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Environmental Technology Verification Report

Evaluation of a Decentralized Wastewater Treatment Technology

International Wastewater Systems, Inc.
Model 6000 Sequencing Batch Reactor System
(With Coagulation, Sand Filtration, and Ultraviolet Disinfection)

Prepared by

NSF International

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**DECENTRALIZED WASTEWATER TREATMENT – BIOLOGICAL, SAND FILTRATION, AND ULTRAVIOLET TREATMENT**
APPLICATION:	**DOMESTIC WASTEWATER TREATMENT FOR A RESIDENTIAL DEVELOPMENT**
TECHNOLOGY NAME:	**MODEL 6000 SEQUENCING BATCH REACTOR SYSTEM**
COMPANY:	**INTERNATIONAL WASTEWATER SYSTEMS**
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NSF International (NSF) operates the Water Quality Protection Center (WQPC) under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program. The WQPC evaluated the performance of a sequencing batch reactor biological treatment system, with media filtration and ultraviolet disinfection, for treatment of residential wastewater in a decentralized application. This verification statement provides a summary of the test results for the International Wastewater Systems Model 6000 Sequencing Batch Reactor (SBR) System. The Eagle Sewer District acted as the Testing Organization (TO) for the verification testing, which was performed near Boise, Idaho.

EPA created the ETV Program to facilitate deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; stakeholder groups consisting of buyers, vendor organizations, and permitters; and the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and verifiable quality are generated, and that the results are defensible.

TECHNOLOGY DESCRIPTION

The following technology description is provided by the vendor and does not represent verified information.

The International Wastewater Systems' (IWS) Model 6000 SBR includes a 6,000 gallon (gal) equalization tank, a 6,000 gal modified SBR, a 3,000 gal holding tank, a coagulation injection system, a gravity sand filtration system, and an ultraviolet (UV) disinfection system. The IWS SBR is designed to provide treatment by optimizing the treatment conditions using a computer controlled and monitored system of pumps, floats, and probes to measure, monitor, and adjust the treatment parameters within the unit. The computer control system uses a programmable logic controller (PLC) and a software program, written by IWS, for the master control of the SBR and for communication outside the facility by modem and phone line installed with the unit.

Residential wastewater is discharged to an equalization tank and is pumped to the SBR for aerobic/anoxic biological treatment. In the treatment process, the wastewater/biological solids mixture (mixed liquor) is alternately mixed with, then deprived of, oxygen and is then periodically pumped to the clarification chamber, where quiescent conditions allow the solids to settle. A pump transfers the settled solids back to the aeration chamber and clarified effluent is pumped to the 3,000 gal holding tank. A portion of the mixed liquor is periodically wasted to a sludge holding tank to maintain optimal operating conditions in the treatment process.

A high-level switch in the effluent holding tank starts the coagulation-filtration system by injecting a coagulant, poly aluminum chloride (PAC) or aluminum sulfate (alum), ahead of a sand filter. The sand filter is a Centra-Flow dynamic sand bed filter that provides for continuous sand cleaning by using an airlift pump to extract the sand and solids from the filter, and lifting the mixture to a separation box. Cleaned sand is returned to the top of the filter and waste solids are piped to the equalization tank. A turbidity meter, used with an electronically actuated valve, monitors the effectiveness of the sand filter and reroutes the filtrate to the 3,000 gal holding tank for further treatment if the turbidity exceeds 5 Nephelometric Turbidity Unit(s) (NTU). Filtered water flows by gravity to the disinfection process.

The disinfection system consists of two UV disinfection units operating in parallel, with electronically actuated solenoid valves for each unit to prevent untreated water from reaching the post equalization tank. Each unit is designed to handle 20 gpm and achieve total coliform levels of <2.2 MPN/100 mL for water having suspended solids <10 mg/L and turbidity of <5 NTU.

IWS expects the system to require operator attention on a two to three visits per week basis, with additional time needed if special maintenance activities are required.

VERIFICATION TESTING DESCRIPTION

This verification was completed following the procedures described in the Verification Test Plan, which was prepared in accordance with the *Protocol for Verification of Wastewater Treatment Technologies,* dated April 2001.

Test Site

The verification test was performed at the Moon Lake Ranch Subdivision, located a few miles west of Boise, Idaho, which consists of 18 homes in an area not served by a centralized wastewater collection system. Each home has a holding tank and grinder pump system that is connected to a force main that delivers wastewater to the IWS Model 6000 SBR. The system, owned by the Moon Lake Ranch Homeowners Association, discharges treated effluent to a lake on the subdivision property and is permitted by the State of Idaho for surface water discharge.

Methods and Procedures

The system startup evaluation was made by shutting down one SBR and keeping the second unit on line while the out-of-service SBR was cleaned and prepared for startup. The startup time and conditions were documented. The verification test included sixteen sampling and analysis events over the one-year test period, and included monthly four-day sampling events, and one special four-day sampling event each season of the year. Sampling locations included the untreated wastewater, treated effluent from the SBR, and final effluent from the system after filtration and UV disinfection. Flow-weighted composite and grab samples were collected during sampling events, depending on the requirements and holding time for each analysis. Grab samples were collected each sample day for pH, temperature, turbidity, and total coliform. The samples for total coliform were collected and placed directly into sterile bottles provided by the laboratory. Flow-weighted, 24-hr composite samples were collected each sampling day for total suspended solids (TSS), five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and alkalinity. Four-day composite samples were collected for total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrite plus nitrate (NO_2+NO_3-N), and total and soluble phosphorus (TP and SP, respectively) by taking an aliquot of each 24-hr composite sample and combining them to make the 96-hr composite. All of the 96-hr composites were prepared in the laboratory to ensure proper preservation and cooling was maintained.

When the sludge holding tank was nearly full, arrangements were made to have the sludge removed by a licensed hauler. The volume of sludge pumped from the tank was recorded each time the tank was emptied and a sample of the sludge was taken for analysis of percent solids and metals (As, Ba, Cd, Cr, Hg, Pb, Ni, Zn).

All analyses were completed in accordance with EPA approved methods or *Standard Methods for the Examination of Waster and Wastewater*, 20th Edition. An established quality assurance/quality control (QA/QC) program was used to monitor sampling and laboratory procedures. Details on all analytical methods and QA/QC procedures are provided in the full verification report.

PERFORMANCE VERIFICATION

Overview

Evaluation of the IWS Model 6000 SBR began in April 2004 when one SBR was taken off line and cleaned. The verification testing started July 1, 2004 and proceeded without interruption through June 30, 2005. All sixteen four-day sampling events were completed as scheduled, yielding 64 sets of analytical data for daily composite and grab sample parameters, and 16 sets of data for the 96-hr composite parameters.

One major change was made to the test system approximately two and one half months after the start of the verification test. The original system included two 6,000 gal SBR units, with no equalization or distribution tank ahead of the SBR units. One of the SBR units was converted to an equalization tank, while the second SBR unit continued to operate as an SBR. IWS made this same change to all of their systems to provide better flow control to the SBR unit and to reduce the potential for upsets in the SBR during very high inlet flow rates.

Startup

The SBR startup proceeded without difficulty. Startup and acclimation procedures were easy to follow and the SBR system established a viable biomass that would provide treatment of the wastewater within two to three weeks.

Verification Test Results

The average daily flow based on daily averages calculated for each month in the twelve-month verification period, was 2,277 gal and ranged from 1,827 to 3,690 gal. The peak single day flow of 6,026 gal occurred in November 2004 and the lowest single day flow of 259 gal occurred in October 2004.

Table 1 presents the results for BOD_5 and TSS. The SBR effluent achieved a mean reduction of 95% for BOD_5. The final treated effluent had a mean value of 4 mg/L giving a mean reduction of 98% for BOD_5. Most of the BOD_5 results in the final effluent were below the detection limit of either 3 or 4 mg/L.

The mean influent COD was 480 mg/L, with a range of 120 to 1,440 mg/L. The SBR effluent mean COD concentration was 49 mg/L, ranging from <20 to 240 mg/L, and the COD concentration in the treated effluent had a mean of 22 mg/L with a range of <20 to 45 mg/L. The mean value was very close to the detection limit for the COD test (20 mg/L), as most of the test results were below the detection limit.

Table 2 presents the results for TKN, NH_3-N, NO_2+NO_3-N) and total nitrogen (TN). TN was determined by adding the concentrations of the TKN (organic plus ammonia nitrogen), and NO_2+NO_3-N in the effluent. The SBR demonstrated a mean reduction of 83% in TN for the verification test period. The final treated effluent nitrogen concentrations were similar to the SBR effluent except for a somewhat lower mean concentration of TKN. The overall system removal efficiency for TN was 88%.

Table 1. BOD_5 and TSS Data Summary

	BOD_5 (mg/L)			**TSS (mg/L)**		
	Influent	**SBR Effluent**	**Final Effluent**	**Influent**	**SBR Effluent**	**Final Effluent**
Mean	230	12	4	170	26	6
Maximum	580	39	8	440	160	23
Minimum	86	<4	2	15	3	3
Std. Dev.	99	8.3	1.4	90	28	4

Note: Data are based on 64 samples.

Table 2. Nitrogen Data Summary

	TKN (mg/L)			**NH_3-N (mg/L)**		
	Influent	**SBR Effluent**	**Final Effluent**	**Influent**	**SBR Effluent**	**Final Effluent**
Mean	37.6	3.23	1.23	29.8	0.44	0.33
Maximum	50.2	6.40	3.54	40.0	2.99	2.53
Minimum	17.9	1.17	0.40	11.9	<0.04	<0.04
Std. Dev.	9.95	1.86	0.90	8.65	0.94	0.76

	NO_2+NO_3-N (mg/L)			**TN (mg/L)**		
	Influent	**SBR Effluent**	**Final Effluent**	**Influent**	**SBR Effluent**	**Final Effluent**
Mean	0.08	3.1	3.1	38	6.3	4.4
Maximum	0.232	9.9	8.8	50	15	9.8
Minimum	<0.02	0.50	0.6	18	2.0	1.0
Std. Dev.	0.06	2.4	2.2	9.9	3.3	2.3

Table 3 presents data for TP and SP. The SBR demonstrated a mean reduction of 56% of the TP and 59% of the SP present in the influent. The trends are very similar with SP representing approximately 65-75% of the TP concentration in both the influent and SBR effluent for the verification test period. The final treated effluent showed a small additional decrease in SP (mean of 1.1 mg/L versus 1.6 mg/L), while the TP concentration decreased from a mean of 2.4 mg/L to 1.3 mg/L. Overall the full treatment system achieved a 76% reduction in TP concentration and 72% reduction in SP concentration.

Table 3. Phosphorus Data

	Total Phosphorus (mg/L)			**Soluble Phosphorus (mg/L)**		
	Influent	**SBR Effluent**	**Final Effluent**	**Influent**	**SBR Effluent**	**Final Effluent**
Mean	5.4	2.4	1.3	3.9	1.6	1.1
Maximum	7.4	4.7	2.7	5.7	3.5	2.5
Minimum	2.9	0.37	0.08	1.5	0.12	<0.05
Std. Dev.	1.5	1.1	0.75	1.2	0.89	0.76

Note: The data in Tables 2 and 3 are based on 16 samples.

Total coliform results are presented in Table 4. The UV system reduced total coliform levels to below the detection limit on most sample days. Only one day exceeded 100 MPN/100 mL and two additional days exceeded 10 MPN/100 mL.

Table 4. Total Coliform Data Summary

	Total Coliform (MPN/ 100 mL)		
	Influent	**SBR Effluent**	**Final Effluent**
Geometric Mean	7.1×10^6	1.2×10^5	4
Maximum	1.6×10^9	5.0×10^6	120
Minimum	2.3×10^5	2.4×10^3	2

Note: Data are based on 63 samples of influent and SBR effluent, and 53 smaples of final effluent.

Verification Test Discussion

High influent volumes in November (several days above 4,000 gal and two days over 5,000 gal) resulted in high water alarms in the system. During this time, the filter was not meeting turbidity requirements, resulting in reject water from the filtration system going to the SBR in addition to the high influent volume. Five truckloads (15,500 gal) of raw wastewater from the equalization tank were hauled away to stabilize the system. In response, the process cycle time was also changed from four hours to six hours and the aeration cycle was lengthened from two 45-minute periods to two 90-minute periods. Following this change, the maximum daily flow during the test (6,026 gal) occurred three days later, followed by continued high flows for several more days, but the high flows did not significantly impact system performance.

SBR effluent BOD_5 exceeded 20 mg/L on eight of the 64 monitoring days, and exceeded 30 mg/L on three of those days. While there was no distinct pattern or cause identified for the days with higher BOD_5, the higher BOD_5 concentrations did tend to correspond with higher TSS concentrations. The highest BOD_5 concentration of 39 mg/L corresponded to the maximum TSS concentration of 160 mg/L. TSS varied considerably in the SBR effluent with eight of the 63 monitoring days exceeding 50 mg/L. Clarification of the biomass was generally successful, but poorer settling did at times challenge the coagulation/filtration system. The filtration system and the on-line turbidity monitor worked as designed, rejecting filtrate with higher turbidity and TSS. On days when TSS was elevated in the SBR effluent, the final effluent was typically 5 mg/L or less.

Operation and Maintenance Results

In December, a total of 10,500 gal of wastewater was removed from the equalization tank and trucked to the local municipal wastewater treatment plant. The high water condition was most likely due to a faulty low level UV intensity reading on the UV unit, based on system pumping records, UV readings, filter turbidity and effluent coliform data collected when UV readings were properly acquired by the PLC. Once the problem was resolved, the unit returned to normal operation and no additional high water alarms were encountered.

The Model 6000 SBR used an aluminum salt (alum or poly aluminum chloride) as a coagulant to treat the SBR effluent prior to filtration and used methanol as a supplemental carbon source for the denitrification process. These chemicals were added from 55 gal storage tanks by chemical metering pumps activated by the PLC during flow to the filter (aluminum) and during the anoxic cycle in the SBR (methanol). The chemical dose for aluminum was approximately 2.5 mg/L as Al. The average coagulant use, based on an average daily flow of 2,280 gal, was approximately 0.5 lbs/day as Al. This translates to approximately 1.1 pounds of PAC per 1,000 gal treated or 2.8 lbs of alum per 1,000 gal treated. The average methanol solution feed rate was 1.7 gal (2.8 lbs) per day, which translates to approximately 50 mg/L as carbon or 1.2 lbs of methanol per 1,000 gal treated.

The IWS Model 6000 SBR, while complex, is highly automated and PLC controlled so that operator intervention is not required on a daily basis. The operator can access the PLC via the Internet and the PLC can send various alarms to an operator when there is a potential problem. Based on the records maintained during the verification test, four to five hr/week are needed to handle routine operation and maintenance activities, with additional time needed for mechanical problems or upset conditions. There were no major operational upsets in the SBR during the verification test, only adjustments in the SBR master cycle (aeration, anoxic, transfer, clarification). The most significant change was the November adjustment mentioned in the previous section.

There were no major mechanical component failures or major downtime periods during the verification test. When the process was changed in September to switch one SBR to an equalization tank, the switch was completed in two days, with flow to the one SBR maintained throughout the period. There was one structural failure during the test, when the baffle in the SBR between the aeration chamber and the clarifier chamber separated from the tank wall.

Quality Assurance/Quality Control

During testing, NSF completed a QA/QC audit of the Moon Lake Ranch site and Analytical Laboratories Inc. (ALI), the analytical laboratory. This audit included: (a) a technical systems audit to assure the testing was in compliance with the test plan, (b) a performance evaluation audit to assure that the measurement systems employed at the test site and by ALI were adequate to produce reliable data, and (c) a data quality audit of at least 10 percent of the test data to assure that the reported data represented the data generated during the testing. The audit determined that procedures being used in the field and the laboratory were in accordance with the established QAPP. EPA QA personnel also conducted a quality systems audit of NSF's QA Management Program.

Original Signed by
Clyde R. Dempsey for
Sally Gutierrez *September 27, 2006*
Sally Gutierrez Date
Director
National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency

Original Signed by
Robert Ferguson *October 2, 2006*
Robert Ferguson Date
Vice President
Water Programs
NSF International

NOTICE: Verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. EPA and NSF make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Mention of corporate names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products. This report in no way constitutes an NSF Certification of the specific product mentioned herein.

Availability of Supporting Documents

Copies of *The Protocol for Verification of Wastewater Treatment Technologies,* dated April 2001, the Verification Test Plan, Verification Statement, and the Verification Report are available from the following sources:

1. ETV Water Quality Protection Center Manager (order hard copy)
   NSF International
   P.O. Box 130140
   Ann Arbor, Michigan 48113-0140
2. NSF web site: http://www.nsf.org/etv (electronic copy)
3. EPA web site: http://www.epa.gov/etv (electronic copy)

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

EPA's Office of Wastewater Management has published a number of documents to assist purchasers, community planners and regulators in the proper selection, operation and management of onsite wastewater treatment systems. Two relevant documents and their sources are:

1. *Handbook for Management of Onsite and Clustered Decentralized Wastewater Treatment Systems* http://www.epa.gov/owm/onsite
2. *Onsite Wastewater Treatment Systems Manual* http://www.epa/gov/owm/mtb/decent/toolbox.htm

The accompanying notice is an integral part of this verification statement.

Environmental Technology Verification Report

Decentralized Wastewater Treatment Technology

International Wastewater Systems
Model 6000 Sequencing Batch Reactor System
(With Coagulation, Sand Filtration, and Ultraviolet Disinfection)

Prepared for

NSF International
Ann Arbor, MI 48105

Prepared by

Scherger Associates
In cooperation with
Eagle Sewer District

Under a cooperative agreement with the U.S. Environmental Protection Agency

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August 2006

Notice

The U.S. Environmental Protection Agency (EPA), through its Office of Research and Development, has financially supported and collaborated with NSF International (NSF) under a Cooperative Agreement. The Water Quality Protection Center (WQPC), operating under the Environmental Technology Verification (ETV) Program, supported this verification effort. This document has been peer reviewed and reviewed by NSF and EPA and recommended for public release.

Foreword

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

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Acronyms and Abbreviations

ALI	Analytical Laboratory, Inc.
ASTM	American Society for Testing and Materials
BOD_5	5-day biochemical oxygen demand
°C	Celsius degrees
COD	Chemical oxygen demand
DQI	Data Quality Indicators
EPA	U.S. Environmental Protection Agency
ESD	Eagle Sewer District
ETV	Environmental Technology Verification
ft^2	Square foot (feet)
gal	Gallons
gpm	Gallon(s) per minute
GP	Generic Protocol
HP	Horsepower
hr	Hour(s)
in.	Inch(es)
IWS	International Wastewater Systems, Inc.
Kg	Kilogram(s)
L	Liter
lbs	Pounds
MDL	Minimum Detection Level
min	Minute(s)
MPN	Most Probable Number method for coliform
Model 6000 SBR	Model 6000 Sequencing Batch Reactor System
NH_3-N	Ammonia nitrogen
NO_2+NO_3-N	Nitrite plus nitrate nitrogen
NRMRL	National Risk Management Research Laboratory
µg/L	Microgram(s) per liter
mg/L	Milligram(s) per liter
mL	Milliliter(s)
NSF	NSF International
NIST	National Institute of Standards and Technology
O&M	Operation and maintenance
PAC	Poly aluminum chloride
PLC	Programmable Logic Controller
PM	Project Manager for the Testing Organization (TO)
ppb	Parts per billion (µg/L)
QA	Quality assurance
QC	Quality control
RPD	Relative Percent Difference
scfh	Standard cubic feet per hour
SBR	Sequencing batch reactor
SCFM	Standard cubic feet per minute
SP	Soluble phosphorus

SOP	Standard operating procedure
T	Temperature
TKN	Total Kjeldahl nitrogen
TO	Testing Organization
TP	Total phosphorus
TSS	Total suspended solids
VO	Verification Organization (NSF)
VAC	Volts – AC
VTP	Verification Test Plan
WQPC	Water Quality Protection Center

Acknowledgments

The Testing Organization (TO), Eagle Sewer District, was responsible for managing the testing sequence on site at the Moon Lake Ranch Subdivision, including collection of samples, checking that instruments were being monitored and maintained, collection of field data, and data management. Mr. Lynn Moser was the Project Manager for the TO.

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The Verification Report was prepared by Scherger Associates.

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The manufacturer of the equipment was:

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The TO wishes to thank NSF International, especially Mr. Thomas Stevens, Project Manager, and Ms. Maren Roush, Project Coordinator, for providing guidance and program management.

Chapter 1
Introduction

1.1 ETV Purpose and Program Operation

The U.S. EPA created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The ETV Program's goal is to further environmental protection by substantially accelerating the acceptance and use of innovative, improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations (TOs); stakeholders groups that consist of buyers, vendor organizations, consulting engineers, and regulators; and the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

In cooperation with EPA, NSF operates the Water Quality Protection Center (WQPC), one of six centers under ETV. The ETV program has developed verification testing protocols that serve as templates for conducting verification tests for various technologies. The *Protocol for the Verification of Wastewater Treatment Technologies*, April 2001[1] (GP) was published as the guidance document for test plan development for verification testing of decentralized wastewater treatment systems for residential and non-residential wastewater with flow rates greater than 1,500 gallons per day (gpd).

The WQPC evaluated the performance of the International Wastewater Systems (IWS) Model 6000 Sequencing Batch Reactor System (Model 6000 SBR) for the removal of total suspended solids (TSS), biochemical oxygen demand (BOD_5), and nutrients, including phosphorus, Total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH3-N), and nitrite plus nitrate nitrogen (NO_2+NO_3-N) present in residential wastewater. The performance for reduction of total coliform bacteria was also determined. This report provides the verification test results for the Model 6000 SBR in a residential subdivision application, in accordance with the GP[1], and the technology specific test plan, *Verification Test Plan for Water Quality Systems, Inc,* August 2004[2] (VTP). International Wastewater Systems is the successor to Water Quality Systems Inc.

1.2 Testing Participants and Responsibilities

The ETV testing of the Model 6000 SBR was a cooperative effort between the following participants:

- NSF
- Eagle Sewer District
- Analytical Laboratories Inc.
- Scherger Associates
- International Wastewater Systems
- EPA

1.2.1 NSF International - Verification Organization (VO)

The WQPC of the ETV is administered through a cooperative agreement between EPA and NSF. NSF is the verification partner organization for the WQPC and the SWP area within the center. NSF administers the center and contracts with the Testing Organization (TO) to develop and implement the VTP, conduct the verification test, and prepare the Verification Report.

