS 66061 KANSAS WATER POLLUTION CONTROL PERMIT NO. M-M027-OO01	)))))))))))	Case No. 15-E-39 BOW

CONSENT ORDER

Now on this _____ day of _____, 2016, the Kansas Department of Health and Environment ("KDHE") and Johnson County Wastewater ("Respondent") (collectively, the "Parties"), having agreed that settlement of this matter is in the best interests of the Parties and conducive to protection of public health and the environment, hereby represent and state as follows:

The Parties acknowledge that this Consent Order ("CO"), upon execution by the Secretary of KDHE ("Secretary"), shall be a final agency order. Respondent shall not contest the authority of the Secretary to issue this CO or any action by KDHE to enforce this CO. Respondent voluntarily and knowingly waives the right to an appeal or review of this CO and matters leading up to the execution of this CO under the Kansas Administrative Procedure Act ("KAPA"), K.S.A. 77-501, *et seq.* or the Kansas Judicial Review Act. K.S.A. 77-601, *et seq.* KAPA authorizes KDHE to enter into an informal settlement of this matter without the necessity of proceeding to a formal hearing, K.S.A. 77-505.

The Secretary and Respondent deem that the Findings of Fact and Conclusions of Law in this CO are true and correct as related to the Johnson County Wastewater – Tomahawk Creek M.S.D. No. 1 Wastewater Treatment Facility.

As used in this CO, "Facility" shall mean the Johnson County Wastewater – Tomahawk Creek M.S.D. No. 1 Wastewater Treatment Facility and all associated real property, buildings, structures, fixtures, and appurtenances located in the Southwest Quarter of Section 10, Township 13 South, Range 25 East, Johnson County, Kansas.

Findings of Fact

1. The KDHE issued Kansas Water Pollution Control Permit Number M-M027-OO01 for the Facility ("Permit") to the Respondent, with an effective date of October 1, 2008 and an expiration date of December 31, 2009. The Permit has been administratively extended and remains in effect until superseded by an approved permit. Section B of the Permit, states that the Respondent shall comply with the Standard Conditions dated August 1, 1996 ("Standard Conditions").

2. The Facility is adjacent to Indian Creek ("Stream") and the Permit authorizes discharges to the Stream subject to effluent limitations.

3. The Permit identifies an aerated lagoon located at the facility as outfall 002A ("002A"). 002A was used as a peak flow basin when the wet weather flow rate exceeded the capacities of the mechanical plant and the service connection with the Kansas City, Missouri separate sanitary system ("Interceptor Line"). Discharges from 002A were subject to effluent limitations on biochemical oxygen demand, total suspended solids, and Escherichia coli ("E. coli") parameters.

4. On April 20, 2009, a Water Pollution Control Permit Application was received from the Respondent to renew the Facility's Permit.

5. In October 2009, a draft permit ("2009 Draft Permit") was sent to the United States Environmental Protection Agency Region 7 office ("EPA"). As part of the 2009 Draft Permit, effluent limitations on discharges from the 002A aerated lagoon were removed. The 2009 Draft Permit now identifies the 002A aerated lagoon as 002A1 ("002A1").

6. On November 2, 2009, KDHE received a letter from the EPA objecting to the 2009 Draft Permit ("EPA Objection"). In regard to 002A1, the EPA objected to the removal of effluent limits from discharges from 002A1 and wished to require secondary treatment of 002A1 discharges in compliance with 40 C.F.R. §133. The EPA Objection continued further and stated that discharges from 002A1 should be prohibited unless the requirements of 40 C.F.R.§122.41(m) have been satisfied. Additionally, the EPA Objection requested that the 2009 Draft Permit be revised to prohibit wet weather transfers of sewage to the Interceptor Line.

7. A review of historical Discharge Monitoring Reports, submitted to KDHE by the Respondent, indicates that 002A1 has had no reported discharges since June 14, 2010.

8. On December 20, 2006, the EPA approved the 2006 Kansas Section 303d list ("2006 303d list"). The Stream is listed on the 2006 303d list and designated as being impaired for Nitrate.

9. The 1998 Consent Decree No. 95-2490-JWL set a schedule for the State of Kansas to develop Total Maximum Daily Loads ("TMDLs") in each of the twelve river basins in the State of Kansas.

10. On February 28, 2008, the EPA approved the Nitrate TMDL developed by KDHE for the Stream. The Nitrate TMDL states that the Stream is dominated by wastewater discharges. The Nitrate TMDL is assigned a high priority classification.

11. On December 13, 2013, the Respondent notified KDHE that a study had been conducted to evaluate options for replacement of the Facility.

12. On November 2, 2015, KDHE received a document titled "Tomahawk Creek WWTF Project Definition Phase Antidegradation Review" dated October 15, 2015 from the Respondent ("Antidegradation Review").

13. Section 7.1 of the Antidegradation Review states in pertinent part:

> Alternative 0.2 (Complete conveyance to the KCMO system and Tomahawk WWTF and KCMO storage) is not a viable option based on environmental, social, and cost considerations....
>
> ...In the far-field (i.e.,Missouri River) Alternative 0.2 will result in the highest pollutant loadings of any alternative.

14. Section 9 of the Antidegradation Review states in pertinent part:

> Proposed treatment Alternative 19.1-ENR1 (19MGD ENR1 with auxiliary treatment of wet weather flows) meets all state and federal antidegradation regulations...
>
> ...Alternative 19.1-ENR1 not only meets, but exceeds the intent of antidegradation and any additional treatment is unjustified through antidegradation...
>
> ...Any alternative that involves diverting flow to the KCMO system is more degrading to water quality and is not cost effective...

15. Section 5.1 of the Antidegradation Review states in pertinent part:

> <u>19.1-ENR1:</u> Alternative 19.1-ENR1 represents a 19 MGD ENR facility (enhanced phosphorus removal) that would treat all flows at the Tomahawk WWTF with wet weather flows greater than 57 MGD treated through an auxiliary treatment system. Auxiliary treatment flows are combined with flows from ENR prior to discharge.

16. Section E of the Permit states in pertinent part:

    (A) The effluent limits and monitoring requirements for outfalls 001A and 002A listed in this permit are subject to change if water quality criteria violations in Indian Creek can be attributed to the treatment plant effluent.

Conclusions of Law

17. The KDHE is a duly authorized agency of the State of Kansas created by an act of the legislature. The Secretary has general jurisdiction over matters involving the environment and the public health of the people of Kansas, K.S.A. 65-101 *et seq.*, including general jurisdiction of matters involving the discharge of sewage, K.S.A. 65-161 *et seq.*

18. Pursuant to K.S.A. 65-164 *et seq.*, any person discharging wastewater or planning to discharge wastewater to waters of the State is required to obtain a KDHE-issued permit for such discharges. The permit provides information about the permitted facility, operating and record keeping requirements and other conditions required pursuant to Kansas Statutes and Regulations. Requirements of the permit are enforceable under the authority of the Secretary of the KDHE (K.S.A. 65-101 and 65-164 *et seq.*) and the KDHE Director of the Division of Environment (K.S.A. 65-170 *et seq.*).

19. K.S.A. 65-161 states in pertinent part:

    (a) "Waters of the state" means all streams and springs, and all bodies of surface and subsurface waters within the boundaries of the state;

20. K.A.R. 28-16-28c (d) states in pertinent part:

    (A) All effluent shall receive appropriate minimum levels of treatment in accordance with 40 C.F.R. 122.44, dated July 1, 2012.

21. K.A.R. 28-16-28e (d)(2) states in pertinent part:

    (A) Nutrients. The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life.

22. Based upon the above Findings of Fact, the Secretary concludes and the Respondent agrees that continued discharges from the Facility would lead to further degradation of the Stream and are not consistent with K.A.R. 28-16-28c (d) and K.A.R. 28-16-28e (d)(2).

ORDER

23. Based upon the above-referenced Findings of Fact and Conclusions of Law and pursuant to the authority vested in the Secretary of the Kansas Department of Health and Environment under the above referenced statutes, the Secretary hereby orders the Respondent, and the Respondent hereby agrees to comply with the following Schedule of Compliance:

    (A) Within 90 days of the Effective Date of this CO, the Respondent shall initiate design of the facility recommended by the Antidegradation Review.

(B) Within 3 years of the Effective Date of this CO, the Respondent shall issue a notice to proceed with construction.

(C) The Respondent shall provide a status report by February 28 of each year which documents the previous calendar year's progress.

(D) Within 5 years of the notice to proceed with construction, the Respondent shall achieve substantial completion of the project.

(E) Within 1 year following the substantial completion of the project, the Respondent shall achieve compliance with the final permit limits.

(F) In conjunction with the Respondent's submittal of the design-plans and specification for the project, the Respondent shall submit an analysis plan to assess treatment and performance of the systems when sewage flow rates exceed 57 MGD.

1. The Respondent shall complete an Auxiliary Treatment Performance Study by sampling effluent parameters during high flow events that are greater than 57 MDG flow rate. The Study shall contain a minimum of eight sampling events. The Respondent shall inform KDHE once the eight sampling events are completed and submit the Study within 120 days of the eighth sampling event. Each sampling event shall have a minimum of 24 hours between events.

(G) Effective immediately upon service of this Order, discharges from outfall 002A1 shall be considered in-plant diversions.

1. Any in-plant diversion from the Facility necessary to maintain permit compliance is prohibited, except: (a) where the in-plant diversion was unavoidable to prevent loss of life, personal injury, or severe property damage; (b) where there were no feasible alternatives to the in-plant diversion, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime; (c) the Respondent submitted a notice as required in the Incident Reporting paragraph below. The Director may approve an anticipated in-plant diversion, after considering its adverse effects, if the Director determines that it will meet the three conditions listed above.

2. Incident Reporting: The Respondent shall report any unanticipated collection system diversion to waters of the state, in-plant diversion, in-plant flow through occurrences, spill, upset or any violation of a permitted daily maximum limit within 24 hours from the time the Respondent became aware of the incident. A written submission shall

be provided within 5 days of the time the Respondent became aware of the incident. The written submission shall contain a description of the noncompliance and its cause, the period of noncompliance, including exact dates and times; and if the noncompliance has not been corrected, the anticipated time it is expected to continue; and steps taken or planned to reduce, eliminate, and prevent recurrence of the noncompliance.

Any release into the Stream from a 002A1 in-plant diversion shall be reported to KDHE as described in paragraph 23(G)(2) and shall be sampled for ammonia, biochemical oxygen demand, E. coli, flow, pH, temperature, total nitrogen, phosphorus, total residual chlorine, and total suspended solids. Sampling results are to be included in the written notification.

24. The Schedule of Compliance provided in paragraph 23 supersedes the Schedule of Compliance in the Permit.

25. The activities conducted pursuant to this CO are subject to approval by KDHE. The Respondent shall provide to KDHE all information requested by KDHE consistent with this CO.

26. The Respondent shall continue to operate the Facility as effectively as possible to minimize the concentration of pollutants discharged to waters of the State during this interim time period.

Terms of the Settlement

27. The Respondent agrees to comply with the terms of this CO and the applicable regulations. Failure to comply with the terms of this CO may subject the Respondent to further enforcement action as provided for under Kansas law.

28. **Additional Tasks May Be Required.** KDHE may determine that tasks may be required that are in addition to those specified in this CO. In the event KDHE makes such a determination, it shall notify Respondent in writing that additional tasks are necessary in order to meet the goals and objectives of this CO, to conform to applicable laws, and/or to protect public health or safety or the environment. If such tasks are required, they shall be completed as specified by KDHE and within the timeframes established by KDHE. KDHE's issuance of written notice of additional tasks shall constitute a final decision subject to Dispute Resolution of this CO.

29. This CO shall apply to and be binding upon the Parties, their respective agents, successors, and assigns. The Parties agree to undertake all actions required of them by the terms and conditions of this CO.

30. Notwithstanding the terms of any contract, the Respondent is responsible for compliance with this CO and for insuring that its contractors and agents comply with this CO.

31. This CO is meant to be a full resolution of the matters set forth herein.

32. **Liability.** Nothing herein shall be legally binding or have any effect on the position of the Parties on any matter that may be included in any other agreements negotiated between them. Neither the State of Kansas, nor any agency thereof shall be held out as a party of any contract entered into by the Respondent in carrying out activities pursuant to this CO.

33. **Force Majeure.** The following shall constitute the governing terms for force majeure, excusable delay and modification of the CO.

    (A) Respondent shall perform the requirements under this CO within the time limits set forth herein unless the performance is prevented or delayed solely by events which constitute force majeure. For purposes of this CO, force majeure is defined as any event beyond the control of the Respondent which could not be overcome by due diligence and which delays or prevents performance by a date required by this CO. Such events do not include increased costs of performance or changed economic circumstances. Any delay caused in whole or in part by action or inaction by state or federal authorities shall be considered a force majeure event but shall not extend the period of performance of the obligation required by the CO by more than the period of delay.

    (B) Respondent shall have the burden of proving all claims of force majeure. Failure to comply by reason of force majeure shall not be construed as a violation of this CO.

    (C) Respondent shall notify KDHE in writing within seven (7) days after becoming aware of an event, which the Respondent knew, or should have known, constituted force majeure. Such notice shall estimate the anticipated length of delay, its cause, measures to be taken to minimize the delay, and an estimated timetable for implementation of these measures. Failure to comply with the notice provision of this section shall constitute a waiver of Respondent's right to assert a force majeure claim and shall be grounds for KDHE to deny the Respondent an extension of time for performance.

    (D) Within seven days of the receipt of written notice from the Respondent of a force majeure event, KDHE shall notify the Respondent of the extent to which modifications to this CO are necessary. In the event that KDHE and the Respondent cannot agree that a force majeure event has occurred, or if there is no agreement on the length of the extension, the dispute shall be resolved as set forth in Paragraph No. 35.

    (E) Any alterations to any schedule for performance or completion of a task required by this CO pursuant to this paragraph shall not alter the schedule for performance or completion of any other task required by this CO unless specifically agreed to by the parties in writing and incorporated into this CO.

34. **Modification**. This CO may be amended by written agreement of KDHE and the Respondent.

35. **Dispute Resolution.** The Parties recognize that a dispute may arise between them regarding implementation of the action to be taken as herein set forth or other terms or provisions of this CO.

    (A) If Respondent disagrees, in whole or in part, with any final action or decision made by KDHE under this CO, Respondent may invoke dispute resolution, as follows: Respondent shall send written notice to the KDHE project coordinator stating the specific terms of the disputed KDHE action or decision, and shall provide copies of relevant information; KDHE must receive such notice within fifteen (15) days of the date of KDHE's final action or decision.

    (B) Within thirty (30) days of receipt of any such notice of dispute from Respondent, KDHE and Respondent shall meet by telephone or in person to negotiate an agreement on the matter in dispute. If the Parties cannot reach agreement by consent during this period, KDHE shall issue a brief written decision on the dispute. The final written decision or resolution shall be incorporated as a part of this CO. As authorized by applicable law, issuance of the final written decision under this subparagraph shall be deemed an "Order" as defined by K.S.A. 77-502(d) and shall trigger applicable time limits for requesting a hearing.

    (C) In the event that Respondent seeks dispute resolution concerning a date for performance of an act set out in the CO or an incorporated document or submittal, the date for performance of such act shall be extended for a period equal to the delay resulting from the invocation of the dispute resolution provision. However, such extension does not alter the schedule for performance of completion of any other tasks required by this CO.

36. **Other Claims And Parties.** Nothing in this CO shall constitute or be construed as a release for any claim, cause of action or demand in law or equity against any person, firm, partnership, or corporation not a signatory to this CO for any liability it may have arising out of or relating in any way to the subject violations alleged in this CO.

37. **Effective Date.** This CO shall become effective when signed by the Secretary of the Kansas Department of Health and Environment.

38. **Termination.** This CO will be terminated upon written notice by KDHE to the Respondent that the requirements of this CO have been satisfied. Such notice shall not be unreasonably withheld by KDHE. KDHE reserves the right to unilaterally withdraw this CO for substantial non-compliance.

IT IS SO ORDERED AND AGREED.

KANSAS DEPARTMENT OF
HEALTH AND ENVIRONMENT
By:

_____
Susan Mosier, MD
Secretary

_____
Date

JOHNSON COUNTY WASTEWATER – TOMAHAWK CREEK M.S.D. NO. 1
By:

John P. O'Neil
Signature

John P. O'Neil
Name (Typed or Printed)

General Manager
Title

07 APR 2016
Date

CERTIFICATE OF MAILING

The undersigned hereby certifies that on the _____ day of _____, 2016, a true and correct copy of the above and foregoing Order was placed in the U.S. Mail, postage prepaid, first class, return receipt and addressed to:

Johnson County Wastewater -
Tomahawk Creek M.S.D. No. 1
11811 S. Sunset Dr. Suite 2500
Olathe, KS 66061

_____
Staff Member

FINAL

TOMAHAWK CREEK WWTF IDENTIFICATION, EVALUATION, AND SELECTION OF SECONDARY TREATMENT ALTERNATIVES

Technical Memorandum 3

JCW NO. THM1-C026

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PREPARED FOR

JOHNSON COUNTY KANSAS Wastewater

Johnson County Wastewater

1 MARCH 2016

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HDR

B&V PROJECT 185289

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Acronyms and Abbreviations

Abbreviation	Meaning
A	
AA	Annual Average
AADF	Average Annual Daily Flow
ADF	Average Daily Flow
AFDM	Ash Free Dry Matter
AGS	Aerobic Granular Sludge
ALE	Alginate-like-exopolysaccharides
AL-E	Expected Aquatic Life Support
ANSI	American National Standards Institute
AQL	Warm Water Aquatic Life
AUX	Auxiliary
B	
B&V	Black & Veatch
BAF	Biological Aerated Filters
BFE	Base Flood Elevation
BFP	Belt Filter Press
BioMag	Biological Flocculation System from Siemens
Bio-P	Biological Phosphorous
BLDG	Building
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
BRIS	Blue River Interceptor Sewer
BRM	Blue River Main
C	
C	Hazen-Williams Equation Roughness Coefficient
C:Chl	Carbon to Chlorophyll Ratio
CA	Calcium
CANDO	Coupled Aerobic-anoxic Nitrous Decomposition Operation (Emerging)
CBOD	Carbonaceous Biochemical Oxygen Demand
$CBOD_5$	5-day Carbonaceous Biochemical Oxygen Demand
CEA	Cost Effective Analyses
CEAM	EPA's Center for Exposure Assessment Modeling
CEPT	Chemically Enhanced Primary Treatment
cf	Cubic Feet
CFD	Computational Fluid Dynamics
cfm	Cubic Feet per Minute
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CFUs	Colony Forming Units
CHP	Combined Heat and Power
CIPP	Cured-in-place Pipe
CLOMR	Conditional Letter of Map Revision
cm	Centimeters
CMF	Compressible Media Filters
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
COM	CoMag
CoMag	Chemical Flocculation System from Siemens
CR-B	Primary B Contact Recreation
CSBR	Continuous Sequencing Batch Reactor
CSOs	Combined Sewer Overflows
CT	Concentration Time
CWA	Clean Water Act
D	
D	Depth
DFM	Dry Weather Forcemain
DGC	Digester Gas Control Building
DIG	Digester
DISC	Disc Filters
DLSMB	Douglas L. Smith Middle Basin
DN	Down
DO	Dissolved Oxygen
DP	Dual Purpose
DS	Domestic Water Supply
dt	Dry Ton
DWF	Dry-weather Flow
DWS	Drinking Water Supply
E	
E. coli	Escherichia Coli
EA	Each
EFF	Effluent
EFHB	Excess Flow Holding Basin
EL	Elevation
ELA	Engineering, Legal, Administrative
ENR	Enhanced Nutrient Removal
EPA	Environmental Protection Agency

Abbreviation	Meaning
EPS	Extracellular Polymeric Substances
EQ	Equalization
F	
F/M	Food/Microorganism Ratio
FEMA	Federal Emergency Management Agency
Fe_3O_4	Non-abrasive Iron Ore, Magnetite
ff	Flocculated and Filtered
$ffCBOD_5$	Flocculated Filtered Carbonaceous Biochemical Oxygen Demand
ffCOD	Flocculated Filtered Chemical Oxygen Demand
ffTKN	Flocculated Filtered Total Kjeldahl Nitrogen
FG	Finish Grade
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FITOT	Fraction of Total Insolation
FL	Flow Line
floc	Flocculent
FM	Flow Meter
FP	Food Procurement
FSTE	Final Settling Tank Effluent
ft	Feet
FTE(s)	Full Time Equivalent(s)
G	
gal	Gallons
GAS	Granular Activated Sludge
GGE	Gallons of Gasoline Equivalent
GP	General Purpose
gpd	Gallons per Day
gpm	Gallons per minute
GR	Ground Water Recharge
H	
HB	Hallbrook Facility
HDD	Horizontal Directional Drilling
HEC-RAS	Hydraulic Engineering Center River Analysis System
HEX	Heat Exchanger
Hf	Friction Head
HI	Hydraulic Institute
HL	Head Loss
hp	Horsepower
hr	Hour

Abbreviation	Meaning
HRT	Hydraulic Retention Time
HVAC	Heating, Ventilation, Air Conditioning
HWE	Headworks Effluent
HWLA	High Water Level Alarm
Hypo	Hypochlorite
I	
I&C	Instrumentation and Controls
I/I	Inflow and Infiltration
IC	Internal Combustion
IFAS	Integrated Fixed-Film Activated Sludge
IMF	Interagency Metering Facility
in	Inches
IND	Industrial
INF	Influent
IP	Intellectual Property
IPS	Influent Pump Station
IR	Irrigation Use
IRR	Irrigation
IW	Industrial Water Supply Use
J	
JCW	Johnson County Wastewater
K	
kcf	Thousand Cubic Feet
KCMO	Kansas City, Missouri
KDHE	Kansas Department of Health and Environment
K_e	Light Extinction Coefficient
KU	University of Kansas
kWh	Kilowatt-hour
L	
L	Length, Liter
LBVSD	Little Blue Valley Sewer District
lb	Pound
lb/d	Pounds per Day
LF	Linear Feet
LIC	Lower Indian Creek
LOMR	Letter of Map Revision
LOX	Liquid Oxygen
LPON	Labile Particulate Organic Nitrogen
LPOP	Labile Particulate Organic Phosphorous
LS	Lump Sum
LWLA	Low Water Level Alarm

Abbreviation	Meaning
LWW	Livestock & Wildlife Watering
M	
m	Meter
MAD	Mesophilic Anaerobic Digestion
MARB	Mississippi-Atchafalaya River Basin
MBBR	Moving Bed Bioreactors
MBR	Membrane Bio-reactor
MCC	Motor Control Center
mg	Milligrams
Mg	Magnesium
MG	Million Gallons
mg/L	Milligrams per Liter
mgd	Million Gallons per Day
min	Minute, minimum
mJ	Millijoules
MLE	Modified Ludzack Ettinger
MLSS	Mixed Liquor Suspended Solids
MM	Maximum Month
mm	Millimeter
MMADF	Maximum Month Average Daily Flow
mmBtu	Million British Thermal Units
mpg	Miles per Gallon
MPN	Most Probable Number
N	
N	Nitrogen
NACWA	National Association of Clean Water Agencies
NaOH	Sodium Hydroxide (Caustic)
NCAC	New Century Air Center
NDMA	N-Nitrosodimethylamine
NFIP	National Flood Insurance Program
NH3-N	Total Ammonia
NOx-N	Nitrate + Nitrite
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NPV	Net Present Value
NTS	Not to Scale
O	
O&M	Operation and Maintenance
OCP	Overflow Control Plan
OMB	Office of Management and Budget
OUR	Oxygen Uptake Rate

Abbreviation	Meaning
P	
P	Phosphorous
PAOs	Phosphorous Accumulating Organisms
PC	Primary Clarifier
PD	Peak Day
PDF	Peak Daily Flow
PE	Primary Effluent
PFE	Primary Filtered Effluent
PFM	Peak Flow Forcemain
PHF	Peak Hour Flow
PIF	Peak Instantaneous Flow
PLC	Programmable Logic Controller
PO_4-P	Orthophosphate Phosphorous
ppd	Pounds per Day
pph	Pounds per Hour
PPI	Producer Price Index
ppy	Pounds per Year
PS	Pump Station
psf	Pounds per Square Foot
psi	Pounds per Square Inch
PWWF	Peak Wet-weather Flow
Q	
Q	Flow
R	
RAS	Return Activated Sludge
rbCOD	Rapidly Biodegradable Chemical Oxygen Demand
RDT	Rotating Drum Thickener
RECIRC	Recirculation
RIN	Renewable Identification Number
RM	River Mile
R&R	Repair and Replacement
RWW	Raw Wastewater
S	
SAB	USEPA Science Advisory Board
SBOD	Soluble Biochemical Oxygen Demand
SBR	Sequencing Batch Reactor
SCADA	Supervisory Control and Data Acquisition
SCE	Secondary Clarifier Effluent
scfm	Standard Cubic Feet per Minute
sCOD	Soluble Chemical Oxygen Demand
SCR	Secondary Contact Recreation
Sec	Second, Secondary

Abbreviation	Meaning
SF	Square Foot
SG	Specific Gravity
SLR	Solids Loading Rate
SMP	Stormwater Management Program, Shawnee Mission Park Pump Station
SND	Simultaneous Nitrification/ Denitrification
SOD	Sediment Oxygen Demand
SOR	Surface Overflow Rate
SOURs	Specific Oxygen Uptake Rates
SP	Single Purpose
S.P.S.	Sludge Pump Station
SRT	Sludge Retention Time
SS	Suspended Solids
SSOs	Sanitary Sewer Overflows
SSS	Separate Sewer System
sTP (GF)	Soluble Total Phosphorous (Glass Fiber Filtrate)
SVI	Sludge Volume Index
SWD	Side Water Depth
T	
TBL	Triple Bottom Line
$TBOD_5$	Total 5-day Biochemical Oxygen Demand
TDH	Total Dynamic Head
Temp	Temperature
TERT	Tertiary
TF	Trickling Filters
TFE	Tertiary Filter Effluent
THC	Tomahawk Creek
THM	Trihalomethanes
TIN	Total Inorganic Nitrogen
TKN	Total Kjeldahl Nitrogen
TM	Technical Memorandum
TMDL	Total Maximum Daily Loads
TN	Total Nitrogen
TOC	Top of Concrete
TP	Total Phosphorous
TPS	Thickened Primary Solids
TS	Total Solids
TSS	Total Suspended Solids
TWAS	Thickened Waste Activated Sludge
TYP	Typical
U	
µg/L	micrograms per Liter
UCT	University Cape Town
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultraviolet
UV LPHO	Ultraviolet Low Pressure, High Output
UV MPHO	Ultraviolet Medium Pressure, High Output
V	
VFA	Volatile Fatty Acids
VFAs	Volatile Fatty Acids (Speciated)
VFD	Variable Frequency Drive
VS	Volatile Solids
VSL	Volatile Solids Loading
VSr	Volatile Solids Reduction
VSS	Volatile Suspended Solids
W	
W	Width
WAS	Waste Activated Sludge
WASP	Water Quality Analysis Simulation Program
WBCR-A	Whole Body Contact Recreation – Category A
WBCR-B	Whole Body Contact Recreation – Category B
WFM	Wet Weather Forcemain
WL	Water Level
WK	Week
WS	Water Surface
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant
Y	
YR	Year

1 Executive Summary

1.1 BACKGROUND AND OBJECTIVES

This executive summary highlights the key findings and recommendations of Technical Memorandum No. 3 - Identification, Evaluation and Selection of Secondary Treatment Alternatives (TM No. 3). This TM is one in a series of technical memoranda for the definition phase study of the Tomahawk Wastewater Treatment Facility (WWTF) expansion.

The purpose of this TM is to present findings from the identification and screening of proposed secondary treatment alternatives at the Task No. 4 Pre-Workshop conducted on October 14, 2014; present the evaluation of four alternatives selected for further consideration, and present the recommendation of a preferred secondary treatment alternative with an analysis of carbon augmentation.

1.2 FINDINGS

The Task No. 4 Pre-Workshop, held on October 14, 2014, identified 17 potential secondary treatment technologies for consideration. The objective of the Pre-Workshop was to eliminate technologies not feasible to meet the objectives of the Tomahawk Creek WWTF site and treatment constraints and to identify a limited number of technologies for further evaluation. The two primary criterion of paramount importance to the screening of a secondary treatment technology were 1) a small footprint to minimize Tomahawk Creek flood impacts, and 2) ability to treat to a low effluent ammonia concentration to meet regulatory requirements.

Of the 17 technologies, four were recommended for further in-depth evaluation:

- Alternative 1 – Integrated Fixed Film Activated Sludge (IFAS).
- Alternative 2 – Membrane Bioreactor (MBR).
- Alternative 3 – BioMag.
- Alternative 4 – Granular Activated Sludge (GAS).

Facility sizing for each of the IFAS, MBR and BioMag alternatives was determined from preliminary process calculations based on data presented in TM No. 1 and from the manufacturer, considering both CoMag and conventional primary clarification methods. The sizing for the granular activated carbon alternative was provided only by the manufacturer and does not require primary clarification.

For preliminary calculations, a spreadsheet-based activated sludge model called Completely Mixed Activated Sludge (CMAS) was used for the selected alternatives to analyze and preliminarily size facilities to meet the effluent quality limits. Modified Ludzack Ettinger (MLE) arrangement of the secondary treatment process was considered with anaerobic, anoxic and oxic zones. A mixed liquor suspended solids recycle flow was designed from the end of oxic zones to the anoxic zones to supplement denitrification. Provisions were made in the design to add future zones to handle more stringent effluent total nitrogen limits.

Conceptual capital cost, operation and maintenance (O&M) cost and a life-cycle cost analysis were developed for each of the secondary treatment alternatives. The conceptual capital cost opinion was developed as a 20-year net present value (NPV) which includes the effects of inflation, time-value of money, timing of capital outlay, equipment replacement, and remaining value at the end of the planning period.

A triple bottom line (TBL) analysis was completed as the basis for selection of the alternatives for further consideration. Social, environmental and operational criteria were weighted and scored to determine the benefit-cost of each alternative.

1.3 SUMMARY OF RECOMMENDATIONS

With the use of CoMag as primary clarification, a comparison of total NPV suggests Biomag could achieve the lowest cost over a 20-year period with IFAS closely behind. With the use of conventional primary clarification, a comparison of total NPV suggests GAS could achieve the lowest cost over a 20-year period with IFAS and BioMag alternatives closely behind. MBR is estimated to have the highest capital, O&M and Total NPV under both scenarios.

With the use of CoMag as primary clarification, a comparison of total TBL analysis suggests IFAS is the preferred alternative with BioMag and GAS alternatives as the next closest. With the use of conventional primary clarification, a comparison of TBL analysis suggests IFAS is the preferred alternative with GAS alternatives as the next closest. MBR ranks last under both scenarios and without the use of CoMag, BioMag does not score favorably.

The recommendations arising from this analysis based on discussions and workshops, economic and non-economic analysis, include a 5-stage IFAS secondary treatment process with conventional primary clarification. A 5-stage arrangement is based on the sidestream nutrient removal evaluation presented in TM No. 5. Further, carbon augmentation is recommended in the form of MicroC 2000 carbon supplementation to aid with denitrification and biological phosphorus removal.

2 Introduction

2.1 BACKGROUND

The purpose of this conceptual study is to present findings from the identification and screening of proposed secondary treatment alternatives at the Task No. 4 Pre-Workshop conducted on October 14, 2014; present the evaluation of four alternatives selected for further consideration, and present the recommendation of a preferred secondary treatment alternative.

The following sections summarize how the evaluation was performed and describes the results for each alternative. A comparative analysis of non-economic factors and the results of the TBL scoring evaluation are tabulated at the end of this TM for the purpose of selecting a preferred secondary treatment alternative.

2.2 DESIGN CRITERIA

The secondary influent loading criteria that were developed in TM No. 1 were used as the basis to design the secondary treatment alternatives for this TM. Two sets of influent loads were developed based on the type of primary clarification provided to the wastewater: CoMag and conventional primary treatment. As discussed in TM No. 6, conventional primary treatment will use CEPT during wet weather flows. Throughout this TM, these are referred to as Alternatives A and B, respectively.

Each criterion is presented in Table 2-1 and Table 2-2. Side stream return characteristics presented in these tables are presented in TM No.1. Since no primary clarifiers are used with the granular activated sludge alternative, the design criteria are the same as the influent flows and loads presented in TM No.1. The effluent requirements for the facility are summarized in Table 2-3. The applicable design aspects for each alternative are summarized in each alternative discussion.

For Alternative A it was assumed that about 500 pounds per day of biochemical oxygen demand (BOD) and total suspended solids (TSS) would be returned back from the biosolids treatment facilities. In addition, around 1,200 pounds per day of ammonia would also be recycled. For Alternative B, 450 pounds per day of BOD, TSS and 1,100 pounds per day of ammonia are assumed to be returned.

Table 2-1 Enhanced Primary Treatment Effluent Design Criteria

PE POLLUTANT CONC WITH SIDE STREAM RETURNS - COMAG[1]				
	Annual Average		**Maximum Month**	
	Pounds per day (ppd)	Milligrams per liter (mg/L)	Pounds per day (ppd)	Milligrams per liter (mg/L)
Pollutant				
BOD, Total[2]	7,527	47	9,827	41
BOD, Soluble[1]	4,904	30.9	6,745	28
BOD, Suspended	2,623	17	3,082	13
TSS	3,665	23	5,196	22
VSS	2,855	18	4,054	17
Ammonia	4,015	25.3	5,120	21.4
TKN	5,299	33.4	6,692	28.0
TP	885	5.6	1,186	5.0

Notes:
[1] With CoMag operation (90% TSS Removal)
[2] 72% BOD removal

Table 2-2 Conventional Primary Treatment Effluent Design Criteria

PE POLLUTANT CONC WITH SIDE STREAM RETURNS - CONVENTIONAL[1]				
	Annual Average		**Maximum Month**	
	Pounds per day (ppd)	Milligrams per liter (mg/L)	Pounds per day (ppd)	Milligrams per liter (mg/L)
Pollutant				
BOD, Total[2]	15,592	98	20,299	85
BOD, Soluble[1]	4,904	30.9	6,745	28
BOD, Suspended	10,688	67	13,554	57
TSS	16,579	104	23,525	98
VSS	14,277	90	20,271	85
Ammonia	3,888	24.5	4,925	20.6
TKN	5,638	35.5	7,069	29.6
TP	913	5.8	1,202	5.0

Notes:
[1] With conventional PC operation (50% TSS Removal)
[2] 40% BOD removal

Table 2-3 Target Secondary Treatment Effluent Design Criteria

CRITERIA	VALUE
Influent TSS to Filters	20 mg/L
Effluent Ammonia (monthly average)	Varied Limits
Effluent TN (monthly average)	8 mg/L
Effluent TP (annual average)	< 0.5 mg/L

Further detail on flow and load characteristics are discussed in TM No. 1.

The possibility of lower future total nitrogen (TN) limits (< 5 mg/L) was considered to evaluate the impact on footprint (for floodplain impact) due to the need for additional basins. The cost of these potential future basins is not included in this TM although the additional cost is estimated to be equivalent for each alternative.

2.3 COST ANALYSIS CRITERIA

Capital costs for each alternative are contained in Section 3.6 of this TM. The capital costs include facilities that are unique to each alternative and do not reflect comprehensive future project costs. The costs of common facilities among all alternatives were ignored to develop a relative cost analysis. The following facility criteria were assumed to be similar among alternatives and were not included in the secondary treatment evaluation:

- Biosolids processing and conveyance.
- Influent pumping, screening and grit facilities.
- Maintenance costs of typical biological basin equipment.
- Support facilities (chemical feed, administration, odor control and operations and maintenance).
- Dry weather flow UV disinfection and wet weather flow chlorine contact basin disinfection facilities.

Comparative construction costs besides those directly projected based on conceptual facility layout were estimated by applying a percentage to the facility and equipment cost. These percentages were determined using the engineer's opinion of probable values based on experience.

The costs were estimated for each alternative as follows:

- Electrical and instrumentation and controls (I&C) applied at 20 percent of capital cost.
- Allowance provided for all non-structural related sitework associated with the facility, including finish grading, drives and sidewalks, utilities, and associated yard piping local at 20 percent of capital cost.
- Contractor's general requirements estimated at 15 percent of capital cost.
- Contingency applied due to the conceptual nature of this cost estimate at 25-35 percent based upon the engineer's opinion of relative cost accuracy.
- Engineering, legal, and administration fees applied at 25 percent of capital cost.

2.4 PROCESS MODELING AND FACILITIES SIZING

Facility sizing for each of the IFAS, MBR and BioMag alternatives was determined from preliminary process calculations based on data presented in TM No. 1. The sizing for the granular activated carbon alternative was provided by the vendor - HaskoningDHV.

For preliminary calculations, a spreadsheet-based activated sludge model called CMAS was used for the selected alternatives to analyze and preliminarily size facilities to meet the effluent quality limits presented above. MLE arrangement of the secondary treatment process was considered with anaerobic, anoxic and oxic zones. A mixed liquor suspended solids recycle flow was designed from the end of oxic zones to the anoxic zones to supplement denitrification. Provisions were made in the design to add future zones to handle more stringent effluent total nitrogen limits. The Design Condition Influent Data used for the modeling are presented in Table I-3 of TM No. 1. The biological treatment facilities were sized for each alternative based on the results of the process modeling. The following criteria were used in the CMAS model for preliminary facility sizing:

- Mixed liquor suspended solids (MLSS) Concentration - For IFAS the mixed liquor concentration in the suspended growth zone was limited to 3,000 mg/L. All other alternatives were designed for a higher MLSS concentration as appropriate for that process with a limiting MLSS concentration between 8,000-10,000 mg/L.

- Oxygen Uptake Rate (OUR) - The uptake rate by the aerobic bacteria dictates how heavily loaded a particular zone is. For the initial sizing, the OUR in the first pass of any of the aerobic zones was limited to 120 mg/L/hr.

- Sludge Age/Solids Retention Time (SRT) - The aerobic SRT of the MLSS in the system was limited to 15 days at 13°C. This SRT ensures complete nitrification of the influent wastewater even when the liquid temperature drops below 13°C.

- Hydraulic Retention Time (HRT) - The minimum HRT for sizing the anoxic zone was limited to 60 minutes. Advanced process modeling with Biowin will be needed to confirm the correct anoxic zone volume.

- Solids Loading Rate (SLR) - The limiting SLR for clarifier design for IFAS process was 30 pounds per day per square foot (ppd/ft^2) and for the BioMag process was 90 ppd/ft^2.

- Surface Overflow Rate (SOR) - The limiting SOR for clarifier design for IFAS process was 1,400 gallons per day per square foot (gpd/ft^2) and for the BioMag process was 2,500 gpd/ft^2.

One key point is that the models did not include hauled septage as part of the influent flow and loading. Secondary treatment systems are sensitive to a higher concentration of influent TSS. Specifically, the higher TSS concentration requires the activated sludge basin size to be increased and increases the solids loading rates on the final clarifiers.

Provisions were made in designing all four alternatives to include future tankage for enhanced TN removal in event the facility is required to comply with more stringent effluent total nitrogen limits. The first three alternatives (IFAS, MBR and BioMag) would have a post anoxic zone downstream of

the aeration tanks for denitrification, followed by a reaeration tank to increase the dissolved oxygen (DO) before the flow enters the clarifiers. An HRT based criterion was used to design these two zones. For the GAS alternative, a moving bed bioreactor (MBBR) reactor would handle the future nitrogen limits.

3 Secondary Treatment Alternatives

3.1 ALTERNATIVES IDENTIFICATION AND SCREENING

The Task No. 4 Pre-Workshop, held on October 14, 2014, identified 17 potential secondary treatment technologies for consideration. The objective of the Pre-Workshop was to eliminate technologies not feasible to meet the objectives of the Tomahawk Creek WWTF site and treatment constraints and to identify a limited number of technologies for further evaluation. A matrix was developed to summarize the 17 secondary treatment technologies and to screen the technologies against initial criteria to narrow the field to up to four alternatives for further consideration. The two primary criterion of paramount importance to the screening of a secondary treatment technology were 1) a small footprint to minimize Tomahawk Creek flood impacts, and 2) ability to treat to a low effluent ammonia concentration to meet regulatory requirements.

Refer to Appendix A for the summary matrix. Technologies identified were not meant to be all-inclusive, but were meant to capture the majority of potential treatment technologies available.

Technologies reviewed include:

- Simultaneous Nitrification / Denitrification (SND) Processes:
    - Orbal Process, by USFilter Envirex.
    - Vertical Loop Reactor, by USFilter Envirex.
    - Schreiber Counter Current Aeration Process, by Schreiber, Inc.
    - Numerous Oxidation Ditch Process Variations.
    - Symbio Process, by Enviroquip, Inc.
- Five-stage Bardenpho.
- Integrated Fixed Film Activated Sludge (IFAS).
- Membrane Bioreactors (MBRs).
- Moving Bed Bioreactors (MBBRs).
- Biological Aerated Filters (BAFs).
- Granular Activated Sludge (GAS).
- Step-Feed Denitrification.
- BioMag.
- Cyclic Activated Sludge/Sequencing Batch Reactor (SBR).
- Phased Isolation Ditch/continuous SBR (CSBR).
- CANDO (Coupled Aerobic-anoxic Nitrous Decomposition Operation) (emerging).

- Algae biomass cultivation for biofuels production combined with wastewater treatment.

Of these technologies, four were recommended for further in-depth evaluation:

- Alternative 1 – Integrated Fixed Film Activated Sludge (IFAS).
- Alternative 2 – Membrane Bioreactor (MBR).
- Alternative 3 – BioMag.
- Alternative 4 – Granular Activated Sludge (GAS).

All of the screened four technologies met the initial objectives of a small footprint and have the ability to treat to a low effluent ammonia concentration. The following sections focus on evaluating each alternative to a greater depth.

3.2 ALTERNATIVE 1 – IFAS

3.2.1 Process Discussion

IFAS combines suspended growth and fixed film activated sludge within the same bioreactor to increase the overall mass of bacteria that can be maintained, thus reducing the required activated sludge aeration basin volume. The media also retains biomass and limits the solids loading to the final clarifiers thereby minimizing clarifier area.

A free floating plastic media is used to provide surface area for biomass to attach and grow. The floating media are added to the aeration zone of a conventional suspended growth nitrification process and kept in place via screens. The media supplies surface area for nitrifying organisms to grow on, transforming the suspended growth process into a biofilm process.

Figure 3-1 presents snapshot of the retaining sieves and plastic media.

Figure 3-1 IFAS Retaining Sieves and Plastic Media

3.2.2 Alternative Schematic, Layout, Footprint, and Hydraulic Considerations

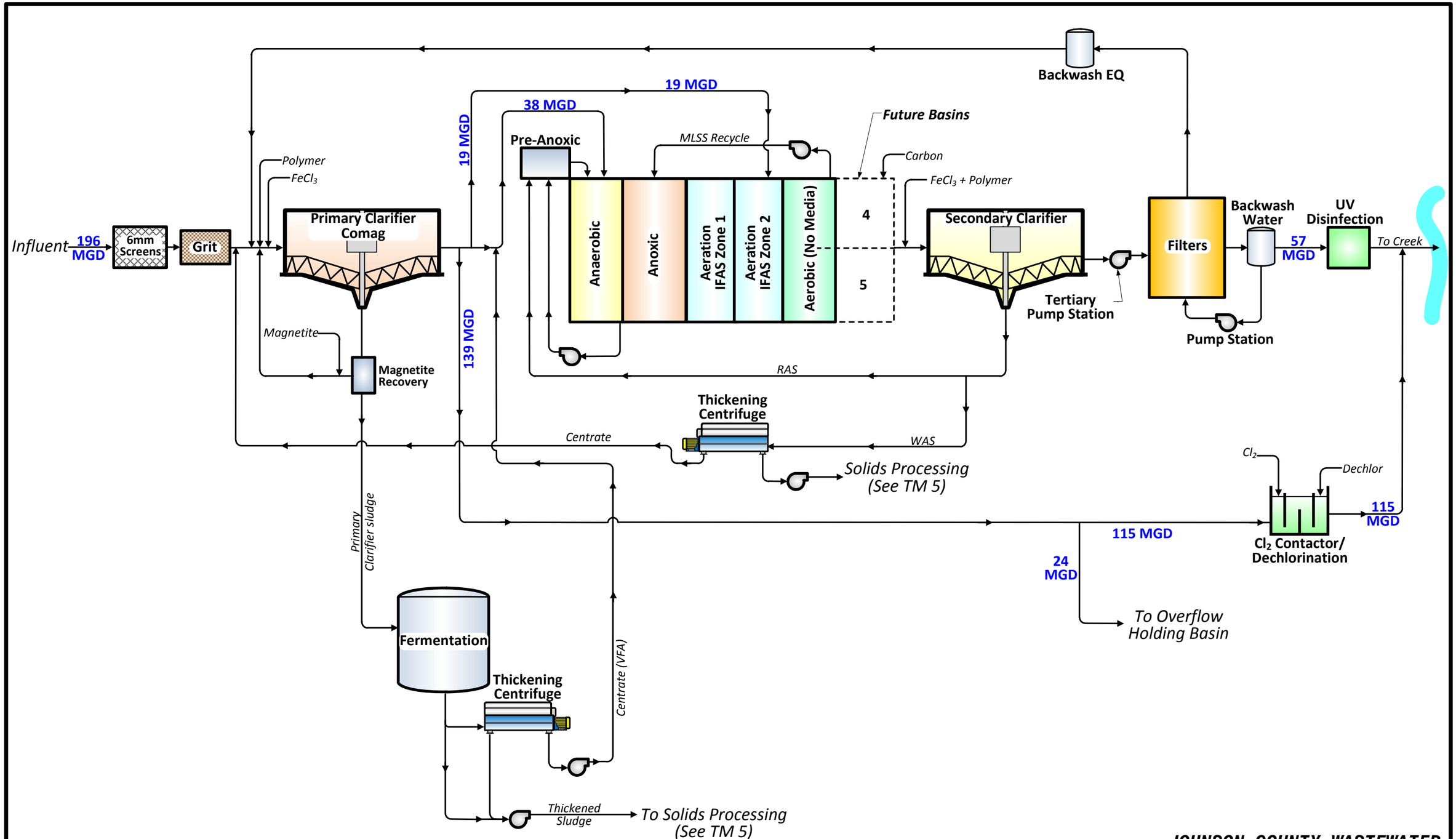
The overall schematic of the IFAS secondary treatment process and related facilities is shown in Figure 3-2 and Figure 3-3 based on CoMag and conventional primary clarification, respectively. The facility would be designed to handle 196 mgd flow, of which up to 57 mgd receives complete secondary treatment, and 115 mgd flow would receive auxiliary wet weather treatment. For Alternative 1A using CoMag primary clarification, auxiliary wet weather treatment would be provided via the CoMag process. For Alternative 1B using conventional primary clarification, influent flow up to 57 mgd receives primary and secondary treatment, while the rest of the flow is treated by auxiliary treatment facilities. For Alternative 1B Enhanced primary clarification is provided to the influent wastewater in excess of 35 mgd by adding polymer and ferric chloride chemicals. TM No. 6 provides further details on primary treatment options.

Of the 57 MGD flow, three-stage secondary treatment would be provided to 38 mgd flow and the remaining 19 mgd would be step-fed at the end of the aerobic zone. The primary effluent flow along with pre-conditioned RAS enters the anaerobic zone. Pre-conditioning of RAS occurs in the pre-anoxic zone and is required to strip out nitrates and any DO present in the RAS. In the absence of the pre-anoxic zone, the anaerobic zone might have “nitrate-poisoning”, which consumes carbon and interferes with Bio-P removal.

After the anaerobic zone, the wastewater then flows into the anoxic zone and then into the aerobic zone with floating plastic media. The aerobic zone is divided into three cells, and media and screens would be present in the first two cells. A small volume of non-media cell is provided at the end to pump the MLSS recycle to the anoxic zone. Using the non-media zone to pump the MLSS recycle will ensure that no media is lost to the anoxic zone. The remaining 19 mgd flow is step-fed into the second aerobic zone. This arrangement ensures that the entire 3Q flow undergoes biological treatment, without risking a process upset.

From the biological tanks the wastewater flows into four circular secondary clarifiers. There is a provision to add ferric chloride upstream of the clarifiers as a backup for phosphorus removal. As shown in Figure 3-2 and Figure 3-3, provisions are also made in the design to accommodate future stricter effluent nutrient limits. The future conditions will include a second anoxic zone for further denitrification and a reaeration zone for DO polishing.

The secondary effluent then flows through a filtration process to reduce the effluent total phosphorus concentration to less than 0.5 mg/L. Details on the filtration process are described in TM No. 4. Ultraviolet disinfection of the filtrate is provided before discharging the treated water to the creek. Auxiliary treated effluent is also disinfected with hypochlorite.



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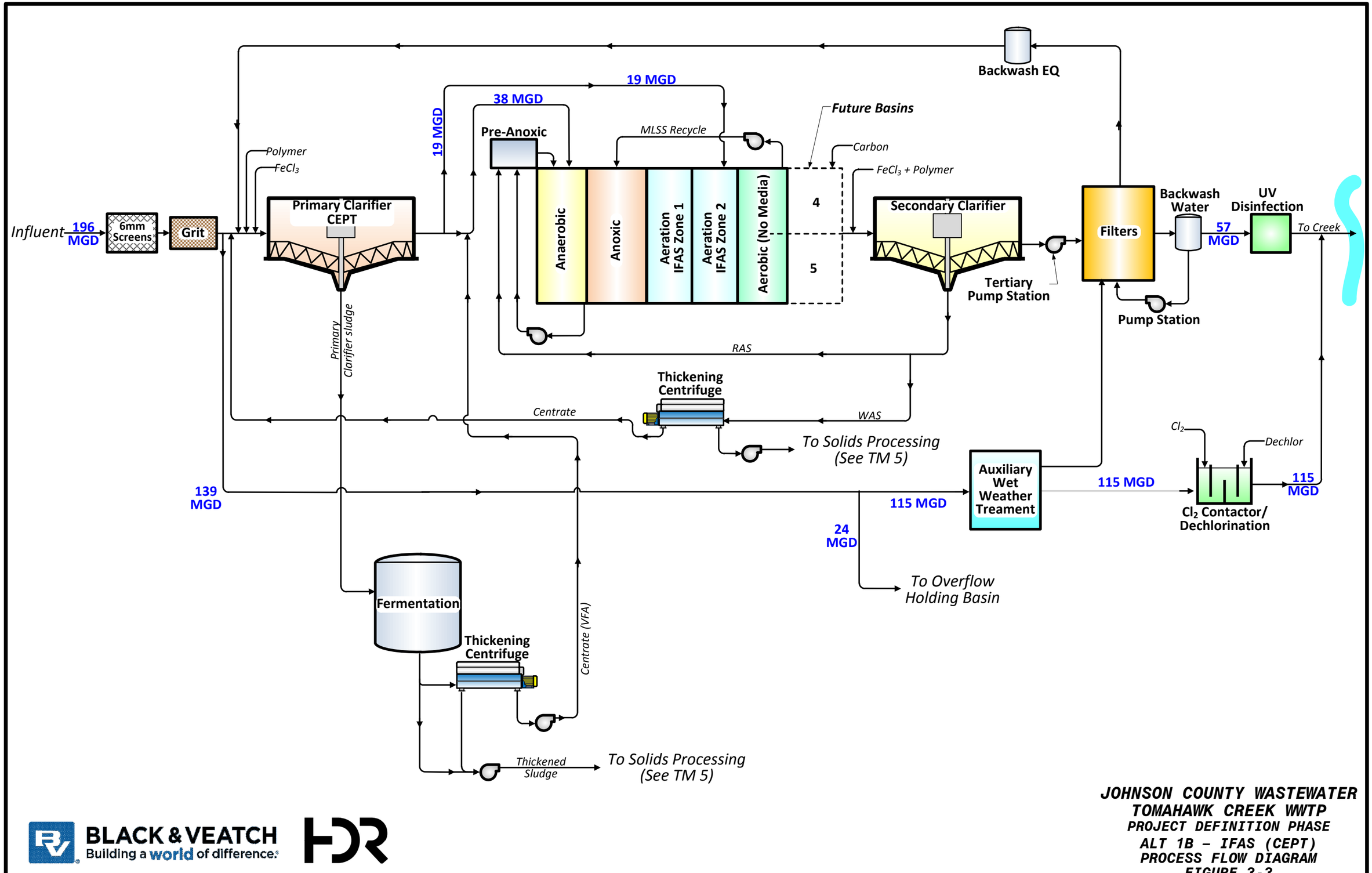
TOMAHAWK CREEK WWTP
PROJECT DEFINITION PHASE
ALT 1A – IFAS (COMAG)
PROCESS FLOW DIAGRAM
FIGURE 3-2



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JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTP
PROJECT DEFINITION PHASE
ALT 1B – IFAS (CEPT)
PROCESS FLOW DIAGRAM
FIGURE 3-3

Two RAS pump and one WAS pump per clarifier would be provided with one redundant pump of each type per two clarifiers. For Tomahawk, this would equal 10 RAS pumps and 6 WAS pumps in total. Figure 3-4 shows a typical perspective view of a sludge pump station for each pair of clarifiers. For Tomahawk, this facility would be double the capacity.

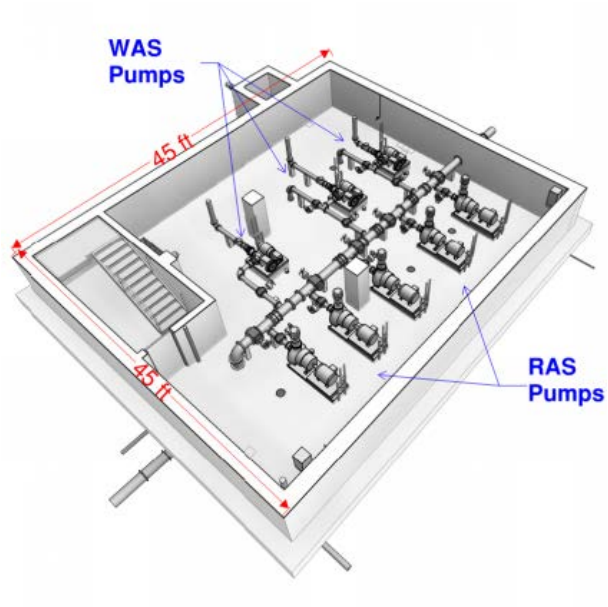


Figure 3-4 Typical Secondary Sludge Facility

Aeration requirements for Alternative 1 are approximately 25,000 standard cubic feet per minute (SCFM) sized for maximum month flow. This would suggest 5 blowers at a maximum of 5,000 SCFM per blower. The aeration blowers would be enclosed in a blower building similar to Figure 3-5.

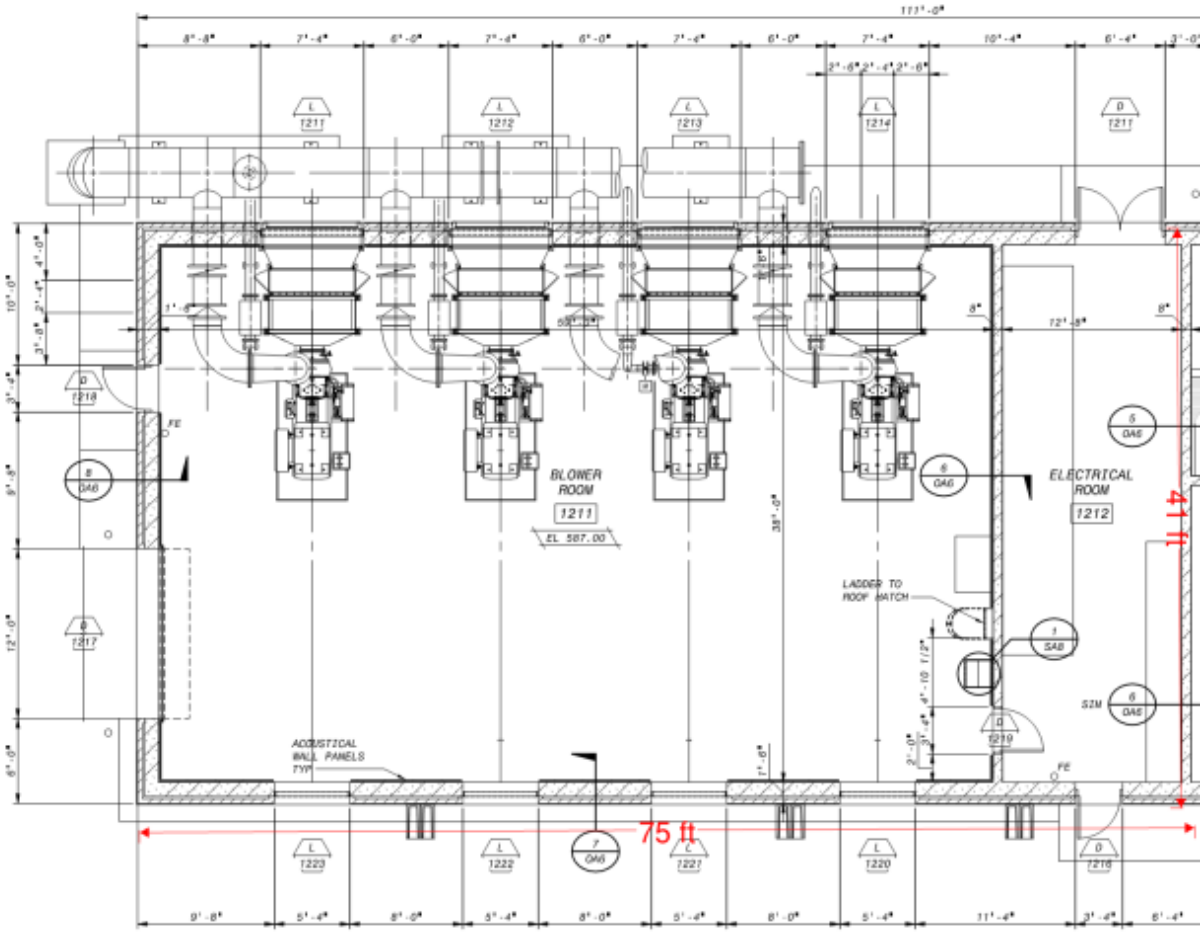


Figure 3-5 Typical Aeration Blower Building

A single hydraulic profile depicting the IFAS secondary treatment alternative is shown in TM No. 6. There is anticipated to be approximately 6 feet of headloss through the secondary process with approximately 0.5 feet of headloss produced by the IFAS sieves. This alternative will require the installation of a tertiary pump station after the secondary clarifiers. However, all alternatives discussed in this TM will require intermediate pumping downstream of the secondary process.

3.2.2.1 Black & Veatch Design

A plug-flow secondary treatment facility with anaerobic, anoxic and aerobic zones was designed using a limiting MLSS concentration of 3,000 mg/L with a 15 day sludge age at 13°C. The tank sizes are also limited by a maximum oxygen uptake rate of 100 mg/L/hr in the various passes of the plug-flow reactor.

Table 3-1 presents the design criteria applicable to Alternatives 1A and 1B.

Table 3-1 IFAS Black & Veatch Design Criteria

SECONDARY TREATMENT ZONES	DESIGN CRITERIA	ALTERNATIVE 1A FACILITY SIZING (COMAG)	ALTERNATIVE 1B FACILITY SIZING (CONVENTIONAL)
Pre-Anoxic Zone	Hydraulic Retention Time= 15 min	39,800 ft^3	39,800 ft^3
Anaerobic Zone	Hydraulic Retention Time= 60 min	159,800 ft^3	159,800 ft^3
Anoxic Zone	25-35% of the combined anoxic and oxic tank volume; Hydraulic Retention Time= 60-90 min	151,420 ft^3	300,300 ft^3
Aerobic Zone 1- With Media	MLSS= 3,000 mg/L, Effective SRT= 15 days	135,260 ft^3	247,320 ft^3
Aerobic Zone 2- With Media		135,260 ft^3	247,320 ft^3
IFAS Media	Specific surface area= 650 m^2/m^3, Equivalent MLSS= 2,500 mg/L	33%	37%
Aerobic Zone 3- No Media		30,060 ft^3	30,060 ft^3
Aeration Requirements		20,000 SCFM	20,000 SCFM
Final Clarifier	Solids Loading Rate= 30 ppd/ft^2, Surface Overflow Rate= 1,400 gpd/ft^2	4- 125 ft dia	4-125 ft dia

3.2.2.2 Vendor Design

Three different IFAS vendors, HeadworksBIO, Kruger and World Water Works, were contacted to provide preliminary facility sizing for Alternative 1 at Tomahawk Creek WWTP. The information provided by them is consolidated and presented in Table 3-2. The basin volumes provided by each of the vendors are different and therefore an average value was selected to present in the table.

Table 3-2 IFAS Vendor Design Criteria

SECONDARY TREATMENT ZONES	FACILITY SIZING (COMAG)	FACILITY SIZING (CONVENTIONAL)
Pre-Anoxic Zone	63,000 ft^3	63,000 ft^3
Anaerobic Zone	152,000 ft^3	157,000 ft^3
Anoxic Zone	207,000 ft^3	225,000 ft^3
Aerobic Zone 1- With Media[1]	176,000 ft^3	247,000 ft^3
IFAS Media	45%	45%
Aerobic Zone 2- No Media	166,000 ft^3	247,000 ft^3
Note: [1] MLSS= 3,000 mg/L, Effective SRT= 15 days		

The vendors suggested using the first aerobic zone with plastic media and a second zone with no media. This approach reduces the capital cost of the alternative but may not provide full

nitrification during high flow events. The Black & Veatch approach proposes the use of two aerobic media zones in series as discussed in Section 3.2.2.3.

The information provided in Table 3-1 and Table 3-2 were used to determine the final design volumes for the IFAS alternative. This is discussed in the following section.

Table 3-3 presents the scope of equipment comprising the IFAS vendor equipment cost shown in Appendix B. Equipment required for Alternative 1 outside this scope is accounted for separately.

Table 3-3 IFAS Components

EQUIPMENT
Biofilm Media
Sieve Assemblies
Aeration Grid (Air Scour) System
Oxygen Transfer Testing
Performance Testing
Sieve scour system
Start-up Field Service

3.2.2.3 Proposed Design

Table 3-4 and Table 3-5 present the proposed basin volumes that were used for further cost analyses for Alternatives 1A and 1B, respectively. Although the proposed volumes are within the range of the vendor provided volumes, they are closer to the Black & Veatch design than the vendor design. The designs provided by the three vendors varied significantly, and therefore, an average volume cannot be considered an accurate representative design. A detailed Biowin model with updated wastewater characteristics must be carried out to confirm the proposed volumes.

The SRT calculation for an IFAS system includes the summation of solids that are attached on the media and suspended in the bulk liquid. Although the solids concentration in the bulk can be estimated using a standard TSS test, the concentration on the media cannot be accurately estimated. Therefore, an average concentration of MLSS is established for the media. The SRT that is calculated using the average attached solids and suspended solids concentration is termed as effective SRT of the system.

Table 3-4 Proposed Alternative 1A Design – IFAS with CoMag PC

SECONDARY TREATMENT ZONES	FACILITY SIZING	NUMBER OF UNITS	DIMENSIONS (LxWxD, FT)
Pre-Anoxic Zone	42,600 ft^3	4	22 x 22 x 22
Anaerobic Zone[1]	159,400 ft^3	4	51 x 45 x 22
Anoxic Zone	150,500 ft^3	4	38 x 45 x 22
Aerobic Zone 1- With Media[2,3]	138,600 ft^3	4	35 x 45 x 22
Aerobic Zone 2- With Media[2,3]	138,600 ft^3	4	35 x 45 x 22
Aerobic Zone 3- No Media	31,700 ft^3	4	8 x 45 x 22
Final Clarifier		4	125 ft dia

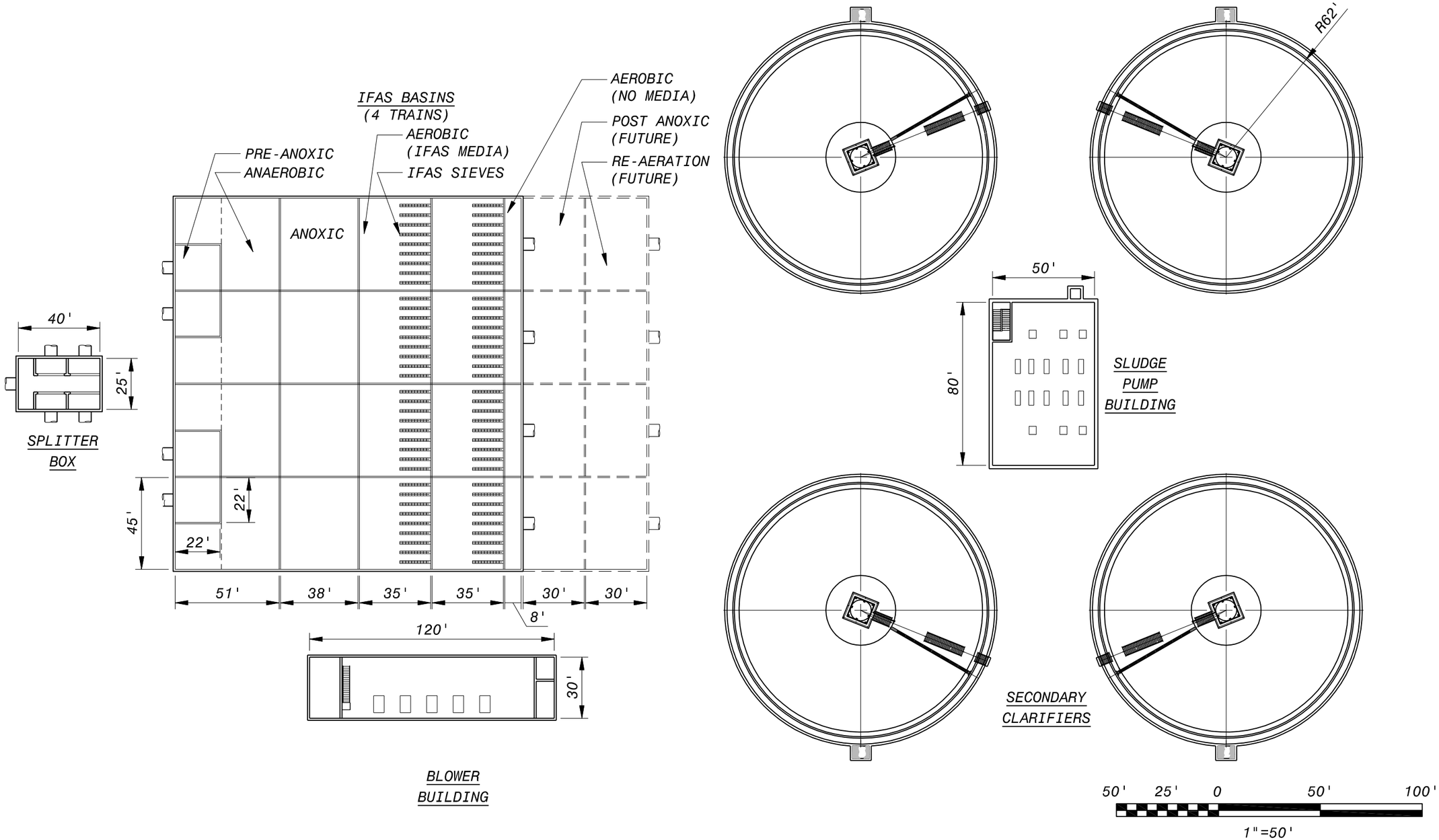
Notes:
[1] Footprint of pre-anoxic tank is within anaerobic tank dimensions
[2] Total media fill is 43%
[3] MLSS = 3,000 mg/L, Effective SRT = 15 days

Table 3-5 Proposed Alternative 1B Design – IFAS with Conventional PC

SECONDARY TREATMENT ZONES	FACILITY SIZING	NUMBER OF UNITS	DIMENSIONS (LxWxD, FT)
Pre-Anoxic Zone	42,600 ft^3	4	22 x 22 x 22
Anaerobic Zone[1]	159,400 ft^3	4	51 x 45x 22
Anoxic Zone	300,300 ft^3	4	76 x 45 x 22
Aerobic Zone 1- With Media[2,3]	245,500 ft^3	4	62 x 45 x 22
Aerobic Zone 2- With Media[2,3]	245,500 ft^3	4	62 x 45 x 22
Aerobic Zone 3- No Media	31,700 ft^3	4	8 x 45 x 22
Final Clarifier		4	125 ft dia

Notes:
[1] Footprint of pre-anoxic tank is within anaerobic tank dimensions
[2] Total media fill is 43%
[3] MLSS = 3,000 mg/L, Effective SRT = 15 days

Figure 3-6 and Figure 3-7 present the proposed IFAS basin footprint and related support facilities for Alternatives 1A and 1B, respectively. As mentioned previously, each vendor proposed only one aerobic media zone. However, based on Black & Veatch experience it was evaluated that two aerobic media zones in series are required to ensure nitrification during high flow events. Two equally sized media zones with a third non media aerobic zone are proposed for Alternatives 1A and 1B.



NOTES:
1. LAYOUT BASED ON COMAG PRIMARY CLARIFICATION
2. COMAG PROCESS AND RECOVERY BUILDING NOT SHOWN
3. 22'SWD IN IFAS BASINS, 12' SWD IN SECONDARY CLARIFIERS
4. 10' SWD IN RE-AERATION BASINS

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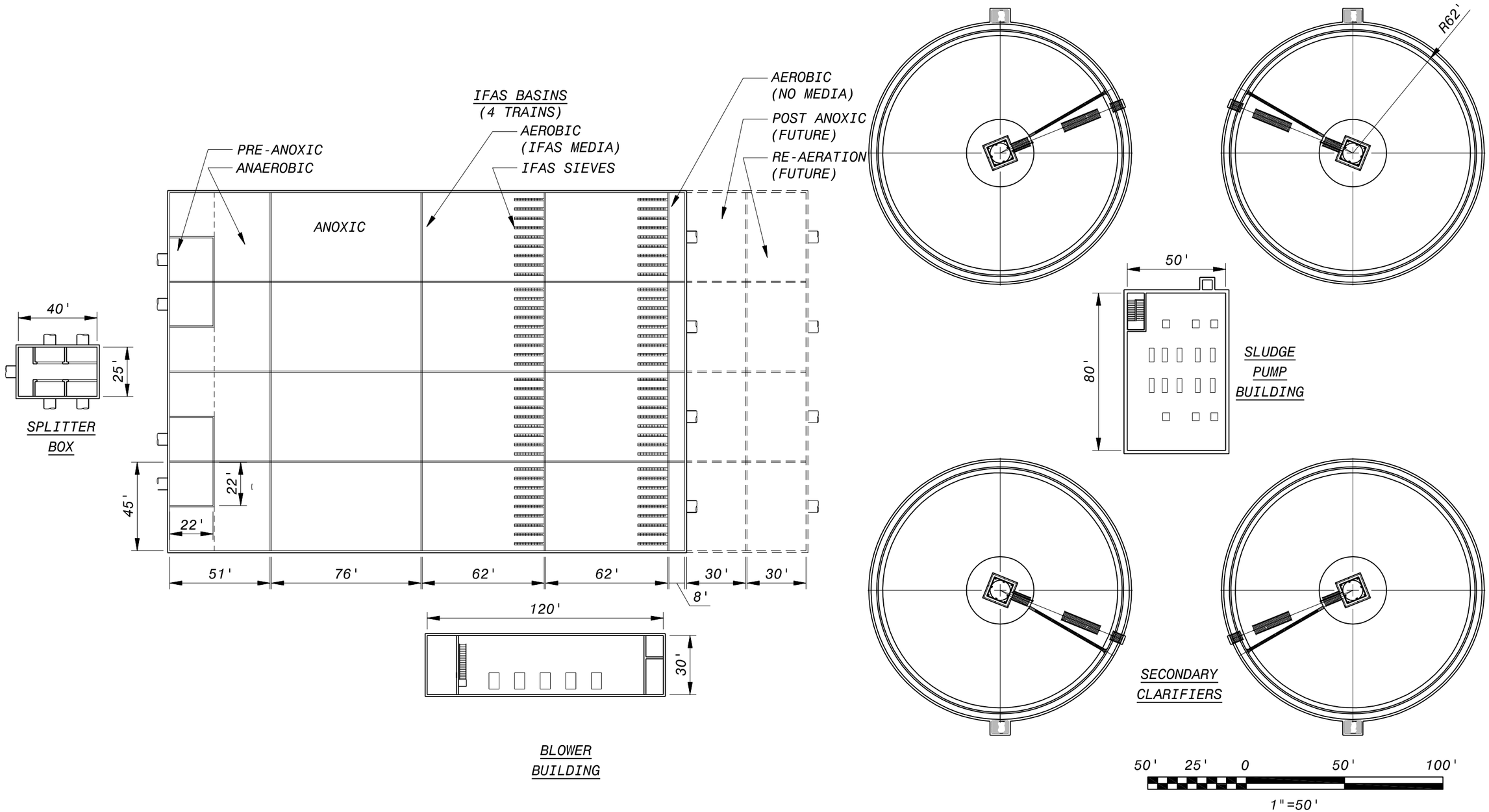
ALT 1A - IFAS (COMAG)
PLAN LAYOUT
FIGURE 3-6

BFIGBORD



NOTES:
1. LAYOUT BASED ON CEPT PRIMARY CLARIFICATION
2. 22'SWD IN IFAS BASINS, 12' SWD IN SECONDARY CLARIFIERS
3. 10' SWD IN RE-AERATION BASINS

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ALT 1B - IFAS (CEPT)
PLAN LAYOUT
FIGURE 3-7

BFIGBORD

3.3 ALTERNATIVE 2 - MBR

3.3.1 Process Discussion

Membrane Bioreactors (MBRs) combine a bioreactor with suspended biomass and solids separation by microfiltration membranes. Membrane nominal pore sizes range from 0.1-0.4 µm.

MBR membranes are installed in aeration basins where the MLSS solids are separated from the treated water. Therefore, with membranes, it is not necessary to rely on gravity separation of solids in secondary clarifiers. Additionally, tertiary filters are not needed with this process since the membranes reduce solids more efficiently than gravity media filters. Diffused aeration equipment is provided in the membrane tank to keep the MLSS aerobic and to provide agitation to clean the membranes. The membrane modules typically include the manufacturer's diffuser design developed specifically for membrane cleaning, and the aeration rate for membrane cleaning is sufficient to meet the demands of the process.

Figure 3-8 shows a hollow fiber membrane assembly and the enclosed MBR basin platform.

Figure 3-8 MBR Basin Platform and Hollow Fiber Membranes

3.3.2 Alternative Schematic, Layout, Footprint, and Hydraulic Considerations

The overall schematic of the MBR secondary treatment process and related facilities is shown in Figure 3-9 and Figure 3-10 based on CoMag and conventional primary clarification, respectively. For Alternative 2A using CoMag, the facility is designed to handle 196 mgd flow, of which up to 38 mgd receives complete biological secondary treatment and 115 mgd flow receives auxiliary wet weather treatment via CoMag primary clarification. The flow in excess of 38 mgd bypasses the secondary treatment and is conveyed to the hypochlorite disinfection process.

For Alternative 2B, influent flow up to 38 mgd receives primary and secondary treatment, while the rest of the flow is processed by auxiliary treatment facilities. As discussed in TM No. 6, enhanced primary clarification is provided to the influent wastewater in excess of 35 mgd by adding polymer and ferric chloride chemicals. If Alternative 2B were selected as the preferred treatment method, further consideration would be made to increase the size of the primary clarifiers to process all 38

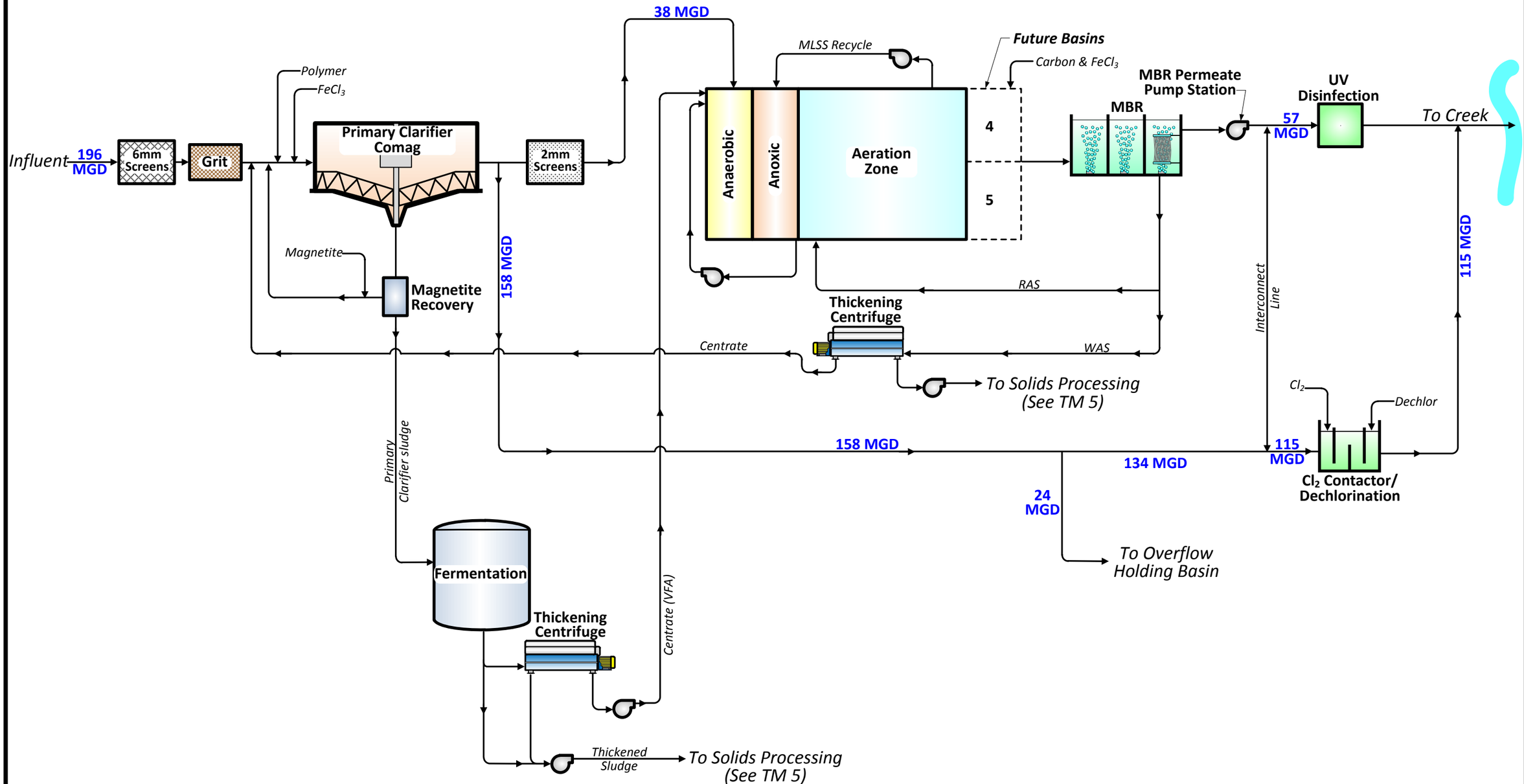
MGD to eliminate upstream chemical addition. Ultraviolet disinfection of the membrane permeate is provided before discharging the treated water to the creek. Auxiliary treated effluent is also disinfected with hypochlorite and bisulfite. Both membrane permeate and auxiliary streams combine downstream of the disinfection processes.

Ahead of the biological treatment train, a separate 2 mm fine screen is provided to screen the wastewater after primary clarification. This fine screen is provided to remove any solids that could clog the downstream membranes. For the three-stage biological process anaerobic, anoxic, and aerobic zone are provided. From the biological basins the wastewater flows into four rectangular tanks with membranes. Permeate is pulled through the membranes by permeate pumps. The internal recycle flows are setup using a UCT (University of Cape Town) arrangement. RAS flows from the membrane tanks, which are high in DO content, and is recycled to the head of the aeration zone. The MLSS recycle to the anoxic zone is taken from the end of the oxic zone where the DO is controlled. As RAS is returned to the oxic zone, a second recycle is provided from the end of the anoxic zone to the anaerobic zone to move MLSS to the head of the anaerobic zone. This arrangement ensures that by the time the RAS reaches the anaerobic zone, it does not contain any DO or nitrate.

The WAS from the membrane tanks is thickened using centrifuges and sent for further treatment. Primary treatment sludge is also used to augment secondary treatment through the use of fermentation. The magnetite from the CoMag primary sludge is recovered before sending the solids to a fermentation process to produce volatile fatty acids (VFA). The VFA-rich centrate is fed to the anaerobic zone of secondary treatment to augment soluble carbon Bio-P. Further details of the biosolids handling facilities are provided in TM No. 5.

Aeration requirements are approximately 15,000 to 20,000 SCFM for the biological basins with an additional 15,000 to 20,000 SCFM for the membrane basins, both sized for maximum month flow. This would suggest 6-8 blowers at a maximum of 5,000 SCFM per blower. The blowers would be enclosed in a blower building similar to Alternative 1, although with a larger footprint, as shown in Figure 3-11 and Figure 3-12.

RAS and WAS sludge pumps, and permeate pumps, will be located adjacent to the MBR basins in an enclosed facility. In total, there will be approximately 9 permeate pumps with two duty pumps per membrane basin and 1 redundant pump; 4 WAS and 4 RAS pumps, each system with one duty and one standby pump per two membrane basins. Due to the use of permeate pumps with MBR, this alternative does not require a tertiary pump station similar to all other alternatives since the pumps can be used to add head to the flow. As such, the MBR secondary treatment alternative will have the lowest headloss of alternatives.



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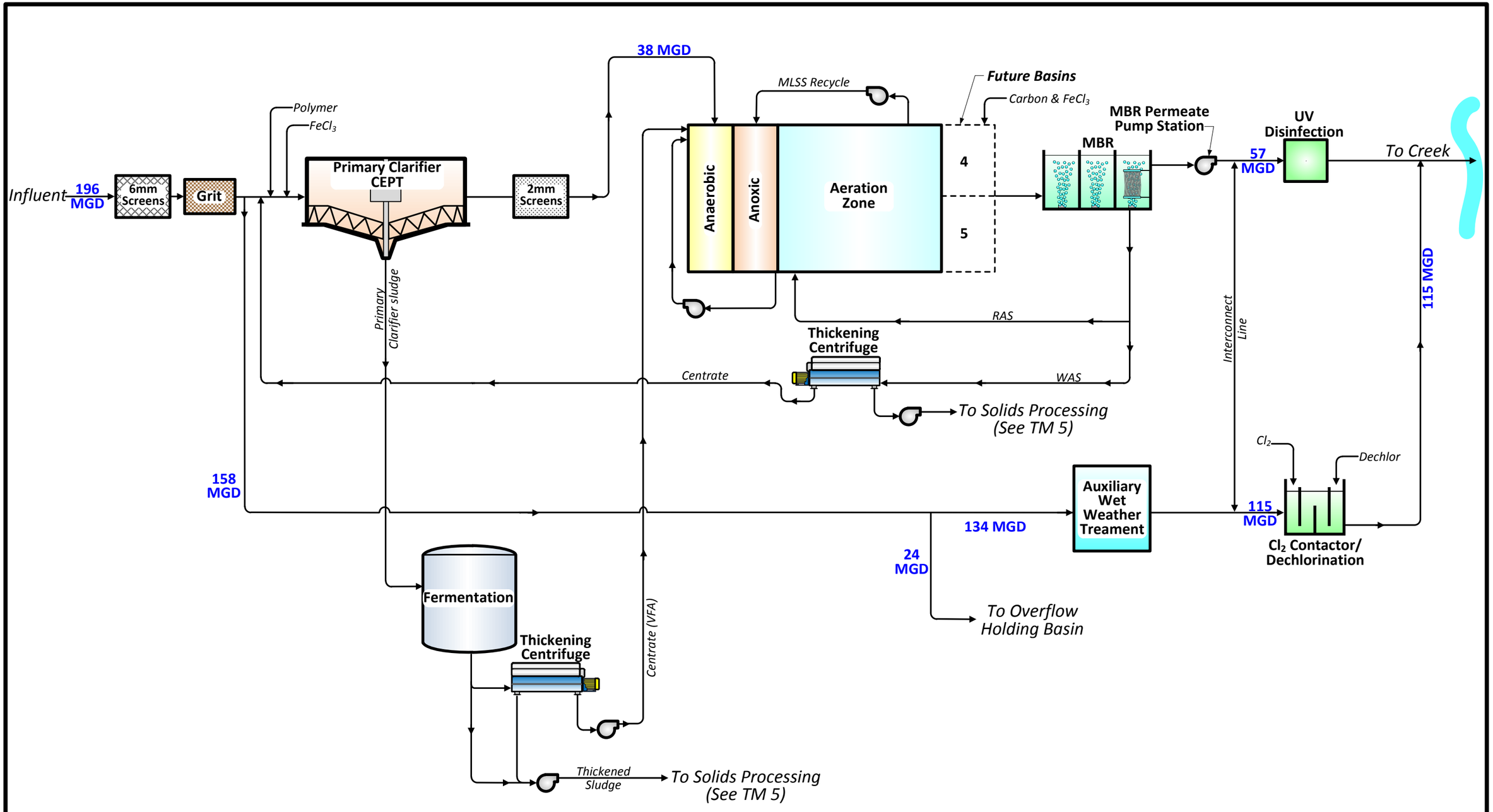
PROJECT DEFINITION PHASE
ALT 2A – MBR (COMAG)
PROCESS FLOW DIAGRAM
FIGURE 3-9



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TOMAHAWK CREEK WWTP
PROJECT DEFINITION PHASE
ALT 2B – MBR (CONV PC)
PROCESS FLOW DIAGRAM
FIGURE 3-10

3.3.2.1 Black & Veatch Design

A plug-flow secondary treatment facility with anaerobic, anoxic and aerobic zones was designed using a limiting MLSS concentration of 8,000 mg/L. The tank sizes are also limited by a maximum oxygen uptake rate of 120 mg/L/hr in the various passes of the plug-flow reactor. The MLSS concentration in the aerobic zone is restricted to 6,000 mg/L under maximum month conditions because of the limiting oxygen uptake rate criterion.

