

ALTOONA WATER AUTHORITY

**EASTERLY AND WESTERLY
WASTEWATER TREATMENT FACILITIES**

SLUDGE DIGESTION EVALUATION

JULY 16, 2009

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LIST OF ABBREVIATIONS

AWA	Altoona Water Authority
BFP	Belt Filter Press
BOD	Biochemical Oxygen Demand
CF	Cubic Feet
CFM	Cubic Feet per Minute
COD	Chemical Oxygen Demand
DEP	Department of Environmental Protection
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
EQ	Equalization Flow
FOG	Fats, Oil and Grease
GBT	Gravity Belt Thickener
HRT	Hydraulic Retention Time
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
NPDES	National Pollutant Discharge Elimination System
PF	Press Feed
RAS	Return Activated Sludge
SC	Sludge Cake
SCADA	Supervisory Control And Data Acquisition
SLR	Surface Loading Rate
SOR	Surface Overflow Rate
SOUR	Specific Oxygen Uptake Rate

LIST OF ABBREVIATIONS (Continued)...

SU	Standard Unit
SWD	Side Water Depth
TD	Thickener Discharge
TF	Thickener Feed
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TS	Total Solids
TSS	Total Suspended Solids
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge
WOR	Weir Overflow Rate
WWTF	Waste Water Treatment Facility



GWIN
DOBSON &
FOREMAN INC

CONSULTING ENGINEERS

July 16, 2009

Mark Perry, General Manager
Altoona Water Authority
20 Greenwood Road
Altoona, PA 16602-7114

**RE: Easterly and Westerly Wastewater Treatment Facilities
Sludge Digestion Evaluation**

Dear Mark:

Please find enclosed our Sludge Digestion Evaluation report performed at the Easterly and Westerly Wastewater Treatment Facilities. This report assesses the activated sludge, aerobic digestion and sludge handling processes.

The study includes a performance assessment and comparison of the existing aerobic digestion at the Easterly and Westerly facilities. We have also included results of a two week intensive sampling and testing program. In addition, we have incorporated data analysis of different sub processes. This report should provide sufficient information for optimization of the aerobic digestion process.

We are available to discuss this report with operating personnel at your convenience. Meanwhile, if you have any questions or require additional information, please contact our office at your convenience.

Sincerely,
GWIN, DOBSON & FOREMAN, INC.

Mark Glenn, P.E.
President

Enclosures
MG/mad
reports/82006-31.doc

cc: Central File
Ravi Bhardwaj, GD&F
Jim Butler, GD&F

EXECUTIVE SUMMARY

1. Influent organic concentration and loading are higher at the Westerly plant than that at the Easterly, which leads to higher cell growth and thus higher total suspended solids and volatile suspended solids in mixed liquor, return activated sludge, waste activated sludge and digested sludge at Westerly.
2. Aeration tanks at the Westerly plant receive higher organic loading but have less retention time to treat. This implies that the process at the Westerly is more taxed than that at the Easterly plant.
3. The Westerly plant received almost twice the amount of septage per day than that received at the Easterly plant. The volume of septage waste received at the Westerly was three times more than that received at the Easterly. However, the Easterly received higher organic and solids loadings than the Westerly implying that septage waste delivered to the Easterly is more concentrated.
4. Considerable foaming was observed at both the Easterly and Westerly aerobic digesters due to the lack of dissolved oxygen. Low DO values (below 2.0 mg/L) were observed in both the digesters, particularly in the primary digester. Foaming could be resolved by maintaining DO above 2.0 mg/L in the digesters through operating more blowers. It can also be addressed by adding chemical oxidants such as hydrogen peroxide.
5. A high volume of sludge digestion is occurring in the secondary digesters. This finding is vindicated by low pH in the secondary digester at both plants. Also, higher VSS reduction is observed in the secondary digester than that in the primary digester.
6. Aerobic digestion can be maximized by transferring sludge from the primary to secondary digesters more frequently. Current operation strategy is to transfer sludge once a week. We recommend that sludge transfer be done 2.4 times per week. We recommend that sludge transfer be done 2.4 times per week.
7. The lime addition facility at the Westerly plant is not operational. However, lime should be added to digesters (even manually) to maintain pH above 5.5 for better sludge digestion.
8. Gravity belt thickening (GBT) at the Westerly uses considerably more (i.e. 2.4 times) polymer than the Easterly GBT. Though thickened sludge has a higher solids percentage at the Westerly, the solids percentage is not proportional to polymer usage.
9. From January - April 2009, VSS reduction is higher at the Easterly plant than that at Westerly. In fact, VSS reduction at the Westerly digesters is below 38%, the minimum value recommended by the PADEP for Class B biosolids. However, during our study, VSS reduction at the Westerly plant (44%) met the minimum 38% reduction criteria, while the Easterly plant at 35% did not. The Easterly plant passed the SOUR test (0.5 mg O₂/hr/gTSS) with a better result than the Westerly WWTF (1.4mg O₂/hr/gTSS).

EXECUTIVE SUMMARY (Continued)...

10. Of the total VSS reduction at the Easterly plant, 45% was accomplished in the primary digester and 55% in the secondary digester. At the Westerly plant, primary and secondary digester VSS reductions were 48% and 52%, respectively. This finding contradicts the notion that practically all VSS destruction occurs in the primary digester leaving the secondary digester to act as a variable level holding tank and emphasizes the need to maximize digester volume.
11. The primary digestion process at both plants provided for the first phase (biomass oxidation) of the aerobic solids stabilization only. No nitrification occurred in the primary digester due to the low (< 1.0) DO content.
12. As anticipated, the concentration of fats, oils, and grease (FOG) in the Westerly plant waste activated sludge exceeded the concentration in the Easterly (by a factor of 1.8). The impact FOG has on digestion process could not be independently evaluated due to the addition of FOG digesting bacteria in the primary digester feed. This bacteria feed is effective in minimizing FOG impact on the digestion process.
13. During the study, the activated sludge production/waste rate for the Easterly WWTF (5,046 lbsTSS/d) closely matched the sludge process loadings the system could be expected to handle. The Westerly WWTF sludge processing facilities, on the other hand, were substantially underloaded at 4,657 lbs/TSS/d.
14. The characteristics of aerobically digested sludge solids (as determined by the study) indicated that the Easterly plant achieved a significantly greater degree of nitrification than the Westerly. This is evidenced by filtrate ammonia values of 5.3 mg/L for the Easterly as opposed to 39.4 mg/L for the Westerly.
15. Digester loadings monitored during the study were significantly less than loadings predicted for BNR design conditions. Future higher loadings anticipated by design in addition to low wintertime temperatures (5.0°C) emphasize the importance of optimizing the aerobic digestion process at both plants. Elements included in optimization are: increase effective digester volume by increasing frequency of primary to secondary sludge transfer, increase air supply to primary digester to maintain a minimum DO of 2.0 mg/L and provide for pH adjustment to maintain a minimum pH of 5.5.
16. According to data for 2009, sludge production rates for the Westerly WWTF that have a direct bearing on aerobic digester loadings are lower than predicted values based upon BOD and fixed suspended solids (FSS) removals. This imbalance must be resolved in order to accurately define aerobic digester loadings.
17. We recommend that accurate data be recorded for proper digester operation. These parameters include waste sludge pumping rates and volumes, feed solids pumping rates and volumes, volatile suspended solids reduction, filtrate concentration and solids percentage (waste and feed solids). Resulting calculations related to these tests should be performed for sludge retention time. These testing and computational methods will provide greater control of the sludge digestion and handling process.

EXECUTIVE SUMMARY (Continued)...

18. Daily operational sheets of Easterly and Westerly plant should include air flow (cfm), DO, temperature, pH and sludge level in primary and secondary digester. The existing DO, temperature, pH and level sensors at the digesters should be either repaired or replaced. All the abovementioned data can be configured and archived in the SCADA system.
19. At the Westerly plant, waste activated sludge analysis samples should be collected from the bleed off valve of the waste sludge transfer pump.

Section 1

INTRODUCTION

The Altoona Water Authority (AWA) Easterly and Westerly Wastewater Treatment Facilities are both scheduled for facilities upgrade to provide Biological Nutrient Removal. Design plans commensurate with PA Department of Environmental Protection (DEP) permit application requirements is completed for the Westerly WWTF. During the design phase, an assessment was made of existing equipment and unit operations to determine compatibility and adequacy for integration into the future facility. This assessment resulted in revisions to the sludge Handling/Processing System Section of the Design Engineer's Report which were included in the DEP Part II Permit Amendment submitted for the Westerly WWTF BNR upgrade. The proposed improvements consisted of three (3) major elements consisting of: a new dual functioning centrifuge for sludge thickening and dewatering redundancy, provision for wasting mixed liquor solids from aerobic reactor zones and a new sludge holding tank for digested sludge storage ahead of the solids dewatering unit.

Further review of the waste sludge processing systems of the Easterly and Westerly WWTF revealed noteworthy differences in performance between the two facilities even though the physical arrangement and operations are identical. This finding, in addition to the need to better define waste sludge operations, prompted a project proposal to evaluate aerobic sludge digester process performance. The study plan called for conducting intensive sampling and testing of both Easterly and Westerly systems, focusing on sludge handling operations as well as the aerobic sludge digestion processes. One week of data collection was scheduled for each plant. The Study was initiated in the latter part of April 2009. The fieldwork phase of the Study involved one week of intensive sampling and operations monitoring at each facility. Data collection for the Easterly plant began April 20, 2009. Sampling at the Westerly Plant was initiated a week later on April 27.

This report discusses the findings of the Study and documents a considerable amount of data in the form of laboratory results, operations monitoring and process computations. Following the Introduction, the report is divided into four (4) sections. Section 2: Methodology details the Study Plan and describes how it was carried out. Section 3: Activated Sludge Operations provides a brief review of the treatment processes at both plants, concentrating on the process and operating parameters of significance to characterizing sludge solids. Section 4: Waste Sludge Handling Operations discusses sludge thickening and dewatering operations. Finally, Section 5 discusses the aerobic sludge digestion processes at both plants and addresses the implications of the study results for BNR upgrade design parameters relative to sludge handling/processing system improvements recommended for the Westerly WWTF.

The project Study was a joint undertaking with participation by AWA plant operators, AWA laboratory personnel and Gwin, Dobson & Foreman (GD&F) personnel. We offer our sincere thanks to Matt Villani, Jim Farrell and other AWA operating staff for providing cooperation and direction during the fieldwork phase. The study wouldn't have been successful without the dedicated testing and analysis by Ken Streilein and AWA laboratory personnel.

Section 2

METHODOLOGY: DIGESTER EVALUATION STUDY

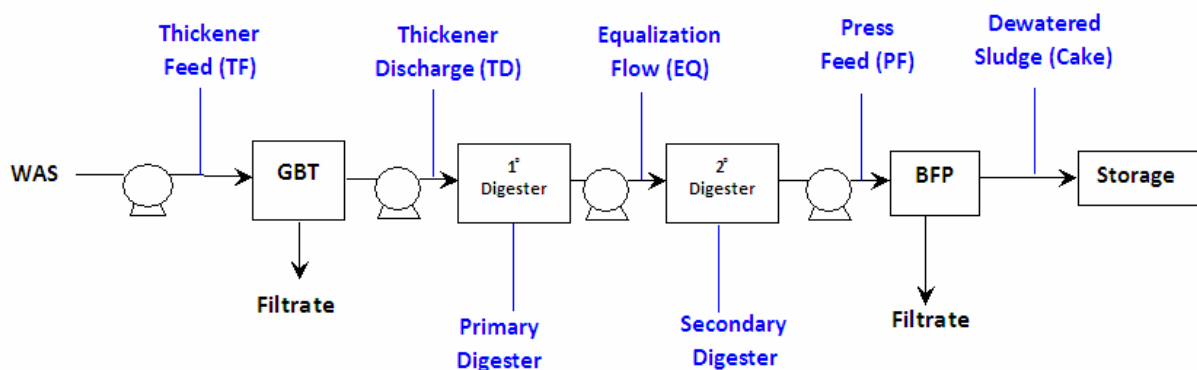
2.1 OVERVIEW OF STUDY PLAN

A study was conducted to compare the Easterly and Westerly WWTF aerobic digester operations and to identify differences that could explain performance disparities. The study lasted five (5) days at each plant for 10-12 hours a day. The study entailed sampling and testing of both digester systems at seven (7) process points with an emphasized focus on four (4) process points. The process points included:

1. Thickener Feed (TF) - WAS feed to gravity belt thickener (GBT)
2. Thickener Discharge (TD) - GBT discharge to primary digester
3. Onsite observation at primary digester
4. Equalization Flow (EQ) - Sludge transfer from the primary to the secondary digester
5. Onsite observation at secondary digester
6. Press Feed (PF) - Digested sludge feed to the belt filter press (BFP)
7. Sludge Cake (SC) - BFP discharge

Colored (blue) notations in Figure 3.1 represent schematic location of process points for sampling.