NSF's responsibilities as the VO included:

- Review and comment on the site specific VTP;
- Coordinate with peer reviewers to review and comment on the VTP;
- Coordinate with the EPA Project Officer and the technology vendor to approve the VTP prior to the initiation of verification testing;
- Review the quality systems of all parties involved with the TO and, subsequently, qualify the companies making up the TO;
- Oversee the technology evaluation and associated laboratory testing;
- Provide quality assurance/quality control (QA/QC) review and support for the TO;
- Carry out an on-site audit of test procedures;
- Oversee the development of a verification report and verification statement; and
- Coordinate with EPA to approve the verification report and verification statement.

Key contacts at NSF for the Verification Organization are:

Mr. Thomas Stevens, Program Manager
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1.2.2 U.S. Environmental Protection Agency (EPA)

The EPA Office of Research and Development, through the Urban Watershed Management Branch, Water Supply and Water Resources Division, NRMRL, provides administrative, technical, and QA guidance and oversight on all ETV WQPC activities. EPA reviews and approves each phase of the verification project. EPA's responsibilities with respect to verification testing include:

- Verification test plan review and approval;
- Verification report review and approval; and
- Verification statement review and approval.

The key EPA contact for this program is:

Mr. Ray Frederick, Project Officer, ETV Water Quality Protection Center
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1.2.3 Testing Organization (TO)

The TO for the verification testing was the Eagle Sewer District (ESD), with support from Scherger Associates for test plan development and report preparation. The ESD is located near the test site and operates a wastewater collection and treatment system in the county. The ESD has experienced wastewater operators and managers who oversaw all operations at the test site, collected all samples and delivered the samples to the laboratory. Scherger Associates, experienced in test plan development, system audits, and verification report writing supported the ESD in these areas. The laboratory performing the analytical work was Analytical Laboratories, Inc. (ALI) of Boise, ID. The laboratory has many years of experience in water and wastewater testing.

Mr. Lynn Moser was the Project Manager (PM) for the TO and was responsible for the successful completion of the field portion of the verification project. The ESD staff monitored the site operation and performed the sample collection. Scherger Associates prepared the Verification Report. ALI provided the laboratory services for the testing program and was responsible for laboratory quality assurance through its QA group. ALI was audited by NSF and approved for this ETV project.

The responsibilities of the TO included:

- Preparation of the site specific VTP;
- Conducting verification testing, according to the VTP;
- Oversight of the startup, operation, and maintenance of the Model 6000 SBR;
- Maintaining safe conditions at the test site for the health and safety of all personnel involved with verification testing;
- Scheduling and coordinating the activities of all verification testing participants, including establishing a communication network and providing logistical and technical support;

- Resolving any quality concerns encountered and report all findings to the VO;
- Managing, evaluating, interpreting and reporting on data generated by verification testing;
- Evaluating and reporting on the performance of the technology; and
- Document changes in plans for testing and analysis, and notify the VO of any and all such changes before changes were executed.

The key personnel and contacts for the TO were:

Eagle Sewer District
Mr. Lynn Moser
General Manager
Eagle Sewer District
44 North Palmetto Avenue
Eagle, ID 83616
(208) 938-3845 email:lynnmoser@qwest.net

Analytical Laboratories, Inc.
Ms. Kellie Hall and Mr. James Hibbs
Analytical Laboratories, Inc.
1804 N. 33rd Street
Boise, ID 83703
(208) 342-5515 email: ali@rmet.net

Scherger Associates
Mr.. Dale Scherger, Consultant
Scherger Associates
3017 Rumsey Drive
Ann Arbor, MI 48105-9723
(734) 213-8150 email: daleres@aol.com

1.2.4 Technology Vendor

The Wastewater Treatment Technology evaluated was the International Wastewater Systems Model 6000 SBR, assembled and distributed by International Wastewater Systems, Inc (IWS). IWS was responsible for supplying the equipment needed for the test and supporting the TO to ensure that the equipment was properly installed and operated during the verification test period. IWS had an existing contract with Moon Lake Ranch Subdivision to provide operation and maintenance for the system, and provided on going operation and maintenance of the system throughout the verification test. Specific responsibilities of the vendor were:

- Initiate application for ETV testing;
- Provide input to the verification testing objectives to be incorporated into the VTP;
- Provide complete ready to operate equipment, and the operation and maintenance (O&M) manual(s) typically provided with the technology (including instructions on installation, start-up, operation and maintenance) for verification testing;

- Provide additional equipment, piping, pumps, valves, flow meters, tanks, etc. needed to setup the test;
- Provide logistical and technical support (IWS is under contract with the site to provide operation and maintenance services);
- Provide assistance to the TO on the operation and monitoring of the technology during the verification testing;
- Review and approve the VTP;
- Review and comment on the Verification Report; and
- Provide funding for verification testing.

The key contact for International Wastewater Systems, Inc. was:

Mr. Claude Smith
International Wastewater Systems, Inc.
2020 Charlotte Street
Bozeman, Montana 59718
406-582-1115 email: claudes1985@yahoo.com

1.2.5 ETV Test Site

The verification test was performed at the Moon Lake Ranch Subdivision Wastewater Treatment Facility, located in Ada County, Idaho. IWS operates and maintains the Model 6000 SBR system installed at the site, under contract with the owner, the Moon Lake Ranch Home Owners Association. The owner is responsible for maintaining the sewer collection system up to the point the wastewater enters the collection box of the IWS system, which is the inlet to the system. The test site owner also provided:

- Space and utilities for the verification test; and
- Access to the existing equipment, piping, pumps, valves, flow meters, tanks, etc. needed to setup the test.

The owner contact was:

Mr. Ronald Sali
Moon Lake Ranch Home Owner's Association
100 N. 9th, Suite 200
Boise, Idaho 83702

1.2.6 Technology Panel

Representatives from the Technology Panel assisted the VO in reviewing and commenting on the VTP.

1.3 Background and Objectives

IWS assembles, installs, and operates decentralized wastewater treatment systems, including the Model 6000 SBR, which are designed to treat wastewater to meet the regulatory requirements for secondary treatment, surface water discharge criteria to lakes and streams, or standards for Class A water for reclamation and reuse. Actual numerical standards for direct discharge or water reclamation will vary by location. The SBR in the Model 6000 is designed to meet secondary wastewater treatment standards [typically 30 mg/L total suspended solids (TSS) and 30 mg/L biochemical oxygen demand (BOD_5)]. The entire Model 6000 system with coagulation, filtration, and UV disinfection processes is designed to meet direct discharge standards, and water reclamation and reuse standards, depending on the local requirements. The Model 6000 SBR tested in this verification is a full scale, commercially available unit. The discharge from the system is to a lake within the housing development.

Verification testing of decentralized wastewater treatment systems under the ETV WQPC protocol for Wastewater Treatment Technologies is designed to verify the contaminant removal performance and operation and maintenance performance of commercial-ready systems, following technically sound protocols and appropriate quality assurance and control. The objective of this verification was to determine the performance of the IWS Model 6000 SBR when used to treat domestic wastewater. Reductions in contaminant loads were evaluated to determine the effectiveness of the system to remove suspended solids (TSS), BOD, nutrients (phosphorus and nitrogen) and total coliform. The SBR was evaluated separately and in combination with the additional treatment steps.

The treatment system was monitored over a one-year test period. Influent and effluent samples from the SBR, and effluent samples after additional treatment by the sand filtration and UV disinfection units, were collected and analyzed for various contaminants or contaminant indicators including biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), nitrogen compounds, phosphorus compounds, and total coliform. These parameters and other operating parameters (flow, pH, alkalinity, turbidity, temperature) were monitored to meet the ETV objective of providing an overall assessment of the technology. The treatment system was also monitored for operation and maintenance characteristics, including the performance and reliability of the equipment and the level of operator maintenance required.

1.4 Test Site Description

The verification test was performed at the Moon Lake Ranch Subdivision, located a few miles west of Boise, Idaho. The subdivision consists of 18 homes and is located in an area not served by a central wastewater collection system. Each home has a holding tank and grinder pump system that is connected to a force main that delivers wastewater to the central wastewater treatment facility. The site and wastewater treatment system are owned by the Moon Lake Ranch Homeowners Association. A location map is presented in Figure 1-1.

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Figure 1-1. Verification test site location map.

The treatment system installed at the Moon Lake Ranch subdivision included two 6000 gpd modified sequencing batch reactors (SBR) operating in parallel, one sand filtration system, and two parallel ultraviolet disinfection treatment units. The treatment system had been in place for over three years prior to the start of the verification. Operating reports required under the State of Idaho permit system showed that the effluent had achieved the required standards.

Table 1-1 shows the discharge permit limits for the facility. Treated effluent is discharged to a lake on the subdivision property and thus permit limits are based on surface discharge requirements.

Table 1-1. Discharge Permit Limits for Test Site

Parameter	Sample Frequency	Sample Type	Permit Limit
Flow	Daily	Meter	10,000 gpd
BOD	1/month	Composite	7.5 mg/L max; 5 mg/L monthly avg.
TSS	1/month	Composite	7.5 mg/L max; 5 mg/L monthly avg.
Turbidity	Continuous	In line meter	2 NTU – 24 hr avg. 5 NTU – instantaneous max.
Total coliform	1/month	Grab	23 MPN/100 mL

IWS operates and maintains the wastewater treatment system under contract with the Moon Lake Ranch Home Owners Association. Licensed wastewater operators visit the site on a regular basis to monitor the system, maintain equipment, and collect samples. The system is also monitored from the IWS office via a modem and telephone hookup between the site and the office in Bozeman, Montana.

Flow rate data for the system had been collected as part of the normal PLC operating system and for reporting to the State of Idaho. A summary of the average daily flow rates for the period January 2000 through May 2001 and for the two months prior the start of the verification test, May and June 2004, is shown in Table 1-2. The data for January 2000 to May 2001 is based on monthly average flow records, while the data for May to June 2004 was obtained by a flow meter installed in the influent line prior to testing.

Table 1-2. Summary Flow Rate Data for Test Site

Parameter	Jan 2000 – May 2001 (gpd)	May – June 2004 (gpd)
Average	1,627	2,311
Maximum	2,639	3,326
Minimum	863	1,187

Prior to the start of the verification test, influent wastewater characterization data were not available, as incoming wastewater was not routinely monitored. All of the wastewater comes from residential homes and it was expected to be typical domestic strength wastewater. Effluent water quality data were available from the quarterly reports prepared for the State Of Idaho. Influent and effluent data were collected throughout the verification test. These data are presented in Section 4 – Results and Discussion of this report.

Chapter 2
Technology Description and Operating Processes

2.1 Technology Overview

The IWS Model 6000 SBR includes a 6,000 gallon (gal) modified sequencing batch reactor (SBR), a coagulation injection system, a gravity sand filtration system, and an ultraviolet disinfection system. A description of each system is provided below. The initial system installed at the Moon Lake Ranch included two 6,000 gal SBRs and two UV systems that operate in parallel to provide a total maximum design capacity of 12,000 gpd. This system was modified in September 2004 to convert one of the SBRs to a 6,000 gal distribution/equalization tank. Thus, the current system at Moon Lake Ranch is a single Model 6000 SBR system with a stabilization/equalization tank. The vendor O&M manual (updated in January 2006) indicates the system is most efficient at average daily flows of 3,000 gal, with a maximum flow of 6,000 gal. The verification test included verification of the entire system to meet surface water discharge standards. Data was also collected of the SBR effluent prior to filtration and disinfection to provide information on the treatment efficiency of the SBR itself.

2.1.1 Modified Sequencing Batch Reactor

Each SBR is a 6,000 gal fiberglass tank constructed for IWS to established specifications. Each SBR tank has three chambers: a comminuting chamber, an aeration chamber, and a clarification chamber. Figure 2-1 illustrates a typical 6,000 gpd SBR. The IWS SBR is designed to provide treatment by optimizing the treatment conditions using a computer controlled and monitored system of pumps, floats, and probes to measure, monitor, and adjust the treatment parameters within the unit. The computer control system uses a programmable logic controller (PLC), associated equipment and a software program written by IWS. The PLC provides for the master control of the SBR, and can communicate outside the facility by way of the modem and phone line installed with the unit.

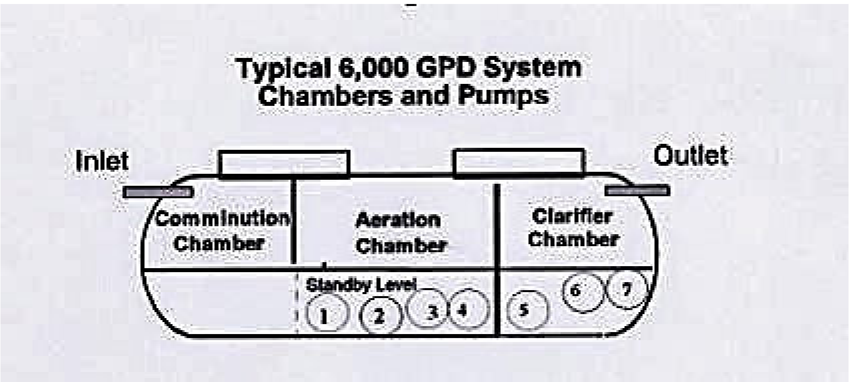

Figure 2-1. Sequencing batch reactor configuration.

The comminution chamber, the first chamber in the unit, receives wastewater pumped through the force main from the homes. Large solids are reduced in size in this chamber to aid in treatment through a process of aeration and circulating pumps (1) and (2) located in the aeration chamber. The divider separating the comminution and aeration chambers is a fiberglass frame supporting pipes and, in the lower half of the tank, a non-corrosive screen that prevents large objects from continuing through the treatment process.

The aeration chamber is located in the second section of the tank. In this chamber, mixed liquor is alternatively mixed with and then deprived of oxygen. This process accelerates the removal of nitrogen from the sewage being treated. Four pumps are located in the aeration chamber. Pumps 1 and 2 provide the main aeration for the treatment process by drawing in outside air (using a venturi system) and mixing it with the mixed liquor circulating against the retention screen between the comminution chamber and the aeration chamber. These pumps also provide mixing during the anoxic period when the pumps operate with the air intake valves closed. Pumps 3 and 4 transfer mixed liquor from the aeration chamber to the clarification chamber. This transfer operation causes the contents of the clarification chamber to overflow back to the aeration chamber through weirs located at the top of the baffle separating the two chambers, returning scum that rises to the top of the clarifier chamber to the aeration chamber.

The clarifier chamber receives mixed liquor from the aeration chamber, providing a quiet settling area for solid/liquid separation. A normal batch cycle consists of two settling periods. The first occurs immediately after the mixed liquor has been received from the aeration chamber. Subsequent to this settling period, pump (5), one of the three pumps in the clarifier chamber, transfers settled solids from the lower section of the contact chamber back to the aeration chamber. After another period of settling, the clarified effluent is transferred to the next treatment phase by either pump 6 or 7. Pumps 6 and 7 provide an identical discharge but alternate in use every other discharge cycle. Pumping time for the discharge pumps is controlled by both level controllers in the clarifier and aeration chambers and by maximum time set in the PLC. The level controllers assure that the discharge matched to the incoming wastewater flow rate. The next phase of treatment in the Model 6000 is coagulation and filtration. In other applications, the treated effluent can be discharged directly for use.

A detailed description of the entire SBR process and pumping cycles is provided in the O&M manual in Appendix A.

2.1.2 Coagulation Injection and Filtration System

The SBR treated effluent is transferred by pumps 6 or 7 to a 3,000 gal holding tank. This water is then pumped thorough a pipe network that contains the coagulation injection system. The coagulation and filtration system is started and stopped by level sensors in the holding tank. When the treated water in the SBR reaches the upper level switch (float switch), the coagulation-filtration system pump is started and water is processed through the coagulation-filtration process, and then flows by gravity through the UV disinfection unit. When the water level in the holding tank reaches the low level switch (float switch), the pump is turned off, and flow through coagulation-filtration-UV processes is stopped. The coagulation injection system consists of an electronic metering pump with a five-function valve, a static mixer, coagulant reservoir, coagulant reservoir mixer, and the coagulant, typically either poly aluminum chloride (PAC) or aluminum sulfate (alum). The system is designed to introduce a coagulating agent into the SBR treated effluent, prior to sand filtration, to improve solids removal in the sand filter. An added benefit of coagulant addition is phosphorus removal. The metering pump provides control over the dose of coagulant that is used in the system. The coagulant solution (PAC or alum) is made on site and stored in a mixed tank, a 55 gal polyethylene drum with a cover. The tank is mixed with ¼ HP stainless steel mixer.

The filtration system consists of a Centra-Flow dynamic bed sand filter designed to remove suspended solids, coagulated materials, and finer solids that cause turbidity. Influent enters at the center of the filter through a feed chamber and flows downward through the layers of increasingly fine sand. Filtered water is collected through a screen around the periphery before exiting the filter. Solids captured in the filter are drawn downward with the sand into the suction of an airlift pump. The sand recirculation rate is typically set to turnover the sand bed every four hours. The turbulent upward flow in the airlift provides a scrubbing action effectively separating the sand and solids before discharge to the filter wash box. The wash box is a baffled chamber that allows for counter current washing, using filtered water, and gravity separation of the cleaned sand and the concentrated solids. Regenerated sand is returned to the top of the filter, and waste solids are piped to the distribution tank. A turbidity meter is used in conjunction with an electronically actuated valve to monitor the effectiveness of the sand filter and reroute the feed stream to the 3,000 gal holding tank for further treatment if the effluent turbidity exceeds allowable levels. The filter can handle flows up to 35 gpm, but normally operates at 10 – 15 gpm.

The Centra-Flow filter is continuously backwashed during normal operation. The “dirty” sand is continuously being drawn out of the main filter unit and passed through the wash box by the air lift system. Filtered effluent is used for backwash water. The backwash water flow rate to the sand wash box is controlled by the water level differential between the elevation of the filtrate overflow and the wash box. This differential is controlled by the weir on the filter unit. No pumping of backwash water is required. Normal flow rate for the backwash water is approximately 3.0 – 3.5 gpm. No storage for backwash water is needed.

2.1.3 Disinfection System

The disinfection system consists of two ultraviolet disinfection units operating in parallel, with electronically actuated solenoid valves for each unit to prevent untreated water from reaching the post equalization tank. The UV system is a standard UV design. Each unit is designed to handle 20 gpm and achieve total coliform levels of <2.2 MPN/100 mL. The inlet water specifications are suspended solids <10 mg/L and turbidity of <5 NTU. The online turbidity meter monitoring the sand filter effluent ensures that suspended solids are low before the water flows to the UV units. If the turbidity level exceeds the set point (typically 5 NTU), the filtrate is routed back to the filter feed-water holding tank for reprocessing to lower the turbidity (thereby the TSS) level in the filtered water. The UV lamps are always on, whether or not there is flow through the process. The filtered effluent flows by gravity from the filter. Flow is intermittent as controlled by the level controllers in the SBR effluent holding tank (coagulation-filtration system influent). The final treated effluent is collected in a sump where it is pumped to the discharge location. At Moon Lake Ranch, the water is discharged to the lake on site, but in other applications, the discharge can be to a drain field or other suitable discharge location.

The UV system is designed to operate at a wave length of 254 nanometers wavelength using standard UV lights, with the minimum dosage of 30 milliwatt-seconds per square centimeter at peak flow. Overall, power consumption is estimated to be 54 watts per unit. Normal lamp replacement occurs prior to the lamp reaching 10,000 hr. The UV units at Moon Lake Ranch do have visual monitors. Cleaning of the quartz sleeves is not automatic but is part of the required routine maintenance performed by the operator. Each operator visit (typically two to three times per week) includes the manual cleaning by operating the cleaning device on each lamp. In addition, every three months the UV unit is shut down and cleaned thoroughly. The UV intensity is monitored, with the solenoid valves closing when lamp intensity reaches 25%. There are both audible and PLC alarms available for the unit, however IWS only facilitates the PLC alarm to contact an operator if a malfunction occurs.

2.1.4 PLC Alarm Equipment

The PLC controls and monitors a wide range of information on the IWS system. The PLC can alert an operator away from the site that a problem has occurred. The system also tracks data on the operating system. Typical alarm equipment and notification include:

Alarm equipment:

- Multi-zone dialer (battery backup)
- GE Programmed Logic Controller (battery backup)
- Level sensors
- I/O Failure alarms
- Dynamic filter alarms (head loss, air flow, liquid level)
- Turbidity meter alarms (lamp failure, high NTU)
- UV lamp failure

Alarm notification:

- Loss of power
- Abnormal noise level in control building
- Abnormal temperature in control building
- Biological treatment
    - Exceed level parameters for system tanks
    - Exceed level parameters for auxiliary tanks (sludge tank, dosing tank)
    - Pump failure
    - Outside of prescribed range of (turbidity)
    - Filter head loss
    - UV lamps

2.2 Test Unit Specifications and Test Setup Description

The installed Model 6000 SBR system is fully described in the Operation and Maintenance Manual presented in Appendix A. The vendor O&M manual indicates the system is most efficient at average daily flows of 3,000 gal, with a maximum flow of 6,000 gal. The reader is referred to the O&M Manual for additional detailed information on all of the individual components of the system. A brief summary of the system is given below. Figure 2-2 is a simple process flow diagram of the unit. Appendix B shows photographs of the system taken at the test location.