Table 3-6 presents the equipment criteria applicable to Alternatives 2A and 2B.

Table 3-6 MBR Equipment Criteria

SECONDARY TREATMENT ZONES	DESIGN CRITERIA	ALTERNATIVE 2A FACILITY SIZING (COMAG)	ALTERNATIVE 2B FACILITY SIZING (CONVENTIONAL)
Anaerobic Zone	Hydraulic Retention Time= 60 min	159,800 ft^3	159,800 ft^3
Anoxic Zone	25-35% of the combine anoxic and oxic tank volume; Hydraulic Retention Time= 60-90 min	150,075 ft^3	300,000 ft^3
Aerobic Zone	MLSS= 8,000-10,000 mg/L, SRT= 15 days	300,000 ft^3	412,540 ft^3
Aeration Requirements		40,000 SCFM	40,000 SCFM

The membrane design for the MBR tanks was not estimated in the Black & Veatch design. The vendor design for membranes was evaluated and used for Alternative 2.

3.3.2.2 Vendor Design

Three different MBR vendors, GE, Kubota and Ovivo, were contacted to provide preliminary facility sizing for Alternatives 2A and 2B at the Tomahawk Creek WWTP. The design criteria provided by them is consolidated and presented in Table 3-7. The volumes of biological basins provided by the vendors are unique to their systems. As such, each is different and therefore an average value is selected and presented in Table 3-7.

Table 3-7 MBR Vendor Design Criteria

SECONDARY TREATMENT ZONES	ALTERNATIVE 2A FACILITY SIZING (COMAG)	ALTERNATIVE 2B FACILITY SIZING (CONVENTIONAL)
Anaerobic Zone	123,000 ft^3	210,000 ft^3
Anoxic Zone	239,000 ft^3	374,300 ft^3
Aerobic Zone[1]	290,000 ft^3	508,000 ft^3
MBR tanks	193,000 ft^3	193,000 ft^3

Notes:
[1] MLSS= 8,000-10,000 mg/L, SRT= 13-15 days

The information provided in Table 3-8 and Table 3-9 were used to determine the final design volumes for the MBR alternative. This is discussed in the following section.

3.3.2.3 Proposed Design

Table 3-8 and Table 3-9 present the proposed basin volumes that were used for further cost analyses for Alternatives 2A and 2B, respectively. The volume of the anaerobic zone in the proposed design is approximately 30% larger than the vendor design. Based on Black & Veatch experience it was recommended that the anaerobic zone volume be increased to have at least 1-hr HRT at maximum month flow rate to ensure good biological phosphorus removal. Although an average of the three MBR tank designs provided by the vendors is presented in Table 3-7, it was proposed to use the maximum of the three volumes, to incorporate conservatism in the design.

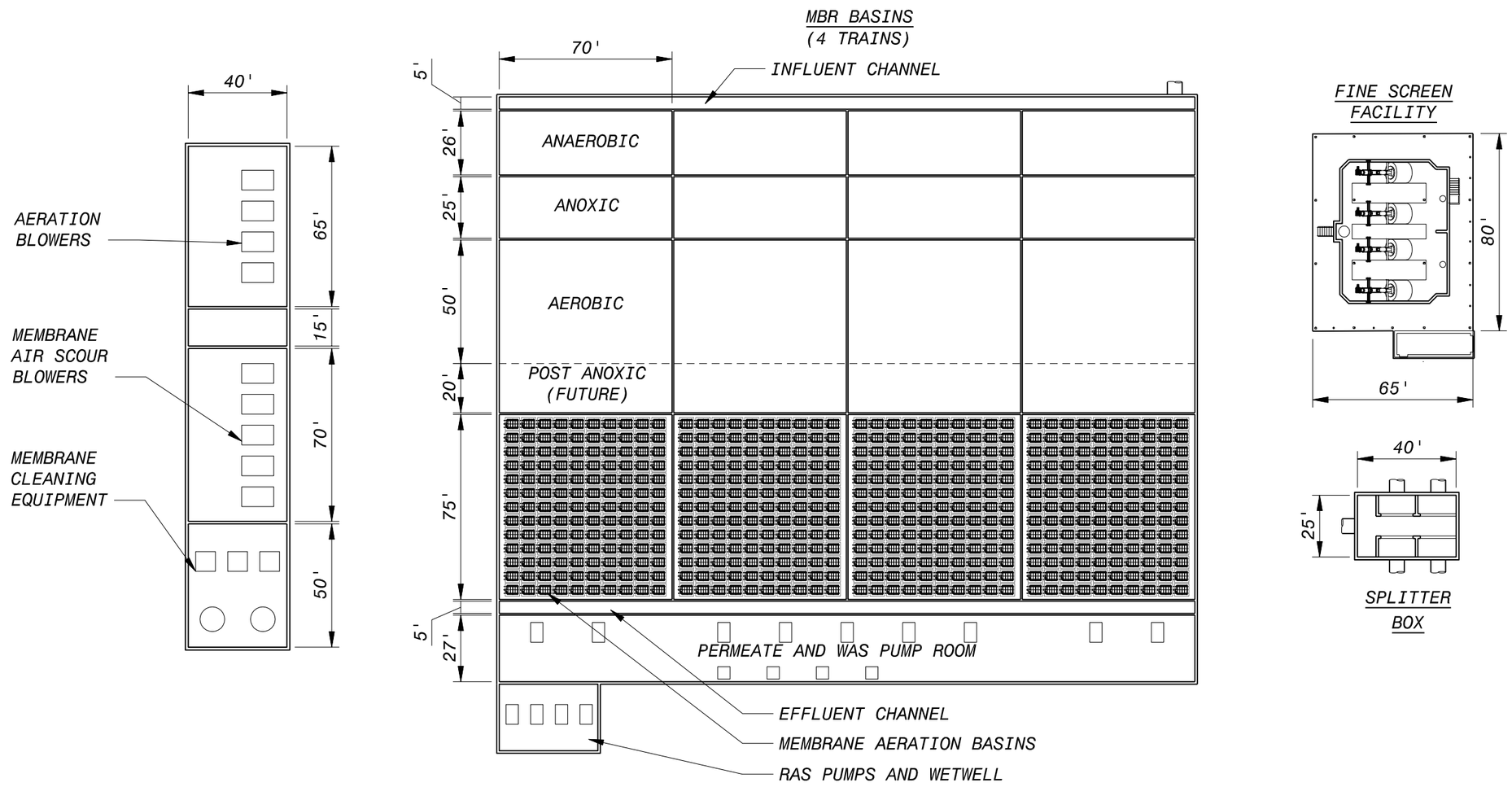
Table 3-8 Proposed Alternative 2A Design – MBR with CoMag PC

SECONDARY TREATMENT ZONES	TOTAL FACILITY SIZING	NUMBER OF UNITS	DIMENSIONS (LxWxD, FT)
Anaerobic Zone	160,200 ft^3	4	26 x 70 x 22
Anoxic Zone	154,000 ft^3	4	25 x 70 x 22
Aerobic Zone	308,000 ft^3	4	50 x 70 x 22
Membrane Tank	252,000 ft^3	4	75 x 70 x 12

Table 3-9 Proposed Alternative 2B Design – MBR with Conventional PC

SECONDARY TREATMENT ZONES	TOTAL FACILITY SIZING	NUMBER OF UNITS	DIMENSIONS (LxWxD, FT)
Anaerobic Zone	160,200 ft^3	4	26 x 70 x 22
Anoxic Zone	301,840 ft^3	4	49 x 70 x 22
Aerobic Zone	412,720 ft^3	4	67 x 70 x 22
Membrane Tank	252,000 ft^3	4	75 x 70 x 12

Figure 3-11 and Figure 3-12 present the proposed MBR tank footprint for Alternatives 2A and 2B, respectively. The proposed design has four MBR trains with the same three stage facility design as described in earlier sections. The proposed aerobic zone would require an additional 20 feet length to accommodate a post-anoxic zone for future stricter effluent limits.



NOTES:
1. LAYOUT BASED ON COMAG PRIMARY CLARIFICATION
2. COMAG PROCESS AND RECOVERY BUILDING NOT SHOWN
3. FINE SCREEN FACILITIES INCLUDES 2mm ROTARY DRUM SCREENS
4. 22' SWD IN BIOLOGICAL BASINS, 12' SWD IN MEMBRANE BASINS
5. FINE SCREEN FACILITY AND PUMP ROOM ARE COVERED

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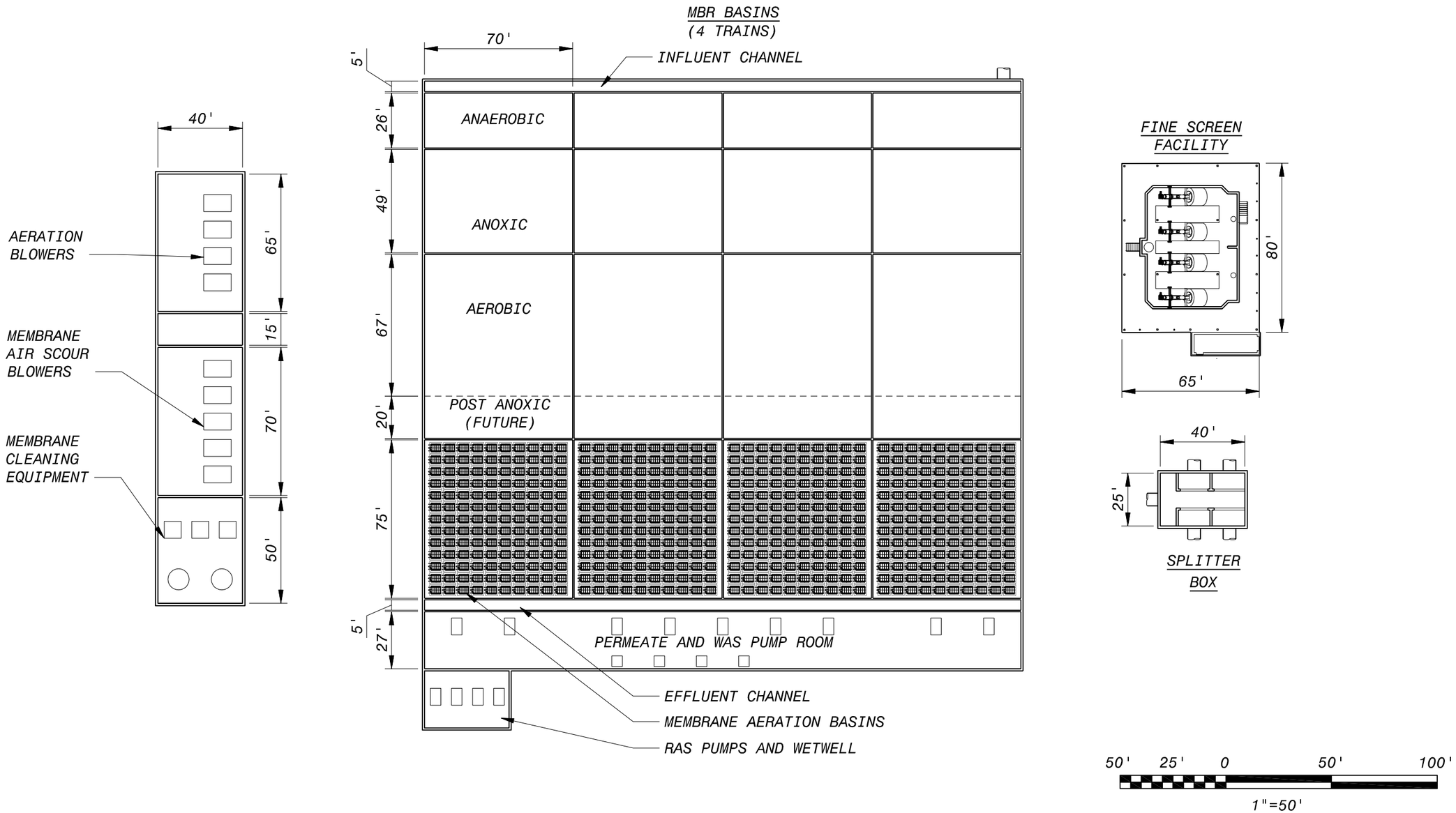
ALT 2A - MBR (COMAG)
PLAN LAYOUT
FIGURE 3-11

BFIGBORD



NOTES:
1. LAYOUT BASED ON CONVENTIONAL PRIMARY CLARIFICATION
2. FINE SCREEN FACILITIES INCLUDES 2mm ROTARY DRUM SCREENS
3. 22' SWD IN BIOLOGICAL BASINS, 12' SWD IN MEMBRANE BASINS
4. FINE SCREEN FACILITY AND PUMP ROOM ARE COVERED

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ALT 2B - MBR (CONV PC)
PLAN LAYOUT
FIGURE 3-12

BFIGBORD

A 2 mm fine screen is necessary upstream of the MLE tanks to remove rags and debris that might interfere with the normal operation of the MBR membranes. For the purposes of this TM a rotary drum screening facility with 3 screens plus 1 standby screen, each sized for 13 mgd, or a total of 39 mgd capacity, is assumed.

Figure 3-13 and Figure 3-14 show a plan and profile of a rotary drum screening facility that would be anticipated for this alternative. The facility would have separate dumpsters for disposal of screening debris from the headworks screening facility discussed in TM No. 5.

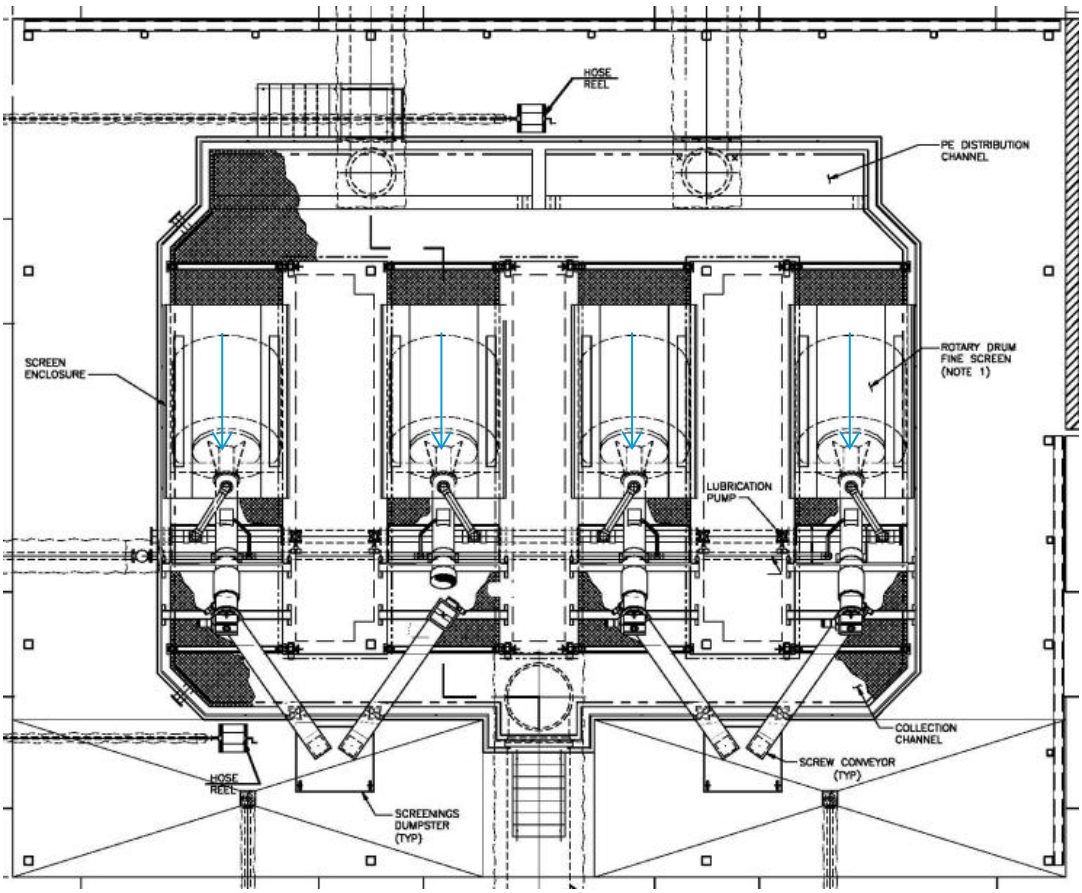


Figure 3-13 MBR Fine Screening Facility Plan

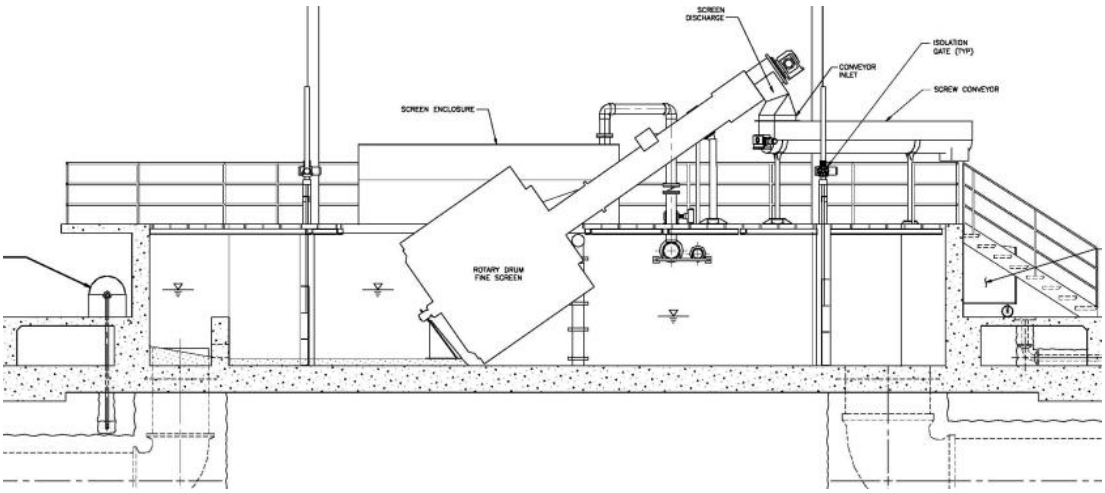


Figure 3-14 MBR Fine Screening Facility Profile

3.4 ALTERNATIVE 3 - BIOMAG

3.4.1 Process Discussion

BioMag is a proprietary enhanced ballasted biological wastewater treatment process that uses magnetite to increase the specific gravity of biological floc. Magnetite is an inert, high specific gravity (SG=5.2), non-abrasive iron ore (Fe_3O_4) with strong affinity for biological solids, which provides the opportunity for attachment of the magnetite to the MLSS to increase the operating mixed liquor concentration, while maintaining adequate settling and thickening in the secondary clarifiers. Magnetite is recovered from the waste activated sludge using a high rate shear mixer and magnetic drum separator.

The final clarifiers for the BioMag alternative can be designed for a significantly higher SLR because of the higher specific gravity of the magnetite. The reported SLR is not for the total MLSS concentration. The 90 ppd/ft^2 SLR is based upon only the biological component of the combined MLSS. As a result, for the same size final clarifier, the BioMag alternative can treat approximately three times more flow because of the higher settling rate of MLSS. The BioMag process is graphically shown in Figure 3-15 and Figure 3-16.

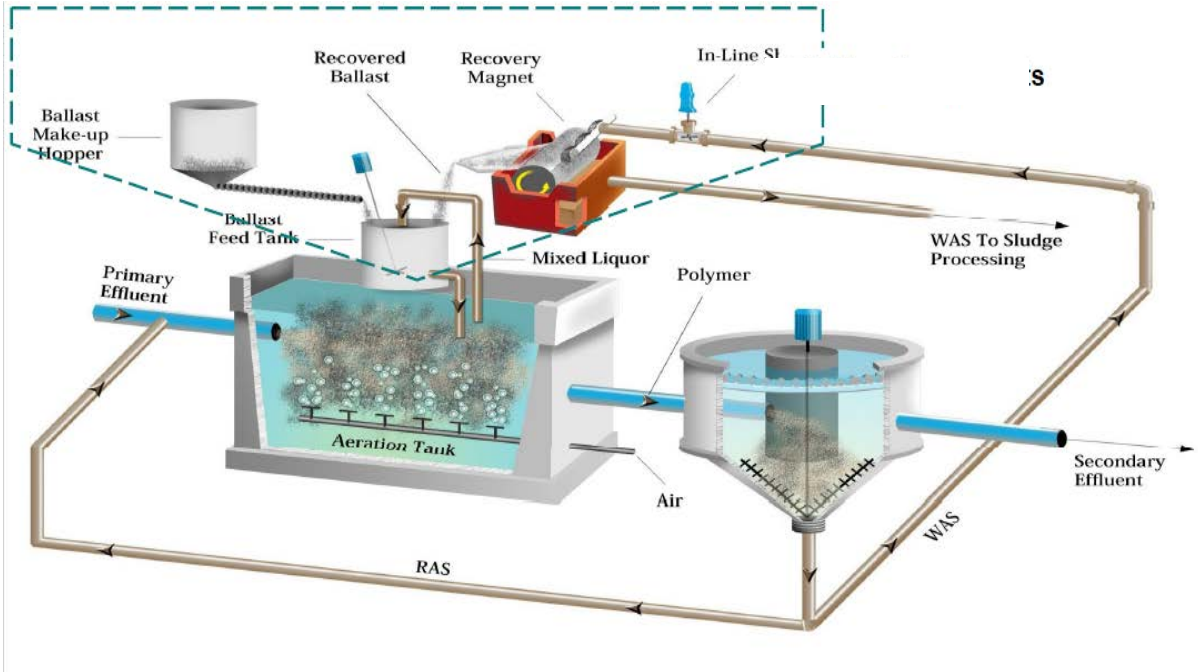
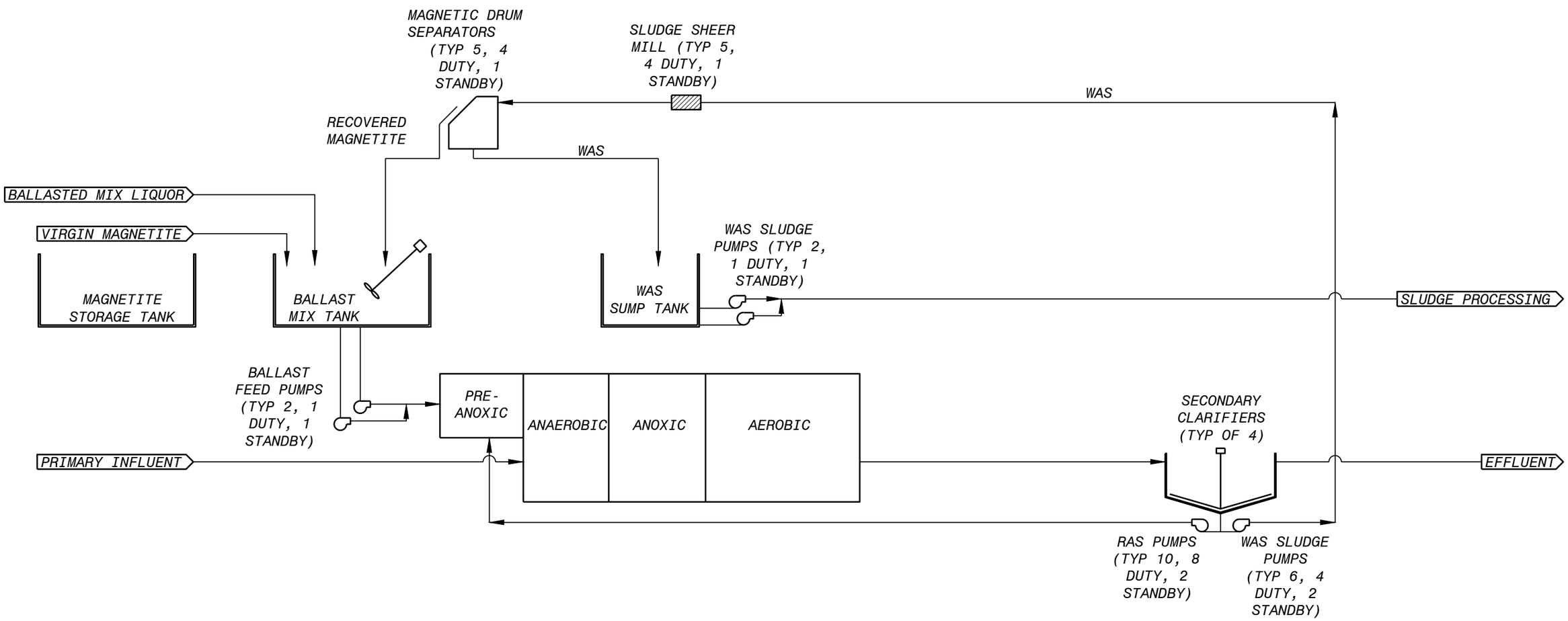


Figure 3-15 BioMag Process

Table 3-10 is a select listing of the largest BioMag municipal installations in the United States. In total, there are 18 facilities. All existing BioMag facilities are located in the Appalachia region nearest magnetite sources. The application at Tomahawk would have approximately three times greater average and peak flows than the largest installed facility.



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BIOMAG
MAGNETITE PROCESS FLOW DIAGRAM
FIGURE 3-16

BFIGBORD
FBFIGBORD

Table 3-10 BioMag Facilities

PROJECT	AVERAGE FLOW (MGD)	PEAK FLOW (MGD)
Conococheague, MD WWTP	6.6	16.3
East Norriton-Plymouth, PA WWTP	5.1	12.0
Front Royal, WA WWTP	5.8	16.9
Marlay Taylor, MD WWTP	6.0	20.0
Marlborough Easterly, MA WWTP	5.5	21.4
Upper Gwynedd, PA WWTP	5.7	12.0

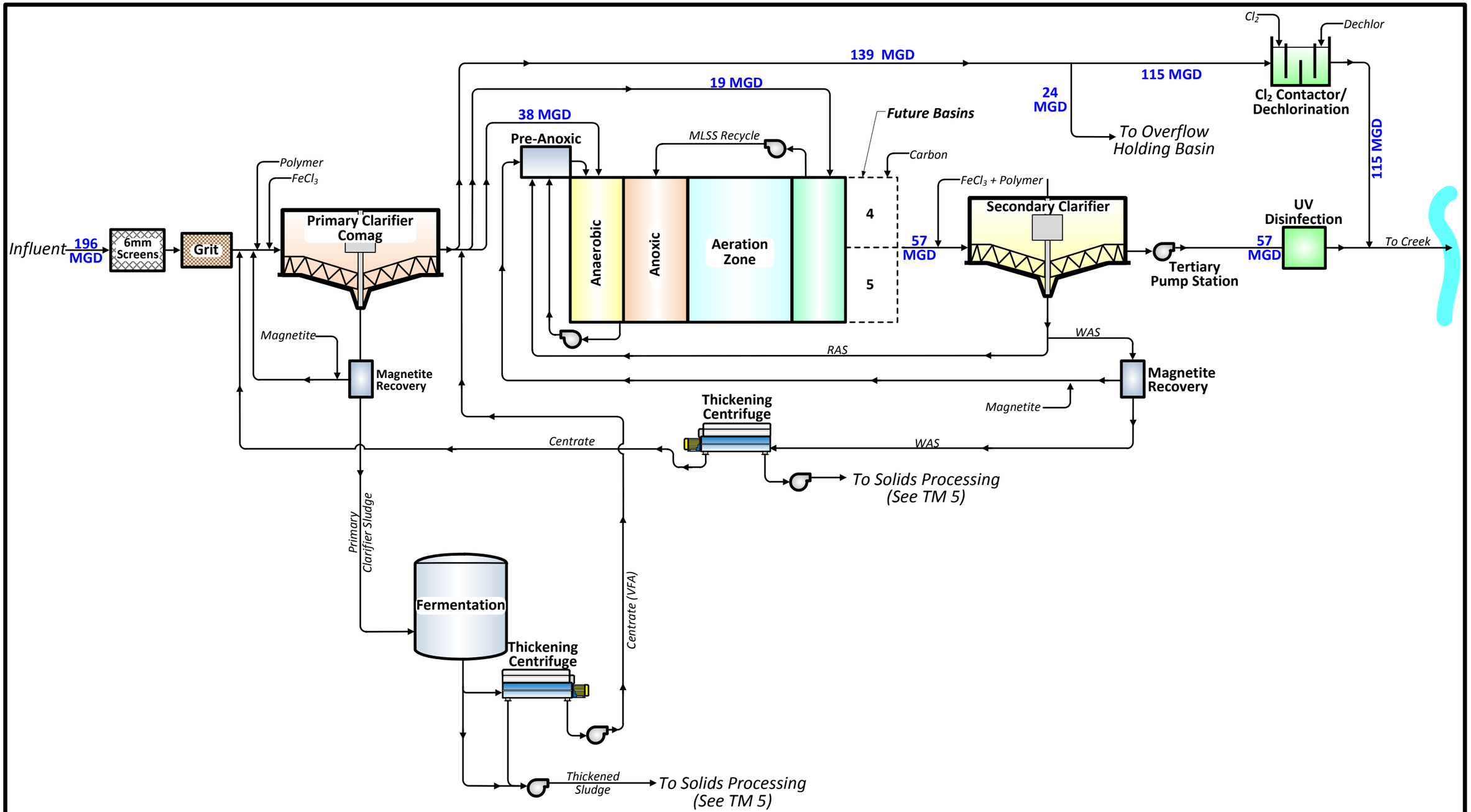
Magnetite is an abundant mineral in the United States as a byproduct of mining operations. The preferred magnetite supplier for Evoqua has facilities located in West Virginia and Indiana. Magnetite would need to be delivered from these locations in 25-ton trucks similar to that shown in Figure 3-17.

Figure 3-17 Magnetite 25-ton Truck Delivery

3.4.2 Alternative Schematic, Layout, Footprint, and Hydraulic Considerations

The overall schematic of the BioMag secondary treatment process and related facilities is shown in Figure 3-18 and Figure 3-19 based on Alternatives 3A and 3B, respectively. The facility is designed to treat 196 mgd of total flow. Although the BioMag tanks can handle higher flows, it was restricted to 57 mgd to be consistent with the other alternatives. For Alternative 3A, additional flow over 57 mgd receives wet weather treatment processing using CoMag primary clarification.

For Alternative 3B, influent flow up to 57 mgd receives primary and secondary treatment, while the 115 mgd flow is processed by auxiliary treatment facilities. Enhanced primary clarification is provided to the influent wastewater in excess of 35 mgd by adding polymer and ferric chloride chemicals. The secondary effluent is disinfected using ultraviolet disinfection process and is blended with the chlorine disinfected auxiliary treatment effluent.



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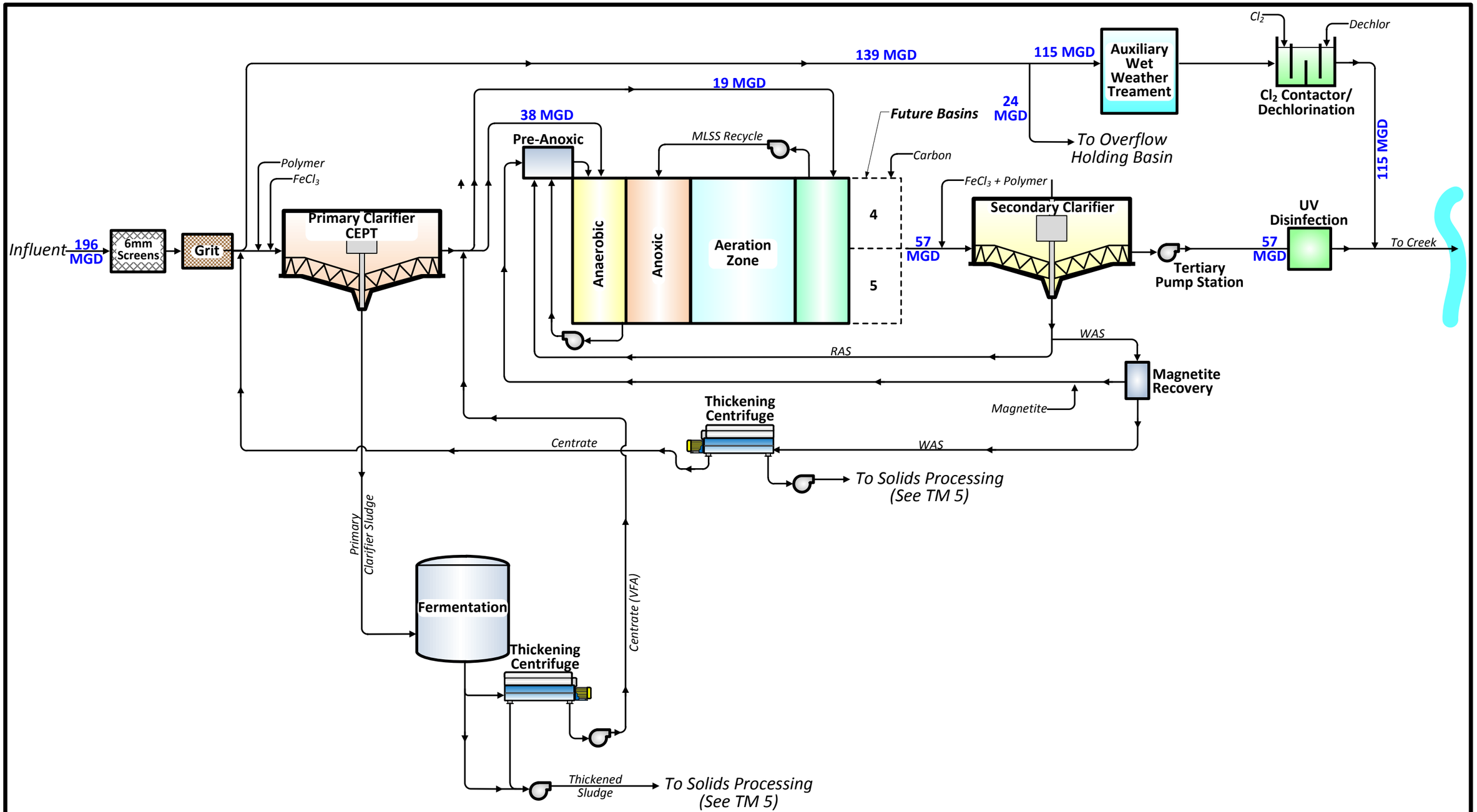
PROJECT DEFINITION PHASE
ALT 3A – BIOMAG (COMAG)
PROCESS FLOW DIAGRAM
FIGURE 3-18



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PROJECT DEFINITION PHASE
ALT 3B – BIOMAG (CEPT)
PROCESS FLOW DIAGRAM
FIGURE 3-19

The biological system is designed to be a three-stage MLE arrangement with anaerobic, anoxic and aerobic tanks. The facility has a provision for a five-stage arrangement for future denitrification requirements. In the future, the fourth-stage post anoxic zone, would be supplemented with an additional carbon source to help with denitrification.

From the biological basins, the MLSS flows into four circular clarifiers. RAS is pumped from the clarifiers to the anaerobic basin via a pre-anoxic zone. The magnetite is recovered from WAS and the WAS is thickened using centrifuges and sent for further treatment. The magnetite from the CoMag primary sludge is recovered before sending the solids to a fermentation process to produce VFA. This additional step would not be required for conventional primary clarification. The primary sludge produced in Alternative 3B would be sent directly to a fermenter to produce VFA. The VFA-rich centrate is fed to the anaerobic zone of secondary treatment to augment Bio-P. Further details of the biosolids handling facilities are provided in TM No. 5.

Alternative 3 would not include a tertiary filter after secondary treatment as the BioMag process is capable of producing an effluent with a very low concentration of suspended solids.

The vendor quote for this alternative was obtained from Evoqua Water Technologies. The basin volumes provided by the vendor were compared to the design by Black & Veatch and are presented in Table 3-11 and Table 3-12 for Alternatives 3A and 3B, respectively.

Table 3-11 Alternative 3A Design Comparison - BioMag with CoMag PC

SECONDARY TREATMENT ZONES	BLACK & VEATCH DESIGN	EVOQUA DESIGN
Pre-Anoxic Zone	42,600 ft^3	-
Anaerobic Zone[1]	159,800 ft^3	158,400 ft^3
Anoxic Zone	150,075 ft^3	44,000 ft^3
Aerobic Zone 1[1]	300,000 ft^3	140,360 ft^3
Aerobic Zone 2[1]		140,360 ft^3
Final Clarifier	4- 125 feet dia	-

Notes:
[1] Black & Veatch Design assumes one zone of plug-flow aerobic zone

The Black & Veatch design assumes only one zone of aerobic volume configured in a plug flow arrangement, while the Evoqua design assumes two equal sized aerobic tanks. Both the designs were evaluated further and a final design was proposed as described in the following section.

The Evoqua anoxic zone volume is less than the anaerobic zone volume, with a hydraulic retention time of less than 20 minutes. This small anoxic zone is likely due to an assumption of simultaneous nitrification-denitrification (SND) happening within the BioMag floc particle based on their experience at operating facilities. However, absent historical data supporting this claim as a newer technology, it is suggested that the more conservative Black & Veatch volumes be used with no credit for SND within the floc particle. Further discussions with Evoqua would need to occur to evaluate the available data regarding the additional SND credit to consider reduced basin volumes.

Table 3-12 Alternative 3B Design Comparison - BioMag with Conventional PC

SECONDARY TREATMENT ZONES	BLACK & VEATCH DESIGN	EVOQUA DESIGN
Pre-Anoxic Zone	42,600 ft^3	-
Anaerobic Zone[1]	159,800 ft^3	123,200 ft^3
Anoxic Zone	300,000 ft^3	133,364 ft^3
Aerobic Zone 1[1]	412,540 ft^3	266,728 ft^3
Aerobic Zone 2[1]		
Final Clarifier	4-125 ft dia	-

Notes:
[1] Black & Veatch Design assumes one zone of plug-flow aerobic zone

The main components provided by Evoqua include the proprietary technology to deliver and recover the magnetite from the treatment process. Most other treatment components are similar to an IFAS process, excluding the media. Table 3-13 lists the equipment that would be contained in the magnetite recovery building.

Table 3-13 Magnetite Recovery Building Components

EQUIPMENT	QUANTITY	CRITERIA
Magnetic drum separator	4 duty + 1 standby	7.5 HP
Ballast Feed Pumps	1 duty + 1 standby	7.5 HP
Magnetite Silo	1	25-ton
WAS Disposal Pump	1 duty + 1 standby	5 HP
Shear Mill	4 duty + 1 standby	40 HP
Ballast Feed Mix Tank & Mixer	1	-
Magnetite Feed Compressor	1 duty + 1 standby	10 HP

The magnetite use ratio in the BioMag process is 1 pound of magnetite per 1 pound waste of activated sludge (WAS). Assuming a 95 percent magnetite recovery rate, the process is estimated to use approximately 1,000 pounds per day, or 120 tons per year. Therefore, each 25-ton silo shipment would last for approximately 40-60 days.

As graphically shown in Figure 3-15, recovered WAS from the secondary clarifiers is pumped to the magnetite recovery building and is separated from the sludge in the magnetic drum separator. The drum separates the magnetite and sludge for separate processing. Recovered magnetite is added to the ballast mix tank and new magnetite is added as needed from the storage silo. The magnetite is mixed with existing mixed liquor before being pumped to the beginning of the secondary treatment process. It is at the drum separator where the loss of magnetite occurs in sludge sent for biosolids processing.

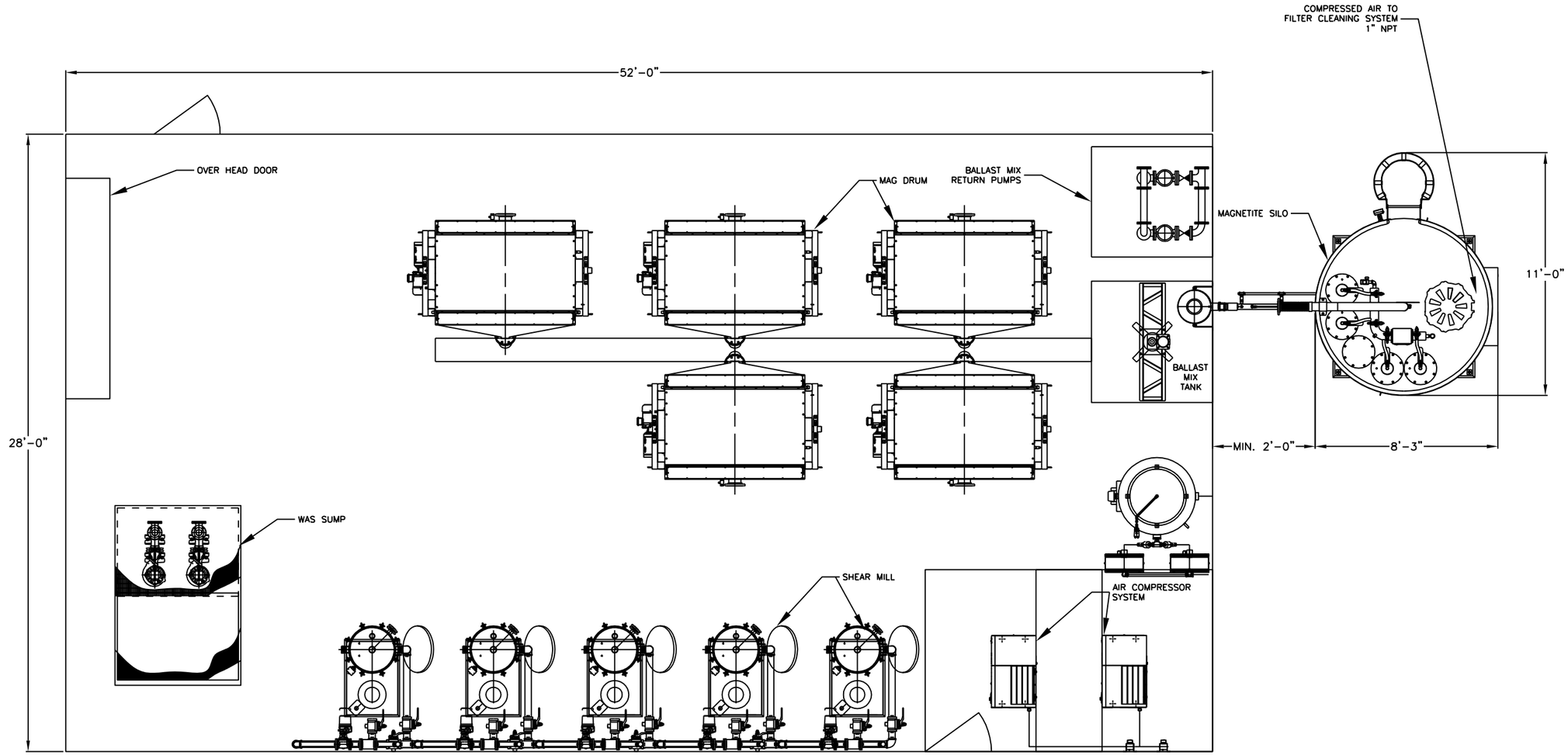
Figure 3-20 shows images of a typical shear mill and magnetic drum separator at the 3 mgd ADF Upper Gwynedd Township WWTF in Pennsylvania.

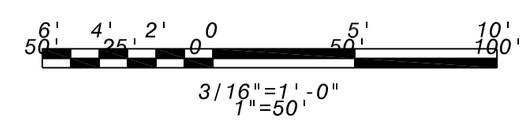
Figure 3-20 Magnetite Shear Mill and Magnetic Drum Separator

Figure 3-21 shows the proposed layout for the magnetite recovery building at Tomahawk. This building is in addition to an aeration blower building similar to Alternative 1. The aeration requirements for BioMag would be similar to those in Alternative 1. Biological basin mixing requirements for BioMag will be greater than for IFAS or MBR due to the increased specific gravity of the MLSS.

The sludge pump requirements for this alternative will be similar to the IFAS alternative. Two RAS pump and one WAS pump per clarifier would be provided with one redundant pump of each type per two clarifiers. For Tomahawk this would equal 10 RAS pumps and 6 RAS pumps in total.

The hydraulic profile for this alternative will be similar to the IFAS alternative. The absence of media sieve equipment will provide a marginal savings in headloss. This alternative will require the installation of a tertiary pump station after the secondary clarifiers.





NOTES:
1. LAYOUT BASED ON COMAG PRIMARY CLARIFICATION
2. COMAG PROCESS AND RECOVERY BUILDING NOT SHOWN
3. 22' SWD IN BNR BASINS EXCEPT FOR 10' SWD IN RE-AERATION ZONE
4. 12' SWD IN SECONDARY CLARIFIERS

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BIOMAG
MAGNETITE RECOVERY BUILDING
FIGURE 3-21

BFIGBORD

3.4.2.1 Proposed Design

Figure 3-22 and Figure 3-23 present the proposed footprint for the BioMag alternative based on CoMag and conventional primary clarification, respectively. The design presents a four train arrangement of the biological tanks. Table 3-14 and Table 3-15 summarize the volumes and dimensions for the different zones based on CoMag and conventional primary clarification, respectively.

Table 3-14 Proposed Alternative 3A BioMag Design – CoMag PC

SECONDARY TREATMENT ZONES	FACILITY SIZING	NUMBER OF UNITS	DIMENSIONS (LXWXD, FT)
Pre-Anoxic Zone[1]	42,600 ft^3	4	22 x 22 x 22
Anaerobic Zone	159,400 ft^3	4	51 x 45x 22
Anoxic Zone	150,500 ft^3	4	38 x 45 x 22
Aerobic Zone	150,500 ft^3	4	38 x 45 x 22
Aerobic Zone	150,500 ft^3	4	38 x 45 x 22
Final Clarifier		4	125

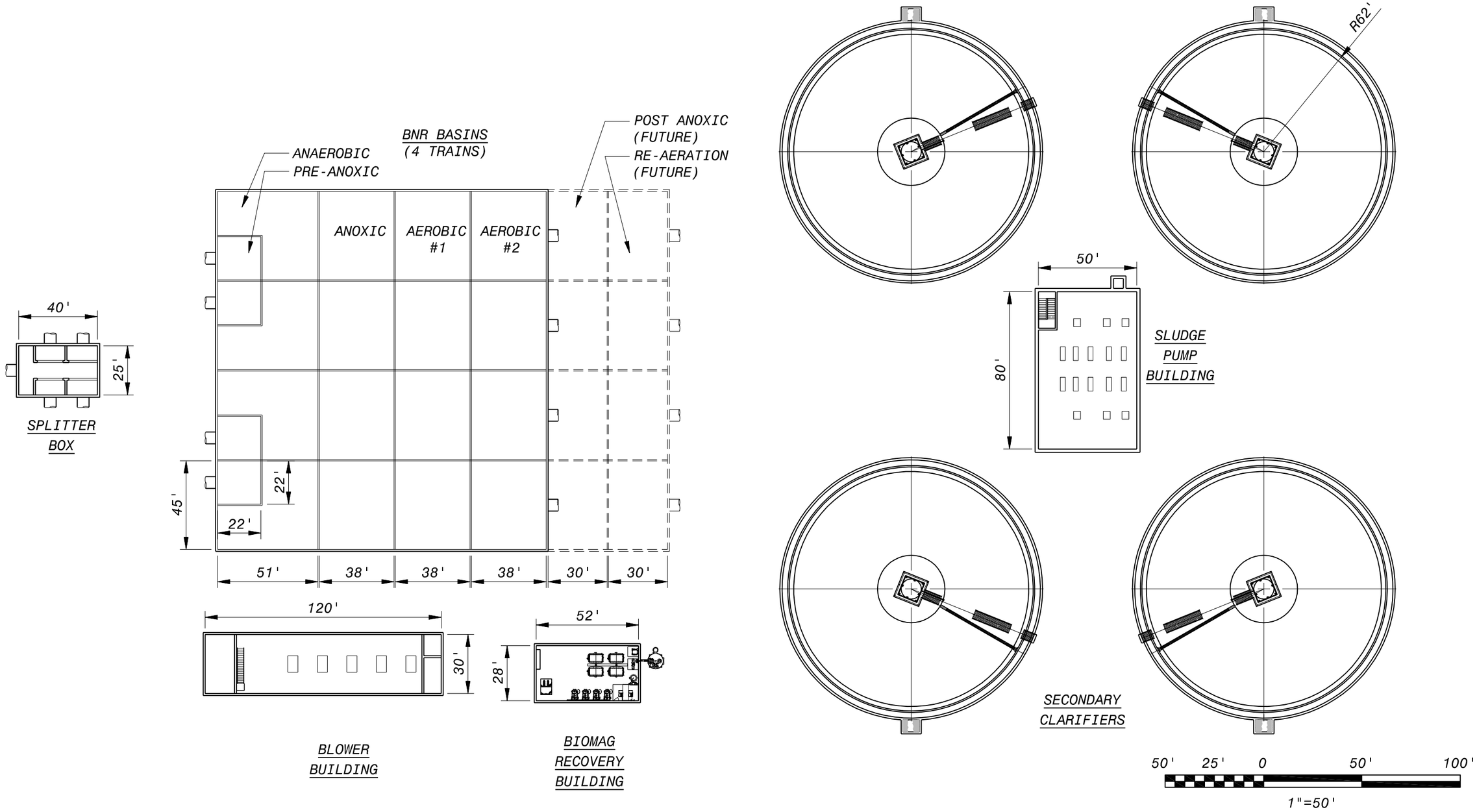
Notes:
[1] Footprint of pre-anoxic tank is within anaerobic tank dimensions

Table 3-15 Proposed Alternative 3B BioMag Design – Conventional PC

SECONDARY TREATMENT ZONES	FACILITY SIZING	NUMBER OF UNITS	DIMENSIONS (LXWXD, FT)
Pre-Anoxic Zone[1]	42,600 ft^3	4	22 x 22 x 22
Anaerobic Zone	159,400 ft^3	4	51 x 45x 22
Anoxic Zone	300,960 ft^3	4	76 x 45 x 22
Aerobic Zone	205,920 ft^3	4	52 x 45 x 22
Aerobic Zone	205,920 ft^3	4	52 x 45 x 22
Final Clarifier		4	125

Notes:
[1] Footprint of pre-anoxic tank is within anaerobic tank dimensions

Although the Black & Veatch design presents one aerobic zone with a plug flow arrangement, it was decided to use the vendor design with two aerobic zones in series.



NOTES:
1. LAYOUT BASED ON COMAG PRIMARY CLARIFICATION
2. COMAG PROCESS AND RECOVERY BUILDING NOT SHOWN
3. 22' SWD IN BNR BASINS EXCEPT FOR 10' SWD IN RE-AERATION ZONE
4. 12' SWD IN SECONDARY CLARIFIERS

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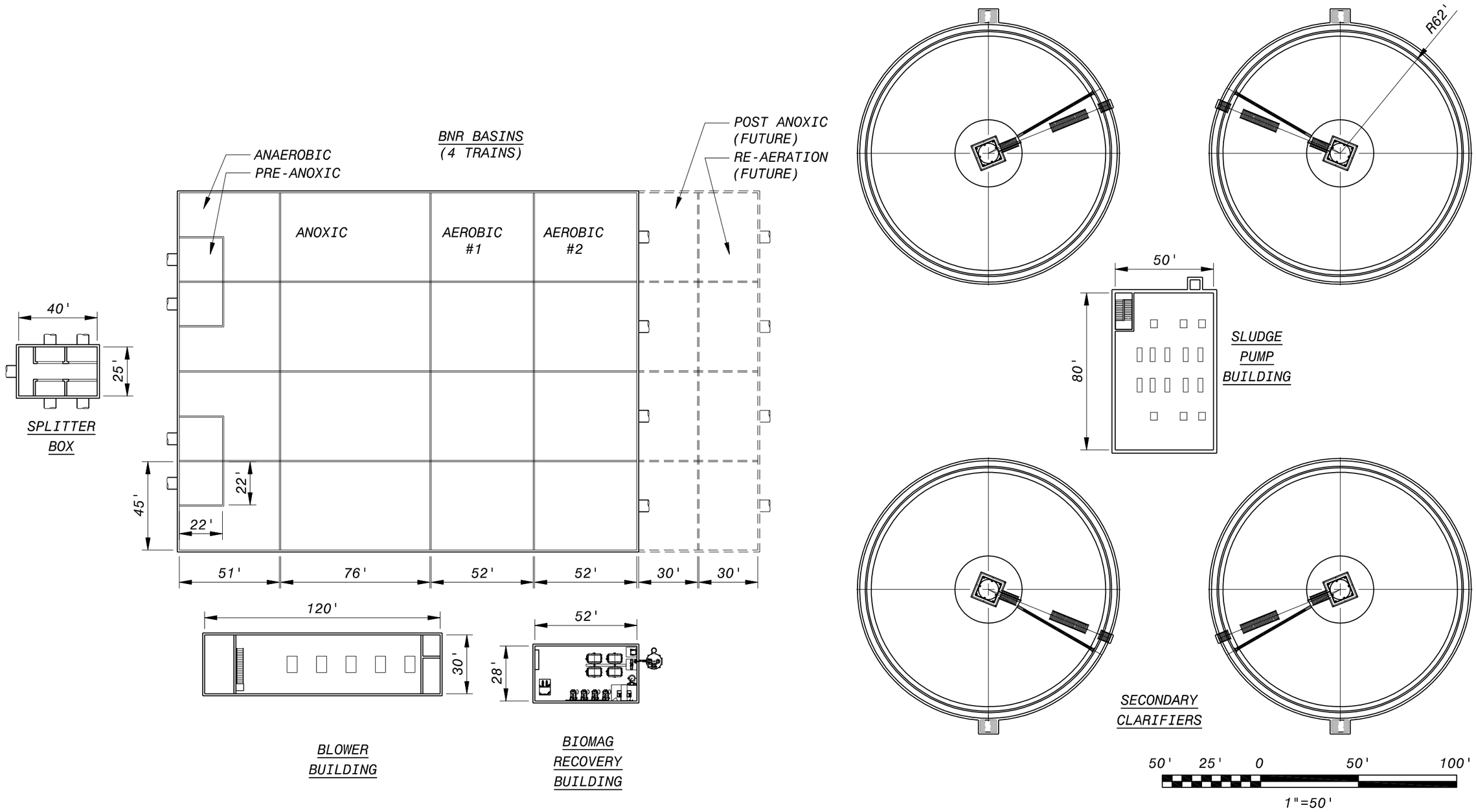
ALT 3A - BIOMAG (COMAG)
PLAN LAYOUT
FIGURE 3-22

BFIGBORD



NOTES:
1. LAYOUT BASED ON CEPT PRIMARY CLARIFICATION
2. 22' SWD IN BNR BASINS EXCEPT FOR 10' SWD IN RE-AERATION ZONE
3. 12' SWD IN SECONDARY CLARIFIERS

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ALT 3B - BIOMAG (CEPT)
PLAN LAYOUT
FIGURE 3-23

BFIGBORD

3.5 ALTERNATIVE 4 – GRANULAR ACTIVATED SLUDGE (GAS)

3.5.1 Process Discussion

Granular Activated Sludge (GAS) is a process whereby granules form due to cell to cell interaction without the help of any solid media. The concept of aerobic granular sludge is used in a system called Nereda® in which granules are formed in sequencing batch reactors (SBR) allowing a high degree of simultaneous nitrification-denitrification and effective phosphorus removal. The external layer of the granules is exposed to oxygen and supports nitrifying bacteria and the inner anoxic/anaerobic layer is home to the denitrifying bacteria. Simultaneous carbon, nitrogen, and phosphorus removal is possible with the diverse biomass. The system provided by Nereda® can treat more than 95 percent of the influent BOD and TSS load and can achieve effluent TN and TP limits of 8 mg/L and 1 mg/L with additional tertiary filtration.

The GAS process has been in development for approximately 20 years with initial installations for industrial applications. Only within the past 5 years has the process been used for municipal applications. At the time of this TM, no GAS facilities have been installed or piloted in the United States. The majority of installations are in the Netherlands, South Africa and Portugal, with planned facilities in Australia, Brazil and other locations. Table 3-16 provides a listing of current Nereda® GAS facilities.

Black & Veatch has visited several full scale granular sludge processes including the Gansbaai facility in South Africa and both the Epe WWTP and Garmerwolde WWTP in the Netherlands. The data reported to Black & Veatch staff indicates that good denitrification and Bio-P performance is possible to the levels required for this project.

Table 3-16 Nereda® Facilities

PROJECT	AVERAGE FLOW (MGD)	PEAK FLOW (MGD)	DATE OF COMPLETION
Vika, Netherlands	0.1	0.1	2004
Gansbaai, South Africa	0.7	1.9	2008
Fano, Netherlands	0.1	0.2	2009
Epe, Netherlands	2.1	9.5	2011
Freilas, Portugal	0.7	2.0	2012
Garmerwolde, Netherlands	5.2	26.6	2013
Dixperio, Netherlands	0.8	4.6	2013
Vroomshoop, Netherlands	0.7	8.0	2013
Wemmershoek, South Africa	1.4	-	2015
Ryki, Netherlands	1.8	-	2014
Utrecht, Netherlands	18.0	95.1	2016

Figure 3-24 provides the close-up view of the granules at the Garmerwolde Municipal WWTP in the Netherlands.

Figure 3-24 Granules Formed at Garmerwolde WWTP

The facility has a smaller footprint than other BNR technologies as it is designed to handle a higher MLSS concentration. As such, the system does not require primary clarification. The system can handle a MLSS of around 15,000-25,000 mg/L, with a typical design of around 8,000 mg/L. As the granules settle much faster than conventional activated sludge the process can be operated as a sequencing batch reactor and therefore, does not require separate tanks for final clarification.

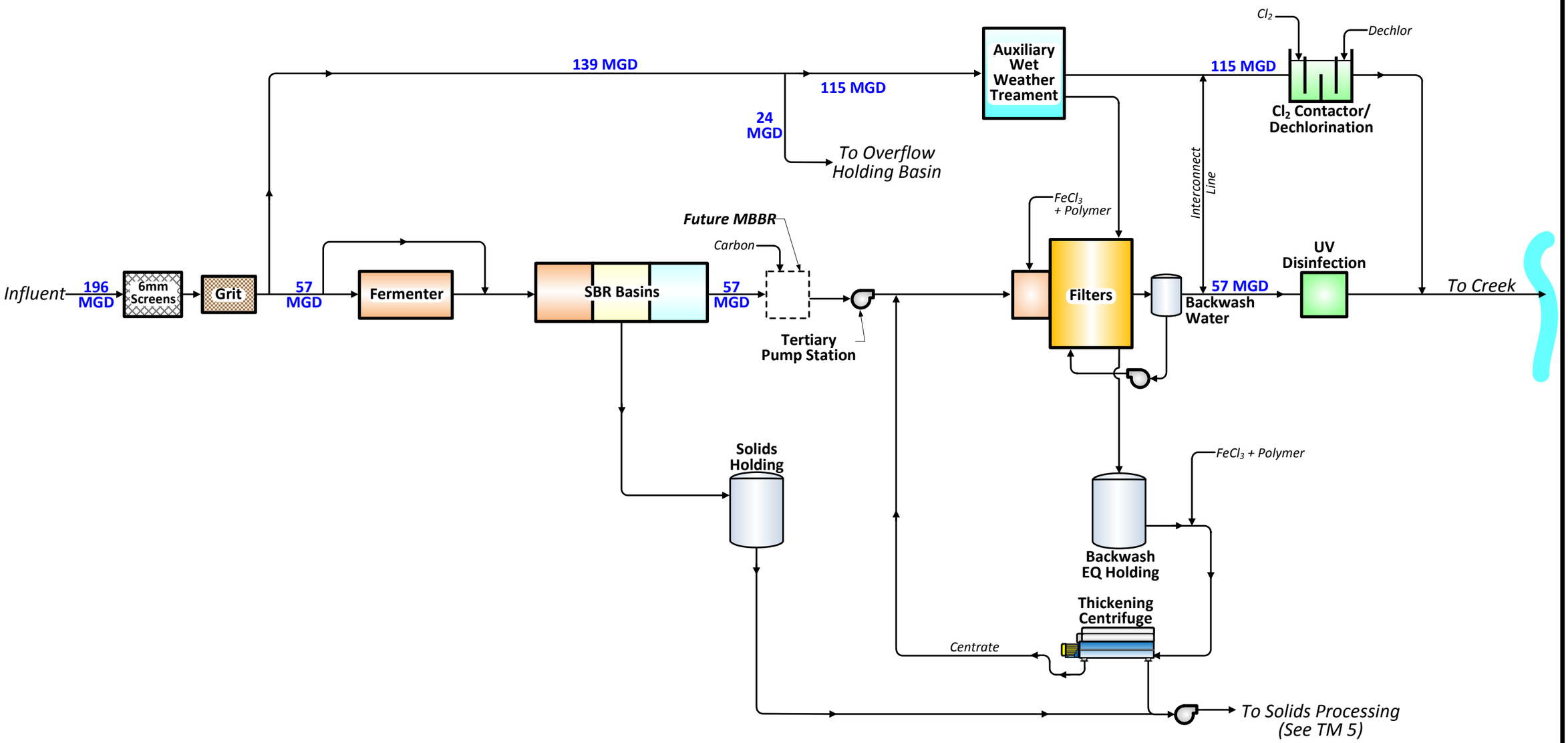
3.5.2 Alternative Schematic, Layout, Footprint, and Hydraulic Considerations

The overall schematic of the GAS secondary treatment process and related facilities is shown in Figure 3-25. The facility is designed to handle 196 mgd flow with 57 mgd receiving biological treatment and 115 mgd receiving auxiliary wet weather treatment.

After preliminary treatment, the dry weather component of the wastewater flows into a fermenter to produce VFAs to enable biological phosphorus removal. The use of a fermenter is need-based and the wastewater can bypass it to flow directly into the biological tanks.

The biological process consists of SBR basins operated in parallel. The tanks operate on a "lag-timer" where one tank is being filled while the others are either being settled or are being decanted. There are no recycles in the SBR arrangement and the solids are wasted from the system at the end of the settling cycle. Conditions within the SBR are manipulated to stimulate denitrification and Bio-P. The solids that are wasted from the system are stored in a solids storage tank for further thickening. The overflow from the SBR tanks flow to tertiary filters, where there is a provision to add ferric chloride as a backup for biological phosphorus removal. The effluent from the filters is disinfected with UV and blended with wet weather flows, which will be disinfected using hypochlorite, before discharging to the creek.

Table 3-17 presents the equipment criteria applicable to Alternative 4. The fermenter volume is based on Black & Veatch design while the SBR basin design is provided by Nereda®. Provisions are made to include a moving bed bioreactor (MBBR) basin followed by a clarifier to handle the future lower effluent TN limits.



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ALT 4 – GRANULAR ACTIVATED SLUDGE
PROCESS FLOW DIAGRAM
FIGURE 3-25

Table 3-17 GAS Design Criteria

SECONDARY TREATMENT ZONES	ALTERNATIVE 4 FACILITY SIZING	DIMENSIONS (LxWXD, FT)
Fermenter[1]	317,520 ft^3	126 x 126 x 20
SBR Basins[2]	1,587,000 ft^3	115 x 115 x 20
Aeration Requirements	20,000 SCFM	-
MLSS Concentration	8,000 mg/L	-

Notes:
[1] Three equal-sized parallel tanks
[2] Six equal-sized tanks

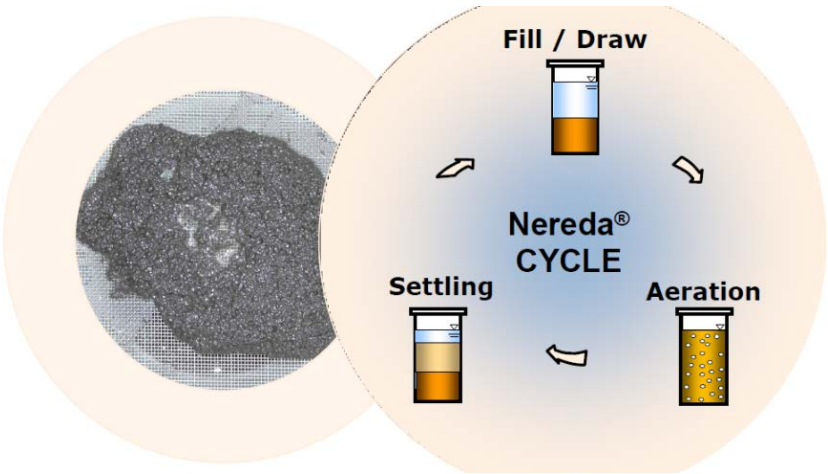
The fermenter volume is divided into three equal volumes operated in parallel with two mixers in each tank. The fermenter operates on a "lag-timer" concept as presented in Table 3-18. Each cycle step interval is set for 30 minutes of mixing once a day. This provides the flexibility to adjust the step interval based on the VFA requirements by the biological process. For instance, if the process needs more VFAs, then the mixing frequency can be changed to once every two days. The mixing period is essentially the sludge wasting time. Heavy solids will settle and accumulate. Mixing will suspend solids and the duration of mixing will control how many of the solids are flushed out of the process. Only one fermenter zone will be mixed at a time. If not much VFA is needed, a portion of the influent flow can bypass the fermenter system. Mixing frequency and duration is adjustable to meet the plant fermentation needs.

Table 3-18 Fermenter Operation

	TYPICAL CYCLE STEP INTERVAL = 30 MINUTES (MIN) MIXING ONCE A DAY		
	Midnight-8AM	8AM- 4PM	4PM - Midnight
Zone 1			30 min Mix
Zone 2	30 min Mix		
Zone 3		30 min Mix	

Note:
For a long SRT in the fermenter, the mixing would not necessarily occur every day or the duration of mixing would be shortened to retain solids longer in the fermenter.

A similar cycle step is setup for the SBR tanks. This arrangement provided by Nereda® is presented in Figure 3-26. A total of 6 SBR tanks are provided. SBR operation will be staggered and rotate through three SBR tanks operated in parallel. In essence the six SBR tanks are arranged and operated as three trains of two independent SBR tanks.



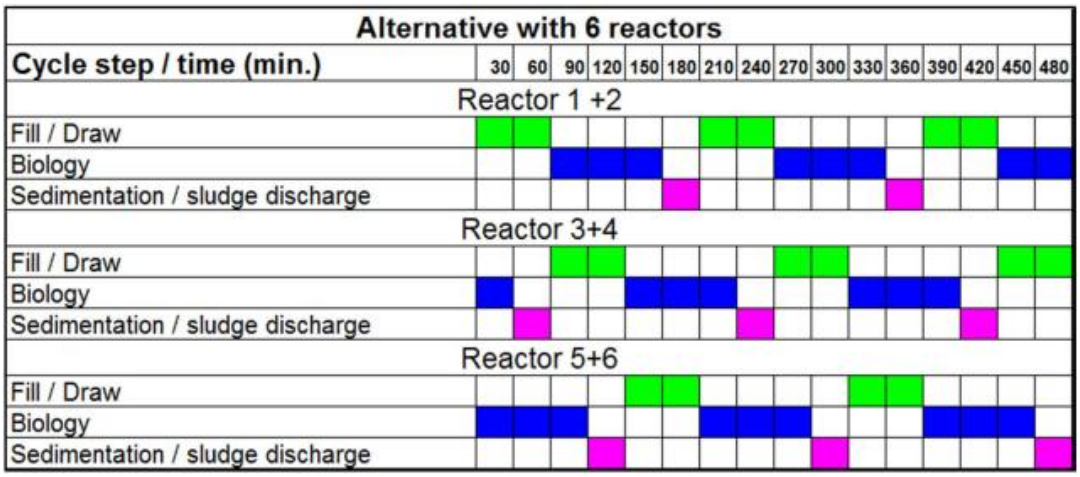


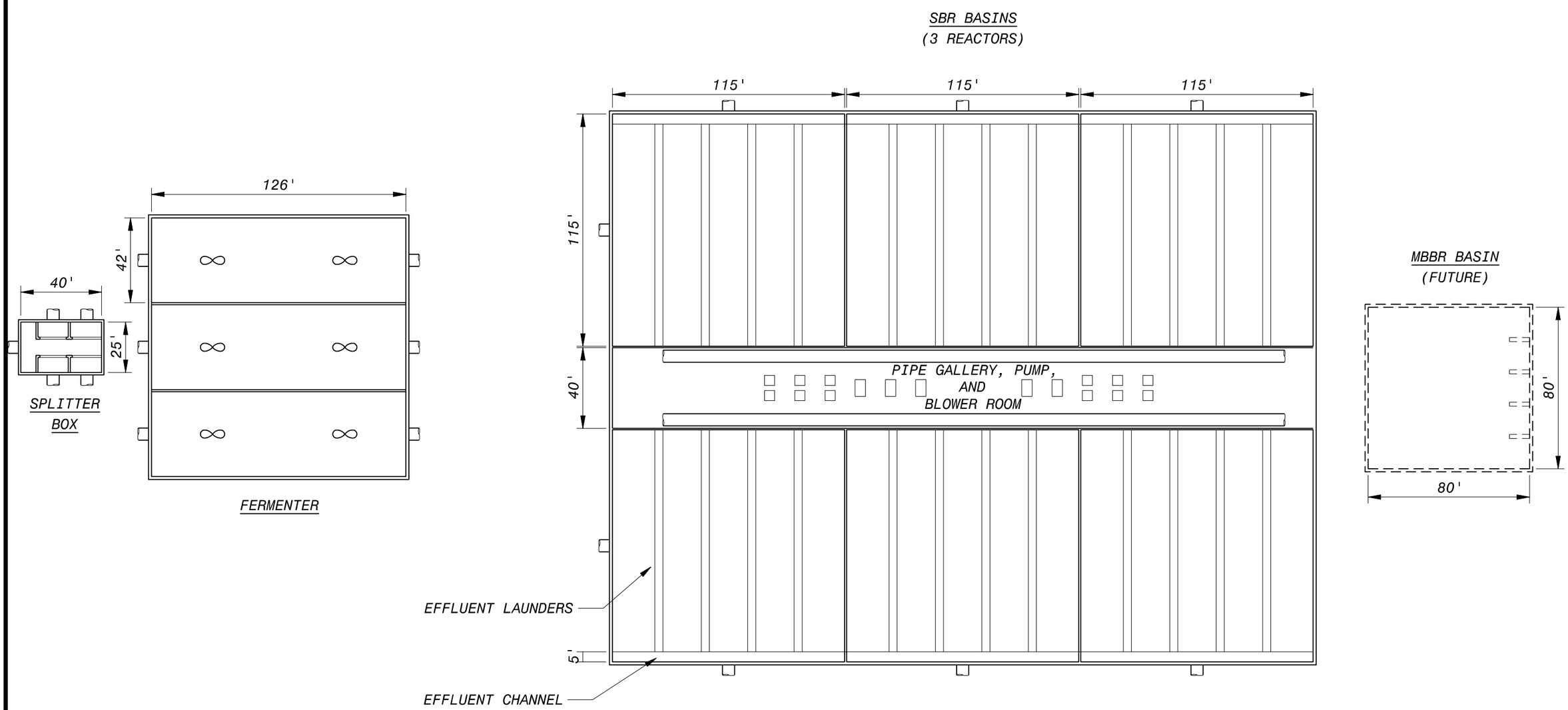
Figure 3-26 GAS Cycle Steps

The vendor quote for this alternative was obtained from Royal HaskoningDHV, based in the Netherlands. The components provided by Royal HaskoningDHV as part of Nereda® include the proprietary process controller, performance testing, and start-up services.

Aeration requirements for Alternative 4 are similar to the other alternatives at approximately 15,000 to 20,000 SCFM sized for maximum month flow. To maximize site utilization, the aeration blowers for this alternative could be enclosed in a blower building between the GAS basins as shown in Figure 3-27.

The sludge pump requirements for this alternative will be modified from other alternatives. The Nereda® process requires sludge recirculation within each basin. One recirculation pump and one WAS pump per two SBR tanks would be provided with one redundant pump of each type per two SBR tanks. For Tomahawk, this would equal 6 recirculation pumps and 6 WAS pumps in total.

The hydraulic profile for this alternative will have fewer process basins to introduce headloss. However, due to site topography constraints this alternative will still require the installation of a tertiary pump station after the biological basins.



50' 25' 0 50' 100'

1"=50'

JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTP
PROJECT DEFINITION PHASE

ALT 4 - GAS
PLAN LAYOUT
FIGURE 3-27

NOTES:
1. FERMENTER SIZED FOR 90 MIN. LIQUID RETENTION TIME AND IS A COVERED FACILITY
2. PIPE GALLERY AND BLOWER ROOM ARE ENCLOSED
3. 20' SWD IN GAS BASINS
4. GAS BASIN SIZING IS FOR 57 MGD

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BFIGBORD

3.5.3 Pilot Testing Summary Report

A bench-scale pilot study was conducted from October 6, 2014 through April 22, 2015 to evaluate the feasibility of a granular activated sludge (GAS), or also known as aerobic granular sludge (AGS), process as an alternative technology at Tomahawk. The pilot study was conducted in conjunction with Professor Belinda Sturm of the University of Kansas. The pilot test demonstrated that the wastewater characteristics at the Tomahawk WWTF are suitable for treatment using an Aerobic Granular Sludge process. The pilot testing overcame initial concerns that bacteria lack the ability to granulate in the low strength wastewater at Tomahawk as compared to the Dutch experience with higher strength wastewater. The granulation rate (initial formation of granules) was found to be lower than expected for the low strength wastewater, which extended the startup phase of the pilot. Sufficient size and number of granules, based on literature and recommendations from Professor Sturm, were achieved in approximately 4 months. Once the level of granulation was satisfactory the granules were found to be stable and the process robust.

The BNR performance results showed very high rates of nitrification were developed with the granules; however total nitrogen and phosphorous removal were limited because of the lack of DO control. The total inorganic nitrogen (TIN) and orthophosphate removal can be improved through better DO control, which could not be achieved given the nature of the bench scale reactor configuration and required operation.

The complete Aerobic Granular Sludge pilot testing report is located in Appendix C.

4 Cost Analysis

Conceptual capital cost, O&M cost and a life-cycle cost analysis were developed for each of the secondary treatment alternatives. Capital costs for structures were estimated based on per square foot or per cubic foot costs derived from historical data for similar structures and escalated to current value. Additionally, costs for excavation, concrete, metals, piping and equipment were developed using estimated quantities derived from the conceptual footprints with unit cost values and equipment quantities and costs from suppliers and historical project data. The expected cost for deep foundations was developed based on providing a similar foundation to existing buildings on site applied on a per square foot basis. Applicable costs for primary treatment, tertiary and wet weather filtration, and the tertiary pump station between secondary and tertiary treatment were implemented from costs developed in Technical Memorandum No. 6.

Equipment costs were based on supplier quotations with installation of equipment projected at an applicable percent of the equipment cost. Except for the proprietary BioMag and GAS alternatives, equipment costs for both the IFAS and MBR alternatives were provided by multiple suppliers. Process piping and valves, as well as other miscellaneous non-building items were estimated on a per square foot or lump sum basis, as applicable.

4.1 CAPITAL COST

The estimated comparative capital cost for each secondary alternative based on CoMag and conventional primary clarification is presented in Table 4-1. A breakdown of capital costs for each alternative is presented in Appendix B. Capital cost estimates presented are planning-level estimates and do not include planning or pre-design costs. All capital cost estimates include estimates for construction, engineering, legal, administration, and construction management. The cost estimates are intended to be used to differentiate between the relative alternatives and are not intended to replace a comprehensive cost analysis.

Table 4-1 Primary, Secondary, and Tertiary Treatment Comparative Capital Costs

	ALTERNATIVE A CAPITAL COST BASED ON COMAG PC	ALTERNATIVE B CAPITAL COST BASED ON CONVENTIONAL PC
Alternative 1 – IFAS	$117,300,000	$141,700,000
Alternative 2 – MBR	$133,800,000	$168,500,000
Alternative 3 – BIOMAG	$100,800,000	$131,600,000
Alternative 4 – GAS	$128,100,000	

4.1.1 Incremental Operations and Maintenance (O&M) Costs

A 20-year relative life-cycle cost analysis was conducted for each alternative based on CoMag and conventional primary clarification as shown in Table 4-2 and Table 4-3. The relative cost analysis performed for each alternative factored in equipment replacement, capital outlays, and O&M costs. O&M costs were included for structures and processes unique to alternatives with applicable costs developed as part of Tech Memo No. 6 for primary treatment and TM No. 4 for tertiary treatment. Additionally, it is assumed that annual maintenance costs on typical biological basin equipment

(valves, piping, aeration equipment, and pumps) would be common among alternatives and are not included in the evaluation. Labor costs are assumed to be common among alternatives and are not included. A breakdown of costs for each alternative is presented in Appendix B.

Secondary treatment conceptual O&M cost estimates mainly include electrical usage, chemical usage, and magnetite replacement costs over the 20-year period. Electricity costs were developed using equipment and aeration information received from suppliers and past project data. Chemical costs for secondary treatment were assumed to be common among alternatives and were not considered. Magnetite replacement costs were developed from dosages and estimated recovery rates provided by Evoqua and estimated solids production from TM No. 5. O&M costs specific to only the secondary treatment are shown in Table 4-2. Combined O&M costs for each alternative are shown in Table 4-3. Unit costs used in the evaluation are based on the criteria presented in TM No. 4. Just as for capital costs, the O&M costs are based on treating an average 19 mgd flow throughout the 20-year period.

Table 4-2 Relative Secondary Treatment Annual O&M Costs

	ALTERNATIVE A ANNUAL O&M COST BASED ON COMAG PC	ALTERNATIVE B ANNUAL O&M COST BASED ON CONVENTIONAL PC
Alternative 1 – IFAS	$560,000	$650,000
Alternative 2 – MBR	$1,426,000	$1,526,000
Alternative 3 – BIOMAG	$935,000	$1,138,000
Alternative 4 – GAS	$560,000	

Table 4-3 Combined Relative Primary, Secondary, and Tertiary Treatment Annual O&M Costs

	ALTERNATIVE A ANNUAL O&M COST BASED ON COMAG PC	ALTERNATIVE B ANNUAL O&M COST BASED ON CONVENTIONAL PC
Alternative 1 – IFAS	$979,000	$834,000
Alternative 2 – MBR	$1,864,000	$1,786,000
Alternative 3 – BIOMAG	$1,300,000	$1,322,000
Alternative 4 – GAS	$681,000	

The comparison of relative O&M costs reveals that MBR and BioMag require much more operational consideration than IFAS or GAS. BioMag generally requires more energy than a similar BNR-type process like IFAS because of the increased mixing energy to keep the heavy mixed liquor in suspension and the energy requirement to operate the magnetite recovery building. BioMag also requires periodic replacement of magnetite due to losses in the WAS. Aeration requirements for IFAS, BioMag, and GAS would be roughly similar, while MBR requires excess aeration to scour the membranes.

4.1.2 Net Present Value (NPV)

The conceptual capital cost opinion was developed as a 20-year net present value (NPV) which includes the effects of inflation, time-value of money, timing of capital outlay, equipment replacement, and remaining value at the end of the planning period.

A breakdown of the life cycle cost analysis is contained in Appendix B. All NPV estimates are based on the following:

- Cost year basis: 2015.
- Mid-point of construction: 2020.
- First year of plant operation: 2021.
- Salvage Value:
    - 60% for structures.
    - 50% for combined costs including structures and equipment.
    - 45% for equipment.
- Capital Escalation rate: 1.9%.
- O&M Expenditures Escalation Rate: 1.9%.
- Interest (Discount Rate): 3.1%.

The capital 20-year NPV and the O&M 20-year NPV were added together to obtain a total 20-year NPV for each alternative, making it possible to compare each on a fair and equal basis.

The resulting NPV for each alternative is presented in Table 4-4 and Table 4-5. The detailed life cycle cost analysis is included in Appendix B.

Table 4-4 Capital, O&M, and NPV Cost Opinion – Alternative A (CoMag PC)

DESCRIPTION	NPV CAPITAL COST	NPV O&M COST	TOTAL NPV WITH SALVAGE VALUE	SALVAGE VALUE AT YEAR 20
Alternative 1 – IFAS	$109,700,000	$16,100,000	$108,800,000	$17,000,000
Alternative 2 – MBR	$124,700,000	$29,800,000	$136,000,000	$18,500,000
Alternative 3 – BIOMAG	$93,800,000	$20,700,000	$100,000,000	$14,500,000
Alternative 4 –GAS	$124,900,000	$11,100,000	$117,100,000	$18,900,000

Table 4-5 Capital, O&M, and NPV Cost Opinion – Alternative B (Conventional PC)

DESCRIPTION	NPV CAPITAL COST	NPV O&M COST	TOTAL NPV WITH SALVAGE VALUE	SALVAGE VALUE AT YEAR 20
Alternative 1 – IFAS	$134,600,000	$14,700,000	$128,000,000	$21,300,000
Alternative 2 – MBR	$154,900,000	$31,700,000	$162,700,000	$23,900,000
Alternative 3 – BIOMAG	$128,400,000	$22,600,000	$129,700,000	$21,300,000
Alternative 4 – GAS	$124,900,000	$11,100,000	$117,100,000	$18,900,000

With the use of CoMag as primary clarification, a comparison of total NPV suggests Biomag could achieve the lowest cost over a 20-year period with IFAS closely behind. With the use of conventional primary clarification, a comparison of total NPV suggests GAS could achieve the lowest cost over a 20-year period with IFAS and BioMag alternatives closely behind. MBR is estimated to have the highest capital, O&M and Total NPV under both scenarios.

5 Triple Bottom Line Analysis

A triple bottom line (TBL) analysis was completed as the basis for selection of the alternatives for further consideration. Social, environmental and operational criteria were weighted and scored to determine the benefit-cost of each alternative as shown in Table 5-6 and Table 5-6.

Criteria used in cost development (i.e. staffing and operational impacts) are removed from the evaluation of social, environmental and economic criteria. High level capital and O&M costs were developed to further differentiate the alternatives from each other and substantiate the chosen alternatives. This high level costing exercise will only be used to identify the relative difference between alternatives and would not be for the purposes of quantifying the actual 20-year present worth of each.

The seven evaluation criteria and weighting factors used in the triple bottom line assessment (TBL) were developed jointly with JCW during the evaluation process. Scoring resulted from the evaluation of the process modeling; facilities layout; conceptual costing and non-economic factors.

5.1 TRIPLE BOTTOM LINE CRITERIA

The secondary treatment technologies evaluated in this TM include a Triple Bottom Line (TBL) analysis to provide a more thorough comparison of the alternatives. The general criteria used in these evaluations are presented in Table 5-1. The non-economic criteria and weighting factor for each secondary treatment TBL analysis based on CoMag primary clarification and Conventional primary clarification remain the same since each evaluation is relative.

Table 5-1 Evaluation Criteria and Weighting Factors

CRITERIA	DESCRIPTION	WEIGHTING FACTOR
Flexibility / Turndown	Is alternative flexible enough to successfully adjust to changing conditions (i.e. flow and load)? How much can be treated through the process?	10%
Performance Reliability	Are there adjustable controls, process options, and/or equipment features available for operators to respond to an upset? Is alternative resistant to an upset, and what are the consequences if upset does occur?	25%
Operational Complexity	How complex is the alternative to operate, control and maintain? Does the alternative rely on more system components operating together? Are there major scheduled replacements and cleanings?	25%
Phasing	How easily and cost-effectively can the alternative be phased to meet the start-up and construction constraints and how easily are the facilities in the alternative upgraded or expanded over time?	10%
Land Requirements / Layout	How well does the alternative fit on the site, require land and impact the floodplain? Do the facilities lay out in an orderly fashion (e.g., do trucks have to drive to through	15%

CRITERIA	DESCRIPTION	WEIGHTING FACTOR
	several facilities in order to access their final destination)?	
Social Impacts	How well does the alternative prevent off-site impacts to public perception such as truck traffic, noise, odor, visual aesthetics, etc. and can these impacts be easily mitigated? (Impacts from construction activities are excluded.)	10%
Environmental Impacts	How well does the alternative minimize the impact to the environment in terms of carbon footprint (during construction and use phase), ecosystem quality, and resource use?	10%
Safety	How well does the alternative minimize safety risks to the plant staff and the public and can the risks be mitigated?	10%
Ease of Regulatory Acceptance	How difficult will alternative be to obtain EPA and KDHE regulatory acceptance? Could alternative acceptance be achieved in desired schedule?	20%
Cost[1]	What are the capital and O&M costs?	
Total		**135%**

Note:
[1] Cost will only be used as an evaluation criterion in the initial screening of alternatives. The cost will be removed from the social and environmental impact analysis performed for the selected alternatives.