Figure 2.1: Sampling Location Schematic



Daily sampling and testing was performed at all the above-mentioned process points except at EQ, PF and SC process points. At the PF and SC process points, sampling and testing was done when the BFP was operated. At the EQ process point, sampling and testing was done for only one day. It was due to the fact that at each WWTF sludge is transferred between the digesters only once a week.

At TF and TD process points, a two (2) liter grab sample was collected and composited in a five (5) gallon container at a regular interval of three (3) hours. The samples were collected beginning 8:30 AM till 5:30 PM or as long as the GBT was operated. Thus, at the end of a normal operating day, four (4) 2L samples were composited in the jar with a total volume of 8L.

A one (1) liter grab sample was also collected whenever a 2L grab sample was composited. This sample was used to conduct a specific oxygen uptake rate (SOUR) test in the lab. TD samples were diluted by 50% for the test whereas TF samples are tested without dilution. The samples were diluted to reduce the %TS to 2% or below (which is a SOUR test precondition). Temperature and pH were also recorded while performing the oxygen uptake rate test. Approximately 250 mL volume of the diluted/undiluted sample was sent to the AWA laboratory for the %TS analysis. The %TS data, as reported by the AWA lab, was used to determine the SOUR.

At EQ and PF process points, two (2) liter grab samples were also collected and composited in separate five (5) gallon containers. Samples were collected at a regular interval of three (3) hours, starting when the processes were initiated. Efforts were made to collect at least three (3) 2L grab samples (six (6) liter sample total) by the end of the operation. Also one (1) liter grab samples were simultaneously collected for the SOUR test, pH and temperature analysis. Samples were diluted by 25% or 50%, contingent upon the %TS in the initial sample. Dilution was performed to lower TS to 2% or below for the sour test. A 250 mL sample of the diluted sample was sent to the AWA laboratory for %TS analysis.

Operating conditions were also observed and recorded at TF, TD, EQ and PF process points. Operating conditions that were recorded included operating pump speed (gpm), total run time and GBT/BFP belt speeds. Operating conditions at each WWTF are discussed in the following subsections.

At the end of each day, a one (1) liter sample was transferred from each five (5) gallon container to separate one (1) liter glass bottles. The bottles were refrigerated overnight and were collected the next morning by personnel from Fairway Laboratories Inc. (Altoona, PA). These samples were analyzed for fat, oil and grease (FOG) content. During the two (2) week study, twenty-eight (28) FOG samples were analyzed.

Also, at the end of every day, five (5) gallon jars (containing the remaining composited sample) were transported to the AWA laboratory at the Westerly WWTF. The AWA lab performed the following tests on each sample (filtered/unfiltered): TSS, TVS, BOD, COD, TKN, NH₃-N, NO₃-N, total phosphorus, alkalinity, acidity, and calcium. Refer to Table 2.1 for tests performed on filtered and unfiltered samples.

Simultaneous onsite evaluations were also conducted at the primary and secondary digesters. These observation/evaluations were also conducted every three (3) hours from 7:00 AM to 4:00 PM. Onsite analyses at the primary and secondary digesters included temperature, dissolved oxygen (DO), and sludge level measurements. Grab samples from each digester were then taken to the laboratory where pH was analyzed. General observations (foaming, etc.) of the digester were also recorded.

When the BFP was operated, dewatered cake samples (discharged from the BFP) were collected and analyzed for %TS using an infrared drying pan (1-hour duration). Thus, depending on the BFP operation time, up to five (5) samples were collected to represent a statistically consistent data set.

Table 2.1: Tests Performed on Composite Samples

Parameter	Thickener Feed (TF)		Thickener Discharge (TD)		Press Feed (PF)		Equalization Flow (EQ)	
	Unfiltered	Filtrate	Unfiltered	Filtrate	Unfiltered	Filtrate	Unfiltered	Filtrate
TSS	X		X		X		X	
TVS	X		X		X		X	
SOUR	X		X		X		X	
BOD	X	X	X	X	X	X	X	X
COD	X	X	X	X	X	X	X	X
FOG	X		X		X		X	
TKN	X	X	X	X	X	X	X	X
NH ₃ -N	X	X	X	X	X	X	X	X
NO ₃ -N	X	X	X	X	X	X	X	X
TP	X	X	X	X	X	X	X	X
Alkalinity	X		X		X		X	
Acidity	X		X		X		X	
Calcium		X		X		X		X

The specific operating conditions observed at the Easterly and Westerly WWTF are set forth below.

2.2 EASTERLY WASTEWATER TREATMENT FACILITY

Easterly WWTF sampling was done from April 20, 2009 to April 24, 2009. A rainfall total of 0.84 inches was recorded on Monday April 20, 2009. From Tuesday to Friday, 0.23 inches of precipitation was recorded. During the 5-day study period, the average temperature was 47.6° F with a low of 35° F and a high of 74° F.

During the study period, the GBT was operated daily, thus sampling and analysis was done everyday at TF and TD process points. The BFP was operated only on Monday and Tuesday, thus PF and SC samples were analyzed only during those days. Though the BFP was operated on Wednesday, sampling was not done as the BFP was operated during the third working shift.

Sampling at EQ process point was done on Thursday as the sludge was transferred from primary to secondary digester on that day. During the EQ process, the thickener was operated so sampling at TF and TD was performed simultaneously. However, the BFP was not operated during the EQ process. Refer to Table 2.2 for detailed sampling schedule followed at the Easterly WWTF.

Table 2.2: Easterly WWTF Sampling Schedule

Sample Time	Day of the Week				
	Monday 4/20/09	Tuesday 4/21/09	Wednesday 4/22/09	Thursday 4/23/09	Friday 4/24/09
7:00 AM	Digesters	Digesters	Digesters	Digesters	Digesters
7:30 AM				EQ	
8:00 AM					
8:30 AM	TF, TD	TF, TD	TF, TD	TF, TD	TF, TD
9:00 AM					
9:30 AM		SC			
10:00 AM	Digesters	Digesters, PF	Digesters	Digesters, EQ	Digesters
10:30 AM		SC			
11:00 AM	TF, TD				
11:30 AM		TF, TD	TF, TD	TF, TD	TF, TD
12:00 PM		SC			
12:30 PM					
1:00 PM	Digesters, SC	Digesters, PF	Digesters	Digesters	Digesters
1:30 PM	PF			EQ	
2:00 PM		SC			
2:30 PM	TF, TD, SC	TF, TD	TF, TD	TF, TD	TF, TD
3:00 PM					
3:30 PM	SC				
4:00 PM	Digesters	Digesters, PF,	Digesters	Digesters	Digesters
4:30 PM	PF				TF, TD
5:00 PM		TF, TD, SC	TF, TD	TF, TD	
5:30 PM	TF, TD, SC				
6:00 PM	PF				

2.2.1. Gravity Belt Thickener Feed

During the study, waste activated sludge (WAS) was pumped to the GBT through a Gorman-Rupp® centrifugal pump (i.e. pump number 4 in the tunnel). The pump was operated continuously between 140 - 188 gpm. A two (2) liter sample was collected from a bleed off valve on the pump. The sample was composited in a five (5) gallon container at a regular interval of three (3) hours beginning at 8:30 AM till 5:30 PM or as long as the process was operated. Thus, at the end of a normal operating day, four (4) 2L samples were composited in the container with a total volume of 8L. Simultaneously a one (1) liter grab sample was also collected for the SOUR analysis.

2.2.2. Gravity Belt Thickener Discharge

The gravity belt thickener (GBT) at the Easterly WWTF is a 3.0 meter Eimco® unit that has been in operation since its installation in 1992. Feed sludge is mixed with a cationic polymer before the sludge enters the belt thickener. The GBT was operated at a speed of 22 ft/min. It was observed that the feed sludge was spread uniformly on the belt thickener and discharged uniformly into the hopper.

The thickened sludge from the hopper is pumped to the primary (i.e. south) digester of the Easterly WWTF. During the study, a Gorman-Rupp® centrifugal pump (i.e. pump number 5 in the tunnel) was used to pump the thickened sludge. This pump operates intermittently (i.e. the pump runs for 2.2 minutes for every 10.3 minutes). This operation is controlled by two (2) separate timers. The speed of the pump varied as the level of sludge in the hopper changed.

A bleed off valve at the pump was used to collect samples. After every three (3) hours, a two (2) liter sample was composited in a five (5) gallon container and a one (1) liter sample was taken to the lab for SOUR analysis.

Lime is usually fed to the hopper to control pH in the primary digester. The operators report that lime-mixed thickened sludge could also be added to secondary digester if the pH falls below 5.0 in the digester.

2.2.3. Belt Filter Press Feed

Digested sludge from the secondary (i.e. north) digester of the Easterly WWTF is pumped to the BFP through a Moyno® positive displacement pump (i.e. pump number 3 in the tunnel). Samples for compositing and SOUR testing were collected from a bleed off valve on the pump.

The pump operations were intermittently halted when the bed of the truck (which transported dewatered sludge to the sludge storage building) was full. This break in the operation generally lasted 11 to 14 minutes for every two (2) hours of operation.

Feed sludge is mixed with the cationic polymer in a small tank on the BFP. The BFP at the Easterly WWTF is a 2.0 meter Eimco® unit installed in 1992. The belt was operated at a speed of 13 ft/min.

2.2.4. Belt Filter Press Cake Solids

Belt filter press cake (i.e. dewatered solids) sampling coincided with belt filter press feed sampling. Therefore, cake sampling took place on Monday April 20, 2009 and Tuesday April 21, 2009. Though the BFP was operated on Wednesday, April 22, 2009, no sampling was done as the press was operated during the third shift (i.e. between 11:00 PM and 7:00 AM).

Samples were collected at the discharge end of the BFP, just before the solids fall on conveyer. A total of nine (9) grab samples were collected during two (2) days of sampling. Each grab sample was analyzed at the AWA laboratory using an infrared drying pan.

2.2.5. Equalization Flow - Sludge Transfer from Primary (1°) To Secondary (2°) Digester

Sludge transfer (or equalization flow) from the primary to secondary digester occurs once every seven (7) days. During the study period, the transfer occurred on April 23, 2009 from 7:10 AM to 1:30 PM. The sludge was transferred via Gorman-Rupp® pump (i.e. pump number 2 in the tunnel). The pump rate fluctuated between 320 gpm to 414 gpm. Grab samples were collected for compositing and SOUR testing through a bleed off valve on the pump.

2.2.6. Aerobic Digester Operations

Daily process measurements were conducted at the primary and secondary digesters every three (3) hours from 7:00 AM to 4:00 PM totaling four (4) onsite evaluations at each digester per day (i.e. total of twenty (20) observations per digester during five (5) day study period). Onsite measurement at the primary and secondary digesters included temperature, dissolved oxygen (DO), and sludge level measurements. Temperature and DO were measured using a Hach® digital DO meter by placing the probe into the digester tanks at mid depth level. The primary digester was observed having DO readings above 1.00 mg/L only once throughout the twenty (20) onsite evaluations.