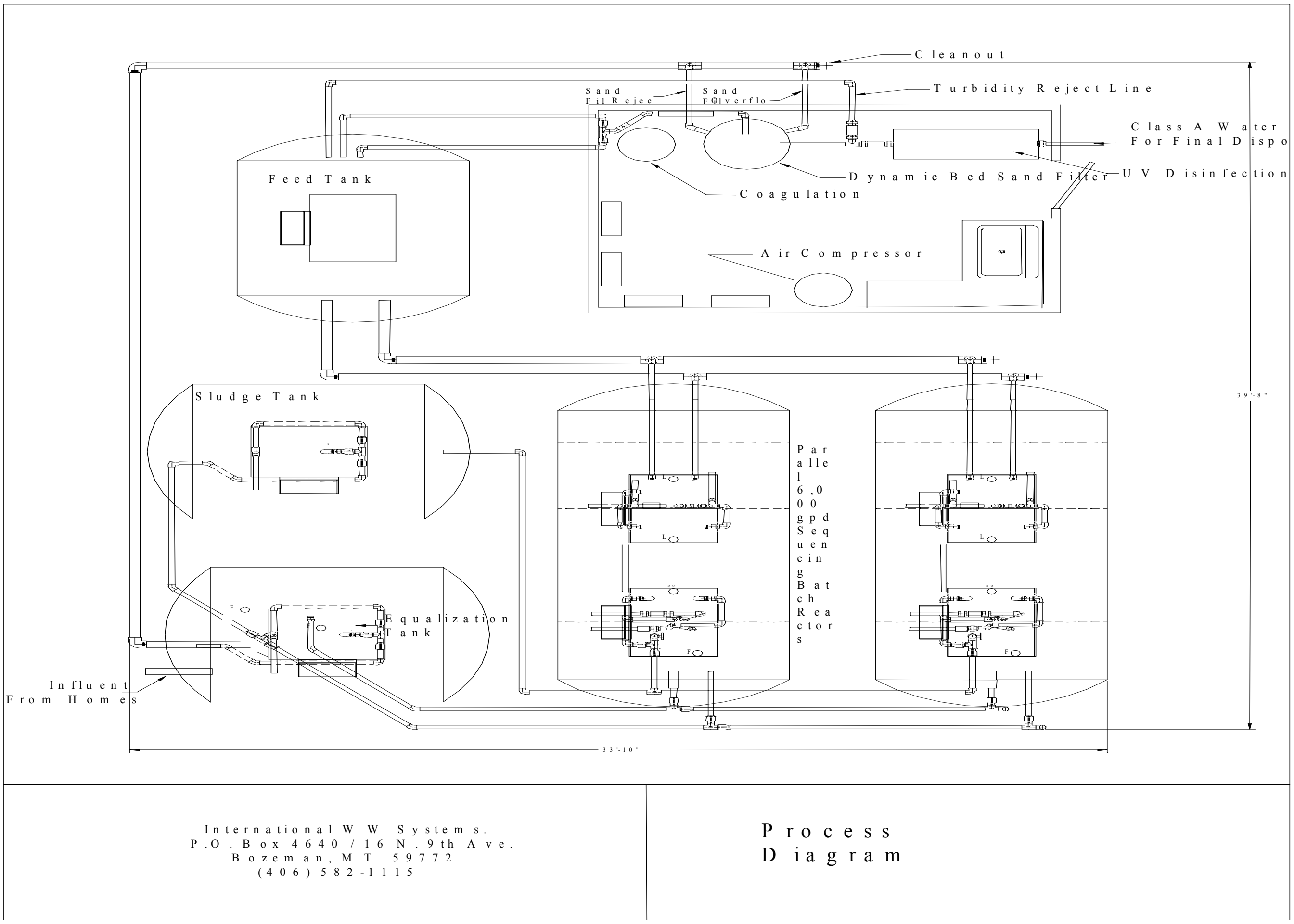

Figure 2-2. IWS Model 6000 process flow diagram.

Summary Specifications

Two Modified Sequencing Batch Reactors (See Figure 2-1 for chamber configuration) - 6,000 gpd capacity, with the most efficient operation at average daily flows of 3,000 gal.

Dimensions16 ft long × 8 ft wide × 8 ft high
Fiberglass tank
Aeration volume- 3,090 gal
Clarifier volume-1,500 gal
Aerator efficiency - 0.809 lbs O_2 per HP-hr
Minimum design oxygen - 2.0 mg/L

One 3,000 gal Fiberglass Holding Tank – Receives SBR effluent

One Coagulation Injection System
Chemical metering pump
Liquid coagulant storage tank - 55 gal
Static mixer – in the feed line after coagulant injector
Feed line control system – to pace coagulant to wastewater flow

One Centra-Flow Dynamic Bed Sand Filter
Dimensions -36 in. diameter, 130 in. high
Sand weight - 4,000 lbs
Peak flow rate- 35 gpm
Normal flow rate-15 gpm
Typical Surface flow rate – 3- 5 gpm/ft^2
Sand size range0.6 – 2.36 mm
Airlift flow rate - 1-5 SCFM
Airlift pressure -35 psi
Design head loss- 48 in.

Two UV Disinfection Units (parallel operation)
Design flow rate - (each unit)20 gpm
Dimensions - 50 ⅜ in. long × 5 11/16 in. wide × 9 ½ in. high
Gross weight -36 lbs
Design TSS - <10 mg/L
Design Turbidity - <5 NTU
Minimum UV dosage @ peak flow30 milliwatt-seconds per square centimeter
Materials- Stainless steel
Voltage -120 VAC single phase
Power consumption - 54 watts
Output- 254 nanometers
Disinfection design - <2.2 per 100 mL of total coliform
Valving criteria - Stop flow in power failure or low UV intensity

2.3 Systems Changes during the Verification Test

One major change was made to the Moon Lake Ranch system in September 2004, approximately two and one half months after the verification test started in July 2004. The system, as described earlier, included two 6,000 gal SBR units, and did not include an equalization or distribution tank ahead of the SBR units. As part of new operating management at IWS, and based on experience at several other locations, IWS changed the basic system approach for all of their systems to include a distribution (equalization) tank ahead of the SBR units. This approach provided better flow control to the SBR units and reduced the potential for upsets in the SBR(s) during very high inlet flow rates.

The flow data collected from January through August 2004 indicated that typical daily flow rates at Moon Lake Ranch were on the order of 2,000 to 3,000 gpd. IWS determined that a single 6,000 gpd SBR could handle the wastewater flows, and that the second SBR could be used as an equalization/distribution tank. In September 2004, SBR 1 was converted to an equalization/ distribution tank that received the raw wastewater. At that time, all of the sludge in SBR 1 was pumped to the waste sludge holding tank and the unit was cleaned. The inlet force main at the treatment plant site was then set to send all wastewater to SBR 1. The pumping system in SBR 1 was used to maintain solids in suspension. The discharge pumps in SBR 1 were piped to the inlet to SBR 2 and the PLC was changed to send raw wastewater from SBR 1 to SBR 2 on a steady basis after the completion of each treatment cycle in SBR 2.

While changes of this type are not normally allowed after a verification test has started, the change was approved in this situation because it was being incorporated in all new system designs. It was determined that it was important that the verification test be performed on the most current design approach, so the verification data would reflect this significant process design change. In addition, flow rate data collected during the startup period and after the installation of the new influent flow meter showed that daily flows were typically 2,000 to 3,000 gpd, which was well below the total maximum installed flow capacity of 12,000 gpd. It was agreed at the time the change was made that if a significant difference in effluent quality occurred after the modification, an additional two months of testing would be added to the verification test.

In November 2004, in response to high flow conditions and to try to improve total nitrogen removal, the operators changed the master cycle from a four-hr cycle to a six-hr cycle. The aeration cycle was lengthened from two 45-minute periods to two 90-minute periods. As shown in Section 4 – Results and Discussion, the effluent quality was not significantly different before and after the system changes.

2.4 IWS Claims and Criteria

IWS claims that the Model 6000 SBR with filtration and disinfection will treat wastewater to meet surface water discharge criteria or recharge criteria. Effluent criteria stated by IWS for the system include:

Table 2-1. IWS Wastewater Treatment Claims

Parameter	Raw Residential Wastewater Characteristics	Effluent Characteristics after Filtration and UV Disinfection
BOD_5	200-290 mg/L	< 10 mg/L
TSS	200-290 mg/L	< 10 mg/L
TKN	18-29 mg/L	< 10 mg/L
Total Phosphorus (TP)	6-9 mg/L	1-3 mg/L
Total Coliform	10^8-10^{10} MPN/100 mL	<2.2 MPN/100 mL

Chapter 3
Methods and Test Procedures

3.1 Verification Test Plan and Procedures

The VTP, *Verification Test Plan for Water Quality Systems, Inc,* August 2004[2], is included in Appendix C. The VTP details the procedures and analytical methods used to perform the verification test, including the various tasks designed to verify the performance of the Model 6000 SBR and to obtain information on operation and maintenance requirements. The VTP covered two distinct phases of fieldwork: startup of the unit and a one-year verification test that included monthly sampling programs and four extra sampling periods. The verification test was completed between July 2004 and June 2005.

This section summarizes each of the testing elements performed during technology verification, including sample collection methods, analytical protocols, equipment installation, and equipment operation. QA/QC procedures and data management approach are discussed in detail in the VTP.

3.2 Moon Lake Ranch Subdivision Test Site Description

A complete description of the test site and historical data for the site operation are presented in Section 1.4. Likewise, a complete description of the IWS Model 6000 SBR installed at the Moon Lake Ranch Subdivision, used for this verification, is provided in Chapter 2.

The historic flow data for the site showed that while there was a variation in the average daily flow, there was no distinct pattern (weekend or seasonal) to the fluctuations in the flow rate. The maximum and minimum flows tended to occur on weekend days. A new influent flow meter installed in preparation for the verification test provided additional data for May and June 2004. These more current data (Table 1-2) confirmed the earlier data obtained from the PLC. Flow rates were somewhat higher as additional homes had been constructed between 2001 and 2004. The maximum flow rate, however, was limited by the capacity of the force main to carry water pumped by the homes through the system.

Given the nature of the residential community, it was not expected that any significant seasonal variation would occur. Based on these data the four special sampling periods were spaced over the year, with one test sequence occurring in each quarter near holiday periods. The special test sequences were placed on or near some holiday to provide data on these special periods.

3.3 Installation and Startup Procedures

The IWS Model 6000 SBR with filtration and disinfection had been installed and operating at the test site since the year 2000. Therefore, it was not possible to shut down the entire system, as untreated wastewater would be discharged from the site in violation of the site's discharge permit. The IWS Model 6000 SBR had two SBR units running in parallel at the site. Based on the flow rates, it was determined that one SBR could carry the load for at least a short period time if needed (1-2 months). Therefore, a startup approach was developed based on shutting down one SBR and keeping the second unit on line, while the out of service SBR was cleaned and prepared for startup. The cleaned SBR was then re-started using the normal startup procedures detailed in the IWS operating manual. This approach allowed for the observation of how the system responded during startup. The startup time and conditions were documented.

For the startup, the valve system on the influent force main was used to divert all of the influent flow to SBR 1. Once it was confirmed that the system was operating properly on one unit, SBR 2 was emptied of all sludge by pumping the sludge to the sludge holding tank. The unit was cleaned and prepared for startup. The SBR was inspected by ESD staff to verify that it was clean and in a "like new" condition. IWS then obtained 1,000 gal of activated sludge from a local wastewater treatment plant (Meridian, Idaho), SBR 2 was "seeded" with this material and an acclimation period started. The sludge holding tank was pumped down by a vacuum truck and taken to a local treatment plant for disposal.

The IWS startup procedure (Appendix D) for acclimating and starting the SBR unit was used for the clean unit. IWS determined through checks of pH, temperature, dissolved oxygen, settleable solids and visual observation when the initial startup was complete and the SBR was ready to receive wastewater feed on a continuous basis. The filtration system and UV disinfections systems were then thoroughly cleaned and placed in "like new" startup condition.

This cleaning procedure included a thorough backwash of the filtration system and cleaning of the tanks, lines, or pumps. The UV unit was cleaned, new lamps installed, and quartz sleeves were inspected to ensure the unit met "like new" manufacturer specifications. All cleaning and operations during this period were performed by the IWS operation and maintenance staff. Once the IWS personnel had finished the cleaning, ESD staff inspected the equipment and confirmed that conditions met the typical initial startup specifications. IWS then resumed splitting the flow between SBR 1 and SBR 2 and a full system startup for SBR 2 was underway.

IWS had indicated that startup typically takes about 2-4 weeks so there was no requirement in the verification protocol[1] for sampling and analysis during the startup period. At the request of IWS, grab samples for the normal startup parameter list, shown in Table 3-1, were collected during the startup. Data was also collected on the operating SBR and filtration/UV system for compliance with the site discharge permit.

3.4 Verification Testing

The verification test was designed to determine the effluent quality achieved by the IWS Model 6000 SBR in typical domestic wastewater applications. There were two verification tests performed under the single test plan. The IWS Model 6000 SBR was tested before the coagulation/filtration and UV disinfection treatment steps to determine the effectiveness of the SBR to meet secondary effluent quality. The entire IWS Model 6000 SBR system (SBR, coagulation/filtration and UV disinfection) was tested by collecting and analyzing samples of the final treated effluent.

Table 3-1. Startup Monitoring – Typical IWS Recommended Schedule

Sample Schedule Parameter	Frequency	Sample Type	Record Keeping
Flow rate (gpd)	Daily	Meter	Recorded by time and date
pH	Daily	Grab	Recorded by time and date
Temperature	Daily	Grab	Recorded by time and date
Influent BOD_5 (mg/L)	Once/month	Composite	Chain of custody and lab reports
Effluent BOD_5 (mg/L)	Once/month	Composite	Chain of custody and lab reports
BOD_5 removal (%)		Calculation	Chain of custody and lab reports
Influent TSS (mg/L)	Once/month	Composite	Chain of custody and lab reports
Effluent TSS (mg/L)	Once/month	Composite	Chain of custody and lab reports
TSS removal (%)		Calculation	Chain of custody and lab reports
TN (mg/L as N)	Once/month	Composite	Chain of custody and lab reports
Total coliform	Once/month	Grab	Chain of custody and lab reports
Settleable solids	Periodic when on site	Grab	Recorded daily during startup
Dissolved oxygen	Periodic when on site	Grab	Recorded daily during startup

3.4.1 Objectives

The objectives for the experimental design for this verification test were:

- Determine the treatment performance of the IWS Model 6000 SBR (stand alone SBR) to remove the key target constituents, including TSS, BOD_5, COD, TKN, NH_3-N, NO_2+NO_3-N, and total and soluble phosphorus (TP and SP, respectively);
- Determine the treatment performance of the IWS Model 6000 SBR system (SBR unit, coagulation/filtration and UV disinfection units) to remove the key target constituents, including TSS, BOD_5, COD, total nitrogen (TN) (TKN, NH_3–N and NO_2+NO_3-N), TP, SP and total coliform;
- Determine the basic operation and maintenance requirements for the system;
- Determine solids residuals produced by the system; and
- Determine the labor time, chemical use and power consumption of the system

3.4.2 Verification Test Period

The test period began at the end of the startup period, and continued for 12 consecutive months. No more than 36 days of upset conditions or downtime was allowed by the protocol during the verification test period. The test included a full range of flow conditions and influent characteristics. The test site flow data (described in Section 3.2) and general information available about the test site indicated that with reasonable spacing of sampling through the year and on weekdays and weekends, all types of conditions would be monitored over the one-year period.

3.4.3 Flow Monitoring

An ISCO magnetic flow meter was installed in the force main sewer ahead of the SBRs. The flow meter monitored the flow rate and volume of untreated wastewater entering the SBR, and the meter output was connected to the system PLC to record the flow data. This flow meter also triggered the influent wastewater sampling equipment so that flow based composite samples were collected.

The IWS Model 6000 SBR system operates in batch mode. Wastewater is received from the force main into the SBR and a sequence of treatment steps occurs in the SBR (see Section 2). The system tracks treatment flow through the SBR, filtration, and UV disinfection units by monitoring the pump cycles on the SBR discharge and the pump cycles on the feed to the filtration unit. The pumps are activated by level controllers in the SBR settling tank and intermediate holding tank (influent to the filtration unit). The pumps are shutdown by level controllers in these same tanks. The PLC monitors the run time of each pump(s), which can be used to estimate the flow data for the SBRs and filtration system. Using the tank dimensions and the distance between the level controllers in conjunction with the pump run times, the pump flow rates can be calculated. The continuous flow of filter backwash water is discharged to the SBRs, resulting in higher flow rates through the SBRs and filtration system than the raw wastewater and final discharge wastewater flow rates (which are approximately equal). If the turbidity in the filtered wastewater indicates that TSS is elevated, the filtrate is diverted back to the filter feed water tank for reprocessing, protecting the UV system from elevated solids levels in the wastewater. The UV system operates on gravity discharge from the filtration system and thus the flow for this unit is the same as for the filtration system. PLC based flow data was collected and was part of the operating record.

The influent flow meter was used as the basis for all raw wastewater and final treated water flow rates presented in this report. An effluent flow meter was installed by IWS during the last two months of the verification test to measure the final treated water discharged from the UV system. Data from the effluent flow meter was similar to the influent flow data collected for the verification test.

3.4.4 Sampling Locations and Procedures

The sampling program covered the entire 12-month test period (July 2004 through June 2005), and included once per month, four-day sampling events, and four special four-day sampling events, one per season of the year. This approach provided samples during 16 of the 52 weeks in the verification test period. As described in Section 3.2, the preliminary site flow data did not indicate any significant difference between weekday and weekend flow so the four-day sampling periods were set to cover typical four-day periods (Monday to Thursday or Tuesday through

Friday). The special sampling periods (four additional sequences) were set to cover holiday and weekend periods, once each quarter during the verification test.

Sampling locations included the untreated wastewater influent, the treated effluent from the SBR, and the treated effluent from the entire system after filtration and UV disinfection. The untreated wastewater from the subdivision homes was collected from the force main before it entered the SBR. The SBR treated effluent was sampled from the discharge pipe that carried the treated wastewater to the intermediate holding tank (feed tank for the filtration unit). The final treated effluent was sampled just downstream of the UV disinfection system and upstream of the final discharge point to the wet well. This location was under gravity flow, with flow only occurring when the pump was feeding water to the filtration unit from the holding tank.

Each sampling locations was setup so that flow weighted composite samples were collected directly into composite sample containers. The site inlet flow meter was wired to the PLC and used to activate the influent automatic sampler to collect a flow weighted composite sample for each 24-hr period. The PLC controlled the flow of the SBR treated effluent and the final effluent by controlling the pumps transferring these waters. The automatic sampling equipment was tied to the PLC, which activated the samplers during periods of flow.

Both grab and composite samples were collected during sampling events, depending on the requirements and holding time for each analysis, as summarized in Table 3-2. Grab samples were collected each sample day for pH, temperature, turbidity, and total coliform. pH and temperature were measured in the field by ESD staff. The samples for total coliform were collected and placed directly into sterile bottles provided by the laboratory. Twenty-four hour flow weighted composite samples were collected each sampling day for TSS, BOD_5, COD, and alkalinity using the automatic sampling equipment. Samples from the large composite container were poured into sample bottles supplied by the laboratory. All of the sample containers used for the composite samples were cooled during the sampling period by placing ice around the composite sample container. Samples were transported to the laboratory in coolers with ice to maintain proper sample temperature.

In addition to the 24-hr composite samples, there were composite samples collected representing a 96-hr period (four-day composite.) These samples were collected by taking an aliquot of each of the 24-hr composite samples and combining them to make a 96-hr composite. The procedure for TKN, NH_3-N, NO_2+NO_3-N, and TP was to take a one-liter aliquot of the 24-hr flow weighted composite and preserve the sample with sulfuric acid. The sample bottle was then cooled until the 96-hr period was complete. The four individual samples were then combined to make a single 96-hr flow-weighted composite. In the case of soluble phosphorus (SP), the same procedure was used except that a separate 250 mL aliquot of the 24-hr composite was filtered through a 0.45-micron filter and the filtrate was preserved with acid and cooled. These individual samples were combined on a relative flow-weighted basis from the four 24-hr periods. All of the 96-hr composites were prepared in the laboratory in order to ensure proper preservation and cooling was maintained.

The automatic sampling equipment was cleaned before each use and after each sampling event. The samplers were inspected to determine that tubing was in good condition. Clean sample containers were used each sampling day.

The general sludge settling characteristics in the SBRs were monitored by the operators periodically using a 1,000 mL graduated cylinder as described in the SBR O&M manual. Sludge levels were typically operated in the 25-55% range to provide good to excellent settling qualities.

Sludge was periodically pumped from the SBRs to the sludge holding tank. The removal frequency was based on the operational needs of the system. When the holding tank is near full, arrangements were made to have the sludge removed by a licensed hauler. Each time sludge was pumped from the holding tank for disposal, the volume of sludge pumped to the tank truck was recorded and a sample taken for analysis. Analysis included percent solids and metals (As, Ba, Cd, Cr, Hg, Pb, Ni, Zn).

Table 3-2. Summary of Sampling Collection and Analysis

Parameter	Sample Type	Frequency	Number of Events	Estimated Number of Samples (2)
pH	Grab	Daily - 4 days per event	16	192
Temperature	Grab	Daily - 4 days per event	16	192
Turbidity	Grab	Daily - 4 days per event	16	192
Total coliform	Grab	Daily - 4 days per event	16	192
TSS	24-hr composite	Daily - 4 days per event	16	192
$CBOD_5$	24-hr composite	Daily - 4 days per event	16	192
COD	24-hr composite	Daily - 4 days per event	16	192
Alkalinity	24-hr composite	Daily - 4 days per event	16	192
TKN	96-hr composite(1)	One per 4 day event	16	48
NH_3-N	96-hr composite(1)	One per 4 day event	16	48
NO_2+NO_3-N	96-hr composite(1)	One per 4 day event	16	48
TP	96-hr composite(1)	One per 4 day event	16	48
SP	96-hr composite(1)	One per 4 day event	16	48

(1) A 96-hr composite was made by taking the 24-hr daily composite, preserving it, and then combining at the end of the four-day event the four samples into one event composite. SP was handled by filtering an aliquot of sample in the laboratory and preserving it each day. The filtered samples were combined for an event sample.

(2) Number of samples is based on three (3) sampling locations, untreated influent, SBR treated effluent, and the final treated effluent after filtration and UV disinfection.

3.4.5 Sampling Schedule

There were 16 four-day sampling events scheduled over the 12-month test period. Twelve of these events were on a once per month basis, while four of the events were special events placed throughout the year. The sampling schedule was:

July 20-23, 2004 (Tuesday to Friday)
August 9-12, 2004 (Monday – Thursday)
September 4-8, 2004 (Saturday- Wednesday; Labor Day weekend)
October 5-8, 2004 (Tuesday – Friday)
October 19-22, 2004 (Tuesday – Friday)
November 16-19 (Tuesday- Friday)
December 14- 17 (Tuesday – Friday)
December 30-January 2, 2005 (Thursday – Sunday; New Year holiday)
January 25-28, 2005 (Tuesday – Friday)
February 8-11, 2005 (Tuesday- Friday)
March 1-4, 2005 (Tuesday– Friday)
March 18-19, 2005 (Friday – Monday; weekend)
April 19-22, 2005 (Tuesday– Friday)
May 10-13, 2005 (Tuesday- Friday)
May 27-30, 2005 (Friday –Monday; Memorial Day)
June 7-10, 2005 (Tuesday – Friday)

The sample dates listed represent the end of each 24-hr sample period. As an example, June 7 is the sample collected from the morning of June 6 through morning of June 7.

3.4.6 Sample Preservation and Storage

The sample bottles required for the various analyses were provided by Analytical Laboratories Inc., the outside subcontracted laboratory for this work. Table 3-3 shows the bottle types, sample size, and preservation required for each parameter. The bottles came with preservative, as needed, and labeled by analysis type. The samples were logged, placed in coolers with ice to maintain temperature, and delivered to the laboratory the same day.