5.1.1 Non-Economic Criteria

Table 5-2 expands upon the information provided in Table 5-1 and provides alternative-specific descriptions of the criteria items. In addition, information defining the scale to be used in ranking the criteria during the subsequent scoring activity is listed.

Table 5-2 Secondary Treatment Ranking Information

CRITERIA	RANKING INFORMATION
Flexibility / Turndown	Alternative 1 - IFAS: Process is flexible to adjust to varying flows within bounds of each of the four trains up to 57 mgd total. Greater flow is directed to auxiliary treatment. Alternative 2 - MBR: Process is flexible to adjust to varying flows within bounds of each the four trains up to 38 mgd total. Greater flow is directed to auxiliary treatment. Alternative 3 - BioMag: Process is flexible to adjust to varying flows within bounds of each the four trains up to 57 mgd total. Greater flow is directed to auxiliary treatment. Alternative 4 - GAS: Process is flexible to adjust to varying flows within bounds of each the six basins up to 57 mgd total. Greater flow is directed to auxiliary treatment. Ranking: 5 = highest flexibility/reliability 1 = least flexibility/reliability
Performance Reliability	Alternative 1 - IFAS: Can have higher SRT without increasing solids loading to secondary clarifiers. More stable nitrification at colder temperatures. Foam removal and control can be more difficult. Technology has proven performance and reliability. Alternative 2 - MBR: High effluent quality. More precise control of SRT. Technology has proven performance and reliability. Can be prone to membrane fouling. Alternative 3 - BioMag: Can have higher SRT without increasing solids loading to secondary clarifiers. Technology has proven performance and reliability with limited, smaller scale facilities. Alternative 4 - GAS: Technology has proven performance and reliability on higher strength wastewater on limited installations internationally but has not been installed in the U.S. Ranking: 5 = high performance reliability 1 = low performance reliability
Operational Complexity	Alternative 1 - IFAS: Involves minimal operational and maintenance complexity. Similar complexity to operation of conventional activated sludge process. Alternative 2 - MBR: Involves greater operational and maintenance complexity as cleaning cycles require opening and closing of multiple valves, requires starting and stopping

CRITERIA	RANKING INFORMATION
	of additional equipment. Requires membrane replacement approximately every 10 years. Alternative 3 - BioMag: Involves moderate operational complexity due to magnetite recovery system, although the process is mostly automated by manufacturer proprietary PLC software. Alternative 4 - GAS: Once stable and operating the process has less operational complexity and less sensitive to process disruptions as it is mostly automated by manufacturer proprietary PLC software in batch operations. Ranking: 5 = minimal operational complexity 1 = high operational complexity
Phasing	Alternative 1 - IFAS: Alternative has minimal construction phasing impacts. Basins expandable in future to meet lower permit limits. Alternative 2 - MBR: Alternative has minimal construction phasing impacts. Basins expandable in future to meet lower permit limits. Alternative 3 - BioMag: Alternative has minimal construction phasing impacts. Basins expandable in future to meet lower permit limits. Alternative 4 - GAS: Alternative has minimal construction phasing impacts. Basins expandable in future to meet lower permit limits. Ranking: 5 = no phasing impact 1 = large phasing impact
Land Requirements / Layout	Alternative 1 - IFAS: Footprint is larger of alternatives. Requires support facilities for aeration; tertiary pumping, tertiary and auxiliary filtration and secondary clarification. Flexibility in location of support buildings. Alternative 2 - MBR: Footprint is smaller of alternatives. Requires support facilities for aeration, fine screening; chemical feed, and permeate pumping. Secondary clarification, tertiary pumping, and tertiary filtration not required. Less flexibility in location of support buildings. Alternative 3 - BioMag: Footprint is larger of alternatives. Requires support facilities for aeration; magnetite recovery, tertiary pumping, tertiary and auxiliary filtration and secondary clarification. Flexibility in location of support buildings.

CRITERIA	RANKING INFORMATION
	Alternative 4 - GAS: Footprint is smaller of alternatives. Biological basins are largest of alternatives. Requires support facilities for fermentation; aeration, tertiary pumping, and tertiary filtration. Less flexibility in location of support buildings. Ranking: 5 = small footprint 1 = large footprint
Social Impacts	Alternative 1 - IFAS: More offsite traffic due to delivery of chemicals. Structure will be mostly above grade due to hydraulics. Process area will be approximately 15 ft. above grade; blower building 25 ft above grade, and secondary clarifiers 10 ft above grade. Minimal noise of operation from enclosed equipment. Comparable odor among alternatives. Alternative 2 - MBR: Structure will be mostly above grade due to hydraulics. Process area will be approximately 10 ft. above grade with another 20 ft for the MBR basin and fine screen superstructures. Attached blower and pump building will be similar height. Minimal noise of operation from enclosed equipment. Comparable odor among alternatives. Alternative 3 - BioMag: More offsite traffic due to delivery of chemicals. Structure will be mostly above grade due to hydraulics. Process area will be approximately 15 ft. above grade; blower building 25 ft above grade, and secondary clarifiers 10 ft above grade. Minimal noise of operation from enclosed equipment. Comparable odor among alternatives. Alternative 4 - GAS: Little offsite traffic due to delivery of chemicals. Structure will be mostly above grade due to hydraulics. Fermenter and process area will be approximately 15-20' above grade. Minimal noise of operation from enclosed equipment. Comparable odor among alternatives. Ranking: 5 = least off-site impact 1 = largest off-site impact

CRITERIA	RANKING INFORMATION
Environmental Impacts	Alternative 1 - IFAS: Moderate energy usage among alternatives. Chemical usage will require the manufacture and delivery of chemicals. Similar sludge production among alternatives. Alternative 2 - MBR: Highest energy usage among alternatives. Chemical usage will require manufacture and delivery of chemicals. Additional chemical usage required for membrane cleaning. Similar sludge production among alternatives with additional fine screening waste. Requires periodic membrane replacement. Alternative 3 - BioMag: Higher energy usage among alternatives. Environmental impact of magnetite mining and long-haul delivery is significant compared to other alternatives. Chemical usage will require manufacture and delivery of chemicals. Similar sludge production among alternatives. Alternative 4 - GAS: Lowest energy and chemical usage among alternatives. No basin mixers required. Similar sludge production among alternatives. Ranking: 5 = no off-site impact 1 = large off-site impact
Safety	Alternative 1 - IFAS: Minimal safety risk associated with operation. Chemicals used are not hazardous but do carry risks. Equipment is controlled automatically by the manufacturer provided PLC and requires minimal operator intervention. Equipment is both below water and open for visual inspection. Equipment bays are open for visual inspection and protected by guardrail. Alternative 2 - MBR: Moderate safety risk due to the additional cleaning chemicals and periodic membrane replacement. Equipment is controlled automatically by the manufacturer provided PLC and requires minimal operator intervention. Equipment is both below water and open for visual inspection. Equipment bays are protected by guardrail. Alternative 3 - BioMag: Minimal safety risk associated with operation. Chemicals used are not hazardous but do carry risks. Equipment is controlled automatically by the manufacturer provided PLC and requires minimal operator intervention. Equipment is mostly open for visual inspection. Equipment bays are open for visual inspection and protected by guardrail. Alternative 4 - GAS: Minimal safety risk associated with operation and limited chemical usage. Equipment is open for visual inspection and protected by guardrail. Ranking:

CRITERIA	RANKING INFORMATION
	5 = no safety risk 1 = large safety risk
Ease of Regulatory Acceptance	Alternative 1 - IFAS: No installations have been permitted in Kansas for this use. Numerous installations in the US. Approval is anticipated by KDHE with minimal delays; no piloting required. Alternative 2 - MBR: Technology has been permitted in Kansas for similar treatment. Numerous installations in the US. Approval is anticipated by KDHE with minimal delays; no piloting required. Alternative 3 - BioMag: No installations of this size have been installed before by the manufacturer. Technology not widely accepted by state regulations. Successful demonstration pilot testing would be required for regulatory approval. Approval by KDHE may be difficult and have schedule impacts. Alternative 4 - GAS: No previous installations or piloting performed in U.S. Successful demonstration pilot testing would be required for regulatory approval. Approval by KDHE may be difficult and a lengthy process. Schedule impacts likely. Ranking: 5 = highest regulatory acceptance 1 = least regulatory acceptance

5.1.2 Criteria Weighting and Scoring

During alternative selection workshops held with representatives of JCW, weighting factors were assigned to each criteria and a ranking was assigned for each alternative based on the defined scale.

Table 5-3 and Table 5-4 are a summary of the resulting weighted scores for each alternative based on CoMag and conventional primary clarification, respectively.

Table 5-3 Triple Bottom Line Scoring—(Alternative A) CoMag PC

CRITERIA	PERCENTAGE	RELATIVE WEIGHT	RAW SCORE							
			Alternative 1—IFAS		Alternative 2—MBR		Alternative 3—BIOMAG		Alternative 4—GAS	
Flexibility/Turndown	10%	1	4	4	2	2	4	4	4	4
Performance Risk	25%	2.5	5	12.5	5	10	4	10	3	7.5
Operational Flexibility	25%	2.5	4	10	2	5	2	5	3.5	8.75
Phasing	10%	1	4	4	4	4	4	4	4	4
Land Requirements/Layout	15%	1.5	4	6	5	7.5	4	6	5	7.5
Social Impacts	10%	1	4	4	3	3	3	3	5	5
Environmental Impacts	10%	1	4	4	2	2	3	3	5	5
Safety	10%	1	4	4	3	3	3	3	5	5
Ease of Regulatory Acceptance	20%	2	5	10	4	8	3	6	3	6
Total Weighted Score	135%									
			58.5		44.5		44		51.75	

Note: Rankings: 5 = Most Important or most positive impact. 1 = Least Important or most negative impact.

Table 5-4 Triple Bottom Line Scoring—(Alternative B) Conventional PC

CRITERIA	PERCENTAGE	RELATIVE WEIGHT	RAW SCORE (WEIGHTED SCORE)							
			Alternative 1—IFAS		Alternative 2—MBR		Alternative 3—BIOMAG		Alternative 4—GAS	
Flexibility/Turndown	10%	1	4	4	2	2	4	4	4	4
Performance Risk	25%	2.5	5	12.5	5	10	4	10	3	7.5
Operational Flexibility	25%	2.5	4	10	2	5	2	5	3.5	8.75
Phasing	10%	1	4	4	4	4	4	4	4	4
Land Requirements/Layout	15%	1.5	4	6	5	7.5	4	6	5	7.5
Social Impacts	10%	1	4	4	3	3	3	3	5	5
Environmental Impacts	10%	1	4	4	2	2	3	3	5	5
Safety	10%	1	4	4	3	3	3	3	5	5
Ease of Regulatory Acceptance	20%	2	5	10	4	8	3	6	3	6
Total Weighted Score	135%									
			58.5		44.5		44		51.75	

Note: Rankings: 5 = Most Important or most positive impact. 1 = Least Important or most negative impact.

5.1.3 Cost/Benefit Scoring

Following the calculation of the total weighted score for each alternative; scores were normalized by dividing each by the larger of the two weighted scores. Using the resulting normalized ratio, a normalize NPV, taking into account social and environmental factors, for each alternative was calculated for final comparison and selection of the favored alternative. Table 5-5 and Table 5-6 contain the resulting NPV to normalized benefit ratio value for each alternative.

With the use of CoMag as primary clarification, a comparison of total TBL analysis suggests IFAS is the preferred alternative with BioMag and GAS alternatives as the next closest. With the use of conventional primary clarification, a comparison of TBL analysis suggests IFAS is the preferred alternative with GAS alternatives as the next closest. MBR ranks last under both scenarios and without the use of CoMag, BioMag does not score favorably.

Table 5-5 NPW to Normalized Benefit Ratio Comparison – (Alternative A) CoMag PC

CRITERIA	PERCENTAGE	RELATIVE WEIGHT	RAW SCORES (*WEIGHTED SCORES*)							
			Alternative 1 – IFAS		Alternative 2 – MBR		Alternative 3 – BIOMAG		Alternative 4 – GAS	
Flexibility / Turndown	10%	1	4	4	2	2	4	4	4	4
Performance Risk	25%	2.5	5	12.5	5	10	4	10	3	7.5
Operational Complexity	25%	2.5	4	10	2	5	2	5	3.5	8.75
Phasing	10%	1	4	4	4	4	4	4	4	4
Land Requirements / Layout	15%	1.5	4	6	5	7.5	4	6	5	7.5
Social Impacts	10%	1.0	4	4	3	3	3	3	5	5
Environmental Impacts	10%	1.0	4	4	2	2	3	3	5	5
Safety	10%	1.0	4	4	3	3	3	3	5	5
Ease of Regulatory Acceptance	20%	2.0	5	10	4	8	3	6	3	6
	Total Weighted Score			**58.5**		**44.5**		**44**		**51.75**
		Normalized Benefit Score	1.00		0.76		0.75		0.88	
		NPW Cost	$108,800,000		$136,000,000		$100,000,000		$117,100,000	
		NPW / Normalized Benefit Ratio	**$108,800,000**		**$179,000,000**		**$133,300,000**		**$133,100,000**	

Table 5-6 NPW to Normalized Benefit Ratio Comparison – (Alternative B) Conventional PC

CRITERIA	PERCENTAGE	RELATIVE WEIGHT	RAW SCORES (*WEIGHTED SCORES*)							
			Alternative 1 – IFAS		Alternative 2 – MBR		Alternative 3 – BIOMAG		Alternative 4 – GAS	
Flexibility / Turndown	10%	1	4	4	2	2	4	4	4	4
Performance Risk	25%	2.5	5	12.5	5	10	4	10	3	7.5
Operational Complexity	25%	2.5	4	10	2	5	2	5	3.5	8.75
Phasing	10%	1	4	4	4	4	4	4	4	4
Land Requirements / Layout	15%	1.5	4	6	5	7.5	4	6	5	7.5
Social Impacts	10%	1.0	4	4	3	3	3	3	5	5
Environmental Impacts	10%	1.0	4	4	2	2	3	3	5	5
Safety	10%	1.0	4	4	3	3	3	3	5	5
Ease of Regulatory Acceptance	20%	2.0	5	10	4	8	3	6	3	6
	Total Weighted Score			**58.5**		**44.5**		**44**		**51.75**
	Normalized Benefit Score		1.00		0.76		0.75		0.88	
	NPW Cost		$128,000,000		$162,700,000		$129,700,000		$117,100,000	
	NPW / Normalized Benefit Ratio		**$128,000,000**		**$214,100,000**		**$172,900,000**		**$133,100,000**	

6 Summary of Findings and Recommendations

6.1 ALTERNATIVE RECOMMENDATION

Based on discussions and Workshops, economic and non-economic analysis, Alternative 1B – IFAS with Conventional Primary Clarification is the recommended alternative to offer the best overall approach for meeting the project objectives.

6.2 PRELIMINARY FLOOD IMPACT ASSESSMENT

A site facility layout incorporating recommendations from other TMs and the corresponding flood impact assessment of Alternative 1B is presented in the Site Optimization Evaluation Memo, TM No. 7.

6.3 CARBON AUGMENTATION ON THE RECOMMENDED ALTERNATIVE

Evaluations in this TM were completed assuming that primary sludge fermentation would be utilized to generate the additional carbon necessary to support nutrient removal. Carbon supplementation is required in the anaerobic and anoxic zones of the biological reactors to aid with denitrification and biological phosphorus removal. Two different carbon sources - carbon from a fermentation process and MicroC 2000 addition - were analyzed and presented in this section.

6.3.1 Alternative F1 - Primary Sludge Fermentation and Treatment to 10 mg/L TN and 0.5 mg/L TP

Based on the process modeling for Tomahawk Creek WWTP and past Black & Veatch experience, the amount of carbon generated by the primary sludge fermenter is considered to be sufficient to meet the effluent TN and TP limits of 10 mg/L and 0.5 mg/L respectively. The process model predicted that 3,520 pounds per day of carbon (as MicroC 2000) is required for nutrient removal, all of which can be supplied by the fermenter.

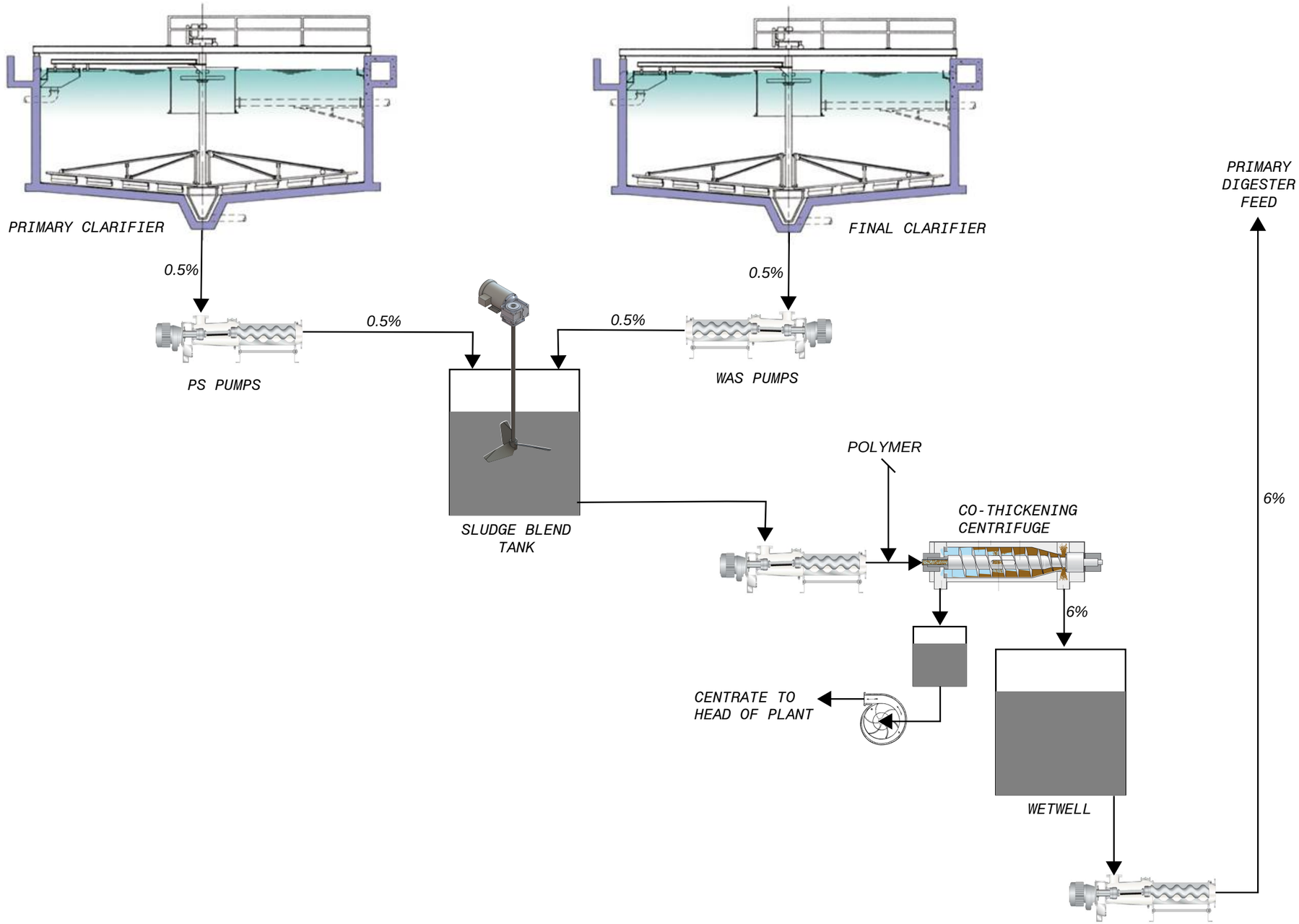
The required fermenter volume is provided in two rectangular concrete tanks, each providing half of the total volume required. Each tank is provided with a mechanical mixer to maintain a homogeneous mixture in the basin and with an aeration system that runs periodically to prevent the methane formation. The tanks are located adjacent to the thickening building to take advantage of common wall construction and to minimize piping length to the discharge pumps located in the thickening building. As discussed in a previous section, separate thickening of the combined primary sludge and fermenter return is required to control the percent solids being provided to the fermentation process. A schematic of solids thickening system including fermentation, but without WASSTRIP, and the layout of the thickening building required to accommodate the thickeners are provided in TM No. 5.

While not required for operation, a supplemental carbon storage and feed facility is included with this alternative as a backup should the tanks need to be taken out of service for a period of time or should process parameters require the addition of supplemental carbon beyond that produced by the fermenters.

6.3.2 Alternative F2 - Carbon Supplementation and Treatment to 10 mg/L TN and 0.5 mg/L TP

In order to supply the carbon required for biological nutrient removal, without any fermentation process, a total of 5,520 pounds per day (ppd) of MicroC 2000 is required. This equates to 352 gallons per day (gpd) of the chemical.

With the elimination of the fermenter, the necessity for separate thickening of the primary sludge is no longer present. Combining the elimination of fermentation with the elimination of WASSTRIP the thickening process is simplified to just co-thickening of the primary sludge and WAS in a single set of thickeners. A process schematic of the thickening process for this alternative is provided in Figure 6-1. The layout of the resulting thickening building is provided in Figure 6-2 and Figure 6-3.



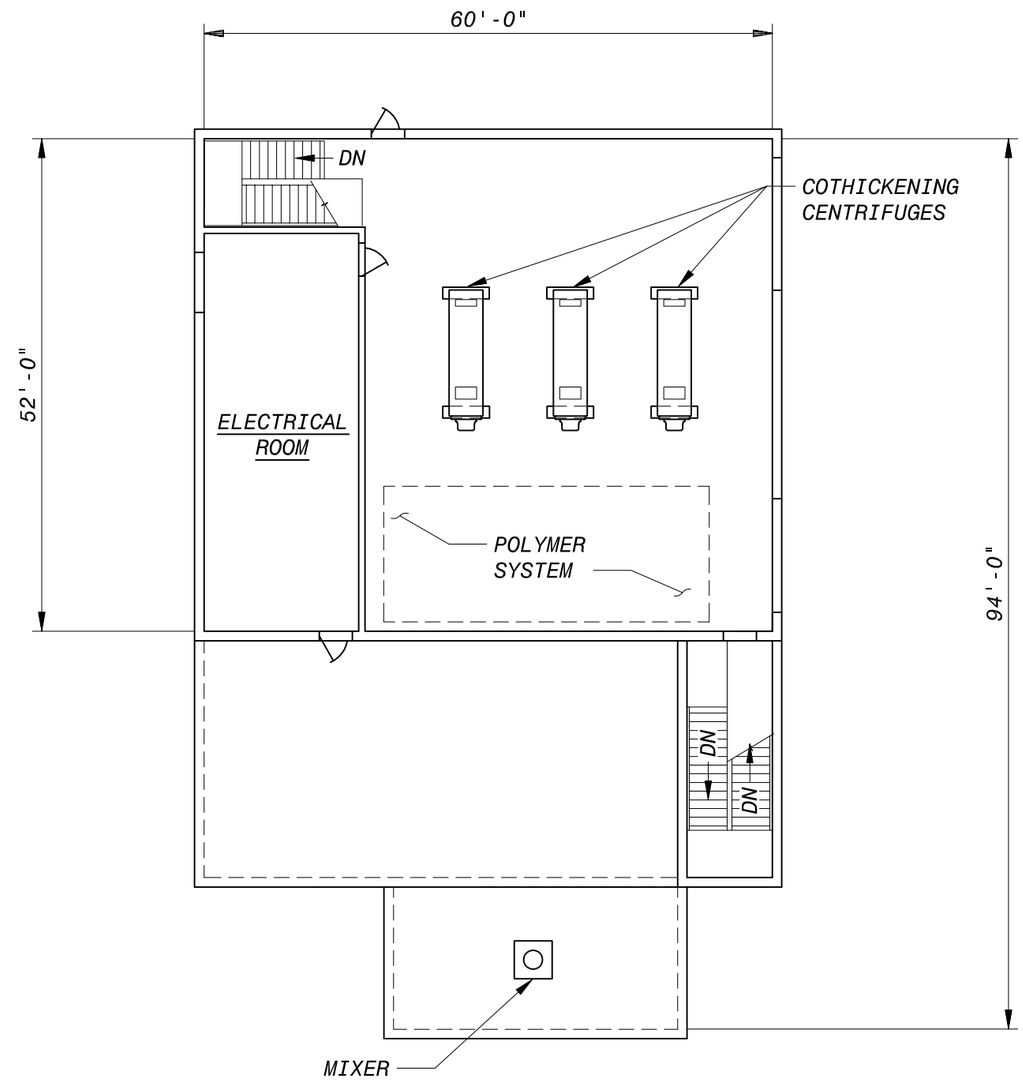
JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTP
PROJECT DEFINITION PHASE

SOLIDS THICKENING SCHEMATIC
NO FERMENTATION/OSTARA OPTION
FIGURE 6-1

BLACK & VEATCH
Building a world of difference.

HDR

BFIGBORD
FBFIGBORD



OPERATING FLOOR

1/16" = 1'-0"

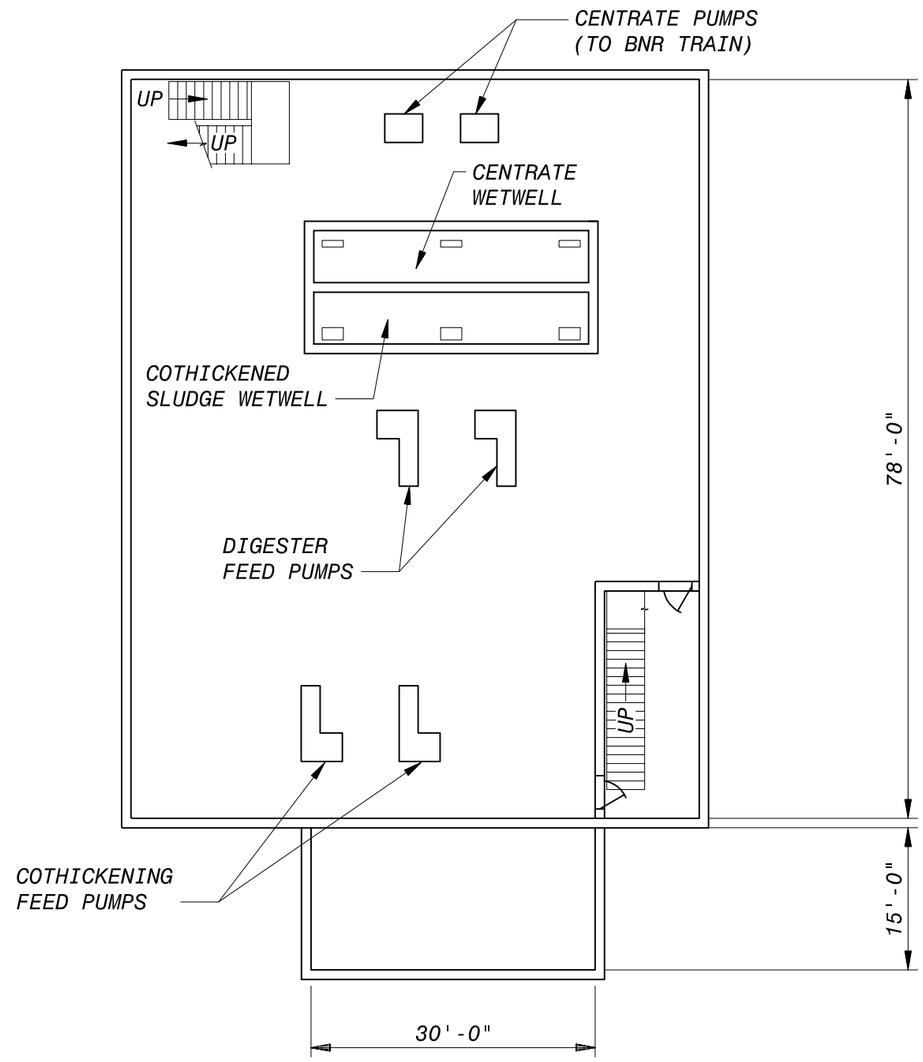
JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTP
PROJECT DEFINITION PHASE

SLUDGE THICKENING BUILDING
NO FERMENTATION
FIGURE 6-2

BLACK & VEATCH
Building a world of difference.

HDR

BFIGBORD
FBFIGBORD



LOWER LEVEL

1/16" = 1'-0"

JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTP
PROJECT DEFINITION PHASE

SLUDGE THICKENING BUILDING
NO FERMENTATION
FIGURE 6-3

BLACK & VEATCH
Building a world of difference.

HDR

BFIGBORD
FBFIGBORD

6.4 COST ANALYSIS

Conceptual level capital costs and O&M costs were developed for each of the carbon augmentation alternatives. These costs were used to develop life cycle net present value costs for each alternative to use in comparisons of the alternatives.

Capital costs for the structures were estimated based on per square feet or per cubic foot costs based on historical cost data for similar structures and escalated to current value. Costs for excavation, concrete, metals, and piping were developed using estimated quantities derived from conceptual layouts with historical unit cost values. The expected cost for deep foundations was developed based on providing a similar foundation to existing buildings on site, applied on a per square foot basis.

Equipment costs were based on supplier quotations with installation of equipment projected at an applicable percent of the equipment cost. Process piping and valves, as well as other miscellaneous non-building items were estimated on a per square foot or lump sum basis, as applicable.

6.4.1 Capital Cost

The estimated capital costs for each of the components making of the cost of each alternative are presented in Table 6-1.

Table 6-1 Carbon Augmentation Alternatives Capital Costs

	ALTERNATIVE F1 - FERMENTATION	ALTERNATIVE F2 – CARBON SUPPLEMENTATION
Thickening Building	$7.64M	$3.81M
Fermentation Tanks	$1.16M	-
Co-Thickening Blend Tank	$0.26M	$0.26M
Conditioned PS Wetwell	$0.28M	-
Carbon Feed Facility	$0.74	$0.74
Civil/Site Work/Elec/I&C	40%	40%
Deep Foundations	$0.55M	$0.29M
General Reqs/Cont/ELA	80%	80%
Preliminary Totals	**$26.3M**	**$12.7M**

6.4.2 Incremental Operations and Maintenance Cost

Operations and maintenance costs include the cost of power, chemicals, operating labor, and general maintenance. The O&M costs are calculated based on annual average conditions and solids production. The unit costs for O&M are based on unit price information provided by Johnson County Wastewater staff, where available, and are the same as those presented in TM No. 5. The cost for MicroC 2000 is based on budgetary pricing provided by a chemical supplier.

Power costs include the cost for operating process equipment based on the anticipated annual average solids production and the number of units in service.

Maintenance costs are based on a percentage of equipment cost basis.

The assumed additional labor required for each of the two alternatives is presented in Table 6-2.

Table 6-2 Carbon Augmentation Labor Cost Assumptions

LABOR CATEGORY	NUMBER	HRS/ SHIFT	SHIFT /DAY	DAYS /WK	HRS / WEEK	COST/YR
ALTERNATIVE F1 – Fermentation						
Operations – Fermentation	1	1	1	7	**7**	$12,354
Maintenance – Fermentation	1	0.5	1	5	**2.5**	$4,412
ALTERNATIVE F2 – Carbon Supplementation						
Operations – Chemical Feed	1	0.5	1	7	**3.5**	$6,000
Maintenance – Chemical Feed	1	0.5	1	5	**2.5**	$4,412

A summary of the expected O&M costs for operation of the facilities for each of the alternatives is presented in Table 6-3. For Alternative F2, because the addition of supplemental carbon results in the production of additional WAS an additional operation cost associated with the thickening, digestion, dewatering, and land application of that additional sludge is included in the O&M costs.

Table 6-3 Carbon Augmentation Annual Operations and Maintenance Costs

	ALTERNATIVE F1 - FERMENTATION	ALTERNATIVE F2 – CARBON SUPPLEMENTATION
Power	$14.0K	$100K
Labor	$16.8K	$11K
Equipment Maintenance	$6.4K	$34K
Carbon – MicroC 2000	-	$463K
Polymer	130K	94K
Additional Sludge Processing & Land Application Costs	-	$30.0K
Annual O&M	$324K	$732K
20 2Kl O&M Sludge	**$5.2M**	**$11.7M**

6.4.3 Net Present Value

The NPV for each alternative is presented in Table 6-4.

Table 6-4 Capital, O&M, and NPV Cost Opinion – Carbon Augmentation

	ALTERNATIVE F1 – FERMENTATION	ALTERNATIVE F2 – CARBON SUPPLEMENTATION
NPV Capital Cost	$24.2M	$11.6M
NPV O&M Cost	$5.2M	$11.7M
NPV Salvage Value	($2.2M)	($1.1M)
Total NPV	**$27.2M**	**$22.2M**
Total NPV w/o Salvage Value	**$29.4M**	**$23.3M**

6.4.4 Net Present Value Sensitivity

For Alternative F2, over half of the NPV cost was associated with the O&M costs which were largely composed of the cost of the supplemental carbon (MicroC 2000). Because MicroC 2000 is a purchased product which is subject to volatility due to both the cost of the components used to make the product and the cost to deliver the product, an evaluation of the sensitivity to that price volatility is prudent.

Based on historical data from the Producer Price Index (PPI) for this class of chemical and from discussions with chemical suppliers, an expected range in which the cost of MicroC 2000 could vary was determined. From the base cost of $0.23/lb, it is expected that MicroC 2000 could range from a low of $0.18/lb to a high of $0.28/lb. Using this range, and applying it to the NPV valve for 20 years of operation for the carbon required for various effluent limits, the sensitivity graph presented in Figure 6-4 was developed.

This graph indicates that under varying effluent TN and TP limits, Alternative F2 – Carbon Supplementation would likely be the lowest NPV except under the extreme situation of strict effluent limits and high chemical cost. Due to a significantly higher (fixed) capital cost, Alternative F1 does not experience fluctuations associated with varying effluent TN and TP limits and chemical costs.

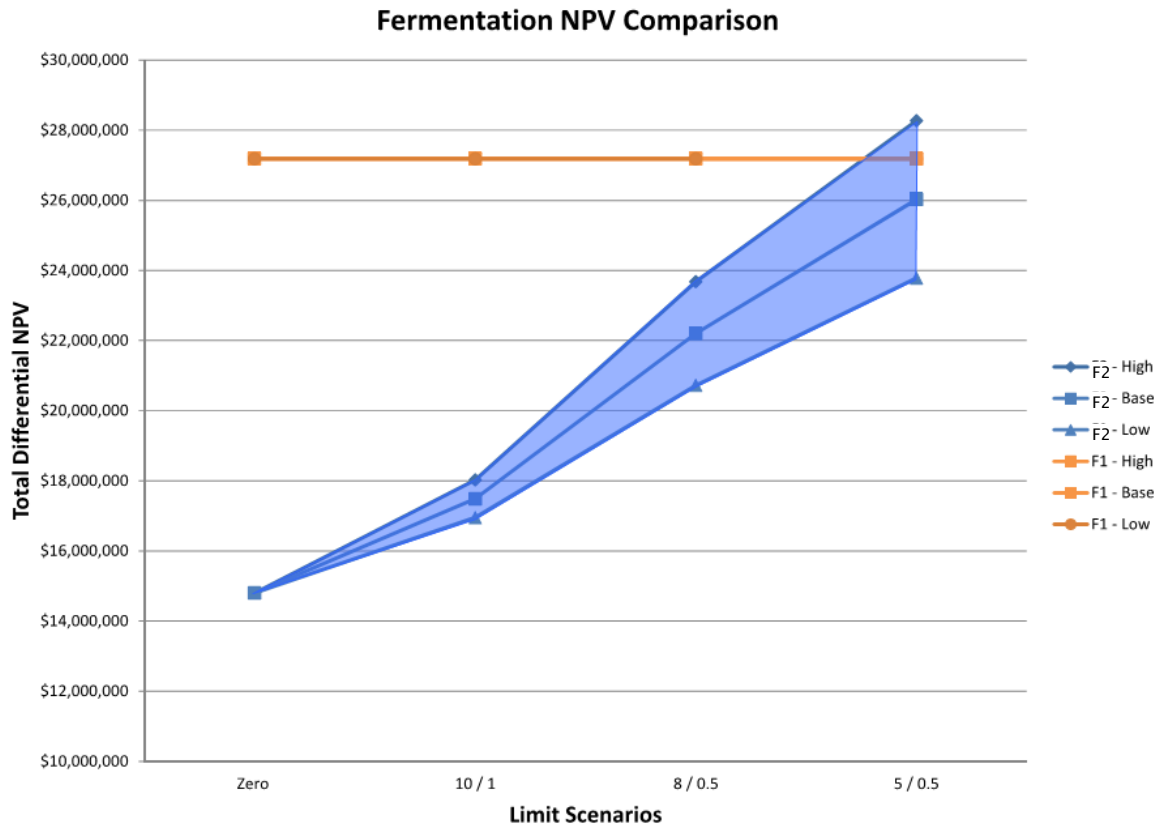


Figure 6-4 Carbon Feed Sensitivity Graph

6.4.5 Triple Bottom Line Analysis

6.4.5.1 Criteria Weighting and Scoring

The general criteria used in the evaluation are similar to those presented in Chapter 5 above.

6.4.5.2 Cost/Benefit Scoring

Rankings for each criteria item were assigned for each alternative and the scoring is provided in Table 6-5. Following calculation of the total weighted score for each alternative; the scores were normalized by dividing each by the larger of the two weighted scores. Using the resulting normalized ratio, a normalized NPV, taking into account social and environmental factors for each alternative, was calculated for final comparison and selection of the favored alternative.

Table 6-5 NPW to Normalized Benefit Ratio Comparison – Carbon Augmentation

CRITERIA	PERCENTAGE	RELATIVE WEIGHT	RAW SCORES (*WEIGHTED SCORES*)			
			ALTERNATIVE F1 – FERMENTATION		ALTERNATIVE F2 – CARBON SUPPLEMENTATION	
Flexibility / Turndown	15.0%	1.5	4	6	4	6
Performance Risk	25.0%	2.5	4	10	4	10
Operational Complexity	25.0%	2.5	3	7.5	4	10
Phasing	10.0%	1	3	3	3	3
Land Requirements / Layout	15.0%	1.5	4	6	5	7.5
Social Impacts	10.0%	1	3	3	3	3
Environmental Impacts	10.0%	1	4	4	3	3
Safety	10.0%	1	4	4	4	4
Ease of Regulatory Acceptance	10.0%	1	3	3	3	3
		Total Weighted Score		46.5		49.5
		Normalized Benefit Score	0.93		1.00	
		NPW Cost	$27,200,000		$22,200,000	
		NPW / Normalized Benefit Ratio	**$28,900,000**		**$22,200,000**	

6.4.6 Recommended Alternative

Based on discussions and Workshops, economic and non-economic analysis, Alternative F2 – Carbon Supplementation appears to offer the best overall approach for meeting the project objectives. However, due to uncertainty of future chemical pricing, it was determined at the July 28, 2015 workshop that a combination of Alternatives F1 and F2 would be implemented. Fermentation of primary sludge will be provided along with a carbon system for supplementation of carbon as needed to meet the permit limits for nitrogen and phosphorus.

Appendix A - Alternatives Identification and Screening Summary Matrix

JCW Tomahawk Creek WWTP Projcet Definition Phase

Technology	Category	Description	Small Footprint	Able to produce low effluent ammonia conc	Wet weather flow limitations	Bio P	Energy Use[1]	Does process need PC?	Higher efficiency for TSS capture
Simultaneous Nitrification / Denitrification (SND) Processes	Established	In general, these processes rely on creating oxic and anoxic environments within an activated sludge basin such that nitrification occurs simultaneously with denitrification	No	Yes	Yes 2Q, 3Q w/ step feed	Yes	C	No	NA
· Orbal Process, by USFilter Envirex			No	Yes	Yes 2Q, 3Q w/ step feed	Yes	C	No	NA
· Vertical Loop Reactor, by USFilter Envirex			No	Yes	Yes 2Q, 3Q w/ step feed	Yes	C	No	NA
· Schreiber Counter Current Aeration Process, by Schreiber, Inc.			No	Yes	Yes 2Q, 3Q w/ step feed	Yes	C	No	NA
· Numerous Oxidation Ditch Process Variations			No	Yes	Yes 2Q, 3Q w/ step feed	Yes	C	No	NA
· Symbio Process, by Enviroquip, Inc.			No	Yes	Yes 2Q, 3Q w/ step feed	Yes	C	No	NA
Five-stage Bardenpho™	Established	The Five-stage BardenphoTM process adds a third and fourth stage to the MLE process to provide more complete nitrogen removal. The second anoxic and aerobic zones provide further removal of nitrates	No	Yes	Yes 2Q, 3Q w/ step feed	Yes	C	Yes	Yes
Integrated Fixed Film Activated Sludge (IFAS)	Established	IFAS combines suspended growth and fixed film activated sludge within the same bioreactor which increases the overall mass of bacteria that can be maintained thus reducing the required activated sludge aeration basin volume. A free floating plastic media is used to provide surface area for biomass to attach and grow.	Yes	Yes	Yes 2Q, 3Q w/ step feed	Yes	C	Yes	Yes
Membrane Bioreactors (MBRs)	Established	Membranes are installed in the aeration basins to separate the MLSS from the treated water. Therefore, with membranes, it is no longer necessary to rely on gravity separation of solids in secondary clarifiers. In addition, tertiary filters are not needed with this process since the membranes reduce solids to very low levels. Diffused aeration equipment is usually used to meet the oxygen demand of the process.	Yes	Yes	2Q limit	Yes	H	Yes	Yes
Moving Bed Bioreactors (MBBRs)	Established	The MBBR technology is also an attached growth process that uses free-floating media within a bioreactor to provide surface area for bacteria to grow. The primary difference between the IFAS process and a MBBR process is that the MBBR process does not incorporate a suspended growth biomass population.	Yes	No	Yes 2Q, 3Q w/ step feed	No	C	Yes	Yes
Biological Aerated Filters (BAFs)	Established	The biological aerated filter (BAF) technology consists of a reactor basin filled with a submerged media serving as both a surface for biological activity and a means for solids separation. The Kruger Biostyr process and the ONDEO Degrement Inc. (ODI) Biofor process are currently the most popular BAF processes marketed in the US.	Yes	No	design for flowrate	No	C/H	Yes	Yes
Granular Activated Sludge	In use and refining capabilities	Granules form due to cell to cell interaction without the help of any solid media. The concept of aerobic granular sludge is used in a system called Nereda in which granules are formed in SBRs allowing a high degree of SND. The external layer of the granules that is esposed to oxygen includes a big number of nitrifying bacteria and the inner layer layer where it's anaerobic includes a big number of denitrifers.	Yes	Yes	4-5Q design flow limit	Yes	C/L	No	No
Step-Feed Denitrification	Established	typically a four-pass system with alternating zones of anoxic and oxic is used where primary effluent is fed to each of the four anoxic zones. To further remove the nitrate formed in the last oxic zone, a deOx zone can be included which allows internal recycle of the mixed liquor (low in DO) from the de-Ox zone to the last anoxic zone.	Yes/ marginal	Yes/ maybe	Yes 2Q, 3Q w/ step feed	Yes	C	Yes	Yes
BioMag	In use and refining capabilities	BioMag™ is an enhanced biological wastewater treatment process that uses magnetite to increase the specific gravity of biological floc. Magnetite is an inert, high specific gravity (SG=5.2), non-abrasive iron ore (Fe3O4) with strong affinity for biological solids which provides the opportunity to increase the mixed liquor concentration, while maintaining adequate settling and thickening in the secondary clarifiers.	Yes	Yes	may be able to take 6Q	Yes	C/H	Yes	Yes
Cyclic Activated Sludge/Sequencing Batch	Established	Generally consists of five stages, fill, react, settle, decant and idle. The react phase could be aerobic or anoxic. An anoxic step could be added by turning the air off and using mechanical mixers to mix the biomass. Settling occurs in the same tank as the reaction phase.	Yes	Yes	may be able to take 3-4Q	Yes	C	Yes	Yes
Phased Isolation Ditch/continuous SBR (CSBR)	Established	A Phased Isolation Ditch system is a continuous flow activated sludge process in which the main treatment phases of the process are isolated into separate oxidation ditches. The process conditions within the oxidation ditches will alternate or phase between oxic, anoxic and/or settling. Phased Isolation Ditch can be designed to operate with or without external clarifiers. These processes include the Double Ditch (D-Ditch), BIO-DENITRO and BIO-DENIPHO.	No	Yes	Yes 2Q, 3Q w/ step feed	Yes	C	Yes	Yes
CANDO (Coupled Aerobic-anoxic Nitrous Decomposition Operation) (emerging)	Embryonic	CANDO has three major steps: 1- Nitritation of NH4 to NO2 2- Partial anoxic reduction of NO2 to N2O by one of the following methods: a. Abiotic Reduction: Fe(II) precipitates with Fe(III) and reduces NO2 to N2O. b. Partial heterotrophic denitrification: alternating pulses of acetate and NO2 are added to select for organisms that store PHB (polyhydroxybutyrate) after acetate pulse and produce N2O after the NO2 pulse. 3- N2O conversion to N2 with energy recovery by the following equation: CH4 + 4N2O CO2 + 2H2O(l) + 4N2; ΔĤR° (heat of reaction) = -1219 kJ mol -1 CH4; The heat of rection of CH4 with O2 is -890 kJ mol -1 CH4.							
Algae biomass cultivation for biofuels production combined with wastewater treatment	Embryonic	Algae biomass can be cultivated alongside biological wastewater treatment for energy generation and nutrient removal. Additional benefits of this process can be removal of heavy metal and some trace elements by algae.							

1 footnote: C= comparable to CAS energy use , L = lower energy than CAS, H = Higher use than CAS

Appendix B - Life Cycle Cost Analysis

THC WWTP

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

IFAS w/ CoMag		Base Year Cost	2015	2016	2017	2018	2019	Mid-Point of Construction 2020	First Year of Service 2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Salvage Value @ 24 years	
Capital Costs (Modify as Required)																													
PRIMARY CLARIFIER & SPS		$9,450,000																										0%	$0
Primary clarifiers			$2,854,000	-	-	-	-	$3,136,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$2,690,000
Flow splitter			$200,000	-	-	-	-	$220,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$157,000
Magnetite Recovery Equipment & Bldg			$6,396,000	-	-	-	-	$7,027,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$5,024,000
ADDITIONAL SCREENING			$0																										$0
SECONDARY TREATMENT		$25,904,235																										0%	$0
Upstream splitter			$450,000	-	-	-	-	$494,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$353,000
Biological basins[1]			$6,922,001	-	-	-	-	$7,605,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$5,437,000
Blower Building[1]			$3,960,000	-	-	-	-	$4,351,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$3,111,000
IFAS technology and vendor IP			$4,200,000	-	-	-	-	$4,614,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Secondary Clarifiers			$6,872,234	-	-	-	-	$7,550,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$5,398,000
Secondary S.P.S.			$3,500,000	-	-	-	-	$3,845,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$2,749,000
INTERMEDIATE PUMP STATION			$1,997,000	-	-	-	-	$2,194,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$1,569,000
AUX/TERT FILTERS			$0																									50%	$0
TERTIARY FILTERS			$5,625,000	-	-	-	-	$6,180,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$4,418,000
Markups																													
Electrical, Instrumentation & Controls	20%		$8,595,000	-	-	-	-	$9,443,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%		$8,595,000	-	-	-	-	$9,443,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
PC and PS Deep Foundation			$1,276,000	-	-	-	-	$1,402,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,203,000
Basin Deep Foundation			$1,545,480	-	-	-	-	$1,698,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,457,000
Sec Clarifier Deep Foundation			$1,521,709	-	-	-	-	$1,672,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,434,000
IPS Deep Foundation			$36,000																									60%	$34,000
Tertiary Filters Deep Foundation			$478,000																									60%	$451,000
General Requirements	15%		$9,754,000	-	-	-	-	$10,717,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%		$18,694,000	-	-	-	-	$20,539,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%		$23,368,000	-	-	-	-	$25,674,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs			$116,839,000	-	-	-	-	$127,804,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year[(1)]				-	-	-	-	$109,711,239	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs [(1)]			$109,700,000																										
NPV of Salvage Value			$17,054,000																										
O&M Costs (Modify As Required)																													
Primary chemical usage			$178,800	-	-	-	-	-	$200,176	$203,980	$207,855	$211,804	$215,829	$219,930	$224,108	$228,366	$232,705	$237,127	$241,632	$246,223	$250,901	$255,668	$260,526	$265,476	$270,520	$275,660	$280,898		
Secondary chemical usage			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
IFAS Replacement	0%		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Primary power usage			$70,100	-	-	-	-	-	$78,481	$79,972	$81,491	$83,040	$84,617	$86,225	$87,863	$89,533	$91,234	$92,967	$94,734	$96,534	$98,368	$100,237	$102,141	$104,082	$106,060	$108,075	$110,128		
Secondary power usage			$590,000	-	-	-	-	-	$660,537	$673,087	$685,876	$698,907	$712,187	$725,718	$739,507	$753,558	$767,875	$782,465	$797,332	$812,481	$827,918	$843,648	$859,678	$876,012	$892,656	$909,616	$926,899		
Magnetite replacement			$24,500	-	-	-	-	-	$27,429	$27,950	$28,481	$29,022	$29,574	$30,136	$30,708	$31,292	$31,886	$32,492	$33,110	$33,739	$34,380	$35,033	$35,698	$36,377	$37,068	$37,772	$38,490		
Intermediate pump station			$89,000	-	-	-	-	-	$99,640	$101,533	$103,463	$105,428	$107,432	$109,473	$111,553	$113,672	$115,832	$118,033	$120,275	$122,561	$124,889	$127,262	$129,680	$132,144	$134,655	$137,213	$139,820		
Tertiary filtration			$57,000	-	-	-	-	-	$63,815	$65,027	$66,263	$67,522	$68,804	$70,112	$71,444	$72,801	$74,185	$75,594	$77,030	$78,494	$79,985	$81,505	$83,054	$84,632	$86,240	$87,878	$89,548		
Labor			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Total, O&M Costs			$1,009,400	$0	$0	$0	$0	$0	$1,130,078	$1,151,549	$1,173,429	$1,195,724	$1,218,443	$1,241,593	$1,265,183	$1,289,222	$1,313,717	$1,338,678	$1,364,113	$1,390,031	$1,416,441	$1,443,354	$1,470,778	$1,498,722	$1,527,198	$1,556,215	$1,585,783		
NPV of O&M Cost at Base Year				$0	$0	$0	$0	$0	$940,928	$929,976	$919,152	$908,454	$897,880	$887,430	$877,101	$866,892	$856,802	$846,830	$836,973	$827,232	$817,603	$808,087	$798,682	$789,386	$780,198	$771,117	$762,142		
Total NPV of O&M Costs			$16,123,000																										

Total Salvage Value $35,485,000

NPV Summary

Capital Cost	$109,700,000
Salvage	($17,054,000)
O&M	$16,123,000
Total NPV	**$108,800,000**
Total NPV w/o Salvage	**$125,823,000**

Economic Assumptions

Capital Escalation Rate	1.90%
O&M Escalation Rate	1.90%
Annual Interest Rate	3.10%

[1] Biological basin equipment and blowers for all alternatives will have similar O&M costs throughout life cycle and are thus not included in this evaluation

THC WWTP

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

MBR w/ CoMag		Base Year Cost 2015	2016	2017	2018	2019	Mid-Point of Construction 2020	First Year of Service 2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Salvage Value @ 20 years	
Capital Costs (Modify as Required)																												
PRIMARY CLARIFIER & SPS		$9,450,000																									0%	$0
Primary clarifiers		$2,854,000	-	-	-	-	$3,136,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$2,690,000
Flow splitter		$200,000	-	-	-	-	$220,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$157,000
Magnetite Recovery Equipment & Bldg		$6,396,000	-	-	-	-	$7,027,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$5,024,000
ADDITIONAL SCREENING		$3,400,000	-	-	-	-	$3,736,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$2,671,000
SECONDARY TREATMENT		$37,501,920																									0%	$0
Upstream splitter		$450,000	-	-	-	-	$494,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$353,000
Biological basins[1]		$9,365,720	-	-	-	-	$10,290,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$7,357,000
Blower Building[1]		$4,950,000	-	-	-	-	$5,438,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$3,888,000
Membrane/Permeate/Air/CIP system		$14,000,000	-	-	-	-	$15,382,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45%	$9,897,000
Membrane replacement @ 10 yrs service		$4,939,200																$5,962,089									0%	$0
Increased permeate pump head		$100,000	-	-	-	-	$110,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45%	$71,000
CIP building		$525,000	-	-	-	-	$577,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$412,000
Permeate/RAS building		$2,744,000	-	-	-	-	$3,015,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$2,155,000
WAS wetwell and pumps		$428,000	-	-	-	-	$470,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$336,000
INTERMEDIATE PUMP STATION		$0																									0%	$0
AUX/TERT FILTERS		$0																									0%	$0
TERTIARY FILTERS		$0																									0%	$0
Markups																											Total Salvage Value	$38,492,000
Electrical, Instrumentation & Controls	20%	$10,070,000	-	-	-	-	$11,064,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%	$10,070,000	-	-	-	-	$11,064,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
PC and PS Deep Foundation		$1,276,000	-	-	-	-	$1,402,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,203,000
Basin Deep Foundation		$2,416,800	-	-	-	-	$2,655,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$2,278,000
General Requirements	15%	$11,128,000	-	-	-	-	$12,226,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%	$21,328,000	-	-	-	-	$23,433,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%	$26,660,000	-	-	-	-	$29,291,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs		$133,301,000	$0	$0	$0	$0	$141,030,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$5,962,000	$0	$0	$0	$0	$0	$0	$0	$0		
NPV of Capital Cost at Base Year[(1)]			$0	$0	$0	$0	$121,064,881	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,658,081	$0	$0	$0	$0	$0	$0	$0	$0		
Total NPV of Capital Costs [(1)]		$124,700,000																										
NPV of Salvage Value		$18,500,000																										
O&M Costs (Modify As Required)																												
Primary chemical usage		$178,800	-	-	-	-	-	$200,176	$203,980	$207,855	$211,804	$215,829	$219,930	$224,108	$228,366	$232,705	$237,127	$241,632	$246,223	$250,901	$255,668	$260,526	$265,476	$270,520	$275,660	$280,898		
Membrane cleaning chemical usage		$165,000	-	-	-	-	-	$184,726	$188,236	$191,813	$195,457	$199,171	$202,955	$206,811	$210,741	$214,745	$218,825	$222,983	$227,219	$231,536	$235,936	$240,418	$244,986	$249,641	$254,384	$259,218		
Primary power usage		$70,100	-	-	-	-	-	$78,481	$79,972	$81,491	$83,040	$84,617	$86,225	$87,863	$89,533	$91,234	$92,967	$94,734	$96,534	$98,368	$100,237	$102,141	$104,082	$106,060	$108,075	$110,128		
Fine Screen Building O&M (equip = 45%)	3%	$45,900	-	-	-	-	-	$51,388	$52,364	$53,359	$54,373	$55,406	$56,458	$57,531	$58,624	$59,738	$60,873	$62,030	$63,208	$64,409	$65,633	$66,880	$68,151	$69,446	$70,765	$72,110		
Membrane Equipment O&M	3%	$210,000	-	-	-	-	-	$235,106	$239,573	$244,125	$248,764	$253,490	$258,306	$263,214	$268,215	$273,311	$278,504	$283,796	$289,188	$294,683	$300,282	$305,987	$311,801	$317,725	$323,762	$329,913		
Secondary power usage		$1,170,000	-	-	-	-	-	$1,309,878	$1,334,766	$1,360,127	$1,385,969	$1,412,302	$1,439,136	$1,466,480	$1,494,343	$1,522,735	$1,551,667	$1,581,149	$1,611,191	$1,641,803	$1,672,998	$1,704,785	$1,737,176	$1,770,182	$1,803,815	$1,838,088		
Magnetite replacement		$25,000	-	-	-	-	-	$27,989	$28,521	$29,063	$29,615	$30,177	$30,751	$31,335	$31,930	$32,537	$33,155	$33,785	$34,427	$35,081	$35,748	$36,427	$37,119	$37,824	$38,543	$39,275		
Labor		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Total, O&M Costs		$1,864,800	$0	$0	$0	$0	$0	$2,087,745	$2,127,412	$2,167,833	$2,209,021	$2,250,993	$2,293,762	$2,337,343	$2,381,753	$2,427,006	$2,473,119	$2,520,108	$2,567,990	$2,616,782	$2,666,501	$2,717,165	$2,768,791	$2,821,398	$2,875,004	$2,929,629		
NPV of O&M Cost at Base Year							$0	$1,738,303	$1,718,070	$1,698,073	$1,678,309	$1,658,775	$1,639,468	$1,620,386	$1,601,526	$1,582,886	$1,564,462	$1,546,253	$1,528,256	$1,510,468	$1,492,888	$1,475,512	$1,458,338	$1,441,364	$1,424,588	$1,408,007		
Total NPV of O&M Costs		$29,800,000																										

NPV Summary

Capital Cost	$124,700,000
Salvage	($18,500,000)
O&M	$29,800,000
Total NPV	**$136,000,000**
Total NPV w/o Salvage	**$154,500,000**

Economic Assumptions

Capital Escalation Rate	1.90%
O&M Escalation Rate	1.90%
Annual Interest Rate	3.10%

[1] Biological basin equipment and blowers for all alternatives will have similar O&M costs throughout life cycle and are thus not included in this evaluation

THC WWTP

Base Year for cost Estimate	**2015**
First Year of Service	**2021**
Mid-Point of Construction	**2020**

BioMag w/ CoMag		**Base Year Cost**	**2015**	**2016**	**2017**	**2018**	**2019**	**Mid-Point of Construction 2020**	**First Year of Service 2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**Salvage Value @ 24 years**	
Capital Costs (Modify as Required)																													
PRIMARY CLARIFIER & SPS		$9,450,000																										0%	$0
Primary clarifiers			$2,854,000	-	-	-	-	$2,854,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,712,000
Flow splitter			$200,000	-	-	-	-	$200,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$100,000
Magnetite Recovery Equipment & Bldg			$6,396,000	-	-	-	-	$6,396,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$3,198,000
ADDITIONAL SCREENING			$0																										$0
SECONDARY TREATMENT		$25,304,706																										0%	$0
Upstream splitter			$450,000	-	-	-	-	$494,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$353,000
Biological basins[1]			$7,120,872	-	-	-	-	$7,824,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$5,593,000
Blower Building[1]			$3,960,000	-	-	-	-	$4,351,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$3,111,000
Magnetite Recovery Equipment & Bldg			$3,401,600	-	-	-	-	$3,737,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$2,672,000
Secondary Clarifiers			$6,872,234	-	-	-	-	$7,550,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$5,398,000
Secondary S.P.S.			$3,500,000	-	-	-	-	$3,845,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$2,749,000
INTERMEDIATE PUMP STATION			$1,997,000	-	-	-	-	$2,194,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$1,569,000
AUX/TERT FILTERS			$0																									50%	$0
TERTIARY FILTERS			$0																									50%	$0
Markups																												Total Salvage Value	$30,146,000
Electrical, Instrumentation & Controls	20%		$7,350,000	-	-	-	-	$8,075,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%		$7,350,000	-	-	-	-	$8,075,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
PC and PS Deep Foundation			$1,276,000	-	-	-	-	$1,402,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$766,000
Basin Deep Foundation			$1,545,480	-	-	-	-	$1,698,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,457,000
Sec Clarifier Deep Foundation			$1,521,709	-	-	-	-	$1,672,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,434,000
IPS Deep Foundation			$36,000	-	-	-	-	$40,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$34,000
General Requirements	15%		$8,375,000	-	-	-	-	$9,201,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%		$16,051,000	-	-	-	-	$17,635,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%		$20,064,000	-	-	-	-	$22,044,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs			$100,321,000	-	-	-	-	$109,287,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year[(1)]				-	-	-	-	$93,815,625	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs [(1)]			$93,800,000																										
NPV of Salvage Value			$14,488,000																										
O&M Costs (Modify As Required)																													
Primary chemical usage			$178,800	-	-	-	-	-	$200,176	$203,980	$207,855	$211,804	$215,829	$219,930	$224,108	$228,366	$232,705	$237,127	$241,632	$246,223	$250,901	$255,668	$260,526	$265,476	$270,520	$275,660	$280,898		
Secondary chemical usage			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Primary power usage			$70,100	-	-	-	-	-	$78,481	$79,972	$81,491	$83,040	$84,617	$86,225	$87,863	$89,533	$91,234	$92,967	$94,734	$96,534	$98,368	$100,237	$102,141	$104,082	$106,060	$108,075	$110,128		
Secondary power usage			$798,000	-	-	-	-	-	$893,404	$910,379	$927,676	$945,302	$963,263	$981,565	$1,000,214	$1,019,218	$1,038,584	$1,058,317	$1,078,425	$1,098,915	$1,119,794	$1,141,070	$1,162,751	$1,184,843	$1,207,355	$1,230,295	$1,253,670		
Magnetite Recovery Equipment O&M	3%		$75,000	-	-	-	-	-	$83,967	$85,562	$87,188	$88,844	$90,532	$92,252	$94,005	$95,791	$97,611	$99,466	$101,356	$103,281	$105,244	$107,243	$109,281	$111,357	$113,473	$115,629	$117,826		
Primary Magnetite replacement			$25,000	-	-	-	-	-	$27,989	$28,521	$29,063	$29,615	$30,177	$30,751	$31,335	$31,930	$32,537	$33,155	$33,785	$34,427	$35,081	$35,748	$36,427	$37,119	$37,824	$38,543	$39,275		
Secondary Magnetite replacement			$61,625	-	-	-	-	-	$68,992	$70,303	$71,639	$73,000	$74,387	$75,800	$77,240	$78,708	$80,203	$81,727	$83,280	$84,862	$86,475	$88,118	$89,792	$91,498	$93,236	$95,008	$96,813		
Intermediate pump station			$89,000	-	-	-	-	-	$99,640	$101,533	$103,463	$105,428	$107,432	$109,473	$111,553	$113,672	$115,832	$118,033	$120,275	$122,561	$124,889	$127,262	$129,680	$132,144	$134,655	$137,213	$139,820		
Tertiary filtration			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Labor			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Total, O&M Costs			$1,297,525	$0	$0	$0	$0	$0	$1,452,649	$1,480,249	$1,508,374	$1,537,033	$1,566,237	$1,595,995	$1,626,319	$1,657,219	$1,688,706	$1,720,792	$1,753,487	$1,786,803	$1,820,752	$1,855,347	$1,890,598	$1,926,520	$1,963,123	$2,000,423	$2,038,431		
NPV of O&M Cost at Base Year				$0	$0	$0	$0	$0	$1,209,508	$1,195,430	$1,181,516	$1,167,764	$1,154,173	$1,140,739	$1,127,462	$1,114,339	$1,101,369	$1,088,550	$1,075,880	$1,063,358	$1,050,981	$1,038,749	$1,026,658	$1,014,709	$1,002,898	$991,226	$979,689		
Total NPV of O&M Costs			$20,700,000																										

NPV Summary

Capital Cost	$93,800,000
Salvage	($14,488,000)
O&M	$20,700,000
Total NPV	**$100,012,000**
Total NPV w/o Salvage	**$114,500,000**

Economic Assumptions

Capital Escalation Rate	1.90%
O&M Escalation Rate	1.90%
Annual Interest Rate	3.10%

[1] Biological basin equipment and blowers for all alternatives will have similar O&M costs throughout life cycle and are thus not included in this evaluation

THC WWTP

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

GAS		Base Year Cost 2015	2016	2017	2018	2019	Mid-Point of Construction 2020	First Year of Service 2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Salvage Value @ 24 years	
Capital Costs (Modify as Required)																												
PRIMARY CLARIFIER & SPS		$0																									0%	$0
Primary clarifiers		$0																									0%	$0
Primary clarifier equipment		$0																									0%	$0
Magnetite Recovery Equipment & Bldg		$0																									0%	$0
Primary Sludge Pump Station		$0																									0%	$0
ADDITIONAL SCREENING		$0																										$0
SECONDARY TREATMENT		$22,870,000																									0%	$0
Concrete		$5,980,000	-	-	-	-	$6,570,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$5,637,000
Excavation		$598,000	-	-	-	-	$657,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$564,000
Blowers[1]		$1,196,000	-	-	-	-	$1,314,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45%	$846,000
Recirc pumps[1]		$968,000	-	-	-	-	$1,064,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45%	$684,000
WAS pumps [1]		$160,000	-	-	-	-	$176,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45%	$113,000
Equipment installation	25%	$581,000	-	-	-	-	$638,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Aeration, diffusion, sludge drawoff system [1]		$5,170,000	-	-	-	-	$5,680,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45%	$3,655,000
Splitter box(es)		$450,000	-	-	-	-	$494,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$353,000
Fermenter		$2,700,000	-	-	-	-	$2,966,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$2,121,000
Pipe Gallery		$550,000	-	-	-	-	$604,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$259,000
Pipe Gallery HVAC		$483,000	-	-	-	-	$531,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45%	$341,000
Miscellaneous metals		$44,000	-	-	-	-	$48,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$21,000
Effluent System		$1,770,000	-	-	-	-	$1,945,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,668,000
Vendor IP/fee		$2,220,000	-	-	-	-	$2,439,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
INTERMEDIATE PUMP STATION		$2,033,000	-	-	-	-	$2,234,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$1,597,000
AUX/TERT FILTERS		$19,466,000	-	-	-	-	$21,387,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$15,291,000
TERTIARY FILTERS		$0																									0%	$0
Markups																											Total Salvage Value	$39,370,000
Electrical, Instrumentation & Controls	20%	$8,874,000	-	-	-	-	$9,750,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%	$8,874,000	-	-	-	-	$9,750,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
GAS Basin Deep Foundation		$3,864,000	-	-	-	-	$4,245,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$3,642,000
Fermenter Deep Foundation		$1,063,692	-	-	-	-	$1,169,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,003,000
IPS Deep Foundation		$39,000	-	-	-	-	$43,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$37,000
Tertiary Filtration Deep Foundation		$1,632,000	-	-	-	-	$1,793,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,538,000
General Requirements	15%	$9,318,000	-	-	-	-	$10,237,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	35%	$27,312,000	-	-	-	-	$30,007,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%	$26,336,000	-	-	-	-	$28,935,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Pilot Testing		$750,000	-	-	-	-	$824,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs		$132,432,000	-	-	-	-	$145,500,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year[(1)]			-	-	-	-	$124,902,079	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs [(1)]		$124,900,000																										
NPV of Salvage Value		$18,922,000																										
O&M Costs (Modify As Required)																												
Primary chemical usage		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Secondary chemical usage		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Primary power usage		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Secondary power usage		$560,000	-	-	-	-	-	$626,950	$638,862	$651,001	$663,370	$675,974	$688,817	$701,905	$715,241	$728,831	$742,678	$756,789	$771,168	$785,820	$800,751	$815,965	$831,469	$847,267	$863,365	$879,769		
Magnetite replacement		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Intermediate pump station		$89,000	-	-	-	-	-	$99,640	$101,533	$103,463	$105,428	$107,432	$109,473	$111,553	$113,672	$115,832	$118,033	$120,275	$122,561	$124,889	$127,262	$129,680	$132,144	$134,655	$137,213	$139,820		
Tertiary/WW filtration		$43,000	-	-	-	-	-	$48,141	$49,056	$49,988	$50,937	$51,905	$52,891	$53,896	$54,920	$55,964	$57,027	$58,111	$59,215	$60,340	$61,486	$62,654	$63,845	$65,058	$66,294	$67,554		
Labor		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Total, O&M Costs		$692,000	$0	$0	$0	$0	$0	$774,731	$789,451	$804,451	$819,736	$835,310	$851,181	$867,354	$883,834	$900,626	$917,738	$935,175	$952,944	$971,050	$989,500	$1,008,300	$1,027,458	$1,046,979	$1,066,872	$1,087,143		
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$645,059	$637,551	$630,130	$622,796	$615,547	$608,383	$601,302	$594,303	$587,386	$580,549	$573,792	$567,113	$560,513	$553,989	$547,541	$541,168	$534,869	$528,644	$522,491		
Total NPV of O&M Costs		$11,100,000																										

NPV Summary

Capital Cost	$124,900,000
Salvage	($18,900,000)
O&M	$11,100,000
Total NPV	**$117,100,000**
Total NPV w/o Salvage	**$136,000,000**

Economic Assumptions

Capital Escalation Rate	1.90%
O&M Escalation Rate	1.90%
Annual Interest Rate	3.10%

[1] Biological basin equipment and blowers for all alternatives will have similar maintenance costs throughout life cycle and are thus not included in this evaluation

THC WWTP

Base Year for cost Estimate	**2015**
First Year of Service	**2021**
Mid-Point of Construction	**2020**

IFAS w/ CEPT		**Base Year Cost**	**2015**	**2016**	**2017**	**2018**	**2019**	**Mid-Point of Construction 2020**	**First Year of Service 2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**Salvage Value @ 24 years**	
Capital Costs (Modify as Required)																													
PRIMARY CLARIFIER & SPS		$5,306,000																										0%	$0
Primary clarifiers			$3,944,000	-	-	-	-	$4,333,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$3,718,000
Splitter			$200,000	-	-	-	-	$220,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$157,000
Primary Sludge Pump Station			$1,162,000	-	-	-	-	$1,277,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$913,000
ADDITIONAL SCREENING			$0																									0%	$0
SECONDARY TREATMENT		$30,723,118																										0%	$0
Upstream splitter			$450,000	-	-	-	-	$494,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$353,000
Biological basins[1]			$10,740,884	-	-	-	-	$11,801,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$8,437,000
Blower Building[1]			$4,160,000	-	-	-	-	$4,571,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$3,268,000
IFAS technology and vendor IP			$5,000,000	-	-	-	-	$5,493,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Secondary Clarifiers			$6,872,234	-	-	-	-	$7,550,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$5,398,000
Secondary S.P.S.			$3,500,000	-	-	-	-	$3,845,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$2,749,000
INTERMEDIATE PUMP STATION			$1,997,000	-	-	-	-	$2,194,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$1,569,000
AUX/TERT FILTERS			$14,455,000	-	-	-	-	$15,881,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$11,355,000
TERTIARY FILTERS			$0																									50%	$0
Markups																												Total Salvage Value	$44,393,000
Electrical, Instrumentation & Controls	20%		$10,496,000	-	-	-	-	$11,532,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%		$10,496,000	-	-	-	-	$11,532,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
PC and S.P.S. Deep Foundation	N/A		$1,378,000	-	-	-	-	$1,514,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,299,000
Basin Deep Foundation	N/A		$2,470,860	-	-	-	-	$2,715,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$2,329,000
Sec Clarifier Deep Foundation	N/A		$1,521,709	-	-	-	-	$1,672,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,434,000
IPS Deep Foundation	N/A		$36,000	-	-	-	-	$40,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$34,000
Tertiary Filters Deep Foundation	N/A		$1,464,000	-	-	-	-	$1,608,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,380,000
General Requirements	15%		$11,021,000	-	-	-	-	$12,109,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%		$22,841,000	-	-	-	-	$25,095,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%		$28,551,000	-	-	-	-	$31,368,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs			$142,757,000	-	-	-	-	$156,844,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year[(1)]				-	-	-	-	$134,640,149	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs [(1)]			$134,640,000																										
NPV of Salvage Value			$21,336,000																										
O&M Costs (Modify As Required)																													
Primary chemical usage			$31,000	-	-	-	-	-	$34,706	$35,366	$36,038	$36,722	$37,420	$38,131	$38,855	$39,594	$40,346	$41,113	$41,894	$42,690	$43,501	$44,327	$45,170	$46,028	$46,902	$47,793	$48,701		
Secondary chemical usage			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
IFAS Replacement	0%		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Primary power usage			$39,000	-	-	-	-	-	$43,663	$44,492	$45,338	$46,199	$47,077	$47,971	$48,883	$49,811	$50,758	$51,722	$52,705	$53,706	$54,727	$55,767	$56,826	$57,906	$59,006	$60,127	$61,270		
Secondary power usage			$727,000	-	-	-	-	-	$813,916	$829,380	$845,138	$861,196	$877,559	$894,232	$911,223	$928,536	$946,178	$964,156	$982,475	$1,001,142	$1,020,163	$1,039,546	$1,059,298	$1,079,425	$1,099,934	$1,120,832	$1,142,128		
Magnetite replacement			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Intermediate pump station			$89,000	-	-	-	-	-	$99,640	$101,533	$103,463	$105,428	$107,432	$109,473	$111,553	$113,672	$115,832	$118,033	$120,275	$122,561	$124,889	$127,262	$129,680	$132,144	$134,655	$137,213	$139,820		
Tertiary filtration			$35,000	-	-	-	-	-	$39,184	$39,929	$40,688	$41,461	$42,248	$43,051	$43,869	$44,703	$45,552	$46,417	$47,299	$48,198	$49,114	$50,047	$50,998	$51,967	$52,954	$53,960	$54,986		
Labor			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Total, O&M Costs			$921,000	$0	$0	$0	$0	$0	$1,031,109	$1,050,700	$1,070,664	$1,091,006	$1,111,735	$1,132,858	$1,154,383	$1,176,316	$1,198,666	$1,221,441	$1,244,648	$1,268,296	$1,292,394	$1,316,950	$1,341,972	$1,367,469	$1,393,451	$1,419,926	$1,446,905		
NPV of O&M Cost at Base Year				$0	$0	$0	$0	$0	$858,525	$848,532	$838,656	$828,895	$819,247	$809,712	$800,287	$790,972	$781,766	$772,667	$763,674	$754,785	$746,000	$737,317	$728,736	$720,254	$711,871	$703,585	$695,396		
Total NPV of O&M Costs			$14,711,000																										

NPV Summary

Capital Cost	$134,640,000
Salvage	($21,336,000)
O&M	$14,711,000
Total NPV	**$128,015,000**
Total NPV w/o Salvage	**$149,351,000**

Economic Assumptions

Capital Escalation Rate	1.90%
O&M Escalation Rate	1.90%
Annual Interest Rate	3.10%

[1] Biological basin equipment and blowers for all alternatives will have similar O&M costs throughout life cycle and are thus not included in this evaluation

THC WWTP

Base Year for cost Estimate	**2015**
First Year of Service	**2021**
Mid-Point of Construction	**2020**

MBR w/ CEPT		**Base Year Cost**	**2015**	**2016**	**2017**	**2018**	**2019**	**Mid-Point of Construction 2020**	**First Year of Service 2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**Salvage Value @ 24 years**	
Capital Costs (Modify as Required)																													
PRIMARY CLARIFIER & SPS		$3,604,000																										0%	$0
Primary clarifiers			$2,629,333	-	-	-	-	$2,889,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$2,478,000
Splitter			$200,000	-	-	-	-	$220,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$157,000
Primary Sludge Pump Station			$774,667	-	-	-	-	$851,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$609,000
ADDITIONAL SCREENING			$3,400,000	-	-	-	-	$3,736,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$2,671,000
SECONDARY TREATMENT		$40,493,509																										0%	$0
Upstream splitter			$450,000	-	-	-	-	$494,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$353,000
Biological basins[1]			$12,157,309	-	-	-	-	$13,357,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$9,550,000
Blower Building[1]			$5,150,000	-	-	-	-	$5,658,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$4,045,000
Membrane/Permeate/Air/CIP system			$14,000,000	-	-	-	-	$15,382,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45%	$9,897,000
Membrane replacement @ 10 yrs service			$4,939,200																$5,962,089									0%	$0
Increased permeate pump head			$100,000	-	-	-	-	$100,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$50,000
CIP building			$525,000	-	-	-	-	$525,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$263,000
Permeate/RAS building			$2,744,000	-	-	-	-	$2,744,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$1,372,000
WAS wetwell and pumps			$428,000	-	-	-	-	$428,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$214,000
INTERMEDIATE PUMP STATION			$0																									50%	$0
AUX/TERT FILTERS			$0																									50%	$0
TERTIARY FILTERS			$16,541,000	-	-	-	-	$18,173,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$12,993,000
Markups																												Total Salvage Value	$49,767,000
Electrical, Instrumentation & Controls	20%		$12,808,000	-	-	-	-	$14,072,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%		$12,808,000	-	-	-	-	$14,072,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
PC and S.P.S. Deep Foundation	N/A		$918,667	-	-	-	-	$1,009,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$866,000
Secondary Deep Foundation	N/A		$2,800,000	-	-	-	-	$3,076,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$2,639,000
Sec Clarifier Deep Foundation	N/A		$0																									60%	$0
Aux Filter Deep Foundation	N/A		$1,708,000	-	-	-	-	$1,877,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,610,000
General Requirements	15%		$13,448,000	-	-	-	-	$14,775,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%		$27,132,000	-	-	-	-	$29,809,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%		$33,915,000	-	-	-	-	$37,262,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs			$169,576,000	-	-	-	-	$180,509,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year[(1)]				-	-	-	-	$154,954,978	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs [(1)]			$154,955,000																										
NPV of Salvage Value			$23,918,000																										
O&M Costs (Modify As Required)																													
Primary chemical usage			$31,000	-	-	-	-	-	$34,706	$35,366	$36,038	$36,722	$37,420	$38,131	$38,855	$39,594	$40,346	$41,113	$41,894	$42,690	$43,501	$44,327	$45,170	$46,028	$46,902	$47,793	$48,701		
Membrane cleaning chemical usage			$165,000	-	-	-	-	-	$184,726	$188,236	$191,813	$195,457	$199,171	$202,955	$206,811	$210,741	$214,745	$218,825	$222,983	$227,219	$231,536	$235,936	$240,418	$244,986	$249,641	$254,384	$259,218		
Primary power usage			$39,000	-	-	-	-	-	$43,663	$44,492	$45,338	$46,199	$47,077	$47,971	$48,883	$49,811	$50,758	$51,722	$52,705	$53,706	$54,727	$55,767	$56,826	$57,906	$59,006	$60,127	$61,270		
Fine Screen Building O&M (equip = 45%)	3%		$45,900	-	-	-	-	-	$51,388	$52,364	$53,359	$54,373	$55,406	$56,458	$57,531	$58,624	$59,738	$60,873	$62,030	$63,208	$64,409	$65,633	$66,880	$68,151	$69,446	$70,765	$72,110		
Membrane Equipment O&M	3%		$210,000	-	-	-	-	-	$235,106	$239,573	$244,125	$248,764	$253,490	$258,306	$263,214	$268,215	$273,311	$278,504	$283,796	$289,188	$294,683	$300,282	$305,987	$311,801	$317,725	$323,762	$329,913		
Secondary power usage			$1,470,000	-	-	-	-	-	$1,645,745	$1,677,014	$1,708,877	$1,741,346	$1,774,431	$1,808,145	$1,842,500	$1,877,508	$1,913,180	$1,949,531	$1,986,572	$2,024,317	$2,062,779	$2,101,972	$2,141,909	$2,182,605	$2,224,075	$2,266,332	$2,309,392		
Magnetite replacement			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Intermediate pump station			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Tertiary filtration			$23,000	-	-	-	-	-	$25,750	$26,239	$26,738	$27,246	$27,763	$28,291	$28,828	$29,376	$29,934	$30,503	$31,082	$31,673	$32,275	$32,888	$33,513	$34,150	$34,798	$35,460	$36,133		
Labor			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Total, O&M Costs			$1,983,900	$0	$0	$0	$0	$0	$2,221,083	$2,263,284	$2,306,286	$2,350,106	$2,394,758	$2,440,258	$2,486,623	$2,533,869	$2,582,013	$2,631,071	$2,681,061	$2,732,001	$2,783,909	$2,836,804	$2,890,703	$2,945,626	$3,001,593	$3,058,623	$3,116,737		
NPV of O&M Cost at Base Year				$0	$0	$0	$0	$0	$1,849,324	$1,827,799	$1,806,525	$1,785,498	$1,764,717	$1,744,177	$1,723,876	$1,703,811	$1,683,980	$1,664,380	$1,645,008	$1,625,862	$1,606,938	$1,588,235	$1,569,749	$1,551,478	$1,533,420	$1,515,572	$1,497,932		
Total NPV of O&M Costs			$31,688,000																										

NPV Summary

Capital Cost	$154,955,000
Salvage	($23,918,000)
O&M	$31,688,000
Total NPV	**$162,725,000**
Total NPV w/o Salvage	**$186,643,000**

Economic Assumptions

Capital Escalation Rate	1.90%
O&M Escalation Rate	1.90%
Annual Interest Rate	3.10%

[1] Biological basin equipment and blowers for all alternatives will have similar O&M costs throughout life cycle and are thus not included in this evaluation

THC WWTP

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

BioMag w/ CEPT		Base Year Cost	2015	2016	2017	2018	2019	Mid-Point of Construction 2020	First Year of Service 2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Salvage Value @ 24 years	
Capital Costs (Modify as Required)																													
PRIMARY CLARIFIER & SPS		$5,306,000																										0%	$0
Primary clarifiers			$3,944,000	-	-	-	-	$4,333,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$3,718,000
Splitter			$200,000	-	-	-	-	$220,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$157,000
Primary Sludge Pump Station			$1,162,000	-	-	-	-	$1,277,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$913,000
ADDITIONAL SCREENING			$0																										$0
SECONDARY TREATMENT		$28,537,670																										0%	$0
Upstream splitter			$450,000	-	-	-	-	$494,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$353,000
Biological basins[1]			$10,153,836	-	-	-	-	$11,156,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$7,976,000
Blower Building[1]			$4,160,000	-	-	-	-	$4,571,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$3,268,000
Magnetite Recovery Bldg			$3,401,600	-	-	-	-	$3,737,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$2,672,000
Secondary Clarifiers			$6,872,234	-	-	-	-	$7,550,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$5,398,000
Secondary S.P.S.			$3,500,000	-	-	-	-	$3,845,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$2,749,000
INTERMEDIATE PUMP STATION			$1,997,000	-	-	-	-	$2,194,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$1,569,000
AUX/TERT FILTERS			$0																									50%	$0
TERTIARY FILTERS			$14,178,000	-	-	-	-	$15,577,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$11,137,000
Markups																												Total Salvage Value	$44,386,000
Electrical, Instrumentation & Controls	20%		$10,004,000	-	-	-	-	$10,991,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%		$10,004,000	-	-	-	-	$10,991,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
PC and S.P.S. Deep Foundation	N/A		$1,378,000	-	-	-	-	$1,514,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$827,000
Secondary Deep Foundation	N/A		$2,203,740	-	-	-	-	$2,421,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,322,000
Sec Clarifier Deep Foundation	N/A		$1,521,709	-	-	-	-	$1,672,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$913,000
IPS Deep Foundation	N/A		$36,000	-	-	-	-	$40,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$34,000
Aux/Tert Filter Deep Foundation	N/A		$1,464,000	-	-	-	-	$1,608,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,380,000
General Requirements	15%		$10,504,000	-	-	-	-	$11,541,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%		$21,784,000	-	-	-	-	$23,934,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%		$27,230,000	-	-	-	-	$29,917,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs			$136,148,000	-	-	-	-	$149,583,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year[(1)]				-	-	-	-	$128,407,063	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs [(1)]			$128,407,000																										
NPV of Salvage Value			$21,332,000																										
O&M Costs (Modify As Required)																													
Primary chemical usage			$31,000	-	-	-	-	-	$34,706	$35,366	$36,038	$36,722	$37,420	$38,131	$38,855	$39,594	$40,346	$41,113	$41,894	$42,690	$43,501	$44,327	$45,170	$46,028	$46,902	$47,793	$48,701		
Secondary chemical usage			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Primary power usage			$39,000	-	-	-	-	-	$43,663	$44,492	$45,338	$46,199	$47,077	$47,971	$48,883	$49,811	$50,758	$51,722	$52,705	$53,706	$54,727	$55,767	$56,826	$57,906	$59,006	$60,127	$61,270		
Secondary power usage			$997,000	-	-	-	-	-	$1,116,195	$1,137,403	$1,159,014	$1,181,035	$1,203,475	$1,226,341	$1,249,641	$1,273,384	$1,297,579	$1,322,233	$1,347,355	$1,372,955	$1,399,041	$1,425,623	$1,452,710	$1,480,311	$1,508,437	$1,537,097	$1,566,302		
Magnetite Recovery Equipment O&M	3%		$75,000	-	-	-	-	-	$83,967	$85,562	$87,188	$88,844	$90,532	$92,252	$94,005	$95,791	$97,611	$99,466	$101,356	$103,281	$105,244	$107,243	$109,281	$111,357	$113,473	$115,629	$117,826		
Magnetite replacement			$164,745	-	-	-	-	-	$184,441	$187,945	$191,516	$195,155	$198,863	$202,641	$206,492	$210,415	$214,413	$218,487	$222,638	$226,868	$231,179	$235,571	$240,047	$244,608	$249,255	$253,991	$258,817		
Intermediate pump station			$89,000	-	-	-	-	-	$99,640	$101,533	$103,463	$105,428	$107,432	$109,473	$111,553	$113,672	$115,832	$118,033	$120,275	$122,561	$124,889	$127,262	$129,680	$132,144	$134,655	$137,213	$139,820		
Tertiary filtration			$20,000	-	-	-	-	-	$22,391	$22,817	$23,250	$23,692	$24,142	$24,601	$25,068	$25,544	$26,030	$26,524	$27,028	$27,542	$28,065	$28,598	$29,142	$29,695	$30,260	$30,834	$31,420		
Labor			$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Total, O&M Costs			$1,415,745	$0	$0	$0	$0	$0	$1,585,003	$1,615,118	$1,645,805	$1,677,076	$1,708,940	$1,741,410	$1,774,497	$1,808,212	$1,842,568	$1,877,577	$1,913,251	$1,949,603	$1,986,645	$2,024,392	$2,062,855	$2,102,049	$2,141,988	$2,182,686	$2,224,157		
NPV of O&M Cost at Base Year				$0	$0	$0	$0	$0	$1,319,709	$1,304,349	$1,289,167	$1,274,162	$1,259,332	$1,244,674	$1,230,187	$1,215,869	$1,201,717	$1,187,730	$1,173,906	$1,160,243	$1,146,738	$1,133,391	$1,120,200	$1,107,161	$1,094,275	$1,081,538	$1,068,950		
Total NPV of O&M Costs			$22,613,000																										

NPV Summary	
Capital Cost	$128,407,000
Salvage	($21,332,000)
O&M	$22,613,000
Total NPV	**$129,688,000**
Total NPV w/o Salvage	**$151,020,000**

Economic Assumptions

Capital Escalation Rate	1.90%
O&M Escalation Rate	1.90%
Annual Interest Rate	3.10%

[1] Biological basin equipment and blowers for all alternatives will have similar O&M costs throughout life cycle and are thus not included in this evaluation

Appendix C - Aerobic Granular Sludge Pilot Testing Report

Executive Summary

A bench-scale pilot study was conducted to evaluate the feasibility of an aerobic granular sludge (AGS) process as an alternative technology for the upgrade of the Tomahawk Wastewater Treatment Plant (WWTP). AGS is a novel biological nutrient removal (BNR) technology that originated in the Netherlands. The first large scale demonstration was in 2008 and the first full scale installation was in 2011. Currently, the only AGS process on the market is called Nereda® by the Dutch company, Royal HaskoningDHV. Several Nereda® systems have been installed since and many more are currently being designed around the world. The recent increase in full-scale applications has made AGS a promising option.