Sludge level measurements in the digesters were conducted using a metal tape. Depth of the surface of the sludge from the top of the tank wall was measured. The measured readings were subtracted from the total height of the tank wall to obtain the level of the sludge in the digesters.

Approximately one (1) liter grab samples from each digester were taken to the laboratory where pH was analyzed. Grab samples were obtained using a PVC sampler tied to a rope and a wooden handle. The samples were then poured into separate one (1) liter bottles and transported to the laboratory for pH analysis.

Observations were made about general operating conditions (i.e., digester foaming). These observations were recorded on daily log sheets. Constant foam was observed on the surface of both digesters. However, the foam was thicker on the primary digester than that on the secondary digester. Foaming is generally attributable to low air in the digesters (which is also supported by low DO readings).

The Easterly WWTF has two (2) blowers dedicated to the aerobic digestion process. Each digester blower is capable of providing 2,770 SCFM at 10.9 psi. As conveyed by the operator, only one digester blower is operated all the time. This was vindicated by the data obtain from SCADA system.

Refer to Appendix A for data generated during the Easterly WWTF digester evaluation study.

2.3 WESTERLY WASTEWATER TREATMENT FACILITY

Sampling took place at the Westerly WWTF from Monday April 27, 2009 through Friday May 1, 2009. Very small drizzle was observed on Tuesday April 28, 2009 (i.e. 0.02 inches) and on Friday May 1, 2009 (i.e. 0.12 inches). No rainfall or precipitation was observed on other days of the sampling period. The average weekly temperature was 60.6 °F with a low of 44 °F and a high of 89°F. It should be noted that the average temperature during the Westerly study was higher than that during the Easterly study.

During the study period, GBT was operated everyday, thus sampling and analysis was done everyday at TF and TD process points. BFP was operated from Monday (4/27/2009) to Thursday (4/30/2009), thus PF and SC samples were analyzed only during that time.

Sampling at EQ process point was done on Friday (4/30/2009) as the sludge was transferred from primary to secondary digester from 7:30 AM to 1:30 PM. At the Westerly WWTF, the EQ process usually happens once every seven (7) days. During the EQ process, neither thickener nor the press was operated so sampling at TF, TD, PF and SC was not performed. However the GBT was operated after EQ process was over. A major difference between the Easterly and Westerly operation is that at the Easterly GBT can be operated even when EQ is occurring, however GBT cannot be operated during the EQ process at the Westerly WWTF.

Refer to Table 2.3 for detailed sampling schedule of the Westerly WWTF.

Bacteria are added to the GBT discharge hopper to reduce fat, oil and grease (FOG) content in the digesters. More FOG producing businesses (like restaurants) are connected to the Westerly wastewater collection system than that to the Easterly collection system. Bacteria are also added to control foaming in the digesters.

Unlike at the Easterly, no lime addition to the digester or to influent channel (to the aeration tanks) takes place at the Westerly. The Westerly has lime addition and storage facility but it is currently not in the operational quality.

Table 2.3: Westerly WWTF Sampling Schedule

Sample Time	Day of the Week				
	Monday 4/27/09	Tuesday 4/28/09	Wednesday 4/29/09	Thursday 4/30/09	Friday 5/1/09
7:00 AM		Digesters	Digesters	Digesters	Digesters
7:30 AM	Digesters				
8:00 AM					
8:30 AM	TF, TD	TF, TD		TF, TD	EQ
9:00 AM					
9:30 AM			Digesters	PF, SC	
10:00 AM	Digesters	Digesters	TF, TD	Digesters	Digesters
10:30 AM		PF, SC	SC		
11:00 AM	TF, TD, SC		PF	SC	
11:30 AM	PF	TF, TD	TF, TD	TF, TD	EQ
12:00 PM		SC			
12:30 PM	SC			SC	
1:00 PM	Digesters	Digesters, PF	Digesters	Digesters, PF	Digesters
1:30 PM	PF		PF		EQ
2:00 PM		SC	SC		TF, TD
2:30 PM		TF, TD	TF, TD	TF, TD	
3:00 PM	TF, TD		SC		
3:30 PM	PF, SC			SC	TF, TD
4:00 PM		Digesters, PF	Digesters, PF	Digesters, PF	Digesters
4:30 PM	Digesters		SC		
5:00 PM	SC	TF, TD, SC	TF, TD	TF, TD	TF, TD
5:30 PM					
6:00 PM					

2.3.1. Gravity Belt Thickener Feed

During the course of the study at the Westerly WWTF, the GBT feed pump was turned on at 7:00 AM except on Friday (5/1/2009) when it was started a 1:10 PM (because on Friday EQ process was operated from 7:30 AM - 1:30 PM). The TF process utilized a Gorman-Rupp® centrifugal pump (i.e. pump number 1 in the tunnel). The pump speed was maintained between 138 gpm and 201 gpm. Grab samples for compositing and SOUR testing were taken from a bleed off valve on the pump.

On Monday April 27, 2009 the GBT was shut down at 9:00 AM due to a problem in the polymer feed system. The GBT was restarted at 2:34 PM. On Wednesday April 29, 2009 the GBT was shut down at 8:00 AM due to a part failure; it was restarted at 9:45 AM.

2.3.2. Gravity Belt Thickener Discharge

The GBT at the Westerly is a 3.0 meter Komline-Sanderson® unit that has been in operation since 1991. A cationic polymer is mixed with feed sludge right before the sludge enters onto the belt of the GBT. The belt of GBT was maintained at a speed of 28 ft/min.

Visual inspection of the GBT revealed that unlike the Easterly GBT, spreading of sludge on the Westerly GBT was not very uniform. This can be rectified either by reducing the belt speed or by using spreaders placed atop on the GBT.

The thickened sludge from GBT is dropped into a hopper. At the Westerly bacteria were added to the hopper to reduce FOG and foaming in the digesters.

The thickened sludge from the hopper is pumped to the primary (i.e. north) digester of the Westerly WWTF. During the study, a Gorman-Rupp® centrifugal pump (i.e. pump number 5 in the tunnel) was used to pump the thickened sludge. Unlike the Easterly, this pump operates continuously, however the speed of the pump fluctuated as the level of sludge in the hopper changed. A bleed off valve on the pump was used to collect grab samples for compositing and SOUR testing.

2.3.3 Belt Filter Press Feed

The BFP at the Westerly WWTF was operated Monday (4/27/2009) through Thursday (4/30/2009). Everyday the BFP was started between 10:00-10:30 AM except on Thursday when it was started at 8:30 AM. The BFP was not operated on Friday (5/1/2009). The sludge from secondary digester was pumped to the BFP by a Netzsch® positive displacement pump (i.e. pump number 4 in the tunnel). Grab samples for compositing and SOUR testing were collected from a bleed off valve on the pump.

The pump operations were intermittently halted when the bed of the truck (which transported dewatered sludge to the sludge storage building) was full. This break in the operation generally lasted 11 to 14 minutes every two (2) hours of operation.

Feed sludge to the BFP is mixed with the cationic polymer, however BFP at the Westerly does not have a mixing zone to facilitate mixing of polymer and sludge. The BFP at the Westerly WWTF is a 2.0 meter Komline-Sanderson® unit installed in 1991. The belt of the BFP was operated at a speed of 13ft/min.

2.3.4 Belt Filter Press Cake Solids

The dewatered solids (i.e. cake) sampling coincided with BFP feed sampling. Therefore, cake sampling took place from Monday (4/27/2009) to Thursday (4/30/2009). No cake sampling took place on Friday (5/1/2009) as the BFP was not operated that day.

Grab samples were collected at the discharged end of the BFP, just before solids drop onto the conveyer. Four (4) samples were collected every day thus a total of sixteen (16) samples were collected during the Westerly study period. Each grab sample was analyzed for %TS in the AWA Westerly Laboratory using an infrared drying pan.

2.3.5 Equalization Flow-Sludge Transfer from Primary (1°) to Secondary (2°) Digester

Sludge transfer from primary (1°) to secondary digester (2°) occurs only once every seven (7) days. At the Westerly, sludge transfer i.e. equalization flow began on Friday May 1, 2009 at 8:15 AM and ended at 1:15 PM. The EQ utilized a Gorman-Rupp® centrifugal pump (i.e. pump number 1 in the tunnel). The flow rate of the pump was maintained at 416.9 gpm. A bleed off on the pump was used to collect grab samples for compositing and SOUR testing.

When equalization flow occurs at the Westerly, neither the BFP nor the GBT can be operated. This is unlike Easterly where GBT can be (and was) operated during the equalization flow.

2.3.6 Sludge Recirculation in the Primary Digester

At the Westerly WWTF, a Gorman-Rupp® centrifugal pump (i.e. pump number 6 in the tunnel) was continuously recirculating the sludge from the bottom of the primary digester to the top of the digester. As per operator, this operation was maintained to reduce foaming in the digester. It should be noted that this operation is unique to the Westerly as it was not observed at the Easterly.

2.3.7 Aerobic Digester Operations

Onsite evaluations were conducted at the primary and secondary digesters. Just like at the Easterly, observations/evaluations at the Westerly were also conducted every three (3) hours from 7:00 AM to 4:00 PM amounting to four (4) onsite evaluations at each digester per day. Onsite analyses at the primary and secondary digesters included temperature, dissolved oxygen (DO), and sludge level measurements. General conditions, like foaming on the digesters were also recorded through visual inspection. Temperature and DO were measured using a Hach® digital DO meter by placing the probe directly into the digester tanks at the mid depth level. The DO in the primary digester was consistently below 1.0 mg/L. It is to be noted that DO readings at the digesters were constantly fluctuating due to agitation/mixing. It took several minutes for the DO readings to stabilize but even after stabilization slight fluctuations were still observed.

Sludge level measurements in the digesters were conducted using a Stanley® PowerLock 12 feet tape. Depth of the surface of the sludge from the top of the tank wall was measured. The measured readings were subtracted from the total height of the tank wall to obtain the level of the sludge in the digesters.

Approximately one (1) liter grab samples from each digester were then taken to the laboratory where pH was analyzed. Grab samples were obtained by using a PVC sampler tied to a rope and a wooden handle.

Visual observations were made about the general conditions, like foaming of the digester. These observations were recorded in the daily log sheets. Constant foam was observed on the both the digesters however the foam was thicker on the primary digester than that on the secondary digester. Moreover foaming was higher at the Westerly digesters than that at the Easterly digesters. Foaming is probably due to the low air (as supported by low DO readings) in the digesters.

The Westerly WWTF has three (3) dedicated blowers for aerobic digestion process. Each blower is capable of providing 2,750 SCFM at 10.5 psi. As per air supply data collected from SCADA system, two (2) digester blowers were operated on Monday (4/27/2009) however from Tuesday onwards only one (1) blower was operated.

Refer to Appendix A for the results log sheets of the Westerly WWTF digester evaluation study.