Table 3-3. Preservation, Bottle Type, and Sample Size by Analysis

Sample Matrix	Analyses	Bottle type/size	Preservation/Holding Time
Wastewater	pH	Plastic 250 mL	None, analyze immediately
	Temperature	Plastic 250 mL	None, analyze immediately
	Turbidity	Plastic 250 mL	Cool to 4º C, 48 hr
	TSS	Plastic, 100 mL	Cool to 4º C, 7 days
	Alkalinity	Plastic, 250 mL	Cool to 4º C, 7 days
	BOD_5	Plastic, 1000 mL	Cool to 4º C, 24 hours
	COD	Plastic, 100 mL	Cool to 4º C, pH < 2 H_2SO_4, 28 days
	TP	Plastic, 500 mL	Cool to 4º C, pH < 2 H_2SO_4, 28 days
	SP	Plastic, 250 mL	Filter, Cool to 4º C, pH < 2 H_2SO_4, 28 days
	TKN	Plastic, 500 mL	Cool to 4º C, pH < 2 H_2SO_4, 28 days
	NH_3-N	Plastic, 500 mL	Cool to 4º C, pH < 2 H_2SO_4, 28 days
	NO_2+NO_3-N	Plastic, 500 mL	Cool to 4º C, pH < 2 H_2SO_4, 28 days
	Total coliform	Sterile glass	Cool to 4º C, 24 hr
Solids	Metals	Plastic or glass, 250 mL or larger	Cool to 4º C, 6 months
	Percent solids	Plastic or glass, 500 mL	Cool to 4º C, 7 days

3.4.7 Chain of Custody

Chain of Custody was maintained for all samples collected during the verification test. The TO operators filled out a chain of custody form for each set of samples. The form was signed and dated for each set of samples delivered to ALI. The receiving technician acknowledged receipt of the samples by signing the chain of custody form and provided a copy of the form to the sample delivery person. All copies of the chain of custody records were maintained by the TO and by the chemical laboratory for all samples. Copies of the completed chain of custody forms were included with all laboratory reports transmitting final analytical results.

3.5 Analytical Methods

All analytical methods used during the verification test were EPA approved methods[3,4] or methods from *Standard Methods for the Examination of Waster and Wastewater*, 20th Edition[5].

Table 3-4 shows the analytical methods used for the verification test and the typical detection limits that were achieved by these methods.

Table 3-4. Analytical Methods

Sample Matrix	Analyses	Reference Methods	Reporting Detection Limit for Matrix (PQL or normal reporting limit)
Liquid	pH	EPA 150.1	N/A (range 1-13 S.U.)
	Temperature	SM 2550 B	N/A
	Turbidity	EPA 180.1	0.5 NTU
	Alkalinity	EPA 310.1	10 mg/L
	TSS	EPA 160.2	3 mg/L
	BOD_5	EPA 405.1	3 mg/L
	COD	EPA 410.4	20 mg/L
	TP	EPA 365.4	0.05 mg/L
	SP	EPA 365.1	0.05 mg/L
	TKN	EPA 351.2	0.1 mg/L
	NH_3-N	EPA 350.1	0.04 mg/L
	NO_2+NO_3-N	EPA 353.2	0.02 mg/L
	Total coliform	SM 9223	2 MPN/100 mL
Solid	Metal	EPA 207.1	Varies by metal and solids content
	Total solids	EPA 160.1	10 mg/kg

Two parameters were measured in the field, pH, and temperature. ALI conducted all other analyses. All work was performed in accordance with QA/QC protocol as described in the Quality Assurance Project Plan developed for the verification test.

3.6 Operation and Maintenance

The IWS Model 6000 SBR was started and operated in accordance with the Operation, Maintenance Manual provided by IWS, presented in Appendix A. IWS provided regular operation and maintenance services for the system at the test site and continued to perform this service during the verification test. ESD staff monitored the system during the test period and reviewed operating conditions, maintenance performed, and kept records of all site visits and site conditions. ESD staff collected all samples for analysis and transported them to the laboratory. IWS maintained a Maintenance Checklist that was filled out each time the site was checked and any work was performed by the licensed operators. The field log was part of the verification test record.

In addition to the operating records kept at the site, the PLC monitored several critical parameters for the operation of the SBR and filtration/UV systems. The PLC monitored pump cycles, flow, turbidity to the filter, electrical components and the operation of floats and sensors related to the operation of the SBR. Flow rates, volume of water processed, amount of coagulant solution (alum or PAC) pumped from the feed tanks, UV lamp intensity, power consumption, backwash flow rate, and related operational data were recorded by the licensed operators in the operational log either at the site or obtained from the PLC records.

Periodically the coagulant solution needed to be replenished. If the feed tank (55 gal capacity) was below the 10 gal level, additional PAC (alum at the beginning of the verification test) was prepared following a detailed procedure provided in the O&M manual. A 5000 mL beaker of PAC added to 50 gal of water and mixed in the holding tank. Each time PAC solution was made; the amount of water and alum was recorded. IWS changed to a liquid PAC solution during the test to make the addition and mixing of the coagulant solution easier to accomplish. The liquid alum was added and the volume recorded by the operators in the operating log.

UV intensity was recorded from the meter on the UV unit on a weekly basis and monitored continuously by the PLC. If intensity dropped below 25%, the inlet valve to the UV unit closed and water was not discharged. The UV intensity meter was calibrated once during the first three months of the test.

Other observations on the operating condition of the unit, or the test system as a whole, were recorded for reference. Observations of changes in effluent quality based on visual observations, such as color change, oil sheen, obvious sediment load, etc., were recorded if they occurred.

Chapter 4
Results and Discussion

This chapter presents the verification test results for the Model 6000 SBR, including the laboratory results for influent and effluent samples, a discussion of the results, and observations on the operation and maintenance of the unit during startup and normal operation. Complete copies of all spreadsheets with individual daily, weekly, or monthly results are presented in Appendix E.

4.1 Startup Test Period

IWS indicated that it typically takes 2 – 3 weeks for the SBR to achieve full treatment capability and complete the startup process. Once the SBR establishes a viable biomass, clarification improves and the filtration and disinfection system typically stabilize within a few hours to a couple of days. The filtration system and disinfection system typically perform better as the SBR performance improves over the startup period.

The startup procedures followed the O&M manual for the system as supplied by IWS (Appendix A and D) and as summarized in Section 3.3. On March 31, 2004, SBR 2 was taken off line and the sludge from the system pumped to the sludge holding tank. The system was inspected by ESD staff on April 1, 2004 and approval to add the new seed material was granted.

The master cycle for the units was set for a 4-hr period. Each cycle consisted of a 45-minute aeration period, followed by a 70-minute anoxic period (no aeration), a second aeration period of 45-min, and then a second anoxic period of 80-min. By April 7, SBR 2 had filled and was beginning to discharge treated effluent to the filter feed-water holding tank. The sludge in SBR 2 gave a settled solids reading of 75% after 30-min of settling, very similar to SBR 1 (which had been in full operation), which had a settled solids reading of 60%. Visual observation indicated that the sludge in SBR 2 was viable and in good condition. Both units had a pH of 7.2 and alkalinity of 120 mg/L, in the normal range. On April 9, SBR 2 was checked again and sludge levels were in the normal range as were pH and alkalinity. A repair was made to the second discharge pump in SBR 2, one of the two pumps that discharge SBR treated water to the holding tank prior to filtration. At this time, SBR 2 appeared to be fully acclimated and operating normally.

On April 26, the filtration system was taken off line, the sand removed and the system cleaned and determined to be in “like new” condition. The filter was then placed back on line to complete the startup process. The UV system was also cleaned and placed back on line. The lamps in both units had been replaced in October 2003 and so had only been in service for six months. The UV intensity was good showing 57 on the top unit and 47 on the bottom unit. Based on the cleaning of these units and the conditions in SBR 2, the startup was considered complete.

The SBR responded during startup as expected and took very little time to establish a viable biomass that could be managed and provide treatment of the wastewater. On April 26, twenty-six days after seeding took place, and approximately 16 days after regular feed and discharge was occurring in the unit, the biomass concentration had increased to the point that the operator wasted sludge from the unit to the sludge holding tank. The 30-minute sludge settling test showed that the sludge settled to 450 mL in a 1,000 mL cylinder (45%) on April 27, the day after sludge was wasted. The pH was 7.2 and the alkalinity was 120 mg/L, both in the normal operating range.

While the startup period was considered successful and the units ready for the verification test to proceed, the actual verification test could not be started on May 1 as planned. The verification test included the startup of the new influent flow monitoring and sampling system to obtain flow weighted composite samples. In addition, samplers were to be installed on the SBR discharge line and the final effluent discharge line, with tie-ins to the PLC for sample collection control. This new systems were not complete at the end of April due to some problems communicating between the new flow meter and the PLC, and between the PLC and the samplers.

During the first two weeks of May, the sampler and flow meter issues were worked on and the equipment was operated to attempt to resolve problems and determine the best settings for obtaining sufficient sample volume at each of the three sample locations. IWS also decided to add a new methanol (carbon source) injection system to have the capability to add methanol during the anoxic cycle to improve denitrification in the SBRs. The new methanol injection was installed and operational by mid May. A successful influent sample was collected on May 21 and flow meter readings were now being acquired. Some difficulties were still being encountered with the other sampling locations.

It was decided that during the month of June the sampling equipment would be run on a regular basis to test it under varying flow conditions. This was considered critical so that reliable sampling could be achieved during the verification test. Also, IWS had experienced some minor operating issues with the PLC program that led to the aeration cycle being in the "on" mode during some of the clarification periods, thus causing solids to not settle and carryover to the filter feed water holding tank. The entire system was monitored during June 2004 in preparation for the start of the verification test. By the end of June, the new sampling systems were operating properly. The SBR and filtration systems were operated in a normal manner during this period.

All systems were operating properly by the end of June and the approval was given to proceed with the verification test. It should be noted that the need for the three-month startup period rather the anticipated one-month period was primarily caused by sampling and monitoring issues related to the verification test rather than operational issue with the Model 6000 SBR system. The system itself was reasonably acclimated and producing treated effluent within the first 30 days after startup. Some operational issues did arise and adjustments were made during the first 90 days. It should be expected that with a system of this type some adjustments would be needed in the first three months of operation. However, the startup experience simulated in this verification indicates that the system is relatively easy to acclimate and can be expected to produce a treated effluent within the four-week startup period indicated by IWS in the O&M Manual.

The system was monitored during May and June as the startup proceeded. Flow data on the influent was collected from mid-May through June as shown in Table 4-1. Two sets of influent samples were collected for basic water quality parameters, as summarized in Table 4-2. IWS was also collecting samples for the final effluent as part of the normal requirements for the site wastewater discharge permit. While these data were not part of the verification program and not subject to the ETV QA review, they are provided in Table 4-3 for informational purposes.

Table 4-1. Flow-Volume Data during the Startup Period

Date	Daily Volume (gal) Average	Maximum	Minimum	Peak Flow Rate(1) (gpm)
May 2004	2,311	3,330	1,200	21
June 2004	2,537	5,570	1,060	20

(1) Peak flow fixed based on force main size and pump capacity from each home

Table 4-2. Influent Wastewater Quality – Startup Period

Date	BOD_5 (mg/L)	TSS (mg/L)	NH_3-N (mg/L as N)	TKN (mg/L as N)	Total Coliform (MPN/100 mL)
05/21/04	160	410	2.70	21.5	>2,400
06/15/04	140	150	19.3	24.7	>1,600

Table 4-3. Model 6000 SBR Final Effluent Permit Monitoring – Startup Period

Date	BOD_5 (mg/L)	TSS (mg/L)	TP (mg/L as P)	Nitrogen (mg/L as N) TKN	NO_2+NO_3-N	TN	Total Coliform (MPN/100 mL)
5/7/04	<4	<3	NA	1.0	4.0	5.0	2
5/15/04	<3	<3	NA	0.97	1.5	2.5	NA
5/20/04	<3	<3	1.1	0.98	3.2	4.2	240
6/1/04	<3	4	0.18	0.64	0.96	1.6	<2
6/7/04	<3	<3	NA	1.1	1.4	2.5	<2
6/14/04	<3	<3	NA	0.88	0.76	1.6	7
6/21/04	<3	<3	NA	0.85	5.9	6.8	2
6/29/04	<3	<3	NA	0.51	7.8	8.3	<2

NA – not analyzed

4.2 Verification Test

The verification test officially started on July 1, 2004. All results for the remainder of the test period were considered part of the verification test. The summary data presented for the verification results do not include data from the startup period.

4.2.1 Verification Test - Flow Conditions

Table 4-4 shows the average daily volumes of raw wastewater received during the verification period. The actual daily wastewater volume varied by as much as a factor of two when comparing the average daily volumes to either the minimum or maximum daily volume. While the variation on a given day was reasonably large, the monthly averages were similar during the twelve-month test.

The influent volume reached the maximum hydraulic capacity of a single SBR in November. This occurred after the system was switched to a single SBR with a flow equalization tank ahead of the SBR (original SBR 1). During this high flow period there were several days with volumes above 4,000 gal, and two days over 5,000 gal. These flow rates stressed the system and required some changes to operating settings. A high water alarm occurred in both the SBR and the filter feed-water holding tank. The filter was not meeting the turbidity requirements so the SBR was receiving reject water from the filtration system in addition to the above normal influent volumes. IWS contacted the homeowners association about the high flows and arranged to have some wastewater trucked away to stabilize the system. A total of five truck loads (15,500 gal) of raw wastewater from the equalization tank were removed over a four-day period. This ensured that wastewater was not discharged from the system that did not meet the state permit requirements. The wastewater was taken to a local wastewater treatment plant. The actual maximum daily flow did not occur until three days after the removal was stopped and flows continued high for several more days. By that time, IWS had adjusted the pumping rates from the distribution tank and the SBR system.

During November in response to the high flow conditions, as part of adjusting the system to the use of the distribution/equalization tank, and to try to improve total nitrogen removal, the operators changed the master cycle from a 4-hr cycle to a 6-hr cycle. The aeration cycle was lengthened from two 45-minute periods to two 90-minute periods. This change did not have a significant impact on the organics or nutrient removal, as shown in the data presented in the following sections. As will be discussed later, the monthly monitoring for the verification occurred from November 16 to 19, which coincided with the peak volume of 6,026 gal that occurred on November 16. While there was some impact on the SBR treated effluent, the final effluent after filtration remained low in BOD_5 and TSS concentrations (3-7 mg/L, and 3-5 mg/L respectively over the four days of monitoring).

It should be noted that the system was able to handle peak wastewater flow rates of 4,094 and 4,798 gpd in May and June 2005 indicating that the changes made in November resolved hydraulic capacity issues.

There was one other period when wastewater was removed from the system and trucked to the local municipal wastewater treatment plant. On December 13, 14, and 15, a total of 10,500 gal (3,500 gal, 3,000 gal, 3,500 gal, respectively) was removed from the distribution tank. The high water condition in the distribution tank and SBR does not appear to be caused by a high influent wastewater flows, but rather due to a faulty low level UV intensity reading on the UV unit or a faulty signal to the PLC, which stopped the discharge of final effluent from the system. The PLC was set to close the inlet valve to the UV system if the UV intensity fell below 25%. In those cases, no discharge was allowed from the system and the filtered wastewater was recycled to the distribution tank. Distribution tank, SBR, and filter feed tank pumping records, UV readings (noted as "bad readings" in the PLC dataset), and turbidity data (turbidity from the filter was acceptable during this time) support that the faulty UV intensity readings were the cause of the problem. Data collected on the discharge that occurred when the readings were being properly acquired by the PLC show that coliform bacteria levels were very low. Thus, the lamps were on and working, but apparently the intensity sensor or the signal to the PLC was faulty. The problem was resolved and the unit returned to normal operation, with no additional high water alarms during the remainder of the test.

Table 4-4. Model 6000 SBR System Influent Volumes – Verification Test Period

		Daily Flow (gal)	
Month	**Average**	**Maximum**	**Minimum**
July 2004	2,135	3,521	918
August 2004	2,102	3,895	449
September 2004	2,124	4,149	1,060
October 2004	2,069	3,785	259
November 2004	3,690	6,026	2,036
December 2004	2,536	4,036	1,613
January 2005	2,206	3,197	1,369
February 2005	2,399	3,716	1,668
March 2005	2,236	3,002	1,244
April 2005	1,992	3,258	1,043
May 2005	2,011	4,094	1,050
June 2005	1,827	4,798	1,452
Number	12	12	12
Average	2,277	3,956	1,180
Max	3,690	6,026	2,036
Min	1,827	3,002	259
Std Dev	482	815	502

4.2.2 BOD_5/COD and TSS Results and Discussion

Figures 4-1, 4-2, and 4-3 show the influent, SBR treated effluent, and final effluent BOD_5, COD, and TSS concentrations during the verification test. Tables 4-5 and 4-6 present the same results with a summary of the data (mean, median, maximum, minimum, standard deviation). Over the course of the verification, the influent wastewater had a mean BOD_5 of 230 mg/L with a range of 86 to 575 mg/L. The mean influent COD was 480 mg/L, with a range of 120 to 1,440 mg/L. Influent TSS ranged from 15 to 440 mg/L with mean value of 170 mg/L. The concentrations were in the typical range expected in residential wastewater that is not diluted with stormwater and other non-residential wastewaters.

During the verification, the SBR effluent had a mean BOD_5 of 12 mg/L, varying from <4 mg/L to 39 mg/L. The SBR effluent mean COD concentration was 49 mg/L, ranging from <20 to 240 mg/L. The SBR effluent achieve a mean reduction of 95% for BOD_5 and a mean reduction of 90% COD. BOD_5 exceeded 20 mg/L on eight days out of 64 monitoring days, and exceeded 30 mg/L on three of those days. While there was no distinct pattern or cause identified for the days with higher BOD_5 in the SBR treated effluent, the higher BOD_5 concentrations did tend to correspond with higher TSS concentrations. The highest BOD_5 concentration of 39 mg/L on March 18, 2005 corresponded to the maximum TSS concentration of 160 mg/L. It should be noted that not all days with higher TSS levels had higher BOD_5 concentrations.

The mean TSS concentration in the SBR effluent was 26 mg/L with a range of <3 to 160 mg/L. TSS varied considerably in the SBR effluent with eight of the 63 monitoring days exceeding 50 mg/L. Clarification of the biomass was generally successful, but poorer settling did at times challenge the coagulation/filtration system. As will be discussed below, the filtration system and the on-line turbidity monitor that rejected filtrate with higher turbidity (higher TSS) worked very well. On days when TSS was elevated in the SBR effluent, the final effluent was typically 5 mg/L or less.

As shown in Table 4-5, the BOD_5 concentration in the final treated effluent had mean value of 4 mg/L with a range of 2 to 8 mg/L. Most of the BOD_5 results were below the detection limit of either 3 or 4 mg/L. The mean value presented in Table 4-5 is based on using the detection limit value as the actual value for calculations purposes. The COD concentration in the treated effluent had a mean of 22 mg/L with a range of <20 to 45 mg/L. The mean value was very close to the detection limit for the COD test as most of the test results were below the detection limit. As can be seen by reviewing the daily data, the final effluent BOD_5 results were not impacted on days when the SBR effluent was at a higher concentration. These data indicate that on days when the SBR effluent had been impacted by poor settling or other conditions that caused an increase in BOD_5, the coagulation/filtration system was able to handle the SBR effluent and lower the BOD_5 to less than 8 mg/L and in most cases to less than 4 mg/L.

The treated effluent TSS mean concentration was 6 mg/L with a range of <3 to 23 mg/L. The median concentration was 4 mg/L. The TSS concentration exceeded 10 mg/L on four of the 63 monitoring days, with two of those days occurring before the system was switched to a single SBR with an equalization tank. The on-line turbidity monitor appeared effective at stopping discharges that may have had elevated TSS levels. During periods of higher TSS levels, filtrate was recycled to the feed-water holding tank and the water was reprocessed through the filter. The PLC recorded the turbidity levels and provided a record for the operator showing when high turbidity occurred. This allowed the operator to make some adjustment in coagulant dose if needed. However, in normal operation the recycling system worked automatically and the filter would reduce TSS levels within one or two cycles. On occasion, the filter required cleaning which was noted by increased head loss through the filter (recorded by the operators when on site) or by extended periods with high turbidity readings.

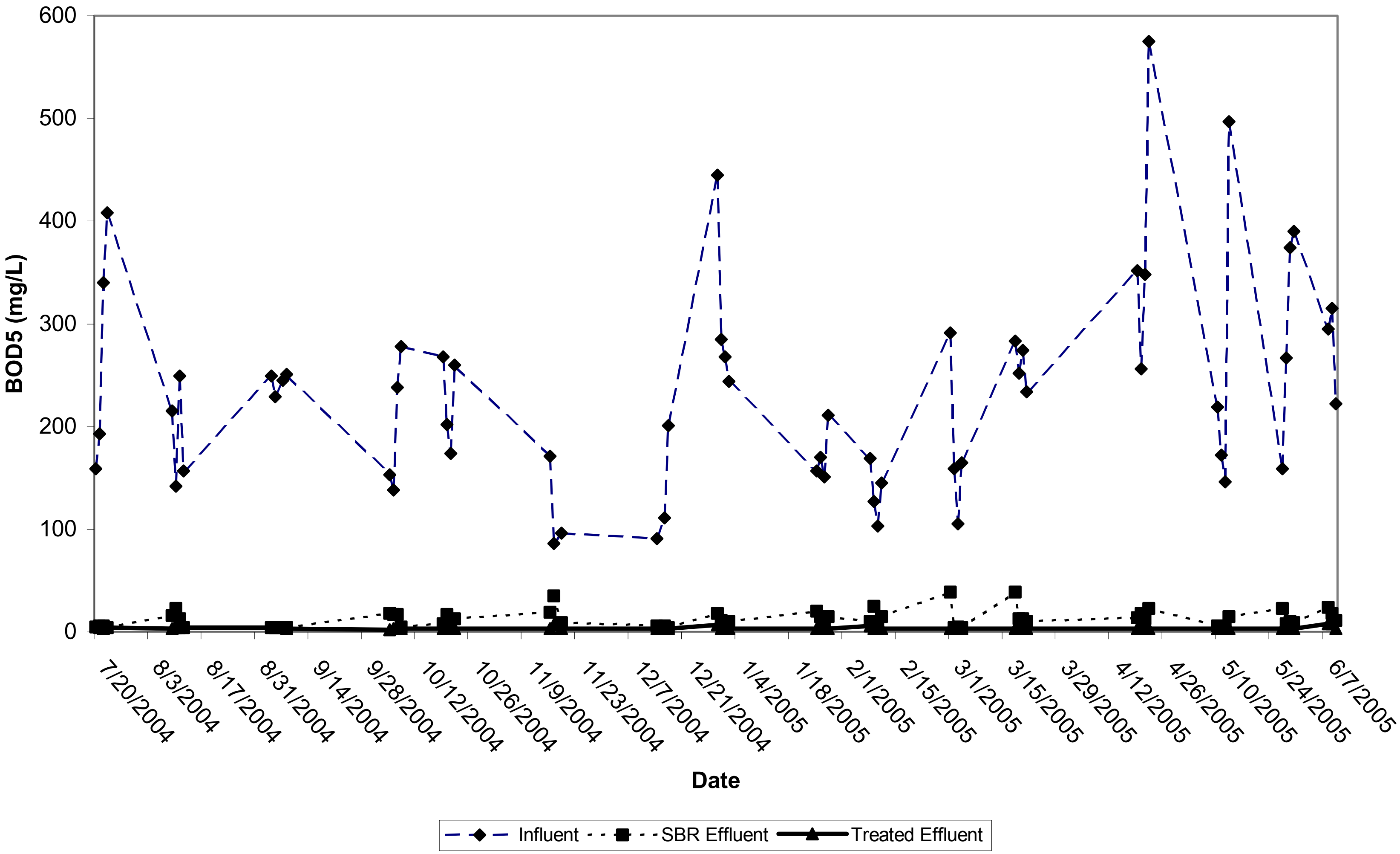

Figure 4-1. Model 6000 SBR System BOD$_5$ results.