AGS has many advantages as a BNR technology compared to conventional activated sludge, such as: easy and efficient nutrient removal, lower energy requirements, reduced footprint, lower capital and operational costs, and increased sustainability. However, due to limited application in the United States, there are some concerns that the influent wastewater in the United States and at the Tomahawk Creek WWTP is too dilute compared to the other operating Nereda® installations. This pilot study was conducted in conjunction with Professor Belinda Sturm of the University of Kansas to evaluate the feasibility of AGS at the Tomahawk WWTP and, in general, low-strength wastewater typically found in the US.

Growth and cultivation of aerobic granules were successful, counter to concerns that the wastewater at Tomahawk was too weak compared to wastewater used in other AGS applications around the world. The project schedule allotted approximately 6-months (October 2014 – April 2015) to the pilot study to achieve aerobic granulation of sludge and prove its stability. Initial granulation took approximately 2-months in the low strength wastewater. The long start up time is in agreement with AGS literature. After granulation was achieved and was found to be stable, then the process performance and characteristics of the maturing granules' were evaluated.

The performance of the AGS pilot showed good biochemical oxygen demand (BOD) and ammonia removal, while BNR performance reached 47% inorganic nitrogen removal and 26% orthophosphate removal. BNR performance is expected to improve from bench scale to a larger demonstration scale pilot using larger, more mature seed granules and better DO and aeration control. The next step in the AGS process evaluation is a larger demonstration scale pilot designed by DHV, which would be seeded with larger, full size, granules so that BNR performance can be evaluated, without a startup period, using Nereda's proprietary process specifications.

1. Introduction

Granular sludge is a phenomenon whereby bacteria agglomerate together into dense particles under certain environmental conditions. These biological granules are considered a certain type of biofilm where the microbial consortium is self-immobilized (without carrier media). Spontaneous formation of granules has been reported in various wastewater treatment systems since 1999, mostly sequencing batch reactor (SBR) systems. Aerobic granulation is currently a popular topic of research and is believed to be induced by several external ecological conditions. The application of this technology is relatively new with the first large demonstration scale application in Gansbaai, South Africa in 2008 and the first full scale plant in the Netherlands in 2011 (Bruin, 2010). Since then several more full scale processes have been brought online around the world.

The advantages of granular sludge compared to ordinary activated sludge are many.

- The compact granules allow for high biomass concentrations (approx. 8,000 mg/L) and fast pollutant removal rates in a smaller reactor.
- The high removal rates of granules allow for treatment of raw influent, eliminating the need for primary clarification and processing of primary sludge.
- The dense granules settle very fast, which eliminates final clarifiers and increases treatment capacity by freeing time previously needed for sedimentation in an SBR configuration.
- Simultaneous BOD removal, nitrification, denitrification, and phosphorous removal occur within the granule depths where environmental conditions are favorable for these specialized bacteria and biological processes.

In general, the process is called aerobic granular sludge (AGS) or granular activated sludge (GAS). Currently there is only one AGS process on the market which is called Nereda® and is provided by Royal HaskoningDHV, the only vender of the AGS process.

B&V has visited several large scale granular sludge processes including the Gansbaai facility in South Africa and both the Epe WWTP and Garmerwolde WWTP in the Netherlands. The data reported to B&V staff indicates that good denitrification and Bio-P performance is possible to the levels required for this project.

1.1 Objectives

The objectives of this study were to design, start from scratch, and operate a bench scale pilot for the purposes of:

- Determining if a granulated sludge could be formed and maintained with low-strength wastewater (as compared to existing AGS systems treating higher-strength wastes).
- Ensuring that the AGS process is a feasible and robust treatment alternative for the Tomahawk Creek WWTP upgrade
- Developing overall confidence in this relatively new technology in order to decide whether or not to take the next step in evaluation, a demonstration unit much larger than bench scale

The objectives were undertaken by developing an understanding of the phenomenon of granulation and the AGS process through bench scale operation and experimentation. If sufficient confidence in the technology and its benefits are established, then a larger Nereda® demonstration scale trial will be conducted on site by Royal HaskoningDHV. The demonstration scale pilot will be started with mature granules and will be large enough to assess the customized design criteria to reach the levels of performance required by the Tomahawk WWTP. It would also provide physical confirmation of equipment selection and process control criteria for transition to full-scale system.

2. Methodology

The phenomenon of bacterial granulation is believed to be induced by several ecological conditions, which were the basis of this methodology (IWA 2005, 2011). The factors that induce granulation are:

a. Selective wasting of biomass - The bench-scale reactors were long and slender in order to classify the biomass according to their settling velocity as the solids settle in the column under quiescent conditions. The slower settling biomass is characterized as being light, fluffy and flocculent, while the faster settling biomass is relatively heavy and compact. As the total biomass settles through the column, the biomass will stratify throughout the column with the fast-settling biomass particles in the bottom layers and the slower-settling biomass particles at the top. A cut off settling velocity is then selected and any biomass that does not settle past the decant port (approx. midpoint of the long column) after the allowed time has elapsed, is washed out of the reactor and wasted. This selection pressure applied to the biomass cause the bacteria to secrete extracellular polymeric substances (EPS) which "glue" the bacteria into granules.
b. Switching between feast and famine conditions - Feeding carbon compounds through the heavier bottom layers creates a high substrate gradient that cause the bacteria to secrete EPS. The feast and famine conditions persuade the bacteria into a sessile state where the bacteria can feed off of stored food within the EPS to endure a famine condition. The bacteria will remain attached to the granule, waiting for a feast condition without being washed out of the reactor. A concern was that the relatively weak Tomahawk wastewater would not provide the appropriate quality and quantity of food during feast conditions to induce granulation.
c. Other factors were identified that either enhance initial granule formation or help maintain granule stability. Two of these are:
    i. Moderate to high shear stress- High shear conditions within the reactor will influence the final macrostructure of the granule. The shearing forces during mixing or aeration will enhance the compactness and smoothness of the granule by shearing off any filament outgrowth, making it less susceptible to degranulation. Degranulation of aerobic granules has been reported during low shear and low DO conditions. Degranulation of aerobic granules has been in part attributed to overgrowth of filamentous bacteria.
    ii. Bottom feed through the sludge blanket will create a fermentation environment where VFA and other readily biodegradable substrate are created and/or used by slower growing organisms typically found in granules. Feeding through the sludge blanket has the added benefit of enriching phosphorous accumulating organisms (PAOs) needed for phosphorous removal. Feeding through the sludge blanket also helps to maintain the feast/ famine cycle by producing a localized high F/M environment.

Particular equipment and procedures were established in order to accomplish the objectives mentioned above. The bench scale pilot reactors were designed and constructed by the University of Kansas' (KU) Professor Belinda McSwain-Sturm's Environmental Engineering Research Group. Dr. Sturm is a

prominent researcher in the field of wastewater engineering and has published widely on the phenomenon of aerobic granulation. Her past and recent experiences guided the methodology of this study. Furthermore, in conjunction with the Tomahawk pilot, Dr. Sturm' research group operated a similar AGS pilot on Lawrence wastewater at the KU Environmental Engineering Laboratory in Lawrence, KS.

The pilot reactors consisted of a Plexiglas cylinder column supported on a PVC platform and an aluminum frame on casters. Each reactor column was made of interchangeable stackable units to achieve various settling distances. For this study there were three reactors in parallel (labeled red, white and blue) with two units stacked on top of each other. Each unit has a 480 mm height and 65 mm inner diameter. The units were constructed with a double wall water jacket for temperature control. The temperature was held constant at 20°C. Aeration was done with compressed air. During aeration phases, compressed air was fed through a fine bubble diffuser. Mixing (without aeration) was performed by bubbling nitrogen gas thought the same fine bubble diffuser. Gas flow was measured and adjusted manually to approximately 1-3 L/min using a 0.4-5 L/min Cole Parmer rotameter. The SBRs (each approximately 3L in volume) were operated with a 4-8 hour HRT and a 50% volumetric exchange ratio. A schematic of the bench scale reactors is shown in Figure 2-1 and a photo of the pilot system is shown in Figure 2-2.

The reactors were operated in a sequencing batch reactor (SBR) mode, meaning that the reactor was batch fed and treated in sequential phases, which when completed were repeated. Each repeat of the sequential phases is a cycle. Figure 2-3 shows an example of the sequential phases comprising one cycle. The cycling was controlled through a 4-circuit Chrontrol programmable timer unit and cycle phases were identical for all three reactors. The only difference between the three reactors was the influent feed during the process performance evaluation component of the study. The influent containers were mechanically mixed during both startup and evaluation. Throughout the entire study the only wasting of biomass occurred via washed out effluent TSS.

The influent to the AGS reactors was raw wastewater collected before primary clarification. The low-strength influent wastewater at Tomahawk Creek was supplemented with fermented primary sludge supernatant (fermentate). Fermentation of primary sludge converts particulate biochemical oxygen demand (BOD) into soluble and readily biodegradable forms. The primary sludge was collected from the primary clarifier underdrain and was allowed to ferment for 2-4 days. The supernatant was then added to the raw influent wastewater in order to increase its strength (by 10-20 percent by volume) and the sludge solids were discarded.

The primary sludge fermentation process was initially operated automatically as a timer-controlled process and temperature controlled at 30°C. Complications with the automatic operation, such as clogged pumps and poor mixing, created methanogenesis and consumption of rapidly biodegradable COD (rbCOD). As an alternative to automatic operation, the primary sludge was collected and fermented in the collection bucket, which was mixed once per day which represents the more likely full-scale scenario. The automatic operation was conducted from October 2014 through December 2014 after which the passive bucket fermentation method was used. Both automatic and bucket

fermentation methods produced approximately 5-10 L/day of fermentate. A photo of the fermenter set-up is shown in Figure 2-4.

Pilot samples were delivered to the Johnson County Wastewater Laboratory 1-3 times per week for analysis. Influent and effluent samples of the Fermenter were analyzed for soluble COD, TSS/VSS and volatile fatty acids (VFAs). Influent and effluent samples of the reactors were analyzed for TSS/VSS, total and soluble COD and BOD, ammonia-N, nitrite + nitrate-N, ortho-phosphorus, and VFA.

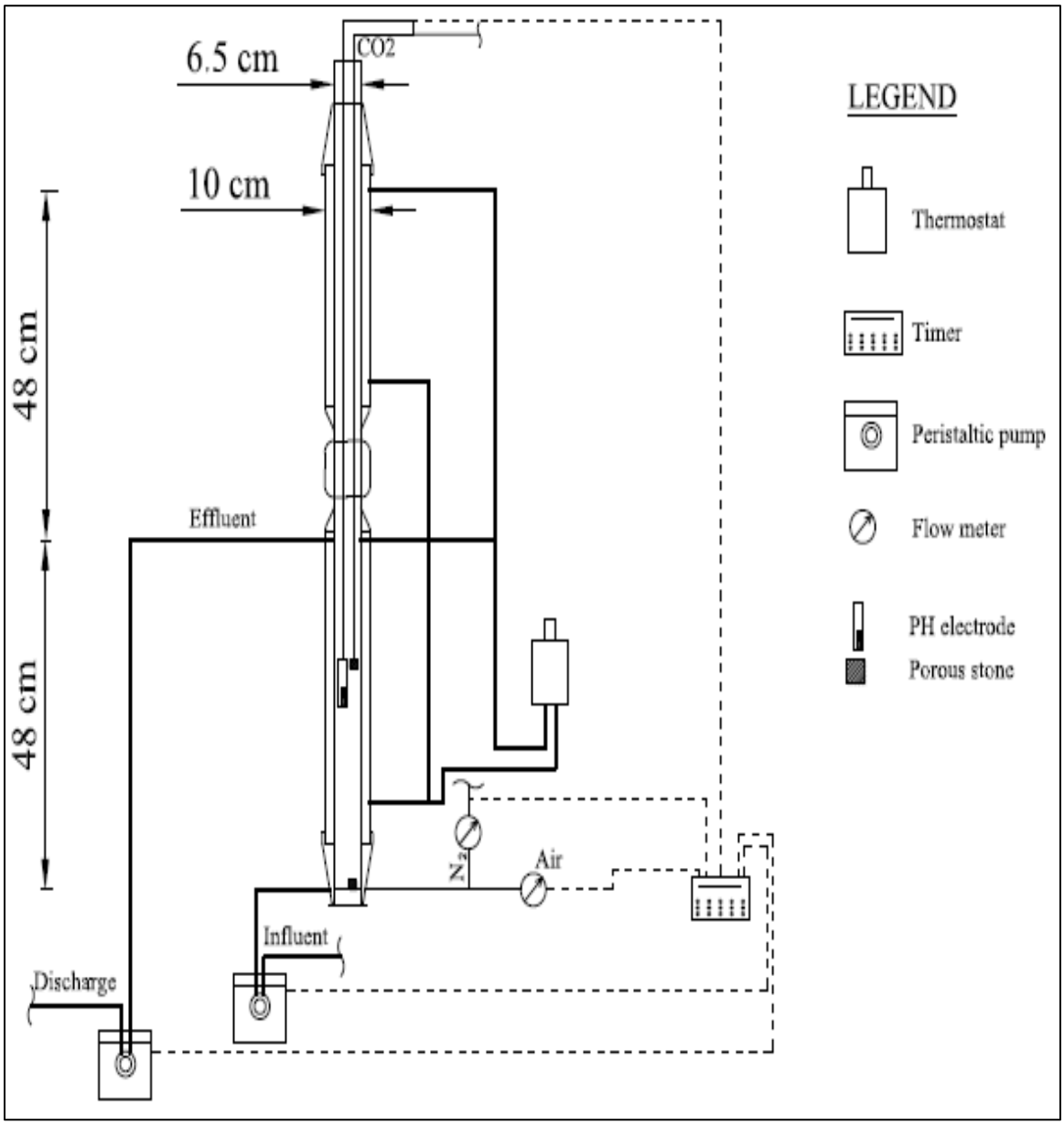


Figure 2-1 – Schematic of the Bench Scale AGS Pilot Reactor

Figure 2-2 – Photo of the bench scale pilot at the Tomahawk WWTP (the reactors from left to right were labeled – red, white and blue)

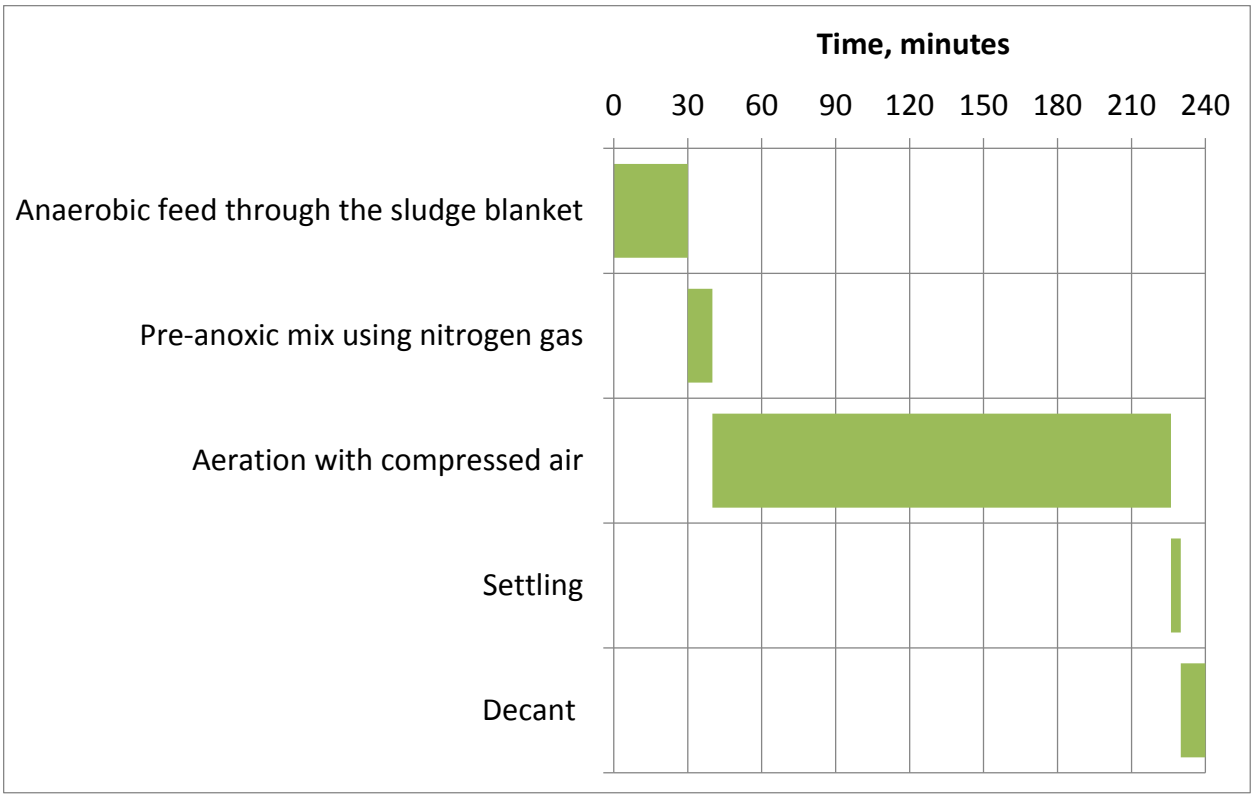


Figure 2-3 – Example of SBR Operating Cycle Phases and Timing (Total cycle time = 240 minutes (4-hours) consisting of: anaerobic feed – 30 min, pre-anoxic mix – 10 min, aeration – 186 min, settling – 4 min, and decant – 10 min)

Figure 2-4 – Photos of primary Sludge Fermenter Setups - automatic fermenter setup (left), passive bucket fermentation (right)

3. Discussion & Results

The AGS pilot operated from October 6th 2014 through April 22nd, 2015. The pilot operation was broadly divided into two phases, 1) granular enrichment (start-up) and 2) process performance evaluation. The first phase of granule enrichment was necessary to develop granules starting from activated sludge, which took approximately 2-months after reseeding (granule formation occurred 4-months into the study). The second phase, which lasted the remaining 2-months, involved an evaluation of process performance and other characteristics of the AGS process in terms of settleability, nitrification, BNR performance, and sludge processing. Although the pilot study was a general evaluation of the technology; the second phase examined reactor performance on various feed strengths – amount of fermentate. Table 3-1 shows a chronological list of major pilot changes and activities.

Table 3-1 – List of Major Pilot Operational Changes and Activities

Date	Day No.	Activity
10/6/2014	1	Started with 2-hour cycle and 15 min settling time
10/14/2014	8	Reduced settling time from 15 min to 5 min
10/24/2014	18	Reduced settling time from 5 min to 2 min
11/14/2014	39	Increased cycle time from 2 hours to 3 hours
11/15/2014	40	Increased settling time from 2 min to 5 min
11/25/2014	50	Added fresh activated sludge
12/2/2014	57	Changed fermenter operation from automatic to bucket method
12/20/2014	75	Reduced settling time from 5 min to 4 min
12/20/2014	75	Increased cycle time from 3 hours to 4-hours
1/19/2015	105	Installed scum control
2/2/2015	119	Granules become predominant form of biomass
3/3/2015	148	Started testing feed composition on reactor performance
3/12/2015	157	Nitrification test on floc and granules
3/17/2015	162	Added pre-anoxic phase to the SBR cycle

3.1 Startup

The reactors were initially charged with activated sludge from the DLSMB WWTP, which is a BNR plant with bio-P and nitrogen removal. The initial strategy was to wash out the lighter biomass by gradually reducing the settling time. The settling velocity selection was based on literature pertaining to computational fluid dynamics (CFD) of final clarifiers in activated sludge plants. From the literature, cut off points were established to categorize activated sludge biomass particles as small, medium, and large according to the settling velocities of < 1.5m/hr, approx. 3m/hr, and > 6 m/hr, respectively (McCorquodale and Griborio, 2004). Typical settling velocities of AGS range from 10-50 m/hr (IWA 2011). During the first 20 days the units were operated with a 15 minute settling time, then 5 minutes, followed by 2 minutes, which corresponds to settling velocities of approx. 2 m/hr, 6 m/hr and 15 m/hr, respectively. A settling velocity of 15 m/hr proved to be too aggressive too soon and too much biomass was wasted from the system. The biomass was quite slow to recover so after 51 days of pilot operation the reactors were recharged with fresh biomass from the DLSMB WWTP. This was the only time the reactors were recharged with fresh activated sludge biomass. Eventually, after another 2 months of operation, a settling velocity of 7.5 m/h was selected and used for the remainder of the study.

During the first 4-months of operation, all three reactors were treated identically in that they received feed from the same influent reservoir; they had the same biomass; and they had the same operating cycle phases. The cycle times during the study ranged from 2-hours to 4-hours. For every cycle, each reactor was fed 1.5 L of wastewater. The reactors were loaded more heavily during the first 2.5-months using a 2-hour and 3-hour cycle, and then the cycle time was increased to 4-hours for the remainder of the study. During this time, on a weekly basis, the reactors' contents were combined, the SVI was measured, and the biomass was split between the reactors again. When the granules reached the target number and size, the reactors were individually tested to ensure and confirm that they behaved similarly to one another.

One issue with expediting the startup of an AGS process, especially at bench scale, is to ensure that biofilm growth on the reactor walls does not consume substrate intended for granule growth. Since the wall growth was a major issue with this type of reactor, the reactors were manually cleaned weekly. Figure 2-5 shows a dirty vs. clean reactor and the modified mop used for cleaning the reactors' inner wall of biofilm.

Another issue during the startup was foaming and the accumulation of biomass onto a scum ring that would build up on the reactor wall at the water surface. The scum ring presented a major problem in regard to monitoring the progress of the process start up. The biomass in the reactor tended to accumulate on the scum ring during aeration to such an extent that most of the biomass in the reactor would deposit on the scum ring within a couple of days. The reduction of suspended biomass in the column due to continuous deposition on the scum ring made representative sampling a challenge. Eventually several modifications to the reactor and procedures were made to control the scum ring, and these modifications worked reasonably well.

Figure 2-5 – Comparison of dirty column with scum ring vs. a cleaned column (left photo), and modified mop cleaning tool (right photo)

At approximately the 4-month mark, the process performance evaluation of the study was initiated, where the three reactors were fed different amounts of fermentate by volume. The total volume of feed to each reactor stayed the same; only the composition varied.

- Red Reactor was fed 80 % raw influent and 20 % fermentate
- White Reactor was fed 90% raw influent and 10 % fermentate
- Blue Reactor was fed 100 % raw influent without any fermentate.

3.2 Granule Enrichment

One challenge of the aerobic granular sludge system is a long startup time especially when treating low-strength wastewater such as found at Tomahawk Creek. The full-scale Nereda® applications have all been designed for much higher influent wastewater strength. The Nereda® facilities are located in parts of the world where more water conservation is practiced or where the per capita water use is much lower than typical US practices. The net result is an influent wastewater roughly twice as concentrated as typical domestic wastewater in the US. At a pilot plant in Switzerland Nereda® claimed to have produced granular sludge in a wastewater of similar characteristics to that at Tomahawk Creek.

Since the reactors were started using activated sludge, a period of enrichment was needed to develop sufficient granular biomass to begin a meaningful evaluation. During the granular enrichment phase all three reactors were treated identically. The reactors were fed a common influent wastewater consisting of primary influent plus a small amount of fermented primary sludge supernatant (10-20% fermentate by volume).

During the granule enrichment phase, efforts were focused on consistent and careful pilot operation in order to maximize the bacterial secretion of extracellular polymeric substances (EPS), while maintaining sufficient suspended biomass within the reactor to achieve treatment objectives, such as full nitrification. Several difficulties were encountered. EPS is produced in response to high substrate concentrations during start-up; EPS production can also be a response to stress conditions. While EPS aids granule formation, it has the negative effect of increasing biofilm growth on the walls of the reactors. Excessive wall growth was an indication that granules were being formed and two deleterious effects of EPS on the suspended biomass were mitigated.

The first is excessive wall growth and accumulation of biomass on the scum ring. Since the reactors are long and slender, they have a large wall surface area to volume ratio. Instead of adhering particles together, the biofilm tended to adhere to the reactor walls. The excess EPS also created a challenge in that the biomass in suspension was lost because it was sticking to a scum ring which formed at the liquid-air interface at the surface of the reactor, quite severely at times. However, wall growth and scum would not be a problem with the full scale reactor because of the much lower wall surface area to volume ratio.

The second is that EPS hindered biological coagulation and subsequent sedimentation. EPS was needed for granule formation but excess EPS acted to increase solution viscosity and inhibit TSS settling. The excess EPS was observed to hinder biological coagulation and sedimentation during the startup process. Initially, the reactor was operated with flocculated biomass (activated sludge from DLSMB). Normally, under quiescent conditions, activated sludge will biologically coagulate, and a zone settling regime is created, which squeezes out the interstitial fluid as the sludge blanket compresses under gravitational forces. Under the same quiescent conditions, in the reactor with excess EPS, the biomass did not coagulate normally but instead remained a colloidal suspension that did not settle, even at much longer settling times. The aggressive settling velocity of 15 m/hr, therefore, created a positive feedback loop which deteriorated the biomass' settling ability. In the positive feedback loop, biomass was washed

out/wasted - EPS was created - settling ability was deteriorated - causing more biomass to be washed out/wasted - more EPS was created - and so on, until almost all biomass was lost within a few cycles.

It was found that a settling velocity of 7.5 m/hr was sufficient for selective wasting without hindering biological coagulation and sedimentation. Recent research at the Delft University in the Netherlands has shown that the substance responsible for granulation is a polymer termed alginate-like-exopolysaccharides (ALE). The ALE polymer is known to strongly bind with water and can thicken or gel liquids. The ALE was not directly analyzed, however, the effect on the matrix was observed to impede startup causing the initial biomass to be washed out/wasted before granules are actually formed.

Upon observing this phenomenon, approximately 2-months into the study, the reactors were reseeded with fresh ordinary activated sludge biomass and a less aggressive settling velocity of 7.5 m/hr was selected. The reactors were reseeded in order to accelerate granule enrichment and nitrification. Theoretically, sufficient granule enrichment could still have been achieved had the reactors not been reseeded, as evidenced by the early observation of granules in the photo progression in Figure 3-1, however, recovery of the reactors would have been slow and likely would have exceeded the pilot schedule. Several particle size distribution tests on the granular sludge were performed at the University of Kansas and the results are shown in Figure 3-2 and Figure 3-3.

The data shown in Figure 3-2 and Figure 3-3 were taken 53 days apart and show an increase in number of particles in the 1.0 - 2.0 mm range. Over the 53 days, the average particle diameter increased from 0.28 mm in Figure 6 to 0.64mm in Figure 3-3. The optimal diameter of the aerobic granule is less than 1.7 mm, considering the absence of the layer of obligate anaerobic bacteria (IWA, 2005). Overall, the depth of biofilm activity zones due to diffusion limitations are a function of bulk concentration, relative surface velocity, bacterial cell density, among many other factors.

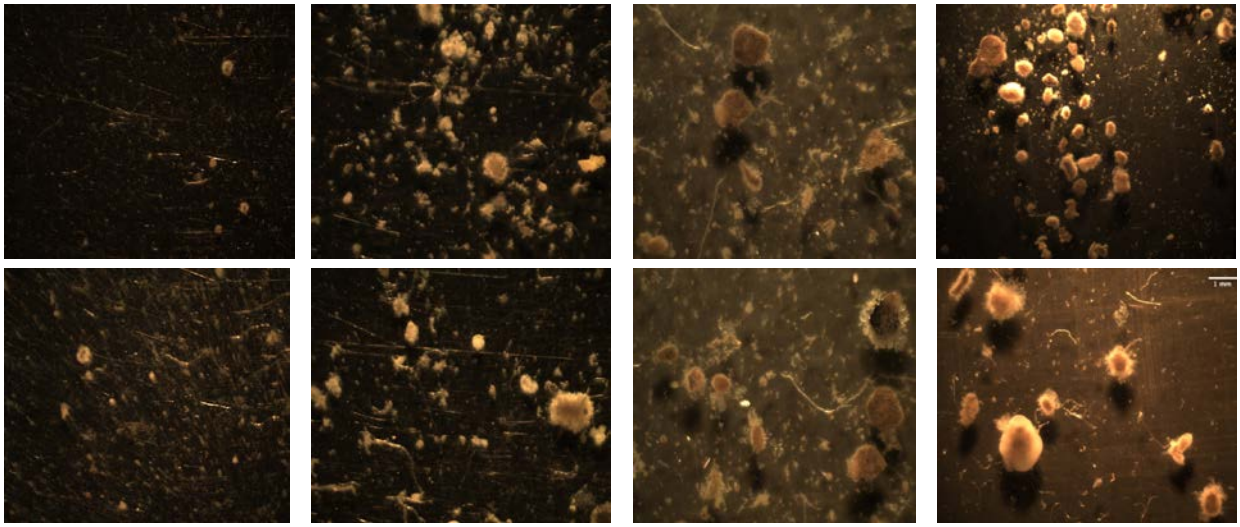


Figure 3-1 – Photo Progression of granule enrichment. From left to right the total days the reactors were in operation before the photo was taken: 32 days (11/7), 50 days (11/25), 86 days (12/31), and 126 days (2/9). Top and bottom photos for each of the four sets are of the same sample.

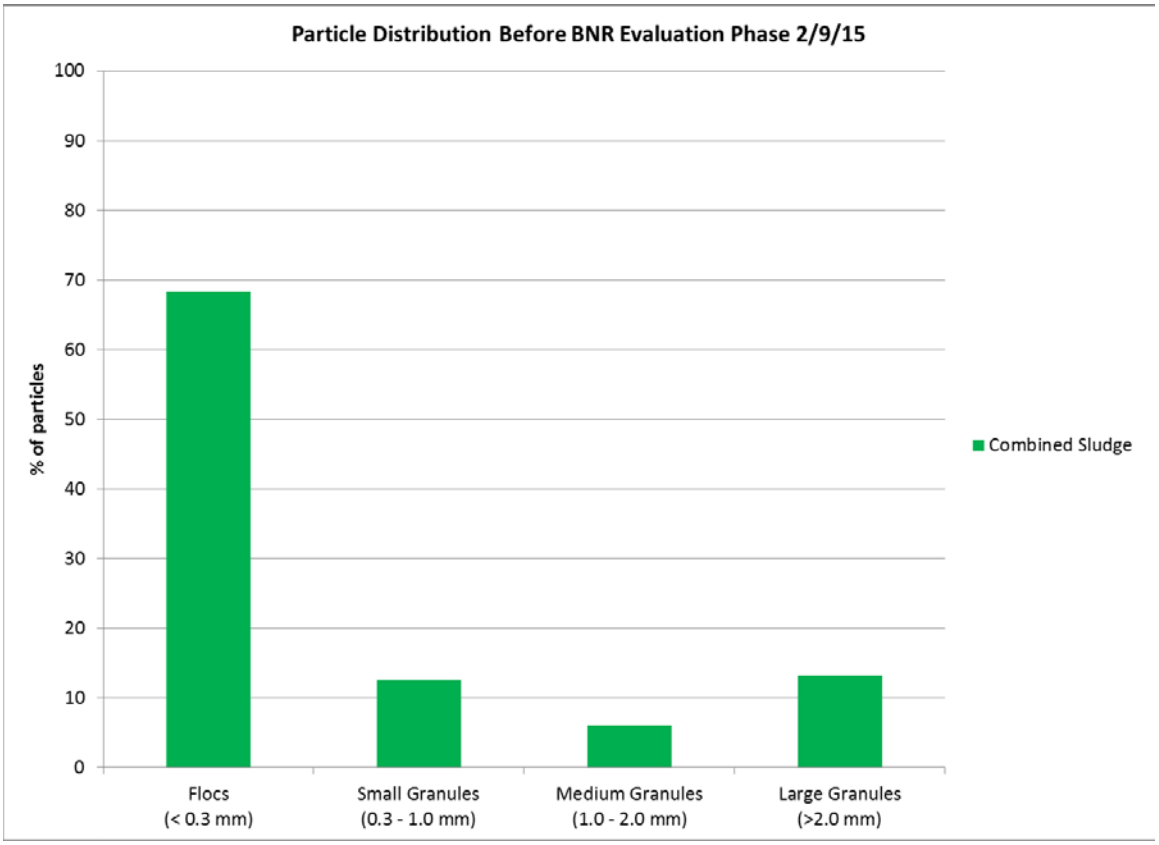


Figure 3-2 – Particle size distribution of a composite sample of sludge from all three pilot reactors from 2/9/15. The total number of particles counted was 1170. The average diameter was 0.28 mm and the average aspect ratio was 0.61.

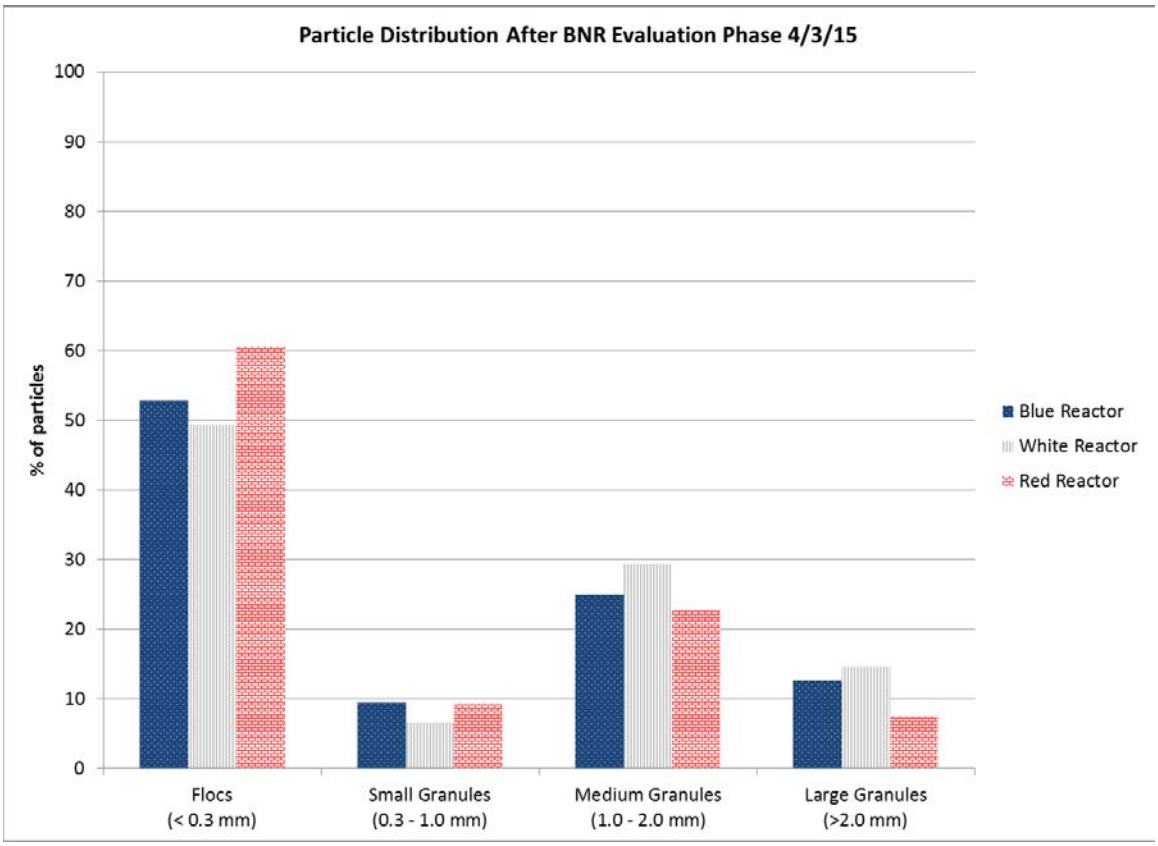


Figure 3-3 - Particle size distribution for each of the three pilot reactors from 4/3/15. The total number of particles counted for Blue, White, and Red were 1279, 1105, and 983, respectively. The average particle diameter for all three reactors was 0.64 mm and the average aspect ratio was 0.60.

3.3 Settleability

A quick settling rate of the granules is an important advantage of the AGS process. A time lapse photo comparing the settling rate of ordinary activated sludge with granular sludge in a settleometer is shown in Figure 3-4.

The settleability of the granular sludge was measured weekly via sludge volume index tests (SVI). The SVI_{30} tests were conducted according to Standard Methods 2710 D. The SVI test consisted of placing a sample of the sludge in a 1-L graduated and cylinder measuring the settled sludge volume after 30-minutes. The results from the SVI30 tests, Figure 3-5, show the decreasing trend of SVI30, indicating improved settleability.

Typically, the AGS SVI at 5 minutes should be similar to the SVI at 30 minutes indicating that the settled sludge at 5 minutes is already compressed to the same compression achieved after 30 minutes of settling. Figure 3-6 shows the variability in the difference between the SVI_5 and SVI_{30}. The variability in the difference between SVI_5 and SVI_{30} was due to fugitive primary sludge solids that were transferred with the fermenter supernatant to the reactor influent containers and repeated failure of the influent reservoir mixer, which caused solids to accumulate on the bottom of the influent reservoir near the feed inlet and were subsequently pumped into the reactors. Influent BOD, either soluble or particulate, tended to increase flocculent biomass which greatly affected the SVI_5.

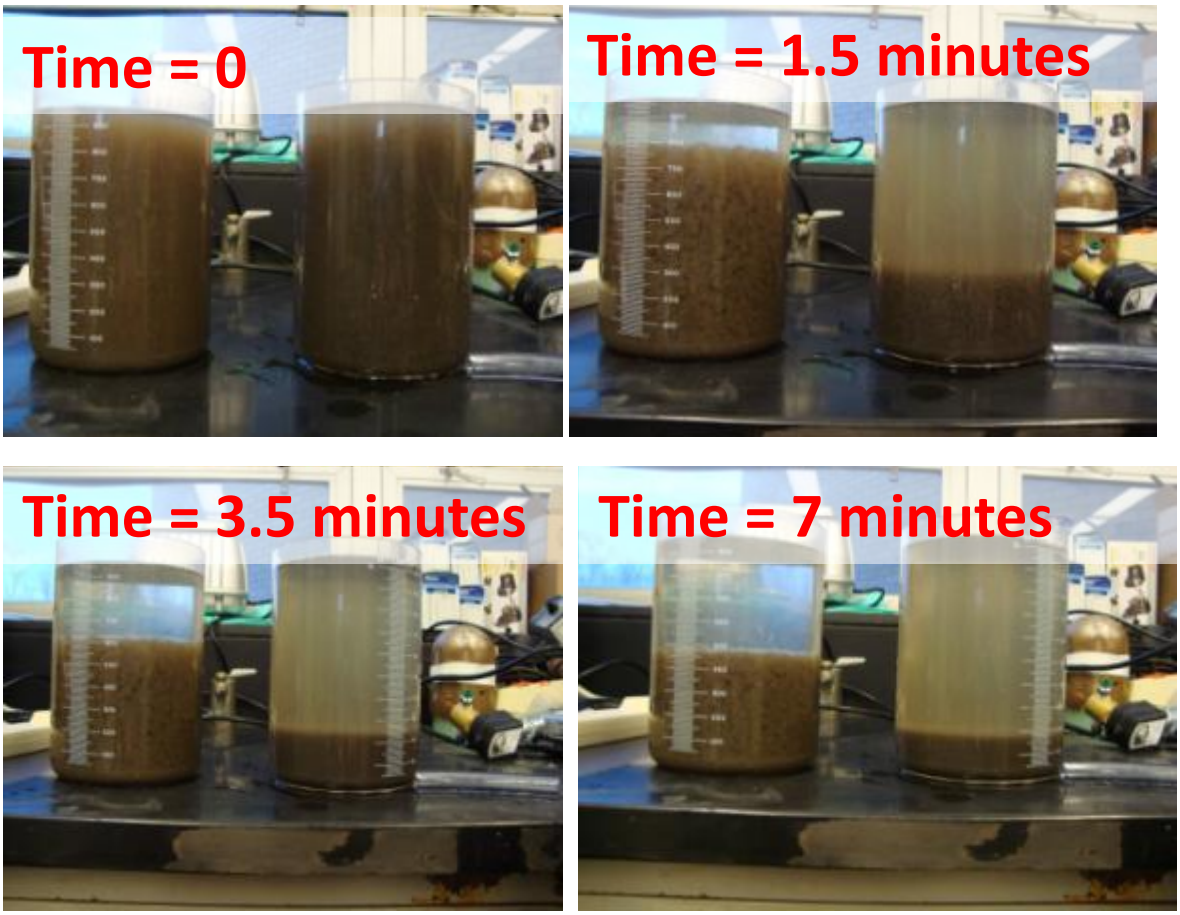


Figure 3-4 – Time lapse photos comparing the settling rates of normal activated sludge taken from the DLSMB WWTP (left) and granular sludge taken from the Tomahawk Creek Pilot (right). Both samples have similar target MLSS concentrations of approximately 2,000 mg/L. (Date: 1/5/15)

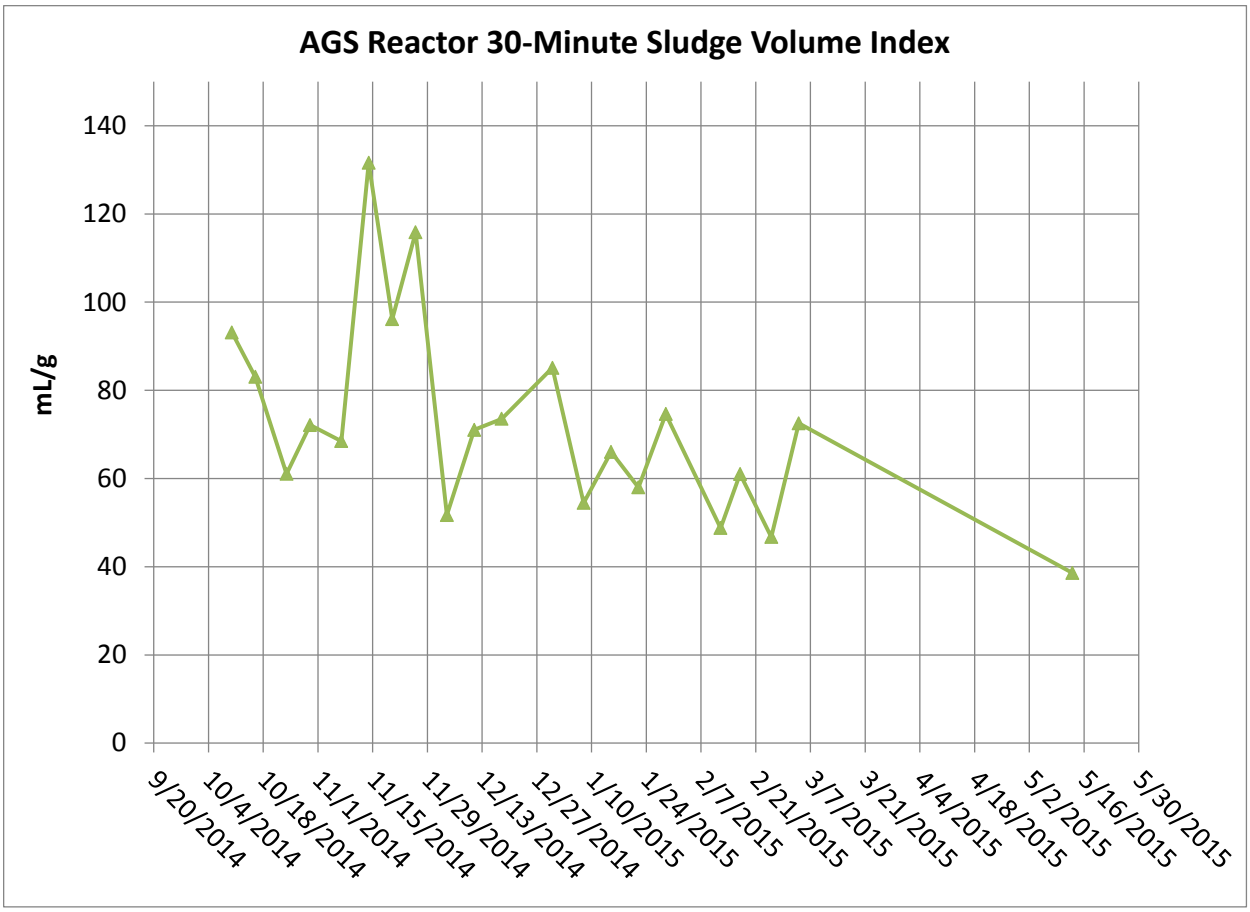


Figure 3-5 – Progression of the 30-minute SVI

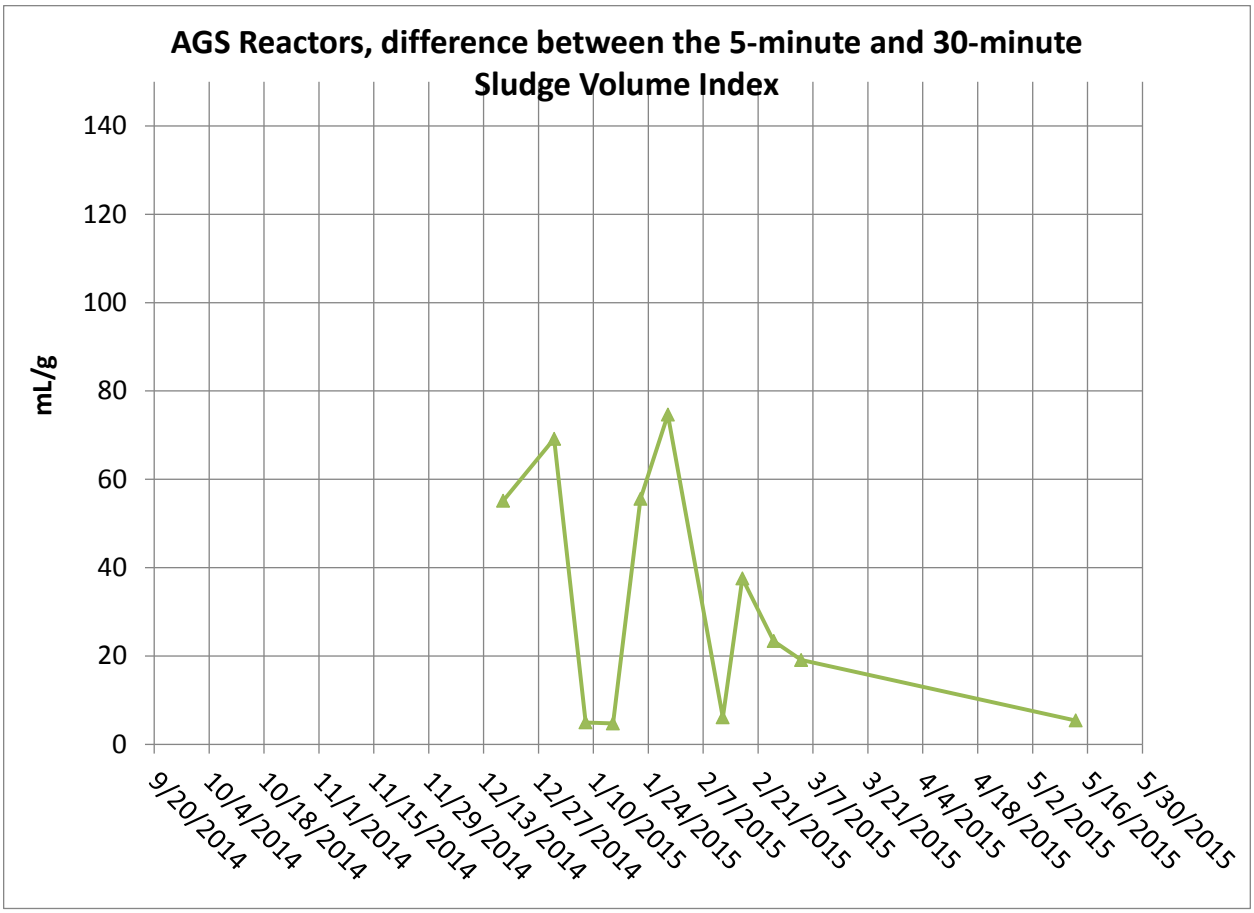


Figure 3-6 – Difference between SVI_5 and SVI_{30}. The difference was calculated as SVI_{30} subtracted from SVI_5.

3.4 Nitrification Rates

As the granules matured, nitrification improved and became complete. The question was raised as to where the nitrification was occurring – on the granule or in the floc? Figure 3-7 shows the experimental results of nitrification rate experiments performed on the two forms of suspended solids (SS) in the reactor, the flocculent (floc) and granule. One experiment was performed on the floc SS (thickened washed out solids without granules) and the other on the total reactor SS (total reactor contents including floc + granules). The results showed that the specific nitrification rate (normalized to VSS concentration) was 50% greater in the floc SS (0.066 mgN/mgVSS (floc)-d) compared to the granules (0.044mgN/mgVSS (granules)-d). The difference in normalized rates can be explained by the fact that only the perimeter volume of a granule is expected to be aerobic and house nitrifier populations.

Of the total reactor contents only a small portion of the mixed liquor is actually washed out as floc during each cycle. The floc concentration was 86 mgVSS/L compared to the total floc + granules concentration of 1,770 mgVSS/L. Therefore, within the reactor, the actual nitrification contribution of the floc, which presumably slough off the granule, is approximately 10 percent and the remaining 90 percent is from the granules themselves. This comparison of nitrification proves that the nitrifiers thrive in the granule structure and the granules provide the long system SRT, which may not be obvious with mass balances.

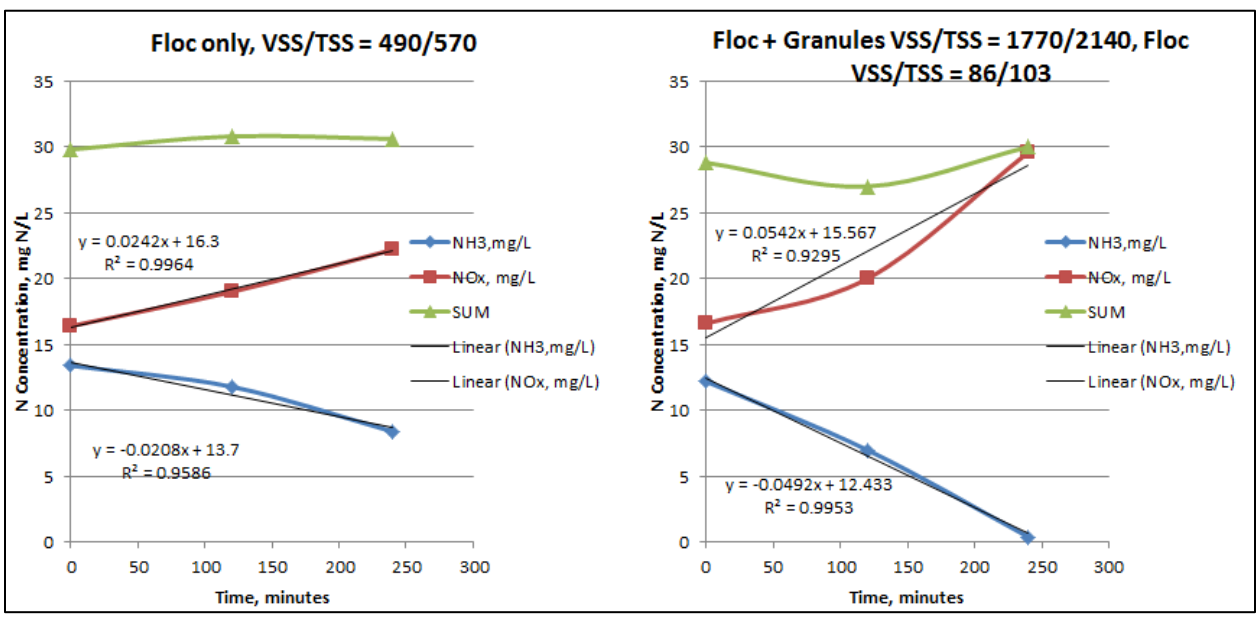


Figure 3-7 –Nitrification experiment results testing the rate of nitrification separately for floc and granular biomass

3.5 Fermenter Performance and Reactor Influent sCOD

The AGS reactor feed was supplemented with sCOD produced by the fermentation of primary sludge. The primary sludge fermenter performance, in terms of soluble COD (sCOD) production, is shown in Figure 3-8. The influent sCOD was very consistent with an average of approximately 100 mg/L. However the variability in effluent sCOD was a result of variability in the primary sludge solids concentration, which was typically low, in the range of approximately 1,000 – 3,000 mg/L.

The sCOD produced by the fermenter was used to supplement the influent sCOD to the Red and White AGS reactors. Fermenter influent during the week of 3/17/15 was high in primary TSS and caused a spike in fermenter effluent sCOD as shown in Figure 3-8. The high fermenter effluent soluble COD continued into the following week and caused a spike in the influent sCOD to the red and white AGS reactors on 3/23/15, as shown in Figure 3-9. All three AGS reactors performed well in terms of sCOD and sBOD removal, with effluent sCOD consistently less than 50 mg/L and average sBOD was always less than 4 mg/L.

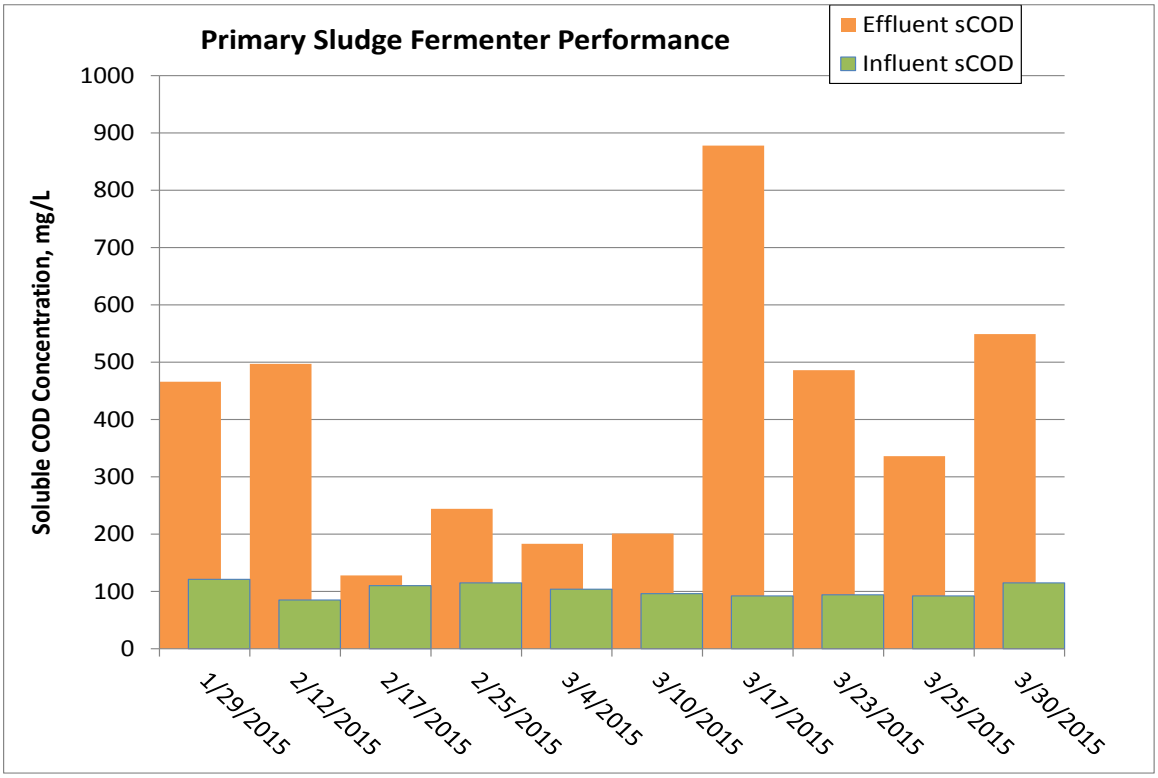


Figure 3-8 – Primary sludge fermenter performance using the bucket method. The fermenter produced 110 mg/L VFA, on Average, of which 45 percent was acetic acid and 40 percent propionic acid.

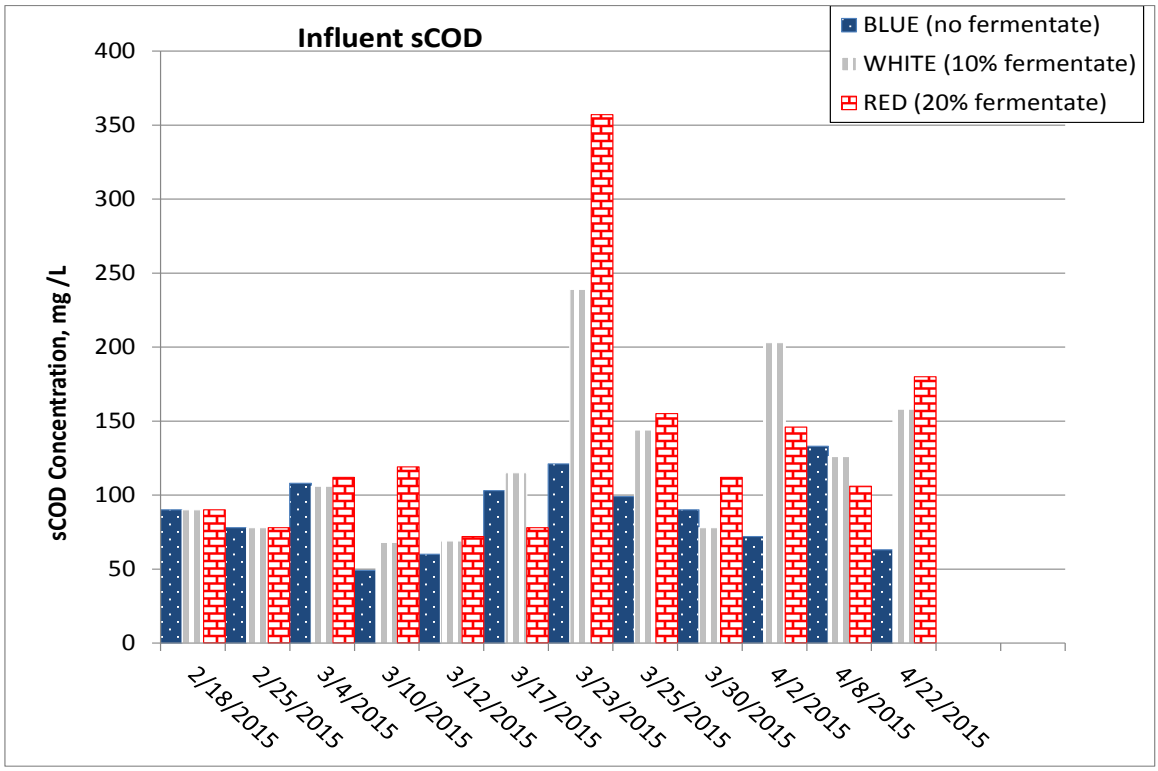


Figure 3-9 – Influent soluble COD for all three reactors.

3.6 BNR Performance

BNR performance was intentionally delayed until after the initial granule enrichment phase. During the granule enrichment phase, several operational conditions were utilized to speed up the growth of granules that were not conducive to the selection of denitrifiers and phosphorus accumulating organisms. The initial cycle time was 2-hours, which allowed for aggressive biomass growth and wasting. The initial short cycle and resulting heavy loading was selected to compensate for the project schedule and low-strength wastewater. The intention was to heavily load the biomass to achieve an adequate level of granule enrichment as soon as possible in order to move on to the next phase of BNR evaluation.

As mentioned earlier, the aggressive settling velocity and heavy loading in a short cycle time created conditions where biomass didn't settle and thus were wasted from the reactor. These conditions resulted in excess EPS that dispersed into the liquid as a gell, inhibiting sedimentation and resulting in biomass loss. For the first 2-months there was insufficient biomass to achieve complete BOD removal or nitrification of all the ammonia. After granule enrichment was well advanced, BOD removal and nitrification were easily achieved with average effluent concentrations of 3 and 0.4 mg/L for BOD and NH_3-N, respectively. The final 2.5-months of effluent nitrogen concentration and nitrogen removal performance is shown in Figure 3-10 and Figurer 3-11, respectively, and effluent phosphorous concentration and phosphorous removal performance are shown in Figure 3-12 and Figure 3-13, respectively.

After 3/17/15, day 162, a pre-anoxic phase, using nitrogen gas mixing, was added to the cycle. The pre-anoxic phase had a significant impact on nitrogen removal, presumably due to heterotrophic denitrification. The pre-anoxic cycle also had an impact on effluent phosphorous. The organisms that accumulate phosphorous (PAOs) are slow growing and are believed to dwell within anaerobic inner cores of the granules, rather than in the flocculent biomass. Because the granules were small (averaging 0.64 mm in diameter) compared to mature granules reported in the literature (IWA, 2005), a longer pilot that allowed granules to increase size is expected to improve phosphorus removal. The summary of average BNR performance efficiency of the pilot units is shown in Table 3-2. Table 3-2 takes into account each reactor's influent P and N concentrations from the differing ratios of fermentate to raw wastewater.

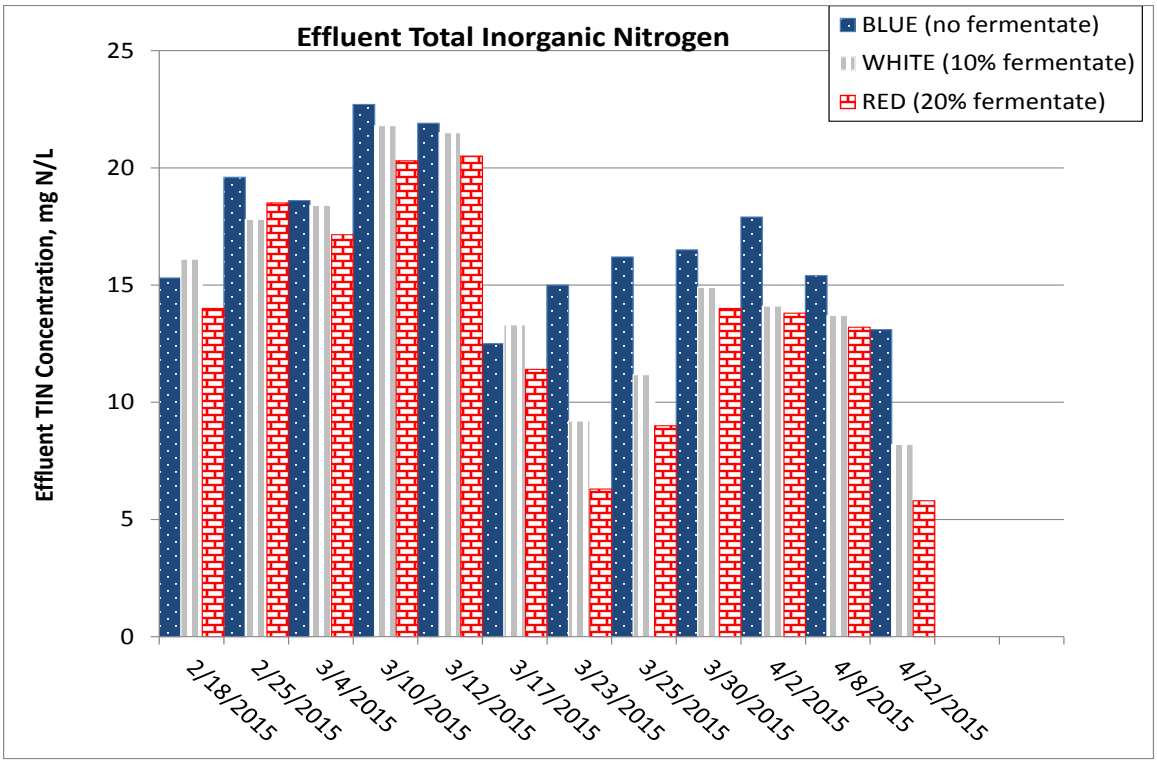


Figure 3-10 – Effluent quality with respect to total inorganic nitrogen (TIN)

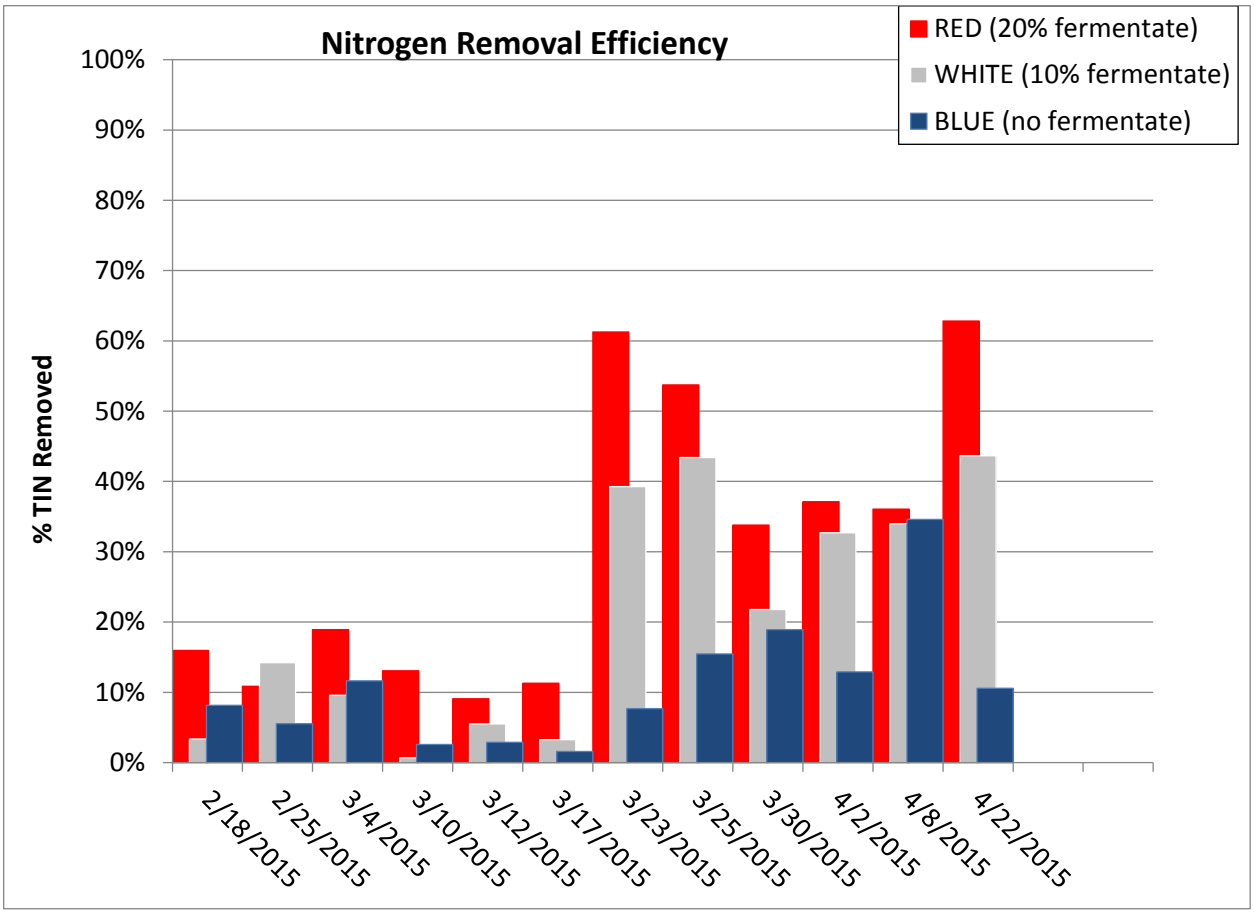


Figure 3-11 – Total inorganic nitrogen removal performance

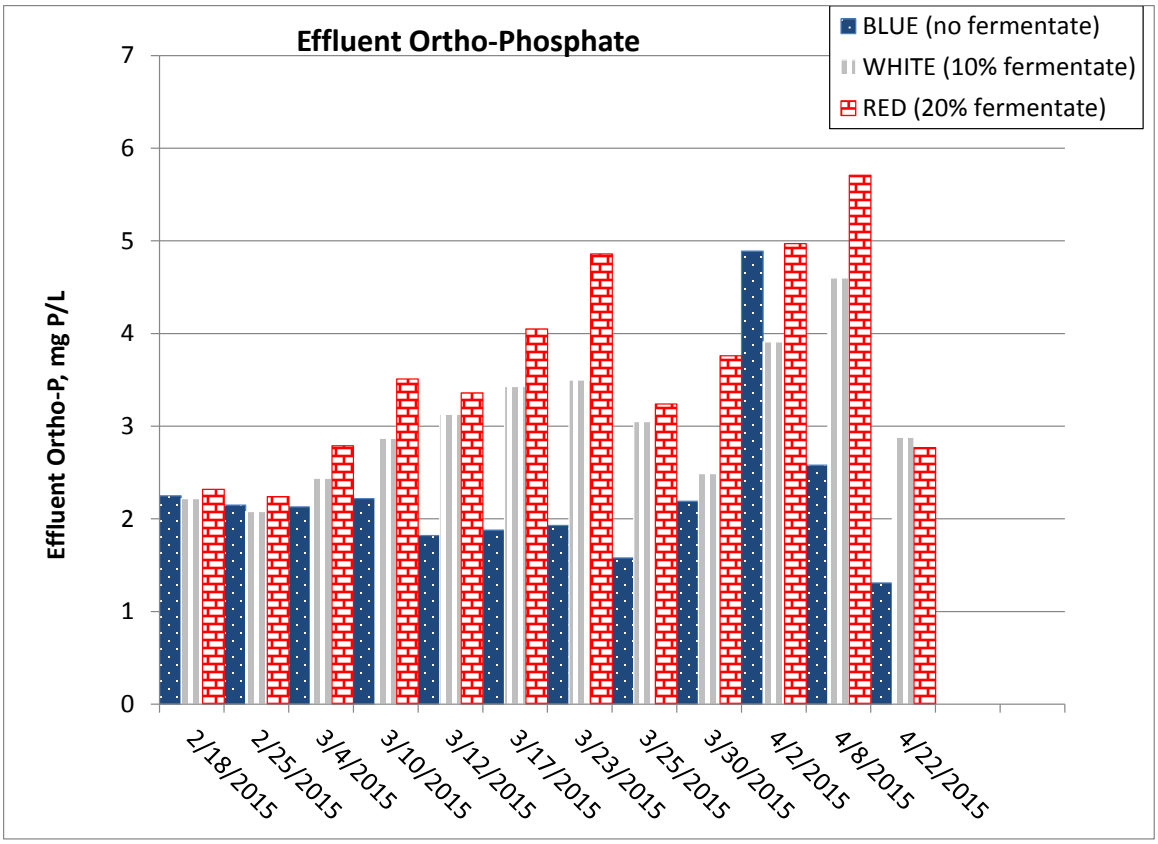


Figure 3-12- Effluent quality with respect to PO_4

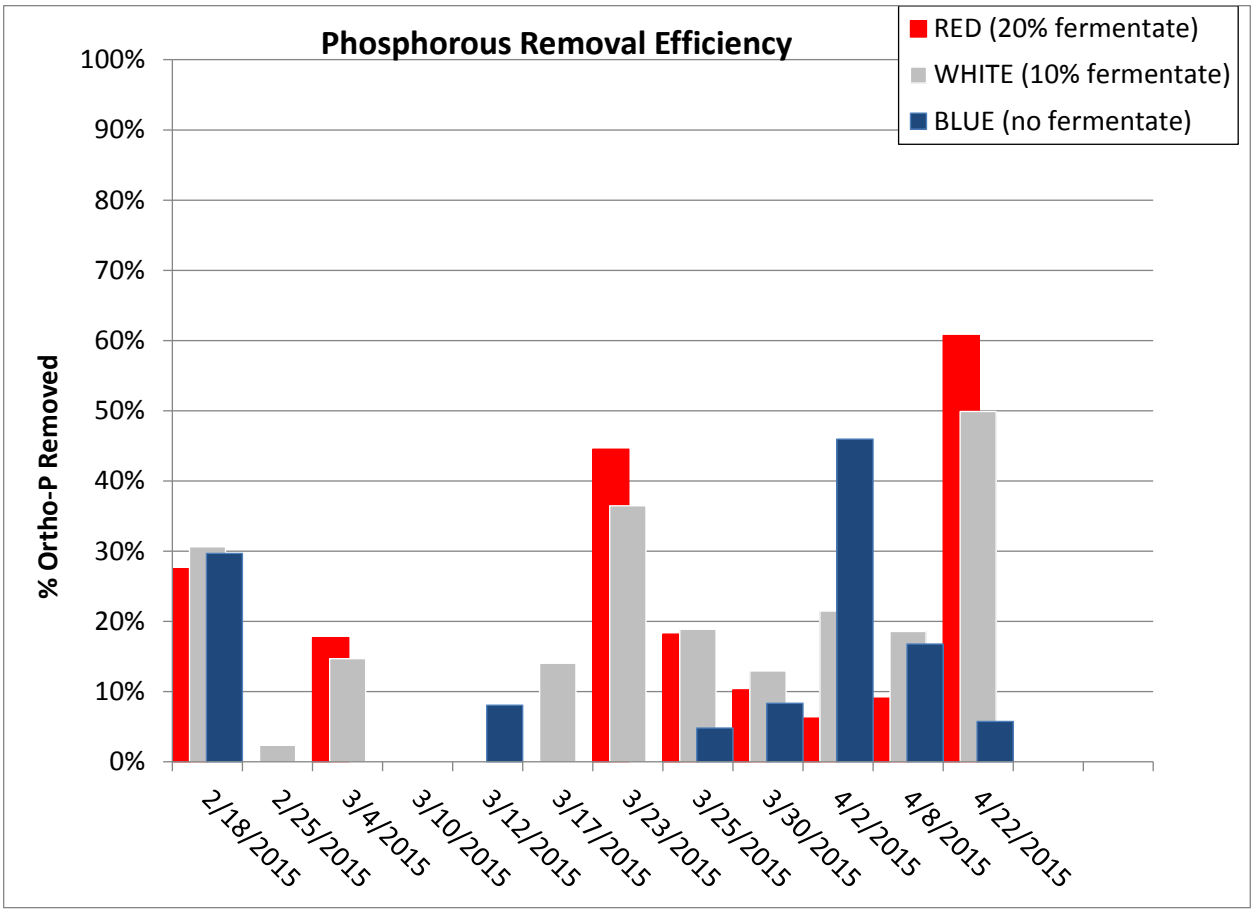


Figure 3-13- Phosphorus removal performance

Table 3-2 – Summary of average BNR performance after 3/17/15

Pilot Reactor	% N removal	% P removal
RED (20% fermentate)	47%	25%
WHITE (10% fermentate)	36%	26%
BLUE (0% fermentate)	18%	16%

BNR performance was limited by the reactor design rather than an inherent limitation of microbial performance. Sufficient time and budget limited a re-design of the reactor to provide mechanical mixing and more effective DO control. What is evident from the results is that with control of the reactor DO, BNR performance improved but could not be pushed any better than as shown in Table 3-2. Follow-on tests require more consideration of equipment selection and DO control/ mixing refinements to demonstrate better AGS BNR performance. The Nereda® systems show historical data of low effluent TN and TP concentrations; low enough to meet the projected Tomahawk Creek permit limits. The question

that is left hanging from this pilot study is this – "Is better DO control the solution or is it a fundamental problem of low strength wastewater?"

3.7 Influent and Effluent Total Suspended Solids

The average influent and effluent total suspended solids of the three reactors are shown in Figure 3-14. The influent TSS of the White and Red reactors was slightly higher than the Blue reactor due to high TSS concentrations of the fermentate added, and the increase in the amount of fermentate and sCOD addition increased the amount of effluent TSS. Given the settling rate of 7.5 m/hr, the minimum TSS was for the Blue reactor at 77 mg/L, which would require subsequent effluent polishing in a full scale application.

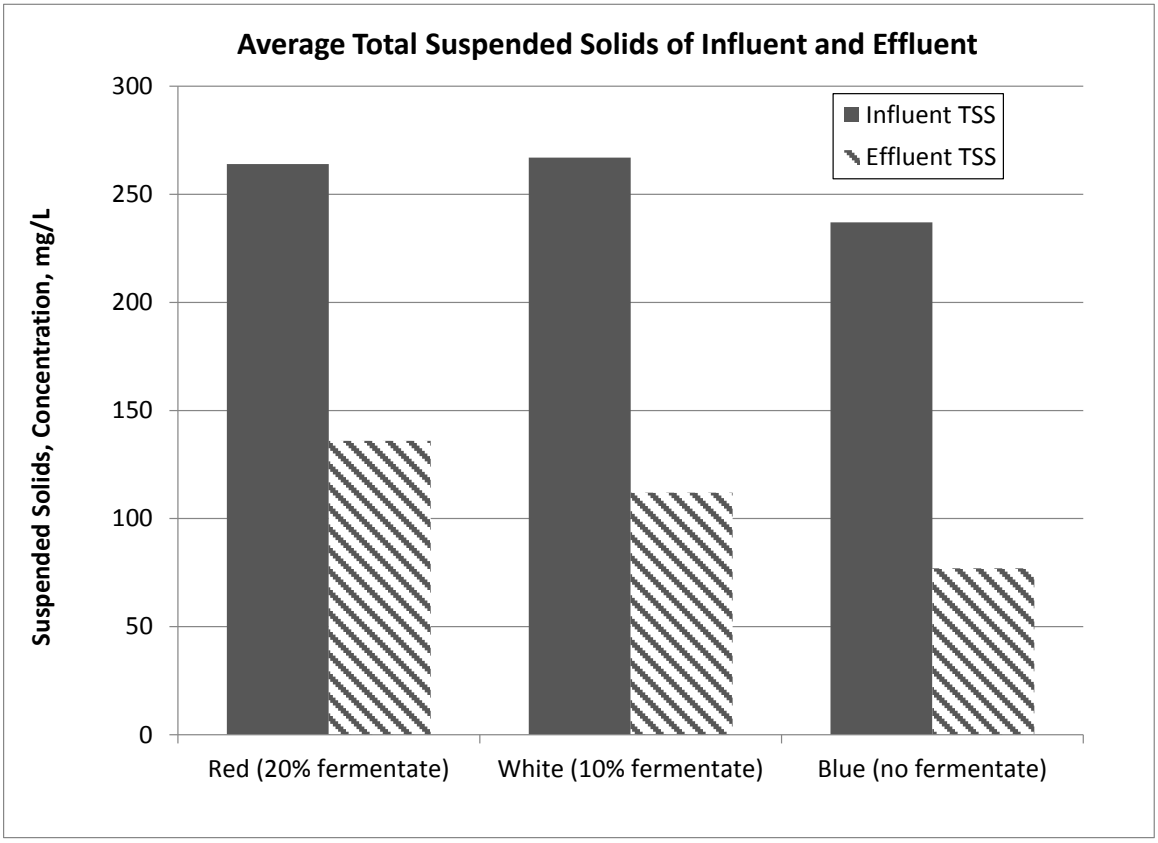


Figure 3-14 – Average total suspended solids concentration of the influent and effluent for all three reactors.

3.8 Sludge Characteristics for Land Application

The sludge characteristics of the AGS reactors were examined in regard to land application. Two separate tests were performed on separate composite samples of sludge from the AGS pilot. The first was a fecal coliform test to determine the pathogen content of the sludge. The second was an Oxygen Uptake Rate (OUR) test to determine the sludge's vector attraction.

3.8.1 Fecal Coliforms Density

According to USEPA 40 CRF Part 503 regulations for Class B sludge pathogen requirements, the monitoring results of fecal coliform density shall be less than 2 million colony forming units (CFUs) per gram of total solids.

Both types of reactor suspended solids, floc and floc + granules, were tested separately; however, only one sample was collected for this testing due to the low solids production and small scale of the pilot unit. While typical activated sludge aerobic stabilization is defined as 40 days of aeration at 20oC and 60 days at 15°C (to meet regulations by definition) more frequent sampling may prove compliance with the regulation at a shorter aeration time of the AGS sludge.

Figure 3-15 shows the most probable number (MPN) of CFU in both the floc and floc + granule sludges. The fecal density of the floc + granule sludge in the BLUE Reactor was above the 2 million CFU limit and reached 3 million CFU. Since the test is probabilistic more routine tests are needed for a better statistical sample. Also a determination of the fecal die off rate would establish the time and volume needed for stabilization via post aerobic digestion.

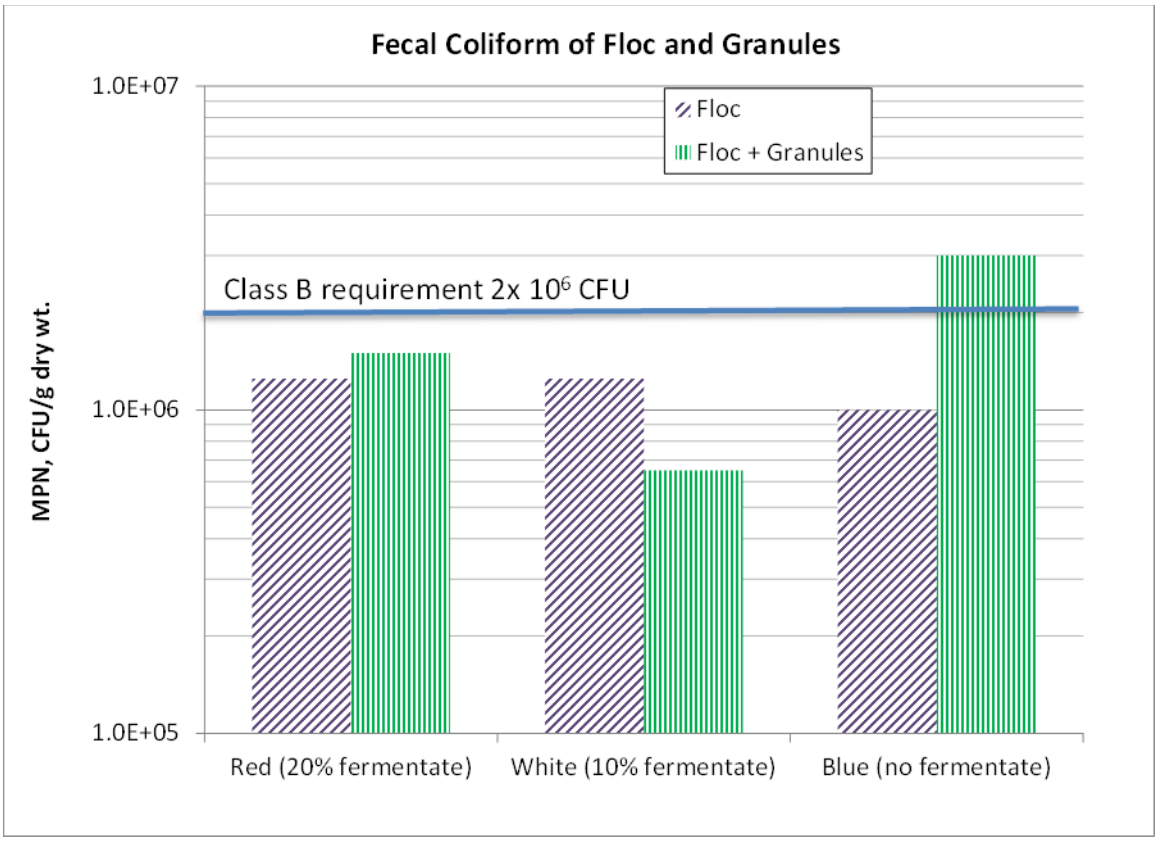


Figure 3-15 – Granular sludge fecal coliform count for each reactor (y-axis in log scale).