Section 3

ACTIVATED SLUDGE OPERATIONS

3.1 GENERAL OVERVIEW

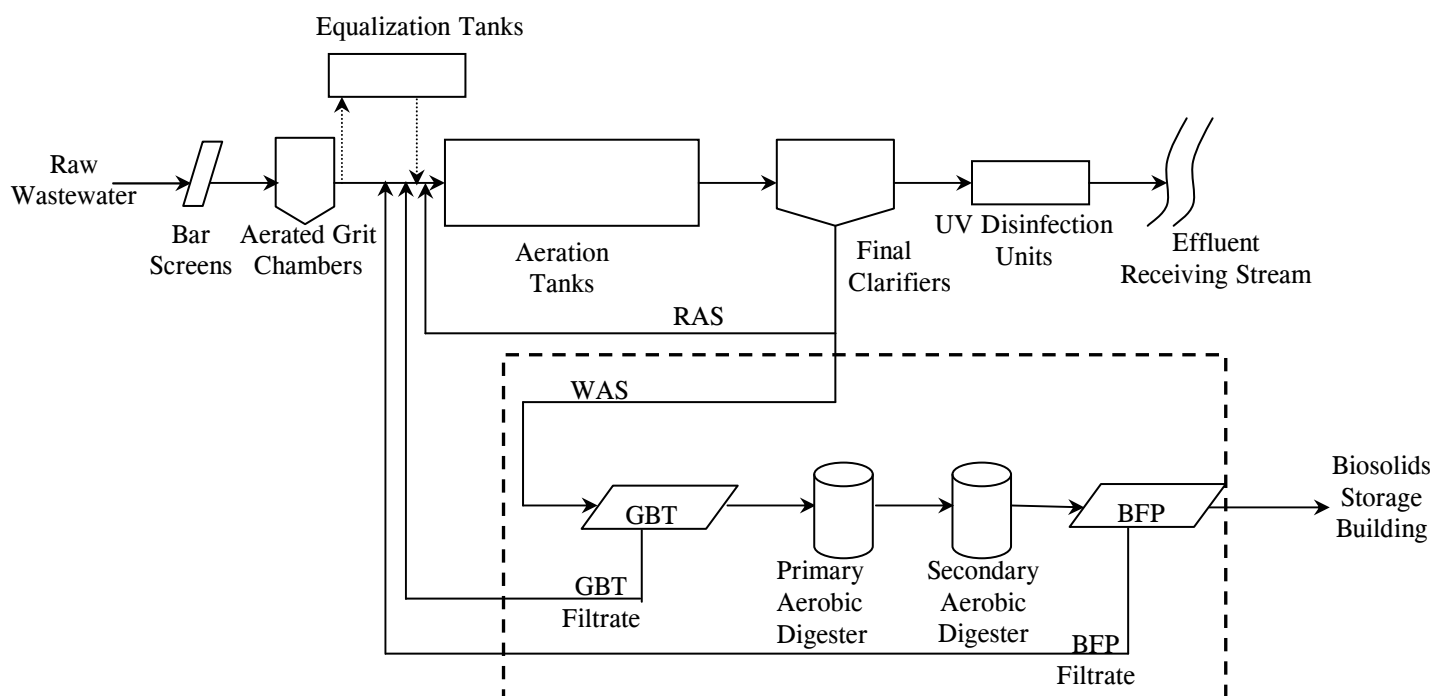
The Easterly and Westerly WWTF's process was designed as a completely mixed, single stage nitrification, activated sludge system. The plant utilizes an aerobic digestion process to treat waste activated sludge produced from aeration process. The aerobic digestion process produces Class B biosolids which are dewatered before agricultural land application use. The reactors use fine bubble, ceramic dome diffusers for aeration and mixing. The aerobic digesters use coarse bubble, stainless steel diffusers to aerate and mix the sludge.

The major activated sludge and digestion process components are:

1. Mechanically Cleaned Screens
2. Aerated Grit Chambers
3. Equalization Storage/Pumping
4. Aeration Tanks (Activated Sludge Reactors)
5. Final Clarification
6. UV Disinfection Units
7. Gravity Belt Thickener
8. Aerobic Digestion
9. Belt Filter Press

The process schematic is shown in Figure 3.1.

Figure 3.1: Process Schematic



The raw wastewater enters the plant where it is processed through bar screens and aerated grit chambers for debris and grit removal. During high flow/wet-weather conditions, flow can be bypassed through pretreatment process and could be diverted to equalization tanks. After the pretreatment process, the flow is combined with additional influent from WWTF's sanitary system, process recycles/washwater and minor flows from other townships. During average flow conditions, all the flow is continued to aeration tanks that are operated as plug flow reactors (PFRs) at the Westerly and as complete mixed activated sludge (CMAS) reactors at the Easterly. The effluent from the aeration tanks enters into clarifiers for settling of solids. Clarified effluent is disinfected through UV disinfection units before being discharged to receiving streams. Settled solids are recovered from the clarifiers and are pumped to the head of the aeration tanks.

The AWA records and maintains daily operational data at each WWTF to complete and submit monthly discharge monitoring reports (DMR) to PADEP. This daily operational data from January to April 2009 is analyzed and discussed in the sections below.

3.2 INFLUENT CHARACTERISTICS

The Westerly wastewater collection system consists of 137.6 miles of sanitary sewer of varying size and shapes. Out of all contributing sewers, 35% are classified as combined sewer originating from the older, center city area. Contributing to the Westerly influent are the Pleasant Valley, Westerly Altoona and South Altoona outfall sewers. The Westerly wastewater collection area contains numerous restaurants and other food businesses along the Pleasant Valley Boulevard.

The Easterly wastewater collection system consists of 95.5 miles of public sewer of varying sizes and shapes. Out of total public sewer, 55% is classified as combined sewer overflow originating from the older portions of the city. Contributing to the WWTF influent are Juniata, Easterly Altoona and Spring Run outfall sewers.

The raw wastewater influent at each WWTF is screened by two (2) coarse bar screens with 1-inch openings. Following the screens, wastewater enters aerated grit chambers. The Westerly has three (3) aerated grit chambers whereas the Easterly WWTF has two (2) chambers. After primary treatment, wastewater flows to aeration tanks through an interconnecting influent channel, which contains a Parshall flume for flow measurement. At each plant, process recycle, WWTF sanitary flow and flows from other townships are added into the channel just after the Parshall flume.

Table 3.1 shows the influent flows and loading to the aeration tanks at the Easterly and Westerly WWTF's from January to April 2009 (i.e. four (4) months).

**Table 3.1: Influent to the Aeration Tanks at Easterly and Westerly
(January - April 2009)**

	EASTERLY			WESTERLY		
	Min.	Avg.	Max. ¹	Min.	Avg.	Max. ¹
Aeration Influent						
Flow, mgd	3.7	5.8	11.3	5.5	7.9	16.8
BOD, mg/L	43	95	175	42	131	338
BOD, lbs/d	2,510	4,377	11,581	3,989	8,222	20,860
TSS, mg/L	56	119	208	32	132	468
TSS, lbs/d	3,062	5,600	18,388	1,892	8,467	28,883
VSS, mg/L	44	98	179	32	105	340
VSS, lbs/d	1,999	4,533	10,785	1,892	6,738	20,983
VSS, %	0.0	81.6	100.0	54.1	80.5	100.0
FSS, mg/L	0	22	86	0	26	128
FSS, lbs/d	0	1,096	7,603	0	1,729	7,900

1. Maximum values indicate highest values recorded during an individual day/event from January to April 2009.

The data above reveals that the influent BOD concentration and loading are substantially higher (40%) at the Westerly than the Easterly WWTF. Though TSS, VSS and FSS concentrations are comparable at the WWTFs, loadings are higher at the Westerly. The higher loadings observed at the Westerly are due to the higher influent flow. Higher BOD and VSS loadings in the raw influent wastewater could lead to higher suspended solids concentration in the mixed liquor, RAS and WAS.

3.3 SEPTAGE WASTE

Both Easterly and Westerly WWTF receives septage waste through independent haulers. The septage waste is discharged into the bar screen influent channel and mixed with wastewater influent. Table 3.2 shows the septage waste data for the period of January - April 2009.

**Table 3.2: Septic Waste Delivered to Easterly and Westerly WWTF
(January - April 2009)**

	EASTERLY			WESTERLY		
	Min.	Avg.	Max.	Min.	Avg.	Max.
Septic Waste						
Haulers/Day	1	1.1	5	1	2.1	9
Vol/Day, gal	2,513	3,188	16,579	1,986	10,540	51,231
BOD, mg/L	251	3,221	12,390	12	1,087	9,330
TSS, mg/L	348	11,230	82,000	32	1,971	22,833
BOD, lbs/day	11	98	1,129	2	62	572
TSS, lbs/day	14	316	6,919	1	133	2,105

Data in the table indicate that the Westerly WWTF received twice the number of septage haulers per day as the Easterly received. The volume of septage received at the Westerly is three times of that received at the Easterly. However, the TSS and BOD loading per day were higher at the Easterly due to a highly concentrated septage waste. The BOD concentration in the Easterly septage is three (3) times higher and TSS concentration is eleven (11) times higher than the Westerly WWTF.

3.4 MIXED LIQUOR CHARACTERISTICS

Wastewater enters the reactors by an influent channel from headworks building. Each plant has two (2) reactor trains which are divided into eight (8) cells each. At the Westerly WWTF, reactor trains are operated as plug flow reactors (PFR) whereas at the Easterly WWTF reactor trains are operated as complete mixed activated sludge (CMAS) reactors.

Table 3.3 shows mixed liquor characteristics of each WWTF from January - April 2009.

Table 3.3: Characteristics of Mixed Liquor at Easterly and Westerly WWTF (January - April 2009)

	EASTERLY			WESTERLY		
	Min.	Avg.	Max.	Min.	Avg.	Max.
Mixed Liquor						
MLSS, mg/L	1,860	2,479	3,930	2,175	2,987	4,665
VSS, %	66.3	70.0	75.1	72.0	77.8	83.0
VSS, mg/L	1,261	1,737	2,775	1,686	2,319	3,639

The volatile suspended solids (VSS) fraction of the mixed liquor suspended solids (MLSS) represents the biological cell mass/concentration in the mixed liquor. This cell mass is primarily responsible for uptake of influent BOD and thus for the reduction of BOD in the effluent. The data in Table 3.2 show that VSS concentration is 25% higher at the Westerly WWTF, which was expected from the aeration tanks influent data shown in Table 3.1. Even the fraction (%) of VSS in MLSS is higher at the Westerly WWTF.

Table 3.4 shows performance parameters of aeration tanks of each WWTF.

Table 3.4: Aeration Tanks Performance Data for Easterly and Westerly WWTF (January - April 2009)

	EASTERLY			WESTERLY		
	Min.	Avg.	Max.	Min.	Avg.	Max.
Aeration Tanks						
Volume, million gallons	3.04	3.04	3.04	3.40	3.40	3.40
HRT, hrs.	6.5	13.5	19.7	4.9	10.9	15.0
Organic Loading, lbs BOD/1000 ft ³	6.2	10.8	28.5	8.8	18.1	45.9

The data shows that average hydraulic retention time (HRT) at the Easterly is approximately 24% higher than that at the Westerly. The average organic loading per 1,000 cubic feet (i.e. lbs BOD/ 1000 ft³) is 68% higher at the Westerly as compared to the Easterly.

3.5 PROCESS PARAMETERS

Table 3.5 shows process parameters i.e. F/M and SRT of Easterly and Westerly from January to April 2009.

**Table 3.5: Process Parameters of Easterly and Westerly WWTF
(January - April 2009)**

	EASTERLY			WESTERLY		
	Min.	Avg.	Max.	Min.	Avg.	Max.
Process Parameters						
F/M Ratio	0.06	0.10	0.27	0.04	0.13	0.34
SRT, days	10	14	19	6	15	51

SRT of both the WWTFs are comparable, however F/M ratio at the Westerly is 30% higher than that at the Easterly. This data vindicates previous data that influent BOD loading is higher at the Westerly, however the cell mass growth is not proportional to the influent BOD loading.

Each WWTF has three (3) final clarifiers. However, generally two (2) are operated. Each clarifier at the Easterly is 105-feet in diameter with 15-feet side water depth (SWD). Clarifiers at the Westerly are of the same SWD but the diameter is 116-feet. Table 3.6 shows the clarifier performance data of each WWTF from January to April 2009.

**Table 3.6: Clarifier Performance Data of Easterly and Westerly
(January - April 2009)**

Clarifiers	EASTERLY			WESTERLY		
	Min.	Avg.	Max.	Min.	Avg.	Max.
Volume, Mgal	1.94	1.94	1.94	2.34	2.34	2.34
RAS, mgd	4.0	4.0	4.0	4.6	5.1	5.4
SOR, gpd/ft ²	214	334	653	261	379	805
SLR, lbs/ft ²	7.2	11.7	25.2	10.2	15.5	28.4
WOR, gpd/ft	5,892	9,214	17,994	7,889	11,449	24,291

3.6 EFFLUENT CHARACTERISTICS

Table 3.7 shows the effluent characteristics of both the WWTFs.