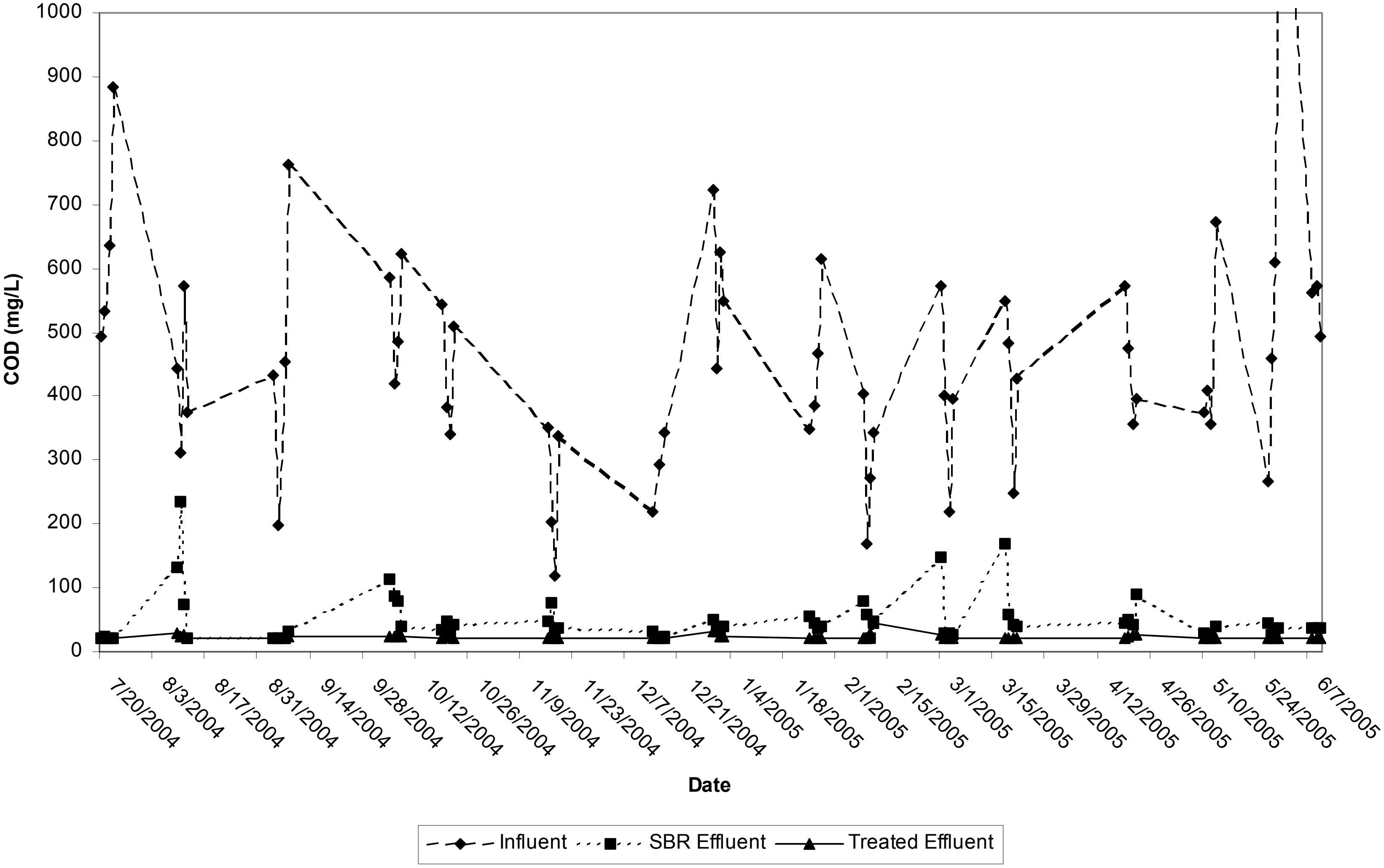

Figure 4-2. Model 6000 SBR System COD results.

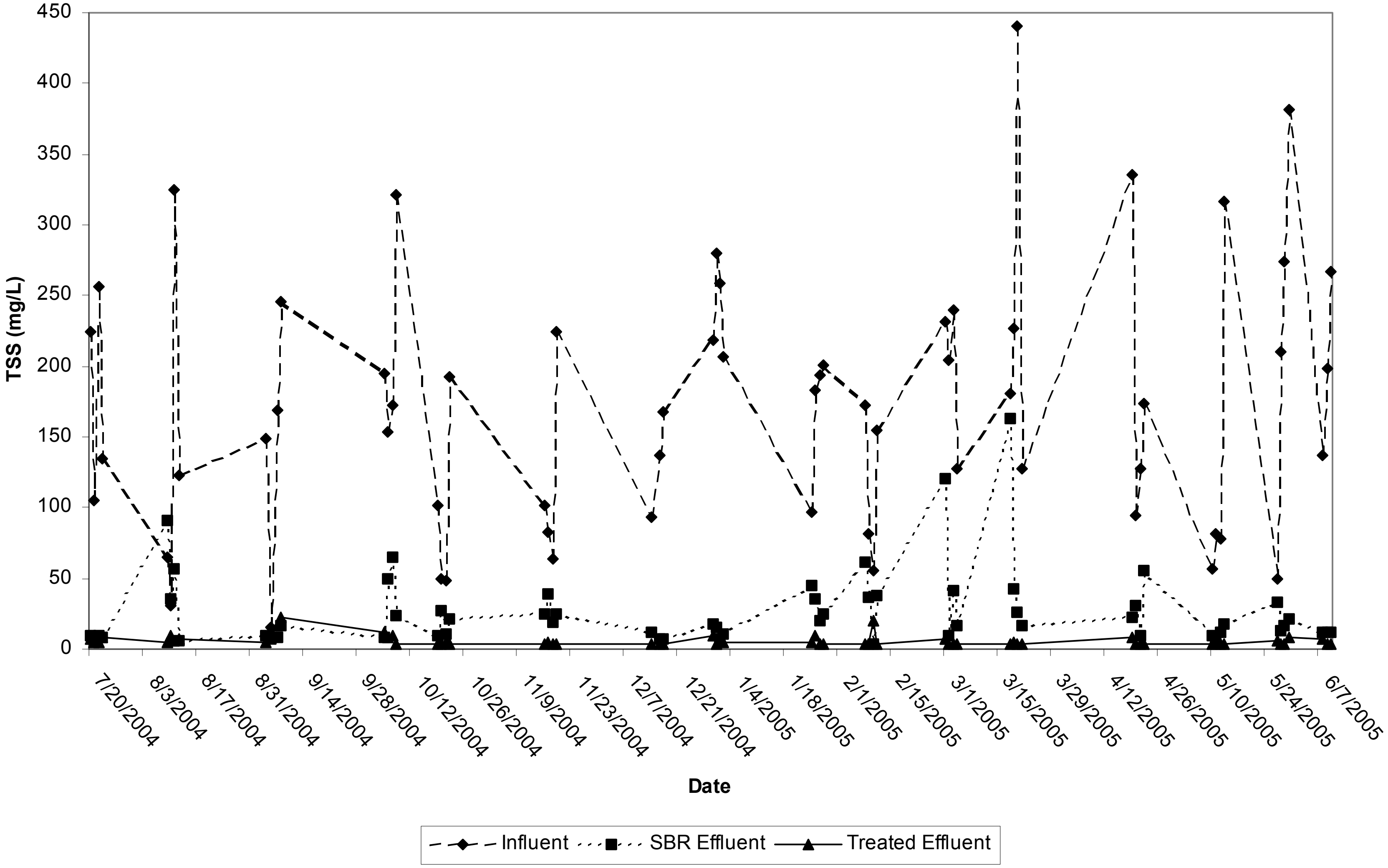

Figure 4-3. Model 6000 SBR System TSS results.

Table 4-5. Model 6000 SBR System BOD_5 and COD Results

Date	COD (mg/L)			BOD_5 (mg/L)		
	Influent	SBR Effluent	Treated Effluent	Influent	SBR Effluent	Treated Effluent
07/20/04	490	21	<20.0	160	5	6
07/21/04	530	23	<20.0	190	6	<4
07/22/04	640	20	<20.0	340	6	<3
07/23/04	880	22	<20.0	410	<4	<4
08/09/04	440	130	28	220	16	<3
08/10/04	310	240	24	140	>23	<4
08/11/04	570	74	25	250	13	<4
08/12/04	380	<20.0	<20.0	160	<4	<4
09/04/04	430	<20.0	<20.0	250	<4	<4
09/05/04	200	21	<20.0	230	<4	<4
09/07/04	450	22	<20.0	240	4	<4
09/08/04	760	32	23	250	4	<3
10/05/04	590	110	24	150	>18	2
10/06/04	420	86	25	140	>17	3
10/07/04	490	78	30	240	17	<3
10/08/04	620	41	22	280	5	<3
10/19/04	540	34	22	270	8	<3
10/20/04	380	48	25	200	17	4
10/21/04	340	32	23	170	9	<3
10/22/04	510	43	<20.0	260	13	<3
11/16/04	350	47	<20.0	170	19	<3
11/17/04	200	76	28	86	35	7
11/18/04	120	31	<20.0	<56	17	<3
11/19/04	340	38	<20.0	96	9	<3
12/14/04	220	31	<20.0	91	6	<3
12/15/04	NS	23	<20.0	NS	6	<3
12/16/04	290	21	<20.0	110	6	<3
12/17/04	340	24	<20.0	200	<4	<3
12/30/04	720	50	32	440	18	7
12/31/04	440	40	31	280	11	3
01/01/05	630	35	25	270	6	<3
01/02/05	550	40	23	240	10	<3
01/25/05	350	56	<20.0	160	20	<3
01/26/05	390	46	<20.0	170	15	<3
01/27/05	470	36	<20.0	150	9	<3
01/28/05	620	40	<20.0	210	15	<3

Table 4-5. Model 6000 SBR System BOD_5 and COD Results (continued)

Date	COD (mg/L)			BOD_5 (mg/L)		
	Influent	SBR Effluent	Treated Effluent	Influent	SBR Effluent	Treated Effluent
02/08/05	400	78	21	170	10	6
02/09/05	170	58	<20.0	130	25	<3
02/10/05	270	<20.0	29	100	<4	8
02/11/05	340	49	45	140	15	<3
03/01/05	570	150	26	290	>39	<3
03/02/05	400	29	<20.0	160	<4	<3
03/03/05	220	28	20	100	5	<3
03/04/05	400	26	<20.0	160	4	<3
03/18/05	550	170	<20.0	280	>39	<3
03/19/05	480	58	<20.0	250	13	<3
03/20/05	250	42	22	270	13	7
03/21/05	430	39	<20.0	230	10	<3
04/19/05	570	46	21	350	14	<3
04/20/05	470	51	22	260	18	<3
04/21/05	360	42	25	350	13	<3
04/22/05	400	91	26	580	23	<3
05/10/05	370	28	<20.0	220	6	<3
05/11/05	410	28	<20.0	170	<4	<3
05/12/05	360	26	<20.0	150	<4	<3
05/13/05	670	39	<20.0	500	15	<3
05/27/05	270	45	<20.0	160	23	<3
05/28/05	460	26	<20.0	270	8	<3
05/29/05	610	34	<20.0	370	10	<3
05/30/05	1,440	37	<20.0	390	9	<3
06/07/05	440	27	NS	310	8	NS
06/08/05	560	36	<20.0	300	24	8
06/09/05	570	37	<20.0	320	18	8
06/10/05	490	37	<20.0	220	11	<3
Number	63	64	63	62	64	63
Average	460	49	22	230	12	4
Maximum	1440	236	45	580	39	8
Minimum	120	20	20	86	<4	2
Std. Dev	200	38	4.3	99	8.3	1.4

NS - No sample
Values below the detection limit are set equal to the DL for calculating statistics

Table 4-6. Model 6000 SBR System TSS and Alkalinity Results

Date	TSS (mg/L)			Alkalinity (mg/L as $CaCO_3$)		
	Influent	SBR Effluent	Treated Effluent	Influent	SBR Effluent	Treated Effluent
07/20/04	220	9	7	220	120	120
07/21/04	100	8	5	240	120	120
07/22/04	260	10	5	360	120	110
07/23/04	140	8	8	260	110	120
08/09/04	65	91	5	250	91	86
08/10/04	31	36	9	260	86	81
08/11/04	320	57	6	220	130	110
08/12/04	120	6	7	110	210	150
09/04/04	150	9	5	180	120	72
09/05/04	15	7	9	87	110	79
09/07/04	170	8	16	230	120	89
09/08/04	250	16	23	350	140	100
10/05/04	200	8	12	200	120	98
10/06/04	150	50	8	160	120	120
10/07/04	170	65	9	210	110	100
10/08/04	320	24	4	210	92	93
10/19/04	100	10	<3	210	120	120
10/20/04	50	27	<3	170	120	120
10/21/04	49	11	5	200	120	120
10/22/04	190	21	<3	180	120	120
11/16/04	100	25	<3	170	120	110
11/17/04	83	39	5	130	140	130
11/18/04	64	19	<3	120	100	97
11/19/04	220	25	<3	170	180	150
12/14/04	93	12	<3	160	98	99
12/15/04	NS	7	<3	NS	95	91
12/16/04	140	7	<3	160	80	82
12/17/04	170	7	<3	110	78	88
12/30/04	220	18	10	250	250	190
12/31/04	280	15	4	250	300	270
01/01/05	260	7	8	240	260	280
01/02/05	210	11	5	210	210	230
01/25/05	97	45	5	240	110	110
01/26/05	180	36	10	150	94	92
01/27/05	190	20	4	170	88	88
01/28/05	200	25	<3	200	82	84

Table 4-6. Model 6000 SBR System TSS and Alkalinity results (continued)

Date	TSS (mg/L)			Alkalinity (mg/L $CaCO_3$)		
	Influent	SBR Effluent	Treated Effluent	Influent	SBR Effluent	Treated Effluent
02/08/05	170	61	<3	210	94	97
02/09/05	81	37	3	110	210	210
02/10/05	55	<3	20	180	170	150
02/11/05	160	38	4	180	120	120
03/01/05	230	120	7	200	100	94
03/02/05	200	10	<3	170	120	110
03/03/05	240	41	<3	140	140	130
03/04/05	130	16	<3	250	130	120
03/18/05	180	160	4	180	110	110
03/19/05	230	43	5	160	110	110
03/20/05	440	26	4	160	140	130
03/21/05	130	17	4	190	160	150
04/19/05	340	23	8	290	100	110
04/20/05	95	31	3	260	120	110
04/21/05	130	9	<3	240	120	120
04/22/05	170	56	3	220	120	120
05/10/05	57	10	<3	280	110	110
05/11/05	82	6	<3	250	120	120
05/12/05	78	12	<3	230	120	120
05/13/05	320	18	3	270	120	120
05/27/05	50	33	6	170	120	140
05/28/05	210	13	<3	260	100	100
05/29/05	270	16	<3	290	100	100
05/30/05	380	21	8	290	110	110
06/07/05	110	7	NS	240	180	NS
06/08/05	140	12	7	280	170	170
06/09/05	200	12	3	270	170	170
06/10/05	270	12	3	240	170	170
Number	63	64	63	63	64	63
Average	170	26	6	210	130	120
Maximum	440	160	23	360	300	280
Minimum	15	3	3	87	78	72
Std. Dev	90	28	4	57	44	41

NS - No sample
Values below the detection limit are set equal to the DL for calculating statistics.

4.2.3 Nitrogen Reduction Performance

Figures 4-4 through 4-7 present the results for the TKN, NH_3-N, NO_2+NO_3-N, and TN in the influent, SBR effluent, and final treated effluent during the verification test. Table 4-7 presents all of the nitrogen results with a summary of the data (mean, maximum, minimum, standard deviation).

The influent wastewater had a mean TKN concentration of 38 mg/L and a mean NH_3-N concentration of 30 mg/L. Mean TN concentration in the influent was 38 mg/L. The NO_2+NO_3-N concentration in the influent was negligible, as would be expected. The SBR effluent had a mean TKN concentration of 3.2 mg/L, and a mean NH_3-N concentration of 0.4 mg/L. The NO_2 +NO_3-N mean concentration in the SBR effluent was 3.1 mg/L. TN was determined by adding the concentrations of the TKN (organic plus ammonia nitrogen), and NO_2+NO_3–N in the effluent. The mean TN in the SBR effluent was 6.3 mg/L for the twelve-month verification period, with a median concentration of 5.4 mg/L. The SBR demonstrated a mean reduction of 83% in TN for the verification test period.

The final treated effluent nitrogen concentrations were similar to the SBR effluent except for a somewhat lower mean concentration of TKN. The mean TKN concentration in the treated effluent was 1.2 mg/L versus 3.2 mg/L in the SBR effluent. These data suggest that some of the TKN in the SBR effluent was in a particulate form, probably associated with biomass that was present in the SBR effluent. The very soluble nitrogen forms, ammonia, nitrite, and nitrate showed virtually identical concentrations the SBR effluent and the final treated effluent. The lower TKN concentration in the final treated effluent yielded a lower mean total nitrogen concentration of 4.4 mg/L. Thus, the overall system removal efficiency for TN was 88%.

The data demonstrated that a well-acclimated nitrifying biomass was established in the SBR from the beginning of the verification, and remained viable throughout the twelve-month period. TKN removal averaged over 96% and ammonia nitrogen concentrations were less than 0.2 mg/L except for two sampling periods. The one period that showed some increase in TKN and ammonia, November 16-19 composite coincided with the maximum flow volumes discussed previously. During this sampling period, influent flow volume was over 4,000 gpd and the system had experienced the high flow rates for several days prior to the sampling period. Even with the heavy flow demand, the TKN removal was 84%.

The denitrification process was also effective during the test in reducing the concentrations of nitrite and nitrate. However, the denitrification process did appear to be somewhat more variable. The NO_2+NO_3–N concentration accounted for about 75% of the TN remaining in the effluent. While the process was somewhat less efficient than the nitrification step, the effluent concentration averaged 3.1 mg/L of NO_2+NO_3–N over the twelve-month period, with a range of 0.6 to 8.8 mg/L. Without the denitrification process, the TKN/NH_3 removed by the nitrification process would have been converted to nitrite/nitrate. This could have resulted in effluent being discharge to the lake with concentrations in excess of 30 mg/L. The highest concentration of

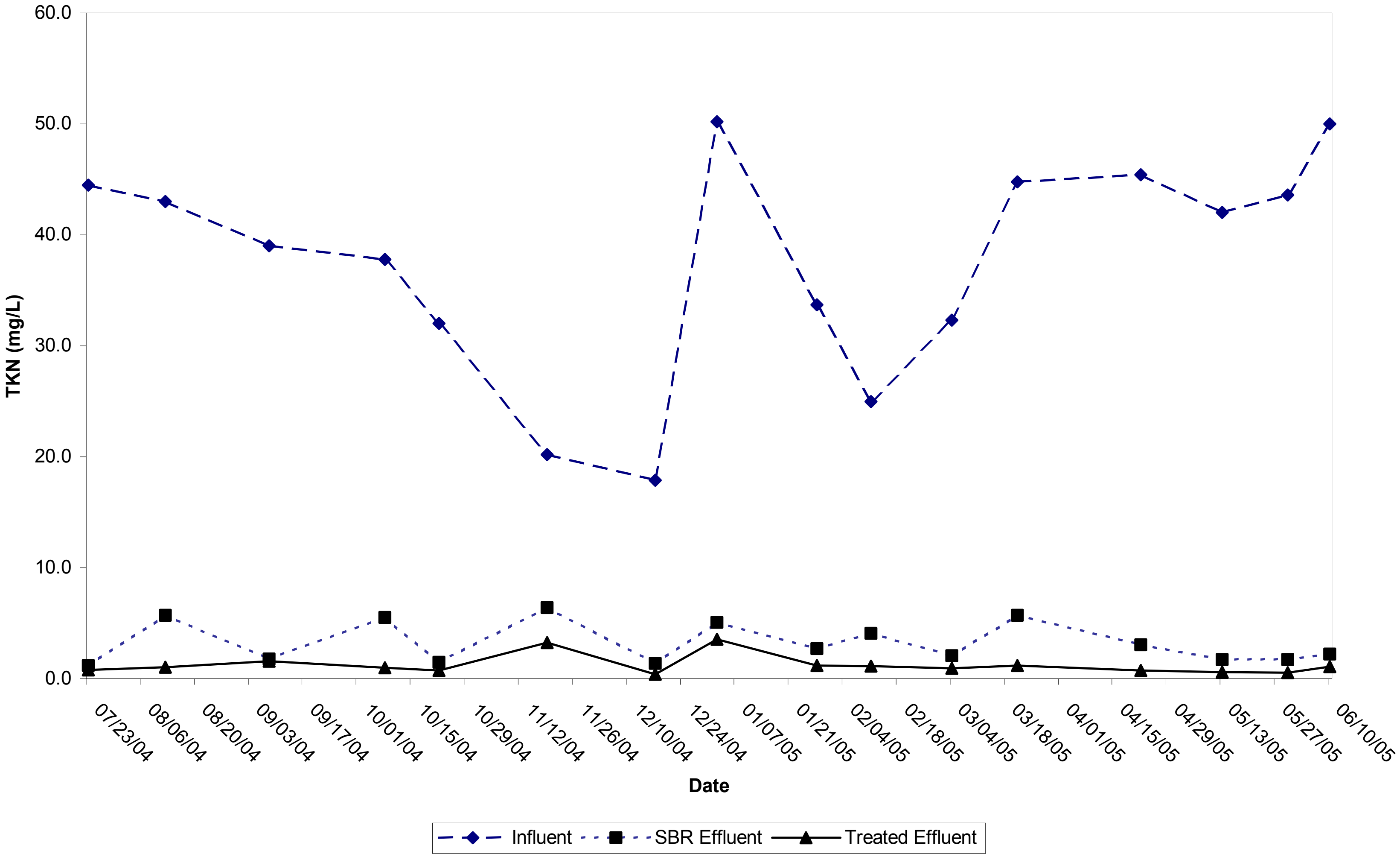

Figure 4-4. Model 6000 SBR System TKN results.