3.8.2 Oxygen uptake Rates (OUR)

Oxygen uptake rate experiments were performed on the three reactors during the final week of the study. The experiments were conducted according to Standard Methods 2710 B and the experimental results are shown in Figure 3-16. According to the 40 CFR Part 503 regulations for sludge pathogen and vector attraction reduction requirements under the option of aerobic digestion, it requires that the specific oxygen uptake rate must be less than 1.5 milligram of oxygen per hour per gram of total biosolids. Table 3-3 shows the actual SOUR of the granular sludge was much higher, ranging from 8-16 mg DO/g TSS-hr.

Based upon these results, it is evident that the granules are still quite active for oxygen uptake. It is recommended that if any other AGS piloting is pursued, further investigation of stabilization of wasted AGS sludge should be performed. The tests performed in this pilot effort were to define the condition of the granular sludge with respect to the 40 CFR Part 503 regulations, as wasted from the process. The testing did not define how quickly the system would endogenate and stabilize the sludge to less than 1.5 mg DO/g TSS-hr. The Blue reactor had the highest SOUR. This may be due to diffusion differences in the sludge particles between reactors, or differences in bacterial density in the granule aerobic zone, which may be a result of higher surface substrate loading of rbCOD. Given how well the granules settle it is envisioned that a gravity settler would thicken the filter backwash and the thickened AGS would be placed in an aerated tank for sludge stabilization. What is not known is the rate of biomass die-off and the retention time under aeration to get the SOUR under the regulatory threshold. It is unlikely that the AGS would prove to be economical for anaerobic digestion as there is probably little methane production potential from the AGS granules (long effective SRT). These hypotheses require further testing in future pilot studies.

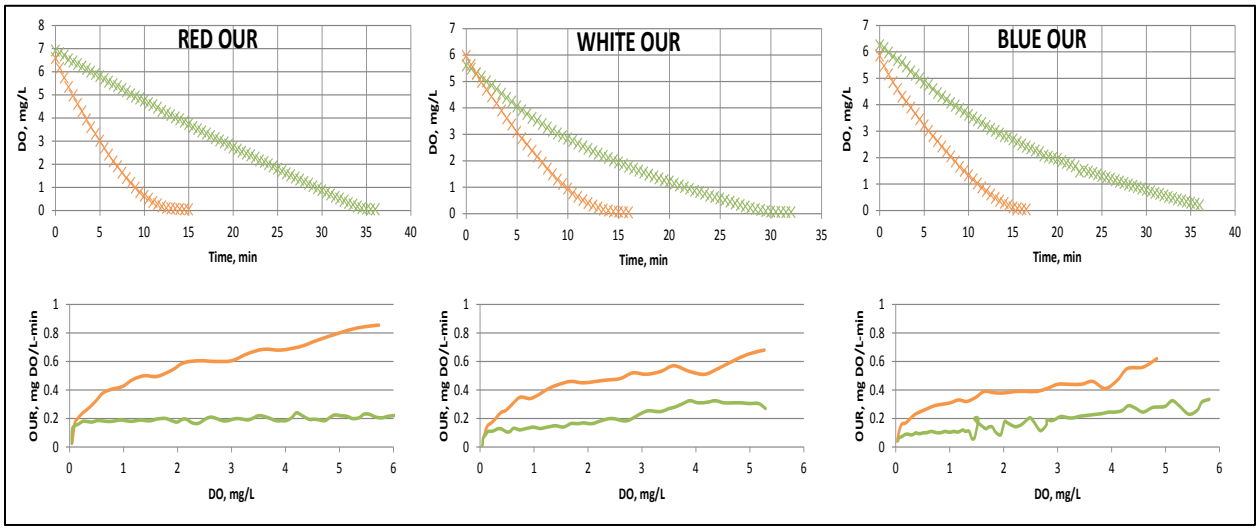


Figure 3-16 – OUR Experimental Results – Green curves are endogenous rates and Orange curves are spiked with 20 mL of influent BOD.

Table 3-3 – Table of endogenous Specific Oxygen Uptake Rates (SOURs)

Pilot Reactor	TSS/VSS	OUR	SOUR
	mg/L	mg DO/L-min	mg DO/mg TSS-hr
RED	1720/1460	0.21	8
WHITE	1300/1140	0.30	14
BLUE	1020/860	0.27	16

4 Conclusion

The main objective of this pilot study was successful in that granulation was achieved with the low strength wastewater found at the Tomahawk WWTP. Once the level of granulation was satisfactory, the granules were found to be stable, and the process was robust.

Highlights that detail the major points gained from the study are:

- Pilot testing showed that the wastewater characteristics at the Tomahawk WWTP (approximately 240 mg/L TSS, and 150 mg/L tBOD5) were suitable for aerobic granulation.
- A granule enrichment phase was used to speed up granule formation through aggressive loading and selective wasting. The granule enrichment phase was carefully controlled and monitored to ensure sufficient biomass was retained while maximizing EPS formation. Foaming and scum accumulation was manageable.
- Initial granulation was achieved in approximately 2-months after reseeding with activated sludge. Particle size distributions showed that the average diameter of the granules at the end of the study increased to approximately 0.64 mm. The average granule diameter increased over the course of the study and a longer study would create granules large enough to develop anoxic and anaerobic zones within the core of the granules for higher levels of simultaneous BNR activity.
- The reactors efficiently removed ammonia and BOD with average effluent ammonia-N and soluble BOD for all three reactors of 0.4 mg/L and 3 mg/L, respectively.
- Fermented primary sludge supplementation was shown to improve both nitrogen and phosphorous removal. With 20% (v/v) supplementation of fermentate, the average total inorganic nitrogen (TIN) and orthophosphate removal efficiency was 47 percent and 25 percent, respectively.
- The pilot reactor effluent TSS, at the settling velocity of 7.5 m/hr, was on average 77 mg/L and would require subsequent effluent polishing.

- The pilot reactor sludge characteristics, in terms of fecal coliform bacteria count and SOUR, showed that subsequent stabilization would be required to meet EPA requirements for land application.

The AGS technology is currently a popular topic of research. New developments are continually being elucidated by independent researchers as to the best method of operation and best reactor configuration. We assume that the Royal HaskoningDHV, the only vender of the AGS process, Nereda®, has performed the necessary research and obtained an advanced understanding of the process to overcome the challenges experienced during this bench scale pilot study to optimize BNR. However the main objective of this pilot study was successful in that granulation was achieved with the low strength wastewater found at the Tomahawk WWTP.

Recommendations

Several items are recommended for further consideration that could not be addressed in this study in that the reactor configurations and operation would require re-design to mimic a large scale system in so far as:

- Provide mechanical mixing or use a recirculation pump to mix the reactor contents.
- Provide more effective DO or aeration control to achieve better BNR performance.

Other items that were not fully addressed in this bench-scale study that would be addressed in a larger Nereda® demonstration study employing Royal HaskoningDHV expertise and using imported Nereda® seed sludge, consisting of large mature granules are:

- Further investigation into the cycle phase order and cycle phase durations to achieve optimal BNR performance.
- Further investigation into the AGS sludge characteristics relative to conformance to 40 CFR Part 503 requirements. Including the determination of fecal density on a statistically significant number of samples and determine the aerobic digestibility of the sludges as to the degradation of SOUR.
- Further investigation into the need for filtration after the AGS process to remove effluent TSS.
- Provide a sufficient amount of sludge to test the dewaterability of the digested AGS sludge.

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FINAL

TOMAHAWK CREEK WWTF TERTIARY PUMPING, TERTIARY FILTRATION, AUXILIARY TREATMENT, AND DISINFECTION

Technical Memorandum 4

JCW NO. THM4-C026

PREPARED FOR

Johnson County Wastewater

2 MARCH 2016

B&V PROJECT 185289

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Acronyms and Abbreviations

Abbreviation	Meaning
A	
AA	Annual Average
AADF	Average Annual Daily Flow
ADF	Average Daily Flow
AFDM	Ash Free Dry Matter
AGS	Aerobic Granular Sludge
ALE	Alginate-like-exopolysaccharides
AL-E	Expected Aquatic Life Support
ANSI	American National Standards Institute
AQL	Warm Water Aquatic Life
AUX	Auxiliary
B	
B&V	Black & Veatch
BAF	Biological Aerated Filters
BFE	Base Flood Elevation
BFP	Belt Filter Press
BioMag	Biological Flocculation System from Siemens
Bio-P	Biological Phosphorous
BLDG	Building
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
BRIS	Blue River Interceptor Sewer
BRM	Blue River Main
C	
C	Hazen-Williams Equation Roughness Coefficient
C:Chl	Carbon to Chlorophyll Ratio
CA	Calcium
CANDO	Coupled Aerobic-anoxic Nitrous Decomposition Operation (Emerging)
CBOD	Carbonaceous Biochemical Oxygen Demand
$CBOD_5$	5-day Carbonaceous Biochemical Oxygen Demand
CEA	Cost Effective Analyses
CEAM	EPA's Center for Exposure Assessment Modeling
CEPT	Chemically Enhanced Primary Treatment
cf	Cubic Feet
CFD	Computational Fluid Dynamics
cfm	Cubic Feet per Minute
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CFUs	Colony Forming Units
CHP	Combined Heat and Power
CIPP	Cured-in-place Pipe
CLOMR	Conditional Letter of Map Revision
cm	Centimeters
CMF	Compressible Media Filters
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
COM	CoMag
CoMag	Chemical Flocculation System from Siemens
CR-B	Primary B Contact Recreation
CSBR	Continuous Sequencing Batch Reactor
CSOs	Combined Sewer Overflows
CT	Concentration Time
CWA	Clean Water Act
D	
D	Depth
DFM	Dry Weather Forcemain
DGC	Digester Gas Control Building
DIG	Digester
DISC	Disc Filters
DLSMB	Douglas L. Smith Middle Basin
DN	Down
DO	Dissolved Oxygen
DP	Dual Purpose
DS	Domestic Water Supply
dt	Dry Ton
DWF	Dry-weather Flow
DWS	Drinking Water Supply

Abbreviation	Meaning
E	
E. coli	Escherichia Coli
EA	Each
EFF	Effluent
EFHB	Excess Flow Holding Basin
EL	Elevation
ELA	Engineering, Legal, Administrative
ENR	Enhanced Nutrient Removal
EPA	Environmental Protection Agency
EPS	Extracellular Polymeric Substances
EQ	Equalization
F	
F/M	Food/Microorganism Ratio
FEMA	Federal Emergency Management Agency
Fe_3O_4	Non-abrasive Iron Ore, Magnetite
ff	Flocculated and Filtered
$ffCBOD_5$	Flocculated Filtered Carbonaceous Biochemical Oxygen Demand
ffCOD	Flocculated Filtered Chemical Oxygen Demand
ffTKN	Flocculated Filtered Total Kjeldahl Nitrogen
FG	Finish Grade
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FITOT	Fraction of Total Insolation
FL	Flow Line
floc	Flocculent
FM	Flow Meter
FP	Food Procurement
FSTE	Final Settling Tank Effluent
ft	Feet
FTE(s)	Full Time Equivalent(s)
G	
gal	Gallons
GAS	Granular Activated Sludge
GGE	Gallons of Gasoline Equivalent
GP	General Purpose
gpd	Gallons per Day
gpm	Gallons per minute
GR	Ground Water Recharge
H	
HB	Hallbrook Facility
HDD	Horizontal Directional Drilling
HEC-RAS	Hydraulic Engineering Center River Analysis System
HEX	Heat Exchanger
Hf	Friction Head
HI	Hydraulic Institute
HL	Head Loss
hp	Horsepower
hr	Hour
HRT	Hydraulic Retention Time
HVAC	Heating, Ventilation, Air Conditioning
HWE	Headworks Effluent
HWLA	High Water Level Alarm
Hypo	Hypochlorite
I	
I&C	Instrumentation and Controls
I/I	Inflow and Infiltration
IC	Internal Combustion
IFAS	Integrated Fixed-Film Activated Sludge
IMF	Interagency Metering Facility
in	Inches
IND	Industrial
INF	Influent
IP	Intellectual Property
IPS	Influent Pump Station
IR	Irrigation Use
IRR	Irrigation
IW	Industrial Water Supply Use
J	
JCW	Johnson County Wastewater
K	
kcf	Thousand Cubic Feet
KCMO	Kansas City, Missouri

Abbreviation	Meaning
KDHE	Kansas Department of Health and Environment
K_e	Light Extinction Coefficient
KU	University of Kansas
kWh	Kilowatt-hour
L	
L	Length, Liter
LBVSD	Little Blue Valley Sewer District
lb	Pound
lb/d	Pounds per Day
LF	Linear Feet
LIC	Lower Indian Creek
LOMR	Letter of Map Revision
LOX	Liquid Oxygen
LPON	Labile Particulate Organic Nitrogen
LPOP	Labile Particulate Organic Phosphorous
LS	Lump Sum
LWLA	Low Water Level Alarm
LWW	Livestock & Wildlife Watering
M	
m	Meter
MAD	Mesophilic Anaerobic Digestion
MARB	Mississippi-Atchafalaya River Basin
MBBR	Moving Bed Bioreactors
MBR	Membrane Bio-reactor
MCC	Motor Control Center
mg	Milligrams
Mg	Magnesium
MG	Million Gallons
mg/L	Milligrams per Liter
mgd	Million Gallons per Day
min	Minute, minimum
mJ	Millijoules
MLE	Modified Ludzack Ettinger
MLSS	Mixed Liquor Suspended Solids
MM	Maximum Month
mm	Millimeter
MMADF	Maximum Month Average Daily Flow

Abbreviation	Meaning
mmBtu	Million British Thermal Units
mpg	Miles per Gallon
MPN	Most Probable Number
N	
N	Nitrogen
NACWA	National Association of Clean Water Agencies
NaOH	Sodium Hydroxide (Caustic)
NCAC	New Century Air Center
NDMA	N-Nitrosodimethylamine
NFIP	National Flood Insurance Program
NH3-N	Total Ammonia
NOx-N	Nitrate + Nitrite
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NPV	Net Present Value
NTS	Not to Scale
O	
O&M	Operation and Maintenance
OCP	Overflow Control Plan
OMB	Office of Management and Budget
OUR	Oxygen Uptake Rate
P	
P	Phosphorous
PAOs	Phosphorous Accumulating Organisms
PC	Primary Clarifier
PD	Peak Day
PDF	Peak Daily Flow
PE	Primary Effluent
PFE	Primary Filtered Effluent
PFM	Peak Flow Forcemain
PHF	Peak Hour Flow
PIF	Peak Instantaneous Flow
PLC	Programmable Logic Controller
PO_4-P	Orthophosphate Phosphorous
ppd	Pounds per Day
pph	Pounds per Hour
PPI	Producer Price Index

Abbreviation	Meaning
ppy	Pounds per Year
PS	Pump Station
psf	Pounds per Square Foot
psi	Pounds per Square Inch
PWWF	Peak Wet-weather Flow
Q	
Q	Flow
R	
RAS	Return Activated Sludge
rbCOD	Rapidly Biodegradable Chemical Oxygen Demand
RDT	Rotating Drum Thickener
RECIRC	Recirculation
RIN	Renewable Identification Number
RM	River Mile
R&R	Repair and Replacement
RWW	Raw Wastewater
S	
SAB	USEPA Science Advisory Board
SBOD	Soluble Biochemical Oxygen Demand
SBR	Sequencing Batch Reactor
SCADA	Supervisory Control and Data Acquisition
SCE	Secondary Clarifier Effluent
scfm	Standard Cubic Feet per Minute
sCOD	Soluble Chemical Oxygen Demand
SCR	Secondary Contact Recreation
Sec	Second, Secondary
SF	Square Foot
SG	Specific Gravity
SLR	Solids Loading Rate
SMP	Stormwater Management Program, Shawnee Mission Park Pump Station
SND	Simultaneous Nitrification/ Denitrification
SOD	Sediment Oxygen Demand
SOR	Surface Overflow Rate
SOURs	Specific Oxygen Uptake Rates
SP	Single Purpose
S.P.S.	Sludge Pump Station
SRT	Sludge Retention Time
SS	Suspended Solids
SSOs	Sanitary Sewer Overflows
SSS	Separate Sewer System
sTP (GF)	Soluble Total Phosphorous (Glass Fiber Filtrate)
SVI	Sludge Volume Index
SWD	Side Water Depth
T	
TBL	Triple Bottom Line
$TBOD_5$	Total 5-day Biochemical Oxygen Demand
TDH	Total Dynamic Head
Temp	Temperature
TERT	Tertiary
TF	Trickling Filters
TFE	Tertiary Filter Effluent
THC	Tomahawk Creek
THM	Trihalomethanes
TIN	Total Inorganic Nitrogen
TKN	Total Kjeldahl Nitrogen
TM	Technical Memorandum
TMDL	Total Maximum Daily Loads
TN	Total Nitrogen
TOC	Top of Concrete
TP	Total Phosphorous
TPS	Thickened Primary Solids
TS	Total Solids
TSS	Total Suspended Solids
TWAS	Thickened Waste Activated Sludge
TYP	Typical
U	
µg/L	micrograms per Liter
UCT	University Cape Town
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultraviolet
UV LPHO	Ultraviolet Low Pressure, High Output

Abbreviation	Meaning
UV MPHO	Ultraviolet Medium Pressure, High Output
V	
VFA	Volatile Fatty Acids
VFAs	Volatile Fatty Acids (Speciated)
VFD	Variable Frequency Drive
VS	Volatile Solids
VSL	Volatile Solids Loading
VSr	Volatile Solids Reduction
VSS	Volatile Suspended Solids
W	
W	Width
WAS	Waste Activated Sludge
WASP	Water Quality Analysis Simulation Program
WBCR-A	Whole Body Contact Recreation – Category A
WBCR-B	Whole Body Contact Recreation –Category B
WFM	Wet Weather Forcemain
WL	Water Level
WK	Week
WS	Water Surface
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant
Y	
YR	Year

1 Executive Summary

1.1 BACKGROUND AND OBJECTIVES

This executive summary highlights the evaluations and recommendations of Technical Memorandum No. 4 – Tertiary Pumping, Tertiary Filtration, Auxiliary Treatment, and Disinfection (TM No. 4). This TM is one in a series of technical memoranda for the definition phase study of the Tomahawk Creek Wastewater Treatment Facility (WWTF) expansion.

The purpose of this TM is to summarize the preliminary alternatives considered, evaluate the alternatives that were confirmed to be carried forward for further analysis, and select the preferred alternative for each facility in a Triple Bottom Line (TBL) workshop. The facilities under consideration in this TM include Tertiary Pumping, Stand Alone Tertiary Filtration, Auxiliary Treatment, Dual Purpose Filtration (tertiary filtration and auxiliary treatment combined into a single facility), Disinfection, and Effluent Reaeration.

1.2 ALTERNATIVE EVALUATION

For each of the facilities, conceptual capital costs, operation and maintenance (O&M) costs, and a life-cycle cost analysis were developed for each alternative evaluated. The conceptual capital cost opinion was developed as a 20-year net present value (NPV) which includes the effects of inflation, time-value of money, timing of capital outlay, equipment replacement, and remaining value at the end of the planning period.

To provide a basis for selecting the recommended alternative for each facility, a triple bottom line (TBL) analysis was undertaken. For this analysis, social, environmental, and operational criteria were weighted and scored to determine the benefit-cost of each alternative.

1.2.1 Tertiary Pumping

From a review of a preliminary plant hydraulic proposal, it was concluded that intermediate pumping would be required to avoid either excessively tall structures or excessively deep structures with rock excavation. The optimum location for this would be a Tertiary Pump Station located immediately after the Secondary Clarifiers.

The Tertiary Pump Station would match the hydraulic capacity of the secondary process, or 57 mgd. Two types of pumping technologies were evaluated:

- Submersible Centrifugal Pumps.
- Submersible Axial Flow Pumps.

The evaluation was based on providing 4 pumps, 3 firm, with variable frequency drives to allow for sufficient turndown to match nighttime low flow conditions.

1.2.2 Stand Alone Tertiary Filtration

Initially, five alternatives for stand alone tertiary filtration were considered. These were narrowed down to the following two alternatives in the Task 5 Alternative Screening Workshop:

- Alternative 1A – Disc Filters with pile cloth media.
- Alternative 2 – Compressible Media Filtration (CMF).

Flow and loading criteria as well as design criteria for each alternative were determined based on the sizing and expected treatment performance of the secondary process. A summary of those criteria is presented in Table 1-1.

Table 1-1 Flow and Loading Criteria

CRITERIA	VALUE
Flow	57 MGD
Influent TSS to Filters	20 mg/l
Effluent TSS	<10 mg/l
Effluent TP	≤0.5 mg/l

Preliminary sizing for each alternative, including overall layout/footprint, necessary auxiliary facilities, and hydraulic requirements, were developed through consultation with vendors based on the design criteria. For Alternative 1A, input was provided by Aqua Aerobic, Inc. for their Disc Filter. For Alternative 2, input was provided by WWETCO for their Flex Filter system.

1.2.3 Auxiliary Treatment

Six separate alternatives were identified for separate auxiliary treatment of peak wet-weather flows. In the Task No. 5 Preliminary Workshop two options were selected for further development and evaluation:

- Alternative 1 – Microsand Ballasted Flocculation using the ACTIFLO® system.
- Alternative 2 – Compressed Media Filtration (CMF).

Flow and load criteria for the auxiliary (wet weather) flows as well as design criteria for each alternative were determined based on the flow requirements for the IFAS alternative for secondary treatment. A summary of these criteria is provided in Table 1-2:

Table 1-2 Auxiliary Treatment Flow and Load Criteria

CRITERIA	VALUE
Total Peak Flow Capacity	115 MGD
Influent TSS at Peak Flow	50 mg/l
Effluent TSS Concentration (Event Average)	<30 mg/l
Minimum Number of Trains	3
Minimum Startup Flow per Train	5 MGD

For this analysis, it was assumed that flow would be diverted to auxiliary treatment two or three times per year for a total of 60 hours per year on average. Approximately 73 million gallons of water would be treated by the facility during that time.

Facility sizing for each alternative (including overall layout/footprint, necessary auxiliary facilities, hydraulic requirements, and chemical usage) was based on preliminary designs provided by vendors based on the design criteria. Sizing for Alternative 1 was provided by Kruger Inc. for their ACTIFLO® system and sizing for Alternative 2 was provided by Wes Tech/WWETCO for their FlexFilter system.

1.2.4 Dual Purpose Treatment

As an alternative to providing separate facilities solely dedicated to treatment of wet weather flows (stand-alone auxiliary) four separate alternatives were identified which could serve a dual purpose where they are regularly used to provide one level of treatment during normal design flows and then to provide a different, or additional, level of treatment during periods of wet weather flows. In the Task No. 5 Preliminary Workshop two options were selected for further development and evaluation:

- Magnetite Ballasted Flocculation using the CoMag®
- Compressed Media Filtration (CMF)

Because of the difference in the process location of these alternatives and the resulting difference in required design flow and type of treatment, CoMag® is evaluated separately in TM-6. In this TM, dual purpose CMF is evaluated against the conventional stand-alone systems selected in this TM that it would replace.

Flow and load criteria, as well as design criteria for the dual purpose CMF alternative were determined based on the flow requirements for the IFAS alternative for secondary treatment. A summary of these criteria is provided in Table 1-3. Criteria for the conventional systems were as indicated in the previous sections.

Table 1-3 Dual Purpose CMF System Flow and Load Criteria

CRITERIA	VALUE
Dry Weather	
Flow	57 MGD
Influent TSS	20 mg/l
Effluent TSS	<10 mg/l
Wet Weather	
Total Peak Flow Capacity	115 MGD
Influent TSS at Peak Flow	50 mg/l
Effluent TSS Concentration (Event Average)	<30 mg/l
Maximum Hydraulic Loading Rate (HLR)	13 gpm/ft2
Maximum Solids Loading Rate (SLR)	27.6 lb/ft2/day

During periods of normal flow, the dual purpose CMF will function similarly to a stand-alone tertiary filter. As the plant influent flow reaches the design capacity of the secondary treatment system and any excess flow storage capacity is filled, the excess flow will be diverted prior to primary settling and conveyed directly to the dual purpose filter. For influent flows up to the dual purpose filter capacity of 115 mgd, the dual purpose filter will provide both tertiary filtration of secondary flows and treatment of wet-weather flows. Once the capacity of the dual purpose filter is exceeded, secondary flows will bypass the filter and go directly to disinfection.

Facility sizing for the dual purpose CMF (including overall layout/footprint, necessary auxiliary facilities, hydraulic requirements, and chemical usage) was based on preliminary designs provided by Wes Tech/WWETCO for their FlexFilter systems, based on the design criteria. Sizing for the conventional systems were as provided in the previous sections.

1.2.5 Disinfection

Initially, nine alternatives for disinfection of dry weather and wet weather flows were identified. These were narrowed down to the following three alternatives in the Task 5 Alternatives Screening Workshop.

- Alternative 1 – Multi-Barrier, with UV followed by chlorination for dry weather flows, and chlorination for wet weather flows.
- Alternative 2 – Ozone for both dry and wet weather flow.
- Alternative 3 – Chlorination for both dry and wet weather flows.

In Alternative 1 and 3 above, chlorination would be accomplished with sodium hypochlorite, with sodium bisulfite for dechlorination prior to discharge.

A primary factor in selecting these three alternatives for further evaluation was their ability to inactivate viruses as well as E. coli. Recent studies have shown that viruses, not bacteria, are the predominant driver causing illness. It is anticipated that EPA may begin to promulgate virus criteria as soon as 2015-2016. Therefore, the criteria to serve as a basis for the disinfection evaluation, shown in Table 1-4, includes both E. coli and virus.

Table 1-4 Wet Weather Treatment Strategy

CRITERIA	VALUE (PROPOSED)	VALUE (FUTURE)
Design Secondary Flow	57 MGD	
Design Wet Weather Flow	115 MGD	
Design Total Peak Flow	172 MGD	
Influent TSS (For Filtered Flows)	<10 mg/L	
Influent TSS (From Auxiliary or Dual Purpose Treatment)	<30 mg/L	
Effluent Disinfection (April to September)	E. coli = 262 cfu/100 ml	5-log removal for polio virus (Anticipated)

CRITERIA	VALUE (PROPOSED)	VALUE (FUTURE)
Effluent Disinfection (October to March)	E. coli = 2,358 cfu/100 ml	5-log removal for polio virus (Anticipated)
Chlorination By-Products - THMs (Free Chlorine)	<1 to 10's µg/L (Potential Future Requirement)	<1 to 10's µg/L (Potential Future Requirement)
Chlorination By-Products - NDMA (Chloramines)	<10 ng/L (Potential Future Requirement)	<10 ng/L (Potential Future Requirement)

Preliminary sizing for the Alternative 1 UV system and Alternative 2 Ozone system were developed through consultation with vendors based on the design criteria. For UV, the design was based on Trojan, Inc.'s Signa Model. For Ozone, the design was based on Prime Ozone. For Alternative 1 and Alternative 3 chlorination, the design was based on industry design standards and prior experience.

1.2.6 Effluent Reaeration

Prior to discharge to Indian Creek, reaeration of the effluent is required to achieve the desired dissolved oxygen (DO) concentration. While several approached to reaeration exist, ample difference in elevation between the 100 year flood protected disinfection facility and the normal water level in Indian Creek dictates that gravity step aeration is the most appropriate and cost effective approach.

The design criteria for the Effluent Reaeration Structure will be as shown in Table 1-5.

Table 1-5 Effluent Reaeration Structure Design Criteria

CRITERIA	VALUE
Peak Hourly Flow	172 MGD
Assumed Influent DO Concentration	1 mg/L
Proposed Effluent DO Concentration [1]	6 mg/L

Note:
[1] Measured as a weekly average, minimum 3 samples per week

1.3 SUMMARY OF RECOMMENDATIONS

The results of the alternative analysis for each facility are presented in the following paragraphs:

1.3.1 Tertiary Pumping

The recommended alternative is submersible, centrifugal style pumps in a 3 firm, 1 standby configuration with VFDs to allow the pumping capacity to be matched with the anticipated range of influent flow conditions.

1.3.2 Stand Alone Tertiary Filtration

Alternative 1 Disc Filters has the lowest NPV and the lowest NPV/Normalized Benefit Ratio and is the recommended standalone filtration alternative.

1.3.3 Auxiliary Treatment

A comparison of the total NPV values for the two alternatives (CMF vs ACTIFLO®) indicates that Microsand Ballasted Flocculation using the ACTIFLO® system would have the lowest cost over a 20-year period.

A comparison of the total TBL analysis for the two auxiliary treatment alternatives indicates that although the CMF system is more favorable from a non-economic standpoint, the impact of the non-economic items is not great enough to overcome the difference in the total NPV cost.

The recommendation for stand-alone auxiliary treatment of wet weather flows based on discussions and workshops and economic and non-economic analysis is Alternative 1 – Microsand Ballasted Flocculation using the ACTIFLO® system.

1.3.4 Dual Purpose Treatment

A comparison of the total NPV values for the two alternatives indicates that two separate conventional, stand-alone facilities would have a lower cost over a 20-year period.

A comparison of the total TBL analysis for the alternatives indicates that the non-economic benefits of the dual purpose CMF facility are greater than those of the separate systems and the dual purpose CMF is the preferred alternative.

The recommendation based on discussions and workshops and economic and non-economic analysis is that a dual purpose CMF facility is preferred over separate stand-alone tertiary and auxiliary treatment facilities.

1.3.5 Disinfection

Alternative 3 Hypochlorite has the lowest Net Present Value. Although Alternative 1 Multi-Barrier had a higher Triple Bottom Line score, Alternative 3 had the lowest NPV/ Normalized Benefit Ratio. Therefore, Alternative 3 Hypochlorite is the recommended alternative.

1.3.6 Effluent Reaeration

It is recommended that filtered and disinfected effluent be reaerated utilizing a concrete step structure with a hydraulic capacity of 172 MGD. The Effluent Reaeration structure will utilize the available hydraulic gradient created by intermediate pumping to facilitate reaeration of the effluent and discharge above the 100 year flood elevation.

2 Introduction

2.1 BACKGROUND

The purpose of this TM is to summarize the preliminary alternatives considered, evaluate the alternatives that were confirmed to be carried forward for further analysis, and select the preferred alternative for each facility in a Triple Bottom Line (TBL) workshop. The facilities under consideration in this TM include Tertiary Pumping, Stand Alone Tertiary Filtration, Auxiliary Treatment, Dual Purpose Filtration (tertiary filtration and auxiliary treatment combined into a single facility), Disinfection, and Effluent Reaeration.

2.2 EXISTING FACILITIES

A brief description of the existing facilities at the Tomahawk Creek (THC) WWTF which correspond to the facility types presented in this TM is as follows:

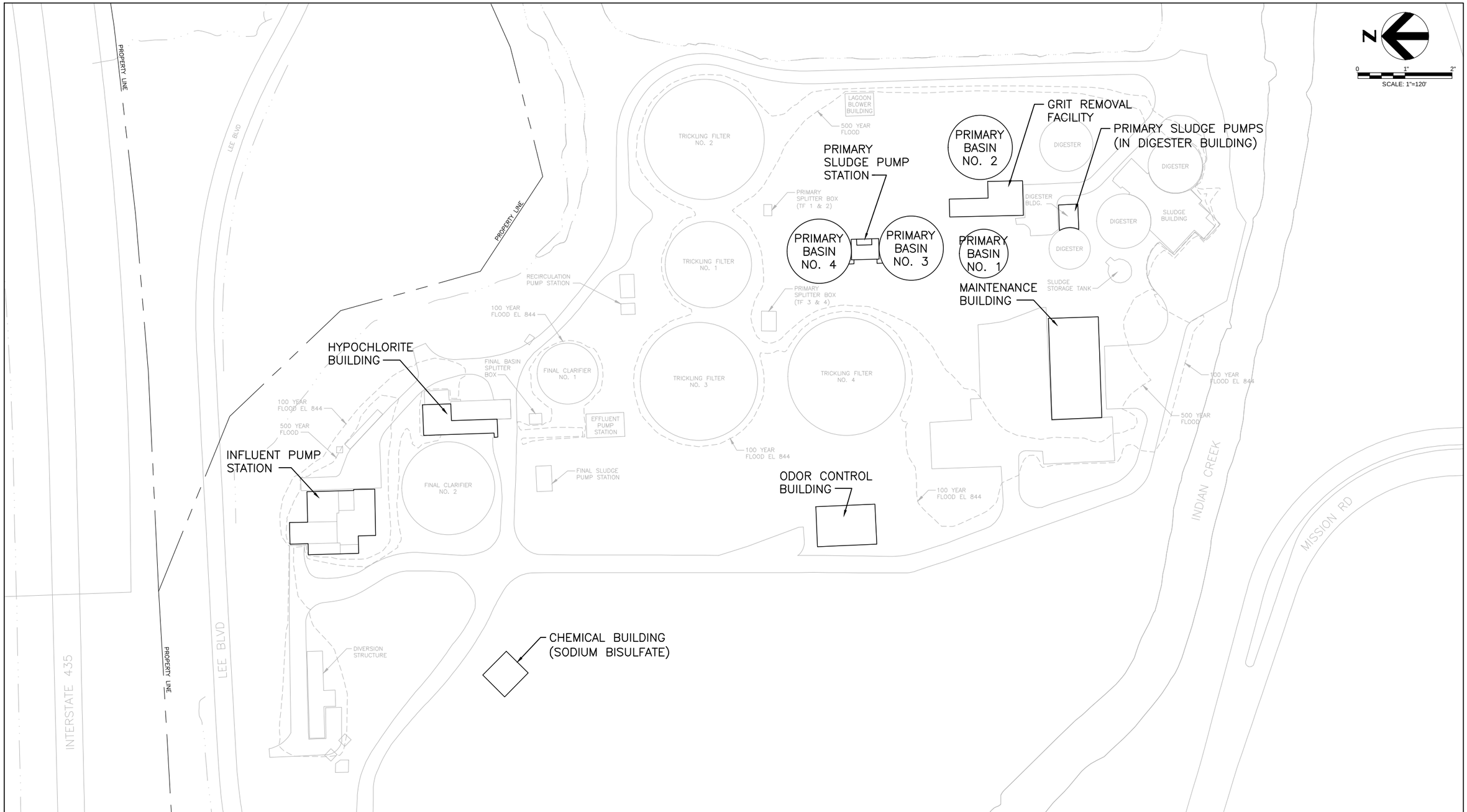
- Tertiary (Intermediate) Pumping – The existing THC WWTF does not have tertiary filtration, however, the existing Effluent Pump Station (which is actually an intermediate pump station) pumps the trickling filter effluent to the secondary clarifiers.
- Tertiary Filtration – None.
- Auxiliary Treatment – Wet weather flow is initially diverted to Kansas City, Missouri (KCMO), via the Diversion Structure and the Linking Interceptor. Once the conveyance capacity to KCMO of 97 mgd is maximized, flows above this level are sent to the Peak Flow Lagoon where they are subjected to primary treatment and disinfection, and discharged through Outfall 002. Hence the wet weather treatment strategy, in order of priority is as shown in Table 2-1:

Table 2-1 Wet Weather Treatment Strategy

FLOW INCREMENT (MGD)	STRATEGY
0 to 10	To Trickling Filter Plant
10 to 107	To KCMO
>107	To Peak Flow Lagoon

- Dual Purpose Filtration – None.
- Disinfection – Flows to both the Trickling Filter Plant and the Peak Flow Lagoon are disinfected with sodium hypochlorite, followed by dechlorination with sodium bisulfate.

Figure 2-1 shows the location of each of the above facilities.



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JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE

EXISTING FACILITIES
SITE LAYOUT
FIGURE 2-1

BFIGBORD
FBFIGBORD

2.3 DESIGN FLOWS

Technical Memorandum No. 1 established the overall design flows for the THC WWTF. As the evaluations in this TM No. 4 were being performed, several other facilities and liquid treatment unit processes were being evaluated simultaneously. The TM's associated with these other unit processes are as follows:

- TM No. 3 – Secondary Treatment Process.
- TM No. 6 – Influent Pumping, Preliminary and Primary Treatment and Support Facilities.

Many of the unit processes under the three TM's were interdependent on each other, resulting in the need to evaluate more than one design flowrate for a particular unit process. For example, some auxiliary processes require fine screening while others did not, and some secondary process required tertiary filtration while others did not. As a result, it was necessary to understand the manner in which the different unit processes combined together to form process streams to ensure that comparison were made on an apples to apples basis.

A list of the number of process/configuration alternatives evaluated for each of the unit processes is presented in Table 2-2:

Table 2-2 Alternatives Evaluated

UNIT PROCESS	NUMBER OF ALTERNATIVES EVALUATED
Fine Screening	1
Grit Removal	2
Primary Clarification	2
Secondary Treatment	4
Tertiary Treatment	2
Auxiliary Treatment	2
Disinfection	3
Dual Purpose Treatment [1]	2

Note:
[1]Combined tertiary and auxiliary process.

A total of 11 different combinations of these unit process alternatives and their corresponding design flowrates were identified. These are presented in Table 2-3 and Table 2-4:

Table 2-3 Peak Flow Summary by Facility for Secondary Treatment Components

SECONDARY TREATMENT COMPONENTS PEAK FLOW THROUGH FACILITY (MGD)						
Alternative	**Screening**	**Grit**	**Primary Clarifiers**	**Secondary Clarifiers**	**Separate Secondary Filtration**	**Disinfection (Secondary)**
IFAS – SP/ACTIFLO®	172	57	57	57	57	57
IFAS – SP/CMF	57	57	57	57	57	57
IFAS – DP/CMF	57	57	57	57	115[1]	57
IFAS – DP/COM	172	172	172[1]	57	57	57
MBR – SP/ACTIFLO®	172	38	38	N/A	N/A	38
MBR – SP/CMF	38	38	38	N/A	N/A	38
MBR – DP/COM	172	172	172 [1]	N/A	N/A	38
GAS – SP/ACTIFLO®	172	57	N/A	N/A	57	57
GAS – SP/CMF	57	57	N/A	N/A	57	57
GAS – DP/CMF	57	57	N/A	N/A	172[2]	57
BioMag/COM	172	172	172[1]	57	N/A	57

Definitions:

IFAS – Integrated Fixed-Film Activated Sludge
SP – Single Purpose
CMF – Compressible Media Filters
DP – Dual Purpose (utilize CMF or COM for both Auxiliary and Secondary Treatment)
MBR – Membrane Bioreactor
COM – CoMag®
GAS – Granular Activated Sludge

Notes:

[1] Sized for Dual Purpose application with full plant flow.
[2] Sized for Dual Purpose application, required 172 MGD capacity due to lack of secondary clarification.

Table 2-4 Peak Flow Summary by Facility for Auxiliary Treatment Components

AUXILIARY TREATMENT COMPONENTS PEAK FLOW THROUGH FACILITY (MGD)							
	Entire Plant	Secondary Treatment	Auxiliary Peak Flow Treatment				
Alternative			Single Purpose ACTIFLO®	Single Purpose CMF	Dual Purpose CMF	Dual Purpose COMAG®	Disinfection
IFAS – SP/ACTIFLO®	172	57	115				115
IFAS – SP/CMF	172	57		115			115
IFAS – DP/CMF	172	57			115		115
IFAS – DP/COM	172	57				172	115
MBR – SP/ACTIFLO®	172	38	134				134
MBR – SP/CMF	172	38		134			134
MBR – DP/COM	172	38				172	134
GAS – SP/ACTIFLO®	172	57	115				115
GAS – SP/CMF	172	57		115			115
GAS – DP/CMF	172	57			172[1]		115
BioMag/COM	172	57				172	115

Note:
[1] Sized for Dual Purpose application required 172 MGD capacity due to lack of secondary clarification.

2.4 TRIPLE BOTTOM LINE ANALYSIS

Facility alternatives will be compared through TBL analysis. By factoring social and environmental considerations into the analysis along with economic information expressed as Net Present Value (NPV), a more thorough comparison of alternatives can be achieved.

The same general TBL criteria categories will be utilized in all of the unit process alternative comparisons. These are shown in Table 2-5.

Table 2-5 Evaluation Criteria and Descriptions

CRITERIA	DESCRIPTION
Flexibility / Performance Reliability/ Turndown	Is alternative flexible enough to successfully adjust to changing conditions (i.e. flow and load)? Are there adjustable controls, process options, and/or equipment features available for operators to respond to changes in flow or meet low flow conditions?
Phasing	How easily can the alternative be phased to meet the start-up and construction constraints and how easily are the facilities in the alternative upgraded or expanded over time? Does an alternative result in reduced contract time or minimize public or staff inconvenience during construction?
Land Requirements / Layout	How well does the alternative fit on the site, require land and impact the floodplain? Do the facilities lay out in an orderly fashion (e.g., do trucks have to drive to through several facilities in order to access their final destination)?
Social Impacts	How well does the alternative prevent off-site impacts to public perception such as truck traffic, noise, odor, visual aesthetics, etc. and can these impacts be easily mitigated? (Impacts from construction activities are excluded.)
Environmental Impacts	How well does the alternative minimize the impact to the environment in terms of carbon footprint (during and after construction), ecosystem quality, and resource use?
Safety	How well does the alternative minimize safety risks to the plant staff and the public and can the risks be mitigated?
Ease of Regulatory Acceptance	How difficult will alternative be to obtain EPA and KDHE regulatory acceptance? Can acceptance likely be achieved in desired schedule?

These general criteria will be refined or modified for each unit process or facility type to better address that process' unique aspects.

3 Tertiary Pumping

3.1 PLANT HYDRAULIC PROFILE

Figure 3-1 presents a hydraulic profile of the dry weather process stream for the plant. It is based on the IFAS secondary treatment process. Profiles are shown for both tertiary disc filtration and tertiary compressible media filtration (CMF), two alternatives that will be discussed later in this TM. It also includes dual barrier effluent disinfection, i.e., ultraviolet light (UV) followed by chlorination/dechlorination, and effluent reaeration, both of which will also be discussed later in this TM.

It can be noted from Figure 3-1 that the profile includes an intermediate pump station, labeled Tertiary Pump Station (TPS), which pumps secondary clarifier effluent to filtration. It can also be noted that the total headloss through the plant not counting the break provided by the TPS and based on the CMF filtration alternative, is estimated to be 38.5 feet.

Approaches to managing the hydraulic profile other than the TPS were considered, but were ruled out due to the following considerations:

- Gravity Flow – The plant must be capable of discharging against the 100-year flood elevation of 844.0. To achieve gravity flow through the entire process stream would require the water level in the upstream channel of the Headworks to be 882.5, which would be 35.5 feet above the preliminary finished grade elevation of 846.0. The water level in the Primary Clarifiers would be 879.0 or approximately 28 feet above grade. Building structures at this height is undesirable from an aesthetic stand point and is cost prohibitive from the stand point of deep foundations, stairs, walkways, etc. The flow through gravity option is not believed to be feasible.

- Effluent Pumping – Under dry weather, the plant would discharge by gravity against the normal pool level in Indian Creek of 828.0. To achieve the required drop through the Effluent Reaeration structure, the water surface elevation upstream of this structure's weir would need to be 835.5. The effluent pumps would activate when the water elevation in the stream reached this elevation during flood conditions. Under this scenario, the water surface in the Headworks would be 872.0 which are approximately 26 feet above final grade. This is still higher than optimal.

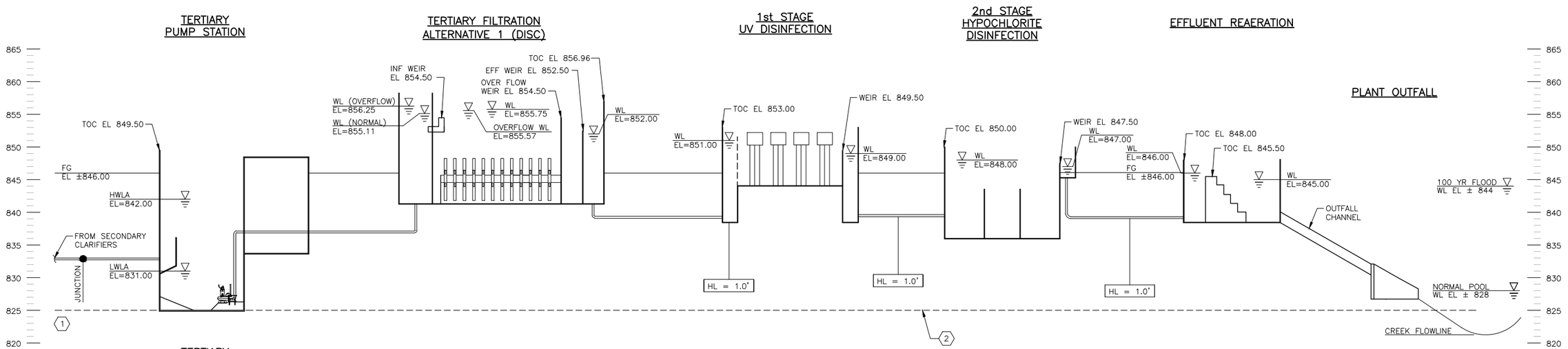
The TPS alternative minimizes structure height, with a Headworks water surface approximately 17 feet above grade and the CMF filter upstream water elevation approximately 15 feet above grade. It also optimizes the subsurface costs with the bottom of the deepest structures, the final clarifiers, just above the expected rock elevation of 825.0, and the large IFAS basin relatively deep to minimize its deep foundation cost. From these considerations, the TPS option is recommended in lieu of gravity flow or effluent pumping.

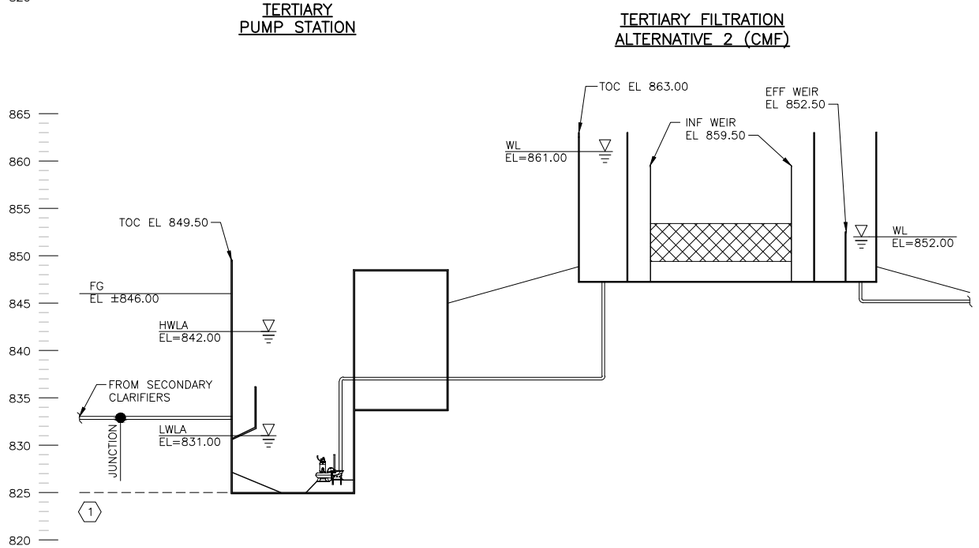
GENERAL NOTES:

1. PROFILE DEPICTS ELEVATIONS FOR ALTERNATIVES 1 (DISC) AND ALTERNATIVES 2 (CMF).

KEY NOTES:

(1) APPROXIMATE SITE ROCK ELEVATION = ±825 PER TERRACON 09/17/07 GEOTECHNICAL REPORT.





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TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE

HYDRAULIC PROFILE (IFAS)
TERTIARY FILTRATION ALTERNATIVES 1 & 2
FIGURE 3-1

BFIGBORD
FBFIGBORD

3.2 PRELIMINARY ALTERNATIVE SCREENING

Preliminary alternatives screened for the TPS consisted of evaluating the use of centrifugal or axial flow submersible pumps. Submersible style pumps were evaluated due to the facility's relatively shallow depth, and because submersible pump stations typically have a smaller footprint and lower capital cost than dry pit installations. Centrifugal style submersible pumps were selected for further alternative development because they provide the more conservative alternative with respect to cost and required site footprint, and are more common than axial flow submersible pumps. This pump type is also utilized at many locations throughout JCW's system. Figure 3-2 shows a typical installation for a submersible centrifugal pump.

Figure 3-2 Submersible Centrifugal Pump

3.3 ALTERNATIVE DEVELOPMENT

As stated above, a single tertiary pumping alternative was carried forward for further consideration. It is assumed all secondary treatment alternatives, with the exception of the Membrane Bioreactor (MBR) treatment alternative, will require a TPS. A design pumping capacity of 57 MGD, which represents a 3:1 design peak to average flow ratio, will also be used for facility sizing. Two pumping head considerations were also evaluated based upon the alternatives being considered for tertiary filtration. Condition 1 is based upon the headloss through a disc type filter, referred to later as Tertiary Filtration Alternative 1, while Condition 2 is based upon the headloss through CMF, referred to later as Tertiary Filtration Alternative 2. Each filter has varying headloss

requirements and therefore will impact the total dynamic head (TDH) required for TPS pump sizing.

3.3.1 Design Criteria

The purpose of the TPS is to hydraulically lift effluent from the Final Clarifiers to an elevation that will facilitate gravity flow through the downstream tertiary filtration and other unit processes and discharge above the approximate 100 year flood elevation of 844.0. Figure 3-3 provides an enlarged hydraulic profile focused on each pumping condition evaluated.

Pumps are recommended to be provided with VFDs that will allow pumping capacity to be matched with the anticipated range of influent flow conditions. As stated earlier, Condition 1 will be the pumping condition if Tertiary Filtration Alternative 1 is selected and Condition 2 will be the pumping condition if Tertiary Filtration Alternative 2 is selected. This variation in required pumping head results in slightly different horsepower pumps being required for each tertiary filtration alternative.

Table 3-1 presents the applicable design criteria for the TPS for each pumping condition.

Table 3-1 Tertiary Pump Station Design Criteria

CRITERIA	VALUE	
	Condition 1 – Disc	**Condition 2 – CMF**
Flow	57 MGD	
TDH @ 3 Pumps On	20.5’	25.0’
TDH @ 1 Pump On	24.5’	29.0’
Wet Well Size (LxWxH)	25’x31’x23.5’	
Valve Vault Size (LxWxH)	18’x31’x13’	
Number of Pumps	4 (3 firm +1 standby)	
Horsepower	90 HP	110 HP
Speed	Variable Speed	

3.3.2 Tertiary Pump Station Layout, Footprint, and Hydraulic Considerations

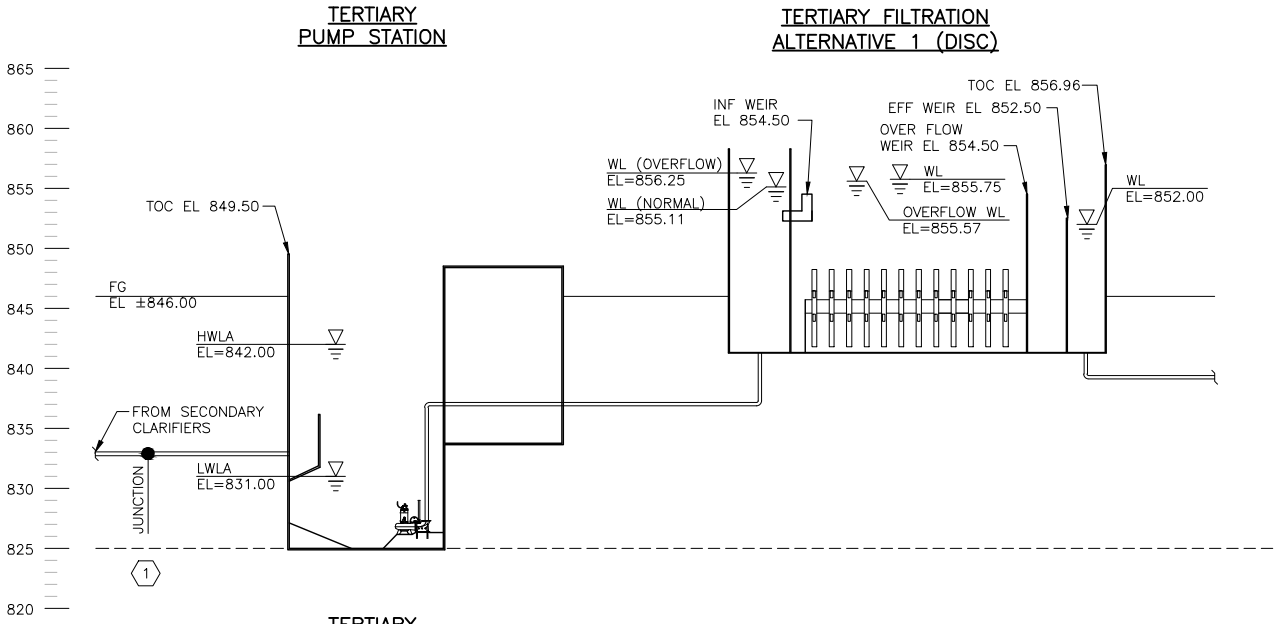
Effluent from the secondary clarifiers will enter the TPS Wet Well and be directed to the pumps through means of a flow straightening/diversion baffle. The TPS Wet Well will be a concrete structure with an attached valve vault to the approximate dimensions shown in Table 3-1. It is recommended to utilize four (4) submersible pumps (three (3) firm and one (1) standby) with VFD’s in order to better match the design pumping capacity to the anticipated range of diurnal influent flow conditions. In the adjacent valve vault, each pump will have a corresponding isolation valve and check valve. A plan and section view of the Tertiary Pump Station can be seen in Figure 3-4 and Figure 3-5.

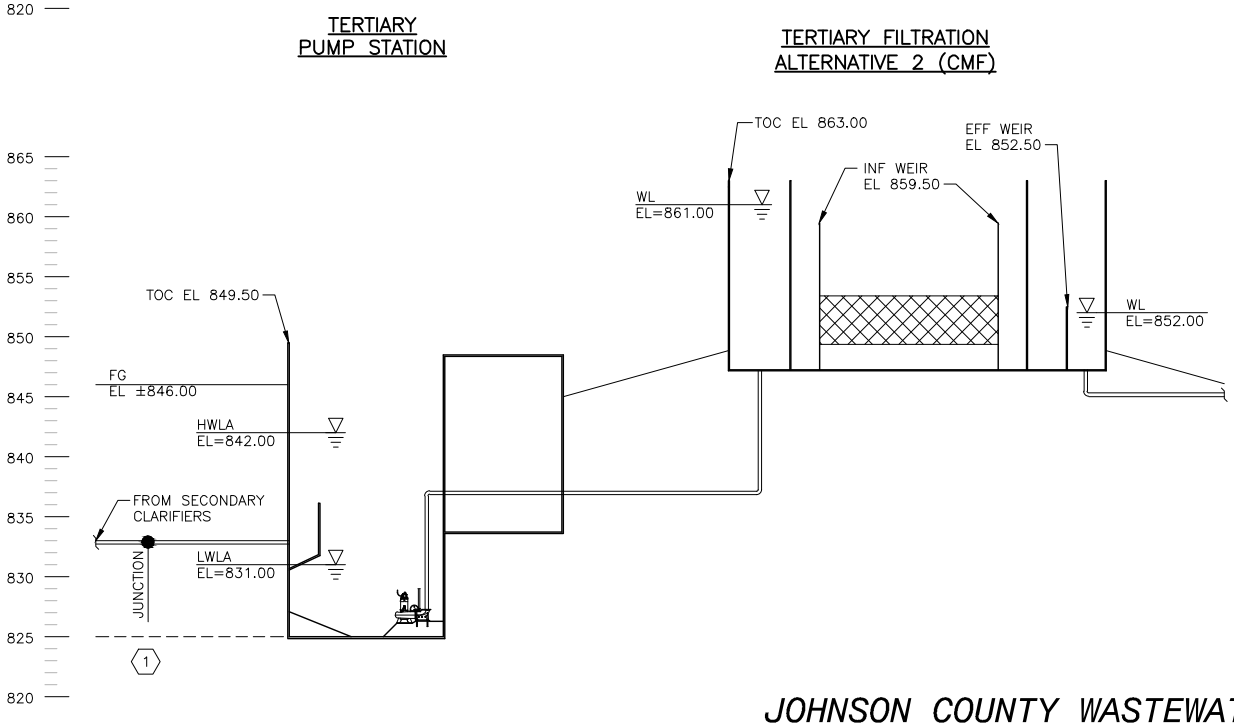
GENERAL NOTES:

1. PROFILE DEPICTS ELEVATIONS FOR ALTERNATIVES 1 (DISC) AND ALTERNATIVES 2 (CMF).

KEY NOTES:

(1) APPROXIMATE SITE ROCK ELEVATION = ±825 PER TERRACON 09/17/07 GEOTECHNICAL REPORT.





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TERTIARY PUMPING HYDRAULIC PROFILE (IFAS)
TERTIARY FILTRATION ALTERNATIVE 1 & 2

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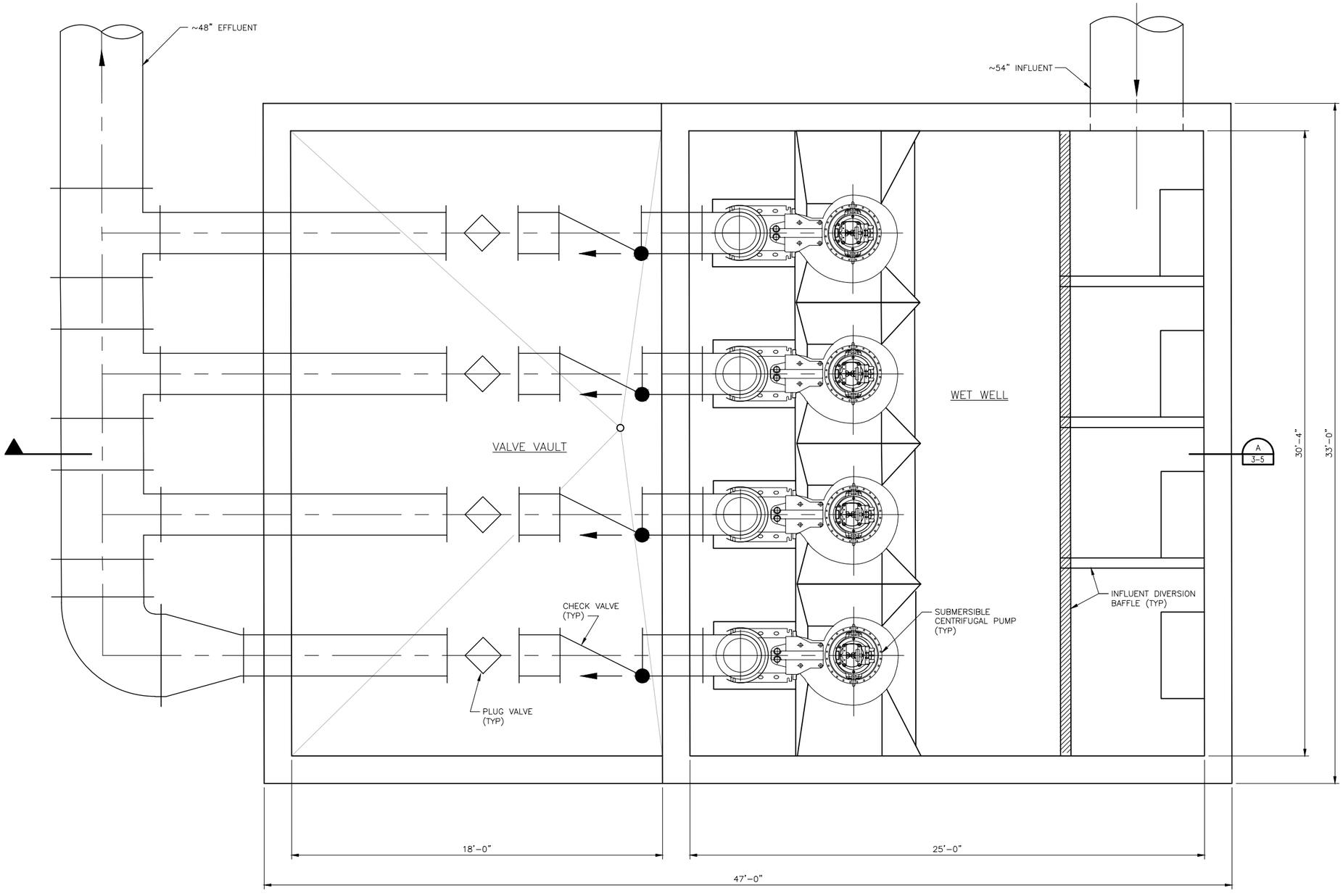
FIGURE 3-3

AFIGBORD
FAFIGBORD



PLAN
3/16"=1'-0"

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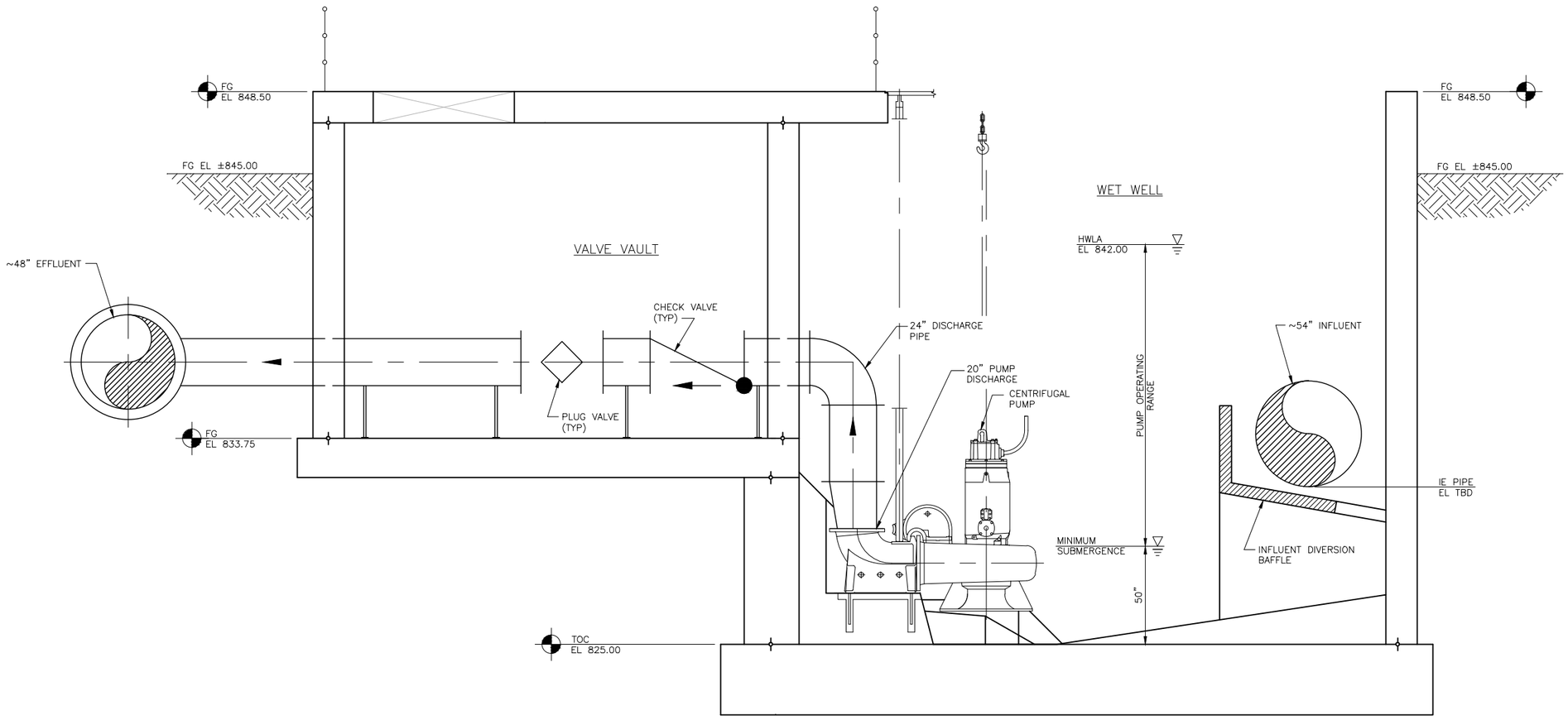
TERTIARY PUMP STATION

FIGURE 3-4

BFIGBORD
FBFIGBORD



SECTION A 3-4
3/16"=1'-0"

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PROJECT DEFINITION PHASE

TERTIARY PUMP STATION

FIGURE 3-5

BFIGBORD
FBFIGBORD

Figure 3-6 shows the pump VFD curves for a single pump in operation and illustrates the pump's ability to meet the anticipated nighttime diurnal low flow condition of approximately 4,200 gpm, or 6 mgd.

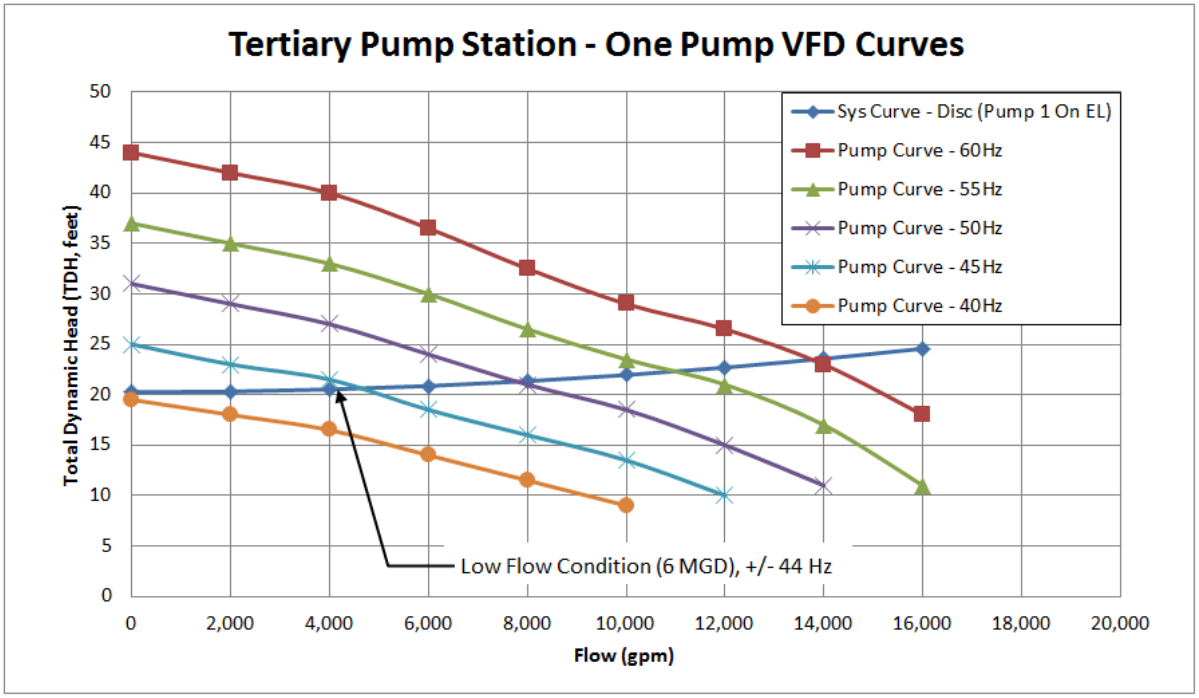


Figure 3-6 Tertiary Pump Station - System Curve

3.4 COST ANALYSIS

Preliminary capital costs were developed assuming the more conservative design pumping condition of conveying flows to Tertiary Filtration Alternative 2 (CMF). Capital costs for excavation, concrete, and metals were developed using estimated quantities derived from the conceptual layouts with unit cost values. The expected cost for deep foundations was developed based on providing a similar foundation to that implemented on existing buildings on site and applied on a per square foot basis. Equipment costs were based on vendor quotes and installation of that equipment was projected at an applicable alternative percent of the equipment cost. Process piping and valves, as well as other miscellaneous non-building items were estimated on a lump sum basis.

O&M costs were developed for each pumping condition so the incremental operational costs associated with the increased pumping head for Alternative 2 (CMF) could be used when later evaluating filtration alternatives.

All estimates are in 2015 dollars. The results of this analysis are presented below.

3.4.1 Capital Cost

The estimated capital cost for the TPS utilizing centrifugal pumps and the Condition 2 pumping head is presented in Table 3-2. Since the estimated capital cost for the pumping equipment under the Condition 1 pumping head is similar to that of Condition 2, they will be assumed to be equal for this TM.

Table 3-2 Tertiary Pump Station Capital Cost

	CAPITAL COST ($)
Tertiary Pump Station	$5,090,000

See **Appendix A** for supporting cost estimate details.

3.4.2 Incremental O&M Cost

The pumping head conditions listed in Table 3-1 were used for TPS pump sizing and applicable power consumption requirements. Repair and replacement costs were assumed to be a representative percentage of 3% of the equipment capital cost. Items assumed to be similar between alternatives such as labor were excluded from the evaluation. The results of this analysis are presented in Table 3-3.

Table 3-3 Tertiary Pump Station Incremental O&M Costs

O&M COSTS	CONDITION 1 (WITH DISC FILTERS DOWNSTREAM)	CONDITION 2 (WITH CMF DOWNSTREAM)
Electricity	$47,000	$57,000
R&R[1]	$32,000	$32,000
Total	**$79,000**	**$89,000**

Note:
[1] Assumes pump equipment R&R costs are similar for each pumping condition.

See **Appendix A** for supporting incremental O&M cost details.

3.4.3 Net Present Value

NPV calculations are presented in Table 3-4. A breakdown of the life cycle cost analysis is contained in **Appendix A**.

Table 3-4 Tertiary Pump Station Net Present Value

DESCRIPTION	CAPITAL COST ($)	O&M COST ($)	TOTAL NPV ($)
Tertiary Pump Station (with Disc Filters downstream)	$5,090,000	$79,000	$5,800,000
Tertiary Pump Station (with CMF downstream)	$5,090,000	$89,000	$5,960,000

3.5 TRIPLE BOTTOM LINE ANALYSIS

A TBL analysis was not performed for this facility since only one alternative was carried forward for consideration.

3.5.1 Criteria Weighting and Scoring

N/A

3.5.2 Cost/Benefit Scoring

N/A

3.5.3 Recommended Alternative

It is recommended to carry forward submersible, centrifugal style pumps in a 3 firm, 1 standby configuration. Pumps will be provided with VFDs to allow the pumping capacity to be matched with the anticipated range of influent flow conditions. For planning purposes, it is assumed that the TPS will include an attached valve vault to provide for pump isolation and to prevent flow reversal after a pump shutdown. This assumption provides a conservative estimate of facility cost as well as site footprint requirements. The final pumping head will vary depending on the tertiary filtration alternative selected. If the head and site layout are conducive to allow pumping vertically to a free surface discharge, a value engineering analysis will be performed during the preliminary design phase to determine if the value vault can be eliminated.

4 Stand Alone Tertiary Filtration

4.1 PRELIMINARY ALTERNATIVE SCREENING

Preliminary alternatives screened for tertiary filtration are shown in Table 4-1. These included traditional sand type as well as synthetic media type filters. The following is a result of the preliminary alternatives screening process.

Alternatives Carried Forward:

- Alternative 1A consists of disc type filtration using a pile cloth media. This media provides additional filtration depth and is considered a more durable material than that presented in Alternative 1B which utilizes a polyester screen.
- Alternative 2 consists of Compressible Media Filtration (CMF) using synthetic fiber ball media. This alternative provides increased filtration depth of +/- 30" (compared to 1 to 2 inches for pile type cloth media) and a filter profile that provides a porosity gradient suitable for capturing varying particle sizes.

Alternatives Eliminated:

- Alternative 1B consists of disc type filtration using a synthetic media in the form of a thin polyester microscreen. This alternative was eliminated since it was determined this material was not as robust as those considered in Alternatives 1A, disc filtration and Alternatives 2, CMF.
- Alternatives 3A and 3B consist of traditional and deep-bed sand type filters. These alternatives were eliminated due to their considerably larger footprint requirements (compared to Alternative1A and 2).

TABLE 4-1 STAND ALONE TERTIARY FILTRATION ALTERNATIVE SCREENING MATRIX

Alternative Carried Forward

Alt.	Types	Description	Footprint	Filtration Rate	Opening Size	TSS Removal	TP Removal	TN Removal	Headloss	Energy Use	Concurrent Filtration / Backwash	Complexity of Backwash System	Media Replacement Cost	Typical Manufacturers
1A	Disk (Pile Cloth)	Disks in vertical configuration, with 1 filter panel per disk segment and 8 segments per disk. Flow direction out to in of disk. Filter material is a pile cloth. Backwash is intermittent through suction pump and valves located on side of basin.	Smallest	5 to 6.5 gpm/sq ft	Varies, 10 or less micron effective opening, 5 or less for microfiber style	Medium to High	Yes, requires upstream Enhanced Biological Phosphorus Removal or chemical coagulation and flocculation	No	Medium, less than 4'	Low	Yes	Medium	Medium	Aqua Aerobic
1B	Disk (Screen)	Disks in vertical configuration, with 2 filter panels per disk segment and 14 segments per disk. Flow direction is in to out of disk. Filter material is a polyester screen. Backwash is intermittent through high pressure backwash pump with spray bars/nozzles.	Smallest	4 to 5 gpm/sq ft	10 micron opening	Medium to High	Yes, requires upstream Enhanced Biological Phosphorus Removal or chemical coagulation and flocculation	No	Medium, less than 4'	Low	Yes	Low	Medium	Kruger, WesTech
2	Compressible Media	Rectangular filter arrangement with flow direction from top to bottom or vice versa. Filter material is comprised of multiple synthetic fiber balls that form a media bed approximately 30" deep. Backwash is intermittent through redirect of influent flow and backwash air sparge, approximately 20 minutes in duration.	Medium	10 to 30 gpm/sq ft,	Varies, 10 or less micron effective opening	Medium to High	Yes, requires upstream Enhanced Biological Phosphorus Removal or chemical coagulation and flocculation	No	High, 4' @ 10 gpm/sq ft, 7' @ 30	Medium to High (Greater headloss increased pumping head)	No	Low to Medium	Low	WesTech (WWETCO), Schreiber
3A	Sand	Rectangular walls and strip filter arrangement with flow direction from top to bottom. Filter material is comprised of granular media with bed depths of 10 to 24". Conventional backwash (offline cell) traveling bridge system.	Largest	4 to 5 gpm/sq ft	Varies, 10 or less micron effective opening	High	Yes, requires upstream Enhanced Biological Phosphorus Removal or chemical coagulation and flocculation. More effective than disk / compressible	No	Medium, less than 4'	Low	Yes - Traveling Bridge No - Conventional	Medium	Low	Aqua Aerobic, Evoqua, Ovivo, etc.
3B	Sand (Deep Bed)	Rectangular walls and circular filter arrangement with flow direction from bottom to top. Filter material is comprised of granular media with bed depths of 40 to 80". Up flow design with continuous or intermittent backwash.	Largest	4 to 5 gpm/sq ft	Varies, 10 or less micron effective opening	High	Yes, requires upstream Enhanced Biological Phosphorus Removal or chemical coagulation and flocculation. More effective than disk / compressible	Yes, carbon source addition	High	Medium to High (Greater headloss increased pumping head)	Yes	Medium to High	Low	Parkson, Blue Water

Of the various filter types reviewed, it was determined that only two alternatives (Alternative 1A and 2 from Table 4-1 would be carried forward for further evaluation. These alternatives include:

- Aqua Aerobic's disc filter, herein after referred to as Alternative 1. This filter type has a large installation base for tertiary applications, including two installations in the State of Kansas, and has been proven through prior installations of meeting the proposed effluent criteria for this project. Figure 4-1 shows a typical section rendering for Alternative 1.

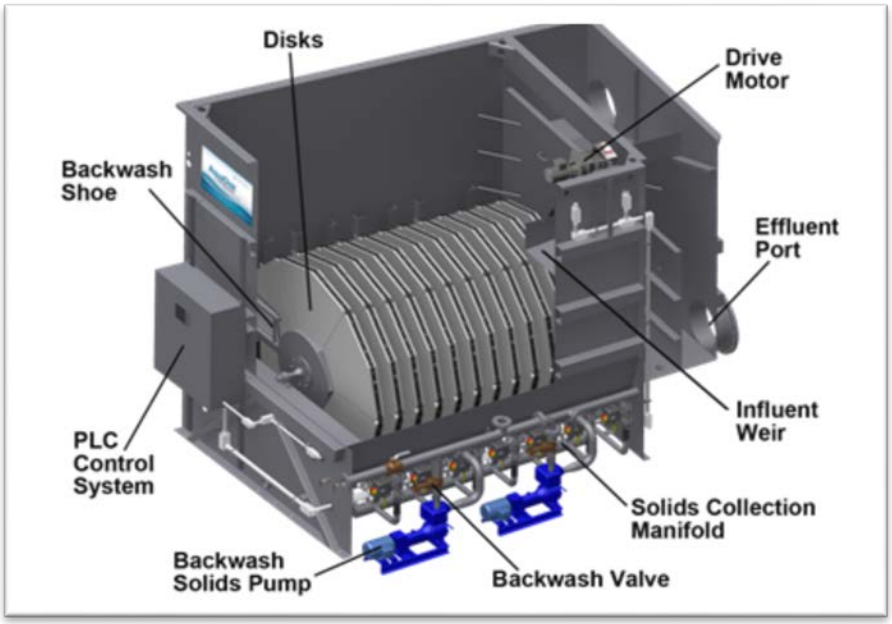


Figure 4-1 Aqua Aerobic – Disc Filter

- WWETCO's CMF, herein after referred to as Alternative 2. This filter has a relatively small installation base of approximately 7 U.S. installations for tertiary applications, but has demonstrated through pilot testing at JCW and other facilities the capacity to meet the effluent criteria for this project. Figure 4-2 shows a typical section rendering for Alternative 2.

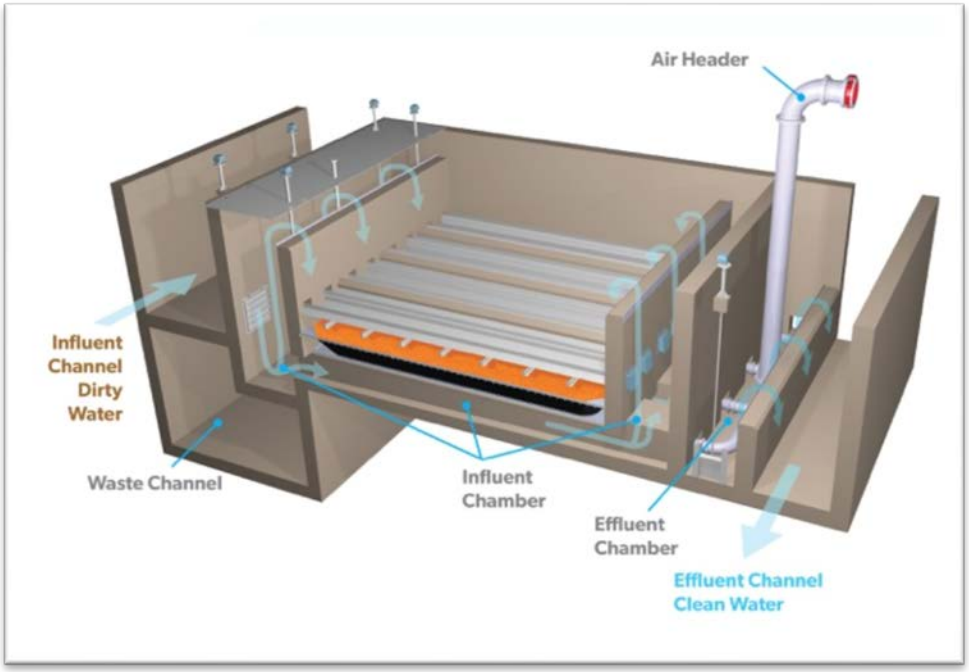


Figure 4-2 WWETCO – CMF

4.2 ALTERNATIVE DEVELOPMENT

Each tertiary filtration alternative considered will be sized to treat a peak flow of 57 MGD. Each filter type has varying headloss requirements and therefore will impact the TDH required for TPS pump sizing. Vendor proposals were obtained for each filter type and from the information obtained, preliminary layouts were developed to determine their applicable site footprint requirements.

4.2.1 Design Criteria

The design influent flow and loading used for alternative sizing criteria as well as effluent requirements for this unit process are summarized in Table 4-2. The applicable design aspects for each alternative are summarized in each alternative section.

Table 4-2 Stand Alone Tertiary Filtration Design Criteria

CRITERIA	VALUE
Flow	57 MGD
Influent TSS to Filters	20 mg/l
Effluent TSS	<10 mg/l
Effluent TP	≤.5 mg/l

Note:
[1] Metal salt addition upstream of secondary clarifiers and filters if required.

4.2.2 Alternative 1 Disc Filters - Layout, Footprint, and Hydraulic Considerations

For Alternative 1 Disc Filters, flow will enter the facility into a main influent distribution channel. Flow will be directed from this channel to each on-line filter through the means of a filter influent isolation gate. Each filter consists of individual disc segments that are fully submerged under all operating conditions and they remain static during normal filter operation. Unfiltered flow passes from the outside to the inside of the disc where filtered flow is collected in the disc's center drum and conveyed to the effluent channel. The flow level through the filter is controlled by an effluent serpentine weir.

As the filter blinds and the level within each filter bay rises to a preset point, a PLC will automatically initiate a filter backwash cycle that includes rotating the disc assembly and activating the suction style backwash pumps that remove filtered material from the outside of each disc where they are then directed back to the plant drain system. During the backwash cycle, the disc continues to filter flow and does not go offline. All filters are provided with one installed firm filter drum and one backwash motor. Additional uninstalled spares will be provided in the event an equipment failure. It is also proposed to provide one complete installed standby filter that can be placed into service as needed.

To bring additional filter units on-line to match influent flow conditions, the influent isolation gate will be opened automatically by the PLC control system based on a flow set point and the filter will commence filtering flows automatically. This control can also be tied to the filter's internal high level alarm. Each filter is equipped with an overflow weir that will automatically bypass unfiltered flow and combine it with filtered flow so as to maintain continuous operation.

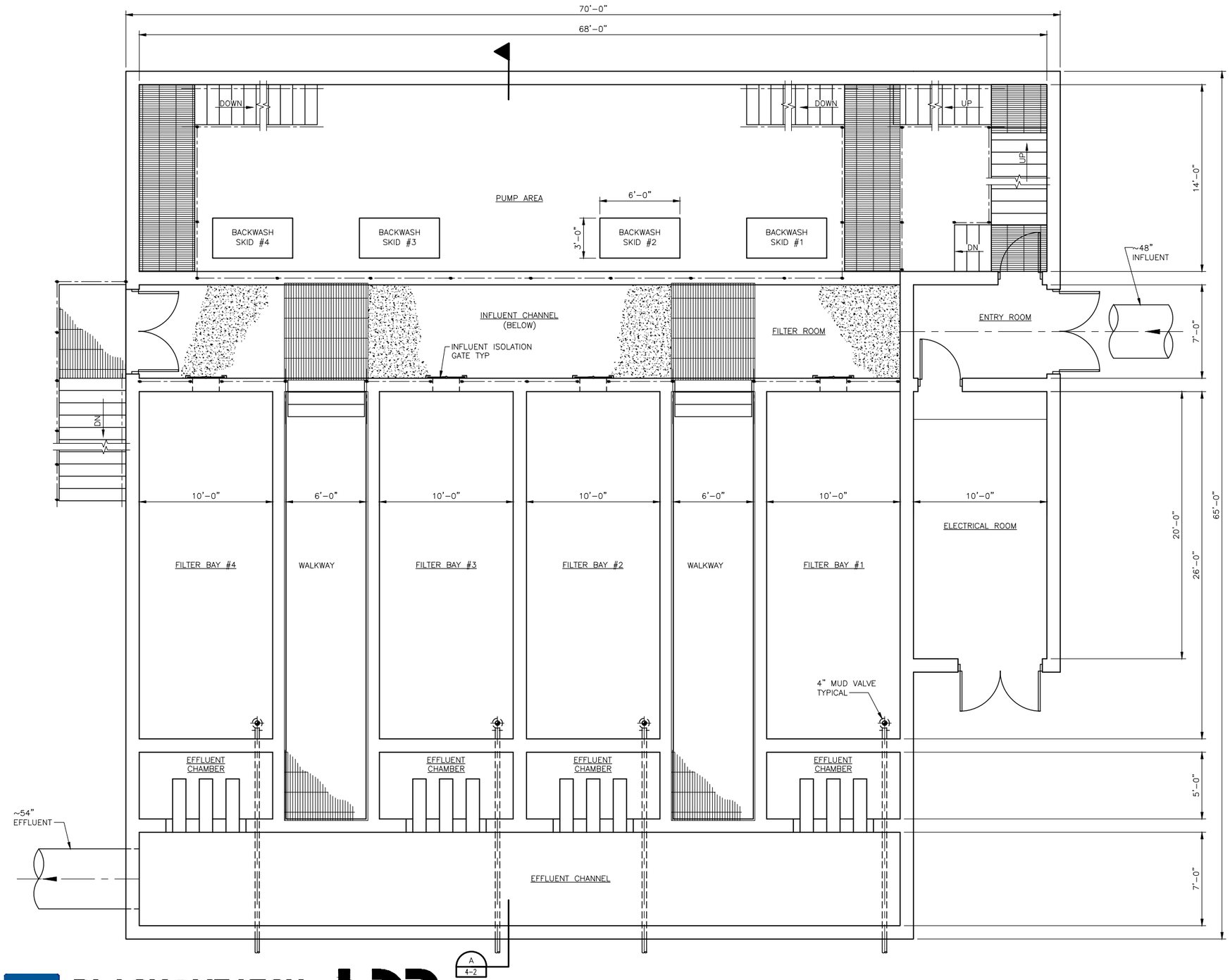
Table 4-3 presents the equipment criteria applicable to Alternative 1.