**Table 3.7: Effluent Characteristics of Easterly and Westerly
(January - April 2009)**

Final Effluent	EASTERLY			WESTERLY		
	Min.	Avg.	Max.	Min.	Avg.	Max.
BOD, mg/L	2.9	2.9	4.0	2.9	3.2	8.0
TSS, mg/L	1.9	5.0	10.9	1.9	8.5	28.9
NH ₃ -N, mg/L	0.19	0.28	1.00	0.19	0.19	0.20
Fecal Coliform, mg/L	19	141	5280	19	60	580

Data in Table 3.7 reveal that both Easterly and Westerly have consistently met the effluent criteria of the NPDES permit. Low ammonia nitrogen (NH₃-N) and BOD values in the effluent indicates that aeration process has performed satisfactorily. Low effluent TSS values vindicate satisfactory performance of the final clarifiers.

Average fecal coliform values are well below the NPDES permit value of 2000 mg/L for winter operation (11/1 to 4/30). The maximum fecal coliform value at the Easterly WWTF is due a high flow encountered.

Section 4

SLUDGE PROCESSING

Settled solids from the clarifier are pumped to the head of the aeration tanks as return activated sludge (RAS) flow. A small fraction of RAS flow i.e. waste activated sludge (WAS) is diverted to the sludge processing area where WAS is thickened to 3-4% total solids content through a gravity belt thickener (GBT). The thickened sludge is then pumped to two (2) aerobic digesters operating in series. The digested sludge, withdrawn from secondary digester, is dewatered through a belt filter press (BFP) and transferred to sludge storage building through a conveyance vehicle (i.e. a truck). The stored dewatered sludge is eventually disposed through land application twice a year (late April and late October).

4.1 GRAVITY BELT THICKENER (GBT) OPERATION

During January - April 2009, the GBT was operated 107 days out of possible 120 days at the Westerly WWTF while it was operated everyday at the Easterly. To compare the performance of GBT at each plant, data is normalized to represent the condition as if GBT were operated everyday. Table 4.1 represents the normalized GBT operation data for both the facilities.

**Table 4.1: GBT Operation and Performance Data
at Easterly and Westerly WWTF (January - April 2009)**

	EASTERLY	WESTERLY
GBT Operations		
TSS in feed sludge to GBT, mg/L	5,592	6,802
GBT Run Time, hrs	9.9	9.4
Feed Rate to GBT, gpm	157	166
Total Flow to GBT, mgd	0.094	0.093
Total Solids to GBT, tons/day	2.20	2.56
Polymer Used, lbs/d	8.0	18.9
Polymer Used, lbs/tons TS	3.6	7.4
Thickened Sludge from GBT, %TS	2.79	3.35
Volatile Solids in Thickened Sludge, %	69.4	76.1

The data also reveals that the Westerly GBT uses 2.4 times more polymer than that used at the Easterly GBT. Although higher polymer usage leads to higher percentage of total solids in the thickened sludge, the difference in %TS is not proportional to polymer usage.

4.2 BELT FILTER PRESS (BFP) OPERATION

The thickened sludge from the GBT is pumped to the primary aerobic digester and then to the secondary digester for sludge digestion process. Eventually, the digested sludge is pumped to the BFP for dewatering operation.

During January - April 2009, the Easterly BFP was operated for 52 days, which indicates a three (3) days per week operation schedule. At the Westerly WWTF, the BFP was operated for 86 days indicating five (5) days per week operation schedule. To compare the performance of BFP at each facility, the BFP operation and performance data is normalized to represent the condition as if the BFP were operated everyday. Table 4.2 represents the normalized BFP data for the Easterly and Westerly.

Table 4.2: BFP Operation and Performance Data at Easterly and Westerly WWTF (January - April 2009)

	EASTERLY	WESTERLY
BFP Operations		
Digested Sludge to BFP, %TS	2.36	2.27
Volatile Solids in Digested Sludge, %	57.7	67.7
BFP Time, hrs	2.2	5.4
Flow Rate to BFP, gpm	123	87
Total Flow to BFP, mgd	0.016	0.028
Total Solids to BFP, tons/day	1.56	2.67
Total Solids in Dewatered Sludge, %	15.9	14.6
Polymer Used, lbs/day	27	54
Polymer Used, lbs/ tons TS	17.1	20.3
Solids Retention on BFP, %	89.3	86.9
% VS Reduction	39.9	34.3

4.3 DEWATERED SOLIDS TO SLUDGE STORAGE BUILDING

Dewatered solids from BFP are transferred through a conveyer to a truck that transports cake to sludge storage building. Table 4.3 shows the quantity (i.e. wet tons) of dewatered solids transported to the building.

Table 4.3: Dewatered solids to Sludge Storage Building at Easterly and Westerly WWTF (January - April 2009)

MONTH	EASTERLY	WESTERLY
	(Tons)	(Tons)
January	274	513
February	235	512
March	274	464
April	315	393
Total	1,098	1,882

4.4 COMPARISON: EVALUATION STUDY RESULTS AND DAILY RESULTS

The AWA records daily concentration of total suspended solids (TSS) and volatile suspended solids (VSS) in waste activated sludge (WAS). This is achieved by taking a grab sample and analyzing it in the laboratory. During the digester evaluation study, TSS concentration was analyzed in the grab samples taken for SOUR testing. TSS concentration was also analyzed in the daily composited samples. Table 4.4 compares concentrations recorded in WAS at the Easterly through the different samples. During the study, three (3) or four (4) SOUR samples were collected and analyzed daily. Thus, the SOUR sample results shown in the table are average values.

Table 4.4: WAS TSS Concentrations Recorded Through Different Samples at Easterly WWTF

Date	SOUR Samples	Composite Samples	Daily Samples
	(mg/L)	(mg/L)	(mg/L)
April 20, 2009	7,250	7,400	6,280
April 21, 2009	7,825	7,900	7,620
April 22, 2009	6,267	6,200	6,460
April 23, 2009	7,275	7,400	6,550
April 24, 2009	6,275	6,100	6,750
Average	6,978	7,000	6,732

Data in table 4.4 indicate that the average daily lab result is fairly close to the SOUR and compositing sampling results at the Easterly WWTF.

Table 4.5 compares concentrations recorded in WAS at the Westerly through the different samples.

Table 4.5: WAS TSS Concentrations Recorded Through Different Samples at Westerly WWTF

Date	SOUR Results	Composite Samples	Daily Samples
	(mg/L)	(mg/L)	(mg/L)
April 27, 2009	8,200	8,300	5,790
April 28, 2009	8,125	8,200	5,980
April 29, 2009	8,050	8,300	8,450
April 30, 2009	8,375	8,200	7,790
May 1, 2009	9,900	9,800	7,880
Average	8,530	8,560	7,178

Data in table 4.5 indicate that the average SOUR and composite sample results are fairly close. However, average daily lab results are lower by 19%. This difference can lead to discrepancy in mass balance and care should be taken to rectify the error. The SOUR and grab samples were collected from a bleed off valve on the WAS pump whereas daily samples were collected from the pipe that drops RAS into the aeration tanks at the head of the tanks. Daily samples are indicative of RAS instead of WAS. It is suggested that separate daily lab samples should be taken for WAS (from the bleed off valve) along with RAS samples.

Section 5

AEROBIC SLUDGE DIGESTION PROCESS

5.1 ORIGINAL DESIGN BASIS

Major components of the aerobic sludge digestion systems common to both Easterly and Westerly treatment plants are: two (2) above ground tanks equipped with coarse bubble aeration diffusers, blowers and ancillary sludge transfer pumping and piping facilities. The digester tanks at the Easterly have a volume capacity of 570,000 gal. (each), while the Westerly tanks have a capacity of 690,000 gal. (each).

Aerobic digesters at both plants were initially designed in late 1987 based on the following criteria:

PARAMETER	EASTERLY	WESTERLY
Total Solids, lbs/day	5,501	5,241
Temperature, °C	10	10
TS, %	1	1
Flow Rate, gpd	65,959	62,842
HRT (based on 1% TS), days	18	22
Volatile Solids Loading, lbs/day/cu. ft.	26	21
Aeration Requirement, cfm/1000 cu. ft.	30	25

Hydraulic retention time (HRT) is based on 1% total solids in the feed sludge to the digesters, however GBT thickens the sludge to 3 - 4% TS content which increases HRT at least by three times.

The Westerly was rerated in December 2004 for higher hydraulic and organic capacity, whereas the Easterly was rerated in November 2006, thus the digesters of both plants were also rerated to following criteria:

PARAMETER	EASTERLY	WESTERLY
Total Solids, lbs/day	6,689	7,276
Temperature, °C	10	10
TS, %	3.5	3.5
Flow Rate, gpd	22,916	24,926
HRT (based on 3.5% TS), days	52	55.2
Volatile Solids Loading, lbs/day/cu. ft.	28	30
Aeration Requirement, cfm/1000 cu. ft.	30	25

The recommended or typical design criteria for the design of aerobic digesters are:

PARAMETER ¹	VALUES
SRT, days	
At 20 °C	40
At 40 °C	60
Volatile Solids Loading, lbs/day/cu. ft.	100 – 300
Diffused air mixing, cfm/1000 cu. ft.	20 – 40

5.2 SYSTEM DESCRIPTION AND OPERATION

Aerobic digesters are operated in series at both plants. The sludge handling flow configuration consists of: 1) pumping waste activated sludge from the return sludge well to the gravity belt thickener (GBT), 2) pumping thickened solids to the primary digester, 3) pumping primary digested sludge to the secondary digester, and 4) pumping digested sludge to the belt filter press (BFP) for dewatering.

Different production schedules for the GBT and the BFP cause the aerobic digesters to be operated in a draw/fill mode, whereby the secondary digester must be depleted of sufficient volume over a shorter work week period (BFP operation) to allow for transfer of primary digested sludge that is generated on a more continuous basis (GBT operation). Currently this sludge transfer from primary to secondary digester is done weekly.

The graphs depicted in Figures 1 and 2 show draw/fill operations for the Easterly and the Westerly WWTF that occurred during the study. These graphs were derived from tank sludge level measurements made at recorded time intervals. They indicate a reduction in effective digester volume of about 10%.

It should be noted that field devices that were intended, by design, to monitor digester levels, pH, temperature and DO are inoperable at both plants. During the course of data collection, these parameters were measured on a grab sample basis. It should also be noted that during the study, digester air supply data normally stored in computer records (SCADA System) were available for the Westerly, but not the for Easterly. Data for the Easterly were estimated based upon typical weekly air supply records generated after the study. Data details are presented in the Appendix B. Summaries of the information are discussed herein.