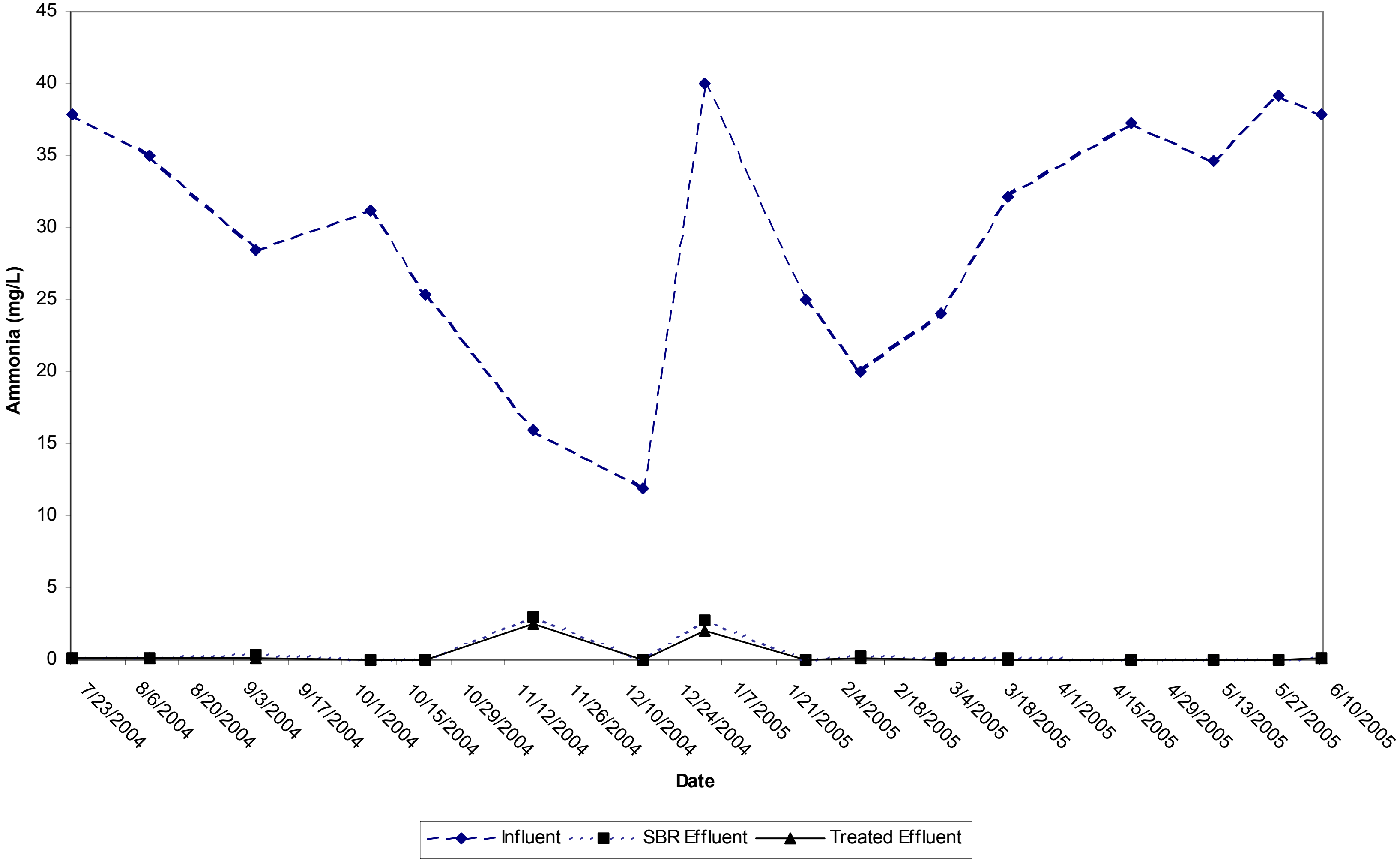

Figure 4-5. Model 6000 SBR System NH_3-N results.

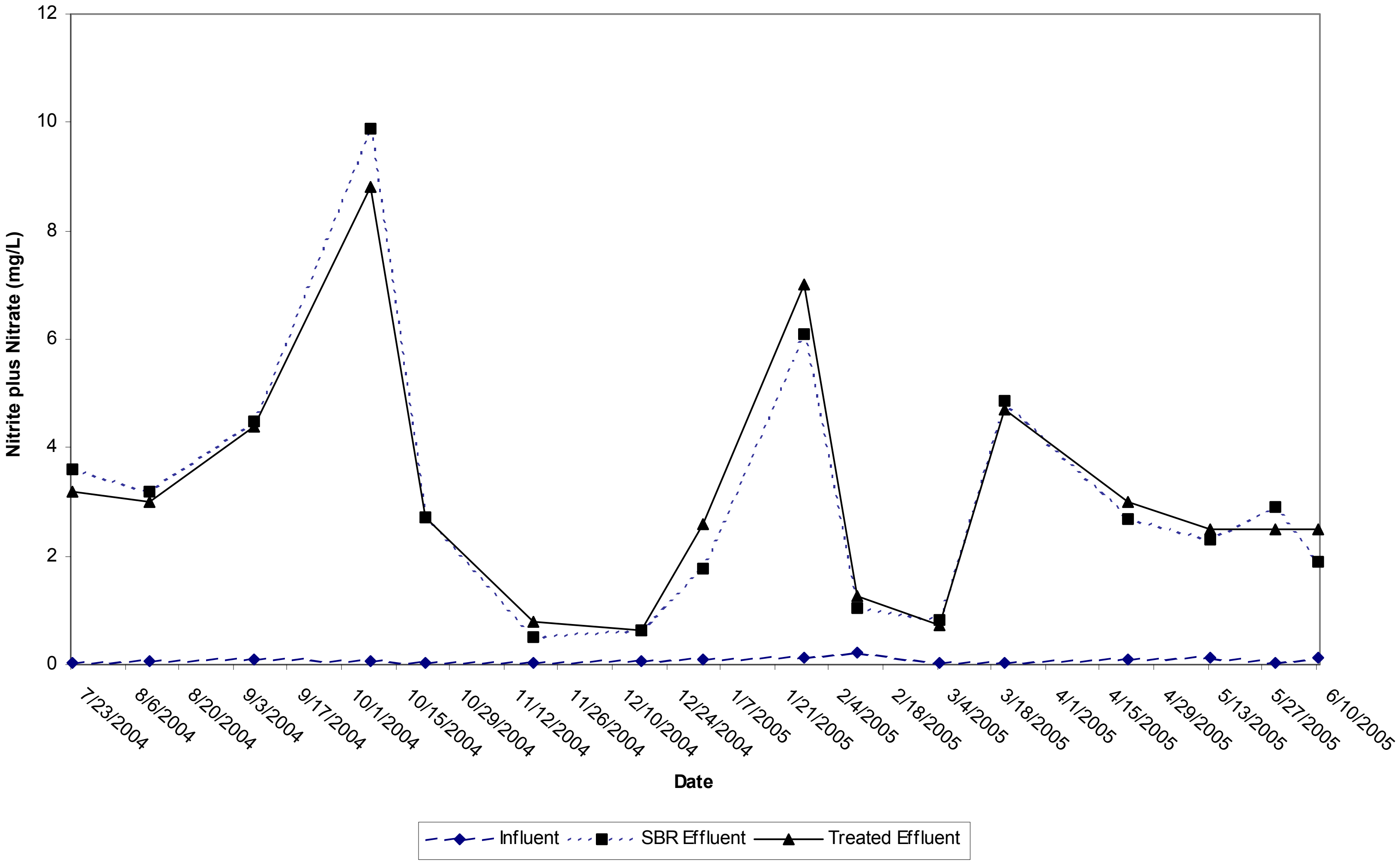

Figure 4-6. Model 6000 SBR System NO_2+NO_3–N results.

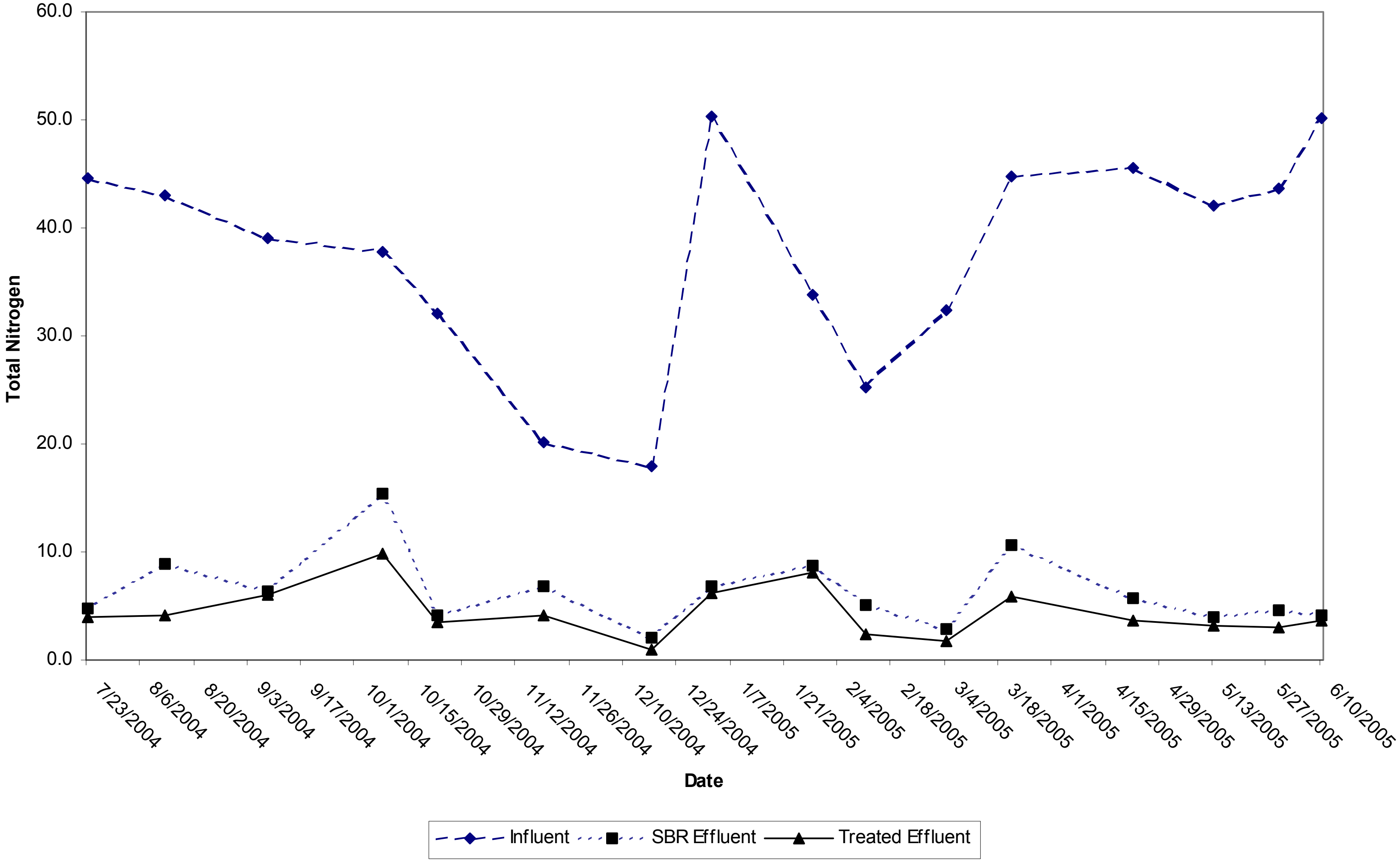

Figure 4-7. Model 6000 SBR System Total Nitrogen results.

Table 4-7. Model 6000 SBR System Influent and Effluent Nitrogen Data

Date	TKN (mg/L as N)			NH_3-N (mg/L as N)			NO_2+NO_3–N (mg/L as N)			TN (mg/L as N)		
	Influent	SBR Effluent	Treated Effluent	Influent	SBR Effluent	Treated Effluent	Influent	SBR Effluent	Treated Effluent	Influent	SBR Effluent	Treated Effluent
7/23/04	44	1.2	0.80	38	0.15	0.06	0.03	3.6	3.2	45	4.8	4.0
8/12/04	43	5.7	1.0	35	0.10	0.07	0.06	3.2	3.0	43	8.9	4.1
9/8/04	39	1.8	1.6	28	0.33	0.14	0.09	4.5	4.4	39	6.3	6.0
10/8/04	38	5.5	0.97	31	<0.04	<0.04	0.05	9.9	8.8	38	15	9.8
10/22/04	32	1.5	0.74	25	0.05	<0.04	0.03	2.7	2.7	32	4.2	3.4
11/19/04	20	6.4	3.3	16	3.0	2.53	<0.02	0.50	0.8	20	6.9	4.1
12/17/04	18	1.4	0.40	12	<0.04	<0.04	0.06	0.62	0.62	18	2.0	1.0
1/2/05	50	5.1	3.5	40	2.7	2.00	0.09	1.8	2.6	50	6.8	6.1
1/28/05	34	2.7	1.2	25	<0.04	<0.04	0.14	6.1	7.0	34	8.8	8.2
2/11/05	25	4.1	1.1	20	0.18	0.07	0.23	1.0	1.3	25	5.1	2.4
3/4/05	32	2.1	0.94	24	0.08	<0.04	0.04	0.83	0.74	32	2.9	1.7
3/21/05	45	5.7	1.2	32	0.10	<0.04	<0.02	4.9	4.7	45	11	5.9
4/22/05	45	3.1	0.72	37	<0.04	<0.04	0.10	2.7	3.0	46	5.8	3.7
5/13/05	42	1.7	0.60	35	0.04	<0.04	0.13	2.3	2.5	42	4.0	3.1
5/30/05	44	1.7	0.53	39	<0.04	<0.04	0.03	2.9	2.5	44	4.6	3.0
6/10/05	50	2.2	1.1	38	0.13	0.06	0.12	1.9	2.5	50	4.1	3.6
Number	16	16	16	16	16	16	16	16	16	16	16	16
Average	37.6	3.23	1.23	29.8	0.44	0.33	0.08	3.1	3.1	38	6.3	4.4
Maximum	50	6.4	3.5	40	3.0	2.53	0.23	9.9	8.8	50	15	9.8
Minimum	18	1.2	0.40	12	<0.04	<0.04	<0.02	0.50	0.6	18	2.0	1.0
Std. Dev.	9.95	1.86	0.90	8.65	0.94	0.76	0.06	2.4	2.2	9.9	3.3	2.3

NS - No sample
Values below the detection limit are set equal to the DL for calculating statistics

NO_2+NO_3–N occurred in the first sampling period after the system was changed to a one SBR process. It would appear that the change to the one SBR system and adjustments made to the operation impacted the denitrifying process. However, the system recovered by the next sampling period which also was the period of the highest flow to the system.

4.2.4 Total Phosphorus Removal Performance

Figures 4-8 and 4-9 present the results for TP and SP in the influent, SBR effluent, and final treated effluent during the verification test. Table 4-8 presents the results with a summary of the data (mean, median, maximum, minimum, standard deviation).

The influent wastewater had a mean TP concentration of 5.4 mg/L and a mean SP concentration of 3.9 mg/L. The mean TP in the SBR effluent was 2.4 mg/L, while the mean SP concentration was 1.6 mg/L. The SBR demonstrated a mean reduction of 56% of the TP and 59% of the SP present in the influent. TP and SP concentrations mirrored each other as can been seen by comparing the results presented in Figures 4-9 and 4-10. The trends are very similar with SP approximately 65-75% of the TP concentration in both the influent and SBR effluent for the verification test period. Data from some municipal wastewater treatment systems indicate that phosphorus removal can be improved or optimized in biological systems, if the COD/TKN ratio is less than 7.5. The ratio for this wastewater was approximately 12. While larger municipal facilities may be able to adjust and control the COD/TKN ratio, control is not typically attempted in small, decentralized systems with limited on site laboratory capability and operator involvement. No attempt was made during this test to optimize or control the COD/TKN ratio.

The final treated effluent showed a small additional decrease in SP (mean of 1.1 mg/L versus 1.6 mg/L), while the TP concentration decreased from a mean of 2.4 mg/L to 1.3 mg/L. Overall the full treatment system achieved a 76% reduction in TP concentration and 72% reduction in SP concentration. These data show that the SBR biological treatment system actually removed more phosphorus from the wastewater than the coagulation/filtration system. There was no attempt made during this verification to optimize or improve the TP removal in the coagulation/filtration process as there was no permit limit for TP at the this site. Additional adjustment in the aluminum feed rates might incrementally improve the TP reduction.

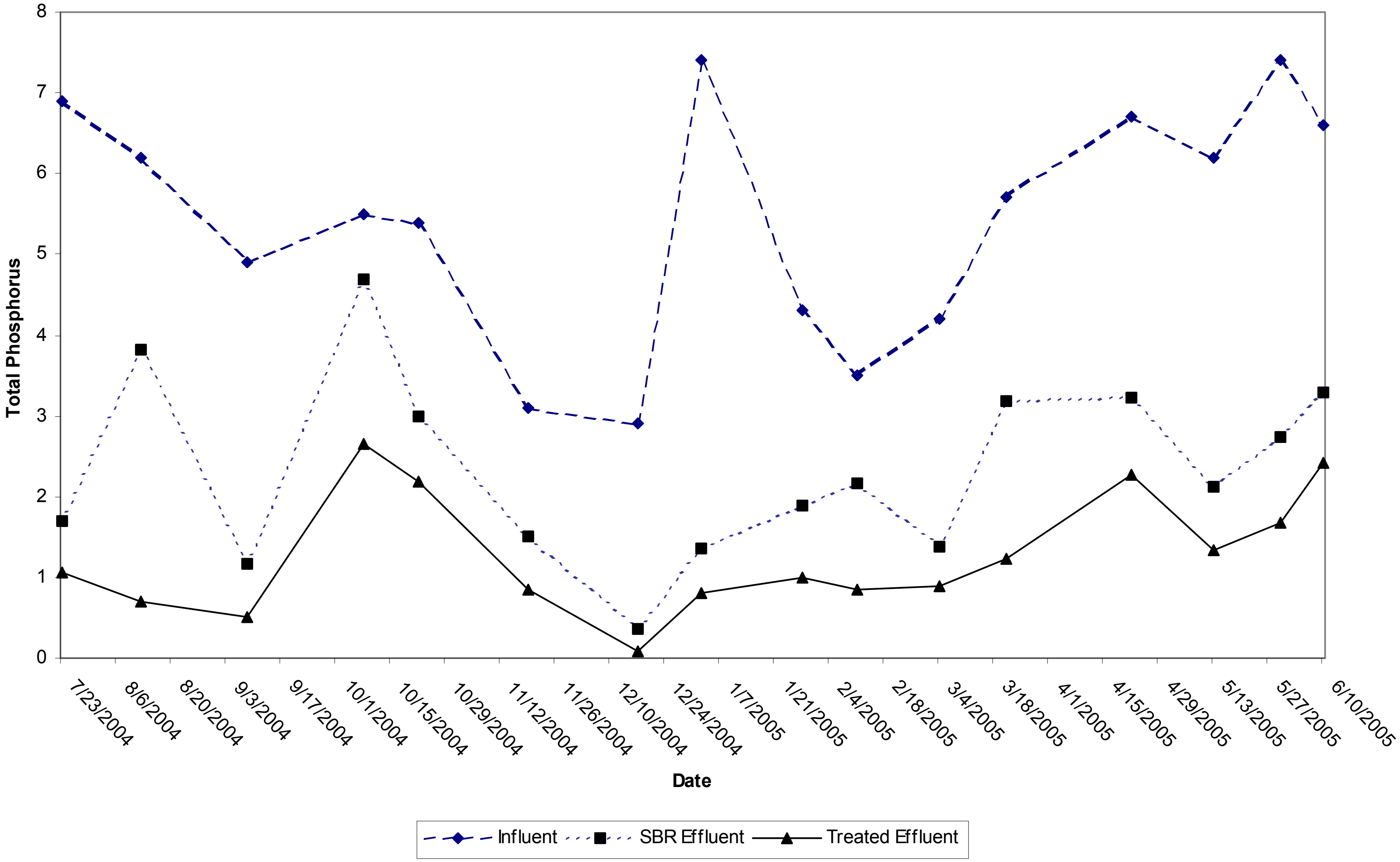

Figure 4-8. Model 6000 SBR System Total Phosphorus results.