Table 4-3 Alternative 1 - Disc Filtration Equipment Criteria

EQUIPMENT CRITERIA	VALUE
Number of Filters	4 (3 firm + 1 standby)
Discs per Filter	22
Filtration Area per Disc	146 sf
Filtration Area per Filter	3,217 sf
Total Firm Filtration Area	9,650 sf
Total Filtration Area	12,868 sf
Firm HLR at 57 MGD	4.1 gpm/ft^2 [1]
Firm SLR at 57 MGD & 20 mg/l TSS	1.2 lbs/ft^2/day [2]
System Headloss (From Upstream to Downstream WL's)	3.75 ft
Backwash Pumps per Filter	1 firm at 15 hp [3]
Filter Drives per Filter	1 firm at 5 hp [3]
Isolation Gates per Filter	1
Approximate Structure Size	65 ft. X 70 ft.
Footprint	4,550 sf
Backwash Rate	~1% (of Filter Throughput)

Notes:
[1] Manufacturer limits max rate to 5.0 gpm/ft^2.
[2] Manufacturer limits max rate to 2.0 lbs/ft^2/day.
[3] One uninstalled spare unit per type of equipment will be provided.

Figure 4-3 and Figure 4-4 depict preliminary plan and section views for Alternative 1. A preliminary facility footprint for this alternative is estimated at 65' x 70', or approximately 4,550 sf, which includes the pumping area for backwash equipment as well as an electrical room for electrical gear and control panels. This alternative assumes the provision of a building to enclose the filter process.



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FILTER BUILDING
1/8"=1'-0"

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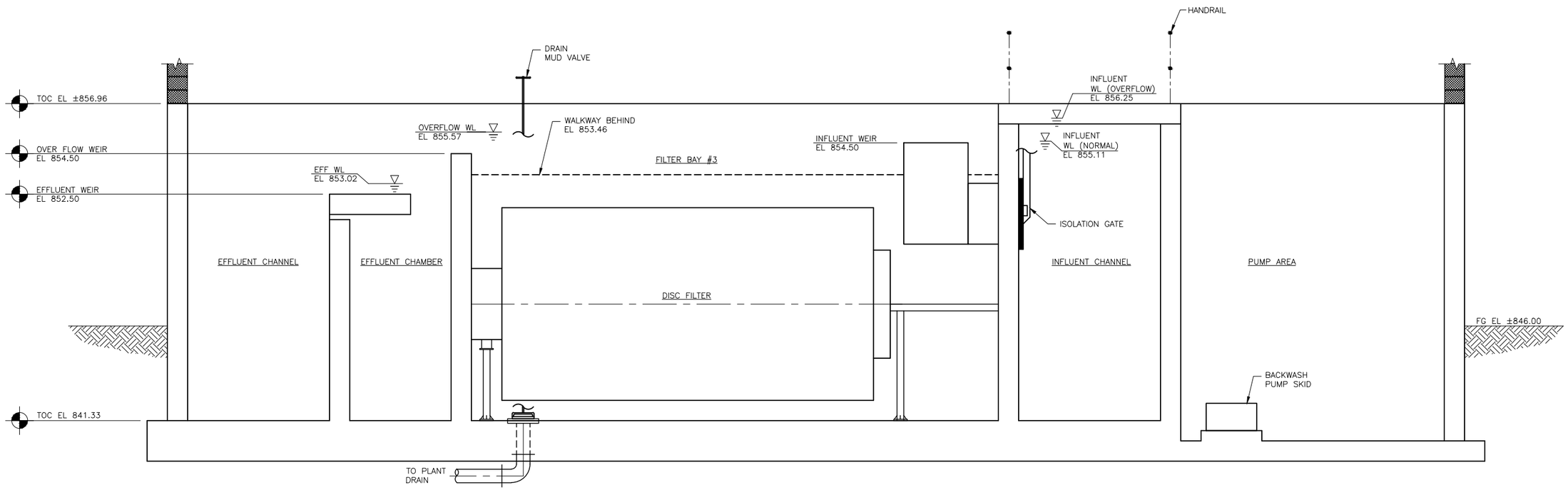
PROJECT DEFINITION PHASE

STAND ALONE FILTRATION
ALTERNATIVE 1 - DISC
FIGURE 4-3

BFIGBORD
FBFIGBORD



SECTION
3/16"=1'-0"
A
4-1

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TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE

STAND ALONE FILTRATION
ALTERNATIVE 1 - DISC
FIGURE 4-4

BFIGBORD
FBFIGBORD

4.2.3 Alternative 2 Compressible Media Filters - Layout, Footprint, and Hydraulic Considerations

Similar to Alternative 1 (Disc), Alternative 2 (CMF) will distribute flow to all on-line filters through a main influent distribution channel. Flow is directed from this channel to each on-line filter through the means of a filter influent isolation gate. Each filter cell consists of two media beds with influent chambers at each end that are hydraulically connected through compression chambers along the lower side walls. As the basin is filled, influent will cause the lower side walls to flex inward and laterally compress the synthetic fiber ball type media forming a cone shaped porosity gradient. The flow will enter the cell at the top and flow downward, through the compressed media, and to the effluent underdrain beneath each cell. The filtrate will then flow to a common effluent channel.

As the filter blinds and the level within each filter cell rises to a preset point, a PLC will automatically initiate a filter backwash cycle that includes isolating the filter from service and utilizing secondary effluent from within the filter and high capacity backwash blowers to agitate and disturb the media. During this process, the filter in backwash is taken out of service and backwash flows from the filter agitation are directed back to the plant drain system. The PLC control system will automatically bring additional filters on-line based upon a preset flow set point.

Table 4-4 presents the equipment criteria applicable to Alternative 2.

Table 4-4 Alternative 2 - CMF Equipment Criteria

EQUIPMENT CRITERIA	VALUE
Number of Cells	8 (7 firm + 1 backwash)
Nominal Dimensions of Each Cell	
Length	30 ft
Width	13 ft
Number of Strip Filters per Cell	2
Nominal Dimensions of Each Strip Filter	
Length	30 ft
Width	6 ft
Filtration Area per Strip Filter	180 sf
Total Firm Filtration Area	2,520 sf
Total Filtration Area	2,880 sf
Depth of Filter Media	+/- 30 in
Backwash Air Scour Blowers	
Number of Blowers	2 (1 firm + 1 standby)
Capacity (each)	7,200 scfm
Motor Horsepower (each)	250 HP

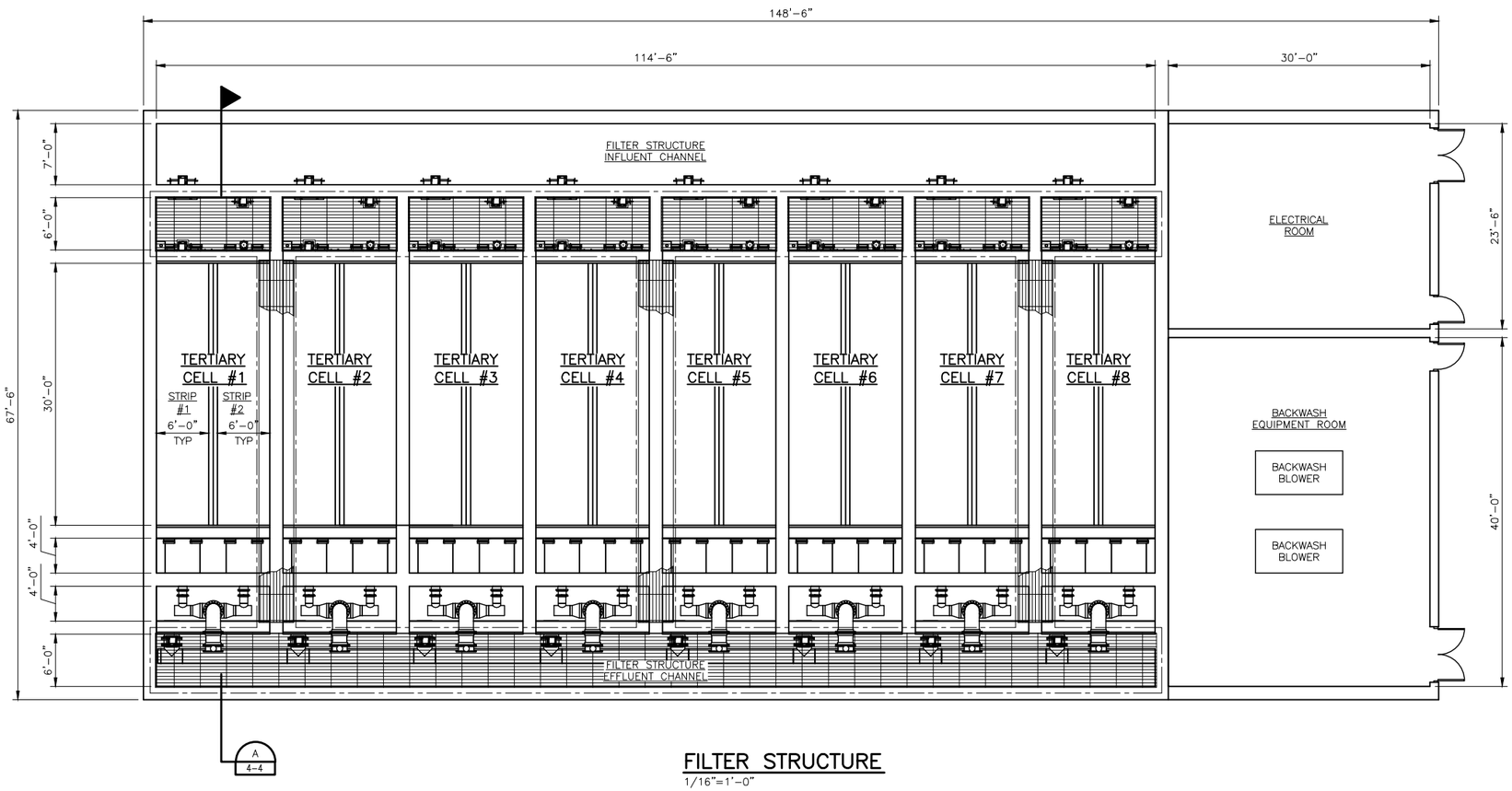
EQUIPMENT CRITERIA	VALUE
Firm HLR at 57 MGD	15.7 gpm/ft^2 [1]
Firm SLR at 57 MGD & 20 mg/l TSS	3.8 lbs/ft^2/day [2]
System Headloss (From Upstream to Downstream WL's)	7.4 ft
Actuated Gates/Valves per Filter	5
Approximate Structure Size	70 ft. X 150 ft.
Footprint	10,500 sf
Backwash Rate	1,800 gpm

Notes:
[1] Manufacturer limits max rate to 20.0 gpm/ft^2.
[2] Within Manufacturer's design SLR.

Figure 4-5 and Figure 4-6 show the preliminary plan and section views for this alternative. A preliminary footprint for this alternative is estimated at 70' x 150', or approximately 10,500 sf, which includes the area for backwash equipment as well as an electrical room for electrical gear and control panels. This alternative assumes the filter process is suitable for outdoor installation, which is comparable to other installations in cold weather climates.

NOTE:

1. ASSUMES BACKWASH FLOWS DRAIN BY GRAVITY TO INFLUENT PUMP STATION.



FILTER STRUCTURE

1/16"=1'-0"

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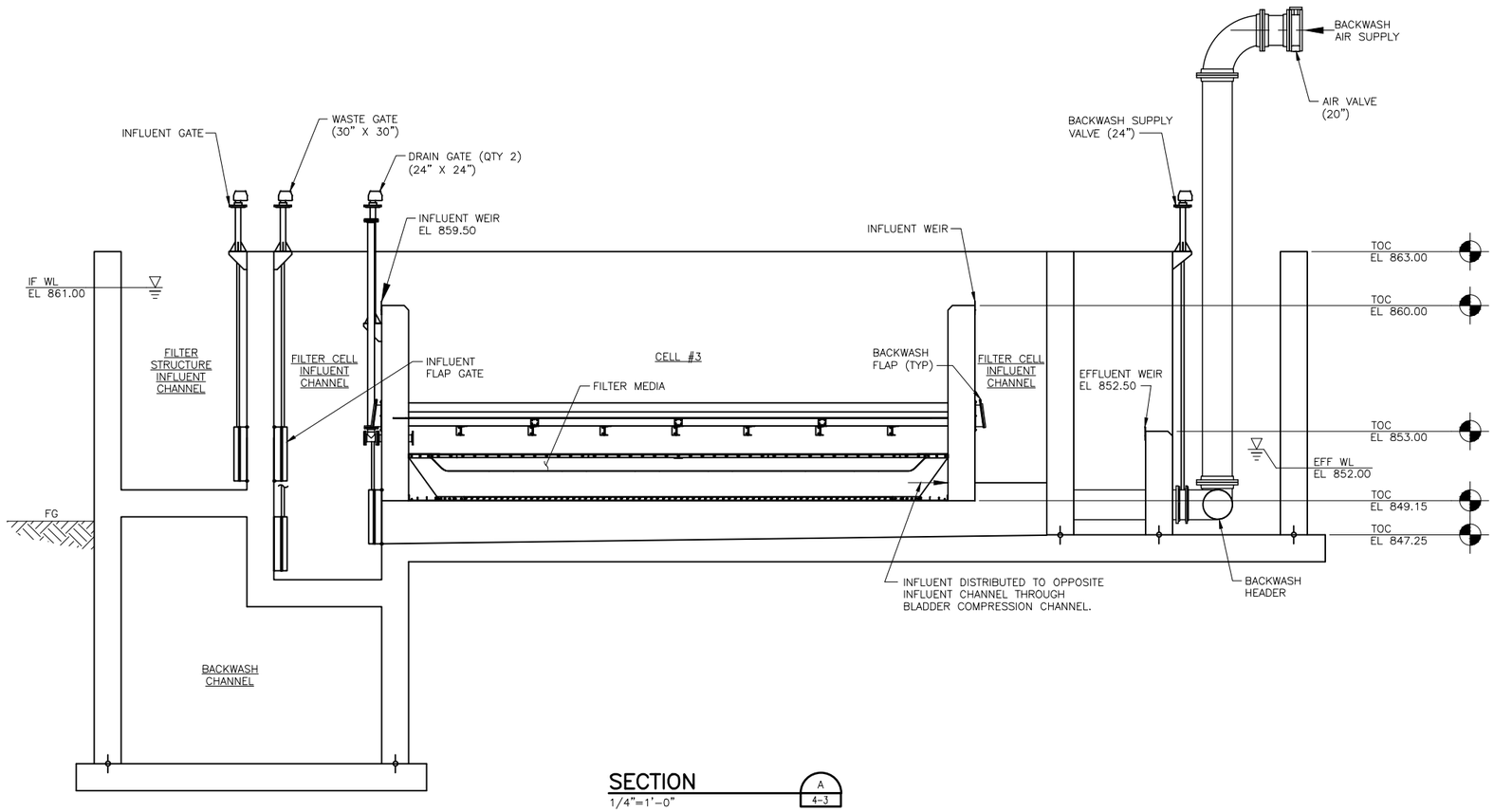
STAND ALONE FILTRATION
ALTERNATIVE 2 - (CMF)
FIGURE 4-5

BFIGBORD
FBFIGBORD



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STAND ALONE FILTRATION
ALTERNATIVE 2 - (CMF)
FIGURE 4-6

BFIGBORD
FBFIGBORD

4.3 COST ANALYSIS

Preliminary capital and O&M costs were developed for Tertiary Filtration Alternatives 1 and 2. Capital costs for superstructure, including HVAC and plumbing were estimated based on per square foot cost derived from historical data and escalated to current value. Costs for excavation, concrete, and metals were developed using estimated quantities derived from the conceptual layouts with unit cost values. The expected cost for deep foundations was developed based on providing a similar foundation to that implemented on existing buildings on site and applied on a per square foot basis. Equipment costs were based on vendor quotes and installation of that equipment was projected at an applicable alternative percent of the equipment cost. Process piping and valves, as well as other miscellaneous non-building items were estimated on a lump sum basis.

The estimates are in 2015 dollars. The results of this analysis are presented below.

4.3.1 Capital Cost

The estimated capital cost for Tertiary Filtration Alternatives 1 and 2 is presented in Table 4-6.

Table 4-5 Stand Alone Tertiary Filtration Capital Cost

	CAPITAL COST ($)
Alternative 1 – Disc	$15,010,000
Alternative 2 – CMF	$21,120,000

See **Appendix B** for supporting cost estimate details.

4.3.2 Incremental O&M Cost

O&M cost estimates were developed for Tertiary Filtration Alternatives 1 and 2. The comparative estimates included applicable power consumption requirements as well as specific repair and replacement costs. Electricity costs associated with the increased pumping head required for Alternative 2 are also included. Items assumed to be similar between alternatives such as labor, chemical usage, etc. were excluded from the evaluation. The results of this analysis are presented in Table 4-6.

Table 4-6 Stand Alone Tertiary Filtration Incremental O&M Costs

O&M COSTS	ALTERNATIVE 1 DISC	ALTERNATIVE 2 CMF
Electricity (Filtration)	$9,000	$9,000
Electricity (TPS)	$0	$10,000
R&R	$48,000	$4,000
Total	**$57,000**	**$23,000**

4.3.3 Net Present Value

NPV calculations are presented in Table 4-7. A breakdown of the life cycle cost analysis is contained in **Appendix B**.

Table 4-7 Stand Alone Tertiary Filtration Net Present Value

DESCRIPTION	CAPITAL COST ($)	O&M COST ($)	TOTAL NPV ($)
Alternative 1 – Disc	$15,010,000	$57,000	$14,038,000
Alternative 2 – CMF	$21,123,000	$23,000	$19,550,000

4.4 TRIPLE BOTTOM LINE ANALYSIS

A TBL analysis was performed to provide a more thorough comparison of the alternatives evaluated. Non-economic criteria, such as social and environmental factors can impact an alternative under evaluation. The general criteria listed in Table 2-5 have been expanded on in Table 4-8 by providing alternative specific descriptions and providing ranking information for subsequent scoring to determine an overall benefit score for each alternative. The results of this scoring process are presented in Table 4-9. This benefit score was then combined with the NPV to determine the benefit-cost of each alternative in Table 4-10.

The relative importance and weighting factors used to score the non-economic criteria were developed jointly with JCW during the alternative selection workshop. This is presented in the following sections.

Table 4-8 Stand Alone Tertiary Filtration Ranking Information

CRITERIA	RANKING INFORMATION
Flexibility / Performance Reliability/ Turndown	**Alternative 1 – Disc:** Less operational complexity since it utilizes one isolation gate, one backwash pump and one drum motor per filter. Has as a proven track record with respect to meeting the proposed effluent limits. Allowable filtration rate is highly variable and suitable for the proposed flow ranges.
	Alternative 2 – CMF: Additional firm units as compared to Alternative 1 allows for greater equipment redundancy. Demonstrated through pilot testing with JCW as well as prior installations that it is capable of meeting the proposed effluent limits. This alternative has more operational complexity since it utilizes multiple gates to control influent and backwash operational states. Allowable filtration rate is highly variable and suitable for the proposed flow ranges. Ranking: 5 = highest flexibility/reliability 1 = least flexibility/reliability
Phasing	**Alternative 1 – Disc:** There are no phasing considerations for this alternative.

CRITERIA	RANKING INFORMATION
	Alternative 2 – CMF: There are no phasing considerations for this alternative. Ranking: 5 = no phasing impact 1 = large phasing impact
Land Requirements / Layout	**Alternative 1 – Disc:** Filtration media is arranged by vertically oriented discs aligned in a row for each filter and therefore is able to provide a significant filtration surface area in a small footprint.
	Alternative 2 – CMF: Filtration media is arranged in a horizontal plane with each filter cell comprised of multiple strips. Hydraulic loading rate is approximately 3 times that of Alternative 1, but arrangement of its filtration area in a horizontal plane results in this alternative having a significantly larger footprint. Ranking: 5 = small footprint 1 = large footprint
Social Impacts	**Alternative 1 – Disc:** Aesthetic considerations are similar between alternatives. Facility will include a masonry superstructure above the filter area which will results in a taller structure.
	Alternative 2 – CMF: Aesthetic considerations are similar between alternatives. Equipment is suitable for outdoor installation and therefore will not include a superstructure above the filter area which results in a shorter structure. Ranking: 5 = no social impact 1 = large social impact
Environmental Impacts	**Alternative 1 – Disc:** Media replacement is anticipated at 7 year intervals. Requires additional construction material types for superstructure. Superstructure requires continuous ventilation and seasonal heating.

CRITERIA	RANKING INFORMATION
	Alternative 2 – CMF: Ten percent media addition is recommended after 10 years. Requires additional construction materials for larger structure footprint. Ranking: 5 = least environmental impact 1 = largest environmental impact
Safety	**Alternative 1 – Disc:** Safety considerations are similar between alternatives. Equipment is controlled automatically by the manufacturer provided PLC and requires minimal operator intervention. Equipment bays are open for visual inspection and protected by guardrail. Primary activities regarding staff safety are associated with disc media replacement, which is performed outside of the filter bay.
	Alternative 2 – CMF: Safety considerations are similar between alternatives. Primary activities regarding staff safety are associated with CMF media addition. This activity is performed from above the filter cell. Ranking: 5 = no safety risk 1 = large safety risk
Ease of Regulatory Acceptance	**Alternative 1 – Disc:** Has a larger installation base, including two installations in the State of Kansas.
	Alternative 2 – CMF: Has a smaller installation base with no installations in the State of Kansas. Approval by the KDHE is anticipated and the manufacturer has engaged KDHE staff regarding potential acceptance. Ranking: 5 = highest regulatory acceptance 1 = least regulatory acceptance

4.5 CRITERIA WEIGHTING AND SCORING

Table 4-9 is a summary of the weighted scores for each alternative.

Table 4-9 Stand Alone Tertiary Filtration Triple Bottom Line Scoring

CRITERIA	CRITERIA PERCENTAGE	RELATIVE WEIGHT	ALTERNATIVE 1 DISC		ALTERNATIVE 2 CMF	
			Ranking	Weighted Score	Ranking	Weighted Score
Flexibility / Performance Reliability / Turndown	20	2	3	6	2	4
Phasing	10	1	2	2	2	2
Land Requirements / Layout	20	2	4	8	2	4
Social Impacts	15	1.5	2	3	3	4.5
Environmental Impacts	15	1.5	3	4.5	4	6
Safety	10	1	3	3	4	4
Ease of Regulatory Acceptance	10	1	4	4	3	3
	100%	10		30.5		27.5

Note:
Rankings: 5 = Most Important or most positive impact. 1 = Least Important or most negative impact.

4.5.1 Cost/Benefit Scoring

Table 4-10 contains the NPV to the normalized benefit ratio. The sum total of the social and environmental weighted scores can be converted to the normalized benefit score based upon the highest scoring alternative. The benefit scores for each alternative are then divided into the respective NPV to express the benefit score in economic terms.

Table 4-10 Stand Alone Tertiary Filtration NPV to Normalized Benefit Ratio Comparison

CRITERIA	ALTERNATIVE 1 DISC	ALTERNATIVE 2 CMF
	WEIGHTED SCORE	WEIGHTED SCORE
Flexibility / Performance Reliability / Turndown	6	4
Phasing	2	2
Land Requirements / Layout	8	4
Social Impacts	3	4.5
Environmental Impacts	4.5	6
Safety	3	4
Ease of Regulatory Acceptance	4	3
Total Weighted Score	30.5	27.5
Normalized Benefit Score	1	0.90
NPV Cost	$14,038,000	$19,550,000
NPV / Normalized Benefit Ratio	$14,038,000	$21,722,000

4.5.2 Recommended Alternative

Alternative 1 Disc Filters has the lowest NPV and the lowest NPV/Normalized Benefit Ratio and is the recommended standalone filtration alternative

5 Auxiliary Treatment

5.1 PRELIMINARY ALTERNATIVE SCREENING

The preliminary alternatives considered for separate auxiliary treatment of peak wet-weather flows were as follows:

1A. Solids Contact/Sludge Recirculation High-Rate Clarification using the DensaDeg® system.

1B. Microsand Ballasted Flocculation using the ACTIFLO® system.

1C. Magnetite Ballasted Flocculation using CoMag®.

2A. Compressible Media Filtration (CMF).

2B. Pile Cloth Media Disk Filters.

Table 5-1 provides the summary description and characteristics used to compare the five options. As depicted in the table, the two options selected for further development and evaluation as stand-alone auxiliary treatment facilities were Options 1B and 2A, microsand ballasted flocculation (hereinafter referred to as ACTIFLO®) and CMF respectively. As discussed during workshop for the selection of the options, wet-weather treatment technologies have been the subject of ongoing regulatory debates. The ACTIFLO® technology has been operating in the City of Lawrence with excellent results for over a decade, and its NPDES permit was recently renewed. The CMF technology was piloted at JCW's Nelson Complex in 2008 with similarly excellent results and full-scale facilities elsewhere are also demonstrating excellent results in both wet-weather and tertiary applications.

Figure 5-1 Side-by-side Piloting of Parkson DynaDisc Pile Cloth Media Filter and WWETCO Compressible Media Filter

Table 5-1 Auxiliary Treatment Alternatives Matrix

REMOVED FROM FURTHER CONSIDERATION								
Alt	**Types**	**Description**	**Footprint**	**TSS Removal**	**Preliminary Screening**	**Preliminary Grit Removal**	**Effluent Disinfection**	**Typical Manufactuers**
1A	Solids Recirculation HRC	Chemically enhanced settling with lamella settlers. Recirculation of thickened sludge to enhance flocculation and floc density.	Small	High	Bar, ½" spacing	Optional (sludge handling)	Coagulant choice may impact UV	Infilco Degremont, WesTech
1B	Microsand Ballasted Flocculation	Chemically enhanced settling with lamella settlers. Microsand ballast to increase floc density.	Smallest	High	Perforated plate, ¼" opening	Optional (event frequency, sludge handling)	Coagulant choice may impact UV	Kruger, WesTech
1C	Magnetite Ballasted Flocculation	Chemically enhanced settling. Magnetite powder to increase floc density.	Smallest	High	Bar, ½" spacing	Optional (sludge handling)	Coagulant choice may impact UV	Evoqua
2A	Compressible Media Filter	Depth filter with 30" deep bed comprised of synthetic fiber balls one to two inches in diameter.	Small	High	Bar, ½" spacing	Optional (sludge handling)	Similar to secondary effluent	Westech (WWETCO), Schreiber
2B	Pile Cloth Media Filter	Surface filter consisting of segmented disks covered with pile cloth media.	Small	High	Bar, ½" spacing	Optional (sludge handling)	Similar to secondary effluent	Aqua Aerobic

Option 2B was not selected for further evaluation due to the lack of operating full-scale facilities for direct filtration of wet weather flows. Furthermore, the side-by-side piloting, illustrated in the above photo, indicated that the effluent TSS concentration from pile cloth media was also slightly higher and more influenced by influent loading rates than the CMF alternative. However, the Parkson DynaDisc filter that was tested at the Nelson Complex used a different pile cloth media than is currently being recommended by AquaAerobic Systems for wet weather flow applications. Option 1A was ruled out because of the greater amount of time required for startup of the system and its slightly larger footprint requirements.

Lastly, Option 1C (CoMag®) was not selected for evaluation as a stand-alone auxiliary treatment option due to its lack of operating reference facilities. In this application, however, its use in a dual-purpose application for both primary treatment and peak wet-weather flow treatment is being further evaluated and will be discussed in a separate TM.

5.2 ALTERNATIVE DEVELOPMENT

Criteria for the sizing and design of the two alternatives were developed based on the design flows and loads for the plant and the proposed secondary treatment alternatives being considered. This information was provided to the vendor for each system and proposals for equipment sizing and cost were requested. From the information provided; preliminary layouts, hydraulic impacts, and ancillary facility requirements were developed for each alternative.

5.2.1 Design Criteria

The overall flow and load design criteria to be applied to each of the high rate systems providing auxiliary treatment is indicated in Table 5-2. While the final peak flow capacity of the auxiliary treatment may vary depending on the secondary treatment system implemented, the evaluation and selection of the preferred auxiliary treatment alternative is based on the flow required for the IFAS alternative. During alternative selection workshops held with representatives at JCW, it was determined that a minimum of 3 trains would be required in order to provide a similar level of turndown and redundancy from the different axillary treatment alternatives.

Table 5-2 Auxiliary Treatment Flow and Load Criteria

CRITERIA	VALUE
Total Peak Flow Capacity	115 MGD
Influent TSS at Peak Flow	50 mg/l
Effluent TSS Concentration (Event Average)	<30 mg/l
Minimum Number of Trains	3
Minimum Startup Flow per Train	5 MGD

It is expected that the influent TSS concentration will vary from higher concentrations at the initial flows to a lower concentration at higher flows.

For the high rate auxiliary treatment systems, as the plant influent flow reaches the design capacity of the secondary treatment system and any excess flow storage capacity is filled, the excess flow

will be diverted prior to primary settling and conveyed to the auxiliary treatment facility. Using a presumed excess flow storage capacity of 4 million gallons, it is expected that flow will be diverted to the auxiliary treatment facility an average of two or three times per year for a total of 60 hours per year on average. The average yearly volume of flow anticipated to be treated by the facility will be 73 million gallons.

Alternative 1 is based on three trains of microsand ballasted flocculation utilizing Kruger's ACTIFLO® process. The specific design criteria utilized in sizing the system is provided in Table 5-3.

Table 5-3 Alternative 1 Flow and Load Criteria

CRITERIA	VALUE
Number of Trains	3
Peak Flow Capacity per Train	38.3 MGD
Peak Hydraulic Loading Rate (HLR)	<60 gpm/ft^2
Waste Sludge Flow at Max Loading	3,816 gpm
Waste Sludge Solids Concentration	0.03-0.4 % TS
Chemical Dosages	
Coagulant (Ferric)	40 – 50 mg/l
Polymer	0.75 – 1.0 mg/l
Microsand	2.0 – 3.0 mg/l

In addition, because experience has shown that microsand ballasted flocculation systems can experience foaming in the downstream processes, facilities for feeding a defoaming agent to the ACTIFLO® effluent is included.

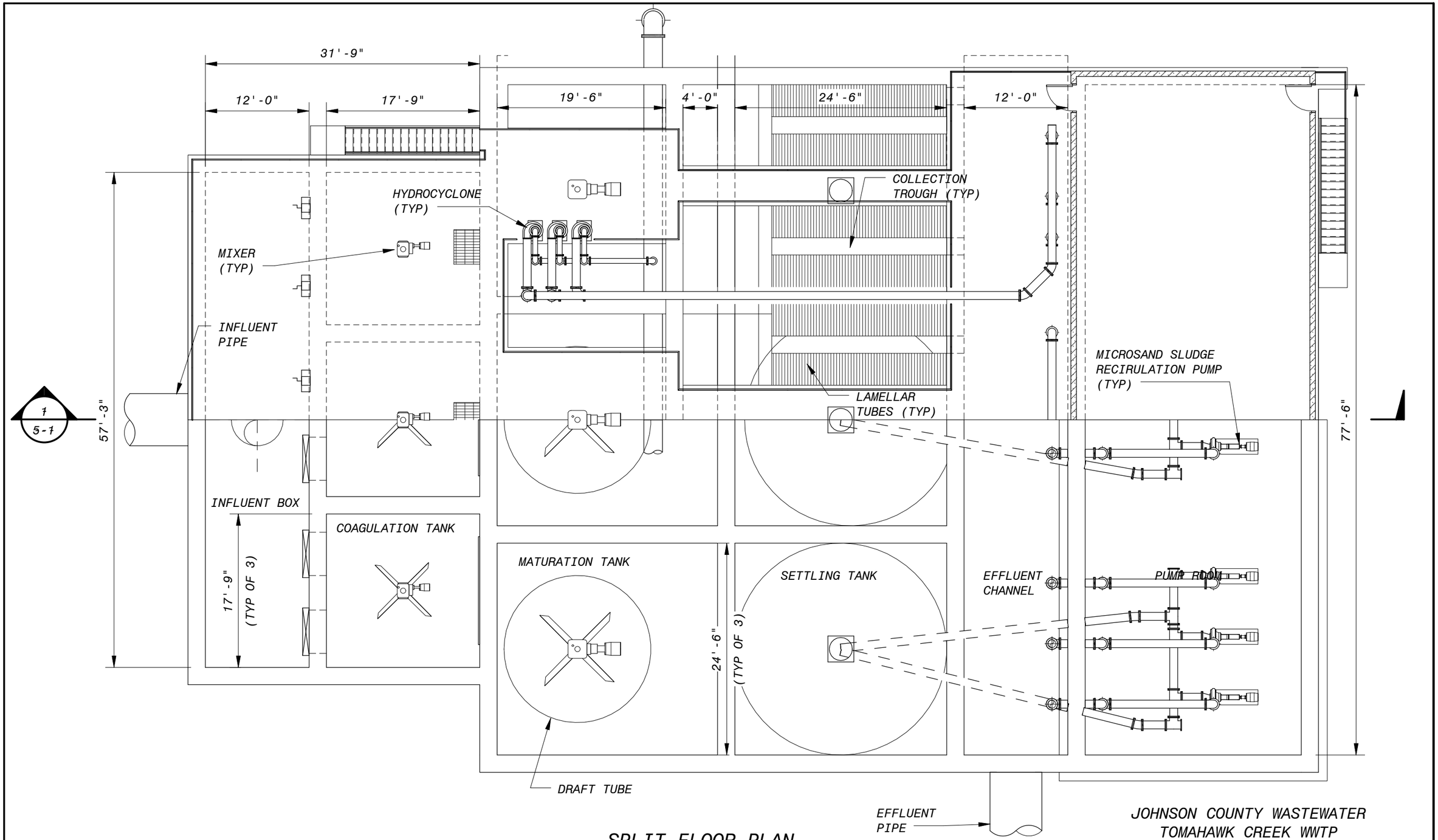
Alternative 2 is based on providing multiple compressible media filter cells. The filter cells are Wes Tech/WWETCO's FlexFilter. The system consists of eleven filter cells (trains), each containing four filter strips. During peak loading, it is anticipated that nine of the filter cells will be in filtration mode and two will be in backwash mode. The specific design criteria utilized in sizing the system is provided in Table 5-4.

Table 5-4 Alternative 2 Flow and Load Criteria

CRITERIA	VALUE
Number of Trains	11 (9 duty + 2 backwash)
Peak Flow Capacity per Train	12.8 MGD
Peak Hydraulic Loading Rate	13.0 gpm/ft^2
Backwash Flow at Max Loading	3600 gpm
Waste Sludge Solids Concentration	0.1-0.2 % TS
Chemical Dosages	
Coagulant (Ferric)	n/a
Polymer	n/a

5.2.2 Alternative 1 ACTIFLO® - Layout, Footprint, and Hydraulic Considerations

ACTIFLO® facilities corresponding to the design criteria would consist of three parallel 38.3 MGD trains with influent and effluent channels and connected pumping, electrical, and sand storage areas. The expected footprint for this structure will be approximately 127' X 78'. The basins will be approximately 25' in depth below the operating floor with approximately 20' of the structure located above grade due to the anticipated hydraulic conditions at the Tomahawk Facility. The tanks will be cast in place concrete and will be open to the atmosphere. The top of the basins will have suspended concrete slabs and grating to provide access walkways and support for suspended equipment. An enclosed area constructed of masonry would be provided above the sand recirculation pump room to house the electrical and control equipment. A plan layout of the facility is shown in Figure 5-2 and a section of the facility is show in Figure 5-3.



SPLIT FLOOR PLAN

3/32" = 1'-0"

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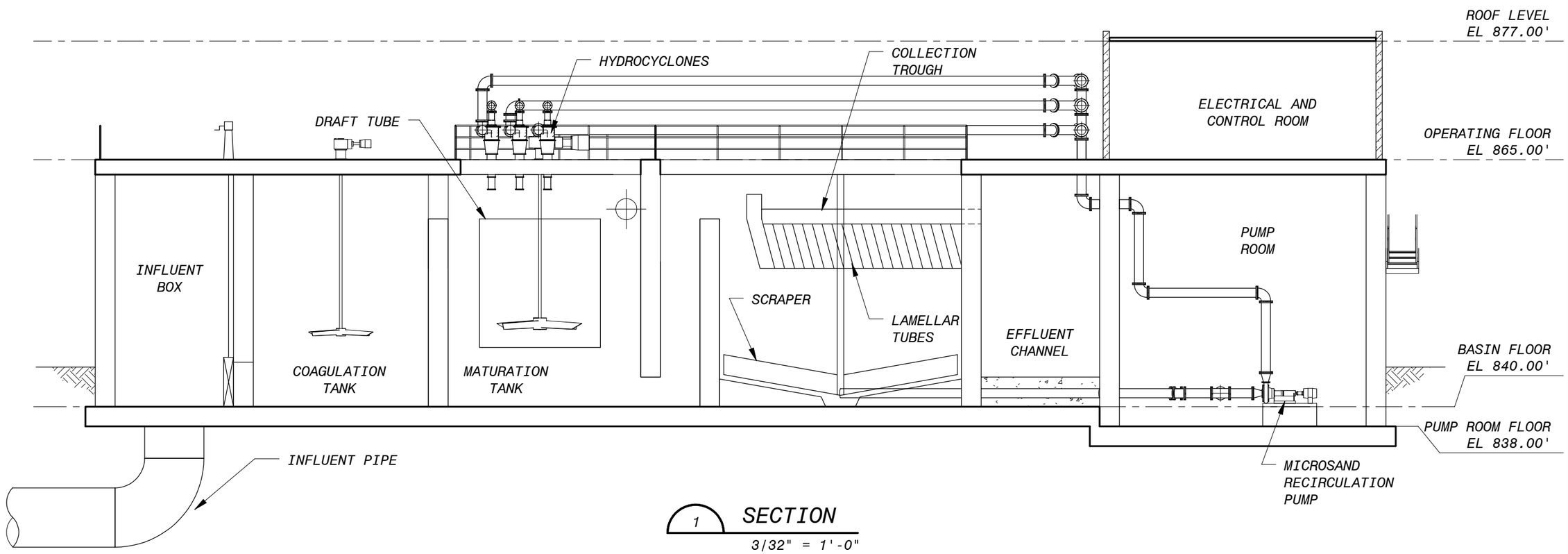
AUXILIARY TREATMENT
ALTERNATIVE 1 - ACTIFLO FACILITY
FIGURE 5-2



1 SECTION

3/32" = 1'-0"

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AUXILIARY TREATMENT
ALTERNATIVE 1 - ACTIFLO FACILITY
FIGURE 5-3

Table 5-5 presents the preliminary process dimensions and equipment sizing for this alternative.

Table 5-5 Alternative 1 - ACTIFLO® Equipment Criteria

EQUIPMENT CRITERIA	VALUE
Number of Trains	3
Coagulation Tank (1 per train)	
Length	17 ft. – 9 in
Width	17 ft. – 9 in
Maturation Tank (1 per train)	
Length	19 ft – 6 in
Width	24 ft – 6 in
Settling Tank (1 per train)	
Length	24 ft – 6 in
Width	24 ft – 6 in
Sand Recirculation Pumps (each train)	3(2 duty + 1 standby)
Capacity (each)	795 gpm
Number of Hydrocyclones per Pump	1
Total Connected Horsepower (Firm)	504 HP
Approximate Structure Size	78 ft. X 128 ft.
Footprint	12,900 ft^2
Ferric Storage and Feed Equipment	
Type of Storage	Tank
Number of Tanks	1
Capacity	11,000 gallons
Number of Metering Pumps	4(3 duty + 1 standby)
Capacity (each)	150 gph
Polymer Storage and Feed Equipment	
Type of Storage	Tote
Number of Totes	3(2 duty + 1 standby)
Number of Feeder Blenders	4(3 duty + 1 standby)
Defoamer Storage and Feed Equipment	
Type of Storage	Tote
Number of Totes	3(2 duty + 1 standby)
Number of Metering Pums Capacity (end)	3(2 duty + 1 standby)

In addition to the basin structure itself, separate buildings will be required to house chemical storage and feed equipment and for microsand storage. The buildings will be slab on grade structures with masonry superstructure.

The chemical building will be approximately 60' X 55 ' (3,300 sf) in size. The building will house the coagulant (Ferric) storage and feed; the polymer storage and feed; and the defoamer storage and feed. The coagulant system will consist of one 11,000 gallon Ferric storage tank in a deep containment area and four feed pumps (one for each basin and a spare) adjacent to the deep containment. For the polymer system, it is assumed that it will be an emulsion polymer system, with neat polymer delivered and stored in totes. The system will consist of three polymer totes (two duty and one standby) tied to a common header and four (three duty and one standby) feeder blenders drawing from the header. The defoamer system will be comprised of three totes (two duty and one standby) tied together with a common header and three (two duty and one standby) metering pumps drawing from the header.

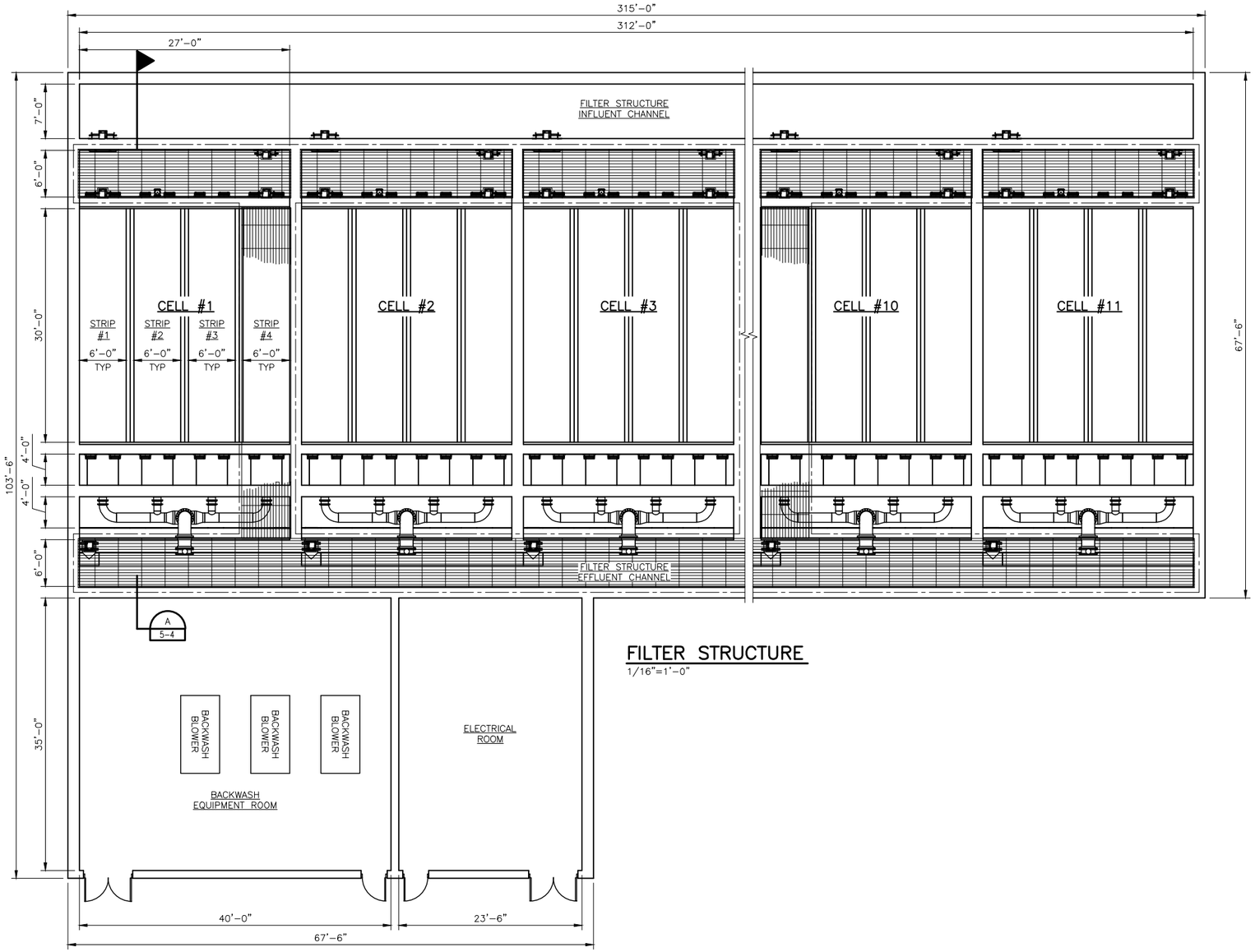
The microsand storage building will be approximately 20' X 15' (300 sf) in size. The building will sit directly adjacent to the upstream end of the ACTIFLO® basins and will be used for protecting and storing pallets of 80 pound bags of microsand.

Expected headloss through the ACTIFLO® basin is minor. Allowing for one foot of differential between the effluent weir and the upstream water surface is conservative, assuming a free discharge from the settling basin effluent troughs results in a total difference of approximately three feet between the water surface in the influent flume and the water surface downstream of the basin. This headloss, coupled with assumed losses for the yard piping feeding the basin, results in an approximate water surface elevation well below the preliminary treatment facility discharge water surface required by the primary and secondary processes. No additional pumping head is required for the ACTIFLO® basins.

Grit removal is not required prior to treatment in the ACTIFLO® basins. Fine screening of the influent is, however, required prior to entering the ACTIFLO® basin. In order to protect the hydrocyclones, which are a critical part of treatment using microsand ballast, perforated plate screens with maximum ¼ inch openings are recommended by Kruger Inc., the system supplier.

5.2.3 Alternative 2 CMF - Layout, Footprint, and Hydraulic Considerations

The CMF filter system consisting of eleven cells (trains), capable of 12.78 MGD each will be constructed in a common wall arrangement with common influent and effluent channels. The blowers and associated electrical equipment will be housed in an adjoining structure. The expected footprint for the filter structure will be approximately 353' X 67'. The depth of the filter basins will be approximately 16' in depth below the operating floor. With almost the entire structure located above the existing grade due to the anticipated hydraulic conditions at the Tomahawk Facility, site fill will be required around the structure. The tanks will be cast in place concrete and will be open to the atmosphere. The top of the basins will have suspended grating to provide access walkways for operational access and monitoring. A plan layout of the facility is shown in Figure 5-4 and a section of the facility is shown in Figure 5-5.



FILTER STRUCTURE
1/16"=1'-0"

NOTE:

1. ASSUMES BACKWASH FLOWS DRAIN BY GRAVITY TO INFLUENT PUMP STATION.

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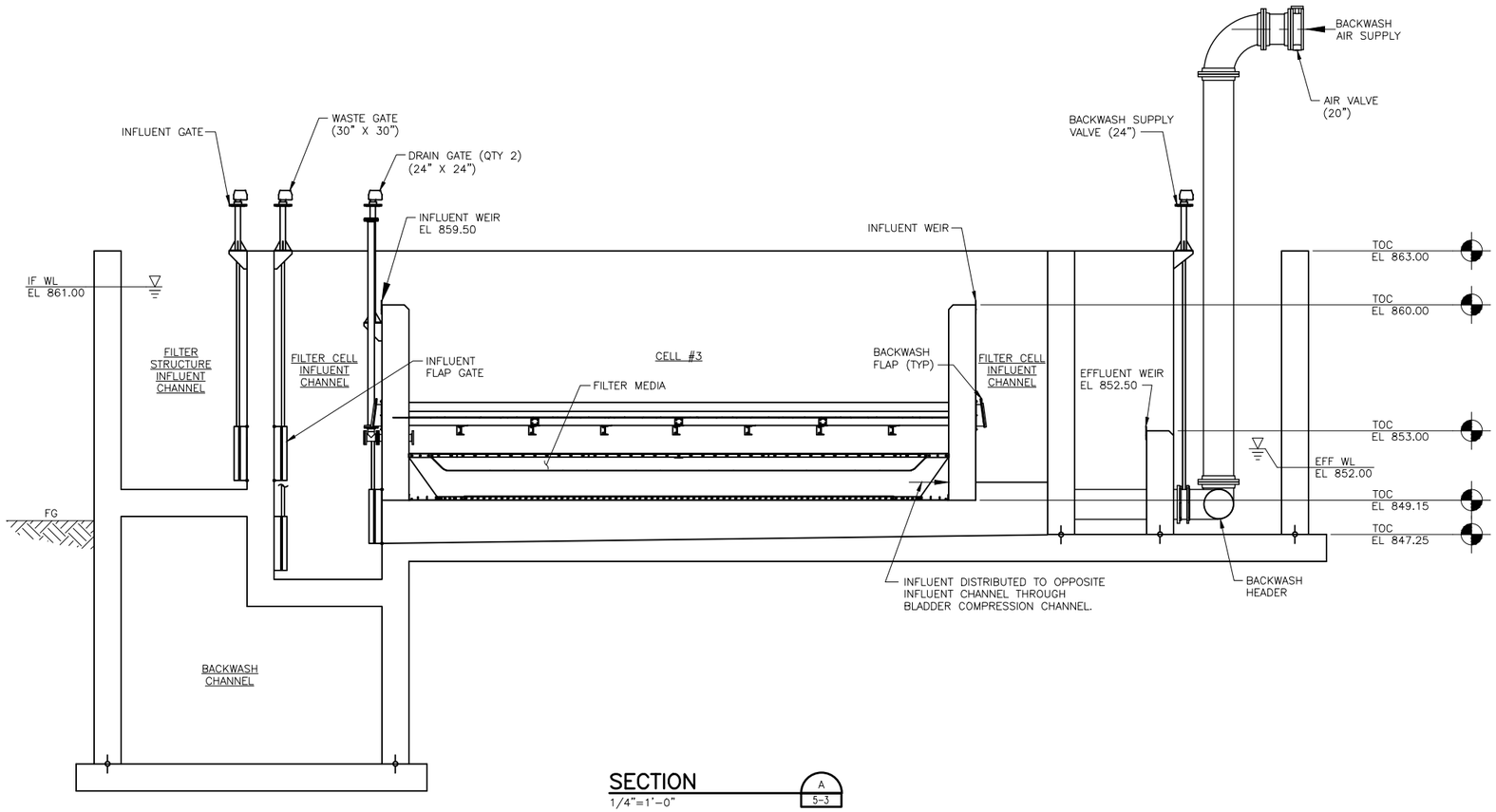
AUXILIARY TREATMENT
ALTERNATIVE 2 - (CMF)
FIGURE 5-4

BFIGBORD
FBFIGBORD

NOTE:

1. ASSUMES BACKWASH FLOWS DRAIN BY GRAVITY TO INFLUENT PUMP STATION.



SECTION A 5-3
1/4"=1'-0"

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AUXILIARY TREATMENT
ALTERNATIVE 2 - (CMF)
FIGURE 5-5

BFIGBORD
FBFIGBORD

Table 5-6 presents the preliminary process dimensions and equipment sizing for this alternative.

Table 5-6 Alternative 2 - CMF Equipment Criteria

EQUIPMENT CRITERIA	VALUE
Number of Cells	11 (9 duty + 2 backwash)
Nominal Dimensions of Each Cell	
Length	30 ft
Width	27 ft
Number of Strip Filters per Cell	4
Nominal Dimensions each Strip Filter	
Length	30 ft
Width	6 ft
Filtration Area per Strip Filter	180 sf
Total Filtration Area	7,920 sf
Total Firm Filtration Area	6,480 sf
Depth of Filter Media	30 in
Backwash Air Scour Blowers	
Number of Blowers	3 (2 duty + 1 standby)
Capacity (each)	7,200 scfm
Motor Horsepower (each)	250 HP
HLR at 115 MGD	12.3 gpm/ft^2 [1]
SLR at 115 MGD & 50 mg/l	7.4 lbs/ft^2/day [2]
System Headloss (from Upstream to Downstream WL's)	7.4 ft
Actuated Gates/Valves per Filter Cell	5
Approximate Structure Size	353 ft. X 67 ft.
Footprint	23,650 ft^2 [3]
Backwash Rate (two filters in backwash)	7,200 gpm

Notes:
[1] Manufacturer limits max rate to 20.0 gpm/ ft^2
[2] Within Manufacturer's design SLR.
[3] Includes blower and electrical building.

The backwash blowers and the electrical and control equipment will be housed in an enclosed building adjacent to the filter structure. The building will be a slab on grade structure with masonry superstructure approximately 65' X 35' (2,275 sf) in size. The building will be split into two separate areas with one being the electrical and control area and the other the blower area.

The backwash air supply manifold will run overhead from the blower building across the width of the filters to supply air to each filter cell.

The hydraulic headloss through the CMF filters is determined by the influent and effluent weir elevations necessary to support the differential pressure setpoint for initiation of backwash. The anticipated headloss through the CMF filters is approximately 8 feet from the effluent weir to the influent channel water surface. Using this headloss, along with assumed miscellaneous inlet chamber losses and losses for the yard piping feeding the basin, results in an approximate water surface elevation just over six inches below the preliminary treatment facility discharge water surface required by the primary and secondary processes. No additional pumping head is required for the CMF filters.

Similar to Alternative 1, grit removal is not required prior to the CMF filter. The screening requirements, however, are not as stringent. WWETCO only requires that the influent pass through coarse (3/4 inch – 1 inch) screening prior to the CMF filters.

5.3 COST ANALYSIS

Preliminary capital costs were developed for the two auxiliary treatment alternatives utilizing conceptual costing methods.

Buildings costs, including HVAC and plumbing were estimated based on per square foot cost derived from historical data and escalated to current value. Costs for excavation, concrete, and metals were developed using quantities derived from the conceptual layouts and unit cost values. The expected cost for deep foundations was developed based on providing a similar foundation to that implemented on existing buildings on site and applied on a per square foot basis. Equipment costs were based on vendor quotes and installation of that equipment was projected at 25 percent of the equipment cost. Process piping and valves, as well as other miscellaneous non-building items were estimated based on cost data from similar previous projects, escalated to current cost and multiplied by a ratio based on the difference in the number of installed trains.

Because fine screens are required for ACTIFLO® and not for CMF, an additional capital cost associated with providing additional screening for 115+MGD is included in the costs for Alternative 1.

5.3.1 Capital Cost

The estimated capital cost for Auxiliary Treatment Alternatives 1 and 2 is presented in Table 5-7.

Table 5-7 Auxiliary Treatment Capital Cost

	CAPITAL COST ($)
Alternative 1 – ACTIFLO®	$32,606,000
Alternative 2 – CMF	$48,236,000

See **Appendix C** for supporting cost estimate details.

5.3.2 Incremental O&M Cost

Expected costs for both the period when the facility is operating and for preventative maintenance during periods of inactivity were developed for each alternative. The costs for operation included the cost for power, chemicals, and for labor required to start, operate, monitor, and shut down the facility. The costs included for maintenance included the cost for replacement of microsand/media lost during operation or through deterioration over time, and for labor and materials used in performing regular maintenance on the facility. Any costs associated with the time the facilities sit idle is considered to be equal for both alternatives and is, therefore, not included in the evaluation.

Table 5-8 outlines the auxiliary treatment assumptions and unit prices used for calculation of the operating costs.

Table 5-8 Auxiliary Treatment Operating Data and Unit Cost

PARAMETER	VALUE
Number of Events per Yyear	3
Average Duration of Event	20 hours
Total Volume Treated	73 MG
Power	$0.08 /KW-Hr
Hourly Labor Cost (with benefits)	$26.33 / Hr
Ferric Chloride (40% bulk)	$1.31 / gal
Polymer	$2.01 / lb
Defoamer	$3.60 / gal
Microsand	$8.30 / 80# bag

The resulting yearly operating cost for each alternative is presented in Table 5-9.

Table 5-9 Yearly Operating Cost

O&M COSTS	ALTERNATIVE 1 ACTIFLO®	ALTERNATIVE 2 CMF
Chemicals	$41,000	$0
Power	$600	$1,300
Operation Labor	$1000	$200
Maintenance	$3,700	$22,600
Total	**$46,300**	**$24,100**

5.3.3 Net Present Value

The NPV for each alternative is presented in Table 5-10. The detailed life cycle cost analysis is included in **Appendix C**.

Table 5-10 Capital, O&M, and NPV Cost Opinion

DESCRIPTION	CAPITAL COST	ANNUAL O&M COST	TOTAL NET PRESENT VALUE
Alternative 1 - ACTIFLO®	$32,606,000	$46,300	$29,109,000
Alternative 2 – CMF	$48,236,000	$24,100	$42,761,000

5.4 TRIPLE BOTTOM LINE ANALYSIS

Table 5-11 expands upon the information provided in Table 2-4 and provides alternative specific descriptions of the criteria items. In addition, information defining the scale to be used in ranking the criteria during the subsequent scoring activity is listed.

Table 5-11 Auxiliary Treatment Ranking Information

CRITERIA	RANKING INFORMATION
Flexibility / Performance Reliability/ Turndown	**Alternative 1: ACTIFLO®** Once started and operating the process has less operational complexity as it is constant run, no start and stop of basins. Most complex item is the chemical feed and assuring correct dosage. Process is flexible to adjust to varying flows within bounds of each train, at increments will require that additional basins be turned on. Does not have infinite turndown, requires minimum flow of approximately 3 to 5 MGD at startup.
	Alternative 2: CMF Startup and run are automatic through control system, but involve greater operational complexity as backwash cycles require opening and closing of multiple valves, requires starting and stopping of blowers. Capable of infinite flow variation. . Ranking: 5 = highest flexibility/reliability 1 = least flexibility/reliability
Phasing	**Alternative 1: ACTIFLO®** This alternative has minimal phasing impacts. Expandable in future but in larger interval.
	Alternative 2: CMF This alternative has minimal phasing impacts. This alternative layout can expand in smaller increments the future if necessary. Ranking: 5 = no phasing impact 1 = large phasing impact

CRITERIA	RANKING INFORMATION
Land Requirements / Layout	**Alternative 1: ACTIFLO®** Process area is more compact, but requires larger support buildings for chemical storage. Allows more flexibility in location of support buildings. Overall approximately the same total square feet of structure.
	Alternative 2: CMF Filter area is greater than alternative, but with smaller sq. ft. requirements for support facilities the overall structure are is similar. Less flexibility with location of blower building. Ranking: 5 = small footprint 1 = large footprint
Social Impacts	**Alternative 1: ACTIFLO®** More offsite traffic due to delivery of chemicals. Structure will be mostly above grade due to hydraulics. Process area will be approximately 10' above grade, with electrical room another 15' higher. Chemical building will be 15' – 20' high to accommodate bulk storage tank for Ferric. Minimal noise of operation.
	Alternative 2: CMF Structure will be mostly above grade due to hydraulics. Process area will be approximately 14' above grade. Blower building will be similar height. Blowers will generate noise, but it will be mitigated in building. Minimal noise due to backwash air scour in filters. Ranking: 5 = least off-site impact 1 = largest off-site impact
Environmental Impacts	**Alternative 1: ACTIFLO®** Environmental impacts are minimal due to infrequency with which the basins will be run. This alternative does have greater carbon footprint as total power usage will be slightly larger and chemical usage will require manufacture and delivery of chemicals.
	Alternative 2: CMF Environmental impacts are minimal due to infrequency with which the basins will be run. No chemical usage just power usage for blowers during backwash. 5 = no off-site impact 1 = large off-site impact

CRITERIA	RANKING INFORMATION
Safety	**Alternative 1: ACTIFLO®** Little safety risk associated with operation, similar to other tankage and pumping systems on site. Chemicals used are not hazardous, but do carry normal risks that are greater than non-chemical alternatives.
	Alternative 2: CMF Little safety risk, similar to other tankage and blower systems on site. Greatest risk is during media replacement, this will require staff to utilize standard safety procedures to mitigate risk. Ranking: 5 = no safety risk 1 = large safety risk
Ease of Regulatory Acceptance	**Alternative 1: ACTIFLO®** Has been permitted in Kansas for similar purpose before.
	Alternative 2: CMF No installations have been permitted in Kansas for this use previously. Approval is anticipated by KDHE. Ranking: 5 = highest regulatory acceptance 1 = least regulatory acceptance

5.4.1 Criteria Weighting and Scoring

During alternative selection workshops held with representatives of JCW, weighting factors were assigned to each criteria and a ranking was assigned for each alternative based on the defined scale. Table 5-12 is a summary of the resulting weighted scores for each alternative.

Table 5-12 Auxiliary Treatment Triple Bottom Line Scoring

CRITERIA	CRITERIA PERCENTAGE	RELATIVE WEIGHT	ALTERNATIVE 1 ACTIFLO®		ALTERNATIVE 2 CMF	
			Ranking	Weighted Score	Ranking	Weighted Score
Flexibility / Performance Reliability / Turndown	20	2	4	8	5	10
Phasing	10	1	3	3	3	3
Land Requirements / Layout	20	2	3	8	3	6
Social Impacts	10	1	3	3	4	4
Environmental Impacts	15	1.5	3	4.5	4	6
Safety	10	1	3	3	4	4
Ease of Regulatory Acceptance	20	2	3	6	2	4
	105%	10.5		33.5		37

Note:
Rankings: 5 = Most Important or most positive impact. 1 = Least Important or most negative impact.

5.4.2 Cost/Benefit Scoring

Following the calculation of the total weighted score for each alternative, scores were normalized by dividing each by the larger of the two weighted scores. Using the resulting normalized ratio, a normalized NPV, taking into account social and environmental factors, for each alternative was calculated for final comparison and selection of the favored alternative. Table 5-13 contains the resulting NPV to normalized benefit ratio value for each alternative.

Table 5-13 Auxiliary Treatment NPV to Normalized Benefit Ratio Comparison

CRITERIA	ALTERNATIVE 1 ACTIFLO®	ALTERNATIVE 2 CMF
	Weighted Score	Weighted Score
Flexibility / Performance Reliability / Turndown	8	10
Phasing	3	3
Land Requirements / Layout	8	6
Social Impacts	3	4
Environmental Impacts	4.5	6
Safety	3	4
Ease of Regulatory Acceptance	6	4
Total Weighted Score	35.5	37
Normalized Benefit Score	0.96	1
NPV Cost	$29,109,000	$42,761,000
NPV / Normalized Benefit Ratio	$31,987,912	$42,761,000

5.4.3 Recommended Alternative

Alternative 1 – Microsand Ballasted Flocculation using the ACTIFLO® system has the lowest NPV and the lowest NPV/Normalized Benefit Ratio and is the recommended separate high rate auxiliary treatment system for the wet weather flows.

6 Dual Purpose Treatment

6.1 PRELIMINARY ALTERNATIVE SCREENING

As an alternative to providing facilities solely dedicated to treatment of wet weather flows (stand-alone auxiliary), options were identified where facilities could serve a dual purpose where they are regularly used to provide one level of treatment during normal design flows and then to provide a different, or additional, level of treatment during periods of wet weather flows. The preliminary alternatives considered for dual-purpose applications were as follows:

1. Compressed Media Filtration (CMF)
2. Microsand Ballasted Flocculation using the ACTIFLO® system
3. Magnetite Ballasted Flocculation using CoMag®
4. Pile Cloth Media Disk Filter

Table 6-1 provides a matrix summary of the characteristics for each of the options. As indicated in the table, the two options selected for further development and evaluation as dual purpose treatment facilities were Options 1 and 3, CMF and CoMag® respectively. As mentioned previously in this TM, the CMF technology was recently piloted at JCW's Nelson Complex with excellent results in both wet-weather and tertiary applications and full-scale facilities are also demonstrating excellent results in both wet-weather and tertiary applications with direct filtration. CoMag® currently has 14 full scale installations in the US (9 in operation and 5 under construction), however, none of these entail primary sedimentation of raw wastewater, which is the application considered in this TM.

Option 2 was not selected for further evaluation due to the need for tertiary filtration of dry weather plant flows going to UV disinfection. Option 4 was ruled out because of the lack of operating full-scale facilities in wet-weather flow applications.

Reviewing the various secondary treatment options and the tertiary filtration and auxiliary treatment alternatives associated with each, it is noted that for only one process (IFAS) is there the option to have either dual purpose CMF or CoMag®. For that option, however, due to the difference in where each process is located in the order of treatment, the required design flow is significantly different for the two processes, as is the type of treatment being accomplished. While CMF is evaluated in this TM as a tertiary treatment application, CoMag® is evaluated in TM 6 in a preliminary treatment application. Considering these factors, it was decided to proceed as follows:

- In this TM 4, dual purpose CMF will be evaluated against the conventional systems that it would replace. This evaluation will look at the dual purpose CMF system versus a combination of the selected standalone tertiary filtration and auxiliary treatment alternatives.

- The selected alternative from this comparison will then be compared to dual purpose CoMag® in TM6.

Table 6-1 Dual Purpose Treatment Alternatives Matrix

REMOVED FROM FURTHER CONSIDERATION								
Alt	**Types**	**Description**	**Footprint**	**TSS Removal**	**Preliminary Screening**	**Preliminary Grit Removal**	**Effluent Disinfection**	**Typical Manufactuers**
1	Compressible Media Filter	Depth filter with 30" deep bed comprised of synthetic fiber balls one to two inches in diameter.	Small	High	Bar, ½" spacing	Optional (sludge handling)	Similar to secondary effluent	Westech (WWETCO), Schreiber
2	Microsand Ballasted Flocculation	Chemically enhanced settling with lamella settlers. Microsand ballast to increase floc density.	Smallest	High	Perforated plate, ¼" opening	Optional (event frequency, sludge handling)	Coagulant choice may impact UV	Kruger, WesTech
3	Magnetite Ballasted Flocculation	Chemically enhanced settling. Magnetite powder to increase floc density.	Smallest	High	Bar, ½" spacing	Optional (sludge handling)	Coagulant choice may impact UV	Evoqua
4	Pile Cloth Media Filter	Surface filter consisting of segmented disks covered with pile cloth media.	Small	High	Bar, ½" spacing	Optional (sludge handling)	Similar to secondary effluent	Aqua Aerobic

6.2 ALTERNATIVE DEVELOPMENT

Criteria for the sizing and design of the alternatives were developed based on the design flows and loads for the plant and the proposed sizing required for secondary treatment using IFAS. This information was provided to vendors and proposals for equipment sizing and cost were requested. From the information provided; preliminary layouts, hydraulic impacts, and ancillary facility requirements were developed for each alternative.

6.2.1 Design Criteria

The overall flow and load design criteria to be applied to the dual use CMF system is as indicated in Table 6-2. Because the filter will be required to function under two different treatment scenarios (dry weather and wet weather), separate design criteria are provided for each scenario and the system will be designed to meet the most restrictive criteria.

Table 6-2 Dual Purpose CMF System Flow and Load Criteria

CRITERIA	VALUE
Dry Weather	
Flow	57 MGD
Influent TSS	20 mg/l
Effluent TSS	<10 mg/l
Wet Weather	
Total Peak Flow Capacity	115 MGD
Influent TSS at Peak Flow	50 mg/l
Effluent TSS Concentration (Event Average)	<30 mg/l
Maximum Hydraulic Loading Rate (HLR)	13 gpm/ft^2
Maximum Solids Loading Rate (SLR)	27.6 lb/ft^2/day

During periods of wet weather flow, it is expected that the influent TSS concentration will vary from higher concentrations at the initial flows to a lower concentration at higher flows.

As the plant influent flow reaches the design capacity of the secondary treatment system and any excess flow storage capacity is filled, the excess flow will be split prior to primary settling and conveyed directly to the dual purpose filter or the auxiliary treatment facility. Using a presumed excess flow storage capacity of 4 million gallons, it is expected that flow will be split to the auxiliary treatment facility two to three times per year for a total of 60 hours per year on average. The average yearly volume of flow anticipated to be treated by the facility will be 73 million gallons.

Alternative 1 will be the dual purpose CMF option. The units provided will be based on providing multiple compressible media filter cells. The filter cells will be WesTech/WWETCO's FlexFilter. The system will consist of eleven filter cells (trains), each containing four filter strips. During peak loading, it is anticipated that nine of the filter cells will be in filtration mode and two will be in backwash mode. The specific design criteria utilized in sizing the system is provided in Table 6-3.

Table 6-3 Alternative 1 Flow and Load Criteria

CRITERIA	VALUE
Number of Trains	11 (9 duty + 2 backwash)
Peak Flow Capacity per Train	12.8MGD
Peak Wet Weather Hydraulic Loading Rate	12.3 gpm/ft^2
Dry Weather Hydraulic Loading Rate [1]	6.1 gpm/ft^2
Backwash Flow at Max Loading [2]	7,200 gpm
Waste Sludge Solids Concentration	0.1-0.2 % TS

Notes:
[1] All duty cells in service.
[2] For two filters in backwash.

Alternative 2 will be based on providing separate stand-alone tertiary filters and high rate auxiliary treatment of the type selected in the previous chapters.

The tertiary filtration will be based on three duty (one standby) trains of synthetic media disc filter units. A summary of the flow and load criteria used for sizing the disc filters is provided in Table 6-4.

Table 6-4 Alternate 2 - Tertiary Disc Filter Flow and Load Criteria

CRITERIA	VALUE
Number of Trains	4 (3 firm + 1 standby)
Peak Flow Capacity per Train	19 MGD
Peak Hydraulic Loading Rate	<5.0 gpm/ft^2
Solids Loading Rate (SLR)	1.2 lb/ft^2/day

The auxiliary treatment will be based on three trains of microsand ballasted flocculation utilizing Kruger's ACTIFLO® process. A summary of the specific design criteria utilized in sizing the system is provided in Table 6-5.

Table 6-5 ACTIFLO® Basin Flow and Load Criteria

CRITERIA	VALUE
Number of Trains	3
Peak Flow Capacity per Train	38.3 MGD
Peak Hydraulic Loading Rate	<60 gpm/ft^2
Waste Sludge Flow at Max Loading	3,816 gpm
Waste Sludge Solids Concentration	0.03-0.4 % TS
Chemical Dosages	
Coagulant (Ferric)	40 – 50 mg/l
Polymer	0.75 – 1.0 mg/l
Microsand	2.0 – 3.0 mg/l

6.2.2 Alternative 1 CMF - Layout, Footprint, and Hydraulic Considerations

The dual purpose CMF filter system consisting of eleven cells (trains), capable of 12.8 MGD each would be constructed in a common wall arrangement with common influent and effluent channels. The blowers and associated electrical equipment will be housed in an adjoining structure. The expected footprint for the filter structure will be approximately 353' X 67'. The depth of the filter basins will be approximately 16' in depth below the operating floor with almost the entire structure located above the existing grade, requiring site fill around the structure due to the anticipated hydraulic conditions at the Tomahawk Facility. The tanks will be cast in place concrete and will be open to the atmosphere. The top of the basins will have suspended grating to provide access walkways for operational access and monitoring. A plan layout of the facility is shown in Figure 6-1 and a section of the facility is show in Figure 6-2.

Table 6-6 presents the preliminary process dimensions and equipment sizing for this alternative.

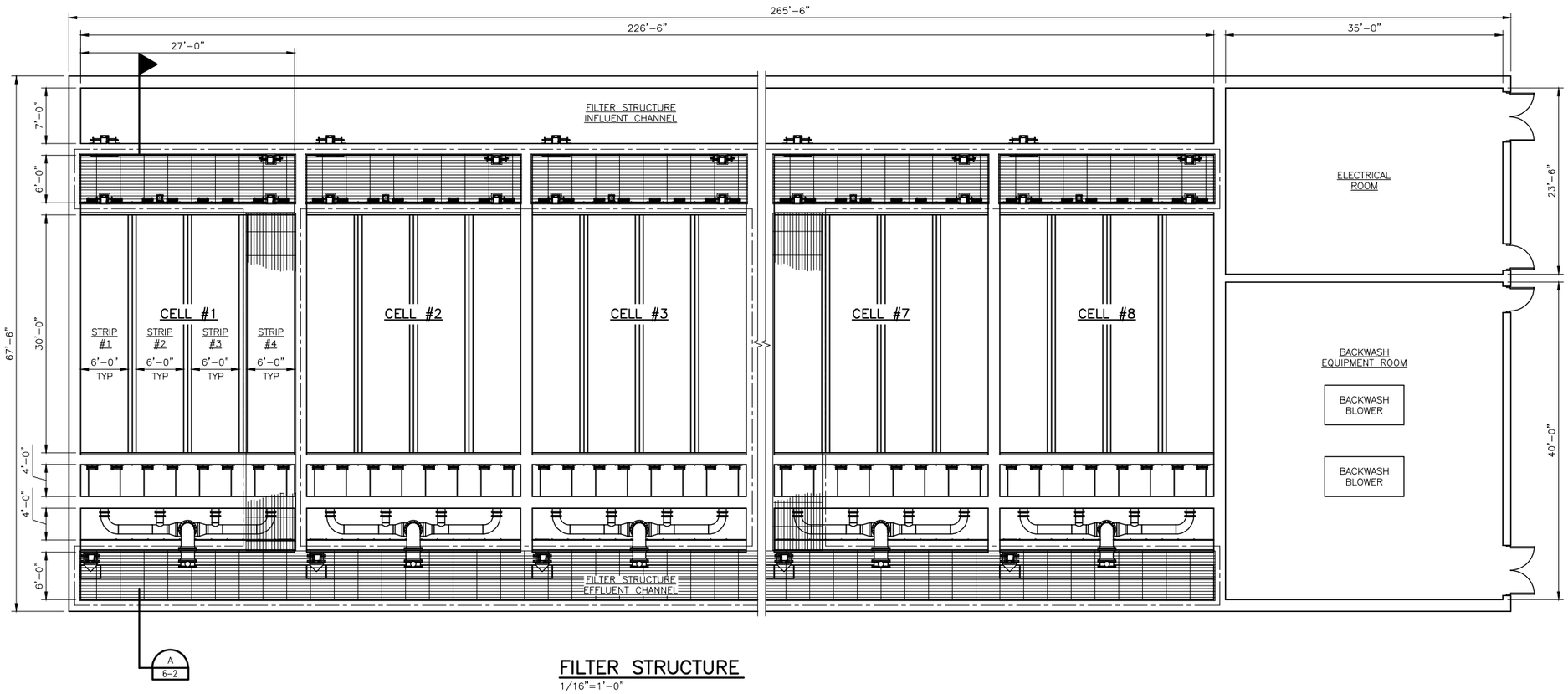
Table 6-6 Alternative 1 - Preliminary Process Dimensions and Equipment Sizing

EQUIPMENT CRITERIA	VALUE
Number of Cells	11 (9 duty + 2 backwash)
Nominal Dimensions of Each Cell	
Length	30 ft
Width	27 ft
Number of Strip Filters per Cell	4
Nominal Dimensions each Strip Filter	
Length	30 ft
Width	6 ft
Filtration Area per Strip Filter	180 sf
Total Filtration Area	7,920 sf
Total Firm Filtration Aera	6,480 sf
Depth of Filter Media	30 in
Backwash Air Scour Blowers	
Number of Blowers	3 (2 duty + 1 standby)
Capacity (each)	7,200 scfm
Motor Horsepower (each)	250 HP
HLR at 57 MGD	6.1 gpm/ft^2 [1]
SLR at 57 MGD & 20 mg/l	1.5 lbs/ft^2/day [2]
HLR at 115 MGD	12.3 gpm/ft^2 [1]
SLR at 115 MGD & 50 mg/l	7.4 lbs/ft^2/day [2]
System Headloss (from Upstream to Downstream WL's)	7.4 ft
Actuated Gates/Valves per Filter Cell	5
Approximate Structure Size	353 ft. X 67 ft.
Footprint	23,650 ft^2 [3]
Backwash Rate	7,200 gpm

Notes:
[1] Manufacturer limits max rate to 20.0 gpm/ ft^2
[2] Within Manufacturer's design SLR.
[3] Includes blower and electrical building.

NOTE:

1. ASSUMES BACKWASH FLOWS DRAIN BY GRAVITY TO INFLUENT PUMP STATION.



FILTER STRUCTURE

1/16"=1'-0"

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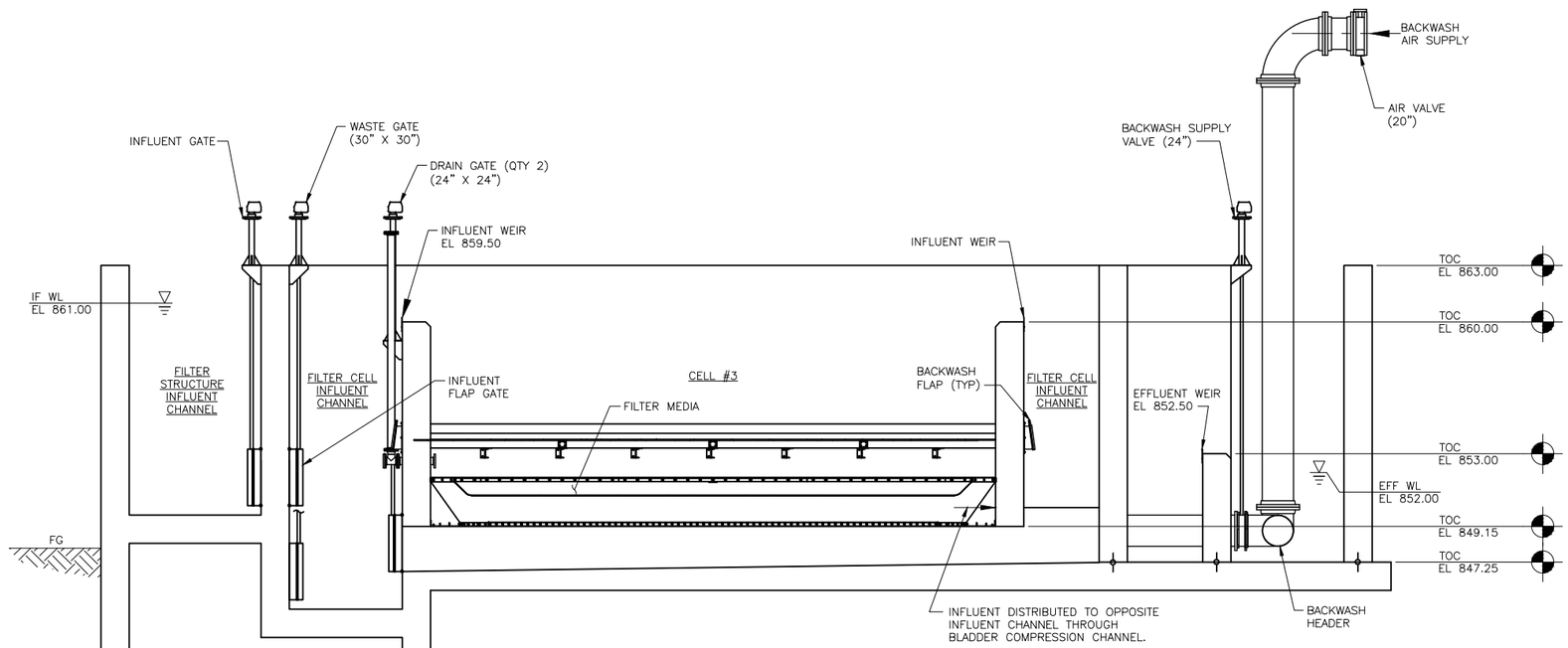
DUAL PURPOSE FILTRATION
ALTERNATIVE 1 - (CMF)
FIGURE 6-1

BFIGBORD
FBFIGBORD

NOTE:

1. ASSUMES BACKWASH FLOWS DRAIN BY GRAVITY TO INFLUENT PUMP STATION.



SECTION A 6-1
1/4"=1'-0"

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TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE

DUAL PURPOSE FILTRATION
ALTERNATIVE 1 - (CMF)
FIGURE 6-2

BFIGBORD
FBFIGBORD

The backwash blowers and the electrical and control equipment will be housed in an enclosed building adjacent to the filter structure. The building will be a slab on grade structure with masonry superstructure approximately 65' X 35' (2,275 sf) in size. The building will be split into two separate areas with one being the electrical and control area and the other the blower area. The backwash air supply manifold will run overhead from the blower building across the width of the filters to supply air to each filter cell.

The dual purpose filter will be located in the treatment process in the same position as a stand-alone tertiary filter facility and will operate primarily in that function. During periods of wet weather, when influent flows exceed the design capacity of the secondary treatment process (57 MGD), the additional wet weather flow will be split directly to the CMF facility for enhanced high rate treatment prior to discharge. During periods when the total flow to the plant exceeds the secondary treatment capacity, but is less than the full capacity of the CMF facility, the entire flow will be filtered. As the total flow exceeds the capacity of the CMF facility, a corresponding amount of secondary clarifier effluent will be split around the CMF facility, directly to disinfection. To facilitate operation as a dual purpose facility, the influent lines (secondary treatment effluent and auxiliary flow) to the dual purpose CMF filter will be on opposite ends of the influent channel and a modulating weir installed adjacent to the secondary treatment effluent line. Additional yard piping and flow metering will be required for dual purpose operation. Figure 6-3 schematically shows the arrangement necessary for dual purpose operation.

As discussed previously, when used for filtering wet weather flows, grit removal and fine screening is not required prior to the CMF filter. It will be assumed that no additional screening or grit facilities will be provided for influent flows above 57 MGD.

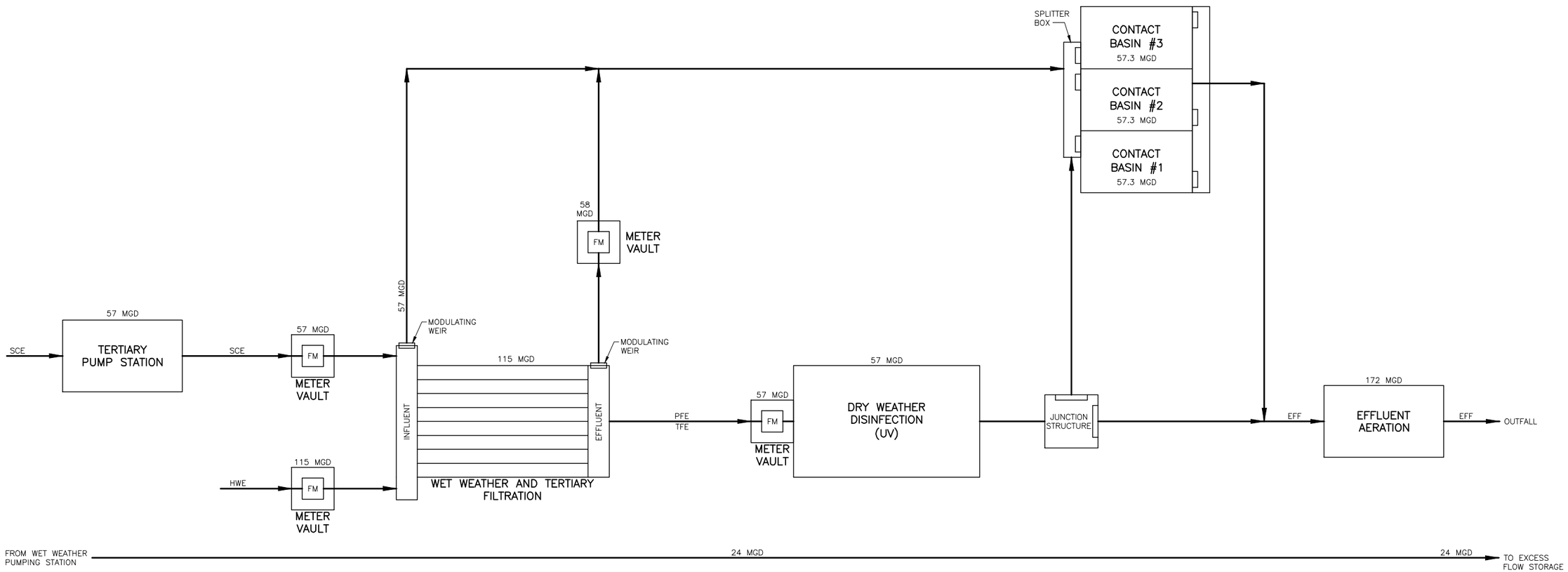
The hydraulic headloss through the CMF filters is determined by the influent and effluent weir elevations necessary to support the differential pressure setpoint for initiation of backwash. The anticipated headloss through the CMF filters is approximately 8 feet from the effluent weir to the influent channel water surface. This is approximately 3.5 feet greater than the headloss through the disk filters, thus additional tertiary pumping head will be required for the CMF filters.