1. Wastewater Engineering: Treatment and Reuse, Fourth Edition, Page No. 1536

Figure 5.1: Easterly WWTF - Aerobic Digester Working Volume

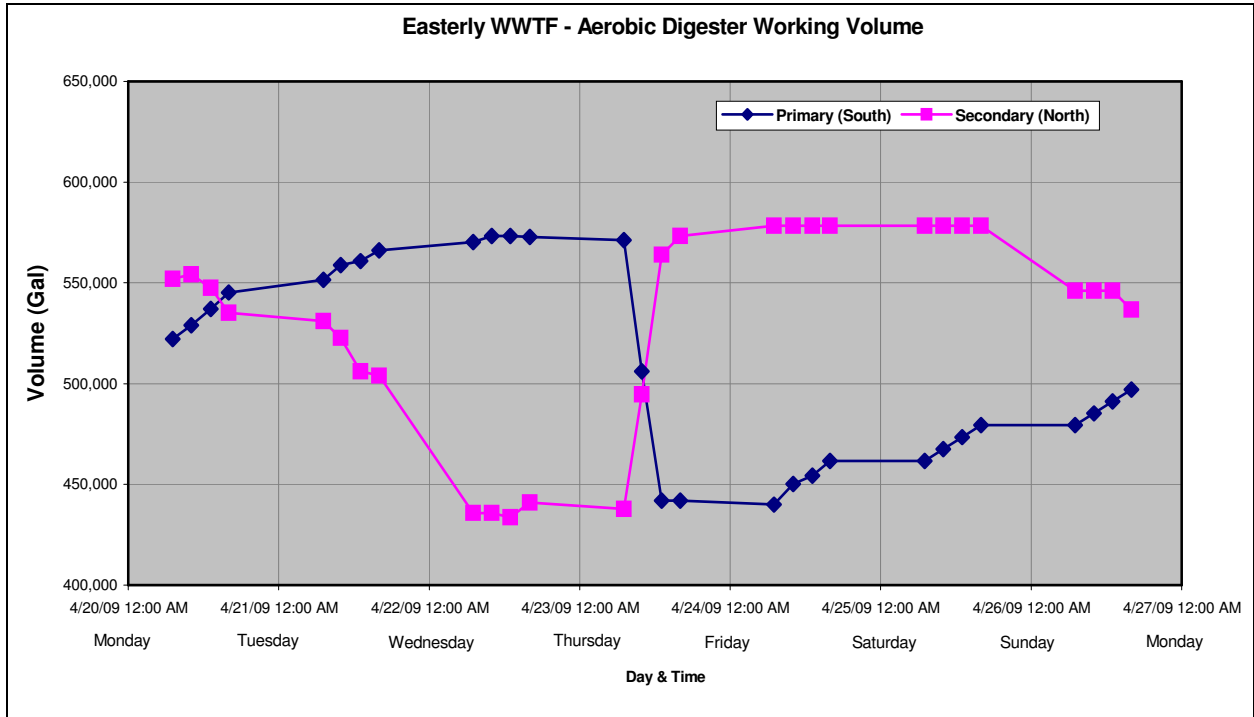
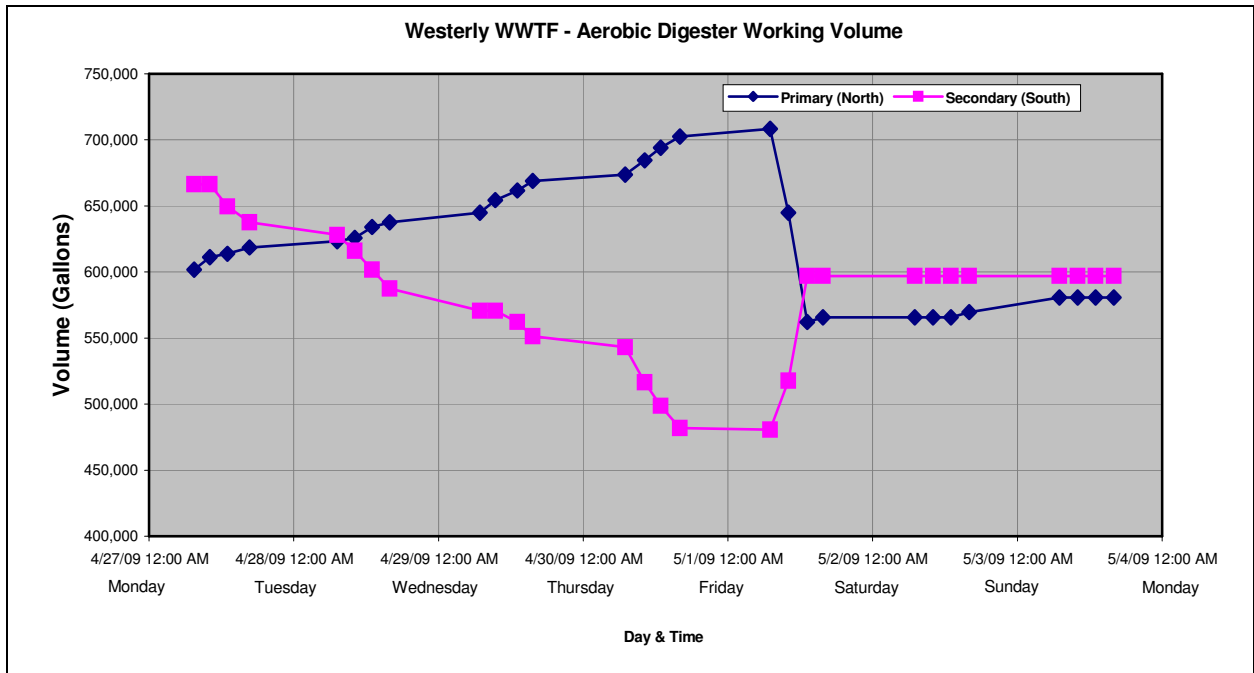


Figure 5.2: Westerly WWTF - Aerobic Digester Working Volume



5.3 EVALUATION AND COMPARISON OF DIGESTER PROCESSES

For discussion purposes, Easterly and Westerly Digester Study data have been summarized under five (5) headings. They are: 1) primary digester influent, 2) primary digester, 3) secondary digester influent (sludge transfer), 4) secondary digester and 5) secondary digester effluent (belt filter press feed). Tables 5.1 through 5.5 present observed conditions and average results for measured parameters. Refer to the Appendix A for data details and minimum/maximum values.

Referring to Table 5.1, within the limits of accuracy afforded by sampling of full-scale operations, the differences between the Easterly and Westerly primary influent sludges in most respects are insignificant. The noteworthy exception is fats, oils, and grease (FOG) content, which will be addressed shortly. Due to variations in solids content, for comparison purposes, test results are expressed on a weight of constituent per equivalent weight of volatile solids (g/kg VSS) basis.

The average FOG analytical value for the Westerly (383 mg/L) is nearly twice the value for the Easterly (208 mg/L). If this finding represents typical sludges at the two plants, it tends to support the assumption that the greater number of restaurants in the Westerly is a potential source and reason for the FOG difference. One aim of the study was to quantify FOG differences between the two plants and assess whether or not excessive FOG could be a negative factor in Westerly aerobic digester performance. Addition of FOG digesting bacteria several weeks prior to the start of the study negated the analytical basis for this evaluation. An unintended consequence of the FOG testing might be the indicated concentration decrease across the primary digester at the Westerly Plant, which could suggest the FOG bacteria were working. The very limited data, however, would not support this as a firm conclusion.

The higher volatile content of the Westerly solids (76.6% versus 67.0%) is a normal characteristic distinction between the Easterly and Westerly Plant sludges and is indicative of the higher BOD loadings and removals at the Westerly facility.

Further inspection of the data in Table 5.1 shows that filtrate chemistry of thickened sludge discharged to the primary digesters is not remarkably different for the two plants. Both can be characterized as having concentrations high in ammonia (greater than 40 mg/L) and low in nitrates (<2.0 mg/L). A stable alkalinity buffering capacity (20% higher in the Easterly) is evident at both plants.

An operational difference is the addition of lime to digesters (primary and/or secondary) in the Easterly, whereas the Westerly does not add an alkaline agent for alkalinity control or pH adjustment. Records of lime (CaO) usage at the Easterly indicate an average daily feed rate of 189 pounds. There are two points of application, the aeration tank influent channel and the digesters. The amount of lime added at these feed points is unknowable due to the absence of measuring devices at either location. The higher alkalinity and calcium values could be a reflection of lime addition in the Easterly primary digester.

For operational perspective it needs to be recognized that digester process loadings measured for the study were substantially below design loadings anticipated for the BNR upgraded plants. During the study, applied VSS loadings compared to BioWin® model predicted loadings were 50% less for the Easterly WWTF, and over 100% less for the Westerly WWTF. The design waste activated sludge production rates of 10,000 lbs/day for the Westerly WWTF are model-based values that were derived from analyses of long term data. It is important to understand that applying these higher loadings (at design capacity) will require optimization of the aerobic sludge digestion processes in order to realize the performance levels evidenced during the study.

With respect to solids testing, it is of interest to note the close agreement between composited sample and the average grab sample results. The variation is less than 2.0%.

Table 5.1: Primary Digester Average Influent Loadings and Constituent Concentrations

<u>Conditions and Parameters</u>	<u>Easterly WWTP</u>	<u>Westerly WWTP</u>
Flow, gpd	18,724	21,920
TSS, % conc.	3.07	2.42
VSS, %	67.0	76.6
TSS, lbs/d	4,794	4,424
VSS, lbs/d	3,212	3,389
No. of Unfiltered composite samples	5	5
BOD, g/kgVSS	620	668
COD, g/kgVSS	1,857	1,625
TKN, g/kgVSS	94	99
NH ₃ N, g/kgVSS	3.8	4.4
TP, g/kgVSS	24.5	20.7
FOG, g/kgVSS	10.1	20.7
Factor x g/kgVSS = mg/L	(20.560)	(18.537)
No. of Filtrate composited samples	5	5
BOD, mg/L	335	349
COD, mg/L	807	653
TKN, mg/L	56.4	60.4
NH ₃ -N, mg/L	43.1	41.0
NO ₃ -N, mg/L	<2.0	<2.0
TP, mg/L	73.0	45.0
Alk., mg/L	335	275
Acidity, mg/L	150	162
Calcium, mg/L	81.8	74.2
No. of Grab samples	19	17
Average values		
SOUR, mg/hr/gTSS	4.6	3.7
TSS % conc.	3.10	2.47
pH	6.6	6.5

Table 5.2 summarizes the primary digester operating parameters in terms of observations made during the study and data derived from sludge handling operations. The data show that both digesters were relatively lightly loaded as evidenced by the average VSS/d/1000 cf of 43.7 for the Easterly and 39.0 for the Westerly, and fairly long hydraulic retention times (HRT) of 28.2 days and 36.4 days, respectively. The typical design range for volatile solids loadings is 100 to 300 lbs VSS/d/1000 cf.

The average primary digester DO level (0.32 mg/L) at both plants was marginal at best. DO below 1.0 mg/L can inhibit aerobic processes and a minimum concentration of 2.0 mg/L is normally recommended. Air supply at the Easterly, 26 cfm/1000 cf, met the minimum criteria (20 cfm/1000 cf), while the Westerly at only 15 cfm/1000 cf did not.

Despite this representation, the Easterly primary digester’s DO concentration showed no improvement over the Westerly. It should be noted, however, that the Easterly air supply was estimated from an analysis of post-study typical operations. Nevertheless, even with these low DO values and the implied potential for developing anaerobic conditions, both primary digesters performed acceptably, achieving VSS reductions of 15% at Easterly and 19% at Westerly. While acknowledging this to be a positive finding, it is worth repeating that conditions during the study were below design loadings.

Under a given set of conditions, VSS reduction achievable by the aerobic sludge digestion process is dependent upon the biodegradability of volatile solids in terms of reaction rates. Temperature has a major impact on these rates. The digester temperatures observed during the study (19°C to 28°C) are compatible with supporting reaction rates in the normally expected range. It is worth noting, however, that wintertime aerobic digestion temperatures for the Westerly WWTF have been reported at less than 10°C and, due to their similarity, it would not be unreasonable to assume that the Easterly aerobic digesters experience equally low temperatures. This is worth mentioning because at these low temperatures and with increased design loadings it will be important to optimize the aerobic digestion processes to ensure effective sludge stabilization, under more challenging conditions.

Table 5.2: Primary Digester Operation

<u>Conditions and Parameters</u>	<u>Easterly WWTP</u>	<u>Westerly WWTP</u>
Effective volume, Mgal	0.55	0.65
HRT, d	28.2	36.4
Air supply, avg. cfm	1,918	1,304
Air supply, cfm/1000 CF	26	15
No. of Grab samples	20	20
Average values		
DO, mg/L	0.32	0.32
Temp., °F	67.5	75.4
pH, SU	7.1	6.6
VSS loading, lbs/d/1000 cf	43.7	39.0
VSS reduction, %	15.1	19.3

As previously mentioned, transfer of primary sludge to the secondary digester is performed on a weekly basis. Table 5.3 is a tabulation of data representing the volume and composition of this sludge. Inspection of analytical values reveals that except for a few parameters, the Easterly and Westerly digester transfer sludges are quite similar.