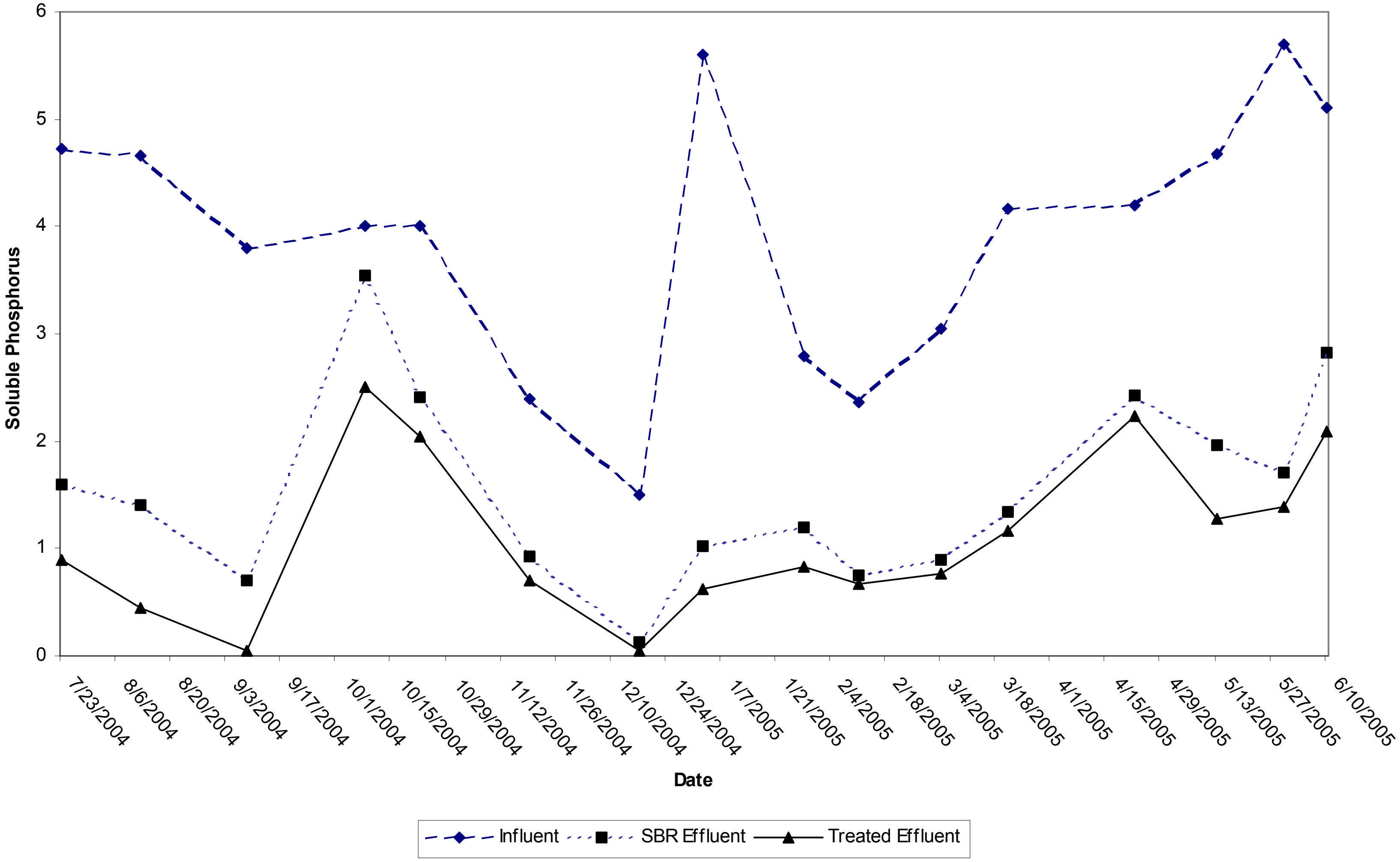

Figure 4-9. Model 6000 SBR System Soluble Phosphorus results.

Table 4-8. Model 6000 SBR System Total and Soluble Phosphorus Data

	TP (mg/L as P)			SP (mg/L as P)		
Date	Influent	SBR Effluent	Treated Effluent	Influent	SBR Effluent	Treated Effluent
07/23/04	6.9	1.7	1.0	4.7	1.6	0.89
08/12/04	6.2	3.8	0.70	4.7	1.4	0.44
09/08/04	4.9	1.2	0.50	3.8	0.70	<0.05
10/08/04	5.5	4.7	2.7	4.0	3.5	2.5
10/22/04	5.4	3.0	2.2	4.0	2.4	2.0
11/19/04	3.1	1.5	0.85	2.4	0.92	0.71
12/17/04	2.9	0.37	0.08	1.5	0.12	<0.05
01/02/05	7.4	1.4	0.81	5.6	1.0	0.62
01/28/05	4.3	1.9	0.99	2.8	1.2	0.83
02/11/05	3.5	2.2	0.85	2.4	0.75	0.67
03/04/05	4.2	1.4	0.89	3.0	0.89	0.77
03/21/05	5.7	3.2	1.2	4.2	1.3	1.2
04/22/05	6.7	3.2	2.3	4.2	2.4	2.2
05/13/05	6.2	2.1	1.3	4.7	1.2	1.3
05/30/05	7.4	2.7	1.7	5.7	1.7	1.4
06/10/05	6.6	3.3	2.4	5.1	2.8	2.1
Number	16	16	16	16	16	16
Average	5.4	2.4	1.3	3.9	1.6	1.1
Maximum	7.4	4.7	2.7	5.7	3.5	2.5
Minimum	2.9	0.37	0.08	1.5	0.12	<0.05
Std. Dev.	1.5	1.1	0.75	1.2	0.89	0.76

Values below the detection limit are set equal to the DL for calculating statistics

4.2.5 Total Coliform Results

Total coliform results for the influent, SBR effluent, and final treated effluent after UV treatment are presented in Table 4-9. The raw wastewater varied from 2×10^5 to 2×10^9 MPN/100 mL. The SBR treated effluent reduced the total coliform concentrations to a range of 2×10^3 to 5×10^6 MPN/100 mL. The influent wastewater had geometric mean of 7.1×10^6 MPN/100 mL and the

SBR effluent had a geometric mean of 1.2×10^5 MPN/100 mL over the one-year verification period. The final treated effluent concentrations of total coliform were generally less than 5 MPN/100 mL, and ranged from <2 to 120 MPN/100 mL.

As can be seen, the UV system was effective in reducing total coliform concentrations to low levels or below the detection limit, typically 2 to 4 MPN/100 mL) on most days of operation. The total coliform concentration exceeded 8 MPN/100 mL on only three days during the year and exceeded 100 MPN/100 mL (actual concentration 120 MPN/100 mL) on only sample. This one higher concentration occurred in November 2005 in the period when the very high flow rates were being experienced and adjustments to the system were being made to handle the increased daily volume.

4.2.6 Other Operating Parameters – pH, Alkalinity, Temperature

Several operating parameters including pH and temperature were measured on regular basis by the IWS operating staff. This data is extensive and is recorded in the operating logs. In addition, the ESD staff measured pH and temperature on grab samples when samples were collected for the verification test. Samples for total alkalinity were analyzed on the 24-hour composites collected during the verification test. The data obtained on verification sample collection days for pH and temperature is presented in Table 4-10. The alkalinity results are shown in Table 4-6.

The pH of the influent ranged from 6.2 to 9.2 with a median value of 7.2. The SBR effluent and final treated effluent showed a similar range with a median pH of 7.2 at both sampling locations. The influent had mean alkalinity concentration of 210 mg/L as $CaCO_3$, and the median concentration was 210 mg/L. The SBR effluent and treated effluent had lower mean alkalinity concentrations of 130 and 120 mg/L $CaCO_3$ respectively. The decrease in alkalinity is expected as alkalinity is consumed in the nitrification process and generated in the denitrification process. Overall, a net decrease of approximately 3.5 mg/L in alkalinity can be expected for each 1 mg/L reduction in TN concentration.

Temperature can also impact both the organic removal and nitrification/denitrification processes. There was little or no impact on the system from temperature variation as the SBR temperature remained at or above 10 ^{o}C throughout the year. The influent temperature did drop as low as 6 ^{o}C in the winter months (December through February).

Table 4-9. Model 6000 SBR System Total Coliform Results

Date	Total Coliform (MPN/100 mL)		
	Influent	SBR Effluent	Treated Effluent
07/20/04	$>2.4\times10^{5}$	$>2.4\times10^{5}$	<3
07/21/04	$>2.4\times10^{5}$	$>2.4\times10^{5}$	<3
07/22/04	$>2.4\times10^{7}$	4.3×10^{5}	<3
07/23/04	4.6×10^{7}	2.3×10^{5}	4
08/09/04	9.3×10^{6}	1.6×10^{6}	4
08/10/04	2.0×10^{6}	1.5×10^{5}	<3
08/11/04	4.3×10^{6}	2.4×10^{5}	<3
08/12/04	2.4×10^{7}	4.0×10^{3}	<3
09/04/04	9.3×10^{5}	4.6×10^{5}	<3
09/05/04	$2.3\ \times10^{5}$	4.6×10^{5}	<3
09/07/04	$>2.4\times10^{6}$	2.4×10^{4}	<3
09/08/04	2.4×10^{6}	2.4×10^{4}	<3
10/05/04	$>2.4\times10^{7}$	$>2.4\times10^{6}$	NS
10/06/04	$>2.4\times10^{7}$	$2.4\times\times10^{5}$	<3
10/07/04	$>2.4\times10^{7}$	1.1×10^{6}	4
10/08/04	$>2.4\times10^{7}$	$<3.0\times10^{3}$	<3
10/19/04	9.3×10^{6}	4.0×10^{4}	<3
10/20/04	$>2.4\times10^{8}$	2.3×10^{4}	<3
10/21/04	2.1×10^{7}	9.0×10^{3}	<3
10/22/04	4.3×10^{6}	9.0×10^{3}	4
11/16/04	9.3×10^{6}	$>2.4\times10^{6}$	120
11/17/04	2.4×10^{6}	9.3×10^{5}	9
11/18/04	1.5×10^{6}	7.5×10^{5}	<3
11/19/04	2.6×10^{6}	2.3×10^{5}	4
12/14/04	$<3.0\times10^{5}$	9.0×10^{4}	4
12/15/04	NS	2.0×10^{4}	<3
12/16/04	2.4×10^{6}	$<3.0\times10^{4}$	<3
12/17/04	$<3.0\times10^{5}$	9.0×10^{5}	<3
12/30/04	$>2.4\times10^{7}$	9.0×10^{4}	<3
12/31/04	2.6×10^{6}	2.3×10^{6}	23
01/01/05	2.3×10^{6}	4.0×10^{5}	4
01/02/05	7.5×10^{6}	1.5×10^{5}	NS
01/25/05	2.4×10^{6}	$<3.0\times10^{3}$	4
01/26/05	1.1×10^{7}	9.0×10^{4}	4
01/27/05	1.1×10^{7}	2.4×10^{3}	4
01/28/05	1.5×10^{7}	4.3×10^{3}	4

Table 4-9. Model 6000 SBR System Total Coliform Results (continued)

Date	Total Coliform (MPN/100 mL)		
	Influent	SBR Effluent	Treated Effluent
02/08/05	1.6×10^{7}	7.0×10^{4}	<2
02/09/05	9.0×10^{8}	5.0×10^{3}	<2
02/10/05	2.8×10^{8}	3.0×10^{3}	2
02/11/05	$>1.6\times10^{9}$	1.1×10^{4}	2
03/01/05	1.1×10^{7}	1.1×10^{4}	2
03/02/05	1.7×10^{6}	8.0×10^{3}	8
03/03/05	5.0×10^{6}	$<2.0\times10^{3}$	7
03/04/05	2.2×10^{6}	NS	NS
03/18/05	3.0×10^{7}	3.0×10^{5}	NS
03/19/05	9.0×10^{7}	1.3×10^{5}	NS
03/20/05	$>1.6\times10^{8}$	1.1×10^{6}	2
03/21/05	$>1.6\times10^{8}$	1.7×10^{5}	30
04/19/05	$>1.6\times10^{8}$	$>1.6\times10^{6}$	<2
04/20/05	2.4×10^{8}	3.0×10^{4}	<2
04/21/05	5.0×10^{7}	4.0×10^{3}	NS
04/22/05	3.0×10^{7}	5.0×10^{4}	2
05/10/05	5.0×10^{7}	2.4×10^{5}	<2
05/11/05	1.6×10^{9}	1.7×10^{5}	2
05/12/05	1.0×10^{8}	5.0×10^{5}	8
05/13/05	1.6×10^{8}	3.0×10^{5}	<2
05/27/05	5.0×10^{7}	5.0×10^{6}	<2
05/28/05	1.7×10^{8}	5.0×10^{5}	2
05/29/05	9.0×10^{8}	3.0×10^{6}	NS
05/30/05	5.0×10^{7}	1.3×10^{6}	NS
06/07/05	9.0×10^{7}	1.7×10^{6}	NS
06/08/05	3.0×10^{8}	1.4×10^{6}	NS
06/09/05	5.0×10^{8}	2.4×10^{6}	<2
06/10/05	8.0×10^{7}	5.0×10^{5}	NS
Maximum	1.6×10^{9}	5.0×10^{6}	120
Minimum	2.3×10^{5}	2.4×10^{3}	2
Geometric Mean	7.1×10^{6}	1.2×10^{5}	4

NS – No sample collected

Table 4-10. Model 6000 SBR System pH and Temperature Results

Date	pH (S.U.) Influent	pH (S.U.) SBR Effluent	pH (S.U.) Treated Effluent	Temperature (ºC) Influent	Temperature (ºC) SBR Effluent	Temperature (ºC) Treated Effluent
07/20/04	7.0	7.3	7.2	20	27	27.5
07/21/04	7.2	7.3	7.2	NS	NS	27.5
07/22/04	7.2	7.3	7.3	NS	28	NS
07/23/04	7.2	7.0	7.2	NS	29	29
08/09/04	7.2	7.1	7.2	19.5	21	27.5
08/10/04	7.0	6.9	7.2	22.5	21.5	27.5
08/11/04	7.5	7.4	7.4	21	24.5	29
08/12/04	7.2	7.1	7.2	20	24	30
09/04/04	NS	NS	NS	NS	NS	NS
09/05/04	7.0	7.3	7.0	15.5	19	26
09/07/04	7.2	7.3	6.8	15.5	19	25.5
09/08/04	7.5	7.3	7.1	16.5	20	24.5
10/05/04	6.5	6.9	7.1	17	23	23.5
10/06/04	7.2	7.2	7.0	17.5	23	25
10/07/04	7.2	7.1	6.9	17.5	22.5	27
10/08/04	6.5	7.1	7.0	18	23	25
10/19/04	6.4	7.2	7.1	13	20.5	18.5
10/20/04	6.7	7.4	7.3	16	19	21.5
10/21/04	7.4	6.6	7.3	12.5	19	19.5
10/22/04	7.6	7.4	7.6	11.5	18	20.5
11/16/04	6.5	7.2	6.9	13	16	16
11/17/04	NS	NS	NS	NS	NS	NS
11/18/04	6.5	7.0	7.2	10.5	15	16.5
11/19/04	7.0	7.4	6.8	10.5	14.5	15
12/14/04	6.9	7.0	7.2	9	15	16
12/15/04	NS	6.6	6.8	NS	11.5	14.5
12/16/04	6.2	6.7	7.0	12	13.5	15
12/17/04	6.4	6.6	7.0	10	13	15
12/30/04	6.4	7.1	7.2	8.5	15	16.5
12/31/04	6.6	7.5	7.1	8	15	15.5
01/01/05	7.3	7.0	7.2	8	12	15.5
01/02/05	6.3	6.4	7.0	8	13	16.5
01/25/05	7.5	7.0	7.2	6.5	11.5	14
01/26/05	8.2	7.0	7.3	7	12.4	14
01/27/05	7.7	7.0	7.1	6	15.5	15.5
01/28/05	7.5	7.1	6.8	7.5	15	15

NS – No Sample Collected

Table 4-10. Model 6000 SBR System pH and Temperature Results (continued)

Date	pH (S.U.)			Temperature (ºC)		
	Influent	SBR Effluent	Treated Effluent	Influent	SBR Effluent	Treated Effluent
02/08/05	7.7	6.9	7.0	6.5	12.5	13.5
02/09/05	7.4	7.3	7.3	8	11.5	12.5
02/10/05	8.2	7.3	7.5	7	12	13.5
02/11/05	6.9	7.2	7.4	6	11.5	13
03/01/05	7.7	7.1	6.9	11	15.5	14.5
03/02/05	7.5	7.3	7.4	11	14.5	15.5
03/03/05	7.4	7.6	7.4	12.5	14.5	14
03/04/05	7.7	7.7	7.5	11	10.5	17.5
03/18/05	7.6	7.7	7.9	10	14.5	18.5
03/19/05	7.6	7.7	7.4	11	15	18.5
03/20/05	6.9	7.4	7.5	13	16	17.5
03/21/05	7.8	8.0	8.0	10	16	16.5
04/19/05	7.7	7.2	7.3	14.5	16.5	17
04/20/05	9.1	7.6	7.6	9.5	17	18
04/21/05	7.6	7.4	NS	16	16.5	NS
04/22/05	7.7	7.0	7.2	16.5	19.5	16.5
05/10/05	7.7	7.3	7.2	14	18	19.5
05/11/05	7.4	7.3	7.5	16	20	20
05/12/05	7.3	7.1	7.3	25.5	20.5	20.5
05/13/05	7.4	7.4	7.3	20.5	20	21.5
05/27/05	7.2	7.1	7.1	20.5	21.5	21.5
05/28/05	7.3	7.3	7.2	20.5	22	22.5
05/29/05	7.2	7.1	7.3	21.5	22.5	23
05/30/05	7.2	7.2	7.2	19.5	20	25
06/07/05	7.5	7.0	NS	20.5	22	NS
06/08/05	NS	7.4	7.2	18.5	23.5	23
06/09/05	7.1	7.3	7.4	22.5	24	23
06/10/05	NS	7.3	7.6	23	22.5	24.5
Maximum	9.1	8.0	8.0	25.5	29.0	30.0
Minimum	6.2	6.4	6.8	6.0	10.5	12.5
Median	7.2	7.2	7.2	13.0	18.0	18.5

NS – No Sample Collected
NC – Not Calculated

4.2.7 Residuals Results

The SBR unit was monitored for solids level in the aeration compartment on a regular basis by the IWS operators. A sample was collected and allowed to settle for 30-min. As the quantity of biomass increased, operators would waste sludge from the SBR to the sludge holding tank. Based on the twelve-month operating record, sludge was wasted from the system approximately three to five times per month during the first six months of the verification test and one to three times per month during the last six months of the test.

Once the sludge had been transferred to the sludge holding tank, it was allowed to settle until the next visit to the site. The clear liquid on the top of the tank was transferred back to the equalization tank (directly to the SBRs prior to the September change in process flow) to make room in the tank for additional sludge transfers as needed.

The SBR system did not make large quantities of sludge and the sludge holding tank was only pumped out twice during the verification test. The first sludge removal occurred in November, seven months after the initial cleanout of the holding tank as part of the startup procedure in April 2004. The November 2004 cleanout occurred in conjunction with the high flow volumes that occurred at that time. Three thousand gal of sludge was removed from the tank and taken to a local wastewater treatment plant. The material removed had a solids content of 0.93%.

The sludge holding tank was pumped again at the end of the verification test on June 30, 2005. This was seven months after the November cleanout. Again, 3,000 gal of sludge was removed form the sludge holding tank by vacuum truck and transported to a local wastewater treatment plant. The solids content of this sludge material was 0.67%.

Based on the twelve-month verification test and the conditions found at this site, cleanout of the sludge holding tank can be expected every 6 to 12 months.

Samples of the sludge from the holding tank were collected and analyzed for solids content and metals. The results of these analyses are shown in Table 4-11. The metals content of the sludge removed from the system were generally low and were acceptable for disposal at the local wastewater treatment facility.

Table 4-11. Model 6000 SBR System Residuals - Metals and Solids Results

Analyte	Units	11/12/04	06/30/05
Arsenic	mg/kg	<0.5	<0.2
Barium	mg/kg	2.9	1.7
Cadmium	mg/kg	<0.05	<0.05
Chromium	mg/kg	0.6	0.9
Lead	mg/kg	<0.5	<0.5
Mercury	mg/kg	<0.02	<0.02
Nickel	mg/kg	0.3	0.4
Selenium	mg/kg	<1.0	<1.0
Silver	mg/kg	0.12	<0.05
Zinc	mg/kg	6.9	5
Total Solids	%	0.93	0.67
Volatile Solids	%	63.9	NA
Density	g/mL	1.001	NA

NA – Not analyzed

4.3 Operation and Maintenance

Operation and maintenance performance of the Model 6000 SBR was monitored throughout the verification test by the TO during weekly visits to the site. IWS operators were responsible for routine operation and maintenance of the system under contract with the Moon Lake Ranch Homeowners Association. Various data and observations were recorded by the IWS operators as part of their normal work practices. In addition to recording data in the field logs, observations on the condition of the system, any changes in setup or operation, or any problems that required resolution were recorded by the operators. A set of field logs maintained by the IWS operators and the weekly log sheet and sampling log sheets maintained by the TO are included in Appendix G.

There were no major mechanical component failures during the verification test. There were also no major downtime periods during the test. When the process was changed in September to include an equalization tank and a one SBR operation, the switch was completed in two days with flow to the one SBR maintained throughout the period. There was one structural failure during the test. The baffle in the SBR between the aeration chamber and the clarifier chamber separated from the tank wall. This failure is described later in this section.

4.3.1 Chemical Use

The Model 6000 SBR system uses aluminum salts as a coagulant to treat the SBR effluent prior to filtration and methanol as a supplemental carbon source for the denitrification process. These chemicals are added from 55 gal storage tanks by chemical metering pumps activated by the PLC during flow to the filter (aluminum) and during the anoxic cycle in the SBR (methanol). The chemical feed pump rates were set at the beginning of the verifications test and did not vary more than 10-15% over the course of the verification test.

Initially, aluminum sulfate (alum) was used as the coagulant. The feed solution was made by adding dry aluminum sulfate to the coagulant feed tank and mixing it with water to achieve a concentration of approximately 5,000 mg/L as Al. The coagulant was changed in August 2004, the second month of the test, to aluminum chloride, which could be purchased as a liquid, to simplify the handling and mixing of the coagulant solution. The aluminum chloride feed solution was also targeted to contain approximately 5,000 mg/L of Al in solution. The chemical metering pump was set to feed at a rate of 0.3 gal per hr with a filter water flow rate of 10 gpm, yielding a coagulant dose of approximately 2.5 mg/L as Al. The chemical metering pumps were tied to the filter feed pumps through the PLC so that coagulant was only added when the filters were in operation. The average daily coagulant use over the twelve-month verification test, based on an average daily influent volume of 2,280 gal, was approximately 0.5 lb per day as aluminum [2.5 lb per day as aluminum chloride or 6.3 lbs per day as aluminum sulfate (alum)].

Methanol was added during the denitrification step as a supplemental carbon source. The methanol feed solution was stored in a 55 gal feed tank. The feed solution was made by diluting methanol with water at a ratio of 1 gal of methanol to 3 gal of water, yielding a feed solution with 1.65 lb of methanol per gal. The chemical feed records show that the average feed rate of solution was 1.7 gpd (2.8 lbs of methanol per day). Using the average influent volume of 2,280 gpd, the supplemental carbon added was approximately 50 mg/L as carbon.

At the chemical rates used during the verification test, the chemical feed tanks required replenishment approximately once per month.

4.3.2 Operation and Maintenance Observations

The Model 6000 SBR system is a moderately complicated biological and filtration/UV disinfection system that requires regular operator checks and routine maintenance. A system of this type typically requires a licensed wastewater treatment plant operator, with the actual license requirement depending on state requirements.