Similarly, the required head, along with assumed miscellaneous inlet chamber losses and losses for the yard piping feeding the basin, when added to the downstream water elevation necessary to pass through the disinfection, results in an approximate water surface elevation at the preliminary treatment facility discharge weir that is approximately 3 feet-4 inches higher than that preliminarily required by the primary and secondary processes. It is assumed that by diverting wet weather flows ahead of fine screening and grit removal, no additional pumping head will be required for wet weather flows.

KEY NOTES:

ABBREVIATIONS:

AV	AUTOMATED VALVE
EFF	EFFLUENT
FM	FLOW METER
HWE	HEADWORKS EFFLUENT
JB	JUNCTION BOX
MV	MODULATING VALVE
PCE	PRIMARY CLARIFIER EFFLUENT
PFE	PRIMARY FILTERED EFFLUENT
SCE	SECONDARY CLARIFIER EFFLUENT
TFE	TERTIARY FILTER EFFLUENT



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DUAL PURPOSE FILTRATION
PROCESS SCHEMATIC
FIGURE 6-3

BFIGBORD
FBFIGBORD

6.2.3 Alternative 2 Disc Filters and ACTIFLO® - Layout, Footprint, and Hydraulic Considerations

A conventional system of separate tertiary filtration and auxiliary flow facilities would be made up of the selected alternatives from the previous chapters on stand-alone tertiary filtration and auxiliary treatment. Tertiary filtration will consist of four trains (3 duty) of disc filter bays, each containing 22 discs per bay. Auxiliary treatment will consist of three parallel 38.3 MGD ACTIFLO® trains.

Descriptions of these facilities can be found in Sections 4.2 and 6.2 of this document.

6.3 COST ANALYSIS

Preliminary capital costs were developed for the two alternatives utilizing conceptual costing methods.

Buildings costs, including HVAC and plumbing were estimated based on per square foot cost derived from historical data and escalated to current value. Costs for excavation, concrete, and metals were developed using quantities derived from the conceptual layouts and unit cost values. The expected cost for deep foundations was developed based on providing a similar foundation to that implemented on existing buildings on site and applied on a per square foot basis. Equipment costs were based on vendor quotes and installation of that equipment was projected at 25 percent of the equipment cost. Process piping and valves, as well as other miscellaneous non-building items were estimated based on cost data from similar previous projects, escalated to current cost and multiplied by a ratio based on the difference in the number of installed trains.

The capital cost for Alternative 2 – Separate Facilities is a sum of the capital costs calculated for the stand alone ACTIFLO® basins and disc filters in the previous chapters.

6.3.1 Capital Cost

The estimated capital cost for Dual Purpose Filtration Alternatives 1 and 2 is presented in Table 6-7.

Table 6-7 Dual Purpose Capital Cost

	CAPITAL COST ($)
Alternative 1 – Dual Purpose CMF	$50,740,000
Alternative 2 – Separate Facilities	$47,616,000

See **Appendix D** for supporting cost estimate details.

6.3.2 Incremental O&M Cost

Expected costs for both the period when the facility is operating and for preventative maintenance during periods of inactivity were developed for each alternative. The costs for operation included the cost for power, chemicals, and for labor required to start, operate, monitor, and shut down the facility. The costs included for maintenance included the cost for replacement of filter discs, for replacement of microsand/media lost during operation or through deterioration over time, and for

labor and materials used in performing regular maintenance on the facility. The costs for operation of the CMF filters include the power cost for the additional tertiary pumping head.

Table 6-8 outlines the wet weather flow assumptions and unit prices used for calculation of the operating costs.

The operating cost for Alternative 2 – Separate Facilities is a sum of the costs calculated for the stand alone ACTIFLO® basins and disc filters in the previous chapters.

Table 6-8 Operating Data and Unit Cost

PARAMETER	VALUE
Number of Events per Year	3
Average Duration of Event	20 hours
Total Volume of Stormwater Treated	73 MG
Power	$0.08 /KW-Hr
Hourly Labor Cost (with benefits)	$26.33 / Hr
Ferric Chloride (40% bulk)	$1.31 / gal
Polymer	$2.01 / lb
Defoamer	$3.60 / gal
Microsand	$8.30 / 80# bag

The resulting yearly operating cost for each alternative is presented in Table 6-9.

Table 6-9 Yearly Operating Cost

O&M COSTS	ALTERNATIVE 1 DUAL PURPOSE CMF	ALTERNATIVE 2 SEPARATE FACILITIES
Chemicals	$0	$41,100
Power	$22,500	$9,600
Operation Labor	$5,600	$6,500
Maintenance	$22,600	$51,700
Total	**$50,700**	**$108,900**

6.3.3 Net Present Value

The NPV for each alternative is presented in Table 6-10. The detailed life cycle cost analysis is included in Appendix D.

Table 6-10 Capital, O&M, and NPV Cost Opinion

DESCRIPTION	CAPITAL COST	ANNUAL O&M COST	TOTAL NET PRESENT VALUE
Alternative 1 - Dual purpose filters	$50,740,000	$50,700	$45,097,000
Alternative 2 – Separate facilities	$47,616,000	$108,900	$43,235,000

6.4 TRIPLE BOTTOM LINE ANALYSIS

Table 6-11 expands upon the criteria provided in Table 2-2 and provides alternative specific descriptions of the criteria items. In addition, information defining the scale to be used in ranking the criteria during the subsequent scoring activity is listed.

Table 6-11 Dual Purpose Filtration Ranking Information

CRITERIA	RANKING INFORMATION
Flexibility / Performance Reliability/ Turndown	**Alternative 1: Dual Purpose CMF** Continuously run process, no separate start for wet weather flow. All effluent flow up to 115 MGD is filtered. Run is automatic and through control system. Operational complexity is greater than disk filter and ACTIFLO when evaluated separately. Offers greatest flexibility and range for turndown
	Alternative 2: Separate Facilities Requires separate start for wet weather flows. Less turndown capability for start of wet weather flows, requires minimum flow of approximately 3 to 5 MGD at startup. Once started operationally less complex as separate start and stop for backwash is not required. Ranking: 5 = highest flexibility/reliability 1 = least flexibility/reliability
Phasing	**Alternative 1: Dual Purpose CMF** This alternative has minimal phasing impacts. Expandable in future in similar increments for filtration, smaller increments for auxiliary treatment.
	Alternative 2: Separate Facilities Potential for limited phasing by allowing tertiary filtration to be constructed at different time than auxiliary treatment. Expandable in the future, smaller footprint for similar flow expansion for filtration. Ranking: 5 = no phasing impact 1 = large phasing impact
Land Requirements / Layout	**Alternative 1: Dual Purpose CMF** Smaller overall footprint due to single process. All facilities located contiguous, not separate locations on site. Requires less drives and access area.

CRITERIA	RANKING INFORMATION
	Alternative 2: Separate Facilities Process footprint is similar, but additional support buildings require more area. More flexibility on location. Ranking: 5 = small footprint 1 = large footprint
Social Impacts	**Alternative 1: Dual Purpose CMF** Structure will be above grade due to hydraulics, may require fill for installation. Process area will be approximately 14 ft. above grade. Blower building will be similar height. Blowers will generate noise, but it will be mitigated in building. Minimal noise due to backwash air scour in filters.
	Alternative 2: Separate Facilities More offsite traffic due to delivery of chemicals for auxiliary treatment. Structure will be above grade due to hydraulics. Disk filters are lower profile than CMF. Auxiliary treatment process area will be approximately 10 ft. above grade, with electrical room another 15 ft. higher. Chemical building will be 15 – 20 ft. high to accommodate bulk storage tank for Ferric. Minimal noise of operation. Ranking: 5 = least off-site impact 1 = largest off-site impact
Environmental Impacts	**Alternative 1: Dual Purpose CMF** Environmental impacts of filtration are greater due to more power usage during backwash. Less power usage during wet weather treatment. No chemical usage. Potential for even larger power usage due to increased influent pump head requirements.
	Alternative 2: Separate Facilities This alternative does have greater carbon footprint for auxiliary treatment as total power usage will be slightly larger and chemical usage will require manufacture and delivery of chemicals, however this is minimized due to infrequency of auxiliary operation and the reduced power usage during dry weather treatment. 5 = no off-site impact 1 = large off-site impact
Safety	**Alternative 1: Dual Purpose CMF** Little safety risk, similar to other tankage and blower systems on site. Greatest risk is during media replacement, this will require staff to utilize standard safety procedures to mitigate risk.

CRITERIA	RANKING INFORMATION
	Alternative 2: Separate Facilities Little safety risk associated with operation, similar to other tankage and pumping systems on site. Chemicals used in auxiliary treatment are not hazardous, but do carry risks that are greater than non-chemical alternatives. Ranking: 5 = no safety risk 1 = large safety risk
Ease of Regulatory Acceptance	**Alternative 1: Dual Purpose CMF** Fewer installations for use as tertiary filters. Permitted installations are operating in Georgia and Ohio; however, no installations have yet been permitted in Kansas for auxiliary treatment. Furthermore, the dual-use approach with secondary effluent intermittently discharged without tertiary filtration during wet-weather flow events is unique. Approval is anticipated by KDHE.
	Alternative 2: Separate Facilities Many filter installations and approved technology. ACTIFLO® has been permitted in Kansas for auxiliary treatment before. Ranking: 5 = highest regulatory acceptance 1 = least regulatory acceptance

6.4.1 Criteria Weighting and Scoring

Table 6-12 Dual Purpose Filtration Triple Bottom Line Scoring

CRITERIA	CRITERIA PERCENTAGE	RELATIVE WEIGHT	ALTERNATIVE 1 DUAL PURPOSE CMF		ALTERNATIVE 2 SEPARATE FACILITIES	
			Ranking	Weighted Score	Ranking	Weighted Score
Flexibility / Performance Reliability / Turndown	20	2	5	10	4	8
Phasing	10	1	3	3	3	3
Land Requirements / Layout	20	2	4	8	3	6
Social Impacts	10	1	4	4	3	3
Environmental Impacts	15	1.5	4	6	3	4.5
Safety	10	1	4	4	3	3
Ease of Regulatory Acceptance	20	2	3	6	4	8
	105%	10.5		41		35.5

Note:
Rankings: 5 = Most Important or most positive impact. 1 = Least Important or most negative impact.

6.4.2 Cost/Benefit Scoring

Table 6-13 Dual Purpose Filtration NPV to Normalized Benefit Ratio Comparison

CRITERIA	ALTERNATIVE 1 CMF	ALTERNATIVE 2 SEPARATE FACILITIES
	WEIGHTED SCORE	WEIGHTED SCORE
Flexibility / Performance Reliability / Turndown	10	8
Phasing	3	3
Land Requirements / Layout	8	6
Social Impacts	4	3
Environmental Impacts	6	4.5
Safety	4	3
Ease of Regulatory Acceptance	6	8
Total Weighted Score	41	35.5
Normalized Benefit Score	1.0	0.87
NPV Cost	$45,097,000	$43,235,000
NPV / Normalized Benefit Ratio	$45,097,000	$49,695,402

6.4.3 Recommended Alternative

Based on the results of the triple bottom line analysis, which included both economic and non-economic criteria, as well as discussions in the Workshops, Alternative 1 – Dual Purpose Compressed Media Filters is the recommended alternative for providing both tertiary filtration of the dry weather flows and high rate auxiliary treatment of wet weather flows.

7 Disinfection

7.1 PRELIMINARY ALTERNATIVE SCREENING

Preliminary alternatives screened for disinfection of flows from secondary treatment consisted of gaseous chlorine, bulk purchase and on-site generation sodium hypochlorite (hypochlorite), ferrate, peracetic acid, ozonation, UV, and a multi-barrier system which includes UV followed by hypochlorite. The preliminary alternative screening matrix from the workshop held on February 17, 2015 is included in Table 1.

When evaluating disinfection alternatives to carry forward, the following regulatory considerations should be taken into consideration:

- The Environmental Protection Agency (EPA) is considering new effluent limits for viruses. Studies performed by EPA in the 2008 – 2010 timeframe show viruses, not bacteria are the predominant drivers related to exposures causing illness. EPA anticipates issuing testing protocols for bacteriophage in the 2015 – 2016 timeframe before issuing a draft implementation plan for peer review and public comment, and ultimately including it in NPDES permits. The addition of virus removal criteria to future NPDES permits will impact the selection and sizing of the disinfection system.

- WWTF's utilizing chlorine disinfection are continuing to see more stringent chlorine residual requirements, with effluent concentration requirements as low as 1 µg/l or less. This low of a residual requirement must be effectively managed through effluent decholrination facilities. In addition to chlorine residual, stringent limits for disinfection byproducts such as trihalomethanes (THM's) and N-Nitrosodimethylamine (NDMA's) have begun to be included in NDPES permits in states such as California, Florida, Washington and Oregon. While disinfection byproducts are an important consideration, recent discussions with KDHE have determined that they are not currently being considered by the State of Kansas and KDHE does not believe the EPA will set criteria in the foreseeable future.

In summary, effluent virus criteria are likely to come into effect within the design life of the improvements presented in this TM and will impact the selection and sizing of the disinfection system. The preliminary alternatives screening matrix provided a preliminary determination of each alternative's virus removal capability. It was determined in this workshop that only alternatives viewed as being capable of virus removal would be carried forward for further consideration. This includes technologies that are currently capable or are able to be readily upgraded to meet this requirement. The following is the result of the decisions made at the preliminary alternative screening workshop:

Alternatives carried forward:

- Alternative 1 – Multi-Barrier: This alternative utilizes both UV disinfection and bulk purchase liquid hypochlorite injection with associated chemical feed/storage facility and contact basin. This alternative was carried forward for the following reasons:

  - Offers the ability to phase operations based upon effluent disinfection requirements.
  - Combines the use of two well established technologies.
  - Will not require the use of hazardous chemicals on a day in and day out basis.

- Alternative 2 – Ozonation: This alternative provides a strong oxidant and virucide that is capable of meeting a future effluent virus criteria as a single barrier disinfectant.
- Alternative 3 – Hypochlorite Only: This alternative consists of utilizing hypochlorite as the sole disinfectant. This alternative reduces the number of unit processes required to accommodate dry and wet weather disinfection.

Alternatives Eliminated:

- Gaseous Chlorine and Sodium Hypochlorite on-site generation: These alternatives were eliminated from further consideration due to the following reasons.
  - Gaseous chlorine was eliminated from further consideration due to the safety hazards associated with gaseous systems as compared to liquid systems.
  - On-site generation was eliminated due to the increased equipment complexity, requirements for an adequate salt supply to meet generation requirements and larger demand that would be required during wet weather disinfection.
- Ferrate and Peracetic Acid: These alternatives were eliminated from further consideration because they have not been shown to be effective for virus removal.
- UV: This alternative as the sole disinfection method was eliminated from further consideration because of its considerably excessive equipment requirements if having to meet a future effluent virus criteria.

All three retained alternatives will be considered for disinfection of dry weather flows. For the disinfection of wet weather flows, a single alternative consisting of bulk purchase hypochlorite followed by sodium bisulfite (bisulfite) dechlorination was selected for further development. Hypochlorite disinfection of wet weather flows will be included in the alternative analysis for all three referenced dry weather alternatives. The multi-barrier approach considered under Alternative 1 will use a portion of the wet weather disinfection facility for flows above a certain set point in the future under a virus removal criteria. Alternative 2 is considered to be capable of meeting this future requirement without the need for a second barrier disinfectant such as hypochlorite and will therefore reduce the sizing of the wet weather disinfection facility under this alternative. Alternative 3 is also considered to be capable of meeting this future requirement without the need for a second barrier disinfectant. These aspects will be taken into account when evaluating NPV costs and TBL considerations in later sections of this TM. The relationship between the disinfection of flows from secondary treatment and those associated with wet weather are also discussed further in Section 7.2.

TABLE 7-1 DISINFECTION ALTERNATIVE SCREENING MATRIX

Alternative Carried Forward

Types	Description	Footprint	Capable of Virus Removal	Capital Cost	O&M Cost	Safety	Dechlorination Required	Availability	Sensitivity to Upstream Effluent Quality	Suitable for Auxiliary (Wet Weather) Treatment	Installation History	Typical Manufacturers
Gaseous Chlorine	Utilize gaseous chlorine for disinfection . Requires sufficient contact time, typically minimum of 15 minutes.	Large	Yes	Medium	Medium	Highest Risk	Yes. Typically use gaseous sulfur dioxide.	TBD	Low	Yes	Large, Common	-
Hypochlorite (Bulk Purchase)	Utilize liquid sodium hypochlorite for disinfection. Requires sufficient contact time, typically minimum of 15 minutes. Typical hypochlorite concentration = 12.5%	Large	Yes	Low to Medium	Medium to High, Chemical Cost Increasing	High Risk	Yes. Typically use sodium bisulfite, concentration 25% or 38%.	High	Low	Yes	Large, Common	-
Hypochlorite (On-site Generation)	Generate liquid sodium hypochlorite for disinfection by converting sodium chloride to sodium hypochlorite and hydrogen gas. Lower concentrations of hypochlorite requires less complex equipment. Requires high quality salt, softened water, significant power consumption.	Large	Yes	High	Medium	High Risk	Yes. Typically use bulk purchased sodium bisulfite, concentration 25% or 38%.	Salt supply can be an issue	Low	Capacity generation could be an issue for wet weather, shelf life of 0.8% solution is up to 6 months	Small, Limited	Electrolytic Technologies Corp (Klorigen System) provides 12.5% generation system; multiple suppliers provide 0.8% generation system
Ferrate (On-site Generation)	Fe(VI), liquid form that must be generated on-site due to short shelf life, less than 6 hours. Quick reacting, degrades to ferric oxide. Has a high redox potential making it a strong oxidant. Provides disinfection and coagulation. Requires use of hazard chemicals such as concentrated bleach (hypochlorite) and caustic.		Unknown	High	High	High Risk	No	Sole source issues for generation equipment, chemical availability	Low	Capacity generation could be an issue for wet weather	None	Ferrate Treatment Technologies
Peracetic Acid	Mixture of acetic acid and hydrogen peroxide in water. Clear, colorless liquid with pungent vinegar odor. Degrades quickly in environment (CO_2, O_2, water) and no known byproducts. Facility requirements similar to Hypochlorite including storage, injection pumps, mixing and contact time. May adds BOD to effluent and potential concern for BOD violation.	Large	Insignificant	Medium	High (e.g. chemical cost)	High Risk	No	Low	Yes	Yes, long shelf life (6-12 months)	1 full scale installation (St. Augustine, FL), primarily used in Europe for last 20 years	PeroxyChem (FMC); Solvay
Ozonation	Strong oxidant and virucide. Created by disassociating oxygen atoms by a high voltage current. Unstable gaseous ozone is created, must be used shortly after generation. Ozone decomposition in water creates hydrogen peroxide and hydroxyl radicals. Requires generation (air or pure oxygen) and transfer equipment, but contact time is less than chlorine (10 to 15 min). Forms bromate byproduct. Adds DO to effluent.	Medium to Large	Yes, more effective than chlorine and UV	High	High	High Risk	No	Generated on-site, equipment manufacturers are few	Yes	Capacity generation could be an issue for wet weather	Small, Limited	Ozonia; Wedeco; Praxair; etc.
UV LPHO (Low dose)	Inactivates organisms through denaturing DNA, dose is measured as product of intensity and exposure time. Dose should be verified through collimated beam and/or pilot testing.	Small to Medium	limited at low dose	High	Low to Medium	Low (UV light exposure, mercury from broken lamps)	No	High	Yes	No, requires equipment oversizing and impacted by water quality (TSS, organics)	Large, Common	Trojan, Wedeco, Ozonia
UV MPHO (Low dose)	Same as above, use of medium pressure lamps results in relatively smaller footprint and higher lamp temperatures. Most often installed in an enclosed reactor.	Small to Medium	limited at low dose	High	High	Low (mercury from broken lamps)	No	High	Yes	No, requires equipment oversizing and impacted by water quality, debris (TSS, organics)	Small, limited	Trojan, Aquionics
Multi-Barrier Example UV LPHO (low dose) and Hypochlorite (Bulk Purchase)	Option utilizes a combination of two disinfection processes noted above. Provides the most flexibility with respect to meeting anticipated virus criteria.	Large	Yes	High, potential for phasing, synergy option with wet weather disinfection	Medium to High	High Risk	Yes when chlorinating	High	No	Yes	Large of each technology, similar to Drinking Water LT2 standards	-

7.2 ALTERNATIVE DEVELOPMENT

The three dry weather disinfection alternatives presented in this TM each assume a peak treatment capacity of 57 MGD of filtered flow.

Alternative 1 will consist of UV followed by hypochlorite, Alternative 2 will consist of Ozone disinfection, and Alternative 3 will consist of bulk purchase hypochlorite. There are two alternatives being considered in this TM for the treatment of wet weather flows, these impact how flows are directed to disinfection and what level of treatment is achieved prior to disinfection. These two alternatives consist of ACTIFLO® and Dual Purpose filtration and are discussed further in Sections 5 and 6 of this TM. Figure 7-1 through Figure 7-6 depict the interrelationship between each wet weather treatment alternative and the associated disinfection alternatives evaluated. These schematics are included simply to relay the operational characteristics associated with each wet weather treatment alternative being considered with respect to disinfection facilities. Furthermore, it is assumed that the dose concentration requirements for the chemical disinfection facilities is the same for both the ACTIFLO® and Dual Purpose filtration alternatives.

Figure 7-1, Alternative 1 Multi-Barrier Disinfection and ACTIFLO®:

- Under proposed E. coli disinfection requirements, alternative consists of the following:
    - UV disinfection sized to treat 57 MGD of filtered secondary flows.
    - Chlorination facility sized to treat wet weather flows up to 115 MGD at a 15 minute contact time.
- Under anticipated future virus removal criteria, alternative consists of the following:
    - UV disinfection sized to treat 30 MGD of filtered secondary flows. Flows up to this amount do not require a second barrier disinfectant. Once exceeding 30 MGD, then all UV disinfected flows receive a second barrier disinfectant. See discussion in Section 7.2.2 for further detail.
    - Chlorination facility sized to treat combined UV disinfected flows of 57 MGD and wet weather flows of 115 MGD, for a total of 172 MGD at a 10 minute contact time.

Figure 7-2, Alternative 2 Ozone Disinfection and ACTIFLO®:

- Under proposed E. coli disinfection requirements, alternative consists of the following:
    - Ozone disinfection sized to treat 57 MGD of filtered secondary flows.
    - Chlorination facility sized to treat wet weather flows up to 115 MGD at a 10 minute contact time.
- This alternative would not require changes for a future virus removal criteria.

Figure 7-3, Alternative 3 Hypochlorite Disinfection and ACTIFLO®:

- Chlorination facility sized to treat 57 MGD of filtered dry weather flow and 115 MGD of wet weather treated flow for a combined flow of 172 MGD at a 10 minute contact time with varying hypochlorite dose based upon influent conditions.

Figure 7-4**,** Alternative 1 Multi-Barrier Disinfection and Dual Purpose Filtration:

- Under proposed E. coli disinfection requirements, alternative consists of the following:
    - UV disinfection sized to treat 57 MGD of filtered wet weather and/or secondary flows.
    - Chlorination facility sized to treat filtered wet weather and secondary flows up to 115 MGD at a 15 minute contact time.
- Under anticipated future virus removal criteria, alternative consists of the following:
    - UV disinfection sized to treat 30 MGD of filtered secondary flows. Flows up to this amount do not require a second barrier disinfectant. Once exceeding 30 MGD, then all UV disinfected flows receive a second barrier disinfectant. See discussion in Section 7.2.2 for further detail.
    - Chlorination facility sized to treat combined UV disinfected flow of 57 MGD, filtered wet weather and secondary flows of 58 MGD and unfiltered wet weather and secondary flows of 57 MGD for a total of 172 MGD at a 10 minute contact time.

Figure 7-5**,** Alternative 2 Ozone Disinfection and Dual Purpose Filtration:

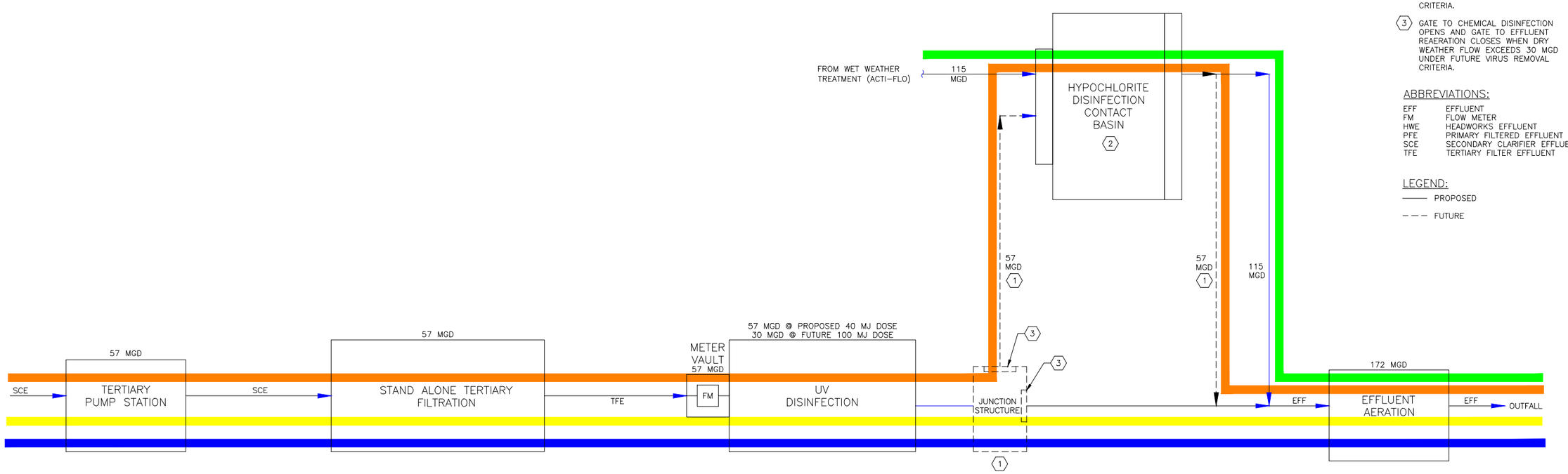
- Under proposed E. coli disinfection requirements, alternative consists of the following:
    - Ozone sized to treat 57 MGD of filtered wet weather and/or secondary flows.
    - Chlorination facility sized to treat filtered wet weather and secondary flows up to 115 MGD at a 10 minute contact time.
- This alternative would not require changes for a future virus removal criteria.

Figure 7-6**,** Alternative 3 Hypochlorite Disinfection and Dual Purpose Filtration:

- Chlorination facility sized to treat 115 MGD of filtered wet weather flow and 57 MGD of unfiltered secondary treated flow for a combined flow of 172 MGD at a 10 minute contact time with varying hypochlorite dose based upon influent conditions.

As stated in Section 7.1, the EPA is developing criteria for the future implementation of virus removal requirements in NPDES permits. At this time, it is unknown what indicators may be selected by the EPA when developing future criteria. For the purposes of this TM, it is assumed the ozone and hypochlorite disinfection systems evaluated will require little to no modifications to meet future virus requirements. For the UV system alternative, it is assumed the system will be

expanded to meet a future virus removal requirement of a 5-log reduction for polio virus. This would entail increasing the UV system design dose from 40 milijoules (mJ) per cm^2 (which is typical for systems meeting an E.Coli requirement for discharge to a receiving stream) to 100 mJ. A 100 mJ dose was selected as a future design dose under a virus removal requirement since it correlates to Title 22 requirements of the California Code of Regulations for treated wastewater effluent reuse standards. It is assumed future virus requirements related to primary and secondary contact in recreational waters will not be more stringent than those currently required for effluent reuse.



ACTI-FLO & STAND ALONE FILTRATION

KEY NOTES:

1. PROPOSED FACILITIES TO MEET FUTURE VIRUS REMOVAL CRITERIA.
2. SIZED TO PROVIDE 15 MINUTE CONTACT TIME AT 115 MGD UNDER PROPOSED E-COLI DISINFECTION REQUIREMENTS AND 10 MINUTE CONTACT TIME AT 172 MGD UNDER FUTURE VIRUS REMOVAL CRITERIA.
3. GATE TO CHEMICAL DISINFECTION OPENS AND GATE TO EFFLUENT REAERATION CLOSES WHEN DRY WEATHER FLOW EXCEEDS 30 MGD UNDER FUTURE VIRUS REMOVAL CRITERIA.

ABBREVIATIONS:

EFF	EFFLUENT
FM	FLOW METER
HWE	HEADWORKS EFFLUENT
PFE	PRIMARY FILTERED EFFLUENT
SCE	SECONDARY CLARIFIER EFFLUENT
TFE	TERTIARY FILTER EFFLUENT

LEGEND:

——— PROPOSED

– – – FUTURE

PROCESS NOTES:

- ALL DRY WEATHER FLOWS UP TO 57 MGD UNDER PROPOSED E. COLI DISINFECTION REQUIREMENTS.
- ALL DRY WEATHER FLOWS UP TO 30 MGD UNDER FUTURE VIRUS REMOVAL REQUIREMENTS.
- ALL UV DISINFECTED DRY WEATHER FLOWS ONCE EXCEEDING 30 MGD ARE DIVERTED TO HYPOCHLORITE DISINFECTION UNDER FUTURE VIRUS REMOVAL CRITERIA.
- ALL WET WEATHER FLOWS (FLOWS EXCEEDING 57 MGD) ARE DIRECTED TO HYPOCHLORITE DISINFECTION FROM WET WEATHER TREATMENT. FLOW PATH THROUGH UPSTREAM FACILITIES NOT SHOWN FOR CLARITY.

JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE
ALTERNATIVE 1 WITH ACTI-FLOW
MULTI-BARRIER UV DISINFECTION
PROCESS SCHEMATIC
FIGURE 7-1

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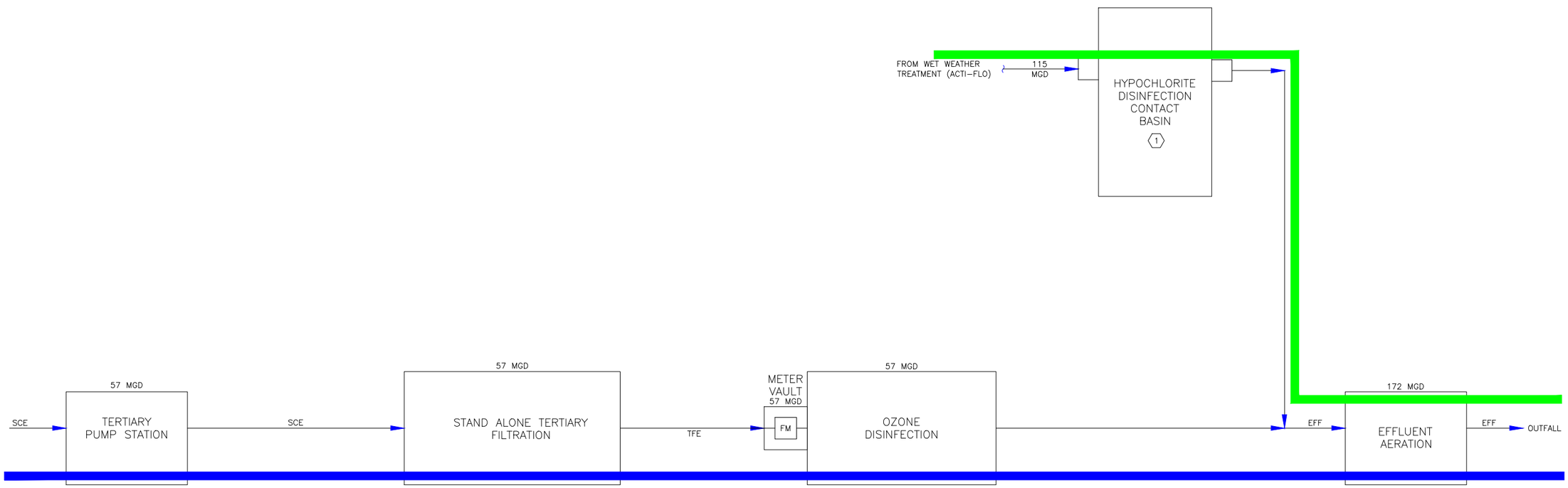
BFIGBORD
FBFIGBORD

KEY NOTES:

(1) SIZED TO PROVIDE 10 MINUTE CONTACT TIME AT 115 MGD.

ABBREVIATIONS:

EFF	EFFLUENT
FM	FLOW METER
HWE	HEADWORKS EFFLUENT
PFE	PRIMARY FILTERED EFFLUENT
SCE	SECONDARY CLARIFIER EFFLUENT
TFE	TERTIARY FILTER EFFLUENT



ACTI-FLO & STAND ALONE FILTRATION

PROCESS NOTES:

- ALL DRY WEATHER FLOWS UP TO 57 MGD UNDER PROPOSED E. COLI AND ANTICIPATED VIRUS DISINFECTION REQUIREMENTS.
- ALL WET WEATHER FLOWS (FLOWS EXCEEDING 57 MGD) ARE DIRECTED TO HYPOCHLORITE DISINFECTION FROM WET WEATHER TREATMENT.

JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE
ALTERNATIVE 2 WITH ACTI-FLOW
OZONE DISINFECTION
PROCESS SCHEMATIC
FIGURE 7-2

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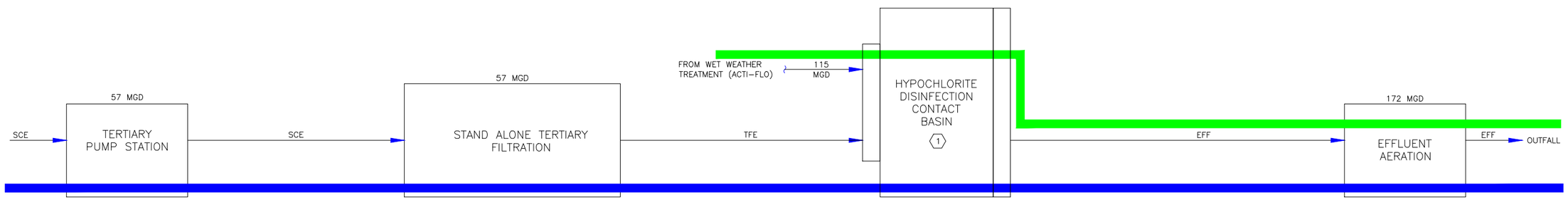
BFIGBORD
FBFIGBORD

KEY NOTES:

(1) SIZED TO PROVIDE 10 MINUTE CONTACT TIME AT 172 MGD.

ABBREVIATIONS:

EFF	EFFLUENT
FM	FLOW METER
HWE	HEADWORKS EFFLUENT
PFE	PRIMARY FILTERED EFFLUENT
SCE	SECONDARY CLARIFIER EFFLUENT
TFE	TERTIARY FILTER EFFLUENT



ACTI-FLO & STAND ALONE FILTRATION

PROCESS NOTES:

ALL DRY WEATHER FLOWS UP TO 57 MGD.

ALL WET WEATHER FLOWS (FLOWS EXCEEDING 57 MGD) ARE DIRECTED TO HYPOCHLORITE DISINFECTION FROM WET WEATHER TREATMENT.

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JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE
ALTERNATIVE 3 WITH ACTI-FLOW
HYPOCHLORITE DISINFECTION
PROCESS SCHEMATIC
FIGURE 7-3

BFIGBORD
FBFIGBORD

KEY NOTES:

1. PROPOSED FACILITIES TO MEET FUTURE VIRUS REMOVAL CRITERIA.
2. SIZED TO PROVIDE 15 MINUTE CONTACT TIME AT 115 MGD UNDER PROPOSED E-COLI DISINFECTION REQUIREMENTS AND 10 MINUTE CONTACT TIME AT 172 MGD UNDER FUTURE VIRUS REMOVAL CRITERIA.
3. GATE TO CHEMICAL DISINFECTION OPENS AND GATE TO EFFLUENT REAERATION CLOSES WHEN DRY WEATHER FLOW EXCEEDS 30 MGD UNDER FUTURE VIRUS REMOVAL CRITERIA.

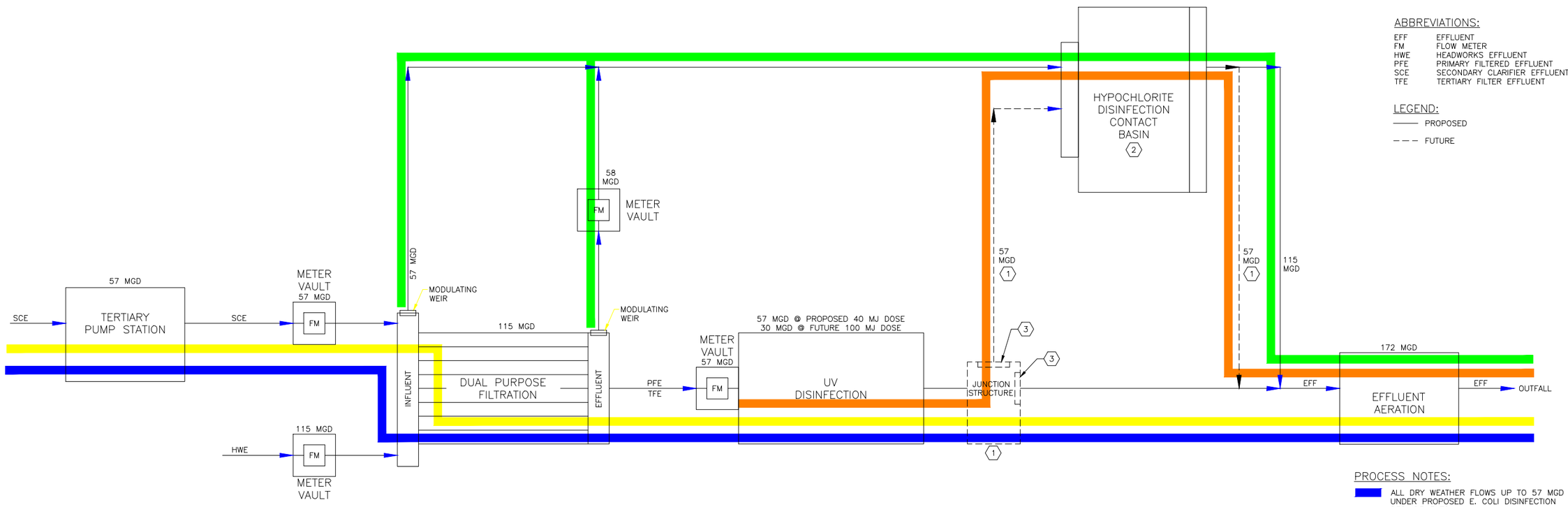
ABBREVIATIONS:

EFF	EFFLUENT
FM	FLOW METER
HWE	HEADWORKS EFFLUENT
PFE	PRIMARY FILTERED EFFLUENT
SCE	SECONDARY CLARIFIER EFFLUENT
TFE	TERTIARY FILTER EFFLUENT

LEGEND:

——— PROPOSED

– – – FUTURE



DUAL PURPOSE FILTRATION

PROCESS NOTES:

- ALL DRY WEATHER FLOWS UP TO 57 MGD UNDER PROPOSED E. COLI DISINFECTION REQUIREMENTS.
- ALL DRY WEATHER FLOWS UP TO 30 MGD UNDER FUTURE VIRUS REMOVAL REQUIREMENTS.
- ALL UV DISINFECTED DRY WEATHER FLOWS ONCE EXCEEDING 30 MGD ARE DIVERTED TO HYPOCHLORITE DISINFECTION UNDER FUTURE VIRUS REMOVAL CRITERIA. FLOW PATH THROUGH UPSTREAM FACILITIES NOT SHOWN FOR CLARITY.
- ALL FLOWS EXCEEDING 57 MGD ARE DIRECTED TO HYPOCHLORITE DISINFECTION. FLOWS TO CONSIST OF 58 MGD FILTERED WET WEATHER AND 57 MGD UNFILTERED SECONDARY TREATED FLOW. FLOW PATH THROUGH UPSTREAM FACILITIES NOT SHOWN FOR CLARITY.

JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE
ALTERNATIVE 1 WITH CMF
MULTI-BARRIER UV DISINFECTION
PROCESS SCHEMATIC
FIGURE 7-4

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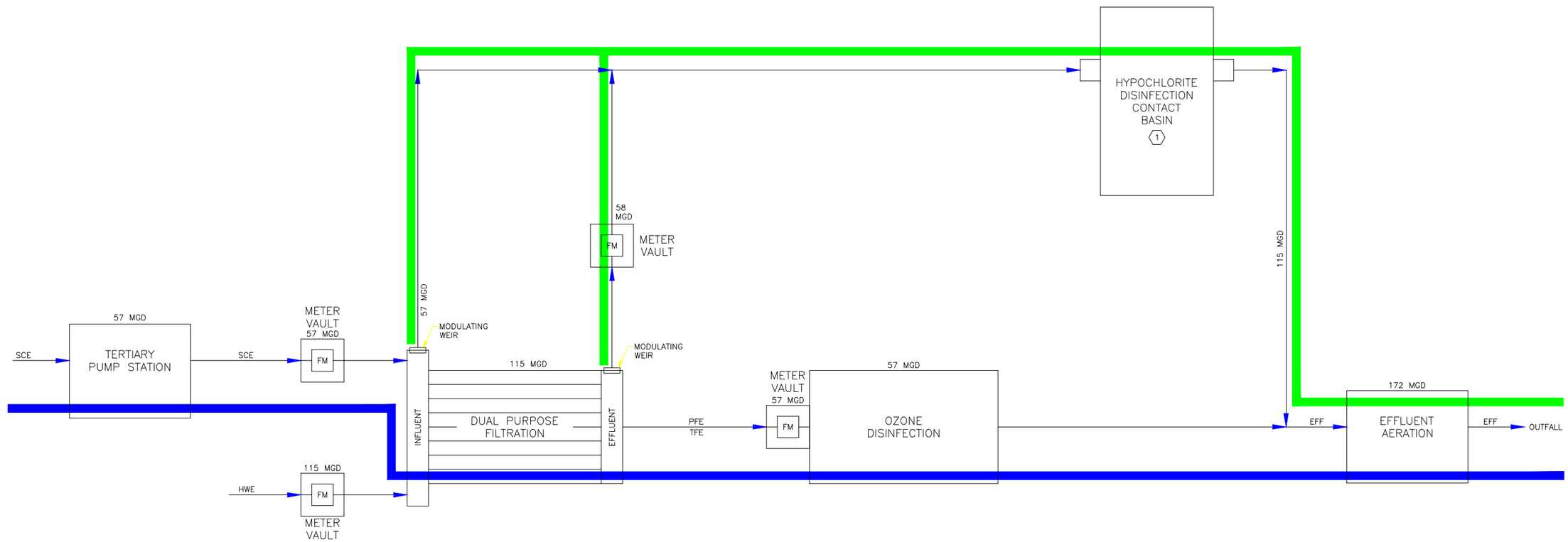
BFIGBORD
FBFIGBORD

KEY NOTES:

(1) SIZED TO PROVIDE 10 MINUTE CONTACT TIME AT 115 MGD.

ABBREVIATIONS:

EFF	EFFLUENT
FM	FLOW METER
HWE	HEADWORKS EFFLUENT
PFE	PRIMARY FILTERED EFFLUENT
SCE	SECONDARY CLARIFIER EFFLUENT
TFE	TERTIARY FILTER EFFLUENT



DUAL PURPOSE FILTRATION

PROCESS NOTES:

ALL DRY WEATHER FLOWS UP TO 57 MGD UNDER PROPOSED E. COLI DISINFECTION REQUIREMENTS.

ALL FLOWS EXCEEDING 57 MGD ARE DIRECTED TO HYPOCHLORITE DISINFECTION. FLOWS TO CONSIST OF 58 MGD FILTERED WET WEATHER AND 57 MGD UNFILTERED SECONDARY TREATED FLOW.

JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE
ALTERNATIVE 2 WITH CMF
OZONE DISINFECTION
PROCESS SCHEMATIC
FIGURE 7-5

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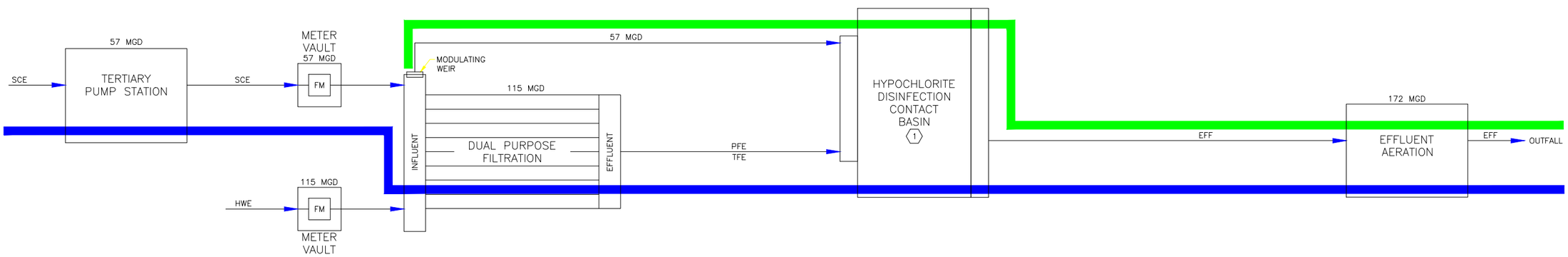
BFIGBORD
FBFIGBORD

KEY NOTES:

(1) SIZED TO PROVIDE 10 MINUTE CONTACT TIME AT 172 MGD.

ABBREVIATIONS:

EFF	EFFLUENT
FM	FLOW METER
HWE	HEADWORKS EFFLUENT
PFE	PRIMARY FILTERED EFFLUENT
SCE	SECONDARY CLARIFIER EFFLUENT
TFE	TERTIARY FILTER EFFLUENT



DUAL PURPOSE FILTRATION

PROCESS NOTES:

- FLOWS UP TO 115 MGD.
- FLOWS EXCEEDING 115 MGD ARE DIRECTED TO HYPOCHLORITE DISINFECTION. FLOW CONSISTS OF 57 MGD UNFILTERED SECONDARY TREATED FLOW.

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JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE
ALTERNATIVE 3 WITH CMF
HYPOCHLORITE DISINFECTION
PROCESS SCHEMATIC
FIGURE 7-6

BFIGBORD
FBFIGBORD

7.2.1 Design Criteria

The design criteria used to size and evaluate disinfection alternatives can be seen in Table 7-2. Design criteria for each alternative carried forward are presented in those applicable sections.

Table 7-2 General Disinfection Design Criteria

CRITERIA	VALUE (PROPOSED)	VALUE (FUTURE)
Design Secondary Flow	57 MGD	
Design Wet Weather Flow	115 MGD	
Design Total Peak Flow	172 MGD	
Influent TSS (For Filtered Flows)	<10 mg/L	
Influent TSS (From Auxiliary or Dual Purpose Treatment)	<30 mg/L	
Effluent Disinfection (April to September)	E. coli = 262 cfu/100 ml	5-log removal for polio virus (Anticipated)
Effluent Disinfection (October to March)	E. coli = 2,358 cfu/100 ml	5-log removal for polio virus (Anticipated)[1]
Chlorination By-Products - THMs (Free Chlorine)[2]	<1 to 10's µg/L (Potential Future Requirement)	<1 to 10's µg/L (Potential Future Requirement)
Chlorination By-Products - NDMA (Chloramines)[2]	<10 ng/L (Potential Future Requirement)	<10 ng/L (Potential Future Requirement)

Notes:
[1] Assumes future criteria is year round and not seasonal.
[2] See discussion in Section 7.1

7.2.2 Alternative 1 Multi-Barrier UV and Hypochlorite Disinfection – Layout, Footprint, and Hydraulic Considerations

Alternative 1 will consist of UV disinfection for flows up to 57 MGD under an effluent E.Coli requirement and UV disinfection followed by hypochlorite under a future virus removal requirement for UV disinfected flows once exceeding 30 MGD. The UV facility will consist of three UV channels. Under the initial proposed criteria, two channels will be populated and one unpopulated. The unpopulated channel will be reserved for future use as required to meet a virus removal criteria. This configuration, along with the future use of the wet weather hypochlorite facility provides a phased approach to meeting the proposed and anticipated future disinfection requirements as shown in Table 7-2 above. The figure provides a view of a UV disinfection module considered for this alternative. This module type utilizes a higher watt lamp than typical UV systems (1000 watt versus 200 to 400 watt) which results in a reduced number of lamps as compared to a traditional system utilizing low pressure high output lamps.

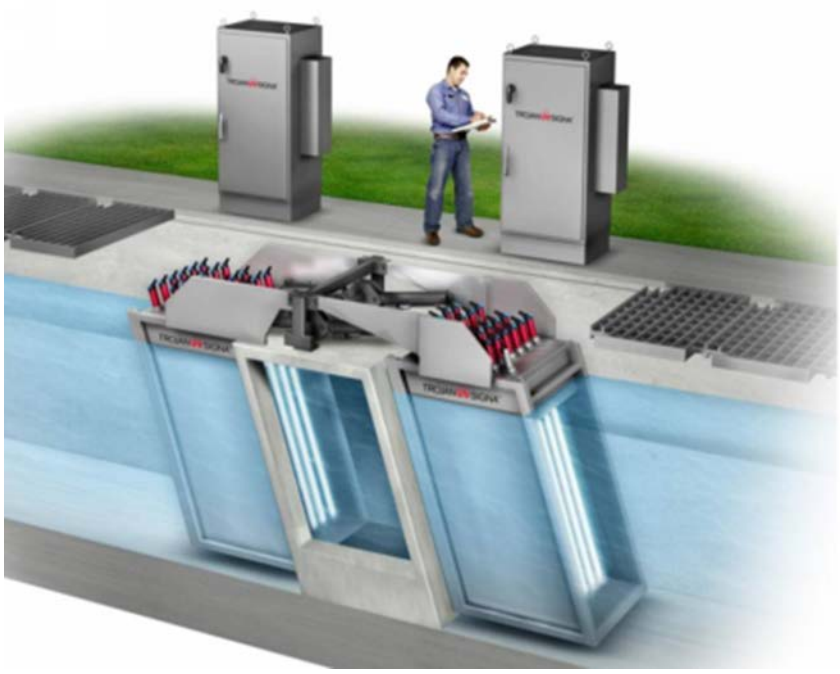


Figure 7-7 Trojan UV Signa

As shown in prior Figure 7-1 and Figure 7-4, flows for this alternative will be disinfected as follows:

- Under proposed E. coli disinfection requirement:
  - Flows up to 57 MGD would receive UV disinfection only, at a dose of 40 milijoules (mJ) per cm^2. This would be considered a "low" dose and suitable for the proposed disinfection requirements.
- Under anticipated future virus removal criteria:
  - Flows up to 30 MGD would receive UV disinfection only, at a dose of 100 mJ. This would be considered a "high" dose meeting the requirements of a 5-log polio virus removal as stated in Section 7.2. The proposed 30 MGD capacity exceeds the calculated future peak diurnal flow rate of 27 MGD based on a factor of 1.4 as determined in TM 1. A future high dose disinfection capacity of 30 MGD would generally allow typical daily peak diurnal flows during drier weather periods to be treated solely with UV. To account for the increased UV dose requirements, the unpopulated UV channel would be populated with matching equipment.
  - Upon exceeding 30 MGD, UV disinfected flows would no longer receive a 100 mJ design dose. At this set point, all UV disinfected flows would then be directed to a portion of the wet weather hypochlorite facility for further treatment.

Table 7-3 presents the UV system design criteria and operational parameters for Alternative 1 based on the proposed and anticipated future effluent disinfection requirements.

Table 7-3 Alternative 1 Multi-Barrier UV Disinfection Design Criteria

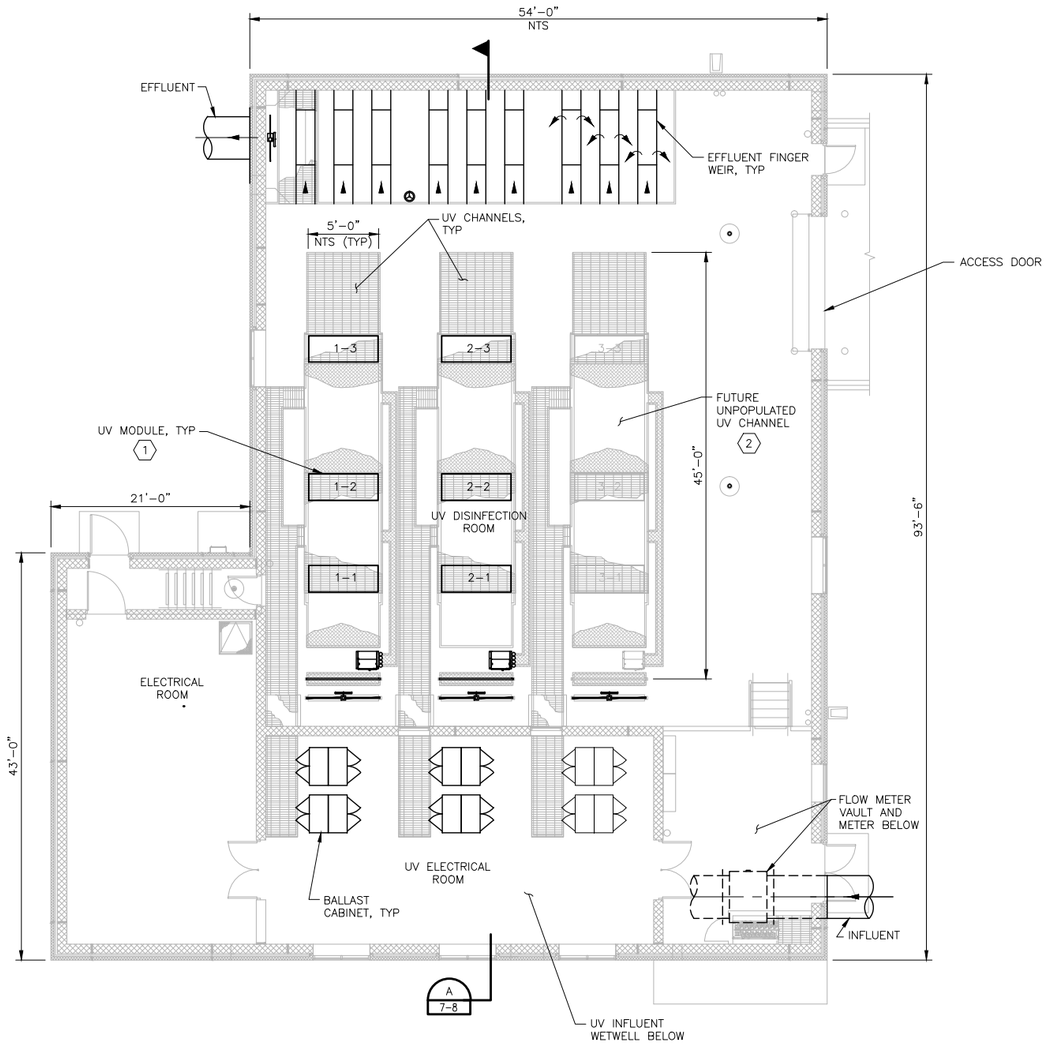
UV CRITERIA	VALUE (PROPOSED DISINFECTION CRITERIA)	VALUE (ANTICIPATED FUTURE DISINFECTION CRITERIA)
Design Peak Flow	57 MGD	30 MGD [1]
Design Dose (MS2)	40 mJ/cm^2	100 mJ/cm^2
Number of Channels	3 (1 Unpopulated)	3
Channel Dimensions (W x D x L)	4'-9" ft x 10'-2" ft x 45 ft	
Banks per Channel	3 (2 Firm, 1 Standby)	3 Firm [2]
Lamps per Bank	39	
Total Number of Lamps	234	351
UVT	60% [3]	
Lamps Operating at Specified Dose and Flow (Peak)	156	351
Power Consumption at Specified Dose and Flow	131 kWh	360 kWh
Power Consumption at Specified Dose and 19 MGD	44 kWh	229 kWh
Headloss (Includes Effluent Weir & Freeboard)	2 ft	
Isolation Gates per Channel	1	
Approximate Facility Footprint	55 ft x 100 ft	

Notes:
[1] Assumes approximately 10 KW of power input per MGD of UV treated flow to achieve 5-log polio virus removal.
[2] Assumes use of chemical disinfection system in the event of a UV bank failure under anticipated future virus criteria.
[3] Assumed value representative of similar installations that utilize synthetic type media filtration.

Figure 7-8 and Figure 7-9 show the preliminary plan and section views for the UV facility. To provide the UV dose listed in Table 7-3 under a future virus removal criteria, 3 UV banks would be added to the unpopulated UV channel to match the equipment in the other 2 channels. This future condition would require all banks in service to disinfect the 30 MGD value listed in Table 7-3, therefore a fully redundant bank in each channel would not be provided. However, in the unlikely event of a complete UV bank failure under this future operating condition, UV disinfected effluent could be temporarily diverted to the wet weather hypochlorite facility for further treatment if needed.

KEY NOTES:

1. ONE STANDBY BANK PER CHANNEL UNDER PROPOSED E-COLI DISINFECTION REQUIREMENT.
2. REQUIRES POPULATION OF "FUTURE" UV CHANNEL AND ALL BANKS IN SERVICE TO PROVIDE "HIGH" DOSE REQUIRED FOR ANTICIPATED FUTURE VIRUS REMOVAL CRITERIA.



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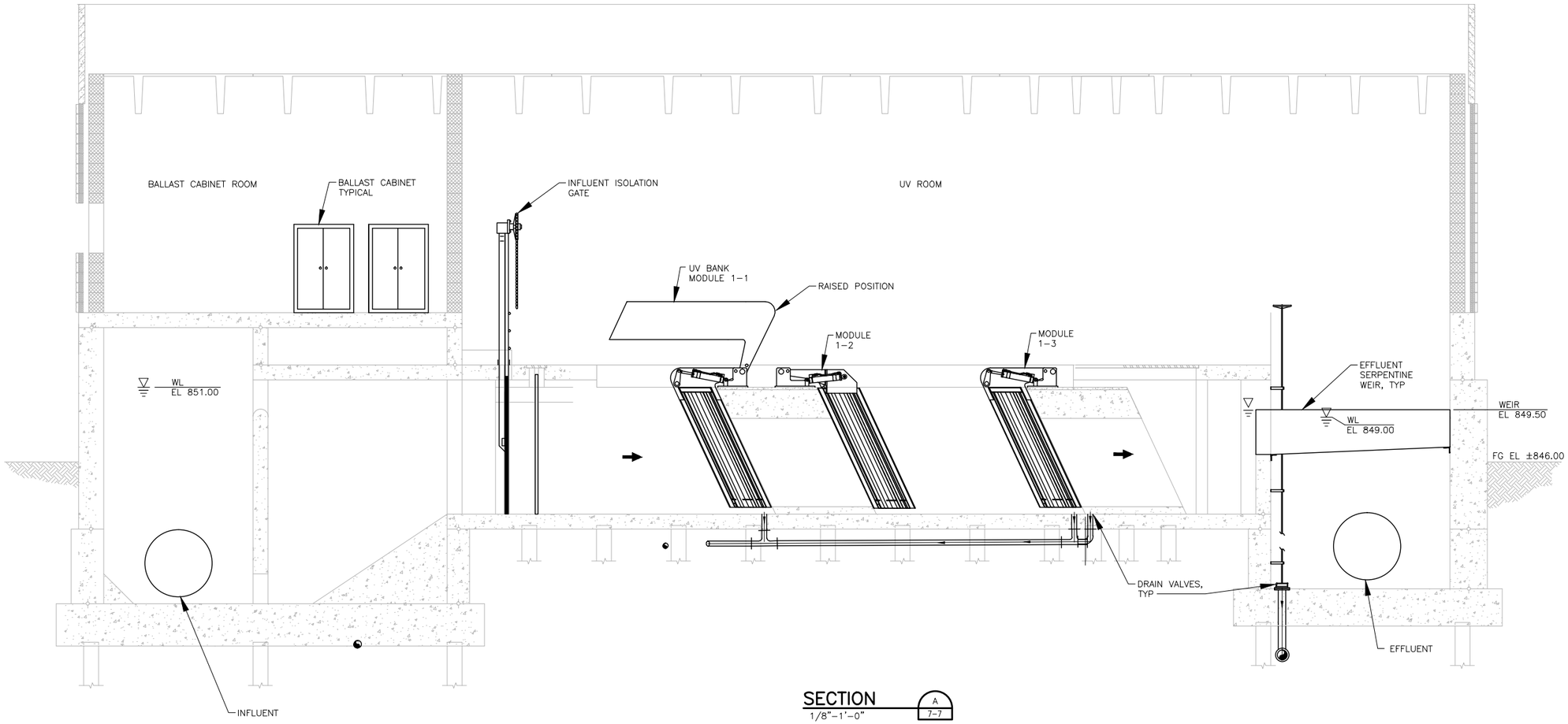
UV DISINFECTION BUILDING
PROCESS PLAN
FIGURE 7-8

BFIGBORD
FBFIGBORD



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UV DISINFECTION BUILDING
PROCESS SECTION
FIGURE 7-9

BFIGBORD
FBFIGBORD

For the wet weather chemical disinfection facilities, the proposed flow schematics associated with Alternative 1 were presented in prior Figure 7-1 and Figure 7-4 and discussed in Section 7.2.2. The facilities included under this alternative will consist of hypochlorite storage and feed building and separate contact basin, all sized to disinfect flows up to 172 MGD (115 MGD from wet weather and 57 MGD from UV).

Under the proposed E. coli disinfection requirements, the contact basin will be sized to disinfect flows that exceed the 57 MGD secondary treatment system capacity. This results in a peak design flow rate of 115 MGD. Under this condition, the basin will provide a design contact time of approximately 15 minutes. Under a future virus removal requirement, all UV flow will be diverted to the contact basin for further treatment when flows begin to exceed 30 MGD, up to the 57 MGD value. This will result in a future peak design flow rate through the chlorine contact basin of 172 MGD. Under this condition, the basin will provide a reduced design contact time of approximately 10 minutes. The variation in contact times will require an increased hypochlorite dose in the future to maintain the design concentration time (CT). CT is defined as the product of the chlorine residual and contact time. A value of 30 mg/L-minute was selected as an effective CT value for chlorination. The following calculations identify the require chlorine residual for the various contact times discussed above:

- Proposed Disinfection Requirement: CT = 2 mg/L residual x 15 minutes = 30 mg/L-minute.
- Future Disinfection Requirements: CT = 3 mg/L residual x 10 minutes = 30 mg/L-minute.

The contact basin under this alternative will be divided into three zones. This will allow for the use of portions of the basin for smaller storm events without having to place the entire basin into service. A single chemical distribution diffuser for the injection of hypochlorite will be provided in the upstream portion of the basin's inlet distribution channel. After flow travels through the serpentine zones, a portion of the hypochlorite will be consumed. To address the remaining residual, a single chemical distribution diffuser for the injection of bisulfite will be provided in the effluent junction box just prior to discharge from the basin. This location will utilize the turbulence created as flow enters the basin effluent pipe to mix the bisulfite. This will allow for dechlorination to occur in the downstream effluent piping and reaeration facility. Generally contact times of approximately 30 seconds are sufficient to remove any residual chlorine in well mixed effluent prior to plant discharge. Figure 7-10 provides a view of some typical components associated with liquid chlorine injection.

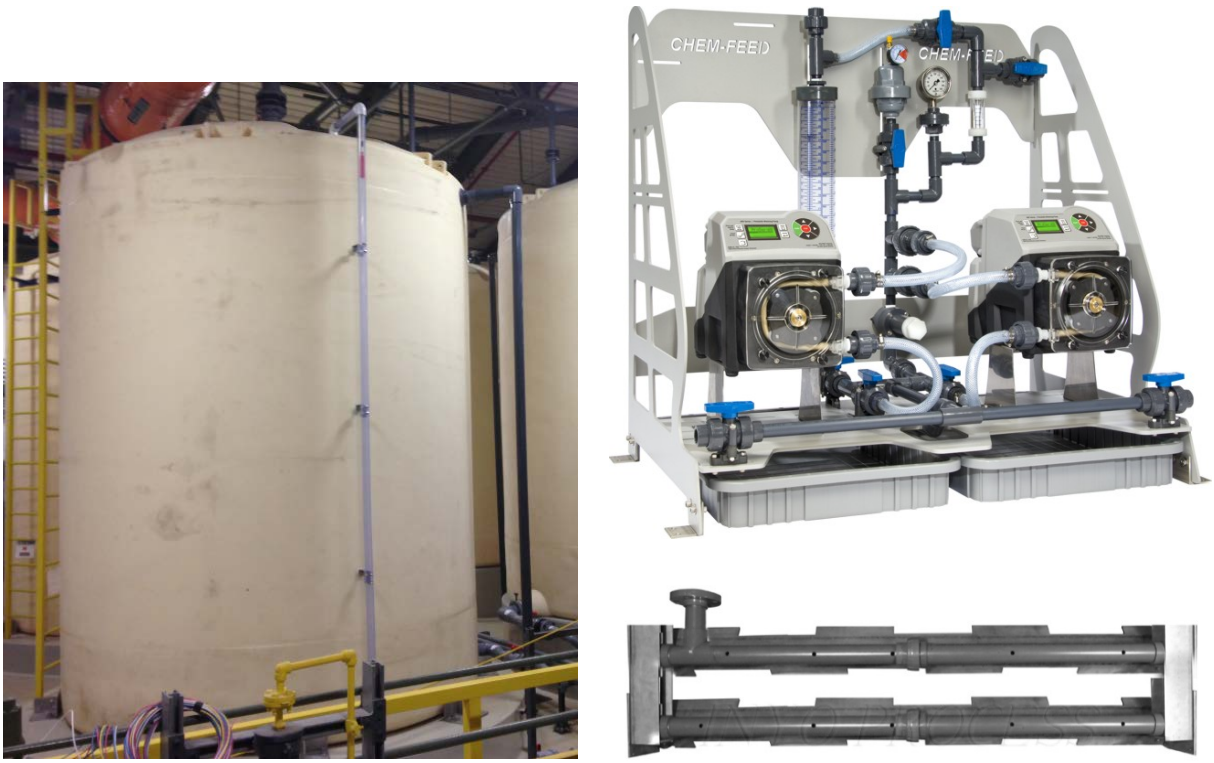


Figure 7-10 Hypochlorite Storage and Feed Equipment

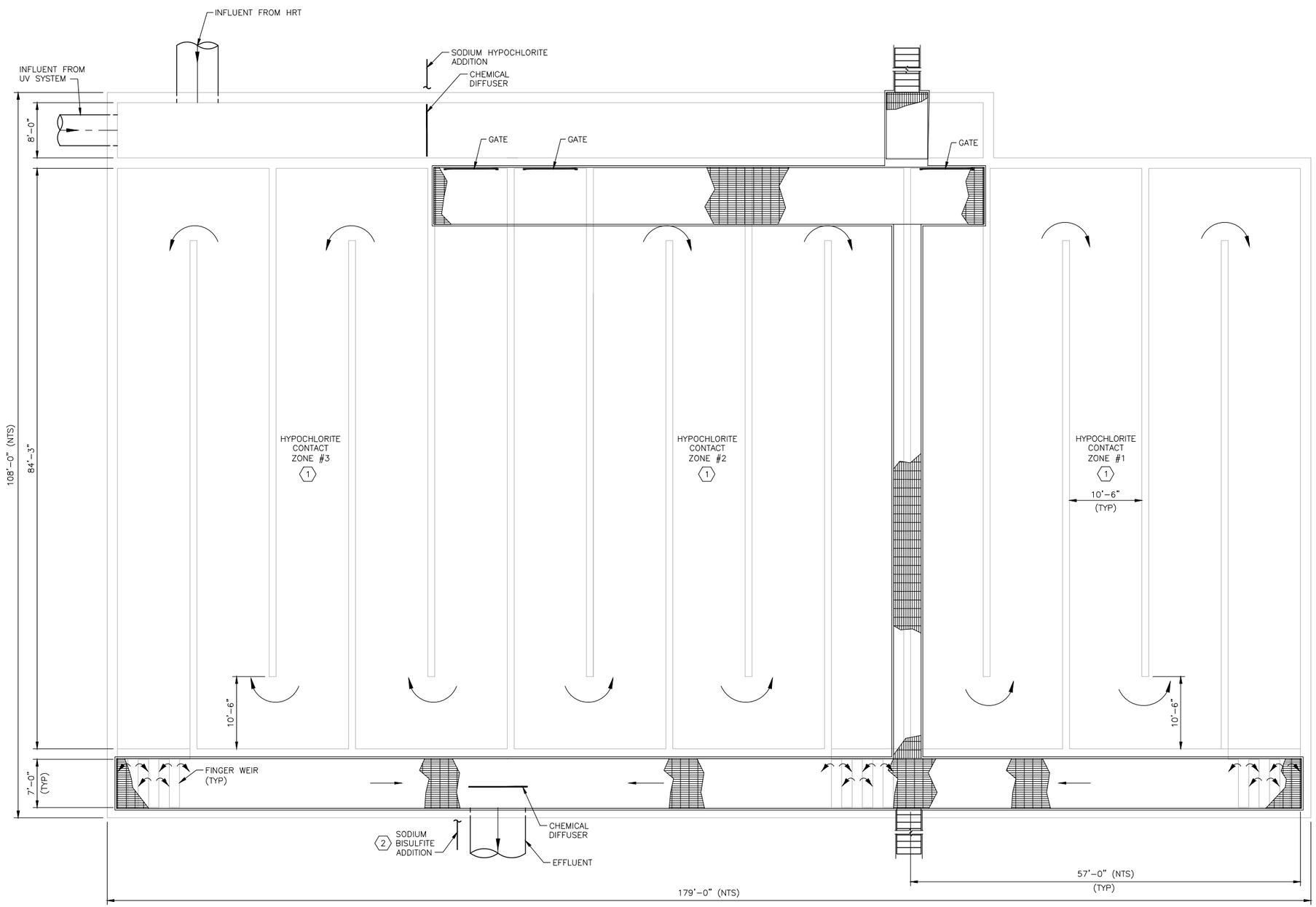
Table 7-4 presents the design criteria applicable to hypochlorite disinfection under this alternative. All values for chemical volumes shown assume a stored solution concentration of 6.25% for hypochlorite and 25% for bisulfite. It is assumed hypochlorite would be bulk delivered at a 12.5% concentration, then diluted on-site through the use of softened water to 6.25%. Storing at this reduced concentration will increase the design storage duration to approximately 3 months without significant decomposition. Storing at 6.25% as compared to storing at 12.5% will also reduce the potential safety concerns with off-gassing and is more suitable for indoor storage which is preferred. With respect to bisulfite, it is a relatively stable chemical that is suitable for longer duration storage at the proposed concentration.

Table 7-4 Alternative 1 Multi-Barrier Hypochlorite Disinfection Design Criteria – 172 MGD Facility

HYPOCHLORITE CRITERIA	VALUE (PROPOSED DISINFECTION CRITERIA)	VALUE (FUTURE DISINFECTION CRITERIA)
Design Peak Flow	115 MGD	172 MGD
Hypochlorite Contact Time	15 minutes	10 minutes
Number of Chlorination Zones	3	
Chlorination Volume Per Zone	500,000 gallons	
Total Chlorination Volume	1,500,000 gallons [1]	
Hypochlorite De-Rating Factor	20%	
Bisulfite Contact Time	Minimum 30 seconds	
System Headloss	.5 ft	
Contact Basin Footprint (L x W x SWD)	108 ft x 179 ft x 15 ft	
Hypochlorite Storage Volume	3 Tanks, 12,500 gal each	
Total Hypochlorite Storage Volume	37,500 gal	
Storage Duration at Specified Flow	2.2 days [2]	1.5 days [2]
Number of Hypochlorite Feed Pumps	2 (1 Firm + 1 standby)	
Bisulfite Storage Volume	2 Tanks, 5,000 gal each	
Total Bisulfite Storage Volume	10,000 gal	
Storage Duration at Specified Flow	2.6 days [3]	1.7 days [3]
Number of Bisulfite Feed Pumps	2 (1 Firm + 1 standby)	
Chemical Building Footprint	60 ft x 75 ft	

Notes:
[1] Assumes a 20% de-rating factor to account for potential short circuiting.
[2] Assumes 6.25% stored concentration.
[3] Assumes 25% stored concentration.

Figure 7-11 depicts the preliminary plan view for the hypochlorite contact basins under this alternative.



GENERAL NOTES:

1. SLOPE CHANNELS TO DRAIN.
2. OPERATING SIDEWATER DEPTH = 15'
3. EFFECTIVE VOLUME = 80%

KEY NOTES:

1. SIZED TO PROVIDE 15 MINUTE CONTACT TIME AT 115 MGD UNDER PROPOSED E-COLI DISINFECTION REQUIREMENTS AND 10 MINUTE CONTACT TIME AT 172 MGD UNDER FUTURE VIRUS REMOVAL CRITERIA.
2. ASSUMES MINIMUM 30 SEC CONTACT TIME TO ACHIEVE DECHLORINATION IN DOWNSTREAM PIPES AND FACILITIES PRIOR TO DISCHARGE.

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HYPOCHLORITE CONTACT BASIN
PROCESS PLAN - ALTERNATIVE 1
FIGURE 7-11

BFIGBORD
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The hypochlorite storage and pumping facility will be located in close proximity to the contact basin. The chemical storage facility will be separated into three rooms, one for the hypochlorite storage tanks, one for the bisulfite storage tanks and a separate electrical room. The hypochlorite room will have a concrete slab elevation approximately 5 feet below grade in order to provide secondary containment for the hypochlorite. The concrete surfaces in this room will receive a chemical resistant protective coating. The bisulfite room is proposed to be approximately 2 feet below grade to provide sufficient secondary containment and will also have a chemical resistant coating. Each room will have a drainage trench with a transfer pump to collect and convey any leaked or spilled chemical. A portable pump connection to serve as backup means for the evacuation of any chemicals will also be provided.

Chemical storage is sized to provide for approximately 1 to 2 days of use at the expected peak demand which would occur at the peak flow rate of 172 MGD under the future operating condition. At this flow rate, peak hypochlorite consumption is estimated to be approximately 25,820 gallons/day, which is based on the following:

- 115 MGD of wet weather flow with an assumed dosing rate of 9 mg/L. This assumes a 4 mg/L chlorine demand and 5 mg/L chlorine residual.
- 57 MGD of filtered UV disinfected flow with an assumed dosing rate of 5 mg/L. This assumes a 3 mg/L chlorine demand and 2 mg/L chlorine residual.

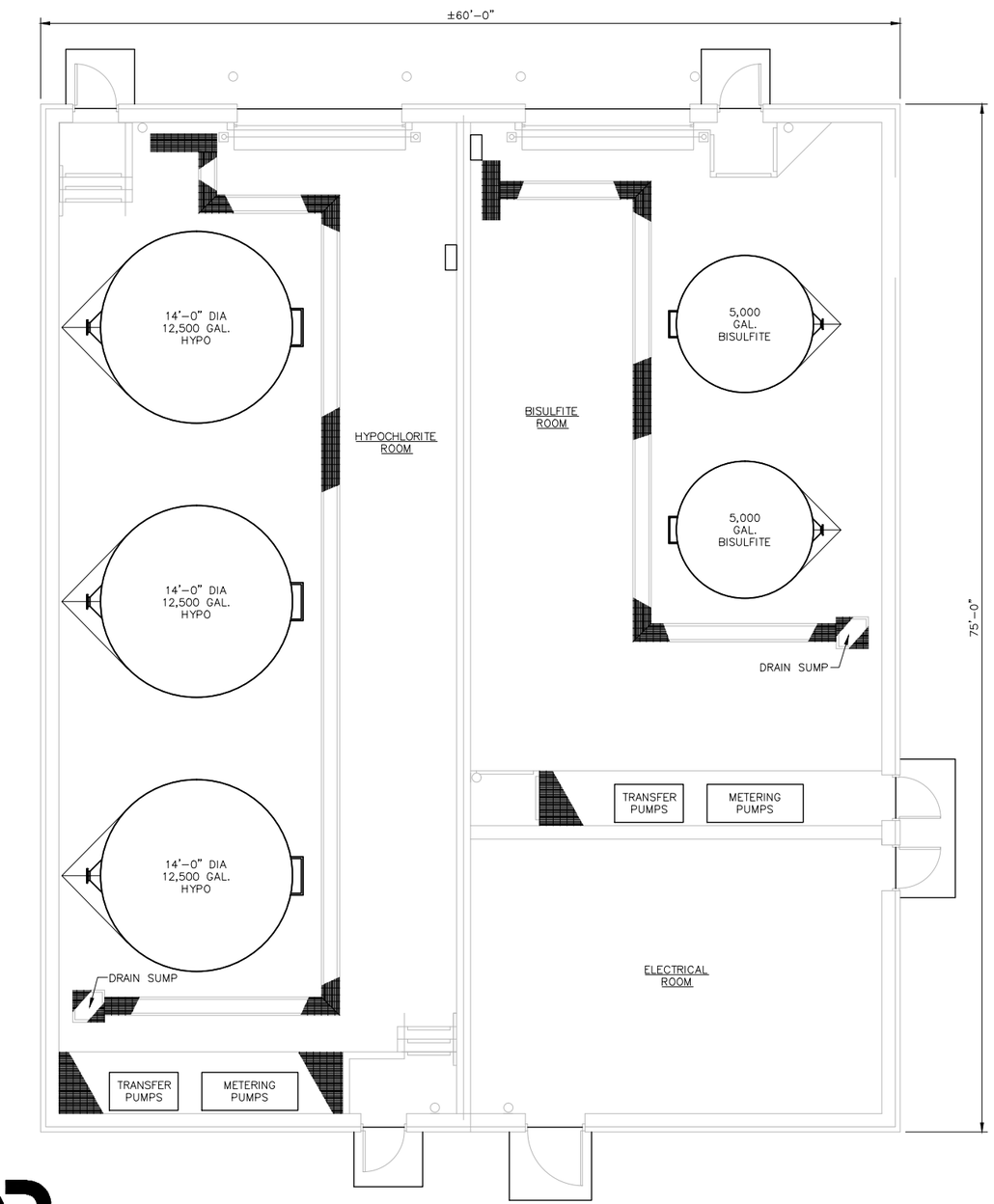
This results in a storage volume of approximately 37,500 gallons of hypochlorite, which is proposed to be stored in three (3) 12,500 gallon chemical storage tanks. Peak bisulfite demand is estimated to be approximately 5,780 gallons/day, which will also occur at the future 172 MGD peak flow operating condition and is based on the following:

- 115 MGD of wet weather flow with an assumed dosing rate of 10 mg/L.
- 57 MGD of filtered UV disinfected flow with an assumed dosing rate of 4 mg/L.

This results in a storage volume of 10,000 gallons of bisulfite, which is proposed to be stored in two (2) 5,000 gallon chemical storage tanks. As stated previously, these estimates are based on an assumed stored chemical solution concentration of 6.25% for hypochlorite and 25% for bisulfite.

A single chemical metering pump skid with two pumps in a 1 firm, 1 standby configuration will be provided in each of the hypochlorite and bisulfite rooms. The metering pump skids will be located on an elevated platform in each room so as to maintain the lower level as secondary containment.

Figure 7-12 shows the preliminary plan view for chemical storage facility.



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CHEMICAL STORAGE
PROCESS PLAN - ALTERNATIVE 1
FIGURE 7-12

BFIGBORD
FBFIGBORD

7.2.3 Alternative 2 Ozone – Layout, Footprint, and Hydraulic Considerations

Disinfection Alternative 2 will utilize ozone gas injection to disinfect secondary treated flows up to 57 MGD prior to discharge. The system will include tankage and associated equipment for the storage of liquid oxygen (LOX) that would be delivered in bulk to the site. The facility will also include ozone generation and injection equipment for delivery of the ozone to the associated contact basin. Figure 7-13 provides a view of an example single ozone generation unit for this alternative.

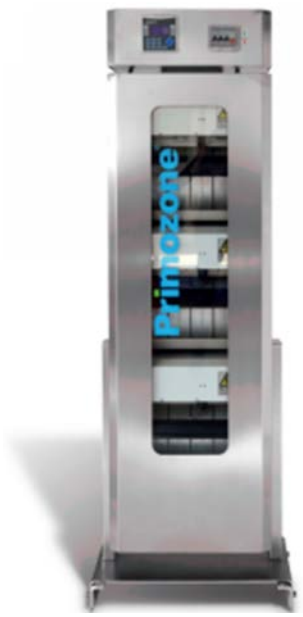

Figure 7-13 Ozone Generation Unit

This alternative also includes a chemical disinfection facility for treatment of wet weather flows up to 115 MGD. The capacity of the chemical disinfection facility is less for this alternative than for Alternative 1 since it is assumed the effluent from the ozone facility will not require further disinfection to meet future virus criteria.

Table 7-5 presents the design criteria applicable to Alternative 2. This alternative has a higher energy demand than Alternative 1 due to the conversion of LOX to ozone gas and the cooling water requirements associated with this conversion.

Table 7-5 Alternative 2 Ozone Disinfection Design Criteria

OZONE CRITERIA	VALUE
Design Peak Flow	57 MGD
Design Peak TSS	<10 mg/L
Number of Generation Units	32 [1]
Cooling Water Requirements	745 gpm @ 10°C (Peak)
Ozone Generation Facility Footprint	75 ft x 75 ft
LOX Storage Volume	2 Tanks, 22,000 gal each (14' Dia x 20' L, Horizontal)
Total LOX Storage Volume	44,000 gal
LOX Consumption at ADF	1,600 lbs/day
Storage Duration at ADF	7 days
Total Power Consumption at ADF	750 kWh
Assumed Ozone Concentration	10%
Ozone Dose	10 mg/L
Ozone Contact Time	10 minutes
Number of Ozone Contact Zones	2
Ozone Volume Per Contact Zone	22,900 gal
Total Ozone Contact Volume	45,800 gal
Total Headloss	.5 ft
Ozone Contact Basin Footprint	70 ft x 40 ft
Number of Ozone Destruct Units	2

Note:
[1] Number will vary between manufacturers.

Figure 7-14 shows the preliminary plan view for the ozone generation facility. The LOX will be delivered in bulk to the plant and stored in one of two LOX storage tanks which are proposed to be located outside and adjacent to the ozone generation facility. The metering pumps will feed the LOX to the individual ozone generation units, where it will be converted to ozone gas prior to injection into the ozone contact basin.

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OZONE GENERATION FACILITY
PROCESS PLAN - ALTERNATIVE 2
FIGURE 7-14

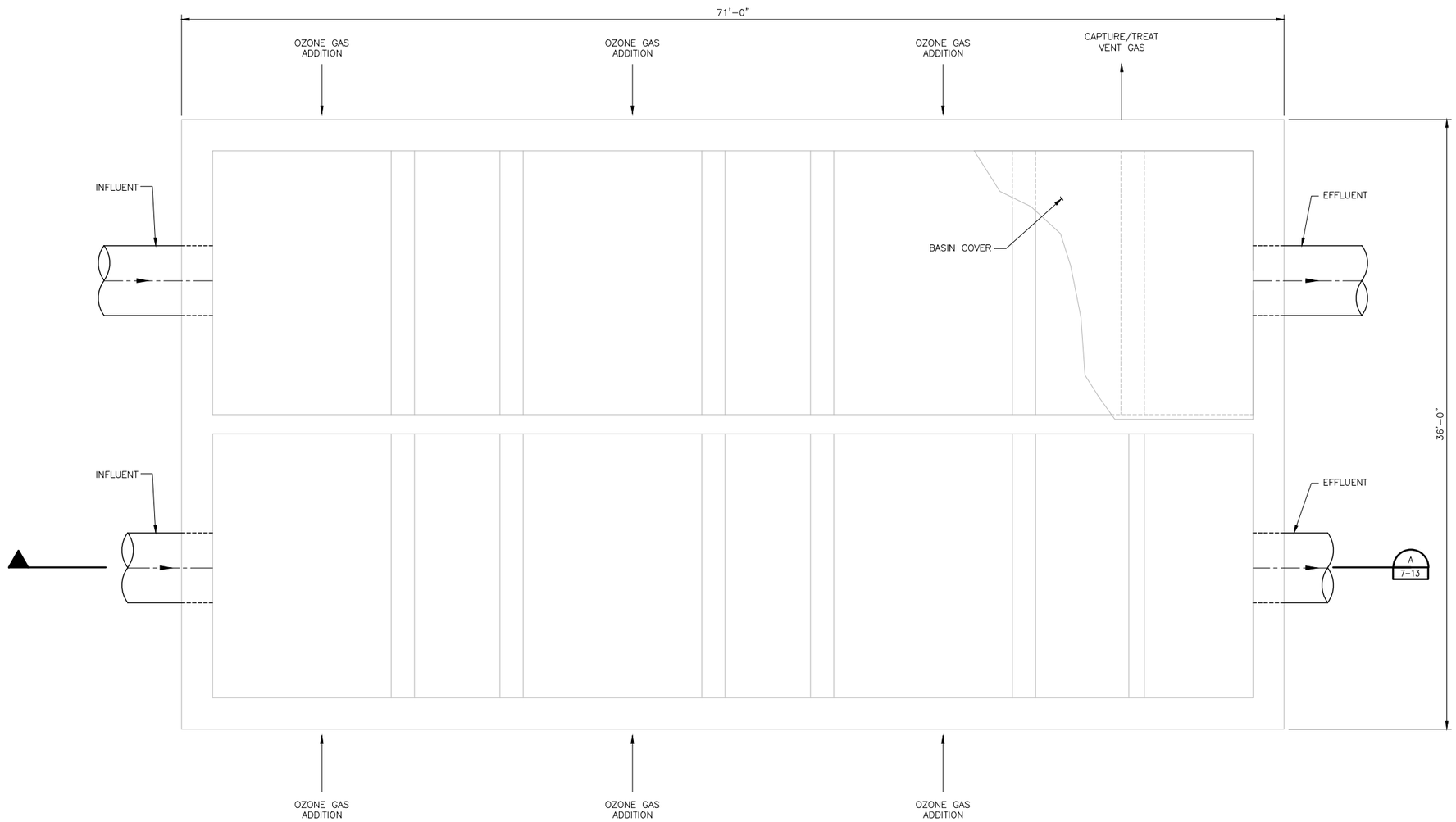
BFIGBORD
FBFIGBORD

Figure 7-16 and Figure 7-17 show the preliminary plan and section view of the proposed ozone contact basins. There will be two parallel basins, each sized for a maximum flow of 28.5 MGD. The flow through the basins will be controlled by a series of vertical baffle walls which will induce a top to bottom flow path. Ozone gas will be side injected at the bottom of the basin in three locations within each basin. Ozone is considered a carcinogen and acute health hazard, therefore the contact basins will be covered to capture and convey any remaining ozone gases to ozone-destruction units to destroy these gases. Figure 7-15 provides a view of an example destruct unit considered for this alternative.