Of particular interest is the fact that volatile solids destruction, which occurred in the primary digesters, is accompanied by an increase in ammonia level, i.e., from 43 mg/L to 79 mg/L at the Easterly, and (although to a lesser degree) from 41 mg/L to 51 mg/L at the Westerly. Concurrently, nitrate values remained at less than detectable concentrations (< 2.0 mg/L).

These findings strongly suggest that biomass stabilization in the primary digesters is limited to the microbial oxidation stage. Nitrification is not taking place, even though HRT, pH and alkalinity values are favorably disposed. The deficient parameter, as noted earlier, is dissolved oxygen which will not support nitrifier growth at the low levels observed.

It should be emphasized that this analysis is necessarily conditional based upon process operations in place at the time of the study, which were indicative of relatively low volatile solids loadings, particularly at the Westerly Plant. Without benefit of continuous monitoring of pH and DO, there is no means to assess the operational track record for the digestion process. It may be reasonably assumed, however, that under typical operations with higher digester loadings and no increase in air supply, borderline DO levels might be the rule rather than the exception. Operating under these conditions runs the risk of developing an anaerobic environment such as experienced at the Westerly Plant in the fall of 2003.

In terms of hydraulic operation of the digesters, it should be pointed out that the total volume of sludge transfer from primary to secondary digesters provides a rough approximation of digester process capacity lost to draw/fill use of the tanks. A more accurate accounting requires knowledge of digester volumes at the start and finish of a cycle. This loss is directly proportional to digester hydraulic loadings, assuming once a week transfer of sludge.

**Table 5.3: Secondary Digester Influent (Sludge Transfer)
Loadings and Constituent Concentrations**

<u>Conditions and Parameters</u>	<u>Easterly WWTP</u>	<u>Westerly WWTP</u>
Flow, gpd	150,000	125,000
TSS, % conc.	2.30	2.03
VSS, %	63.3	72.5
TSS, lbs/d	29,606	21,163
VSS, lbs/d	18,741	15,352
No. of Unfiltered composited samples	1	1
BOD, g/kgVSS	367	365
COD, g/kgVSS	1,707	1,525
TKN, g/kgVSS	98.2	100

Table 5.3 (Continued)...

<u>Conditions and Parameters</u>	<u>Easterly WWTP</u>	<u>Westerly WWTP</u>
NH ₃ -N g/kgVSS	7.35	5.33
TP, g/kgVSS	29.5	25.1
FOG, g/kgVSS	11.8	14.8
Factor x g/kgVSS = mg/L	(14.56)	(14.72)
No. of Filtrate composited samples	1	1
BOD, mg/L	149	143
COD, mg/L	710	493
TKN, mg/L	105	72.5
NH ₃ -N, mg/L	79	50.5
NO ₃ -N, mg/L	<2.0	<2.0
TP, mg/L	68.1	121
Alk., mg/L	343	235
Acidity, mg/L	190	98
Calcium, mg/L	52	69
No. of Grab samples	3	3
Average values		
SOUR (mg/hr/gTSS)	3.1	4.7
TSS, % conc.	2.34	2.02
pH	6.98	6.84

Secondary digester operational data derived from the study are summarized in Table 5.4. As would be expected volatile solids, having undergone reduction in the primary digester, imposed very low loadings on the secondary digester at both treatment facilities.

HRT of Easterly secondary digester is significantly higher than HRT of Westerly secondary digester. This is so because at the Easterly, BFP is operated three (3) days/week as compared to five (5) days/week at the Westerly. Thus, less flow is taken out from the Easterly secondary digester. But HRT of Westerly secondary digester can be increased by transferring sludge more frequently from primary to secondary digester. This operation will also help in achieving higher VSS reduction as secondary digester has higher DO content.

Improved average DO levels, 3.6 mg/L at Easterly and 1.6 mg/L at Westerly, may be attributed to increased air supply for the Westerly (21.9 cfm/1000 cf) but cannot be cited as the cause for Easterly at 14.2 cfm/1000 cf. The reason for lack of correlation between air supply and DO concentration at the Easterly Plant was not determined.

Based on study results, the overall volatile solids reductions accounted for at the Easterly and Westerly Plants were 33.5% and 45%, respectively. While this determination is inconsistent with historical comparisons, it should be noted that: 1) the East's volatile solids feed sludge is

substantially less than the West, 2) the East's digested sludge volatile content is less than the West and 3) results of the East's digested sludge SOUR tests are one third of the West. In addition, as will be discussed in the next subsection, operational data of record suggest that the Westerly aerobic sludge digester loadings are not in keeping with anticipated process loadings.

Table 5.4: Secondary Digester Operation

<u>Conditions and Parameters</u>		<u>Easterly WWTP</u>	<u>Westerly WWTP</u>
Effective volume,	Mgal	0.49	0.58
HRT,	d	26.1	16.8
Air supply,	avg., cfm	931	1,692
Air supply,	cfm/1000 cf	14.2	21.9
No. of Grab samples		20	20
Average values			
DO,	mg/L	3.6	1.6
Temp.,	°F	70.2	83.5
pH,	SU	5.5	5.5
VSS loading, lbs/d/1000cf		36.9	28.2
VSS reduction,	%	24.4	31.2

The average characteristics of aerobically digested solids as determined by the study are presented in Table 5.5. Comparing the Easterly results with the Westerly, the following significant differences are noted.

1. The TKN content of an equivalent weight of VSS in the Westerly sludge is about 17% higher than the Easterly sludge.
2. Filtrate concentrations of TKN and NH₃-N were 7 to 8 times higher in the Westerly sludge sample.
3. Filtrate NO₃-N concentration in the Easterly sludge sample (402 mg/L) was over three (3) times the Westerly value (118 mg/L).
4. Although the alkalinity values were not radically different (62 mg/L at Easterly versus 52 mg/L at Westerly), the alkalinity destroyed in the secondary digestion process measured 50% more in the Easterly (281 mg/L) compared to the Westerly (183mg/L).
5. The specific oxygen uptake rate (SOUR) for the Easterly (0.5 mg/hr/gTSS) was one third of the Westerly value (1.4 mg/hr/gTSS).

It is readily apparent from these results that the Easterly aerobic sludge digestion process achieved a greater degree of nitrification than the Westerly. This observation, for the study at least, is valid despite the fact that the East's process loadings slightly exceeded the West.

It should be noted that the high SOUR results in secondary digester effluent of the Westerly plant indicate high amount of unstabilized volatile solids in the digested sludge. One of the requirements for Class B biosolids is that the SOUR should be less than 1.5 mg O₂/hr/g TSS. The average Westerly SOUR result of 1.4 mg O₂/hr/g TSS therefore indicates marginal performance of the Westerly digesters.

**Table 5.5: Secondary Digester Effluent (Press Feed)
Loadings and Constituent Concentrations**

<u>Conditions and Parameters</u>	<u>Easterly WWTP</u>	<u>Westerly WWTP</u>
Flow, gpd	44,148	50,000
TSS, % conc.	2.27	18.9
VSS, %	56.7	64.5
TSS, lbs/d	8,483	7,768
VSS, lbs/d	4,810	5,010
No. of Unfiltered composited sample	2	4
BOD, g/kgVSS	167	183
COD, g/kgVSS	1,554	1,527
TKN, g/kgVSS	71	83
NH ₃ -N, g/kgVSS	1.64	4.67
TP, g/kgVSS	36	33
FOG, g/kgVSS	< 8.0	< 8.0
Factor x g/kgVSS = mg/L	(12.87)	(12.15)
No. of Filtered composited sample	2	4
BOD, mg/L	16	62
COD, mg/L	222	405
TKN, mg/L	7.1*	57.5
NH ₃ -N, mg/L	5.3*	39.4
NO ₃ -N, mg/L	402	118
TP, mg/L	124	118
Alk., mg/L	62	52
Acidity, mg/L	178	258
Calcium, mg/L	512	179
No. of Grab samples	6	12
Average values		
SOUR, mg/hr/gTSS	0.5	1.4
TSS, % conc.	2.28	1.92
pH	5.61	5.29

Note:

* one (1) composited sample result

5.4 IMPLICATIONS OF THE STUDY FOR BNR UPGRADED FACILITIES

This subsection deals primarily with the Westerly WWTF, except where noted. As mentioned in the Introduction, BNR upgrade design for the Westerly WWTF includes several recommended unit operations aimed at improving the waste activated sludge handling/processing system. The relevancy of these components to optimizing operations and the significance of study results to the aerobic sludge digestion process are examined in the discussion that follows. In support of this discussion, use is made of three (3) reference sources. They are: Wastewater Engineering: Treatment and Reuse, Metcalf & Eddy; Biological Nutrient Removal (BNR) Operations in Wastewater Treatment Plants, Water Environment Federation; and Aerobic Digestion Workshop, Enviroquip, Inc. Complete and appropriate credits are cited in the text. In addition, reference is made to the Second Party Review performed by Dr. Jeanette Brown, submitted earlier this year in fulfillment of Value Engineering (VE) requirements.

First, some explanation regarding excess activated sludge design loadings is in order.

5.3.1 Waste Activated Sludge Design Loading

Table 5.6 was prepared to show the difference between solids loadings used for the original (1987) sludge handling system versus the current (2009) design basis. It should be noted that the earlier sludge production/digester loadings rate were generated from desktop evaluations, while the later data were derived from BioWin modeling, which predicted an average annual sludge production rate of 10,000 lbs/day for the Westerly WWTF. The terms sludge production and waste sludge rate as used herein are interchangeable in the sense that one (waste sludge) needs to balance the other (sludge production) in order to maintain a sludge age consistent with treatment objectives. Referring to table 5.6, the TSS loading of 9,500 lbs/d is the anticipated total suspended solids load applied to the aerobic digester which, throughout our discussion is assumed to be 95% of the waste activated sludge rate (i.e., 95% capture across the GBT).

Table 5.6: Comparison of 1987/2004 and 2008 Aerobic Sludge Digestion Design Basis for the Westerly WWTF

Parameter	1987 Design (Revised/2004 Rerate)	2008 Design (Revised/2009 Amendment)
TSS loading, lbs/d	7,276	9,500
VSS, %	75	75
VSS loading, lbs/d	5,457	7,125
Flow (3.5% TSS), gpd	24,926	32,545
HRT, days	48.1	36.9

The 2008 design basis presented in the table denotes flow and solids loadings that the Westerly upgraded BNR facility should be capable of processing and, according to computer analysis, can reasonably be expected to encounter.

The potential need to feed a supplemental carbon source with additional sludge generation reinforces the validity of this assumption.

With these anticipated loading criteria in mind, it is instructive to review the solids loadings at the Westerly WWTF during and immediately prior to the aerobic digester evaluation study (Jan –Apr 2009). Total TSS applied to the primary digester for the week of the study was 4,424 lbs/day, while the average daily loading rate for the first quarter of 2009 was 5,012 lbs TSS/day. It is readily apparent that aerobic digestion process conditions observed for these low loadings would not be representative of future conditions under design loading. That is not to say the aerobic sludge process is lacking in capacity, but it does suggest the operational optimization to enable handling higher loadings should be a primary goal. The recommended sludge handling/process system improvements are designed to achieve that goal.

5.4.2 Dual Functioning Centrifuge

The proposed system for thickening waste activated sludge (WAS) to 3.5 to 4.0% solids prior to aerobic digestion consists of pumping return activated sludge (RAS) to the GBT, the primary thickening unit, with a dual functioning centrifuge as backup. The existing GBT is a nearly 20 year old Komline Sanderson® unit that can accept a feed rate of at least 500 gpm. The centrifuge (proposed new unit) has a limited hydraulic capacity of 140 gpm.