The Model 6000 SBR system, while complex, is highly automated and PLC controlled so that operator intervention is not required on a daily basis. The operator can access the PLC via the Internet and the PLC can send various alarms to an operator when there is a potential problem. Typically, IWS expects the system to require operator attention on a two to three visits per week basis. During the verification test, more frequent site visits occurred in the first six months of the test (20 plus site visits per month) and less frequently in the last six months of the test (10 to 15 site visits per month). The more frequent site visits at the beginning of the verification were due to some operational issues with the units as the transition was made from a two SBR to a one SBR system. There were more frequent visits at the start of the test associated with the verification test and supporting data collection programs. At least four site visits each month were to support the verification sampling program.

During each site visit, the operator uses a checklist to record various operating conditions (listed below), and routine maintenance checklist that includes cleaning the screens, floats, filter, and UV system as required. Other activities are based on observation of the unit operating conditions, including pumping sludge to the sludge holding tank, making new coagulant and methanol solutions, etc. Based on the routine operation and maintenance activities observed and recorded during the twelve-month verification test, it is estimated that each site visit requires approximately 1 hr for routine work. Additional time is needed if special maintenance activities are required. While the actual operator time will vary by site, it is estimated that approximately 4 to 5 hr per week is needed to handle routine operation and maintenance activities, with additional time needed for mechanical problems or an upset condition.

The Operator Routine Check List includes:

- Coagulant tank level and pump rate
- Methanol tank level and pump rate
- Distribution tank level, pH, alkalinity
- Clean screen in distribution tank
- SBR pH, alkalinity, nitrate, ammonia, dissolved oxygen
- SBR sludge settling level
- Record if sludge wasted sludge holding tank
- Filter feed tank level
- Filter feed tank nitrate and ammonia concentration
- Filter pressure, air flow, head loss
- Turbidity meter reading
- UV units (2) intensity reading
- Record if UV lamps cleaned
- Sludge tank level

There were no major operational upsets in the SBR during the verification test as shown by the data presented in previous sections. The operators made only minor adjustments in the master cycle (aeration, anoxic, transfer, clarification) of the SBR. The most significant change required was a master cycle adjustment from a 4-hr cycle to a 6-hr cycle in November. This was after the system was changed to a one SBR system and higher flow rates were encountered. The aeration cycle was lengthened from two 45-minute periods to two 90-minute periods.

The filter and UV system also had no major operational problems over the one-year test period. The filter system maintained a very steady set of operating conditions. The head loss across the filter did vary over time and occasionally the filter required cleaning with an air pressure backwash to decrease head loss. However, this was required less than once per month and each time the cleaning was performed the filter head loss returned to low levels. Air flow rate on the filter (90-110 scfh) and head loss are parameters that are checked by the operator on each site visit. Air flow remained very steady throughout the test.

The PLC system monitored the UV intensity on both units and programmed to shut down the discharge, if intensity fell below 25%. As discussed in section 4.3.1, a faulty sensor(s) or signal to the PLC apparently caused the system to close the valves to the UV and recycling filtered wastewater in December. This caused a high water alarm in the distribution tank and wastewater was removed from the system and trucked to a local wastewater plant over three days (10,500 gal total). The lamps were operating properly based on data collected on the discharges that occurred when the PLC was getting a signal with an intensity of greater than 25%.

The UV intensity did vary and the lamps required cleaning using the manual cleaning wipers on a regular basis. Cleaning normally was required two or three times per month. The manufacturer of the UV lamps recommends changing the lamps after 10,000 hr of use (416 days of continuous use in this application). However, it has been IWS experience that the lamps will last much longer than 10,000 hr. The lamps had been operating for over 14,000 hr at the end of the verification test and were still providing effective disinfection based on the data collected in the last month of the test. As mentioned, the intensity of the lamps is monitored by IWS operators and if intensity falls and cannot be increased after cleaning, the lamps are replaced.

Given the large number of floats, switches, pumps and automated valves that are part of the Model 6000 system, it can be expected that some maintenance beyond routine cleaning and servicing will be required for this system. The typical maintenance items include cleaning or repair of floats/switches, repair of pumps and motors, etc. A summary list of some of the typical minor repairs and action items outside the normal routine maintenance that were required during the verification test are listed in Table 4-12.

There was one major equipment failure during the test. In November, the baffle between the aeration chamber and the clarification chamber broke away from the tank. It was determined that since the SBR was in true batch mode the baffle was not needed and it was removed from the tank. The cause of this failure is not known but may be related to the joints holding the baffle to the tank being faulty or weak. If the baffle had needed to be repaired, it would have resulted in down time to empty the tank and make the repair. Since the sludge holding tank can be used to hold acclimated material, the biomass could have been saved and then reintroduced for a quick restart. The equalization tank has sufficient capacity to hold two days of flow so the influent raw water would not have needed to be interrupted assuming the repair could be done in one to two days.

IWS updated the O&M manual at the end of the verification period. This updated manual is well written and is easy to follow. Detailed information on the SBR, filtration, and UV processes is provided with a good explanation of the PLC settings needed to operate the system. High and low level controls and switches are described both by location and function. The manual included several troubleshooting tables in an easy to follow format. In addition, several support documents provide information on the equipment as supplied by the equipment manufacturers. This previous manual contained all of the needed information for the system, but the new manual is better organized and easier to understand.

The verification test (startup and testing) ran for a period of 15 months, which provided sufficient time to evaluate the overall performance of the unit, which had been in operation for almost four years at the start of the testing. Based on observations during this test period, the equipment appeared to be properly constructed of appropriate materials for wastewater treatment applications. The verification did not run long enough to truly evaluate length of equipment life, but the basic components of the system appear durable and the overall system design indicate that the system should have a reasonable life expectancy.

Table 4-12. Summary of Minor Maintenance and Action Items

Date	Maintenance or Action Item
07-16-04	Reset PLC clock due to power outage at site.
07-18-04	Clean filter feed tank – high sludge blanket in both SBRs causing high solids carry over to feed tank.
08-02-04	Wasted two batches of sludge from SBR and cleaned feed tank.
08-04-04	Feed tank float hanging; cleaned and repositioned float.
08-19-04	Belt off of compressor pulley – repaired belt.
09-30-04	Filter reject line plugged with sand – line cleaned.
09-05-04	Coagulant feed pump not running in auto mode – float in feed tank problem; floats will be repaired.
10-12-04	Turbidity meter required calibration; routine cleaning did not resolve issue; recalibration done.
11-11\14-04	Very high influent volumes causing high level alarms. Timing of pump cycles adjusted to handle higher flow; homeowners contacted about very high flows.
12-6-04	Compressor has tripped breaker; breaker reset.
12-7-04	PLC fault shown on I10 wire; replaced one wire with terminator I/O.
1-01-05	Filter effluent valve not closing completely; cleaned the valve so that it shuts properly.
1-21-05	Compressor tripped breaker; breaker reset.
01-31-05	High filter head loss; Filter cleaned with air.
03-15-05	Discharge pump malfunction; replace impellor and repair pump.
04-13-05	Compressor tripped breaker; repair motor.
05-15-05	High filter head loss; back flushed and cleaned filter; head loss normal.
05-24-05	Turbidity meter reading high; clean cuvettes inside meter and reset.

Chapter 5
QA/QC Results and Summary

The VTP included a Quality Assurance Project Plan (QAPP) that identified critical measurements and established Data Quality Objectives (DQO). The verification test procedures and data collection followed the QAPP, and summary results are reported in this section. The laboratory reported QA/QC data with each set of sample results as part of the laboratory reports. Each report included the results of blanks, laboratory duplicates, spikes, and other lab control sample results for the various analyses. These QA data are incorporated with the laboratory reports presented in Appendix F. Field duplicates were also collected by the TO and submitted for analysis. The results for field duplicates are summarized in section 5.2.2 and field duplicate data are included in the spreadsheets in Appendix E.

5.1 Audits

NSF conducted audits of test site and ALI (laboratory) prior to and during the verification test. The pretest audit found that the field and laboratory procedures were in place to collect data to meet the QA objectives of the VTP. The laboratory audit found that ALI followed approved analytical methods and documented the methods and QA/QC in an acceptable manner. The pretest audit also provided the opportunity to explain the ETV program and the requirements for a successful verification test to the participants.

The audit performed during the verification test found that the procedures being used in the field and the laboratory were in accordance with the established QAPP. Legible field logs were being maintained. The laboratory had a firmly established QA/QC program, and observation of the analyses and a records review found that appropriate QC data was being performed with the analyses. All members of the testing team were reminded that ETV requires that copies of all logs and raw data records be delivered to NSF at the end of the project.

5.2 Precision

5.2.1 Laboratory Duplicates

The analytical laboratory performed sample duplicates for all parameters at a frequency of at least one duplicate for every ten samples analyzed or one per batch if less than ten samples in a batch. The results of laboratory duplicates were reported with all data reports received from the laboratory. Table 5-1 shows the acceptance limits used by the laboratory.

The Relative Percent Difference (RPD) was calculated using the standard formula:

$$RPD = [(C_1 - C_2) \div ((C_1 + C_2)/2)] \times 100\% \qquad (5\text{-}1)$$

Where:

C_1 = Concentration of the compound or element in the sample
C_2 = Concentration of the compound or element in the duplicate

Table 5-1. Laboratory Precision Limits

Parameter	Acceptance Limits (RPD)
TSS	20
Alkalinity	15
BOD_5	20
COD	20
TKN	25
NH_3-N	20
NO_2+NO_3–N	20
Total P	20
Soluble P	15

The laboratory precision for all parameters, as measured by the laboratory duplicates, was found to meet the QA objectives for the verification test.

5.2.2 Field Duplicates

Field duplicates were collected for influent and effluent samples to monitor the overall precision of the sample collection and laboratory analyses. Summaries of the data are presented in Tables 5-2, 5-3 and 5-4. As can be seen, precision was good for all parameters for most samples. There was some variability for samples that were near the detection limit, as would be expected. As an example, the nitrite plus nitrate concentrations in the influent were at or below the detection limit. Small differences in the field duplicate results at low concentrations can cause large RPD values to be calculated. One influent raw wastewater sample showed a large difference for TSS, which probably was caused by the inherent difficulty in splitting samples with high TSS concentrations. One sample set with a low concentration of TSS showed a large difference, which can be expected at very low concentrations of TSS. The overall dataset showed good precision with no indication of any systemic sampling or analysis problems.

Table 5-2. Duplicate Field Sample Summary – Nutrients

	TKN			NH_3-N		
Sample	**Rep 1 (mg/L as N)**	**Rep 2 (mg/L as N)**	**RPD (%)**	**Rep 1 (mg/L as P)**	**Rep 2 (mg/L as P)**	**RPD (%)**
Influent	44.5	45.3	1.8	37.9	37.9	0
	37.8	40.5	6.9	31.2	30.3	2.9
	50.2	48.3	3.9	40.0	38.9	2.8
	32.3	33.6	3.9	24.0	24.0	0
	43.6	42.2	3.3	39.2	39.8	1.5
SBR Effluent	1.50	1.50	0	0.05	<0.04	22
	1.38	1.20	14	<0.04	<0.04	0
	4.07	3.73	8.7	0.18	0.18	0
	3.07	2.71	12	<0.04	<0.04	0
	2.20	2.00	9.5	0.13	0.07	60
Final Effluent	1.60	1.26	24	0.14	0.17	19
	3.26	3.35	2.7	2.53	2.64	4.3
	1.16	0.73	46	<0.04	<0.04	0
	1.20	1.12	6.9	<0.04	<0.04	0
	0.60	0.80	29	<0.04	0.04	0

	NO_2+NO_3-N			TP		
Sample	**Rep 1 (mg/L as N)**	**Rep 2 (mg/L as N)**	**RPD (%)**	**Rep 1 (mg/L as P)**	**Rep 2 (mg/L as P)**	**RPD (%)**
Influent	0.03	0.04	29	6.9	7.2	4.3
	0.04	0.05	22	5.5	6.3	14
	0.09	0.09	0	7.4	7.7	4.0
	0.03	0.04	29	4.2	4.4	4.7
	0.03	0.04	29	7.4	6.8	8.5
SBR Effluent	2.7	2.7	0	3.0	3.0	0
	0.62	0.62	0	0.37	0.30	21
	1.03	1.10	6.6	2.17	2.02	7.2
	2.68	2.75	2.6	3.22	3.05	5.4
	1.9	1.6	17	3.29	3.25	1.2
Final Effluent	4.4	4.3	2.3	0.50	0.48	4.1
	0.8	0.9	12	0.85	0.91	6.8
	7.0	6.9	1.4	0.99	0.91	8.4
	4.72	4.81	1.9	1.23	1.27	3.2
	2.51	2.85	13	1.34	1.41	2.3

Table 5-3. Duplicate Field Sample Summary – BOD, COD, TSS, Alkalinity

Sample		BOD_5			COD	
	Rep 1 (mg/L)	Rep 2 (mg/L)	RPD (%)	Rep 1 (mg/L)	Rep 2 (mg/L)	RPD (%)
Influent	410	350	16	880	780	13
	140	140	4.9	420	450	6.2
	280	270	3.7	620	970	44
	240	250	0.8	550	540	2.8
	200	160	17	400	380	2.6
	390	390	0	1440	1140	23
SBR Effluent	13	13	0	73.6	72.6	1.4
	13	13	0	43.1	38.9	10
	<4	<4	0	24.2	22.6	6.0
	15	15	0	48.7	39.5	21
	23	24	4.3	90.8	88.0	3.1
	11	11	0	37.4	38.9	3.9
Final Effluent	<3	<3	0	<20	<20	0
	<3	<3	0	<20	<20	0
	<3	4	NC	<20	21.1	NC
	<3	<3	0	<20	<20	0

Sample		TSS			Alkalinity	
	Rep 1 (mg/L)	Rep 2 (mg/L)	RPD (%)	Rep 1 (mg/L)	Rep 2 (mg/L)	RPD (%)
Influent	140	270	68	260	260	0.4
	150	180	16	160	160	0.6
	320	330	2.5	210	210	1.9
	210	180	12	210	220	0.9
	130	150	16	250	250	0.4
	380	360	5.9	290	290	0.3
SBR Effluent	57	56	1.8	90.7	81.4	11
	21	23	9.1	120	120	1.7
	7	3	80	78.0	78.6	0.8
	38	38	0	120	120	0.8
	56	55	1.8	120	120	0.8
	12	12	0	170	170	1.2
Final effluent	<3	6	NC	150	150	2.0
	<3	<3	0	83.6	84.6	1.2
	6	4	40	150	150	0
	5	3	50	120	120	0

NC-Not calculated

Table 5-4. Duplicate Field Sample Summary – Total Coliform

Sample	Total Coliform	
	Rep 1 MPN/100 mL	Rep 2 MPN/100 mL
Influent	$>2.4\times10^{7}$	$4.6\times\times10^{6}$
	$>2.4\times10^{7}$	$>2.4\times10^{7}$
	7.5×10^{6}	1.4×10^{6}
	2.2×10^{6}	1.4×10^{6}
	5.0×10^{7}	1.1×10^{8}
SBR Effluent		
	1.6×10^{6}	1.6×10^{6}
	2.4×10^{5}	9.3×10^{4}
	9.0×10^{3}	1.5×10^{4}
	9.0×10^{5}	$<3.0\times10^{5}$
	1.1×10^{4}	1.4×10^{4}
	5.0×10^{4}	3.0×10^{4}
	5.0×10^{5}	8.0×10^{5}
Final Effluent		
	4	23
	4	4
	30	22
	<2	2

5.3 Accuracy

Method accuracy was determined and monitored using a combination of matrix spikes, laboratory control samples (known concentration in blank water), and proper equipment calibration and traceability depending on the analytical method. Recovery of the spiked analytes was calculated and monitored during the verification test. The laboratory used the control samples and recovery limits as shown in Table 5-5 and reported the data with each set of analytical results.

The equations used to calculate the recoveries for spiked samples and laboratory control samples are as follows:

Matrix Spike Samples:

$$\text{Percent Recovery} = (Cr - C_o)/C_f \times 100\% \qquad (5\text{-}2)$$

Where:

C_r = Total amount detected in spiked sample
C_o = Amount detected in un-spiked sample
C_f = Spike amount added to sample.

Lab Control Sample:

$$\text{Percent Recovery} = (C_m / C_{known}) \times 100\% \qquad (5\text{-}3)$$

Where:

C_m = measured concentration in the spike control sample
C_{known} = known concentration

Table 5-5. Laboratory Control Limits for Accuracy

Parameter	Method Blank	Calibration Curve Check	Lab Control Sample	Matrix Spike	Recovery Limits (%)
TSS	X	N/A	X	N/A	N/A
Alkalinity	X	N/A	X	N/A	80-120
BOD_5	X	N/A	X(1)	N/A	N/A
COD	X	X	X	X	75-125
TKN	X	X	X	X	80-120
NH_3-N	X	X	X	X	80-120
NO_2+NO_3-N	X	X	X	X	80-120
TP	X	X	X	X	80-120
SP	X	X	X	X	80-120

(1) - Seed control sample.
X - Denotes sample collected.
N/A - Not applicable.

All of the specific requirements to document method accuracy are detailed in the QAPP in the VTP in Appendix C. The laboratory supporting data is included with the laboratory reports in Appendix F. Review of the laboratory data shows that the accuracy data met the quality objectives.

The balance used for TSS analysis was calibrated routinely with weights that were National Institute of Standards and Technology (NIST) traceable. Calibration records were maintained by the laboratory and inspected during the on-site audit. The temperature of the drying oven was also monitored using a thermometer that was calibrated with a NIST-traceable thermometer. The pH meter was calibrated using a three-point calibration curve with purchased buffer solutions of known pH. Field temperature measurements were performed using a NIST-traceable thermometer. All of these traceable calibrations were performed to ensure the accuracy of measurements.

5.4 Representativeness

The field procedures were designed to ensure that representative samples were collected of both influent and effluent wastewater. The composite sampling equipment was checked on a routine basis to ensure that proper sample volumes were collected to provide flow-weighted sample composites. Field duplicate samples and supervisor oversight provided assurance that procedures were being followed. The field duplicates showed that there was some variability in the field duplicate samples. However, review of the overall data set for influent and effluent samples did not show specific sampling bias for any of the parameters. These data indicated that while individual sample variability may occur, the data were representative of the concentrations in the wastewater.

The laboratory used standard analytical methods and written SOPs for each method to provide a consistent approach to all analyses. Sample handling, storage, and analytical methodology were reviewed during the on-site audit to verify that standard procedures were being followed. The use of standard methodology, supported by proper QC information and audits, ensured that the analytical data were representative of the actual wastewater conditions.

5.5 Completeness

The QAPP set a goal of 80% completeness for sample collection in the field, and for reporting acceptable analytical results by the laboratory.

All sixteen sets of 96-hr composite samples were collected and samples analyzed by the laboratory for scheduled parameters, yielding 100% completeness for this group of samples. There were 64 days of scheduled sampling for the 24-hr composite samples at each of the three sampling locations, which would generate 192 composite samples. On two occasions, there was insufficient final treated effluent sample volume so a grab sample was collected. On one occasion, there was a sampler failure for the final treated effluent sample and a sample was not collected due to lack of flow. Completeness for the 24-hr composite samples was 98% (189 out of 192 samples, two of the missed samples were collected as grab samples). Grab samples for total coliform, pH, and temperature were scheduled for 64 days at three locations yielding a projected 192 samples for each parameter. A few grab samples were missed or could not be collected due to lack of flow. Twelve samples for total coliform were missed out 192 scheduled for a completeness of 94%. Nine samples were missed for pH and 12 samples were missed for temperature giving a completeness of 95% for pH and 94% for temperature.

All scheduled analyses for samples delivered to the laboratory were completed. A few analytical results appeared to be outliers or anomalies. However, after careful review of the laboratory bench sheets, there was no apparent basis to justify excluding these data. Therefore, all laboratory data were reported in this report, and the laboratory analyses were considered 100% complete.

Appendices

Appendix A –IWS Operation and Maintenance Manual

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

Appendix B – Pictures of Test Site and Equipment

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

Appendix C - Verification Test Plan

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

Appendix D – IWS Startup Procedures Field Operations and Lab Logbooks

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

Appendix E - Spreadsheets with calculation and data summary

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

Appendix F - Lab Data and QA/QC Data

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

Appendix G – Field Logs and Records

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

Glossary of Terms

Accuracy - a measure of the closeness of an individual measurement or the average of a number of measurements to the true value and includes random error and systematic error.

Bias - the systematic or persistent distortion of a measurement process that causes errors in one direction.

Commissioning – the installation of the nutrient reduction technology and startup of the technology using test site wastewater.

Comparability – a qualitative term that expresses confidence that two data sets can contribute to a common analysis and interpolation.

Completeness – a qualitative and quantitative term that expresses confidence that all necessary data have been included.

Precision - a measure of the agreement between replicate measurements of the same property made under similar conditions.

Protocol – a written document that clearly states the objectives, goals, scope, and procedures for the study. A protocol shall be used for reference during Vendor participation in the verification testing program.

Quality Assurance Project Plan (QAPP)– a written document that describes the implementation of quality assurance and quality control (QA/QC) activities during the life cycle of the project.

Residuals – the waste streams, excluding final effluent, which are retained by or discharged from the technology.

Representativeness - a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point, a process condition, or environmental condition.

Standard Operating Procedure (SOP) – a written document containing specific procedures and protocols to ensure that quality assurance requirements are maintained.

Technology Panel - a group of individuals established by the Verification Organization with expertise and knowledge in nutrient removal technologies.

Testing Organization (TO) – an independent organization qualified by the Verification Organization (VO) to conduct studies and testing of nutrient removal technologies in accordance with protocols and test plans.

Vendor – a business that assembles or sells nutrient reduction equipment.

Verification – to establish evidence on the performance of nutrient reduction technologies under specific conditions, following a predetermined study protocol(s) and test plan(s).

Verification Organization – an organization qualified by EPA to verify environmental technologies and to issue Verification Statements and Verification Reports.

Verification Report – a written document containing all raw and analyzed data, all QA/QC data sheets, descriptions of all collected data, a detailed description of all procedures and methods used in the verification testing, and all QA/QC results. The Verification Test Plan(s) shall be included as part of this document.

Verification Statement – a document that summarizes the Verification Report and is reviewed and approved by EPA.

Verification Test Plan (VTP) – A written document prepared to describe the procedures for conducting a test or study according to the verification protocol requirements for the application of nutrient reduction technology at a particular test site. At a minimum, the VTP includes detailed instructions for sample and data collection, sample handling and preservation, and QA/QC requirements relevant to the particular test site.

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