Figure 7-15 Ozone Destruct Unit

GENERAL NOTES:

1. SLOPE CHANNELS TO DRAIN.



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OZONE CONTACT BASIN
PROCESS PLAN - ALTERNATIVE 2
FIGURE 7-16

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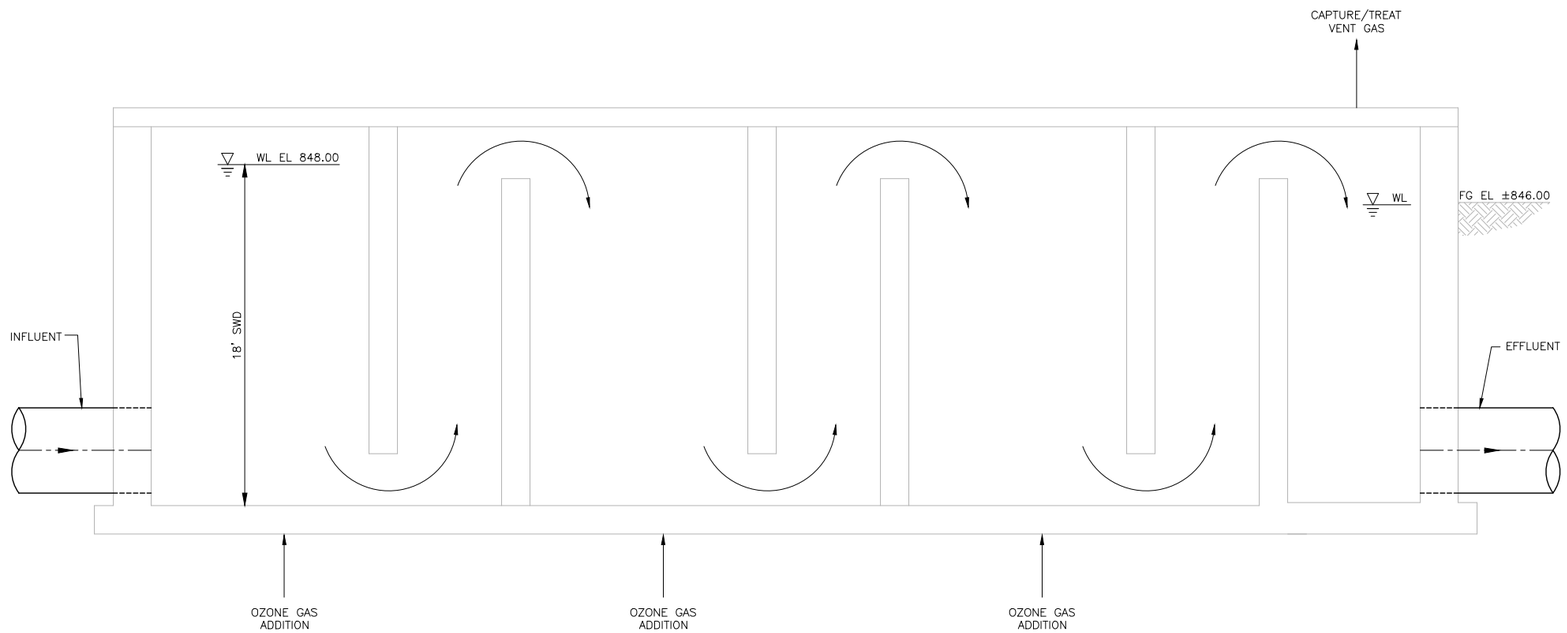
BFIGBORD
FBFIGBORD

GENERAL NOTES:

1. SLOPE CHANNELS TO DRAIN.



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OZONE CONTACT BASIN
PROCESS SECTION - ALTERNATIVE 2
FIGURE 7-17

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BFIGBORD
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Similar to Alternative 1, Alternative 2 utilizes hypochlorite chemical disinfection for wet weather flows that exceed the capacity of the secondary treatment system, or 57 MGD. The chemical storage/feed and contact basins for Alternative 2 will be similar to those discussed under Alternative 1 with the exception of the following:

- 115 MGD capacity vs 172 MGD
- 2 hypochlorite contact zones vs 3

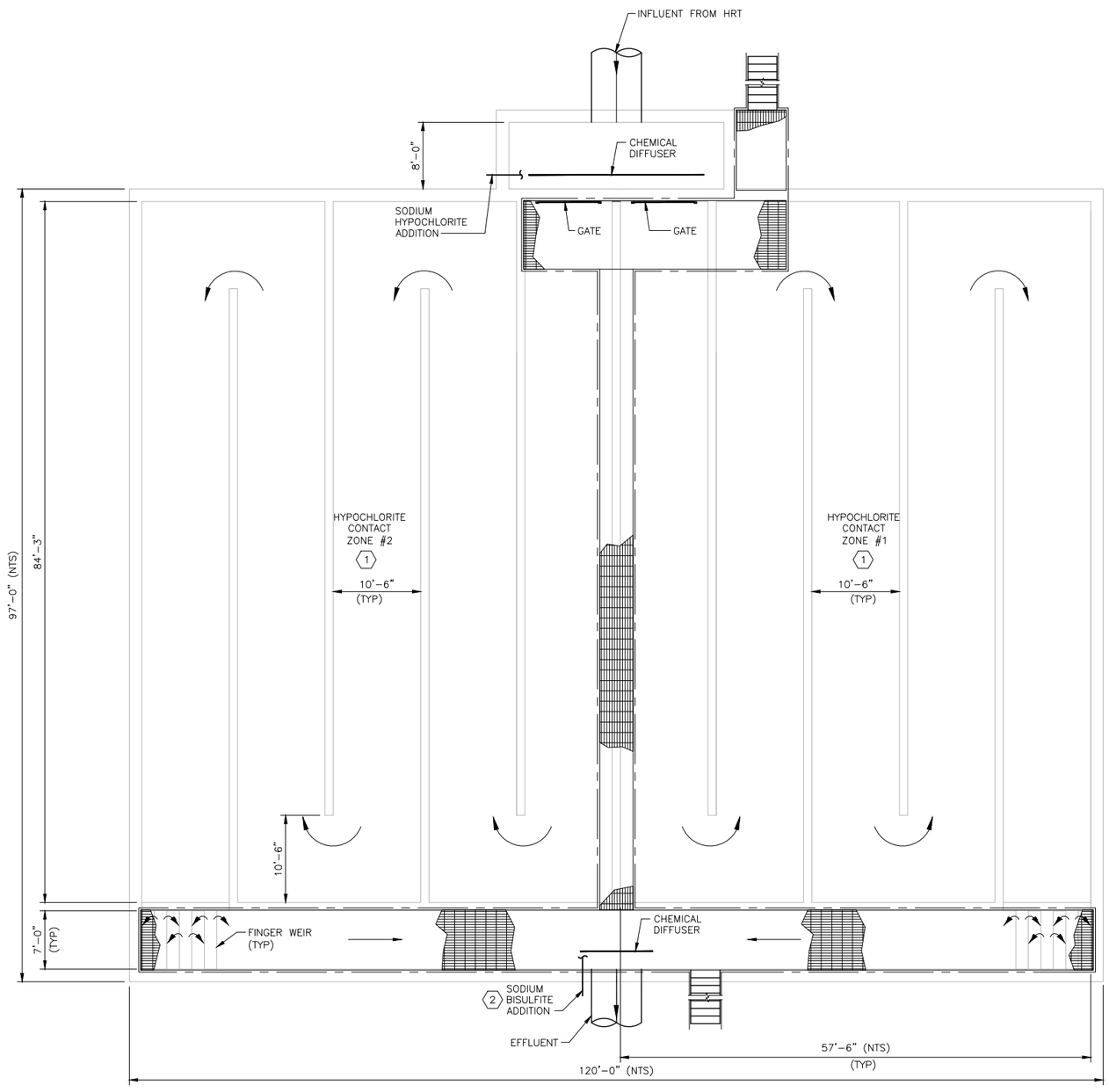
Table 7-6 presents the design criteria applicable to wet weather flows under Alternative 2.

Table 7-6 Alternative 2 Hypochlorite Disinfection Design Criteria – 115 MGD Facility

HYPOCHLORITE CRITERIA	VALUE
Design Peak Flow	115 MGD
Hypochlorite Contact Time	10 minutes
Number of Chlorination Zones	2
Chlorination Volume Per Zone	500,000 gallons
Total Chlorination Volume	1,000,000 gallons [1]
Hypochlorite De-rating Factor	20%
Bisulfite Contact Time	Minimum 30 seconds
System Headloss	.5 ft
Contact Basin Footprint (L x W x SWD)	97 ft x 120 ft x 15 ft
Hypochlorite Storage Volume	3 Tanks, 10,000 gal each
Total Hypochlorite Storage Volume	30,000 gal
Storage Duration at Specified Flow	1.7 days
Number of Hypochlorite Feed Pumps	2 (1 Firm + 1 standby)
Bisulfite Storage Volume	2 Tanks, 3,500 gal each
Total Bisulfite Storage Volume	7,000 gal
Storage Duration at Specified Flow	2.6 days
Number of Bisulfite Feed Pumps	2 (1 Firm + 1 standby)
Chemical Building Footprint	60 ft x 75 ft

Note:
[1] Assumes a 20% de-rating factor to account for potential short circuiting

Figure 7-18 depicts the preliminary plan view for the hypochlorite contact basins under Alternative 2. The layout of this facility is similar to Alternative 1 with the exception of a reduction in the number of contact zones. The hypochlorite storage and feed building is similar to Alternative 1 and is therefore not repeated.



GENERAL NOTES:

1. SLOPE CHANNELS TO DRAIN.
2. OPERATING SIDEWATER DEPTH = 15'
3. EFFECTIVE VOLUME = 80%

KEY NOTES:

1. SIZED TO PROVIDE 10 MINUTE CONTACT TIME AT 115 MGD.
2. ASSUMES MINIMUM 30 SEC CONTACT TIME TO ACHIEVE DECHLORINATION IN DOWNSTREAM PIPES AND FACILITIES PRIOR TO DISCHARGE.

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HYPOCHLORITE CONTACT BASIN
PROCESS PLAN - ALTERNATIVE 2
FIGURE 7-18

BFIGBORD
FBFIGBORD

7.2.4 Alternative 3 Hypochlorite – Layout, Footprint, and Hydraulic Considerations

Alternative 3, which consists of utilizing hypochlorite as the sole disinfectant would be the same 172 MGD facility (chemical building and contact basin) as described under Alternative 1 with the exception of no separate UV facility and the chemical disinfection being used on a daily basis for dry weather flows and periodically for additional flows from wet weather treatment. Therefore, the basin configuration and capital cost are the same for those presented under Alternative 1 for the hypochlorite facility. Table 7-7 provides revised storage durations for the hypochlorite and sodium bi-sulfite based upon operating under average flow conditions. Table 7-7 assumes the chemical tanks sizes presented in Table 7-4 remain the same.

Table 7-7 Alternative 3 Hypochlorite Disinfection Design Criteria – 172 MGD Facility

HYPOCHLORITE CRITERIA	VALUE
Design Average Flow	19 MGD
Hypochlorite Storage Volume	3 Tanks, 12,500 gal each
Total Hypochlorite Storage Volume	30,000 gal
Storage Duration at Specified Flow [1]	23.7 days
Bisulfite Storage Volume	2 Tanks, 3,500 gal each
Total Bisulfite Storage Volume	7,000 gal
Storage Duration at Specified Flow [2]	38.5 days

Notes:
[1] Assumes 5 mg/l hypo dose and 3 mg/l hypo demand at average daily flow conditions for filtered influent.
[2] Assumes 4 mg/l bi-sulfite dose at average daily flow conditions for filtered influent.

7.3 COST ANALYSIS

Preliminary capital and O&M costs were developed for disinfection Alternatives 1 - 3. The estimates are in 2015 dollars. The results of this analysis are presented below.

7.3.1 Capital Cost

The estimated capital cost for the disinfection is presented in Table 7-8.

Table 7-8 Disinfection Capital Costs

ALTERNATIVE	CAPITAL COST ($)		
	Secondary Disinfection	Wet Weather Disinfection	TOTAL
Alternative 1 – Multi-Barrier	$17,296,000	$16,923,000	$34,219,000
Alternative 2 – Ozone	$18,620,000	$13,024,000	$31,644,000
Alternative 3 - Hypochlorite	$16,923,000		$16,923,000

See **Appendix E** for supporting cost estimate details.

7.3.2 Incremental O&M Cost

O&M cost estimates were developed for each disinfection alternative. The comparative estimates included applicable power and chemical consumption requirements as well as specific repair and replacement costs. Items assumed to be similar between alternatives such as labor were excluded from the evaluation. Note that the hypochlorite and bi-sulfite unit costs used in the analysis were based on JCW's current chemical costs of $0.63 and $0.17 per gallon respectively, but were inflated by 25% to provide a level of conservatism and to account for recent variability in chemical costs. The results of this analysis are presented in Table 7-9.

Table 7-9 Disinfection Incremental O&M Costs

ALTERNATIVE	O&M COSTS		
	SECONDARY DISINFECTION	WET WEATHER DISINFECTION	TOTAL
Alternative 1 - Multi-Barrier (Years 1 - 10)	$61,000	$14,000	$75,000
Alternative 1 - Multi-Barrier (Years 11 - 20)	$229,000	$72,000	$301,000
Alternative 2 - Ozone	$1,255,000	$13,000	$1,268,000
Alternative 3 - Hypochlorite	$265,000		$265,000

7.3.3 Net Present Value

The net present value (NPV) calculations are presented in Table 7-5. The detailed life cycle cost analysis is contained in Appendix E. All NPV estimates are based on the following:

- Cost year basis: 2015
- Mid-point of construction: 2020
- Salvage Value for structures, foundations, etc., excluding equipment
- Nominal Discount Rate: 3.10%
- Inflation Rate: 1.90%
- Net Discount Rate: 1.20%

Table 7-10 Disinfection Net Present Value

DESCRIPTION	CAPITAL COST ($)	O&M COST ($)	TOTAL NPV ($)
Alternative 1 - Multi-Barrier [1]	$34,219,000	$301,000	$31,995,000
Alternative 2 - Ozone	$31,644,000	$1,268,000	$47,394,000
Alternative 3 - Hypochlorite	$16,923,000	$265,000	$18,187,000

Note:
[1] Years 11 – 20 cost in 2015 dollars

7.4 TRIPLE BOTTOM LINE ANALYSIS

A TBL analysis was completed to provide a more thorough comparison of the alternatives. Non-economic criteria, such as social and environmental factors can impact the alternative under evaluation. The general criteria listed in Table 2-5 have been expanded on in Table 7-6 by providing alternative specific descriptions and providing ranking information for subsequent scoring to determine an overall benefit score for each alternative. This scoring process is presented in Table 7-7. This benefit score was then combined with the NPV to determine the benefit-cost of each alternative in Table 7-8.

The relative importance and weighting factors used to score the non-economic criteria were developed jointly with JCW during the alternative selection workshop. This is presented in the following sections.

Table 7-11 Disinfection Ranking Information

CRITERIA	RANKING INFORMATION
Flexibility / Performance Reliability/ Turndown	**Alternative 1 (Multi-Barrier):** The UV system staffing requirements are relatively minimal since dose control is paced on water quality and treated flow. Future use of multi-barrier approach will require additional staffing requirements for operation of chemical pumping/metering systems. System is flexible due to multi-barrier approach. Turndown of UV system will be high under proposed E. coli limit with reduced turndown capability in the future under a virus limit. Combines the use of two common disinfection methods.

CRITERIA	RANKING INFORMATION
	Alternative 2 (Ozone): The staffing requirements are considered to be similar to Alternative 1 when operating under a future virus criteria for flows less than 57 MGD. Has a small installation base, but has demonstrated through prior installations to be a proven disinfectant.
	Alternative 3 (Hypochlorite): The staffing requirements are relatively minimal since hypochlorite dose control can be paced to maintain a desired chlorine residual. This alternative is considered less complex than Alternatives 1 and 2 since a single facility/disinfectant is used for dry and wet weather flow. Turndown of hypochlorite dose will be available. Ranking: 5 = highest flexibility/reliability 1 = least flexibility/reliability
Phasing	**Alternative 1 (Multi-Barrier):** Allows for phasing through multi-barrier approach to reduce initial capital and O&M costs.
	Alternative 2 (Ozone): There is no phasing consideration for this alternative.
	Alternative 3 (Hypochlorite): Requires use of hypochlorite for all flows and therefore under E.Coli effluent disinfection requirement, operations cost for this alternative is higher due to use of chemicals for disinfection as compared to Alternative 1 which utilizes electricity for UV dose. Ranking: 5 = no phasing impact 1 = large phasing impact
Land Requirements / Layout	**Alternative 1 (Multi-Barrier):** The site footprint required for Alternative 1 is larger than Alternative 2 when considering the footprint required to provide a future multi-barrier approach for UV disinfected effluent through a chlorine contact tank.
	Alternative 2 (Ozone): The site footprint required for Alternative 2 is large but is less than Alternative 1.
	Alternative 3 (Hypochlorite): Represents smallest site footprint due to lack of UV facility as compared to Alternative 1. Ranking: 5 = small footprint 1 = large footprint

CRITERIA	RANKING INFORMATION
Social Impacts	**Alternative 1 (Multi-Barrier):** Alternative 1 does not require daily or frequent truck traffic for chemical deliveries. Chemical deliveries could occur on a monthly basis under a future virus criteria. Aesthetic considerations are similar between alternatives.
	Alternative 2 (Ozone): Alternative 2 requires frequent truck traffic for LOX deliveries. Aesthetic considerations are similar between alternatives.
	Alternative 3 (Hypochlorite): Alternative 3 requires frequent truck traffic for chemical deliveries. Aesthetic considerations are similar between alternatives. Ranking: 5 = no social impact 1 = large social impact
Environmental Impacts	**Alternative 1 (Multi-Barrier):** Requires consumables in the form of UV lamp and ballast replacement on defined intervals as well as future chemical consumption for secondary flows exceeding 27 MGD under a future virus criteria.
	Alternative 2 (Ozone): Requires daily consumption of liquid oxygen to generate ozone. Power consumption is considerably larger for this alternative. Ozone is considered a greenhouse gas.
	Alternative 3 (Hypochlorite): Requires daily consumption of hypochlorite for disinfection and bi-sulfite to control chlorine residual. Potential future regulatory requirement for disinfection byproducts. Ranking: 5 = least environmental impact 1 = largest environmental impact
Safety	**Alternative 1 (Multi-Barrier):** Alternative 1 does not require day to day interface by operations staff with hazardous chemicals and is therefore considered to have less safety concerns as compared to Alternative 2.
	Alternative 2 (Ozone): Alternative 2 presents a day to day safety concern associated with consistent truck traffic required for LOX deliveries as well as while being stored on-site for subsequent use. Additional safety considerations are associated with ozone generation which is considered a carcinogen.

CRITERIA	RANKING INFORMATION
	Alternative 3 (Hypochlorite): Alternative 3 presents a day to day safety consideration associated with daily hypochlorite use and increased truck traffic required for chemical deliveries as compared to Alternative 1. Ranking: 5 = no safety risk 1 = large safety risk
Ease of Regulatory Acceptance	**Alternative 1 (Multi-Barrier):** It is anticipated that the proposed effluent limits for disinfection will require a 126 effluent E. coli and therefore Alternative 1, with the sole use of UV, is expected to be acceptable to KDHE. Future anticipated effluent virus criteria may require pilot testing of the proposed disinfection method to demonstrate effectiveness to KDHE once criteria is established and ultimately implemented in future NPDES permits.
	Alternative 2 (Ozone): Alternative 2 is expected to be acceptable to KDHE. Future anticipated effluent virus criteria may require pilot testing of the proposed disinfection method to demonstrate effectiveness to KDHE once criteria is established and ultimately implemented in future NPDES permits.
	Alternative 3 (Hypochlorite): Alternative 3 is expected to be acceptable to KDHE. Future anticipated effluent virus criteria may require pilot testing of the proposed disinfection method to demonstrate effectiveness to KDHE once criteria is established and ultimately implemented in future NPDES permits. Ranking: 5 = highest regulatory acceptance 1 = least regulatory acceptance

7.4.1 Criteria Weighting and Scoring

Table 7-12 presents a summary of the weighted scores for each alternative.

Table 7-12 Disinfection Triple Bottom Line Scoring

CRITERIA	CRITERIA PERCENT-AGE	RELATIVE WEIGHT	ALTERNATIVE 1 (MULTI-BARRIER)		ALTERNATIVE 2 (OZONE)		ALTERNATIVE 3 (HYPOCHLORITE)	
			Ranking	Weighted Score	Ranking	Weighted Score	Ranking	Weighted Score
Flexibility / Performance Reliability / Turndown	15	1.5	4	6	3	4.5	3	4.5
Phasing	20	2	4	8	3	6	3	6
Land Requirements / Layout	15	1.5	3	4.5	2	3	4	6
Social Impacts	10	1	4	4	2	2	2	2
Environmental Impacts	15	1.5	3	4.5	2	3	2	3
Safety	20	2	4	8	2	4	3	6
Ease of Regulatory Acceptance	10	1	4	4	4	4	4	4
	105%	10.5		39		26.5		31.5

Note:
[1] Rankings: 5 = Most Important or most positive impact. 1 = Least Important or most negative impact.

7.4.2 Cost/Benefit Scoring

Table 7-13 contains the NPV to the normalized benefit ratio. The sum total of the social and environmental weighted scores can be converted to the normalized benefit score based upon the highest scoring alternative. The benefit scores for each alternative are then divided into the respective NPV to express the benefit score in economic terms.

Table 7-13 Disinfection NPV to Normalized Benefit Ratio Comparison

CRITERIA	ALTERNATIVE 1 (MULTI-BARRIER)	ALTERNATIVE 2 (OZONE)	ALTERNATIVE 3 (HYPOCHLORITE)
	Weighted Score	**Weighted Score**	**Weighted Score**
Flexibility / Performance Reliability / Turndown	6	4.5	4.5
Phasing	8	6	6
Land Requirements / Layout	4.5	3	6
Social Impacts	4	2	2
Environmental Impacts	4.5	3	3
Safety	8	4	6
Ease of Regulatory Acceptance	4	4	4
Total Weighted Score	39	26.5	31.5
Normalized Benefit Score	1	0.68	0.81
NPV Cost	$31,995,000	$47,394,000	$18,187,000
NPV / Normalized Benefit Ratio	$31,995,000	$69,697,000	$22,453,000

7.4.3 Recommended Alternative

Alternative 3 Hypochlorite has the lowest Net Present Value. Although Alternative 1 Multi-Barrier had a higher Triple Bottom Line score, Alternative 3 had the lowest NPV/ Normalized Benefit Ratio. Therefore, Alternative 3 Hypochlorite is the recommended alternative.

8 Effluent Reaeration

8.1 PRELIMINARY ALTERNATIVE SCREENING

The purpose of this facility is to reaerate effluent prior to discharge to meet the anticipated minimum effluent dissolved oxygen (DO) limit. It is anticipated that the NPDES permit will require a minimum DO concentration of 6.0 mg/L, measured as a weekly average of three samples. A step type aeration structure will be used to achieve this requirement. The proposed plant hydraulic profile will facilitate gravity flow through this structure.

8.2 DESIGN DEVELOPMENT

As shown in Figure 8-1, for step type aeration, flow cascades down the concrete stairs ("reaeration steps") and oxygen is entrained into the effluent during this process.

Figure 8-1 Cascade Reaeration Steps

8.2.1 Design Criteria

The Effluent Reaeration Design Parameters are shown in Table 8-1:

Table 8-1 Effluent Reaeration Design Criteria

CRITERIA	VALUE
Peak Hourly Flow	172 MGD
Assumed Influent DO Concentration	1 mg/L
Proposed Effluent DO Concentration [1]	6 mg/L

Note:
[1] Measured as a weekly average, minimum 3 samples per week

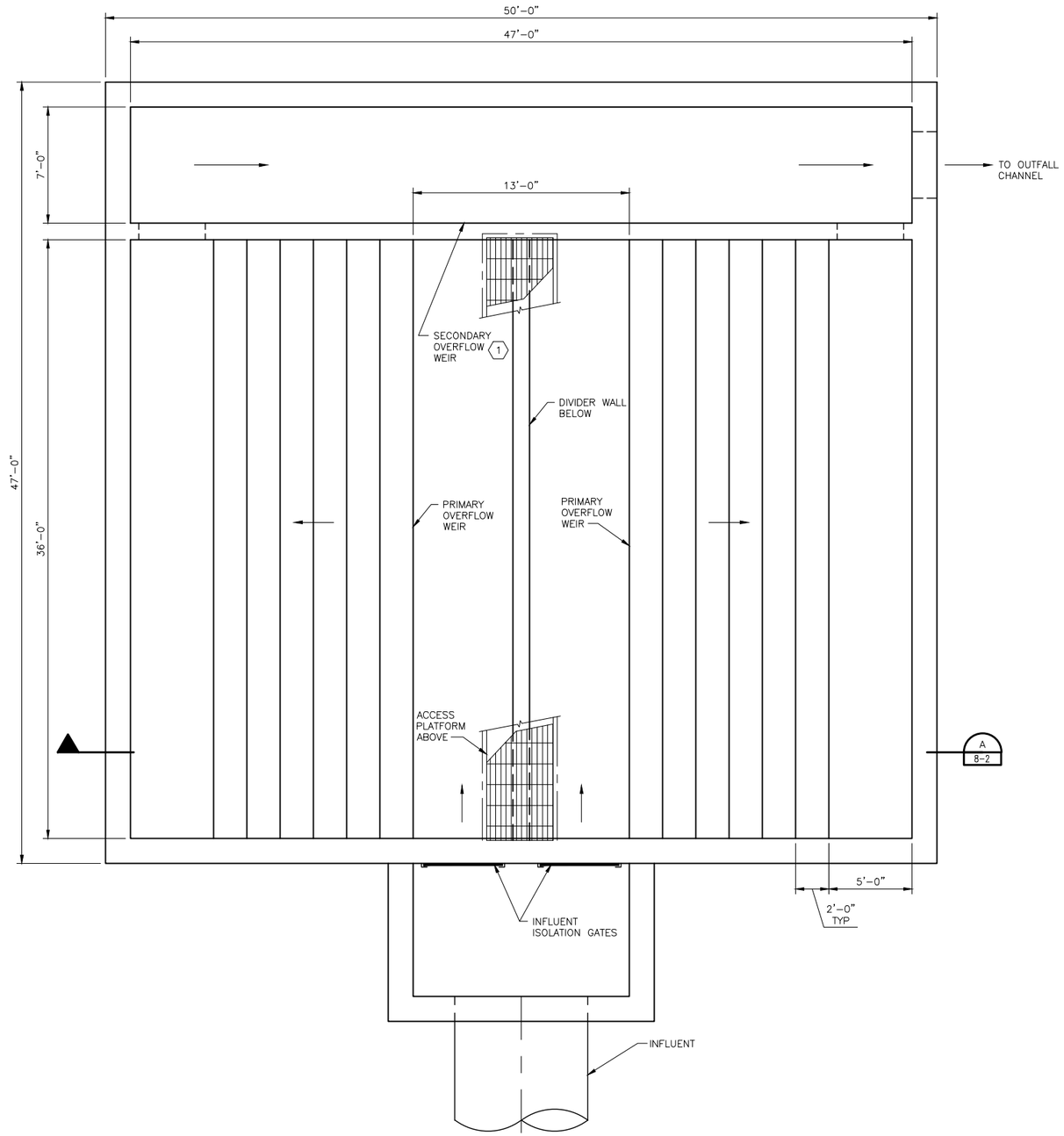
See **Appendix F** for the calculations utilized to determine the minimum height of the reaeration steps.

8.2.2 Layout, Footprint, and Hydraulic Considerations

The Effluent Reaeration Structure will receive all plant flow, including wet weather flow, before discharging treated effluent to the receiving stream. Effluent will enter the center inlet channel of the structure and primarily be split across two 36'-0" long reaeration weirs. After cascading down the reaeration steps, reaerated effluent will exit the structure and be discharged to the plant outfall. The structure is designed to convey the design peak flow rate of 172 MGD hydraulically, with the majority of the flows up to 57 MGD being directed over the reaeration steps.

The controlling elevation for the structure is the top of concrete of the top aeration steps. The elevation of this step was selected to prevent a submerged condition during a 100 year flood event. This assumption results in effluent not being fully reaerated during an elevated discharge stream condition. Effluent DO requirements are anticipated to be expressed as a weekly average with a minimum of three (3) samples per week. It is assumed that samples not meeting the minimum effluent DO requirement during a temporary surcharged stream condition would be averaged with additional samples taken for the same week under non-surcharged conditions, with the average of all samples being able to meet the anticipated criteria. An elevated discharge stream condition due to a wet weather event is temporary in nature and the period in which the conditions in the stream remain elevated is dependent on the severity of the storm event and other factors. To determine a relative duration of elevated stream conditions for Indian Creek due to varying levels of wet weather event severity, stream gage elevations for USGS Stream Site 06893390, located at Indian Creek and State Line were evaluated. Four (4) storm events were analyzed for the period from July 2008 to July 2015. During this period event intensities range from a 1-year to 25-year storm were noted. The longest period in which Indian Creek was elevated above normal pool and subsequently returned to within 3' of normal pool was approximately 12 hours. Therefore, any reduction in the available vertical reaeration distance available in the Effluent Reaeration Structure would be temporary in nature and are typically well less than 24 hours. This approach minimizes the hydraulic profile of the facilities lying upstream of this facility and downstream of the Tertiary Pump Station. It is recommended this approach be coordinated with KDHE during finalization of the NPDES permit.

As stated above, the top of concrete elevation for the top reaeration step (primary weir) was selected to be approximately 1' above the 100 year flood elevation of 844 in the receiving stream. This equates to a top step elevation of 845.0. At this elevation, the maximum headloss over this weir is approximately 1'-0". To minimize the required length of the reaeration steps, a 13'-0" secondary weir with a TOC of 845.27 will also be used. This weir will be located at the end of the center channel. A small portion of the flow up to 57 MGD will cascade over the secondary weir. Flows conveyed over the secondary weir will not flow over the steps, but will still receive aeration through the available fall distance. These flows will be conveyed directly to the effluent channel and discharged to the receiving stream. This configuration is presented in Figure 8-2 and Figure 8-3.



PLAN
SCALE: 1/4"=1'-0"

KEY NOTES:

1. ASSUMES FLOWS EXCEEDING 19 MGD ARE ADDITIONALLY CONVEYED OVER SECONDARY OVERFLOW WEIR.

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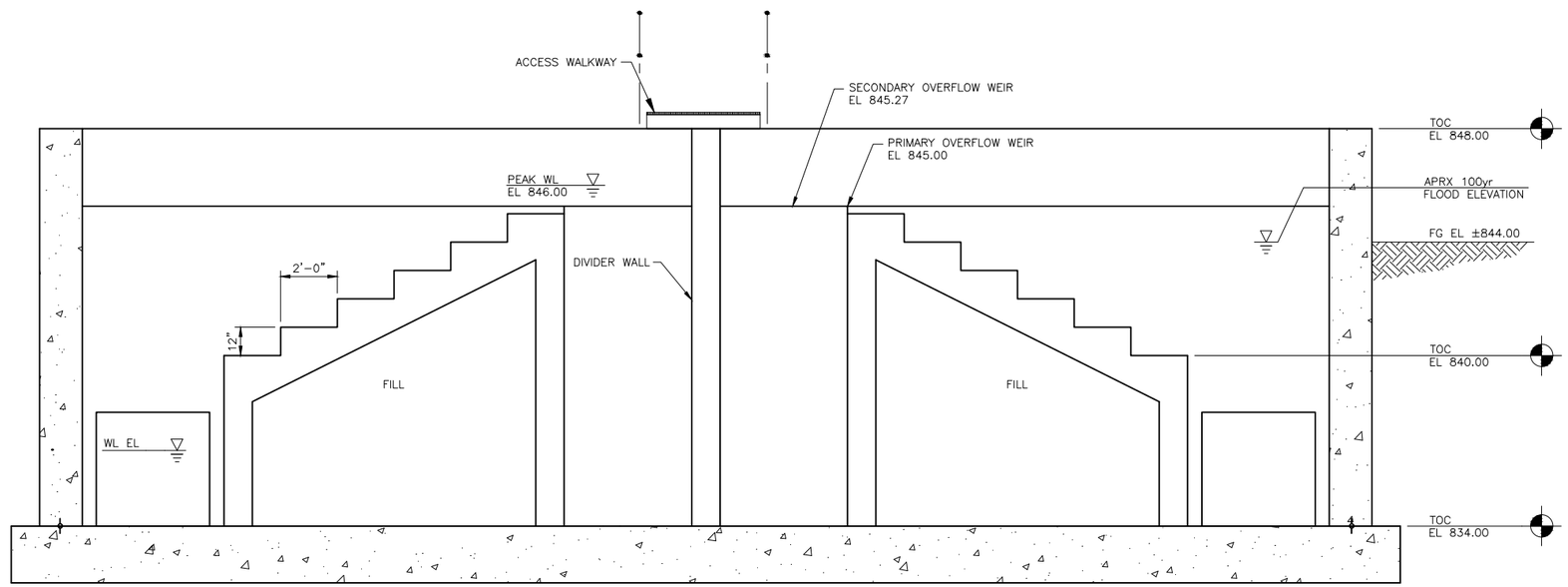
TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE

EFFLUENT REAERATION STRUCTURE
PROCESS PLAN
FIGURE 8-2

BFIGBORD
FBFIGBORD



SECTION A 8-1

SCALE: 3/8"=1'-0"

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JOHNSON COUNTY WASTEWATER
TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE

EFFLUENT REAERATION STRUCTURE
PROCESS SECTION
FIGURE 8-3

BFIGBORD
FBFIGBORD

Table 8-2 displays the estimated distribution of flow through the Effluent Reaeration structure at the design flow rates.

Table 8-2 Effluent Reaeration Design Flows

DESIGN FLOW RATE	FLOW OVER PRIMARY REAERTION STEPS/WEIRS	FLOW OVER SECONDARY WEIR
19 MGD	19 MGD	0 MGD
57 MGD	~54 MGD	~3 MGD
172 MGD	~155 MGD	~17 MGD

8.3 COST ANALYSIS

No other alternatives were considered for effluent reaertion; therefore, the cost analysis consists only of capital costs associated with the Effluent Reaeration Structure described above. All estimates are in 2015 dollars. The results of this analysis are presented below.

8.3.1 Capital Cost

The capital costs for the Effluent Reaeration structure consist of the cost of construction for the structure. There is no equipment required to reaerate the effluent. Capital costs associated with equipment are limited to DO probes and other associated instrumentation. The estimated capital cost for the effluent reaeration is presented in Table 8-3.

Table 8-3 Effluent Reaeration Capital Costs

	CAPITAL COST ($)
Effluent Reaeration	$1,810,000

8.3.2 Incremental O&M Cost

There is no incremental O&M cost associated with the Effluent Reaeration structure.

8.3.3 Net Present Value

NPV calculations are presented in Table 8-4. A breakdown of the life cycle cost analysis is contained in Appendix F. All NPV estimates are based on the following:

- Cost year basis: 2015
- Mid-year of construction point year: 2020
- Salvage Value for structures, foundations, etc., excluding equipment.
- Capital Escalation rate: 1.9%
- O&M Expenditures Escalation Rate: 1.9%
- Interest (Discount Rate): 3.1%

Table 8-4 Effluent Reaeration Net Present Value

DESCRIPTION	CAPITAL COST ($)	O&M COST ($)	TOTAL NPV ($)
Effluent Reaeration Structure	$1,810,000	$2,100	$1,475,000

8.4 TRIPLE BOTTOM LINE ANALYSIS

A TBL analysis was not performed for this facility since only one alternative was carried forward for consideration.

8.4.1 Criteria Weighting and Scoring

N/A

8.4.2 Cost/Benefit Scoring

N/A

8.4.3 Recommended Alternative

It is recommended that filtered and disinfected effluent be reaerated utilizing a concrete step structure with a hydraulic capacity of 172 MGD. This approach requires no mechanical equipment or operator attention. The Effluent Reaeration structure will utilize the available hydraulic gradient created by intermediate pumping to facilitate reaeration of the effluent and discharge above the 100 year flood elevation.

Appendix A – Tertiary Pump Station Costs

TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE - TM 4
LIFE CYCLE COST ANALYSIS
Tertiary Pump Station - 57 MGD

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

		Base Year Cost					Mid-Point of Construction	First Year of Service																			Salvage Value @ 20 years	
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039		
Capital Costs (Modify as Required)																												
Process & Electrical Equipment		$1,055,000	-	-	-	-	$1,159,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Equipment Installation (%)	26%	$264,000	-	-	-	-	$290,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Concrete		$357,000	-	-	-	-	$392,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$312,000
Structural Excavation / Backfill		$155,000	-	-	-	-	$170,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$136,000
Dewatering		$15,000	-	-	-	-	$16,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$13,000
Superstructure(2)		$0																									60%	$0
Metals		$55,000	-	-	-	-	$60,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$26,000
Piping and Valves		$82,000	-	-	-	-	$90,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$39,000
HVAC		$14,000	-	-	-	-	$15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Markups																											Total Salvage Value	$526,000
Electrical, Instrumentation & Controls	20%	$399,000	-	-	-	-	$438,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%	$399,000	-	-	-	-	$438,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Deep Foundations	N/A	$36,000	-	-	-	-	$36,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
General Requirements	15%	$425,000	-	-	-	-	$467,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%	$814,000	-	-	-	-	$894,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%	$1,018,000	-	-	-	-	$1,118,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs		$5,088,000	-	-	-	-	$5,583,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year(1)			-	-	-	-	$4,792,634	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs(1)		$4,793,000																										
NPV of Salvage Value		$253,000																										
O&M Costs (Modify As Required)																												
Electricity(3)		$57,000	-	-	-	-	-	$63,815	$65,027	$66,263	$67,522	$68,804	$70,112	$71,444	$72,801	$74,185	$75,594	$77,030	$78,494	$79,985	$81,505	$83,054	$84,632	$86,240	$87,878	$89,548		
Chemicals			-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Equipment O&M and Replacement (%)(4)	3%	$32,000	-	-	-	-	-	$35,826	$36,506	$37,200	$37,907	$38,627	$39,361	$40,109	$40,871	$41,647	$42,439	$43,245	$44,067	$44,904	$45,757	$46,627	$47,512	$48,415	$49,335	$50,272		
Labor			-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Total, O&M Costs		$89,000	$0	$0	$0	$0	$0	$99,640	$101,533	$103,463	$105,428	$107,432	$109,473	$111,553	$113,672	$115,832	$118,033	$120,275	$122,561	$124,889	$127,262	$129,680	$132,144	$134,655	$137,213	$139,820		
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$82,963	$81,997	$81,043	$80,099	$79,167	$78,246	$77,335	$76,435	$75,545	$74,666	$73,797	$72,938	$72,089	$71,250	$70,421	$69,601	$68,791	$67,990	$67,199		
Total NPV of O&M Costs		$1,422,000																										

NPV Summary

Capital Cost	$4,793,000
Salvage	($253,000)
O&M	$1,422,000
Total NPV	**$5,962,000**

Economic Assumptions

Capital Escalation (Inflation) Rate	1.90%
O&M Escalation (Inflation) Rate	1.00%
Annual Interest (Discount) Rate	3.10%

Notes:
(1) NPV Capital Costs is calculated from Mid Point of Construction Costs
(2) No superstructure required.
(3) Assumes CMF pumping head condition.
(4) Assumes pump capital cost for CMF and DF pumping head conditions is similar.

Appendix B - Stand Alone Filtration Costs

TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE - TM 4
LIFE CYCLE COST ANALYSIS
Stand Alone Tertiary Filtration, Disc - 57 MGD

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

		Base Year Cost					Mid-Point of Construction	First Year of Service																		
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Capital Costs (Modify as Required)																										
Process & Electrical Equipment		$2,550,000	-	-	-	-	$2,802,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equipment Installation (%)	25%	$638,000	-	-	-	-	$701,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Concrete		$773,000	-	-	-	-	$849,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Structural Excavation		$66,000	-	-	-	-	$73,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dewatering		$15,000	-	-	-	-	$16,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Superstructure [2]		$1,251,000	-	-	-	-	$1,374,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Metals		$100,000	-	-	-	-	$110,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous Piping and Valves		$50,000	-	-	-	-	$55,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HVAC		$182,000	-	-	-	-	$200,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Markups																										
Electrical, Instrumentation & Controls	20%	$1,125,000	-	-	-	-	$1,236,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sitework	20%	$1,125,000	-	-	-	-	$1,236,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Deep Foundations	N/A	$478,000	-	-	-	-	$478,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
General Requirements	15%	$1,253,000	-	-	-	-	$1,377,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contingency	25%	$2,402,000	-	-	-	-	$2,639,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ELA	25%	$3,002,000	-	-	-	-	$3,298,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, Capital Costs		$15,010,000	-	-	-	-	$16,444,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NPV of Capital Cost at Base Year [1]			-	-	-	-	$14,116,081	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total NPV of Capital Costs [1]		$14,116,000																								
NPV of Salvage Value		$988,000																								
O&M Costs (Modify As Required)																										
Electricity		$9,000	-	-	-	-	-	$10,076	$10,267	$10,463	$10,661	$10,864	$11,070	$11,281	$11,495	$11,713	$11,936	$12,163	$12,394	$12,629	$12,869	$13,114	$13,363	$13,617	$13,876	$14,139
Chemicals [3]			-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Equipment O&M and Replacement (%) [5]		$48,000	-	-	-	-	-	$53,739	$54,760	$55,800	$56,860	$57,941	$59,041	$60,163	$61,306	$62,471	$63,658	$64,868	$66,100	$67,356	$68,636	$69,940	$71,289	$72,623	$74,003	$75,409
Labor [4]			-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total, O&M Costs		$57,000	$0	$0	$0	$0	$0	$63,815	$65,027	$66,263	$67,522	$68,804	$70,112	$71,444	$72,801	$74,185	$75,594	$77,030	$78,494	$79,985	$81,505	$83,054	$84,632	$86,240	$87,878	$89,548
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$53,133	$52,515	$51,904	$51,300	$50,703	$50,112	$49,529	$48,953	$48,383	$47,820	$47,263	$46,713	$46,169	$45,632	$45,101	$44,576	$44,057	$43,544	$43,038
Total NPV of O&M Costs		$910,000																								

Salvage Value @ 20 years	
0%	$0
0%	$0
60%	$729,000
60%	$62,000
60%	$14,000
60%	$1,179,000
30%	$47,000
30%	$24,000
0%	$0
Total Salvage Value	$2,055,000

NPV Summary

Capital Cost		$14,116,000
Salvage		($988,000)
O&M		$910,000
	Total NPV	**$14,038,000**

Economic Assumptions

Capital Escalation (Inflation) Rate	1.90%
O&M Escalation (Inflation) Rate	1.90%
Annual Interest (Discount) Rate	3.19%

Notes:
(1) NPV Capital Costs is calculated from Mid Point of Construction Costs
(2) Based on structure footprint of 65 X 70
(3) Assumes chemical cost (alum trim for Effluent TP from 1.0 to .5 mg/l) between alternatives is simlar and therefore are excluded
(4) Assumes labor costs between TF options are similar and therefore are excluded
(5) Calculated R&R for alternative vs utilizing a % of equipment cost

TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE - TM 4
LIFE CYCLE COST ANALYSIS
Stand Alone Tertiary Filtration, CMF (57 MGD)

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

Capital Costs (Modify as Required)

PROCESS or Project Element		Base Year Cost 2015	2016	2017	2018	2019	Mid-Point of Construction 2020	First Year of Service 2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Salvage Value @ 20 years	
Stand Alone - CMF Filter																												
CMF Equipment (inc Blowers)		$2,975,000	-	-	-	-	$3,269,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Equipment Installation (%)	[illegible]	$743,750	-	-	-	-	$817,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Superstructure		$0																									60%	$0
Earthwork		$41,275	-	-	-	-	$45,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$39,000
Concrete		$1,072,000	-	-	-	-	$1,178,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,010,000
Metals		$897,540	-	-	-	-	$986,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$423,000
Painting		$7,000	-	-	-	-	$8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Process Piping & Valves		$975,000	-	-	-	-	$1,071,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$460,000
HVAC & Plumbing		$0																									0%	$0
Blower/Electrical Building																												
Structure, Valves, and Piping		$1,455,000	-	-	-	-	$1,599,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$1,143,000
Non-Blower Equipment		$72,000	-	-	-	-	$79,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Miscellaneous Structures & Piping		$0																									60%	$0
Markups																												
Electrical, Instrumentation & Controls	20%	$1,648,000	-	-	-	-	$1,811,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%	$1,648,000	-	-	-	-	$1,811,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Deep Foundation Adder		$759,400	-	-	-	-	$834,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
General Requirements	15%	$1,844,000	-	-	-	-	$2,026,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%	$3,534,000	-	-	-	-	$3,883,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%	$4,418,000	-	-	-	-	$4,854,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs		$22,090,000	-	-	-	-	$24,271,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year[1]			-	-	-	-	$20,835,040	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		

Total Salvage Value	$3,075,000

Total NPV of Capital Costs[1]	$20,835,000
NPV of Salvage Value	$1,478,000

O&M Costs (Modify As Required)

		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Electricity		$8,675	-	-	-	-	-	$9,712	$9,896	$10,084	$10,276	$10,471	$10,670	$10,873	$11,079	$11,290	$11,504	$11,723	$11,946	$12,173	$12,404	$12,640	$12,880	$13,124	$13,374	$13,628
Chemicals[2]			-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Qauipment O&M and Replacement		$3,421	-	-	-	-	-	$3,830	$3,903	$3,977	$4,053	$4,130	$4,208	$4,288	$4,370	$4,453	$4,537	$4,623	$4,711	$4,801	$4,892	$4,985	$5,080	$5,176	$5,274	$5,375
Labor[3]			-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total, O&M Costs		$12,096	$0	$0	$0	$0	$0	$13,542	$13,799	$14,061	$14,328	$14,601	$14,878	$15,161	$15,449	$15,742	$16,042	$16,346	$16,657	$16,973	$17,296	$17,624	$17,959	$18,301	$18,648	$19,003
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$11,275	$11,144	$11,014	$10,886	$10,759	$10,634	$10,510	$10,388	$10,267	$10,148	$10,030	$9,913	$9,797	$9,683	$9,571	$9,459	$9,349	$9,240	$9,133

Total NPV of O&M Costs	$193,000

NPV Summary

Capital Cost	$20,835,000
Salvage	($1,478,000)
O&M	$193,000
Total NPV	**$19,550,000**

Economic Assumptions

Capital Escalation (Inflation) Rate	1.90%
O&M Escalation (Inflation) Rate	1.90%
Annual Interest (Discount) Rate	3.10%

Notes:
(1) NPV Capital Costs is calculated from Mid Point of Construction Costs
(2) Assumes chemical cost (alum trim for Effluent TP from 1.0 to 0.5 mg/l) between alternatives is similar and therefore are excluded
(3) Assumes labor costs between TF options are similar and therefore are excluded

Appendix C - Auxiliary Treatment Costs

THC WWTP

Auxiliary Treatment (Stand Alone) - Alternative 1 - Actiflo (115 MGD)

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

PROCESS or Project Element		Base Year Cost 2015	2016	2017	2018	2019	Mid-Point of Construction 2020	First Year of Service 2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Salvage Value @ 20 years	
Capital Costs (Modify as Required)																												
Actiflo Basin																												
Actiflo Equipment		$4,200,000	-	-	-	-	$4,614,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Equipment Installation (%)	25%	$1,050,000	-	-	-	-	$1,154,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Superstructure		$533,600	-	-	-	-	$586,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Earthwork		$99,610	-	-	-	-	$110,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$593,000
Concrete		$1,996,780	-	-	-	-	$2,194,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$94,000
Metals		$304,758	-	-	-	-	$335,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,882,000
Painting		$92,000	-	-	-	-	$101,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$144,000
Process Piping & Valves		$368,000	-	-	-	-	$404,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
HVAC & Plumbing		$116,000	-	-	-	-	$127,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$173,000
Chemical Building																											0%	$0
Structure, Valves, and Piping		$1,331,000	-	-	-	-	$1,462,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Chemical Feed Equipment		$249,000	-	-	-	-	$274,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$1,046,000
Miscellaneous Structures & Piping		$0																									0%	$0
																											60%	$0
Markups																												
Electrical, Instrumentation & Controls	20%	$2,068,000	-	-	-	-	$2,272,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%	$2,068,000	-	-	-	-	$2,272,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Deep Foundation Adder		$1,030,000	-	-	-	-	$1,132,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
General Requirements	15%	$2,326,000	-	-	-	-	$2,556,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%	$4,458,000	-	-	-	-	$4,898,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%	$5,573,000	-	-	-	-	$6,123,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
115 MGD Fine Screen Total Capital Cost		$4,742,268	-	-	-	-	$5,210,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15%	$1,118,000
Total, Capital Costs		$32,606,000	-	-	-	-	$35,824,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year[1]			-	-	-	-	$30,752,523	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs[1]		$30,753,000																										
NPV of Salvage Value		$2,384,000																										
O&M Costs (Modify As Required)																												
Polymer		$11,661	-	-	-	-	-	$13,055	$13,303	$13,556	$13,814	$14,076	$14,343	$14,616	$14,894	$15,177	$15,465	$15,759	$16,058	$16,363	$16,674	$16,991	$17,314	$17,643	$17,978	$18,320		
Ferric		$11,371	-	-	-	-	-	$12,731	$12,973	$13,219	$13,470	$13,726	$13,987	$14,253	$14,523	$14,799	$15,081	$15,367	$15,659	$15,957	$16,260	$16,569	$16,884	$17,204	$17,531	$17,864		
Microsand		$2,424	-	-	-	-	-	$2,713	$2,765	$2,817	$2,871	$2,926	$2,981	$3,038	$3,095	$3,154	$3,214	$3,275	$3,338	$3,401	$3,466	$3,531	$3,598	$3,667	$3,737	$3,808		
Defoamer	$41,003	$15,548	-	-	-	-	-	$17,406	$17,737	$18,074	$18,417	$18,767	$19,124	$19,487	$19,858	$20,235	$20,619	$21,011	$21,410	$21,817	$22,232	$22,654	$23,084	$23,523	$23,970	$24,425		
Power		$600	-	-	-	-	-	$672	$684	$698	$711	$724	$738	$752	$766	$781	$796	$811	$826	$842	$858	$874	$891	$908	$925	$943		
Operating Labor		$1,000	-	-	-	-	-	$1,120	$1,141	$1,163	$1,185	$1,207	$1,230	$1,253	$1,277	$1,301	$1,326	$1,351	$1,377	$1,403	$1,430	$1,457	$1,485	$1,513	$1,542	$1,571		
Maintenance Materials		$500	-	-	-	-	-	$560	$570	$581	$592	$604	$615	$627	$639	$651	$663	$676	$689	$702	$715	$729	$742	$756	$771	$786		
Maintenance Labor		$3,200	-	-	-	-	-	$3,583	$3,651	$3,720	$3,791	$3,863	$3,936	$4,011	$4,087	$4,165	$4,244	$4,325	$4,407	$4,490	$4,576	$4,663	$4,751	$4,842	$4,934	$5,027		
Total, O&M Costs		$46,303	$0	$0	$0	$0	$0	$51,839	$52,824	$53,828	$54,850	$55,893	$56,955	$58,037	$59,139	$60,263	$61,408	$62,575	$63,764	$64,975	$66,210	$67,468	$68,750	$70,056	$71,387	$72,743		
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$43,162	$42,660	$42,164	$41,673	$41,188	$40,708	$40,235	$39,766	$39,303	$38,846	$38,394	$37,947	$37,505	$37,069	$36,637	$36,211	$35,789	$35,373	$34,961		
Total NPV of O&M Costs		$740,000																										

NPV Summary	
Capital Cost	$30,753,000
Salvage	($2,384,000)
O&M	$740,000
Total NPV	**$29,109,000**

Total Salvage Value $4,960,000

Economic Assumptions

Capital Escalation (Inflation) Rate	1.00%
O&M Escalation (Inflation) Rate	1.90%
Annual Interest (Discount) Rate	3.10%

Notes:

(1) NPV Capital Costs is calculated from Mid Point of Construction Costs

THC WWTP

Auxiliary Treatment (Stand Alone) - Alternative 2 - CMF (115 MGD)

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

PROCESS or Project Element		Base Year Cost 2015	2016	2017	2018	2019	Mid-Point of Construction 2020	First Year of Service 2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Salvage Value @ 20 years	
Capital Costs (Modify as Required)																												
Stand Alone - CMF Filter																												
CMF Equipment (inc Blowers)		$6,960,000	-	-	-	-	$7,647,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Equipment Installation (%)	25%	$1,740,000	-	-	-	-	$1,912,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Superstructure		$0																									0%	$0
Earthwork		$324,210	-	-	-	-	$356,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$306,000
Concrete		$3,547,555	-	-	-	-	$3,898,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$3,344,000
Metals		$1,487,405	-	-	-	-	$1,634,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$701,000
Painting		$12,935	-	-	-	-	$14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Process Piping & Valves		$1,982,000	-	-	-	-	$2,178,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$934,000
HVAC & Plumbing		$0																									0%	$0
Blower/Electrical Building																												
Structure, Valves, and Piping		$1,530,000	-	-	-	-	$1,681,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$1,202,000
Non-Blower Equipment		$72,000	-	-	-	-	$79,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Miscellaneous Structures & Piping		$0																									60%	$0
Markups																												
Electrical, Instrumentation & Controls	20%	$3,531,000	-	-	-	-	$3,879,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%	$3,531,000	-	-	-	-	$3,879,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Deep Foundation Adder		$2,126,250	-	-	-	-	$2,336,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
General Requirements	15%	$4,027,000	-	-	-	-	$4,424,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%	$7,718,000	-	-	-	-	$8,480,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%	$9,647,000	-	-	-	-	$10,599,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs		$48,236,000	-	-	-	-	$52,996,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year[1]			-	-	-	-	$45,493,543	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs[1]		$45,494,000																										
NPV of Salvage Value		$3,118,000																										
O&M Costs (Modify As Required)																												
Polymer		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Ferric		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Media Replacement		$17,800	-	-	-	-	-	$19,928	$20,307	$20,693	$21,086	$21,486	$21,895	$22,311	$22,734	$23,166	$23,607	$24,055	$24,512	$24,978	$25,452	$25,936	$26,429	$26,931	$27,443	$27,964		
Power		$1,300	-	-	-	-	-	$1,455	$1,483	$1,511	$1,540	$1,569	$1,599	$1,629	$1,660	$1,692	$1,724	$1,757	$1,790	$1,824	$1,859	$1,894	$1,930	$1,967	$2,004	$2,042		
Operating Labor		$200	-	-	-	-	-	$224	$228	$233	$237	$241	$246	$251	$255	$260	$265	$270	$275	$281	$286	$291	$297	$303	$308	$314		
Maintenance Materials		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Maintenance Labor		$4,600	-	-	-	-	-	$5,374	$5,476	$5,580	$5,686	$5,794	$5,904	$6,016	$6,131	$6,247	$6,366	$6,487	$6,610	$6,736	$6,864	$6,994	$7,127	$7,262	$7,400	$7,541		
Total, O&M Costs		$24,100	$0	$0	$0	$0	$0	$26,981	$27,494	$28,016	$28,549	$29,091	$29,644	$30,207	$30,781	$31,366	$31,962	$32,569	$33,188	$33,818	$34,461	$35,116	$35,783	$36,463	$37,156	$37,861		
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$22,465	$22,204	$21,945	$21,690	$21,437	$21,188	$20,941	$20,698	$20,457	$20,219	$19,983	$19,751	$19,521	$19,294	$19,069	$18,847	$18,628	$18,411	$18,197		
Total NPV of O&M Costs		$385,000																										

Salvage Value	
Total Salvage Value	$6,487,000

NPV Summary

Capital Cost	$45,494,000
Salvage	($3,118,000)
O&M	$385,000
Total NPV	**$42,761,000**

Economic Assumptions

Capital Escalation (Inflation) Rate	1.90%
O&M Escalation (Inflation) Rate	1.90%
Annual Interest (Discount) Rate	3.10%

Notes:

(1) NPV Capital Costs is calculated from Mid Point of Construction Costs

Appendix D - Dual purpose Filtration Costs

THC WWTP

Dual Purpose Filtration - Alternative 1 - CMF (115 MGD)

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

PROCESS or Project Element		Base Year Cost 2015	2016	2017	2018	2019	Mid-Point of Construction 2020	First Year of Service 2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Salvage Value @ 20 years	
Capital Costs (Modify as Required)																												
Dual Purpose - CMF Filter																											0%	$0
CMF Equipment (inc Blowers)		$6,960,000	-	-	-	-	$7,647,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Equipment Installation (%)	25%	$1,740,000	-	-	-	-	$1,912,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Superstructure		$0																									60%	$0
Earthwork		$324,210	-	-	-	-	$356,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$306,000
Concrete		$3,647,555	-	-	-	-	$3,898,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$3,344,000
Metals		$1,487,405	-	-	-	-	$1,634,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$701,000
Painting		$12,935	-	-	-	-	$14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Process Piping & Valves		$1,982,000	-	-	-	-	$2,178,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$934,000
HVAC & Plumbing		$0																									0%	$0
Blower/Electrical Building																												
Structure, Valves, and Piping		$1,530,000	-	-	-	-	$1,681,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,202,000
Non-Blower Equipment		$72,000	-	-	-	-	$79,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Miscellaneous Structures & Piping		$995,500	-	-	-	-	$1,094,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$938,000
Markups																												
Electrical, Instrumentation & Controls	20%	$3,730,000	-	-	-	-	$4,098,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%	$3,730,000	-	-	-	-	$4,098,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Deep Foundation Adder		$2,126,250	-	-	-	-	$2,336,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
General Requirements	16%	$4,236,000	-	-	-	-	$4,654,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%	$8,118,000	-	-	-	-	$8,919,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%	$10,148,000	-	-	-	-	$11,149,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs		$50,740,000	-	-	-	-	$55,747,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year(1)			-	-	-	-	$47,855,094	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs(1)		$47,855,000																										
NPV of Salvage Value		$3,569,000																										
O&M Costs (Modify As Required)																												
Polymer		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Ferric		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Media Replacement		$17,820	-	-	-	-	-	$19,950	$20,330	$20,716	$21,109	$21,510	$21,919	$22,336	$22,760	$23,192	$23,633	$24,082	$24,540	$25,006	$25,481	$25,965	$26,459	$26,961	$27,473	$27,995		
Power		$22,499	-	-	-	-	-	$25,189	$25,668	$26,156	$26,653	$27,159	$27,675	$28,201	$28,737	$29,283	$29,839	$30,406	$30,984	$31,572	$32,172	$32,783	$33,406	$34,041	$34,688	$35,347		
Operating Labor		$5,635	-	-	-	-	-	$6,308	$6,428	$6,550	$6,675	$6,802	$6,931	$7,062	$7,197	$7,333	$7,473	$7,615	$7,759	$7,907	$8,057	$8,210	$8,366	$8,525	$8,687	$8,852		
Maintenance Materials		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Maintenance Labor		$4,823	-	-	-	-	-	$5,399	$5,502	$5,607	$5,713	$5,822	$5,932	$6,045	$6,160	$6,277	$6,396	$6,518	$6,642	$6,768	$6,896	$7,027	$7,161	$7,297	$7,436	$7,577		
Total, O&M Costs	$22,643	$50,777	$0	$0	$0	$0	$0	$56,848	$57,928	$59,028	$60,150	$61,293	$62,457	$63,644	$64,853	$66,085	$67,341	$68,620	$69,924	$71,253	$72,607	$73,986	$75,392	$76,824	$78,284	$79,771		
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$47,333	$46,782	$46,237	$45,699	$45,167	$44,641	$44,122	$43,608	$43,101	$42,599	$42,103	$41,613	$41,129	$40,650	$40,177	$39,709	$39,247	$38,790	$38,339		
Total NPV of O&M Costs		$811,000																										

Total Salvage Value $7,425,000

NPV Summary

Capital Cost	$47,855,000
Salvage	($3,569,000)
O&M	$811,000
Total NPV	**$45,097,000**

Economic Assumptions

Capital Escalation (Inflation) Rate	1.90%
O&M Escalation (Inflation) Rate	1.90%
Annual Interest (Discount) Rate	3.10%

Notes:

(1) NPV Capital Costs is calculated from Mid Point of Construction Costs

Appendix E - Disinfection Costs

TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE - TM 4
LIFE CYCLE COST ANALYSIS
Disinfection Alternative 1 Multi-Barrier, UV Plus Hypochlorite - 57 MGD UV @ 40 MJ Dose (Years 1 - 10) and 30 MGD UV @ 100 MJ Dose (Years 11 - 20)

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

		Base Year Cost					Mid-Point of Construction	First Year of Service																			Salvage Value @ 20 years	
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039		
Capital Costs (Modify as Required)																												
Process & Electrical Equipment		$3,000,000	-	-	-	-	$3,296,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Equipment Installation (%)	25%	$750,000	-	-	-	-	$824,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Concrete																											60%	$0
Structural Excavation																											60%	$0
Dewatering		$10,000	-	-	-	-	$11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$9,000
Metals																											30%	$0
Building/Super Structure [2]		$2,860,000	-	-	-	-	$3,142,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50%	$2,247,000
Miscellaneous Piping and Valves																											0%	$0
Markups																											Total Salvage Value	$2,256,000
Electrical, Instrumentation & Controls	20%	$1,324,000	-	-	-	-	$1,455,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%	$1,324,000	-	-	-	-	$1,455,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Deep Foundation Adder		$357,500	-	-	-	-	$393,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
General Requirements	15%	$1,444,000	-	-	-	-	$1,586,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%	$2,767,000	-	-	-	-	$3,040,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%	$3,459,000	-	-	-	-	$3,800,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs		$17,296,000	-	-	-	-	$19,002,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year[1]			-	-	-	-	$16,311,954	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs[1]		$16,312,000																										
NPV of Salvage Value		$1,084,000																										
O&M Costs (Modify As Required)																												
Electricity [4]		$27,000	-	-	-	-	-	$30,228	$30,802	$31,388	$31,984	$32,592	$33,211	$33,842	$34,485	$35,140	$35,808	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Electricity [5]		$92,000	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$124,330	$126,692	$129,099	$131,552	$134,051	$136,598	$139,194	$141,838	$144,533		
Equipment O&M and Replacement (%) [4]		$34,000	-	-	-	-	-	$38,065	$38,788	$39,525	$40,276	$41,041	$41,821	$42,616	$43,425	$44,250	$45,091	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Equipment O&M and Replacement (%) [5]		$137,000	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$185,143	$188,661	$192,245	$195,898	$199,620	$203,413	$207,278	$211,216	$215,229		
Labor [3]		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Chemicals		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Total, O&M Costs		$290,000	$0	$0	$0	$0	$0	$68,293	$69,590	$70,913	$72,260	$73,633	$75,032	$76,457	$77,910	$79,390	$80,899	$309,473	$315,353	$321,344	$327,450	$333,672	$340,011	$346,472	$353,054	$359,763		
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$56,862	$56,200	$55,546	$54,900	$54,261	$53,629	$53,005	$52,388	$51,778	$51,176	$189,882	$187,672	$185,488	$183,329	$181,195	$179,086	$177,001	$174,941	$172,905		
Total NPV of O&M Costs		$2,171,000																										

NPV Summary

Capital Cost		$16,312,000
Salvage		($1,084,000)
O&M		$2,171,000
	Total NPV	**$17,399,000**

Economic Assumptions

Capital Escalation (Inflation) Rate	1.90%
O&M Escalation (Inflation) Rate	1.90%
Annual Interest (Discount) Rate	3.10%

Notes:
(1) NPV Capital Costs is calculated from Mid Point of Construction Costs
(2) Assumes 520 $/sf for structure cost (excludes equipment, electrical, dewatering, etc). Used LBVSD Phase 2 WWTP as go by, adjusted items to be more project specific, and add 10% factor for low bid contingency.
Square foot cost represents 2015 dollars, inflated from 2012 at a 2.0% inflation rate
Based on structure footprint of 55' X 100'
(3) Assumes labor costs are similar compared to hypo disinfection alternative and therefore excluded
(4) Assumes 40 MJ (MS2) dose for year round disinfection. Obtained from Trojan.
(5) Assumes 100 MJ (MS2) dose for 7 months and 40 MJ dose for 5 months for year round disinfection. Obtained from Trojan.

TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE - TM 4
LIFE CYCLE COST ANALYSIS
Disinfection Alternative 1 Multi-Barrier, UV Plus Hypochlorite - 172 MGD Hypochlorite

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

		Base Year Cost					Mid-Point of Construction	First Year of Service																			Salvage Value @ 20 years	
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039		
Capital Costs (Modify as Required)																												
Process & Electrical Equipment		$865,000	-	-	-	-	$950,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Equipment Installation (%)	25%	$216,000	-	-	-	-	$237,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Concrete		$2,706,000	-	-	-	-	$2,966,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$2,545,000
Structural Excavation		$491,000	-	-	-	-	$539,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$463,000
Dewatering		$35,000	-	-	-	-	$38,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$33,000
Superstructure (2)		$1,035,000	-	-	-	-	$1,137,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$976,000
Metals		$210,000	-	-	-	-	$231,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$99,000
Miscellaneous Piping and Valves		$100,000	-	-	-	-	$110,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$47,000
Protective Coatings		$50,000	-	-	-	-	$55,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
HVAC		$180,000	-	-	-	-	$198,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Markups																											Total Salvage Value	$4,163,000
Electrical, Instrumentation & Controls	20%	$1,176,000	-	-	-	-	$1,292,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%	$1,176,000	-	-	-	-	$1,292,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Deep Foundation Adder		$1,183,000	-	-	-	-	$1,300,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
General Requirements	15%	$1,413,000	-	-	-	-	$1,552,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%	$2,706,000	-	-	-	-	$2,975,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%	$3,385,000	-	-	-	-	$3,719,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs		$16,923,000	-	-	-	-	$18,591,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year(1)			-	-	-	-	$15,959,138	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs(1)		$15,959,000																										
NPV of Salvage Value		$2,001,000																										
O&M Costs (Modify As Required)																												
Electricity		$400	-	-	-	-	-	$448	$456	$465	$474	$483	$492	$501	$511	$521	$530	$541	$551	$561	$572	$583	$594	$605	$617	$628		
Chemicals (3)		$5,000	-	-	-	-	-	$5,598	$5,704	$5,813	$5,923	$6,035	$6,150	$6,267	$6,386	$6,507	$6,631	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Chemicals (3)		$63,000	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$85,139	$86,756	$88,405	$90,084	$91,796	$93,540	$95,317	$97,129	$98,974		
Equipment O&M and Replacement (%)	1%	$8,650	-	-	-	-	-	$9,684	$9,868	$10,056	$10,247	$10,441	$10,640	$10,842	$11,048	$11,258	$11,472	$11,690	$11,912	$12,138	$12,369	$12,604	$12,843	$13,087	$13,336	$13,589		
Labor (4)			-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Total, O&M Costs		$77,050	$0	$0	$0	$0	$0	$15,730	$16,029	$16,333	$16,643	$16,960	$17,282	$17,610	$17,945	$18,286	$18,633	$97,369	$99,219	$101,104	$103,025	$104,983	$106,977	$109,010	$111,081	$113,192		
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$13,097	$12,944	$12,794	$12,645	$12,498	$12,352	$12,209	$12,068	$11,926	$11,787	$59,742	$59,047	$58,360	$57,680	$57,009	$56,346	$55,690	$55,042	$54,401		
Total NPV of O&M Costs		$638,000																										

NPV Summary

Capital Cost	$15,959,000
Salvage	($2,001,000)
O&M	$638,000
Total NPV	**$14,596,000**

Economic Assumptions

Capital Escalation (Inflation) Rate	1.90%
O&M Escalation (Inflation) Rate	1.90%
Annual Interest (Discount) Rate	3.10%

Notes:
(1) NPV Capital Costs is calculated from Mid Point of Construction Costs
(2) Based on structure footprints of 60 X 75 for Chemical Building and 100 X 170 for Contact Basin
(3) Assumes hypochlorite for flows above 57 MGD for Years 1 - 10 for E. Coli requirement and 30 MGD for Years 11 - 20 for virus requirement
(4) Assumes labor costs are similar between UV and Ozone disinfection alternatives as a whole and therefore excluded

TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE - TM 4
LIFE CYCLE COST ANALYSIS
Disinfection Alternative 2, Ozone - 57 MGD

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

		Base Year Cost					Mid-Point of Construction	First Year of Service																			Salvage Value @ 20 years	
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039		
Capital Costs (Modify as Required)																												
Process & Electrical Equipment		$3,270,000	-	-	-	-	$3,593,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Equipment Installation (%)	25%	$818,000	-	-	-	-	$899,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Concrete		$1,142,000	-	-	-	-	$1,255,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,076,000
Structural Excavation		$148,000	-	-	-	-	$163,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$140,000
Dewatering		$30,000	-	-	-	-	$33,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$28,000
Superstructure [2]		$1,294,000	-	-	-	-	$1,422,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60%	$1,220,000
Metals		$75,000	-	-	-	-	$82,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$35,000
Miscellaneous Piping and Valves		$100,000	-	-	-	-	$110,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30%	$47,000
HVAC		$225,000	-	-	-	-	$247,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	$0
Markups																												
Electrical, Instrumentation & Controls	20%	$1,420,000	-	-	-	-	$1,560,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sitework	20%	$1,420,000	-	-	-	-	$1,560,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Deep Foundation Adder		$421,000	-	-	-	-	$463,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
General Requirements	15%	$1,554,000	-	-	-	-	$1,707,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Contingency	25%	$2,979,000	-	-	-	-	$3,273,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
ELA	25%	$3,724,000	-	-	-	-	$4,091,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total, Capital Costs		$18,620,000	-	-	-	-	$20,458,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
NPV of Capital Cost at Base Year [1]			-	-	-	-	$17,561,833	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total NPV of Capital Costs [1]		$17,562,000																										
NPV of Salvage Value		$1,224,000																										
O&M Costs (Modify As Required)																												
Electricity [4]		$493,000	-	-	-	-	-	$551,940	$562,427	$573,113	$584,002	$595,098	$606,405	$617,927	$629,668	$641,631	$653,822	$666,245	$678,903	$691,803	$704,947	$718,341	$731,989	$745,897	$760,069	$774,511		
Chemicals		$664,300	-	-	-	-	-	$743,720	$757,850	$772,250	$786,922	$801,874	$817,110	$832,635	$848,455	$864,575	$881,002	$897,741	$914,798	$932,180	$949,891	$967,939	$986,330	$1,005,070	$1,024,166	$1,043,625		
Equipment O&M and Replacement (%) [5]	3%	$98,100	-	-	-	-	-	$109,828	$111,915	$114,041	$116,208	$118,416	$120,666	$122,959	$125,295	$127,676	$130,101	$132,573	$135,092	$137,659	$140,274	$142,940	$145,655	$148,423	$151,243	$154,117		
Labor		-	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0		
Total, O&M Costs		$1,255,000	$0	$0	$0	$0	$0	$1,405,488	$1,432,193	$1,459,404	$1,487,133	$1,515,388	$1,544,181	$1,573,520	$1,603,417	$1,633,882	$1,664,926	$1,696,559	$1,728,794	$1,761,641	$1,795,112	$1,829,219	$1,863,975	$1,899,390	$1,935,479	$1,972,253		
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$1,170,241	$1,156,620	$1,143,158	$1,129,853	$1,116,702	$1,103,705	$1,090,858	$1,078,162	$1,065,613	$1,053,210	$1,040,951	$1,028,836	$1,016,861	$1,005,025	$993,328	$981,766	$970,339	$959,045	$947,883		
Total NPV of O&M Costs		$20,052,000																										

Salvage Value @ 20 years

Total Salvage Value $2,546,000

NPV Summary

Capital Cost	$17,562,000
Salvage	($1,224,000)
O&M	$20,052,000
Total NPV	**$36,390,000**

Economic Assumptions

Capital Escalation (Inflation) Rate	1.80%
O&M Escalation (Inflation) Rate	1.50%
Annual Interest (Discount) Rate	3.10%

Notes:
(1) NPV Capital Costs is calculated from Mid Point of Construction Costs
(2) Based on Building Footprint of 75' X 75' and Contact Basin Footprint of 40' x 70'
(3) Assumes labor costs are similar between UV and Ozone disinfection options and therefore are excluded

TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE - TM 4
LIFE CYCLE COST ANALYSIS
Disinfection Alternative 2 - 115 MGD Hypochlorite

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

		Base Year Cost					Mid-Point of Construction	First Year of Service																			
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Salvage Value @ 20 years
Capital Costs (Modify as Required)																											
Process & Electrical Equipment		$770,000	-	-	-	-	$846,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0% $0
Equipment Installation (%)	25%	$193,000	-	-	-	-	$212,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0% $0
Concrete		$1,603,000	-	-	-	-	$1,981,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60% $1,700,000
Structural Excavation		$337,000	-	-	-	-	$370,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60% $318,000
Dewatering		$30,000	-	-	-	-	$33,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60% $28,000
Superstructure (2)		$966,000	-	-	-	-	$1,061,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60% $911,000
Metals		$195,000	-	-	-	-	$214,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30% $92,000
Miscellaneous Piping and Valves		$100,000	-	-	-	-	$110,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30% $47,000
Protective Coatings		$50,000	-	-	-	-	$55,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0% $0
HVAC		$168,000	-	-	-	-	$185,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0% $0
Markups																											Total Salvage Value $3,096,000
Electrical, Instrumentation & Controls	20%	$922,000	-	-	-	-	$1,013,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Sitework	20%	$922,000	-	-	-	-	$1,013,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Deep Foundation Adder		$792,000	-	-	-	-	$870,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
General Requirements	15%	$1,087,000	-	-	-	-	$1,194,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Contingency	25%	$2,084,000	-	-	-	-	$2,290,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
ELA	25%	$2,605,000	-	-	-	-	$2,862,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total, Capital Costs		$13,024,000	-	-	-	-	$14,309,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
NPV of Capital Cost at Base Year(1)			-	-	-	-	$12,283,325	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total NPV of Capital Costs(1)		$12,283,000																									
NPV of Salvage Value		$1,488,000																									
O&M Costs (Modify As Required)																											
Electricity		$400	-	-	-	-	-	$448	$456	$465	$474	$483	$492	$501	$511	$521	$530	$541	$551	$561	$572	$583	$594	$605	$617	$628	
Chemicals (3)		$5,000	-	-	-	-	-	$5,598	$5,704	$5,813	$5,923	$6,035	$6,150	$6,267	$6,386	$6,507	$6,631	$6,757	$6,885	$7,016	$7,150	$7,285	$7,424	$7,565	$7,709	$7,855	
Equipment O&M and Replacement (%)	1%	$7,700	-	-	-	-	-	$8,621	$8,784	$8,951	$9,121	$9,295	$9,471	$9,651	$9,835	$10,021	$10,212	$10,406	$10,604	$10,805	$11,010	$11,220	$11,433	$11,650	$11,871	$12,097	
Labor (4)			-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Total, O&M Costs		$13,100	$0	$0	$0	$0	$0	$14,666	$14,945	$15,229	$15,518	$15,813	$16,113	$16,420	$16,732	$17,049	$17,373	$17,703	$18,040	$18,383	$18,732	$19,088	$19,450	$19,820	$20,197	$20,580	
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$12,211	$12,069	$11,929	$11,790	$11,653	$11,517	$11,383	$11,251	$11,120	$10,990	$10,862	$10,736	$10,611	$10,487	$10,365	$10,245	$10,125	$10,008	$9,891	
Total NPV of O&M Costs		$209,000																									

NPV Summary

Capital Cost	$12,283,000
Salvage	($1,488,000)
O&M	$209,000
Total NPV	**$11,004,000**

Economic Assumptions

Capital Escalation (Inflation) Rate	1.90%
O&M Escalation (Inflation) Rate	1.90%
Annual Interest (Discount) Rate	3.10%

Notes:
(1) NPV Capital Costs is calculated from Mid Point of Construction Costs
(2) Based on structure footprints of 60 X 70 for Chemical Building and 100 X 100 for Contact Basin
(3) Assumes hypochlorite for flows above 57 MGD
(4) Assumes labor costs are similar between UV and Ozone disinfection alternatives as a whole and therefore excluded

TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE - TM 4
LIFE CYCLE COST ANALYSIS
Disinfection Alternative 3 - 172 MGD Hypochlorite

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

		Base Year Cost					Mid-Point of Construction	First Year of Service																			
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Salvage Value @ 20 years
Capital Costs (Modify as Required)																											
Process & Electrical Equipment		$865,000	-	-	-	-	$950,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0% $0
Equipment Installation (%)	25%	$216,000	-	-	-	-	$237,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0% $0
Concrete		$2,700,000	-	-	-	-	$2,966,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60% $2,545,000
Structural Excavation		$491,000	-	-	-	-	$539,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60% $463,000
Dewatering		$35,000	-	-	-	-	$38,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60% $33,000
Superstructure [2]		$1,035,000	-	-	-	-	$1,137,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60% $976,000
Metals		$210,000	-	-	-	-	$231,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30% $99,000
Miscellaneous Piping and Valves		$100,000	-	-	-	-	$110,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30% $47,000
Protective Coatings		$50,000	-	-	-	-	$55,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0% $0
HVAC		$180,000	-	-	-	-	$198,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0% $0
Markups																											Total Salvage Value $4,163,000
Electrical, Instrumentation & Controls	20%	$1,176,000	-	-	-	-	$1,292,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Sitework	20%	$1,176,000	-	-	-	-	$1,292,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Deep Foundation Adder		$1,183,000	-	-	-	-	$1,300,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
General Requirements	15%	$1,413,000	-	-	-	-	$1,552,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Contingency	25%	$2,708,000	-	-	-	-	$2,975,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
ELA	25%	$3,385,000	-	-	-	-	$3,719,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total, Capital Costs		$16,923,000	-	-	-	-	$18,591,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
NPV of Capital Cost at Base Year[1]			-	-	-	-	$15,959,138	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total NPV of Capital Costs[1]		$15,959,000																									
NPV of Salvage Value		$2,001,000																									
O&M Costs (Modify As Required)																											
Electricity		$3,100	-	-	-	-	-	$3,471	$3,537	$3,604	$3,672	$3,742	$3,813	$3,886	$3,959	$4,035	$4,111	$4,189	$4,269	$4,350	$4,433	$4,517	$4,603	$4,690	$4,779	$4,870	
Chemicals [3]		$253,000	-	-	-	-	-	$283,247	$288,629	$294,113	$299,701	$305,395	$311,198	$317,111	$323,136	$329,275	$335,531	$341,907	$348,403	$355,022	$361,768	$368,641	$375,646	$382,783	$390,056	$397,467	
Equipment O&M and Replacement (%)	1%	$8,650	-	-	-	-	-	$9,684	$9,868	$10,056	$10,247	$10,441	$10,640	$10,842	$11,048	$11,258	$11,472	$11,690	$11,912	$12,138	$12,369	$12,604	$12,843	$13,087	$13,336	$13,589	
Labor [4]			-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Total, O&M Costs		$264,750	$0	$0	$0	$0	$0	$296,402	$302,034	$307,772	$313,620	$319,579	$325,651	$331,838	$338,143	$344,568	$351,114	$357,786	$364,584	$371,511	$378,569	$385,762	$393,092	$400,560	$408,171	$415,926	
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$246,791	$243,918	$241,079	$238,273	$235,500	$232,759	$230,050	$227,372	$224,726	$222,110	$219,525	$216,970	$214,445	$211,949	$209,482	$207,044	$204,634	$202,252	$199,898	
Total NPV of O&M Costs		$4,229,000																									

NPV Summary	
Capital Cost	$15,959,000
Salvage	($2,001,000)
O&M	$4,229,000
Total NPV	**$18,187,000**

Economic Assumptions

Capital Escalation (Inflation) Rate	1.00%
O&M Escalation (Inflation) Rate	1.00%
Annual Interest (Discount) Rate	3.10%

Notes:
(1) NPV Capital Costs is calculated from Mid Point of Construction Costs
(2) Based on structure footprints of 60 X 75 for Chemical Building and 100 X 170 for Contact Basin
(3) Hypochlorite for disinfection of all effluent flows
(4) Labor costs excluded

Appendix F - Effluent Reaeration Costs

TOMAHAWK CREEK WWTF
PROJECT DEFINITION PHASE - TM 4
LIFE CYCLE COST ANALYSIS
Effluent Reaeration - 172 MGD

Base Year for cost Estimate	2015
First Year of Service	2021
Mid-Point of Construction	2020

		Base Year Cost					Mid-Point of Construction	First Year of Service																		
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Capital Costs (Modify as Required)																										
Process & Electrical Equipment		$70,000	-	-	-	-	$77,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equipment Installation (%)	20%	$14,000	-	-	-	-	$15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Concrete		$491,000	-	-	-	-	$539,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Structural Excavation		$81,000	-	-	-	-	$89,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dewatering		$15,000	-	-	-	-	$16,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous Piping and Valves		$40,000	-	-	-	-	$44,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Markups																										
Electrical, Instrumentation & Controls	5%	$36,000	-	-	-	-	$40,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sitework	20%	$142,000	-	-	-	-	$156,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Deep Foundations	N/A	$118,000	-	-	-	-	$118,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
General Requirements	15%	$151,000	-	-	-	-	$166,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contingency	25%	$290,000	-	-	-	-	$319,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ELA	25%	$362,000	-	-	-	-	$398,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, Capital Costs		$1,810,000	-	-	-	-	$1,977,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NPV of Capital Cost at Base Year[1]			-	-	-	-	$1,697,123	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total NPV of Capital Costs[1]		$1,697,000																								
NPV of Salvage Value		$256,000																								
O&M Costs (Modify As Required)																										
Electricity			-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Chemicals			-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Equipment O&M and Replacement (%)	3%	$2,100	-	-	-	-	-	$2,351	$2,396	$2,441	$2,488	$2,535	$2,583	$2,632	$2,682	$2,733	$2,785	$2,838	$2,892	$2,947	$3,003	$3,060	$3,118	$3,177	$3,238	$3,299
Labor		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Additional O&M		$0	-	-	-	-	-	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total, O&M Costs		$2,100	$0	$0	$0	$0	$0	$2,351	$2,396	$2,441	$2,488	$2,535	$2,583	$2,632	$2,682	$2,733	$2,785	$2,838	$2,892	$2,947	$3,003	$3,060	$3,118	$3,177	$3,238	$3,299
NPV of O&M Cost at Base Year			$0	$0	$0	$0	$0	$1,958	$1,935	$1,912	$1,890	$1,868	$1,846	$1,825	$1,804	$1,783	$1,762	$1,741	$1,721	$1,701	$1,681	$1,662	$1,642	$1,623	$1,604	$1,586
Total NPV of O&M Costs		$34,000																								

Salvage Value @ 20 years	
0%	$0
0%	$0
60%	$429,000
60%	$71,000
60%	$13,000
30%	$19,000
Total Salvage Value	$532,000

NPV Summary

Capital Cost	$1,697,000
Salvage	($256,000)
O&M	$34,000
Total NPV	**$1,475,000**

Economic Assumptions

Capital Escalation (Inflation) Rate	1.00%
O&M Escalation (Inflation) Rate	1.00%
Annual Interest (Discount) Rate	3.10%

Notes:
(1) NPV Capital Costs is calculated from Mid Point of Construction Costs