In keeping with the second party reviewer's recommendation, provisions will be made for wasting MLSS from the aerobic section of the bioreactors directly to the thickening equipment. The ability to waste RAS will be retained as an optional thickener feed source. The GBT will be the primary thickening device. It can accommodate waste activated sludge production rates of 6,000 to 10,000 lbs./day across a feed solids concentration range of 0.35 to 1.2 %. All cases examined will permit a GBT operating schedule of 2 shift/5 d-wk.

Due to hydraulic limitation, the centrifuge as a thickener backup is less flexible and in most instances requires continuous 24/7 operation unless the solids feed source is shifted to RAS. At the maximum sludge production rate of 10,000 lbs./day, however, continuous operation of the centrifuge would be required assuming RAS solids in the range of 0.6 to 1.0 %. It should be noted that although the centrifuge does not duplicate the GBT hydraulic capacity, it does provide sufficient standby sludge thickening capability to allow for unscheduled repairs to the GBT. In addition, the GBT 80 hr/week operating capacity will permit down time for scheduled maintenance.

In its role as a dual functioning machine (both thickening and dewatering) the centrifuge's main use will be to dewater aerobically digested solids. Deployment of the centrifuge as the primary dewatering unit with the existing belt filter press (BFP) as backup, is appropriate based upon higher percent dry cake solids possible with centrifuge technology.

5.4.3 Mixed Liquor Wasting Provisions

As recommended by the second opinion reviewer, provisions will be made to waste sludge from the combined return activated sludge (RAS) distribution box or to waste mixed liquor suspended solids (MLSS) from the first aerobic zone of the BNR reactors. Both waste streams will be directed to either the gravity belt thickener (GBT) or to the centrifuge for thickening solids to 3.0 to 4.0% TSS. Waste activated sludge from the RAS distribution box will be about 0.80% (8,000 mg/L) solids. MLSS are assumed to be about 0.35% (3,500 mg/L).

In addition to the recommendation made by the eminently qualified second opinion reviewer, the rationale for the wasting of MLSS as opposed to RAS is supported by the Manual of Practice (MOP) No. 29 of the Water Environment Federation (WEF) which states: "The BNR bioreactor should be designed with the flexibility to waste sludge from the end of the aerobic zone of the bioreactor to keep the sludge fresh and minimize the likelihood of releasing phosphorous downstream."² This same reference offers that: "wasting mixed liquor is the simplest method to implement sludge age control, because it does not require measurement of solids concentration."²

5.4.4 Sludge Holding Tank

A major recommendation for the sludge handling/processing system is a 200,000 gallon tank designed to provide in-line storage of digested sludge prior to dewatering equipment feed. The purpose of the holding tank is to maximize aerobic digester capacity and provide flexibility for the belt filter press (BFP) or centrifuge operating schedule. Isolating the digester sludge content levels from dewatering operations is an important part of optimizing the aerobic sludge digestion process. Essentially, the north and south digesters would operate at near constant levels while sludge level in the holding tank would vary depending upon BFP or centrifuge operating schedule. The capacity of the holding tank will provide a minimum of three (3) days of storage (dewatering unit downtime) at design flow/solids input.

2. Biological Nutrient Removal (BNR) Operation in Wastewater Treatment Plants, Water Environment Federation, MOP No.29, McGraw-Hill (2005) pp. 362 and 523

Sludge storage is not a new or unique concept. Two references are cited in support of the sludge holding tank concept. Metcalf & Eddy recommends that, "Storage should be provided to smooth out fluctuations in the rate of solids and biosolids production and to allow solids to accumulate during periods when subsequent processing facilities are not operating, e.g., night shifts, weekends and periods of unscheduled downtime. Storage is particularly important in providing a uniform feed rate ahead of the following processes: mechanical dewatering, lime stabilization and heat drying."³

In addition, provision for sludge storage was advocated by Jim Scisson, an operation specialist who was a presenter at the 1999 Enviroquip® Aerobic Digestion Workshop. Following is an excerpt from that presentation referring to waste activated sludge (WAS) storage: "Why include waste storage? This reduces labor cost. The waste flow needs to be continuous, but it's not necessary that you thicken it all the time. If you put it in storage before thickening you can waste 24 hours a day, but you can run your thickening operation 8 hours a day, 5 days a week and feed the digester that way. This will depend upon the size of the plant and the owner's philosophy. I'm going to make provision for 3 days of waste activated sludge at the design rate plus 20% overage. Why 3 days? Saturday, Sunday and the Holiday. So you have to have 3 days."⁴

Granted, Mr. Scisson is proposing WAS storage for labor savings on thickener operations (GBT), but the same logic applies to digested sludge storage ahead of dewatering (BFP) operations. And it makes more sense for AWA sludge handling operations since extra manpower is required for the BFP and not for the GBT. In addition, a much smaller holding tank is required.

5.4.5 Operating Conditions and Process Parameters

Temperature, pH and dissolved oxygen (DO) are critical parameters contributing to performance of the aerobic sludge digestion process. The optimum temperature range for VSS destruction is 30°C to 35°C with the minimum of 25°C. A consideration of temperature is important because both Easterly and Westerly digester tanks are uncovered and subject to the extremes of potentially single digit wintertime ambient temperatures. On the plus side, the tanks are deep (23 ft. East and 24 ft. West), partially below ground and of concrete construction.

3. Metcalf & Eddy, Inc. (2003) Wastewater Engineering: Treatment and Reuse, 4th ed., McGraw hill, New York, p.1485

4. Scisson, J. (1999) "Practical Digester Design from the Dirty-Fingernail Side", Aerobic Digestion Workshop, vol. III, sponsored by Enviroquip, Inc., Austin, p. 32

Temperatures are not routinely measured, but in response to our request, a reading was taken on January 31, 2009 at the Westerly WWTF north digester. The reported temperature was 2.6°C (36.7°F). According to reference literature, little or no VSS destruction can take place below 10°C. Consequently, the assumption would have to be that the aerobic digestion process was severely impaired for an unknown period of time, or that the temperature reading did not represent an average value for the digester contents. In any event, if temperatures approaching 10°C are common in wintertime at design loadings, optimization of digester operations will be even more essential.

During the study, digester pH at the Westerly WWTF fell from 6.6 in the north tank to 5.5 in the south tank. Control of pH according to one reference source states that: "To improve digestion, the pH in the 1st and 2nd stage digesters must be maintained above 6.5. The easiest way to raise the pH is with sodium hydroxide (caustic soda). The chemical feed system is compact, simple and does not generate extra sludge. Soda ash is also easy to feed. Lime should be avoided if possible because it generates extra sludge, it is difficult to handle (it must be dissolved into a slurry), does not like to be a liquid, (note, there are some commercial stabilized liquid lime products) and does not stay in suspension."⁵

Our recommendation for aerobic digester pH control at the Westerly WWTF is to provide a day tank and metering pump for caustic feed to either, or both digesters.

Grab sample monitoring indicated low concentrations of DO (less than 1.0 mg/L) in the primary digester at both the Easterly and Westerly plants. Despite this condition, both units achieved a respectable level of VSS destruction. Reasons for this could be the low VSS loading rates and the fact that the oxygen supply and demand balance was such that it slightly favored aerobic conditions.

At the Westerly plant, maximum digester air supply is provided by two (2) blowers, each having a capacity of 2,750 SCFM at 10.5 psig. A third blower is standby. Normally, only one (1) blower is used which results in providing less air than the DEP standard 30 cfm/1000 cf of digester volume (see Tables 5.2 and 5.4). During the study, air supply to the Westerly primary digester not only failed to meet the DEP standard, but at 15 cfm/1000cf fell below the minimum mixing criteria (20 cfm/1000 cf). The Easterly secondary digester air supply rate (14.2 cfm/1000cf) failed to meet the mixing criteria. Some settling of solids would not be unheard of under these conditions. Increased VSS loadings applied to the aerobic digesters will require two (2) blower operation. Preferably, DO monitoring and air control valves could be employed to deliver air proportionally based upon oxygen demand in the primary and secondary digesters.

5. Aerobic Digestion Workshop, Vol. III, Enviroquip, Inc (1999) p. 77

The O&M manual suggests operating digesters in series with primary digester be used to hold waste activated sludge and secondary digester be used to stabilize the thickened sludge. The current strategy of operating both the digesters in series to stabilize thickened sludge is a better approach to optimize the operations and available digester volume. The AWA staff maintains exhaustive records of daily operational data at both the plants. However, few more parameters like airflow, DO, pH and sludge level in the digesters should be incorporated in the operational sheets. These parameters represent the health of the digestion process and will aid in optimizing the sludge digestion process. For instance, pH recorded in secondary digesters at both the plants was fairly low because almost all of the nitrification occurred in the secondary digester. Regular record keeping of pH will allow operator to add alkaline agent to the digester.

5.4.6 Sludge Wasting Rate and Sludge Production.

Loadings applied to sludge handling operations and aerobic digestion processes are directly related to the quantity and quality of solids that require wasting. The required amount of wasting is dependent upon sludge production rates. Table 5.7 was constructed to assess the level of agreement between actual waste rates and theoretical sludge production rates computed for the Easterly and Westerly WWTFs.

Table 5.7: Estimated Sludge Production and Activated Sludge Waste Rate

Parameter	Easterly WWTP		Westerly WWTP	
	Jan.-Apr. 2009	Apr. 2009	Jan.-Apr. 2009	Apr. 2009
<u>Theoretical Sludge Quantities</u>				
BOD removed, lbs/d	4,237	4,537	8,011	7,601
Biosolids produced, lbs/d	3,728	3,992	7,050	6,689
FSS removed, lbs/d	975	1,371	1,449	1,537
Total Sludge produce, lbs/d	4,704	5,364	8,499	8,226
VSS produced, lbs/d	3,169	3,393	5,992	5,686
VSS produced, %	67.4	63.3	70.5	69.1
<u>Actual Sludge Quantities</u>				
Total Sludge wasted, lbs/d	4,368	5,100	5,070	4,280
Total VSS wasted, lbs/d	3,031	3,432	3,858	3,210
VSS wasted, %	69.4	67.3	76.1	75.3

Assumptions:⁶

1. SRT = 15d
2. Temp. = 20°C
3. MLVSS yield factor = 0.75
4. Biosolids volatile fraction = 0.85
5. Biosolids production factor = 0.88

Two periods were used to quantify the sludge rates. Data for the first quarter (Jan.-Apr.) of 2009 were examined to compare relatively long term average values. Solids waste and production rates were also computed for the month of April to define conditions immediately prior to the study.

Referring to the table, the actual waste sludge rate for the Easterly WWTF correlates fairly well with the theoretically predicted quantities, i.e., within 10%. The Westerly WWTF, however, shows poor agreement with theoretical sludge production rates that are nearly double the actual waste rates. It should be noted that these theoretical sludge production rates are based upon a 15 day sludge age for both plants which is consistent with process data for the selected operating periods. This level of detail was deemed appropriate for identifying major disparities between theoretical and actual sludge quantities.

6. Wastewater Engineering, Metcalf & Eddy, 4th Edition, p. 682

The point of this computational exercise and data comparison is to consider the possibility that the actual rate of excess solids removal at the Westerly WWTP exceeds the amount represented in operational reports. This speculation obviously assumes that Westerly treatment performance is not compromised by insufficient sludge wasting.

The reported quantity of waste activated sludge is based upon daily RASS grab sample tests and GBT feed pump operation (rate x time=volume). For the Westerly system, pounds of waste sludge computed in this manner have consistently failed to generate enough solids to justify the pounds of digested sludge pumped to the BFP. This solids imbalance remains a problem even though some positive correction was attained earlier this year through use of more accurate pump operations data.

The finding that RASS concentrations determined via intensive sampling during the study were nearly 20% higher than Westerly RASS grab samples, presents a case for representing increased waste activated sludge production data by improving the accuracy of RASS results. While this may not account entirely for the waste activated sludge/digested sludge rate imbalance, it should provide a closer approximation to actual sludge production rates. It would seem prudent, therefore, to devise and implement a program to increase the confidence level for RASS test results.

APPENDIX A

DIGESTER EVALUATION STUDY RESULTS

APPENDIX B

OPERATION DATA